DIMIA

Future Dilemmas

Options to 2050 for Australia's population, technology, resources and environment

CSIRO

Report to the Department of Immigration and Multicultural and Indigenous Affairs

By CSIRO Sustainable Ecosystems

Barney Foran
Franzi Poldy

October 2002

Working paper series 02/01

CSIRO Resource Futures Working Paper 02/01
Barney Foran, Franzi Poldy
CSIRO Sustainable Ecosystems
GPO Box 284
CANBERRA ACT 2601

Published by
CSIRO Sustainable Ecosystems
GPO Box 284
CANBERRA ACT 2601
Phone: +61-2-6242-1600
Fax: +61-2-6242-1555
This report is available online at
http://www.cse.csiro.au/futuredilemmas

ISBN 0 95808453 X

The views expressed in this report are those of the authors and do not necessarily represent those of the Department of Immigration and Multicultural and Indigenous Affairs.

Disclaimer
The results presented in this report are a product of the model used and the assumptions stipulated.

To the maximum permitted by law, CSIRO, its agents and employees, exclude all liability to any person arising directly or indirectly from using the information in this paper.

The user accepts all risks and responsibility for losses, damages, costs and other consequences resulting directly or indirectly from their use of any information or material in this paper.

Contents

Foreword by Authors

When in 2050, a dusty copy of this report is located in the storage room of a library, the reader may wonder what led the authors to their conclusions.

However many things won't have changed. A joule of energy will still be a joule of energy, a kilogram of coal will still be a kilogram of coal and a litre of pure water will still be a litre of pure water. Humans will still require food, habitation, water and warmth. Australia has a wide range of options explored in this report, to ensure that the physical foundations of its quality of life will endure.

If accepted into policy design, many of the graphs, tables and commentary in this report will not eventuate. The study will have contributed to changing national function and how the nation thinks about itself. If by 2050 we are still following the paths described in many chapters of this report, then our cities, the air around them, our farmlands, our rivers and export industries could be struggling. This research explores many options for change, but tries to remain dispassionate about which are better or worse directions. These decisions must be made by the Australian people and their leaders.

During the process of the scenario development and testing, some analytical errors will have occurred. Inevitably, the size and complexity of this undertaking sometimes produces interactions not fully understood nor fully revealed. However the model development and grounding procedure have been designed to limit the flow-on effect of errors, which do not multiply throughout the system. Generally some system wide indicators may be underestimated since effects such as inter-sectoral rebound, and increasing diversity of personal consumption, are not automatically enabled in the simulation. As information becomes more comprehensive, then the robustness of the modelling outcomes will improve markedly.

By 2050 many current global issues will have been played out and there may be a new set of seemingly protracted issues which seem insoluble. By 2050 the globe will have decided whether global warming and climate change are major issues, whether supplies of oil and natural gas are unlimited, whether globalised trade helps or hinders environmental quality in each of its participating nations, and whether technological progress and the 'factor 10' economy can allow virtually unlimited growth in consumption without declining environmental consequences.

Many readers may find some of these issues challenging. In particular, the concepts from the theory of physics that, notwithstanding the many opportunities for substitution, many of the transactions that underpin modern day economies and lifestyles have physical and thermodynamic limits. Some may interpret these concepts as being antagonistic to contemporary societal values and political views. No challenge or antagonism is intended! Rather the analysis seeks to complement contemporary ideas with concepts of physical realism. This blending should help, rather than hinder, political decisions and business planning.

Lastly, there are many thanks due. First thanks go to the Department of Immigration and Multicultural and Indigenous Affairs who collaborated with us and helped fund this study, and in particular Neil Mullenger, Monica Millhouse, John Ryan, Chris Smith, and Abul Rizvi. For CSIRO, Joshua Conroy, Tory Quinnell, Michael Dunlop, Don Lowe, Doug Cocks, Ray Bemelman, Mark Howden, Graham Turner, Allen Kearns, Andrew Johnson, Shona Miller and Hugh Tindale Biscoe were important contributors to the processes of organising, workshopping, writing and editing. In the final phase of completion, our editors Robin Taylor of *Page One* and David Salt of *Ywords* added polish and completeness. More than 500 experts from a wide variety of fields contributed to the workshop process and subsequent reporting that preceded the writing of this report. The depth of their insights show partly in this report, but they will become more apparent as the national modelling capability invested in the *Australian Stocks and Flows Framework* becomes more developed during the next decade. The external reference group chaired by Roger Bradbury made many fair challenges to the analyses and provided sound advice on structure, content and style.

In an earlier era, there were many colleagues who laid the foundation for bringing Australia's policy world and its physical world into potential confluence. Our colleague Doug Cocks, and the then Chief of CSIRO Wildlife and Ecology, Brian Walker, decided as early as 1990 that CSIRO should do something *scientific* to provide numerate and analytical contributions to the national population debate. Over the ensuing decade, Brian Walker, Dave Spratt and Steve Morton continued with intellectual and funding support, through many difficult periods of scientific development when the project was frequently under scrutiny from corporate managers who thought it too dangerous, or beyond the safe margin of contemporary policy inquisition. Former chief executive officers of CSIRO, John Stocker and Roy Green supported the early days of the project with funding and credibility.

The warmest thanks should go to our friends and colleagues at Robbert Associates in Ottawa Canada, Rob Hoffman, Bert McInnis and Michael Hoffman. They, and other colleagues formerly in Statistics Canada in the early 1980s, developed the philosophies and concepts behind the *WhatIf* analytical platform which we use today. Research and development sometimes take 20 years or more to bloom, and produce edible fruit. We hope this research offering from Australia helps Robbert Associates further expand their intellectual and analytical capability.

The biggest and most heartfelt thanks must go to the families of Franzi Poldy and Barney Foran who ceded many family night times and family weekends to this analytical task, as well as the occasional lapse in good humour from their spouses and fathers.

Foreword by External Reference Group

In the world of modelling and simulation, practitioners talk of the *Cassandra problem*. Cassandra, was a daughter of Priam, the king of Troy, and had the gift of prophecy. She, alone of all the Trojans, was alarmed at the Greek's wooden horse, and begged her father not to allow it into the besieged city. She had foreseen the fall of Troy. No one believed her, and the rest, as they say, is history. Cassandra lacked street-cred in a big way, and so gave her name to the problem of how one can describe the future accurately and still be believed.

The future need not be catastrophic, or even a Greek tragedy, for the problem to rear its head. All it really needs is to be complex enough that our common sense and our past experience are not adequate guides. Of course, each of these is a good guide for the local neighbourhood – for the short term and the immediate environment. Indeed, we — or any other species — would not have survived if this were not so.

Alone among living things, human beings, in a sense, have moved beyond their local neighbourhood. Our problems are no longer local or short-term. They are, instead, global, long-term and complex. Their futures are sure to contain a Cassandra or two. Common sense and past experience might have helped us handle the small problems of the past, but they just are not up to dealing with the complexity of issues such as ecologically sustainable development.

This is where modelling and simulation come in, and where the Cassandras lurk. We can see this clearly in the present report. It tries to come to grips with a big complex problem — the future of Australia's human population and its interactions with the natural resource base.

The future, for something as complex as this, of course is not predetermined. It is not as if the authors set out to discover some already-written future chapters of the history of Australia. Those chapters do not exist, today's chapter is being written only today. The real world works in real time. Thus, instead of prediction (which only works for the future of relatively simple systems), the CSIRO team had to do something quite different.

What they did was this. They first built a model of Australia as a bio-physical system; that is, they took all the major components of the physical environment of Australia — the water, the soils, the air and so on — and created a framework which incorporated the history, the trends and, importantly, the interactions among all the components. They then did the same for the living fabric of the continent — the animals and plants. And finally, and in great detail, they added human beings to the mix — where people are in Australia and what they do in terms of how they interact with each other and the world.

The authors have called this description of the stocks and flows of all the things that make up Australia 'a model of the *physical* economy'.

This is a powerful and novel construction. It has never been attempted in such depth (that is, with so many different components) or breadth (at the scale of a whole continent) anywhere else in the world. The Department of Immigration and Multicultural and Indigenous Affairs, as the sponsor of the research, and the CSIRO Division of Sustainable Ecosystems, as the research agency, are to be congratulated for having the vision to undertake this project.

The work is novel because it offers a new and different way to look at the problems associated with the future of Australia's human population. Traditionally, demographic projections of the human population have been used as inputs to economic models to examine issues such as the future structure of the labour force or problems associated with, say, national infrastructure development. The success of these traditional studies has depended on two things: the extent to which they have been able to focus on these important single issues; and the extent to which they have been able to squeeze 'non-economic' components, such as environmental factors, into an economic framework.

The present study is quite different from this. It offers an opportunity to examine 'simultaneously' all the major components bearing on the human population. It does not require us to focus on some and ignore others. It also offers the opportunity for all the components to be dealt with in a 'natural' form. All models need a common 'currency' with which their components interact with one another. Broadly speaking, economic models use dollars, and so need to dollarise all their components, even though this may be rather forced for some of them. In the present study, the components are represented as physical objects, and measured using the units of physics — kilograms of this and joules of that. Science thus provides an objective external constraint on the model, ensuring that its physical budget of our bit of the universe observes the laws of physics, and in particular that matter and energy are properly accounted for.

This physicality gives the model its power. It does not depend on one's beliefs in this or that socio-political system or on the economic theories that spring from them. Instead it is an objective, neutral scientific description of the problem, even though it is, of course, like all science subject to revision and improvement.

The model's physicality is also its greatest weakness, in terms of making it useful and accessible to policy makers and the general public. It stands quite separately from the more usual (economic) modelling efforts with which most policy makers are familiar. Neither its structure, nor dynamics, nor results are directly comparable with those of economic models. Although, of course, the insights and understandings may be argued across the different domains.

The second thing the CSIRO team did was, having built the model, to then use it to attack the Cassandra problem obliquely. Instead of purporting to predict, which is neither feasible in practice nor really possible in principle, they have used it to explore possible futures through scenarios. By taking major trends in society, such as the growth of population or the growth in the standard of living, they were able to examine the likely future effects of such trends continuing in a very subtle way. The model, obeying as it does, the laws of physics, cannot, for example, resolve an exponential growth in the use of water (as required, say, by an assumed steady increase in the standard of living), with the physical reality of the continent's finite stock of water, regardless of any political, social or economic requirements to the contrary. There are only so many water molecules to go around. Thus, unlike many economic models, which make assumptions about the system striving for equilibrium, the CSIRO model simply will not bend the scientific laws of reality. Instead, it reports such problems as tensions or dilemmas.

This unique ability to identify dilemmas in scenarios gives the model its power and utility. The development of scenarios allows us to examine the future in terms of an envelope of possibilities, and the identification of the dilemmas allows us to zoom in on potential problems that will need our attention, our careful consideration and our action, if they are to be resolved.

So, the CSIRO modellers acknowledge Cassandra, she of the foreknowledge, but in a very modern way. They describe an envelope of possible futures, and then, within that, warn, as she would have done, of likely problems. But, unlike Cassandra, they offer with that foreknowledge the chance to examine and resolve the dilemmas before they come to be, by providing a solid scientific framework for the public debate.

Dr. Roger Bradbury, Chair, External Reference Group

Executive summary

1 **Three population scenarios are physically feasible to 2050**

Using an analytical framework which represented the physical transactions underpinning the Australian economy, this study compared the effect of three population scenarios on infrastructure, resource and environmental issues out to the year 2050. The three population scenarios were determined by net immigration rates of (i) zero persons per year, (ii) 70,000 persons per year, and (iii) two thirds of one percent (0.67%) of the current population size each year. These population scenarios were meant to reflect approximately (i) the policy position of some environmental organisations (ii) the most likely outcome of current immigration program settings and (iii) the population growth rate preferred by Australian business interests. After the many permutations and combinations of numerous simulation experiments, all three scenarios were found to be physically feasible. All three scenarios carry with them a number of rewards and risks that merit wider public debate by proponents of each policy position. More detailed analysis of the many issues that lie outside the terms of reference of this research report, would also benefit from such debate.

2 **The zero scenario gives close to 20 million people by 2050**

The zero scenario sees a domestic population of 20 million by 2050. The rewards of this scenario include smaller increases in energy usage and subsequent emissions, potentially more robust physical trade balances and perhaps the opportunity to focus on refurbishing national infrastructure, rather than making more of it. The risks include the possibility that mature aged workers may have to work longer and harder, a potential loss in economic confidence if the nation cannot replace economic growth due to population increase with another source, the potential for terminal population decline if birthrates do not increase, and the problem of decline in rural areas and some regional cities.

3 **The base case scenario gives 25 million people by 2050**

The base case scenario gives 25 million people by 2050 and that population size should be maintained indefinitely if the assumed birth rates and immigration rates are maintained. This scenario involves continuing growth in a number of major cities and regions, perhaps the continuance of current beliefs as an aid to innovation, a steady progression to a more or less balanced population size and structure by 2050, the potential to refurbish the physical metabolism of our urban areas under conditions of moderate growth, and options to enhance the transition from the old economy to the new economy. The risks of the base case scenario include the potential to stay with moderate but inadequate measures of environmental management because they are comfortable and known, and a retention of the old industries because they are profitable and historic.

4 **The 0.67%pa scenario gives 32 million people by 2050**

With net immigration of 0.67%pa, Australia's population increases to 32 million people by 2050, and to 50 million people by 2100. The rewards of this scenario lie with a continually growing economy, a strong home base from which to mount export industries, possible synergies that come from service clusters and competition, and the formation of a number of world-sized cities to act as hubs for international commerce. The risks lie with the potential for continually expanding energy use and greenhouse emissions together with a potential decoupling of the large urban agglomerations from the base of ecosystem services that support their lifestyle and function.

5 **Ten important issues**

Running parallel to the direct population effects posed by the three population scenarios, the study has identified ten major issues that must be dealt with during the next human generation, whatever the population number and structure by 2050 and 2100.

- Air emissions in city airsheds and traffic congestion
- Dependence for personal mobility on continuing supplies of oil and natural gas
- Loss of land in the agricultural heartlands and increasing salinity levels in river systems
- Dependence of physical trade exports on old economy manufactures and commodities
- The place of mature-aged citizens in the national workforce
- Greenhouse gas emissions from the fossil energy sector
- The per capita levels of material flow underpinning the monetary economy
- The energy and material content of personal consumption
- Incentives for large-scale investment in long term natural capital
- The steady transition from an old 'physical' economy to a new 'brain' economy

6 **Four levels of population influence**

In accounting for the direct and indirect effects of population on resource availability and environmental quality, the study has proposed four levels of population influence (direct influence to more diffuse influence). Behind these levels is the assumption that over the long term, all national management is eventually undertaken for the good and betterment of the nation's citizens. The first level is a direct one where a population has basic requirements of food, water, habitation and transport. The second level relates to the effects of lifestyle and scale where rising standards of living enable more sophisticated requirements to be met. This can have both positive influences (better systems of environmental management) and less positive influences on resource use (more leisure time, more short holidays, more transport energy usage and more greenhouse gas emissions). The third level relates to the physical trade effect whereby Australia exports of goods and services are exchanged for imports. The physical trade balance is the physical component of the nation's balance of trade accounting where goods from agriculture, mining and manufacturing contribute to payments for imports. The fourth level relates to the level of international debt. Positive population influences occur when moderate imports and strong exports produce lower international debt levels and a more resilient economic structure. The opposite is true over the long term, when higher imports and lower exports increase international debt levels and potentially increase the complexity of managing the nation's future affairs.

7 **Where will new cities be located?**

The key urban issues in all scenarios relate to the increasing material flows into our cities, and the degree to which this continues to grow as population grows and affluence increases. There are many opportunities for technological and management efficiencies but there is little evidence of major change. Adoption of the higher population scenarios would require a decision on whether to grow the current cities on their margins, or form new cities. If the latter option were chosen, by 2100 under the 0.67%pa scenario, the equivalent of 90 cities the size of Canberra would have to be located and established.

8 **Bold actions required for farmlands and rivers**
Most resource issues relate to the broadscale loss of land in the farming heartlands, the prospect of increasing river salinity and river depletion and the continuing loss of habitat and biodiversity resources. Bold actions are required under all population scenarios: for example it may be necessary to reforest and refurbish 10 to 20 million hectares of cleared land. This might reverse the broadscale slow moving trends now underway, but the physical and monetary requirements of such a proposal are enormous.

9 **Greenhouse gas targets may not be achieved**
The underpinning of current national productivity and lifestyle by fossil energy resources, and the complement of current technologies will continue to see total greenhouse gas emissions growing for all population scenarios, even if advanced technologies are implemented. A combination of the zero population scenario and a 'factor-4' economy (a radical innovation in material processing) does bring greenhouse emissions close to the 1990 benchmark levels, but this is considered an unlikely combination. The supplies of domestic oil and gas are critical to the nation's mobility and constraints on availability may occur after 2030. Strategic options for transport fuels should be explored with time horizons of the next 50 to 100 years.

10 **Water use set to double**
Water extraction from the managed water system is simulated to increase from its current level of 24,000 gigalitres per year to over 40,000 gigalitres per year in line with continued growth in agricultural production under all population scenarios. Supply constraints mean that the only way to meet these expectations would be through a major expansion of irrigated agriculture in northern Australia. Such expansion brings many risks, not least the risk of irrigation salinity and river decline, but this need not be so. While population size strongly influences the need for urban water, transfers from current agricultural usage are expected to maintain requirements in most areas. The location of new cities is critical for the 0.67%pa scenario in the period 2050 to 2100, when large urban concentrations might outgrow regional water availability. While urban water systems are sometimes characterised as being creaky with age and under-investment, with the right mix of technology and policy innovation, we should be able to maintain water quality particularly if the integrity of city water catchments, and their ecosystem services, are improved.

11 **The physical economy**
For much of the twentieth century, growth and development proceeded unhindered by any shortage of natural resources. That situation may well continue in this century as technological innovation and substitution of materials (eg ceramics for metals) continue. While the concept of limits is still hotly debated by opposing ideologies, it is apparent that the capacity of the natural world to assimilate the waste and effluent from modern industrialised economies is reaching its limits. Thus, productive agricultural systems in Europe pollute water bodies and natural vegetation with overflows of nutrients. Modern cities accumulate a wide range of toxic materials caused by the products of both industrial metabolism, and personal consumption. Understanding the physical dimensions of modern economic systems is central to the concept of ecologically sustainable development (ESD). The philosophy of the physical world that underpins the monetary economy has been implemented in the *Australian Stocks and Flows Framework* used in this study. Some of the outcomes of the study will inevitably differ with contemporary viewpoints. However in time, the 'physical economy' viewpoint should develop

as a strong complement to traditional macro-economic analysis, as both streams of national analysis are used together.

12 **Resource use and the rebound effect**

When technical efficiencies are introduced into a nation's energy system or its farming, fishing and mining sectors, it is often assumed that the resource requirements from the physical economy will stabilise and then fall, as the innovation penetrates the production system. In fact, resource use generally increases as production efficiencies improve. In both the physical and monetary economies this perverse outcome is termed the 'rebound effect'. This study has not implemented the rebound effect in any of the technological innovations simulated in the various scenarios. It is therefore possible that we may have underestimated simulations of resource use, pollution generation and personal affluence effects. Managing the rebound effect within the physical economy is one of the greatest challenges to national policy design, whatever population and development options are chosen for Australia's future.

13 **Six core dilemmas requiring national policy consideration**

While there is no single solution to the complete set of options and challenges facing the nation over the next 50 years, six core dilemmas posed by the population scenarios are presented. These relate to population ageing, physical trade balances, energy use and greenhouse gas emissions, per capita material flows, resource availability and environmental quality. It is perhaps possible for a concerted policy attack on two or even three dilemmas in unison, but there are many interactions, where advances in one area can undermine the function of another. Perhaps a revolution in thinking is needed before a combined resolution of the six dilemmas is possible.

14 **Australian affluence and lifestyle**

At the core of the analyst's inability to design more reasonable environmental outcomes for the three population scenarios is the issue of physical affluence and lifestyle, that is the degree to which energy and material flows are entrenched in our daily lives. In general, even an aggressive implementation of technological innovations did not solve the challenge satisfactorily. Under the current economic and social structure, the growth of lifestyle and affluence represent important stimuli to economic growth. More thought and analysis of the energy and material implications of Australian lifestyle patterns and trends are required before reasonable conclusions and new designs, can be proposed.

15 **Population proponents and defence of their scenarios**

Finally in drawing a list of 10 conclusions in Chapter 7, a set of challenges is presented to the policy proponents of the three scenarios. This is an attempt to set some boundary conditions for the next round of the national population debate. The zero scenario proponents might suggest how economic growth rates can be maintained in the face of a declining population. The base case scenario proponents might develop detailed plans to deal with greenhouse gas emissions, land loss, river salinity and urban air emissions. The 0.67%pa scenario proponents might present well honed plans on the location of 90 new cities the size of Canberra over the next 100 years, greenhouse issues, oil and gas availability and everything else as well. While there is much work to be done by the proponents of each scenario option, this analysis should facilitate innovative thinking by highlighting the nature and the scale of the many challenges that face Australia over the next two human generations.

Chapter 1
Modelling physical realities

ABSTRACT

The concept of sustainability, fossil energy use and greenhouse negotiations, population policy and lifestyle options are all linked to environmental quality in the long term. This does not mean that larger populations live less sustainably than smaller ones. Nor does it assume that technology will find a way to overcome all environmental challenges or constraints to resource use. This opening methodological chapter makes three key points. Firstly, sustainability must deal with the long term. Secondly, long-term issues must be explored with long-term methods which quantify slow moving variables such as population momentum and infrastructure inertia. Thirdly, decision makers must be comfortable with long-term 'beyond the horizon' analyses and accept that such analyses are a valid and necessary part of the national policy process.

In order to examine the long-term consequences of many policy interactions, analytical frameworks are required to design and test different functions and structures for the physical economy. The term 'physical economy' is coined to describe the vast array of physical transactions which underpin the monetary economy. For every dollar exchanged in Australia's gross domestic product, there is a chain of physical transactions that bring that final good or service to the shopkeeper's counter and the consumer's basket. In Australia, more than 200 tonnes per person per year must be moved to supply our essentials, our lifestyle and the exports needed to pay for our imports. By contrast, Japan moves around 40 tonnes, while the USA moves 80 tonnes per person.

The ability to analyse these transactions is described within two analytical frameworks, the Australian Stocks and Flows Framework and the *OzEcco* embodied energy flows model. The first (ASFF) is a set of 32 linked calculators which follow, and account for, the important physical actions that underpin our everyday life. The second (*OzEcco*) is based on the concept of embodied energy, the chain of energy flows from oil well and coal mine which eventually are included or embodied in every good and service in both the domestic and export part of our economy. Both analytical frameworks are based on systems theory and implemented in a dynamic rather than an equilibrium approach. This allows transition pathways towards new states of the physical economy to be designed and tested for physical feasibility using concepts of age and inertia. These concepts are critical to the process of infrastructure renewal and market penetration by new technologies. The concept of physical feasibility is important, but does not reflect feasibility in a political, social or economic sense.

While these approaches are relatively novel in Australian and international policy terms, the underlying concepts are slowly gaining acceptance in parallel to a range of policy debates that are underpinned by physical realities. Energy and greenhouse, land degradation and river salinity, population growth and air emissions, oil depletion and transportation systems all represent physical realities with slow moving response times to policy interventions. Current use of the modelling frameworks is focussed on long-term population policy, land and water futures, fisheries management and the de-carbonisation of the transport fuels cycle. Importantly, the frameworks are used with clients and stakeholders. Understanding the physical issues involved is a vital precursor to accepting the radical redesigns of Australia's physical economy that may be required if the concepts behind sustainability are to be eventually implemented.

INTRODUCTION

Public policy, world views and analytical approaches

The capacity for public policy analysis and decision making implies that people have a choice: the future is not pre-determined but can be influenced by what we decide to do. There are many alternatives from which we might choose and the choice to do nothing, is a wilful one (Robbert

Associates, 2000). Within this context, some of the more difficult issues of public policy involve balancing longer-term societal interests and shorter-term individual or private interests. This is particularly so in the case of public policy concerned with the environment, natural resource management and public health. Many of these problems involve externalities — situations where the activities undertaken by one individual or group in pursuit of its objectives, have adverse unintended consequences for other individuals, groups or society at large. Some externalities are characterised as 'problems of the commons' where the lack of a clear and just system of property rights, decouples the link between shorter-term opportunities, from a longer-term possibility of a run down in system function or productivity. The issues of global climate change and marine fisheries are typical examples where short-term expediency can lead society to overload the waste assimilation capacity of the atmosphere, or to over-harvest particular fish resources in wild fisheries.

Science can help to identify and resolve environmental and resource management issues. Where common resources (atmosphere, marine fisheries, rangelands) are at stake, science is able to quantify their state, as well as possible pathways along which they might evolve. Science might estimate concepts such as sustainable yield as well as providing the basis for technologies which might reduce externalities, or increase productivity. However science as a discipline is limited in its ability to comprehend policy analysis, since this process requires a fuller understanding of how institutional and political systems might change in response to a particular policy innovation or new technology. Various processes such as expert panels, computer modelling and community workshops can help bridge the gap between science and policy development with different levels of success. Systems simulators offer another scientific approach which combines observations of past states of the system with an understanding of the drivers of the system. This can provide the foundation for active learning on how the simulated system responds to policy intervention and technological innovation.

Over the last 40 years, system simulators have been used to aid integrated policy advice with mixed success. The scenarios developed and tested by The Club of Rome *World* models in the early 1970s (Meadows et al., 1972, 1992) were widely interpreted as predictions. Today those predictions are judged by many to have been incorrect, particularly in regard to resource depletion issues. However, The Club of Rome scenarios ran until 2070, and many issues (fisheries collapse, environmental pollution and social equity) examined in their scenarios are supported by an increasing weight of evidence (Ehrlich and Ehrlich, 2002). Many large systems simulators of global climate systems have gained wide acceptance in global science and policy circles. These simulators link issues such as population growth, energy use, agriculture, forestry, water use and so on to climate dynamics at a global level. A new era appears to be emerging where policy deliberations are again open to simulation approaches of this type.

This fledgling era of policy analysis has strong links to core debates of nearly two centuries ago. In an effort to tease apart some of the foundations of current and future policy debating platforms, four quadrants of world view and analytical paradigm are proposed (Figure 1.1). These are derived from analytical views that are either 'technologically guarded' or 'technologically optimistic', and whether those world views are guided by an understanding of the 'momentum' embodied in population growth and economic growth, or the 'inertia' embodied in national infrastructure and societal institutions. Being 'guarded or optimistic' about the prospects of technological innovation is neither right nor wrong. Rather it helps classify a philosophical foundation and the analytical procedures used to promulgate those views (the glass 'half empty' versus the glass 'half full' analogy).

The understanding of momentum (quantity of motion) in an economic and demographic sense is based on an understanding of the structure of human populations and monetary economies, the potential for growth, and the time required before a different structure of population or economy can be reached. The understanding of inertia (sluggishness) in an infrastructural and institutional sense is derived from the observation that infrastructure (houses, roads, bridges, power plants) and institutions (courts, laws, parliaments, schools, business affiliations) have a wide range of characteristics that enforce their current structure and limit the rate of change. This inertia restricts the capacity of new technologies and new modes of organisation to replace the status quo. The mapping of a particular policy approach or method of analysis in the four quadrants helps us describe the methods used, the disciplinary base of the analysts and ways in which the results might be extended into policy relevant discussions.

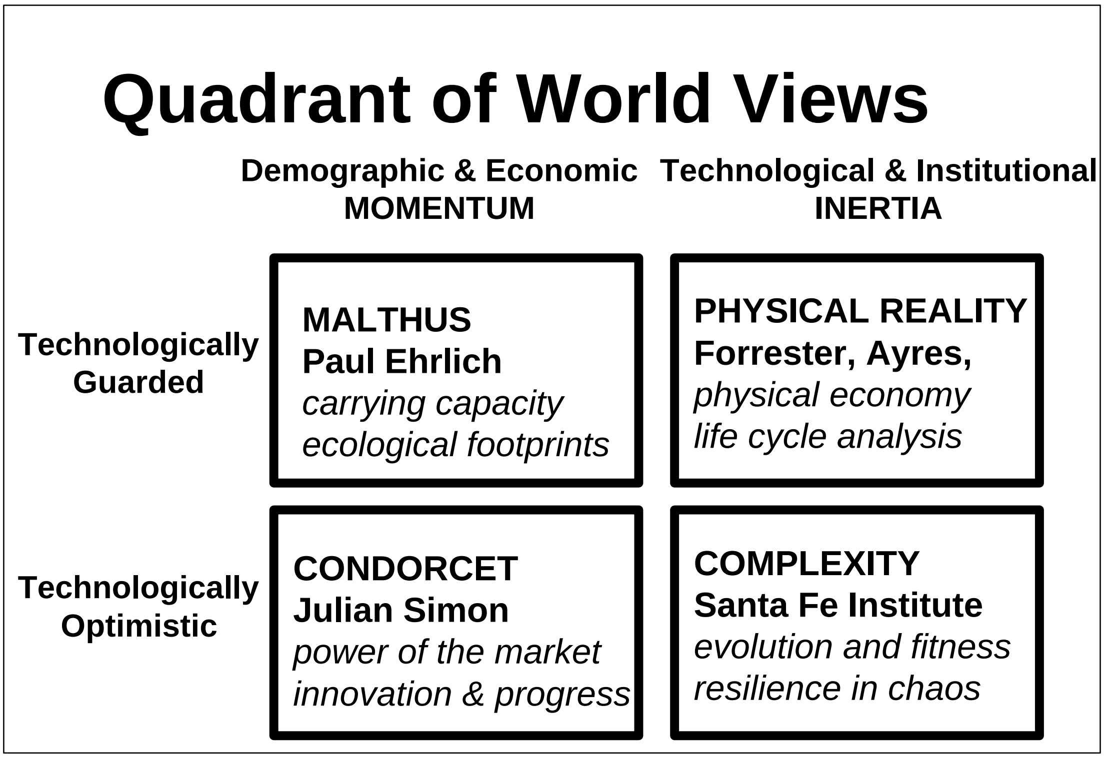


Figure 1.1. An organising framework of four world views within scientific disciplines. Different world views determine how people understand, analyse and act on the realities within the physical economy.

When the Reverend Thomas R. Malthus first wrote his essay, *A Summary View of the Principle of Population* as a supplement to the 1824 version of the *Encyclopaedia Britannica* (Mentor Books, 1960), he would not have expected the debate to still be raging at the start of the second millennium. Scientists such as Paul Ehrlich (1968) and Lester Brown (1998) still propose that continuing population growth and linked lifestyle and resource consumption pose a serious threat to the ecological integrity of world ecosystems. The analytical philosophies used in this quadrant (technologically guarded, demographic and economic momentum) are well versed in demography, ecology, pollution generation and use of natural resources. The concepts of human carrying capacity (Cohen, 1995) and ecological footprints (Wackernagel and Rees, 1996) are good examples of concepts developed in this quadrant. These analyses are based on comprehensive data and are relatively straight forward. As such they often attract criticism because they are seen as static (rather than dynamic), present problems (rather than solutions) and they ignore much of humankind's history of innovation and progress.

In the same era when Malthus was promoting the world view of the first quadrant, Marquis de Condorcet was promoting the views of the technologically optimistic group (University of Berkeley, 2000). He espoused that the richness of the human spirit had the potential to overcome all odds, and that there was no limit to humankind's capacity to invent and solve. These views are still being repeated and many of Condorcet's disciples, most notably Julian Simon (1990) and Boserup (1999), have won a number of important debating points over the their technologically guarded colleagues.

The analytical methods of this group generally include many economic approaches most notably the computable generalised equilibrium (CGE) models at the heart of national decision making in macro-economic areas for most developed economies. In Australia these include the MONASH model (formerly the ORANI Model) developed at Monash University, the TRYM model used by Commonwealth Treasury, the Murphy Model used by the private firm EconTech and the Salter Model used by the Federal Department of Foreign Affairs and Trade (EPAC, 1994). Some criticisms directed at this analytical approach include the 'absence of equilibrium' in most functional economic and natural systems and the limited long-term validity of the behavioural assumptions that describe the concept of elasticity. Nevertheless, such approaches are underpinned by an extensive body of theory and data and represent a comprehensive understanding of how economic structures react to policy innovation and shocks, particularly in the short term.

Adherents to the third quadrant are technologically guarded and attuned to the inertia in most infrastructure and institutional systems. This approach is typified by the work of Ayres (1998), Slesser et al. (1997) and Forrester (1961) and has two key components not found in the left hand quadrants of Figure 1.1. These proponents argue that the economic and social world views are within the physical world, and must therefore eventually conform to physical laws. These laws include the laws of thermodynamics and mass balance which impose constraints on the optimism of the world views residing in the second quadrant. The physical realists use dynamic systems modelling techniques to enhance the analysis and understanding of dynamics. They avoid assumptions of notional equilibrium structures or resting points, where all forces are in balance. They also seek to ensure that important forces such as population growth and economic growth are linked to the biophysical realities of resource requirements, and the production of waste and pollution. Critics of this approach question the degree to which improvements in human management, substitution between materials, and innovation are excluded from modelling considerations. The modelling approaches used in this study (ASFF and *OzEcco*) lie predominantly within this third quadrant, but use theory and data from other quadrants.

The fourth quadrant includes those who are both technologically optimistic and also aware of inertias in infrastructure and institutions. Their work is typified by the complex systems research underway in the Santa Fe Institute USA (Santa Fe Institute, 2000) and made popular by concepts such as emergent properties (Ruitenbeek and Cartier, 2001) and books such as *Complexity* (Waldrop, 1994). The complexity quadrant brings together seemingly disparate groups such as evolutionists, economists, ecologists and pure mathematicians to help foster order and understanding on complexity and chaos from the level of genes to money markets to climate systems and the intricacies of the future human mind. The overall methodological approach employed by this quadrant is difficult to typify beyond being based on complex mathematics, agent based modelling and advanced analytical approaches. A criticism of the approach might be that it is difficult for a policy analyst to understand and apply, outside its immediate research environment.

Population-development-environment studies in Australia

The development of economy-wide modelling in environmental issues was stimulated in Australia by the continuing population debate. The concepts of population targets and carrying capacity were introduced into Australia starting in the 1920s when a Sydney university geographer Thomas Griffith Taylor set Australia's estimated carrying capacity at 65 million people and later reduced this estimate to 20 million people (Cocks, 1996). The 1980s and 1990s have seen several national inquiries on population, the most recent of which, the Jones Inquiry (Long Term Strategies Committee, 1994), stopped short of recommending a national population policy (Cocks, 1996). By default, Australia's population seems to be moving towards a more or less stable number of around 23-25 million people within one or two human generations. During the 1990s, the national population debate evolved to cover a wide range of issues such as resilience of ecological systems, material consumption levels, sustainability issues and population size as a determinant of domestic market efficiencies and Australia's place in world affairs.

It was against this background that CSIRO initiated a strategic project to underpin the population debate, and its linkages to resource use and environmental quality, with scientific analysis. The project's initial aim was to focus on the environmental aspects of population impact with particular emphasis on the quality and quantity aspects of water, soils, biodiversity, atmosphere and natural amenity. Initially the work followed a conventional scientific route to examine the effect of population on water resources, land resources and so on. However because of the complex linkages between all sectors of society and the economy, this approach would have been difficult to implement. In addition, the project was challenged with a future focused and long-term topic which required integrated advice and a range of possible solutions. At this time the project became aware of two important methodological approaches. The first was the work of Godet (1991) on *strategic prospectives* and thence the use of foresighting and scenario development by multinational companies such as Royal Dutch Shell. The second was the implementation of population-development-environment simulators, particularly the work by IIASA in Mauritius (Lutz, 1994), the physical analysis paradigm using the design approach (Gault et al., 1987) and the embodied energy approach of Slesser (1992) and Slesser et al. (1997).

The project design then evolved to "influencing national policy agenda in regard to population policy and the impact of humans on the environment". Two linked themes of work emerged; first scenario development, proposed a number of robust and well documented national scenarios to lead and inform debate on national development and sustainability issues. Three scenarios, *Economic Growth*, *Conservative Development* and *Post Materialism* have been published in book form (Cocks, 1999). The second theme of work developed in order to underpin the scenario work with quantitative analyses. Two system simulators were developed based on different paradigms of physical analysis. One of these, *OzEcco* (Foran and Crane, 1998), used the embodied energy approach of Slesser (1992, 1997) to construct a top-down and aggregated simulator of Australia's physical economy. This analytical approach assumes that the delivery of goods and services to a domestic economy, and its human population, is a function of the extraction, delivery and efficiency of use of energy resources, most of which are derived from fossil sources.

The second simulator, the *Australian Stocks and Flows Framework* (ASFF), was a disaggregated set of linked models which access a database describing the last 50 years of Australia's physical function or physical metabolism. The 'design approach' used by ASFF is philosophically attractive for two reasons: firstly it treats the complete range of physical functions as separate entities (crops, animals, people, cars, steel production, chemical production) and allows a detailed treatment of 'vintaging' or age for most big-ticket items of physical infrastructure. Secondly, physical functioning is retained within the modelling code and termed 'machine space'. The management and policy decisions that guide this physical functioning are retained as part of a scenario under development and testing by the user or policy analyst and are termed 'control space'. Gault et al. (1987) describe the design approach in the quotation which follows:

> The design approach is a philosophy for building computer based simulation frameworks, which represent socio-economic systems, and for using the simulation framework to design alternative futures through repeated simulation. It is the exploration of alternative futures by the user, who forms part of the system, which distinguishes this approach from that of macro-economics with its emphasis on prediction. The exploration and the involvement of the user result from the absence of optimisation or equilibrating mechanisms in the physical representation of the socio-economic system. This ensures that the user, working alone or with the aid of a model of decision processes, controls the system. The policy decisions necessary to exercising this control are required to be explicitly stated,

and they form a record of how the future, resulting from the simulation, was arrived at.

The following sections describe the system simulators in more detail. For reference purposes, an example of a global approach to physical modelling — the IMAGE global change model (Alcamo et al., 1994; 1998) — is also included. This model has been used in a wide range of international policy studies. Some examples of model use within policy and science processes are also described in this chapter as well as some challenges for these analytical approaches in achieving a goal of 'influencing national policy'. The chapter concludes with some insights into the many conundrums which researchers face when they use integrative modelling of the physical economy to implement approaches of this type.

MODEL DESCRIPTIONS

Models of global climate change

The issue of global climate change has stimulated the development and use of a large variety of modelling frameworks. Some of them deal comprehensively with one issue, such as carbon metabolism at a global level, and others attempt to integrate all important issues in an approach termed 'integrative assessment' (Goudriaan et al., 1999). An example of the latter is IMAGE (Alcamo et al., 1994; 1998) developed by the National Institute for Public Health and the Environment in The Netherlands. It combines three distinct areas: the energy-industry system, the terrestrial-environment system and the atmosphere-ocean system (Figure 1.2). The nationally scaled models described next in this chapter use the first two of these systems but lack the ocean-atmosphere system. The key difference between this approach and the latter ones is one of scale. IMAGE models the physical metabolism of the entire globe in 13 different regions, whereas the national models deal with one nation described by many sub-divisions.

The IMAGE model links the effects of human management through the full chain of physical processes that run the globe. Thus, population growth and increased per capita affluence cause land use change and increasing energy use, all of which increase the emissions of carbon dioxide and other greenhouse gases such as methane. These emissions cause changes in function of the earth-ocean system, leading to changes in rainfall and temperature which, over the duration of the model simulations, can feed back to affect sectors such as agricultural productivity and water yield from catchments. While models such as IMAGE are generally used to test scenarios, they can also be used for prediction and back(hind)-casting. In prediction mode, model analysts make assumptions covering the full range of possibilities for the driving forces.

The simulation outputs include issues such as atmospheric concentrations of greenhouse gases, temperature changes, rises in sea levels and changes in agricultural productivity. Since the future is relatively unknown, such assumptions usually include a full range of sensitivity testing so that ranges of error, or probabilities of outcomes, can be measured. After making predictions, the model can then be used for back-casting. In this case, key assumptions that drive global climate change (population growth, fossil energy use, land use change) are altered in an attempt to reduce or change the nature or the severity of the initially simulated outcome. Using the model in this way, can give new insights or understanding leading to improved policy design and targets for technological innovation. At some stage in the global simulation process, these broader insights must be applied on a national scale, where more detailed investigations are required to substantiate the social and political changes required. This is where the more detailed national modelling is required.

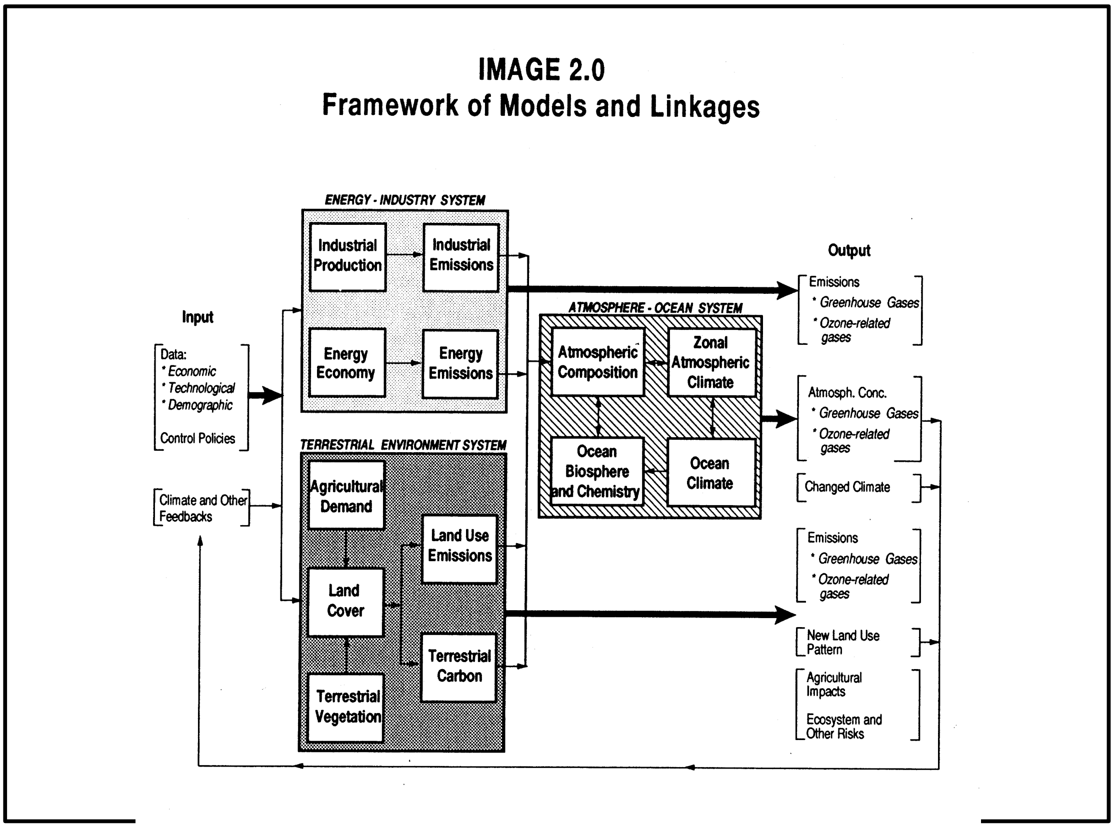


Figure 1.2. A schematic representation of the IMAGE 2.0 integrated assessment model (From Alcamo et al., 1994)

The *OzEcco* embodied energy model

The *OzEcco* model is designed to integrate the driving forces of population, lifestyle, organisation and technology and to explore their possible impacts on the environment within the context of Australia's physical and economic structure. The model integrates the structure of the national economy and its energy accounts so that capital stocks are expressed in a physical measure of petajoules of embodied energy rather than in monetary terms. Activities within the economy are expressed as energy flows, in petajoules per year. In this way, economic activity has been converted to physical activity, which is consistent with the first and second laws of thermodynamics. All economic transactions are represented by the physical transformations which underpin them. This representation is consistent with the long term physical processes which are central to the functioning of any modern economy.

Conceptually the *OzEcco* model has five broad components: natural resource stocks, the energy transformation sectors, consumption activities, pollution generation and whole system indicators. The core modelling concept is that access to and transformation of energy (typically stocks of fossil fuel) are the determinants of physical growth in a modern industrial economy. Thus, all goods and services are expressed in terms of the chain of energy processes that eventually become included (embodied) in a final good (a motor car) or a service (banking and education). Some sectors, such as domestic housing, act as long-term accumulators of fixed energy capital (embodied energy), whereas personal consumption dissipates embodied energy relatively quickly. The concept is shown in Figure 1.3. The capital stock of industry (stock of embodied energy) is the primary focus through which human made capital is created. Industry contributes to other sectors such as agriculture (fertiliser, machines), domestic housing (bricks, carpets, stoves) and so on.

.

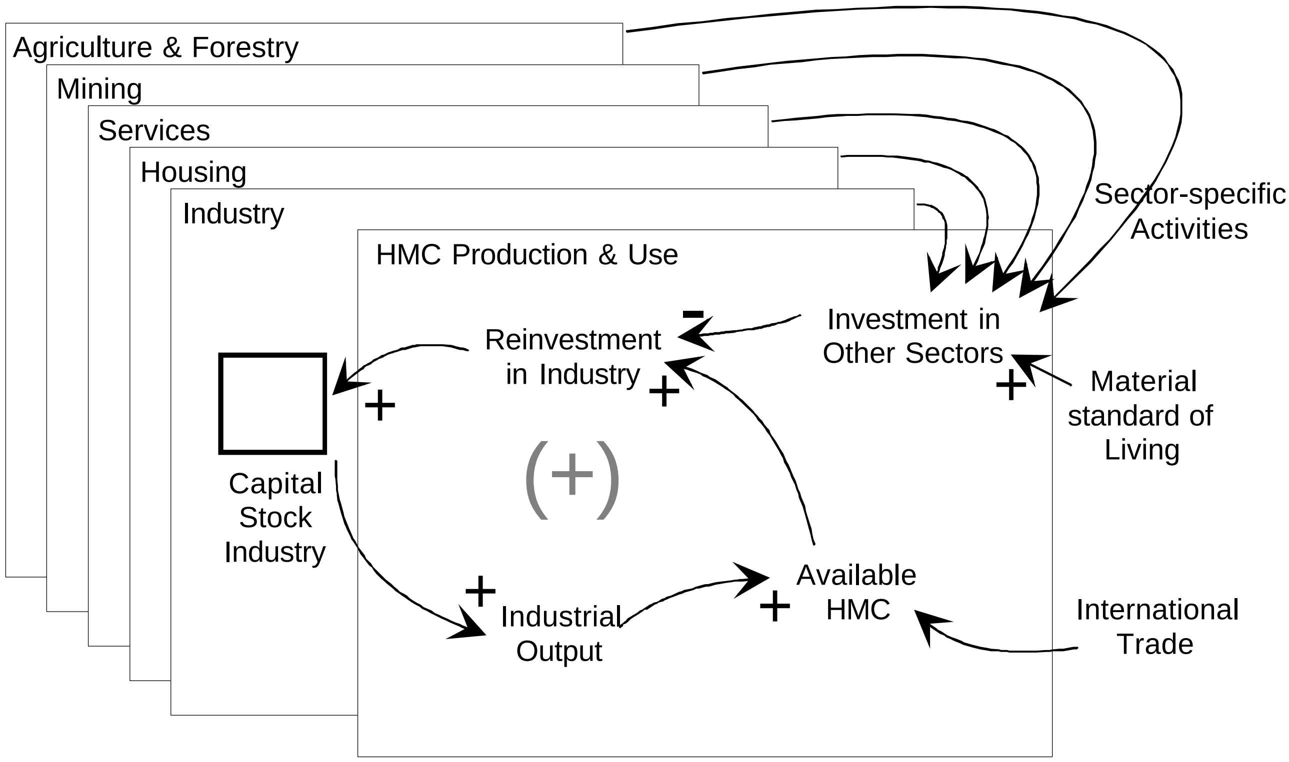


Figure 1.3. The central growth-determining loop in the *OzEcco* model, with the aggregated industrial sector depicted here as the core resource for growth. The processes of fixed, or human made, capital (HMC in diagram) are depicted as an influence diagram, illustrating the main causative features represented in the model. The total human made capital available is the sum of imports and domestic production.

The rate at which industry can grow in a year is limited by the contribution which this sector makes to other sectors of the physical economy and the consumption activities of the population at large. Both of these activities (industrial growth and personal consumption) act as negative feedbacks to restrict the rate at which the physical economy can grow. The effects of international trade and financial flows can be both positive and negative. Exports are regarded as negative because they reduce the amount of embodied energy that can be used nationally. Physical imports and monetary inflows are interpreted as positive influences because they increase a nations capability to undertake physical work. All of these factors are linked in a systems dynamics framework (Richardson and Pugh, 1981). The simulated economy is allowed to grow as fast as is physically feasible (governed by the first and second laws of thermodynamics) in a physical economy constrained by the availability of fossil energy, and the requirement to maintain national infrastructure together with personal consumption activities. Global monetary issues (e.g. balance of payments and international debt) are regarded as flows and stocks of virtual embodied energy which, in the short term, might override a number of resource and infrastructure issues confronting the physical economy.

For a number of reasons, both the science and the policy community have found it difficult to accept the *OzEcco* approach. The use of an integrating concept such as embodied energy is difficult for some policy analysts to comprehend, although it is functionally similar to the use of money as a numeriare in economic analysis. However, two recent developments in the energy and greenhouse area of the physical economy have increased the potential acceptability of this approach. The first is the acceptance of static analyses of energy embodiment using input-output tables of the monetary economy to determine the energy use and greenhouse gas generation by different sectors of the economy (Lenzen, 1998). The second is the use of *OzEcco* in designing transitions towards a biomass based transportation cycle, which is attracting a degree of national technical interest (Foran and Mardon, 1999; Foran and Crane, 2000).

The Australian stocks and flows framework (ASFF)

General description

ASFF is a highly disaggregated simulation framework which keeps track of all physically significant stocks and flows in the Australian socio-economic system. In this context, stocks include people, livestock, trees, buildings, vehicles, capital machinery, infrastructure, land, air, water, energy and mineral resources — disaggregated, as appropriate, according to their physical characteristics and importantly, age or 'vintage'. Flows, resulting from physical processes of many kinds, represent the rates of change of stocks and constitute the development of the system in more or less desirable directions.

The framework contains a simulation model and a database. The model consists of 32 hierarchically connected modules or calculators which account for the physical processes of demography, consumption, buildings, transport, construction, manufacturing, energy supply, agriculture, forestry, fishing, mining, land, water and air resources and international trade. Each calculator deals with the stocks and flows relevant to a sector and with the physical processes through which they interact.

Calculator assumptions are based on technical and scientific understanding of the processes involved and are intended to provide a plausible representation in physical terms of the workings of the sector. One of the criteria used to validate the calculator, is that a professionally informed person should be able to understand its structure and conclude that the process description and the parameter values, are plausible and appropriate to the level of aggregation of the treatment.

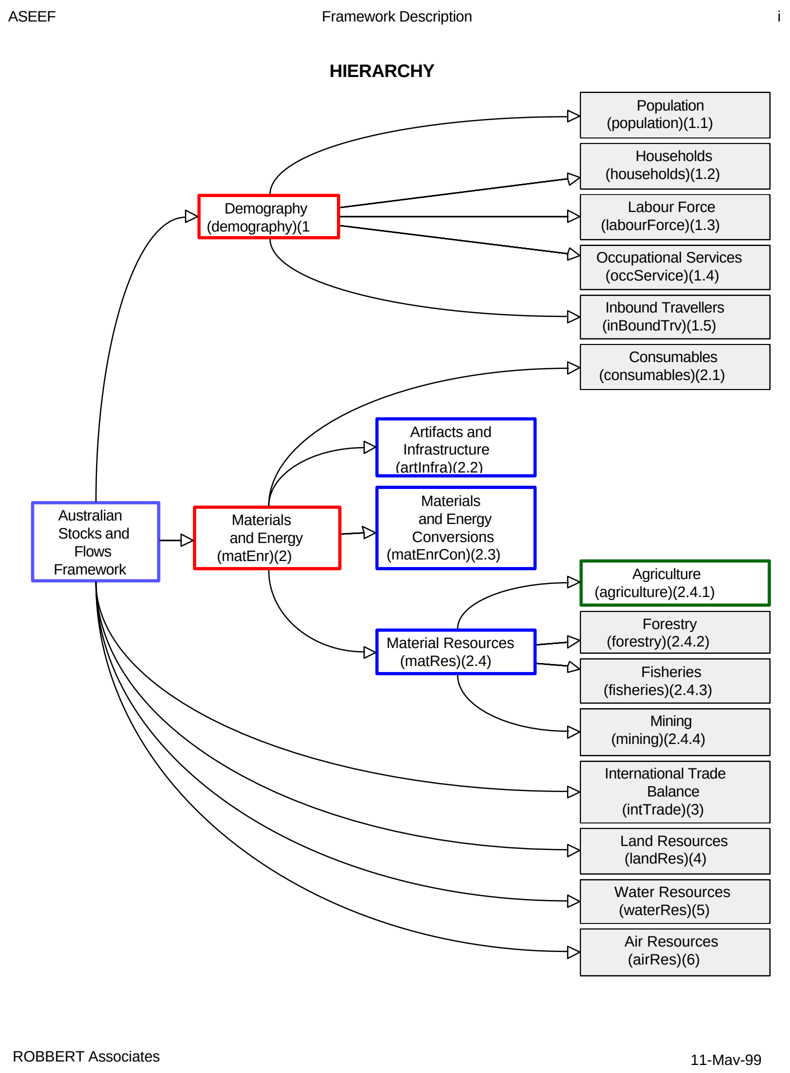
An overview of the whole framework is given in Figure 1.4, where the arrows link calculators arranged in functionally similar and hierarchically related groups (note that the arrows do not represent sector linkages or information flows, — these are shown in Figure 1.5).

The model calculators

At the highest level, the Australian socio-economic system is conceived of in terms of people (**Demography**) and the physical needs of their way of life (**Materials and Energy**). Population is an important driver in the framework and, other things being equal, more people require more materials and energy. Other things are not necessarily equal, and one of the goals of the ASFF approach is to explore the interplay and trade-offs among issues such as Population, Lifestyle, Organisation and Technology, — the PLOT factors.

The five **Demography** calculators deal with population (including overseas and internal migration) and issues which depend directly on population and its distribution over age, sex and location: education needs, morbidity and health needs, internal travel, household formation, labour force participation, demand for personal services and inbound tourism. Population and inbound tourist numbers are independent drivers in the framework, that is, the parameters which determine their level and growth are specified outside the model in the control space. Information from these demography calculators is passed to later calculators and used to determine the requirements for infrastructure, goods and services of all types.

The **Consumables** calculator determines the need for food and other consumable items directly from population (including overseas visitors) on a per capita basis. The four **Buildings** calculators use information from demography to determine the needs of the population for residential, commercial, educational, health care and institutional buildings.



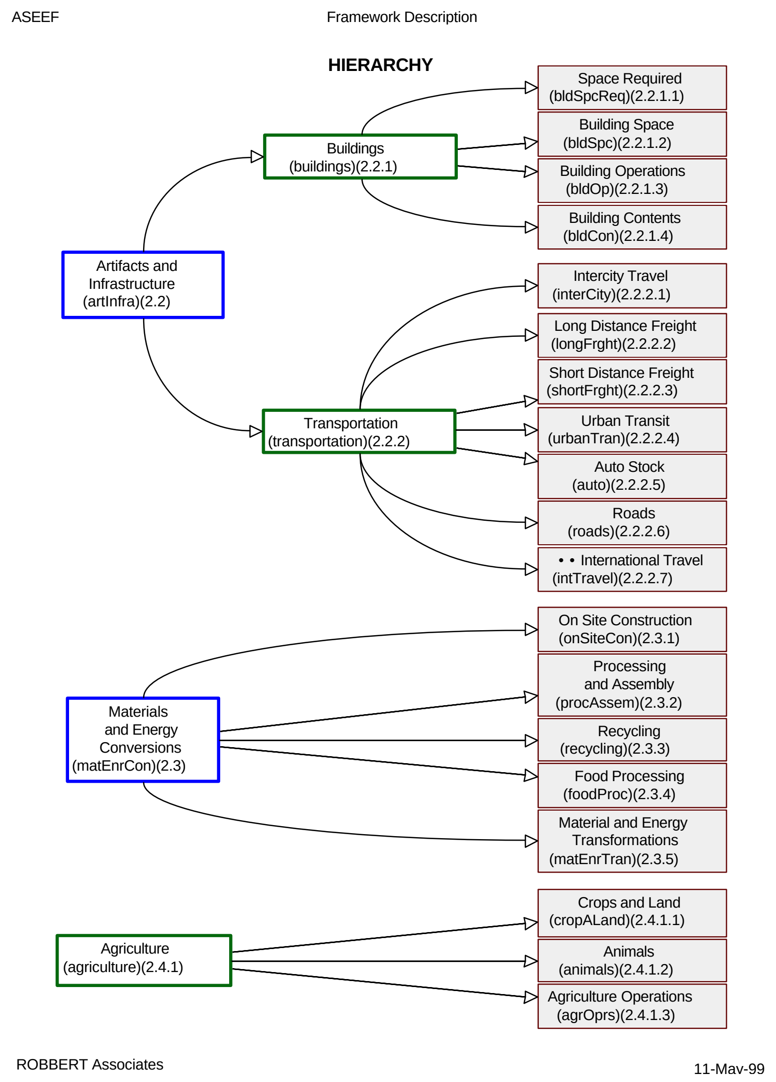


Figure 1.4. Hierarchy of calculators in the *Australian Stocks and Flows Framework*. The clear boxes with bold borders represent hierarchical groupings, shaded boxes represent calculators. See Figure 1.5 for information flow between calculators.

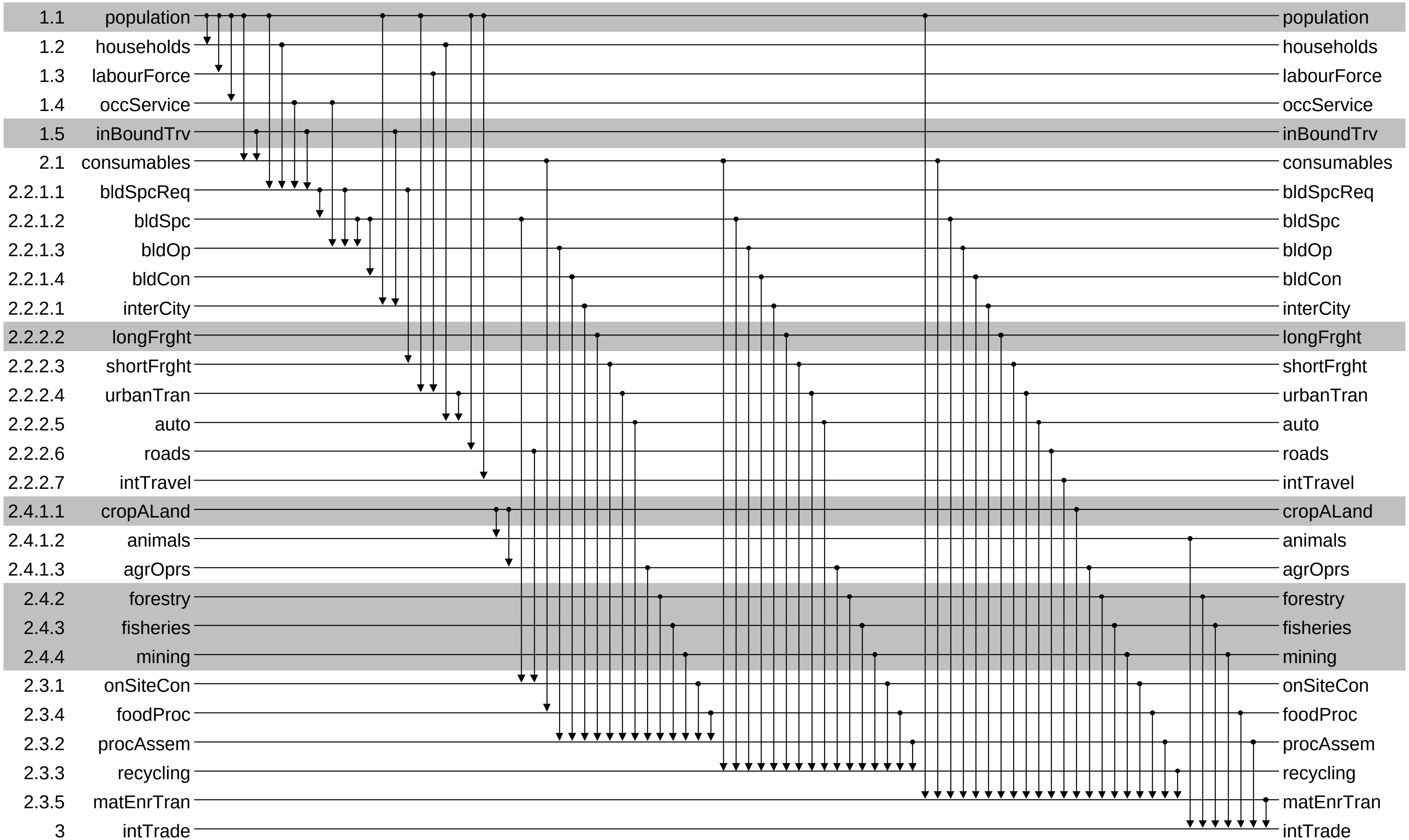


Figure 1.5. One way information flow (vertical arrows) between calculators (horizontal lines) of the *Australian Stocks and Flows Framework*. Shaded calculators receive only exogenous input (no arrow heads on shaded lines).

Seven calculators deal with various aspects of **Transportation**. Broadly, these cover domestic passenger and freight transport in urban and rural areas. Separate calculators deal with the car fleet, roads and their maintenance, and fuel for international travel. In most cases, a transport task is determined in relation to demographic parameters and, with the help of load factors and average yearly distance travelled, the task is translated into a need for vehicles. The **Material Resources** calculators describe production processes in the primary industries: agriculture, forestry, fisheries and mining. Like population, tourism and long distance freight, they are independent drivers in the framework and receive no information from earlier calculators. Their planned levels of production are specified exogenously because much of the produce from Australian primary industries is destined for export.

Agriculture is covered by three calculators which deal with crops and land, livestock and agricultural operations in each statistical division. Cropping deals with the areas of land devoted to each of 10 different crops (or land may remain fallow or idle), the impact of cropping activity on four indicators of soil quality (acidity, dryland salinity, irrigation salinity and soil structure) and the effect on yield of genetic improvements to crop varieties, the application of fertiliser and irrigation and of declining soil quality due to the cumulative effects of previous cropping. The **animals** calculator deals, in each statistical division, with the stocks of animals of different types, the quantities of animal products they yield and their feed requirements in terms of crops and area of grazing land.

Forestry deals with 15 different types of forest managed under regimes which vary from full protection, to clear cutting and managed plantations. Fire frequency and tree growth and survival rates are taken into account. Inventories are kept of land areas and tree numbers and wood volumes by age. **Fisheries** deals with both wild fishing and aquaculture. Wild fish stocks vary in response to reproduction and mortality rates, and to the level of fishing. Each fishery can sustain a moderate level of fishing but, if overfished, the stock collapses to a level at which catch per unit effort no longer warrants fishing. Fishing effort is allocated among fisheries in an attempt to meet planned production levels at minimum effort.

Mining covers exploration for mineral and energy resources, evaluation and classification of resources as reserves, and extraction of minerals and energy materials to meet planned production. 'Resources ever found' is the estimate of the nation's total endowment of a material. Unless augmented by new discoveries, cumulative production will never exceed this quantity. The **Materials and Energy Conversions** group of calculators covers construction, manufacturing and energy supply. Its calculators deal with the need for materials, energy, goods and infrastructure identified in earlier calculators. **Processing and Assembly** consolidates the requirements for vehicles, machinery, building contents and operating goods of all types from previous calculators and, allowing for imports and exports, determines the level of domestic production of these goods. **Recycling** consolidates all discarded goods, vehicles and machinery and determines the proportions to be recycled or disposed of to land fill. The material content of the recycled fraction is determined by a knowledge of the material composition and vintage of the goods and vehicles. **Material and Energy Transformations** ensures that the needs of the whole economy for materials and energy are met.

The **International Trade** calculator consolidates domestic production and domestic requirements for primary materials, secondary materials, vehicles and machinery, intermediate and final demand goods and determines import and export quantities. These are combined with a set of import and export prices and an interest rate, to determine the value of the trade flows, the current merchandise trade balance in nominal dollar terms and its contribution to the international debt (or surplus) again in nominal dollar terms. Finally, **Land Resources**, **Water Resources** and **Air Resources** consolidate information from the whole framework into accounts which provide an overview of the state of these important resources.

The framework is grounded in a database for a 50-year historical period which is complete (all data gaps are filled) and where variables are consistent with each other and with the assumptions in the calculators. These assumptions are based on technical and scientific understanding of all the processes required to describe physical stocks and flows underneath the Australian socio-economic system. At the most basic level this ensures that fundamental requirements such as the conservation of matter and energy and the laws of thermodynamics are observed. For particular calculators, the assumptions need to be consistent with a specialist's understanding of the processes involved.

Calculator linkage, feedback and tensions

The calculation linkages are shown in Figure 1.5 where arrows flow downwards only, indicating that feedbacks caused by demand and supply imbalances are controlled by the user, who separates 'control space' from 'design space'. In order to calculate the quantities demanded within the physical economy, the population calculator (1.1 in Figure 1.5) passes down

- the requirements for households (1.2) through an age and sex determined household formation rate)
- the availability of a labour force (1.3) through an age and sex determined participation rate
- the demand for employment in non-physical sectors of the economy, such as services (1.4) as a proportion of the total population
- consumables such as food, plastics, paper, pharmaceuticals and chemicals (2.1) on a per capita per year basis
- the demands for building space (2.2.1.1), intercity travel (2.2.2.1), urban transit (2.2.2.4), roads (2.2.2.6), international travel (2.2.2.7) and material transformations (2.3.5)

This process is continued down the hierarchy of calculation procedures giving a complete set of quantities demanded by the population driver and subsequent flow-on effects. In order to supply the quantities demanded, production or control variables are set in the primary material sectors (agriculture, forestry, fishing, mining) or the international trade sector, so that the quantities demanded by the population might equal the quantities supplied over the period of the simulation.

The design approach which lies behind the implementation of the ASFF model distinguishes 'control space' from 'machine space' (Figure 1.6). The user or analyst who makes assumptions on the basis of current knowledge and future expectations and then alters control variables in the ASFF, model occupies 'control space'. The modelling code and the equations which describe the processes which drive the physical economy, occupy 'machine space'. This is the domain of materials, energy and physical processes.

What happens in machine space depends on physical laws and on choices made in control space according to people's values. However, people's control of the physical world is imperfect both because the physical world is very complex, and also because their goals and values conflict with those of others. From control space, the analyst can monitor what happens in machine space during model simulation and evaluate the outcomes according to goals and values set by a policy analyst or a research group. In practice, the iterative nature of design and testing can be slow and spasmodic as simulation outcomes are delivered to clients as documents with scenario graphs and written interpretations. In a perfect world, a policy client and a simulation analyst could sit together at the computer screen and accelerate the process of learning and design.

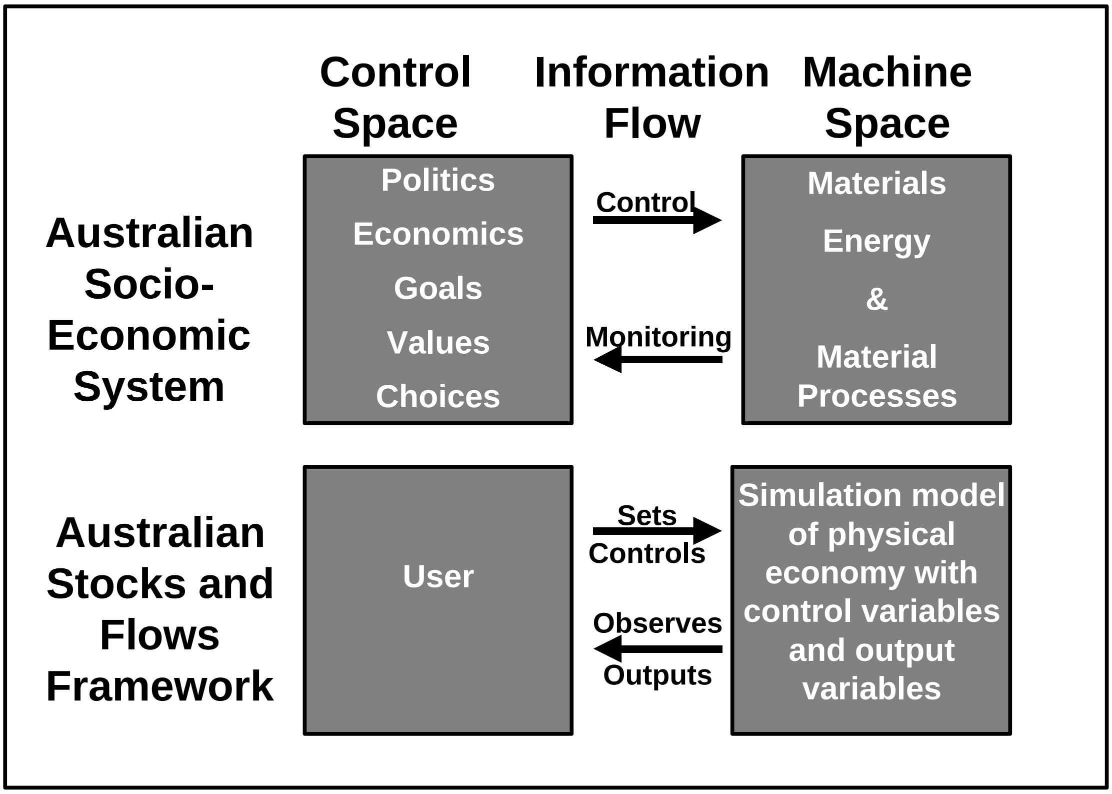


Figure 1.6. Content and information flow between control space and machine space in the reality of the Australian socio-economic system and in the control and machine space of the *Australian Stocks and Flows Framework*.

In the design approach used in ASFF, only the physical processes in machine space are modelled. The user occupies control space, observes the situation in machine space and makes decisions about the settings of the control variables. The user is therefore an integral part of the feed back loop, acting as a proxy for society and its political and economic agents, and is in a position to learn a great deal about the system behaviour.

Resolving tensions (imbalances between quantities demanded and quantities supplied) may be obligatory or optional. If a tension indicates a physical or accounting inconsistency, it must be resolved. For example, if insufficient primary energy is supplied to meet electricity and transport requirements, then its supply and delivery must be increased. Another form of tension might indicate the failure to meet some non-physical goal or desirable criterion. In this case, its resolution is judged to be optional, e.g. an imbalance between labour demand and the labour supply. Where labour supply exceeds demand, there is unemployment and the scenario is still physically feasible. If labour demand outweighs supply, then the production goals might be regarded as infeasible. Production goals might have to be decreased, or the labour force increased.

APPLICATIONS AND RESULTS

The OzEcco embodied energy model

For a policy client interested in alternative landuse scenarios to help re-mediate landscapes suffering from dryland salinity, scenarios were implemented within *OzEcco* to produce alcohol fuels from woody biomass (Foran and Mardon, 1999; Foran and Crane, 2000). A number of assumptions underpinned this methanol production scenario: (i) The scenario would aim to supply 90% of Australia’s total oil requirements specifically to meet 100% of the requirements for transportation fuels; (ii) The feedstock share would be 100% woody material from plantation biomass resources, which are currently managed as forests with a 20-year rotation and an average 20 m^3 per year mean annual increment; (iii) Approximately 60% of the woody biomass would be derived as logs and the remainder as branches and waste wood; (iv) The rate of plantation biomass establishment (basically forests) would be 400,000 hectares per annum; (v) The capital cost in constant dollar terms of the methanol plant was $50 million per petajoule of production capacity and the lifetime of plant was 20 years.

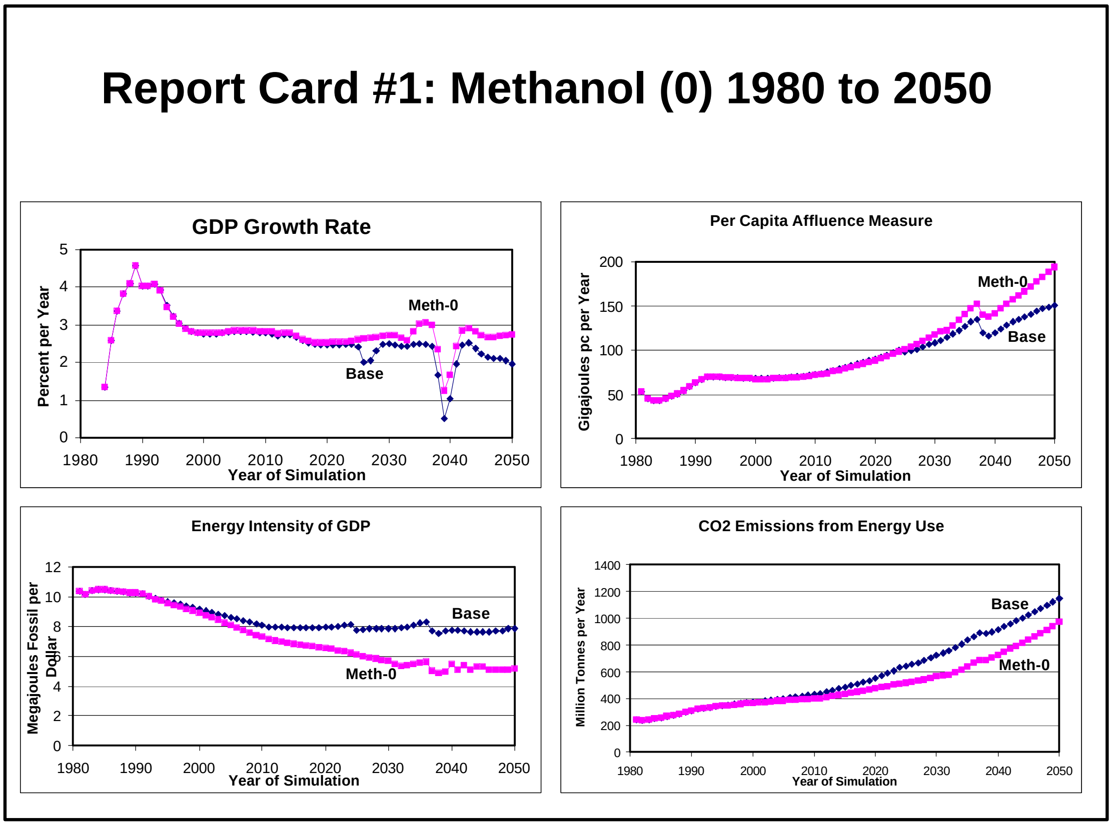


Figure 1. 7. Report card #1 for the methanol scenario (Meth-0) compared to the base case (Base) showing growth rate in GDP, per capita affluence index, energy intensity of GDP and carbon dioxide emissions from energy use.

The aggregate indicators simulated by the *OzEcco* model with these scenario assumptions are shown in Figure 1.7. The simulated growth rate in GDP for the methanol scenario tracks with or above the base case scenario for the duration of the simulation. The first dip in the curve due to oil depletion is avoided, and the second drop due to the depletion of natural gas stocks is not as large. The per capita consumption measure (gigajoules (10^9J) per capita of energy embodied in personal consumption) tracks with the base case until 2030 and then takes a higher trajectory. The energy intensity of GDP (megajoules (10^6J) of fossil energy per constant dollar of GDP) is decreased by about 30% (from 8MJ to 5MJ per dollar) by 2050. The emissions of carbon dioxide from the energy sector diverge from the base case after 2005 and rise gradually to 1000 million tonnes per annum by 2050, a reduction of 200 million tonnes per year compared to the base case.

Analyses such as these are not predictions in a traditional sense. Rather they test the likely behaviour of the simulated physical economy to policy innovations and new structural designs. A measure of their success is the degree to which indicators for a scenario under test diverge from (CO2 emissions) or remain with (GDP growth rate) the base case scenario. While physical processes drive the *OzEcco* model, it is possible to derive a number of economic indicators such as nominal GDP because of the strong relationship in the current structure of the economy, between the valued-added dollars and fossil energy usage. These relationships are well analysed in studies by Lenzen (1998).

Each scenario is able to display hundreds of indicators. These are grouped into a number of report cards displaying four indicators simultaneously. Figure 1.7 shows the macro-level indicators, which are then supplemented by more detailed report cards of the operations of the physical sectors being restructured in particular scenarios. What constitutes a successful scenario in a policy or industry context is difficult to say. The advantage of the physical modelling approach, compared to the indicator sets commonly used in state of environment reporting, is that the indicators are structurally linked to each other within a quantitative analysis of the physical economy. Provided that the modelling is philosophically and bio-physically sound, this provides a thorough basis for interpretation and understanding, as well as a cogent and robust look-ahead capability.

The Australian stocks and flows framework

The following scenarios show how the ASFF approach can be applied. The first is a single sector approach which concentrates on population issues. The second is a multi-sector approach linking population scenarios and vehicle scenarios and the resultant demand for energy use and generation of emissions. The third application seeks to identify possible bottlenecks or constraints to the availability of water in urban situations.

Single sector scenarios

Within the ASFF approach, the population calculator is implemented as one of the main drivers of demand of food, paper, water and energy and subsequent flow-on effects. However, many analytical insights are important in their own right, particularly in Australia where immigration policy is an important policy lever. Future population stocks or targets will depend on the degree to which immigration is used to offset declining birth rates. Three scenarios of net immigration (zero, 70,000 per year, and 0.67%pa (two-thirds of 1% of total population per year)) were combined with the declining total fertility rate (from 1.78 to 1.65 children per woman), and increasing longevity (1 years life extension for each decade of the simulation out to 2050). The results are presented for the years 2050 and 2100 (Table 1.1).

Australia in 2050 could be home to 20, 25 or 32 million people depending on its choice of net immigration rate. While a zero net immigration is the policy position of several environmental groups, detailed demographic analysis (McDonald and Kippen, 1999) shows that this option produces eventual population decline, and substantial falls in the size of the labour force. The ASFF analysis is consistent with this more detailed work, and shows total population declining from 20 million in 2050 to 17 million in 2100 under the zero net immigration scenario. Under the 70,000 net immigration scenario, the population increases by 0.4 million people between 2050 and 2100, and with 0.67%pa net immigration it increases by 18 million people to 50 million people over the same period, and is still growing at 2100.

Table 1.1. Scenarios for Australian population size based on zero, 70,000 and 0.67%pa (two-thirds of 1% of total population each year) net overseas migration, declining fertility rates and increasing longevity.

Year	Zero Net Immigration per Year	70,000 Net Immigration per Year	0.67%pa Net Immigration per Year
2050	20.6	25.1	32.5
2100	16.7	25.5	50.6

Higher rates of net overseas migration are assumed to result in a younger population. The scenarios modelled here assume that future immigration has the same age and gender distribution as the immigration that took place over the last decade. The results show a higher proportion of population over 65 years of age with zero immigration (Table 1.2). On a proportional basis, 27% of the population is older than 65 years in 2050 for zero immigration, versus 25% for 70,000 net immigration and 20% for the 0.67%pa scenario. While the more detailed analyses of McDonald and Kippen (1999) show that levels above 80,000 net immigration do not slow the ageing of the population, under the 0.67%pa scenario, immigration is constantly increasing and the scenario includes specific assumptions about the younger age distribution of the immigrants.

Table 1.2. The effect of three population scenarios on the percentage of the population over 65 years of age in the year 2050

Scenario>	Zero Net Immigration per Year	70,000 Net Immigration per Year	0.67%pa Net Immigration per Year
Proportion >65 years of age (percentage)	27	25	20
Number >65 years of age (millions)	5.65	6.32	6.52

Another insight to the data is given if absolute numbers are viewed instead of proportions. There are 5.65, 6.32 and 6.52 million people over 65 in 2050 for the zero, 70,000 and 0.67%pa scenarios respectively. So, social tasks such as aged care, personal security and pensions could be larger in absolute terms with higher net immigration rates, if all other policy variables are kept neutral. The effect of population ageing is distributed unevenly throughout Australia. In a number of lower population states, younger people are moving in and people are leaving. If this trend continues, these states (and particularly their capital cities) will maintain a relatively younger population.

Multi-sector scenarios

While a wide range of specialist research agencies can supply the analyses from any of the ASFF calculators, it is the onward chain of computation through other parts of the physical economy that allows scenarios to become more technically explicit and useful to policy. For the 70,000 net immigration population scenario, this example shows how population and location parameters can be linked to motor vehicle usage, fuel consumption and subsequent vehicle emissions (Figure 1.8). The driving variable for vehicle ownership in ASFF is the individual household, which locates vehicle ownership in capital cities and regional areas around Australia. Each household is assumed to require 1.3 vehicles, each vehicle is driven 15,000 kilometres per year in non-commuting use, and the fuel use per kilometre driven declines by 60% over the next 100 years.

The analysis from these explicit assumptions shows that the total energy used by the automobile fleet and the subsequent vehicle emissions reach their peak around 2030 and then start to decline. The continued demand for vehicle ownership is built into the continued growth in population and therefore younger households coming into the market for car ownership. At the mature end of the population age distribution, people are living and staying healthy and active longer, and car ownership and usage might be maintained longer than in the past.

These simulated outcomes might change in many ways, particularly by technological innovation. Car ownership per household might decline, less kilometres per year might be driven, and engine technology might leapfrog the current energy use parameters and solve the problem of vehicle emissions entirely. However Australian lifestyles may also dictate that more cars are demanded per household and more kilometres are driven per year. The long timeframes required to alter vehicle energy use under these particular assumptions could help frame a policy trade-off, where the capacity to overcome the inertia facing technological innovation is judged against the political risks inherent in forcing a change in consumer behavior.

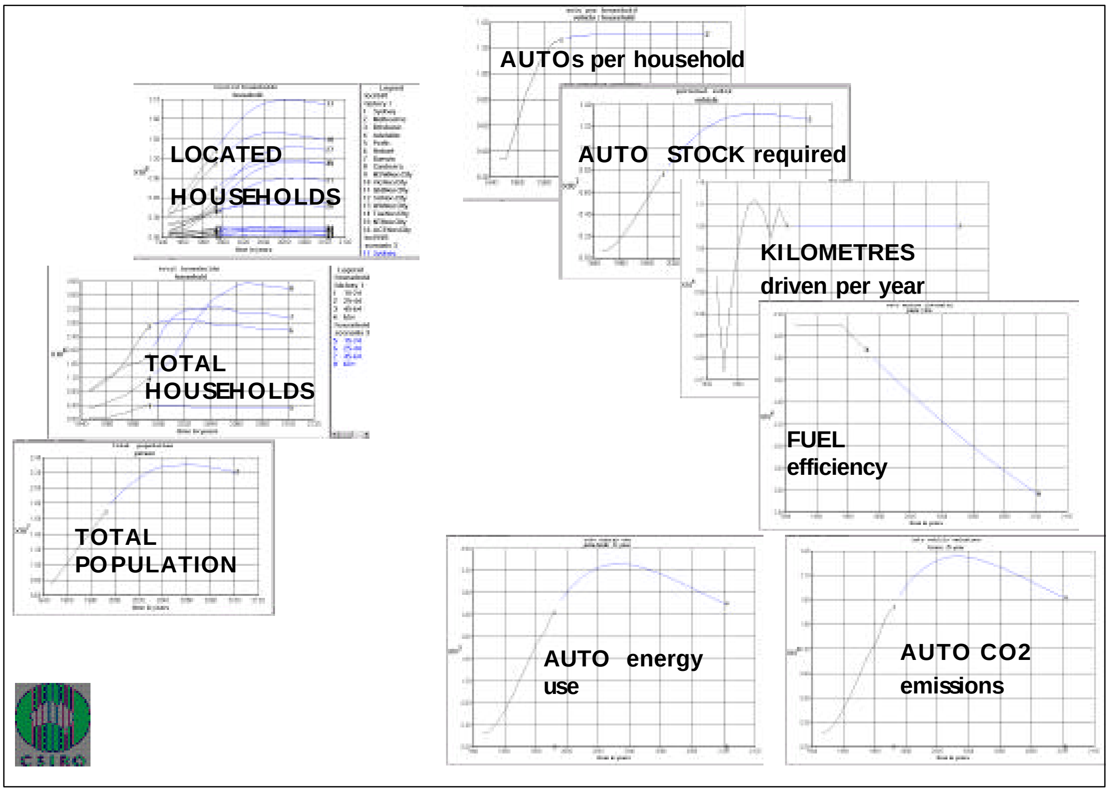


Figure 1.8. The stepwise computation within the *Australian Stocks and Flows Framework* linking population change scenarios to the personal vehicle calculator, total energy use, and vehicle emissions.

Identifying possible bottlenecks

Australia is a relatively dry continent with a highly variable annual rainfall and a reliance on irrigated agriculture for many of its higher-value commodity exports such as wine, cotton and dairy products. In the more populated parts of Australia there is competition for the use of water and concerns for both the quality and quantity of future water supplies (Thomas et al., 1999).

In considering people's direct requirements for water, significant infrastructure and management issues are directed towards maintaining clean catchments and ensuring the chemical and biological quality of water supplies for most major cities. If Australia's population continues to grow at its current rate, it will be about 25 million by 2050 (the base case scenario) which suggests urban requirements of about 6,000 gigalitres (10^9L)of water per year (Figure 1.9). This assumes that water can be transferred from agricultural usage. However, if that were not possible, for the base case scenario a sufficent range of options exists in terms of take-back from other uses and industries for sufficient water savings to ensure that enough water is available.

When the other population scenarios are compared to the base case, the requirements are 2000 GL per year more for the higher scenario with 32 million people and 1000 GL less for the lower scenario with 20 million people. By 2100 however, a number of water availability tensions could appear as the direct population requirements are 12,000, 6,000 and 3,000 GL per year for the higher scenario, the base case and the lower scenario respectively. The requirement for the higher population scenario is six times that of current urban consumption (2,000 GL per year) and approximately half of current total Australian consumption (24,000 GL per year).

It is likely that the high value of urban water would result in extra dams, interbasin transfers and pipelines being made available to supplement urban water supplies. Thus the perceived resource problem becomes one of allocation of available water, rather than a lack of water. The problem then enters the preserve of economics and politics, and moves outside the sphere of physical analysis. The modelling framework has helped quantify the size and nature of a possible problem. The eventual solutions are deemed to be more social and political, rather than than physical.

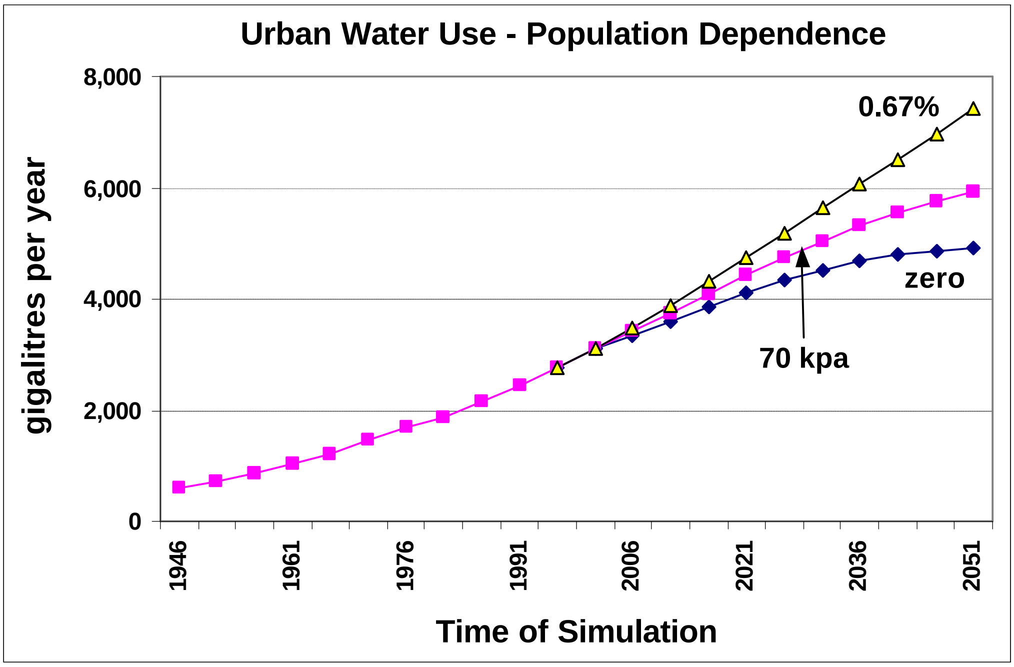


Figure 1.9. Simulated urban water requirement to 2050 in gigalitres (10^9 litres) per year , for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

STRATEGY FOR NATIONAL INFLUENCE

Strategic plan

The strategic plan for the project where the ASFF and *OzEcco* models are used, has three linked goals. The first is to underpin the debate for transforming the physical economy to more sustainable modes of operation such as the dematerialised, Factor-4 or Factor-10 economy as detailed by von Weizsacker et al. (1997), Ayers (1998) and others. A factor-4 economy aims to halve energy and material usage while doubling the financial returns. The second goal is to have the concepts of physical analysis of the national economic function accepted at national policy levels. The third goal is to contribute to changing national policy on a number of key aspects relating to the physical economy.

The route to achieving these goals is complex and difficult, with two important considerations. The first is the dominance of economic theory and debate in assessments of national population-development issues allied with the belief that market mechanisms will deal with environmental problems if they are sufficiently important to require a solution. Allied with these economic views is the belief that technological innovation is a driver of progress in its own right which will bypass those functions of the physical economy which require change. The second consideration is that integration and modelling within these physical economy models is a challenging task where scientific proof (in a traditional reductionism sense) is difficult. In addition, a modelling framework is always open to improvement. In a project management sense, this can result in an imbalance between investment into modelling, the outputs from scenario simulations and subsequent contributions to long-term analysis of national policy issues.

Given these constraints, the route chosen to reach the project's strategic goals is a partial and iterative one with an overall integration phase in the final two years of the process. Although the insights into strategic policy require an analysis of the whole physical economy, the way forward requires that 20 important sectors such as agriculture, building, manufacturing, and energy are each partially investigated for a client who will underwrite the task and with whom we might investigate and learn about an important physical sector. The base case scenario is also further developed in an iterative manner, with additional insights from the client and the particular analysis undertaken. With this approach, it could take 10 years or longer to fully analyse 20 important sectors of the physical economy. Using this client focussed partial approach, it is possible that important whole-economy insights might be lost in a welter of detail, or simply not recognised. Thus a project which sought to move beyond the marginal nature of national decision making, might itself be bogged down by marginalism.

Analyses underway

The plan is being implemented with three main tasks underway. The study reported in this document is the main one. It details the infrastructure requirements and environmental loadings resulting from three alternative population scenarios out to the year 2050. The second project, funded by Land and Water Australia, develops alternative scenarios for land and water use out to 2050 and beyond. It aims to maintain national agricultural productivity, export income, food security in parallel with improving the ecological integrity of farmed landscapes. The third project, funded by the Fisheries Research and Development Corporation, aims to develop scenarios for the management of Australia's marine fishery resources, and to explore the linkages between growth in population and tourism, domestic and export demand for fisheries product with the marine resources in the south east region of Australia. Another project will deal with the energy metabolism of Australia, particularly the use of fossil energy resources and subsequent greenhouse gas emissions. Most of the work is of a government or quasi-government nature and direct links with industry policy remain elusive. Attracting business clients requires a focus on seeking future opportunities, rather than seeking solutions for perceived problems. In the next year, an analysis of the top 100 companies will attempt to match the analytical capability of the project with strategic directions of suitably orientated companies.

DISCUSSION

The approach

This chapter has described a framework of analysis for the opportunities and problems relating to future population-development-environment issues in Australia's physical economy. The approach aims to help reveal physical flaws in national plans, assist in designing for approaches which are physically feasible and to display the scenario consequences for stocks of infrastructure (buildings, roads and power plants) and natural resources (oil, natural gas, marine fish and forests).

The project relies on three key criteria if it is to achieve its stated goal of influencing national policy directions. The first is that policy makers, together with model analysts, become active learners within the analytical process. Central to the analytical approach is that the analyst or user is seen as the human dimension within the modelling procedure, rather than being a value-free controller outside the simulation process. The second criterion concerns the understanding of the physical economy and its relationship to the monetary economy. The physical economy is used to represent the vast array of physical transactions that underpin the function of the economy and it should obey the laws of thermodynamics and material mass balance. By its more virtual nature, the monetary economy is open to a wider array of innovation, beliefs and behaviour than the physical economy.

Both views of the economy are valid and should be used together to inform national policy making.

The third criterion concerns the nature of predictive analysis versus scenario analysis. The concept of scenario analyses used in this approach relies on a wide array of expert opinion and data analysis. These help set the control variables which drive simulation outcomes in a transparent and explicit manner. A simulation of a scenario may seek to test the physical feasibility of a particular national policy. Alternatively, it may seek to design the pathways along which a policy must progress, if it is to reach an explicit goal in future. The use of scenario design and testing is linked to the world views and analytical methodologies of the four quadrants proposed in the introduction to this chapter. To what degree policy analysts regard themselves as either observers or architects in national affairs may be important. An observer may anticipate incremental policy changes at the margin, whereas an architect may seek to redesign and foster entirely new structures that could force the transition towards concepts of long-term sustainability.

Advantages and disadvantages of the physical modelling approach

The approach to simulation modelling, which combines the design of physical economy functions with a complete and consistent database that underpins it, is proposed as the key advantage for integrated physical models. Within this concept are complex calibration and validation procedures which set a foundation for the model in the historical period before the scenario is run forward to the future. These 'grounding' procedures enable the modellers to display a proof of concept and gain an acceptance that the underlying modelling procedures compute appropriately. The treatment of stocks of people, cars, houses, agricultural fields and so on, is central to the concepts of momentum and inertia within the physical economy which were introduced with the four quadrants of world view in Figure 1.1. Most forms of economic analysis do not implement a full description and vintaging of stocks but this process is central to the concept of environmental sustainability. The associated concept of physical realities within the production process is also vital, and usually not included in economic models.

The modular and stepwise nature of model design and computation procedure allows partial simulations to be undertaken relatively easily, and for further model development to be undertaken on a component, without disturbing the integrity of the whole. The level of detail is reasonably flexible and ranges in the ASFF model from 58 regions for agricultural productivity to 16 regions for human population dynamics to eight city airsheds for vehicle emissions and one national account for balance of trade computation. An advantage in national and international terms is that a limited amount of simulation modelling of physical economies has been undertaken in a policy context, when compared to the dominant force of econometric modelling. This provides a possible advantage in the policy marketplace for concepts and analyses pertaining to physical sustainability. However, there is little historical precedent in the promotion and refutation of integrative theories which deal with population-development-environment linkages and concepts.

The size and complexity of the analytical undertaking present an immediate disadvantage to scientific management, funding agencies, national policy analysts and scientific colleagues. The gulf between the constrained boundaries and reputable sureness of traditional reductionist research approaches, and a nationally scaled modelling approach which uses scenarios, has never been greater. Lutz (1994) noted the challenge of population-development-environment modelling as one of combining "a hard-wired model which only includes unambiguous relationships on which scientific consensus can be expected" with "the soft model which can quantify all kinds of feedbacks and interactions that the user wants to define".

This approach in design and implementation appears to be meeting these philosophical goals. However the absence of price mechanisms in both the ASFF and *OzEcco* models, which equilibrate shorter-term imbalances of supply and demand, seems to pose a significant barrier to acceptance by analysts dealing with national policy issues. Some argue that the physical and economic approaches should be hybridised and blended, whereas others are satisfied to keep them as distinct and separate analytical approaches, each of which contributes discrete insights to the policy process. The philosophical approach behind the development of physical economy simulators agrees that prices and market mechanisms are critical to balancing the economic concepts of supply and demand in the short term. However, strategically long-term physical modelling approaches are designed to provide an information flow from longer-term horizons to current market, policy, and business agendas. For these long-term horizons, price and market mechanisms become diffuse and indeterminate, while the workings of the physical economy will still depend on people and the flows of energy and materials.

Future designs and policy insights

Once distilled though a process of repetitive design and testing, future design options and policy insights do not seem particularly innovative. So it is, with initial distillations from the many partial analyses so far performed by these physical economy simulators. Before the analysis of population issues and with a view to 2050, the lower population stocks given by the zero net immigration flow may have seemed preferable since they stabilised a wide range of environmental loadings such as vehicle emissions. However, with the advantage of the 2100 view, the medium population scenario might seem preferable since it avoids a rapid decline in total population and the available workforce later in the 21st century and beyond. Thus, the societal and policy requirement to balance non-environmental with environmental criteria was an insight that emerged. With hindsight it is rather obvious and does not require the whole modelling process to reach this conclusion.

However within a stabilising population, the design challenge is to seek technological and behavioural changes which rapidly stabilise environmental loadings and then decrease them. Unfortunately the age profile of most big ticket infrastructure items may dictate that many environmental pressures might trend upwards for at least the next human generation. This may be so for vehicle emissions where increasing car ownership and kilometres driven are possible for at least the next 20 years. After that a stabilising human population causes energy use and subsequent emissions to plateau and then slowly decline. The rapid penetration of new car technologies using much less energy may be limited by a relatively saturated vehicle ownership and a relatively old car fleet which is slowly replaced. Combined with these factors is a market demand for larger, more powerful vehicles, the use of which balances out the declining energy use by smaller more energy efficient vehicles. Thus, consumer behaviour may continue to outpace technological innovation, potentially giving neutral outcomes for potential opportunities to decrease resource use.

As analyses and policy interactions proceed, the design task for the next generation of physical economy becomes more skewed. Simple solutions to resource use and environmental loadings such as behavioural change and reducing personal consumption levels are often deemed less acceptable because of the flow-on effects on the monetary economy. The technological challenges then become more difficult as the redesign of the physical economy evolves to also include the redesign of the monetary economy and the social system. While this chapter describes a modelling approach centred on the physical economy, it recognises the importance of the monetary economy and seeks to ground financial and monetary viewpoints in physical reality. However, the physical concepts underpinning the concept of long-term sustainability suggest that more profound changes might be required. If fundamental changes occur, then economic structures, consumer behaviour and environmental technology will have to form radical new configurations.

THE POPULATION STUDY: DESIGN AND STRUCTURE OF THIS REPORT

The purpose of this study was to increase the range and depth of insights into the effect of future population size on infrastructure and environmental issues within Australia's physical economy. Three population scenarios driven by the yearly rate of net immigration formed the organising structure of the report. The **base case scenario** has a net immigration rate of 70,000 persons per year and represents a contemporary policy position. The **zero scenario** had a net immigration rate of zero persons per year where the number of immigrants equalled the number of emigrants. The zero scenario represents the philosophical position of a number of non-government organisations concerned primarily with environmental issues. The **0.67%pa scenario** had a net immigration rate of two-thirds of one percent of the domestic population in each year of the simulation and represented the position of a number of national business organisations.

The Department of Immigration and Multicultural and Indigenous Affairs as the policy client requested that an issue-based reporting structure be used to present the results from the simulation experiments (Figure 1.10). In an attempt to simplify the complex nature of the population effect, a four-level system of population influence (from primary to quaternary) was used. This grading scheme is presented at the end of Chapter 2 and is used in each chapter to describe the more-direct and less-direct effects of population size.

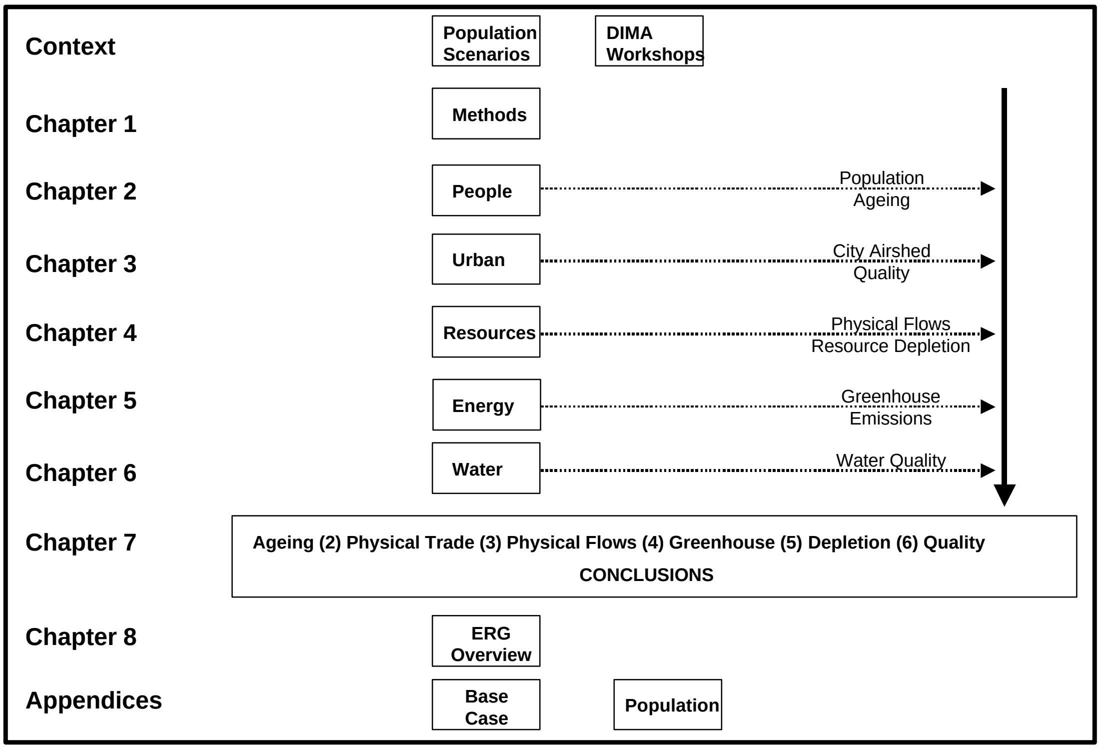


Figure 1.10. Schematic structure of population report which contrasts three population scenarios driven by different rates of net immigration.

Chapters 2 to 6 are essentially issue based and cover people, urban issues, natural environment, energy and water. However, because of the interactions between different sectors of the physical economy, a number of interactive effects emerged from the issue-based chapters. These issues are presented in Chapter 7 in the form of six future dilemmas. Apart from the demographic assumptions which drive the population scenarios, there are a wide range of starting assumptions for future trends and technological progress in all sectors of the physical economy. These are presented under 20 sectors in Appendix 1. Finally in Appendix 2 a comparison is made between the population projections from the ASFF simulator and those produced by the Australian Bureau of Statistics.

REFERENCES

Alcamo J Kreileman GJJ Krol MS and Zuidema G (1994). Modelling the global society-biosphere-climate system: part 1: Model description and testing. in *Image 2.0: Integrated Modelling of Global Climate Change*. (Eds) J Alcamo, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Alcamo J Kreileman E Krol M Leemans R Bollen J van Minnen J Schaeffer M Toet S and de Vries B (1998). Global modelling of environmental change: An overview of IMAGE 2.1. in *Global Change Scenarios of the 21st Century: Results from the IMAGE 2.1 Model*. Eds J Alcamo R Leemans and E Kreileman. Pergamon, Elsevier Science, Oxford UK.

Ayers RU (1998). *Turning Point: An End to the Growth Paradigm*. Earthscan Publications, London.

Boserup E (1999).*My Professional Life and Publications 1929-1998*. Museum Tusculanum Press, University of Copenhagen.

Brown LR Renner M and Flavin C (1998). *Vital Signs 1998: The Environmental Trends That are Shaping Our Future*. Worldwatch Institute, Norton and Company, New York.

Cocks D (1996). *People Policy: Australia's Population Choices*. University of New South Wales Press, Sydney, 347 pp.

Cocks D (1999). *Future Makers, Future Takers: Life in Australia 2050*. University of New South Wales Press, Sydney, 332 pp.

Cohen JE (1995). *How Many People Can the World Support?* Norton and Company, New York.

EPAC (1994). *A Comparison of Economy-Wide Models of Australia: Responses to a Rise in Labour Productivity*. Economic Planning Advisory Commission. Papers resulting from an EMBA symposium held in Canberra on 13 April 1994. Edited by Colin Hargreaves, October 1994.

Ehrlich PR (1968). *The Population Bomb*. Ballantine Books, New York.

Ehrlich PR and Ehrlich AH (2002). Population, development and human natures. Environmental and Development Economics 7,158-170.

Forrester JW (1961). *Industrial Dynamics*. Cambridge Ma, The MIT Press.

Foran BD and Crane D (1998). The OzECCO embodied energy model of Australia's physical economy. In *Advances In Energy Studies: Energy Flows in Ecology and Economy* Conference held at Porto Venere, Italy, 26-30 May 1998. pp 579-596.

Foran BD and Mardon C (1999). Beyond 2025: Transitions to the Biomass-Alcohol Economy using Ethanol and Methanol. CSIRO Resource Futures Working Document 99/07. http://www.cse.csiro.au/research/Program5/RF/publications/Biomassfuels.pdf accessed 07-05-02

Foran BD and Crane D (2000). Modelling the transition to a biofuel economy in Australia. in *Advances in Energy Studies: Exploring Supplies Constraints and Strategies*. Conference held at Porto Venere Italy, 24-27 May 2000, pp 423-439.

Gault FD Hamilton KE Hoffman RB and McInnis BC (1987). The design approach to socio-economic modelling. Futures 3-25, February 1987.

Goudriaan J Schugart HH Bugmann H Cramer W Bondeau A Gardner RH Hunt LA Lauenroth WK Landsberg JJ Linder S Noble IR parton WJ Pitelka LF Stafford Smith M Sutherst RW Valentin C and Woodward FI (1999). Use of models in global change studies. in *The Terrestrial Biosphere and Global Change: Implications for Natural and Managed Ecosystems.* B Walker W Steffen Canadell J and Ingram J (eds) IGBP Book Series 4. Cambridge University Press, Cambridge UK.

Godet, M (1991). *From Anticipation to Action: A Handbook of Strategic Prospective*. UNESCO Publishing Paris.

Long Term Strategies Committee (1994). *Australia's Population Carrying Capacity: One Nation-Two Ecologies*. House of Representatives Standing Committee for Long Term Strategies, Australian Government Publishing Service, Canberra.

Lenzen M (1998). Primary energy and greenhouse gases embodied in Australian final consumption: an input-output analysis. Energy Policy 26,6,495-506.

Lutz W (editor) (1994). *Population-Development-Environment: Understanding Their Interactions in Mauritius.* Springer-Verlag, Berlin.

Meadows DH Meadows DL Randers J and Beherens WW (1972). *The Limits To Growth: A Report for The Club of Rome on the Predicament of Mankind*. A Potomac Associates Book, Universe Books, New York.

Meadows DH Meadows DL and Randers J (1992). *Beyond The Limits: Global Collapse or a Sustainable Future.* Earthscan Publications. London.

Mentor Books (1960). *Three Essays on Population: Thomas Malthus, Julian Huxley, Frederick Osborn*. Mentor Books New York.

McDonald P and Kippen R (1999). The impact of immigration on the ageing of Australia's population. Discussion Paper, Department of Immigration and Multicultural Affairs, May 1999, 36pp

Richardson GP and Pugh AL (1981). *Introduction to System Dynamics Modeling with DYNAMO.* Productivity Press Portland, Oregon.

Robbert Associates (2000). Web Site. http://www.robbert.ca/demog.html accessed 07/05/02

Ruitenbeek J and Cartier J (2001). The invisible wand: Adaptive co-management as an emergent strategy in complex bio-economic systems. Centre for International Forestry Reserach Occasional Paper No 34, October 2001, Bogor, Indonesia.

Santa Fe Institute (2000). Web Site: http://www.santafe.edu/index.html accessed 07-05-02

Simon JL (1990). *Population matters: People, resources, environment and immigration*. New Brunswick, NJ/London.

Slesser M (1992). *ECCO User Manual Part 1. Third Edition*. The Resource Use Institute, Edinburgh, Scotland.

Slesser M King J and Crane DC (1997). *The Management of Greed: A BioPhysical Appraisal of Environmental and Economic Potential*. The Resource Use Institute, Edinburgh, Scotland. 332pp.

Thomas JF Adams P Hall N and Watson B (1999). *Water and the Australian Economy*. Australian Academy of Technological Sciences and Engineering, April 1999.

University of California Berkeley (2000). *Sketch for a Historical Picture of the Progress of the Human Mind (1795)*. Condorcet: The Education of Progress. Web pages http://ishi.lib.berkeley.edu/~hist280/research/condorcet/pages/progress_main.html accessed 20-04-2000

von Weizsacker E Lovins AB and Lovins LH (1997). *Factor 4: Doubling Wealth-Halving Resource Use*. Allen and Unwin, St. Leonards, Australia.

Waldrop, MM (1994). *Complexity: The Emerging Science at the Edge of Order and Chaos*. Penguin Books, London.

Wackernagel M and Rees W (1996). *Our Ecological Footprint: Reducing Human Impact on The Earth*. New Society Publishers, Gabriola Island and Philadelphia.

Chapter 2
People and their needs

ABSTRACT

This chapter describes a number of human population and consumption issues that largely frame the remainder of the report. By 2050 Australia could be home for 20, 25 or 32 million people under the zero, base case and 0.67%pa immigration scenarios respectively. By 2100 the population could be 17, 25 or 50 million people under those same scenarios. By 2050 both Sydney and Melbourne could each remain the same size (zero migration), grow by one million (base case) or by three million people (0.67%pa). By 2100 under the 0.67%pa scenario, Sydney and Melbourne could become megacities with populations of about 10 million people. Apart from the zero migration scenario, regional cities continue to grow in most states especially in New South Wales and Queensland. Rural areas continue their population decline under zero migration, generally remain stable under base case, and grow under 0.67%pa.

The number of Australians aged 65 years and over by the year 2050 varies from five million in the zero migration scenario to between six and seven million for the base case and 0.67% scenarios. As a proportion of total population in 2050, this represents 25-26% for the zero and base case scenarios and 20% for the 0.67% scenario. The lower proportion of Australians aged 65 years and over, for the higher population scenario agrees with some other studies and is caused by specific assumptions on the age distribution of immigrants and emigrants based on data from the past decade. When the age classes are converted to a total dependency ratio then six dependents for every 10 non-dependents results for the 0.67%pa scenario whereas the zero and base case scenarios give seven to eight dependents for every 10 non-dependents by the year 2050. The population requiring institutionalised aged care by 2050 is 470,000 for the zero scenario and more than 600,000 for the 0.67%pa scenario. The incidences of medical problems generally follow the patterns of population size and population ageing with issues relevant to younger people such as pregnancy, being stable or declining because of declining birth rates. By comparison, medical problems related to older age increase in all scenarios and are highest in the 0.67%pa scenario where the absolute number of aged persons is highest.

The total labour force stabilises at around 11 million by 2010 in the base case scenario due to stabilising population. For the zero scenario, it declines to nine million and increases to 15 million for the 0.67% scenario in 2050. The educational task stabilises or declines for the zero and base case scenarios by 2010, but continues to rise after 2020 for the 0.67%pa scenario. Population stability in the base case scenario obscures a number of regional patterns where states such as New South Wales and Victoria decline while Queensland and Western Australia continue to grow. Domestic tourism increases to 700 million visitor nights by 2050, due to an ageing population continuing to travel until they are 80 years old. The zero scenario stabilises slightly below 600 million visitor nights by 2020 whereas the 0.67%pa scenario increases continuously to 900 million visitor nights by 2050. Assumptions of growth in international inbound tourism lead to 550 million visitor nights by 2050 and 34 million visitors per year. This equates to 1.5 million full-time citizens in 2050 but with higher travel and consumption impact than an average citizen. Applying the current patterns of visitation gives a ratio of up to 5:1 of international to domestic visitor nights in Australian cities by 2050. Regional areas, with the exception of Queensland, are still dominated by domestic tourism.

The food required for the domestic population and inbound travellers increases with the population number in each scenario and we assume no major changes in dietary habits. The direct dietary requirement for grains varies from two to 3.5 million tonnes compared with current annual production of 30 million tonnes. The total meat required varies from 2.3 to 3.8 million tonnes and current production levels are around 3.5 million tonnes. The total fish required varies from 0.3 to 0.6 million tonnes with current production at 0.2 million tonnes. Apart from fish production, it is reasonable to assume that Australia will retain a positive food balance out to 2050 and beyond. However, domestic consumption may reduce the amount available for trade.

The requirement for general consumables such as paper and plastic continues to rise in line with growing population and rising affluence. By 2050 the requirement for paper could exceed four million tonnes for the zero scenario and seven million tonnes for the 0.67% scenario. Similarly the requirement for plastics could vary from 1.5 to 2.5 million tonnes per annum. In both cases recycling will reduce the requirement for virgin materials but increase the requirement for process inputs, energy and transport.

Within the perspective of this scene-setting chapter, each population scenario has advantages and disadvantages depending on the reader's world view. The base case scenario gives a stable population number overall with continuing growth for the next 25 years in capital cities and main regional areas while maintaining an ageing population with linked effects of health and aged care. The 0.67%pa scenario gives population growth in most cities and regions and looming challenges for Sydney and Melbourne to function as megacities of nine to 10 million people in 2100. While the proportion of aged persons and total dependants is appreciably smaller in this scenario, the absolute number is larger and continues to grow, producing an ever expanding need for health and aged care. The zero scenario stabilises the size of most capital cities at around current levels but the population may continue to fall in many regional and rural areas. The proportion of aged and dependent persons is similar to the base case scenario out to 2050, but with lower numbers, and therefore lower health needs in an absolute sense. The overall population in the zero scenario declines by 15%, or three million people, in the period 2050 to 2100.

The real analytical task takes place in the subsequent chapters of this report and is largely driven by the decisions on human population contained in each of the three scenarios. Subsequent chapters will focus on both the advantages and the disadvantages of each scenario. As well, they contain a range of sub-scenarios, where particular innovations are implemented to grapple with areas of concern or to take advantage of perceived opportunities.

ISSUES FROM THE DIMA WORKSHOP SERIES

In preparation for the design and testing of the population scenarios with ASFF, a workshop series was conducted in 1999 (Conroy et al., 2000), to critically review the structure of the analytical framework and the implementation of the scenarios. Six important issues for this chapter are described briefly below but many more were documented in the workshop report. The six issues are as follows:

- There was reasonable agreement with the fertility and mortality assumptions underlying the population projections but less agreement on future rates of net immigration underlying the base case population scenario and the patterns of internal migration which spread people around the country. The three population scenarios used in the study are meant to give a range of population outcomes. This should deal with claims that the 70,000 net immigration flow, which drives the base case scenario, is an underestimate of policy settings that are currently in place. The internal migration issues were examined and scenario settings were adjusted to reduce the effect of sun-belt migration which took place in the early 1990s.

- There was some concern that the methods used in ASFF to determine number of households, did not adequately reflect trends such as rising divorce rates and the increasing numbers of single person households. This was important as households are key drivers of consumption for items such as houses, personal motor vehicles and furnishings. An examination of these issues showed that the newer methods of household formation produced by the Australian Bureau of Statistics agreed reasonably closely with the ASFF results, but that further methodological development, particularly if it was tied to specific consumption information for the different types of households, would improve the information about future material and energy flows under different population scenarios.

- The issue of the 'service economy' or the 'new economy' was discussed in depth, in particular its requirement for labour in the face of technological innovation and its future requirement for energy and materials. The starting position for all population scenarios assumes a steady transition towards the service economy and with it, employment located in offices rather than factories. However, most consumption is driven by households and commuter transport is still necessary whether it transports workers to the office or the factory. In addition, the assumptions behind exported commodities and manufactured goods see continual expansion as Australian industry focuses on globalised trade for the next 50 years. Thus, material and energy flows continue to expand under all population scenarios in spite of continual technological improvement and development of the service economy.

- The growth rates for inbound international tourism were widely discussed. In the scenario assumptions it was set at 7% per year until 2010, decreased to 3-4% per annum by 2020 and then stabilised at that rate until 2050. Many tourism industry views assume that growth rates of up to 10% per annum are possible well into the future. Compounding these rates of growth over the next 50 years gives very large numbers which the CSIRO analysts considered were over-optimistic. The more moderate rates of growth described above give 34 million inbound tourists by 2050.

- A number of definitional issues in national statistical terms describe the entry into Australia of students, business workers and tourists. The simulation analyses treat these in aggregate, but more detailed treatments of the issues, particularly when they are attached to consumption and affluence, could become important when considering resource use and environmental quality.

- The workshops considered the increased use of coastal areas for both domestic population settlement and tourism as one of the most important resource issues facing Australia. Any assessment of environmental impact resulting from the size and spread of population use must be related to detailed resource descriptions at a reasonable level of spatial detail. While the ASFF approach could be developed to higher levels of spatial detail, this version of the model could not provide detailed assessments of future population impact at the level of a statistical local area (SLA) or a collection district (CD) for example.

The following sections now detail and discuss the results of the population scenarios for issues such as future population size, education, health and tourism.

POPULATION SIZE AND LOCATION

Three population scenarios

The three net overseas migration options that form the basis of this study result in three different future populations for Australia. The **zero** scenario has a net yearly immigration rate of zero each year i.e. long-term arrivals equal long-term departures. The **base case** scenario has a net yearly immigration rate of 70,000 persons per year (70kpa in figure captions) and is meant to reflect a contemporary policy position. The **0.67%pa** scenario has a net yearly immigration rate of two-thirds of one percent of the current domestic population in each year. This chapter compares the three populations in terms of size, trajectory, age profile, household formation, location and labour force composition. It also explores their education, health and age care requirements and their basic food and material needs. These characteristics form the starting point for the assessment of environmental and resource implications, in the following chapters. This chapter also examines possible future levels of tourism, which will have significant physical impacts in addition to those of the resident population. Subsequent chapters explore the possible effects of each scenario on key aspects of the physical economy.

Total population

The total population for Australia under the base case scenario is 25.1 million by the year 2050 and 25.5 by the year 2100 (Figure 2.1). Under the zero net immigration scenario the population in 2050 could be 20.6 million and 16.7 million in 2100. Under the 0.67%pa scenario (a net immigration rate of 218,000 people per year by 2050) the population in 2050 could be 32.5 million and 50.6 million in 2100.

These outcomes are similar to a wide range of demographic analyses available in Australia but may vary slightly. The computational methods in the ASFF model are generally on a 5-year time step because of the scale and breadth of the model, and also to match the 5-yearly intervals between national population census activities. Thus the results could lack the finer resolution of a demographic analysis that runs on a one-yearly time step. Another reason for slight differences lies in the assumptions behind each scenario and how they are implemented over time in the simulation. The most important assumptions relate to the total fertility rate (declining to 1.65 children per woman by 2010), the death rate (longevity increases by one year for every 10 years of simulation out to 2050, i.e. a total of five years increase), the patterns of internal migration (similar to the past decade but with alterations to departures from Victoria and arrivals in Queensland), and the age structures for both immigrants and emigrants (patterns of the last decade).

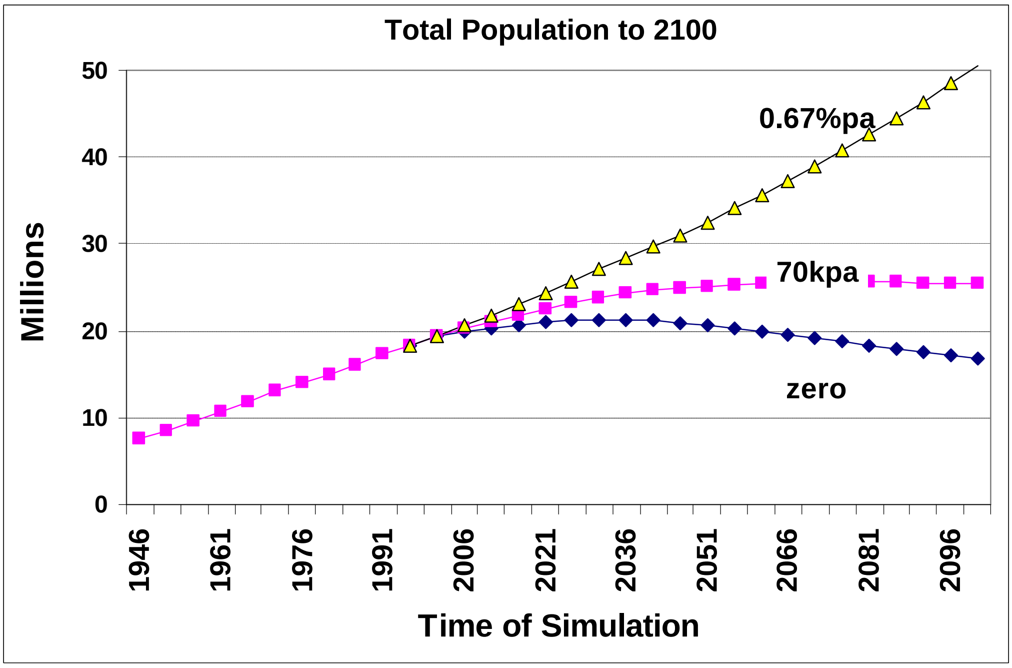


Figure 2.1. Simulated total population size in millions out to the year 2100 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

The total numbers in 2050 for the base case scenario are within 0.3 million of the mid range *Series II* population projection developed by the Australian Bureau of Statistics (1998, 2000-b), but 2.7 million lower than their *Series I* and 1.43 million above their *Series III* projections. The assumptions and their implementation differ slightly between the ABS report and the ASFF results, but both studies would agree reasonably if all modelling parameters were standardised. The results for both the zero and 0.67%pa scenarios also agree closely with data tables in the ABS report using different levels of net overseas migration. The results for the base case scenario at 2050 are approximately 2 million persons higher than population projections published by the Department of Immigration and Multicultural Affairs (1999) and the standard projection of McDonald and Kippen (1999-a). This is due to small differences in the net immigration rates assumed, a greater longevity assumed in this study and the age distribution of immigrants and emigrants. An overall assessment suggests that the three scenarios defined as inputs to this study cover the range of reasonable possibilities currently developed by other groups for the national policy debate. A full comparison of population projections by CSIRO and ABS is given in Appendix 2.

Future city population

By 2050 under the base case scenario, the capital cities of Sydney, Melbourne, Brisbane and Perth may increase by about one million people each, with smaller increases in the other capitals (Table 2.1). The zero scenario constrains most capitals to their current size, except Brisbane and Perth which both grow by 0.3 to 0.4 million people. The 0.67%pa scenario sees both Sydney and Melbourne growing by nearly three million people while both Brisbane and Perth double in size to around three million people. Other cities grow by 40-100%.

Table 2.1. Simulated population size in millions for capital cities in states and territories in 1998, 2050 and 2100 for three population scenarios.

	Estimate 1999 ABS	Zero 2050	Base case 70kpa 2050	0.67%pa 2050	Zero 2100	Base case 70kpa 2100	0.67%pa 2100
Sydney	4.041	4.280	5.254	6.878	3.448	5.303	10.717
Melbourne	3.417	3.529	4.365	5.826	2.789	4.354	9.098
Brisbane	1.601	2.152	2.561	3.114	1.839	2.695	4.880
Adelaide	1.092	1.226	1.523	2.047	0.989	1.550	3.250
Perth	1.364	1.840	2.221	2.798	1.561	2.332	4.445
Hobart	0.194	0.224	0.279	0.377	0.178	0.280	0.593
Darwin	0.088	0.078	0.098	0.139	0.065	0.102	0.221
Canberra	0.309	0.268	0.333	0.455	0.216	0.335	0.706

By 2100 the patterns are enhanced with the zero scenario seeing the populations of Sydney and Melbourne shrinking by about 0.8 million people, while Brisbane and Perth continue to grow slightly. In the base case scenario the population levels in 2100 are similar to the 2050 patterns because the population has stabilised. Under the 0.67%pa scenario both Sydney and Melbourne grow to populations of about 10 million or what is termed a megacity. Functionally the cities would be much larger than 10 million as Sydney, Newcastle and Wollongong would effectively join and become one much larger unit. Similar linkages would increase the functional size of Melbourne as it amalgamated with Geelong, Ballarat and Bendigo. Under this higher population scenario, Brisbane, Adelaide and Perth might triple in size to the functional equivalents of today's Sydney and Melbourne, while the other capitals might double in size. The development of megacities brings many problems of scale, equity and environmental challenge. These issues are briefly described below by reference to the megacities of today.

.

City size and economies of scale

In the year 2000, nearly one half of the world's population lived in cities and about 20 urban regions had populations in excess of 10 million people (Fenger, 1999). In this context, the 0.67%pa scenario in the year 2100 may be worthy of more scrutiny since both Sydney and Melbourne may develop population levels of between nine and 10 million people should the present patterns of internal migration be maintained.

Table 2.2. Issues of environmental, functional and social concern in six megacities with populations greater than 10 million people in the year 2000.

City	Estimated population in millions for 1998	Management and Environmental Challenges
Tokyo-Yokohama	29.344	• Earthquake hazard • Urban heat islands • Traffic congestion and air pollution
New York	14.642	• Open space greening • Noise • Waste prevention and recycling • Water quality
London	7.074	• Air quality • 24 hour noise • Traffic and parking
Seoul	20.736	• Water supply • Maintaining reasonable ratios of health professionals to urban residents • Air quality • Sanitation and solid waste
Sao Paulo	23.715	• Settlement of risk prone areas • Air and water quality • Fiscal resource constraints • Health of human population • Lack of urban infrastructure for the poor
Mexico City	26.176	• Air pollution and public health • Inequality between core city and surrounding regions • Personal security and crime

In an effort to foresee possible areas of environmental challenge should Sydney and Melbourne grow to the megacity size, a literature search was conducted to note possible areas of concern. This was undertaken for three cities that were likely to be around 10 million people in the year 2000 in more developed economies (Tokyo, New York, London) and three in less developed economies (Seoul, Sao Paulo, Mexico City) (Table 2.2). Large cities are becoming the hubs of the new economy with synergies gained from the scale of investment as well as a diversity of activity and markets (Brotchie et al., 1995). However, a number of studies centred on functional, environmental and social concerns (eg Newman and Kenworthy, 1999; Yenken and Wilkinson, 2000) note than cities beyond a certain size, while possessing all the positive attributes of scale and diversity, also exhibit a number of structural and functional fragilities.

The developed cities noted in Table 2.2 all exhibit problems associated with motor vehicles, traffic congestion and air quality. Both London and New York have noise problems and Tokyo has a number of social problems in spite of its relative affluence. Cities in developing countries have similar environmental problems but with the added dimension of being directly linked to human health issues. In both Mexico City and Sao Paulo air pollution can be directly linked to human health problems. These cities are limited in their capacity to overcome the problem by fiscal restrictions, and ever growing problems in social inequality.

Although these problems exist in the megacities of today, they would not necessarily exist in Sydney or Melbourne in the year 2100. Many options are available with new technologies and strategic planning, which could avoid or minimise many of the possible problems of size and form. However a number of these issues of size, function and form are already evident in Australian cities today. These will be analysed and discussed in later chapters. While there are strong possibilities that solutions will be implemented, in the year 2002 it is worth debating the possibility of equal or better solutions in a city that might double or triple in size over the next 100 years.

Regional cities and rural Australia

Regional cities in New South Wales and Queensland would increase in size by 2050 under the base case scenario, while in most other states they would remain stable or decline slightly (Table 2.3). The zero scenario would give population declines in regional cities while the 0.67%pa scenario might give population increases of one million people in New South Wales and Queensland but relatively minor increases in the other states.

Table 2.3. Simulated population size (millions) for three population scenarios for non-capital city urban areas in states and territories in 2050 and 2100 compared to the 2001 modelled value for the base case scenario.

	Model Value 2001	Zero 2050	Base 70kpa 2050	0.67%pa 2050	Zero 2100	Base 70kpa 2100	0.67%pa 2100
New South Wales	1.500	1.572	1.930	2.526	1.260	1.937	3.915
Victoria	0.578	0.516	0.638	0.852	0.395	0.617	1.290
Queensland	1.276	1.785	2.124	2.583	1.520	2.227	4.033
South Australia	0.128	0.091	0.113	0.152	0.065	0.102	0.214
Western Australia	0.187	0.168	0.202	0.254	0.124	0.185	0.352
Tasmania	0.131	0.099	0.123	0.167	0.076	0.119	0.252
Northern Territory	0.042	0.037	0.047	0.066	0.029	0.046	0.099

By 2050, rural areas (outside regional cities) of New South Wales, Victoria, Queensland and Tasmania all show moderate population growth under the base case scenario while the other states decline marginally (Table 2.4). Under the zero scenario, by 2050 the rural population grows marginally in New South Wales, Victoria and Queensland but declines in the others. Under the

0.67%pa scenario the rural populations of New South Wales, Victoria and Queensland nearly double by 2050 with moderate increases in the other states. These patterns are maintained until 2100 with continuing population reductions under the zero scenario, and stabilisation or small increases under the base case and large increases under the 0.67%pa scenario.

Table 2.4. Simulated population size in millions for rural areas in states and territories in 2050 and 2100 compared to the 2001 modelled value for the base case scenario.

	Model Value 2001	Zero 2050	Base case 70kpa 2050	0.67%pa 2050	Zero 2100	Base case 70kpa 2100	0.67%pa 2100
New South Wales	0.781	0.822	1.009	1.321	0.662	1.017	2.056
Victoria	0.606	0.627	0.775	1.035	0.486	0.759	1.586
Queensland	0.679	0.787	0.937	1.139	0.665	0.974	1.765
South Australia	0.214	0.176	0.218	0.293	0.127	0.199	0.418
Western Australia	0.234	0.142	0.172	0.217	0.103	0.154	0.294
Tasmania	0.139	0.133	0.165	0.224	0.105	0.165	0.349
Northern Territory	0.046	0.031	0.039	0.054	0.024	0.036	0.079

Households

The numbers of people per household continues to decline from a historical value of 3.75 in 1947 (Hugo, 1999) to its current level of around 2.6 (Australian Bureau of Statistics, 2000-b) to a range of 2.3 to 2.4 people per household by the year 2050 (Figure 2.2). This is caused by a wide number of factors that relate to the changing nature of human relationships, increased affluence, the changing nature of work and the evolution of city structure and transportation systems. The change is related to social and economic issues but has important implications for the physical economy. The number of households increases from about seven million currently to 8.2 million for the zero scenario, 10.6 million for the base case and 13.6 million for the 0.67%pa scenario.

The conversion of total numbers of people to numbers of households is an important modelling construct for two reasons. Firstly the number of households is growing at a faster rate than the population itself. Hugo (1999) notes that while population grew at an annual rate of 1.21% between the 1991 and 1996 census periods, the household growth rate was 2.23% for the same period. Secondly much of the demand for houses, motor vehicles, furnishing, electrical goods and energy usage in the real world is driven by household units rather than by individual people. For example every household, whether it has one or four persons, requires a refrigerator. There is a possibility that these simulations slightly underestimate the total numbers of households by 2050. Changes in social trends, such as one parent households and people living alone, are included in improved methods of household projections developed by the Australian Bureau of Statistics (1999) but the ASFF model does not yet include them. However, the ABS estimates of number of households for the year 2021 lie in the range of 9.4 to 10 million which is similar to the base case scenario simulated at that date by the ASFF model. A number of European studies highlight the importance of the changing structure of households. Lutz (1999) showed that social trends such as increasing divorce had the potential to increase greenhouse gas emissions as family units split into two, each of them requiring a functioning household and independent transportation. Work on sustainable development in the Netherlands focuses on household consumption and behaviour rather than that of the individual (Noorman and Uiterkamp, 1998).

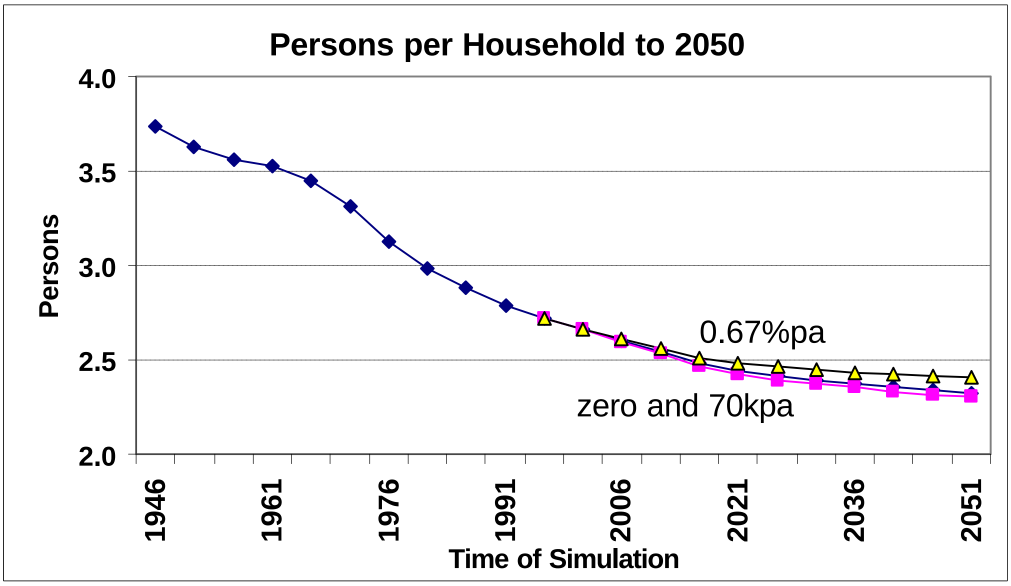


Figure 2.2. Simulated number of persons per household out to the year 2050 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

In modelling terms, households are separated into classes described by the age of the head of the household (termed the age class of households) (Figure 2.3). There are differences between the scenarios which could signal a change for many consumption sectors of the economy. There is little difference between the three scenarios for the youngest age group of households. However the number of households in the 24-44 age group could be two, three or 4.5 million by 2050. For a range of sectors in the economy these are important differences, as this age group potentially represents the ageof prime employment, relationships and marriage, home establishment and child rearing. These factors are important drivers of economic growth and physical requirements in the economy.

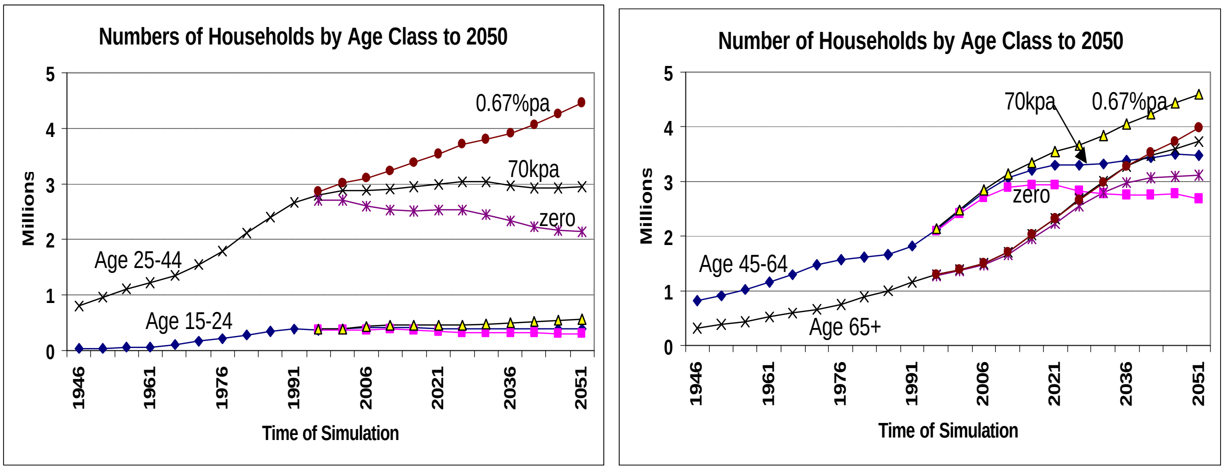


Figure 2.3. Simulated numbers of households out to the year 2050 for household age groups (15-24, 25-44, 45-64, 65+) and three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Out to 2020, the 45-64 age group represents the most rapidly growing number of households. After 2020 the zero and base case scenarios enter a period of relative stability with around three to 3.5

million households while the 0.67%pa scenario continues to grow to 4.5 million households by 2050. By the mid-2030s the 65+ age households are potentially the most numerous in the zero and base case scenarios with between three and four million households. In the 0.67%pa scenario where the younger age cohorts are more numerous, there are about 4.5 million 25-44 and 45-64 age households, and about four million 65 and older age households. These changes in household age composition could herald large changes in type and level of consumption. For example, in the Netherlands, Noorman and Uiterkamp (1998) found that the use of cars, computers, washing machines and bathing was less important for older households than younger ones.

POPULATION AGEING AND HEALTH ISSUES

Proportion of Australians aged 65 years and over

By 2050 the numbers of Australians aged 65 years and over could be 5.7, 6.3 and 6.5 million people for the zero, base case and 0.67%pa scenarios respectively (Figure 2.4). By 2100 these numbers could be five, seven or 11 million. Figure 2.5 illustrates these numbers as a proportion of the total population. After 2050 the proportion of people aged 65 and over, stabilises around 20% for the 0.67%pa scenario and it is about 27% and 29% for the base case and zero scenarios respectively. This compares with around 12% at present. These differences could pose important demarcations between the scenarios in national policy terms, especially for the long-term policies concerning health care, superannuation and social security issues.

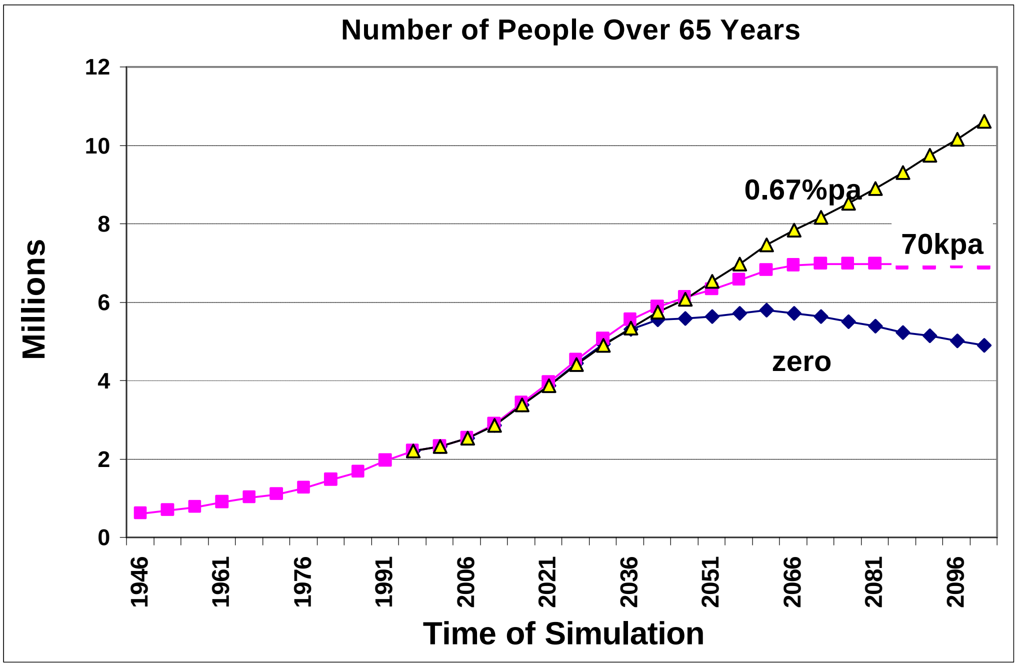


Figure 2.4. Simulated numbers of people to 2100 who will be over 65 years of age for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

These simulation results warrant further examination since they differ slightly from other analyses. The population projections of the Australian Bureau of Statistics (1998) report that the proportion of 65 years and older at 2051 varies from 23.7 to 25.6% depending on the assumptions behind the particular series of projections. This agrees well with the base case population scenario at 2051 which is the most relevant scenario for comparison (Figure 2.5). The graph then depicts this for the next 50 years to the year 2100 with a small increase in proportion.

The work of McDonald and Kippen (1999-a; 1999-b) is also important in relation to the effect of immigration on the proportion, as opposed to the absolute number, of persons aged 65 years and older. One interpretation of their work suggests that increases in immigration alone (beyond a net immigration rate of 50,000 to 100,000 per annum), have a marginal negative effect in reducing the effect of ageing which continues for the duration of their analyses. Selecting younger immigrants does have an effect, particularly when there are high levels of immigration. This feature is represented in the ASFF model since it is based on age distributions of immigrants and emigrants over the last decade. Although the proportion of people aged 65+ is maintained around 20% by the 0.67%pa scenario, this represents a constant proportion of an ever increasing number and therefore an increasing number of aged people. A recent study reported by the Business Council of Australia (McDonald and Kippen, 2000) concurs with the results developed from the 0.67%pa scenario. In simulating a number of high population growth projections, the study found that the proportion of persons aged 65 or more, fell to between 20.3 and 21.6% depending on the specific assumptions made. Thus the results from these two studies are compatible.

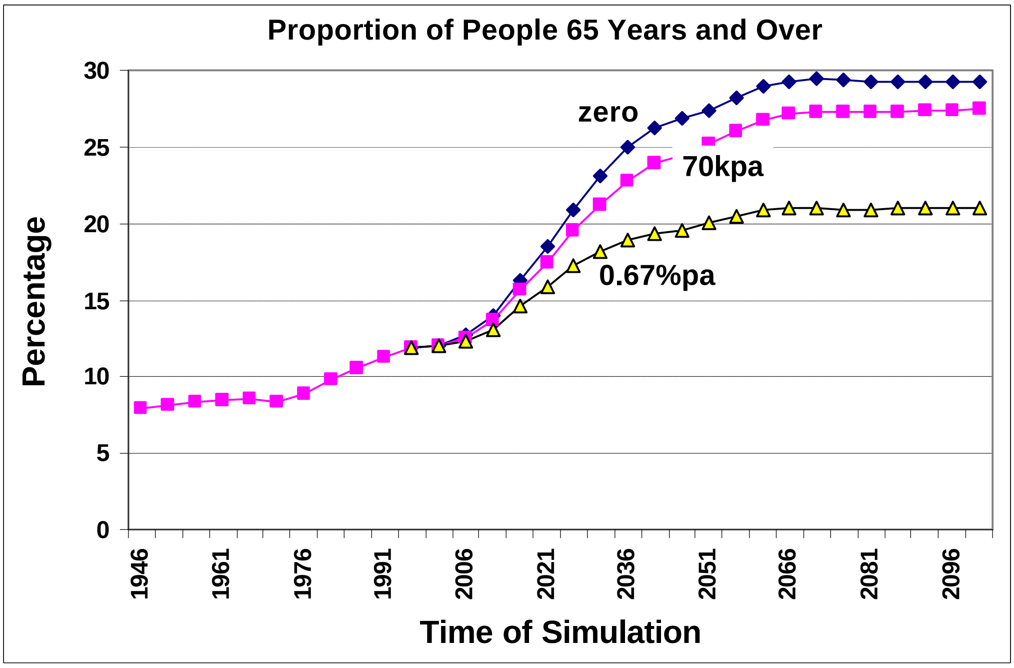


Figure 2.5. Simulated proportion of total population to 2100 who will be over 65 years of age for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Dependency ratios

The issue of ageing can be examined further by examining the total dependency ratio which compares the sum of the 0-15 and 65+ age groups with the 16-64 age group (Figure 2.6). The total dependency ratio presents a proportional view of the young and older potentially dependent groups in relation to the age cohorts which make up the bulk of the workforce. The historic period shows a peak in the 1960s corresponding to the baby boom and then a decline to the current period before a rise for the scenario period out to 2100. The zero scenario rises to 70% in 2050 before stabilising around 80% after 2060. The base case scenario is around 68% at 2050 and stabilises at 75% soon after. The 0.67%pa scenario rises to 60% in the mid 2030s and stabilises at that level thereafter until 2100.

Lower values could be seen as better than higher ones, but this interpretation hides a number of factors. The first is that proportional values mask absolute numbers, an issue already in the discussion on ageing. In this case, the lower total dependency ratio of the 0.67%pa scenario actually represents a larger number of dependents, potentially supported by a larger population of working age. The second issue is that many of the service, infrastructure and environmental issues reported in this study are related to per capita or per household consumption issues, and how those might change over time.

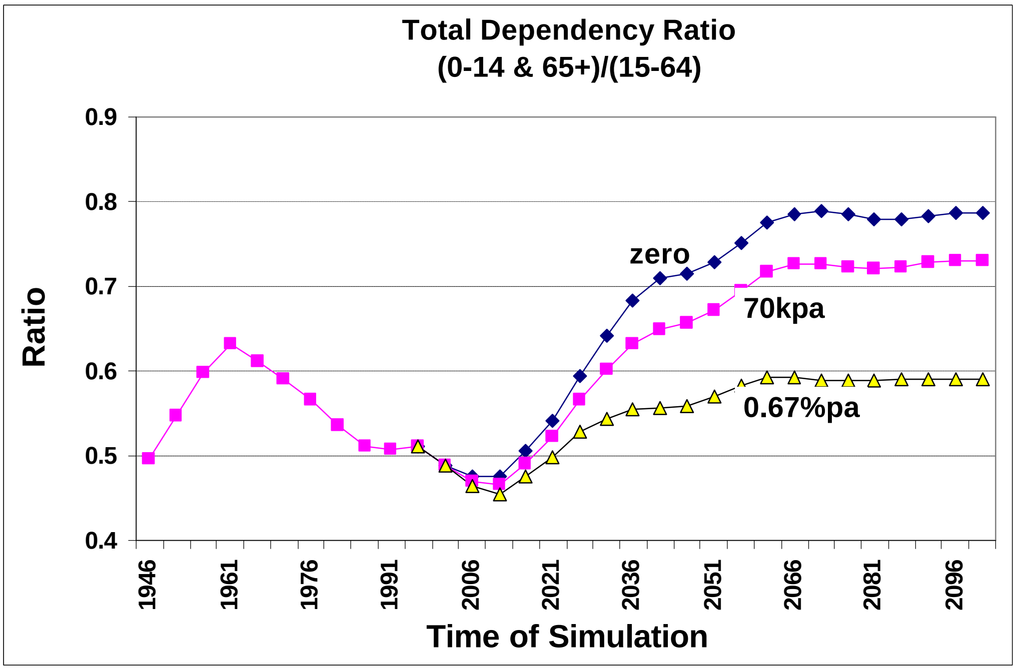


Figure 2.6. Simulated total dependency ratio to 2100 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa). These data may differ slightly from other published data due mainly to modelling aggregations which use 5 year cohorts rather than 1 year cohorts. However the trends in the data and the differences between the scenarios are consistent and reasonably robust.

The third issue relates to the work activity and contribution to society in general of Australians in the 65 and over age bracket. Hugo (1999) discusses a number of these issues and notes that the 65 and over age group are not necessarily dependent in the traditional sense, and might continue to work and contribute. Alternatively, the demand for goods and services from this group, if they are predominantly self-funded retirees in the next 50 years, could be seen as business opportunities rather than burdens on the economy and the working population. The 75+ population are by far the heaviest users of health, welfare and specialised housing services for the aged (Hugo 1999). In assessing the effect of ageing and the dynamics of retirement incomes Bacon (1999) notes that wealth and savings potentially grow more quickly in the 55+ age groups as education and mortgage costs decrease. He also notes that lowering unemployment may increase the incentive for older people to stay in the workforce both to maintain lifestyle as well as for personal fulfilment. Increasing pressure on public outlays may be due to rising health care costs rather than pension support. Within the context of Bacon's analyses, these comments apply mainly to the base case and zero scenarios.

Long-term health care

By the year 2050, the number of people requiring aged care, could be about 500,000 and nearly stable for the zero scenario or 650,000 and continuing to grow for the 0.67%pa scenario (Figure 2.7). These results should be viewed in the context of today, where 2.3 million people or 12% of the population are in the 65+ age bracket. In 1996 about 7% of older Australians were in health care establishments with the proportion increasing with increasing age. The remainder lived within a household. About 1.2 million people in the 65+ group have a disability and 880,000 require help living their daily lives (Australian Bureau of Statistics, 2000-a).

These results have physical implications, including future requirements for facilities dedicated to the care of the aged. Some of these issues are addressed in later chapters. The results also lead to the consideration of alternative options for addressing the issues related to aged care. Many of these options are already taking place, e.g. people staying in their own homes with daily care and retrofitting of homes for health, safety and security. Some local government areas in Japan, a country already in the transition to an aged society, have invoked planning laws where all hallways in new homes must be built with wheelchair traffic in mind and provisions must be made for lifts in multilevel dwellings.

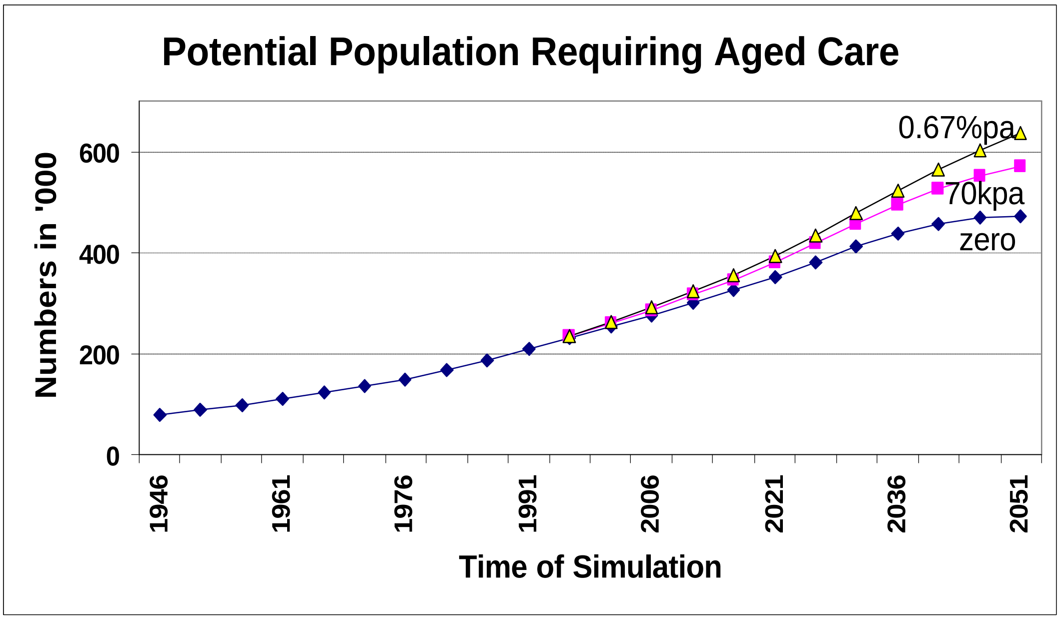


Figure 2.7. Simulated potential numbers of persons requiring aged care to 2050 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Health care issues in the future

As the age composition of the population changes it is possible that the incidence of chronic health problems linked to age will also rise (Figure 2.8). In health issues that relate to younger age groups, the incidence of 'pregnancy related complications' varies between the scenarios with greater incidence in the 0.67%pa scenario and lowest in the zero scenario. Due to declining birthrates the simulated results to 2050 are of the same order as the historical period. Pregnancy related complications remain a considerable health delivery task with 1.13 million patient days devoted to it in 1996 (Australian Institute of Health and Welfare, 1998). By contrast, a medical problem such as circulatory diseases becomes more prevalent with ageing and continues to expand with the ageing population and in the absence of changes in behaviour and breakthroughs in medical technology. The simulated results for this condition show a steady increase until 2030 when the zero scenario starts to stabilise while the base case and 0.67%pa scenarios continue to grow until 2050 and beyond. In 1996 this condition required 2.1 million patient days. The modelling framework reports on 18 different category areas that relate to hospital stays and thereby to the building infrastructure required. However many health conditions are treated at home or after a visit to the doctor so the simulation underestimates the medical conditions that may be prevalent in future populations.

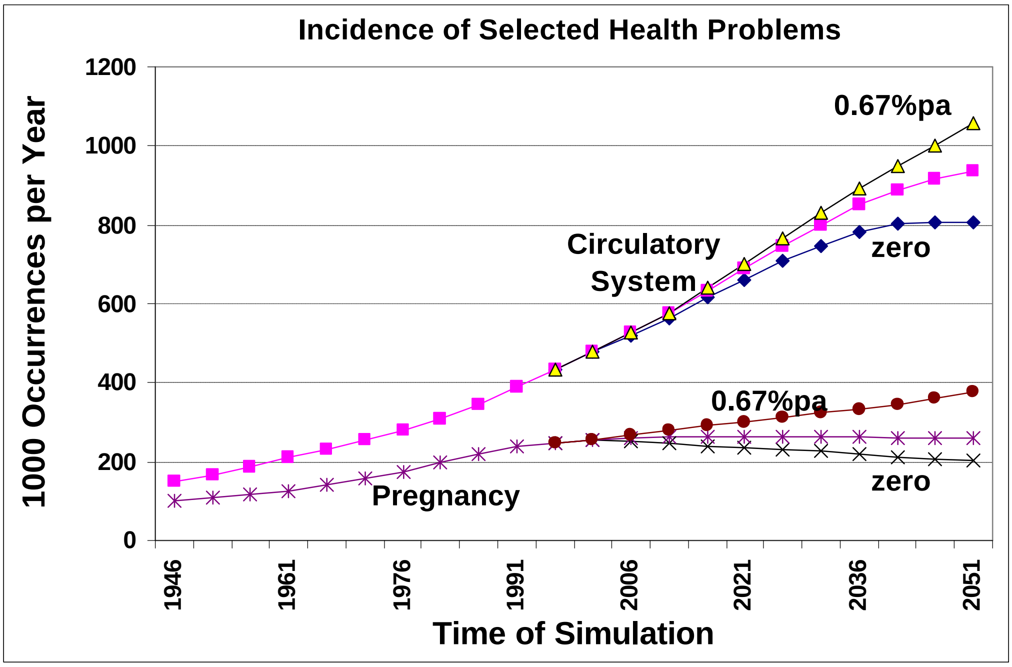


Figure 2.8. Simulated morbidity rates for two selected health conditions to 2050 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

While the nation's citizens are living longer, the total health task will continue to grow. National priority areas include cardiovascular health, cancers, injury prevention and control, mental health and diabetes. Many of these are linked strongly to age, but also to the life and lifestyle before ageing. Bacon (1999) reports that total health costs in monetary terms are 8.5% of GDP and this proportion could rise to 16% in 2031 and 19% in 2041. According to health literature "A pension costs much the same for an 85 year old as for a 65 year old and is capped" (Bacon, 1999). Health costs on the other hand rise rapidly with age and the group with the largest increase (compared to now) is expected to be the over 80 age group. The medical literature notes the challenges of an ageing population and how services must adapt to a permanent change in population structure in many developed countries that have undergone the demographic transition. In regard to the three population scenarios under discussion, the larger populations have a larger number of ageing people and therefore larger health tasks. They also have larger physical and monetary economies, and possibly greater potential to service these needs. In parallel with these issues is the potential of a rebound effect, whereby fewer health problems earlier in life (lower morbidities due to better health programs) have the potential to concentrate health services at higher intensities in the last 10 to 20 years of life.

THE LABOUR FORCE AND THE EDUCATION TASK

The total labour force

The number of people in the labour force depends on the number of people of working age in each population scenario and labour force participation rates. By 2050 the total labour force could number nine million in the zero scenario, 11 million in the base case and 15 million in the 0.67%pa scenario (Figure 2.9). This compares to a total labour force in 1999 of 9.4 million (Australian Bureau of Statistics, 1999). By the year 2100 the zero scenario declines to 7.5 million, the base case remains relatively stable at 11 million and the 0.67%pa scenario increases to 22.6 million people. The projections made by the Australian Bureau of Statistics out to 2016 give a labour force of 10.84

million people which agrees closely with the 10.96 million people simulated for the base case scenario at that time.

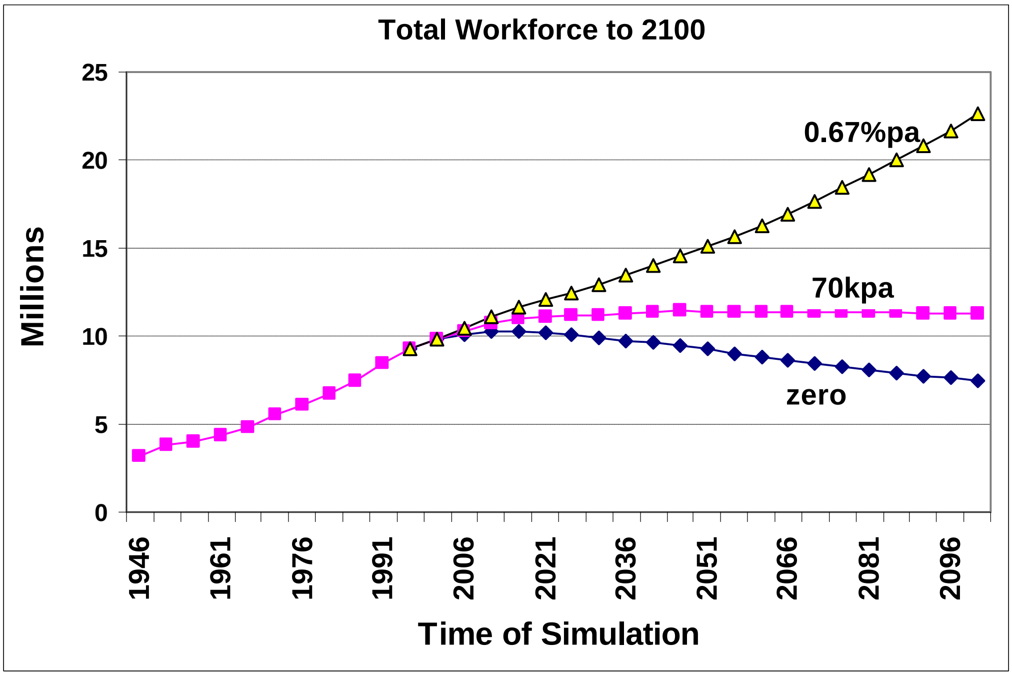


Figure 2.9. Simulated total labour force to 2100 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

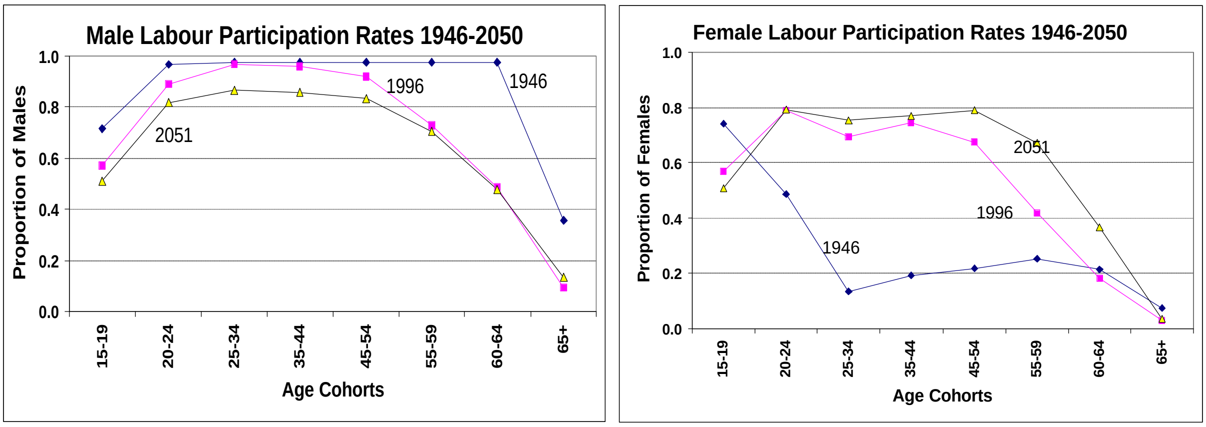


Figure 2.10. Labour force participation rates for the years 1946, 1996 and 2051 for males and females for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

While calculating the number of people of labour force age is relatively simple, defining the number of people in the labour force is complex. Within this modelling context it depends on the interaction of the demographic results already presented in this chapter with the labour force participation rates shown in Figure 2.10. For females there has been a large increase in participation rates in the period 1946 to 1996 as women have moved towards equal status and opportunity in the workplace. These rates are maintained in each of the future scenarios and increased particularly in the 45-64 year category. Male participation in the labour force has fallen from almost full participation in 1946 to lower rates in 1996 and will fall further by 2051, as the rate of male and female participation in the workforce becomes more equal. The issues of changes in the workplace and the relative mix of ages and genders in the workforce are extremely complex and treated in a relatively superficial manner in the ASFF modelling approach.

The changing nature of the workforce in relation to both technology and ageing of the population appears to be surprisingly under-researched (The Economist, 1999). While firms in many sectors and countries aim to make their workforces younger in an attempt to speed the cycle of innovation and make work practices more flexible, other views promote the advantages of age in bringing history, experience, better educational status and more strategic views to the workplace. There seems little doubt that the processes of technological innovation and the up-skilling of the workforce will continue. However, the emergence of the service economy and the change from blue collar to white collar jobs are accompanied by a number of new white collar tasks equal in drudgery to blue collar jobs (Jonsson, 1998). Job training, employee participation, inter-firm cooperation and penalising short-termism by firms are all crucial to developing attractive work opportunities in future labour markets (Marshall, 1999). Many of these issues lie outside the parameters of this study but they could pose important social boundaries to the relatively optimistic assumptions of future levels of physical productivity which are the starting point for all three population scenarios.

The national student body

Under the base case scenario, the number of students participating in the three levels of education will remain more or less stable until 2051. Low oscillations in the curve are produced by changes in the number of children being born, which is driven by the age structure of mothers and a shift in age distribution of births (Figure 2.11). The zero scenario gives a declining educational task of nearly 50 million student days lower than the base case at both primary and secondary level, but a relatively minor decline in the tertiary sector as the educational task is spread across a much wider range of ages. The 0.67%pa scenario produces a similar educational task to the current level out to the year 2020, when it rises to 500 and 400 million student days for the primary and secondary tasks respectively. The relative stability to 2020 is due to the balancing dynamics of a declining birth rate and increasing immigration which has a lag period before the increased number of immigrant mothers starts adding substantially to the total number of births. The tertiary education task increases continually from 2000 in the 0.67%pa scenario because the adult population from which the tertiary sector draws its students is continually growing.

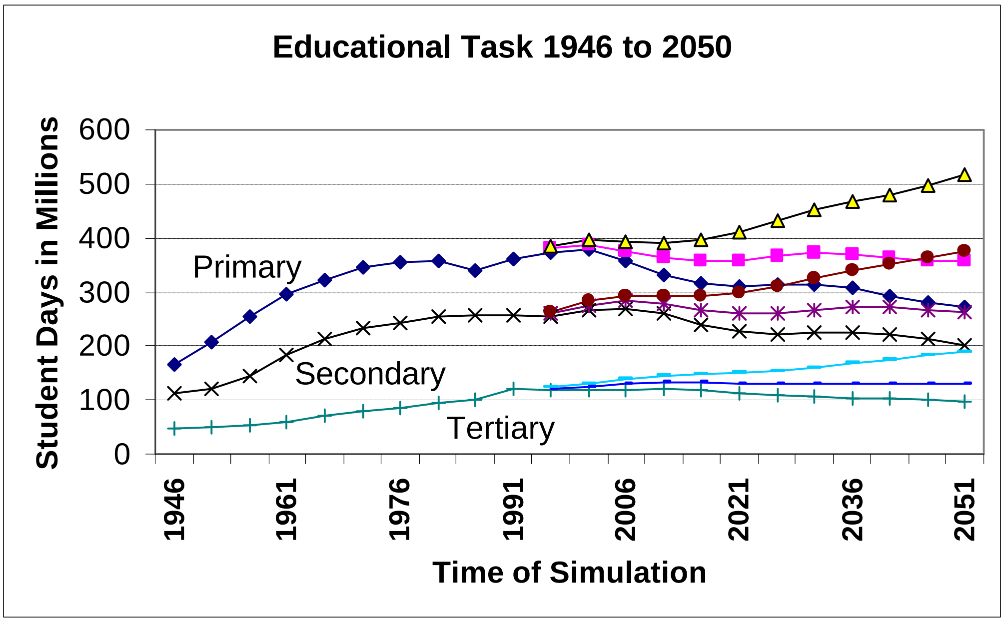


Figure 2.11. Educational task in million student days for primary, secondary and tertiary students. These are presented for three population scenarios: zero net immigration per year (lowest graph in each case), the base case of 70,000 net immigration per year (middle graph in each case), and 0.67% of current population as net immigration per year (top graph in each case).

In 1998 there were 3.2 million students in primary and secondary levels and 0.67 million students in tertiary and higher education courses. A teaching staff of 209,000 for primary and secondary, and 76,000 at tertiary level serviced this student population (Australian Bureau of Statistics, 2000-c, 2000-d, 2000-e). In the scenarios, the educational participation rates have been increased to reflect the increasing retention rates and increased use of tertiary education. However the settings do not reflect a functional change in the nature of Australian education, such as large increases in overseas participation, although this is an increasing trend. On the basis of the zero and base case scenarios, the demand for teachers appears to be relatively constant or slowly declining in the absence of major change within the education sector. In the 0.67%pa scenario the educational task increases after 2020 which would require a scaling up of teacher training around 2015. An uneven age structure of teaching staff may necessitate increased teacher training in different 5-year periods despite a relatively even demand for teaching effort out to the year 2020.

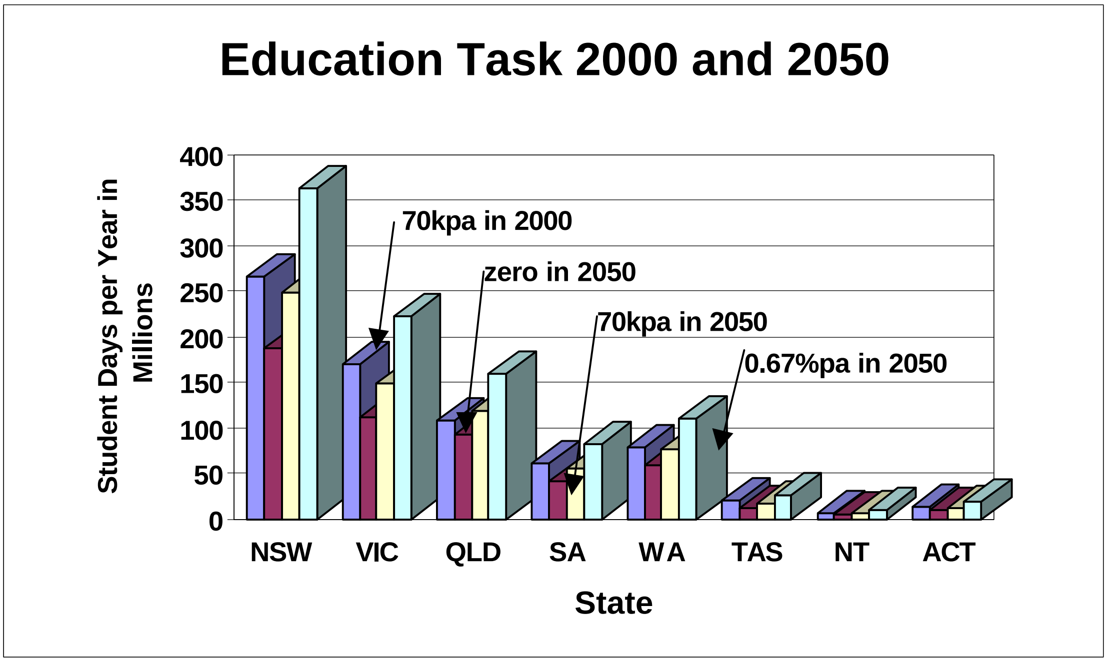


Figure 2.12. Total educational task in million student days for different Australian states and territories. These are presented for each state with a series of four bars. The bar on the left of the state group represents the base case scenario for the year 2000. Then to the right of that bar the zero, base case (70kpa) and 0.67%pa scenarios are presented for the year 2050.

The relative stability of the educational task in some scenarios obscures a number of regional dynamics that are driven by internal migration (Figure 2.12). Under the zero scenario the educational task declines in all states, while the task increases under the 0.67%pa scenario. For the base case scenario for both Queensland and Western Australia, the educational task in 2050 is similar to that in 2000 due to simulated population increases from assumptions on internal migration. It is possible that the patterns of internal migration will change markedly over the next 50 years and these educational analyses be rendered less useful. However, the analyses show that the dynamics of population policy decisions have linked effects that flow into areas such as education, its teachers and its infrastructure. Testing options such as these may allow long-term strategic planning to be undertaken with more focus and insight for the training and retraining of education professionals.

Domestic travellers

Although domestic tourists do not alter the total population of the nation, they do compound the pressures exerted by international tourists on particular locations at particular times. By 2050 domestic tourism could increase from its current level of around 300 million nights in 1998 (Australian Bureau of Statistics, 2000-f) to 700 million nights for the base case scenario or 850 million nights for the 0.67%pa scenario (Figure 2.13). The zero scenario increases to 550 million nights and then stabilises. The key driver of domestic tourism activity is the state of origin of the traveller (West Australians tend to travel within the state whereas Canberra's citizens mostly travel interstate) and their tendency to travel (characterised by age). This is relatively well known for travellers up to 50 years of age, but surprisingly under-researched for older Australians. Based on work by Benghezal et al. (2000), assumptions have been made, that the tendency to travel in the 50 to 64 age brackets is maintained until 75, declines rapidly until 85 and is zero at 90. Thus, the scenario results combine three sources of interaction (internal migration, population ageing and lowering birth rates) with changing of population size and location.

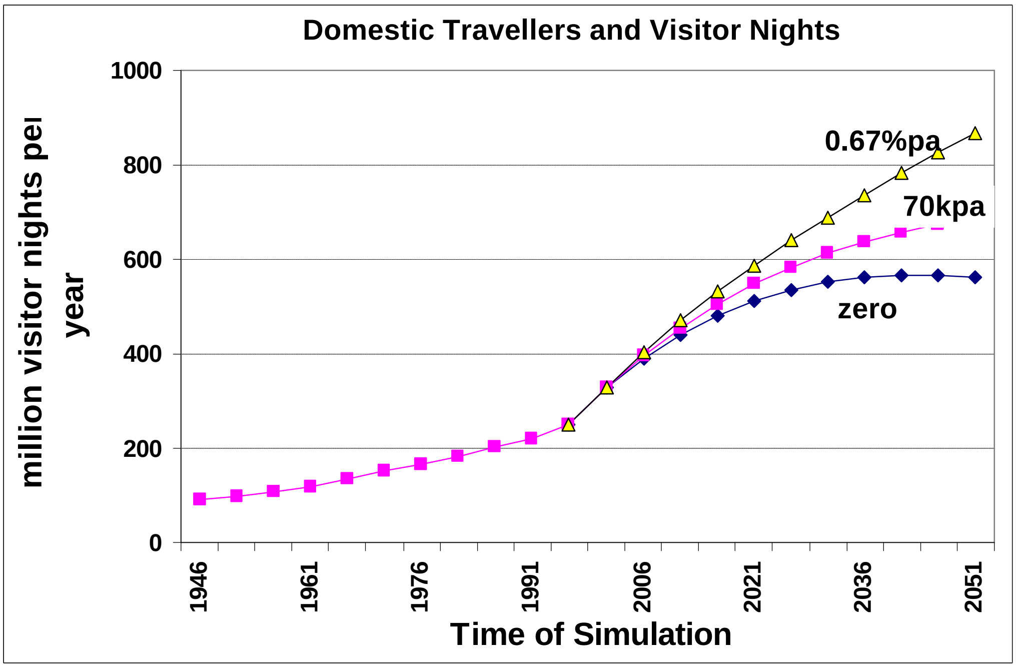


Figure 2.13. Simulated visitor nights for the domestic tourism task for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Inbound international travellers

In addition to the domestic tourism loadings discussed above, international tourism will add to the number of people in Australia. This will have implications for the environment as well as in terms of demands for services and infrastructure. For the purposes of the current study, the future levels of inbound international tourism are considered to be the same under all of the three alternative population futures. The number of visitor nights for inbound international travellers is projected to increase from 100 million in 1998 (Australian Bureau of Statistics, 2000-g) to nearly 600 million nights by 2050 (Figure 2.14). This result is independent of the domestic population scenarios and is driven by assumptions of growth rate in international inbound numbers derived from the DIMA tourism workshop and other sources. A growth rate of 7% has been assumed for the first 10 years, stabilising at 3% per year for the rest of the simulation period beyond 2020. This is less than the optimistic forecasts offered in workshops that inbound tourism will grow at 8-10% per annum for the next 25 to 50 years. The composition of the inbound mix was derived from a study on tourism to 2020 by Foran et al. (2000) which found that the numbers of tourists from traditional sources such as Japan, North America and Europe would stabilise and most growth could be expected from Asian countries. These possible changes in composition have important implications for physical activity within Australia. Increasing numbers of short stay visitors could increase energy and material usage per visitor day and produce knock-on effects to other physical sectors.

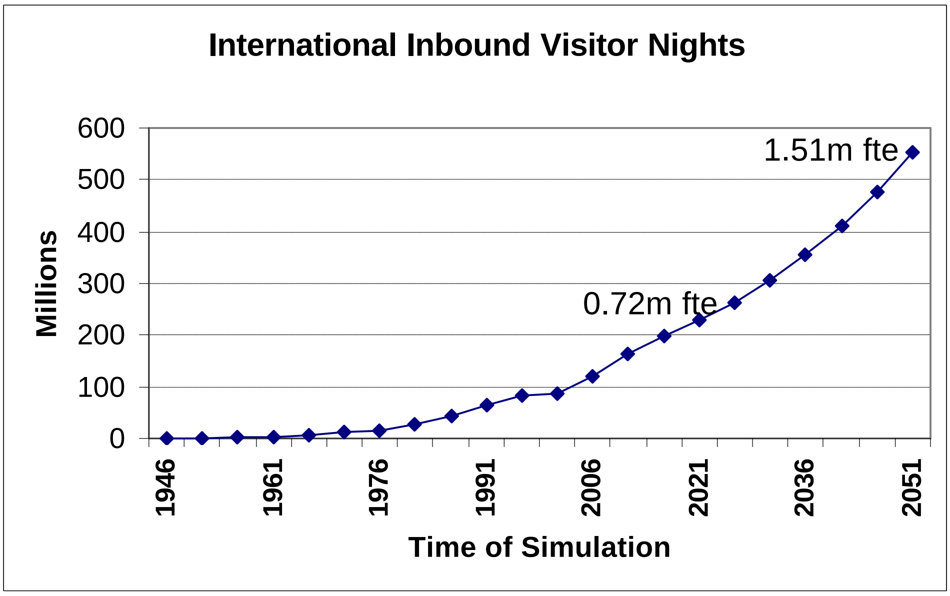


Figure 2.14. Simulated visitor nights for inbound international tourism to 2050.

Based on these assumptions, the total number of international inbound visitors in 2050 could be 34 million people with an average stay length of 16 days. This compares with 4.2 million people in 1998 (Australian Bureau of Statistics, 2000-h) with an average length of stay of 24 days. This reflects the trend towards more holidays per year, but a shorter length of stay for each holiday. In a dynamic industry such as tourism, these assumptions could easily change depending on events in the inbound country as well as the marketing and promotion efforts by Australian tourism companies and international travel firms. Both Boeing (2000) and Airbus (2000) project growth in air traffic in the Asia-Pacific region of between 4.7 and 6.1% per annum for the next 20 years, and an average growth in cargo traffic of 6.4% per year. Much of the requirement for new planes lies with the medium sized single aisle variety, although Airbus suggests that the Asia Pacific region will drive the development of aircraft larger than anything flying today.

The international inbound nights correspond to a full time equivalent population of 0.72 million in 2020 and 1.51 million in 2050 (Figure 2.14). This assumes visitors and residents have the same resource requirements and environmental loadings. Given the amount of travel and lifestyle services embodied in a typical international tourist day, this ratio could vary between 1:1 and 2:1. Using the higher value could place the equivalent environmental loading of international inbound visitors as high as 3 million people by 2050. On a 1:1 basis this represents between 5% and 7% of the population numbers in the scenarios at that time, while on a 2:1 basis it represents between 9% and 15%. Thus in comparing growth in international tourism with growth in domestic population, generally tourism (i.e. full time population equivalents) represents less than the growth in the base case scenario out to 2050. However tourism is generally highly concentrated in location and time rather than being spread equally across the landscape. In addition, tourism is an energy intensive industry and recent New Zealand analyses suggest that, on a full life cycle analysis, inbound and domestic tourism account for more than 20% of the primary energy use in that country (Patterson, pers. comm.).

Destinations

Spreading the tourism task on the basis of current patterns of visitation enables us to assess future challenges for tourism management and the development of infrastructure (Figure 2.15). By 2050, inbound international tourism could be much greater than domestic tourism in most capital cities; especially so in Sydney and Melbourne where the ratio of international to domestic visitor nights for the base case scenario varies between 5:1 and 6:1. In general, the situation for the other areas in each state is reversed, as most residents of capital cities take their holidays within their own state. The exception is for Queensland where the domestic and international visitor nights are approximately equal due to the Gold Coast and the Great Barrier Reef.

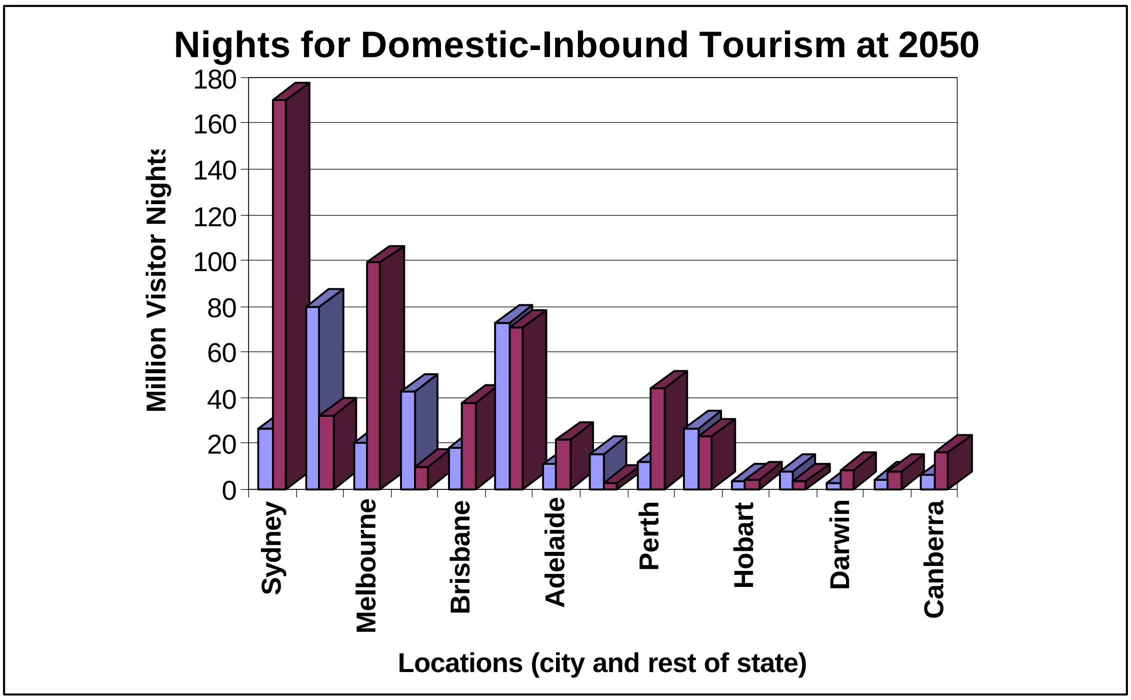


Figure 2.15. Simulated visitor nights for domestic and inbound international visitors in 2050. Domestic nights are the column on the left and international nights are on the right. The bars without a legend to the right of each capital city represent the rest of the regions within that state. Domestic nights are for the base case population scenario and inbound nights do not vary between scenarios.

The patterns presented by these analyses present some obvious opportunities and threats. The opportunities lie with the large tourism task presented to many of the capital cities and regions and the employment and development that might follow. The pattern of visitation described also presents another opportunity. When these data are disaggregated to reflect visitation to different tourism regions in each state, inbound tourism visitation is restricted to a limited number of areas. National policies which aim to spread the visitor load could reduce pressure on the main cities and bring tourism revenue to enhance regional development opportunities. The threats lie with the large concentrations of visitors in a limited number of areas and the extent to which development of key infrastructure is able to cope with them. The influence of large concentrations of visitors on the lifestyle of city inhabitants could also be an issue.

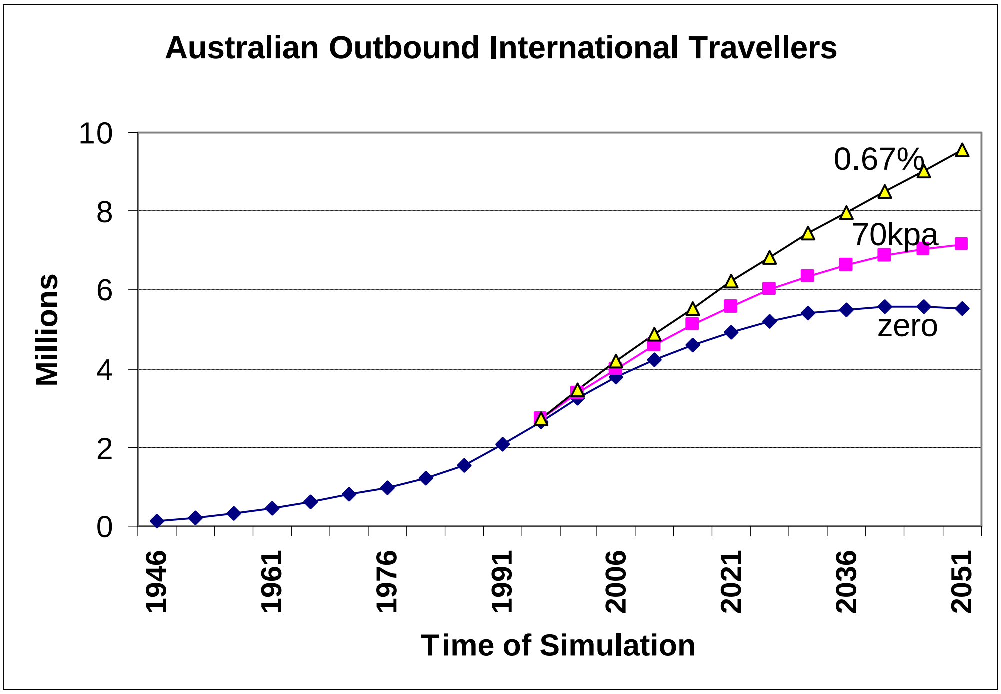


Figure 2.16. Simulated numbers of Australian outbound travellers for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Australians travelling abroad

By 2050 the numbers of outbound international trips could be approximately six, seven or nine million per year for the zero, base case and 0.67%pa scenarios respectively (Figure 2.16). In 1998, about 3.2 million Australian residents travelled abroad (Australian Bureau of Statistics, 2000-i). The scenario results are driven by both changing population number and age structure, as well as an expected increase in outbound travel propensity over the duration of the scenario. The past decade has seen an average yearly growth in outbound travel by Australians and Hamal (1998) projects a growth rate of 4.5% per annum over the next decade. While there are many opportunities to alter the balance between domestic and outbound international tourism, the expectation of increasing affluence linked to disposable income suggests that these scenarios for outbound tourism are feasible.

Fuel uplifted for international tourism

Population influences the use of resources for tourism in two ways, both requiring the same resources and producing greenhouse emissions. In a direct influence, domestic population levels drive domestic tourism activity and Australians departing for abroad. At a more remote level, international inbound travel acts in the same way as export trade by attracting inflows of international currency that eventually become included in the nation's overall trade balance.

Aviation activity in Australia totals 26.7 billion passenger kilometres and nearly 200,000 tonnes of freight. International activity includes 7.2 million passenger departures and 340,000 tonnes of freight (Australian Bureau of Statistics, 2000-j). In the process, the industry uses 185 petajoules (10^{15}J) per year (Bush et al., 1999). When both international visitors and Australians travelling overseas depart from Australia, the aviation fuel must be sourced from the country's physical economy or be imported. By the year 2050, the energy required for international departures could exceed 400 PJ per year (Figure 2.17). There is little difference between the population scenarios as the majority of the influence is due to international travellers departing (34 million) rather than Australians leaving (5-9 million).

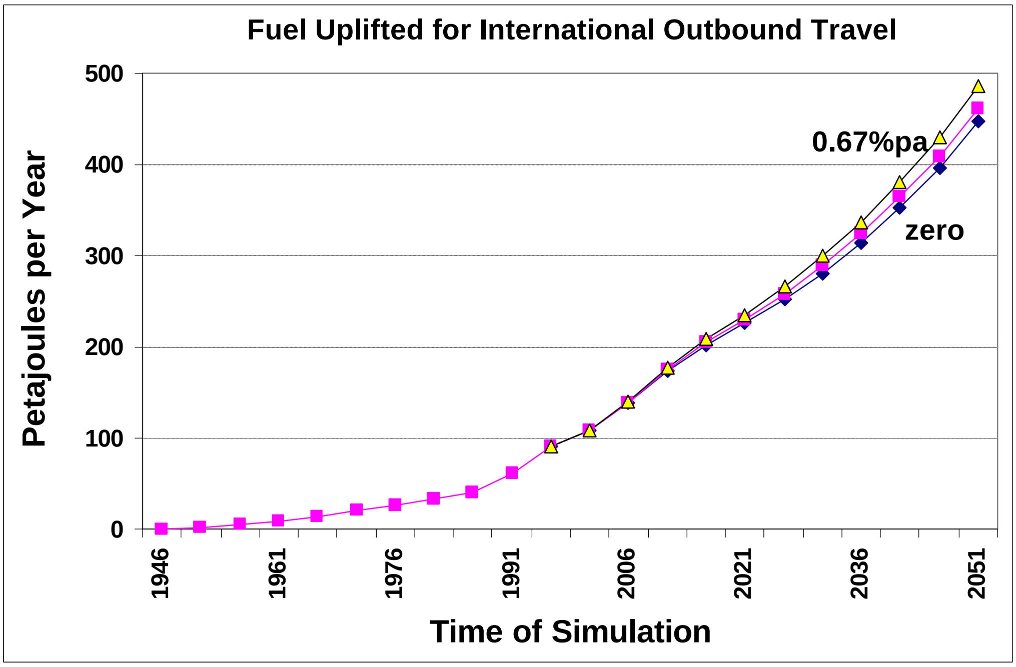


Figure 2.17. Simulated amount of fuel required for international outbound travel for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

When both international outbound and domestic air travel are combined, about 600 PJ of aviation fuel could be required by 2050, almost all of it directed towards passenger services. The total transport task in Australia currently requires approximately 1,200 PJ per year. In future, air transport could use more than 50% of the current transport energy. Given future market developments, there are unlikely to be constraints on energy for aviation, although the monetary cost of air travel may rise appreciably. The greenhouse gas implications could also be significant, in international terms. Jet fuel for international aviation is included in national energy usage, and combustion products are allocated to Australia's greenhouse gas account since the national economy benefits from visitors and their expenditure.

Few technological surprises are expected in international aviation and the scenarios have relatively optimistic settings for a decline in energy use per passenger kilometre into the future. Increases in physical efficiency could come from a mixture of better technology (slicker planes and better engines) and better management (better load management). Within Australia, shifts between modes of transport are possible. Lenzen (1999) reports the energy cost of air travel as 5.7 and 3.1 megajoules (10^6J)per person kilometre, for domestic and international air travel respectively. Values for train and bus transport vary from one to three MJ per passenger kilometre — about half that of air. There is scope for savings, but it is unlikely that other transport modes will match the timeliness and speed of air travel in many situations. Some of these issues will be examined in more depth in Chapter 5.

The total food basket

Australia has the capacity to maintain a positive food balance in all main food commodity items, apart from fish, out to 2050 and beyond for the three scenarios (Table 2.5). The primary requirement for grain in 2050 for human diet varies from two to 3.6 million tonnes per year, which is well within the 31 million tonnes of grain that was produced in 1998 (Australian Bureau of Statistics, 2000-k, 2000-l, 2000-m). The total requirement for all meats (beef, veal, lamb, chicken, pork) in 2050 varies from 2.3 to 3.8 million tonnes. In 1998 Australia produced 3.5 million tonnes of meat but over the past 30 years, sheep and cattle numbers have been up to eight percent higher than current numbers. There is capacity to increase animal numbers, depending upon allocation of land to other uses. A number of scenarios are analysed in Chapter 4. The total requirement for fish in 2050 varies from 0.35 to 0.58 million tonnes per annum compared to 0.22 million tonnes produced in 1998. This demand will present some challenges to Australia's fisheries resource which are examined in Chapter 4.

Table 2.5. Human consumption requirements in 2050 for three categories of foodstuffs for the three population scenarios compared to actual production in 1997-98 (millions of tonnes per year).

	Zero scenario in 2050	**Base case scenario in 2050**	**0.67%pa scenario in 2050**	**Actual production in 1997-98 (ABS)**
Total grain	2.136	2.713	3.568	31.578
Total meat	2.278	2.893	3.804	3.514
Total fish	0.346	0.439	0.577	0.223

Over the last 50 years, Australians have made significant changes to their diets, the consumption of red meat and dairy products has declined and grains, fruits and vegetables have increased. In the future scenarios out to 2050 the dietary composition is assumed to remain much the same. Major changes could take place (e.g. a widespread shift to vegetarian diet), the only constraint being large increases in fish consumption. There are however a number of important considerations that lie, hidden from view, within the food chain.

The large substitution of white meats such as chicken and pork for red meats such as beef and lamb include significant volumes of grain, embodied in the production system. To produce one kilogram of chicken requires two to three kilograms of grain, pork, four to five kilograms and feedlot cattle, eight to 10 kilograms. Fish grown under aquaculture require two to four kilograms of grain, depending on the species and management system, with the added proviso that the diet generally contains 20-30% fish meal, i.e. feeding fish to fish. Much of this fish meal is derived from productive fisheries elsewhere such as the Peruvian anchovetta fishery. Aquaculture in general requires that biological capital be transferred from a wild ecosystem to a managed one, although there are substantial opportunities for technological improvement. This is more fully discussed in Chapter 4.

When the embodied grain requirements of meat production are used with the population scenarios, an extra six, 7.6 and 10 million tonnes of grain are required for the zero, base case and 0.67%pa scenarios respectively. Using a conservative value of the current levels of total grain production as a basis, this means that under the three population scenarios, about 25 to 45% of Australia's current grain production could be required to supply internal food requirements. Meat for export would consume extra grain above this estimate if lot fed. While Australia is expected to maintain a positive grain balance well into the future on the basis of direct human requirements, the grain consumption embodied in meat products such as chicken, pork, feedlot beef and aquaculture could reduce the balance, and thus reduce the volume available for export. Analyses that relate agricultural production issues to Australia's land and water futures are explored in Chapters 4 and 6.

Paper and Plastics

A wide variety of materials underpin our contemporary lifestyle and consumption. Paper and plastic have been chosen as examples and there is a steady increase in the amount required by the three population scenarios out to 2050 (Figure 2.18). By 2050, there could be a requirement for four, five or seven million tonnes of paper under the zero, base case and 0.67%pa population scenarios respectively. Currently, Australia consumes 3.3 million tonnes of paper in all its various forms, of which 1.4 million tonnes or about 40% is recycled (Visy Recycling, 1999). The per capita consumption levels used in the scenarios gradually rise from the current level of 170 kg (2000) to 200 kg per person per year by 2030.

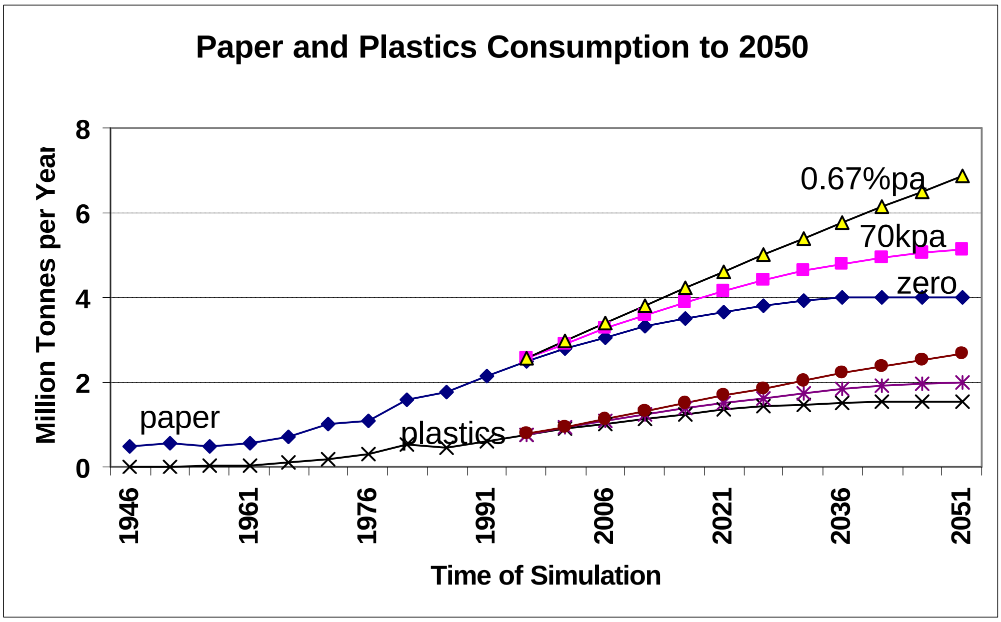


Figure 2.18. Simulated consumption of paper and plastics for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Clearly the scenario includes a strong primary driver due to population growth as well as growth in areas that relate to affluence and lifestyle. An assumption could be made that paper use is stabilised and then rapidly or gradually reduced as innovations such as the paperless office gain momentum. The new information media and paper products seem to have developed an amiable coexistence that has increased the demand for information products rather than one form replacing another (von Ungern-Sternbarg, 1999). The scenario simulations presented could potentially stabilise and decline over times scales of five to 10 years, but this remains possible rather than probable. Alternatively the use of recycling could reduce the requirement for virgin fibre. Recycling could be increased over time up to a maximum of 70% according to industry experts in the DIMA workshops. But there are two limitations: (i) the paper supply is too widely spread to allow collection above a certain level; (ii) unlike aluminium which can be continually recycled without degrading the basic material, paper fibres can only be recycled a maximum of three to four times. Each recycling step results in a 10% loss of fibres and each step requires a drop in the subsequent quality of the end product e.g. photocopy paper to newsprint to cardboard.

The consumption of plastics could continue to increase under the primary drivers of the population scenarios from about one million tonnes annually to two million tonnes by 2050 for the base case scenario. At 2050, the zero scenario is 0.4 million tonnes below, and the 0.67%pa scenario is 0.8 million tonnes above the base case. The per capita consumption level in the scenario increases from 50 to 80 kg per capita per year during the simulation period. These assumptions are open to large changes over the next 50 years particularly as regards substitution of materials. About 90,000 tonnes of plastics were recycled in 1997 and many opportunities exist to increase the proportion of recycling undertaken (SIRA, 1999). Whole economy analysis in Germany suggests that the use of plastics may quadruple in the next 25 years and that they have a mean residency time (as materials in the physical economy) of 14 years with a range of a few months to 30 years (Patel et al., 1998).

TESTING SUB-SCENARIOS

Each chapter in the report explores a number of 'sub-scenarios'. These are technological, policy or management changes, that break-out scenarios from the base case scenario to explore a set of management issues in detail. In particular, these sub-scenarios will explore interactions within the model that bring together a number of linkages. A number of population-driven effects can be comprehended without model analysis. If, in the section above, the question was asked "what would be the effect of halving paper or plastics consumption on a per capita basis", then it is relatively easy to interpolate the answer on the graph in Figure 2.18. For example, a halving of the per capita consumption of paper would allow the 0.67%pa scenario to operate with the same resource intensity for paper as the zero scenario. Other linked effects could include a loss of employment (less paper production and recycling activity), less energy use, more wood available for export and so on. However other population issues are more complicated. The following sub-scenario explores the interplay between the domestic 'total fertility rate' and the immigration rate.

What birth rate is necessary to equal the effect of immigration?

The *What-If* question relates to the increases in total fertility rate required to elevate one scenario from its population result at 2050, to the population result of the next scenario. Thus, changes to control parameters are limited to the total fertility rate in the zero scenario required to increase the population from 20 million to the 25 million target achieved by the base case in 2050. Likewise, the total fertility rate of the base case scenario is increased while retaining the net immigration rate at 70,000 per annum so that the population of 25 million is increased to the 0.67%pa scenario of 32 million by 2050 (Table 2.6; Figure 2.19).

An overall rise in the total fertility rate from 1.65 to 2.07 is required for the transition from the zero scenario to the base case scenario, to compensate for the differences in net immigration rate. For the transition from the base case to the 0.67%pa scenario, a rise from 1.65 to a steadily increasing rate which reaches 2.51 by 2050 is required. Apart from New Zealand and the USA, very few developed countries have total fertility rates in excess of 2.0 (Australian Bureau of Statistics, 1999: Hugo, 1999) and the potential that these rates might rise, seem unlikely. However McIntosh (1998) reports a number of relatively high rates in Scandinavian counties following the implementation of tax reforms and the introduction of parental insurance programs. Total fertility rates fell again in the 1990s as economic recession and cuts to social welfare made family maintenance more difficult.

The changes in total fertility which achieve population targets with lower immigration rates, also have an effect on the age structure of the population and in particular the proportion of people aged 65 years and over (Figure 2.19). Achieving a population target of 25 million by 2050 with zero net immigration also reduces the proportion of the population 65 years and over, so that it lies midway between the 26% at 2050 achieved by the base case and the 20% achieved by the 0.67%pa scenario.

For the transition from the base case to the 0.67%pa scenario, the adjustments to the aged profile are more marginal with the proportion of greater than 65 year olds stabilising about 1% below the original scenario.

Table 2.6. The changes in total fertility rate required to elevate the total population number by 2050 (a) from the zero scenario to the base case scenario and (b) from the base case scenario to the 0.67%pa scenario.

Year of Simulation	Base case scenario: total fertility rate	(a) Raising the zero scenario to the base case scenario	(b) Raising the base case scenario to the 0.67%pa scenario
1996	1.88	1.88	1.88
2001	1.74	2.06	2.07
2006	1.67	2.07	2.12
2011	1.65	2.07	2.16
2016	1.65	2.07	2.21
2021	1.65	2.07	2.26
2026	1.65	2.07	2.30
2031	1.65	2.07	2.34
2036	1.65	2.07	2.38
2041	1.65	2.07	2.42
2046	1.65	2.07	2.46
2051	1.65	2.06	2.51

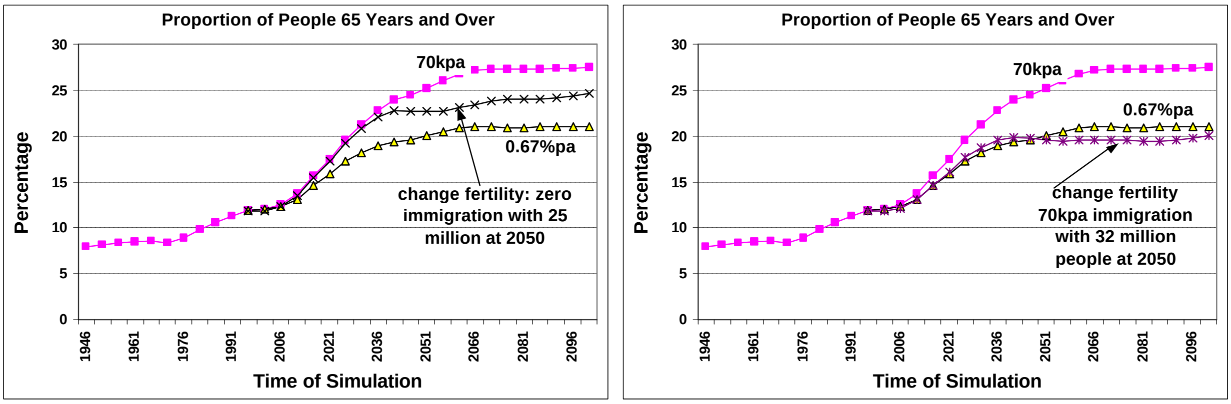


Figure 2.19. Simulated effect on proportion of people over 65 years old out to 2100, through reaching population targets at 2050 using lower immigration rates with higher domestic fertility rates. The left hand graph shows zero net immigration with changed fertility, and the right hand graph shows the base case with changed fertility.

DISCUSSING POPULATION EFFECTS

Throughout the report, an attempt will be made to highlight issues and effects that are linked directly to domestic population size, and also where those population effects are more diffuse. This chapter has set the population boundaries for the following chapters which are linked to physical transactions and the workings of the physical economy. The terminology of **primary**, **secondary**, **tertiary** and **quaternary** has been developed to describe effects of population size (Figure 2.20). The terminology is proposed whereby human population size drives the requirement for goods and services. These requirements may be direct or indirect. While the direct drivers are the key focus of this study, in reality it is impossible to ignore the 'knock-on' effects that cascade through the physical economy. This understanding is crucial to policy formulation in important areas that relate to the concepts of sustainable development, particularly in the area of fossil energy use and greenhouse gas emissions.

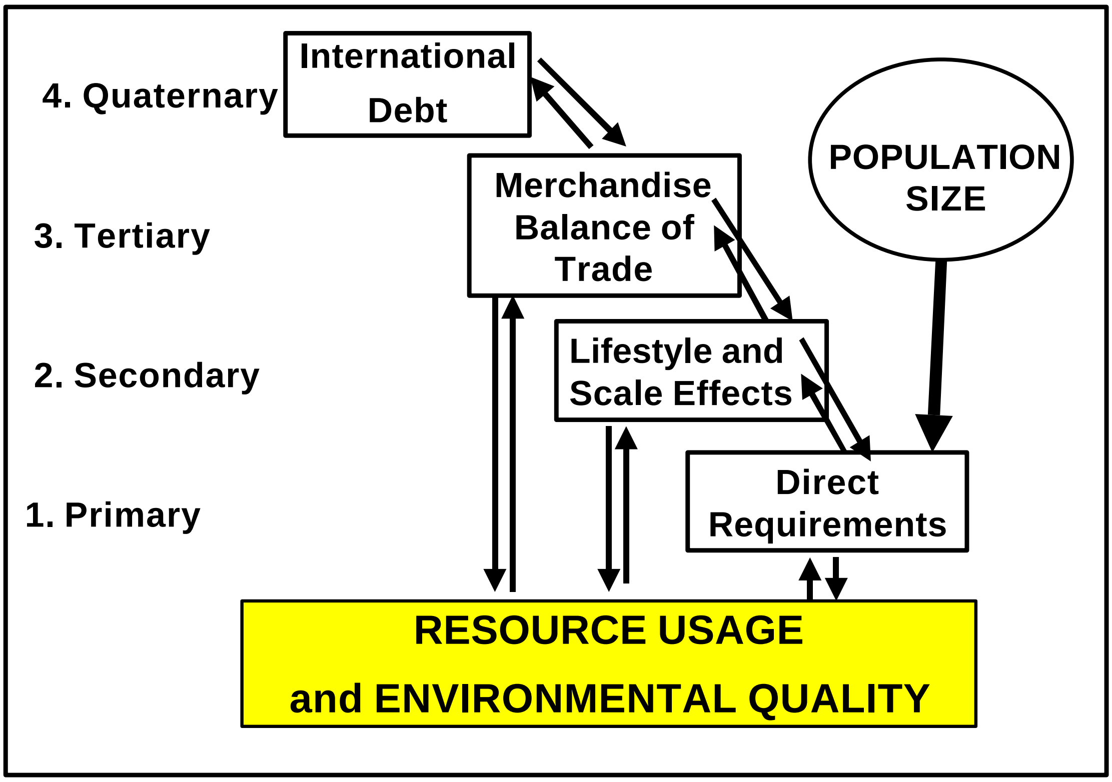


Figure 2.20. A representation of the four levels of population influence from the primary or first order influence to the more diffuse quaternary or fourth order effect.

The four levels of population influence have been defined as follows:

- **Primary** (or first order) drivers are linked directly to individuals who require food, households that require houses, cars, newspapers, televisions and refrigerators, and communities that require schools, hospitals, public transport and sporting ovals. The distinction between a 'need' and a 'want' is relevant, but is not addressed in this analysis.

- The **secondary** (or second order) drivers of population growth are linked to affluence, lifestyle and scale issues. Affluence and lifestyle issues describe the expansion of a direct requirement or need into a higher level of consumption or quality that could require more energy and materials to deliver that good or service. Thus, airline travel which allows a yearly requirement (a need) of one month's holiday at a distant location, might be expanded by higher levels of affluence into four such flights for holidays of one weeks duration. Scale issues relate threshold effects such as the presence of international airports, convention centres and five star hotels which expand opportunities for industries such as tourism and thereby transactions in the physical economy. For example the Sydney Olympics could not have been staged until that city had reached a certain level of size, sophistication, competence and complexity.

- The **tertiary** (or third order) drivers of population growth occur when the domestic requirements for imported goods and services have to be covered by revenue from the goods and services from the nation's export industries. The rising level of imports linked to consumption growth on a per capita of per household basis, have to be paid for by exporting commodities such as coal, aluminium and wheat and importing international tourists.

- The **quaternary** (or forth order) drivers occur when the lagged effects of previous population growth and economic development have contributed to issues such as international debt and weakness of currencies. These may drive the requirement for physical activity particularly in export industries well into the future until these pressures are reduced. In the function of economic, social and political systems there are many mechanisms which constrain these quaternary drivers within reasonable limits, and allow them to adjust to short-term crises. While the driver is only loosely linked to population size, its functional effect proposes that a heavily indebted nation may be more obliged to increase its physical transactions than a less indebted nation.

Most issues discussed in Chapter 2 are related to the primary influence of population number. Thus the size of the total population will directly affect the size of the major capital cities, the domestic consumption of food, paper and plastic and the requirements for urban water supply.

THE NEXT CHAPTER

The next chapter will use the population scenarios described in this chapter to analyse the range of urban issues that are derived from them. The issues addressed will include the following:

- Housing requirements for the different scenarios of population size to 2050
- Other buildings for education, health care, and institutions
- Tourism accommodation
- Personal transport and intercity transport
- Technological options for cars, houses, and industry
- Urban water
- Air emissions and waste
- Structural and environmental problems with current Australian cities

REFERENCES

Airbus Industrie (2000). Global Customer Base: Asia Pacific. http://www.airbus.com/market.html accessed 13-04-2000

Australian Bureau of Statistics (1998). *Population Projections 1997 to 2051*. ABS Catalogue Number 3222.0 July 1998.

Australian Bureau of Statistics (1999). Labour Force Projections 1999 to 2016. Catalogue Number 6260.0, September 1999.

Australian Bureau of Statistics (2000-a). Australia Now, A Statistical Profile, Income and Welfare: Mini Article - Support for older people. http://www.abs.gov.au/websitedbs/c311215.NSF/20564c23f3183fdaca25672100813ef1/e442e2a58dfcf93cca25685f00008a82!OpenDocument accessed 13-04-2000

Australian Bureau of Statistics (2000-b). Population Projections, Australia, 1999 to 2101. Catalogue Number 3222.0, September 2000.

Australian Bureau of Statistics (2000-c). Australia Now, A Statistical Profile, Education and Training, Participation in Education http://www.abs.gov.au/websitedbs/c311215.NSF/Australia+Now+-+A+Statistical+Profile/A6DAE7FBEB2162D2CA2567220072EA86/ accessed 13-04-2000

Australian Bureau of Statistics (2000-d). Australia Now, A Statistical Profile, Education and Training, Schools, Students and Teaching Staff http://www.abs.gov.au/websitedbs/c311215.NSF/Australia+Now+-+A+Statistical+Profile/0D855A2F2C911D5CCA2567220072EA7F/ accessed 13-04-2000

Australian Bureau of Statistics (2000-e). Australia Now, A Statistical Profile, Education and Training, Higher Education http://www.abs.gov.au/websitedbs/c311215.NSF/Australia+Now+-+A+Statistical+Profile/34FCC575F6666740CA2567220072EA84/ accessed 13-04-2000

Australian Bureau of Statistics (2000-f). Australia Now, A Statistical Profile, Tourism, Domestic Tourism http://www.abs.gov.au/websitedbs/c311215.NSF/Australia+Now+-+A+Statistical+Profile/E92575F7C0FF74EACA2567220072EA28/ accessed 14-04-2000

Australian Bureau of Statistics (2000-g). Australia Now, A Statistical Profile, Tourism, International Inbound Tourism, Characteristics http://www.abs.gov.au/websitedbs/c311215.NSF/Australia+Now+-+A+Statistical+Profile/148B902B17B5AAC6CA2567220072EA92/ accessed 14-04-2000

Australian Bureau of Statistics (2000-h). Australia Now, A Statistical Profile, Tourism, International Inbound Tourism, Expenditure http://www.abs.gov.au/websitedbs/c311215.NSF/Australia+Now+-+A+Statistical+Profile/445808714D57D1A6CA2567220072EAAE/ accessed 14-04-2000

Australian Bureau of Statistics (2000-i). Australia Now, A Statistical Profile, Tourism, International Outbound Tourism http://www.abs.gov.au/websitedbs/c311215.NSF/Australia+Now+-+A+Statistical+Profile/10DA848B3AC2AD17CA2567220072EAB1/ accessed 14-04-2000

Australian Bureau of Statistics (2000-j). Australia Now, A Statistical Profile, Transport, Air Transport, Domestic Activity http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/a73a9b6a25ca7457ca2568a900154b26!OpenDocument Accessed 14-04-2000

Australian Bureau of Statistics (2000-k). Australia Now, A Statistical Profile, Agriculture, Meat Production and Slaughterings http://www.abs.gov.au/websitedbs/c311215.NSF/Australia+Now+-+A+Statistical+Profile/C621F7872F8D6EEACA2567220072E9F1/ 5/4/2000 accessed 15-04-2000

Australian Bureau of Statistics (2000-l). Australia Now, A Statistical Profile, Agriculture, Crops http://www.abs.gov.au/websitedbs/c311215.NSF/Australia+Now+-+A+Statistical+Profile/F0D4CD91F9E9AE63CA2567220072E9ED/ accessed 5/04/2000

Australian Bureau of Statistics (2000-m). Australia Now, A Statistical Profile, Agriculture, Apparent Consumption of Foodstuffs http://www.abs.gov.au/websitedbs/c311215.NSF/Australia+Now+-+A+Statistical+Profile/F3342B8281355710CA2567220072E9F4/ accessed 5/4/2000

Australian Institute of Health and Welfare (1998). *Australia's Health 1998*. http://www.aihw.gov.au/publications/health/ah98.html accessed 13-04-2000

Bacon BR (1999). Ageing in Australia: Some modelling results and research issues. Department of Treasury, Retirement and Income Modelling Unit. http://www.treasury.gov.au/default.asp?main=/publications/retirementincomemodelling(rim)taskforce/models.asp accessed 13/04/2000

Benghezal V Foran BD and Baker B (2000). Unfogging the Future in 2020: Balancing the opportunities and challenges for Australian tourism in the long term. CSIRO Resource Futures Working Document 00/09. http://www.dwe.csiro.au/research/futures/

Boeing (1999). Current Market: World market demand and airplane supply requirement http://www.boeing.com/commercial/cmo/index.html accessed 14-04-2000

Brotchie J Batty M Blakely E Hall P and Newton P (1995). *Cities in Competition: Productive and Sustainable Cities for the 21st Century.* Longman Australia, Melbourne.

Bush S Dickson A Harman J and Anderson J (1999). Australian Energy: Market Developments and Projections to 2014-15. Australian Bureau of Agricultural and Resource Economics, Research Report 99.4

Conroy J Foran BD Poldy F and Quinnell T (2000). Future Options to 2050: DIMA Workshops Report. CSIRO Resource Futures Working Paper Series 00/03, March 2000. http://www.dwe.csiro.au/research/futures/publications/WkgDocs00.htm accessed 16-6-01

Department of Immigration and Multicultural Affairs (1999). *Population Flows: Immigration Aspects*. Commonwealth of Australia, December 1999.

Fenger J (1999). Urban air quality. Atmospheric Environment 3,29,4877-4900.

Foran B Bartram G and Cumpston R (2000). *Australian Inbound Tourism to 2020: Old markets Stabilising and New Markets Growing.* CSIRO Resource Future Working Document Number 2000/02 http://www.cse.csiro.au/research/Program5/RF/publications/WkgDocs00.htm accessed 07-05-02

Hamal K (1998). Australian outbound holiday travel demand: Long-haul versus short-haul. BTR Conference paper 98.2, Bureau of Tourism Research, Canberra.

Hugo G (1999). Demographic trends influencing housing needs and demands in Australia. Paper presented to AHURI workshop on innovation in housing. Melbourne 15 April 1999.

Jonsson JO (1998). Class and the changing nature of work: Testing hypotheses of deskilling and convergence among Swedish employees. Work Employment and Society 12,4,603-633.

Lenzen M (1999). Total requirements of energy and greenhouse gases for Australian transport. Transportation Research Part D: Transport and Environment 4, 4,265-290.

Lutz W (1999). Population, number of households and global warming. POPNET Population Network Newsletter No 27, Fall 1995.

Marshall MG (1999). Flexible specialisation, supply side institutionalism, and the nature of work systems. Review of Social Economy, 57,2,199-210.

McDonald P and Kippen R (1999-a). Population futures for Australia: The policy alternatives. Vital Issues Seminar 31st March 1999, Parliamentary Library Seminar Series, Parliament House, Canberra.

McDonald P and Kippen R (1999-b). The impact of immigration on the ageing of Australia's population. Department of Immigration and Multicultural Affairs Discussion Paper, May 1999.

McDonald P and Kippen R (2000). Population projections for Australia. BCA Papers 2,2,96-104. Business Council of Australia, Melbourne.

McIntosh A (1998). European population policy in the twentieth century: Is it relevant for Australia? People and Place 6,3,1-16.

Newman P and Kenworthy J (1999). *Sustainability and Cities: Overcoming Automobile Dependence.* Island Press, Washington.

Noorman KJ and Uiterkamp TS (1998). *Green Households? Domestic Consumers and Sustainability*. Earthscan Publications, London.

Patel MK Jochem E Radgen P and Worrell E (1998). Plastics streams in Germany-an analysis of production, consumption and waste generation. Resources Conservation and Recycling 24,3-4,191-215.

SIRA (1999). Australian Plastics Materials Recycling Survey. Report for Plastics and Chemicals Industries Association, March 1999, Strategic Industry Research and Analysis, Canberra.

The Economist (1999). Ageing Workers: A Full Life. The Economist September 4th, 1999, p 69-71.

von Ungern-Sternberg (1999). Paper consumption and information media. Journal of Information Science 25,3,229-233

Visy Recycling (1999). *Harvesting the Urban Forest*. Visy Recycling, Laverton North, Victoria.

Yencken D and Wilkinson D (2000). *Resetting the Compass: Australia's Journey Towards Sustainability*. CSIRO Publishing, Melbourne.

Chapter 3
The urban environment

ABSTRACT

Population numbers are the primary or most direct driver of resource use in urban Australia. Most of the differences between scenarios observed in this chapter are due to population size. The trend towards maintaining and expanding lifestyle and affluence is a secondary population effect, which drives for example the steady expansion of floor area of dwellings and retail space, the maintenance of car ownership levels and yearly driving distance, and the relatively minor role that public transport systems play in our daily lives.

The key concept introduced in this chapter is the importance of understanding the size, distribution and longevity of the nation's stocks of infrastructure. Each cohort of infrastructure stock, requires resources and generates waste, the levels of which are determined to a large degree by the design and technology present in that stock. These technological factors determine whether resource use and waste generation will keep rising in line with growing population number and growing affluence. Any national policy which aims to stabilise and then reduce resource usage and waste generation within a human generation of 25 years, would require that every new unit of infrastructure from the year 2002 meets the four to five star specification of leading edge technology. Changing human behaviour so that household consumption of energy and water is, for example, reduced by 50%, gives a similar physical outcome. However relying purely on behavioural approaches could stifle technological innovation and 'lock-in' archaic approaches. A combination of both (improved technology and reduced consumption) could provide the best way forward. But, a number of high-level economic and social issues may also affect the choices made. The widescale privatisation of energy and water utilities over the past two decades has been based on reasonable expectation of increasing physical levels of usage, increasing cash-flow and profits, and reasonable returns on investment. If resource usage is stabilised or declines, then unit price to the consumer must continue to rise to maintain reasonable business expectations. This could increase the cost of living for a household and the costs of doing business for a company. Taken to an extreme, decreasing physical consumption and increasing price, could produce consumer backlash. On the other hand, countries such as Japan have twice the electricity costs of Australia and seemingly thrive in globalised world markets although many of their physical transactions are undertaken in other countries. Thus, many things are possible, which may not seem so in shorter-term political settings.

This chapter looks at a number of sub-scenarios which, by 2020, halve resource use per unit of service delivery. In the areas of energy and water use by built infrastructure, and in motor car transportation services, these sub-scenarios show that by 2050, the higher population levels in the 0.67%pa scenario could function effectively for levels of resource use that are similar to those of the year 2002, when the population is approaching 19.6 million people. However, the degree to which consumer sentiment, market dynamics and national governance are amenable to fundamental (as opposed to marginal) changes of this nature, remains a topic for considerable debate.

INTRODUCTION TO THE URBAN ANALYSIS

This chapter uses the three population scenarios to study the requirements for a number of key infrastructure items central to life in Australia's cities and towns. These include the requirements for housing, transport and roads as well as a number of key resource issues such as the demand for water by the built infrastructure, energy requirements and the subsequent generation of emissions. Energy and water will be investigated in more detail in later chapters, but are included here because of their integral importance to built infrastructure and urban function.

The concepts of stocks and flows described in Chapter 1 come to the fore in this chapter. Big ticket items of infrastructure, such as domestic housing and the car fleet, drive the flows of energy and materials. The 'people stock', or numbers of people in particular age categories, drives the requirement for houses and motor cars rather than the 'people flows' from domestic births and immigration. The relationship between the number of houses and their age, interacts with the number of people and their age, to determine the requirement for new houses on a yearly basis. Under lower scenarios of population growth, the requirement for new houses does not cease but is driven mainly by the turnover or death of old buildings, rather than population growth. The relationships between the stock of motor cars, their age distribution and the population driven requirements for motor vehicles can interact to limit the rate at which new technologies are infused into the vehicle fleet. That is, the size of the vehicle stock, the saturation of consumer requirements (every household has a car) and the slow rate of scrappage of older vehicles (an ageing vehicle fleet) limits the penetration of technological innovation (in engine design and efficiency). A number of sub-scenarios will be implemented to test the capacity of consumer behaviour and technological innovation to moderate levels of energy usage and subsequent air emissions.

ISSUES FROM THE DIMA WORKSHOP SERIES

In preparation for the design and testing of the population scenarios with ASFF, a workshop series was conducted in 1999 (Conroy et al., 2000), to critically review the structure of the analytical framework and the implementation of the scenarios. The following issues, which are important for this chapter, emerged:

- The treatment of spatial patterns in urban settlement is especially important in the future metabolism of Australian cities. Choosing a balance between the continuing spread of the suburban quarter acre block and high density urban infill modes of habitation will determine eventual transport needs and the energy they use. The population scenarios implement a gradual change to higher density settlement in the major cities and altered modes of transport linked to the changes.

- The refurbishment and renovation of old industrial areas and working class suburbs is a trend that should be reflected in the treatment of building age (building vintage), materials recycling and construction. This trend could limit the spread of urban areas, help stabilise the requirement for concrete and other building materials and help reduce material flows associated with the building industry. The retro-fitting of old building shells to five star energy ratings could help stabilise energy use by the domestic and commercial building sectors. While the scenarios are implemented to accommodate this trend, a focussed treatment is difficult because of lack of data and the way in which ASFF treats each city as one unit.

- The confluence of biotechnology, nano-technology, information technology and new materials has the potential to radically transform the way cities are run. It is possible to envisage a city that has less than one-third of current material and energy flows because services and goods are produced and delivered with lighter and leaner high-tech production systems. The scenarios do not implement these ideas but the sub-scenarios, which halve energy and water use for example, give indications of what might be achieved. While the potential certainly exists to realise these concepts during the next century, the long-lived nature of infrastructure items and their yearly material and energy requirements, suggest that the reality is a long way off.

- Improvements in the logistics of freight transport and the increased use of pipelines to move bulk materials will change the nature of transport in Australia over the next 50 years. The pipeline effect is an important one and natural gas and water are good examples of its use for fluids and gases, but the concept has not been implemented for other materials such as ore slurries etc. The management of logistics appears to be increasing energy use in transport as higher efficiencies and quicker delivery times increase the demand for delivery services, rather than the opposite.

- The future shape and management of Australia's extensive transport systems is predicated on the availability of cheap and readily available transport fuels. What happens if oil supplies become constrained domestically or internationally during the period under test out to 2050? The analyses in Chapter 4 propose that supplies of domestic oil may become constrained around 2020 to 2030 and natural gas around 2050 to 2060 if current technology trends and trade issues develop as expected. The problem of oil and gas availability then becomes a trade matter, as we assume that the Middle East will remain as a supplier of hydrocarbon fuels for most of this century. If transport fuels were not available from international trade then the existing road network will provide a good carriageway for improved bus networks and other modes of transport with low energy costs per passenger kilometre.

- The resilience of Australia's urban areas in the face of shocks such as water quality crises (the Sydney water crisis) and a breakage in energy flows (the Longford gas explosion) suggest more robust utility systems should be installed incorporating inbuilt redundancy. This issue is not explored in the scenarios but many references are made to the general topic. Distributed energy generation where heat and electricity are generated by a large number of small plants (e.g. gas turbines and fuel cells), is one approach that could be implemented in later studies of the physical economy.

The following sections detail and discuss the results of the population scenarios for urban issues such as domestic and commercial building stocks, transportation systems, requirements for energy and water and the problem of pollution.

BUILDING REQUIREMENTS

Domestic housing

By 2050 Australia could require between 6.5 and 10 million single houses and between 3 and 4.5 million other types of dwellings such as flats, townhouses and high rise apartments (Figure 3.1). This compares to about 7 million buildings in 2000, of which 79% are single houses, 9% are semi-detached dwellings and the remaining 12% are flats or apartments (Australian Bureau of Statistics, 2000-a). The three population scenarios simulate continued growth to 2050 in the requirement for housing stock with an additional 30% for the zero scenario, 60% for the base case scenario and 100% for the 0.67%pa scenario. For populations that are stabilising or slowly declining, the increases are due to several factors. Firstly, the declining number of persons per household gives more households per unit of population number. Secondly, internal migration increases the requirement in cities such as Brisbane and Perth as well as non-capital city areas of New South Wales and Queensland. There are declines in some rural areas and vacant dwellings are presumably left to decay.

The simulation results shown in Figure 3.1 are reasonably robust and reflect a wide range of important issues that are included in the requirement for housing although price mechanisms and social dynamics are not included in the modelling approach. The simulated outcomes could be viewed as reasonably optimistic. For example, a series of economic downturns might force more people to share households, thus increasing the number of people per household and decreasing the overall requirement for numbers of dwellings. In the 0.67%pa scenario the requirement for dwellings continues growing out to 2050. However in both the zero scenario and the base case the requirement for dwellings continues to grow out to at least 2030, before declining population numbers in the zero scenario produce stability and then decline.

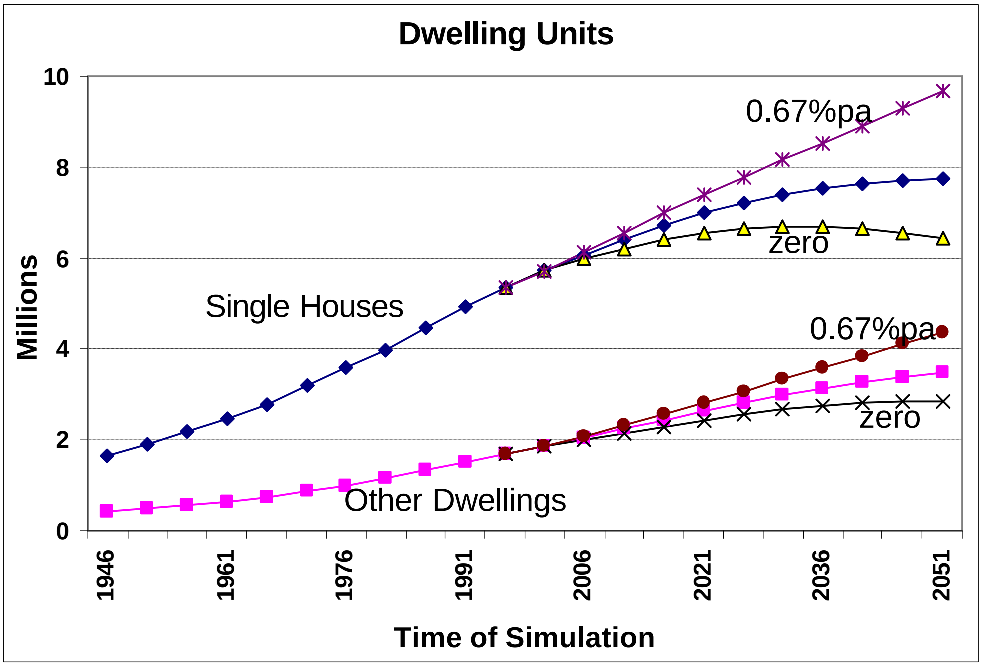


Figure 3.1. Simulated requirements for both single and other domestic housing units out to 2050 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Also affecting the requirements for future housing infrastructure are quality of life, lifestyle and affluence. One of the physical parameters describing how lifestyle is related to requirements for dwellings and linked resource and environmental issues, is that of dwelling size in square metres (Figure 3.2). During the historical period for the simulation from 1940 to 2000, the area of the single dwellings in metropolitan areas rose from 100 to 150 square metres per dwelling. In the scenario period from the present to 2050, it is assumed that the dwelling area will continue to increase and will saturate or plateau at approximately 200 square metres per single dwelling although it may reach 250 square metres if current trends continue (Newton et al., 2001). Similar assumptions are made for non-metropolitan houses plateauing at 150 square metres per dwelling, and the category of other (flats and appartments etc.) which plateau at lower levels. These assumptions are derived from a wide range of expert opinion including the DIMA workshop series held during 1999.

This lifestyle choices of larger houses will significantly influence the amount of material required for housing and the amount of energy used in homes. The effect is quite separate from changes in demand for housing arising from changing levels of population or changing patterns of household formation. Considering all these factors, the eventual outcomes in terms of material and energy usage will be derived from interactions between them, rather than just population numbers. As the requirement for dwellings continues to increase in spite of population stability or decline, demand for materials will also increase because of the relationships assumed in Figure 3.2. (larger dwelling space and increasing materials intensity accompanying higher levels of affluence and quality). This trend can be seen in any new suburban development, or infill development, within existing suburbs.

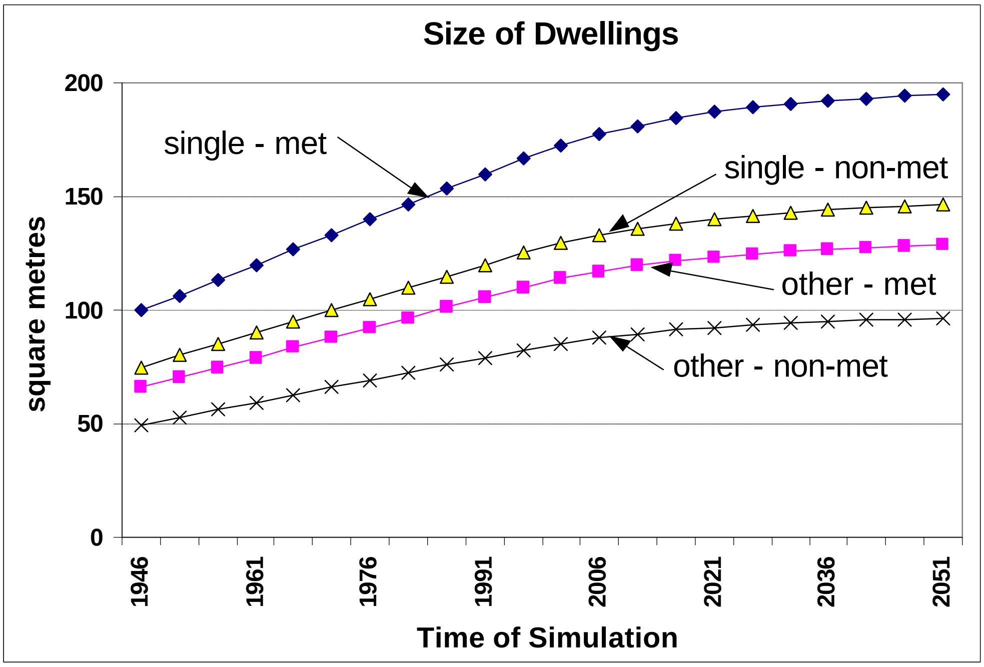


Figure 3.2. Assumptions for floor areas of domestic housing for both single and other dwelling types in metropolitan (met) and non-metropolitan (non-met) areas.

A number of the analytical concepts describing built infrastructure may give rise to counter intuitive outcomes. Using the concepts of embodied energy (Treloar, 1997; Slesser et al., 1997) and embodied materials (Bouman et al., 2000; Dellink and Kandelaars, 2000) for example, as design and materials become more sophisticated and complex, the requirements for inputs of materials and energy tend to increase. So, as a housing design increases from a one-star to a five-star energy rating, the requirement for construction materials (thicker walls, more insulation, double glazing, electronic climate controls) can markedly increase the material and energy intensity of construction. There is a payback period in terms of total capital investment versus yearly operating expenses, but in some Australian examples, the payback period for an advanced energy design may be of 12 years or more (Treloar et al., 2000). Thus, the possible trade offs between material affluence, better technology and the intensity of energy and materials, have time dynamics that may mean an increase in overall resource use for one or two decades, before the reduced operational requirements of the infrastructure stocks start to have an overall impact at a national level. By contrast a reduction in household consumption levels can be achieved literally overnight by altering the temperature thermostat, or turning off the garden hose.

The interaction between the requirement for total dwellings, increasing space requirement per dwelling and the de-construction or death rate of buildings is portrayed in Figure 3.3. The base case scenario requires new dwelling space to be constructed at a rate similar to the historical period from the 1940s to 2000 i.e. the steady rate of expansion continues but it does not accelerate. In this scenario, the requirement grows from about 25 million square metres in 2000 to 35 million square metres by 2050. The 0.67%pa scenario grows at a faster rate to reach 53 million square metres per year by 2050 while the zero scenario stabilises at around current levels. In terms of future options for the housing industry the assumptions behind all scenarios offer relatively good news. The zero scenario stabilises construction activity at around current levels, while both the base case and the 0.67%pa scenario offer considerable expansion. The aggregated result hides some differences between locations that are important for regional development prospects. New housing construction continues strongly in Brisbane, coastal Queensland and Perth for example, while the rate of growth is more moderate, but against a much larger base, in the major cities such as Sydney and Melbourne.

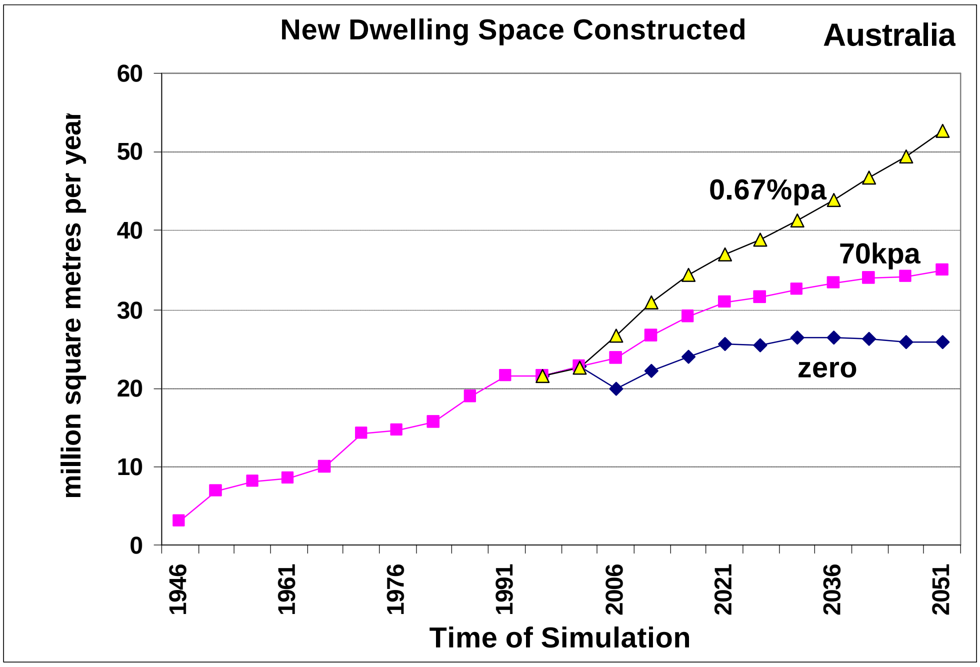


Figure 3.3. Simulated requirements to 2050 for the construction of new dwelling space on a yearly basis for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Age of the housing stock

The age distribution of buildings determines the level of building activity (demolition and construction) required to replace older buildings. It also imposes constraints on the feasible rates of change (Figure 3.4). The current stock of buildings is the result of construction over many decades and, whatever their characteristics, these buildings will remain for some decades to come. The stock as a whole cannot be substantially changed in a short time, although forward thinking municipalities can plan for wide-scale retro-fitting of roofs and insulation e.g. when natural disasters such as freak hailstorms hit suburban areas. Governments can also offer incentives to significantly upgrade older buildings in terms of heating appliances and insulation. The age distribution of buildings is also important because building materials and construction techniques have changed over the decades and so, when these buildings need to be renovated or demolished, these materials of different types will need to be disposed of, or will become available for recycling. In the case of some larger buildings, past construction techniques make safe demolition difficult and costly.

Looking at the age distribution of the housing stock, shows its slow turnover rate, through two factors (Figure 3.4). The first is the inertia which results when annual turnover rate is small compared to the total size of the housing stock. Time slices have been presented over the period from 1950 to 2050. These portray different eras of housing development relating to post-war population growth, and the first evidence of the baby boom. The obvious point is that these stock characteristics are maintained for a substantial period into the future. They parallel to some extent, similar structures in human demography. Once built, a housing development is part of the nation's infrastructure for a long time, usually for much longer than the lives of the people it was built to house. Meeting the challenge of sustainability, and its requirement for the reduction of energy and material flows, will require that stock characteristics are managed to reflect both lifestyle aspirations of the occupants, as well as sustainability aspirations of the nation. Currently, the two sets of aspirations are travelling on different pathways.

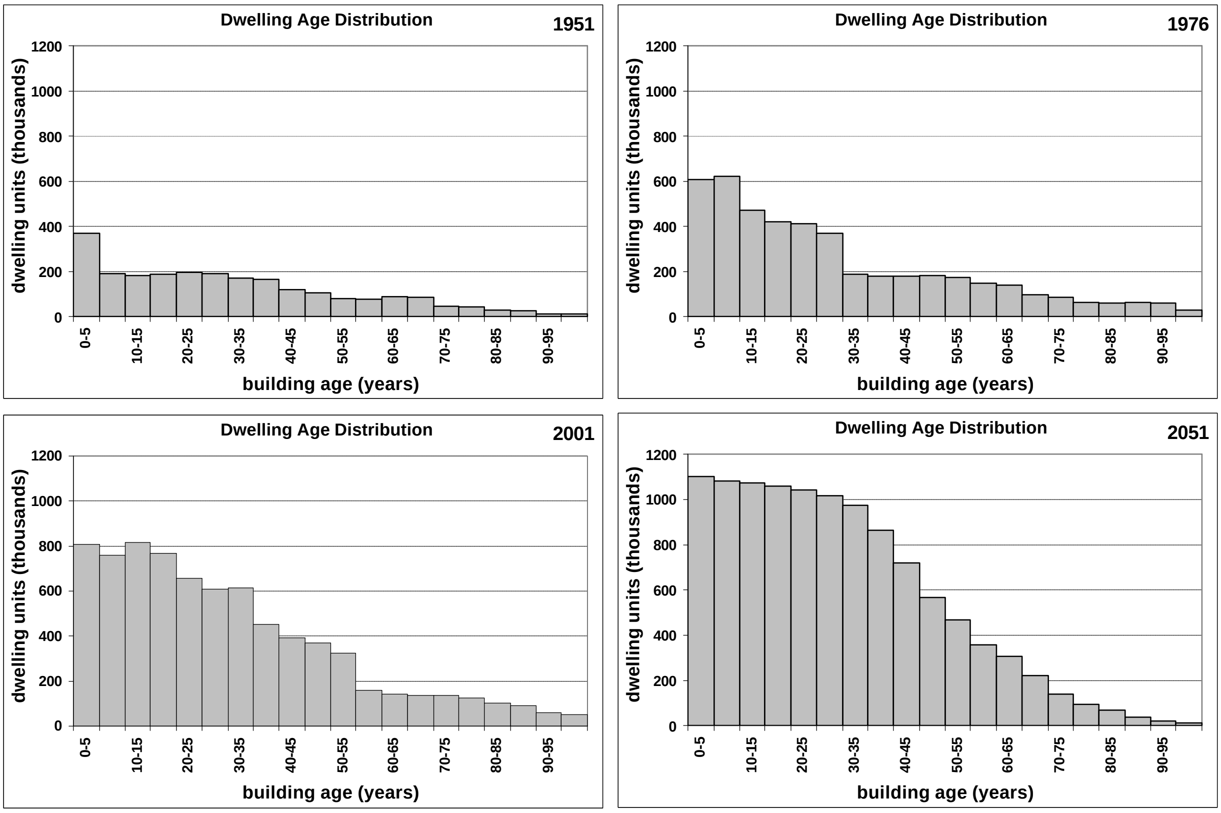


Figure 3.4. Simulated age distribution of domestic dwelling stocks of dwelling units in 1951, 1976, 2001 and 2051 for the base case scenario.

The second point relates to the continuing demand for resources and services such as energy, water and waste disposal. Nearly half of the total housing stock is in the first five age categories, which roughly equate to one human generation of 25 years. The rest is 30 to 100 years old or more. If energy efficiency and greenhouse friendly housing designs are to have some effect on total energy use, considerable time is required before the new designs start to dominate the overall housing stock. Once this occurs, resource use can stabilise and start to decline. The rates of ageing or vintaging are the key factors limiting the rate of technological progress. This vintaging concept applies to all infrastructure items such as domestic housing, motor vehicles, power plants, agricultural paddocks and manufacturing plant. However, as discussed below, practical measures, such as retrofitting of insulation can be carried out to improve the environmental efficiency of older buildings

Another aspect of the performance of the building stock is its location or spatial distribution, in other words, the shape or form of our cities. Urban form is one of the most important factors affecting traffic and transport and the viability of more energy efficient public transport systems. To a considerable degree a nation becomes locked into the present shape of its cities by the impossibility of making large changes in a short time, and by the incompatibility of old and new systems during a period of transition.

All other buildings

The requirement for all other building stock is shown in Figure 3.5. This aggregated category includes offices, hospitals, schools, theatres and traveller accommodation. Under the zero scenario the requirement could grow from current levels of around 200 million square metres to 250 million square metres in the mid 2030s before it slowly returns to 200 million square metres by 2100. The base case scenario gradually expands to more than 300 million square metres and then stabilises for the rest of the simulation period. The 0.67%pa scenario provides a requirement for built infrastructure that expands to 400 million square metres by 2050 and to more than 600 million square metres by 2100.

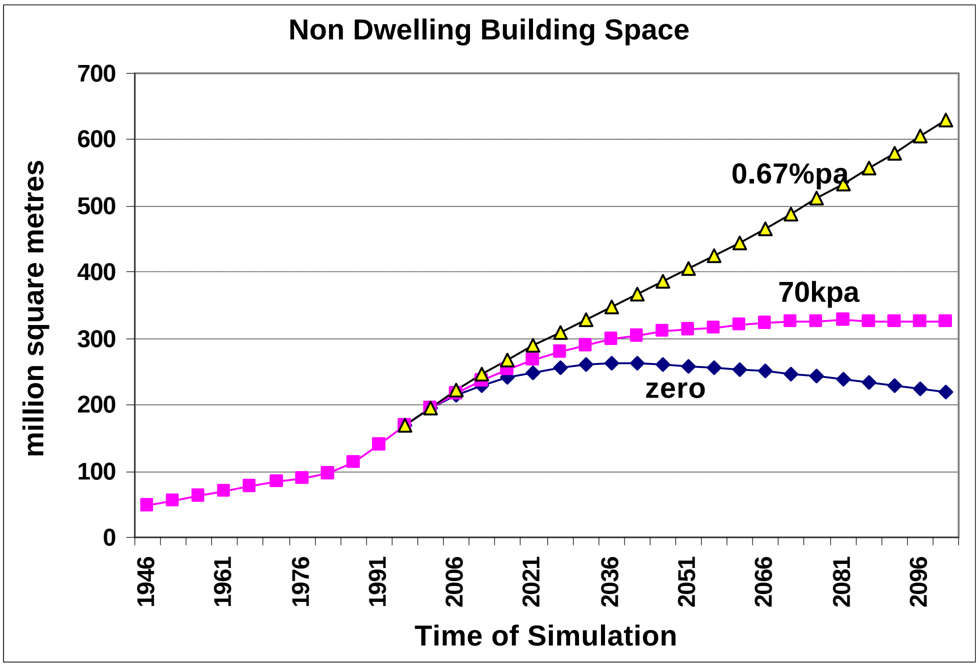


Figure 3.5. Simulated requirements to 2100 for the stock of total non-dwelling space for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

The continuing expansion of built infrastructure promised by the 0.67%pa scenario offers an active construction industry, employment prospects, and many flow-on multiplier effects for the producers of building goods and materials. The base case scenario promises a lesser expansion of infrastructure to 2050 and then a stabilisation. The zero scenario is stable for the period 2020 to 2050 before declining population drives a gradual decline in infrastructure requirement. As in the domestic housing sector, a stabilising stock does not mean that construction activity stops altogether. The replacement and refurbishment of infrastructure is an ongoing physical task that requires labour and materials, despite the decline in new construction activity.

While these data tend to mimic the shape of the population graphs, the requirements are driven from a diverse set of sources. The requirement for school space is driven by the numbers of students in those age categories and locations. Accommodation and recreational infrastructure for tourism is driven by internal demography for domestic travellers, and the numbers and types of international visitors (Figure 3.6). The requirement for traveller space in 2050 varies from 11 to 14 million square metres, for the different population scenarios. The contribution from domestic travel to traveller space for the zero scenario in 2050 is minus 8% compared to the base case scenario, and for the 0.67%pa scenario it is plus 16%. Currently, the ratio of domestic to international tourism is about 70:30. During the next 50 years this ratio will change to about 50:50 under the growth assumptions for international tourism nights (the same for all population scenarios). This transition represents a gradual shift from mainly domestic tourism, primarily driven by domestic population numbers, to a tourism industry with a tertiary driver of population effect, i.e. where domestic employment and balance of payment issues drive the requirement for export income and the further development of an international inbound tourism industry.

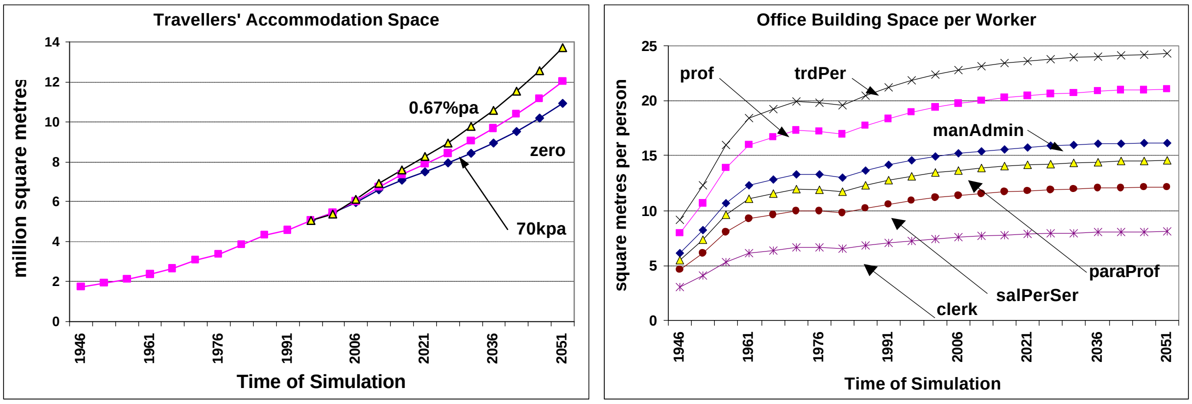


Figure 3.6. (a) Simulated requirements to 2050 for tourism accommodation space for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa); (b) Settings for all scenarios in m^2 per person for use of office space by employment categories (clerical, sales, para-professionals, administrators, professional and trades).

The requirement for office space is an important component of the non-dwelling part of the nation's building stocks and implements the transition towards a services economy where employment and productivity are increasingly generated in office buildings. As in the other building sectors, an assumption is made that the physical space per office worker expands gradually during the course of the scenario. The increases assumed are relatively modest in comparison to those in domestic housing. For the 'professional' category, office space increases from 17 to 20 square metres over the scenario period. This expansion reflects a move to more affluent and better appointed surroundings that most office workers expect, although the clerical class (office workers in large open plan offices and call centres) remains at about 7 square metres per person. It is possible that management innovations such as hot-desking (reduced permanent accommodation for mobile workers) and working from home could substantially reduce the overall requirement for built infrastructure, and the operational requirements accompanying it.

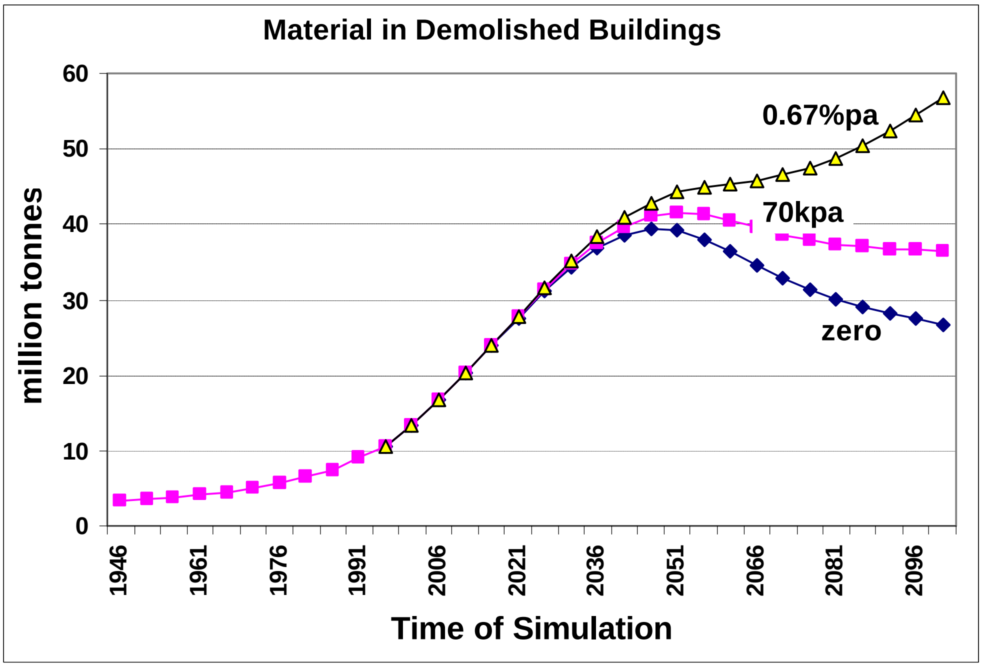


Figure 3.7. Simulated generation of materials from demolished buildings to 2100 for total dwelling and non-dwelling space for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Demolition, waste and recycling

By 2050, about 40 million tonnes of waste material is generated from demolished buildings under all scenarios (Figure 3.7). After 2050, the situation changes because of the ageing and death of the infrastructure stocks built to accommodate the different population levels in each scenario. By 2100, the primary effect of population is minus 20% for the zero scenario and plus 50% for the 0.67% scenario compared to the base case. Depending on the decision maker's perspective, this demolition waste presents an opportunity or a problem. In 100 years time the recycling and reuse of building materials on site or nearby, may have become established practice and the use of virgin materials for building may be greatly reduced. The task of separating and reusing demolition material may provide a wide range of employment opportunities depending on the size, skills and attitude of the workforce. Alternatively, disposing of the waste may be regarded as a challenge. The DIMA workshops noted that landfill space for demolition material may become limiting within reasonable cartage distance of the sites being de-constructed and re-constructed, particularly in Sydney and Melbourne.

Energy use by buildings

By 2050, energy use directly attributable to the building sector could be 800, 900 or 1,200 petajoules (10^{15}J) per year for the zero, base case and 0.67%pa scenarios respectively (Figure 3.8). In percentage terms, the zero scenario uses 12% less energy and the 0.67%pa scenario uses 33% more energy than the base case. Thus, there is a range of 400 PJ of energy per year for built infrastructure, which is directly related to the level of population growth. Currently the energy use by both residential and other built infrastructure is about 600 PJ per year (Bush et al., 1999). The increase of 300 PJ simulated in the base case scenario is the result of a combination of both population growth (6 million more people by 2050), and increasing affluence (greater size of dwelling and more fittings) although there is an underlying assumption of a steady reduction in energy use per square metre, particularly in the residential sector.

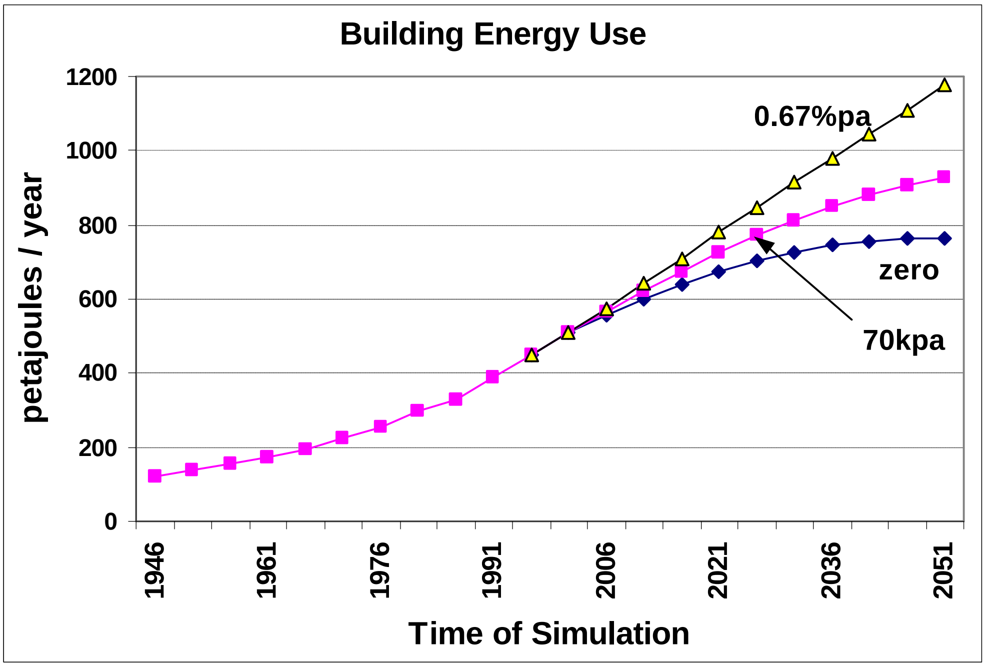


Figure 3.8. Simulated total energy use in petajoules (10^{15}J) per year to 2050 for total dwelling and non-dwelling space for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

.

A number of contemporary policy studies assume that lifestyle and affluence drivers may bypass increasing energy efficiency. For example, an examination of residential energy use to the year 2010 by the Australian Greenhouse Office (1999-a), suggested that energy demand in 2010 would increase by another 40% from the year 2000, under a business as usual scenario. The main drivers of the increase were space heating and cooling, electrical appliances and equipment and a general increase in floor area of dwellings. A parallel study on commercial buildings (Australian Greenhouse Office, 1999-b) suggested that total energy usage would increase by 30% from current levels of about 220 to 290 PJ per year. Space heating, cooling and ventilation accounted for nearly 70% of the energy use in the commercial buildings sector. There is a world wide trend towards increasing amenity and comfort in the workplace, although many technical and behavioural adaptations could stabilise or reduce energy usage. These are tested in a break-out scenario later in the chapter. In a contemporary Australian setting we judge the analyses of future energy use by the total building stock outlined in this report to be conservative, because of the assumptions of reducing energy use per square metre. It is possible that lifestyle and affluence influences will continue to expand energy use at a rate that outpaces the installation of more efficient devices and designs.

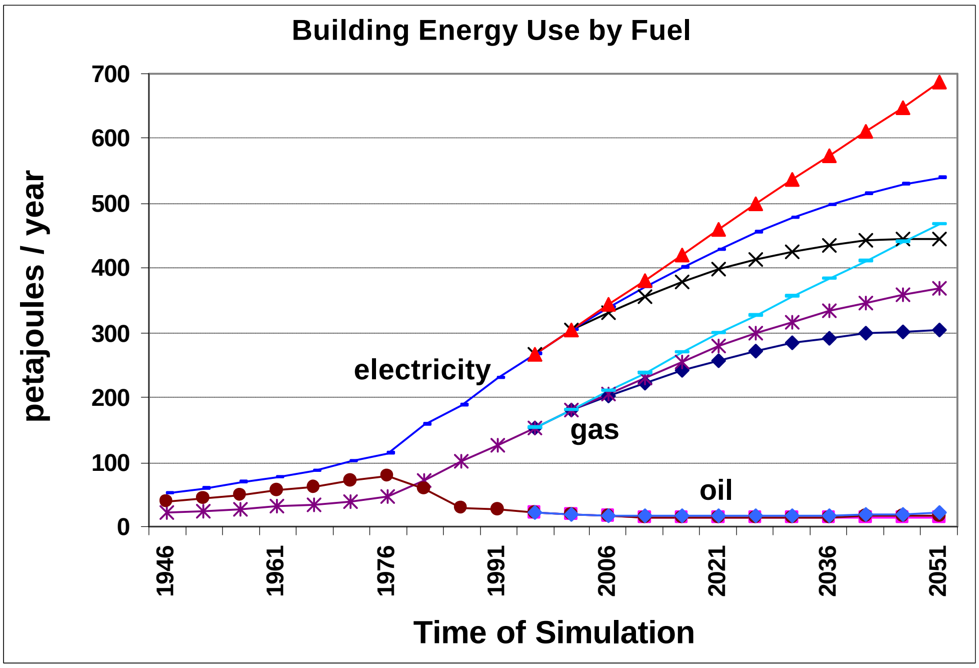


Figure 3.9. Simulated total energy mix of electricity gas and oil in petajoules (10^{15}J) per year to 2050 for total dwelling and non-dwelling space for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa). For electricity and gas past the year 2000, the trios of graphs from upper to lower, represent the 0.67%pa, the base case and the zero scenarios respectively.

The use of both electricity and natural gas by the total building stock continues to grow until 2050 in all scenarios (Figure 3.9). The use of electricity in 2050 could vary from 450 to 700 PJ per year while the use of gas could vary from 300 to 470 PJ per year. The use of oil as a fuel for heating in buildings declines to a relatively low level, mainly due to the availability and cleanliness of gas. The increased use of electricity and gas occurs for a number of reasons, including the fact that energy use in the model is driven by square metres of floor area. For both domestic and non-domestic dwellings, floor areas on a per unit basis are assumed to rise over the simulation period, whether they be dwellings, offices or motels. While electricity use stabilises for the zero scenario, the use of gas continues to grow. This is due to the proportion of gas in building energy use rising at the expense of electricity and oil. This accords with recent gas industry analyses (Bush et al., 1999, Australian Gas Association, 1999) which suggest that gas usage (including industrial uses) will grow at 4.3% per annum to 2015, and agrees with energy use overall growing at 1.4% per annum, and electricity use growing at 0.6% per annum.

Consumption of energy in the form of electricity and gas is linked to the price the consumer has to pay. Recent reforms in the electricity and natural gas markets have been designed to increase the choice for consumers and the physical access to different suppliers of energy (Carver, 1996; Rann, 1998). The price of electricity in Australia is among the lowest in the industrialised world and less than half the price in Japan on a kilowatt hour basis (Electricity Supply Association of Australia, 2000). Thus, the constraints to achieving the increases in energy use suggested in the scenario analyses are gradually being removed.

Sub-scenario: halving energy use by 2020

Although the energy usage scenarios described above include a wide range of technological efficiencies, the range of technological and behavioural possibilities is even wider. Realising these possibilities will be important because, depending on the source of the energy (renewable or fossil), increasing use of energy may also affect Australia's ability to meet its greenhouse gas targets. In this sub-scenario, energy use intensity on a per unit area basis in the dwelling and non-dwelling sectors is reduced to one half of the level in the base case scenario by the year 2020, and that level retained for the duration of the simulation period. The consequences for total energy use are shown in Figure 3.10. By 2050 this sub-scenario constrains total energy use for buildings to between 400 and 600 PJ per year. For the zero and base case scenarios, these levels are about the same as the levels in 1990, the reference year for the Kyoto greenhouse gas negotiations. For the 0.67%pa scenario, total energy use in 2050 is 600 PJ, about the same as the estimate for the year 2000 made by Bush et al. (1999). Provided that energy usage is reduced to these levels by 2020, the building energy requirements of an extra 13 million people by 2050 could be met, for levels similar to those of today.

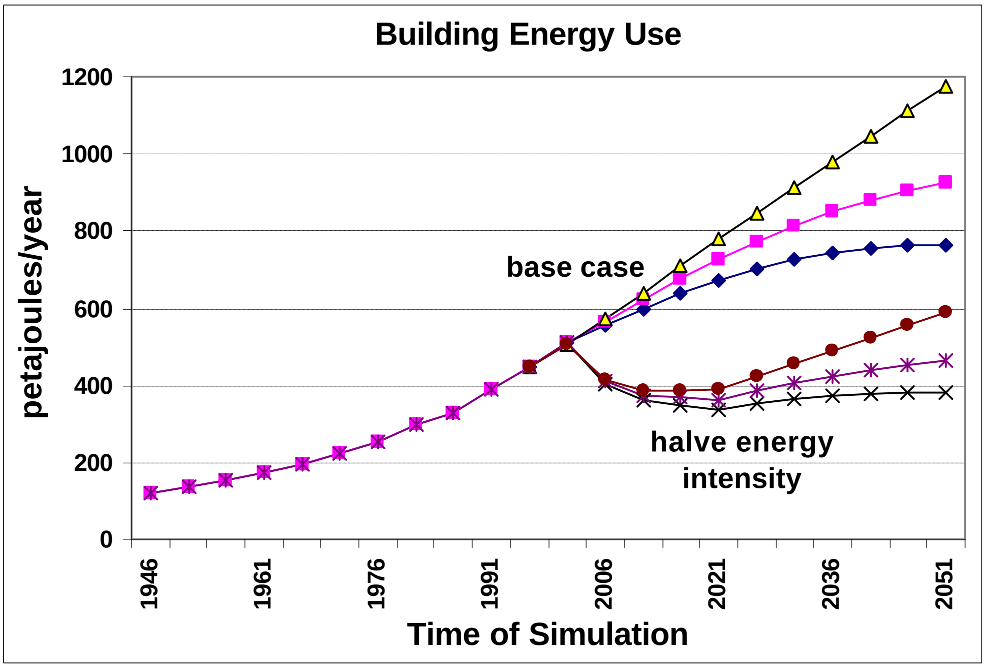


Figure 3.10. Sub-scenario of total energy use to 2050 where energy use in megajoules (10^6J) per square metre per year is reduced by 50% for total dwelling and non-dwelling space for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa). In main scenario and sub-scenario the graph order is from higher to lower population number.

The energy consumption per unit of floor area used in the simulation agrees with levels quoted in international studies (Shipper et al., 2000) and national studies (EMET, 1999; Community Partnerships, 1998) and thus could be judged to be reasonably feasible. Whether the transition to the assumed energy use per unit floor area is met, depends on a complex mix of consumer behaviour, implementation of appropriate technology and regulations from business and government. A wide array of consumer goods and building infrastructure are readily available that could achieve this reduction of 50% per physical unit by 2020. Moving from the 'standard' to the 'efficient' home yielded savings of 40 to 50% by using solar-gas or heat pump hot water systems, installing full insulation and purchase of five star rating appliances such as fridges (Community Partnerships, 1998). In the commercial sector, the use of appropriately designed lighting and heating/cooling systems can achieve similar savings (EMET, 1999). The discussion of the age of building stocks above is relevant to achieving this building energy use transition. It requires that every building constructed from today implement five star design and operation immediately and that old buildings are retrofitted. Implementing five star energy ratings for all new buildings immediately would ensure that the larger population in the 0.67%pa scenario would be able to operate their building stock, at today's energy consumption levels.

TRANSPORT REQUIREMENTS

Non-urban transport, urban public transport and urban delivery

Non-urban transport

The transport task required to service intercity travel and tourism is shown in Figure 3.11. The base case shows changes in mode of transport during the past and then to 2050. Motor cars are retained as the dominant mode requiring nearly 100 billion passenger kilometres (pkm) by 2050, compared to air transport with 80 billion and bus with 50 billion pkm. Rail declines over the historic period and maintains a low level for the duration of the scenario. The pattern of modal share depicted for the base case occurs in all population scenarios (Figure 3.12). For non-car, non-urban travel in 2050, the transport required varies from 120 to 160 billion pkm for the zero and 0.67%pa scenarios respectively.

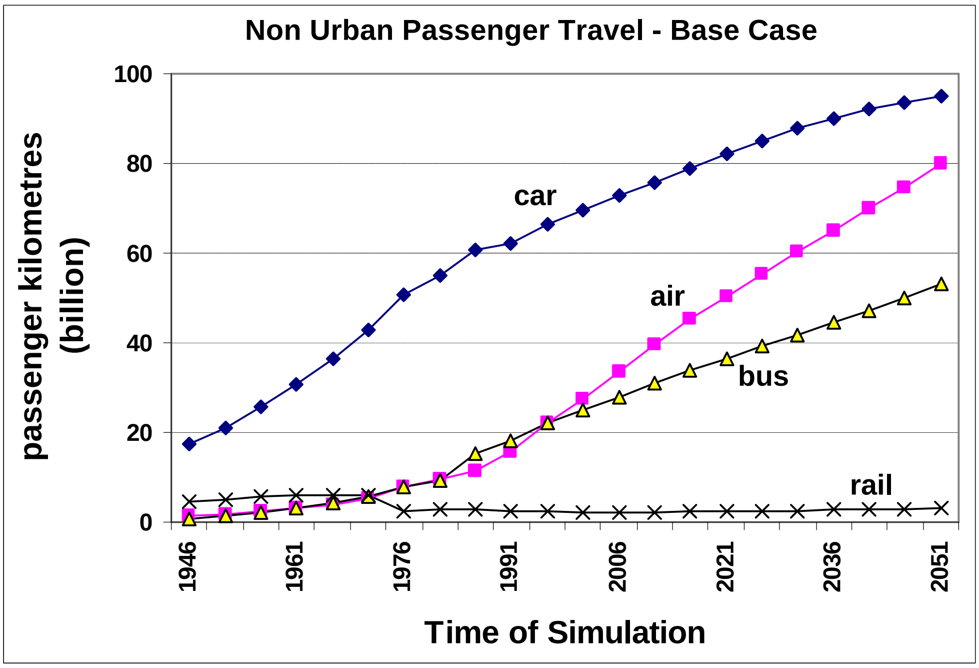


Figure 3.11. Non-urban transport task for car, air, bus and rail transport modes to 2050 for the base case scenario.

There is almost no tendency for non-car, non-urban travel to plateau or decline along with the trends in total population because of the continuing strong influence of international inbound tourism. Continued growth at around 3% per year is assumed and layered on top of the domestic population effect. In comparison, non-urban travel by car reflects the patterns in total population growth with about 80, 90 and 120 billion pkm for the zero, base case and the 0.67%pa scenarios respectively. In the car transportation mode, the zero scenario is stable after 2030 while the base case and 0.67%pa scenarios continue to grow. These analyses generally concur with shorter-term projection analysis undertaken to 2015 and 2020 by Federal Government transport groups which report a growth of 3% per year for all road traffic, with freight forming a major component (Bureau of Transport Economics, 2000-a).

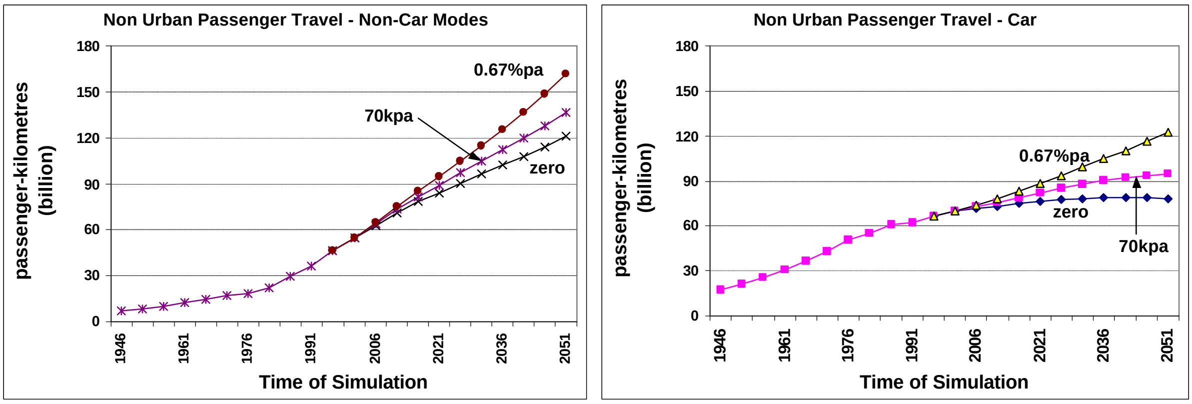


Figure 3.12. Non-urban transport requirements for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa). Non-car modes (left) and cars (right).

Urban public transport

In the 50 years since the Second World War, Australian cities have been transformed from fairly tightly knit core and spoke configurations to sprawling suburban low density ones (Bureau of Transport Economics, 2000-b). Public urban transport was the growth area in the first part of the 20th century, but after the 1950s, the motor car replaced bus, train and tram transport. Today, more than 90% of urban transport is undertaken in motor cars. Nevertheless, public urban transport occupies an important part of the fabric of any city and roads built for cars today offer considerable potential as carriage-ways for a wide range of future forms of urban transport. Based on current modal shares, the task for urban transport could vary from 25 billion pkm per year in the zero scenario, to 30 billion in the base case and 40 billion in the 0.67%pa scenarios (Figure 3.13). Thus the zero scenario stabilises around today's level, while the base case and 0.67%pa scenarios increase by 5 and 15 billion pkm respectively.

While public transport looms large in many urban sustainability discussions, the size of the requirements in 2050 (30-40 billion pkm) should be compared to the non-urban non-car task (120-160 billion pkm) for strategic decisions on which mode might require greatest investment and attention. Within cities, the results suggest many opportunities. The stabilising transport requirements in the zero and base case scenarios offer opportunities to increase the quality of the infrastructure in an attempt to win back a greater modal share from the motor car. The prospect for further growth (and higher flows of investment funds) in the 0.67%pa scenario may provide the impetus for major investments in new modes of public transport, which are fully integrated with new concepts of city design and function (Newton, 1997). Australian cities spend 13% of their wealth on transport compared to wealthy Asian cities such as Tokyo and Singapore with 5% and European cities with 8% (Newman and Kenworthy, 1999). In spite of advantages accruing to cities with appropriate urban transport infrastructure, those cities are also experiencing further growth in car usage.

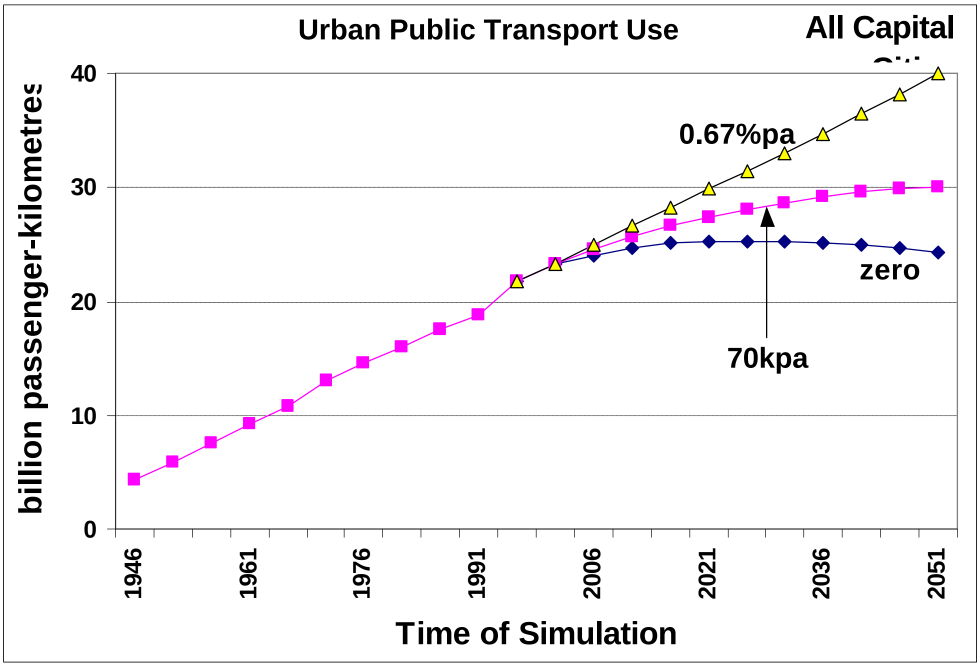
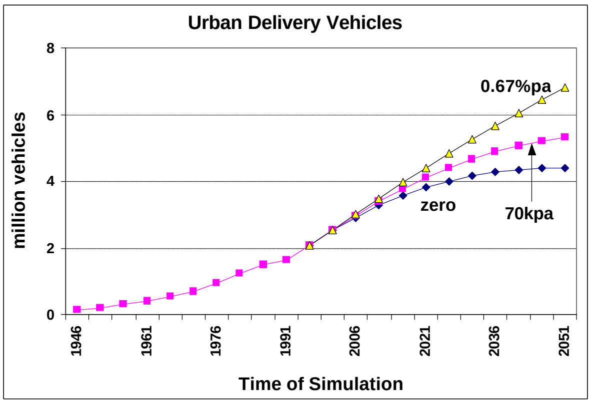


Figure 3.13. Urban transport requirements for all capital cities for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Urban delivery vehicles

One of the fastest growing modes of urban transport is delivery by light trucks, vans and trucks. This is due to the increased diversity and timeliness of deliveries which the service economy requires, the 'just in time' approach to manufacturing and fabrication, as well as the normal daily expectations of fresh food and express document services. The vehicle stock required to undertake this task increases from its current level of about three million vehicles to five million vehicles in 2050 for the base case scenario (Figure 3.14). The zero and 0.67%pa scenarios require four and seven million vehicles respectively in 2050. The requirement for new delivery vehicles (the yearly flow) could vary from 200,000 to 350,00 per year (Figure 3.14) and this compares to a requirement for new motor cars at the same time of between 400,000 and 750,000 (Figure 3.16).



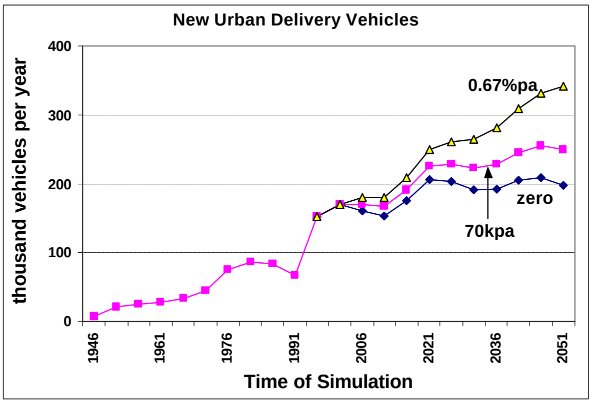


Figure 3.14. Required stock of urban delivery vehicles to 2050 (left) and yearly requirement for new urban delivery vehicles (right) for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Growth in total traffic under today's economic and physical structures is often linear (Bureau of Transport Economics, 2000-a). This linear increase is set against car ownership patterns that are relatively saturated and is due mainly to increasing commercial traffic. This increase is driven by both economic growth and export opportunities, i.e. the secondary and tertiary effects of population size described in Chapter 2. According to the same research, non-commodity freight (domestic goods and manufactures) and delivery are growing at a faster rate than the economic growth rate and there is no indication that demand is becoming saturated. This has implications for the possible congestion problems in many Australian cities where over the last 20 years, trucks have increased notably as a component of inner-city traffic flows. A relatively short-term analysis to 2015 suggests that road congestion problems could increase by a factor of three to four times in Melbourne, Brisbane, Perth and Canberra (Bureau of Transport Economics, 2000-b). Trends in North America indicate that large articulated trucks are increasingly being used to deliver goods directly to shopfronts, bypassing smaller delivery trucks and warehousing facilities in a quest to reduce double-handling and increase economic efficiencies. Traffic congestion and air pollution loadings will increase in inner city areas if this trend develops in Australia.

While many innovations in technology and organisation can still be implemented in the battle against traffic congestion, the key analytical point is that congestion problems are non-linear, i.e. the congestion delay increases at a faster rate than the volume of traffic. Electronic road pricing is being implemented to ease congestion in cities such as Singapore, but the results suggest that peak periods elongate rather than diminish in total volume. Most of the megacities referred to in Chapter 2 note problems with traffic congestion, noise and air emissions. This suggests that the innovations required to deal with traffic congestion are lagging behind the traffic requirements and mobility options chosen by today's urban citizens.

The energy use required in 2050 by urban delivery services could vary from 500 to 800 PJ per year depending on the population scenario (Figure 3.15). Currently Australia uses about 1000 PJ of energy (mostly petroleum) for the entire road transport task (passenger plus freight). Thus, by 2050 the energy for the freight task within urban areas could be equivalent to 50% of today's total transport energy requirements for the zero scenario, or 80% of today's total for the 0.67%pa scenario. The effect of such increases on air emissions will be analysed in a later section. A sub-scenario is presented in Figure 3.15 which assumes that delivery vehicles with halved energy requirements are developed by 2020. The energy requirement for urban delivery remains similar to today's with continuing growth past 2030 for the base case and 0.67%pa scenarios. This occurs once the automotive technology is saturated, and the physical economy continues to expand.

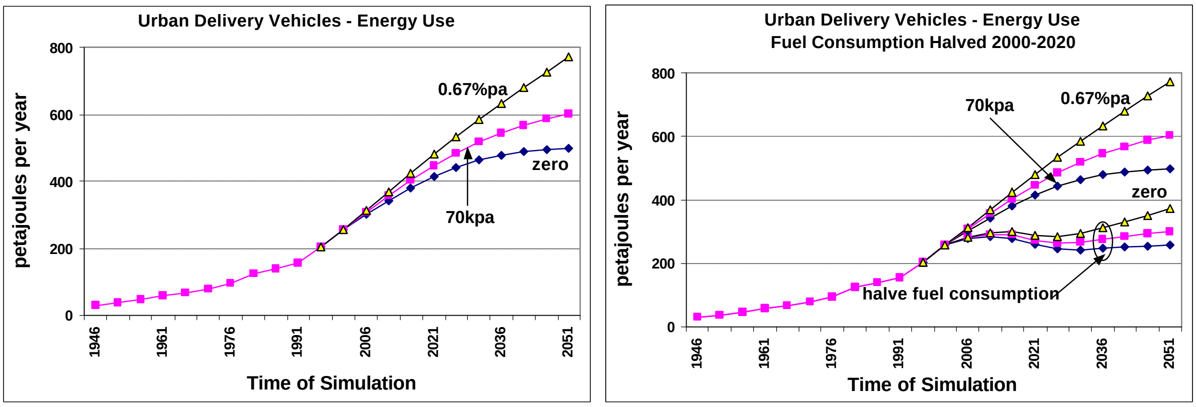


Figure 3.15. (a) Fuel energy required for stock of urban delivery vehicles to 2050 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).(b) Sub-scenario which reduces to 50% the energy per unit travelled by 2020 for delivery vehicles.

Motor cars

Future vehicle requirements

By 2050, the total requirement for the national stock of motor cars could be 12, 14 or 17 million vehicles for the zero, base case and 0.67%pa scenarios respectively (Figure 3.16). This compares to a national fleet of about 10 million cars currently (Australian Bureau of Statistics, 2000-c). The requirement stabilises around 2030 for the zero scenario and around 2040 for the base case but continues growing to 2050 for the 0.67% scenario. These analyses assume a saturation in requirement for motor cars of around one car for every two people (500 cars per 1000 population) in the domestic population (excluding light delivery vehicles and motor cycles). Australia shares with USA, Germany and Canada the highest rate of car ownership in the industrialised world, although most developed countries are converging on the rate of 500 cars per 1000 population (Shipper et al., 2000). The exceptions are Denmark (300 cars per 1000 population) and Japan (350 cars per 1000 population).

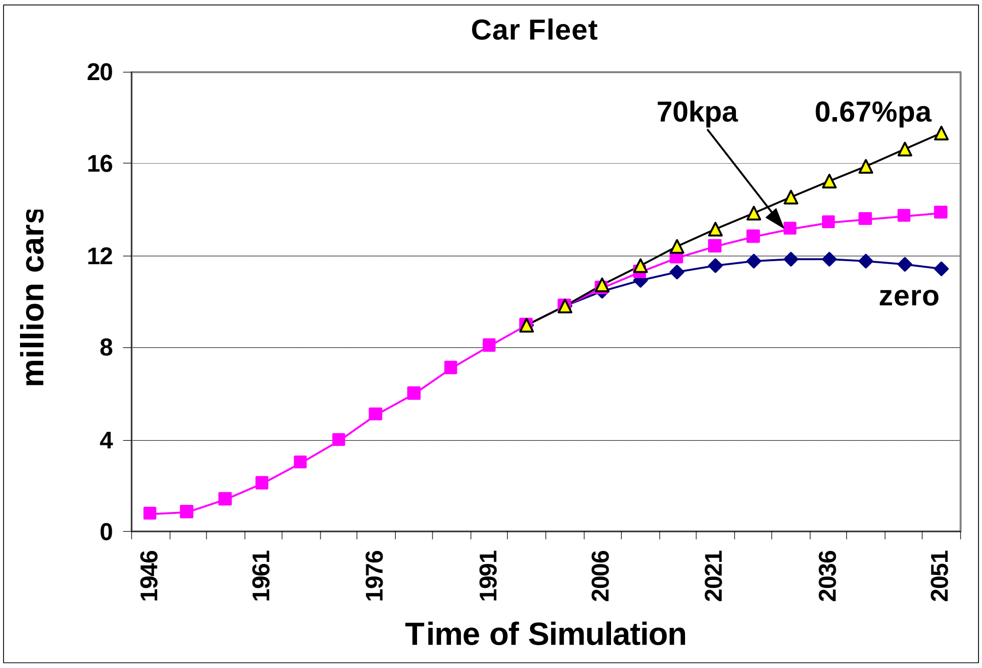


Figure 3.16. Simulated requirement for the future stock of motor cars to 2050 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

The requirement for new cars per annum in 2050 varies from 400,000 to 700,000 depending on the population scenario (Figure 3.17). Compare this with today's figures of between 530,000 and 670,000 new car registrations per annum over the last five years. Historically, car makers and importers have been able to expect a reasonable rate of growth in new car sales for two reasons: (i) the ownership requirement was not saturated and; (ii) there was steady growth in raw population numbers. While the simulated futures are conservative, they suggest that under the base case and zero scenarios, the current levels of new car numbers represent what might be reasonably expected in the long term. A number of shorter-term dynamics in short-run statistical data, e.g. the age structure of the car fleet, may reflect political and market innovations outside the scope of this long-run analysis. The 0.67%pa scenario offers continuing expansion of new car sales in line with population growth out to 2050 and beyond. Some similarities appear in the requirement for new cars and new dwellings for the zero and base case scenarios (Figure 3.3). In the case of new dwellings there are more opportunities for growth because of expanding floor area per dwelling and regional growth possibilities because of internal migration dynamics. The relative stability of future car and housing requirements under these scenarios, signals a possible change in the well accepted development concept of continual expansion for many domestic economies where demographic structures are stabilising.

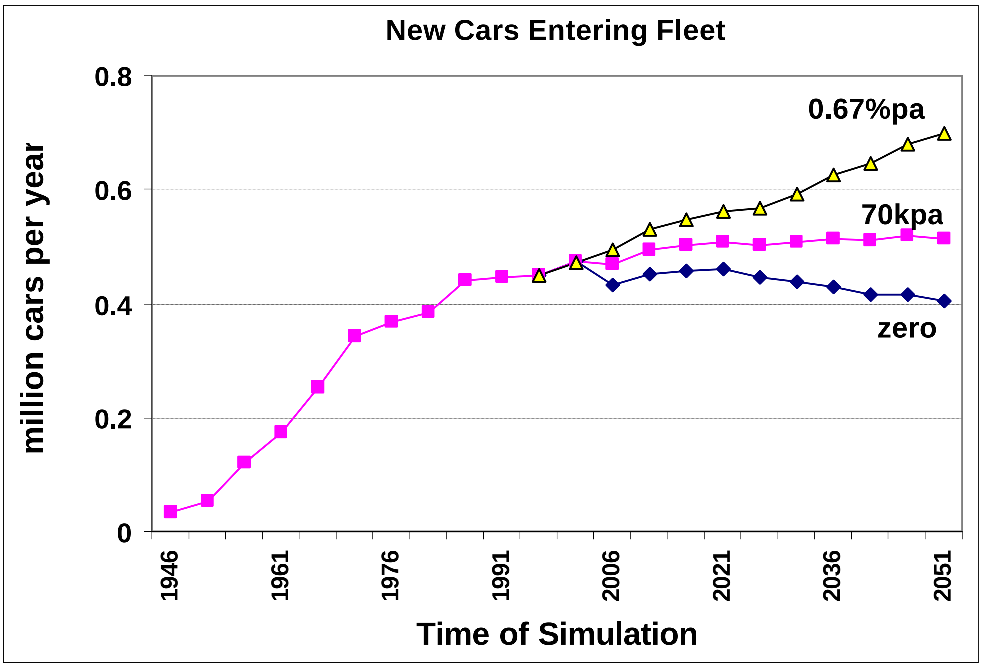


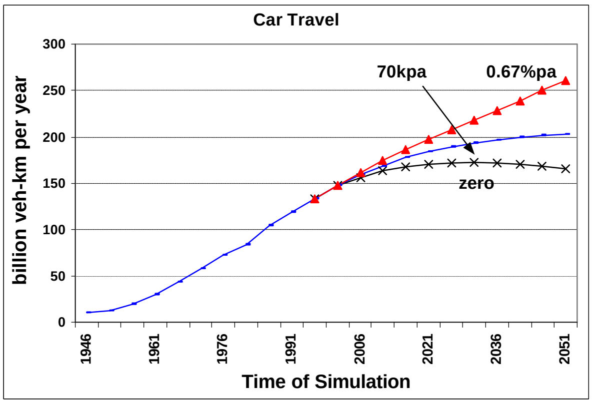
Figure 3.17. Simulated requirement for new motor cars on a yearly basis for three population scenarios to 2050: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

The introduction of a range of market and regulatory based innovations could obviously overturn these analyses. The social movement towards car sharing underway in a number of European cities offers the potential to reduce the number of cars in urban areas but the implication of yearly kilometres driven per car are not clear from the analyses (Prettenthaler and Steininger, 1999). As the personal rationale for car ownership changes from 'distance' to 'distance plus availability' and then to 'prestige', the proportion of households that find car sharing potentially useful, decreases from 69% to 22% to 9%. Alternatively, the introduction of a new generation of motor car which was cheap, built of recycled components and was turned over every 5-6 years instead of the current 10-12 years would markedly change the shape of the relationship in Figure 3.17.

However, making substantial alterations to yearly flows (new houses and new cars) means that the age structure of the stock (total houses and total cars) is substantially altered. The dynamics of these age structures, already described in the context of domestic dwellings, are complex relationships built up over periods of 20 to 100 years and cannot be easily changed in the short term. The longevity and slow turnover rate of major infrastructure stocks require that any new technical innovation be implemented totally and immediately if the technology alone (as distinct from behavioural change) is to have any effect on the operational resources required, or delivered, by that infrastructure stock.

Travel task and energy requirements of motor cars
The average yearly distance driven by cars in Australia is about 15,000 kilometres compared to 20,000 kilometres in USA and 16,000 kilometres in the UK. Future decades could see an increase in the yearly distance driven per car with increasing consumer affluence and longer commuting distances as the nature of work and workplace dynamics changes. The total transport task in 2050 for motor cars is simulated as 160 billion pkm for the zero scenario, 200 billion for the base case and 250 billion for the 0.67%pa scenario (Figure 3.18). The breakdown by mode of car usage shows that

personal use is the largest component with about 60% of total for each scenario. The commuting component (30%) and fleet component (taxis and hire cars, 10%) are important but the overall task is dominated by personal usage. Interactions could occur between the modes. If the commuting mode were substantially replaced by urban transport, or if most workers worked from home, a rebound effect could occur with increased frequency of long weekend trips, for example. Astute design of policies is required to avoid such rebound or perverse effects of innovations in policy and technology.



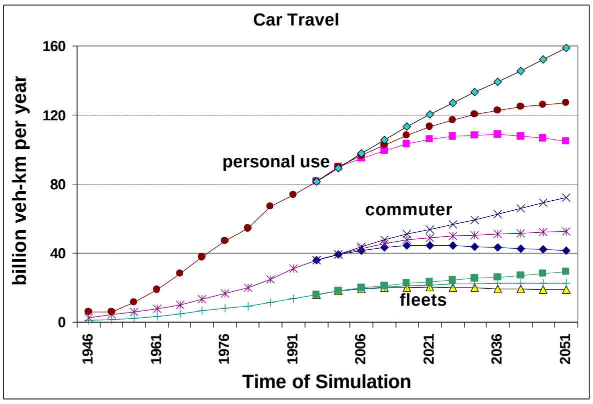


Figure 3.18. Urban transport task required by motor cars displayed by total (left) and by mode (right) for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa). In the breakdown by car mode (left), the individual graphs are in order of population size from higher to lower.

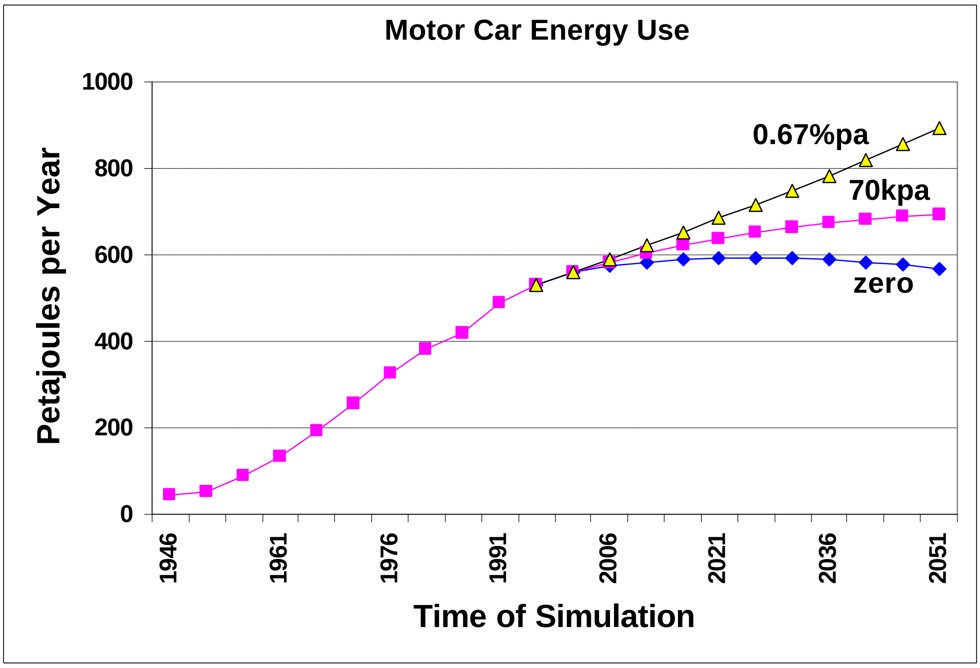


Figure 3.19. Total energy consumption by stock of motor cars for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

The energy required for this urban plus non-urban motor car transport task stabilises at around 600 PJ per year for the zero scenario and grows to around 700PJ for the base case or 900 PJ for the 0.67%pa scenario (Figure 3.19). With a total transport task in Australia requiring about 1000 PJ per year currently, the car component alone has the potential to grow to between 60 and 90% of the total current transport task. The analysis presented below is based on the assumption that the car fleet will continue to use 10 litres of petrol or equivalent energy fuel per 100 kilometres driven. Although this assumption contradicts technical assumptions of motoring progress, it reflects the reality in the Australian consumer market. Motoring is one area where rebound effects between engine technology (more efficiency), motoring luxury (air conditioning and fittings) and driver behaviour (driving faster or further) continually take place. The increasing proportion of four-wheel-drive and sports/recreational vehicles in the car fleet is a good example of this consumer/behavioural phenomenon. Also, in spite of engine improvements over the last 30 years, the International Energy Agency report grouped Australia and Japan together with an on-road car fuel intensity of 11 litres per 100 kilometres for the period since 1970. Australian six cylinder vehicles consume between 11 and 13 litres per 100 kilometres in city driving and seven to nine litres per 100 kilometres in highway driving. All population scenarios in 2050 consume more energy than the Kyoto Target base year of 1990. The amounts in excess are 100, 200 and 400 PJ per year for the zero, base case and 0.67%pa scenarios respectively. This has implications for greenhouse gas emissions and will be further analysed and discussed in the energy (Chapter 5) and crosscutting (Chapter 7) chapters of this report.

Sub-scenario: increasing fuel efficiency by 30% and 60%
Automotive technology is already available to reduce fuel consumption by 30 to 60%. The fuel consumption profiles in Figure 3.20 have been applied to every new car entering the Australian car fleet from the year 2000 (see Figure 3.17). The titles of the scenarios describe a mix of market and technological tensions. The 'affluence preference' was described above as the tendency for automotive technological advances to be soaked up in more luxury and greater performance. The 'best current technology' makes relatively quick progress to automotive technology where the whole fleet uses six litres for every 100 kilometres travelled over all driving cycles by 2020. The 'hybrid/hyper car' scenario advances the whole fleet to a fuel consumption of three litres per 100 kilometres by 2020.

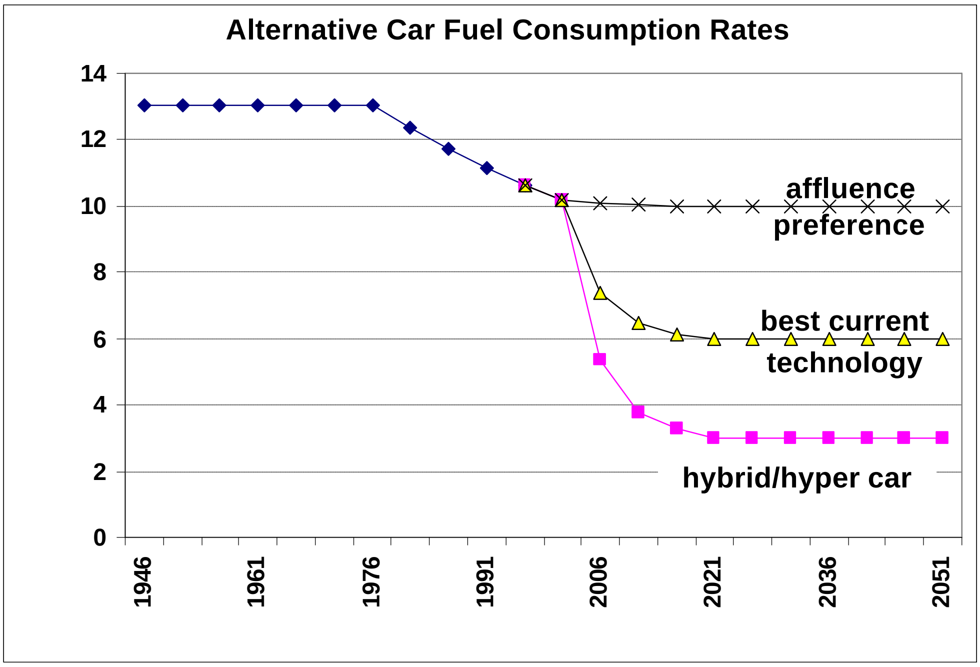


Figure 3.20. Fuel consumption (number of litres required per 100 kilometres travelled) for Australia's motor car fleet used in the car technology sub-scenario. Fuel consumption assumption is applied to flows of all new cars entering the total motor car stock.

.

During the year 2000, Australian industry and CSIRO launched two hybrid cars (a compact sized *aXcessaustralia* Low Emission Vehicle and a Holden Commodore sized car) based on technologies described as series hybrid (where the engine drives the electric motors on each wheel) and parallel hybrid (where the engine drives the power train as well as the electric motors) (Madden 2000; CSIRO, 2000-a). The Holden Commodore sized car (the ECOmmodore)is reported to deliver a fuel consumption of about six litres per 100 kilometres while the compact *aXessaustralia* car might deliver 3.5 litres per 100 kilometres. The Honda Insight vehicle, another hybrid which is now on sale in USA, delivers between 3.85 and 3.36 litres per 100 kilometres over all driving cycles (Moore, 2000; AutoWeb, 2000). It is a two seat coupe, sells for US$20,000 ($ 33,000) and the 'psychographic/demographic' market segment is described as 'engineers interested in new technology, predominantly male, married, of average age 48 years and with a household income in excess of US $75,000' (Moore, 2000). The hypercar concept is a complete redesign of the concept of personal mobility and offers fuel cell powered four person cars delivering two to three litres per 100 kilometres over the full driving cycle (Lovins and Williams, 1999). Some versions will enter the marketplace by 2005.

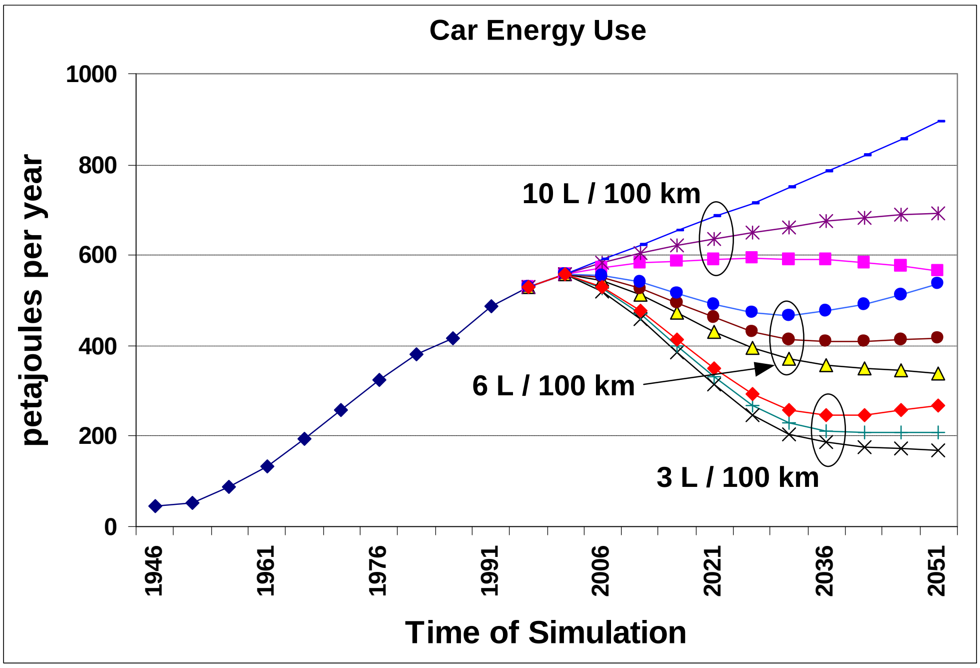


Figure 3.21. Sub-scenario of total energy consumption by stock of motor cars under three engine technologies for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa). Within each engine technology scenario (ringed) the three population scenarios are in order from higher to lower.

Whether the consumer market as we know it today will take on these new mobility systems without mandatory measures by central governments and local authorities is debatable. The Economist (2000-a) notes that the fuel saving from hybrids might amount to 1,400 litres or $US500 per year, which is a moderate saving in relation to the extra capital cost at current fuel prices. The environmental return from hydrogen as a fuel source for fuel-celled hypercars depends on the processes used to make and deliver it (The Economist, 2000-b). Hydrogen produced from the electrolysis of water using hydro-electricity sets the lowest benchmark for carbon dioxide emissions per 1000 kilometres travelled although there are concerns about methane and carbon dioxide emissions from buried landscapes under hydro lakes. If the hydrogen is produced from fossil fuel powered electrolysis then the carbon dioxide emissions per unit travelled are similar to today's engine.

The 'best current technology' giving an overall car fleet performance of 6 litres per 100 kilometres has the potential to reduce motor car energy consumption to approximate 1990 levels by 2020 and so meet the emissions expectations of the Kyoto greenhouse gas negotiations for that sector (Figure 3.21). There is a tendency for the 0.67%pa scenario to grow again once the technology has saturated the vehicle stock because of continuing population growth. However, a continuing mix of technology and regulation could be expected to hold energy consumption stable provided that behavioural rebound did not occur. The 'hybrid/hypercar' sub-scenario gives 3 litres per 100 kilometres over the entire car fleet, reduces the absolute energy consumption to 1970 levels and maintains it in that zone for the duration of the simulation period. For the car fleet to achieve these marked reductions in energy consumption would require every new car in the fleet from the year 2000 meeting the fuel consumption specifications assumed in Figure 3.19. The complexities of fleet composition, market incentives and government regulation are well outside the capability of this modelling approach which concentrates on the physical realities of the transitional process.

While price based measures for fuel represent a traditional approach to implementing new technologies, more detailed transport modelling in the United Kingdom showed that fuel price has only a minor effect (Kirby et al. 2000). Their review noted in general that the price elasticity for vehicle fuel was low (i.e. a unit increase in price gave a relatively small reduction in use of fuel). While the USA stands out as having high fuel consumption and relatively lower fuel prices, the remainder of the OECD countries span a wide range of fuel prices for approximately similar motor car fuel use per capita (Shipper et al., 2000). In September 2000, prices varied from US$1.17 per litre in some European countries to US$0.50 in Australia and US$0.43 in USA (International Energy Agency, 2000).

While automotive technology has been the focus of this sub-scenario, the same physical results could be achieved by behavioural change. The current modelling assumption maintained out to 2050, is that every vehicle in the car fleet travels 15,000 kilometres per year. Reducing the average yearly distance to 9,000 kilometres (equivalent to the 60% technology) or 4,500 kilometres (equivalent to the 30% technology) would give the same physical outcome but produce a range of positive effects (less accidents, less congestion, more time off the road) as well as negative effects (less vehicle maintenance activity, less employment in automotive services, perhaps an older car fleet).

ROADS, LAND AND WATER

Requirements for roads

By 2050, the base case scenario requires an additional 3,000 to 4,000 km of urban roads (modelled as main roads and suburban roads) in Sydney, Melbourne and Brisbane; under the 0.67%pa scenario, roads increase by 7,000-10,000 km and under the zero scenario roads retract in Sydney and Melbourne but expand slightly in four other capitals where internal migration drives continuing urban development(Figure 3.22). The modelling of road requirements attaches a proportional length of road required to each household at a whole of suburb level. Using this approach, the total urban road in capital cities at 2050 could vary from 60,000 to 100,000 kilometres in length, of which 70% is suburban road (i.e. side streets) and the remainder is main arterial roads.

These increases have to be examined in the context of Australia's total road network, which is more than 800,000 km long, of which 320,000 km or 40% is sealed (Australian Bureau of Statistics, 2000-d). The expansion of the urban road network by 50% in the case of the 0.67%pa scenario does not pose any physical limitations apart from the materials and energy required for construction. The 'ecological footprint' concept (the per capita land area required to support contemporary lifestyle requirements) applied to South East Queensland estimated that roads appropriated 210 square metres per capita of land (Simpson et al., 1998, 2000). A similar study in Canberra estimated the value as 140 square metres per capita (Close and Foran, 1998). The main problem lies with the prospect for increased congestion on urban roads, where, due to increased car and truck traffic, even allowing for organisational efficiencies to occur, the economic cost is estimated at more than $30 billion by the year 2015 (Bureau of Transport Economics, 2000-b). The authors of that study note that cities already exist with worse congestion problems than those forecast for 2015, and that long-range strategies need to be implemented now to avoid the same problems.

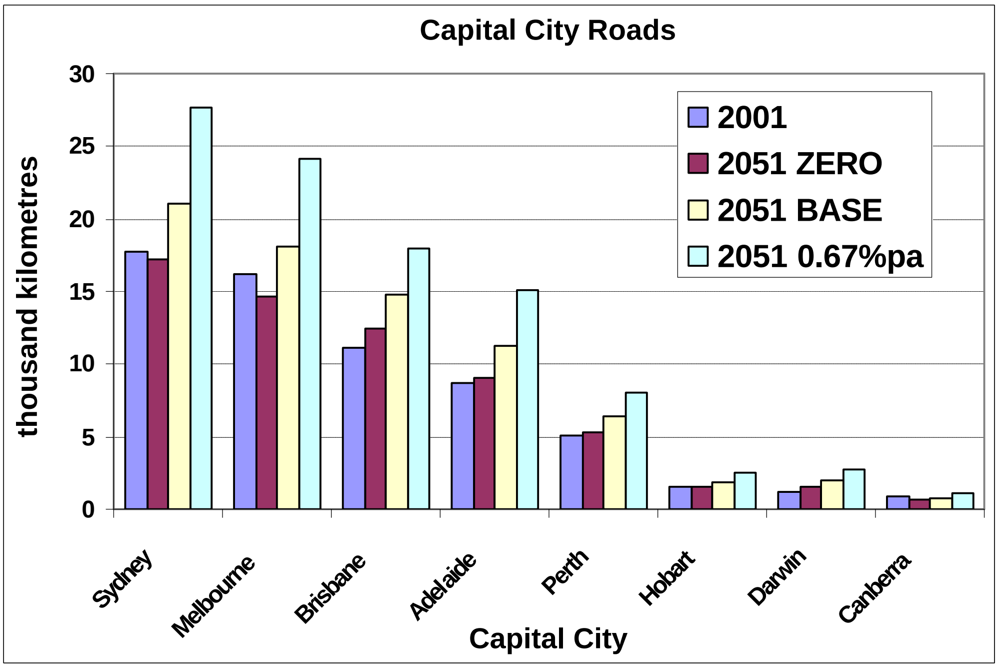


Figure 3.22. A comparison of the requirement for capital city roads now in 2000, and in 2050 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

The required stock of urban land could increase from a current level of about 10,000 to a range of 12,000 and 15,000 sq km depending on the scenario (Figure 3.23). By 2050 the yearly requirement for new land is zero, 40 or 120 sq km for the zero, base case and 0.67% scenarios, respectively. This yearly value for new land requirements, shows similar patterns to new housing starts and new motor cars. Because it declines rather than grows, the concept of real estate development may have to be redefined to focus primarily on the re-development of previously built areas, a process now well underway in many inner city areas.

Although Australia, covering a vast area of more than seven million sq km, has few land limitations in an overall sense, a number of issues in land use planning within, and on the edge of, capital cities could cause a wide range of local debate. In a completely deregulated system of landuse, this additional suburban land use could occupy a length of 2,000 to 5,000 kilometres of coastline, with suburbs one kilometre deep for the entire length. The task of supplying services to and ensuring adequate standards of waste treatment for this type of spatial arrangement would be considerable in terms of both physical effort and financial capital. Another option is to allow this development to take place on the edge of existing cities and place further strain on the networks for service delivery and waste management. Over the 30-year period from 1960 to 1990, the public sector capital expenditure fell from 9% to 4% of GDP, producing a potential crisis in many areas of the nation's infrastructure (The Institution of Engineers Australia, 1999). Alternatively, these new urban developments could become test beds for innovation in new urban designs along the style of Newton (1997) where central business districts are linked by fast transit systems to grapelike clusters of villages in rural Australia but still centrally connected to the business power houses of the modern economy. With some forward estimate of the potential requirements, these options could be further considered.

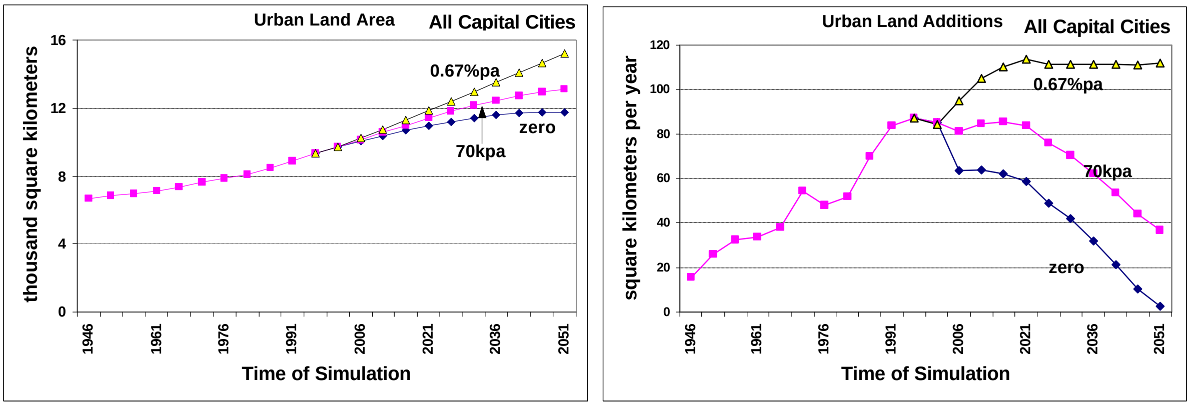


Figure 3.23. A comparison of the stock of urban land (left) and the yearly flow of urban land required (right) to 2050 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Water for Buildings

By 2050 the water requirement for urban buildings could vary from 3,000 to 5,000 gigalitres (10^9L) per year depending on the scenario (Figure 3.24). Water use has been kept at current levels for each building type on the assumption that increasing affluence levels will balance technological efficiency gains across the full socio-economic range of urban consumers. These simulated levels of water use compare to a current usage of approximately 2,000 GL per year for all buildings within a total water usage nationally of approximately 22,000 GL per year Buildings thus use 14% of total water use (Australian Bureau of Statistics, 2000-e). This 2,000 GL water use by built infrastructure compares with the 1,300 GL estimated in both 1970 (Department of Minerals and Energy, 1975) and 1985 (Department of Primary Industries and Energy, 1987). In each city, domestic dwellings use most of this water (Figure 3.25).

The system-wide implications for water will be fully examined in Chapter 6, but the urban consumption is examined here as there are potentially many interactions with other components of the built environment. Total water usage is expected to increase to nearly 33,000 GL per year by 2020 (Thomas, 1999) and continue to keep expanding thereafter in line with economic growth, The allocation of 5,000 GL to people in the built environment appears guaranteed, especially since the price urban consumers are prepared to pay is generally higher than for any industrial or agricultural usage. As well, the long-distance transport of water in Australia for urban use has been practiced for Adelaide and other towns in South Australia (from the Murray River) and for the goldfield region in Western Australia (from the Mundaring Weir in the Darling Ranges near Perth). Thus, the engineering approach can always provide a solution provided the capital and operational costs are within reasonable bounds.

In an attempt to rank the infrastructure challenges posed by future water supply under the assumptions of this study, the future water requirements from Figure 3.25 are compared to the established water resources in the near city regions listed in Table 3.1. For the five major cities listed in the table, the yearly requirement in 2050 is equal to, or greater than, the classification category of a 'major divertible resource' (the feasible engineering options for storing water) used by the 1985 Australian Water Resources Council Review (Department of Primary Industries and Energy, 1987). However, the total water flows in the near-city regions are two to four times the urban resource requirement in 2050. If the total rainfall in the region is taken into account, then five to 20 times the urban requirement falls from the sky in an average year, but most of this is difficult to harvest and is used in evapotranspiration by plants and a wide variety of ecosystems services.

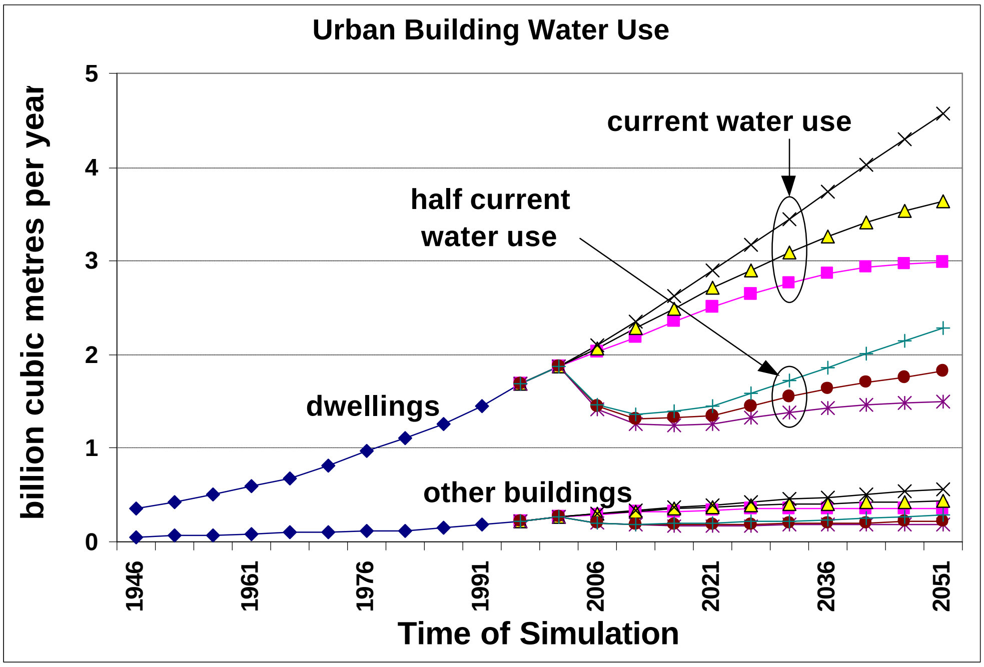


Figure 3.24. The yearly requirement (the flow) for water for buildings to 2050 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa). Both dwellings and other buildings are shown.

.

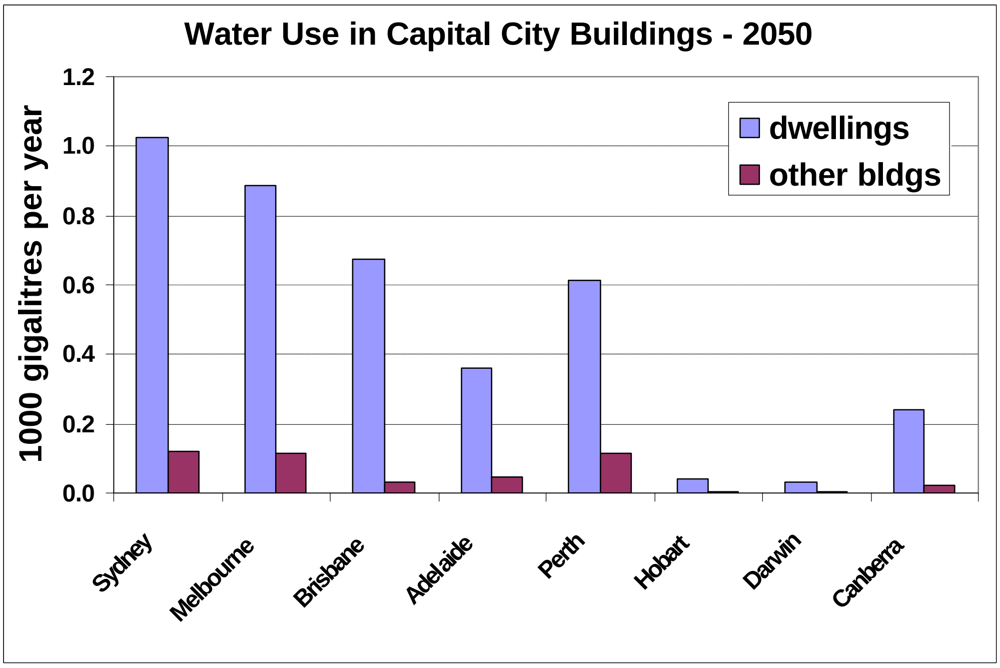


Figure 3.25. The yearly requirement (the flow) for water at 2050 for the base case scenario showing the breakdown between dwelling and other building types for the capital cities.

The imbalances are most obvious for Adelaide which has a ratio of 400 GL requirement to about 150 GL 'major divertible supply'. This imbalance is already supplemented from the Murray River in most years. Although Perth's 700/370 GL imbalance is already supplemented by groundwater pumping, this is being reduced to maintain water quality and to guard against salt water intrusions into underground aquifers. Most of Melbourne's water is harvested from 156,000 hectares of uninhabited catchments and industry sources note that another 500 GL per year is potentially available to augment supply in the next 20 to 30 years. These catchments, covered by old growth forests, pose a cautionary tale that is applicable in some way to most city water catchments. The old growth forest ecosystems have delivered high quality water to the city for more than a century. However if they are destroyed by wildfire, water yield falls by 50% and the ecosystems require 150 years to return to the previous physical state that can deliver similar levels of ecosystem service.

Table 3.1. The flow of water in gigalitres (10^9L) in the water regions near each capital city showing the annual outflow, the amount that can reasonably be diverted and the yearly resource in total precipitation. Figures in parentheses in column five are RAWR estimates of stocks of groundwater in the near city regions.

Capital city	Water region name (from 1985 Review of Australia's Water Resources: RAWR)		Mean annual outflow GL/year (RAWR Table S5 p44)	Major divertible resource GL/ year (RAWR Table S5 p44) (groundwater in brackets)	Rainfall in region GL/ year (ASFF: area of region by yearly rainfall)
Sydney	II_2	II_C	3,900	1,020 (29)	21,748
Melbourne	II-6	II-F	1,650	772 (28)	10,300
Brisbane	I_10	I_J	1,860	553 (65)	11,872
Adelaide	V_1	V_A	433	131 (28)	3,326
Perth	VI_5	VI_E	1,260	369 (370)	8,510
Hobart	III_2	III_B	6,210	507 (22)	19,605
Darwin	VIII_6	VIII_F	5,000	720 (180)	13,825
Canberra	IV_5	IV_E	2,730	2,510 (160)	36,954

As well as the risks posed by destruction of ecosystem services, Australia's climate is highly variable and most cities undergo periods of low levels of water storage during droughts. In order to buffer urban consumers against this inevitability, engineers have built storages to retain yearly flows of water for longer periods (Table 3.2). Most cities in Australia store enough water to supply three to four years at current levels of consumption. This ratio drops marginally when the 2050 requirement is imposed on the current set of dams and storage infrastructure. But innovations in water supply and re-use over the next 50 years are likely to accommodate this shortfall. In the next four years, water re-use in Australia's urban areas will increase from 113 to 225 GL per year (CSIRO, 2000-b). If Sydney and Melbourne become megacities of 9 to 10 million people by the year 2100, as simulated under the 0.67%pa scenario (see Chapter 2), large investments in interbasin transfers or a considerable reduction in water use per household would be required.

The possibility of reducing water use is assessed in the sub-scenario shown in Figure 3.24. The consumption profile reduces water use to 50% of current levels by the year 2020, i.e. nearly one human generation from now. Households in most Australian states use between 200,000 and 400,000 litres per year (550-1,100 litres per day). If water saving technologies and behaviours, which retain the amenity and service of water usage, but reduce the overall amount were implemented, then the zero and base case population scenarios would be physically feasible to the year 2050 with current storages and levels of catchment yearly water flow. However the 0.67% scenario may require reductions of 60% in water use to stay within the confines of the present water infrastructure. After 2035, as water requirements continue to rise in line with population growth, transfers from agriculture and inter-basin transfers seem to be inevitable to retain a reasonable buffer between yearly requirement and total storage and in the face of possible reductions in stream flow due to altered rainfall patterns stemming from global climate change.

Table 3.2. Contemporary water industry data on water storages and weekly usage, transposed to water weeks and water years stored.

City	Dams	Total storage GL	Weekly usage GL per week	Potential water-weeks stored	Potential water-years stored	Comments
Sydney	11	2,400	13.1	183	3.5	Sydney water web site
Melbourne	9	1,825	12.0	152	2.9	500 GL per year available for further development. Melbourne Water web site.
Brisbane	3	1,890	7.0	270	5.2	Weekly consumption and storages data requires more checking as water restrictions are usual in summer periods. Brisbane City Council web site
Perth	11	803	5.6	143	2.8	Storage includes yearly pumping of ground water. Perth Water web site
Canberra	4	215	1.3	166	3.2	ACTEW web site

Quality considerations pose the biggest challenge for urban water delivery. Flow-on effects from population growth combined with poor land use planning give a prognosis of poorer quality in the future with increasing physical effort and increased costs being required for water treatment. Against a background of uninhabited catchments such as the Thompson River which supplies Melbourne (Melbourne Water, 2000), delivering cheap high quality water, the increasing requirement for houses, cars, urban land, and roads in the base case and 0.67%pa scenarios may give either good or poor water quality outcomes. Good quality outcomes may derive from a realisation that each person in a city requires about 600 square metres (0.06 hectares) of clean uninhabited catchment to supply high quality water for urban use. The more a water catchment area is dissected for urban development and hobby farms, broken up by roads and used for agriculture or high impact recreation, then the lower will be the subsequent water quality, the more difficult the treatment process and the higher its costs. An alternative option is to purchase whole catchments and manage them solely for contemporary and future urban water delivery. New York City recently purchased and refurbished important parts of the Catskill/Delaware and Croton water catchment areas to supply the 1,800 GL per year (5 GL daily) required for its 8 million inhabitants (The City of New York, 2000). The purchase of about 20,000 hectares of catchments is being achieved for less than US$2 billion capital cost compared to US$6-8 billion capital cost for state of the art treatment plants with a US$300 million per year running cost (Chichilnisky and Heal, 1998).

Introduction

Although Australia does not have the population size or density to cause the air pollution problems of cities such as Mexico City and Los Angeles, the physical nature of the airsheds surrounding our capital cities limits their assimilative capacity, i.e. the capacity to process and disperse atmospheric pollutants. Australian city airsheds, at times, hold and concentrate atmospheric pollutants. Mannins (1992) describes Melbourne's 'Spillane Eddy' and Sydney's sea breeze drainage system as products of the local topography and nearby mountains. These winds cause pollutants to recirculate and buildup in city airsheds, thus lowering their assimilative capacity. Johnson (1992) describes the most important types of air pollution in Sydney as urban haze and photochemical smog. The latter is caused when sunlight causes a reaction between reactive organic compounds (mostly hydrocarbons) and nitrogen oxides. With a likely population growth in Sydney of one million more people by 2010, it is probable that air pollution problems in the Sydney Basin will worsen (Johnson, 1992). A previous study tightened the linkage between air pollution problems and human health in Sydney with a 'biomedical atlas' that linked emission locations and concentrations with various respiratory ailments by postcode (Gibson, 1979; Gibson and Johansen, 1979)

The issue of urban air pollution continues to pose significant challenges for environmental and city planning agencies in Australia. While engine technology and emission controls have helped improve air quality in city airsheds during the past decade, saturation of improvements in engine technology and increasing vehicle kilometres driven cause concern for future trends (Department of Environment State and Territories, 1996). The sections below show the yearly transport emissions for components important for phytochemical smog, namely nitrogen oxides and volatile organic compounds, for the airsheds of Sydney Brisbane and Perth. The proposal to introduce EURO 3/4 engine and fuel standards that fully penetrate the engine technology is a complex task compounded by interactions between the local vehicle manufacturers, local fuel refineries and an increasing trend towards heavier sports utility vehicles with much lower fuel efficiency ratings (Environment Australia, 2000-a).

The Sydney airshed

The modelled profiles of emissions in the Sydney basin show a steady increase to 2050 for the 0.67%pa scenario, a flattening by 2050 for the base case and stability by 2020 for the zero scenario (Figure 3.26). The data for nitrogen oxides range from 80,000 to 120,000 tonnes per year in 2050 and from 120,000 to 180,000 tonnes per year for volatile organic compounds. An emissions inventory in 1985 for the Sydney airshed showed 60,000 tonnes of nitrous oxides and 75,000 tonnes of hydrocarbons (Farrington, 1985). A subsequent inventory by the New South Wales Environmental Protection Agency in 1998 for an extended airshed including Newcastle and Wollongong gave 120,000 tonnes of nitrogen oxides and 96,000 tonnes of volatile organic compounds (Environment Australia, 2000-b). The simulated emissions profiles shown thus represent the correct order of magnitude.

According to the 1997 NSW State of Environment Report (EPA, 2000), chemical precursors of photochemical smog are a continuing problem and by 2021 vehicle kilometres travelled will increase by 36%. Diesel engines appear likely to cause a disproportionate part of the emissions problem due to the increase in truck transport and also to poor tuning of many diesel engines. The policy response notes a number of standard-setting agendas for vehicle technology and other issues that relate to summer months when the rise of photochemical smog is most prevalent. More importantly, the report suggested land planning innovations to help locate workplaces nearer to households to reduce the requirement for commuter traffic. However, technological solutions were not expected to bring the air emissions problem under control for the next 25 years.

The base case scenario in this study would concur with the transport assumptions in the New South Wales report. The 0.67%pa scenario gives an emissions profile which continues growing to 2050 and beyond. The zero scenario gives a stable emissions profile by the year 2020.

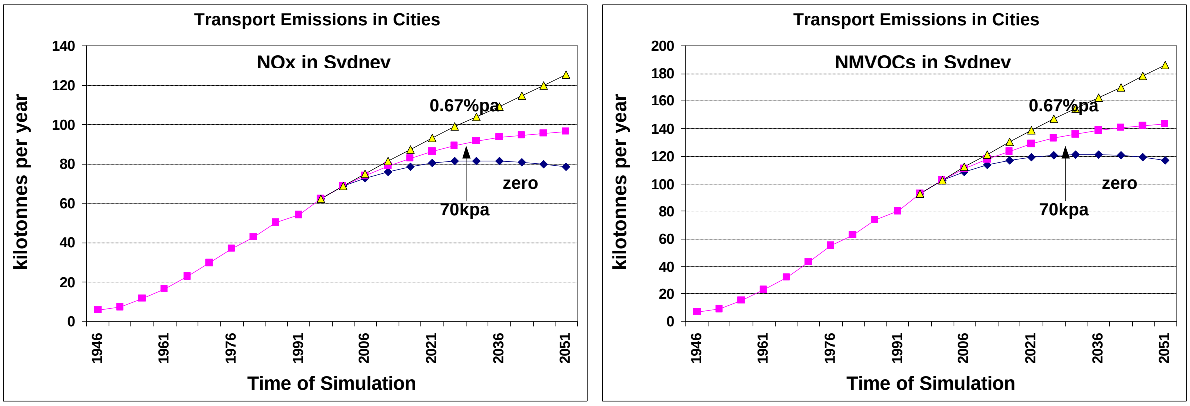


Figure 3.26. The generation of NOx emissions (left) and volatile organic compounds (right) to 2050 for the Sydney airshed for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

The Brisbane airshed

The vehicle emissions profile for the Brisbane airshed shows slightly different trajectories for the zero and base case scenarios due to effects of internal population migration. Thus, vehicle emissions for Brisbane continue to grow to 2040 in the zero scenario and to 2050 for the base case (Figure 3.27). The 1985 airshed inventory gave vehicle emissions for nitrous oxides of 25,000 tonnes per year and for hydrocarbons of 30,000 tonnes (Farrington, 1985). The 1998 inventory for a much larger airshed including Toowoomba and the Gold Coast gave a value for nitrogen oxides of 69,000 tonnes and volatile organic compounds of 51,000 tonnes. These values suggest the modelled profiles are of the correct order.

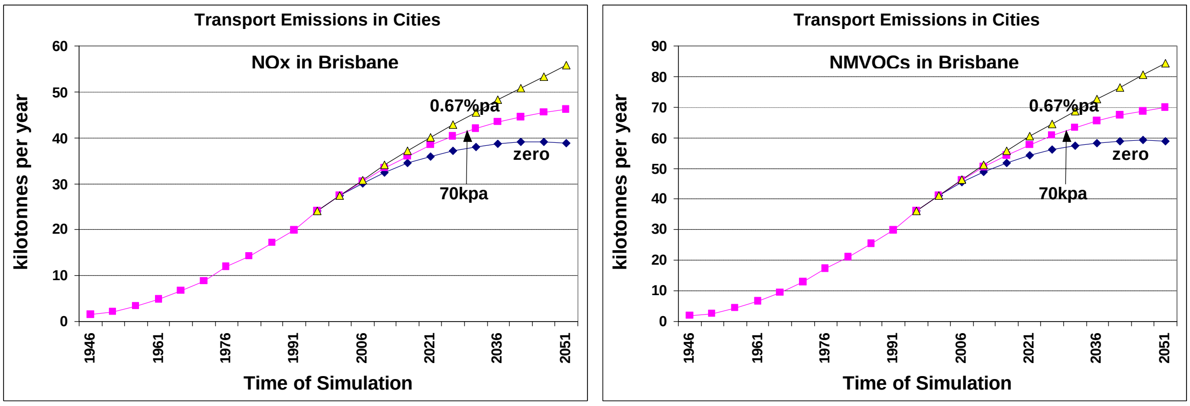


Figure 3.27. The generation of NOx emissions (left) and volatile organic compounds (right) to 2050 for the Brisbane airshed for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

The 1999 Queensland State of Environment Report noted that Brisbane has the highest potential for phytochemical smog problems of any city in Australia due to climatic and geographic factors (Queensland Environmental Protection Agency, 2000). The report also notes that air quality has generally improved in the last 20 years due to the removal of power stations from the airshed and the banning of backyard incineration. In addition, the problems of emissions from transport are being held reasonably constant by improvements in vehicle technology. A number of government policy initiatives such as integrated regional transport planning and a regional air quality strategy aim to maintain the balance between increased vehicle traffic volumes and atmospheric quality. However, with the possibility that that three million people could be living in the greater Brisbane area by the year 2011, (an increase of 800,000) an extra 80,000 tonnes of vehicle emissions per year is possible (Brisbane City Council, 2000).

The Perth airshed

The Perth airshed shows a stable emissions profile after 2030 for the zero scenario and profiles that grow steadily, although at different rates, for the base case and 0.67%pa scenarios (Figure 3.28). The spread of emission levels at 2050 is 30,000 to 50,000 tonnes per annum for nitrogen oxides and 50,000 to 75,000 tonnes per annum for volatile organic compounds. This compares to the 1985 inventory level of 24,000 tonnes for nitrous oxides and 30,000 tonnes for volatile organic compounds (Farrington, 1985). The 1998 emissions inventory noted 28,000 tonnes for nitrous oxides indicating that the simulated values are of the right order.

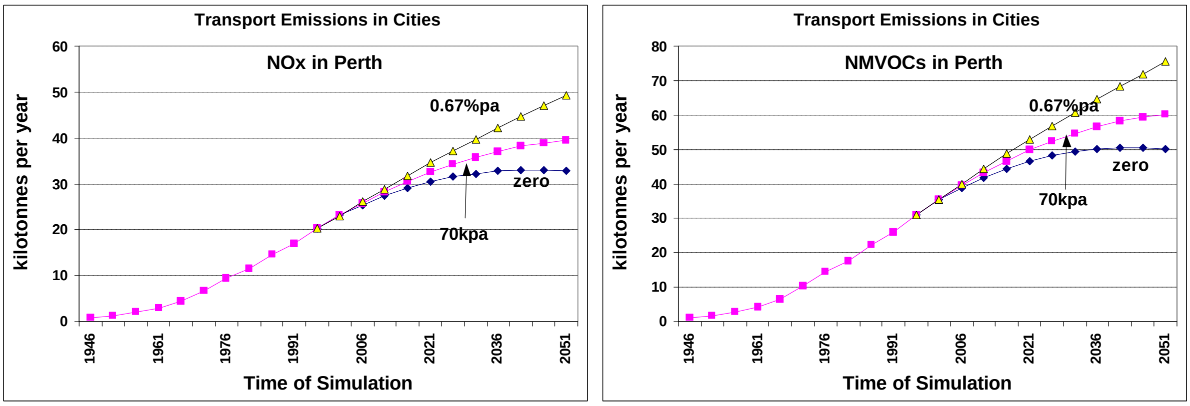


Figure 3.28. The generation of NOx emissions (left) and volatile organic compounds (right) to 2050 for the Perth airshed for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

The 1998 State of Environment Report (Western Australia Department of Environmental Protection, 2000) notes that emissions of nitrogen oxide from transport are likely to rise to 40,000 tonnes per annum by 2011 and that use of public transport is trending downwards on a per capita basis. While there is no discernible trend in the incidence of photochemical smog occurrences, there are 12 days per year when ozone concentration levels exceed World Health Organisation standards. A wide range of integrated policy responses are being mooted as well as a technological approach promoting the conversion of car fleets to natural gas, which produces 50% less nitrogen oxides when combusted.

Sub-scenario: emissions from new vehicle technology

The less fuel a car or truck burns per person kilometre or per tonne kilometre then the lower the emissions produced for the same delivery of service. Thus, the sub-scenarios where improved engine technologies are introduced (Figures 3.18, 3.19 and 3.20) approximate the effect of better vehicle technologies on air pollutants such as nitrogen oxides and volatile organic compounds. The potential for new vehicle technology depends on a number of factors. A range of urban transport and freight transport systems, such as trucks and buses, are already approaching thresholds where energy efficiency cannot be substantially improved. Changing fuel types from diesel to natural gas, as suggested in the Perth airshed study is possible and buses with hydrogen powered fuel cells will soon be available (Ballard Systems, 2000). However motor cars and increasingly into the future, delivery vehicles are the source of most of the energy use and subsequent emissions result. To change the emissions profile and resultant occurrences of phytochemical smog will require a major changeover in motor car technology or an equally major long-term investment in public transportation systems and changes in modal share (compare Figures 3.12 and 3.17 where passenger task for urban transit and urban car are displayed).

SYNTHESIS OF POPULATION AND TECHNOLOGY EFFECTS

Primary driver effect of population on urban infrastructure

One of the key policy challenges in this study is to gain insights into infrastructure and environmental issues that are directly linked to population numbers, and hence to domestic birth rates, death rates and to immigration policy. The concept of population drivers described as primary, secondary, tertiary and quaternary in effect, was introduced in Chapter 2 to describe the diffuse and long-term linkages of population number and structure. Secondary and lower order drivers become more diffuse in their influence, and might be seen as the responsibility of 'some other government portfolio'. However a 'whole of government' view might find it useful to order the population effect, especially where an innovative policy for one portfolio might produce perverse or negative effects in another policy area, or another sector of the economy. Perverse effects are increasingly the topic of policy research in areas such as long-term international debt (Cole and Kehoe, 2000), competition policy (Hoff and Stiglitz, 1998; Bratton and McCahery, 1999), certification of agricultural products (Menard, 1998) and the use of telemedicine in national health policy (Rigby, 1999).

When viewed in 2050 and compared to the base case scenario, a primary or first-order effect of population should show a minus 18% effect for the zero scenario, and plus 29% effect for the 0.67%pa scenario (Table 3.3). Other effects are less directly linked to domestic population size or driven strongly by issues and policies quite removed from domestic population policy, i.e. in terms of this discussion, a secondary, tertiary or quaternary effect. Since most urban infrastructure is built to service the requirements of the domestic population, it is reasonable to expect that many physical issues will display a primary effect due to domestic population size. The judgements hereafter use the base case scenario at 2050 as the benchmark with which the zero and 0.67%pa scenarios are compared.

The starting case behind all scenarios assumes a wide range of technological improvements and growth in lifestyle and affluence. In terms of the 15 issues assessed for the zero scenario, 10 show a primary effect due to domestic population numbers as would be expected (Table 3.3). The exceptions are traveller space, non-urban passenger task, new motor cars, total stock of urban land and yearly requirement for new urban land. These less than expected effects on traveller space and non-urban passenger task are due to the effect of international inbound tourism described in Chapter 2. The new motor cars show a greater reduction than expected due to interactions with the formation of households (which drives requirements for motor cars). The total urban land stock and yearly requirement for new urban land is due to the total building stock in 2050, being in excess of that required by a stabilised population on the cusp of beginning to decline out to 2100.

.

.

Table 3.3. Overall assessment of the primary effect for domestic population numbers for the three scenarios on key stock and flow issues within the urban environment at the year 2050. In all cases the base case scenario is indicated as 100% and includes a wide range of technological and policy innovations compared to today's situation.

Issue	Zero	Base case	0.67%pa	Comment
Population at 2050	**Minus 18%**	**100%**	**Plus 29%**	**Basic population assumptions driving the 3 scenarios**
Dwelling units	Minus 17%	100%	Plus 25%	Slight difference from population due to age cohort effect
Traveller space	Minus 10%	100%	Plus 14%	Dominant effect is from inbound international travellers
Total non-dwelling space	Minus 18%	100%	Plus 29%	Directly driven by population and effect of traveller space in total stock is small
Energy use by building stock	Minus 18%	100%	Plus 27%	Lag in requirement for domestic housing in relation to total population due to age effect
Non-urban passenger task	Minus 14%	100%	Plus 23%	Inbound international traveller task reduces the importance of domestic population levels
Stock of urban delivery vehicles	Minus 20%	100%	Plus 28%	Similar to population levels
Energy use by urban delivery vehicles	Minus 17%	100%	Plus 28%	Similar to population levels
Total stock of motor cars	Minus 18%	100%	Plus 25%	Saturation and structure within the numbers of households produce a lag effect in relation to total population numbers
New motor cars required	Minus 22%	100%	Plus 35%	Distributional bump in younger age cohorts in 0.67% scenario require more cars
Energy use by motor car fleet	Minus 18%	100%	Plus 29%	Directly related to population numbers
Stock of urban roads in capital cities	Minus 18%	100%	Plus 30%	Directly related to population numbers
Land stock for urban development	Minus 10%	100%	Plus 16%	Higher density settlement constrains this stock so that it is not directly proportional to population.
Flows of land for new urban development	Minus 92%	100%	Plus 300%	The 0.67% scenario is compared to a saturating value in the base case thereby inflating the 0.67%pa scenario.
Requirement for urban water	Minus 18%	100%	Plus 26%	Zero scenario is same as population. The 0.67%pa is slightly less than population due to a larger stock of flats and high rise accommodation.
Urban vehicle emissions in Sydney	Minus 18%	100%	Plus 30%	Reflects population numbers

.

The 0.67%pa scenario shows nine of the 15 areas where the primary effect of population is diluted or enhanced particularly by distributional effects and stock issues. The dwelling unit requirement is less than expected because a higher proportion of the population at 2050 are younger (see Chapter 2) but not yet old enough to form households and require housing. This interaction of distribution and size of population (currently allied with the baby boom effect) will continue to cause departures from expected outcomes throughout the study particularly in the analysis of crosscutting issues (see Chapter 7). The non-urban passenger task effect is due to international inbound travellers. The higher than expected yearly new car requirement is due to a number of stock management and scrappage issues that appear to become more pronounced with larger vehicle fleets. Subtle changes in life table characteristics describing the age of the vehicle fleet might diminish this effect.

The total land stock is smaller than expected on a direct population basis because of a younger population and a slightly larger number of people per household requiring fewer dwellings. The modelling procedure is driven by an age and gender modelling protocol and forms more households pro rata because of the younger age distribution overall (see Chapter 2). The higher ratio for this scenario compared to the base case for flows of new urban land, is a good example of the importance of stock effects, a concept described earlier in this chapter. The requirement for new urban land in the base case has been declining as new dwelling requirements saturate and replacement dwellings are erected on previously used sites. The requirement for new urban water is slightly less than the population number would indicate, as increasing proportions of dwellings in cities such as Sydney are flats which have a lower water requirement.

Thus, two effects have come to the fore in this examination of the primary driver effect of population number on size and function of Australia's future urban infrastructure. The first is a stock saturation effect, where the requirement for infrastructure is diminished because of stable or declining population. Because houses and people do not have equivalent lifespans, the long-term balance between infrastructure stocks and requirements can move out of phase for a number of decades. The dynamics of real world property markets may fix this simulated result.

The second is a distributional effect where the bumps in human age distribution, which drive requirements for houses and cars when they interact with distributions of stocks, can produce requirements higher (or sometimes lower) than would be expected by a simple pro-rata treatment of total population numbers. In this chapter, these two effects are generally smaller than the overall primary driver of population number. The next section will bring together the results of the sub-scenarios, where improved technologies have been aggressively implemented in an attempt to reduce the primary effect of population, and potentially allow higher population levels to function for similar or less resource requirements or waste generation than current levels.

Effect of potential technology implementation

All technologies tested in the sub-scenarios are well developed. The time profiles for their implementation are set to halve the base case per unit resource use by the year 2020 (Table 3.4). For both the base case and zero scenarios, resource use in 2050 is less than one half of the 'non-innovation' base case at that time because technology has changed and population numbers are stable or declining. For the 0.67%pa scenario, the implementation of the improved resource use technologies generally reduce the issue by 40% in relation to the base case at 2050. The exception is the '60% of current standard' motor car engine technology where growth in total energy use occurs when the car fleet stock is fully saturated with the technology. After 2030, continuing population growth in this scenario causes pro-rata growth in energy use. This probably means that under the 0.67%pa scenario, it could be advantageous to leapfrog the six litres per 100 km and immediately plan for three litres per 100 km technology. In summary, the sub-scenarios of technology innovation, if implemented on the time profile used, will allow higher levels of population to operate with resource use and waste generation similar to current levels while retaining similar levels of physical service and physical affluence.

Table 3.4. Assessment at the year 2050 of the specific effect of technological innovations included in sub-scenarios computed for different issues in the urban environment. In all cases the base case scenario without this particular technological innovation (see table 3.1) is used as the basis for the assessment.

Issue	Zero	Base case	0.67%pa	Comment
Population numbers at 2050	**Minus 18%**	**100%**	**Plus 29%**	**Basic population assumptions without technological innovation.**
Halve energy use per square metre in all building space (megajoules per square metre)	Minus 59%	Minus 50%	Minus 37%	Five star designs meet these specifications but market acceptance lags well behind technological feasibility.
Automotive technology improvements for energy use of delivery vehicles (litres per 100 km)	Minus 57%	Minus 50%	Minus 38%	Local government could mandate energy standard for all commercial vehicles with little political fallout.
Automotive technology to 60% of current fuel use by 2020 (litres per 100 km)	Minus 51%	Minus 40%	Minus 23%	Hybrid cars with contemporary shape, size, and comfort levels are available but seem poorly promoted by major manufacturers.
Automotive technology to 30% of current fuel use by 2020 (litres per 100 km)	Minus 75%	Minus 70%	Minus 41%	Possible that hypercar vehicles will be acceptable to home market by 2020, but high fuel prices might spur earlier acceptance
Halve per unit urban water use by 2020 (litres per square mere of dwelling space)	Minus 59%	Minus 50%	Minus 37%	Changes are feasible, but life style and amenity values of suburban living may suffer

In considering the implementation of technological sub-scenarios, particularly potential barriers to implementation and the perverse effects which might occur, several issues are worth considering. The first is the degree to which declining resource use is compatible with economic growth. In far reaching analyses combining both physical and economic data over several major economies, Cleveland et al. (2000), Stern (1993, 2000), and Kummell and Linderberger (1998) conclude that energy use and economic growth are so closely intertwined, that energy use substantially causes economic growth, rather than merely being a by-product of it. Aiming to stabilise and then reduce the total physical flows of energy and materials, and thereby the financial flows of a range of key utility companies which deliver energy and water for example, could challenge some current concepts of economic function, but need not be incompatible with it. Both von Weizsacker et al. (1997) in the book *Factor 4*, and Hawken et al. (1999) in *Natural Capitalism*, cite many examples where the service content of a physically-based good can be gradually increased as the physical content declines with behavioural changes and technological innovations. Thus, many utility companies are becoming energy service companies (e.g. selling a warm, well lit, comfortable dwelling) rather than merely selling units of electricity, gas and water.

The second issue is the degree to which the rebound effect occurs for different technologies. Rebound effects occur where increases in technical or physical efficiency stimulate the requirement for more good or service, rather than the same amount for less physical resource. A study on household appliances in Austria spanning a 35 year times series indicated that rebound for these technologies was low, and that increasing technical efficiency was the key way forward in decreasing electricity consumption (Haas et al., 1998; Haas and Schipper, 1998). It is possible that saving in one component of household spending may stimulate greater consumption in other areas that were previously constrained. Studies of fuel economy and rebound with the US household vehicle fleet, for example, found that over a 15 year period about 20% of potential fuel savings was 'taken back' by increased travel distance (Greene et al., 1999). A greater understanding of the degree to which consumption activities continue to expand once basic needs have been met, is necessary to ensure that hard won technological and policy gains are not frittered away by previously unthought of consumption possibilities and opportunities.

The third issue relates to the degree to which reductions in resources such as water become difficult to implement in consumer terms, and where lifestyle and natural amenity of urban areas start to decline, once certain thresholds of household consumption are passed. Water consumption in urban Australia has oscillated in a band of 150,000 to 200,000 litres per capita since 1980 (Thomas, 1999) and it was generally assumed that price increases per unit of water would remain an effective tool for controlling urban consumer usage. However contemporary studies underway in water futures (Dunlop and Foran, 2001) suggest that privatised water authorities have philosophical and economic difficulties in promoting reductions in household water use because of expanding consumer affluence and requirements of companies to generate reasonable economic returns. Older studies in the US (Billings and Agthe, 1979) note that a 10% rise in income produces a 2.3% rise in water consumption in Arizona. Contemporary studies in Sweden suggest that a 5% rise in water prices, while representing a good revenue raising mechanism for national taxes, will only reduce urban water consumption by 1% (Hoglund, 1999). Dinar and Subramanian (1998), in a study covering 22 countries including Australia, found that while many utilities were increasing charges, many of the block-based pricing schemes did not move smoothly with increasing water usage. An inappropriate charging mechanism, while able to be adjusted through time, might not be able to provide the policy outcomes designed into these sub-scenarios. The water sub-scenario under discussion will require a mechanism to be designed and implemented, which reduces the per capita consumption of 163,000 litres per year under the base case, down to 82,000 litres per year by 2020. It is possible that consumer preference and behaviour have not been tested at this interface of water use and lifestyle in Australia.

The final point relates to the unforeseen effects of technology innovation. Many of the automotive (and other) technologies, while relatively inefficient in terms of energy use, have a development period of nearly one century behind them, and are now reasonably robust and reliable. The rapid introduction of new forms of technology might provide a less useful replacement and spur a reversion to true and tested, but more resource-intensive ways.

URBAN INFRASTRUCTURE CONCLUSIONS

For future urban infrastructure issues in Australia, the domestic population size will continue to be the primary driver of influence. The exception to this is in the area of tourism infrastructure and transport where the increasing number of international inbound travellers has a substantial effect. A number of stock related issues, particularly in the zero and base case scenarios, see population stabilise or start to decline. This gives saturated stocks of infrastructure in relation to the population driven requirement and reasonably rapid declines in the requirement for new urban land, roads, domestic building space and new cars. This might signal the requirement for a radically different structure of economy where new types of goods and services need to be phased in to supplement the traditional areas that are slowing. A number of sub-scenarios of technological innovation were tested which allow higher stocks of domestic population, with levels of service and lifestyle equal to today, to exist with similar resource use levels evident in the year 2000. To achieve the goal by 2020 and maintain it, such sub-scenarios rely on the aggressive application of leading edge technology and best design standards for every new item of infrastructure introduced into the national stocks.

References

Australian Bureau of Statistics (2000-a). Australia Now, A Statistical Profile, Housing, Types of Dwellings:http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/a82ebf34b536d7dbca2568a900154a61!OpenDocument accessed 5-5-2000

Australian Bureau of Statistics (2000-b). Australia Now, A Statistical Profile, Construction, Building activity in chain volume measures: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/844900151a4c13bbca2568a900154aa0!OpenDocument accessed 5-5-2000

Australian Bureau of Statistics (2000-c). Australia Now, A Statistical Profile, Transport, Registered motor vehicles: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/05484497fc8525d2ca2568a900154b1c!OpenDocument accessed 11-5-2000

Australian Bureau of Statistics (2000-d). Australia Now, A Statistical Profile, Transport, length of road system http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/437f171ae2273e90ca2568a900154b1b!OpenDocument accessed 11-5-2000

Australian Bureau of Statistics (2000-e). Water Account for Australia 1993-94 to 1996-97. ABS Catalogue No. 4610.0.

Australian Gas Association (1999) Press release: *Natural Gas Fastest Growing Energy Source* 16 April 1999 http://www.gas.asn.au/MAIN.HTM accessed 10/5/2000

Australian Greenhouse Office (1999-a). Australian Residential Building Sector Greenhouse Gas Emissions 1990-2010. http://www.greenhouse.gov.au/energyefficiency/building/emissions.html accessed 7-5-2000

Australian Greenhouse Office (1999-b). Australian Commercial Building Sector Greenhouse Gas Emissions 1990-2010. http://www.greenhouse.gov.au/energyefficiency/building/emissions.html accessed 7-5-2000

Autoweb (2000). Honda Insight achieves world's best fuel economy. http://www.autoweb.com.au/id_HON/doc_hnd9910051/article.html accessed 11-5-2000

Ballard Systems (2000). Transportation Applications. http://www.ballard.com/trans_app.asp accessed 15-5-2000

Billings RB and Agthe DE (1979). The impact of socioeconomic status on residential water use: A cross section time-series analysis of Tucson Arizona. Hydrology and Water Resources in Arizona and the Southwest 9,167-173.

Bouman M Heijungs R van der Voet E van den Bergh JCJM and Huppes G (2000). Material flows and economic models: an analytical comparison of SFA, LCA and partial equilibrium models. Ecological Economics 32,195-216.

Bratton WW and McCahery JA (1999). Comparative corporate governance and the theory of the firm: The case against global cross reference. Columbia Journal of Transnational Law 38,2,213-297.

Brisbane City Council (2000). Clean Air Fact Sheet: Brisbane City Council's Commitment to Clean Air. http://www.brisbane.qld.gov.au/council_at_work/environment/air/clean_air/council_commitment.shtml accessed 15-5-2000

Bureau of Transport Economics (2000-a). Trends in trucks and traffic. Information Sheet 15 http://www.dotrs.gov.au/bte/publist3.htm accessed 10-5-2000

Bureau of Transport Economics (2000-b). Urban transport-looking ahead. Information Sheet 14 http://www.dotrs.gov.au/bte/publist3.htm accessed 10-5-2000

Bush S Dickson A Harman J and Anderson J (1999). *Australian Energy: Market Developments and Projections to 2014-15*. ABARE Research Report 99.4.

Carver L (1996). Electricity reform in Australia- progress and prospects for market trading. Gilbert and Tobin web site http://gtlaw.com.au/pubs/electricity-reform.html accessed 10/5/2000

Chichilnisky G and Heal G (1998). Economic returns from the biosphere. Nature 391,629-630 12 February 1998.

Cleveland CJ Kaufmann RK and Stern DI (2000). Aggregation and the role of energy in the economy. Ecological Economics 32,2,301-317.

Close A and Foran BD (1998). Canberra's Ecological Footprint. Resource Futures Program Working Document 98/12 http://www.cse.csiro.au/research/Program5/RF/publications/WkgDocs98.htm accessed 07-05-02

Cole HL and Kehoe TJ (2000). Self-fulfilling debt crises. Review of Economic Studies 67,1,91-116.

Community Partnerships (1998). Strategic assessment of potential greenhouse gas reductions in the household sector. Report to The Australian Greenhouse Office, October 1998 25 pp.

Conroy J Foran BD Poldy F and Quinnell T (2000). Future Options to 2050: DIMA Workshops Report. CSIRO Resource Futures Working Paper Series 00/03, March 2000. http://www.dwe.csiro.au/research/futures/publications/WkgDocs00.htm accessed 16-6-01

CSIRO (2000-a). Clean green cars: Aussies show the way. CSIRO Media Release Ref 2000/63 Wednesday 1st March 2000. http://www.csiro.au/ accessed 11-5-2000

CSIRO (2000-b). Call for national focus on water re-use. CSIRO Media Release Ref 2000/272 Thursday 19th October 2000. http://www.csiro.au/ accessed 19-10-2000

Dellink RB and Kandelaars PAAH (2000). An empirical analysis of dematerialisation: Application to metal policies in The Netherlands. Ecological Economics 33,205-218.

Department of Environment State and Territories (1996). *Australia State of Environment 19*96. CSIRO Publishing, Collingwood, Victoria.

Department of Primary Industries and Energy (1987). *1985 Review of Australia's Water Resources and Water Use. Volume 2:Water Use Data Set.* Australian Water Resources Council November 1987.

Department of Minerals and Energy (1975). *Atlas of Australian Resources Second Series: Water Use.* Geographic Section, Department of National Mapping, Canberra.

Dinar A and Subramanian A (1998). Policy implications from water pricing experiences in various countries. Water Policy 1,239-250

Dunlop M and Foran BD (2001). Water Futures Workshop: Issues and Drivers. CSIRO Resource Futures Working Paper 01/04. http://www.cse.csiro.au/research/Program5/RF/publications/01-04f.pdf accessed 07-05-02

Electricity Supply Association of Australia (2000). Data and prices: electricity prices. http://www.esaa.com.au/ accessed 10/5/2000

EMET (1999). Baseline study of greenhouse gas emissions from the commercial buildings sector, with projections to the year 2010. Report to The Australian Greenhouse Office by EMET Consultants Pty. Ltd and SOLARCH GROUP, May 1999, 53 pp.

Environment Australia (2000-a). Review of Fuel Quality: Report Stakeholder Consultation and Scenario Development. http://www.environment.gov.au/epg/fuel/review.html accessed 20-6-01

Environment Australia (2000-b). National Pollutant Inventory Database. http://www.environment.gov.au/cgi-bin/epg/npi/database/npi3/npiquery.pl?query_name=location accessed 15-5-2000

Environmental Protection Authority (2000). *New South Wales State of Environment Report 1997*. http://www.epa.nsw.gov.au/soe/97/ch1/6_2.htm

Farrington V (1985). Air Emissions Inventories (1985) for the Australian Capital Cities. Australian Environment Council Report No22 Australian Government Publishing Service Canberra.

Greene, DL Kahn JR Gibson RC (1999). Fuel economy rebound effect for US household vehicles. Energy Journal 20,3,1-31.

Haas R Biermayr P Zoechling J and Auer H (1998). Impacts of electricity consumption of household appliances in Austria: a comparison of time series and cross section analyses. Energy Policy 26,13,103-1040.

Haas R and Schipper L (1998). Residential energy demand in OECD countries and the role of irreversible efficiency improvements. Energy Economics 20,4,421-442.

Hawken P Lovins A and Lovins HL (1999). *Natural Capitalism: Creating the Next Industrial Revolution.* Rocky Mountain Institute Snowmass Colorado.

Hoff K and Stiglitz JE (1998). Moneylenders and bankers - price-increasing subsidies in a monopolistically competitive market. Journal of Development Economics 55,2,483.

Hoglund L (1999). Household demand for water in Sweden with implications of a potential tax on water use. Water Resources Research 35,12,3853-3863.

Gibson JB (1979). Mapping respiratory health in Sydney. Habitat 10,6,25-27.

Gibson JB and Johansen A (1979). *The Quick and the Dead: A Biomedical Atlas of Sydney*. Reed Publishing, Terry Hills, Sydney.

International Energy Agency (2000). End user oil product prices and average crude oil import costs September 2000. http://www.iea.org/stats/files/mps.pdf accessed 20-10-2000

Johnson GM (1992). Air pollution and western Sydney. Australian Planner July 1992 112-114

Kirby HR Hutton B McQuaid RW Raeside R and Zhand XY (2000). Modelling the effects of transport policy levers on fuel efficiency and national fuel consumption. Transportation Research Part D-Transport and the Environment 5,4,265-282.

Kummell R and Linderberger D (1998). Energy, technical progress and industrial growth. In *Advances in Energy Studies: Energy Flows in Ecology and Economy*, Conference held in Porto Venere, Italy May 26-30 1998, p 207-222

Lovins AB and Williams BD (1999). A strategy for the hydrogen transition. Hypercar centre web site http://www.hypercarcenter.org/whats_a_hypercar.html accessed 11-5-2000

Madden J (2000). Hybrid car mops up pollution. The Weekend Australian. March 18-19 2000 p 20.

Mannins P (1992). Clean air: An oxymoron? Search 23,10,305-307.

Melbourne Water (2000).Melbourne Water Fact Sheet: The Water Supply System. http://www.melbwater.com.au/water/index.html accessed 14-5-2000

Menard C(1998). Maladaptation of regulation to hybrid organisational forms. International Review of Law and Economics 18,4,403-417.

Moore B (2000) Inside the Insight. http://evworld.com/reports2/inside_insight.html accessed 11-5-2000

Newman, P. and Kenworthy, J. (1999). *Sustainability and Cities: Overcoming Automobile Dependence.* Island Press, Washington.

Newton PW (Chair)(1997). *Urban Infrastructure: Reshaping Cities for a More Sustainable Future.* An Inquiry by the Australian Academy of Technological Sciences and Engineering, October 1997.

Newton PW Baum S Bhatia K Brown SK Cameron AS Foran B Grant T Mak SL Memmott PC Mitchell VG Neate KL Pears A Smith N Stimson RJ Tucker SN and Yenken D (2001). *Human Settlements*, Australia State of Environment 2001 (Theme Report). CSIRO Publishing on behalf of the Department of Environment and Heritage, Canberra.

Prettenthaler FE and Steiniger KW (1999). From ownership to service use lifestyle: the potential of car sharing. Ecological Economics 28,443-453.

Queensland Environmental Protection Agency 2000. *State of Environment Queensland 1999.* http://www.env.qld.gov.au/environment/science/environment/welcome.html accessed 15-5-2000

Rann A (1998) Electricity Industry Restructuring-A Chronology. Science, Technology, Environment and Resources Group. 30 June 1998 Australian Parliament House Library http://www.aph.gov.au/library/pubs/bp/1997-98/98bp21.htm#INTRO accessed 10/5/2000

Rigby M (1999). The management of the policy challenges of the globalisation effect of informatics and telemedicine. Health Policy 46,2,97-103

Shipper L Unander F Marie C and Walker I (2000). Energy use in Australia: An international perspective. International Energy Agency powerpoint presentation June 2000.

Simpson R Petroeschevsky A and Lowe I (1998). *The Ecological Footprint of Australia with a Focus on South East Queensland*. Griffith University 1998.

Simpson RW Petroeschevsky A and Lowe I (2000). An ecological footprint analysis for Australia. Australian Journal of Environmental Management 7,11-18.

Stern DI (1993). Energy use and economic growth in the USA, a multivariate approach. Energy Economics 15,137-150.

Stern DI (2000). A multivariate cointegration analysis of the role of energy in the US macroeconomy. Energy Economics 22,267-283

Slesser M King J and Crane DC (1997). *The Management of Greed: A BioPhysical Appraisal of Environmental and Economic Potential*. The Resource Use Institute, Edinburgh, Scotland. 332pp

The City of New York (2000). Department of Environmental Protection: 1998 Water Supply Statement http://www.ci.nyc.ny.us/html/dep/html/wsstate.html accessed 14-5-2000

The Economist (2000-a). Fuel efficient cars: hybrid vigour ? The Economist January 29th. 2000 p 98.

The Economist (2000-b). How green is your hydrogen? The Economist April 1st 2000 p 74.

The Institution of Engineers Australia (1999). A Report Card on the Nation's Infrastructure. December 1999.

Thomas JF (1999). Water and the Australian Economy. A joint study project of the Australian Academy of Technological Sciences and Engineering and the Institution of Engineers, Australia. April 1999 Melbourne.

Treloar GJ (1997). Extracting embodied energy paths from input-output tables: towards an input-output based hybrid energy analysis method. Economic Systems Research 9,4,375-391.

Treloar G Fay R Love PED and Iyer-Raniga U (2000). Assessing the life-cycle energy of an Australian residential building and its householders. Building Research and Information 28,3,184-195.

von Weizsacker E Lovins AB and Lovins LH (1997). *Factor 4: Doubling Wealth-Halving Resource Use*. Allen and Unwin, St. Leonards, Australia.

Western Australia Department of Environmental Protection (2000). *The State of the Environment (SoE) Report 1998*. http://www.environ.wa.gov.au/DEP/soe/soe10.htm accessed 15-5-2000

Chapter 4
Natural resources and environment

ABSTRACT

The tertiary population effect dominates the analyses presented in this chapter. Production characteristics of the minerals and agriculture industries, and to a lesser extent forestry and fisheries, are driven not by domestic population levels, but by demand from global export markets. Those export markets are, in turn, driven by populations in the globalised marketplace, and their requirements for subsistence, lifestyle and affluence. Australia engages in export activities in order to pay for the goods and services that it chooses to import. Apart from oil and natural gas, Australia has few resource constraints which will prevent it meeting increased global requirements for its mineral products provided that technology and exploration develop new provinces and processes to access high quality mineral resources. Tensions between domestic requirements and domestic production of oil may be evident from 2015 and natural gas production from 2030. Because of the critical importance of oil and gas to the nation's physical metabolism, it may be necessary to develop a 50-100 year view of these resources and the possible transition pathways to other energy sources such as shale oil, biomass, methane hydrates on the seafloor and liquefaction of extensive coal resources. National and global requirements relating to greenhouse gas emissions may constrain these transitions. Given Australia's large land mass, agricultural production will meet the domestic requirements for food production out to 2050 and beyond. A large number of substitutions over relatively short timeframes, are feasible in dealing with issues such as domestic dietary change, encroachment of agricultural land by urbanisation and changes in globalised trade requirements. However, the environmental effects of agricultural production are substantial and may become further evident from 2020 onwards. Modelling indicates that more than 10 million hectares of agricultural land may be lost to dryland salinity, irrigation salinity and soil acidification by 2050. This will produce a knock-on effect in making rivers and streams more saline and more acidic, which in turn may increase the difficulty and cost of water treatment for urban and industrial use and limit the productive potential of many irrigation areas. Forestry production, mainly from managed plantations, is likely to expand several fold by 2050. This is driven by trade opportunities such as the reduction of wood and wood fibre imports, and by environmental opportunities such as carbon sequestration and dryland salinity mitigation. Domestic fisheries production and domestic dietary demand will continue to extend the physical deficit although expansion of aquaculture may moderate this outcome. There are a number of financial and trade nuances where more valuable fisheries exports (lobsters, tunas and pearls) may pay for the higher volumes of less valuable fish imports from neighbouring countries. The three main areas of resource and environmental concern are the adequacy of future oil and gas production levels, the loss of agricultural land and linked effects on water quality, and a trade imbalance in fish products for domestic dietary requirements.

INTRODUCTION

Domestic population levels have relatively minor primary or direct effects on resource and environmental issues related to mining and agriculture but more pronounced effects on forestry and fisheries. This is because production in the primary commodity sectors is geared to meeting the requirements of global trade, defined in this study as a tertiary or third order population effect. Tertiary effects occur where a nation exports goods to pay for its imports of goods and services. It is often claimed that domestic population levels have little effect on the land degradation now evident in parts of Australia's agricultural landscapes. It is also claimed that most of the land was developed, and thus damaged, in the early 1900s when there was a domestic population of about five million people (Chisholm, 1999). The argument continues that, if most of the land was degraded in a period with a population of five million, then how could a population of twenty million be blamed for the localised effects of drought, bad farming practices and inappropriate government policies.

Using the concept of the tertiary population effect, it could equally be argued that early Australian agriculture was developed to supply the food requirements and manufacturing feedstock for Great Britain which, at the time, was undergoing its own human population explosion. The industrial revolution was being constrained by lack of domestic resources — in essence, a primary effect of human population in that country. In a global and historical context, Cohen (1995) suggests four periods of evolution in human population growth, the first related to development of local agriculture (8000 BC), the second related to global agriculture (AD 1750), the third related to public health (1950) and the fourth related to fertility (1970). The tertiary population effect proposed in this report has its genesis in Cohen's second period, when new world and old world agricultural food species were exchanged (potatoes, maize and winter grains), and international trade and shipping routes were developed. This period allowed the requirements of local populations to be decoupled from the resources available within each country's borders, and saw substantial flows of bulk food and feedstock materials being transported long distances by improved modes of sea transport.

Advances in industrial and agricultural technologies introduced more complexities. The invention in the late 1800s of the Haber-Bosch process for fixing atmospheric nitrogen in the form of ammonia, allowed production of grains and other food to be decoupled from natural recycling processes based on organic wastes and animal manure (Smil, 2000). World food production now depends on the 80 million tonnes of nitrogen produced industrially in this way each year. A number of European countries, which were previously food importers, now use nitrogen and industrialised agriculture to export food and out-compete their previous suppliers in the globalised market place, a more complex example of the tertiary population effect. Concerns about oil availability may produce knock-on effects as natural gas becomes the fuel of choice for electricity generation and personal transport. One tonne of nitrogen (as urea fertiliser) requires 65 gigajoules (10^9J) of energy for both processing and as feedstock (Smil, 2000), and most of this energy is sourced from natural gas.

This tertiary population effect and its subsequent knock-on effects are pervasive in today's world of globalised trade. Australia exchanges large flows of raw commodities for a wide range of elaborately transformed goods and materials. Japan, Singapore and Korea accept our food and mineral exports while we in turn accept their electronic goods, motor cars and heavy machinery. A number of attempts have been made to reconcile the international balance sheet in terms of impacts and land area with concepts such as ecological space (IUCN, 1994), ecological rucksacks (von Weizsacker et al., 1997) and ecological footprints (Wackernagel and Rees, 1996). The tertiary effect of population is well documented in the scientific literature and increasingly being examined in terms of its specific spatial effects. The Netherlands for example (IUCN, 1994) uses six million hectares of foreign crop land to produce forage for its milk and meat cattle herds. New Zealand imports the equivalent land requirement of 3.2 million hectares in goods and services while it exports the equivalent to a land footprint of 14 million hectares, mainly in agricultural commodities (Bicknell et al., 1998). Most developed countries in the world run an ecological footprint deficit, that is, they are net importers of ecological goods and services. Canada and Australia have a footprint surplus because of their relatively low population levels and large land areas (Wackernagel and Rees, 1997).

This chapter examines the response of four resource sectors of the Australian economy to future domestic requirements (the primary population effect) and export opportunities (the tertiary population effect). The sectors are: minerals with a major focus on oil and gas, agriculture both plant and animal based, fisheries with a particular emphasis on the wild caught marine fishery and forestry with emphasis on the expected expansion of managed plantations.

KEY ASSUMPTIONS

Since most sectors dealt with in this chapter seek to supply export markets, the organising structure of the three population scenarios is not used, although those scenarios are examined in relation to oil, gas and fisheries. The mineral sector is generally expanded on the assumption that Australian commodities will maintain a trading advantage in the world marketplace and that improved exploration will continue to locate high grade ore deposits. Oil and gas stocks are quantified on the basis of 95%, 50% and 5% probability estimates of the Australian Geological Survey Organisation (1999) and are judged to be a discrete stock, rather than an unlimited flow. Agriculture is expanded in line with a market analysis undertaken for broadacre commodities several years ago (LWRRDC, 1997) but using the constraints imposed by the three landscape scenarios which attempt to deal with the problem of declining land function.

The treatment of Australian fisheries reflects recent decades where harvesting levels were not constrained, particularly in the fin fish categories. Because of the relatively speculative results of the simulation modelling, the treatment is set within a world context of wild catch fisheries and also bounded by recent State of the Environment Reports from different states on the status of individual fisheries. The treatment of forestry is derived from the expected expansion of forest plantations to deal with the nation's forest products deficit as well as prospective markets for carbon trading. Finally, since much of the chapter does not involve a primary or direct population effect, the influence of population is examined in a descriptive manner where elements of domestic demand are set within the emerging context of expected trends in the global marketplace.

ISSUES FROM THE DIMA WORKSHOP SERIES

In preparation for the design and testing of the population scenarios with ASFF, a workshop series was conducted in 1999 (Conroy et al., 2000), to critically review the structure of the analytical framework and the implementation of the scenarios. The six important issues for this chapter and the scenario implementation response are as follows:

- The treatment of resources and reserves in mining covers some important definitional issues as well as philosophical ones in relation to the decline in resource quality and availability. It is possible that within one human generation the domestic resources of gold, diamonds, copper, crude oil and natural gas may be constrained. The simulation framework uses a full stock and flow for the simulation of all important mineral resources with data sourced mainly from the Australian Geological Survey Organisation (AGSO). In implementing the scenarios, it was assumed that technological innovation leading to exploration success would ensure that most mineral stocks were not constrained in availability or quality for the duration of the simulation. Because of the importance of oil and gas to national economic function, the stock and flow approach was implemented using the 5%, 50% and 95% probability estimates from AGSO to ensure that all petroleum not yet found, was located and developed during the simulation period.

- It is uncertain whether Australia will develop value adding processes for its mining and mineral industries or whether it will continue to supply raw and partly refined commodities to lower wage countries nearby. The simulations have implemented a steady expansion of current practice and export mix in line with industry opinion sourced at the workshop and from key commodity groups. The development of newer metal types such as magnesium is covered in material and energy terms by the expansion of energy intensive commodities such as aluminium. Process efficiencies improve steadily until 2030 and then stabilise as thermodynamic and physical limits take hold.

- Australian crop and animal industries will increasingly be driven by the quality standards expected by a globalised marketplace. An opportunity exists to increase economic returns per unit of product, thereby allowing production levels to be stabilised and more attention to be given to the environmental problems facing the production system. The reality of agricultural commodity trade is that once quality standards are set (apart from highly specialised niche markets) trade in each commodity is then driven by volume. This is the driving assumption for the 'starting position' or base case scenario as well as the 'technological advance' scenario. A 'landscape integrity' scenario implements the concept of environmental care being linked to product quality and increased acceptability by the global marketplace.

- Since many modes of agricultural production are based on the use of irrigation water, the steady expansion of commodity production will increase the requirements for water in southern Australia's already stressed inland water systems. The scenarios assume both technological progress and expansion into areas that are underdeveloped in water terms. For example the expansion of dairy production takes place with a water use coefficient of 500 litres of irrigation water per litre of milk produced, a level currently attained by the top 10% of farmers. Expansion of crops such as sugar, cotton and tropical horticulture takes place in northern Australia. Chapter 6 presents the overall implications for water resources.

- Management reforms underway in the Australian fishing industry will allow the recovery of important fish stocks. As well, aquaculture has considerable potential to supply major portions of the domestic market and meet expanding global demand. The implementation of the wild caught fishing scenarios was undertaken against a considerable body of inquiry into the long-term sustainability of marine production systems and a more detailed investigation into 'national fish futures' by the CSIRO Resource Futures team. Two scenarios were implemented: an 'open slather' approach which allowed initial high production levels followed by the collapse of many fin-fish fisheries; and a 'sustainable fishing' scenario which reduced the catch but allowed it to be maintained in the long term. The opportunity for aquaculture was left as a tension in fish supply under the different population scenarios; a major expansion may occur, or alternatively, fish could be supplied from international marine resources by trade.

- Over the next human generation it is likely that environmental concerns and political forces will compound to cease most harvesting from Australian native forests. This is accepted in the implementation of the forest scenarios which assume a steady expansion of the plantation estate out to 4 million hectares by 2050 under the 'starting position' and 'technological advance' scenarios used for agriculture or an estate of 13 million hectares under the 'landscape integrity 'scenario. Over the inter-generational periods required for wood stocks in plantations to develop, there is at least a doubling of national wood and pulp production.

The following sections detail and discuss the results of the simulation analyses for natural resource issues such as minerals, oil and gas, crop and animal agriculture, wild caught marine fisheries and plantation forestry.

OIL, GAS AND MINERALS

Oil and gas

The potential domestic production of oil may peak at between 26 and 30 million tonnes per year (1,220 to 1,400 PJ) depending on success in finding new resources (Figure 4.1). The graphs need to be interpreted keeping in mind the following points. Firstly, the resource production levels simulated include those that are classed as economic and sub-economic today, as well as the resources that are still to be found. The probability curves relate to surer but smaller estimates (95%) and less sure but larger estimates (5%) with the median probability (50%) positioned in between these two. The assessment is thus reasonably optimistic encompassing the full expectations and opinions of the Australian Geological Survey Organisation (1999) within the current state of geological knowledge and with the use of advanced recovery technologies. The total resource of oil and condensate (pentane and heavier hydrocarbons), is represented by the area under the curve. The shape of the curve can be adjusted to potentially produce more now but less later, provided that the area under the curve stays the same. Generalised curves of this nature, while different for every major oil field, relate to the physical difficulty in extracting the last portion of a resource (e.g. the last 20%). The curves are well developed over long-term empirical data sets for oil and gas reserves in the USA (US Department of Energy, 2000). In general, resource extraction is physically easier for the first 70% of a resource (up to and just past the peak) and more difficult for the final 30%. This is sometimes reported as increasing economic costs of production but usually reflects the degree of physical difficulty.

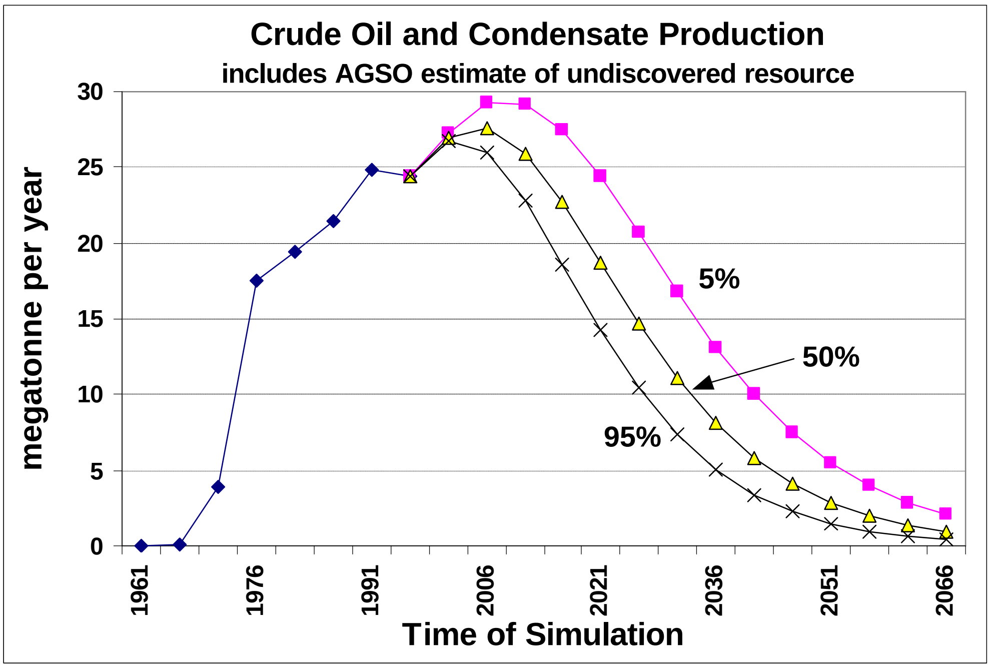


Figure 4.1. Crude oil and condensate production to 2066 based on the 95%, 50% and 5% probability estimates of the Australian Geological Survey Organisation (1999). The total area under each curve reflects the accumulation of past production, current economic and sub-economic reserves and an estimate (the probability levels) of those resources that are still to be found.

This interpretation of future production potential is based on the concept of the Hubbert Curve, which is attracting considerable debate and criticism in the resource and environmental literature (Hubbert, 1967). Laherrere (2000) notes that the method works well when it is "applied to oilfields in the natural domain which are unaffected by political and economic interference and to areas of unfettered activity". The curve also requires a time lag of 30 years post discovery before it can be fitted. The case of Australian oil provinces meets most of these analytical constraints adequately. If the scenario assumptions and analytical approach are accepted as reasonably valid, then a growing imbalance between domestic requirements and domestic production for Australia's oil resources could occur from 2010 onwards.

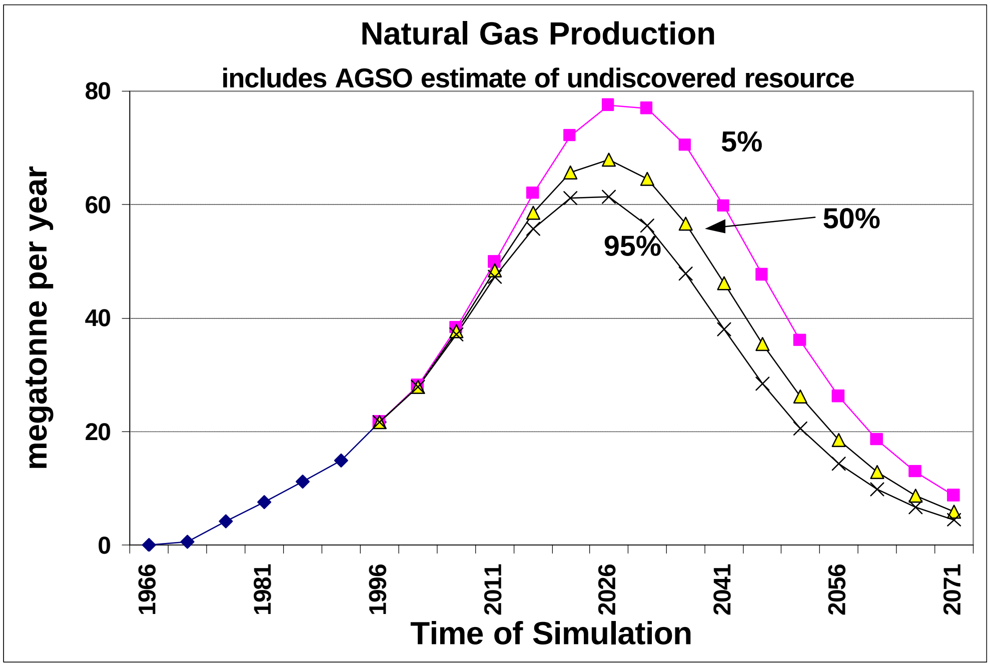


Figure 4.2. Natural gas production to 2070 based on the 95%, 50% and 5% probability estimates of the Australian Geological Survey Organisation (1999). The total area under each curve reflects the accumulation of past production, current economic and sub-economic reserves, and an estimate (the probability levels) of those resources that are still to be found.

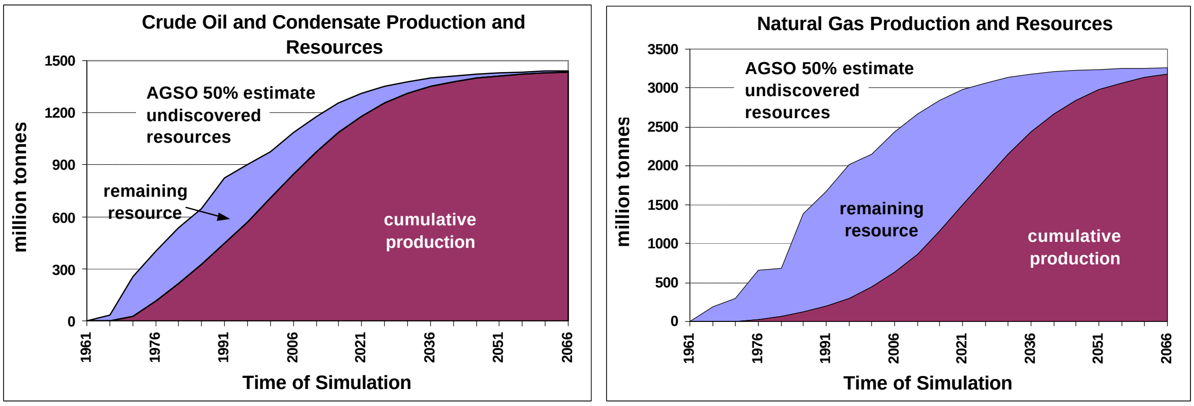


Figure 4.3. Cumulative production and remaining resource for oil and condensate (a) and natural gas (b) to 2066 based on the 50% probability estimates of the Australian Geological Survey Organisation (1999).

The same approach is used for domestic resources of natural gas (Figure 4.2). Because the resources are more plentiful, the peak production of 60 to 80 million tonnes per year (3,200 to 4,400 PJ per year) occurs in the period 2025 to 2035 and a tension between domestic and export requirements and domestic production may occur sometime after that. It is assumed that reserves of both oil and natural gas are developed and exploited as fast as is physically possible and that markets are available for any excess available after domestic requirements have been met. In the case of natural gas, world consumption in 1998 was about 90,000 PJ of which 13,200 PJ was exported by pipeline and 5,000 PJ as liquefied natural gas, giving a total world trade of about 18,000 PJ (BPAmoco, 2000). With the world market for natural gas growing at about 2% per year over the last decade, it is possible that the 1,000 to 2,000 PJ (20 to 40 million tonnes) per year that may be in excess of domestic requirements during the period 2020 to 2030, will find markets with Australia's major trading partners.

Table 4.1. Potential surplus and deficit between potential requirement and potential production for summed oil and gas in petajoules (PJ or 10^{15} J) for 2020 and 2050 using the 50% probability curve from AGSO (1999).

Population scenario	**Potential oil and gas requirement in 2020 (PJ)**	**Potential energy surplus in 2020 (PJ)**	**Potential oil and gas requirement in 2050 (PJ)**	**Potential energy deficit in 2050 (PJ)**
Zero	3,030	1,405	3,540	2,034
Base case	3,180	1,255	4,060	2,554
0.67%pa	3,410	1,025	4,880	3,374
Summed oil and gas production in 2020 and 2050 in PJ from Figures 4.1 and 4.2	4,435		1,506	

The likely time to looming constraints for domestic oil and gas reserves under the 50% probability assumption is shown in Figure 4.3. By 2030 the space between the total oil and condensate resource and the cumulative production over time has narrowed and by 2050 the 'availability' gap has closed completely. For natural gas the picture is more optimistic with the gap beginning to close in 2050 and closing completely by 2070. These outlooks depend on the 50% probability estimates used, and also on the approach which is used to infer possible rates of production and ultimately recoverable resources. It is possible that both sources of inference could attract stringent criticism from experts who expect that oil and gas production could go on forever. However major oil companies such as Shell (Skinner, 2000) note that traditional resources could be affected by both biophysical and political limitations. A report on the oil and gas industries in Texas notes that in order to maintain current natural gas production, 6,400 new wells per year need to be drilled as opposed to 4,048 wells, two years ago (Swindle, 1999). These data represent both the physical cost and the monetary cost of extracting resources from a constrained resource base. Oil output in Texas reached its peak in 1973 when 656 million barrels per year (4,000 PJ) were produced and production rates are now down to 312 million barrels (1,970 PJ) per year (The Economist, 2000). The possibility that vast reserves of shale oil could be brought into production may be limited by energy balance considerations (energy used versus energy recovered) of the process and the greenhouse gas implications (the process releases considerable quantities of greenhouse gas per unit of shale oil produced).

The prospective run down of oil and gas reserves over a 25 to 50 year period is due to a mixture of primary and tertiary population effects. Oil is mainly used domestically, although Australian light crudes are effectively bartered for heavy crudes for bunker oil and bitumen. Oil that is used to transport export goods cannot be assigned directly to domestic population size, i.e. export transport is a tertiary, not a primary population effect. Natural gas is somewhat different, being mainly used at the moment for domestic purposes but with an increasing emphasis on its export potential as a low carbon, greenhouse friendly fuel. Currently one-third of total natural gas production is exported (422 PJ exported of 1,200 PJ total production). Table 4.1 shows some possible linkages between these issues and the three population scenarios. Using the information on oil and gas production trajectories from Figures 4.1 and 4.2, there are potential energy production levels, summed across oil and gas, of 4,435 PJ and 1,506 PJ in the years 2020 and 2025. This leads to a potential surplus of (oil and gas) energy of 1,025 to 1,405 PJ in the year 2020 and a potential deficit of 2,034 to 3,374 PJ in the year 2050. The model exports any surplus, and imports to cover any deficit, with the dollar equivalents added to the merchandise trade portion of the balance of payments calculator. The reason for summing oil and gas is that there are many opportunities for substitution between them, particularly in the transportation sector where cars and buses can be converted to run on compressed natural gas. Chapter 5 explores options for dealing with the potential deficit.

Minerals

In line with industry expectations, the starting position scenario in Figure 4.4 has most key mineral commodity groups set to steadily expand production out to 2050. Production of black coal expands from about 300 million tonnes in 2000 to 1.24 billion tonnes per year by 2050. Total world production in 1998 was about 3.2 billion tonnes (BPAmoco, 2000) and the extent to which this keeps growing depends on a wide range of issues particularly the extent to which natural gas replaces coal in the generation of electricity. Royal Dutch Shell (Skinner, 2000) compares two scenarios for Asia — 'People Power' and 'The New Game'. Under 'People Power' the requirement for both oil and coal continues to expand, whereas under 'The New Game', coal is steadily replaced by natural gas from the year 2010 onwards. By comparison the Shell scenario of power sources for the OECD countries contains virtually no coal by the year 2020.

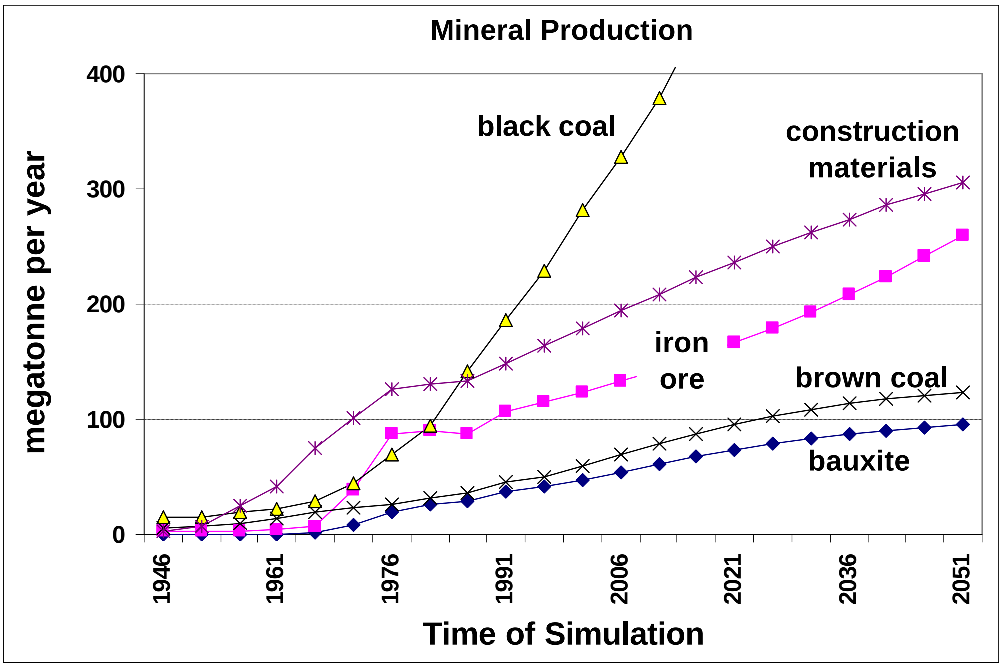


Figure 4.4. Production of major mineral commodities: black coal, brown coal, iron ore, bauxite and construction materials to 2050 for all scenarios.

The base case scenario in this analysis is guided by expert opinion from the DIMA workshop series (Conroy et al., 2000) which suggested growth in production of black coal of 3% per annum and a slower rate for brown coal which is only used in the Australian domestic market. Brown coal production in the base case scenario grows from its current level of 65 million tonnes to 120 million tonnes per year by 2050. A second consideration is the technological development underway to produce 'clean coal' thermal electricity plants. The 'Advanced Pressurised Fluid Bed Combustion' (APFBC) and Integrated Gasification Combined Cycle (IGCC) technologies could give conversion efficiency ratios of coal energy to electrical energy of 44- 47% allowing electricity production to keep growing for the equivalent use of coal and carbon emissions in evidence today. Australia's ability to compete with countries such as South Africa and the USA relies on the proximity of high-grade coal deposits close to deepwater port facilities and it is unlikely that these competitive advantages will disappear by the year 2050. Of more importance will be the global and national attitudes to the use of coal as a fuel in greenhouse gas emission terms, and the competitive advantages to the fuel source that the technological developments noted above might bring.

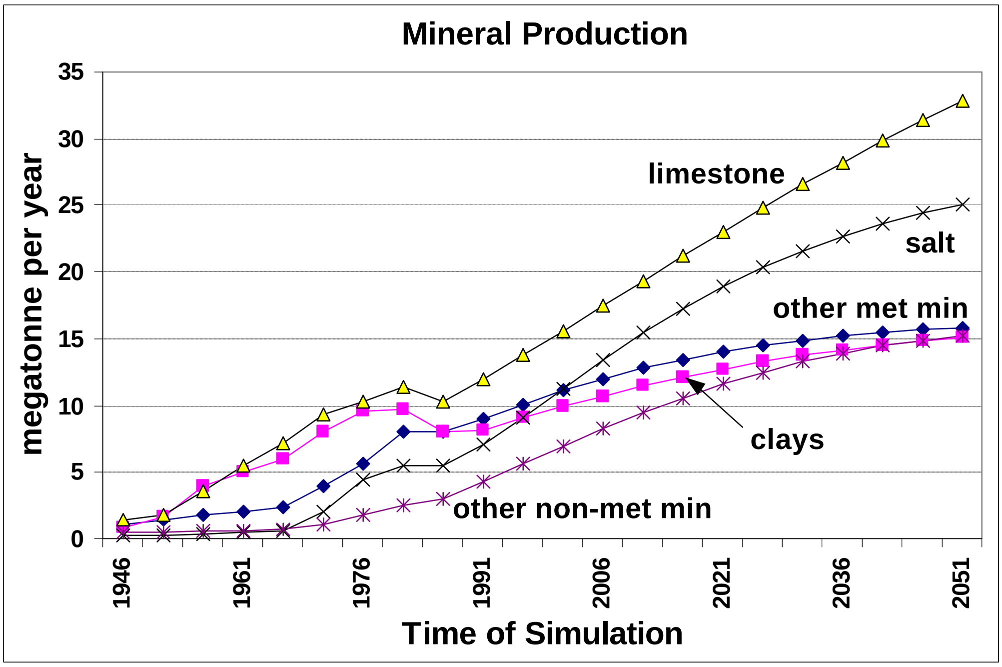


Figure 4.5. Production of major mineral commodities limestone, salt, clays, metallic minerals and non-metallic minerals to 2050 for all scenarios.

Australia's advantages in iron ore production are expected to be maintained with production expanding at the rate of 1.5% per annum from current levels of 160 million tonnes per year (ABARE, 1999) to 260 million tonnes by the year 2050. Most of this production is for export and, while facilities such as the hot iron briquette plant in Port Hedland are not modelled directly, the results can be interpreted to include a range of value adding processes that might take place in the future. The increase in production of construction materials from 180 million tonnes currently to 300 million tonnes per year in 2050 is driven primarily by the construction and maintenance of the built environment described in the previous chapter. The expansion of bauxite production from 45 million to 100 million tonnes per year by the year 2050 is derived from industry expectations of a continuing growth rate of 2 to 3% per year, which in turn is driven by the opening up of a major aluminium smelter somewhere in the world every three to four years. The world requirement for both aluminium and magnesium is expected to continue to expand (perhaps at the expense of steel) as machinery and cars become lighter and stronger in response to fossil energy and greenhouse considerations.

The next tier of mineral production in volumetric terms is shown in Figure 4.5. Limestone and salt are both relatively large items that grow from contemporary levels of about 10 million tonnes to 25-30 million tonnes by 2050. Limestone is used in cement and steel making, and while most is produced in Australia, about 10% of requirement is imported mainly from Japan. Clays are mined predominantly to produce building bricks, but specialised types such as bentonite and kaolin are exported to countries including New Zealand, Japan and the United Kingdom. Production of both metallic minerals (nickel, tin, manganese etc) and non metallic minerals (talc, silica, beach sands etc.) increases to about 15 million tonnes by 2050.

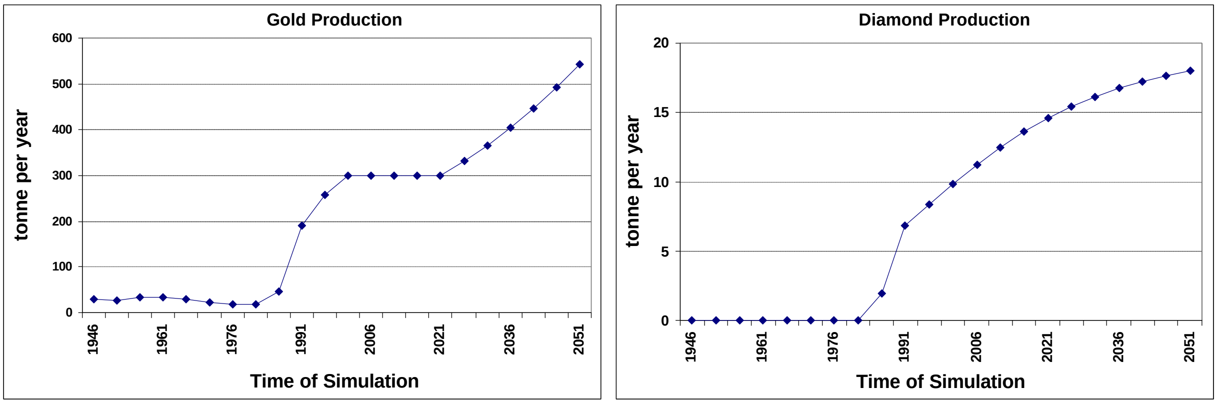


Figure 4.6. Production of precious mineral commodities: gold and diamonds, to 2050.

Gold production has increased from relatively low levels in the 1970s to about 300 tonnes per year. Production is expected to remain at about this level until 2020, influenced by a complex range of external factors (e.g. central bank sales, strength of currencies, demand for jewelry) (Figure 4.6). After 2020, the confluence of new exploration technologies which locate higher grade deposits, new treatment methods for lower grade deposits, political agreements on access to land and an increasing world requirement for gold, is expected to increase production by 2% per year. Production of diamonds is expected to grow from its current level of 41 million carats (eight tonnes) to 18 tonnes by 2050. The levels of gold and diamond production affect a number of material flow indicators that are used in the crosscutting issues in Chapter 7. Because of the low concentrations of gold and diamonds in their respective ore and earth matrices, large amounts of material must be moved and processed to obtain the forecast levels of production. These (generally) hidden material flows contribute to relatively large material flows being attributed to Australia's domestic population, in comparison to other industrial economies with which they might be compared. The high monetary value of gold and diamonds makes them important for future international trade.

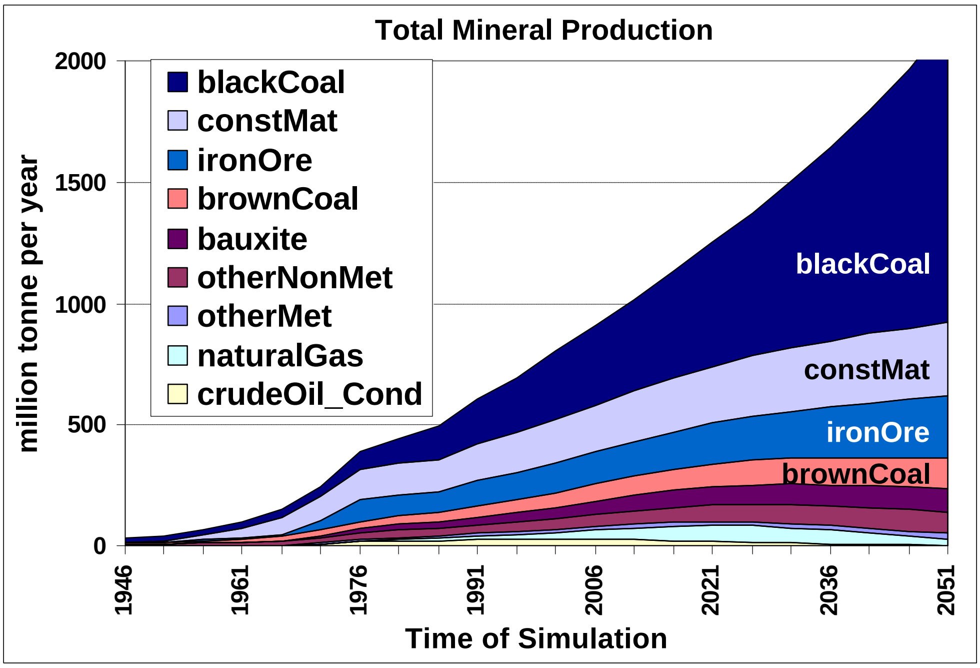


Figure 4.7. Total production of minerals, oil and gas in millions of tonnes per year to 2051.

When all the expectations for future energy and mineral commodity production are considered, total physical production of minerals, oil and gas increases from around 800 million tonnes per year currently to 2,000 million tonnes by the year 2050 (Figure 4.7). More than half of this amount is due to black coal production, most of which is exported. Whether or not this occurs, depends on decisions about the potential greenhouse and environmental consequences of the continued use of coal, mainly for electricity production. The future production of other mining commodities may shrink due to technological developments and changes in market requirements of a number of traditional trading partners. Even if the overall total were reduced by 50% from the 2050 level shown in Figure 4.7, yearly mineral production would be 50, 40 and 32 tonnes per capita per year for the zero, base case and 0.67%pa scenarios.

Apart from domestic oil and gas, this study has assumed that either mineral stocks or reserves are large enough to accommodate 50 years of expanding production, or that exploration is successful in finding appropriately concentrated deposits well ahead of production requirements. Industry expectations are that rich reserves of many minerals are waiting to be found once exploration procedures can see effectively beneath the sand layer that cloaks much of Australia's mineralised areas. It is worth noting that the DIMA workshop series (Conroy et al., 2000) reported "possible constraints on production within one human generation" of copper, diamonds, lead, gold, zinc and high quality iron ore.

AGRICULTURE

Crops

Overall production

Annual production of harvested crop and orchard commodities grows from 60 million tonnes to about 90 million tonnes by the year 2050 (Figure 4.8). The largest components are raw sugar cane and grain. Other harvested crop commodities such as hay, fruit, vegetables and cotton make up the remainder. Grazed pasture production for animals is not included in this analysis.

The problems related to agricultural production

The most important feature of current agricultural systems in Australia is not the limitation on production levels, but the looming environmental challenges posed by the problems of dryland salinity (PMSEIC, 1998; Alexander et al., 1998; Commonwealth of Australia, 2001-a), irrigation salinity (MDBMC, 1999), soil acidification and general structural and nutrient decline (PMSEIC, 1999; Gorrie and Wonder, 1999). Problems with dryland salinity affect 2.5 million hectares and potentially more than 12.5 million hectares of prime agricultural land (PMSEIC, 1999). Recent estimates from the National Land and Water Audit put the area of possible land affected by dryland salinity in 2050 at 17 million hectares (Commonwealth of Australia, 2000-a). Monetary assessments value the contemporary damage at $130 million per year in lost agricultural production, $100 million per year in damage to infrastructure and $40 million per year in loss of environmental assets. Overall, more than 24 million hectares of soil is considered acidic and, while much of this is natural, agricultural management technologies such as legume pastures without balancing lime applications, and the application of nitrogenous fertilisers, are causing the soil acidification process to accelerate. Losses due to soil acidification are estimated to exceed $134 million per year.

The problem of irrigation salinity is locally important in terms of crop production with 560,000 hectares affected by high water tables in the Murray Darling Basin. In a regional sense, irrigation salinity is also important as excess salt loads are transferred to river systems. By 2020, many of Australia's main inland river systems will exceed the 800 EC (exchangeable cations) limit, that defines water of acceptable drinking quality. In 100 years, several important rivers will have passed the 1,500 EC threshold, which then precludes the water from being used for irrigation (Commonwealth of Australia, 2001-b). The direct cost of irrigation salinity is estimated at $46 million per year in the Murray Darling Basin and is expected to continue rising as salt levels in rivers increase (MDBMC, 1999).

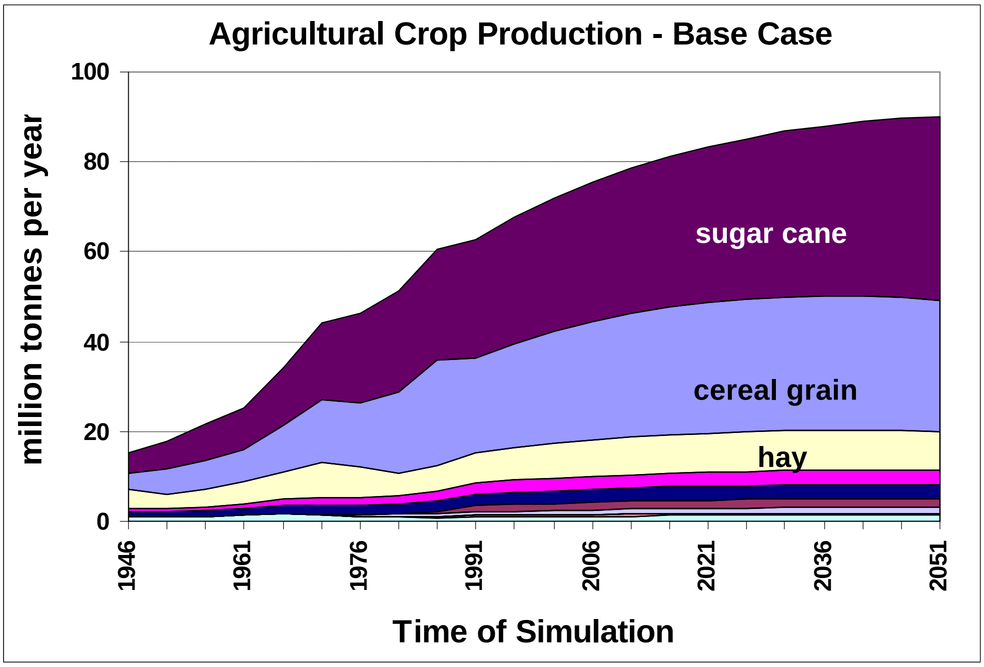


Figure 4.8. Total production of agricultural crop commodities under the starting position scenario to 2050.

As many resource management and commodity production issues are not linked directly to population size in a primary or a direct sense, the next set of analyses does not include the population scenarios as components of the agricultural sector. Production levels are several times higher than required to feed the resident population, be it 20, 25 or 32 million people by the year 2050. The base case scenario leading to 25 million people is used as the template to develop two additional approaches to dealing with the complex set of nested and linked issues described in the previous paragraphs. The key elements of the three scenarios have been developed by Dunlop et al. (2000) and are briefly described below.

The 'starting point' scenario for agricultural production

The starting point or base case scenario for agricultural production is developed from an integrated history of land development over the last 50-100 years with future development in each area reflecting past development. This has been a period of intense technological development with large increases in production. The scenario includes modest (slowing) increases in the area of cropland, representing a shift from grazing to cropping, some further clearing and more use of previously cleared land that is not currently used for agricultural production. It includes conversion of agricultural land to plantation forestry or other woody vegetation, but at a rate about half that required to meet the target contained in the 'Forests 2020 Vision' (DPIE, 1997). Some additional cropland is converted to plantation or other woody vegetation as it degrades below a threshold cropping yield. Reductions in the rates of increase of dryland salinity follow from the establishment of woody vegetation. Genetic improvements to yield, pest and disease resistance, and climatic tolerance lead to small but steady increases in crop yields. The rate of fertiliser application increases with concomitant yield benefits. The use of soil conditioner (e.g. lime and gypsum) increases, but not to the extent that it balances soil acidity and soil sodicity at a broad scale. Similarly, introductions of new crops and cropping systems (e.g. industrial quality oil-seed, agro-forestry, and alley cropping), and improvements in irrigated water use are not large enough to yield significant environmental and production gains.

The 'landscape integrity' scenario

The landscape integrity scenario aims to create agro-ecological systems that are inherently more robust and resilient by restoring hydrological and soil chemical balances that better match Australian landscapes. This approach results in lower total production and may take decades to yield significant benefits. However, it should use less energy and material inputs, reduce the on-site and off-site effects of biophysical decline, and better conserve and restore biodiversity and ecosystem services — those unpriced natural processes that contribute to overall economic value. This scenario is motivated in part by the growing interest in more biological production systems such as organic farming and consumer demand for 'clean green' food and fibre.

The scenario includes retiring at least 30% of arable cropland with matching planting of woody vegetation and no new additions to the area of cropland. More cropland is converted to woody vegetation once it becomes moderately degraded. This further concentrates production on only the best cropland and should also significantly reduce the external effects of land degradation (e.g. off-site discharge, salinisation, silting and acidification of streams and wetlands, effects on biodiversity). Conversion of cropland to woody vegetation provides direct positive hydrological outcomes which will help sustain the remaining cropland by preventing salinity. It also provides direct and indirect benefits for biodiversity. This scenario sees more legumes being incorporated into the cropping system, returning nitrogen to the landscape and also assisting with recharge control by using perennial species. Fertiliser use and its rate of application increase. More animals have been included in the farming system; in the model this is represented by increasing the proportion of cropland used to produce animal feed (hay and silage). The establishment of extensive areas of deep-rooted perennial vegetation is accompanied by significant slowing in the spread of dryland salinity. The rate of soil acidification and soil structural decline also gradually decrease when modified cropping systems are adopted over the first half of the simulation period. It is assumed the increased acidification caused by extra legumes and fertiliser use is more than balanced by better control of nitrate leaching and use of lime.

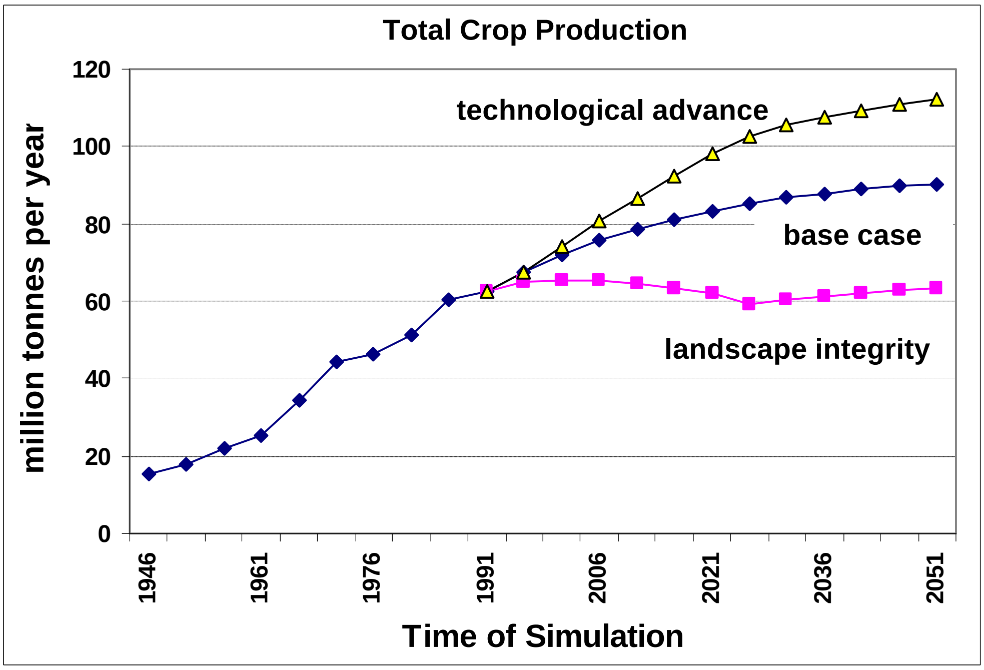


Figure 4.9. Total production of agricultural crop commodities to 2050 under three scenarios: the starting position (base case), landscape integrity and technological advance.

.

The 'technological advance' scenario

The technological advance scenario uses and develops crop technology and farming systems to minimise the negative effects of the significant changes to the hydrological and soil chemical balances caused by European style agriculture in Australia. Resources are deployed with the aims of maximising yields and total production and achieving rapid reductions in the effects of landscape biophysical decline. As in the base case, this scenario includes some additions to cropland. Significant areas of agricultural land are converted to plantation forests to meet the *2020 Vision* target and the most severely degraded cropland is converted to woody vegetation. The changes in the mixtures of crops in this scenario are aimed at increasing profitability by increasing the area of high value crops e.g. vegetables, fruit and oil-seed. The use of fertiliser and irrigation is increased significantly in this scenario. As in other scenarios, the rate of increase in dryland salinity is reduced as a function of the establishment of woody vegetation. Landscape biophysical condition is also managed by more direct interventions such as deep drains and pumping to address rising water tables and increasing the application of lime and gypsum to address soil acidity and soil sodicity.

Scenario results

The technological advance scenario increases total harvested crop production to about 110 million tonnes per annum compared to the base case at 90 million and the landscape integrity scenario which maintains crop production at about the current levels of 70 million tonnes per annum (Figure 4.9). The major crops, cereal and sugar cane account for much of the difference between the scenarios (Figure 4.10). Sugar cane production increases by five million tonnes a year by 2050 under the technological advance scenario, and falls by nearly 15 million tonnes in the landscape integrity scenario, relative to the base case. For total grains, the advantage of the technology scenario is again an extra five million tonnes per annum whereas the landscape scenario reduces the base case by 12 million tonnes per annum and takes total grain production at 2050 back to levels of the late 1970s. The responses of the other crop types are similar but much smaller.

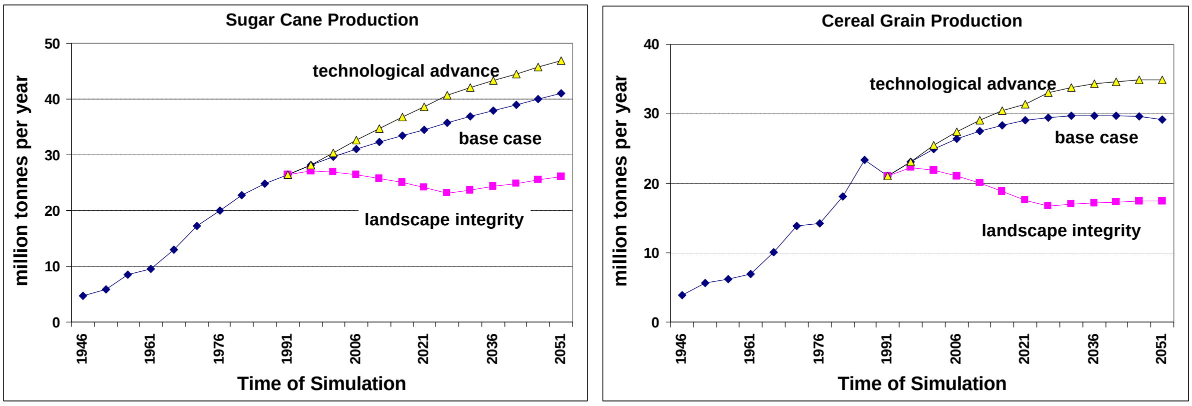


Figure 4.10. Total production of sugar cane and cereal grain to 2050 under three scenarios, the starting position (base case), landscape integrity and technological advance.

The complexity of these scenarios is based on radically changed landscapes over 60 million hectares or more in Australia. The experimental results, where catchments or sub-catchments are repaired and then refurbished as the ecosystem services are re-established, have not yet been implemented at a practical scale. At a theoretical level, research and development is accelerating along several scenario directions. Agricultural technologists are developing crop types and management systems that seek to adapt to, and live within, systems that are seemingly constrained in a bio-physical sense. Land and water scientists who study landscapes over hydrological timescales, lean towards the landscape integrity scenario and seek to re-establish across regional landscapes, the key elements of pre-European water balance and nutrient flow characteristics.

Regarding the future production context for both domestic and export agricultural products, it is possible that certain markets at a regional or product level will be regulated and that the starting position (base case) or technological advance scenarios will not be accepted because of related (real or perceived) external effects due to their production systems. Whether the amelioration and refurbishment activities included in the landscape integrity scenario are cost effective or politically acceptable is then less relevant. If the starting position scenario is precluded because of market requirements (i.e. trading partners will not accept Australian exports because of perceptions of unsustainable land management practices), then agricultural land users and the nation's citizens may be obliged to change their practices or, alternatively, accept a declining importance as an exporting sector.

Additional key biophysical issues are on the policy horizon, but are not yet being addressed. The importance of a full complement of biodiversity (or landscape process diversity) which enables ecosystems to provide the services that humans want, is now recognised commercially at a wide range of levels, e.g. the urban water catchment issues discussed in Chapter 3. A similar issue is that of carbon trading and carbon sequestration in relation to global concerns about greenhouse gas emissions. Implementation of carbon trading could see farms re-forested, arable paddocks managed specifically for carbon accumulation, and harvested products becoming a secondary consideration. Once again, the landscape integrity scenario is compatible with these views because it provides a decrease in overall production, but with assumed increases in landscape values and products that are currently not valued or rewarded in the marketplace.

Another issue is related to national or regional perceptions external to the agricultural production system but which feed back to regulate activities within that system. The concentration of salt in inland river systems and streams and how it affects urban supplies and services in cities such as Adelaide is a typical example. The issues listed above — and many others — allow the three agricultural production scenarios to be evaluated in the context of whether trade-offs can be made between more or less production for less or more delivery of ecosystem services.

Recent work at a landscape level on the macro-changes wrought by European farming methods since 1800, suggests the type of biophysical principles that help underpin scenario explorations such as this study (Gordon et al., 2000). Since 1800, 30-50% of forests and woodlands have been cleared to develop arable and pasture land. This has resulted in a general reduction in the amounts of water vapour transpired by the annual crops and pastures that have replaced the wooded vegetation types. This reduction in evapo-transpiration or water vapour flow, is in the order of 10% of the continental totals, from 3.44 billion gigalitres (10^9L) in 1780, to 3.1 billion GL per year in 1980. This reduction of 339,000 GL per year is roughly equal to 600 times the water contained in Sydney Harbour (Sydney Harbour contains approximately 540 GL). The water no longer used in plant growth has increased both river flows (enabling more irrigation than might have been possible), and the recharge of underground water, some of which elevates groundwater tables and causes dryland salinity, as previously buried salt layers are brought closer to the root zones of crops and pastures. Part of the solution is to develop new farming systems (e.g. deep-rooted perennial grain crops) which use or transpire more water, before it percolates past the root zone in the top two metres. Another approach is to replace crops and pastures with the forest and woodland types that previously covered Australia's farming zones as described in the landscape integrity scenario. The regional areas, where these landscape problems are most evident, are also those where the transpiration rates have been lowered by as much as 30% to 50% compared to pre-agricultural situations.

Land

The concept of total land stock is an important descriptor of past and present production potential. Australia has a large land area of 770 million hectares, but less than 30 million hectares of this (less than 4%) is of good or very good quality in terms of broadscale cropping potential (Dunlop et al., 1999). Compared to the more fertile soils on younger landscapes in North America and Europe, Australia is poorly endowed with good quality soils, most of them being located on narrow floodplains along rivers, or in areas with relatively recent volcanic activity.

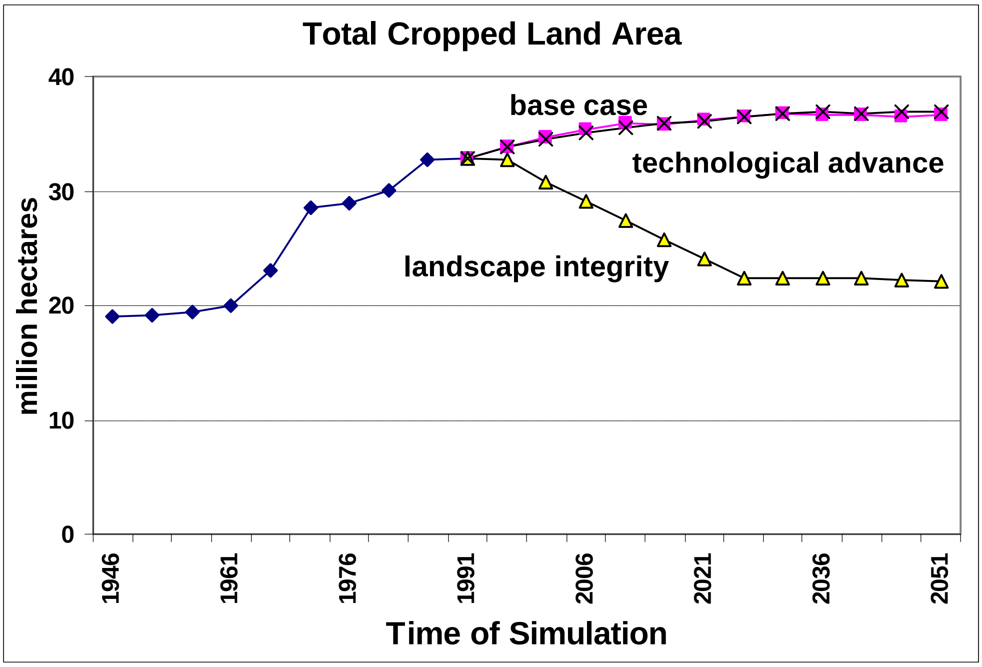


Figure 4.11. Total area of arable land to 2050 under three scenarios: the starting position (base case), landscape integrity and technological advance.

The land use implications of the three scenarios result in the stock of ploughed land increasing marginally to 37 million hectares under the starting position, and technological advance scenarios, and decreasing to 22 million hectares by the mid 2020s for the landscape integrity scenario (Figure 4.11). As noted in the scenario descriptions the changes are due to a mix of pro-active and reactive strategies. For the starting position and the technological advance scenarios, some extra areas of ploughed land are added to the stock of agricultural land. In all three scenarios, land was retired when it became degraded and could no longer maintain a sufficient level of production. The levels were set at very high thresholds of degradation and require yields to drop to 20% of that expected in the starting position and 10% of that expected in the technological advance scenarios. By comparison, in the landscape integrity scenario, land is actively retired at 30% of the expected yield and additional land is reforested. These defensive actions are assumed to reverse the degradation trends set in place by alteration to the landscape hydrology described above and other soil and biophysical processes.

The issues that relate to infrastructure size and age are portrayed for the arable land stock in Figure 4.12. All three graphs show an aggregated picture of the history of land development in the Australian farming zone over the last 50 years since the 1940s. From 1965 to 1975, about one million hectares of land were developed per year, or nearly 10 million hectares for that decade. During this period, cropping areas in Western Australia and Queensland were greatly expanded. If problems with landscape function were simply related to the length of time of arable usage, then the 'age of arable stock' factor might cause a crisis in land productivity some 100 years or more into the future as most of the arable stock loses function at the same time. However regional differences in landscapes, soils, clearance rates and farming practices mean that reductions in landscape function do not appear uniformly over time. Within the stocks and flows modelling approach used in ASFF, agricultural land use is simulated in 58 different statistical regions and the landscape function changes are tailored to current estimates of local conditions and landscape processes.

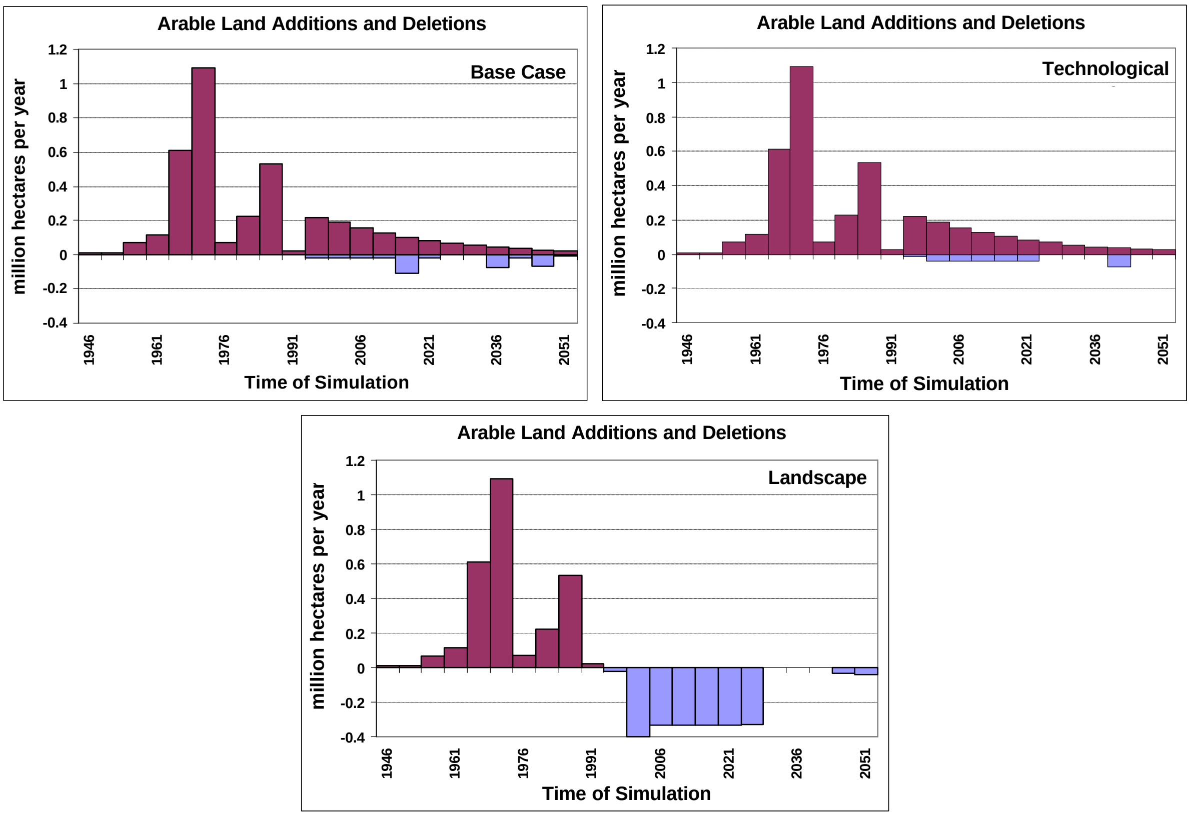


Figure 4.12. Rates of arable land development (additions) and arable land loss (deletions) under the starting position (base case), technological advance and landscape integrity scenarios. The bars represent millions of ha cleared and developed over a five-year period.

With these methodological constraints imposed, the progressive loss or alteration of the arable land stocks is shown in Figure 4.12 after 1990, for the three scenarios. Both the base case and technological advance scenarios require the further development of more than one million hectares to maintain production levels and to make up the land lost to degradation or transferred to forestry. By contrast, the landscape integrity scenario actively places 11 million hectares of land into forest or woodland vegetation, to halt and reverse the multiple causes of loss in landscape function.

The areas of land potentially prone to losing their landscape function and service are shown in Table 4.2. Three categories of threshold are presented with the 50% threshold (i.e. land where due to landscape function problems, crop production is 50% lower than expected) being the most defensible (i.e. it is unlikely that a land function effect giving a 25% reduction in yield, could be distinguished from the yearly effects of climatic variation). Using this threshold value, both the base case and technological advance scenarios could have 8-9 million hectares of arable land with low landscape function, compared to 2 million hectares in the landscape integrity scenario. In this last scenario, a large area has already moved from the cropping estate into the forest estate, and overall agricultural production has been deliberately reduced to lower absolute levels, but not necessarily a lower value of production either per unit of physical production or per farm enterprise.

.

Table 4.2. Potential changes in cropping land function in millions of hectares under 75% and 50% yield thresholds for the starting position, technological advance and landscape integrity scenarios.

Yield threshold for land deletion	Starting Position	Technological advance	Landscape integrity
Voluntary or pro-active cropping land retirement by 2050 under different scenario assumptions	0.6	1.1	10.1
Cropping land with 75% of base yield by 2050	20	16	9
Cropping land with 50% of base yield by 2050	9	8	2
Degraded cropping land (zero productivity) by 2050 under different scenarios	1.3	0.4	0.7

The key point about losses in landscape function is that they occur over long time scales. If the problems keep developing past 2050 to 2100, then much of the land categorised under the 75% yield threshold may have progressed to the 50% threshold, thereby putting 16-20 million hectares, or half the arable land stock, potentially at risk of permanent decline. By contrast, moving the land back into the forested or wooded state evident a century ago, could give a landscape composition that is more resilient in an ecological sense, and one potentially with a wider array of uses. Non traditional uses for this substantial increase in stocks of forest and woodland could include a partial transition to a biomass based energy economy. Foran and Mardon (1999) compare a number of scenarios that require between 17 and 31 million hectares of forested or wooded land to power an economy which uses methanol and ethanol (from biomass) as transport fuels, and distributed electricity plants fuelled by gasified wood. The key advantages of these systems is that they are carbon neutral in greenhouse emission terms, and they stimulate employment and economic development in rural areas. Thus a biomass based fuel cycle could allow the implementation of the landscape integrity scenario for an economic rationale with shorter-term financial rewards. If landscape rehabilitation and purely biophysical returns provide the main stimulus, then it may be difficult to attract the large capital sums required for implementation of the scenario.

Animals

Animal production is simulated to expand for most commodities to meet trade expectations (sheep, beef and dairy) and domestic requirements (pig meat, chicken, eggs). Under the base case scenario sheep numbers increase from current levels of about 117 million to 170 million by 2050 (Figure 4.13). This is a rather surprising assumption, given recent constraints in the wool industry. It is based on opinion in the DIMA workshop series which saw that potential improvements in gene technology will be able to deliver a fibre grown to whatever specification is required (Coleman, 1999; Tian and Yang, 1998; Conroy et al., 2000). The fact that Australia has de-pastured flocks in excess of 150 million in the past suggests that increasing flock numbers to this level will again be physically feasible. A parallel assumption is that the effectiveness and efficiency of management must increase to best practice to deal with inevitable droughts and the many negative impacts of grazing over the past 200 years.

Under the starting position scenario, the beef cattle herd increases from about 26 million to 50 million by 2050. The peak cattle herd achieved in recent history was 34 million in 1976 (LWRRDC, 1997), a time of exceptional rainfall conditions over many parts of pastoral Australia. Some analyses suggest a systematic under-reporting of livestock numbers of more than 10%, implying that real numbers at any time are greater than national statistics might indicate (Howden, 2001).Changes in world market opportunities at that time led to restrictions in slaughterings, significant pressure being applied to the grazing land and considerable landscape degradation. Thus the physical feasibility of this component of the animal base case scenario is perhaps more contentious when run concurrently with the increasing sheep flock. The market rationale for the beef scenario is that many of Australia's trading partners will have increased their per capita wealth and their citizens will require a higher proportion of meat protein in their diets. Global food projections to 2020 suggest that beef demand will increase by 30 million tonnes, of which 15 million tonnes will be in nearby Asian countries (Rosegrant et al., 2001). While Smil (2000) proposes that world food requirements will be met in a more sustainable manner with less, rather than more animal protein, Australia has substantial capacity to produce beef from pasture provided that the country retains an adequate disease-free status. A pasture-based industry might achieve trading advantages in comparison with the more intensively managed feeding systems of other countries.

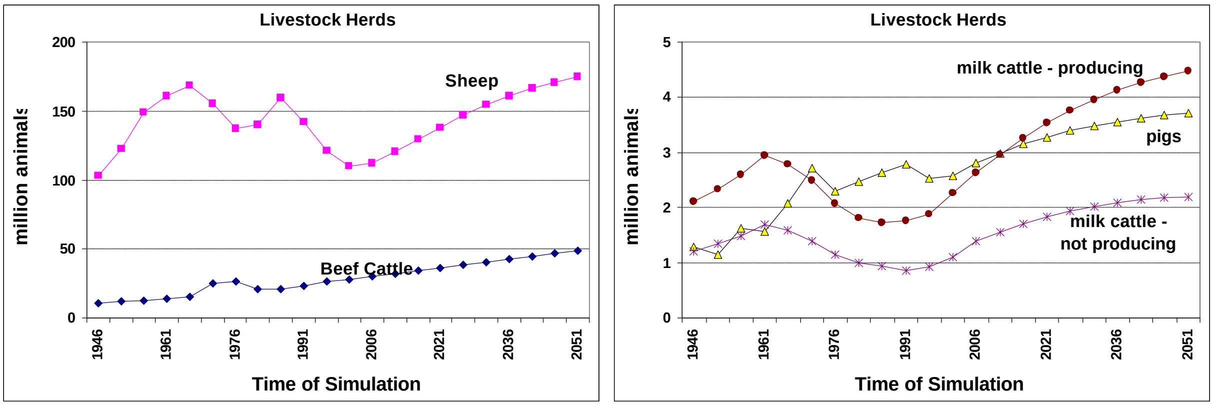


Figure 4.13. Animal numbers in millions for the starting position (base case) scenario to 2050.

.

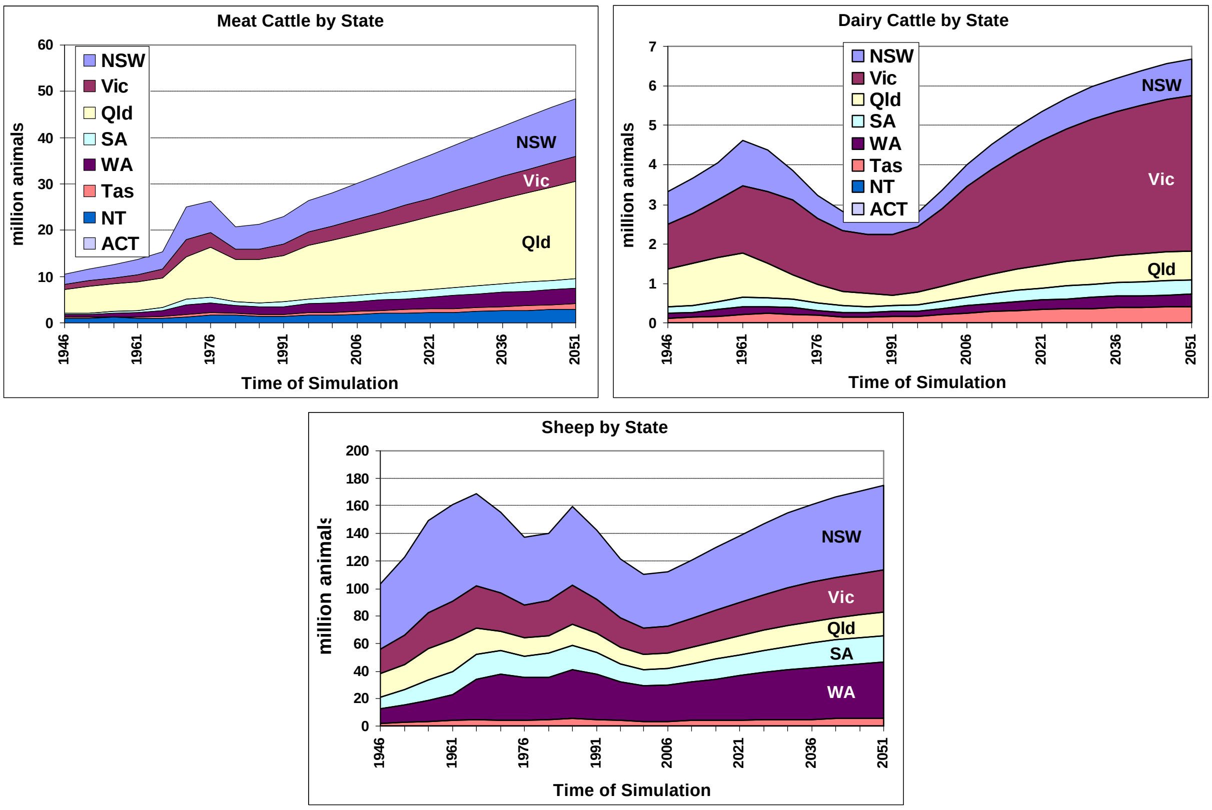


Figure 4.14. Location by state of meat cattle, dairy cattle and sheep to 2050.

Another rationale for the beef herd part of the animal scenario is based on a 2020 exploration of agricultural trade potential undertaken by the Land and Water Resources Research and Development Corporation (1997). The continuing expansion of the beef herd continues the trend to 2020 developed in this study on the basis of population and GDP per capita growth in Australia's potential export markets. Conventional wisdom might indicate that the combined grazing pressure of the beef cattle and sheep scenarios surpasses sustainable limits. The nation's pastoral industry has not operated at this level in the past. An optimistic interpretation might assume that the next 50 years could bring substantial changes to both grazing technology and grazing management. Domestic livestock consume nearly 30% of managed yearly pasture production. Some experts argue that 60% of grown pasture could be consumed leaving enough ground cover and plant litter to ensure soil health and nutrient recycling. This may be optimistic. However by viewing these future options as scenarios, rather than as predictions, this analytical approach seeks to explore the implications of development, expansion and growth of a wide range of sectors. In general, expanding physical activity within an array of linked sectors (such as agricultural production in regional economies) stimulates the growth and development that most modern economies rely on for their continuing function and optimism.

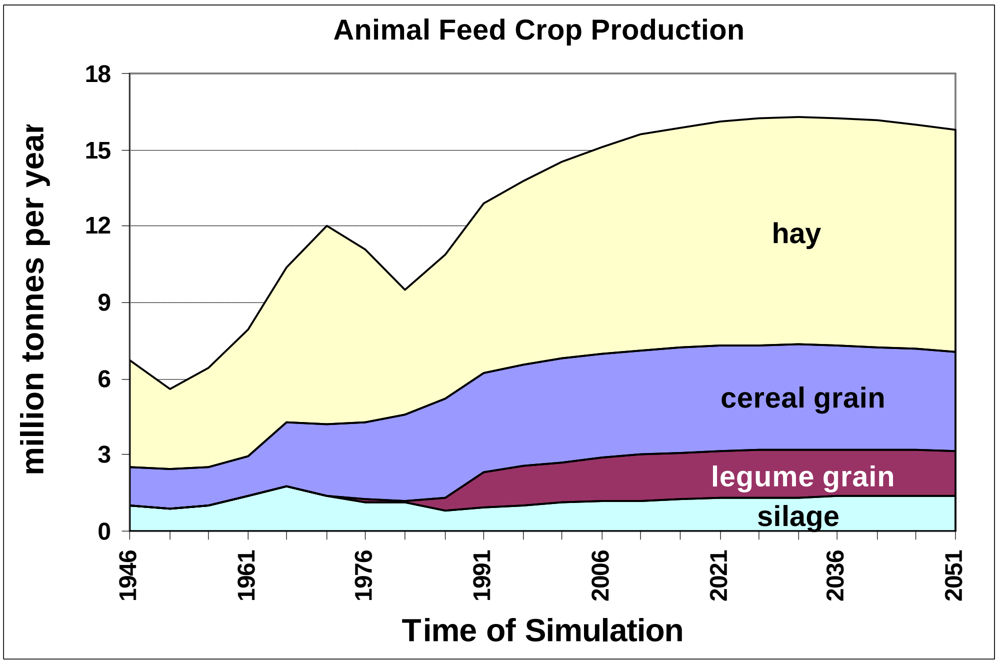


Figure 4.15. Crop production requirements for livestock feed (excluding grazed pasture) for the starting position scenario to 2050.

Under the starting position scenario, the number of dairy cattle doubles by 2050 from a contemporary level of about three million with a ratio of 2:1 for the producing versus non-producing parts of the dairy herd. The number of pigs increases from a current level of 2.6 million to nearly 4 million by 2050. The chicken flock (not shown) increases from about 90 million to 150 million by 2050. The distribution of animal numbers by state is shown in Figure 4.14. Queensland retains the greatest share of the beef cattle herd with New South Wales in second place. For dairy cattle, Victoria retains the dominant share of the industry with more than 60% of total numbers. The rest are spread around the states in proportions that reflect recent reality. The recent deregulation of the dairy industry could see Victoria gaining a greater share of the national dairy herd than assumed in this scenario. This, in turn, could affect the sectoral use of water in Victoria. Western Australia and New South Wales share most of the national sheep flock as it grows to former levels. For all animal groups, the changes in numbers and productivity shown in the historical period to 1990 are due to interacting effects of international commodity prices, domestic political decisions and climatic variability. These effects are not included in the simulations from 2000 to 2050.

The key assumption in the starting position scenario is that most of the additional forage required for livestock comes from both intensive and extensive pastures. The forage requirement produced by the arable land stock is shown in Figure 4.15 with modest increases in both hay and grain. It is assumed that the energy and environmental implications of cattle feedlots (Smil, 2000) cause a shift back to pasture feeding and that all the grain is fed to pigs and poultry. The 500,000 cattle in feedlots in 1999 (ABARE, 1999) could be assumed to gain 150 kg in liveweight over their 120-170 day stay. Assuming eight kg of grain per kg of liveweight gain, this requires approximately 600,000 tonnes of grain, or 1.2 million tonnes if there are two turnarounds of cattle per year. This is well within the grain allocation to livestock of nearly five million tonnes per year shown in Figure 4.15. The 1.2 million tonne allocation to cattle feedlots would furnish the feeding requirements (to marketable size) of two million pigs and 200 million chickens. The feed budget from the cropping sector shown above is thus within the correct order of magnitude.

Table 4.3. The feed requirements per kilogram of animal liveweight gain and edible product (after Smil, 2000). (note that low values such as 0.9 for salmon describe the wet animal weight per unit of dry feed)

	Milk	Eggs	Chicken	Pork	Beef feedlot	Salmon
Kilograms of dry feed per kilogram of product or liveweight gain	1	2.5	2.5	4.0	8.0	0.9
Kilograms of dry feed per kilogram of edible product	1.1	2.8	4.5	7.3	20.0	1.4

Decisions about the nature and extent of intensive livestock feeding are important ones within a future context. Authors such as Smil (2000) argue cogently that potential human hunger crises could be averted by feeding the 700 million tonnes of grain crops currently fed to animals, to people, so providing a largely vegetarian diet to more than three billion people. Australian consumers may not wish to revert to a largely vegetarian diet, but it is worth considering the amount of grain and other inputs required for intensive animal feeding to produce a kilogram of liveweight gain, or a kilogram of edible product (Table 4.3). In this context, the issue of food composition choice for a domestic population, is one area where the tertiary or trade effect of population might revert to a secondary (more directly linked) population effect. Although the use of concentrate feed to produce milk has a relatively high efficiency, in Australia there is an added dimension that each litre of milk production requires between 500 and 1,000 litres of irrigation water under many intensively managed systems (Doyle and Kelly, 1998). Salmon and many aquaculture systems achieve similar levels of feeding performance to milk, but they also have a number of environmental problems particularly their reliance on fish meal. Both chicken and pork do not perform as efficiently when the terms of conversion are changed from liveweight to edible product. Beef in feedlots gives the poorest performance under these measures of physical performance, although the resultant product might be more highly valued in financial terms, or more easily sold in export markets.

In line with assumed increases in numbers of animals in the base case scenario, the production of all levels of animal products rises steadily to 2050 (Figure 4.16). The most notable is beef and veal production which rises from two million tonnes per year (MLA, 1999) to more than four million tonnes by 2050. Mutton and lamb grow from the current 0.63 million tonnes per year (MLA, 1999) to one million tonnes by 2050 while wool production (or fibre derived from sheep) grows from 0.7

million tonnes currently to 1.8 million tonnes in 2050. There is an increase in chicken meat production grows from 0.62 million tonnes to 1.8 million tonnes over the same period. A number of other animal products, shown in Figure 4.17, double in physical production levels over the next 50 years. Milk production also doubles from a current level of 10 million tonnes of whole milk to 22 million tonnes by 2050.

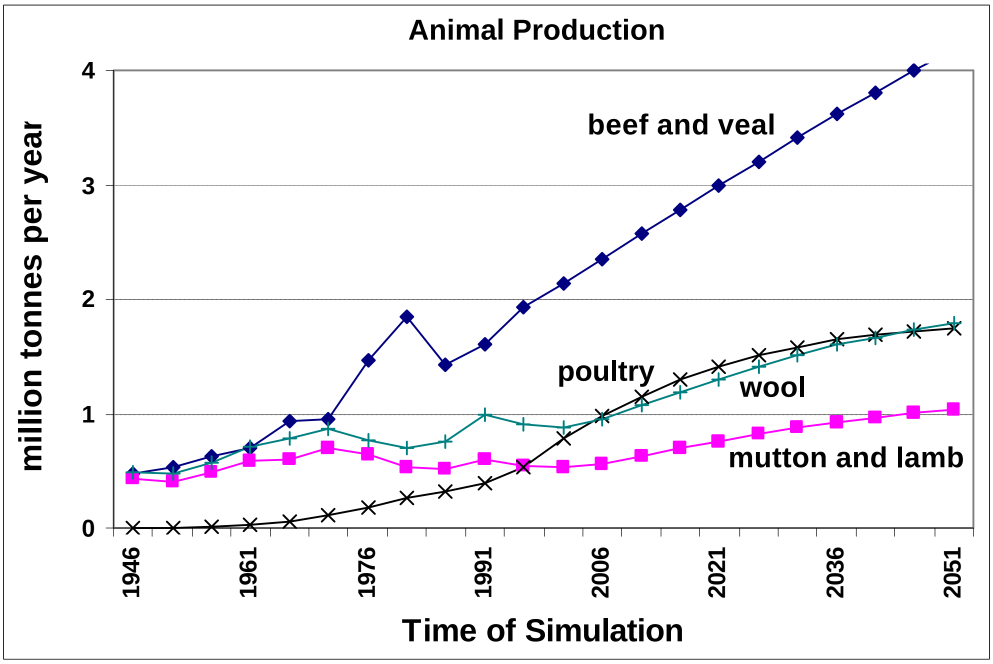
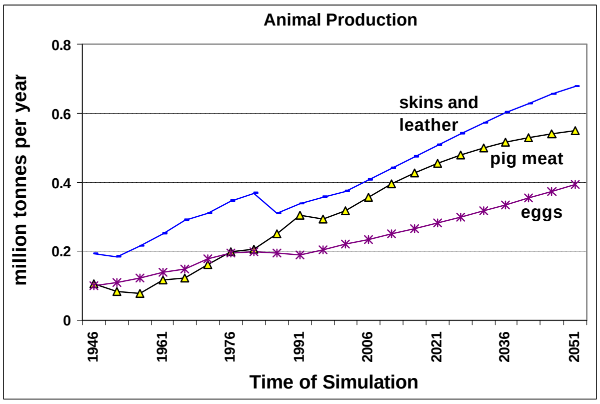


Figure 4.16. Animal production to 2050 for key commodity groups in the base case scenario.

.



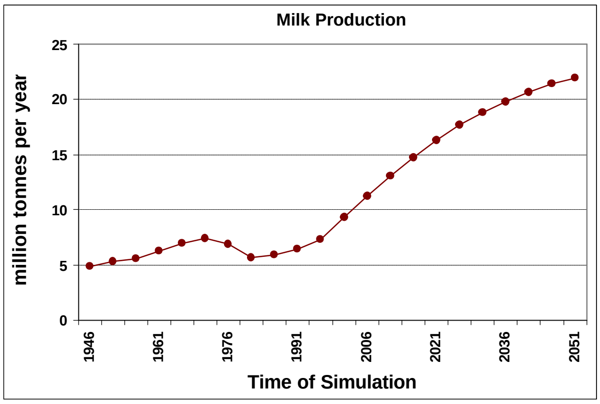


Figure 4.17. Animal production (skins and leather, pig meat, eggs) and milk production for the base case scenario to 2050.

Apart from the concurrent increase of the sheep and cattle herds already discussed, most of these increases in production appear feasible. While the full water account will be presented in Chapter 6, the implication of a doubling of milk production warrants comment here. Assuming that the entire industry moves to best practice and uses 500 litres of irrigation water for each litre of milk produced, this requires 11,000 gigalitres (10^9 L)or nearly one half of the current managed water use in Australia (ABS, 2000-b). Estimates for water usage in dairy production vary from 3,470 GL (Thomas, 1999) to 4,167 GL (Lenzen pers. comm.) per year, or approximately one sixth of the Australian total. The 2050 level of use required by dairy production would sit within a total water use of about 40,000 GL per year, or one quarter of the national total. Perhaps this is feasible, but the question of where dairy production is located in relation to requirements of other industries, the problem of salt load in rivers and high water tables in irrigation areas, and the relationship of environmental flows and overall river health, require a comprehensive and detailed study beyond the scope of this analysis.

FISHERIES

Global overview

In an effort to place Australian wild caught fisheries in a suitable context of production and management, this section opens with an expanded description of the global situation. In 1996 the production of wild caught fish was about 95 million tonnes of which 90% came from the marine areas (oceans, seas and estuaries) of the world (FAO, 1999-a). Aquaculture contributed a further 26 million tonnes of which China contributed 70%, although Chinese aquaculture now appears to have been overestimated. Seven countries (China, Peru, Chile, Japan, USA, Russian Federation and Indonesia) account for more than half of the world's wild capture. Global landings of marine fish are continuing to level off, and this is so for most of the world's major fishing areas. The main fisheries in the Atlantic Ocean and many areas in the Pacific Ocean are considered to have levelled off and substantial catch increases from these areas are therefore unlikely. Forty four percent of major world fisheries are considered fully exploited, 16% are over exploited and 10% are depleted, with expected long lead times if they are to recover former levels of production. Nearly 32 million tonnes of fish, representing nearly 30% of total world fish production, is used for high quality protein to feed other animals in the human food chain such as aquaculture fish, pigs and poultry. Environmentalists assert that fisheries decline is linked directly to human population size and will affect poor nations first, where fish protein forms a critical part of nutritional adequacy and where per capita consumption could fall by 50% by 2050 (Population Action International, 1995).

The world's fisheries literature contains considerable debate on the future untapped potential and how to manage fisheries at risk from depletion. One view (Pauly and Christensen, 1995) argues that humans are gradually eating their way down the trophic levels (the web of life) by exploiting successive layers of marine life that depend on the lower levels for their growth and reproduction. This process can lead to higher catches in the short term as top level predator species are removed, and the next layer of fish species take advantage of a wider range of ecological niches. These researchers further argue that ecosystem changes then occur because the fisheries ecosystem becomes unbalanced resulting in stagnating and/or declining catches. This leads to an overall assessment that fisheries production from wild caught world fisheries is set on unsustainable patterns of exploitation and management. There are many caveats on broad generalisations of this type and Beddington (1995) points to poor data in all national and international fisheries. By-catch production is not assessed or data is not collected and most fisheries are essentially un-managed commons where the unaccounted for, or the shadow catch, may also be substantial.

Although most informed commentators agree about the state of world's fisheries, there are many different ideas about how to move to more sustainable pathways (Caddy, 1999). In an overview of world fisheries management Mace (1996) suggests concerted action in three key areas: (i) reduce global fishing capacity by 50%; (ii) implement a workable rights system in wild fisheries; and (iii) implement a precautionary approach. The key scientific principle of the precautionary approach is that a single species 'maximum sustainable yield' represents a harvesting limit that should never be exceeded. In practice, this limit is routinely exceeded. A recent review of marine issues in New Zealand (Parliamentary Commissioner for the Environment, 1999) found that the institutional, legal and knowledge bases regarding marine and fisheries issues were fragmented and that management for sustainability was unlikely to be effective until organisational issues were reformed and integrated. The importance of incorporating up-to-date fisheries biology into fisheries management (Beverton, 1998) is an obvious, but routinely overlooked factor. Some highly productive species that are generalist feeders can recover reasonably quickly after a crash due to natural disasters or overfishing. Other long-lived and slow-growing species such as orange roughy and deepwater dories, that gather in localised areas such as sea mounts, can be quickly over-exploited when technological advances allow substantial catches to take place.

A number of more optimistic views run counter to the pervading sense of gloom on wild-caught fisheries. Nutrient enrichment of near coastal areas from agricultural and urban runoff and sewage can cause a bottom-up effect due to stimulation of algal growth and in turn the growth of a range of marine organisms which feed on the lower trophic levels (Caddy et al., 1998; Pauly et al., 1998). However the stimulation of algal growth can quickly turn to eutrophication, toxic algal blooms and 'red tides', while the entry of heavy metals into the food chain can pose problems of accumulation for human health. The importance of aquaculture and its potential for covering imbalances if wild catch fisheries decline, is also attracting attention in government policy and commercial development. Smil (2000) notes that aquaculture in China, based on plant-eating carp species, produces more than six million tonnes of fin fish yearly, with feeding efficiencies approaching those of chicken egg production. Once again, this optimism needs to be tempered by a number of developing realities.

Marine aquaculture species that are favoured in the international marketplace require an input of fish protein two to five times that of the eventual output (Smil, 2000). Further elaboration by Naylor et al. (1998, 2000) indicates that while the farming of Atlantic salmon had grown to 0.65 million tonnes per year by 1997, the industry required 1.8 million tonnes of wild fish to be added as fish meal to the diet, giving a conversion ratio of 2.8:1. The aquaculture of shrimps or prawns requires feed with 30% fish meal and fish oil. It can result in a net loss of fish protein over the whole production cycle and the system of management often produces long-term environmental damage to surrounding ecosystems. Much research is being carried out into aquaculture and breakthroughs can be expected whereby plant based proteins will eventually replace fish proteins in aquaculture diets. This will help break the trophic dependency of higher valued species such as salmon and shrimp on lower-valued species such as anchovetta, sardine, telapia and carp.

Local examples of the global situation

Australia represents a microcosm of the world situation. The simulation results reported in this study are well supported by a body of world literature. The added dimension is that Australian waters — like its arable land — are amongst the least productive in the world. This lack of productivity is exacerbated by the lack of upwelling areas, where deep cold currents rise to the surface, bringing food, nutrients and increased fish productivity, around our coasts. The Australian fishing zone is the third largest in the world, occupying 10 million square kilometres, but the tonnage caught there is 54^{th} in the world (FRDC, 1999). The south east fishery produces 25,000 tonnes per year for all species with blue grenadier contributing 5,000 tonnes of that total. By contrast the blue grenadier (or hoki) fishery in New Zealand, produces 250,000 tonnes per year, more than the total tonnage of the entire Australian fishery. Australia produces about 220,000 tonnes valued at almost $2 billion per year. One-quarter of all fish production is exported and much of this is high value species such as lobster, tuna, abalone and pearls. Aquaculture produces about 30,000 tonnes per annum or one-eighth of the total. Australians consume more than 12 kilograms of fish per capita per year of which 70% or more is fin fish.

While the exact status or health of Australian fisheries is unknown, it generally reflects the world situation, with the proviso that many important fisheries are now under close management and monitoring and could therefore improve. Fishery status reports in 1997 and 1999 on a limited group of Commonwealth fisheries reported that four species were overfished, 10 to 12 are fully fished, 1 underfished and the status of 13 to 15 fisheries is uncertain (Caton et al., 1998; Caton and

McLoughlin, 2000). The status of species such as southern school shark, orange roughy, eastern gemfish, tiger prawns and southern bluefin tuna is questionable and these species are now subject to higher scrutiny and more deliberate management actions such as changes in the levels of total allowable catch.

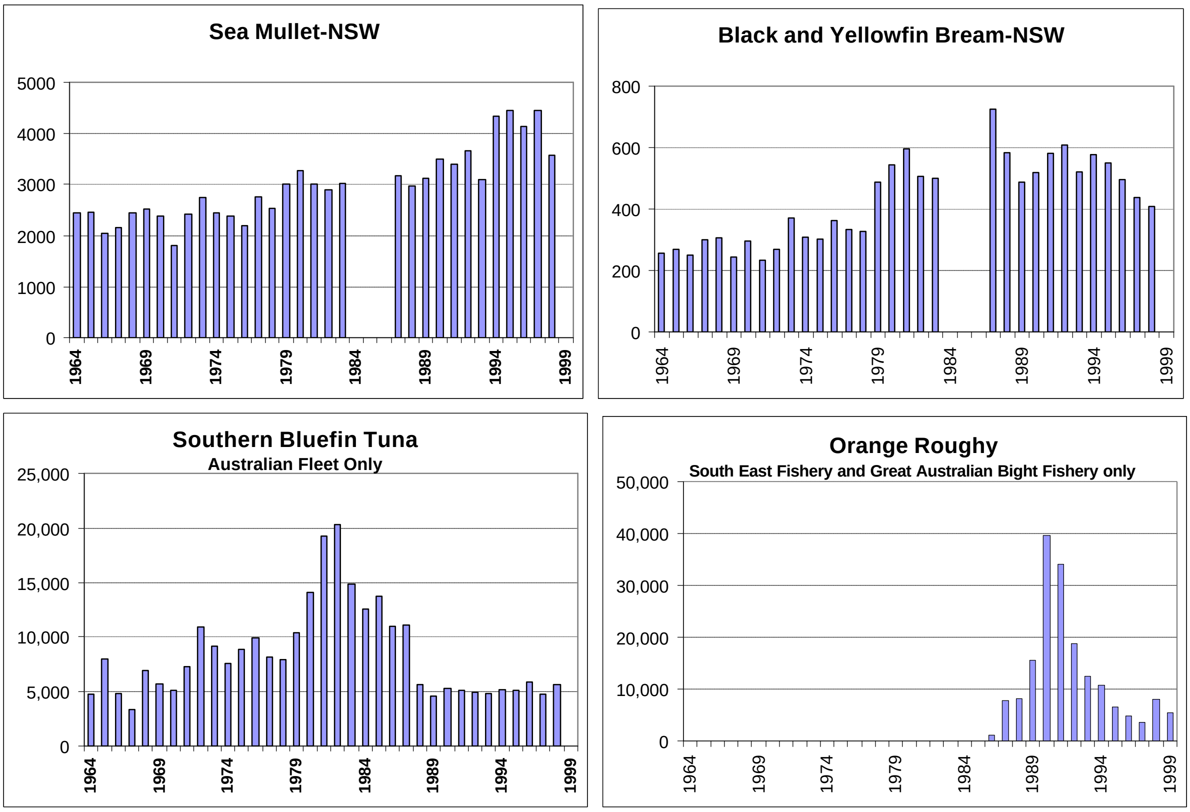


Figure 4.19. Time series of production for selected wild caught fisheries for period 1964 to 1999. Note difference in scales on y axis. (Data sources are BRS Working Paper No. WP/14/91 and ABARE Fisheries data 1990 to 1999).

The dynamics of fisheries and the management imposed on them is shown in Figure 4.19 where the actual recorded catch from four discrete species fisheries are portrayed for the last 35 years. The upper pair of graphs for sea mullet and black and yellow fin bream show moderate but increasing rates of catch for the period. Some hypotheses propose that these species are maintained by the bottom-up stimulation of algal growth due to agricultural and urban runoff. By contrast, the bottom two graphs portray data for long-lived cold-water species typical of those more prone to over fishing. Southern bluefin tuna reached a peak catch of 20,000 tonnes in the early 1980s, while orange roughy peaked at nearly 40,000 tonnes in the early 1990s. The yearly catch for both species has declined to levels much less than the peak catch and their fisheries are now subject to quotas. Studies on similar fisheries suggest that it is unlikely they will recover in the short term (Matsuda et al., 1998; Polacheck et al., 1999). In a well documented New Zealand example, more than 70% of orange roughy caught were taken from seamounts, and fish populations in those areas showed a strong decline over a ten-year fishing period (Clark, 1999; Clark et al., 2000).

The aggregated modelling approach used in ASFF uses a database from over 50 individual fisheries and a relatively simple traditional fisheries modelling approach to develop its numerical representation of past and present production. After modelling at a single fishery level, the fisheries are combined into five broad market types (freshwater, tunas, other marine fish, molluscs, crustaceans). Fishing effort is assumed to move from one fishery to another of the same type, if fish stocks in one location become exhausted. Some important biological parameters of particular fisheries, such as the time it takes to recover after a crash, are currently unknown. While this modelling presents an over-aggregated and simplified view of complex biological dynamics, the general picture is supported by more detailed work at the level of 160 different marine fisheries, under a research contract from the Fisheries Research and Development Corporation.

'Open slather' fisheries scenario to 2050

An 'open slather' management scenario is used to simulate the free market approach to marine fisheries management, overtly or covertly prevalent in many of the world's fisheries. This is followed by a 'sustainable fishing scenario'. Under an 'open slather' approach, yearly production in the 'other marine fish' category rises from 40,000 tonnes to 150,000 tonnes per year by 2010 (Figure 4.20). The production goal, implicit in the number of boats and therefore the fishing effort, is set to increase to 200,000 tonnes per year by 2040. However, simulated production from the fisheries declined to less than 50,000 tonnes per annum by 2020 and then crashed completely by 2040. The overall crash was composed of a set of sequential events that related to the dynamics under increasing fishing effort of a large number of individual fisheries (Figure 4.21).

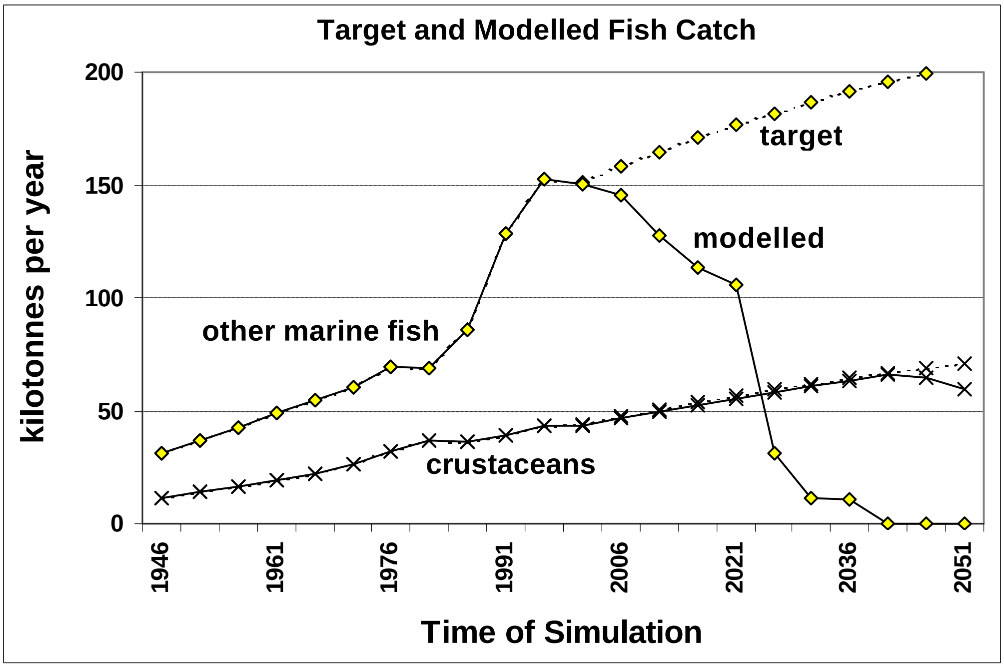


Figure 4.20. Simulated fisheries production to 2050 for an 'open slather' management scenario for fish groups 'other marine fish' and 'crustaceans' comparing the target catch and the modelled catch.

Each one of these individual; fisheries (represented by different layers in Figure 4.21) is exploited under the assumption that fishing effort moves on, if fish catch drops below a predefined level. A large proportion of total production is made up of long-lived 'orange roughy' types. It is assumed for the purposes of the simulation that further resources of this type are continually located and exploited. It could be argued that the fishing effort would not be maintained for long enough to drive the entire fishery down to virtually zero production. Long before this point of absolute crash, total allowable catch management arrangements would be implemented, or the reduction in economic return would force fishers into bankruptcy. The crustacean fishery continues a steady increase in production to about 60,000 tonnes per year by 2040 (Figure 4.20) and only in the last decade do the catch target and the actual catch start to diverge, giving early indications of a simulated decline.

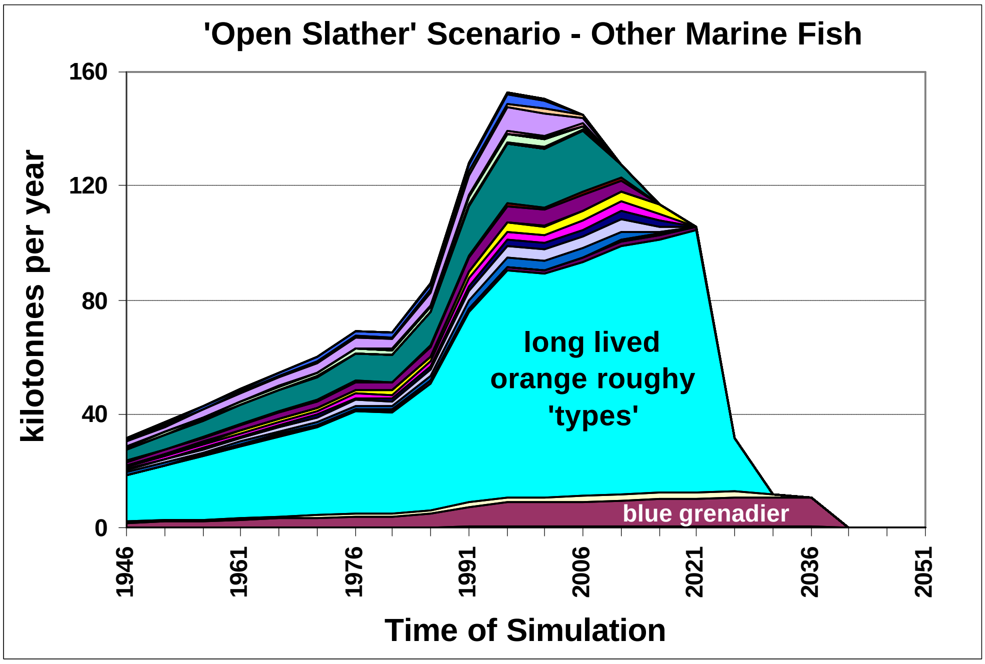


Figure 4.21. Simulated fisheries production to 2050 in the 'open slather' scenario for other marine fish showing the contribution of individual fisheries to the overall production aggregation.

.

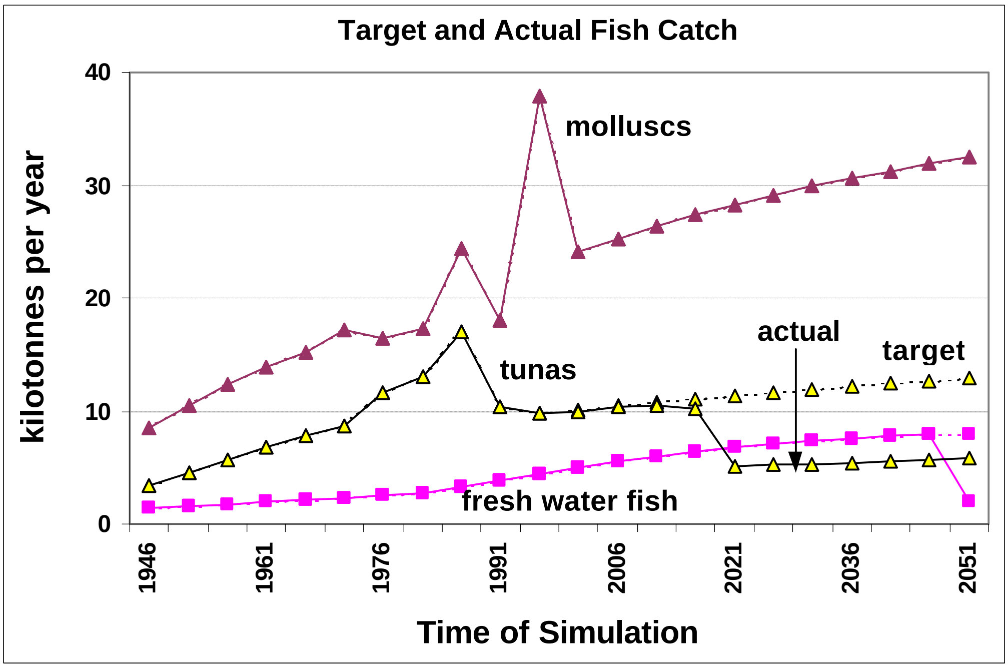


Figure 4.22. Simulated fisheries production to 2050 for the 'open slather' scenario for fish groups 'freshwater fish', 'tuna' and 'molluscs' comparing the target and actual catch. The target and actual catch are the same for molluscs and freshwater fish.

The mollusc fisheries continue a steady increase to 32,000 tonnes per year by 2050 after a range of high fluctuations in the recent historical period (Figure 4.22). The fresh-water fishery continues a steady increase to 8,000 tonnes per year by 2040 and then starts to decline. After some initial high catches in the 1980s, the combined tuna fishery fails to meet its production target of 10,000 tonnes rising to 12,000 tonnes by 2050. In the period 2015 to 2020 the simulated production declines to about 5,000 tonnes per annum which reflects the current catch by the Australian fleet for bluefin tuna only. The composition of the simulated tuna catch is shown in Figure 4.23. After an initial decline in both the southern bluefin and an aggregated class of other tuna, the fishing effort continues on the latter class until it crashes around 2020, leaving a slowly increasing southern bluefin stock to keep producing around 5000 tonnes per year.

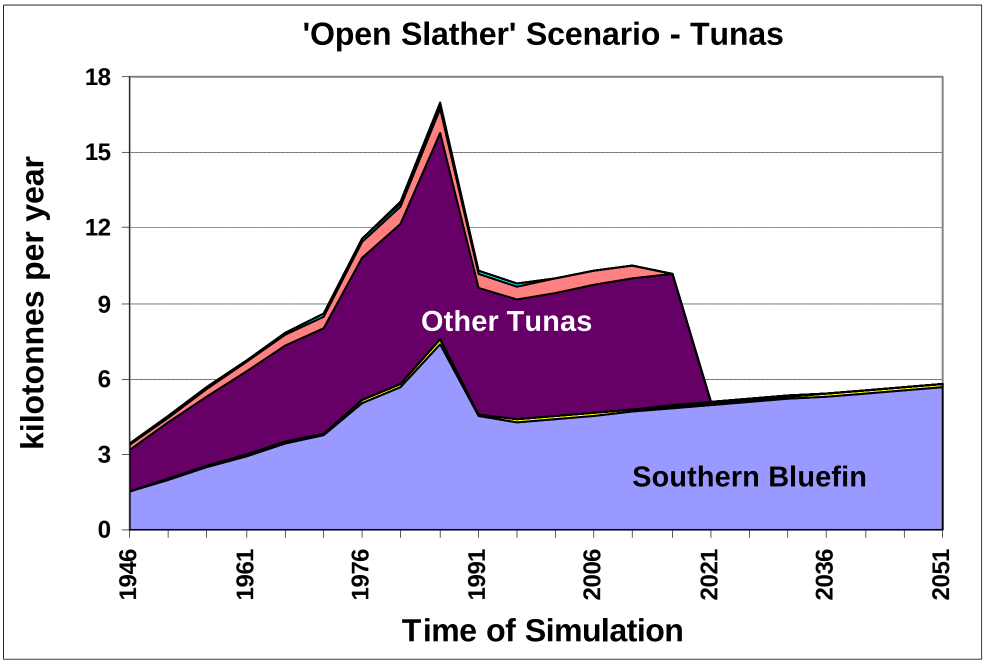


Figure 4.23. Simulated fisheries production to 2050 for tuna showing the contribution of different tuna fisheries to overall production.

.

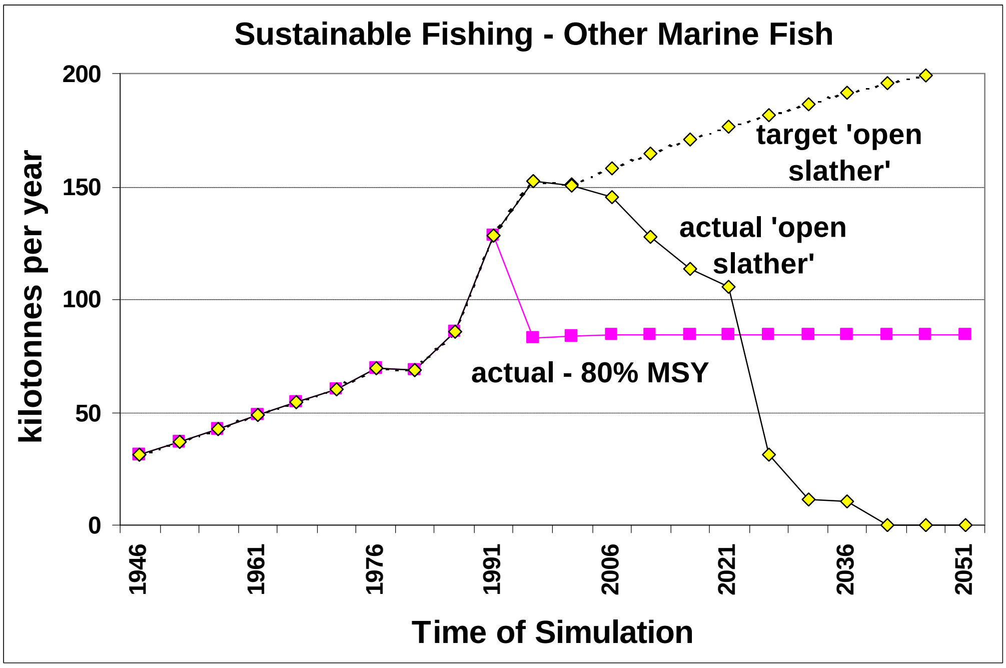


Figure 4.24. Sub-scenario of simulated fisheries production to 2050 for 'other marine fish' where production targets are reduced to 80% of the assumed maximum sustainable yield used in the 'open slather' fisheries scenario.

Sub-scenario: Sustainable Fishing to 2050

Government regulation and industry management which invoke concepts such as total allowable catch (TAC), the closure of fisheries to allow stock recovery and the buy back of fishing effort (boats) and quotas, are superseding management regimes where excess fishing effort causes a continual decline in fisheries production. The new approach is implemented in a sustainable fishing scenario for the two fin fish classes ('other marine fish' and 'tuna') which crashed in the initial 'open slather' scenario (see Figures 4.24 and 4.25). For the 'other marine fish' category, the target catch was replaced with a production goal which approximated 80% of maximum sustainable yield over all the fisheries in this category. When applied in 1996, this approach almost halved the simulated catch compared to the 'open slather' scenario, reducing it from 150,000 tonnes to 85,000 tonnes per year. The combined fishery could then operate at that production level for the rest of the simulation period. A similar result emerges for the combined tuna fishery, where relatively minor adjustments to the catch goal resulted in the fishery being maintained at round 10,000 tonnes per year for the rest of the simulation (Figure 4.25).

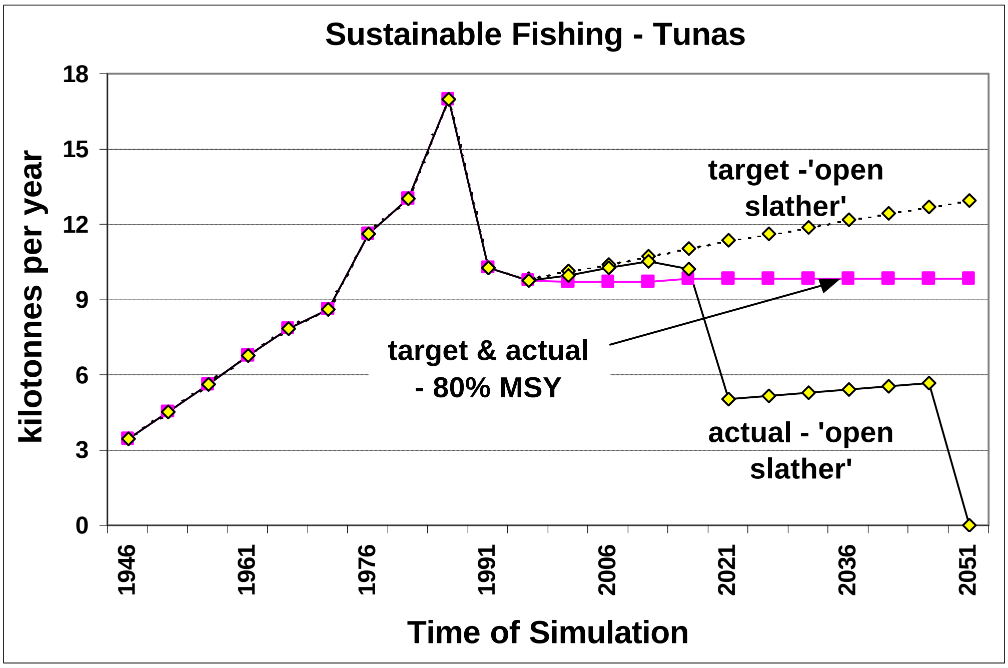


Figure 4.25. Sub-scenario of simulated fisheries production to 2050 for the tuna category where production targets are reduced to 80% of the assumed maximum sustainable yield used in the 'open slather' fisheries scenario.

Substantiating these simulated results is difficult but observations from other studies can help place them in context. There is a reasonable consensus that the production of wild fishing in marine areas is near to the maximum level, that can be sustained. Some scientific opinion argues that we have already passed the level but it is not reflected in overall production levels due to a number of lagged effects as we continue to fish down the trophic levels. At a national level, a number of economically important fisheries show evidence of being fully fished while others are overfished. At a state level, a number of State of Environment Reports suggest that difficulties in maintaining fisheries production are being experienced, or that many fisheries are near to their maximum level of exploitation (Table 4.5). The most recent SOE report from Queensland (Environmental Protection Agency, 1999) notes that six important fisheries are probably declining or declining. Almost half of the marine commercial species in South Australia are fully exploited (Department of Environment Heritage and Aboriginal Affairs, 1998). In Tasmania, 10 of the 36 species listed were overfished or fully fished. To counter this somewhat pessimistic viewpoint, institutional arrangements for many fisheries are now being changed to a total allowable catch basis. This approach promises some stability for future production levels and also suggests that fisheries production will conform more to the 'sustainable sub scenario' developed in this section, than to the 'open slather' scenario where effort was maintained until the entire complement of fin fish fisheries crashed.

.

Table 4.5. Comments on the catch and productivity of individual fisheries from recent State of Environment Reports from Queensland, Tasmania and South Australia.

State of Environment Report	Resume of the status of marine fisheries
Queensland SOE Report 1999 (Environmental Protection Agency, 1999)	Commercial catch is 19,000 tonnes annually valued at $175 million and undertaken by 1,900 commercial fishing vessels. Most commercially harvested stocks appear to be fully exploited with several being over-exploited. The status of barramundi, coral trout and mud crab fisheries is listed as 'probably declining' while the king prawn, saucer scallop and Spanish mackerel fisheries are listed as 'declining'.
South Australia SOE Report 1998 (Department of Environment Heritage and Aboriginal Affairs, 1998)	Approximately 2,700 tonnes of freshwater fish is caught in inland rivers and over 19,000 tonnes per year of commercial catch from marine areas. Catches of two species (Murray cod, black bream) are declining in the inland fishery. Of the 20 species listed as key commercial species for the marine areas, 10 (black bream, cuttlefish, garfish, King George whiting, mulloway, ocean leatherjacket, pilchard, sandcrab, snapper, western king prawn) were fully exploited and 1 (mud cockle) was over exploited
Tasmania SOE Report 1996 (State of the Environment Unit, 1996)	Of the 36 major fisheries listed in the report, 4 were overfished (scallops, shark, southern bluefin tuna, orange roughy) and 6 were fully fished (jackass morwong, blue-eye trevalla, southern rock lobster, Australian salmon, abalone, warehou).

One implication of a reduced but more stable pattern of production from Australian marine fisheries is that aquaculture will play a more important role in meeting domestic and export requirements. Annual aquaculture production exceeds 30,000 tonnes, with a value of more than $500 million. The industry aims to expand this production, in terms of volume and value, to more than $2.5 billion by 2010. More than 90% of the current value of this production comes from six species: pearls, lobsters, tuna, salmon, oysters and prawns. By 2050, the domestic fish production deficit could be between 190,000 and 460,000 tonnes per year (see next section) or 6-15 times the current level of production from aquaculture. Despite a number of important environmental considerations (CSIRO, 2000), expanding aquaculture to fill this deficit could be feasible. Achieving it depends on reasonable expectations of technological progress and management improvement in the wild caught fishery (lower but more sustainable levels of production) and in the aquaculture industry (reducing the proportion of fish in aquaculture diet and minimising localised site effects).

Table 4.6. Total simulated production at 2050 in tonnes, for the 'open slather' and sustainable fisheries scenarios, and the human requirements for fish at 2050 for the zero, base case and 0.67%pa human population scenarios.

Fish type	'Open slather' fisheries production at 2050	Sustainable fisheries production at 2050	Zero scenario requirement at 2050	Base case scenario requirement at 2050	0.67%pa scenario requirement at 2050
Fresh water fish	6,840	7,754	7,640	9,211	11,767
Tuna	6,186	9,948	36,925	44,517	56,870
Other marine fish	18,765	76,946	260,730	314,334	401,556
Crustaceans	61,863	64,489	49,106	59,202	75,630
Molluscs	21,748	27,057	18,309	22,073	28,198

Total	115,000	186,000	373,000	449,000	574,000

.

Fisheries surplus and deficit to 2050

Under the 'open slather' scenario, by 2050 the simulated total catch for all fish categories in Australia's fisheries was 115,000 tonnes per year. In contrast, the sub-scenario (80% of maximum sustainable yield) gave 186,000 tonnes per year. The human food requirements at 2050 were 373,000, 449,000 and 574,000 tonnes per year for the zero, base case and 0.67% population scenarios respectively (Table 4.6). Depending on the choice of production and population scenario the difference between catch and domestic dietary requirement could vary from 190,000 to 390,000 tonnes per year (Table 4.7).

Australia imports nearly 132,000 tonnes of fish product at an average value of $6,300 per tonne giving a total monetary value of imports in 1997/98 of $819 million. In the same year, exports of fish products (excluding pearls) reached 62,000 tonnes at a value of $24,000 per tonne, a total of $1,510 million. Thus the export balance reflects a surplus of about $700 million per year (Australian Bureau of Statistics, 2000-c; ABARE, 1999). As noted above, it may be possible to redress the physical imbalance between future food requirements and production, or it is possible to rely on imports. If, as expected, world supplies of wild-caught fish become constrained or decrease in per capita availability because of population growth, the price for imports will possibly rise. A rise in price will have a number of flow on effects within Australia possibly leading to improved management of wild caught fisheries and a stimulus to local aquaculture production. Alternatively an advantaged trade position for Australia may see domestic requirements being drawn from the fisheries of near neighbours. In many cases the imported fish might be more important to domestic dietary balances in those countries where protein is at a premium particularly for the poorer part of those populations. Thus fish trade might promote regional inequalities especially when protein sources are in abundance in Australia, and fish protein is a discretionary rather than an obligatory part of the human diet.

Table 4.7. Simulated surplus and deficit production levels in tonnes at 2050 by fish type for two fisheries scenarios ('open slather' and sustainable) and three population scenarios (zero, base case and 0.67%pa).

Fish type	'Open slather' fishing management			Sustainable fishing management		
	Zero population scenario	Base case population scenario	0.67%pa population scenario	Zero population scenario	Base case population scenario	0.67%pa population scenario
Fresh water fish	-800	-2,371	-4,927	114	-1,457	-4,013
Tunas	-30,739	-38,331	-50,684	-26,977	-34,569	-46,922
Other marine fish	-241,965	-295,569	-382,791	-183,784	-237,388	-324,610
Crustaceans	12,757	2,661	-13,767	15,383	5,287	-11,141
Molluscs	3,439	-325	-6,450	8,748	4,984	-1,141
Total	**-260,000**	**-330,000**	**-460,000**	**-190,000**	**-260,000**	**-390,000**

Two other wild cards are worth acknowledging in future options for fisheries. Fish consumption in Australia might rise as its health advantages are perceived by Australian consumers, particularly older people. With a base case population scenario of 25 million by 2050, and an increase in fish consumption of two kilograms per capita per year, this would require an extra 50,000 tonnes per year. This represents one-quarter of the current wild catch, and twice total aquaculture production. The second wild card is the impact of tourism. Many domestic and inbound tourists like to fish while on holidays and some of Australia's important commercial fisheries from Queensland to South Australia are also popular holiday destinations. Some of these fisheries are now fully-fished and others are over-fished, allowing scant return for the recreational fisher. Much anecdotal evidence points to the decline in recreational fishing experience along Australia's east coast, particularly for predators from the top of the trophic web which are some of the most sought-after recreational species. According to the 1999 Queensland State of Environment Report, "the frequency of schools of king salmon on usual fishing grounds and the number of fish in the schools have declined". Such information is part of an increasing weight of evidence that points to the state and productivity of fisheries as being key indicators of humankind's pressure on environmental processes. Similar evidence is emerging for Australia's inland fisheries (Davis et al., 2000). In the DIMA workshops, it was suggested that most commercial fisheries in coastal rivers, estuaries and near coastal areas would be closed in the next 20 years to facilitate the recreational fishing experience (Conroy et al., 2000). Monitoring and management will still be necessary and it is possible that recreational fishers could be harder to control than a limited number of professional fishers.

FORESTRY

Concern about world forests continues as demand for wood and paper continues to rise and forest land is cleared to make way for crop and animal production. Between 1980 and 1995, the area of forest cover fell by 180 million hectares; 200 million hectares were lost in developing countries while developed countries gained 20 million hectares (FAO, 1999-b). Environmental groups note that with increasing population growth, the forest to people ratio will have decreased from 1.2 hectares per capita in 1960, through 0.6 hectares per capita in 1995 to a possible 0.4 hectares per capita in 2025 (Gardner-Outlaw and Engelman, 1999). In Australian terms these ratios could change by 2050, from 2.2 hectares per capita currently (40 million ha native, 1 million ha plantation), to 1.3 hectares per capita under the 0.67%pa population scenario, 1.7 hectares under the base case and remain at 2.2 hectares for the zero scenario. The demand for industrial forest products is expected to grow at 1.7% per annum and this will continue to enhance trade flows of forest products between countries. Australian consumption of paper and packaging is expected to grow to 238 kilograms per capita per year by 2040 (Love et al., 1999) and while paper recycling is widely practiced, redressing the $2 billion deficit in total forest products presents a considerable challenge.

In the scenarios presented here, land retired from agriculture scenarios is transferred to the forest estate. Improved management and technological innovation is assumed to allow the establishment of productive forests that replicate current growth rates for particular rainfall zones (Figure 4.26). For the base case and technological advance scenarios this sees the Forests 2020 Vision (DPIE, 1997) policy implemented, with a three million hectare forest plantation stock by 2020 growing to four million hectares by 2050. For the landscape integrity scenario, large areas of land are reforested in an attempt to restore the hydrological balance and to slow the spread of dryland salinity. This gives a forest estate of 12 million hectares by 2020, increasing to 13 million hectares by 2050. The native forest estate (similar categorisation to that used in ABARE, 1999) stabilises at 41 million hectares by 2050.

The combined production of roundwood and pulpwood grows to 32 million and 41 million cubic metres for the base case and landscape integrity scenarios respectively (Figure 4.27). While the silvicultural and production technologies are currently different, in the future the confluence of a variety of production technologies will blur the distinction between wood grown for structural use and building and that grown for pulp (Conroy et al., 2000). The combined production of roundwood and pulpwood is currently about 20 million cubic metres per year (ABARE, 1999). Future scenarios of forest production (Love et al., 1999) anticipate an expansion of total wood production to 34 million cubic metres by 2040, of which 13 million will be used for saw logs and 21 million for pulp and other logs. The scenarios in this analysis are thus in accordance with industry expectations and plans. Expansion of the forest estate in line with the base case and technological advance scenarios, sees Australia developing a positive balance in most categories of wood products with the exception of paper, where one million tonnes of imports will be required in the base case population scenario if present trends in paper and packaging consumption continue.

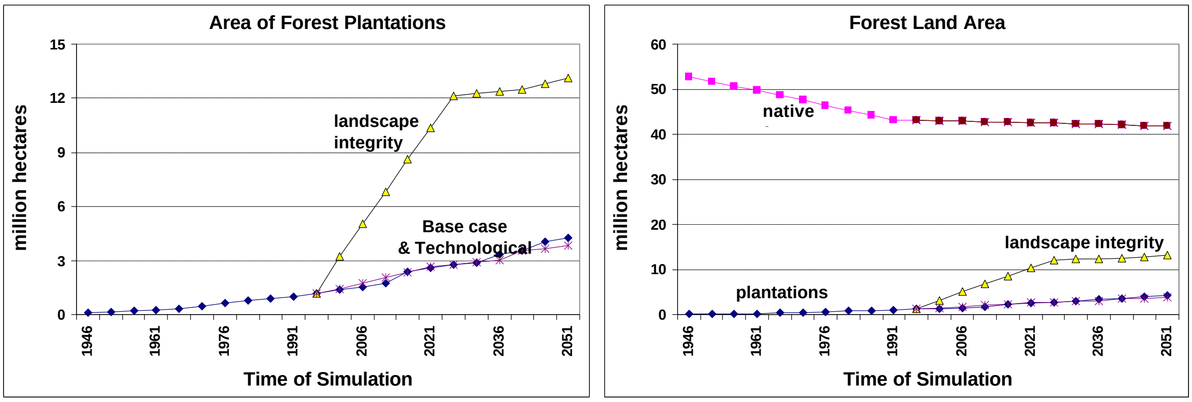


Figure 4.26. Areas of forest estate to 2050 derived from land use scenarios developed for agriculture.

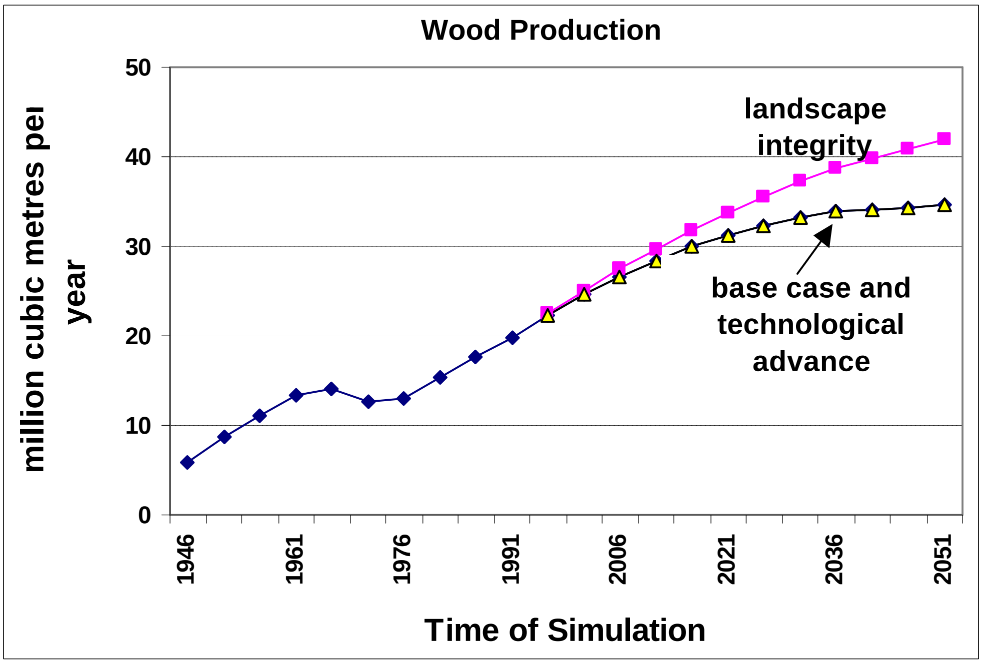


Figure 4.27. Production of roundwood and pulpwood to 2050 derived from the three land use scenarios developed for agriculture and landuse.

By 2050 the landscape integrity scenario has approximately doubled the area of plantation forest and potentially, also the volume of wood, to turn a balanced forest products account into one with a large surplus for export. In this simulation however, about half of the plantation area is left as a standing stock of forest trees for two reasons. Firstly, a key rationale of reforesting cleared land in Australia is to restore some of the hydrological balance with potential additional returns for a wide range of ecosystems services. Secondly, trees are left to act as a sink for carbon dioxide emissions from the fossil energy sector. Burns et al. (1999) in a regional analysis of farming land found that potentially 19 million hectares of cleared farming land was suitable for plantations. Much of this land could be used for either production forestry or carbon sequestration. It is possible that a range of longer lived tree species could be planted which continue growing to 60-80 years of age, about 2-3 times the length of a rotation in a normal production forest. If a market were developed for carbon sequestration at the rate of $50 per tonne of carbon ($13.50 per tonne of CO2), an actively growing forest of one hectare might sequester between 15 and 20 tonnes of CO2 per hectare per year, giving a potential monetary income of between $200 and $270 per hectare per year while the forest was actively growing. A measured 42 year old stand of *Pinus radiata* contained nearly 500 tonnes of wet biomass per hectare. This is the equivalent of 100 tonnes of carbon or a sequestration of 370 tonnes of CO2 (Australian Greenhouse Office, 1998). Given a range of management options, the implementation of the landscape integrity scenario is thus judged to be reasonably feasible.

THE EFFECT OF POPULATION ON NATURAL RESOURCES

Most of the effect of future domestic population size (apart from the effect on petroleum stocks and marine fisheries) can be interpreted through the tertiary population effect, where the arrangements and requirements of international trade drive production and the domestic population effect is less important (Table 4.8). For minerals generally, the production implemented in the base case scenario represents much higher levels than is required by the domestic population, whatever the population scenario. For oil and gas specifically, a view of a discrete, and an eventually constrained, resource has been presented. Making reasonable assumptions on the substitution options between oil and natural gas, this does not present a problem in 2020 or nearly one human generation away. However, by 2050 when the physical economy is larger in size and with more physical transactions, there could be a substantial gap in the domestic availability of easily available and easily delivered energy for the transport sector. In the case of oil and gas (but not minerals generally) population size is regarded as a primary influence on resource use, with trade in natural gas being an additional tertiary population effect which could restrict energy options over longer time scales.

Table 4.8. Description of the different levels of population effect in key natural resource areas.

Commodity	Issue	Importance of population effect
Minerals	Mineral stocks	Generally driven by the tertiary population effect due to international trading arrangements and domestic policies which form these arrangements. General assumption for most mineral stocks is that resources will not be constrained in the next 100 years as exploration and extraction technologies improve several fold in sophistication and efficiency.
	Oil and gas stocks	Domestic population drives possible constraints on traditional stocks of domestic oil in a primary sense, although there is a complex mixture containing secondary drivers of lifestyle (car technology, frequent plane trips) and tertiary drivers of international trade (inbound international tourism, transport for export goods). The importance of the tertiary population driver for future constraints on natural gas stocks will increase as liquefied natural gas exports seek to supply a rapidly expanding world market for lower carbon fuels.
Agriculture	Agricultural commodities	An export trade requirement, interpreted as a tertiary population effect, is the main driver of volume of agricultural commodities. However about 50% of many commodity food groups is for domestic consumption. Many food groups such as vegetables, fruit and whole milk products are best produced closer to major markets.

	Grain for livestock feed	A positive grain balance is maintained under all population scenarios. The use of grain for livestock feed may emerge as an ecological and energy issue within the next human generation. It may also be tied to animal welfare issues (e.g. free range versus battery hens) and to regional pollution issues (e.g. disposal of feedlot manure). Within this context, domestic population numbers will drive production of grain for chickens, pigs and aquaculture in a primary sense. Currently 25-30% of feedlot cattle are produced for domestic consumption and this proportion will be driven by domestic population levels.
	Water requirement for dairy production	Under current starting position scenario assumptions by 2050, the dairy industry produces twice the current domestic requirement for raw milk under the highest 0.67% population scenario. Thus at 2050 the domestic population effect on water requirement for dairy production could be attributed 35%, 43% and 52% to domestic population levels (a primary population effect) and the remainder to the tertiary effect of international trade. The location and availability of the required water resource could represent a water tension that may require resolution
	Land loss and river salinity	Generally driven by a tertiary (and relatively long-term) population effect due to international trading arrangements and historic land use policies, rather than a primary or direct effect of current population numbers. There will be some primary effect blending into the tertiary effect (eg grain for feed and water for dairy) as domestic population requirements become a higher proportion of total production.
Fisheries	Fish stocks and sustainability of catch levels	Both globally and at a national level, the status and productivity of wild caught fisheries are driven mostly by a primary population effect. In future the effect can be neutralised in two ways. Where fisheries are fully fished or declining, institutional arrangements can be changed and 'total allowable catch' procedures applied to each fishery. Alternatively aquaculture can be increased to make up the shortfall provided that local environmental issues and the use of fish for fish feed do not produce knock-on effects on marine situations either locally or in other countries. A 100,000 tonne per year fish products deficit is covered by imports from abroad. Additional population effects could be caused by recreational fishing pressure from domestic tourism (a secondary effect) and international tourism (a tertiary effect).
Forestry	Managed plantations	Increasing plantation areas will be driven by government and industry policy (e.g. Forests 2020 Vision) and by requirements for carbon sequestration. This transition could see relatively large increases in plantation area and an eventual neutralisation of the national forest products deficit. Thus any perceived negative effects of domestic population size on forests will become relatively neutral when the requirement for forest products starts to equalise with managed plantation production.
	Harvests from natural forests	Mainly a tertiary population effect as woodchips from native forests are exported to derive export income. The effect is more a historic one, as the reform of land use in the forestry industry will see most woodchip exports derived from managed plantations by 2020.
	Forest products in general	Currently about 70% of woodchips are derived from broadleafed species; woodchips contribute $0.6 billion of a $1.3 billion export trade in forest products. Imports of forest products are $3.3 billion per year giving a $2.0 billion forest products deficit. This deficit is mainly a primary population effect (due to the direct requirements of Australia's population). Australia's domestic requirement has a tertiary population effect on the forests of New Zealand, Indonesia, Finland, North America and many other countries.

Domestic population affects agriculture indirectly through the tertiary effect where domestic requirement by the highest population scenario (0.67%pa) does not exceed 50-60% of total production for the broadacre commodities. Another way of saying this is that any environmental effect of land use or agricultural production can be allocated at least 25-50% to the primary population effect. For some commodities, such as eggs, chicken, pork, fruit and vegetables, we assume that bulk production is geared mainly to domestic requirements as well as exports to near neighbours. However there are specific items such as wine, dried fruit, citrus and tropical fruits that form the basis of important export industries. For most items where the requirement and the production are closely matched towards the end of the simulation, production levels can be adapted relatively quickly. It is unlikely that a prolonged domestic deficit in bulk agricultural commodity items would occur for any physical reason.

A check on the food balance for each population scenario showed that no imports were required for most food commodity groups at 2050 (Table 4.9). The exceptions are fruit and vegetables, for which the scenarios have not allocated enough land, and pork for which 20% of the requirement will need to be imported by 2050. A relatively minor reallocation of irrigated land to fruit and vegetables would allow this physical tension to be resolved. Similarly an increase in pig numbers to four million by 2050 would allow domestic self sufficiency.

Table 4.9. Percentage of domestic requirement of agricultural commodity groups simulated as imported at 2050 for zero, base case and 0.67%pa population scenarios.

Agricultural commodity group	Zero population scenario	Base case population scenario	0.67%pa population scenario
Grain	0	0	0
Sugar	0	0	0
Cotton	0	0	0
Fruit	0	14	35
Vegetables	25	35	50
Beef and Veal	0	0	0
Mutton and lamb	0	0	0
Pork	0	0	20
Poultry	0	0	0
Eggs	0	0	0
Milk	0	0	0

In the fisheries sector, a primary or direct population effect was allocated. The current fish products deficit of 100,000 tonnes per year, could increase four-fold under the 0.67%pa scenario. With many wild fish stocks already fully fished, the challenge is for aquaculture to meet the requirement and allow a longer-term replenishment of fish stocks. The aquaculture option is judged to be marginally feasible, if the requirement for fish protein as a critical component of the diet can be removed. A number of location issues and environmental externalities must also be addressed. In the meantime, Australia's domestic requirements could be delivering their own tertiary population effect to wild caught fisheries or aquaculture in countries with whom we trade.

The requirement for forest products could also be considered a primary population effect. Australia maintains a sizeable forest products deficit, in that we locate part of our requirements within the forest stocks of other countries. Some of these countries are judged to have unsustainable forest production practices and Australia's domestic requirement may be directly implicated in the shrinkage of world forest resources. Within the next human generation it is probable that an expansion of domestic forest plantations and a cessation of logging in native forests will see Australia redress its forest products deficit. It is possible that if elements of the landscape integrity scenario are followed, that a substantial positive stock could be developed. This could facilitate a substantial increase in the amount and quality of ecosystem services, as well as a wide range of new products such as biomass based energy services which could be carbon neutral and help in reducing greenhouse gas emissions.

REFERENCES

ABARE (1999). 1999 Australian Commodity Statistics. Australian Bureau of Agriculture and Resource Economics, Canberra.

Alexander D Williams B and Trewin R (1998). Dryland Salinity R&D Foresighting Analysis. Land and Water Resources Research and Development Program Occasional Paper Series No 22/98

Australian Bureau of Statistics (2000-a). Australia Now, A Statistical Profile, Population, Population Size: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/66c4681ef3e774a1ca2568a900154b07!OpenDocument Accessed 10/6/2000

Australian Bureau of Statistics (2000-b). Water Account for Australia 1993-94 to 1996-97. ABS Catalogue No. 4610.0

Australian Bureau of Statistics (2000-c). Australia Now, A Statistical Profile, Forestry and Fishing, Production, processing, and exports and imports of fisheries products: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/5bd6df240ea47a5bca2568a900154b96!OpenDocument Accessed 23/10/2000

Australian Geological Survey Organisation (1999). Oil and Gas Resources of Australia 1999. Australian Geological Survey Organisation, Canberra.

Australian Greenhouse Office (1998). *Greenhouse Challenge Vegetation Sinks Workbook Version 1.0. Quantifying Carbon Sequestration in Vegetation Management Projects: A Summary*. Australian Greenhouse Office, Canberra.

Beddington J (1995). The primary requirements. Nature 374,213-214 16 March 1995.

Beverton R (1998). Fish, fact and fantasy: a long view. The Larkin Lecture. Reviews in Fish Biology and Fisheries 8,229-249.

Bicknell KB Ball RJ Cullen R and Bigsby HR (1998). New methodology for the ecological footprint with an application to the New Zealand economy. Ecological Economics 27,149-160.

Burns K Walker D and Hansard A (1999). *Forest Plantations of Cleared agricultural land in Australia; A Regional Economic Analysis.* ABARE Research Report 99.11, September 1999, Canberra.

BPAmoco (2000). Statistical Review of World Energy 1999. http://www.amoco.com/worldenergy/ accessed 22-6-2000.

Caddy JF Csirke J Carcia SM Grainer RJR (1998). How pervasive is "fishing down marine food webs"? Science 282,1383a, 20 November 1008.

Caddy JF (1999). Fisheries management In the twenty-first century: will new paradigms apply? Reviews in Fish Biology and Fisheries 9,1-43.

Caton A McLoughlin K and Staples D (1998). Fishery Status Reports 1998. Resource Assessments of Australian Commonwealth Fisheries, Bureau of Resource Sciences, Agriculture Fisheries Forestry Australia, Canberra.

Caton A and McLoughlin K (2000). Fishery Status Reports 1999. Resource Assessments of Australian Commonwealth Fisheries, Bureau of Resource Sciences, Agriculture Fisheries Forestry Australia, Canberra.

Chislolm A (1999). Land resource and the idea of carrying capacity. BCA Papers 1,2,19-26 Business Council of Australia, Melbourne.

Clark M (1999). Fisheries for orange roughy (Hoplostethus atlanticus) on seamounts in New Zealand. Oceanologica ACTA 2,6,593-602 Nov-Dec 1999.

Clark MR Anderson OF Francis RICC Tracey DM (2000). The effects of commercial exploitation on orange roughy (Hoplostethus atlanticus) from the continental slope of the Chatam Rise, New Zealand from 1979 to 1997. Fisheries Research 45,3,217-238.

Cohen JE (1995). *How Many People Can the World Support?* Norton and Company, New York.

Coleman A (1999). Dolly Polly and other "ollys": Likely impact of cloning technology on biomedical uses of livestock. Genetic Analysis-Biomolecular Engineering. 15,3-5,167-173.

Commonwealth of Australia (2001-a). *Australian Dryland Salinity Assessment 2000*. The National Land and Water Audit, January 2001, Canberra.

Commonwealth of Australia (2001-b). *Australian Water Resources Assessment 2000*. The National Land and Water Audit, January 2001, Canberra.

Conroy J Foran BD Poldy F and Quinnell T (2000). Future Options to 2050: Workshops Report. CSIRO Resource Futures Program Working Paper Series 00/03, March 2000.

CSIRO (2000) Environmental report card for Tasmania's Huon. CSIRO Media Release Friday 23 June 2000. http://www.csiro.au/page.asp?type=mediaRelease&id=Prhuon accessed 34-6-2000

Davis KM Kearney RE Beggs KE (2000). Research priorities for Australia's freshwater fisheries. Australian Journal of Environmental Management 7,28-37.

Department for Environment Heritage and Aboriginal Affairs (1998). *State of Environment Report for South Australia*. Adelaide South Australia October 1998.

Department of Primary Industries and Energy (DPIE) (1997). *Plantations for Australia: The 2020 Vision*. http://www.affa.gov.au/agfor/forests/2020/vision.html Accessed 19 May 1999.

Doyle PT and Kelly KB (1998) The Victorian dairy industry-Improving performance. In *Agronomy-Growing a Greener Future*, Proceedings of the Ninth Australian Agronomy Conference, Charles Sturt University, Wagga Wagga NSW 20-23 July 1998, page 31-36.

Dunlop M McKenzie N Jacquier D Ashton L and Foran BD (1999). Australia's Stocks of Quality Soils. CSIRO Resource Futures Program Working Paper Series 99/06, November 1999.

Dunlop M Foran BD and Poldy F (2000). Changing agricultural production and the natural resource base: Three long term scenarios for land use. CSIRO Resource Futures Program, Working Paper Series 00/05, Draft Report for the Land and Water Resources Research and Development Corporation, 26 May 2000.

Environmental Protection Agency (1999). *State of Environment Queensland 1999 Executive Summary*. Brisbane 1999.

Fisheries Research and Development Corporation (FRDC)(1999). From Antarctica to the tropics: a snapshot of the Australian fishing industry. FRDC Canberra.

Food and Agriculture Organisation (FAO)(1999-a). *The State of World Fisheries and Aquaculture 1998. Part 1: World Review of Fisheries and Aquaculture, Fisheries Resources: Trends in Production, Utilisation and Trade* http://www.fao.org/docrep/w9900e/w9900e00.htm accessed 25-6-2000.

Food and Agriculture Organisation (FAO)(1999-b). *State of the World's Forests 1999*. http://www.fao.org/forestry/FO/SOFO/SOFO99/sofo99-e.stm accessed 28-6-2000

Foran BD and Mardon C (1999). Beyond 2025: Transitions to a biomass-alcohol economy using ethanol and methanol. CSIRO Resource Futures Program, Working Paper Series 99/07. A consultancy report for the National Dryland Salinity Program of the Land and Water Resource research and Development Corporation, December 1999.

Gardner-Outlaw T and Engelman R (1999). *Forest Futures: population, Consumption and Wood Resources.* Population Action International, Washington.

Gordon L Dunlop M and Foran BD (2000). Water vapour flows from vegetation in Australia 1780-1980. CSIRO Resource Futures Program, Working Paper Series 00/0?

Gorrie G and Wonder B (1999). *Managing Natural Resources in Australia for a Sustainable Future: A Discussion Paper for Developing a National Policy*. National Natural Resource Management Task Force, Agriculture Fisheries Forestry Australia, Canberra, January 1999.

Howden SM (2001). Analysis of national livestock statistics: Assessment for systematic reporting bias. Proceedings of MODSIM 2001, Australian National University, Canberra, 10-13 December 2001. Volume 4, General Systems pp 1841-1852.

Hubbert MK (1967). Degree of Advancement of Petroleum Exploration in the United States. The American Association for Petroleum Geologists 51,11, 2207-27

IUCN (1994). *The Netherlands and World Ecology*. The Netherlands Committee for IUCN, Amsterdam, The Netherlands.

Laherrère JH (2000). The Hubbert Curve: Its Strengths and Weaknesses. (submitted to Oil and Gas Journal on 18 Feb 2000) http://dieoff.com/page191.htm accessed 24/4/2000

Land and Water Resources Research and Development Corporation (LWRRDC) (1997). Using foresighting to identify R&D priorities for LWRRDC. LWRRDC Occasional Paper Series 10/97 July 1997, Canberra.

Love G Yainshet A and Grist P (1999). *Forest products: Long term consumption projections for Australia*. ABARE Research Report 99.5 April 1999, Canberra.

Mace PM (1996). Developing and sustaining world fishery resources: The state of the science and management. Keynote paper at 2nd World Fisheries Conference 1996, page 1-20.

Matsuda H Takenaka Y Yahara T Uozumi Y (1998). Extinction risk assessment of declining wild populations: The case of southern bluefin tuna. Researches on Population Ecology 40,3,272-278.

Meat and Livestock Australia (MLA) (1999). Australian Cattle and Sheep Industry Projections 1999. Meat and Livestock Australia, North Sydney may 1999.

MDBMC (1999). *The Salinity Audit of the Murray Darling Basin: A 100-Year Perspective*. The Murray Darling Basin Ministerial Council.

Naylor RL Goldburg RJ Mooney H Beveridge M Clay J Folke C Kautsky N Lubchenco J Primavera J and Williams M (1998). Natures subsidies to shrimp and salmon farming. Science 282,883-884, 30 October 1998.

Naylor RL Goldburg RJ Primavera JH Kautsky N Beveridge MCM Clay J Folke C Lubchenco J Mooney H and Troell M (2000). Effect of aquaculture on world fish supplies. Nature 405,1017-1024, 29 June 2000.

Parliamentary Commissioner for the Environment (1999). *Setting Course for a Sustainable Future: The Management of New Zealand's Marine Environment*. Wellington, December 1999.

Pauly D and Christensen V (1995). Primary production needed to sustain global fisheries. Nature 374,255-257 16 March 1995.

Pauly D Froese R and Christensen V (1998). Response to 'How pervasive is "fishing down marine food webs"?' Science 282,1383a, 20 November 1998.

Polacheck T Klaer NL Millar C and Preece AL (1999). An initial evaluation of management strategies for the southern bluefin tuna fishery. ICES Journal of Marine Science 56,6,811-826.

Population Action International (1995). Catching the Limit: Population and the Decline of Fisheries. http://www.populationaction.org/why_pop/fish.htm accessed 23-6-2000

PMSEIC (1998). Dryland salinity and its impacts on rural industries and the landscape. The Prime Minister's Science Engineering and Innovation Council. Second Meeting Friday, 4 December 1998 Parliament House Canberra, http://www.isr.gov.au/science/pmseic/2ndmeeting.html accessed 21-6-2000

PMSEIC (1999). Moving forward in natural resource management: The contribution that science engineering and innovation can make. The Prime Minister's Science Engineering and Innovation Council. Third Meeting Friday, 25 June 1999, Parliament House Canberra. http://www.isr.gov.au/science/pmseic/3rdmeeting.html accessed 21-6-2000

Rosegrant MW Paisner MS Meijer S and Witcover J (2001). *Global Food Projections to 2020: Emerging Trends and Alternative Futures*. International Food Policy Research Institute, Washington, August 2001.

Skinner P (2000). Asian Energy-Challenges and Opportunities. Royal Dutch Shell Group of Companies website http://www.shell.com/library/speech/1,5833,,00.html?article=50255&type=speech&siteid=1160 accessed 9-6-2000

Smil V (2000). *Feeding The World*. MIT Press Cambridge USA. http://mitpress.mit.edu/book-table-of-contents.tcl?isbn=0262194325 accessed 9-6-2000

State of Environment Unit (1996). *State of the Environment Tasmania 1996: Volume 1 Conditions and Trends*. Land Information Services, Hobart Tasmania.

Swindell GS (1999). Texas production data show rapid gas depletion. Oil and Gas Journal June 21. 1999 page 61. http://oil.server4.com/tx-depl.htm accessed 6-6-2000

The Economist (2000).Oil in Texas- A Dim Gurgle. The Economist April 15th 2000 page 31

Tian XC and Yang XJ (1998). Life on the bio-pharm: Therapeutic proteins from transgenic organisms. Molecular Medicine Today 4,10,424-425 October 1 1998.

Thomas JF (1999). Water and the Australian Economy. A joint study project of the Australian Academy of Technological Sciences and Engineering and the Institution of Engineers, Australia. April 1999 Melbourne.

US Department of Energy (2000). Long term World Oil Supply: A Resource Base/Production Path Analysis. Energy Information Administration 28/07/2000. http://www.eia.doe.gov/pub/oil_gas/petroleum/presentations/2000/long_term_supply/sld007.htm accessed 21-06-01

von Weizsacker E Lovins AB and Lovins LH (1997). *Factor 4: Doubling Wealth-Halving Resource Use*. Allen and Unwin, St. Leonards, Australia.

Wackernagel M and Rees W (1996). *Our Ecological Footprint: Reducing Human Impact on the Earth*. New Society Publishers Garbiola Island BC Canada.

Wackernagel M and Rees WE (1997). Perceptual and structural barriers to investing in natural capital: Economics from an ecological footprint perspective. Ecological Economics 20,3-24.

Chapter 5
The future of energy

ABSTRACT

Energy is responsible for at least half the industrial growth in a modern economy while representing less than one tenth of the costs of production. This unseen or unacknowledged contribution of energy lies behind much of the debate on how economic and physical structures might change in response to concerns about global greenhouse emissions. In addition, the consumption driven inter-sectoral rebound effect, or the Jevons' Paradox, suggests that, at the level of the whole economy, increases in energy efficiency may catalyse increases in energy usage, rather than allowing more production for the same or less energy usage. Simulations of the population scenarios show growth in primary energy use from 4800 petajoules per year currently, to between 6000 and 8000 petajoules per year by 2050, using a wide range of aggressively optimistic technical assumptions contained in the base case. These outcomes do not include a revolution in energy production (eg solar, nuclear or the hydrogen economy) but do include significant changes in composition of primary fuel use. The greenhouse gas implications (expressed in terms of carbon dioxide from the energy sector) suggest that, by the year 2050, emissions may rise to between 170% and 230% of the 1990 baseline levels, even under exacting technological assumptions. Failure to meet the technical assumptions in the base case may mean that emissions rise to more than 300% of 1990 levels by 2050. Possible oil constraints in the transport sector can be moderated by a transition to the widespread use of natural gas for transport fuel. However, this has the effect of constraining natural gas self sufficiency and lessens export income towards the end of the simulation period. When a number of sub-scenarios from previous chapters (buildings, cars, freight etc) are implemented in combination, the result is a cap on primary energy use which begins to fall, and with it the carbon dioxide emissions to 120% of 1990 levels. Implementing these sub-scenarios in combination is judged to be technically possible but only marginally feasible in a political and social sense under current economic and political structures. The population effect on energy use and carbon dioxide emissions is 6-9% lower than the raw population numbers in the year 2050 would suggest, due to energy use related to export industries (i.e. the tertiary population effect).

INTRODUCTION

Energy and the economy

From a physical perspective, the use of energy drives economic productivity and industrial growth and is central to the functioning of any modern economy. Recent events demonstrate this dependence. The failure of four out of five electricity cables supplying the city of Auckland in 1998 cost down-town business an estimated $50 million per week, and reduced economic growth by an estimated 0.2 percentage points (CNN Interactive 1998). An explosion which cut off natural gas supply to Melbourne and most of Victoria in September 1998 could result in insurance claims of $350 million and a class action is currently underway for $1 billion (Lateline, 2001). Most of the development in Australia over the 20th century took place in an era when energy supplies were plentiful and relatively cheap. Energy, like oxygen, water and soil organic matter, was treated as a virtually free resource from the biosphere where only the costs of exploration and extraction were paid. Economic growth and quality of life in most nations depend on the unbroken supply of high quality energy resources.

Some energy analysts argue that growth in energy use directly causes growth in GDP rather than simply representing an input to the production process. Cleveland et al. (2000) confirm statistical causality (proof) between quality corrected energy use (accounting for the difference in usefulness of a tonne of coal, oil or natural gas) and real GDP for the US economy in the period 1947 to 1996. They further note the concept of energy use causing growth in GDP (rather than the reverse) "runs counter to much of the conventional wisdom that technical improvements and structural change have decoupled energy use from economic performance". In an empirical analysis covering the economies of the USA, Germany and Japan for the period 1960 to 1992, Kummel and Linderberger (1998) were able to attribute the contribution of energy to overall industrial production. For the three economies they found that energy use was responsible for 45-53% while labour contributed 5-21% and capital 35-45%. Subsequent analysis, which included innovation and creativity as explanatory variables, confirmed the major contribution of energy use to growth in GDP, while attributing 5-11% of that growth to technological innovation (Henn et al., 2000).

Kummel and Linderberger (1998) further note that the contribution that energy makes to industrial production (about 50% in their whole economy analysis) is seven to ten times its factor cost of 5-7% (Stern, 1999). The apparent disparity between the real effect in a thermodynamic or work sense and the factor cost of energy challenges a number of critical assumptions on which neoclassical economic theory is based, particularly that the contribution of an input to production should approximate its factor cost. Kummel and Linderberger extend the implications of their analysis by suggesting that a transition of theory to reality in OECD economies (in terms of the function importance of energy use in relation to the proportion it represents of the costs of production) might stimulate higher employment as human labour is used to partially replace fossil energy use, and primary energy use and greenhouse gas emissions are subsequently lowered.

Paralleling the importance of energy in industrial production and generation of GDP is the idea that increases in energy efficiency (more product or service delivered per physical unit of energy used) may not lead to a plateau in, or a reduction of, energy use at the level of the whole economy (Inhaber, 1997). In a counter intuitive fashion, energy efficiency improvements may lead to lower energy prices, which in turn stimulate larger requirements. This behavioural characteristic of economic function is termed the "inter-sectoral rebound effect" or the Jevons' Paradox and is currently the subject of scientific and policy debate on its extent and longevity (Shipper, 2000). One side of the debate claims that rebound effects are pervasive and that technological innovation leading to energy efficiency improvements should be accompanied by price increases per unit of energy to contain them (Brookes, 2000; Herring, 1999,2000-a; Sanne, 2000; Saunders, 2000).

The other side of the rebound debate argues that rebound effects, mainly within specific sectors, are limited because of a wide variety of saturation effects (Schipper and Grubb, 2000). Rebound from innovations in automotive technology is real but limited to a range of 10-30% (i.e. if a new energy technology promises the same vehicle kilometres for 100 less units of fuel, then 30 units of these potential savings are used in driving more kilometres). The most obvious example of rebound or take-back is the increases in power, size and luxury of vehicles that has accompanied increasing engine efficiencies (Greening et al., 2000). Well documented examples with limited rebound effects are presented for space lighting and space heating and cooling where physical comfort levels show obvious saturation effects as technological improvements lower the cost of energy services.

What is notable in the current debate on energy rebound effects is that potential energy savings (from technological innovation for example) are not followed from one sector to another, as knock-on effects cascade throughout the function of a real economy. These knock-on effects occur when household consumption patterns are widened, production costs are saved by industry or subsequent profits are invested back into the economy. While there is no one solution to stop the potential for energy rebound (or as some analysts term it, policy-backfire), three issues are generally agreed upon. The first is that energy efficiency, while a reasonable goal in itself, is an extremely blunt policy or market instrument to target carbon dioxide and other greenhouse gas emissions (Brookes, 2000).

The second is that setting a physical limit on the amount and composition of carbon based energy usage will enable markets to do what they do best, i.e. to enable the allocation of scarce resources (Herring, 2000-b). The third is that current modes of employment and production in OECD countries are producing a financially rich but a time poor workforce where machines and energy are substituted for time and lifestyle (Schenk, 2000). In this last case, the traditional role of prices in controlling lifestyle requirements diminishes as the time available for consumption purposes becomes an important driver of personal consumption behaviour.

Both of the factors discussed above; the centrality of energy usage to total economic productivity and the inter-sectoral rebound effect, relate to behavioural aspects of the economy and lie outside the scenarios developed here. However, both factors have the capacity to substantially change many of the technological assumptions within the scenarios. The functional importance factor, if accepted by economic theory and implemented by policy, could cause a substantial change in the relationships between capital, labour, energy usage and material flows. The expected rebound effects of 10-30% within sectors, and potentially much larger between sectors are not included in the simulation. The additional caveat guiding this chapter is that technological innovations are maintained throughout the simulation period. This is based on an economy wide assumption that market and regulatory mechanisms have been developed which continually facilitate technological innovation. By choosing to ignore important whole-economy effects operating outside the physical modelling focus of the ASFF framework, conclusions that relate to energy use and subsequent greenhouse gas emissions can be assumed to be under-estimates of potential outcomes, rather than the opposite.

Philosophies of energy analysis

Due to the importance of energy, a number of well developed analytical approaches have been developed, all of which offer different insights depending on the boundaries of the analysis (car, house, factory, city, region, production sector, nation), the measurement units used and the intent of the analysis. Four approaches, each with a rich lineage of research and publication, are briefly described below. Information from all of these energy analysis approaches is used in this chapter to complement insights from the main analytical approach.

Process accounting

The approach used in the Australian Stocks and Flows Framework (ASFF) is centred on the physical laws of thermodynamics and mass balance (Gault et al., 1987; Perrings, 1986; Poldy et al., 2000). These laws require all key processes in the physical economy to be described in terms of the quantity and types of inputs (coal, coke, limestone, iron ore, oxygen) needed to make certain intermediate products (iron and steel), which are then used to make houses and cars. Ayres (1998) describes the first and second laws of thermodynamics as follows. The first law (or law of mass conservation) states that matter can be neither created nor destroyed. Thus, raw materials are not consumed by an economic process, rather they are processed and eventually end up as waste.

The second law relates to the progressive decrease in the quality of energy as it is used. Thus, energy materials of higher quality (coal, gas, petrol) eventually end up as waste heat that is dissipated to the environment along with combustion products. Some combustion products, such as carbon dioxide are useful to a degree, because trees and crops often have faster growth rates under higher concentrations of carbon dioxide. Innovative design approaches to electricity generation and manufacturing, for example, aim to capture and use as much of this potential energy as is possible, for useful work and heat. The central core of the ASFF approach is a relatively complex input-output table that blends raw materials and energy to form intermediate and then final products for both domestic consumption and export. Technological innovation can alter the nature and efficiency of various stages of the transformation process, and a wide range of substitutions may be available to supply the same good or service. From a bottom up or basic process viewpoint, the ASFF approach continually performs a full accounting for all steps of the energy use process, each of which must conform to realistic operational parameters set by their level of technical sophistication and the laws of mass balance and energy dissipation.

Energy accounting

Energy accounts are usually prepared by national statistical agencies to break down total energy into the usage by all relevant sectors of the economy and generate indicators for use by policy makers and industry (Bush et al., 1999; Australian Bureau of Statistics, 2000-a; 2000-b, 2001). Thus, the energy accounts for Australia in 1998 show that 4,810 petajoules were supplied domestically and 8,857 PJ were exported. Of the 4,810 PJ for domestic usage, 1,587 PJ were used in energy conversion processes, mostly to generate electricity. The final or end use of energy was apportioned to agriculture (68 PJ), mining (265 PJ), industry (1,036 PJ), transport (1,202 PJ) and buildings (650 PJ), to give a final direct usage by various consumers and industries of 3,223 PJ. Different statistical measures such as the gross domestic product can be combined with energy statistics, to derive an energy intensity of GDP which has declined from 9.56 PJ per billion dollars of GDP in 1993 to 8.52PJ/$bn in 1998.

Embodied energy analysis

A further development of energy accounting called embodied energy analysis is used to analyse the flows of energy from one economic sector to another as various processes of production are brought together to form final goods and services. This process was developed by analysts (Bullard and Herendeen, 1975; Herendeen and Sebald, 1975) following oil market crises in the early 1970s, but its antecedents can be traced back to the principles developed by Leontief (1966) which underpin the national accounting principles used in all developed economies. The national input-output tables which describe the flows of dollars between economic sectors are integrated with the national energy accounts to apportion energy to each economic sector, and from there the inclusion or embodiment of energy in the dollar value of final goods and services can be derived (Common and Salma, 1992; Lenzen, 1998-a). Typically, the procedures can attribute five levels of linkage from direct to quite diffuse levels and account for more than 95% of energy use in each sector. At a whole economy level, embodied energy analysis replicates the national energy accounts but gives additional insights. For example, the energy embodied in Australia's exports (1,379 PJ in 1992/93) was roughly in balance with the 1,222 PJ embodied in imports (Lenzen, 1998-a).

The sectoral intensities expressed as megajoules (Joules*10^6) per dollar of GDP (MJ/$) are perhaps more interesting from a technical point of view. The Lenzen (1998) analysis shows that agriculture requires 15.9 MJ per dollar of output compared to 55.9 MJ for clay products and 61 MJ for basic non-ferrous metals. By comparison, the service economy including sectors such as education, banking, and community services have energy embodiments that range from 5.5-9.6 MJ/$. This approach is also used in building design where detailed life cycle analysis of building materials is used to compute the total energy embodied in construction activities (Treloar, 1997).

E<u>m</u>ergy analysis

E<u>m</u>ergy analysis is an environmental accounting approach that was developed to include environmental inputs, that are otherwise regarded as free inputs into the human production system. E<u>m</u>ergy refers to energy memory and the accounting procedure includes natural sources of energy such as deep heat from the earth's crust, wind, precipitation and flows from rivers and tides. In the case of coal, oil and gas resources, an e<u>m</u>ergy approach traces the development of these resources back to the original joules of solar energy that grew vegetation and the energy from the earth's core that eventually helped form an energy deposit. By converting or transforming all contributions to production systems back to a benchmark of solar e<u>m</u>joules (joules from the sun), e<u>m</u>ergy analysis seeks to provide a universal measure of real wealth of human society from a common basis (Scienceman, 1987; Brown and Ugliati, 1997; Odum, 1996; Odum, 1998; Odum et al., 2000).

A preliminary emergy analysis for Australia in 1990-91, (Scienceman, pers. comm.) found that 3.5 times more emergy was exported than imported, yet this was not reflected in international monetary transfers where the balance of payments was negative in the long term. The emergy theory of value proposes that low monetary prices paid for Australian exports reflect a failure to value a wide range of free environmental inputs that are included in wood, grain, meat, fibre and mining products. Although 88% of the total emergy used in Australia was derived from within the national boundary, more than 70% of that total was obtained from outside the monetary economy, i.e. a free good from the biosphere. A focused emergy study on the benefits derived from a barrel of oil suggest that the consumer is obtaining ten times more emergy than they are paying for at a cost of $US30 per barrel. This times-ten factor concurs with the findings of Kummel and Linderberger (1998) discussed in the introduction to this chapter. The potential implications of this method of environmental accounting, for issues surrounding sustainability are enormous, and lie well outside the scope of this particular study.

ASSUMPTIONS USED IN THIS CHAPTER

This chapter begins the task of synthesis from the perspective of energy requirements for the three population scenarios. The key elements already described in the previous chapters include:

- The three population scenarios and associated consumption demands
- Domestic and international tourism and travel related to that sector
- The requirement for domestic housing, commercial buildings and institutional space
- The requirements for personal transportation, intra-city delivery and intercity travel and freight
- Domestic and export requirements from the primary industry sectors

This chapter makes some new assumptions not discussed previously. These include the prospective gains in the efficiency of thermal electricity plants, the nature of material and energy requirements in the material transformation and industrial sectors, and compositional change in primary energy sources. Appendix 1 includes details of these additional assumptions.

ISSUES FROM THE DIMA WORKSHOP SERIES

In preparation for the design and testing of the population scenarios with ASFF, a workshop series was conducted in 1999 (Conroy et al., 2000), to critically review the structure of the analytical framework and the implementation of the scenarios. Energy was the pervasive theme in most physical economy sectors examined. Six issues arising from the workshop, together with the scenario implementation response are described briefly below:

- The technical and political acceptability of the concept of limits to high quality energy stocks (oil and gas) was a common theme for discussion at many workshops. While the concept of 'running out of' is an anathema to technological optimists, it is considered under the ASFF analytical approach. Eventually it may be necessary to chose between the new sources of transport energy (shale oil, methane hydrates, ethanol and methanol from biomass) and traditional oil from the Middle East and the new modes of transport technology (hypercars, buses, light and heavy rail, virtual tourism and meetings). All of theses choices have more and less positive consequences. The most optimistic interpretation of the middle probability (50%) for traditional oil and gas from the Australian Geological Survey Organisation was used to implement the population scenarios. When domestic oil and gas stocks started to become constrained in Australia, the additional requirements were sourced from international trade and were automatically imported and accounted for by the physical trade calculator.

- The transition to completely different energy supply systems dominated by solar photovoltaic, solar thermal, wind power and distributed generation systems was suggested as an obvious transition route for a new energy economy in Australia. While this presents an attractive option to the philosophy behind the ASFF approach, the pragmatic realism implemented in the scenarios is that fossil fuels have a commanding cost advantage in today's Australia. As a starting point for the population scenarios, it was assumed that brown and black coal thermal electricity would retain this cost and market advantage for the duration of the simulation period during which technological improvement would see them reaching their thermodynamic limits for generation efficiency.

- Some workshop attendees argued that the response of Australian consumers to price incentives and market mechanisms, which help improve energy end use efficiency, was a logical way ahead to help resolve tension between the (increasing) use of fossil energy and the international pressures from greenhouse gas politics. In implementing the population scenarios, most technologies and end uses of energy were incrementally improved to meet reasonably accepted standards. However personal consumption areas such as tourism, vehicle use, human diet, domestic housing and so on were not constrained, and some areas grew in line with industry expectations. This is a difficult area to explore in practical and political terms and some key issues are discussed (but not simulated) in this chapter.

- Workshop opinion commonly argued that progressive increases in energy efficiency for consumer appliances (motor vehicles and home fittings) and major industrial processes (concrete, aluminium, steel) would allow fossil energy use to be stabilised and then reduced as these items eventually dominated the technological stocks. The efficiency approach is widely accepted by both policy circles and environmental experts. The scenarios have implemented energy efficiencies in line with industry recommendations and expert opinion. However the introduction of energy efficiency alone, ignores the "inter-sectoral rebound effect" or the "Jevon's Paradox" which shows that efficiencies applied to one sector give savings which then stimulate growth in another sector and more energy use. Airline travel is a good example of this effect. The rebound effect has not been simulated in these population scenarios so energy use and greenhouse gas emissions are therefore underestimated. Policy innovations such as 'cap and trade' arrangements, that are being used in Australia's water industry, may serve to stifle the rebound effect but these policies have not been realistically canvassed to date in the energy sector.

- A transition to the hydrogen economy was often suggested as a way to decarbonise the whole economy and decouple it from the negative consequences of fossil energy use. The scenarios did not implement the hydrogen economy as hydrogen is an energy carrier rather than an energy source. This means that the hydrogen must be obtained from somewhere, the usual source being natural gas, itself a fossil energy source. Hydrogen fuel is an attractive fuel option for transport in cities as water vapour is the only product from its combustion. Only countries such as Iceland, with large hydro resources in relation to a relatively small population, can envisage making the transition to a full hydrogen economy that is relatively carbon neutral in a global sense.

- Some workshop views argued that the greenhouse gas policy issue will eventually drive Australia's energy sector towards major breakthroughs in both energy supply technologies as well as consumer behaviour and the cars, appliances and machines that use energy to supply goods and services. The scenarios were implemented with two approaches. The starting point assumed steady technological improvements (lower energy use per unit of good or service delivered) for most major items of infrastructure and service, but without radical restructuring of society. In addition, sub-scenarios were developed around high-tech and low-tech approaches to energy use as well as a factor-4 transition which restructured a set of major material transactions underpinning the physical economy.

The following sections now detail and discuss the results of the simulation analyses for the energy sector and greenhouse gas emissions.

TOTAL ENERGY USE

By the year 2050, the use of primary energy will continue to increase from current levels of 4,810 PJ per year to 6,000 PJ/year in the zero scenario, 7,000 PJ/year in the base case and 8,300 PJ/year in the 0.67%pa scenario (Figure 5.1). Thus, the primary population effect is obvious by the end of the simulation period with plus or minus 1,000 PJ/year representing the lower and upper population cases on either side of the base case. Note that energy usage continues to increase even with the declining population size in the zero scenario. This is due to development and expansion of the physical economy to accommodate issues of scale and lifestyle (a secondary population effect) and issues of international trade (a tertiary population effect).

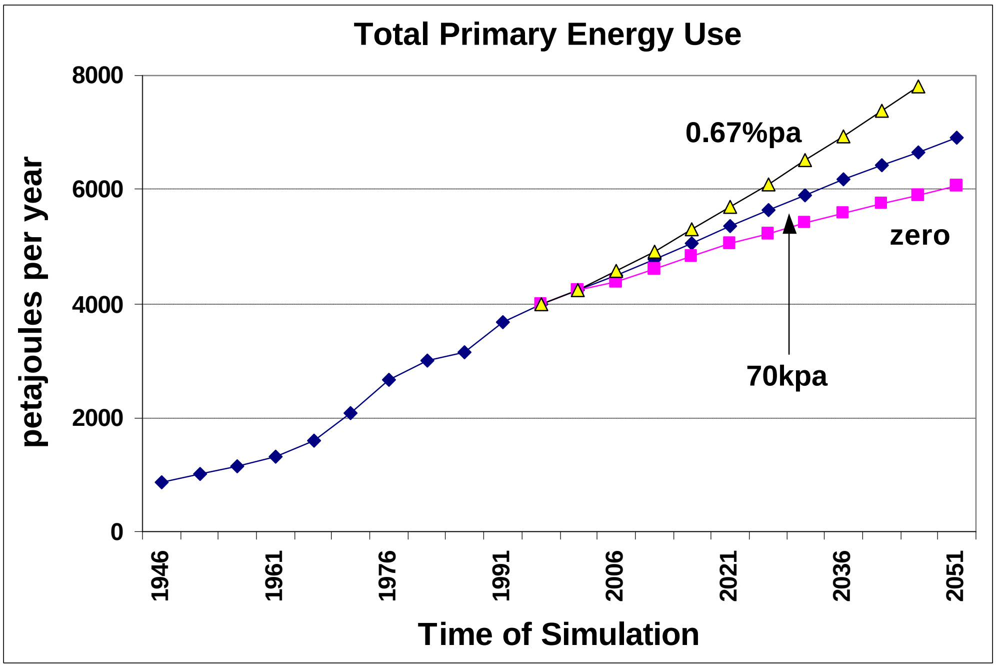


Figure 5.1. Total primary energy use in petajoules (10^{15}J) per year to 2050 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

.

While energy use by itself is not necessarily an environmental negative, the issues of long-term security of high quality energy supplies and emissions of combustion products derived from energy use, particularly carbon dioxide and other greenhouse emissions are environmental concerns. Sub-scenarios developed around these issues portray a range of feasible technological approaches to reducing energy usage but herein lies a quandary for modern economies. Energy use is central to economic growth and societal development (Kummel and Linderbeger, 1998; Cleveland et al., 2000; Lenzen, 1998-a).

Reducing the use of energy will disadvantage a wide range of energy producing industries which aim to maintain high quality, low-cost supplies. Increasing the relative cost of energy to consumers so that it bears a reasonable relationship to its usefulness in productivity terms could stimulate a profound structural change in the nature and function of all developed economies. The implications of the analysis presented in Figure 5.1, are supported by recent population and greenhouse gas studies in Australia (Turton and Hamilton 1999; Hamilton and Turton, 1999). Their study used similar zero and base case scenarios to the ones in this analysis, but assumed a net immigration rate of 140,000 per annum for the high immigration scenario. While it only ran to 2020, their analytical outcomes are remarkably consistent with this study.

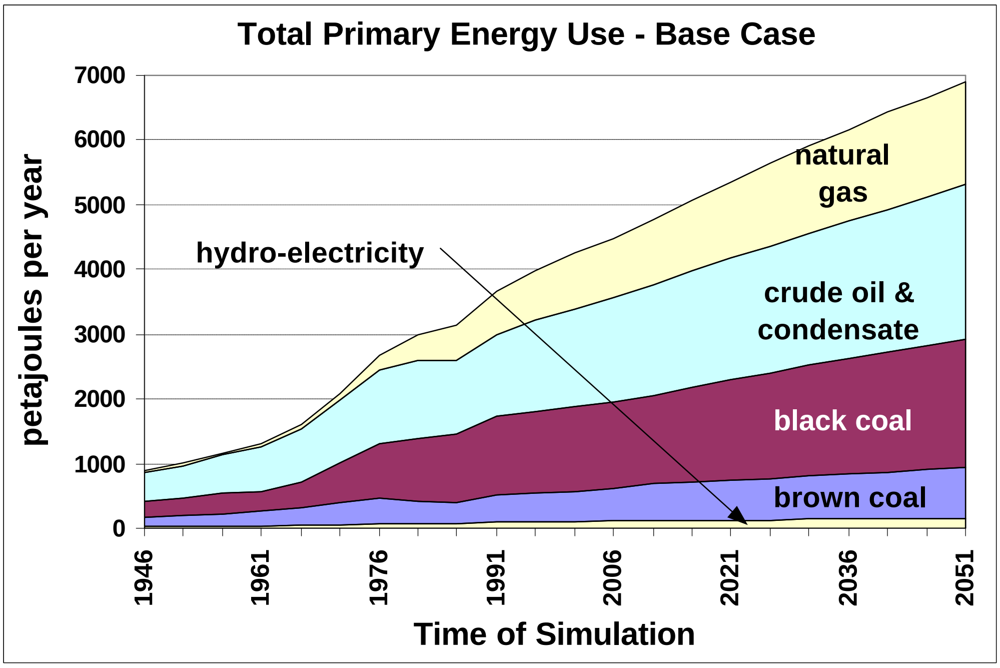


Figure 5.2. Total composition by fuel type of total primary energy use in petajoules (10^{15}J) per year to 2050 for the base case population scenario. The zero and 0.67%pa scenarios will be similar in composition but different in magnitude (see Figure 5.1).

The breakdown of primary fuels used to supply energy services is shown for the base case in Figure 5.2. The physical requirement for all fuel types expands in line with the assumed requirements by end users. Natural gas supplies 22% of the total energy requirement by the end of the simulation period. This may be less than anticipated considering its value as a lower carbon fuel and the potential for carbon taxes to disadvantage coal powered thermal electricity plants. However the DIMA workshop series (Conroy et al., 2000) reinforced the potential for both brown and black coal fired electricity to maintain their competitive position and for technological innovations to increase their thermal efficiency. Hydro-electricity and renewables undergo moderate expansion and while the potential for wind and solar technologies is large, the pragmatic assumption in the base case is that fossil fuels will continue to dominate.

USE BY SOURCE OF ENERGY

The use of each main fuel type is broken down by end users for the base case scenario in Figure 5.3. For liquid petroleum fuels, energy for motor cars begins a slow decline after 2010 when the effect of engine technologies allowing 6 litres per 100 kilometres for the whole vehicle fleet begins to permeate the total stock of vehicles. Other modes of transport dominated by the freight sector expand considerably as intercity transport and exports of bulk freight commodities are delivered to ports. The number of departing international air travellers and visitors returning home, also increases liquid fuel requirements. Other sectors, such as primary and secondary industry, and buildings and construction, do not increase liquid fuel usage appreciably.

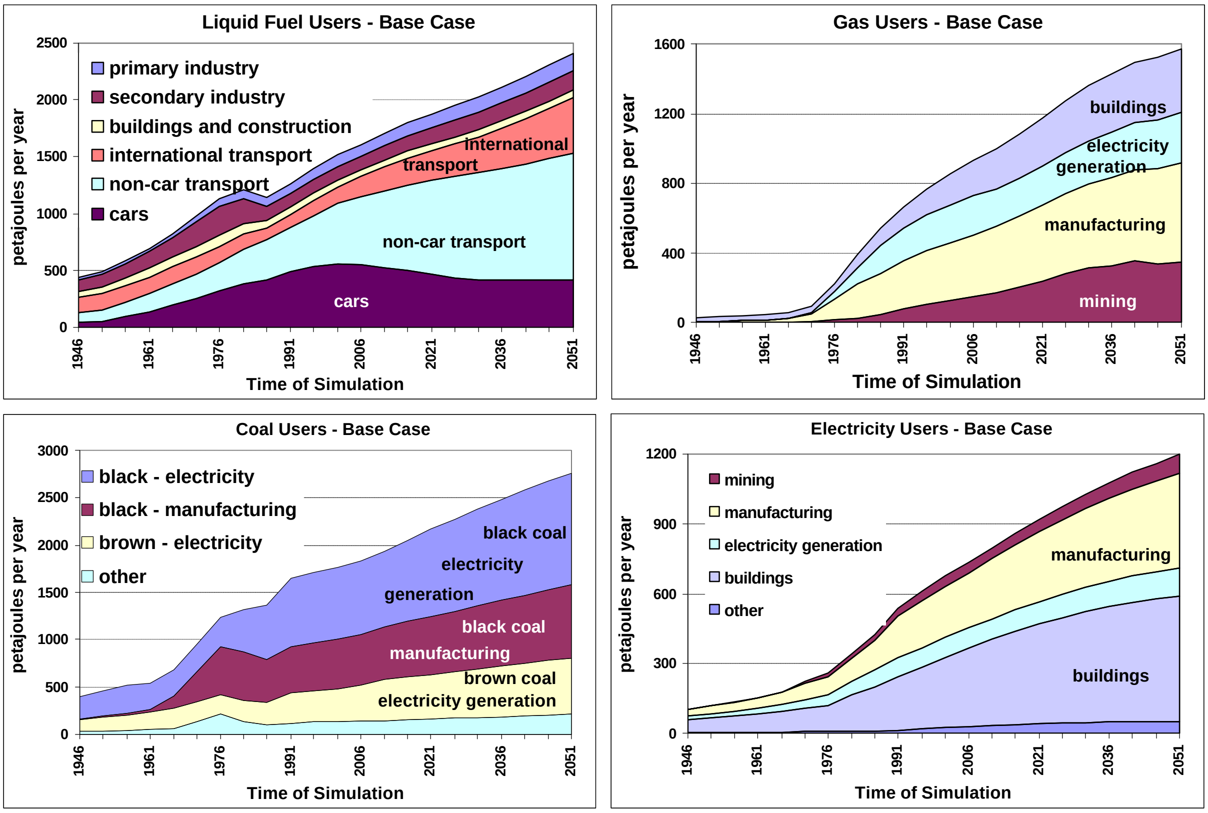


Figure 5.3. The usage by important sectors of different fuel types: liquid fuels, natural gas, coal and electricity in petajoules (10^{15}J) per year to 2050 for the base case population scenario. The zero and 0.67%pa scenarios will be similar in composition but different in magnitude (see Figure 5.1).

The use of natural gas increases appreciably in buildings, manufacturing and mining, and to a lesser extent, for electricity generation. It is possible that significantly more gas may be required to generate electricity in the next 50 years through greater use of distributed gas turbines or even more widely distributed fuel cells for electricity and heat generation at the level of the household or the suburban block. Plans for the addition of new fossil fired generating capacity include 5,000 MW of coal fired and 6,000 MW of gas fired plant under consideration (Environment Australia, 1999). One of the rationales for retaining coal fired plant as the dominant technology in the base case is that natural gas supplies in eastern Australia may become constrained in the next 20 years although large stocks would still remain on the North West Shelf of Western Australia. The possibilities that pipelines might connect the western and eastern parts of the country, or that natural gas might be retained for higher-value uses such as buildings and specific industries will be left to market dynamics to decide. Large stocks of black and brown coal exist in eastern Australia and these stocks underpin the rationale to retain natural gas as a moderate contributor to electricity generation.

Both black and brown coal electricity generation dominate the use of coal, with brown coal expanding less than black coal because its use is restricted to Victoria — although other deposits occur in Tasmania, South Australia and Western Australia. Most of the coal shown for manufacturing is used in metal smelting and reforming such as iron and steel, and the manufacture of cement, glass and ceramics. Buildings and manufacturing are the dominant users of electricity, accounting for over three quarters of its usage by 2050. The use of electricity within the electrical users' data graph (Figure 5.3) is related to the electricity required to run pumps, conveyors and pollution equipment within electricity plant, as well as transmission loss along power lines.

THE PHYSICAL COST OF ENERGY EXTRACTION

Central to the analytical procedures used in process analysis, is the assessment of the physical requirements for the extraction of raw materials, and how that process varies over time as particular petroleum basins or ore bodies become depleted. The simulated relationships for Australia's oil and gas reserves are shown in Figure 5.4. After 2030, the energy required to extract and produce oil (not including refining) will approximately equal the energy extracted. For natural gas, this break-even point occurs in the mid 2050s. It is worth noting that substantial stocks of oil and gas are still available at the crossover points. The discovery of more accessible oil and gas resources, that are cheap to produce from a physical as well as a monetary point of view, will delay the timing of the crossover point.

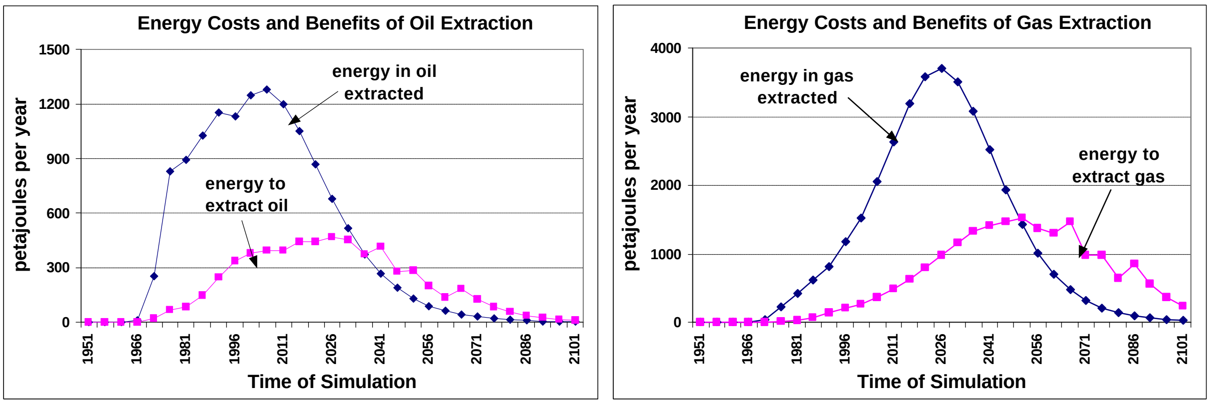


Figure 5.4. The simulated energy cost of energy production for oil and natural gas to 2100 in petajoules (10^{15}J) per year.

There may be strategic reasons to continue producing oil and natural gas under these physically constrained circumstances and to facilitate cross subsidies of other energy sources such as coal and electricity in order to maximise the physical production of high quality liquid and gaseous energy. It is reasonable to assume that technological innovations will change the extent and timing of these curves. However, as noted in the 'embodied energy' and 'emergy' sections of the introduction, physical economy analysis reveals many complex linkages that otherwise remain hidden. Financial arrangements at a macro-economic level that allow development grants, 'tax holidays' and fuel rebates (APPEA, 2002) can be interpreted in part, as the degree of physical difficulty associated with the exploration and production processes.

The terms 'energy profit ratio' (EPR) (Fleay, 1995), 'energy return on investment' (EROI) (Cleveland et al., 2000; Hall et al., 1986) and 'emergy yield ratio' (Odum, 1996) have been used to describe the energy cost of energy with particular emphasis on energy extraction and production. Cleveland et al. (2000) present a time series for 1950 to 1990 for petroleum extraction in the USA showing that EROI has declined from a maximum of 20 in 1970 to a level of 10 today (i.e. 10 units of energy output are obtained for one unit of energy input). Hall et al. (1986) display data for Louisiana oil and gas extraction showing a peak EPR of 36 (36 units of output for one unit of input) when 75% of the resource was extracted followed by a sharp decline to zero. Odum (1996) quotes 'emergy yield ratios' of Texas crude oil (3.2), imported Middle East oil (8.4), on-shore Texas natural gas (10.3) and off-shore Texas natural gas (6.8). The ratios for both oil and gas for Australia are currently below 10 according to this simulation.

In the absence of detailed analyses to substantiate the simulated results, there is reasonable agreement with the theory of physical depletion as well as a range of published figures from similar production situations. In unpublished studies using the embodied energy approach on the Australian 1994-95 national input-output tables Lenzen (2001) derived the equivalent of EPR and EROI ratios for black coal (45), crude oil and condensate (12), natural gas (15), liquefied natural gas (13), brown coal (50) and the national electricity system (0.33). While these are based on a hybrid analysis of monetary and energy data and are not based on direct physical analysis, they nevertheless represent the correct orders of magnitude in relation to the fuel types and the international literature. Because of the possibility that future EPR and EROI ratios may become constrained to the levels implied in Figure 5.4, physical energy profit accounting procedures should complement monetary accounting procedures for all important energy companies and for overall national accounts. These EPR/EROI rates are as important for the feasibility of future energy planning as interest rates and discount rates are for any business planning.

ELECTRICITY GENERATION

Since electricity generation remains a major consumer of coal and was responsible for 37% of national greenhouse emissions in the 1998 national greenhouse gas inventory (Australian Greenhouse Office, 2000), the future thermodynamic efficiency of the main electricity generating technologies is important (Figure 5.5). Under optimistic assumptions, thermal coal advances to 45-50% efficiency and gas turbines to 65% efficiency by 2020.

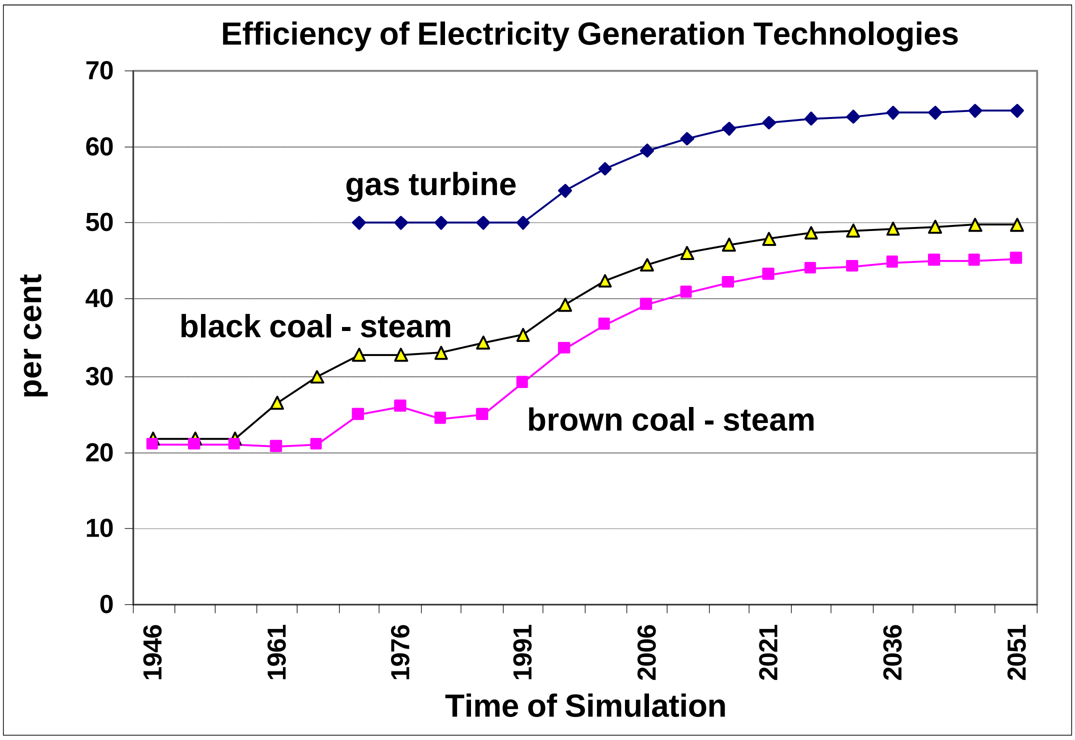


Figure 5.5. The assumed increases in process efficiency (percentage petajoules of electricity generated to petajoules of primary fuel type used) to 2050 for gas turbines, and thermal black and brown coal.

As these efficiencies are progressively applied to new electricity generating stock, the model simulates the requirement for the delivery of primary fuels (Figure 5.6). Black coal continues to represent more than 50% of total primary energy for electricity followed by brown coal and then natural gas. It is possible that markets and regulations could substantially change this representation of primary fuel requirements. The Council of Australian Governments (COAG) electricity and gas reforms (Australian Bureau of Statistics, 2000-c) could allow electricity from brown coal mainly from Victoria to compete with black coal generators in other states as the national electricity grid becomes fully functional. The introduction of carbon taxes would benefit gas generators and improve the opportunities for the introduction of renewable electricity technologies, currently a small proportion subsumed in the hydro category. The use of oil for electricity generation continues as a small proportion for diesel electricity generation in isolated towns and communities. At present oil prices, wind generators and some integrated solar electricity modules are cost competitive with small diesel generators (Department of Industry Science and Resources, 2000-a), and therefore the balance between oil and renewables may alter in the next 30 years. It is possible that hydro-electricity may increase but there are physical and political constraints to large increases in capacity.

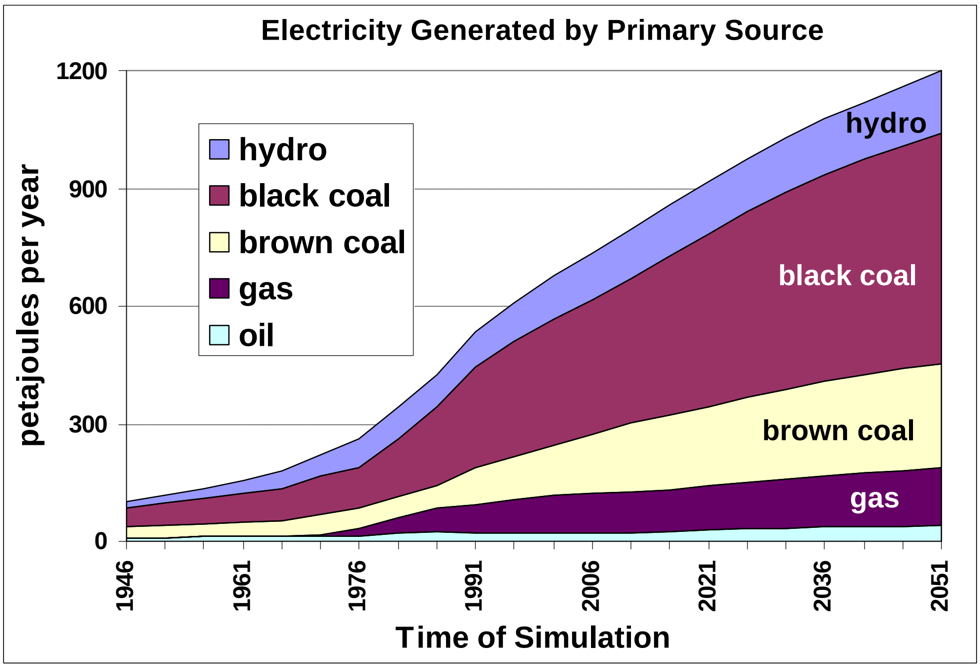


Figure 5.6. The primary fuels used in electricity generation to 2050 for the base case scenario in petajoules (10^{15}J) per year.

OVERALL USE BY SECTOR

The increasing requirement for high quality energy in the form of electricity will continue to represent the largest component for primary energy (about 30% in 2050) (Figure 5.7). Manufacturing and non-car transport are the next biggest sectors, representing about 20% each by 2050. With the exception of car transport, all sectors continue to expand in their requirements for primary energy, in spite of reasonably optimistic technological assumptions included in the base case. Figure 5.1 showed the overall difference between the scenarios and that energy use does not plateau in the zero scenario, because of the continuing growth in export orientated sectors. In the base case for cars, the technological assumptions for engines and fuel usage drive general decline from 2020. A period of stability then ensues where the population stability and the requirement for cars and vehicle kilometres, are kept in balance by advancing technology. However for the 0.67%pa scenario, the effect of car technology has saturated by 2030 and a growing population continues to increase the requirement for liquid hydrocarbons. The increase in energy use in the primary industry sector is driven mainly by an increase in activity in the mining sector.

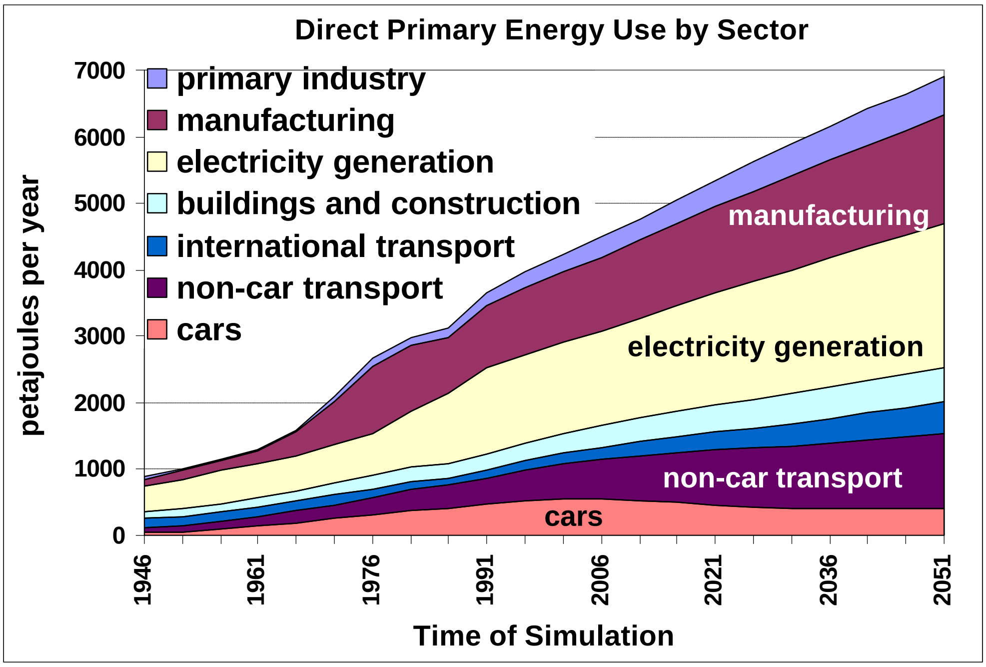


Figure 5.7. Breakdown of total energy use by important sector to 2050 for the base case population scenario. The zero and 0.67%pa scenarios will be similar in composition but different in magnitude (see Figure 5.1).

CARBON DIOXIDE EMISSIONS FROM ENERGY USE

Emissions of carbon dioxide from the energy sector continue to rise until 2050 for all population scenarios (Figure 5.8). Driven by the assumptions on fuel mix, physical activity and future technological transitions, emission levels at 2050 are 475, 541 and 651 million tonnes per year for the zero, base case and 0.67%pa scenarios respectively. These values represent 167%, 190% and 229% of the 1990 emission levels which are used as the benchmark for the international political negotiations on greenhouse gas emissions. By 2010 when progress in greenhouse emission reductions will be evaluated as part of the Kyoto Protocol, carbon dioxide emissions from the energy sector may be 27%, 32% and 36% above the 1990 levels for the zero, base case and 0.67% pa scenarios respectively.

The 1998 National Greenhouse Gas Inventory (Australian Greenhouse Office, 2000) reported that carbon dioxide emissions from the energy sector in 1998 were 363 million tonnes, or 21% above the 1990 levels. The results in this study are conservative for two reasons. The first is that the base case assumptions do not adequately represent some aspects of economic growth as it relates to emerging areas of personal consumption and the subsequent effect on energy usage. The second is that many of the technological assumptions in the base case are optimistic and reflect the continual application of best practice in a range of important areas such as electricity generation and motor car engines. Also, as noted in the introduction, the base case assumptions deliberately avoid a number of well documented aspects of consumer behaviour such as the inter-sectoral rebound effect. For these reasons it is possible that real world outcomes for greenhouse gas emissions will be appreciably higher than those presented here. One 'low tech scenario' presented in the next section gives carbon dioxide emissions from the energy sector by the year 2050 of 188%, 215% and 260% of the 1990 levels for the zero, base case and 0.67%pa scenarios respectively. Another physically based modelling framework, *OzEcco*, using the embodied energy paradigm of analysis (described in the introduction), gives carbon dioxide emissions from energy use at 2050 of more than 1 000 million tonnes or 300% of 1990 levels (Foran and Crane, 1998, 2000; Foran and Mardon, 1999). This embodied energy modelling approach allows the physical economy to grow as fast as fossil energy supplies allow, and also allows the rebound effect to occur automatically. These parallel studies support the judgement that the analysis presented here is a conservative one.

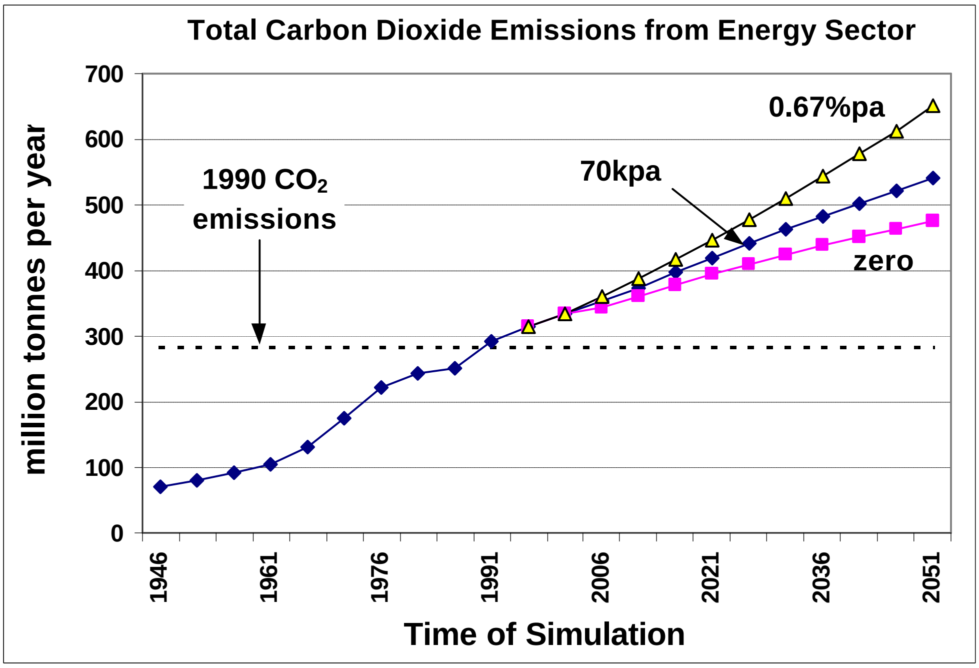


Figure 5.8. Carbon dioxide emissions in million tonnes per year from the energy sector to 2050, for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

ENERGY SUB-SCENARIOS

The oil to natural gas transition

Analyses presented in this study suggest that domestic supplies of easily available or traditional oil may become constrained around 2020. A large body of work suggests that world production from traditional supplies of oil will soon peak, and that the production decline will force difficult transitions in many modern economies (Blanchard, 2000; Simmons, 2000; Duncan and Youngquist, 1998; World Resources Institute, 2001). In a local context the Australian Geological Survey Organisation (2000) notes that "by 2010 Australia will have produced somewhere between about 64% and 73% of the average estimate of its ultimately recoverable crude oil resources". Fleay (1998) quotes an industry source, The Petroleum Gazette in 1998 which shows total Australian oil and condensate production declining from the year 2000. Recent media releases from the industry (APPEA, 2002) now promote this issue more widely. Since oil is the central input into the nation's goods transport and personal mobility, the possibility of constraint represents a strategic issue that is considered in the inter-generational timeframes of this study.

The ASFF modelling approach deals with a physical deficit in a traded commodity (e.g. oil or meat) by importing it through the balance of trade calculator. This reconciles any shortfalls between domestic production and domestic requirements. Thus, no constraints are imposed on the physical capability to produce a good or a service, apart from the implications of a physical balance of trade. Alternatively, one material can be substituted for another. In the following sub-scenario for example, a transition is made from domestic stocks of traditional oil, to domestic stocks of natural gas. The guiding assumption in this case is that national self interest might ensure security of fuel for transport services and allow, or facilitate, a domestic energy market to compete effectively with export markets under a range of reasonable long-term price futures.

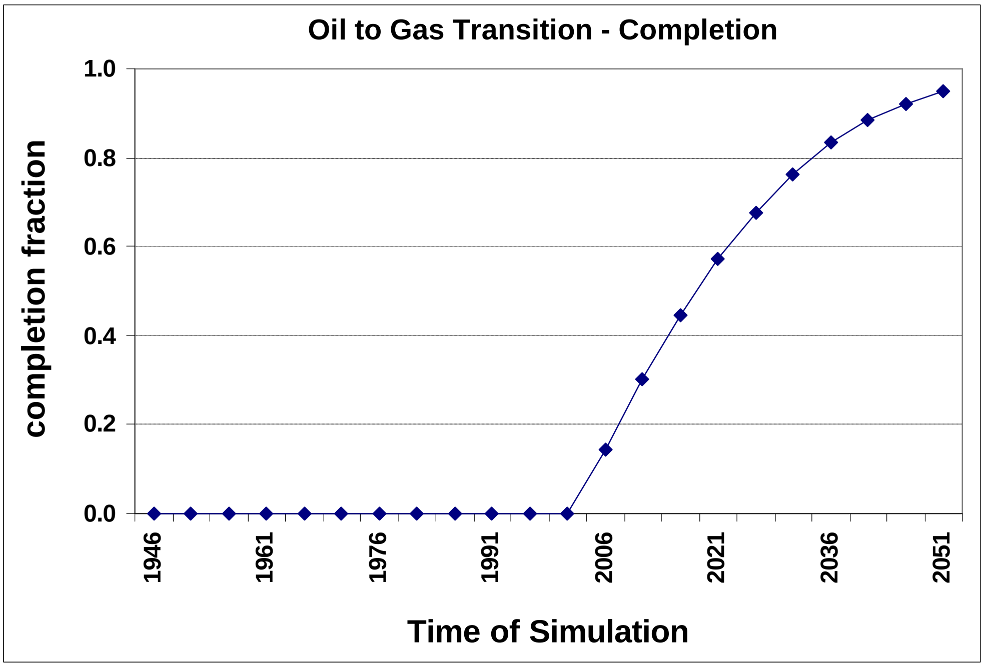


Figure 5.9. The transition over time from a total requirement for oil to its replacement by natural gas.

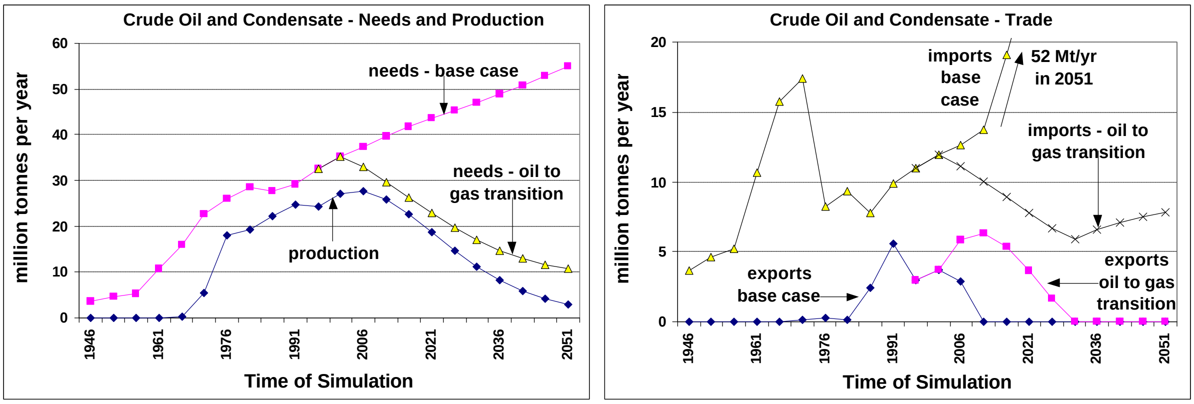


Figure 5.10. The domestic requirements and production of oil and condensate (a) and the flow-on trade implications (b) for the base case scenario and the 'oil to gas transition' sub scenario to the year 2050.

A simulated run down of domestic oil production as the energy profit ratio approaches 1 guides the transition (Figure 5.9). Natural gas replaces oil only as a source of energy (eg not bitumen for roads which is classed as a material and still imported). The transition is nearly 50% complete by 2020 and is 95% complete by 2050. The oil to gas transition is a reasonably easy one as much of the technology exists today and the main actions required to stimulate it are organisational and market based, rather than a requirement for a technology breakthrough. Natural gas as a fuel offers a 26% reduction in carbon dioxide and potentially 70% reduction in other emissions compared to petrol and diesel (Black et al, 1998; Di Pascoli et al., 2000; Maclean and Lave, 2000; Yu et al., 2000; Strickland, 2000). Generally, motor cars can be retrofitted to run on compressed natural gas (CNG) for under $2000. Volvo markets a wide range of bi-fuelled vehicles, including cars and buses that run on petrol or diesel and compressed natural gas (Volvo, 2000) and most vehicle manufacturers will probably follow this lead in the next decade. Countries such as Argentina (450,000 vehicles), Italy (320,000) and the USA (90,000) have large CNG powered fleets and New Zealand was once a leader in CNG technology (a number of political and market changes have halved CNG outlets there in the last decade). Liverpool City Council in Sydney, with a number of other organisations, is promoting the use of CNG in an attempt to combat the growing problems of vehicle emissions in Australia's city airsheds (Liverpool City, 1998).

For the base case to 2050, the requirement for oil grows from 30 million tonnes currently to more than 50 million tonnes per year. Domestic production peaks at about 30 million tonnes per year between 2000 and 2015 (Figure 5.10). The increasing gap between simulated production and simulated requirements grows to the full 50 million tonnes per year towards the end of the simulation period. Under the oil to natural gas transition the relationship between needs and production narrows to no more than 5 million tonnes per year as natural gas technology is fed into the transport system. Up until the early 1970s, Australia imported most of its oil requirements but even as the nation approached oil self sufficiency, imports and exports still took place as market opportunities arose and the lighter Australian crude oils were sold for lubricants, bitumens and specialist feedstocks. Continuing imports and exports are still assumed under the oil to gas transition, which enables oil exports to continue until 2030.

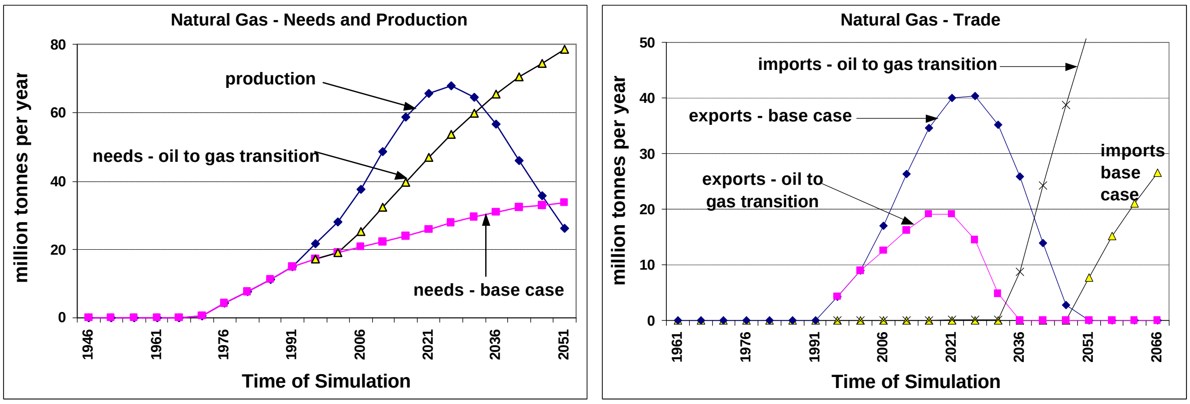


Figure 5.11. The domestic requirements for natural gas, and associated trade implications for the base case scenario and the 'oil to gas transition' sub scenario to the year 2050.

Under the base case, without the oil to gas transition, domestic natural gas requirements reach 35 million tonnes per year by 2050 (Figure 5.11). However in the interim period, the gap between gas production and domestic gas requirements allows a peak of potential exports of 40 million tonnes per year in the mid 2020s. Recent exports of liquefied natural gas stood at 3.4 million tonnes per year (ABARE, 1999) and projections from Bush et al. (1999) suggest that 23.5 million tonnes per year could be exported in 2015 (1,278 PJ at 54.4 PJ per million tonnes). Industry sources describe potential doubling of export capability every four to five years with each gas train (the plant to liquefy natural gas) able to process 3.4 million tonnes per annum (Woodside Petroleum, 1998). To achieve the maximum export tonnage would thus require 12 gas trains at peak development which is entirely feasible. Government sources note the potential for exports of 25 million tonnes per annum worth five billion dollars (Department of Industry Science and Resources, 2000-b). The gas export tonnages within the scenario are thus reasonably consistent with industry and policy views, but most of those views judge natural gas to be a continuing flow rather than an eventually constrained stock.

Under the oil to gas transition, gas exports are halved to peak at 20 million tonnes per annum in the mid-2020s with the remainder of production being taken up by the transition process. A possible constraint on natural gas supplies emerges after 2030, or one human generation away from now based on estimates from the Australian Geological Survey Organisation (1999) (Figure 5.11). Under the simulation of the base case (without the oil to gas transition), the natural gas constraint does not emerge until 2045. Inevitably the details of the sub-scenario could change appreciably as more reliable estimates of oil and gas stocks become available, and as new oil and gas reserves are discovered and brought into production. Industry information notes that Australia has "Proven and probable natural gas reserves of 92,063 PJ - equal to about 92 years supply at current production levels" (Australian Gas Association, 2000). This statement, if interpreted optimistically, might lead policy makers and industry leaders to ignore the potential for growth in exports, and the consequent long-term implications for domestic requirements. A number of other energy sources could potentially replace oil, in particular shale oil (Suncor Energy, 2000), liquefaction of coal (Sasol, 2000) and alcohol fuels from biomass (Foran and Mardon, 1999), but these are not investigated in this study. A number of new power systems such as fuel cells are well advanced in prototype vehicles and major manufacturers will launch mass market versions within the next decade.

Implementing high-tech or staying with low-tech

The assumptions surrounding energy use and subsequent greenhouse gas emissions are open to considerable uncertainty driven both by global trade and political forces as well as national government policy and technological innovation. The key elements of two sub-scenarios: low-technology and high-technology are described in Table 5.1.

Table 5.1. Key elements of low-tech and high-tech sub-scenarios. All other settings remain as in the base case.

Element	Low-tech scenario	High-tech scenario
Energy use in buildings	Base case	Reduced to 50% of base case levels by 2020
Energy use by delivery vehicles	Base case	Reduced to 50% of base case levels by 2020
Energy use by motor cars	Keep at 10 litres per 100 kilometres until 2050	Reduce to 3 litres per 100 kilometres by 2020
Efficiency of black coal electricity generation	Saturates at 35%	Saturates at 48%
Efficiency of brown coal electricity generation	Saturates at 30%	Saturates at 45%

The two scenarios bracket the base case as expected (Figure 5.12). Whereas primary energy use for the technological base case (Figure 5.1) ranges from 6,000 to 8,000 PJ per year by 2050 depending on population size, the high-tech scenario at that time ranges from 5,000 to 7,000 PJ per year and the low-tech scenario from 7,000 to 9,000 PJ per year. Thus a bracket of 2,000 petajoules per year (at 2050) describes the effect of population (the range in three population scenarios) and the degree to which technology either decreases (high-tech) or increases (low-tech) the total energy requirement. The implementation of high technology policies combined with the 0.67%pa high population scenario could produce the same primary energy usage as maintaining the current technology policies with the zero population scenario.

Carbon dioxide emissions from the energy sector follow the use of primary energy and are mediated by the fuel mix described in Figure 5.2. Depending on the population scenario, the high-tech case at 2050 produces from 400 to 530 million tonnes of carbon dioxide per year, whereas the low-tech approach produces from 530 to 750 million tonnes per year. The base case ranges from 475 to 650 million tonnes per year (Figure 5.8). The ranges are slightly broader for the low-tech scenario because it uses more coal for electricity generation and this produces higher carbon dioxide emissions. In general though, each population scenario produces a zone of 200 million tonnes per year by 2050 depending on the level of technology applied. Thus aggressive implementation of currently available technologies can move the emissions zone, downwards or upwards by 200 million tonnes per year over the next 50 years. Once again, the base case scenario is judged to be reasonably conservative, and future emissions may be higher than the low-tech scenario when behavioural factors such as growth in new areas of personal consumption and intersectoral rebound are included.

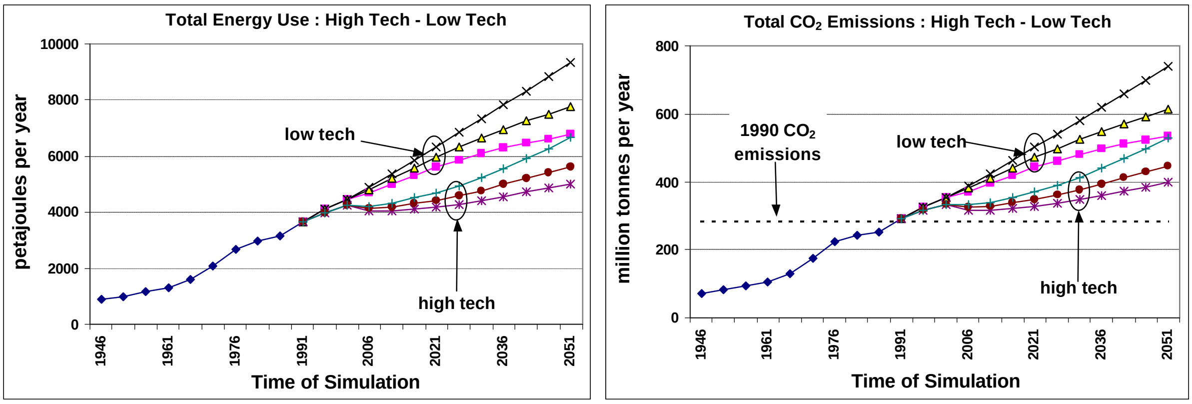


Figure 5.12. Sub-scenarios comparing total energy requirements and subsequent carbon dioxide emissions for the implementation of the 'high-technology' option or staying with the 'low-technology' option typical of the current stocks of technology.

The transition to a factor-4 physical economy

The potential factor 4 revolution was first given publicity in the seminal publication *Factor 4: Doubling Wealth-Halving Resource Use* (von Weizsacker et al. 1997) and has been followed by books such as *Natural Capitalism: The Next Industrial Revolution* (Hawken et al. 1999). The core message is that application of current technologies and knowledge can halve resource usage. By both saving inputs and attracting green market premiums, economic returns can then be doubled. If the requirement for improvement is a redesigned concept (e.g. transportation services rather than a car) there is potential for much greater savings and 'factor 10' concepts have been well documented and implemented for specific buildings and manufacturing processes. A first approximation to a 'factor 4' concept has been implemented in this study by bringing together a number of sub scenarios tested in Chapter 3. A full test of the concept should be implemented through close analysis for each individual process both in the production of materials (cement, aluminium and pulp for example) as well as in the construction of a building, the manufacture of a good or in the delivery of a service.

Table 5.2. Key elements of low-tech and high-tech sub scenarios. All other settings remain as in the base case.

All factors reduced to half of base case scenario by 2020
Building mass intensity (honeycomb concrete and bricks, substitution of materials)
Building operating goods requirement (computers, air conditioning, water)
Building operating materials requirement (maintenance, refurbishment and upkeep)
Building operating energy requirement (heating, cooling and lighting)
Building contents mass (furniture, white goods etc)
Car and delivery vehicle energy consumption (hypercar)
Car and delivery vehicle mass (hypercar and hyperute equivalents)
Fuel per passenger on international flights (bigger aircraft, more efficient and higher load factors)

The factor-4 sub-scenarios were implemented by halving the material and energy intensity in relation to the base case assumptions, for a range of big ticket items in construction and transport (Table 5.2). Building mass intensity, for example, could be halved by using more wood and iron roofing to replace concrete, bricks and tiles. Honeycombing techniques can be used to make less dense but equally robust slabs and bricks. The material intensity of carpets, furniture and equipment can likewise be halved as can the operational energy requirements for maintenance and refurbishment. The energy requirement for motor cars and delivery vehicles can be implemented as hyper-car and hyper-van technologies, but heavy trucks do not offer much scope for improvement as the continuing requirements for mechanical efficiency and company profits have ensured the progressive implementation of up-to-date technologies. International air transport is assumed to decrease its per passenger use of energy but for domestic airlines improved technologies are assumed to be taken up with rebounds due to increased frequency of services and less than optimum flight profiles.

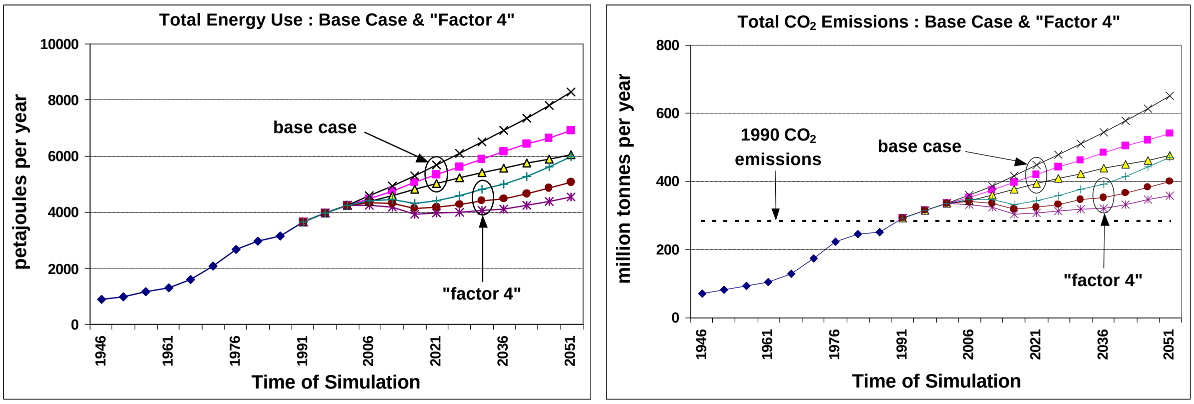


Figure 5.13. Sub-scenario comparing total energy requirement and subsequent carbon dioxide emissions for the implementation of a 'factor four' paradigm of technological change compared to the base case scenario for three population scenarios.

Implementing a factor-4 approach for a limited number of important physical transactions immediately alters the trajectories of both primary energy use and subsequent carbon dioxide emissions from the energy sector (Figure 5.13). Under the zero scenario, primary energy use stabilises by 2040 and carbon dioxide emissions are close to the 1990 benchmark year for the Kyoto protocol on global greenhouse emissions. In spite of population stability in the base case scenario, a number of secondary (lifestyle) and tertiary (export trade) effects cause energy use and emissions to rise after 2040. For the 0.67%pa scenario, primary energy usage and carbon dioxide emissions decrease initially but are driven up by population growth to levels of the zero scenario (without factor-4) by 2050. Thus by 2050, the aggressive implementation of a partial factor-four concept may allow greenhouse gas targets to be nearly achieved (for the zero scenario), or allow the energy transactions of twelve million more people (for the 0.67%pa scenario) to be less than the zero scenario without factor-4.

Many practical and academic studies offer support for the factor-4 concept as a feasible option for individual factories, houses and items of equipment. This study does not address the likelihood of such changes being achieved under the impact of changing consumer preferences, differential rates of technology uptake and economic market dynamics. The 1998 Greenhouse Gas Inventory (Australian Greenhouse Office, 2000-a) provides ample evidence for the decoupling of national policy intent and actual consumer behaviour. In spite of the opportunities for technological and consumer innovations which might use less energy, or emit less carbon per unit of electricity used, both electricity use and the carbon intensity of its production have increased. The carbon dioxide intensity of electricity production is now greater than that in the base year of 1990 because of declines in the thermal efficiency of power stations in Queensland and a greater share of brown coal electricity from

Victoria. According to the inventory, the average fuel consumption of Australia's motor car fleet (11.8-11.9 litres per 100 km) has not changed since 1990 in spite of potentially large changes in vehicle technology. The per capita use of energy for households has increased by 7% since 1990 due to more labour saving devices, a greater requirement for comfort and an increase in dwelling space. Thus the technological potential to implement a shift to the 'factor 4' paradigm exists, and practical and successful examples are commonplace. However the centrality of energy use to economic growth, and differential rates of technology uptake, present major stumbling blocks to a full transition to a factor-4 economy.

In the longer term, there may be insufficient appropriate energy technologies to implement a replacement program for fossil based electricity. As well, the incentives and penalties in place to stimulate a comprehensive change in consumer behaviour, appear to be inadequate. In principle, the institutional setting could change rapidly with a capping of fossil energy usage or a carbon tax. However, because of long lags and slow turnover of key stocks of national infrastructure, the energy and emission trajectories would respond slowly to technological innovations. An alternative approach, with a rapid change to consumption characteristics (halving vehicle kilometres by car pooling, moderating entertainment and household energy usage) could shock the balanced economic and social systems on which employment, national optimism and a civil society depend. A revolution in national perception and attitude will be required to respond to the energy and greenhouse challenge. Australia is not alone in this challenge, although some European countries such as Denmark appear to be more advanced in their perception of the problem.

ENERGY, CONSUMPTION AND LIFESTYLE

Understanding the energy implications of current consumption patterns is a necessary precursor to facilitating change in the structure and function of a modern economic system. Table 5.3 presents weekly household expenditure patterns for the 1998-99 financial year for the lowest and highest 20% of households at an aggregated national level. Energy intensity factors are assigned for each category of consumption, derived from the embodied energy analyses of Lenzen (2001); and dollar consumption is multiplied by energy intensity to derive the total energy usage implicated in these amounts and patterns of consumption, on a weekly basis, and then on a yearly basis.

The household weekly expenditure patterns of $353 and $1,826 convert to primary energy consumption at a whole economy level of 5,065 and 18,920 megajoules per household per week for the lowest and highest 20% categories respectively. These convert to values of 263 and 983 gigajoules (10^9J) per year. Thus the higher 20% group of households have yearly monetary expenditure that is 5.2 times that of the lower 20% group, and require 3.7 times the energy expenditure. Because of different numbers of persons per household in the two groups, these data convert to 173 and 295 GJ per capita per year for the lowest and highest 20% respectively. The implication is that a person belonging to a high income household is directly responsible for 1.7 times the primary energy usage of a person belonging to a low income household. In 1998, the average energy expenditure on a per capita basis was approximately 260 GJ (4,884 PJ primary energy usage, 18.75 million people).

.

.

.

Table 5.3. Primary energy consumption embodied in the weekly expenditure of the lowest 20% of households and the highest 20% of households. Table is based on 1998-99 Household Expenditure Survey (ABS, 2000-d).

Category of expenditure	Dollars for lowest 20%	Dollars for highest 20%	Energy intensity MJ/$	MJ Energy lower 20%	MJ energy higher 20%	National accounts categorisation to economy sector based on analysis by Lenzen (2001)
Current housing costs	55.1	140.9	6.5	357.7	914.4	7702 property development and real estate
Domestic fuel/power	12.9	23.1	130.0	1,670.0	2,999.5	3601 electricity supply
Food and non-alcoholic beverages	67.2	194.9	11.1	746.0	2,165.5	Average of 2102(dairy), 2103 (vegetables), 2105 (cereal), 2106 (bread)
Alcoholic beverages	7.3	40.4	3.5	25.3	141.1	2110 beer and malt
Tobacco products	6.6	12.8	3.6	24.0	46.6	2112 tobacco
Clothing and footwear	12.8	63.9	7.7	98.6	494.3	Average of 2204 (clothing) and 2205 (footwear)
Household furnishings	21.7	73.8	9.0	195.6	664.5	2902 furniture
Household operation	27.0	60.6	11.0	297.3	668.1	5402 repairs of household
Health	17.2	52.9	3.2	55.6	170.9	8601 health
Transport	48.2	208.8	21.7	1,045.3	4,532.2	6101 road transport
Recreation	37.2	165.5	6.3	235.8	1,049.3	9301 sport and gambling
Personal care	6.7	24.5	8.7	58.4	213.3	9501 hairdressing and laundry etc.
Miscellaneous	23.1	109.2	9.2	212.9	1,004.7	Average energy intensity of whole economy in 1995
Income tax	1.8	530.9	6.4	11.7	3,408.6	8101 government administration
Mortgage repayments	5.2	59.3	4.1	21.2	242.1	7301 banking
Superannuation	3.3	65.0	3.2	10.4	205.9	7302 money market corporation
Total weekly values per household	**353.1**	**1,826.6**		**5,065.9**	**18,920.9**	
Total yearly values per household	18,363	94,984		263,428	983,887	
Total yearly energy per capita within households				173,308	295,461	Lower 20% has 1.52 persons/hh and higher 20% has 3.33 persons/hh

These analyses are very approximate and should be further investigated at a finer level of detail but they make three important points. Firstly, the responsibility for primary energy usage and subsequent greenhouse gas emissions is not evenly spread across the whole population. This is also true at a global level. Secondly, obvious problems of equity need to be addressed in any policy that attempts to decrease the energy usage of households. Thirdly, Table 5.3 presents a simple static picture of the inter-sectoral rebound effect (described in the introduction) in action. As income increases, the disposable portion of it can be allocated to a wide range of energy using sectors. Although saturation effects apply (there is only so much food, beverage and health care one household or one person can consume) there are also plenty of opportunities for the energy savings from one category of consumption to stimulate energy use in another area of personal consumption.

Scientific and technical aspects of the economy-wide effects of consumption have been poorly researched for two reasons according to Princen (1999). The first is that the analysts may be members of the 'over-consuming class' themselves. The second is that seeking to change consumption patterns is analytically complex and inevitably challenges the dominant economic paradigm. Issues such as expanding globalisation, which has produced wide-ranging effects on energy use particularly in regard to the availability of goods for consumption and associated transport energy (van Veen-Groot and Nijkamp, 1999), provide further complexities.

Several European research agencies are focusing on households as the primary node of consumption in a modern economy. They propose that the system supplying household energy services and lifestyle requires radical redesign, if lowered primary energy usage and greenhouse emissions are to be attained at the level of the whole economy. The results are far from encouraging. A wide ranging social science survey found that householders in the Netherlands expected industry to design energy-saving appliances and government to implement greenhouse policies (Noorman and Moll, 1998; Noorman and Uiterkamp, 1998). However when householders were asked if they would forgo overseas holidays and private motor cars as part of their contribution to the national greenhouse effort, the response was an emphatic negative. In implementing the concepts of a materially less intensive service economy as proposed by Stahel (1994), Jansson (pers. comm.) places psychological understanding of consumer motivation at the nexus of change, rather than promoting solutions based on technology alone.

In addressing patterns of individual consumption in Australia in 1993-94, Lenzen (1998-b) began by stating, "living means consuming and consuming requires producing consumer items…". He found that per capita requirements of direct energy (electricity and gas for homes, petrol for cars) saturated with minor differences between different per capita expenditure levels shown in household expenditure surveys. However, the energy embodied in non-necessities and luxuries continued to increase with per capita expenditure. For the 1993-94 input-output tables, per capita expenditure of $10,000 equated to 75 GJ of primary energy consumption, whereas per capita expenditure of $28,000 equated to 280 GJ per year. This simple breakdown of primary energy consumption into necessities and non-necessities, provides some insights into the vital linkages between population growth and energy usage.

Support for increasing population size could be expected to come from those industries with limited export potential and where consumption levels (and therefore energy use) saturate independently of per capita income. These industries have limited opportunities to expand other than by population growth. For the previous generation, a number of constraints were imposed on luxury consumption, by taxation of middle incomes, the cost of rearing children, and a limited number of opportunities to progress to top income levels. In the next generation, promotion of a consumer lifestyle attempts to maximise consumption activities and lifestyle options where saturation effects are less obvious (The Australian, 2000). Household sizes and human birth rates are dropping. These trends limit opportunities for growth in the easily saturated industries (basic foods, print media, basic household fittings) but stimulate less necessary and/or luxury consumption in other related sectors (eating out, high definition television, spa baths). Primary energy usage and greenhouse emissions can only increase under these driving forces. The introduction of 'cap and trade' policy innovations for energy use, or a change in society's views on the physical nature of affluence and lifestyle may offer alternatives that are worth evaluating.

In attempting to deal with this quandary, Dey and Lenzen (1996) suggested that a globally responsible level of fossil energy use (where less affluent countries increased their per capita use and more affluent countries decreased it) in Australia might be about 50 GJ per capita per year. Changing to this level required a predominantly vegetarian diet, a large reduction in energy-using household appliances, reliance on public transport and no private cars, and a large reduction in expenditure on personal consumption. Similar proposals for Australia and other developed economies, have been described by Trainer (1995, 1996) and Jackson and Marks (1999). Their central proposal is that cities must be de-constructed into numerous self sufficient villages where human labour replaces machines for many household and community chores, and where interactions with the monetary economy are moderated. Societal futures such as these depend on advanced technology for communications and information exchange in ways that are not incompatible with the 'natural capitalism' concepts proposed by Hawken et al. (1999). However Trainer and colleagues deliberately attempt to decouple the monetary and physical economies whereas the followers of natural capitalism believe that innovation and correct design principles will win the day. Contemporary society will probably find the latter approach more palatable, although the former has many thoughtful adherents, particularly when preparing for a world with the possibility of constrained supplies of oil, and eventually natural gas.

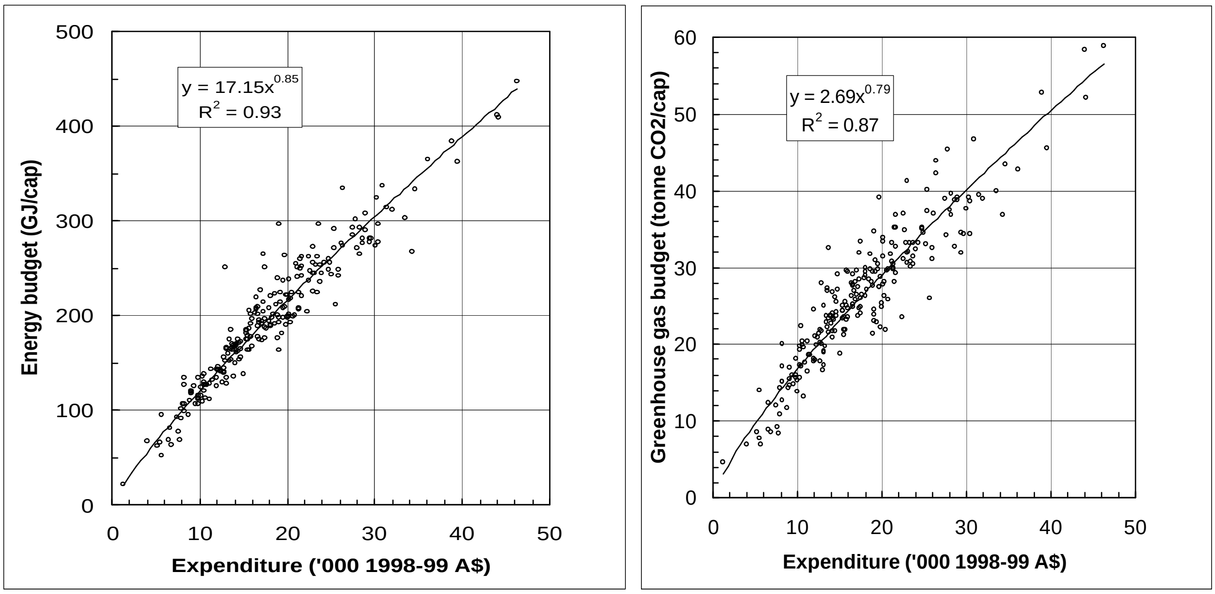


Figure 5.14. The per capita energy budget (GJ per capita) (a) and the per capita greenhouse gas budget (tonnes per capita) (b) for per capita consumption expenditure for the household expenditure survey in dollars ('000) in the greater Sydney area in 1998-99 (Lenzen and Dey, 2001).

The biggest challenge in decoupling the link between lifestyle and energy use is shown in Figure 5.14. These graphs show the relationship between per capita expenditure in dollars and energy consumption (a) and greenhouse gas emissions (b). There is a very tight statistical relationship between expenditure, energy use and greenhouse emissions with correlation coefficients (R^2 values) ranging from 0.87 for greenhouse gas to 0.93 for energy use across a sample of more than 1200 households. The most challenging aspect of these graphs is the linear nature of the relationship and that there is very little saturation effect at higher consumption levels i.e. the graphs show little flattening when per capita consumption increases above $40,000 per capita per year. The energy embodied per unit of consumption at higher levels of expenditure is less but the absolute amount of consumption overwhelms the efficiency effect. These graphs are a good visual depiction of the inter-sectoral rebound effect that was shown in more detail in Table 5.3.

EFFECT OF POPULATION SIZE ON ENERGY INDICATORS

An assessment of the primary effect of population on energy and greenhouse indicators is presented in Table 5.4. Most indicators of energy usage are driven by the primary population effect but are also influenced by the tertiary population effect where energy transactions for traded goods and commodities are undertaken in Australia. Thus, the energy and greenhouse savings driven by technological innovation are less than if they were driven purely by domestic population requirement. By 2050, issues such as domestic production of crude oil and natural gas have effectively progressed beyond any population effect, but energy imports will be directly related to population size. The assumed production of black coal at 2050 is far in excess of domestic requirements, and is driven by a tertiary trade effect.

In assessing the greenhouse gas implications of energy usage it is possible that the tertiary effects of trade will be taken into account in future international negotiations. It is possible that energy use and carbon emissions for traded goods will be attributed to the country where the goods and materials are consumed rather than where they are produced. In embodied energy terms for the 1993-94 input-output tables, Lenzen (1998-a) notes that 1,379 PJ of primary energy was embodied in exports while 1,222 PJ was embodied in imports. Because of differences in carbon intensity of the traded products the equivalent in carbon dioxide terms was 223 million tonnes exported and 138 million tonnes imported. In the next version of the national input-output statistical tables three years later, the balance had become negative with exports of 1,438 PJ and imports of 1,595 PJ. On these figures, the high imports fuelled by domestic consumption allied with population growth, and their carbon dioxide implications, could further disadvantage the nation's energy and greenhouse negotiating position. Assigning similar embodied energy values to both exports and imports is difficult as most economies are structurally different in the energy consumption of their industries. In comparing the agricultural and industrial sectors of seven European Union countries, Battjes et al. (1998) found differences between the same sectors (in different countries) due to variation in energy intensive modes of production. Nevertheless, this approach provides a reasonable first approximation which can be improved.

Both the high-tech and factor-4 scenarios moderate the primary population effect and facilitate a higher national population while keeping primary energy usage and carbon dioxide emissions below those of the base case population level (which uses base case technology) (Table 5.5). The high-tech scenario with the 0.67%pa population scenario provides energy services with emissions that are 2% lower than normal base case, while 'high-tech/base case population' and 'high-tech/zero population' allow reductions of 17% and 27% respectively. The factor-4 scenario allows all population levels to decrease emission levels below the base case by 13-34%, while in the low-tech scenario, emissions increase by 8-17% above the base case and could be considered an extension of the current management and technology. The technological options considered do provide choices for negating the primary population effect as far as primary energy usage and greenhouse emissions are concerned. Equally of course, the factor-4 and high-tech scenarios would allow the zero population scenario to reach very high environmental standards. While these scenarios may be considered feasible in a technical sense, the arguments advanced in other parts of this chapter suggest that advanced technological scenarios have a low probability of implementation under current societal consumer attitudes and behaviour.

Table 5.4. Overall assessment of the primary driver effect for domestic population numbers for the three scenarios on key stock and flow issues for energy at the year 2050. In all cases the base case scenario is indicated as 100% and includes a wide range of technological and policy innovations compared to today's situation i.e. it is not a linear projection from the year 2000.

Issue	Zero	Base case	0.67%pa	Comment
Population at 2050	**Minus 18%**	**100%**	**Plus 29%**	**Basic population assumptions driving the 3 scenarios**
Primary energy use	Minus 12%	100%	Plus 20%	A population effect of 6-9% lower than expected if a primary population effect was dominant. This reduction is due to energy use in export industries. i.e. a tertiary population effect
Carbon dioxide emissions from the energy sector	Minus 12%	100%	Plus 20%	As above
Natural gas requirement	Minus 12%	100%	Plus 18%	As above
Oil requirement	Minus 12%	100%	Plus 20%	As above
Coal requirement	Minus 14%	100%	Plus 21%	As above
Electricity requirement	Minus 17%	100%	Plus 21%	As above
Total crude oil production	100%	100%	100%	No difference between population scenarios as domestic production at 2050 is determined by physical constraints on the resource and most oil is imported
Total natural gas production	100%	100%	100%	No difference between population scenarios as domestic production at 2050 is determined by physical constraints on the resource, and most natural gas is imported
Total black coal production	100%	100%	100%	No difference between population scenarios as total black coal production is much larger than domestic requirements
Total brown coal production	Minus 13%	100%	Plus 21%	Brown coal only used in situ for electricity generation for domestic and export purposes

.
.
.
.
.
.

Table 5.5. Assessment at the year 2050 of the specific effect of technological and management innovations included in sub-scenarios simulated for energy requirements. In all cases, the base case scenario without this particular technological innovation (see Tables 5.1, 5.2) is used as the basis for the assessment. Base case scenario at 2050

requires 6,900 petajoules of primary energy use, and emits 541 million tonnes of carbon dioxide from the energy sector.

Issue	Zero	Base case	0.67%pa	Comment
Population numbers at 2050	**Minus 18%**	**100%**	**Plus 29%**	**Basic population assumptions**
CO_2 emissions for low-tech scenario	Minus 1%	Plus 13%	Plus 37%	8-15% extra CO_2 emissions produced by maintenance of current technology relative to starting point assumptions.
CO_2 emissions for high-tech scenario	Minus 27%	Minus 17%	Minus 2%	Requirements for 8 million extra people relative to base case can be supplied for the same CO_2 emissions
CO_2 emissions for factor-4 scenario	Minus 34%	Minus 26%	Minus 13%	Requirements for 8 million extra people relative to base case accommodated for 10% less CO_2 emissions. Zero scenario approaches 1990 Kyoto benchmark.

CONCLUSIONS ON THE FUTURE OF ENERGY

This chapter presents the possibility that two important tensions — carbon dioxide emissions from the energy sector and the long-term availability of high quality transportation fuels — might not be resolved by the current economic structure, national preference and technological possibilities. Within the 50-year timeframe of these simulations, greenhouse gas emissions pose a political problem rather than a physical constraint. This political problem will have to be solved at a global level, or not at all. The 1-2% of global emissions produced by Australia will not affect the prospect of global climate change, although the feed-back from the global climate system could mean that many Australian regions could be affected in the long term by changed temperature and rainfall patterns. Some of these changes could be severe e.g. a 30% reduction of rainfall over parts of Western Australia.

The energy focused analyses in this chapter suggest that integrated sets of exacting technological innovations, implemented uncompromisingly over the next 20 years, will not force carbon dioxide emissions towards the 1990 benchmark levels for most scenarios. The exception is the zero population scenario combined with the 'factor-4' paradigm of dematerialisation — an unlikely combination. Two important avenues of analysis that have not been explored could alter this assessment. Halving the physical consumption in all Australian lifestyles could provide the physical precursors for an energy and greenhouse lifestyle where feasible and achievable rates of technical progress might stabilise primary energy use from fossil sources, and subsequent greenhouse emissions. A variant of this concept might see fossil energy use capped at 1990 levels and market mechanisms allowed free rein in the re-allocation of a regulated energy scarcity. Each citizen could be given x units of primary energy to use or sell. However, energy use and personal consumption drive economic growth and therefore facilitate the maintenance of the current structure and function of national systems. The prospect of effectively halving material consumption and thereby economic growth, would be difficult for any government in a modern free market economy. Simply put, most nations do not have the knowledge, or more realistically the control, to attempt any profound change in the current economic system. The second unanalysed option could be the total replacement of the fossil electricity sector and some transport fuels by some combination of solar, wind, nuclear and biomass derived energy services. Carrying out the transition process to this future unproven design would require the use of current fossil resources to effect the transition. Therefore greenhouse emissions could increase markedly before greenhouse friendly infrastructure is fully in place and emission levels begin to decline.

The possibility that domestic sources of oil and natural gas might become constrained in the period 2030 to 2050 represents an important topic for assessments of future economic and social risk. It is possible that world production of traditional oil may peak within the next 10-20 years and that the energy profit ratios of production might cause price volatility and supply constraints on world markets (Mitchell et al., 2001). Given these possibilities, a strategically orientated nation might choose two parallel strategies. The first strategy would invest heavily in advanced exploration techniques to extend knowledge of the ultimate resource base for oil and gas within Australia's land and marine base. The second strategy would ensure that it retained 50 year options for high quality energy resources, rather than the 10 year rolling target that is now the commonly accepted policy norm. The decision to export natural gas for export income might be balanced against a requirement to import it at a higher price 40 years hence, when it may be the transportation fuel of choice for the globe. The option to implement oil shale and coal gasification technologies should be assessed, but it is possible their use will further increase greenhouse gas tensions. The production of methanol and ethanol from biomass offers the possibility of a largely carbon neutral production system. However the energy profit ratios for biomass fuels are 50% lower than current petroleum based systems and they will require large biomass resources and land areas to sustain them. The long-term landscape sustainability implications of biomass fuel production and extraction systems are as yet unproven at the scale required to sustain current levels of physical metabolism and economic development.

REFERENCES

ABARE (1999). 1999 Australian Commodity Statistics. Australian Bureau of Agriculture and Resource Economics, Canberra.

APPEA (2002). A crude oil development strategy for Australia. Australian Petroleum Production and Exploration Association web site. Press Release 14-04-2002. http://www.appea.com.au/whats_happening/index.html accessed 27-04-2002.

Australian Bureau of Statistics (2000-a). Australia Now, A Statistical Profile, Energy, Energy end use in Australia. http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/e861484b4031ee3dca2568a900154a0d!OpenDocument Accessed 15/7/2000

Australian Bureau of Statistics (2000-b). *Energy Accounts for Australia 1992-93 to 1996-97*. ABS Catalogue No. 4604.0, Canberra.

Australian Bureau of Statistics (2000-c). Australia Now, A Statistical Profile, Energy, Special Article - Reforms in the Australian electricity and gas industries. http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/e9c6e4e43f11918eca2568a900154b9b!OpenDocument Accessed 15/7/2000

Australian Bureau of Statistics (2000-d). *1998-99 Household Expenditure Survey Australia: Summary of results*. ABS Catalogue No. 6530.0, June 2000, Canberra.

Australian Bureau of Statistics (2001). *Energy and Greenhouse Gas Emission Accounts, Australia1992-93 to 1997-98*. ABS Catalogue No. 4604.0, May 2001, Canberra. http://www.abs.gov.au/ausstats/ABS%40.nsf/dddcf05472f88677ca2568b5007b8615/63f8092c2770d762ca256a4d0083a051!OpenDocument accessed 22-06-01.

Australian Gas Association (2000). Australia's gas industry in profile, natural gas at a glance. http://www.gas.asn.au/MAIN.HTM accessed 15-7-2000

Australian Geological Survey Organisation (2000). *Oil and Gas Resources of Australia 1999*. Australian Geological Survey Organisation, Canberra.

Australian Greenhouse Office (2000). 1998 National Greenhouse Gas Inventory. http://www.greenhouse.gov.au/inventory/facts/facts_content.html accessed 14-7-2000.

Ayres RU (1998). Eco-thermodynamics: economics and the second law. Ecological Economics 26,189-209.

Battjes JJ Noorman KJ and Besiot W (1998). Assessing the energy intensity of imports. Energy Economics 20,67-83.

Black F Tejada S and Gurevich M (1998). Alternative fuel motor vehicle tailpipe and evaporative emissions composition and ozone potential. Journal of the Air and Waste Management Association 48,7,578-591.

Blanchard R (2000). The impact of declining major North Sea oil fields upon future North Sea production. http://www.hubbertpeak.com/blanchard accessed 18-7-2000

Brookes L (2000). Energy efficiency fallacies revisited. Energy Policy 28,355-366.

Brown MT and Ugliati S (1997). Emergy based indices and ratios to evaluate sustainability: Monitoring economies and technology towards environmentally sound innovation. Ecological Engineering 9,51-69.

Bullard CW and Herendeen RA (1975). The energy cost of goods and services. Energy policy 3,268-278.

Bush S Dickson A Harman J and Anderson J (1999). *Australian Energy: Market Developments and Projections to 2015-15.* ABARE Research Report 99.4. Australian Bureau of Agricultural and Resource Economics, Canberra, April 1999.

Cleveland CJ Kaufmann RK and Stern DI (2000). Aggregation and the role of energy in the economy. Ecological Economics 32, 301-317.

CNN Interactive (1998). Power failure brings New Zealand's largest city to standstill. February 24, 1998. http://www.cnn.com/WORLD/9802/24/nzealand.blackout/ accessed 14-7-2000

Common MS and Salma U (1992). Accounting for changes in Australian carbon dioxide emissions. Energy Economics July 1992 217-2225.

Conroy J Foran BD Poldy F and Quinnell T (2000). Future Options to 2050: Workshops Report. CSIRO Resource Futures Program Working Paper Series 00/03, March 2000.

Department of Industry Science and Resources (2000-a). *New Era New Energy*. Renewable Energy Action Agenda Discussion Paper, December 1999, Canberra.

Department of Industry Science and Resources (2000-b). Resources and energy, petroleum, the Australian LNG industry, recent developments. http://www.disr.gov.au/resources/index.html accessed 15-7-2000.

Dey C and Lenzen M (1996). Do we really care about climate change? Search 27,8,277-280.

Di Pascoli S Femia A Luzzati T (2000). Natural gas, cars and the environment: A relatively clean and cheap fuel looking for users. In *Advances in Energy Studies: Exploring Supplies Constraints and Strategies*. Conference held at Porto Venere Italy, 24-27 May 2000.

Duncan RC and Youngquist W (1998). The world petroleum life cycle. http://www.dieoff.com/page133.pdf accessed 18-7-2000.

Environment Australia (1999*). Possible Application of a Greenhouse Trigger under the Environment Protection and Biodiversity Conservation Act 1999*. Consultation paper prepared by ICF Consulting. Environment Australia Canberra, December 1999.

Fleay BJ (1995). *The Decline of the Age of Oil: Petrol Politics and Australia's Road Ahead*. Pluto Press Annandale, New South Wales.

Fleay BJ (1998). Climaxing oil: How will transport adapt? Paper presented to a symposium *Beyond Oil Transport and Fuel for the Future*. Launceston November 6-7 1998. http://wwwistp.murdoch.edu.au/OilFleay/climaxingoil.html accessed 26-10-2000

Foran BD and Crane D (1998).The OzECCO embodied energy model of Australia's physical economy. in *Advances in Energy Studies: Energy Flows in Ecology and Economy*. Conference held at Porto Venere Italy, 26-30 May 1998, pp 579-596.

Foran BD and Crane D (2000). Modelling the transition to a biofuel economy in Australia. In *Advances in Energy Studies: Exploring Supplies Constraints and Strategies*. Conference held at Porto Venere Italy, 24-27 May 2000, pp 423-439.

Foran BD and Mardon C (1999). Beyond 2025: Transitions to a biomass-alcohol economy using ethanol and methanol. CSIRO Resource Futures Program, Working Paper Series 99/07. A consultancy report for the National Dryland Salinity Program of the Land and Water Resource Research and Development Corporation, December 1999.

Gault FD Hamilton KE Hoffman RB and McInnis BC (1987). The design approach to socio-economic modelling. Futures 19,3-25 February 1987.

Greening LA Greene DL and Difiglio C (2000). Energy efficiency and consumption - the rebound effect- a survey. Energy Policy 28,389-401.

Hall CAS Cleveland CJ and Kaufmann R (1986). *The Ecology of the Economic Process: Energy and Resource Quality.* John Wiley and Sons, New York.

Hamilton C and Turton H (1999). Population policy and environmental degradation: Sources and trends in greenhouse gas emissions. People and Place 7,4,42-62.

Hawken P Lovins AB and Lovins H (1999). *Natural Capitalism: The Next Industrial Revolution*. Earthscan Publications, London.

Henn J Lindenberger D and Kummel R (2000). Energy, creativity and economic growth. In *Advances in Energy Studies: Exploring Supplies Constraints and Strategies*. Conference held at Porto Venere Italy, 24-27 May 2000, pp 581-590.

Herendeen R and Sebald A (1975). Energy employment and dollar impacts of certain consumer options. *The Energy Conservation Papers.* R Williams (editor), Ballinger, pp 131-170.

Herring H (1999). Does energy efficiency save energy? The debate and its consequences. Applied Energy 63,209-226.

Herring H (2000-a). Is energy efficiency environmentally friendly? Energy and Environment 11,3,313-325.

Herring H (2000-b). Why energy efficiency is not enough. In *Advances in Energy Studies: Exploring Supplies Constraints and Strategies*. Conference held at Porto Venere Italy, 24-27 May 2000, pp 349-359.

Inhaber H (1997). Why Energy Conservation Fails. Quorum Books, Westport and London.

Jackson and Marks (1999). Consumption, sustainable welfare and human needs- with reference to UK expenditure patterns between 1954 and 1994. Ecological Economics 28,421-441.

Janssen MA (unpublished). Diffusion of green consumption: Simulating the co-evolution between firms and consumers. Unpublished manuscript m.janssen@econ.vu.nl June 2000.

Kummel R and Linderberger D (1998). Energy, technical progress and industrial growth. in *Advances in Energy Studies: Energy Flows in Ecology and Economy*. Conference held at Porto Venere Italy, 26-30 May 1998, pp 207-222.

Lateline (2001) ESSO guilty. ABC Lateline, TV Program Transport, Broadcast: 28/06/01 http://www.abc.net.au/lateline/s320793.htm accessed 27-4-2002

Lenzen M (1998-a). Primary energy and greenhouse gases embodied in Australian final consumption: an input-output analysis. Energy Policy 26,6,495-506.

Lenzen M (1998-b). Energy and greenhouse gas cost of living for Australia during 1993/94. Energy 23,6,497-516.

Lenzen M (2001). A generalised input-output multiplier calculus for Australia. Economic Systems Research 13,65-92.

Lenzen M and Dey C (2001). *The Sydney Environmental Atlas*. Draft manuscript, Department of Applied Physics, University of Sydney.

Leontief W (1966). *Input-Output Economics*. University Press, New York.

Liverpool City (1998). Press Release: Service station's natural gas facility to be launched. 20/9/1998 http://www.liverpool.nsw.gov.au/council/press/press20_8.htm accessed 15-7-2000.

Maclean HL and Lave LB (2000). Environmental implications of alternative-fuelled automobiles: Air quality and greenhouse gas tradeoffs. Environmental Science and Technology 34,2,225-231.

Mitchell J Morita K Selley N and Stern J (2001). *The New Economy of Oil: Impacts on Business, Geopolitics and Society*. Earthscan Publications, London.

Noorman KJ and Moll H (1998). Energy flows in ecology and economy: From methodological approaches to real life applications. In *Advances in Energy Studies: Energy Flows in Ecology and Economy*. Conference held at Porto Venere Italy, 26-30 May 1998, pp 559-578.

Noorman KJ and Uiterkamp TS (1998). *Green Households? Domestic Consumers, Environment and Sustainability*. Earthscan Publications, London.

Odum HT (1996). *Environmental Accounting: Emergy and Environmental Decision Making*. John Wiley and Sons, New York.

Odum HT (1998). Emergy evaluation. in *Advances in Energy Studies: Energy Flows in Ecology and Economy*. Conference held at Porto Venere Italy, 26-30 May 1998, pp99-111.

Odum HT Brown MT and Brandt-Williams S (2000). Handbook of Emergy Evaluation: Folio #1 Introduction and Global budget. Centre for Environmental Policy, University of Florida, Gainesville, May 2000.

Perrings C (1986). Conservation of mass and instability in a dynamic economy-environment system. Journal of Environmental Economics and Management 13,199-211.

Princen T (1999). Consumption and environment: Some conceptual issues. Ecological Economics 31,347-363.

Poldy F Foran BD and Conroy J (2000). Future Options to 2050: Australian Stocks and Flows Framework. CSIRO Resource Futures Program Working Paper Series 00/04, April 2000.

Sasol (2000). Sasol processes: oil from coal process. http://www.sasol.com/sasolprocesses/oil.html accessed 16-7-2000.

Sanne C (2000). Dealing with environmental savings in a dynamical economy-how to stop chasing your tail in pursuit of sustainability. Energy Policy 28,267-495

Saunders HD (2000). A view from the macro side: rebound, backfire and Khazzoom-Brookes. Energy Policy 28,439-449.

Schenk EAM (2000). Time budget and money budget in household energy/transport demand. in *Advances in Energy Studies: Exploring Supplies Constraints and Strategies*. Conference held at Porto Venere Italy, 24-27 May 2000, pp 257-264.

Scienceman DM (1987). Energy and emergy. In *Environmental Economics- The Analysis of a Major Interface.* G Pillet and T Murota (editors) pp 257-276.

Shipper L (2000). On the rebound: The interaction of energy efficiency, energy use and economic activity: An introduction, Editorial. Energy Policy 28,351-353.

Shipper L and Grubb M (2000). On the rebound? Feedback between energy intensities and energy uses in IEA countries. Energy policy 28,367-388.

Simmons MR (2000). The oil world: 1973 compared to 2000. http://www.simmonsco-intl.com/web/downloads/whitepaper.pdf accessed 18-7-2000.

Stahel W (1994). The utilisation-focused service economy: Resource efficiency and product-life extension. In BR Allenby and DJ Richards (editors) *The Greening of Industrial Ecosystems*. National Academy of Engineering, Washington DC pp 178-190.

Stern DI (1999). Use value, exchange value and resource scarcity. Energy Policy 27,469-476.

Strickland P (2000). Australian Greenhouse Office backs the future of alternative fuels. Greenhouse News 3,1,6 Autumn 2000.

Suncor Energy (2000). Australian oil shale. http://www.suncor.com/about/about_australia.html accessed 15-7-2000.

The Australian (2000). Holidays no escape for the battlers. Special feature "Advance Australia Where" Tuesday 20th June 2000 p14.

Trainer T (1995). *The Conserver Society: Alternatives for Sustainability*. Zed Books, London and New Jersey.

Trainer T (1996). *Towards a Sustainable Economy: The Need for fundamental Change*. Envirobook, Sydney.

Treloar GJ (1997). Extracting embodied energy paths from input-output tables: towards an input-output based hybrid energy analysis method. Economic Systems Research 9,4,375-391.

Turton H and Hamilton C (1999). Population growth and greenhouse gas emissions: Sources, trends and projections in Australia. Australia Institute Discussion Paper Number 26, Lyneham Canberra, December 1999.

van Veen-Groot DB and Nijkamp P (1999). Globalisation, transport and the environment: New perspectives for ecological economics. Ecological Economics 31,331-346.

Volvo (2000). Volvo and the environment 1998-99. http://www.volvocars.com.au/ accessed 16-7-2000

von Weizsacker E Lovins AB and Lovins LH (1997). *Factor 4: Doubling Wealth-Halving Resource Use*. Allen and Unwin, St. Leonards, Australia.

Woodside Petroleum (1998). Australia's NW Shelf Project: Opportunities for Growth. http://www.woodside.com.au/anws/growth.html accessed 15-7-2000

World Resources Institute (2001). Global oil production for resources of 1800, 2200 and 2600 billion barrels. http://www.wri.org/powerpoints/oil2/sld012.htm accessed 22-06-01

Yu TY Lin YC and Chang LFW (2000). Optimised combinations of abatement strategies for urban mobile sources. Chemosphere 41,3,399-407.

Chapter 6
The future of water

ABSTRACT

Water, like energy, is essential to the nation's economic productivity, its lifestyle characteristics and the maintenance of biodiversity values and ecosystem services. In economic terms however, its undervaluation has resulted in a number of unintended environmental consequences in southern Australia with irrigation salinity and high water tables in irrigation areas, as well as degraded river systems. By 2050 the water requirement for urban Australia could vary from 5,000 to 8,000 gigalitres per year depending on the population scenario. By contrast, the base case scenario simulated a total managed water usage expanding from a contemporary level of 24,000 gigalitres per year to more than 40,000 gigalitres per year by 2050. This is due to a major expansion of irrigated agriculture in northern Australia as constraints on the availability and quality of water are experienced in the south. This expansion is not without its risks, and it is possible that the southern experience could be repeated in the north. The water requirements for industry, mining and domestic use represent about 20% of the total and while there is a population effect due to the scenarios, it could be met by transfer of water from agriculture. It is assumed that the integrity of key urban water catchment areas will be improved and that with appropriate regulation and technology innovations, high quality water supplies will be maintained for domestic use. The Australian water system appears to have many similarities to water systems in developing countries and it is critical that the transition is made to equitable and just water allocation between competing uses. In international trade terms it could be to Australia's advantage to quantify the embodied water content of the goods and services it imports and exports. Australia exports an estimated 4,000 gigalitres of embodied water more than it imports. This is about the same amount used each year by urban Australia. If we receive relatively poor trade prices for these products, then the nation accepts a double loss as funds are sought to repair the integrity of its inland river systems. It is possible that technical and management innovations could reduce the overall requirements from the managed water resource, and allow the delivery of similar water services for less water.

AUSTRALIA AND WATER

Water, like energy, clean air and soil organic matter, makes an essential contribution to the maintenance of economic productivity, social well being and lifestyle and the maintenance of nature and ecosystem services. There is a very close connection between water and energy. We use energy to help clean and transport the fresh water we need, and we use water to help us produce the energy we need (Gleick, 1994, 2001). Services provided by the water system remain under-valued with charges being made on the repairs and maintenance of built water infrastructure, rather than on the repairs and maintenance of the whole water system including the catchments, rivers, wetlands and estuaries.

This chapter reports on the amount of water required for the maintenance of national productivity as defined by the assumptions in the base case scenario. In particular it investigates:

- Analytical approaches that integrate the physical aspects of the water system with economic and other measures including process analysis, water accounting, embodied water analysis and water vapour flows;
- The water required by manufacturing, mining and urban areas to 2050;
- The water required by agriculture including a major expansion in northern Australia;

- Issues that relate to trade in 'virtual water', the water embodied in goods and services that countries import and export;

- The particular population dependent issues for water in Australia, and how they link to the tertiary population issues of trade.

WATER METHODOLOGIES

Process analysis

The process analysis approach used in the modelling framework ties the water requirements to the size, type and location of infrastructure in the case of houses and commercial buildings and to a wide number of specific manufacturing processes, whether they are basic materials such as paper and textiles, or more elaborately transformed items of a manufactured nature (Table 6.1). As houses are required, manufactured items made or agricultural crops grown, the water requirements are totalled and compared to the water available in that location. If there is a tension between requirement and available supply in a region then decisions must be made to resolve it by adjusting the requirement or shifting the activity to another water region. This process has been undertaken in the simulations reported in this chapter, and a major expansion of irrigated agriculture made in northern Australia.

Table 6.1. Examples of water applied in different processes in the modelling framework.

Good, process or service in model	Water required and units of measure	Comments and caveats
Domestic housing	4,700 litres per square metre per year	Varies throughout Australia with a range of 3,000 to 10,000 litres per square metre
Commercial buildings	2,700 litres per square metre per year	Varies throughout Australia with a range of 1,600 to 4,700 litres per square metre
Manufacture of office machines and space conditioning	19,600 litres per tonne produced	General figures applied across the full industrial cycle to give correct outputs for industrial sectors
Manufacture of motor cars and heavy machinery	47,600 litres per tonne produced	General figures applied across the full industrial cycle to give correct outputs for industrial sectors
Manufacture of paper	23,400 litres per tonne produced	New processes and water recycling will reduce this value
Manufacture of textiles	13,100 litres per tonne produced	New processes and water recycling will reduce this value
Dairy cows	1 megalitre (10^6L) per dairy cow	Data represent the irrigation requirement of pasture but are applied to cow numbers over whole herd and milk cycle
Fruit and vegetables	3-6 megalitres (10^6L) per hectare	Varies depending on location and nature of the crop

.

Water accounting

The water accounts maintained by national statistical agencies are central to understanding where water is used, for what purpose, and to show the developing trends. A simplified account is portrayed in Table 6.2, which shows that Australia's water usage increased by 7,400 gigalitres per year or 14 Sydney Harbours over the 12-year period from 1985 to 1997. Most of the change was in agriculture followed by a combination of all manufacturing and commercial interests. The latest set of water accounts (Australian Bureau of Statistics 2000-a) breaks the water usage down to 38 economic sectors, displayed by state for the years 1994-1997. It also includes a number of summary indicators that compare economic productivity and labour generation per unit of water used. These data are central to the modelling work reported in this chapter as well as the water embodiment analysis reported in the next section.

Table 6.2. Water account for managed water resource in 1970, 1985 and 1997.

<table>
<tr><th>Aggregate sector</th><th>Water use 1965-1970 (Department of Minerals and Energy 1975) (GL/year)</th><th>Water use 1977 (Newton et al., 2001) (GL/year)</th><th>Water use 1985 (Department of Primary Industries and Energy 1987) (GL/year)</th><th>Water use 1997 (Australian Bureau of Statistics 2000) (GL/year)</th><th>Water use 1996/97 (National Land and Water Resources Audit; Commonwealth of Australia 2001) (GL/year)</th></tr>
<tr><td>Agriculture</td><td>4,688</td><td>14,596</td><td>10,200</td><td>15,520</td><td>17,935</td></tr>
<tr><td>Domestic</td><td>1,330</td><td>1,780</td><td>1,790</td><td>1,828</td><td rowspan="2">4,754</td></tr>
<tr><td>Industry, commercial and mining</td><td>n/a</td><td>890</td><td>1,200</td><td>3,067</td></tr>
<tr><td>Other</td><td>n/a</td><td>534</td><td>100</td><td>1,770</td><td>1,369</td></tr>
<tr><td>Total</td><td>6,018</td><td>17,800</td><td>14,600</td><td>22,185</td><td>24,058</td></tr>
</table>

Water embodiment

The concept of water embodiment of economic output parallels the use of the concept used for energy analysis applications in Chapter 5. The analytical procedure combines the economic input-output tables with the detailed water accounts provided by the *Water Account for Australia* (Australian Bureau of Statistics, 2000). The results are presented in Tables 6.3 to 6.6 for selected sub-sectors of the agricultural, mining, manufacturing and service sectors along with the energy and labour embodiments for those sectors. The selected data for the agricultural sector shows a wide range, with more than 7,000 litres required per dollar of output for rice compared to 245 litres for wheat and other grains (Table 6.3). Sugar cane, milk and seed cotton are roughly comparable in the range of 1,220 to 1,600 litres per dollar of output. These data represent only the input of the managed water resource and do not include the green water or soil water that comes from rainfall. The data are not intended to portray a water theory of value but, with labour and energy requirements being roughly equivalent, they can help indicate priorities for water policy development.

.

.

.

Table 6.3. Embodiment of water, primary energy and labour in each 1994-95 Australian dollar for the selected agricultural sectors (After Lenzen 1999; Lenzen and Foran, 2001).

Sector	Litres of water per dollar of output	Megajoules (Joules*10^6) of primary energy per dollar of output	Minutes of required labour per dollar of output
Rice in the husk	7,458	11.6	1.8
Wheat and grains	245	11.6	1.8
Beef cattle	812	11.6	1.9
Dairy cattle and whole milk	1,470	14.3	1.8
Sugar cane	1,239	15.3	1.9
Seed cotton	1,600	15.3	1.9
Vegetable and fruit growing	379	15.3	1.9

In the case of mining, the selected industries have roughly similar requirements for energy and labour, but bauxite uses more water than the others (Table 6.4). Water is integral to the bauxite process and its preparation for conversion to alumina. Even small values for some minerals may be critical since large tonnages of ore are processed. In addition, many ore bodies are in water poor areas. Therefore water may have to be piped over long distances or, if obtained locally, it may represent a large proportion of the yearly water flow.

.

Table 6.4. Embodiment of water, primary energy and labour in each 1994-95 Australian dollar for the selected mining sectors (After Lenzen, 1999; Lenzen and Foran, 2001).

Sector	Litres of water per dollar of output	Megajoules (Joules*10^6) of primary energy per dollar of output	Minutes of required labour per dollar of output
Black coal	22	16.8	1.4
Crude oil	13	16.8	1.4
Iron ores	23	15.2	1.4
Bauxite	366	15.9	1.7
Gold and lead	15	15.9	1.7

Greater differences in water and energy requirements emerge between the manufacturing sectors (Table 6.5). Both pulp/paper and aluminium require 50 litres of water per dollar of output generated while basic chemicals and aluminium require 40-50 megajoules of primary energy per dollar of output. Compared to the mining sector, the manufacturing sector has slightly higher requirements for labour and generally uses more water and energy.

.

.

.

Table 6.5. Embodiment of water, primary energy and labour in each 1994-95 Australian dollar for the selected industrial sectors (After Lenzen, 1999; Lenzen and Foran, 2001).

Sector	Litres of water per dollar of output	Megajoules (Joules*10^6) of primary energy per dollar of output	Minutes of required labour per dollar of output
Pulp, paper and paperboard	51	30.2	1.9
Basic chemicals	36	52.7	1.9
Pharmaceutical goods, insecticides and agricultural chemicals	24	10.2	2.0
Cement lime concrete and mortar	15	26.2	1.8
Alumina, Aluminium alloys and aluminium recovery	52	41.1	1.6

The services sector generally requires less water and energy and slightly more labour. The exceptions are accommodation and restaurants, and community services which have higher water and energy requirements on par with the average of the whole economy. However, both these sectors also have a higher labour requirement, which might compensate in social terms.

Table 6.6. Embodiment of water, primary energy and labour in each 1994-95 Australian dollar for the selected service sectors (After Lenzen, 1999; Lenzen and Foran, 2001).

Sector	Litres of water per dollar of output	Megajoules (Joules*10^6) of primary energy per dollar of output	Minutes of required labour per dollar of output
Accommodation, cafes and restaurants	75	9.6	2.4
Banking	9	4.5	1.8
Education	7	3.7	2.5
Health	7	3.2	2.1
Community services	27	12.4	3.2

From the water embodiment data, a detailed picture of the extent water (and labour and energy) are required to help in the production of economic output begins to emerge. In a relative sense, the services sector has lower requirements and the mining sector is equivalent to the average of the whole economy. The manufacturing sector has some processes that require more water requirements such as aluminium and pulp/paper but these are relatively low compared to the high water requirements of the agricultural sector. Depending on one's values, these data can be interpreted in a number of ways. Food is central to the maintenance and enjoyment of life, so it could be argued that the water requirements of agriculture are justified. If the food was imported from elsewhere, then water flow from another country would be required and Australia would be the cause rather than the recipient of the tertiary population influence of trade. Alternatively it could be argued that consumers, both domestic and in other countries, pay the full cost of the water services embodied in each kilogram or dollar's worth of food. Developing this argument, both domestically and in export trade terms, and then using it to make strategic decisions, is a key foundation to understanding any transition towards the concept of a more resilient national water system.

Water vapour flows

As the emergy concept is used to integrate the full life cycle of energy and environmental services (see Chapter 5 for a discussion of emergy), so does the concept of water vapour flows attempt a similar integration for the continental water cycle of Australia (Rockstrom et al., 1999; Gordon et al., 2000). The concept links the ideas of blue water (rivers, dams and underground aquifers), green water (water in the root zone available for plant growth) and white water (water transpired by soil and plant surfaces plus some evaporation from water surfaces). It was developed by Falkenmark (1997, 1999) and others in order to focus global and continental water policy on areas other than blue water flows alone. In these terms, blue water conceptually represents the tip of the iceberg. It may be worth concentrating on green and white water as small changes in those areas may reap bigger rewards for the whole water sector.

Table 6.7. Components of water vapour flow and liquid water flow in gigalitres per year (10^9 litres) in pre-European and contemporary times.

Category of flow	Amount of flow in gigalitres per year	Comments
Total precipitation	3,314,000 to 3,390,000	Range of published estimates that obviously vary significantly from year to year
Total water vapour flow in 1780 (pre-European settlement)	3,436,000	Estimate is based on known transpiration rates of vegetation applied to the continental map of pre-European vegetation distribution
Total water vapour flow in 1980 (post development)	3,097,000	Decrease is due to removal of perennial deep-rooted vegetation and replacement by annual cropping systems and grass-legume pastures
Difference between 1780 and 1980	339,000	Difficult to determine how the (now) liquid water flows are apportioned between systems but some would go to stream flow, some would re-fill groundwater aquifers and the rest would contribute to the emerging dryland salinity problem.
Continental runoff	362,000 to 397,000	Range of estimates in published literature
Total managed water use in 1995-96	22,000	Could expand to 40,000 gigalitres by 2050 under base case assumptions
Crop and animal agriculture use on 1995-96	15,500	Could expand to 32,000 gigalitres by 2050 under base case assumptions

.

The net outcome of land clearing in the wheat sheep zone and higher rainfall pasture zone, after 200 years, is a decrease in yearly flows of Australian white water (evapo-transpiration) of 339,000 gigalitres per year (Table 6.7). This becomes part of the green water (soil water) but it is unclear how it is then partitioned between the different parts of the hydrological system at a continental level. Some may be added to surface runoff, some may replenish underground aquifers and a significant portion contributes to a slow-moving underground flow that is the root cause of dryland salinity on Australian farms. This decrease in continental evapo-transpiration represents the volume contained in 600 Sydney Harbours and is a yearly event (or non-event). It is 15 times the volume of the managed water flows of 22,000 gigalitres per year, and is approximately equal to the entire yearly runoff from the continent.

Capturing this unintended water flow could provide productive returns for crop and animal agriculture as well as avoid the knock-on effects of dryland salinity and the land loss that will result with the continuance of marginal approaches. Chapter 4 presents some options for exploring these issues. The challenge presented by the water vapour flows approach is to capture a green water flow that is 15 times the size of the current managed blue water flow. If this is possible over the next century, it might be possible that additional blue water resources are not required and that additional blue water could be returned to the environment.

ISSUES FROM THE DIMA WORKSHOP SERIES

In preparation for the design and testing of the population scenarios with ASFF, a workshop series was conducted in 1999 (Conroy et al., 2000), to critically review the structure of the analytical framework and the implementation of the scenarios. Six important issues for the scenario implementation responses in this chapter are described below.

- The timescale and partitioning of flows and stocks were examined particularly with reference to Australia's highly variable rainfall regime, and the passage of surface water to soil water and aquifer water. The water calculator in ASFF does not yet bring together the entire stock and flow of Australia's water resources at a continental level. One simplification is to treat the surface flows and soil water both as flows, but to treat the aquifers as stocks, as these are the resources at risk of depletion. The time for a particular unit of water to pass through a system, is in terms of decades for aquifers, three months for soil water and five years for large water supply dams. In implementing the population scenarios, these issues were dealt with in two ways. Firstly, the water requirements for cities and agriculture were checked against the yearly flow rates for the river basins that surrounded them. In the case of agriculture, the new development was located in northern Australia where large underdeveloped water resources were still available. Secondly, most effort was devoted to ensuring that water requirements for key physical processes adequately reflected regional realities and expert opinion about future technological trends. The enumeration and balancing of the entire Australian water system was deferred to another round of model development.

- The need to decrease managed water use and increase environmental flows was an important topic of discussion at workshops. One suggestion was to classify the environment as a user in its own right (equivalent to mining or industry) and to allocate water on the specific requirements for each river basin. The scenarios do not take account of the environmental requirement for water flows. In real life, the environmental flows for, e.g. bird and fish breeding are needed at a specific time of year, temperature and so on, that lie outside the scope and timestep of the modelling approach. Nevertheless, all water requirements were checked to ensure that over allocation of surface water resources did not occur. The northern

Australian development represents a partial approach to the reconciliation of increasing and competing demands.

- Workshop participants regarded the effect of global climate change on Australia's water resources as an important issue. The recent release of updated climate change scenarios for Australia (CSIRO, 2001-a) reinforces the outlook for rainfall declines of 20% in the south-west corner of Western Australia by 2030 and up to 60% by 2070. The outlook for northern Australia, by contrast, is for increasing rainfall. The implications of climate change are acknowledged in the discussion of population scenarios but not actively included as part of the analysis. The sub-scenarios developed in this chapter show the likely water requirement when the same goods and services are delivered for 30% less water, which is technically feasible in most cases. An increased water requirement, due to increased temperature (when rainfall might also decline) is therefore possible, up to 30%. The view of the industry is that climate change is important, but less so (perhaps a longer timeframe) than the challenge of infrastructure renewal and augmentation facing both urban and agricultural water sectors (Dunlop and Foran, 2001).

- Water quality rather than quantity is the key water issue in Australia and should be the prime focus of futures modelling work. Water quality is not modelled in this version of ASFF but is the subject of detailed modelling exercises for areas such as the Murray Darling Basin. Like environmental flows, water quality is influenced by many local issues that cannot be represented in a nationally scaled model. At a larger scale however, the amount of land used for cropping, the amount of irrigation, and demand from domestic and industrial users, all contribute to the water quality equation. In general, the larger the allocation of managed water use, the higher the pressure that exists on water quality indicators, although treatment technologies have a part to play. Although water quality scenarios are not simulated in this chapter, water quality (through reference to the reports from The National Land and Water Audit) is one of the crosscutting issues of environmental quality presented in Chapter 7.

- The problem of inconsistencies in the water statistics available at local, state and national levels is an ongoing one that is important for the type of modelling being undertaken in this study. Two comprehensive water accounts were available at a national level for 1985 and the period 1994 to 1997, which were used as the grounding for the model. Subsequent revisions of the water account by the National Land and Water Audit (Commonwealth of Australia, 2001) have increased estimates of national water use from 22,000 to 24,000 gigalitres per year due to new information from Queensland irrigation statistics. Another water project working parallel to this population study (Dunlop, 2001) has undertaken a comprehensive analysis of all water uses at a statistical division level which reveals a wide range of anomalies and gaps in information. The population scenarios implemented here concur with the best national information available. In addition, the full process accounting of most water using sectors in the physical economy used in the ASFF approach is proposed as a robust and defensible approach (in addition to survey and reporting) to underpin national physical accounting for all sectors.

- A number of potential land uses such as reforesting large areas of farmland to help deal with dryland salinity, could potentially dry up the overland flows from many catchments that contribute to river flow and thereby water available for irrigation use. The scenarios were implemented on the basis of three premises The first is that the social and policy drivers behind the widescale reafforestation of farmland would probably be attempting to deal with irrigation salinity as well as dryland salinity, i.e. they would not attempt to solve one issue while ignoring another one that was closely linked to integrative issues such as water quality.

Thus implementation of the scenarios for land and water use must be logical and mutually compatible. The second is that the science underpinning these broadscale issues (eg Vertessy, 2001) provides qualitative input to scenario implementation, which will be used in subsequent redevelopments of the water calculator. Thirdly in an annual sense, much of Australia's irrigation water is derived from limited areas of higher altitude catchments and from non-normal rainfall events. Prior to European settlement, rivers still flooded or ran dry, but today's management infrastructure (weirs and dams) has modified the dynamics and ensured that water is supplied on a year-round basis. In a general sense therefore, the water scenarios have a good basis for ensuring that water is available in spite of radical land-use changes.

SCENARIO ASSUMPTIONS

Since water is critical for most transactions in the physical economy, enough water was allocated to enable the full set of physical transactions detailed in the starting scenario. General assumptions made in the implementation of the scenario are tied to each tonne of ore processed, each square metre of domestic housing built, and each hectare of irrigated land by crop. The important assumptions were as follows:

- That water use, along with energy use, would continue to expand as it underpinned economic growth and development, although this challenges national perceptions about water quality and quantity. Two lines of argument support this scenario driver. Water experts such as Thomas (quoted in Dunlop and Foran, 2001) note that most studies report expanded water use of about 2-3% per annum over the last 30 years, closely linked to economic growth. The recent revision of water use in the National Land and Water Audit (Commonwealth of Australia, 2001) puts the growth rate at nearly 4% over the last decade between water accounts. This represents a doubling time of approximately 20 years. The scenarios conservatively implement the doubling over 50 years, to 2050, taking account of proposals to implement better technologies and institutional arrangements.

  The second line of argument is derived from detailed analyses of the water content (embodied water) of personal consumption (Lenzen and Foran, 2001; Lenzen et al., 2002; Figure 6.1). The data relationships presented in the left hand graph show that as personal consumption (expressed in dollars per capita) rises, so does the total water content of that expenditure. For example, the average per capita expenditure of A$20,000 across nearly 2,000 Sydney households had a water content of 1,000 kilolitres (or one megalitre). Doubling personal consumption to A$40,000 per capita gave a water content of 1,700 kilolitres (or 1.7 megalitres). Thus, there is a reducing water content as per capita consumption rises, but the data relationship does not suggest any saturation or levelling out until reasonably high consumption levels. These data include direct consumption (showers, clothes washing and gardens) as well as the indirect (food, milk products, beverages, industrial production). It could be argued that as per capita consumption rises, then so too does the sophistication of house fittings (furnishings and swimming pools), the frequency of restaurant meals and the incidence of travel. All these sectors use water, which is allocated back to the consumer through this analytical approach.

  Under the current structure and function of the Australian economy, it is anticipated that consumer expenditure will double in real terms over the next 50 years simulated in these population scenarios. Economic modelling over the whole economy, aimed at estimating the interactions between population ageing, national savings policies and household expenditure in the long run (Guest and McDonald, 2001) supports this view. In historic terms, over the period 1950-1996, per capita consumption in constant dollar terms grew at a little more than 3% per annum (Hamilton and Saddler 1997) giving a doubling time of about 24 years. Given both the future orientated modelling and the historic precedent, a doubling of personal consumption (if not a quadrupling) in real terms is feasible over the next 50 years. A doubling of the water embodied in that consumption through the full life cycle of all products and services is also feasible.

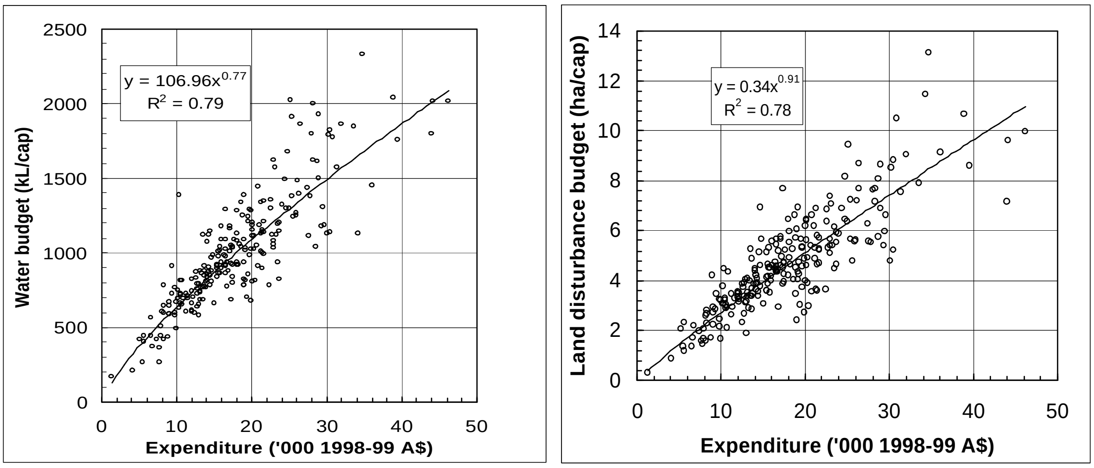


Figure 6.1. The water (gigalitres per capita) and land disturbance (hectares per capita) embodied in personal consumption expenditure in the household expenditure survey for Sydney 1998. (Data from Lenzen and Foran 2001; Lenzen et al., 2002).

.

- That additional irrigated agriculture would follow available water resources. Irrigated agriculture in northern Australia would need to expand to meet the physical production expectations of the base case scenario. The future commodity expectations were derived from a collaborative study by the CSIRO Resource Futures Program and The Centre for International Economics undertaken for the Land and Water Resources Research and Development Corporation (LWRRDC, 1997).

- The move to northern Australia was the result of a tension resolution exercise within the modelling framework when it was found that future productivity assumptions in the base case to 2050 could not be met by the water resources of established irrigation areas. While the problems of river quality and water salinity were not modelled, they were used as corroborative evidence to support the opening of new areas in the north. All new irrigated requirement for cotton, sugar, rice and some horticulture and vegetables were located in northern Australia from the year 2000.

- That domestic, commercial and general urban requirements would be met by a mixture of re-allocation and pricing, pipelines, inter-basin transfers and recycling technologies over the timescale of the simulation.

- That best practice technologies would allow a 30% reduction in water requirements for the same delivery of product, service or lifestyle and that this would be implemented in a sub-scenario rather than embedded in the base case.

The most recent water resources data contained in *Water and the Australian Economy* (Australian Academy of Technological Sciences and Engineering, 1999) and *Water Account for Australia* (Australian Bureau of Statistics, 2000) were used as the basis for current consumption levels by different sectors. The *1985 Review of Australia's Water Resources and Water Use* (DPIE, 1987) was used to determine water availability in different river catchments and groundwater provinces.

Data on water requirements for crops, industrial and food processing, mineral refining and urban usage were obtained from a wide range of sources, many of them conflicting. The calibration procedure in the model was used to aggregate and balance a wide range of information and to reflect current estimates contained in the national water account.

SCENARIO RESULTS

Secondary industry

The water requirements of secondary industry increase from 800 gigalitres per year currently to 1,400 gigalitres per year by 2050 (Figure 6.2). The major requirements are for thermal electricity, food processing and non-vehicle manufacture. Differences due to population occur; the 0.67%pa scenario requires 300 gigalitres per year more than the base case in 2050, and the zero scenario uses 50 gigalitres per year less than the base case. Many opportunities exist for reducing the industrial water requirement in all scenarios by treatment and recycling of water, as well as by developing new processes which have a much lower requirement per unit of good or service delivered. By 2050 the water requirement for secondary industry represents 3% of the national total (see Figures 6.8 and 6.9) and while it could equal 25% of the urban requirement at that stage, many adaptations and management options are available to ensure that industry receives its required allocation. An important feature of industrial water, once it has been used, is the route taken for its disposal and its concentration of nutrients, heavy metals, organic chemicals and its waste heat content. It is assumed that continued improvement in industrial processes and a strong regulatory framework implemented by state environmental protection agencies will result in a decreasing environmental load on locations where waste water is discharged. This total water requirement for secondary industry is approximately equal to the mean annual outflow from one river basin such as the Brisbane River in Queensland or the Hunter River in New South Wales.

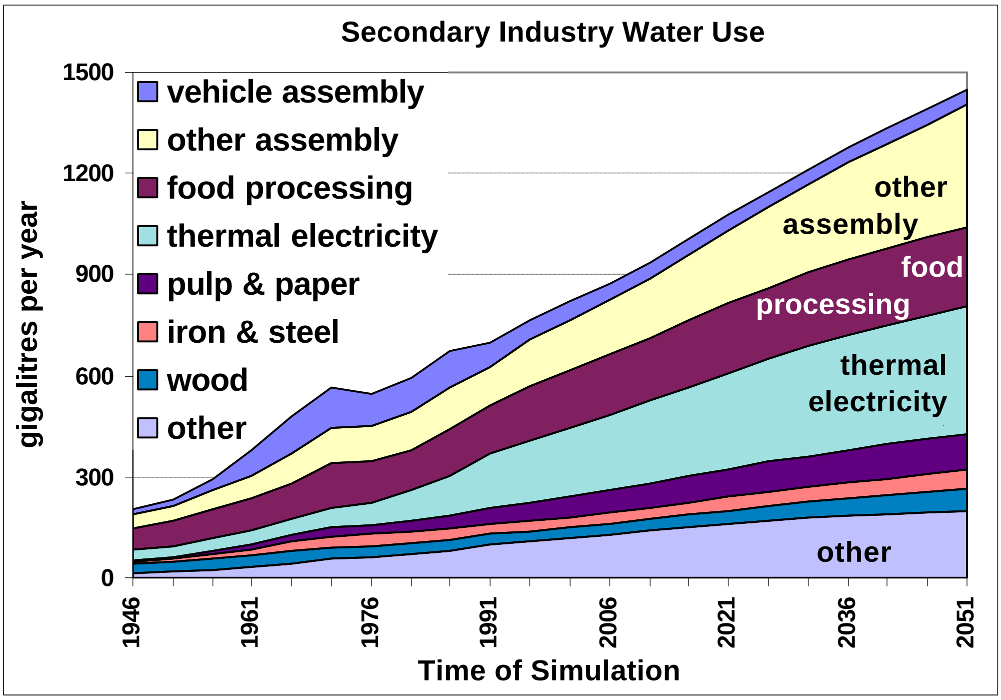


Figure 6.2. Total water required in gigalitres (10^9 litres) per year by secondary industry, in the base case scenario to 2050.

Mining

The water requirement for the mining industry rises from 400 gigalitres per year to nearly 1,000 gigalitres per year by 2050 in line with the assumptions in growth of output from the mining sector (Figure 6.3). Bauxite and coal together account for more than 70% of the industry's water requirement. In coal and bauxite processing, water is generally used to remove contaminants, dirt and other minerals to improve the quality of the material delivered to the next stage of processing. Reducing the amount of water used in coal and bauxite treatment may be possible but subsequent use of the material may be negatively affected. When dirty coal is used for electricity generation, for example, combustion qualities are reduced and the efficiency of electricity generation declines. The 1998 greenhouse gas report (Australian Greenhouse Office, 2000) noted this effect, where thermal power station efficiencies fell during the 1990s due to the use of cheaper and poorer grades of coal. Similar effects could occur for bauxite mining, particularly in the conversion stage to alumina where poorer quality bauxite ore would require more energy and more chemicals for the treatment process. A number of innovations in metal concentration allow for dry treatment of some ores and increased efficiency of water use in others. Many metal types require one tonne of water (1,000 litres) for every tonne of ore processed and, while water recycling can reduce total amounts, the lack of water in drier regions sometimes restricts the development of ore bodies that would otherwise be attractive. Like manufacturing, mining is simulated to use about 3% of total water requirements by 2050, or the total yearly flow of one medium sized river. The quality of the water after processing is important environmentally, as minor concentrations of metals such as arsenic and cadmium can produce significant biological effects (Minerals Council of Australia, 1999). However, industry in this area strives to maintain best practice and is open to overt and continual scrutiny by environmental protection agencies.

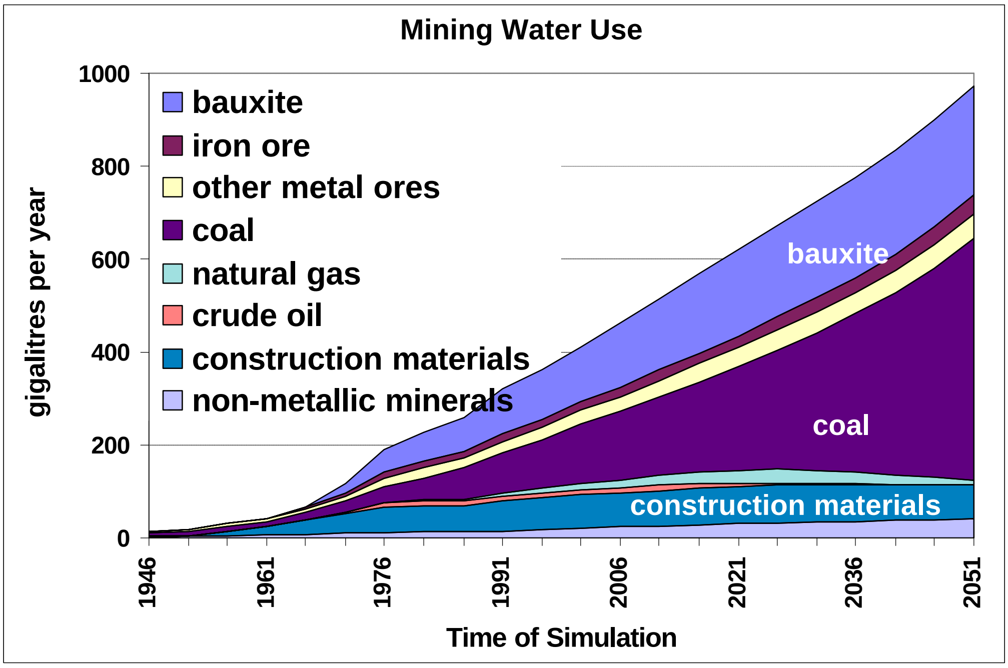
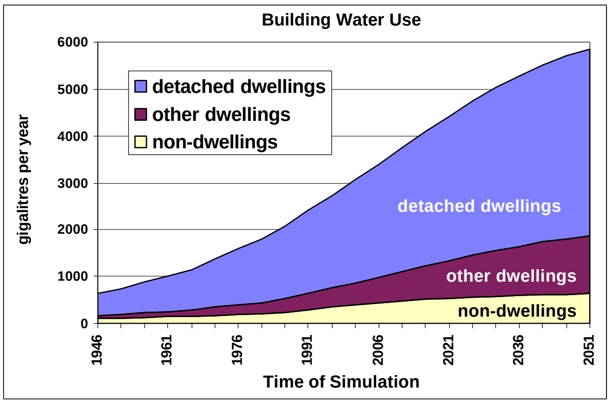


Figure 6.3. Total water required in gigalitres (10^9 litres) per year, in the base case scenario to 2050 for the requirements of mining.

Buildings

For the base case scenario, the total water requirement for buildings by 2050 is nearly 6,000 gigalitres per year compared to a contemporary value of about 3,000 gigalitres per year (Figure 6.4). Nearly 60% of the building water use is for a category entitled 'detached dwellings' which represents the normal Australian suburban home. The water use for dwellings appears to expand at a faster rate than the population for two reasons. (i) The model attaches water use per unit of floor area for all dwellings and this expands considerably on a per dwelling basis as affluence levels are assumed to rise over the next 50 years. While the number of people per household is declining, the increased water use could be interpreted as the amenity use of water for labour-saving devices such as dishwashers, the increase in the number of swimming pools and spas and the use of water for home activities such as gardening. (ii) Expansion of inbound tourism and the service economy is accompanied by a steady expansion of that sector of the built environment, and with it, the requirement for water.



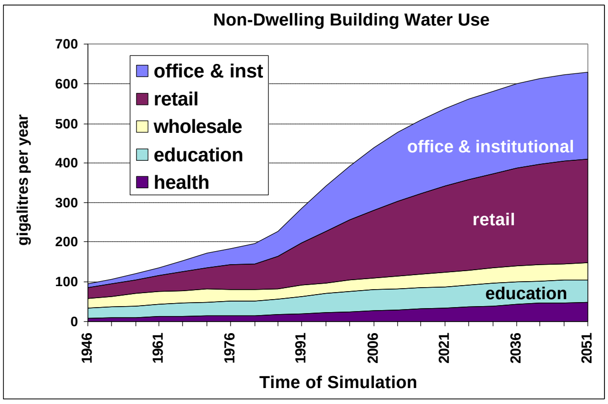


Figure 6.4. Total water required in gigalitres (10^9 litres) per year, in the base case scenario to 2050 for (a) domestic and (b) commercial buildings.

The breakdown in non-dwelling buildings shows that the major requirement for water by 2050 is due to the retail and office parts of the commercial sector with wholesale education and health taking less than 20% of the total (Figure 6.4). More than 80% of total water requirements for building is due to domestic dwellings. This is about 5,000 gigalitres per year, with New South Wales, Victoria and Queensland requiring the major portions (Table 6.5). Total building water use represents 14% of the total Australian water requirement by 2050, and combined with the manufacturing and mining requirements, represents 20%.

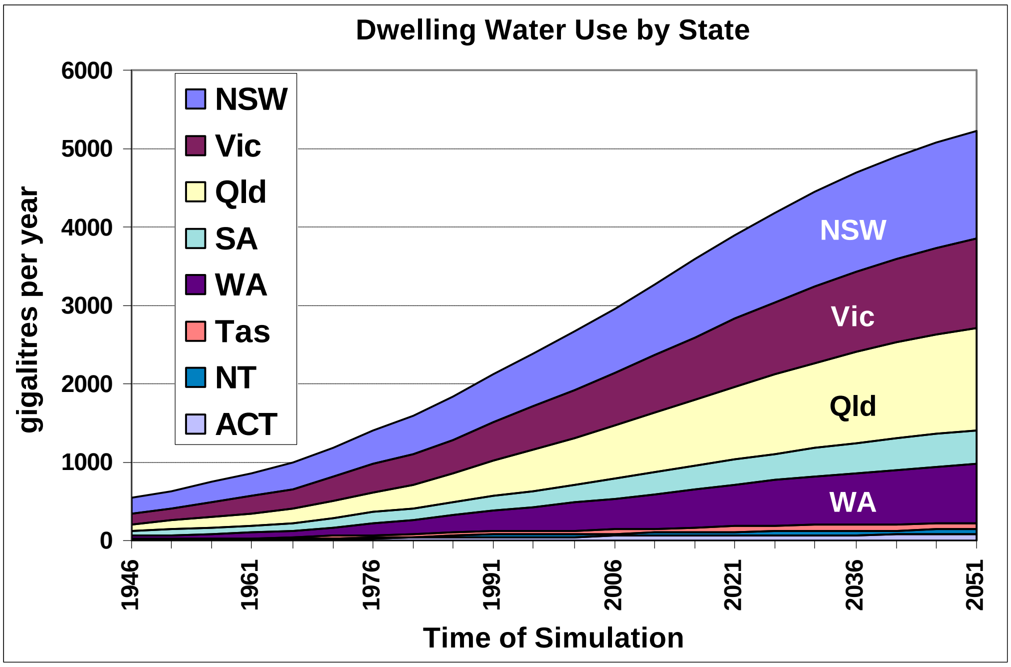


Figure 6.5. Total water required in gigalitres (10^9 litres) per year, in the base case scenario to 2050 to supply domestic buildings.

As noted in Chapter 3, there are significant infrastructure and management issues associated with maintaining clean catchments and ensuring the chemical and biological quality of water supplies for most major cities. However, for the base case scenario at least, there are a sufficent range of options in terms of takeback from other uses and industries and water savings in each home, to ensure enough water is available. When the other population scenarios are compared to the base case, the requirements are 2,000 gigalitres per year more for the 0.67%pa scenario and 1,000 gigalitres less for the zero scenario (Figure 6.6). By 2100 however, a number of water availability tensions could appear as the building requirements are 12,000, 6,000 and 5,000 gigalitres per year for the 0.67%pa, the base case and the zero scenarios respectively. The requirement for the 0.67%pa scenario is six times that of current urban consumption (2,000 gigalitres per year) and about half the total consumption (24,000 gigalitres per year). Yet, it's possible that the high value of urban water would ensure additional dams, interbasin transfers and pipelines would supplement the current urban water supplies. The challenge becomes one of allocation of available water supply in an equitable manner, rather than a lack of water. The problem enters the preserve of politics and economics and moves outside the sphere of physical analysis.

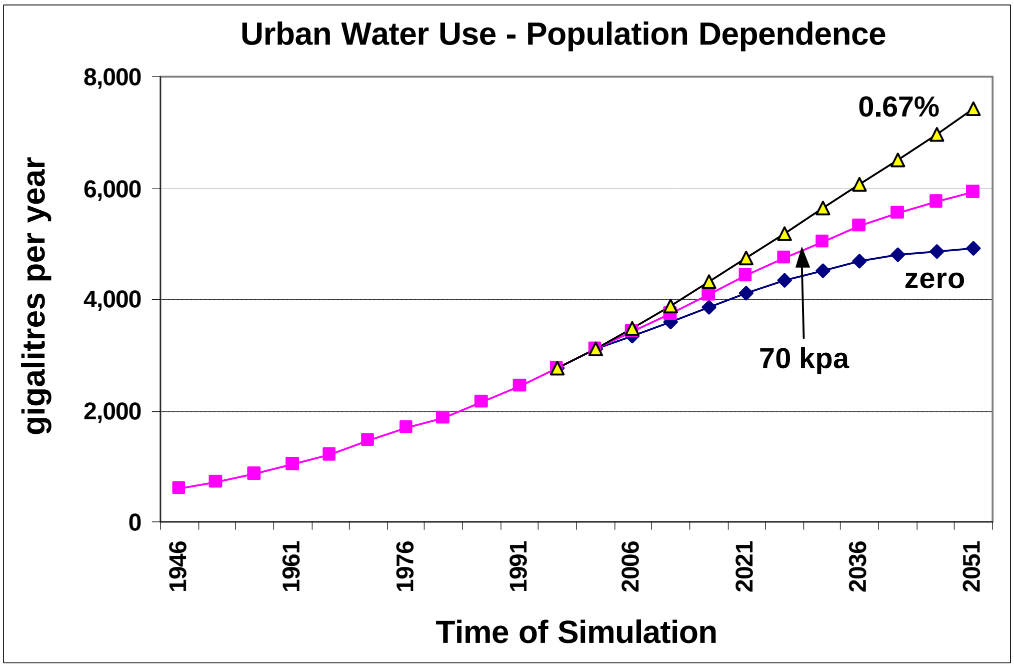


Figure 6.6. Simulated urban water requirement to 2050 in gigalitres (10^9 litres) per year , for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Irrigated agriculture

The area of irrigated crop land doubles from today's level of 2.5 million hectares to 5 million hectares by 2050 (Figure 6.7). This expansion was necessary to meet the production expectations in the starting position and to increase the contribution of agriculture to physical trade and regional development. Some of the expansion was considered feasible in southern Australia for a range of crop types with lower irrigation requirements and the areas of irrigated land increased in New South Wales and Victoria. However due to constraints on the availability of water in southern Australia, all extra requirements from the year 2000 for water intensive crops such as rice, sugar cane, cotton and some horticulture were undertaken in the northern areas of Western Australia and the Northern Territory. Although this new area was less than one million hectares, it required an extra 10,000 gigalitres per year by 2050 or about the same amount as the total current irrigation crop water use. The water resources that are termed divertible and available for development total 46,000 gigalitres per year in the four large drainage divisions in northern Australia (DPIE, 1987), so the simulated requirement is about 25% of the potentially available water resource.

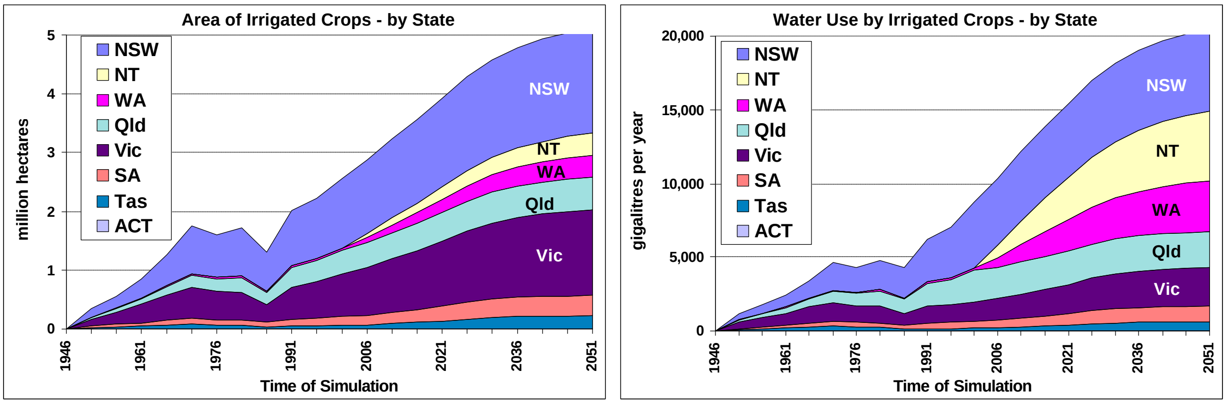
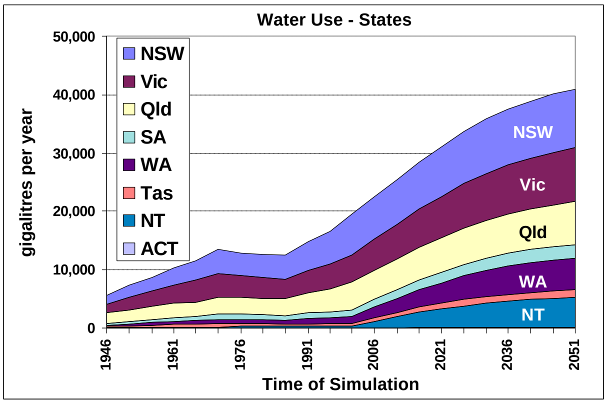


Figure 6.7. Total area of irrigated crop land (million hectares) and irrigation water (gigalitres=10^9 litres) per year, in the base case scenario to 2050 for domestic and export agriculture.

The development of large-scale irrigation in northern Australia could see a repeat of the undesirable flow-on effects observed with previous irrigation development. There are several large projects already underway which aim to complement the original Ord River scheme of 14,000 hectares. These include the Ord Stage 2 with 64,000 hectares, the West Kimberley project with 20,000 hectares and the further developments based on groundwater in the Katherine and Douglas Daly areas of the Northern Territory. The information and technology required for more sustainable irrigation is now more available, with work focused specifically on the sustainability requirements for tropical irrigation. For example Muchow and Keating (1998) in simulation studies of sugar cane grown on the Ord River scheme, pointed to a high water requirement in excess of 40 megalitres per hectare per year and the need to refine irrigation scheduling to optimise sucrose yield and profit. The problems of pesticide contamination that occurred in the early period of Ord River development showed what can happen when cropping systems and their pests become unbalanced (Kookana et al., 1998). The continuing problem of irrigation salinity can be moderated by appropriate water pricing which restricts water application, and use of integrated measurement and information systems which can monitor the onset of salinity problems and allow timely management responses (Rhoades et al., 1997).

Overall water use

The total managed water use for Australia by 2050 under the base case scenario is 40,000 gigalitres per year (Figure 6.8). This compares to water usage of 22,000 gigalitres per year in 1996-97 reported in the national water account (Australian Bureau of Statistics, 2000), 24,000 gigalitres per year in the National Land and Water Audit (Commonwealth of Australia, 2001), and scenario estimates of 25,000 to 33,000 gigalitres per year for 2020-21 reported in the *Water and the Australian Economy* report (Australian Academy of Technological Sciences and Engineering, 1999). The main users of water are New South Wales, Victoria and Queensland, but water requirements in Western Australia and the Northern Territory increase appreciably over the simulation period because of the northern agricultural development. Due to the scenario assumptions, water use by crops and animals represents 80% of total water use, with the remainder due to buildings, secondary industry and mining. The large amount attributed to animals is for irrigated pasture for animal feeding, in particular dairying where cattle numbers double over the next 50 years in line with the assumptions relating to export trade opportunities.



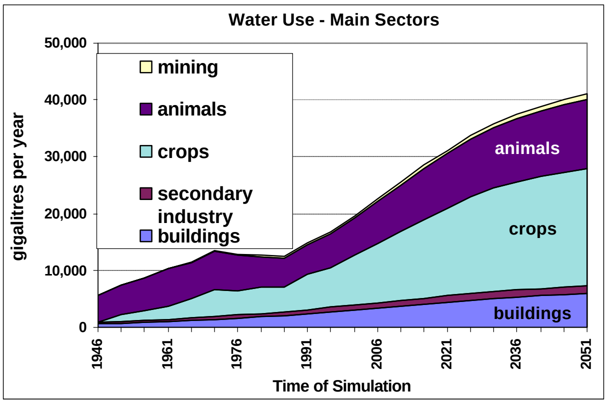


Figure 6.8. Total water requirement to 2050 by (a) state, and (b) by major use, in gigalitres (10^9 litres) per year for the base case scenario.

.

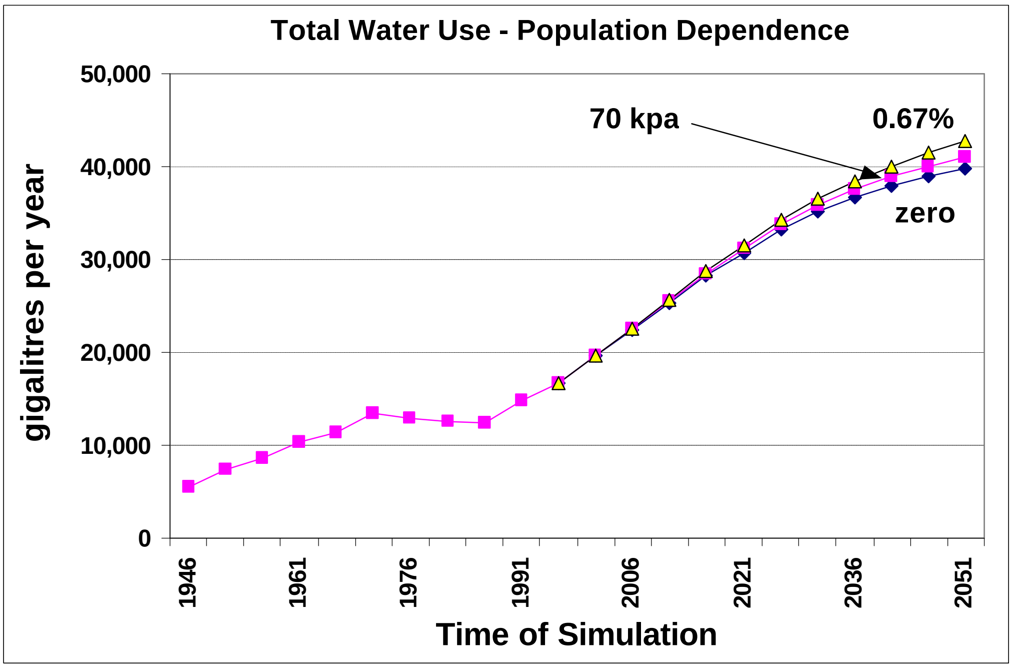


Figure 6.9. Simulated total water requirement to 2050 for all industries and population, in gigalitres (10^9 litres) per year for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

.

Population numbers make a substantial difference to the amount of water required for urban usage by 2050 (Figure 6.6). Overall, population size by 2050 represents a range of 3,000 gigalitres per year in a total managed usage of 40,000 gigalitres per year, or 8% of the total (Figure 6.9). Crops and animals use most of the water to provide products for domestic use and export trade. Commodities such as grain, sugar and cotton are assumed to expand so that they exceed domestic requirements by a factor of 4 to 8. This excess agricultural production together with mining exports contributes strongly to the positive balance for physical trade discussed in the crosscutting sections of Chapter 7. Other commodities such as beef, lamb, poultry and milk products are produced at levels approximately twice the domestic requirements shown by the 0.67%pa scenario. Thus, the tertiary population influence — the trade effect — accounts for a large proportion of Australia's simulated water use out to 2050. A number of analytical approaches can be used to balance the use of water with its economic productivity and employment generation. The *Water Account for Australia* (Australian Bureau of Statistics, 2000) presents data suggesting that vegetables, fruit and grapevines give a gross dollar return of more than $1000 per megalitre of water used. By comparison, sugar, pastures and rice give gross returns of approximately $500 per megalitre of water used. In productivity terms for the manufacturing industry, clothing and footwear, wood products and basic metals give lower values per unit of water used than plastic goods, machinery and transport equipment.

Without accessibility to water of appropriate quality, volume, and timeliness, a modern economic and social structure could not function. However, past actions to bring Australia's water resources under more direct human control have led to a range of negative effects such as irrigation salinity, depleted inland and estuarine fisheries and an altered biodiversity complement in swamps and wetlands. The integrity and cleanliness of urban catchment areas are essential to maintain flows of high quality cheap water to urban Australians. The future development and use of Australia's water resources do not have to repeat the lessons of the past. If elements of the 'develop northern Australian agriculture' scenario tested in this chapter were to proceed, the proponents and managers of these enterprises should be well warned by changes wrought over the past 150 years of water development in Australia.

Sub scenario for 30% water efficiency

There are many opportunities to improve the efficiency of water use, and to reduce its absolute use, the key aim being to maintain the quality of the good, the service or the amenity value while reducing its water content. The options available for urban areas are many. Some of them are technological (better designed washing machines, low flow shower heads, drip irrigation) while some are behavioural (watering the garden at night, shorter showers, dryland gardens, hand-washing dishes). When an assumption is made that the same level of water service and amenity can be delivered with 30% less water, then the urban water requirement for the 0.67%pa scenario can be reduced to the base case scenario requirement, and the base case requirement to that of the zero scenario (Figures 6.6b, 6.10).

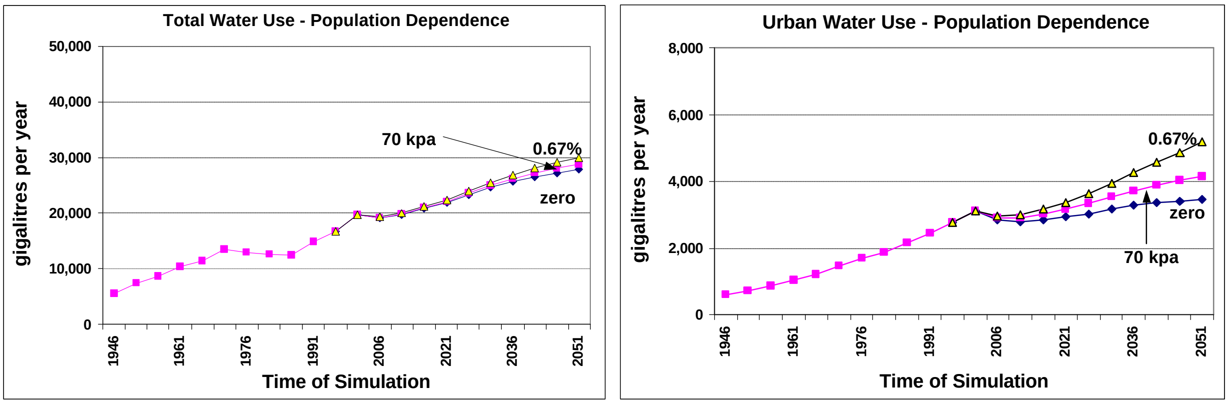


Figure 6.10. A sub-scenario of 30% reduction in water requirement for the same delivery of product, services and lifestyle to 2050 (a) for all industries and population and (b) for urban water requirement. Data are in gigalitres (10^9 litres) per year for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

A number of catchment and city specific details relating to drought risk, catchment integrity, water infrastructure and the possible effects of global warming need to be considered. It is possible that processing urban waste water flows for use in city parks and gardens could contribute a major portion of the 30% saving envisaged (CSIRO, 2000-b), so that one technological application with some behavioural change could allow Australia's current urban water flows to service the requirements of the three population scenarios. The Hunter River region in New South Wales has achieved a per capita water use reduction from about 230,000 litres per year in 1975-76 to 150,000 litres per year in 1995-96 through a combination of water pricing and education innovations. Sydney and Melbourne maintained a relatively constant usage throughout the same period. Climatic differences will also play a role. More water is used per capita in Australia's northern regions and water use also increases during periods of heatwaves. The implications of global warming and climate change are not included in these water analyses. But the possibility looms of changing rainfall patterns, constraints in surface water supplies and longer periods of hot weather. The combination and severity of these effects in different regions will influence the management and investment required for the water system overall.

A similar result to that shown in Figure 6.10b is obtained for the entire water system (urban, manufacturing, mining and agriculture combined) under the 30% reduction sub-scenario (Figure 6.10a). Total water use by 2050 is about 30,000 gigalitres per year, which approximates the scenario estimates for 2020 in the *Water and the Australian Economy* report (Australian Academy of Technological Sciences and Engineering, 1999). The physical and economic feasibility of achieving such a reduction has not been fully analysed and there are a number of institutional, bio-physical, economic and technological barriers to overcome. At an institutional level, the delivery of irrigation water along open canals allows large losses — in the order of 30% — and water applications are often made on schedule (when the water is delivered along the canal) rather than when the orchard or crop requires it in plant physiological terms. Dealing with losses before the water is delivered to the paddock is an engineering problem and national trade offs are required to balance water infrastructure for farms versus those for cities, especially for cities that are growing. The problem then changes from a physical constraint to an economic and political one.

The realities of photosynthesis process and how plants grow in a productive manner also affect water use. High value crops, such as vegetables and fruit, must maintain the correct water balance in order to maximise product quality for discerning markets, and to meet timely delivery schedules. Over-watering in these circumstances can be a wise economic decision if the alternative is rejected and unsaleable produce. Water delivery systems that greatly reduce the absolute requirement for water are widely used but they are mainly applicable to high-value perennial crops. As well, focusing water delivery onto a restricted area of the root zone could exacerbate any problems due to water quality and soil interactions. Many irrigation systems and plants themselves require leaching ratios that remove the accumulated salts in the plant root zone. Farming systems with good management and economic practice deliver more product per unit of water used. In a study of the Victorian dairy industry, Doyle and Kelly (1998) found that the top 10% of farmers used 500 litres of irrigation water per litre of milk produced. By comparison, the average farmer used 700 litres per litre of milk, and the bottom 10% of farmers used 1,000 litres. In this case, a reduction of 50% in water use was possible. However, 500 litres of irrigation water per litre of milk produced could set a physical, economic and environmental threshold that cannot be changed. It is possible that a physical limit may have been reached!

Similar comments can apply to the many manufacturing and mining processes represented in the simulations. While each of these sectors, with about 1,000 gigalitres per year required by 2050, represents only 3% of national water use by that time, many industries and mines are region specific and cannot move to a water source, because of the large physical transactions required to be undertaken in situ. The development of a uranium mine in South Australia required the extraction of 15 megalitres of water per day (5.5 gigalitres per year) from the Great Artesian Basin and a possible expansion to 43 megalitres per day (16 gigalitres per year) with a doubling of mine output. There is no suggestion of negative effect in this example, but the water requirement should be compared to the water use in South Australia by pastoral industry bores of 130 megalitres per day (47 gigalitres per year) and seepages from natural springs of 66 megalitres per day (24 gigalitres per year) (Parliament of Australia, 1997). An assessment of water use in this case, is best made in relation to a number of social, economic and national goals where competing uses (and no use) are ranged against each other.

DISCUSSION

Water and the world

A brief perusal of the world water literature reveals a challenge looming by 2020 when 34 countries will be water-poor. Substantial transfers from agriculture to industry and urban areas will be required, which may restrict the ability of many countries to feed their growing populations. While 40% of the world's accessible water is presently allocated for human use, Falkenmark (1998) suggests that this will have increased to 80% by 2025 because of anticipated pollution loadings in rivers and their requirement for dilution. In rating world water priorities, Falkenmark lists the three main security threats as (i) Water quality degradation reducing the alternative use options (ii) Food insecurity risk and (iii) Growing river depletion in response to intensified food production in the tropics and sub-tropics. The first and third of these threats are well on the way to becoming reality in a number of Australia's important river basins. Food security is not at risk if the reasonable assumptions in the starting scenario for agricultural production are maintained out to 2100.

Policy and management options

Blue, green and white water

Faced with the possibility of an increase in water requirement to 2050, particularly for crop and animal agriculture, five sets of water theory and practice can contribute to changing the way the nation views and manages its water resources. The first set concerns the concept of interactions between the blue, green and white portions of the nation's water resources (Falkenmark, 1995; Savenje, 2000). 'Blue' water is the managed water in rivers, dams and underground aquifers. 'Green' water is the water stored in the soil and available for plant growth while 'white' water is the water in the atmosphere generated by evapo-transpiration from plants and soil, and evaporation.

Human management of Australia's water cycle since European settlement has created imbalances in the blue-green-white water interactions. Because of tree clearing and annual cropping systems, not enough green water is transpired as white water, and this becomes blue water travelling through the landscape, producing dryland salinity and land loss, and also saline seepage causing river salinity. Enthusiastic irrigation practices have led to more blue water being added to regional hydrological systems resulting in irrigation salinity and further leakage to river systems that increases river salinity. If a balance can be found between these two issues, white water flows from landscapes to the atmosphere must increase, and less blue water and more green water must be used for agricultural production systems. More than 60% of the world's staple food production relies on rainfall and hence green water, while the crops that produce fresh attractive products in the market place (fruit and vegetables) or high quality (cotton, tobacco) are irrigated. Information and management systems may have to be implemented that allow decisions to be made on product mixes in relation to blue-green-white water mixes and flows.

Water allocation

Knowledge of the blue-green-white water mix can help reconcile the second issue concerning water allocation. The world water literature describes a three phase water transition where the first phase represents continuing development of water resources, the second is scarcity and competition between users, and in the third phase, people are forced to use water more efficiently and to reduce pollution (Hoekstra, 2000). These phases map easily onto the cultural theory types of Thompson et al. (1990) where phase one is 'individualist' and prefers free market approaches, phase two is 'hierarchical' and prefers government regulation and phase three is 'egalitarian' and requires community cooperation and shared responsibility (Hoekstra, 1998). Australian water appears to be through phase one, well into phase two and experimenting in some regions with phase three.

There are a number of widely differing views on how to achieve better outcomes for the whole water system and its knock-on effects. In comparing the 'panglossian' (blindly or naively optimistic) and 'pragmatic' views of contemporary water economics, Green (2000) claims the 'panglossian' view is content to stay with economic theory and impose a 'one size fits all' solution on the intricate and complex world represented by national water systems. The 'pragmatic' view refutes the pure concepts of efficiency, perfect markets, prices and behavioural change and asserts that privatisation is the only route to the delivery of efficient water services. At a more socio-political level, Allan (1999) asserts that the real job of water policy is to achieve equitable and efficient allocation of water resources, and that decision makers mostly take the water efficiency route which has few political downsides and good economic returns for the makers of pipes, pumps and equipment. By contrast, Allan claims that the real gains for the water system are to be made in understanding the trade in virtual water embodied in traded food and manufactured goods and making appropriate national allocations of water within that context. These issues have important parallels with energy issues, where efficiency policies cause rebounds and many externalities (airshed emissions, greenhouse gases) which go uncosted. However, in comparison to energy and greenhouse issues, the cap on water use in the Murray Darling Basin (Murray Darling Basin Commission Ministerial Council, 1996) sets a physical benchmark and brings physical reality to which social and economic systems will have to adjust.

Trade in virtual water

The third practice that can contribute to a change in water management is the trade in virtual water, i.e., water embodied in the goods and services imported and exported in globalised trade. At a global level, many countries obtain their food necessities through the virtual water trade, by bartering commodities such as oil and elaborately transformed manufactures through the medium of international currency exchange. In a managed water use of 24,000 gigalitres per year, Australia exports the equivalent of 7,500 gigalitres of water embodied in goods and services and imports the equivalent of 3,500 gigalitres. This leaves a net outflow of about 4,000 gigalitres per year, roughly equivalent to the water consumption of the entire urban sector excluding manufacturing (Table 6.8; Lenzen and Foran, 2001). If 'white' water or 'transpired' water is used, then the export in agricultural produce is about 28,000 gigalitres per year (Dunlop, pers. comm.). Similar analytical procedures for embodied energy show that trade exchanges (imports versus exports) which have been roughly in balance, are now moving into a deficit (Lenzen, 1999). Given the possibility of future environmental and social fragilities in Australia's water system (river salinity, depleted inland fisheries, rural decline) an important national question to be addressed is whether Australia receives adequate monetary return for the net outflow of 4,000 gigalitres of its managed water resource. The current status of export farm prices, the physical trade balance, the current account deficit, and the status of international debt levels suggest that the trade in 'virtual or embodied' water could be a loss leader for the nation and many of its land and water regions.

A nation seeking to garner reasonable economic returns from international trade could adopt a strategic approach to the monetary returns expected from the virtual water trade. It is well documented that there are countries with a looming problem of water stress and water scarcity (Raskin et al., 1996; Ohlsson, 2000; Falkenmark, 1999). National water scarcity is usually declared at a threshold of 1,000 cubic metres per capita of water flow per year (one cubic metre equals 1,000 litres). Trading partners such as Japan have more than 4,000 cubic metres per capita and with a stable or declining population, the country's relative water security is assured. Other countries such as the Republic of Korea (1470 m^3 per capita), Singapore (220 m^3 per capita), Saudi Arabia (225 m^3

per capita), United Arab Emirates (566 m^3 per capita), former Soviet Union (1240 m^3 per capita), and Venezuela (208 m^3 per capita) all have oil reserves and/or advanced manufacturing capability that Australia might require in the future. A series of trade negotiations which attempt to balance the export price received for goods and services with various embodiments of water, energy, labour, intellect and environmental integrity, could help fund re-investment into the repair and maintenance of Australia's water resources. Focusing on countries with looming water deficits does not avoid Australia's obligation for food aid and crisis assistance to a wide range of countries that are already badly stressed in water and food terms. Rather it focuses on building reasonable foundations for physical and monetary exchange mechanisms over timeframes of human generations. Then, the prices exchanged in international trade could cover the full cost of the exchanged goods and services.

Table 6.8. Gigalitres (10^9L) of water embodied in exports and imports in the 1995-96 national water account and monetary input-output tables (adapted from Lenzen and Foran, 2001).

	Exports	Consumer imports	Industrial imports
Mains water supply	3,555	630	1,059
Self extracted water supply	3,884	669	1,207
Total	7,439	1,299	2,266

Water management boundaries

The fourth issue relates to the need to reconcile the political, economic, social and physical boundaries within which the nation's water resources are managed. By defining management authorities that deal with entire spatial issues such as The Great Barrier Reef or the Murray Darling Basin, Australia has acknowledged leadership in the area of institutional reform. New Zealand led the way in the late 1940s when it co-located its regional government boundaries with the catchment boundaries of the major river basins. Global water policy circles acknowledge that 'whole of river basin' approaches are the only effective way to manage and integrate the many issues involved in water management. While it may take 50-100 years or more to see the bio-physical returns from social and financial investments in river catchments and their human capital, there is world consensus that this is the only way forward (Bjerregaard, 1998). Although Australia may not yet have the allocative mechanisms in place to ensure equity of access to and use of water, the Council of Australian Governments (COAG) water reforms are already in place and moving at a steady pace towards policy conclusion in 2020 (Agriculture Fisheries and Forestry Australia, 2000). This is good news!

Global climate change

The fifth issue, not analysed at all in these scenarios, is the effect of global climate change in altering the hydrological regimes which contribute to the balances between blue, green and white water flows. Spatial studies of temperature/rainfall/runoff characteristics at a global level (Hulme et al., 1999), in the United Kingdom (Sefton and Boorman, 1997) and for continental Europe (Arnell, 1999) show the possibility of large geographic and time shifts in major precipitation events and the same is possible for Australia. CSIRO (2000, 2001) regional modelling experiments show that Queensland could be warmer with more downpours, with the possibility of more cyclones, storm surges and flood events. The effect of regional climate change on particular sectors has been examined for rangelands (Howden et al., 1999-a) and for wheat cropping (Howden et al., 1999-b). These studies show, that while it is possible to adapt production systems in many areas, and that some areas may in fact benefit, in other areas production systems could become marginalised and disappear altogether. The blue and green water systems will be driven by global change and human management, and more resilient systems have the best chance of long-term survival.

The population effect

By 2050, many areas of the world could be suffering impaired living standards and quality of life due to water scarcity. Withdrawals from natural water sources and bodies have far in exceeded the growth in population numbers — about two and a half times more rapid (Falkenmark and Lundqvist, 1998). Around the year 2025, about 3 billion people are likely to live in areas of water scarcity and water stress (Falkenmark and Rockstrom, 1993). While Australia may be a water poor continent in world terms, even with a population of 32 million people by 2050 presented by the 0.67%pa scenario, it will still be relatively well off compared to many of its neighbours and trading partners. However in some regions, water supply and water quality may present real challenges.

Table 6.9. A comparison of the population effect on water use at 2050 in gigalitres (10^9L) per year. A proportional use in comparison to the base case is shown in brackets (base case equals 100% at 2050).

Category of water use	Zero scenario at 2050 (proportion of base case in brackets)	Base case scenario at 2050 (proportion of base case in brackets)	0.67%pa scenario at 2050 (proportion of base case in brackets)
All buildings	4,839 (82%)	5,875 (100%)	7,395 (126%)
Manufacturing	370 (90%)	409 (100%)	476 (116%)
Food processing	195 (82%)	236 (100%)	301 (127%)
Material and energy transformation	662 (86%)	768 (100%)	942 (123%)
Mining	959 (98%)	974 (100%)	1,023 (105%)
Crop agriculture	20,483 (100%)	20,483 (100%)	20,483 (100%)
Animal agriculture	12,268 (100%)	12,268 (100%)	12,268 (100%)

The direct population effect for water use at 2050 is shown in Table 6.9. As already noted (Figure 6.5), the direct requirement by buildings spans a range of 2,500 gigalitres per year and reflects the difference in population levels with minor differences due mainly to inbound tourism. The population effect for manufacturing spans a range of 100 gigalitres per year and does not directly reflect a population effect due mainly to assumptions about import-export ratios of manufactured goods. Food processing shows a population effect of about 100 gigalitres per year between the zero and the 0.67%pa scenarios and directly reflects population differences. Material and energy transformation shows a population effect of about 300 gigalitres per year with direct population effects due to building materials and electricity generation, but with some dilution due to export industries such as aluminium. The mining sector shows differences of 100 gigalitres per year due to population effects and most of this is due to mining of basic inputs for building construction and roads. Both crop and animal agriculture are the same for all population scenarios, assuming that all production not for domestic requirements is exported. The direct water requirements for urban Australia, even including manufacturing and materials processing, are relatively small in relation to the total use. Technological innovations will ensure that water recycling is standard, and that urban quality standards are met. In terms of a direct population effect, Australia appears to have sufficient water availability. There are however challenging problems in future in the area of water quality (CSIRO, 2000-c, 2001-b; Fisher, 2000).

By 2050, the tertiary trade effect of population will continue to have the dominating influence on the nation's water usage and subsequent water quality and river depletion problems linked to it. If issues such as lifestyle/affluence and the intellectual/technological capability to export advanced goods and services become decoupled, then Australia's physical trade balance and international debt levels may become problems in the eyes of the world's financial managers. Continuing to manage debt levels and trade balances may increasingly depend on areas where Australia retains some comparative advantage such as mineral resources and land area, relatively low population, reasonable water supplies and proximity to large markets requiring food and fibre. In these situations, supplies of water may still be adequate, but, if history is any guide, water quality and river depletion issues will continue to increase.

This bleak prognosis need not occur! If difficult decisions are made about the water content of all exported goods and services and the embodied water is reconciled with the energy used, the labour required, the export dollars gleaned and the ecosystem services required and altered, then reasonable balances will be maintained between water use, water no-use and the environmental water flows required to maintain ecosystems, fish populations, waste processing functions and the amenity given by healthy waterways. De Jong et al. (1995) conclude with the following, 'the major challenge that faces us is whether we are really prepared to implement theoretically and practically the integration that is needed'.

CONCLUSIONS

By the year 2050 Australia's managed water use could be about 40,000 gigalitres per year based on the direct population requirements and the needs of the domestic and export industries that contribute to the tertiary trade effects and the quaternary international debt effect. This compares to a water use today of about 24,000 gigalitres. The direct population effect in 2050 for total urban requirements is 5,000, 6,000 and 7,500 gigalitres per year for the zero, base case and 0.67%pa scenarios respectively. By comparison, the manufacturing industry will require 1,500 gigalitres and the mining industry, 1,000 gigalitres per year at that time.

Crop and animal agriculture requires more than 80% of the total water use by 2050 (more than 30,000 gigalitres per year). The expansion of irrigated production requires the development of more than one million hectares of irrigation in northern Australia because of constraints in water availability and water quality in traditional irrigation areas. It is possible that improvements in the efficiency of water usage could allow the higher population levels to function comfortably and equitably for the same water requirement as the zero population scenario without technology improvement. Equally, at the level of the whole economy, technically feasible improvements could reduce the total water requirement to 30,000 gigalitres per year, but achieving this reduction involves a range of plant growth, infrastructure, economic and social effects which produce constraints, generally outside the boundary of the paddock where the water is applied.

The most critical issue for the future of water in Australia is not about finding and acquiring enough to use. Rather it relates to the plethora of side effects associated with our requirement for, and use of water. The issues of irrigation salinity, river salinity, depletion of inland fisheries, maintenance of economic and social vitality in regional areas, heavy metal and pesticide contamination and the beauty and amenity of our urban areas are tied to water use (Young 2001).

It is relatively easy to promote the cause of water use efficiency as there are many employment prospects and company profits tied to the sale of pipes, valves and pumps. Much more difficult and usually evaded by decision makers, are the challenges of just and equitable allocation of water. Tied into this allocation challenge is the physical aspect of how much water is embodied in each product we consume domestically or export, and whether just monetary and social costs are being obtained in the international market place for the water used. A lateral view might conclude that a country with a balanced physical trade account, and a low level of international debt, would not have to rely on water based agriculture to the same extent as Australia does today. The nation's water system could then be more relaxed and possibly more natural.

A nation with a long-term strategic view would know the extent to which water, precious to its people, its industries and its environmental integrity, is embodied in each good, service and product that it produces for domestic consumption, for export or that it imports. Such analyses could form the basis of understanding which allows water use to be aligned with the values for physical production, monetary return, labour generation, energy use, export trade and environmental externalities. Equitable decisions could then be made on the integration of economic, social and environmental considerations.

REFERENCES

Agriculture Fisheries and Forestry Australia (1999). Progress in implementation of the COAG water reform framework. 1999 Report to COAG. High Level Steering Group on Water; Occasional Paper Number 1. AFFA Canberra.

Allan T (1999). Productive efficiency and allocative efficiency: why better water management may not solve the problem. Agricultural Water Management 40, 71-75.

Arnell NW (1999). The effect of climate change on hydrological regimes in Europe: a continental perspective. Global Environmental Change 9,5-23.

Australian Academy of Technological Science and Engineering (1999*). Water and the Australian Economy*. A joint study project of the Australian Academy of Technological Science and Engineering and the Institution of Engineers, Australia. Published by AATSE April 1999, Parkville Victoria.

Australian Bureau of Statistics (2000). *Water Account for Australia*. ABS Catalogue No 4610.0 May 1st 2000.

Australian Greenhouse Office (2000). 1998 National Greenhouse Gas Inventory. http://www.greenhouse.gov.au/inventory/facts/facts_content.html accessed 14-7-2000.

Bjerregaard R (1998). Getting Europe's waters cleaner: getting its citizens involved. Water Policy 1,73-80.

Commonwealth of Australia (2001). *Australian Water Resources Assessment 2000*. The National Land and Water Audit, January 2001, Canberra.

CSIRO (2000-a). Queensland warmer, with more downpours. CSIRO Press Release 2000/169 Wednesday 28th June 2000. http://www.csiro.au/ accessed 10-8-2000.

CSIRO (2000-b). Call for national focus on water re-use. CSIRO Press Release 2000/272 Thursday 19th October 2000. http://www.csiro.au/ accessed 20-10-2000.

CSIRO (2000-c). Water quality: real test for Australia's health. CSIRO Press Release 2000/270 Tuesday 17th October 2000. http://www.csiro.au/ accessed 20-10-2000.

CSIRO (2001-a). Climate change in Australia. CSIRO Atmospheric Research, Aspendale Victoria. http://www.dar.csiro.au/publications/projections2001.pdf accessed 26-06-2001.

CSIRO (2001-b). Water limit to Australia's economic growth. CSIRO Press Release 2001/151 Wednesday 20th June 2001. http://www.csiro.au/ accessed 26-06-2001.

Department of Minerals and Energy (1975). Atlas of Australian Resources, Second Series: Water Use. Geographic Section, Division of National Mapping, Department of Minerals and Energy, Commonwealth of Australia.

Doyle PT and Kelly KB (1998). The Victorian dairy industry - improving performance. Proceedings of the 9th Australian Agronomy Conference, Wagga Wagga, 20-23rd July 1998, pages 119-127.

DPIE (1987). *1985 Review of Australia's Water Resources and Water Use*. Australian Water Resources Council, Department of Primary and Energy, November 1987. Australian Government Publishing Service, Canberra.

Dunlop M (2001). Australian Water Use Statistics. CSIRO Resource Futures Working Document 01/03 http://www.dwe.csiro.au/research/futures/publications/01-03f.pdf accessed 26-06-01

Dunlop M and Foran BD (2001). Water Futures Workshop: Issues and Drivers. CSIRO Resource Futures Working Document 01/04 http://www.dwe.csiro.au/research/futures/publications/01-04f.pdf accessed 26-06-01

Falkenmark M and Rockstrom J (1993). Curbing rural exodus from tropical drylands. Ambio 22,7,112-118.

Falkenmark M and Lundqvist J (1998). Towards water security: political determination and human adaptation crucial. Natural Resources Forum 21,1,37-51.

Falkenmark M (1997). Meeting the water requirements of an expanding world population. Philosophical Transactions of the Royal Society of London 352,929-936.

Falkenmark M (1998). Dilemma when entering the 21st century - rapid change but lack of sense of urgency. Water Policy 1,421-436.

Falkenmark M (1999). Forward to the future: A conceptual framework for water dependence. Ambio 28,4,356-361.

Fisher P (2000). Dampened expectations: Will our major cities escape a water crunch? Review Section, The Australian Financial Review, p1-2,7,10 Friday 11th August 2000.

Gleick PH (1994). Water and energy. Annual Review of Energy and Environment 19,267-299.

Gleick PH (2001). Making every drop count. Scientific American: Feature Article, February 2001. http://www.sciam.com/2001/0201issue/0201gleic.html

Gordon L Dunlop M and Foran BD (2000). Water vapour flows from vegetation in Australia 1780 to 1980. Draft manuscript July 2000, CSIRO Resource Futures Program, Canberra.

Green C (2000). If only life were that simple: Optimism and pessimism in economics. Physical and Chemical Earth (B) 25,3,205-212.

Guest RS and McDonald IM (2001). Ageing, optimal national saving and future living standards in Australia. Draft manuscript Department of Economics, University of Melbourne. http://melbecon.unimelb.edu.au/staffprofile/imcdonald/balance.html accessed 26-06-01.

Hamilton C and Saddler H (1997). The Genuine Progress Indicator: A New Index of Changes in Well-being in Australia. Discussion Paper Number 14, October 1997, The Australia Institute, Canberra.

Hoekstra AY (1998). Appreciation of water: four perspectives. Water Policy 1, 605-622.

Hoekstra AY (2000). Water supply in the long term: A risk assessment. Physical and Chemical Earth (B) 25,3,221-226.

Howden SM McKeon GM and Reyenga PJ (1999-a). Global change impacts on Australian rangelands. CSIRO Resource Futures Program Working Paper Series 99/09.

Howden SM Reyenga PJ and Meinke H (1999-b). Global change impacts on Australian wheat cropping: Studies on hydrology, fertiliser management and mixed crop rotations. CSIRO Resource Futures Program Working Paper Series 99/13.

Hulme M Mitchell J Ingram W Lowe J Johns T New M and Viner D (1999). Climate change scenarios for global impact studies. Global Environmental Change 9,S3-S19.

Kookana RS Baskaran S and Naidu R (1998). Pesticide fate and behaviour in Australian soils in relation to contamination and management of soil and water: a review. Australian Journal of Soil Research 36,715-764.

de Jong J van Rooy PTJC and Hosper SH (1995). Living with water: At the cross-roads of change. Water Science Technology 31,8,393-400.

Lenzen M (1999). A generalised input-output multiplier calculus for Australia. Unpublished manuscript, Department of Applied Physics, University of Sydney, December 1999.

Lenzen M and Foran BD (2001). An input-output analysis of Australian water usage. Water Policy 3,321-340.

Lenzen M Dey C and Foran BD (2002). Energy requirements of Sydney households. Draft manuscript submitted to Environment and Planning A, April 2002. Department of Applied Physics, University of Sydney.

LWRRDC (1997). Using foresighting to identify R&D priorities for LWRRDC. Occasional Paper No 10/97, Land and Water Resources Research and Development Corporation, Canberra ACT, July 1997.

Minerals Council of Australia (1999). Environment: Fact sheets for the 13 NPI priority substances: The simple guide. http://www.minerals.org.au/pages/page6_186.asp accessed 8-8-2000

Muchow RC and Keating BA (1998). Assessing irrigation requirements in the Ord sugar industry using a simulation modelling approach. Australian Journal of Experimental Agriculture 38,245-254.

Murray Darling Basin Ministerial Council (1996). Setting the Cap: Report of an Independent Audit Group. November 1996.

Newton PW Baum S Bhatia K Brown SK Cameron AS Foran B Grant T Mak SL Memmott PC Mitchell VG Neate KL Pears A Smith N Stimson RJ Tucker SN and Yenken D (2001). *Human Settlements*, Australia State of Environment 2001 (Theme Report). CSIRO Publishing on behalf of the Department of Environment and Heritage, Canberra.

Ohlsson L (2000). Water conflicts and social resource scarcity. Physical and Chemical Earth (B) 25,3,213-220.

Parliament of Australia (1997). Appraisals of environmental performance at Ranger and the Olympic Dam operation. The Senate, Committees, Select committee on uranium mining and milling, http://www.aph.gov.au/senate/committee/uranium_ctte/report97/ch2_4.htm accessed 9-8-2000

Raskin PD Hansen E and Margolis RM (1996). Water and sustainability: Global patterns and long-range problems. Natural Resources Forum 20,1,1-15.

Rhoades JD Lesch SM LeMert RD and Alves WJ (1997). Assessing irrigation/drainage/salinity management using spatially referenced salinity measurements. Agricultural Water Management 35,147-165.

Rockstrom J Gordon L Folke C Falkenmark M and Engwall M (1999). Linkages among water vapour flows, food production and terrestrial ecosystem services. Conservation Ecology 3,2,5 http://www.consecol.org/Journal/vol3/iss2/art5/ accessed 9-8-2000.

Savenije HHG (2000). Water scarcity indicators: The deception of numbers. Physical and Chemical Earth (B) 25,3,199-204.

Sefton CEM and Boorman DB (1997). A regional investigation of climate change impacts on UK streamflows. Journal of Hydrology 195,26-44.

Thompson M Ellis R and Wildawsky A (1990). *Cultural Theory*. Westview Press, Boulder.

Vertessy RA (2001). Impacts of plantation forestry on catchment runoff. In *Plantations, Farm Forestry and Water*, Proceedings of a national workshop, 20-21 July 2000, Melbourne edited by EK Sadanandan Nambiar and AG Brown, RIRDC Publication No 01/20.

Young WJ (editor) (2001). *Rivers as Ecological Systems: The Murray Darling Basin*. The Murray Darling Basin Commission, Canberra.

Chapter 7
Crosscutting issues and conclusions

ABSTRACT

This chapter seeks to integrate the national population analysis by highlighting a set of issues that operate at a higher level than the individual analyses presented in the previous five chapters. Six dilemmas are presented which link population policy, ageing, physical trade, material flows, greenhouse emissions, natural resource depletion and environmental quality. Each dilemma and the interactions between them are guided by the assumptions of the underpinning starting scenario, and the laws that constrain the physical world. Single dilemmas are mostly open to resolution within the current settings of technology and ideology. Resolving two, three or more dilemmas in parallel is more difficult because of human behavioural dynamics that lie outside this analytical capability and generally outside the comprehension of policy development. Dilemma one is that population is ageing and birth rates seem destined to decline. High immigration can offset this in a proportional sense, but absolute numbers of aged citizens continue to rise so the levels of support and caring tasks do not decline. Dilemma two is that higher populations might maintain a lower balance of trade in physical goods and commodities. Expanding populations require more imports and consume more domestic production leaving less for export. Dilemmas three (material flows) and four (greenhouse gas emissions) are linked to dilemma two as physical trade expands to pay for continuing import of investment funds and personal consumption requirements. Dilemma five is that domestic requirements and trade activities will inevitably cause overuse of agricultural soils, marine fisheries, and domestic stocks of oil and gas. Dilemma six is that environmental quality issues such as urban air quality, river water quality and biodiversity quality seem destined to decline unless radical solutions are found for the other dilemmas. An integrated resolution to dilemmas three, four, five and six might require a reduction in Australia's physical transactions. Knock-on effects might reduce the physical trade balance, and require services exports, or trade in information, to fill the gap. An information rich economy with low material transactions requires a highly educated workforce that might be willing to moderate lifestyle and physical demands as their contribution to resolving dilemmas three to six. How radical requirements for change such as this might feed back to the vital rates (births, deaths, emigration and immigration) that drive population number and age structure, is beyond the scope of this study but requires investigation if concepts such as 'ecologically sustainable development' are to be implemented at an economy-wide level. The dilemmas form a framework against which 10 conclusions from the study are drawn.

INTRODUCTION

Throughout the previous five chapters, individually focussed problems or challenges in the physical economy have generally been resolved, or potentially so, by the introduction of an improved technology or the alteration of a requirement in the face of different rates of population growth. Examples of this include better engines in motor cars to reduce energy use and airshed emissions, reduced energy use in houses and commercial buildings to reduce greenhouse gas emissions and the transition to compressed natural gas to avoid possible constraints in domestic oil supplies.

However many sub-scenarios have flow-on effects that impact at higher levels in economic and social areas of national function. The transition to a factor-4 economy, for example, involves some of these potential higher order effects. If material and energy flows were halved, a flow-on effect might be fewer employment opportunities, unless compensating opportunities in the service economy opened up to replace the employment based on material flows. This chapter brings together a number of cross cutting issues, four of which link at the level of the whole economy, and presents system wide views of potential effects of population size and structure. The fifth and sixth issues describe a number of resource depletion and environmental quality topics not all of which are directly related to future population size. Each issue is presented as a dilemma since there are always several logical options and the analysis to date has not provided a clear-cut solution. Also, some of the potential solutions presented are open to a wide range of behavioural, political or economic unknowns. The dilemmas presented in order are:

- **The ageing dilemma**: The choices are either to accept that Australia will age markedly over the next two human generations with possible challenges to the cost of health care and pension schemes or to lower the age structure, by increasing the level of younger immigrants and/or increasing the fertility rate. This choice has flow-on effects to the following five dilemmas.

- **The physical trade dilemma:** We can either continue to expand production levels from the physical economy with the goal of maintaining reasonable levels of monetary balances with the rest of the world or constrain physical trade flows in an attempt to manage the greenhouse gas and material flow dilemmas.

- **The material flow dilemma:** The first choice is to accept that Australia's future in the globalised trading world lies in being a materially intensive economy on a per capita basis, and to ensure that international agreements acknowledge and reward this strategy by attributing environmental cost to the consumer, rather than the producer. The other choice is to make a transition away from materially intensive products and commodities into new industries characterised by low material and embodied energy content, and high intellectual and information content.

- **The greenhouse gas dilemma:** The choice here is to either continually improve the technology and efficiency of the nation's energy metabolism, but with the knowledge that the emission goals set by the Kyoto Protocol negotiations will not be met, or to halve the levels of material consumption for all citizens with possible short-term effects on economic growth, personal affluence and social cohesion.

- **The resource depletion dilemma:** One choice is to accept that resource depletion over timescales of centuries is inevitable and to ensure that finite resources such as arable soils, marine fisheries and domestic stocks of oil and gas are used effectively to maximise social and economic returns for the nation's citizens. The other choice is to fully embrace the concept of sustainability and to ensure that stocks of agricultural land and marine fish do not decline, and that domestic oil and gas reserves underpin the transition to a low carbon, renewable energy economy.

- **The environmental quality dilemma:** We can either use technology to deal with negative aspects of declining water quality, biodiversity quality and urban air quality or treat the cause rather than the symptom. This requires that our water catchments be reforested, our biodiversity habitat and ecological function be re-established and that future personal mobility in cities is based on low-carbon, low-emission forms of personal transportation.

POPULATION AND AGEING DILEMMA

The issue

Many OECD countries are concerned with the implications of population ageing in relation to the provision of pensions, health care, general community services and the potential problems of maintaining a workforce of sufficient size and skill base to undertake a full range of tasks central to the maintenance of national economic productivity. The nature of the dilemma for Australia is portrayed in Figure 7.1. Both the 1946 and 1996 population have a relatively young age structure with declining tails of older people. By 2050, the ageing tail has expanded and the proportion of younger age classes has declined slightly. The 0.67%pa scenario follows this pattern but also has an added bump of people in the 20-40 year age group due to the immigration characteristics of that population scenario. The analyses presented in Chapter 2 suggested that while the 0.67%pa scenario was able to provide a population with a lower proportion of people over 65 years of age, the absolute number of aged people would continue growing, to reach 10 million people by the year 2100 in a total population of 50 million people (Figure 7.2). Thus, higher rates of net immigration would mitigate the proportional issues (provided that the overall intake of immigrants was markedly younger) but the absolute issues would remain unsolved.

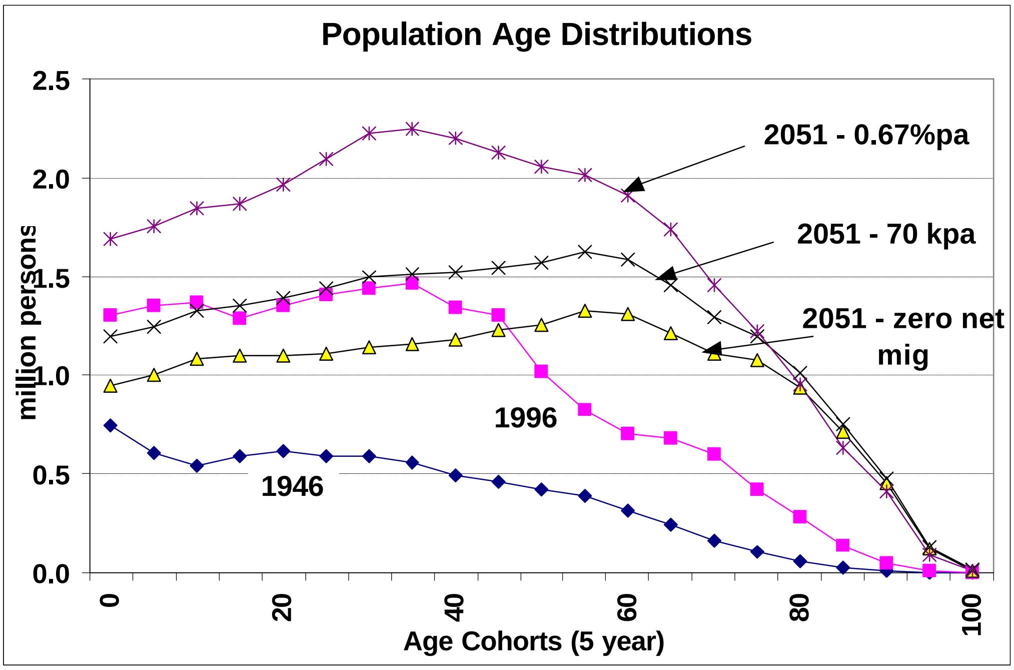


Figure 7.1. Age distribution in millions of persons per 5-year cohort for the Australian population in 1946 and 1996, and the three population scenarios in 2050.

Business leaders are concerned about the 'disappearing worker' as population ageing limits the supply of labour and the effects flow on to overall economic performance (HSBC, 2000-a). Analyses such as these lead to proposals for the maintenance or increase of rates of population growth (Chadwick, 1999) which are paralleled in Western Europe where low growth and absolute decline of population are already well underway (The Economist, 2000-a). There is no universal agreement on the presumed load and increased difficulties that changed population structures might impose in future economies and societies. Recently published books, *Social Security: The Phoney Crisis* (Baker and Weisbrot, 1999) and *The Imaginary Time Bomb* (Mullan, 2000) postulate that reasonable rates of economic growth could provide sufficient funds for social security and health care and that while health care costs are higher in the over-65 class, people are living for longer and are healthier, with most health care concentrated in the last few years of life.

Bacon (1999) integrates a number of these themes to form a reasonably positive view for Australia, assuming population outcomes similar to those arising from the base case population of 70,000 net migration per year. He reports that household wealth per capita is rising at 10% per year in line with a moderately growing economy, which could result in larger inheritances, more leisure and a declining rate of unemployment due to a declining workforce. Economic modelling by Guest and McDonald (2001) found that a moderate expansion of national savings by 3.2 percentage points of GDP to the year 2010 and a slow decline thereafter would be sufficient to underpin the ageing transition and to ensure a steady expansion of personal consumption until the year 2050. There is continued speculation about the interaction between the 'health effect' and the 'wealth effect' where people save effectively during their working lives to maintain comfortable lifestyles in retirement (The Economist, 2000-b). Some of these opinions are expanded in shorter-term analyses to 2010 by Harding and Robinson (1999), who foresee an increase in disposable income for households in the top 40% of income bracket, and a more than adequate income from self-funded retirees. These higher disposable incomes and changing leisure patterns will drive strong consumption demand for the 'striving to stay young baby-boomers and older retirees'. In a related study, King et al. (1999) conclude that "due to its unique and flexible retirement income system, Australia is expected to have less difficulty than most other countries in meeting this challenge from accelerated population ageing" given that population outcomes are similar to the base case used in this study.

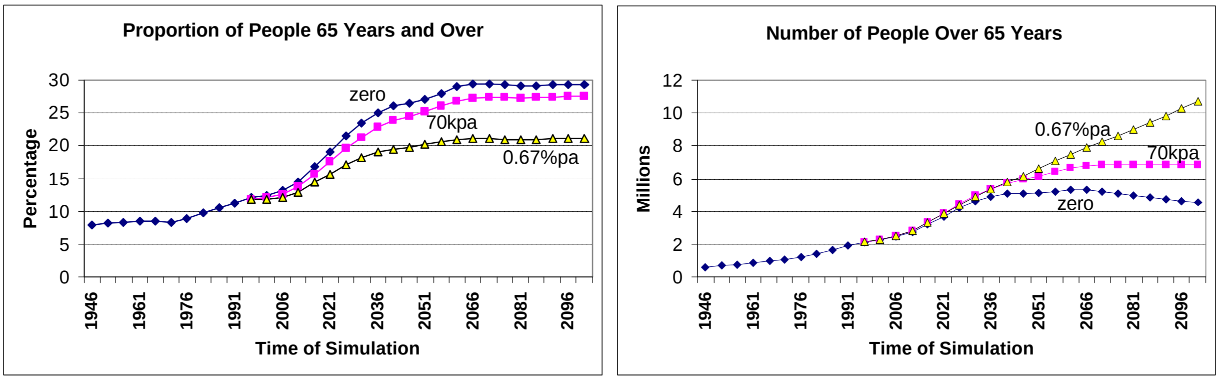


Figure 7.2. Simulated proportion and number of total population to 2100 who will be over 65 years of age for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

.

The crosscutting implication

The dilemma of population ageing is whether it is a dilemma at all! National business interests (Business Council of Australia, 2001) certainly promote it as a major issue facing Australia. On the surface, solving the problem of the ageing of the population is simple from a biological viewpoint, but probably infeasible from a gender equity, social and political point of view. Replacing the number of immigrants with an increase in the total fertility rate can moderate the proportional aspect of ageing, but it will not enable a return to the age structures present from 1950 to 1970 when Australia was, demographically speaking, a young country. The sub-scenario presented in Chapter 2, where increases in fertility were used to replace the population growth now provided by immigration, shows this conclusively. Moderate increases in the total fertility rate allowed the zero net immigration scenario to achieve the same total population number at 2050 and 2100 as the base case scenario, with slightly more younger age cohorts and fewer of mature age. The same result was true of using total fertility rate to partially replace net immigration in matching the 0.67%pa population outcome to the base case net immigration rate. These results generally concur with the more detailed demographic analysis of McDonald and Kippen (1999).

However, such increases in the total fertility rate cannot be forced into modern economic and social systems. The nature of and reason for the decline in total fertility rates remain a subject of considerable debate among demographers who are concerned about the possibility of terminal decline in national populations if low fertility rates lock in for periods beyond one or two human generations. According to McDonald (2000), at a total fertility rate of one child per woman, it will take 90 years or three human generations for the generation at that time to be one eighth the size of the original generation. Whether nations can function effectively under these new demographic structures then becomes the core concern of national population policies.

There is much debate in western economies on the reason for, and policy responses to, birth rates that are declining below those levels required for population replacement. Coleman (2000) postulates that extremely low birth rates in countries such as Italy and Spain "arise from an incoherence between unequal levels of gender equity in different social institutions of society". These societies have traditional family structures, that are male dominated and where households often house people from three generations (McDonald, 2000). This structure seems to present a partial answer to the ageing dilemma (in that aged parents are cared for at home) but retains the lowered fertility rates that concern demographers with a long view. In terms of forming policy to help resolve the ageing dilemma, McDonald (2000) postulates that most young women in Australian society would like two children. However the increasing risk of partnerships breaking down, the financial disincentives to rearing children and lack of support in workplace arrangements for working parents (and many other factors) combine to reduce their opportunities and the desire to maintain an average of two children over the whole population.

Some policy responses centre on supporting families who desire more than one child by ensuring working mothers are not disadvantaged by workplace conditions and taxation arrangements. In what are complex social and personal areas, Birrell (2000) notes that many younger mothers who are maintaining Australia's fertility rate at a higher level than it might otherwise be, are poorly educated and financially constrained. As Australia's future workforce, with its requirement for advanced skills and flexibility will depend on these children, Birrell recommends targeted policies for the education and training of both mothers and children. Any simplistic notions of increasing birth rates to deal with the ageing dilemma, must have wide social and educational underpinnings that are thought through in the long term.

The key dilemma of ageing in physical economy terms, is that mature demographic structures may stimulate consumption and national output, rather than reducing business activity, as some business commentators assume. This is appropriate for the personal lifestyle and its enjoyment by ageing consumers, but may interact with several other dilemmas in this chapter to increase the management challenge in a number of physical sectors such as energy, greenhouse gas and material flows. The synergy between the increasing number, longer active life and the accumulated wealth of self-funded retirees and the changes in consumption patterns projected by Harding and Robinson (1999), could imply a consumption boom that could last at least one human generation. The Guest and McDonald modelling simulated feasible growth in personal consumption of 1% per year leading to levels 80% greater than current levels by 2050. It is likely that consumption expansion of this level would increase the material flow and energy/greenhouse dilemmas, particularly in the zero and base case population scenarios, where international balance of payments might trend more positively than the 0.67%pa scenario. Thus, the physical flows associated with each population scenario could shift upwards due to stimulation by grey-power consumption patterns. The global status of oil and gas reserves might retard the consumption boom past 2030, as might major changes in trade prices and market opportunities for coal, minerals and agricultural exports, or protracted security problems in Asia and the South Pacific.

A tangential sub-set of the ageing dilemma is the relationship between the increasing wealth of the ageing population, the flows of wealth in superannuation funds and other investments, and whether that stock of wealth acts as a stimulus or a retardant on important material flows within the physical economy. Both Hawken et al. (1999) and Herring (2000) focus on the requirement to deflate the environmental and material implications of continued economic growth by large and continuing investments in social capital and natural capital. Natural capital investments potentially soak up large flows of investments and return profits slowly over long time periods, thus limiting the capacity for rebound effects. Social capital investments presumably provide a transition to an equitable society where basic requirements are met, and where wants are couched less in terms of material consumption, and more in terms of community caring and sharing. In the 1995 Boyer Lecture Series, Cox (1995) explained social capital as, "the store of trust, goodwill and co-operation between people in the workplace, voluntary organisations, the neighbourhood, and all levels of government. The degree of accumulated social capital is a measure of the health of communities, societies and nations." It would require a revolution in financial paradigms for the accumulated wealth of retirees to be invested in natural and social capital, but practical examples such as water catchments, renewable electricity, the carbohydrate economy and urban transportation systems abound. The trend towards ethical investments may be a precursor of this changing paradigm. Currently however ethical investment approaches tend to target what 'not to invest in' rather than a concerted effort to develop the concepts of natural capitalism to their fullest extent.

The way forward for the population-ageing dilemma

It appears that Australia's population will have about 25% of citizens over 65 years of age by 2050. If national savings and superannuation schemes accord with policy objectives, then this portion of the population will be reasonably affluent and reasonably healthy. In physical economy terms, the key challenge is how to channel this spending power, affluence, experience and wisdom away from activities that are intensive in material and energy terms. Emerging elsewhere in this study are proposals for major investment requirements into the nation's farmlands, waterways, biodiversity stocks and renewable energy systems. Perhaps these two areas can be guided into confluence.

POPULATION AND PHYSICAL TRADE DILEMMA

Some issues

The essence of this dilemma is that historically and (we assume) well into the future, Australia's physical economy will underpin and remain a major component of the nation's international trading position. While international trade balances are primarily a financial artefact described in dollar terms (and therefore marginal to the physical economy approach), the population/physical trade dilemma arises for two reasons. The first is the possibility that, in future, international trade may be assessed in physical flow and energy flow terms (as detailed in the greenhouse and physical flow dilemmas). The second is that international trade in the physical sectors of the Australian economy is three-quarters the dollar value of total trade, which includes services or invisibles (e.g. in 1998-99, exports totalled $112 billion comprising $26 billion of services and $86 billion of merchandise trade). Thus, Australia relies primarily on the physical sector to earn hard currency to pay for imports. Perceived problems with the physical trade balance result in pressure on the physical economy to increase its contribution to Australia's international trading position. Responding to physical trade issues helps Australia deal with international payment deficits, but may negatively affect the greenhouse and material flow dilemmas. The analysis of this dilemma will concentrate on the physical trade portion (i.e. the import and export of real goods and commodities in the physical economy) but some initial discussion points below focus on a number of the broader issues affecting Australia's international financial position.

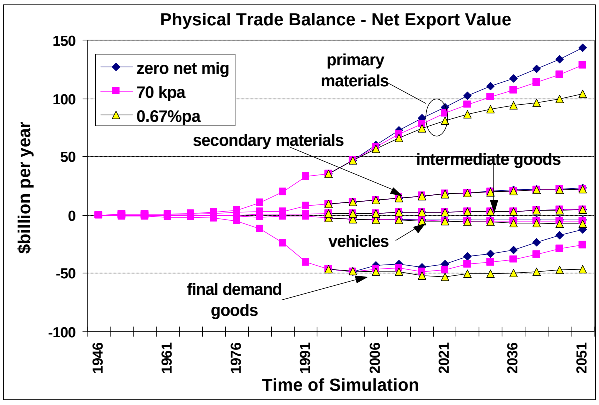
Some economic commentators are concerned about Australia's high balance of trade deficit (about 6% of GDP), one of the largest in the OECD (HSBC 2000-a, 2000-b). The prospect of slower rates of population growth may reduce the problem, according to these analysts, as a higher proportion of population reaches peak savings years and retirement causing a drop in consumption and an easing of imports. Similar concerns are voiced about the US economy (Godley, 1999) based on a balance of payments deficit of 4% of GDP and net foreign debt of 20% of GDP. Godley postulated the development of a debt trap as net income paid abroad started to explode (return on profits on investments made in the US by foreign interests), causing the entire system to deflate with harmful implications for overall economic activity and employment. Opposing views come from private sector economists (Shostak, 1999) who view import and export flows as individual decisions between individuals and firms at a global level, with little relevance for national governments. Foreign debt is also seen as a function of individual companies decisions that are perceived to make rational trading decisions and individually bear the brunt of any poor decisions. However, government debt is of more concern to these commentators since interest and principle must eventually be recovered to the detriment of lifestyle and profits.

Whatever the outcome of the debate noted above, a range of government publications voiced concern about the rise in the current account deficit from between 2 and 3 per cent of GDP in the 1960s and 1970s, to between 4 and 6 per cent in the 1980s and 1990s (Parliament of Australia, 1999). Views from the Reserve Bank on the nation's international financial position are more upbeat (Mcfarlane, 1999). They note that while net foreign debt has been steady at 40% of GDP since 1992, the servicing requirements of that debt have fallen from a high of 20% of exports in 1990 to about 10% currently. Although the current account balance fluctuates between -4% and -6% of GDP, the balance on goods and services fluctuates between zero and -2%. The net foreign debt level is high by world standards, and similar to countries such as Canada, New Zealand and Sweden. The US example above rings warning bells, the US has current account deficits similar to Australia on a proportional basis, but a net foreign debt of only 20% of GDP. Australia's trading position shows that the balance on total merchandise trade (physical trade) for the last five years has varied from a near balanced account in 1993-94 and 1996-97, to a peak of $11.6 billion deficit in 1998-99 (Australian Bureau of Statistics, 2000). For the services portion of the trade balance (e.g. travel, insurance, transport, royalties, licence fees etc), the position for the last five years has varied from a zero balance in 1996-97, to a deficit of $2 billion in 1998-99. The remaining portion of the 'balance on current account' comprises a number of outgoing flows of currency, such as interest repayments on foreign debt.

This analysis

The steady expansion of the physical economy assumed in the starting position for all population scenarios potentially provides a strong positive trade balance in primary materials (Figure 7.3). These include most of the commodities such as agricultural, forestry and mining products that are covered in this analysis. There is a population effect, with the 0.67%pa scenario starting to fall from 2020 as the growing population increases domestic demand for food and energy products. Nevertheless, the primary materials trade balance is large enough to provide a positive balance in overall physical trade measured in nominal dollar terms.

The group of final demand goods describes a wide range of consumption items which Australia imports from abroad, is in negative balance for the simulation period. There is a population effect for this category, with the 0.67%pa scenario maintaining a steady negative position, while the zero and base case scenarios trend back to neutral by 2050. This is due both to population number and age structure effects, driven mainly by the formation of households. In the modelling assumptions, the formation of a household requires a dwelling, a number of motor cars, furnishings, white goods and electronic equipment. A proportion of these physical goods is imported. With the increasing population of the 0.67%pa scenario and the assumptions of age structure of the immigrant population, there is a continual influx of age groups at peak household formation and consumption ages. By contrast, in the base case scenario the number of households is stabilising and for the zero scenario it is declining, further moderated by the age structure of the households. The work of Harding and Robinson (1999) and Guest and McDonald (2001) referred to earlier, suggesting maintenance of consumption with age, signals a note of caution for these simulation results. If, however, the requirement for goods saturates for older age groups, these simulations may provide reasonable insights.



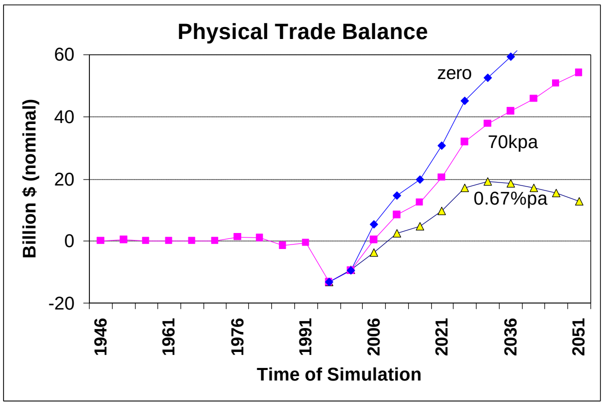


Figure 7.3. The net export value of broad categories of physical trade (vehicles, intermediate goods, primary materials, secondary materials and final demand goods) for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa). Note services exports or invisibles are excluded from this simulation.

A number of other components of the physical trade balance — vehicles, intermediate goods and secondary materials — are relatively small compared to those for primary materials and final demand goods, but are still important components of trade. For example, we currently import $7 billion and export $3 billion worth of motor cars or car components such as engines, leaving a trade balance on motor cars of minus $4 billion. The vehicle trade balance is slightly larger for the 0.67%pa scenario because higher populations will require larger numbers of imported cars, but the growing negative balance is moderated by increasing exports. The other categories show a negligible population effect as they represent inputs into manufacturing and commodity industries where most of the physical activity is driven by exports. In an aggregate sense, physical trade remains strongly positive from 2010 driven by the assumptions of growth in the export orientated industries and the nominal dollar prices attached to each unit of import and export. Based on these assumptions there is a population effect by 2050 with the zero scenario being 146% of the base case (plus 46%) and the 0.67%pa scenario being 24% of the base case (minus 76%).

These simulation results are relatively optimistic and do not attempt to gauge possible trends in export or import prices. For example, the real price of coal per tonne fell from A$60 to A$45 in the period 1992 to 1999 (ABARE, 1999). The analysis does not continue the trend out to 2050. The extent to which world prices of commodities fluctuate with business cycles, trade politics and natural disasters affecting dominant trading positions in particular commodities, merits wider and deeper analysis but is outside the scope of this study. It would be possible to bound each commodity by higher and lower expectations and use them as scenarios within the analytical procedures as a provisional risk analysis of our physical trade position.

Trade in oil and natural gas

The importance of oil and natural gas to the function of the physical and financial economies has been discussed extensively in Chapter 5. In purely financial terms, some implications of possible future constraints on domestic oil and gas availability are presented in Figure 7.4. Australia imports and exports about $5 billion of oil and natural gas products currently, so the trade position is roughly in balance. However, with a possible constraint in domestic oil stocks, oil imports may have to increase. With a price assumption of A$395 per tonne (about US$30 per barrel) the oil import bill could reach more than $20 billion per year in 2050. Until about 2020, liquefied natural gas exports from the North West Shelf and Timor Gap will balance the value of oil imports. For the period 2020 to 2050, the balance becomes increasingly negative but this result obviously depends on the assumptions made about the future world price of oil and natural gas. In this example, oil has been kept at A$395 per tonne and natural gas at A$245 per tonne. There is a plausible future where the export value of natural gas could increase to be greater than oil because it is seen as a lower carbon fuel that is more environmentally friendly. This could allow the trade balance of oil and gas to remain relatively neutral.

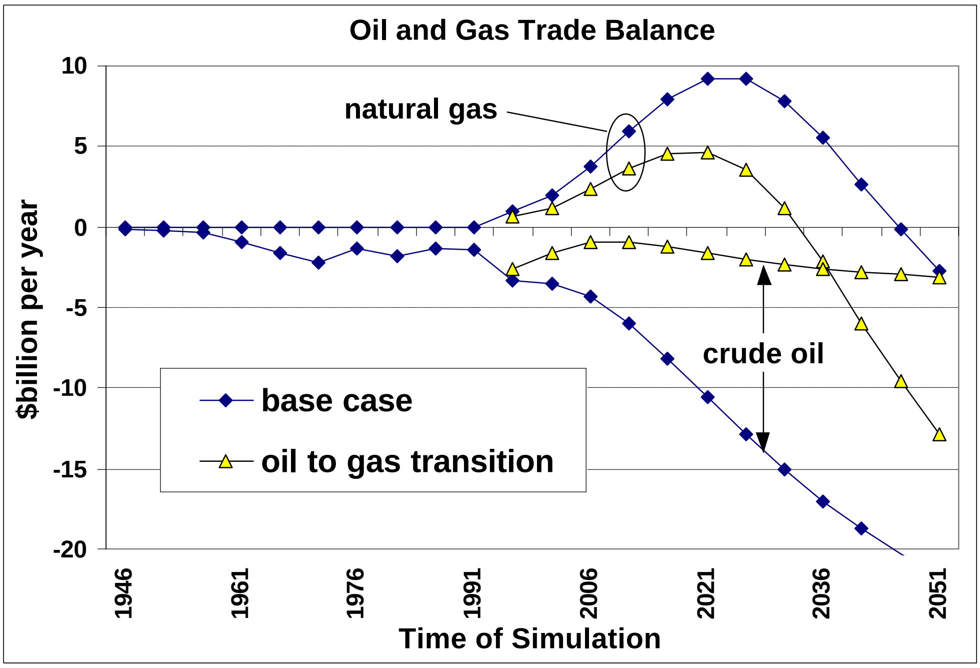


Figure 7.4. The trade balance in monetary terms for crude oil and natural gas to 2050 for the base case and for the oil to gas transition (see Chapter 5).

In Chapter 5, a scenario was proposed for the domestic transport fleet to change from oil based fuels to compressed natural gas, the so called 'oil to natural gas transition' (Figure 7.4). This gives a slightly more advantageous position in monetary terms because the price assumptions for gas are lower than oil. Under both the base case and the transition scenario, the oil plus gas position becomes negative in trade terms in the period 2030-2045. This analysis has already postulated that energy is significantly underpriced in terms of its functional importance to the current structure and organisation of the economy. If in the next 50 years this presumption is realised, then the physical imbalances of high quality energy sources such as oil and gas will become more important in monetary terms. There are many options to redress the balance such as shale oil, liquefaction and gasification of coal, ethanol and methanol from biomass and methyl hydrates from the sea floor. All should be considered as substitutes for oil and natural gas. However the process involved in liberating functional fuels from each resource base, has important implications in terms of the energy profit ratio (units of energy into the process to produce a unit of useful fuel), and the emissions of greenhouse gas.

Australia has many investment options available which might help buffer the physical economy against variable prices for high quality transport fuels. Some of them require long lead times to implement while others have relatively shorter time frames. For example, analyses over a wide range of transport modes currently operating in Australia (Lenzen, 1999) show that light rail, public bus and heavy rail have half the energy intensities per passenger kilometre of the private car. Behavioural changes in transport usage could also increase the resilience of the physical economy to the external trade implications of future oil and natural gas prices.

The crosscutting implication

Which way for physical trade?

The population/physical trade dilemma has three crosscutting implications. The first is that higher populations may lessen the physical trade balance. The important components are a potential lessening of commodity exports because of higher domestic consumption (e.g. food and energy) and the higher import requirements of new households. Nevertheless, the simulation assumptions determine that the physical trade balance remains positive for all population scenarios past 2010. It is also possible that the services or invisibles portion of trade will increase to counter any deficits caused by the population effect on physical trade.

The second implication is that the components of physical trade, by their type and composition, strongly increase the material and energy flows within the physical economy and thus increase greenhouse gas emissions. Possible changes in Australia's manufacturing base and its high technology industries could emphasise more elaborately transformed manufactures for trade, but Brain (2000) argues that Australian business in aggregate is a follower rather than a leader in this area. Further investment in industrial research and development would be required to launch this transition and most countries contemplating such a future require long-term investments into engineering and technological education.

The third implication is that many of the items contributing to the physical trade balance generate less employment during the course of the simulation because labour productivity assumptions allow more product to be generated for less labour. These are for industries such as agriculture and mining which have been open to global competition for many decades and are now efficient with respect to the cost of inputs and the requirements for labour. By comparison, a number of the raw commodity transforming industries such as clothing and footwear, which require more labour and less energy (Table 7.1) have been transferred to lower wage countries, giving Australians access to lower priced consumer goods.

The unconcerned viewpoint

A wide range of influential commentators and analysts led primarily by the Pitchford viewpoint (Pitchford 1989-a, 1989-b, 1992, 1995; Kriesler 1995), believe that Australia's international payments situation is not a matter of business or policy concern. This viewpoint proposes that if private individuals and firms are responsible for investment and consumption decisions that give rise to an imbalance of monetary flows and subsequent (increasing) foreign debt, then those individuals bear the brunt of any inappropriate decisions. They argue that the collective situation represented by accounting terms such as a national balance of payments does not therefore represent an issue of national concern. The lack of a theoretical basis to underpin many policy attempts to manage balance of payments issues is another concern of the Pitchford view which is well argued in several publications. If a nation's industries are performing poorly, causing industries to close and domestic consumers to import more, then policy should be directed towards industry improvement, rather than attempting to decrease consumer demand. The theoretical arguments are well developed but empirical testing with real time series data is somewhat limited. Pitchford (1998) also deals with economic growth theory that does not adequately deal with long run issues, particularly where population issues and exhaustible resources are concerned. He argues that growth based on exhaustible resources must inevitably be followed by decline. While Pitchford does not specifically deal with petroleum resources, in the ASFF approach these issues contribute substantially to the population effect in physical trade.

The concerned viewpoint

In contrast to the Pitchford viewpoint is the argument that Australia's economy faces long-term challenges in economic resilience and function if it passes important thresholds. Short-term concerns about the strength of Australian currency are linked to long-term issues of national management (e.g. HSBC, 2000-b). Their analysis, *The Cheap Australian Dollar: Not Accidental, Not Irrational, Not Temporary* reports that Australia's balance of payments deficits and rising international debt levels impose a negative perception for international investors. Their answer is to increase growth in exports by 12% per year until 2005, and to reduce the growth in domestic demand. These suggestions could give both positive and negative stimuli to the physical economy. Much of the export growth would be in commodities, manufactures and inbound tourism, potentially increasing the greenhouse gas and material flow dilemmas. Reducing growth in domestic demand might moderate domestic requirements from the physical economy.

Major international investment funds cite the current account deficit as the greatest area of concern, with increasing problems if currency levels decline and debt servicing ratios rise (Tradeport, 2000). Major newspaper columns (e.g. Wood, 2000) and leading business groups such as the Business Council of Australia (Larkin, 1994) frequently discuss these issues. They suggest a wide range of solutions, some of which are domestic (e.g. increase domestic savings) and others that relate to increasing external trade in commodities, goods and services, and therefore potentially affect the physical economy.

The way forward for the physical trade dilemma

The commodities and manufactured goods that contribute to Australia's physical trade are responsible for a significant proportion of the transactions in the physical economy. From a purely physical perspective there are two ways forward. If large amounts of energy, water or soil organic matter exist as part of the production process for a traded good, then the export price gleaned per unit traded, should reflect this resource intensity. In order to make these assessments, each commodity and manufactured item should be assessed by a full life cycle analysis. Consumers, as well as producers, could be made aware of these physical costs and adjust financial parameters accordingly to ensure that ecological and economic equity is achieved in the exchange. For open economies, world trade will inevitably head this way as both consuming and producing nations seek to internalise the full environmental cost of physical activities within their national boundaries (Munksgaard and Pedersen, 2001; Dellink et al., 1999). The second (probably infeasible) option is to reduce physical trade, or at least reduce the influence of the driving parameters of international debt and international trade balance. Both these macro-economic issues relate to the tertiary and quaternary population effects. Any attempt to diminish their influence in driving the physical economy will be at best marginal, in today's increasingly globalised trading world.

THE POPULATION AND MATERIAL FLOW DILEMMA

Background

As the world's population grows and economic development proceeds, the size of the material transactions which underpin everyday life is becoming more of a concern (Yenken and Wilkinson, 2000). Most physical transactions that take place in the world are undertaken to supply the requirements of people living in cities. The concept of urban metabolism describes the functional flows of materials and energy required by all modern cities, which continue to grow as both affluence increases, and cities grow in size and sophistication. The city of Vienna, for example, requires material flows of about 200 tonnes per capita per year into and out of the city (Brunner, 2000; Yenken and Wilkinson 2000). The stock of material retained within the city stands at 350 tonnes per capita and is growing at a rate of up to 3% per year. Similar studies comparing Sydney for the years 1970 and 1990 note that all flows had increased appreciably (Department of Environment Sport and Territories, 1996). Since a large proportion of humankind will live in cities by 2050, they will serve as the processing hub for large material flows both in an absolute sense as well as on a per capita basis. Scaling up from the material flow requirements of a city to a nation allows the concept to include all the levels of human requirement from the primary to the quaternary, that are required for the nation to function.

In the past, these material flows were moderate in size and limited in spatial effect. The capture and processing of the world's useable resources was relatively small in relation to the total amount or stock of those resources. However, estimates made at the close of the 20th Century suggested that the management of humankind dominated 40% of the land surface of the globe, 50% of its water use and nitrogen cycle, and 60% of its marine fisheries (Vitousek et al., 1997). Apart from the loss of habitats and biodiversity caused by such dominance of natural systems, the chain of effects caused by the widescale alteration to natural processes is now limiting the productivity and waste assimilation of many semi-natural ecosystems. Brunner (1999) highlights the importance of the concentrated stock of material that is accumulating close to major centres of population. As well as being a potential resource, this stock has the potential for liberating concentrated pulses of materials in the future, perhaps to the detriment of human and ecosystem health. In addition, local effects such as soil acidification and nitrification are often transported through soil and water systems to cause follow-on effects in areas tens to hundreds of kilometres away. Trade policies also encourage the worldwide flows of materials wherever resource availability and quoted price allow either the exporting or the importing country to gain an advantage.

Accounting for materials flows and attributing them to both countries of origin and those of consumption is becoming one of the conceptual foundations for sustainability issues. The concept of an economy's 'total material requirement' describes the total use of natural resources required for national economic activity (Adriaanse et al., 1997). It can be used to account for material requirements undertaken in situ, as well as for transactions undertaken in one country on behalf of the economic activity in another country. Much analysis is required to understand the material and environmental impacts of globalised trade, both at national, regional and global levels. However, it could be argued that concepts of competitive and comparative advantage promoted by Porter (1990) and others, do not result in win-win outcomes for all countries in material and environmental terms (Munksgaard and Pedersen, 2001; Dellink et al., 1999), although the financial rewards and economic development advantages seem obvious.

This analysis

Australia has maintained a materially intensive economic system for many reasons and this study assumes that expansion will continue for many primary exports. This results in a material flow account that continues to expand beyond a contemporary level of 200 tonnes per capita per year, to 300 tonnes for the 0.67%pa scenario, 370 tonnes for the base case and 450 tonnes for the zero population scenario (Figure 7.5). The higher population scenarios allow lower indices of material flow because of a comparative dilution effect. For comparison purposes, the analyses of Adriaanse et al. (1997) are presented for the material requirements of the USA, Germany, The Netherlands and Japan. For the period 1970 to 1990 the structural and trade arrangements of those countries allowed much lower material flows on a per capita basis, although higher populations in Germany, USA and Japan would give comparable or larger material flows on an aggregated whole nation basis.

These data can be examined in many ways. For the base case scenario, the direct and hidden flows for domestic requirements are maintained at below 100 tonnes per capita for the duration of the simulation due to a stabilising population (Figure 7.6). Most of the effect is due to hidden flows of material tied to the nation's exports and specifically refers to items such as overburden for open cut mines, material removed in ore concentration activities and effects of crop and animal agriculture. In general, the mining industry, for both metals and energy materials, accounts for most of the increase in per capita material flows.

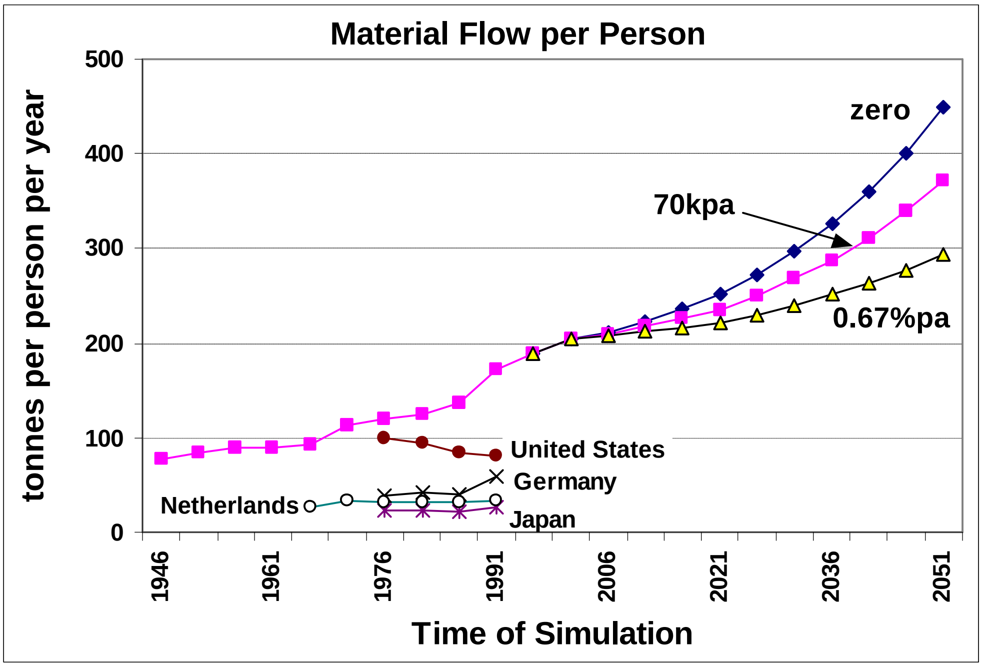


Figure 7.5. Total material flow in tonnes per person per year for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa). Data for four industrialised countries is also displayed (Adriaanse et al., 1997).

.

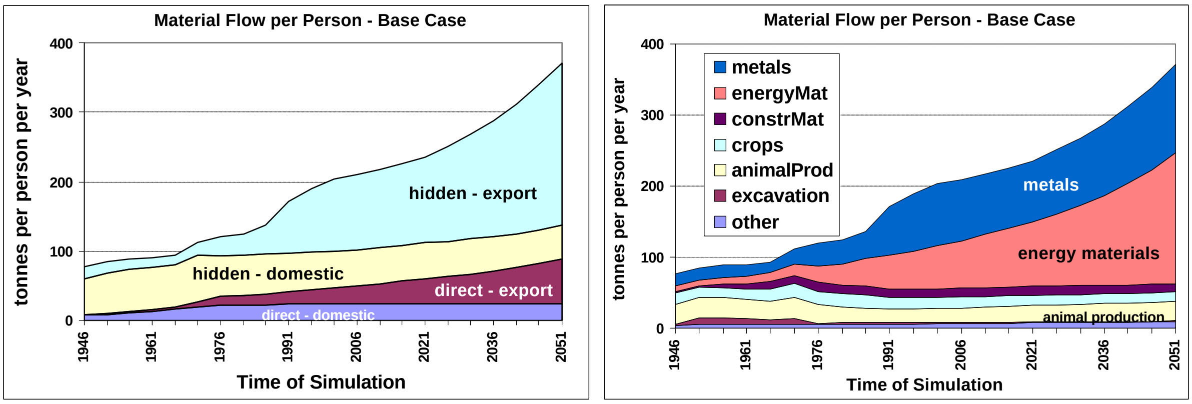


Figure 7.6. The composition of total material flow in tonnes per person per year for the base case scenario of 70,000 net immigration per year, giving a breakdown by (a) direct and hidden flows as well as (b) material types.

.

The crosscutting implication

A number of material flow indicators for the Australian economy will be higher than those of other developed economies, and will also trend upwards. This is due to a mixture of historical antecedents, contemporary policy directions and future strategic directions already being practiced by major commodity groups with production bases in Australia. None of these indicators are pre-ordained and global trade and political forces may cause major changes to the base case scenario and the analyses derived from it. A carbon tax on coal usage in countries such as Japan, South Korea and the European Union would cause a significant reduction in per capita material flow but have large implications for the level of export income. The question of what energy source might replace coal in those countries also presents a large imponderable for both industry and policy. The transition to a factor-4 or factor-10 economy in countries such as Japan, South Korea, China and the European

Union, which currently take the majority of Australia's minerals exports, would also have large repercussions. However many factor-4 transitions rely on advanced composite materials for lightness and strength and many of these materials themselves rely on large hidden material flows.

In terms of crosscutting policy issues, three important areas determine the implications of Australia's future material flow account. The first and most immediate link is to energy use and greenhouse gas emissions. The more material that is moved, the more energy that is required, even allowing for increasing efficiencies, and so total energy use must increase. In physical law terms, these are the realities of thermodynamics and mass balance, which lie behind all modern economic systems. Depending on the source of the energy, greenhouse emissions do not necessarily increase, but for all practical purposes they must.

The second important issue for material flows would arise if countries were to negotiate about how to account for, and apportion, the responsibility for such flows. In this analysis, the material flow is apportioned directly to the nation and each person is classified as a citizen. The rationale for this is that all citizens reap the reward of the material transactions, whether it be a direct effect (employment, food and housing) or an indirect effect (export income to purchase a video recorder or an overseas holiday). However it is equally valid to apportion the material flows to the countries which use the material Australia exports. Thus, in both material and energy terms, Australia's major trading partners would take on the direct and hidden flows of the material exported to them.

If a full life cycle analysis were implemented and full system boundary applied, the chain of attribution would not stop there. Logically, the next step would be to attribute the hidden material flows embodied in the array of goods that each nation imports. Thus, the copper, aluminium, steel and magnesium in each imported car would be finally attributed back to the country that uses it. Most OECD countries would be disadvantaged in this system which would see the accounting responsibility for 80% of the world's material and energy flows attributed to 20% of the world's citizens in the richer countries. The balance could change over the next 50 years as populous less-developed countries become more developed. According to Wernick and Ausubel (1999), without the data collection and the formation of GDP-like metrics that describe material flows, an economy and its political system are navigating blind on the course that leads inexorably upwards to higher and higher levels of material consumption.

The third important issue in the material flow dilemma concerns the type of economy (materially heavy or materially light) which the nation's citizens wish to maintain. In commenting on the structure and performance of the US economy, Greenspan (1998) questioned, "whether over the past five to seven years, what has been without question, one of the best economic performances in our history, is a harbinger of a new economy, or just a hyped up version of the old, will be answered only in the inexorable passage of time". In examining the progress of transition to the knowledge based economy for Canada, Gera and Mang (1998) concluded that "Canadian industrial structure is becoming increasingly knowledge-based and technology-intensive, with competitive advantage being rooted in innovation and ideas, the foundations of the new economy".

Despite the undeniable growth in employment and economic activity in the services portion of the US economy over the last three decades, Salzman (1999) notes that manufacturing in America has not declined. The dilemma is that the service economy exists to service the old economy and to make it more efficient in terms of finance, labour, quality and delivery schedule. What has been saved materially through efficiencies in production processes has been taken up in increasing the diversity of products and opportunities, few of which have zero material and energy contents. The dilemma of material flows could be that in order to halve national material flows, each citizen would also have to halve their total material consumption, while properly accounting for direct and indirect flows, as well as the exported and imported components of globalised trade.

Technological and policy innovation could remove this material flow dilemma in a number of ways. The two most obvious are material substitution and product re-design, and a breakthrough in the delivery of energy services. Examples of simple material substitution could centre on a return to the type of low mass intensity housing of the 1950s, i.e. predominantly wood. This would save considerable material and energy flows centred on the provision of concrete, bricks and roofing tiles to the building industry, but would require increased investment in the forest industry (to supply the wood), and perhaps increased maintenance, labour intensity and financial expenditure. This option is probably not available for office and institutional buildings which are larger and require greater structural integrity.

The widespread diffusion of decentralised photovoltaic and solar thermal energy technologies has the potential to decrease the material flows associated with the provision of energy services to households, provided that a 'whole of life cycle' approach is used in a thoroughly original approach to the provision of human shelter. By 2010 full energy chain analysis suggests that whole of life cycle greenhouse gas emissions for solar thermal power could be 20-30 grams of carbon dioxide per kilowatt hour compared to 800-1,000 grams for best practice coal-fired plants (Norton et al., 1998). This does not solve the problem of the provision of base load electricity on which modern economies depend. However these figures suggest a factor improvement of 30-50 times for marginal power requirements such as the provision of air cooling services in hot periods when solar intensities are high. The important dynamic requiring more examination is that investment in new infrastructure would require a substantial increase in material flows perhaps for 10 to 20 years, before the savings in flows of energy materials would drive an overall decline in national material flows.

The way forward for the physical flow dilemma

Unless the nature of physical trade is altered, the physical flow dilemma seems to inevitably follow from the structure and function of the physical economy. Both energy materials and metals, the majority of which are exported, represent most of the expansion in physical flows (Connor et al., 1995). New methods of mining may allow micro-extraction techniques from well targeted ore bodies. But the nature of gold and diamond mining in particular, where economic returns dictate that relatively small amounts of commodity are returned from a large amount of material moved, present a physical imponderable. At one level it is easy to dismiss the physical flow dilemma, especially where landscape rehabilitation is applied after mining to return land to better than pristine condition. In a macro sense though, the dilemma serves to remind us that on a per capita basis, Australia's physical economy seems set to remain 'heavy and wet' rather than 'light and dry'.

POPULATION AND GREENHOUSE EMISSION DILEMMAS

Background

Many political and scientific groups view the continuing emissions of carbon dioxide and other greenhouse gases from the energy sector, as an issue of global concern. The possible effects within the span of two to eight human generations include the increased frequency and intensity of weather events, the displacement of agricultural systems, the loss of amenity and infrastructure close to regions of possible sea level rise, and the loss of process diversity in natural systems. While Australia is a small emitter of greenhouse gas in world terms, an affluent lifestyle and a lower population base in relation to the sum total of its physical transactions makes it a high per capita emitter, amongst the top five in the world. As a relatively advanced country in technological terms, Australia might be expected to have the capacity to reduce greenhouse emissions by a mixture of technological innovations and changes in the volume and composition of personal consumption. Alternatively, in the future, new institutional arrangements at an international level might implement greenhouse accounting measures which allocate the responsibility for greenhouse emissions back to the consumer of the final product or service. Australia would not necessarily be advantaged by such arrangements as the country imports more embodied energy, and therefore carbon emissions, than it exports.

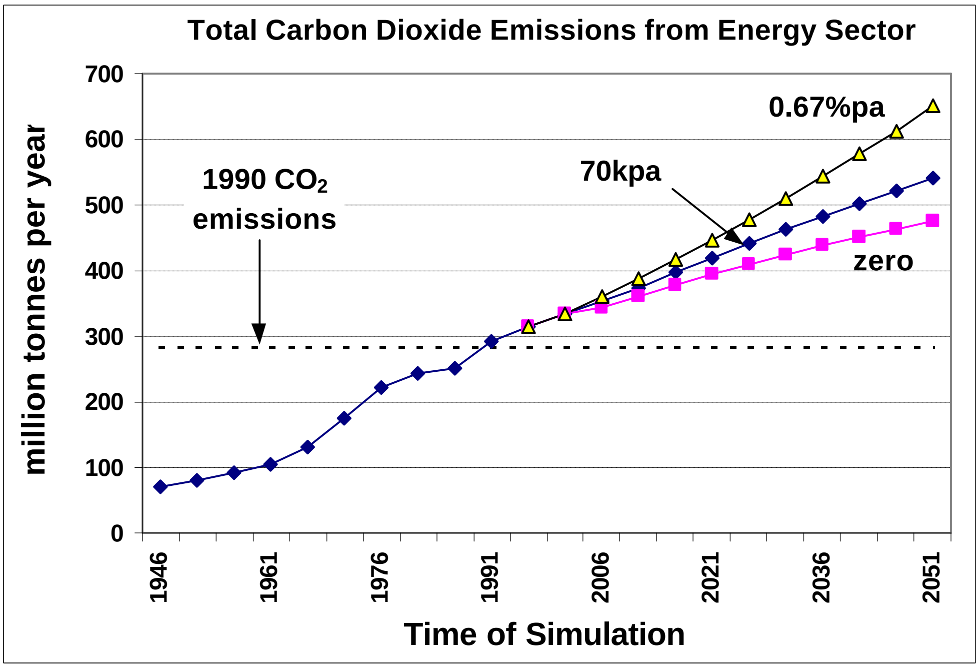


Figure 7.7. Carbon dioxide emissions in million tonnes per year from the energy sector to 2050, for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

.

This analysis

The starting point assumptions underlying all population scenarios suggest that carbon dioxide emissions will continue to expand until 2050 for all scenarios (Figure 7.7). In fact these simulations underestimate potential emissions for three reasons (Chapter 5). Firstly, the scenario includes very advanced technological innovations in relation to current practice. Secondly it does not account for the rebound effect and thirdly it does not include continual innovation in the consumption of lifestyle goods and services, many of which are energy intensive. Innovations in technology and behaviour for particular areas such as energy use by houses and motor cars make a difference for those sectors but, in general, the hard won gains are swamped by expansion in other sectors. When a series of technological innovations are combined in sub-scenarios such as high-tech and factor-4 the emission profiles change markedly. In the Chapter 5 analysis, three bands of emissions of 200 million tonnes per year overlapped at 2050. These bands represent measures of the population effect, the low technology or business-as-usual effect, and the high technology effect. In most cases the lower emission trajectories are still above the 1990 emission level which represents the benchmark set by the global policy community. The one exception is the factor-4 approach combined with the zero net immigration population scenario, which diverges to track closely to the 1990 policy benchmark level. If the implementation of the factor-4 scenario is further developed to concentrate on specific process details (e.g. aluminium, cement, transportation, construction), it is possible that a greenhouse design might be distilled for Australia's physical economy which will meet the Kyoto protocol standards.

Table 7.1. Embodiment of fossil energy (megajoules), labour (minutes) and water (litres) in one dollar of output in the Australian economy (After Lenzen, 2001).

Sector	Fossil Energy (megajoules per $ of output)	Labour (minutes of labour per $ of output)	Water (litres per $ of output)
Education	3.7	2.5	50
Retail trade	7.2	3.0	130
Clothing	8.9	2.5	170
Grains	11.6	1.7	280
Commercial fishing	16.0	2.1	150
Basic non-ferrous metals	41.0	1.6	1440
Basic chemicals	52.7	1.9	590
Whole economy	**9.8**	**2.1**	**150**

.

Scenarios capable of resolving the greenhouse emission dilemma are revolutionary in technological terms. It is possible that a combination of moderate technological innovation combined with halving a wide range of consumption characteristics of the average (or more well off) Australian could also cause convergence on the policy benchmark. However, the depth of analysis required (social, psychological, economic, physical) to gauge the feasibility of these scenarios is beyond the scope of this study.

The crosscutting implication

The greenhouse and energy dilemma is central to the function of modern societies and economies. Without the use of energy, and increasing amounts of it, there is little employment, few material flows, little trade and little capability to access the resources available in the physical environment. Since fossil energy is so easily available, it has become the powerhouse of all modern economies. Replacing fossil energy usage to some extent requires a revolution in the technology of supplying energy and a revolution in the manner it is used by consumers in the home, office and factory.

Because linkages in the economy are complex, it is difficult to focus on particular physical transactions or industries as the means to improve the nation's energy metabolism. However it is possible to analyse the energy metabolism behind each dollar of output (Table 7.1). In comparing the fossil energy use per dollar of output for a number of sectors described in the national accounts, it becomes obvious that retail and education sectors use lower amounts of energy per dollar of output, grains and fishing are a little higher and aluminium and basic chemicals are much higher. This does not produce an energy theory of value, rather it is a rigorous way of assessing the energy intensity and thereby the carbon intensity of each sector in the economy. The next level of assessment could be in terms of societal good, as judged by the labour required for each dollar of output. Education, clothing and retail had higher requirements for labour than primary and secondary industries. Finally, the requirement for other environmental goods, such as water, could be assessed. Again, for these examples, the lower energy users and the higher labour providers have the lower water requirements per dollar of economic output. More complex analyses could then partition the embodiments of energy, labour and water on the basis of whether they are used in domestic consumption or for export income.

As noted above, an economy wide analysis of embodiment of energy and other factors should not be aimed at individual sectors to locate energy positive and negatives since all sectors are potentially interdependent. If an aluminium or a chemical industry were closed down, the country would still have to import its requirements of those materials, i.e. the product and the associated emissions would be transported overseas. At a whole economy level it may be possible to develop mathematical solutions to this conundrum, across the 100 or more sectors that make up an economy. A theoretical solution would aim to maximise social gains while reducing the use of fossil energy and water. Implementing this solution in a real economy would be difficult, but it would provide a guide to government and industry policy. Also it would provide a way forward for implementing the principles of triple-bottom-line accounting that are currently being promoted by business and environmental interests (Elkington, 1997; CPA, 1999).

The way forward for the greenhouse gas dilemma

Since the population and greenhouse gas dilemma essentially covers the entire structure and function of Australia's physical economy, it is difficult to find a way forward. However, four steps are obvious from a physical economy perspective. Firstly, international trading arrangements could apportion greenhouse gas emissions to the country of consumption, rather than the country of production. Secondly, Australia's international debt and trading position could be examined to see if the expectation for the physical economy to balance the nation's international accounts can be wound back over the next human generation. Thirdly, 'five star' energy efficiency ratings could be mandated immediately for all new infrastructure and consumer items since it takes decades for new technology to penetrate the present stocks of infrastructure. Finally, investment mechanisms could be designed to effectively manage the rebound effect, to reallocate personal consumption to the development of a renewable energy economy, and to develop a consumer culture that does not expand its requirements for carbon based energy sources.

POPULATION AND RESOURCE DEPLETION DILEMMAS

Introduction

The resource depletion issues refer to the population linkage with the use of non-renewable or renewable resources such as oil and gas, fisheries production and agricultural land. Each of these combines the primary, secondary and tertiary population effects; fish contribute to the human diet (primary), seafood restaurants and recreational fishing define the Australian lifestyle (secondary) and seafood exports contribute more than $1 billion to export income (tertiary). Each resource depletion dilemma is, thus, directly tied in the first instance to population size. Each dilemma has a solution, even if that solution means doing nothing and adapting to the eventual consequences. While doing nothing will not cause a national crisis, it may also preclude taking advantages of new opportunities in the future.

Oil and gas depletion

Oil and gas are extracted from domestic stocks primarily to meet the requirements of the domestic population, but also to supply energy for trade opportunities such as liquefied natural gas exports and international inbound tourism. Simply put, the higher the domestic population, the higher the requirements for oil and gas. Improved technology such as better engines in motor cars and gas turbines for electricity instead of diesel generators will help improve the delivery of a service or a good. But these gains may be off-set by the inter-sectoral rebound effect, described in Chapter 5, whereby at the level of the whole economy, improvements in energy efficiency can stimulate 'take back' effects such as more kilometres driven in response to better energy efficiencies in motor car engines.

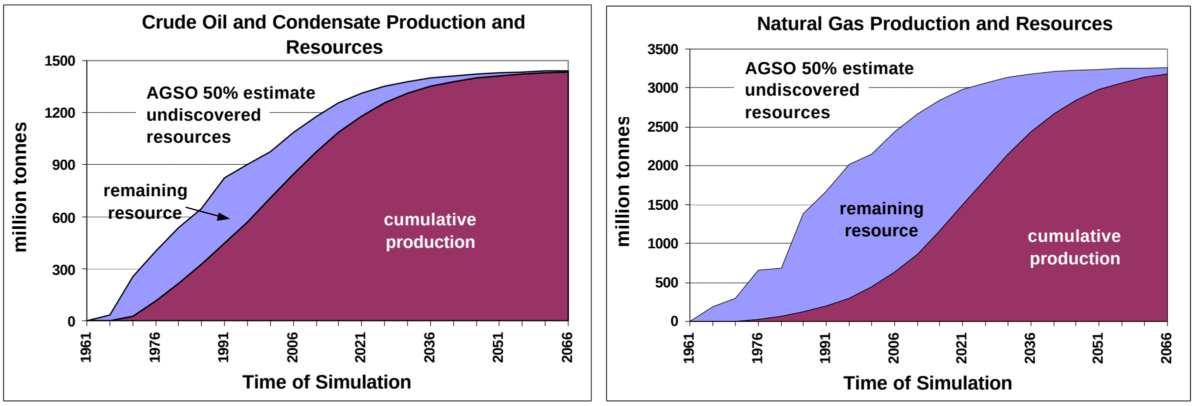


Figure 7.8. Cumulative production and remaining resource for (a) oil and condensate and (b) natural gas to 2066 based on the 50% probability estimates of the Australian Geological Survey Organisation (1999).

.

Three 'mini-dilemmas' are posed by the economy's dependence on oil and gas. The first is the link between the availability of oil and gas, economic performance and employment generation. The second is whether oil and gas are viewed as stocks or flows. The third relates to transport infrastructure and how the possibility of constraints in oil and gas availability might affect personal mobility, the domestic and inbound tourism industry and the national freight task. In this analysis, the supply of oil and gas is eventually constrained at a national level and is subject to a wide range of political interference at a global level (Mitchell et al., 2001). Under the base case population scenario, supplies of oil and natural gas may become constrained around 2030 and 2050 respectively (Figure 7.8). The narrowing gap between the total resource, that expands over time through further discoveries, and the cumulative production and use which progressively eats away at this total resource, represents the possibility of constraint.

Substitutions are possible for both fuel types, but the physical characteristics of the new production systems will be different, as will their cost structure. Whether increases in oil and gas prices spur innovations in exploration and production technology and effectively turn the oil stock into an oil flow is a critical issue for an energy and transport dependent economy. Most OECD countries are in a similar situation, but many have transport systems that offer alternatives to the personal car and lorry. The subject requires a dispassionate analysis and subsequent debate with a focus on a time-frame of the next 50 years and more.

Fisheries deficit

The fisheries dilemma highlights an increasing gap between the requirements of the domestic population and the ability of the domestic wild caught fishery to supply them, due primarily to the relatively poor productivity of the Australian marine fishery (a similar situation to Australia's poor soil resource base)(Table 7.2). Some solutions are reasonably simple and others are more complex. Australians have many sources of dietary protein and removing fish from the menu would be a relatively easy lifestyle adaptation. In addition, higher prices for fish in response to shortfalls in availability could cause a fall in domestic demand. This, in turn, would improve the market prospects for aquaculture and also ensure that imports from a wide range of global fisheries would become more attractive, if they were cheaper. There is an added nuance that higher-value Australian fish such as lobsters and tuna would continue to be exported, while domestic requirements were met by lower-value imports.

.

Table 7.2. Simulated wild caught deficit production levels in tonnes at 2050 for two fisheries scenarios (open slather and sustainable) and three population scenarios (zero, base case and 0.67%pa).

Fish type	'Open Slather' fishing management			Sustainable fishing management		
	Zero population scenario	Base case population scenario	0.67%pa population scenario	Zero population scenario	Base case population scenario	0.67%pa population scenario
Total	**-260,000**	**-330,000**	**-460,000**	**-190,000**	**-260,000**	**-390,000**

.

A wide range of biologically efficient fish-farming systems are based primarily on herbivorous fish species such as carp and telapia. When deep fried in batter at the local fish and chip shop, these products could probably be made to suit the dietary preference of Australian consumers. However if consumers continue to prefer fish species higher up the food chain (the carnivorous species), other fish are generally required as an important part of the aquaculture diet. Technological progress is expected to resolve this problem and effect a substitution of vegetable protein for fish protein in the aquaculture feeding system.

The lifestyle component of the fisheries dilemma relates to recreational fishing and whether a functional recreational industry can be maintained under the fisheries production deficits simulated for the three population scenarios. Many practical solutions to this dilemma are already being implemented. The DIMA workshop series (Conroy et al., 2000) and other published material, document the progress of many Australian fisheries to management based on the total allowable catch concept, the possible closure of river estuary areas to commercial fishing, and the establishment of an extensive network of marine protected areas. It is also possible to envisage a highly regulated system for recreational fishing where fishers have to pay the full cost of an effective management regime. Both the commercial and recreational fisheries in inland waters pose a different level of dilemmas for management authorities. The organised disruption to natural flows by weirs and dams, the substantial extraction of water for irrigation, the lowered run-off in many catchments due to farm dams, and the increasing problems of water quality caused by alteration of riverbank conditions and increasing salinity loads have substantially changed inland waters. Designing integrated solutions to this set of pressures requires a revolution in land and water use. The economic importance of water for irrigation could mean that, apart from lakes and storages, inland waters generally become lost to recreational fishing.

Agricultural land loss

The dilemma of the potential loss of productive agricultural land due to combinations of dryland salinity, irrigation salinity, acidification and loss of soil structure, is well documented. Some scenarios exploring future options have been analysed in Chapter 4 (Table 7.3). The potential loss of land estimated in this study could be around 10 million hectares by 2050 and twice that by 2100. These figures concur with other estimates, such as those quoted in Yenken and Wilkinson (2000), who report 12 million hectares lost to dryland salinity alone when the changed landscape and hydrological processes reach equilibrium. Donges and Henry (2000) report higher values of 15.5 million hectares at equilibrium. The National Land and Water Audit (Commonwealth of Australia, 2001-a) found that 5.7 million hectares are currently at risk from dryland salinity alone, and the figure could climb to 17 million hectares by the year 2050.

.

Table 7.3. Potential decreases in arable land function in millions of hectares under 75% and 50% yield thresholds for the starting position, technological advance and landscape integrity scenarios.

Yield threshold for land deletion	Starting position	Technological advance	Landscape integrity
Arable land with 75% of base yield by 2050	20	16	9
Arable land with 50% of base yield by 2050	9	8	2

.

Once again, the result of accepting a slow decline in the productive capacity and functional attributes of Australia's arable soils will not be disastrous. The agricultural knowledge base and adaptability of farmers and their production systems should ensure sufficient food to feed Australians of whatever population number by 2050. More importantly though is the potential risk of loss in export income if non-tariff trade barriers are used to exclude the nation's non-mineral primary production from the global marketplace. Trade in rural goods is valued at more than $20 billion per year and the expansion of this export sector is an important contributor to the development of a strong positive balance for physical trade past 2010 in the starting position on which the population scenarios are based. If international trade negotiations give equitable prices for export commodities, much of the cost of repairing the productivity of crop and pasture land could come from within the farm sector. If not, the estimated cost of repair of $50 billion plus would have to be transferred from sectors of the physical economy. This would require the resolution of multiple dilemmas which compete for constrained resources of capital and managerial acumen. The ensuing set of linked decisions may result in decision gridlock and a tendency to continue marginal innovations which treat symptoms, rather than attacking the physical causes of these linked dilemmas.

The way forward for the resource depletion dilemmas

Australia can learn from the cases of civilisations over the last three millennia who squandered their initial resource endowments with poor management and lack of foresight. Trade and substitution of materials will always cover most requirements that cannot be met domestically, but international financial markets will probably require a parcel of goods and services to barter for the food, fish and transport energy required to fill the domestic gaps. For domestic wild caught fisheries we will probably have to reduce our expectations of yearly production levels and allow up to a human generation for some fish stocks, particularly finfish stocks, to recover to larger and more resilient levels.

An interesting synergy is emerging for transport energy and agricultural land. It is generally accepted that domestic oil stocks will be depleted but natural gas can cover most applications, up to a point. A 50-year strategic view is required to balance domestic requirements with export opportunities, particularly for compressed natural gas exports from the North West Shelf of Western Australia. The depletion of arable land could be helped by reforesting large areas of the agricultural heartlands. If the plant materials grown were used as feedstock for a transport system based on alcohol fuels (methanol and ethanol), then domestic transport fuels could be supplied well into the future and the reversal of biophysical problems of agricultural landscapes commenced (Foran and Mardon, 1999).

POPULATION AND ENVIRONMENTAL QUALITY DILEMMA

Environmental quality issues are not modelled directly in this analysis because many of the physical processes operate at a finer scale of resolution than the macro-level approach used in this study. However the quality considerations are directly linked to the wider physical economy drivers and other dilemmas. Some examples of more detailed studies are presented, and while no quantitative linkage to the population scenarios is undertaken, some qualitative issues are discussed. The water quality and biodiversity quality dilemmas are linked directly to export trade drivers and thereby to the tertiary and quaternary effects of population number.

Table 7.4. Percentage of inland water samples classified by quality status (conductivity) depending on position in the landscape (after Smith 1998).

	Excellent	Good	Moderate	Poor	Degraded
Mountain	5	75	12	3	5
Valley	32	34	10	4	20
Plain	14	20	13	1	52
Total	**20**	**36**	**11**	**3**	**30**

.

Water quality

The dilemma of future water quality is not analysed within the stocks and flows framework although many of the contributing pressures are enumerated. A selection of regional studies show the nature of the problem, and its potential future trajectory. Smith (1998) quotes a study of rivers in Victoria where electrical conductivity measurements (related to salt concentrations) were used to classify the quality status of inland waters by topographic sequence from mountains to valleys and plains (Table 7.4). In the mountain areas more than 80% of the samples were classified as good or excellent quality compared to 34% on the plains. More than 50% of samples from the plains were classed as poor or degraded, compared to 20% or less for the mountains and valleys. The implication is that the human effects of management and production activities increase progressively downstream from the mountain catchments.

Salinity data for the Murray Darling Basin over the next 100 years are presented against a background of a generally accepted standard of 800 EC for drinking purposes, and a limit of 1,500 EC for irrigation purposes (Table 7.5). A number of rivers in the New South Wales portion of the Murray Darling Basin such as the Murrumbidgee and the Darling retain salinity indices well within both drinking and irrigation standards out to 2100. Others such as the Bogan and the Macquarie, have exceeded drinking standards by 2020 and irrigation standards by 2050. These outcomes are linked back to the loss of land dilemma where, by the year 2020, the dryland salinity issue will be mobilising 7 million tonnes per year of salt to the land surface, 3 million tonnes of which is exported to the river systems. By the year 2100 this could reach more than 10 million tonnes per year being liberated, with 4 million tonnes per year entering the river systems. Irrigation adds to this problem in many areas where over-irrigation causes water tables to rise bringing buried salts into the root zones of crops, and discharging salt back into rivers. These are not easy issues to turn around in either a policy sense or a physical sense as the last century of land use and agricultural production has unleashed slow moving and generally unseen hydrological forces beneath the land surface, which operate over distances of several hundred kilometres and timescales of centuries. Thus the dilemma of land loss is tied to water quality issues and inland fisheries issues. As well, it affects urban issues in many regional cities and towns, where the integrity of both road and housing foundations is being challenged by salt encroachment.

Table 7.5. Estimated river salinity New South Wales 1998-2100 (Adapted from Table 5, in Murray Darling Basin Ministerial Council, 1999).

River Valley	Salinity in 1998 (EC)	Salinity in 2020 (EC)	Salinity in 2050 (EC)	Salinity in 2100 (EC)
Murrumbidgee	250	320	350	400
Lachlan	530	780	1,150	1,460
Darling River	360	430	490	530
Bogan	730	1,500	1,950	2 320
Macquarie	620	1,290	1,730	2,110
Castlereagh	640	760	1,100	1,230
Namoi	680	1,050	1,280	1,550
Gwydir	560	600	700	740
Macintyre	450	450	450	450

We will have to adapt to the declining quality of inland waters, as it is physically implausible that the situation can be reversed to the pre-European settlement standard. However there are limits to how far the symptoms of water quality can be dealt with before the causes (widespread landscape clearance and irrigated agriculture) have to be treated. Already competent treatment technologies can provide drinking quality water for smaller settlements and towns at a cost of $2 per 1000 litres of treated water, but with additional energy and material flow consequences. These options are less applicable for bigger cities, industrial purposes and definitely not for irrigated agriculture. The Israeli example of irrigated agriculture which uses saline waters is generally not possible in Australia, although saline water technologies such as spray irrigation and brine shrimp aquaculture are used. Australian irrigated lands are generally on flat old landscapes with little drainage gradient whereas Israeli irrigation uses a strong drainage gradient to the Dead Sea to allow high leaching rates that take suspended salts lower down into the soil profile and eventually back to sea. Examples of this approach are being practised in south-eastern Australia where large corporate vineyards have been developed on sandhills above the Murray River. Eventually, if irrigated with increasingly saline water from the river, salts will be transported down the profile and back to the river.

The recent release of the water quality assessments in the National Land and Water Audit (Commonwealth of Australia, 2001-b) confirm many of the more limited assessments documented above. For most quality issues, the guidelines are exceeded in more than 50% of the river basins assessed. As water quality problems are compounded by water use issues, the report notes that 25-30% of both surface water and ground water resources are either fully developed or over-developed. In the water scenarios in Chapter 6, water use is simulated to almost double by the year 2050, mainly due to a continual expansion in export trade commodities. Maintaining water quality while doubling water use presents many challenges, particularly for river basins where resource development has not yet occurred.

Table 7.6. Exceedance of water quality guidelines on a river basin basis. (Table 4, Australian Water Resources Assessment 2000, Commonwealth of Australia, 2001-b).

	Major exceedances	Significant exceedances	Number of basins assessed

Nutrient: total nitrogen	19	19	50
Nutrient : total phosphorus	40	20	75
Salinity: electrical conductivity	24	18	74
Turbidity	41	10	67
PH (acidity and alkalinity)	7	6	43

The water quality issue is a persuasive example of the many lagged and diffuse effects which form this environmental quality dilemma. Lower rates of population growth may impose slightly lower requirements for fresh irrigated produce and may require lower levels of export trade to balance import requirements. But, smaller populations result in smaller economies and less options to direct the large investments required for wide-scale refurbishment of inland water systems. Higher rates of population growth will require more urban water and, more importantly, more fresh irrigated product and higher volumes of exports, all other things being equal. Expecting that water management might be improved incrementally rather than by a total transformation would probably mean that requirements for water would increase and water quality would come under more pressure. Meanwhile, the base load of salt transport in the river systems is already partly determined by the extent of dryland salinity and the area of irrigated land. A large monetary investment is required to refurbish natural systems. This need would compete directly with the large investments required to renew city infrastructure where most of the population will continue to live.

Air quality in urban airsheds

The dilemma of air quality in urban airsheds, which was discussed in Chapter 3 (Figure 7.9), is also related to the oil and gas dilemma. It is perhaps the most solvable of all the environmental quality dilemmas, where a relatively aggressive introduction of fuel celled vehicles, hybrid electric-petrol vehicles, or the transition to compressed natural gas vehicles, will reduce the fastest growing mobile source of air emissions, the private motor vehicle. The stationary sources of airshed emissions are generally under strong regulatory frameworks and open to intense public scrutiny. Complementary approaches include incentives to attract greater usage of public transport although most cities could not meet the commuting requirement if a major modal shift occurred in the next decade, based on current capacity. Roads and freeways provide excellent infrastructure for potential shifts to on-demand bus and minibus systems, which could connect to potential new investments in light rail systems along major arterial roads.

It seems difficult however to evoke the type of institutional and consumer changes required to achieve a better outcome than the one projected. Personal mobility on demand appears critical to time-poor workers and parents who find it fulfilling or obligatory to be in paid employment. This links air quality tenuously to the employment and ageing dilemma. Personal mobility contributes to greenhouse gas emissions and is one of the fastest growing components of it, thus linking it to the greenhouse dilemma and eventually the material flows dilemma. The possibility that domestic oil and gas supplies might become constrained and the flow-on effect to merchandise balance of trade, also links personal mobility and population levels to these effects. Central to the dilemma is not whether it can be resolved, but over what timeframe and whether through crisis or by strategic intent. It is true that vibrant lifestyles are maintained in the air pollution capitals of the world such as Mexico City and Los Angeles. While airshed pollution and increased respiratory ailments are the prices to pay for personal mobility on demand, it is possible that fuel cells and hypercars may offer feasible solutions within 20 to 30 year timeframes.

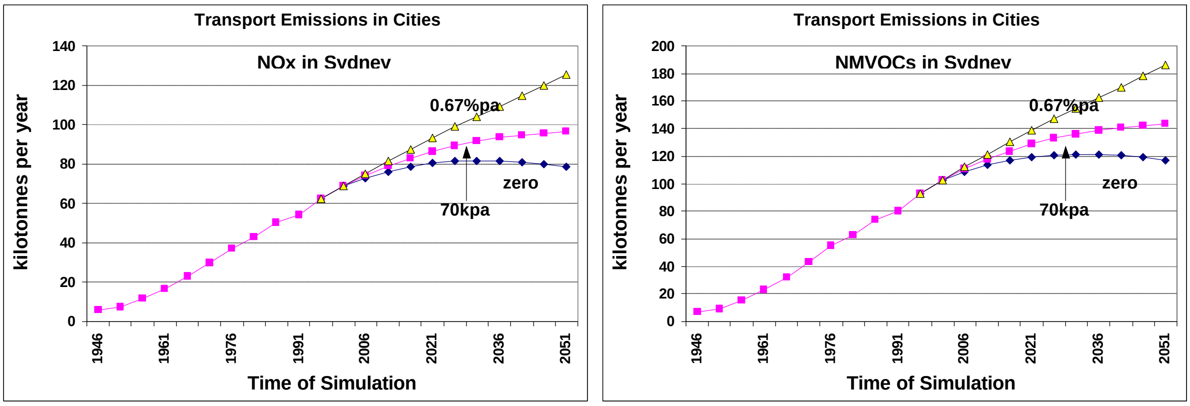


Figure 7.9. The generation of NOx emissions (left) and volatile organic compounds (right) to 2050 for the Sydney airshed for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Biodiversity quality

The inclusion of biodiversity quality as a population dilemma is linked to the tertiary trade effect. Primary population effects due to urban settlement patterns (e.g. linear development along coast lines; habitat fragmentation due to roads) can also simplify habitat structure and potentially reduce the diversity of native plants and animals in an area. Australia, along with many countries settled in the colonial era of the past three centuries, has suffered from the introduction of rabbits, foxes, cats, and a plethora of other exotic plants and animals. At a world level there seems little doubt that continued population growth and economic development will challenge many biodiversity hotspots that are rich in plants and animals (Cincotta et al., 2000) and that increased global food requirements and affluence will require more land clearance and produce more ecosystem pollution (Tilman et al., 2001).

Whether the concept of biodiversity is important for the continued existence of humankind, represents a cultural belief that is open to intense speculation, investigation and debate. The development of the concept of ecosystem services (de Groot, 1992; Daily, 1997) has begun to link the complement of biodiversity to a wide range of currently un-costed and unacknowledged services that the ecological web of life provides to modern economies. Costanza et al. (1998) estimated the value of the world's ecosystem services to be US$33 trillion per year, compared to the world's gross domestic product of US$18 trillion per year, i.e., nearly twice the amount of value adding in traditional accounting terms. While this example could be regarded as an artefact of monetary valuation, it makes a point about the value of ecosystem services. The examples in Chapter 3 of the higher quality and lower cost of urban water from forested and intact catchments close to major cities, are perhaps more practical and relevant within the context of this report.

That Australia's complement of biodiversity has suffered since European settlement is not in question (Table 7.7). Approximately 20 species each of mammals and birds have become extinct while another 50 species of those same groups are considered endangered and vulnerable. Nearly 80 species of plants have disappeared and 1000 more are considered vulnerable or endangered. While strong ethical and philosophical arguments can be mounted against systems of management which allow the extinction of species it is difficult to claim that the function of the economy or the physical well being of Australia's domestic population have been negatively affected by such extinctions. In fact mounting the technological capability to re-clone the Tasmanian Tiger or developing advanced breeding programs for endangered plants and animals may, in time, compensate for previous declines in species abundance and range, but at substantial monetary cost. Cloning the Tiger's habitat may prove more difficult. What is more important though are suggestions that humankind is on the cusp of a period of mega-extinctions driven by development activity and the landscape taming process that is central to modern urban environments, farming and forestry systems. In the BBC Reith Lecture series, Lovejoy (2000) asserts that biodiversity is entwined so deeply in our daily lives that few of us even notice it. He emphasises that turning around the loss of biodiversity requires global decisions that are integrated with nature's plans and frameworks, rather than merely serving the wishes of humankind and national development.

Table 7.7. Conservation status of Australia's flora and fauna since European settlement (After Yenken and Williamson, 2000; Burgman and Lindenmayer, 1998).

Taxon	Number of extinct taxa	Number of endangered and vulnerable taxa
Birds	21	50
Mammals	19	43
Fish	0	17
Amphibians	0	29
Reptiles	0	51
Molluscs	2	0
Insects	3	118
Plants	79	1,009
Annelids	0	1
Crustaceans	0	7

The extinction of these species probably represents a unique confluence of many isolated events, not all of which can be traced to deliberate human management or human population number. Within Australia, many of the mammal and bird extinctions can be traced to a combination of habitat clearance and predation by introduced animals such as foxes and cats. Such broad generalisations belie an increasing simplification of the landscape as crops and pastures replaced a wide range of species and structural combinations of plants which had co-evolved with the species that grew to depend on them.

Not all effects of human management are negative. The increase in the number of waterpoints in the dry pastoral country has increased the number and range of large kangaroos compared to pre-European levels with similar effects on some seed eating birds whose range is greatly increased by access to water and human settlements. Future expansion of irrigated cropping land, particularly in northern Australia, could effect similar changes to a range of plants and animals located there. Alternatively, an Australia whose national intent is attracted to scenarios such as 'landscape integrity' analysed in Chapter 4, could re-establish large stocks of biodiversity habitat with many more uses and outputs than simply visiting national parks and communing with nature.

The biodiversity quality dilemma is similar to the water quality dilemma. A smaller population might make fewer requirements on the land base, but not necessarily. Some thresholds of damage and landscape alteration have already been passed in a number of ecosystems. A larger population, if it were richer in aggregate, might choose to devote a significant proportion of its national wealth to conservation management and landscape refurbishment. However, increased affluence, tourism and expectations of landscape productivity can operate as multipliers of human activity and run counter to positive efforts. All population scenarios will project against a background of significant biodiversity loss over the past two centuries and current attitudes which focus on saving individual attractive species, rather than habitats in their entirety.

The way forward for the environmental quality dilemmas

Quality is essentially linked to quantity. The air quality dilemma has feasible technological solutions that reduce the amount of energy combusted per passenger kilometre travelled in the airsheds of our main cities. If these solutions are combined with regulations and incentives that reduce emissions from stationary sources, practical solutions to the air quality dilemma could be achieved by 2020. Halving the passenger kilometres travelled could also provide a behavioural solution to the same physical problem. The dilemmas of water quality and biodiversity quality are essentially linked to broadscale landscape issues and thus to export trade issues. The biomass based transport fuels option described above could help redress both the water quality and the biodiversity quality issues. However, it would probably have to work in unison with a reduction in physical production from dryland and irrigated agriculture. If export income is to continually increase to deal with international trade and debt, then this implies increasing returns of real dollars for each physical unit exported. The wine industry may offer some useful lessons in this regard, but a nation clothed with vineyards will not solve the full nest of intertwined challenges.

RESOLUTIONS OF DILEMMAS

The national goals espoused by most modern democracies generally include continuing moderate levels of economic growth, reasonably full employment levels, progress towards reasonable levels of social and economic equity and a transition towards sustainability. These goals present a number of difficult trade-offs which could remain insoluble without the introduction of revolutionary changes.

From the perspective of the physical economy, this chapter contains six dilemmas — four of which are physical in their derivation and two of which are social and related to economic and behavioural issues. The two sets are related and have critical interdependencies between them.

The physical dilemmas (material flows, greenhouse emissions, resource depletion and environmental quality) are intimately linked through the structure of the economy, the industries which function in it and the technologies and procedures of management used. Past management decisions, such as the adoption of European style agricultural systems, have set in train land loss due to dryland salinity, subsequent increases in river salinity, decline of inland fisheries and some extinction of animal and plant species. The next phase of development led to the development of Australia's mineral resources which, when combined with the farm economy, led to a material and energy intensive economy on a per capita basis. While the development was deliberate, much of the subsequent physical impact was unintentional and realised only in hindsight. Of many positive aspects along the way, the major one must be that a modern industrial and service economy has been built on the wealth derived from the export products of the farm, the mine and the factory. Within a globalised trade and environmental context, the appropriateness of this structure for the economy is now being examined and prospects for redesign are being considered.

Parallel to the physical dilemmas are the social dilemmas that deal with population ageing, and physical trade balance. Physical trade balance links the physical to the social dilemmas since trade in commodities and manufactured goods is how the nation pays for many of its imports of goods and services. While contemporary economic theory allows for increasing imbalances between imports and exports, the dynamics of international financial flows may disadvantage countries where trade imbalances and total international debt exceed certain threshold levels of gross domestic product. Prudent economic managers attempt to retain a balance between imports and exports while maximising opportunities for full employment. Possible interactions occur when, in an attempt to counter population ageing by higher immigration rates, imports are increased and exports are decreased, possibly altering the long-run resilience of the economic system. The debate remains as to whether the overall outcomes of these complex interactions are positive or negative.

The key challenge in the resolution of the six dilemmas is this: Each of the dilemmas may well be solvable within one to two human generations if concerted action is focused on it alone. However as solutions are sought to pairs or triplets of dilemmas in parallel, the task grows in complexity because of the strong interactions between dilemmas. It is possible to propose grand solutions, but more investigation is needed into the fine structure and dynamics of each dilemma because they are all linked. Answers to the preliminary questions presented below could help reduce the dimensions that need to be addressed to solve the six dilemmas in parallel:

- For the ageing dilemma, do mature aged persons prefer to remain in the workforce and could their potential economic productivity and consumption patterns compensate for the options available in a strong growing physical economy with an expanding population? What are the performance indicators that policy makers might assess in the resolution of this dilemma?

- For the physical trade dilemma, how might the future material flows and embodied energy flows associated with the full complement of export and import goods and services, be reconciled with future hard currency values placed on those items? Are environmental trade-offs possible between the material and energy content of imports and exports, and could institutional arrangements for more sustainable trade patterns be developed from such accounting principles?

- For the material flow dilemma, what are the production and consumption characteristics of a factor-4 and factor-10 philosophy implemented throughout the whole economy? What are the economic, employment, social and transitional risks associated with the progression to such a future?

- For the greenhouse gas dilemma, what are the transitional and continuing energy and material flows associated with a 50% renewable energy economy based on solar thermal, solar photovoltaic, wind, nuclear and biomass energy sources?

- For the resource depletion dilemma, is it socially and politically feasible to use market and institutional mechanisms to ensure that potentially renewable resources such as marine fisheries and arable land are retained as such? For non renewable resources such as domestic oil and gas, is it possible to strategically use this resource advantage to smooth the transition to the next energy economy over the next human generation?

- Is it possible to resolve the environmental quality dilemma within a physically growing economy using the expansion process as leverage to introduce leading edge technology and management? Alternatively, will it be necessary to reduce the sum total of the physical transactions in order to replenish the ecosystem services that underpin issues such as water quality in inland rivers?

While solutions to the set of six interlinked dilemmas have not been developed in this study, they set a framework against which a number of conclusions can be drawn. In distilling the limited number of 10 conclusions the following criteria have been used:

- What can be concluded about population number and its effect on the physical economy, resource use and environmental quality?
- Does population effect have a number of more obvious and less obvious aspects that can lead to innovations in controlling future population impact?
- Can technological innovation, if applied surely and well, control human impact on resource use and environmental quality?
- Are there any sleeping issues that might emerge over the next 30 years, which will require action now, if they are to be averted?
- What are the essential messages for the proponents of the high, medium and low population scenarios out to 2050?

TEN OVERALL CONCLUSIONS FOR THREE POPULATION SCENARIOS AND THEIR EFFECTS ON AUSTRALIA'S PHYSICAL-ECONOMY

1. Direct effects of population growth

Many issues in Australia's physical economy are directly affected by population growth. More people means economic growth and development stimulated by the requirements for more infrastructure, more industrial output, more services, more food, more tourism, more energy and water use and more waste and emissions. Given these practical realities, the high, medium and low population scenarios tested in this study are physically feasible out to 2050 and beyond.

Ceasing population growth will not cause the physical economy to stall, nor will it immediately make key issues of resource use and environmental quality disappear. A number of drivers of the physical economy, such as lifestyle and affluence, international trade and inbound tourism affect key resource and environmental issues. They are indirectly linked to population size and population growth rate.

Any significant progress towards sustainability in Australia's physical economy will require that population futures are managed in unison with the futures of infrastructure, lifestyle and personal consumption, energy, international trade, inbound tourism and technological innovation.

2. The good news on population growth

Under all population scenarios, growth in a range of key sectors of the physical economy continues, at least until 2020. Even under the low population scenario, declining household size, internal migration patterns and requirements for tourism accommodation stimulate activity for the building industry — although less than for the higher population scenarios. This growth occurs in many other sectors, with notable exceptions.

In terms of the physical economy, growth brings three immediate causes for optimism, although later conclusions suggest caution about the prospect of growth (as we currently know it) in the long run.

Firstly, 20 years of assured activity gives time to implement substantial institutional innovation in a robust marketplace. Secondly, it allows advanced stocks of buildings, motor cars, passenger transport and freight systems to penetrate the national system, and to begin stabilising the flows of energy, materials and waste. Thirdly, and provided that points one and two eventuate, growth could underpin new export industries that are rich in services and information, to substantially replace the current materially and energy intensive export mix.

3. Three population scenarios: the detailed demographic outcomes

By the year 2050, the low, medium and high population scenarios give domestic populations of 20, 25 and 32 million people respectively. By 2100 the scenarios give 17, 25 and 50 million people. The results are broadly consistent with other national demographic analyses. The low scenario does not decline as precipitously as shown in some other studies due to slight differences in assumptions about the fertility rates of younger females.

The high population scenario gives a younger population in a proportional sense. It projects that by 2050, 20% of people will be over 65 years of age. This compares to 27% and 25% for the low and medium scenarios respectively. We also project further 2% increases in the low and medium scenarios by 2070. For indices of dependency that relate the number of younger and older people to those of working age, the next 20 years will see the lowest dependency ratio since the 1940s. The low and medium scenarios will, by 2030, have dependency ratios similar to those at the height of the baby boom in the 1960s. After 2030, the low and medium scenarios reach a ratio of between 7 and 8 dependents per 10 of working age, whereas the high scenario stabilises at 6 dependents per 10 of working age.

The changing demographic structures and the assumptions tied to them highlight three potential issues. Firstly, regional Australia is likely to age more than the cities, due to assumptions about internal migration. Secondly, regional ageing is compounded by increasing aged medical problems compared to the younger cities. Thirdly, the extent of demands for services such as education will fluctuate, driven by slow moving changes in demographic structures. It is feasible to prepare the workforce, and its infrastructure, well ahead of time to better accommodate these issues.

4. Technological innovation offers promise *but…*

Aggressive implementation of technical solutions to key resource use and environmental quality problems show much promise. For example, cutting edge designs that already exist for houses and motor vehicles can reduce energy use and greenhouse gas emissions. The transition to a 'factor-four' economy where process intensity for basic materials is reduced in unison with rapid implementation of new consumer technologies, also provides the potential for large reductions in energy use and subsequent greenhouse gas emissions.

However five important caveats limit the potential for feasible technological solutions. Consumer sentiment, in general, stimulates the requirement for larger buildings, more quality and luxury, more powerful motor vehicles and more frequent air travel. An efficient consumer-led economy generally embraces growing volumes of cheaper goods and services, which, in turn, have increasing energy and material content in their total life cycle. While pricing policies can moderate the use of resources such as energy and water, they are seldom applied to stabilise resource use in a physical sense, although there are exceptions. Furthermore the direct and indirect requirements for energy, water and land are directly related to per capita expenditure. As per capita expenditure grows, so too does the resource quotient required for the sum total of goods and services included in measures of total personal consumption. Finally, there is the 'rebound effect' where efficiencies gained in one sector give savings (in resources or money) that inevitably migrate to stimulate resource use in another sector.

Therefore, while technology can be a powerful ally, it will struggle to reach its full potential under the current structure and function of Australia's economic and social system. As the population and the economy grow, so too will the physical transactions required to underpin economic success.

5. Direct and indirect effects of population influence

To effectively manage the effect of population growth on resource and environmental outcomes, the population issue in Australia can be regarded as having four levels or tiers of influence.

The first level is the direct influence. More people consume more energy and materials and thereby produce more waste and emissions. The primary influence has been reasonably well documented over the last 30 years. Under all population scenarios, this study has confirmed that, barring unforeseen catastrophes, Australia has enough land, water, and energy to provide food and a moderate lifestyle for all its citizens out until 2100. However there will be significant pressures on marine fisheries and domestic stocks of oil and gas.

The second level of population influence is driven by discretionary, rather than obligatory, lifestyle factors. Rising affluence and its effect on consumption patterns is a strong driver of modern economies, some of which are exiting the industrial economy and entering the service or new economy. However, affluence is underpinned by energy and material transactions which increase as discretionary spending rises. Rising affluence is one contributor to rising resource use, even in the low scenario where population is declining. Technical innovation must continue to outrun lifestyle requirements, if material and energy use are to stabilise.

International trade in goods and services drives the third level of population influence. Most nations have export industries to pay for imports. In a modern consumption driven economy, import volume is related to population size, its growth rate and its per capita affluence. Many of Australia's commodity and manufacturing industries are export focused with only part of their production being consumed domestically. The outcomes of total production, be they profits, jobs or regional development, still flow back to the domestic population, at least in a theoretical sense.

The fourth level of population influence is driven by international debt levels. Long-term investment funds flow in to assist project development and the expansion of industry and infrastructure. Whether this happens in anticipation of, or in response to population growth, is a moot point and the real answer is probably both. Failure to balance the costs of imports and exports, the third population influence, is another contributor to international debt as the nation borrows to fund its current account deficit.

Much media and policy analysis tends to ignore the second, third and fourth levels of the population debate.

6. Resource and environmental issues of concern

Direct population effects (the more people the bigger the issue) are important in three resource and environmental quality areas.

Australia runs a sizeable deficit in the volumetric account of its fish trade while some of its marine fish stocks are considered over utilised. As population grows, per capita consumption is also expected to grow, bringing more tensions between volumetric supply and demand. Although managerial and technological responses are well underway, the response times are usually long and Australian waters are relatively unproductive by world standards. Pressure on fish stocks globally and in international waters near Australia, will increase with the steady expansion of consumer demand in developing countries, where disposable income and population are growing strongly. Part of this pressure will occur in Australian waters.

Modelling of domestic oil stocks shows some parallel with the fisheries situation. The study highlights a growing gap between domestic oil production and domestic requirements past 2010. This generally agrees with expert opinion in petroleum geology and oil industry circles. The higher the rate of population growth, then the bigger the gap will grow. Imports will fill the gap in the medium term, vast new petroleum provinces could be discovered and a new generation of fuel miserly vehicles could penetrate and dominate the vehicle stock. Other fuel sources such as natural gas, oil shale and biomass could be developed. In the 50-year timeframe, alternatives to cheap oil pose large, though not unsurmountable challenges of transition. The higher the population, the larger the challenge.

Air quality in the airsheds of capital cities could decline substantially if population and car use grow strongly, especially given that circulation patterns to disperse air pollutants are relatively ineffective in city airsheds. Better car engines, cleaner fuel, car free days and more public transport will all help. However, world-wide trends suggest that delivery vehicles and articulated trucks, central to the just-in-time service economy, will counteract emissions saved by the better cars.

The study has not linked the problems of agricultural lands, biodiversity depletion and the water quality of inland rivers directly to the primary population effect. Rather, these are due to the third level of population influence, our export industries. Most countries export goods and services to pay for imports. In a consumer driven economy, imports are strongly linked to population issues, but moderated by a range of volatile shorter-term issues such as currency exchange rates.

Surprisingly, the study identifies that water availability is not likely to be a constraining factor under any of the population scenarios, provided that big changes occur over the next 50 years. Although water is almost as important as energy as a precursor to social advancement and economic growth, the volume of water is sufficient and a wide range of opportunities exist for innovation, both institutional and technological. To make physical space for the repair of southern water systems, we have developed physically consistent scenarios that expand irrigated agriculture in northern Australia. This carries the same risks as the southern experience over the last century unless new technological and institutional innovations are implemented.

7. Management of slow moving variables (stocks versus flows)

Greenhouse gas issues and immigration issues have much in common. Most attention currently focuses on the flows (immigrants and greenhouse gas emissions) rather than the stocks (domestic population size and age, total complement of machines that use energy) that control those flows. This reality leads to an important theoretical point that has emerged throughout the study. Most systems in the world, be they natural or human made, usually seek to maintain a measure of robustness or resilience. Forests store their nutrients in biomass, workers invest in superannuation and nations have constitutions. Resilience allows those systems to both innovate and take new directions, as well as being able to resist shocks.

The size or structure of the slow moving variables (the stocks) in relation to the demands of the faster moving variables (the flows) determines the degree of resilience. In population terms, the slow moving variable is the population size (changes only slowly) and the faster moving variables are the births, deaths, emigrants and immigrants (variations year to year) that determine the rate at which the stock will change.

The slow moving variables govern all the important issues linked to population outcomes in this study. Australia is poorly placed to understand such issues in aggregate, with some notable exceptions.

In examining technical innovation through the stock of houses and cars, the analytical outcome suggests that better cars and better houses will have little moderating effect on total energy use and subsequent greenhouse emissions. If vehicle and housing policies are to affect future energy use, then each year's complement of new houses and new cars must meet the highest, rather than the average, technical standards. Only then will the technical characteristics of the stocks (and thence the flows driven by the stock characteristics) be improved over timescales of 20 to 40 years.

Without a focus on the slow moving variables, policy design for the physical economy is running blind. As an example of a slow moving variable, the demographic focus on population ageing with 50 year timeframes is appropriate. The same focus and timescale should be applied to most sectors of the physical economy. Policy design for guiding the slow moving variables is probably best left to government, while the discipline of the market is probably better at managing the fast moving flows.

8. Challenges for the low population scenario

A number of environmental and political advocates who see that population stability, or even population shrinkage, might lessen pressures on resource use and environmental quality advocate the low population scenario (20 million people by 2050 driven by an assumption of zero net immigration).

Within the assumptions and methodology used in this study, a lower population size and the beginning of population decline, allowed a range of environmental quality issues (emissions in the airsheds of capital cities) and resource use issues (household water use) to stabilise. Total greenhouse gas emissions were lower and physical trade balance was higher. The per capita material flow account was also higher (because of the dominating influence of international trade and fewer people).

The key challenges in this scenario relate to rapidly declining population after the year 2100, a larger proportion of aged citizens and the possibility that health care and pensions systems will not be able to cope. Under the scenario assumptions, the population declines in many rural areas and key sectors of the economy such as building and motor vehicles stabilise. Other analyses suggest that the size of the labour force may not be sufficient to ensure both the maintenance and expansion of key sectors of the economy. It is suggested that without substantial structural change, maintaining economic growth in a declining population could be difficult.

Countries already further advanced in the transition to an ageing population than Australia may already have solutions to the problems presented by this scenario. Many of the problems may even disappear as the nation adapts to issues, long before they become critical. The low scenario could also stimulate home-grown innovations that could be turned to the nation's economic, social and environmental advantage, since the rest of the developed world will eventually be travelling along similar transition pathways.

9. Challenges for the medium population scenario

The medium population scenario (25 million people by 2050, driven by an assumption of 70,000 net immigration per year) represents the status quo and the average policy position of the past decade. Apart from its federal policy origins, a range of analysts and social commentators support this scenario, as rational in a demographic sense, practical in maintaining a balance between the economic and social aims of an immigration policy, and helping to maintain the contribution of population growth to economic growth.

The key element of this scenario is a stabilisation of population size that occurs after 2050. Even with stabilisation though, resource use and environmental quality issues keep growing due to scenario assumptions of non-revolutionary technological progress and growth in personal affluence, export trade and inbound tourism.

The medium scenario projects the past 50 years onto the next 50 years. Thus it is sufficiently comfortable to avoid major decisions that might be forced by population decline in the low scenario, or rapid population growth in the high scenario. Its key challenge is to move from relative inactivity, into aggressive and positive action on several major fronts. For example, how does the nation enable major investment to proceed in parallel on marine fisheries, biodiversity, land degradation and inland river quality? How do capital cities restrict edge growth while re-inventing urban transport and energy systems to provide low carbon transport and energy services with reasonable equity? How could the nation's endowments of domestic oil and gas stocks, be diverted past short-term personal consumption, into innovative capital stocks that produce low carbon electricity and transport fuels for subsequent human generations?

There is a very real possibility that a moderate sized and stable population, reasonably endowed with natural resources, could manage a physically intensive economy with steady adaptation, to the national and international advantage of its citizens well into the future. This may be unlikely, given the current success of information rich economies versus commodity based economies.

10. Challenges for the high population scenario

A wide range of business leaders, past and present politicians, economic analysts and technological optimists who promote the advantages of growth and size support the high population scenario (32 million people by 2050, driven by an assumption of net immigration per year of two thirds of 1%)

Continuing growth is the key element of this scenario with an eventual population of 50 million by 2100. While the resource use and environmental quality issues are more challenging than in the other scenarios, some ageing issues are moderated in a proportional sense. Possible constraints to the size of the labour force are avoided and with them, various dependency ratios that relate numbers of non-workers to workers. Melbourne and Sydney become megacities of 10 million people by 2100, with possible constraints to their resource requirements and efficient function.

The key challenge for the high population growth scenario is coping with accelerating growth without a detailed national 'flight plan'. This 'flight plan' should ensure that material and energy issues do not interact to stimulate a hyper-materiality. The co-evolution of material production and skills to ensure that key physical elements actually appear on time and to specification is critical, given difficulties seen in major projects currently, and the experience of re-building East Germany. Along with the challenge of just making it happen, the dilemmas of resource use and environmental quality, already a challenge for low and medium scenarios, must be solved with faster moving trajectories. The balance of trade deficit for oil (by 2020) and natural gas (by 2040) becomes more critical and keeps growing to 2100 and beyond, in the absence of fuel transitions that are not as yet contemplated in policy and industrial circles. Finally, a key demographic challenge emerges if the required numbers of young immigrants cannot be found to fulfil the scenario assumptions. Then the scenario rapidly defaults to the demographic profile of the low or medium scenarios it was designed to escape. The inevitability of the ageing issue thus emerges, only as a much larger one within a larger physical economy with the same set of protracted environmental dilemmas.

REFERENCES

ABARE (1999). *1999 Australian Commodity Statistics*. Australian Bureau of Agriculture and Resource Economics, Canberra.

Adriaanse A Bringezu S Hammond A Moriguchi Y Rodenburg E Rogich D and Schütz H (1997). *Resource Flows: The Material Basis of Industrial Economies.* World Resources Institute, Washington D.C. USA.

AGSO (Australian Geological Survey Organisation) (1999). *Oil and Gas Resources of Australia 1999*. Australian Geological Survey Organisation, Canberra.

Australian Bureau of Statistics (2000). Australia Now, A Statistical Profile, International Accounts and Trade, Total merchandise exports and imports. http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/e48e943fdfd9293dca2568a900154b12!OpenDocument accessed 27-7-2000.

Bacon BR (1999). Ageing in Australia: Some modelling results and research issues. Department of Treasury, Retirement and Income Modelling Unit. http://www.treasury.gov.au/default.asp?main=/publications/retirementincomemodelling(rim)taskforce/models.asp 13/04/2000

Baker D and Weisbrot M (1999). *Social Security: The Phony Crisis*. University of Chicago Press.

Birrell B (2000). Australian mothers: Fewer and poorer. People and Place 8,2,33-42.

Brain P (2000). A slowcoach on the road to the future. Business Review Weekly June 30th 2000 p44.

Brunner PH (2000). Institute for Water Quality and Waste Management, Vienna, Austria. http://awsnt.tuwien.ac.at/AWS_2264e.htm/aws_welcome.htm accessed 25-7-2000.

Brunner PH (1999). In search of the final sink. Editorial in Environmental Science and Pollution Research 6,1,1.

Burgman and Lindenmayer (1998). *Conservation Biology for the Australian Environment*. Surrey Beatty and Sons, Chipping Norton.

Business Council of Australia (2001). Population Policy: Policy Agenda. http://www.bca.com.au/default.asp?pnewsid=855 accessed 7-6-2001

Chadwick R (1999). Why population policy matters. BCA Papers 1,2,17-18 Business Council of Australia, Melbourne Victoria.

Cincotta RP Wisnewski J and Engelman R (2000). Human population in biodiversity hotspots. Nature 404,6781,990-992.

Coleman DA (2000). Reproduction and survival in an unknown world. People and Place 8,2,1-6.

Commonwealth of Australia (2001-a). *Australian Dryland Salinity Assessment 2000*. The National Land and Water Audit, January 2001, Canberra.

Commonwealth of Australia (2001-b). *Australian Water Resources Assessment 2000*. The National Land and Water Audit, January 2001, Canberra.

Connor MA Evans DG and Hurse TJ (1995). Waste flows in the Australian economy. Waste Disposal and Water Management in Australia 22,2,9-29 June 1995.

Conroy J Foran BD Poldy F and Quinnell T (2000). Future Options to 2050: Workshops Report. CSIRO Resource Futures Program Working Paper Series 00/03, March 2000.

CPA (1999). Triple bottom line accounting: looking for balance. CPA Australia March 1999. http://www.cpaonline.com.au/03_publications/02_aust_cpa_magazine/1999/03_mar/3_2_3_31_reporting.asp accessed 12-6-01

Costanza R d'Arge R de Groot R Farber S Grasso M Hannon B Limburg K Naeem S O'Neill RV Paruelo J Raskin RG Sutton P and van den Belt M (1998). The value of the world's ecosystem services and natural capital. Ecological Economics 25,3-15.

Cox E (1995). *A Truly Civil Society*. ABC Books, Sydney.

Daily GC (editor) (1997). *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press Washington DC.

Dellink R Bennis M and Verbruggen H (1999). Sustainable economic structures. Ecological Economics 29,1,141-154.

Department of Environment Sport and Territories (1996). *Australia State of Environment 1996.* CSIRO Publishing Collingwood Australia.

Donges I and Henry D (2000). Farmers and environmentalists call for national commitment to save natural environment. Australian Conservation Foundation and National Farmers Federation media release. http://www.acfonline.org.au/campaigns/landm/briefs/qa.htm accessed 4-8-2000.

Elkington J (1997). *Cannibals With Forks: The Triple Bottom Line of 21st Century Business.* Capstone Publishing, Oxford.

Foran BD and Mardon C (1999). Beyond 2025: Transitions to a biomass-alcohol economy using ethanol and methanol. CSIRO Resource Futures Program, Working Paper Series 99/07. A consultancy report for the National Dryland Salinity Program of the Land and Water Resources Research and Development Corporation, December 1999.

Gera S and Mang K (1998). The knowledge based economy: Shifts in industrial output. Canadian Public Policy - Analyse de Politiques 24,2,149-184.

Godley W (1999). Interim report: Notes on the U.S. trade and balance of payments deficits. http://www.levy.org/docs/sreport/stratan.html accessed 28-7-2000.

Greenspan A (1998). Is there a new economy? California Management Review 41,1,74-85 Fall 1998.

de Groot RS (1992). *Functions of Nature: Evaluation of Nature in Environmental Planning, Management and Decision Making.* Wolters-Noordhoff, Amsterdam.

Guest RS and McDonald IM (2001). Ageing, optimal national saving and future living standards in Australia. Draft manuscript Department of Economics, University of Melbourne.

Harding and Robinson (1999). Forecasting the characteristics of consumers in 2010. Discussion Paper No. 40, March 1999, National Centre for Social and Economic Modelling, University of Canberra. http://www.natsem.canberra.edu.au/pubs/dps/dp40/dp40.html accessed 25-7-2000

Hawken P Lovins AB and Lovins H (1999). *Natural Capitalism: The Next Industrial Revolution*. Earthscan Publications, London.

Herring H (2000). Is energy efficiency environmentally friendly? Energy and Environment 11,3,313-326.

HSBC Economics and Investment Strategy (2000-a). Shifting gears: The Australian economy in the new decade. http://www.hsbc.com.au/ accessed 3-3-2000

HSBC Economics and Investment Strategy (2000-b). The cheap Australian dollar: Not accidental, not irrational, not temporary. http://download.hsbc.com.au/markets/cheap_aust_dollar.pdf accessed 27-10-2000.

Kriesler P (1995). *The Australian Economy: The Essential Guide.* Allen and Unwin, St Leonards, Australia.

King A Walker A and Harding A (1999). Social security, ageing and income distribution in Australia. Discussion Paper No. 44, August 1999, National Centre for Social and Economic Modelling, University of Canberra. http://www.natsem.canberra.edu.au/pubs/dps/dp44/dp44.html accessed 25-7-2000

Larkin T (1994). *Investing in Australia's Future: Achieving the 2020 Vision*. Research report prepared for the Business Council of Australia, Melbourne 1994.

Lenzen M (1999). Total requirement of energy and greenhouse gases for Australian transport. Transportation Research Part D 4,265-290.

Lenzen M (2001). A generalised input-output multiplier calculus for Australia. Economic Systems Research 13,65-92.

Lovejoy T (2000). Biodiversity. BBC Reith Lectures 2000. http://news.bbc.co.uk/hi/english/static/events/reith_2000/lecture2.stm accessed 1-8-2000

McDonald P (2000). Low fertility in Australia: Evidence, causes and policy response. People and Place 8,2,6-21.

McDonald P and Kippen R (1999). The impact of immigration on the ageing of Australia's population. Department of Immigration and Multicultural Affairs Discussion Paper, May 1999, Belconnen, Canberra.

McFarlane IJ (1999). Notes for talk to CLSA investors forum. Hong Kong Friday 21st May 1999 http://www.rba.gov.au/speech/sp_gov_210599.html

Mitchell J Morita K Selley N and Stern J (2001). *The New Economy of Oil: Impacts on Business, Geopolitics and Society*. Earthscan Publications, London.

Mullan P (2000). *The Imaginary Time Bomb: Why an Ageing Population is Not a Social Problem*. IB Tauris and Co. UK.

Munksgaard J and Pedersen KA (2001). CO2 accounts for open economies: producer or consumer responsibility? Energy Policy 29,4,327-334.

Murray Darling Basin Ministerial Authority (1999). The Salinity Audit of the Murray Darling Basin: A 100 year perspective, 1999. Murray Darling Basin Commission, Canberra.

Norton B Eames PC and Lo SNG (1998). Full-energy-chain analysis of greenhouse gas emissions fro solar thermal electric power generation systems. Renewable Energy 15,131-136.

Parliament of Australia (1999). Monthly economic and social indicators: Historical supplement 1999. http://wopared.aph.gov.au/library/pubs/mesi/features/bop.htm accessed 28-7-2000.

Pitchford J (1989-a). A sceptical view of Australia's current account and debt problem. The Australian Economic Review 2, 2nd Quarter 1989.

Pitchford J (1989-b). Does Australia have a current account problem? Policy 5,2,2-5.

Pitchford J (1992). Sustainability and private sector foreign debt. In Colin P Hargreaves (editor) *Macroeconomic Modelling of the Long Run.* Edward Elgar, Cheltenham and Camberley, United Kingdom.

Pitchford J (1995). *The Current Account and Foreign Debt*. Routledge, London and New York.

Pitchford J (1998). Variable returns to scale and population. In *Increasing Returns to Economic Analysis* p 432-444 (editors) KJ Arrow YK Ng and X Yang. Macmillan, Basingstoke.

Porter ME (1990). *The Competitive Advantage of Nations*. Macmillan Press, London and Basingstoke.

Salzman J (1999). Beyond the smokestack: Environmental protection in the service economy. UCLA Law Review 47,2,411-489.

Shostak F (1999). The balance of payments myth. In *The New Australian* online newsletter no. 133 13-19 September 1999. http://www.newaus.com.au/econ133frank.html accessed 28-7-2000.

Smith DI (1998). Water in Australia: Resources and Management. Oxford University Press, Melbourne and Oxford.

The Economist (2000-a). Europe's immigrants: A continent on the move. The Economist May 6th 2000, p17,21-25.

The Economist (2000-b). The health effect. The Economist June 3rd 2000, p92.

Tilman D Fargione J Wolff B Dantonio C Dobson A Howarth R Schindler D Schlesinger WH Simberloff D and Swackhamer D (2001). Forecasting agriculturally driven global environmental change. Science 292,5515,281-284 April 13.

Tradeport (2000). Australia: economic trends and outlook. http://www.tradeport.org/ts/countries/australia/trends.html accessed 10-10-2000

Vitousek PM Mooney HA Lubchenco J and Melillo JM (1997). Human domination of earth's ecosystems. Science 277,445-608 25 July 1997.

Wernick IK and Ausubel JH (1999), National material metrics for industrial ecology. in *Measures of Environmental Performance and Ecosystem Condition* P Schulze (ed.) National Academic Press, Washington DC. also http://phe.rockerfeller.edu/NatMatMetIndusEcol/ accessed 26-7-2000.

Wood A (2000). Dollar slump confounds analysis. The Australian, Tuesday August 29th 2000 page 13.

Yenken D and Wilkinson D (2000). *Resetting the Compass: Australia's Journey Towards Sustainability.* CSIRO Publishing, Collingwood Australia

Chapter 8
Overview of the report by the External Reference Group

ABSTRACT

In assessing the merit of the CSIRO study, the External Reference Group notes the tension between the depth and understanding of each of the disciplines represented in our group and the extent to which these intricacies are portrayed in the modelling approach and the results reported. Inevitably, each portion of the study does not itself represent the state of the art in each of our disciplines. However the study effectively brings together many individual issues in demography, the physical sciences, ecology and economics that normally remain unconnected in many national policy processes. Therein lies the strength, in both the scale and the connectedness of the study. The CSIRO model is different from most national models in that it simulates the physical processes that underpin the functioning of the nation, the so called 'physical economy'. In our critique of the approach and the results, we asked to what degree the disciplines of demography, economics and ecology were appropriately represented in the study. In general we were satisfied that the conclusions of the study are robust and defensible. We found that the results related well to the published literature, including in those areas where the analyses themselves were necessarily limited. From our perspective, there are three important learnings from the study, and the social process that surrounded it. The first is that the complexity and richness of the analytical approach affords both government and business the ability to look across sectors and institutional silos in a long-term context that spans human generations. Secondly it provides an empirical basis to refresh the national debate on sustainable development. Thirdly it suggests that federal government policy should focus mainly on managing national stocks (people, infrastructure, energy and natural resources) rather than national flows. In the main, the shorter-term national flows should be left to the fleet footedness of market forces. Finally the study demonstrates that no one population scenario represents an unalloyed good – a clear and unrestricted path to the future. Instead it shows that each scenario creates its own opportunities and challenges that need resolution at the policy table, and eventually at the household level. A moment's reflection suggests that this is good common sense. We would be alarmed and suspicious, knowing what we do about the way the world works, if there appeared to be some 'Yellow Brick Road' to the future.

INTRODUCTION

What are we to make of something that tries to look at everything when we usually spend our days looking at some particular thing? In an age of ever-increasing specialisation, how are we to cope with generalisation? This is the task and dilemma facing the External Reference Group, specialists all, in commenting on this report. It is a dilemma compounded by the fact that our specialities are all different – that while we each know a lot about our own specialisation, we know much less about our colleagues'. But we have come together, at the request of the Department of Immigration and Multicultural Affairs, to provide an independent frame of reference for the report.

Our group comprised Roger Bradbury (Australian National University, chair, ecology), Ian Burnley (University of New South Wales, human geography), Chris Murphy (Econtech, economics), Chris Ryan (RMIT University, technology) and Mark Wooden (University of Melbourne, economics) and was ably assisted by Neil Mullenger of the Department.

Within each of our specialities – whether it is economics or ecology, demography or technology – our task seems relatively simple: we need only to compare those aspects of the report that bear on our native discipline with what we understand to be 'best practice' or 'leading edge' or whatever is the current jargon for what the best and most creative people are doing. And if we do that, the answer will be simple and crisp: this report is not 'leading edge' in any of our disciplines. However a moment's thought reminds us why this is a trivial response, one which sidesteps the reason we have come together. On reflection, we should expect that a study of everything, using tools and techniques which are not mainstream within any of our disciplines, cannot produce insights or understanding within a discipline that are better than a study of some discrete phenomenon, using finely honed tools and specialised techniques peculiar to that discipline.

The very things that make for the success of specialisation also create its own Achilles' heel. We spend so much time mastering the details, that we have trouble with the whole.

To gain the benefits of specialisation, and to survive in the modern world, we have had to forego our heritage from Renaissance Man, that ideal creature, personified by Leonardo da Vinci, who knew everything there was to know. To reclaim that heritage we need to become a Renaissance Team. Thus our Group needs to take a different tack in its approach to the report, one that does not dismiss the claims and arguments of the specialist, but rather one that puts those claims and arguments into the context of the whole. We need to see, say, the ecology or economics in the report from two points of view: one which looks into the discipline concerned and examines it from the perspective of that discipline, and one which looks out from the discipline and examines it from the perspective of the 'problem of everything'. And we need to have these perspectives simultaneously.

We need to ask, not 'What does this piece of the report contribute to the discipline?' but rather 'What does the discipline contribute to the whole problem, through this piece of the report?'

Thus the fact that the report cannot mix it with the 'leading edge' within any particular narrow discipline does not mean that it is not 'leading edge' in itself. The report needs to be judged on its own terms as an attempt to look at the whole and not the parts. It needs, to be sure, to offer competent and thoughtful analyses from the perspective of any one discipline, but it also needs to be judged on the extent to which new understandings of the larger problems emerge from the interplay of the various specialisations and disciplines.

In our discussions during the course of the project this tension was obvious, as it is in our comments here. Nevertheless we have striven to provide a framework within which specialised issues may be discussed and argued on their own terms and in terms of their contribution to the whole enterprise.

In addition to the broad analysis and critique for which we take collective responsibility, we have also included some amplifying material in separate boxes. These comments focus on some disciplinary issues a little more deeply, and are attributed to individual members of the External Reference Group.

APPROACH – CONTEXT AND CRITIQUE

Our objective in this chapter, therefore, is to provide a context for, and a critique of, the CSIRO project, drawing on the range of expertise within the External Reference Group.

The discussion of the **context** will seek to embed the report within the large body of work in both the natural and social sciences on population issues in particular and modelling in general. It will explain where the CSIRO approach fits *vis à vis* other work in these areas. It will acknowledge and describe the report's multidisciplinary 'heritage' while providing an overview of its own contribution to the population and sustainable development debates.

The key contextual issues we will examine are:

- The use of models in science – and how to read them – with particular reference to the report.
- The biological tradition *vs* the economic tradition (that is, natural *vs* social sciences traditions) – the key similarities and differences between modelling and simulation in the social and natural sciences, with particular emphasis on the approaches of economic and ecological modelling – as sources of understanding and confusion.
- The problem of sustainable development as an interaction between biophysical and socio-economic processes – and, thus, how to place the report in the context of sustainable development.

The **critique** will be a more focussed analysis of the general strengths and weaknesses of the issues chapters and the crosscutting analysis.

- Are there 'issue' sub-models with counterpart 'disciplinary' models? One of the strengths of the design framework approach is that it can produce both single-issue models, such as population, employment, energy and water, as well as holistic models synthesising all the issues. But for each of these issues models, other 'disciplinary' models exist. How well do these models relate to each other? What can we say of any differences that we observe?
- How are the soft systems joined to the hard systems, and what can we say about it? The report makes much of its basis in physical reality, but much (beyond the actual three population cases driving the scenarios) depends on how the softer, more subjective aspects of the problem (such as the degree of acceptance of technological change, or of different lifestyles) intrude into the analysis. Does the report handle this well, and are there other ways that could be used?
- How is 'the physical economy' distinguished from 'the (monetary) economy' — or how does economics get a look in? The report makes it clear that it is not a 'traditional' economic analysis, and argues that it should sit side by side with such economic analyses. It argues that its strength is that it provides policy makers and the public with additional avenues of understanding. That said, there is still room for some analysis on how notions from the one approach can be represented in the other, beyond relatively trivial procedures like contingent valuation. Can we use the notion of information (as a notion as fundamental as energy or mass) to give some scope for ideas about markets (which are essentially information processing objects) to penetrate the model?
- Creating the link between people and their environment – or how does demography get a look in? An analysis of how the sustainable development debate often does not include one of the key drivers – human population – and how this report makes a significant attempt to remedy that problem.
- How does the model deal with the essentially spatial notions implicit in the concepts of sustainable development – or how does ecology get a look in? In linking population to the

physical environment, the report moves solidly into the debate on sustainable development. One of the key concepts here is that of spatial distribution – it matters not only how much or how fast things happen, but exactly where they happen. From this flows an idea about the graininess or heterogeneity of processes. The present model makes some attempts at this, particularly in terms of population. We will examine the sufficiency of the report's spatial thinking, and the effects this may have on its conclusions.

- How does the model deal with innovation and change, both technological and social – or how does 'Factor 4' thinking get a look in? The report attempts to project not only physical trends but also intellectual, technology and social trends, with its thinking being informed by the results of the workshops. How well is this aspect of the work done, and what can be said about it in comparison to what else is being done around the world?

CONTEXT

The use of models in science

Modelling is so very close to what doing science mostly is that we often confound them (Bradbury, 1997). More than that, we often make the assumption (either implicitly or explicitly) that, since there is really only one kind of science, that there must be only one kind of modelling. And that leads to all sorts of misunderstandings not only about modelling, but also about the science that flows from it (Bradbury, 1999). In its simplest form, this problem is expressed in the inability or unwillingness to understand another's models. In a more perverse form, it is seen in the inability or unwillingness to accept the contribution to understanding that another's models might make.

Here, we will explore the nature of the model used in the report and its relation to other sorts of modelling, remembering that the model is the tool, the means to an end. It is the scientific understanding that is the end. While the model may colour that understanding, may inhibit or enhance it, it is not the understanding itself.

Modellers choose their models not only for the job in hand – their intended use (Pielou, 1981) – but also for their ease of use – their structure (Hogeweg and Hesper, 1985) – and the type of understanding they seek – their philosophical bias (West, 1985). These three different characteristics of models are more or less independent of one another. The result is that there are potentially a lot of different classes of models, many more than most modellers believe. Indeed, when modellers talk of different models, they usually mean different models within the one class – the class they use. Much of the debate and confusion about modelling – a sort of academic white noise – is caused by this myopia.

Most workaday models in both the natural and social sciences have as their intended use some sort of prediction, but there are at least three other quite distinct uses of models: explanation, hypothesis generation and as standards of comparison. Similarly, most models have an underlying structure that is variable-oriented, which is to say a structure built on the behaviour of variables linked together in mathematical equations. But individual-oriented (sometimes called agent-based) and event-oriented models are each distinctive alternatives. Finally, there are at least five kinds of truth that models may seek: Lockean or empiric; Leibnizian or analytic; Kantian or synthetic; Hegelian or dialectic; and Heisenbergian or pragmatic. Most modellers see themselves as synthesisers, but the other classes are just as justifiable.

The CSIRO model that underlies the report is quite different from most models in use today. Firstly, in its emphasis on scenarios, it is being used to generate hypotheses not to test them. So it immediately distinguishes itself from the raft of models that seek to predict (many of which also claim to explain). Secondly, it is event-oriented, the different components of the model sending messages to other components to which those components then respond. This is quite different from many ecological, economic or demographic models based on sets of mathematical equations. Lastly it is empiric in its attempt to describe its world as a physical economy – a practical, hard-nosed realistic description of how this world actually works. This is quite distinct from more analytic or synthetic models that embed their work in a framework of theory.

How to read the CSIRO model

Since the CSIRO model does not aim for prediction, its results need to be treated differently from those of more traditional predictive or explanatory models. In such models, the results purport to inform us about the way the world is – by explaining – or about how it will be – by predicting. Thus their results form part of a story whose beginning is a description of how the world is, whose middle is an argument about how the bits of the world interact, and whose ending – the model results – is the dénouement: either why it is so (the explanation) or what it will become (the prediction). Thus such models can be read quite easily as the ending to the story.

Models that develop scenarios are different because they have a different relationship to the rest of the story. And so they need to be read differently. Scenaric models are not an ending to a story about the way the world is. Instead they are beginnings of new stories, but fictions to the facts of the earlier ones. That is, they take, as a beginning, the way the world is, and then, as a middle, they ask 'What if …?' – making a plausible case for the way things might be. Finally they unfold their ending as the working through of the interactions of the model.

It is important to note what we mean here by 'fictions': a plausible, scientifically lawful description of the possible. We do not mean 'fantasies' – things that are beyond the possible.

If traditional predictive or explanatory models are detective stories, revealing at the end 'whodunit', then scenaric models are romances, exploring possibilities, revealing unexpected intricacies. They are sustained by their links to the real world, and also inform it, but, in their focus on the possible rather than the contingent, they are a wholly richer enterprise.

Thus we need to read scenaric models differently. We need to treat them as helpful lies, whereas we might treat predictive or explanatory models as unhelpful truths.

Almost the first thing we should do with such model outputs is to disbelieve them. But we should do this with the results of any scientific enterprise, since science thrives on and depends on scepticism. This proper posture of disbelief is not to be confused with our pursuit of understanding that emerges from it. We should examine the results to find the source of our disbelief – that is, we should look for surprises. What unexpected things emerged from the analysis? How did this or that surprise arise, given our prior knowledge of the system?

Then we should check the results against those of other studies. In the present case, this is one of the most important things we need to do, but we need to do it carefully. Each of the major components of the model will have equivalent 'single issue' studies against which they may be compared. We need to be mindful of the strictures discussed above about the relationship between the multidisciplinary and single discipline studies, and keep our checks and comparisons at a suitably high level. Thus we need to ask 'Does the broad thrust of some component of the model accord with the broad understanding within the discipline?' rather than 'Do the nuts and bolts of this component of the model match the nuts and bolts of the standard disciplinary model?'

Finally, we should look for deeper links in the system. The surprises we find in the results are due as much to our inability to imagine the (non-linear) consequences of the relationships that we have faithfully described in the model as to the emergence of truly novel phenomena. With the wisdom of hindsight, we can now track back our surprises to their sources, and examine the ways in which the links and relationships allow the propagation of surprises through the system. The use of different scenarios may help significantly in revealing these tracks, since the scenarios each emphasise different forces in the model.

The modelling traditions in the natural and social sciences

It used to be a sort of 'Sydney or the bush' thing, scientific modelling. It could be like physics, proper and grand, or it could be a less reputable activity altogether, hardly worth considering as real science. Respectability in science, for many new scientific disciplines struggling for respectability, has usually been measured by closeness to physics, or at least adherence to its mores. Thus we see in the emergence of the three main disciplines represented in the report – the natural science discipline of ecology, and the social sciences of economics and demography – an adherence to the physics of the time of their emergence. The neo-classical synthesis in economics depends on a mathematics and world-view of 19th century physics (Reder, 1999), just as surely as the demographic transition theory of demography (Lutz, 1996) or trophodynamics of ecology (Bradbury et al., 1996) depends on an early 20th century physics.

In this sense the modelling traditions in the natural and social sciences of the report are more alike than they might realise. They share some implicit assumptions about how to do scientific modelling: it should be informed by theory (how the world should be), it should be describable in a mathematics that stresses linearity and equilibrium (sets of differential equations, usually), and it should be predictive or explanatory. Whether the mathematics harks back to Newton as in much of economics, or uses post-Einstein work as in some ecology, the message is the same.

It is not our intention here to argue the merits of this sort of modelling within any of these disciplines, even as we acknowledge that even physics has moved on in its own approach to modelling, no longer asserting the primacy of theory in all cases (Wolfram 1984). Instead, we note that modelling approaches that work well within a discipline may not work at all well in a multidisciplinary context. By far the best example of both hubris and naiveté has been the Club of Rome program (Meadows et al., 1972), which sought to apply the common modelling approach of the economics and ecology of the 1950s to the multidisciplinary problem of the interaction of the human population and its environment. The failure of that program, in terms of furthering our scientific understanding of the problem, is due in no small part to the naïve adoption of a theory-bound modelling approach.

The empiric approach of the CSIRO report, then, has much to commend it in the present circumstances. It sits to one side of the mainstream modelling tradition in both the natural and social sciences. That is a strength rather than a weakness, since that tradition makes an (often implicit) assumption of theory, and at our present level of understanding of the larger problem, we are in advance of a comprehensive theory. The CSIRO approach allows us to push forward the frontier of our understanding of the problem, and gives space for theory to grow up behind it. It allows us to get on with the job.

The problem of sustainable development

If there is a 'theory of everything' underlying the multidisciplinary problems addressed by the report, it may well be found in the ideas of sustainable development. These ideas have exercised the minds of policy makers and the public for the last decade or so, and have firmly entrenched themselves in the public policy agenda of all developed countries. They seek to reconcile environmental, social and economic concerns, so they are explicitly multidisciplinary. They also seek a global perspective, so are explicitly systems-oriented. They try to articulate a coherent argument about the interdependence of environmental, social and economic concerns, so they are a precursor to a theory. But it is not a theory (or not yet) in a scientifically accepted sense. It is more an intellectual scaffolding that could support the construction of theory.

The empiric modelling work reported here then has an unusual, but potentially enormously productive, relationship with the ideas of sustainable development. To understand this, we need to understand a little more deeply, the depth of the failure of the Club of Rome program discussed above. This work preceded the formalisation of the central ideas of sustainable development, and was implicitly and rigidly theory-bound in a modelling formalism called system dynamics. Hence it has been unable to contribute effectively to the evolution of sustainable development ideas that necessarily go into 'soft' areas where system dynamics fears to tread. It has also been unable to benefit from the continuing evolution of those ideas that are seeing a progressive merging of soft and hard sciences.

The CSIRO work is able to contribute directly to the development of a theory of sustainable development. Its scenaric results yield statements that have meaning across the full spectrum of thinking on sustainable development, since they do not presuppose an underlying theory. Conversely, the work can be informed by sustainable development thinking in an unconstrained way. It has no theory to be defended at all costs, and so its results can stand the test of time, and are worthy of progressive reinterpretation in the light of unfolding theory.

Much more than any theory-bound approach, the CSIRO modelling is the precisely right partner to today's sustainable development thinking. It can be seen as catalysing rather than inhibiting the emergence of the new ideas that will be essential if we are to construct a coherent theory and robust policy for sustainable development.

CRITIQUE

Are there 'issue' sub-models with counterpart 'disciplinary' models?

As an approach, the 'design framework' modelling protocol is not focussed on any particular discipline (Gault et al., 1987). It is not peculiarly economic, ecological, demographic or whatever. Nor is it focussed on any particular level of problem. It makes no difference if the problem is within some small bit of the economy, an entire ecosystem or the world's whole human population. It is an entirely generic construction, and is given its meaning by the problem under attack.

It is also naturally hierarchical. We may think of each calculator as a model of some bit of the system in its own right – as a sub-model. Thus we might expect to find calculators that represent disciplines, that there might be an economic calculator and a technology calculator and so on.

This is only partly true, but mostly untrue. The world is not really divisible into non-overlapping bits called disciplines. Even the sectoral workshops referred to in the report that preceded the model-building are highly multidisciplinary. Where it is partly true – that is, where a calculator is mostly concerned with the problems of one discipline – we may compare the sorts of results the calculator produces with the sorts of results that a standard disciplinary model produces.

We see this best in the population area. The five demography calculators together generate population projections. While the way in which each of these calculators works might not mimic exactly the standard processes of the discipline of demography, the results should at least be directly comparable. It is comforting to find, as described in the report's appendices, that the population calculators not only 'hindcast' the Australian population accurately over the last 50 years, but that they produce projections which are in very close agreement with the standard projections produced by official sources such as the Australian Bureau of Statistics. Where the power of the present approach exerts itself, of course, is in the way that these projections are able to interact intimately with the rest of the model because of the way in which they have been constructed.

However, there is really nowhere else in the model where discipline maps closely to calculator. Areas such as forestry, fisheries or transport are thorough mixtures of disciplines. This can become a problem if the theory underpinning a discipline has no path into the model given the model's focus on an empiric, data-intensive protocol. The very thing that the proponents of the 'design framework' proclaim as a virtue – its empiricism – could then become a vice.

Disciplines are deeply bound with theory, often to the point where the theory is so embedded that it is no longer even recognised as such. Theory is, after all, what gives a discipline its distinctiveness. Economics would be unrecognisable without its general equilibrium theory, ecology has its underpinning of evolutionary theory, and demography, its demographic transition theory. None of these has a place in the model proper, but yet each has an important contribution to make, not only to understanding the immediate problem but also to setting it in a wider context.

But being excluded from the model proper does not mean theory is excluded from the whole framework. Theory intrudes, properly, in the workshops where the relationships among the variables are argued out. For example, the types of growth exhibited by fish and human populations are informed by ecological and demographic theory respectively. Similarly, human demand for food and fibre or the human propensity to substitute one technology for another are informed by economic theory and 'Factor 4' ideas respectively.

Disciplinary theory may also intrude in the part of the framework the modellers call 'control space' – the place where the model is interpreted and decisions start to be made. It is here that disciplines and their theories mix it with the ideas, values and goals of the users of the model. This will be explored further in the next section.

A final caveat is needed however. The fact that the disciplines are mostly smeared out across the model carries a sting in its tail. If there are important aspects of a discipline that are not adequately accounted for in the model, then the model is weakened systemically. We will consider this issue in the sections that follow.

How are the soft systems joined to the hard systems, and what can we say about it?

We argued above that disciplines are spread across the model's components to the point that there is not a one-to-one correspondence of discipline to calculator. And we have also argued that the modellers see as a strength their focus on the material world, the thing they call the physical economy. Together these two parts of the protocol create problems for the soft sciences – the sciences concerned with the non-material, such as human behaviour or human ideas.

We might expect that a solution to the problem might be to locate the soft sciences (such as political science and sociology) in the control space of the framework where the users observe and control the model. Then we would locate the hard sciences (physics, biology, geology and so on) in the machine space where they would describe the material world or physical economy. We could then say that all the sciences are joined within the design framework.

But this is not a complete solution. Some sciences straddle the boundary between hard and soft – the distinction is not at all clear. The problem is most acute with economics, since it is the most chimeric of the sciences, with both hard and soft tightly entwined. In its use of reasonably sophisticated mathematics and empirical data, it looks like a hard science. In its reliance on behavioural processes in the dynamics of markets, and its existence in ideological flavours – market economics, Marxist economics, political economy – it looks decidedly soft.

Clearly, disciplines like economics need to be able to find homes in both the control space and the machine space. If the framework is faithfully representing economic phenomena and at least acknowledging economic theory, we should expect to find evidence of the harder parts of economic thinking in the machine space and the softer parts in the control space.

To a large extent, this is what we find when we examine the framework. We find, for example, a neat conjunction between the hard economics of national accounting (Leontief, 1966) and the ideas of embodied energy and embodied water. They each use a highly empirical data system, and rely on notions of balanced accounts to reveal their dynamics. This conjunction goes even further, allowing national accounts data to be used to create embodied energy accounts.

But we do not find Adam Smith's invisible hand in the model proper. We do not find, in fact, market behaviour – the automatic adjustments between supply and demand through the price mechanism. Nor should we expect to, since these are not material processes. We must seek for such soft dynamics in the control space.

The control space is where tensions or dilemmas are resolved and it is here that soft dynamics like market behaviour are revealed in the ways in which users respond to the dilemmas and rework the model.

How is 'the physical economy' distinguished from 'the (monetary) economy'– or how does economics get a look in?

With a complex area like economics, as we have just described, the problem is not simply reducible to deciding that this or that should reside in machine space or control space.

The fact that the physical economy does not include prices does not imply that prices are not important. The scenarios provide a physical description of transactions in possible future economies. If those transactions come to pass it will be because, in some sense, people choose them. There may be many reasons for people's choices, but economic conditions as reflected in prices will certainly be among the most important.

The framework omits prices, not because they are not important, but because of the timescale and scope of its concerns. The empirical base for economics (and related behavioural sciences) is observed behaviour under current conditions. Its theories are based on the choices people are observed to have made, and are summarised in parameters such as elasticities of various kinds. This may be a sound basis for predicting the consequences of small changes from the status quo, but it provides little guidance if we are concerned with the possibility of major structural changes when choice sets or even the psychological bases of preference may differ.

Future developments will be the result of people's (dynamically changing) preferences and the physical world in which those preferences are expressed. Whatever the merits of economics (and related behavioural sciences) for predicting short-term marginal developments about the status quo, it provides no basis for long-term predictions of substantial dynamic change. We just do not, and cannot, know the future elasticities. That is why ideas of the scenario and the control space are so important: they allow for the choice component to be guided as much as possible by actual human input (consultation, discussion, workshops – all the social activity in 'control space').

On the other hand, we do know a fair bit about the physical world. There is a wealth of scientific, engineering (and economic) information about energy efficiencies, material intensities, crop yields, consumption patterns, labour productivities, and so on. These can change, but the changes are bounded. Existing technologies can be improved, but the improvements are subject to saturation (as will be discussed below). Radically new technologies may be introduced, but they cannot come in overnight. New infrastructures need to be provided and, while they build up (absorbing resources) old infrastructures need to be maintained to 'keep the show on the road'. Evaluation of such scenarios in physical terms is the first step in identifying directions for sustainability policy.

But there is no question that the implementation of such policies will need to take account of – and manipulate – the prices of goods and resources.

An economic modeller's perspective

In *Future Dilemmas*, Barney Foran and Franzi Poldy of the CSIRO conduct an exercise in assessing alternative migration policies. They feed three alternative assumptions about future migration policy into a complex model to generate three scenarios for Australia to 2050. The reader is invited to compare the three scenarios to make judgements about which migration policy best serves the national interest.

The contribution of such work can be assessed by comparing it with related work that is already in the public domain. In the early 1990s in a consultancy for a bureau of the immigration department, Econtech developed a system for assessing the economic effects of alternative migration policies. Alternative migration scenarios are fed into a demographic model which in turn generates inputs for a widely-used model of the Australian economy known as MM2. This system has been used often, its most recent use being earlier this year.

In this most recent analysis, Econtech used the system to estimate the economic impacts on Australia of the 2002/03 migration program for the immigration department. These economic impacts were relative to a baseline scenario in which the 1995/96 migration program continued without change.

The economic impacts for 2007/08 were as follows:

- a net addition to the total population of 0.29 per cent or 60,000 people;
- an addition to the population of working-age (15-64 years) of 0.89 per cent or 126,000 people (the populations for the younger and older age groups were lower);
- a gain in labour force participation of 0.71 per cent;
- a gain in annual funds transferred to Australia by migrants of about $1.7 billion;
- a gain in the skill level of the Australian workforce of 0.24 per cent;
- a gain in GDP per head of 1.15 per cent; and
- a gain in annual consumption per head of 1.22 per cent or $344.

The most important result is the bottom line for Australian living standards, as measured by consumption per head. The significant gain in living standards of 1.22 per cent reflected the following policy developments in the 2002/03 program compared with the 1995/96 program:

- the capping of the parent component of the family stream, making the migrant intake younger;
- the shift since 1995/96 in the composition of the migration program from the family stream to the skill stream; and
- measures taken to improve the skill level of components of the skill stream.

These results confirm that the various changes in migration policy are likely to yield an economic dividend. They also provide ballpark estimates of the amount of that dividend taking into account an extensive set of linkages from demographic to economic outcomes. It is interesting to compare this Econtech analysis with the CSIRO analysis.

The CSIRO modelling only provides estimates of the first three of the seven economic impacts listed above. These cover demographic and labour force outcomes, which rely on relatively simple mechanical modelling. The remaining four economic outcomes are not covered by the CSIRO model, reflecting the simple nature of its economic component. The lack of any recognised summary measure of the net economic benefit of alternative migration policies, such as the effect on GDP or consumption per head, is the first limitation of using the CSIRO model to assess migration or other policies.

Similarly the CSIRO model does not capture the effects of the migration policy developments that affect the average skill level and wealth of migrants, neither of which appear as variables in the CSIRO model. So a second limitation of the CSIRO model is that it cannot be reliably used to assess the impact of changes to the composition of the migration program.

Indeed, Foran and Poldy appear to realise this and instead focus on the impact of changes in the level of migration, in the three scenarios referred to at the outset of this note. In three scenarios, annual net immigration is varied from zero to 70,000 to 0.67% of existing population.

However, even this approach raises problems. The economic effects on Australia of these changes to the level of the migration program are quite different depending on the balance of the program between migrants with high economic attributes (young, wealthy, high-skilled) and low economic attributes. For example, this balance has changed to an important extent since 1995/96, as demonstrated by the Econtech economic modelling described above. Foran and Poldy do not explain what this may mean for their results.

The CSIRO model includes a standard demographic model based on the cohort-component method, as well as physical relationships which are better assessed by scientists rather than economists such as myself.

The economic component of the model is simple. Everything is measured in physical quantities such as kilograms, joules and litres, leading the authors to describe it as a model of the ‘physical economy’. Production and consumption decisions are assumed to be based on simple physical relationships. It is a mistake to believe that such an approach avoids reliance on economic theory. Rather, it assumes that decisions by consumers and businesses are not systematically affected by prices and costs, when there is a mountain of empirical evidence to the contrary. Indeed, prices do not even appear in the CSIRO model, even though they play a fundamental role in balancing supply and demand right across a market economy such as that of Australia. This is a third limitation of the CSIRO model.

The suggestion that modelling the ‘physical economy’ is a novel or new idea is incorrect. In fact it is a form of the input-output method that was set out far more comprehensively by Wassily Leontief in his 1941 book on ‘The Structure of the American Economy’. In the last 60 years this strand of economy-wide modelling has developed considerably to cover prices, and to allow for the price-sensitive nature of decisions by consumers and businesses (in CGE models), but Foran and Poldy have not taken on board these important developments.

One potential contribution of the CSIRO modelling is in addressing the issue of possible economies and diseconomies of scale from expansion of the Australian economy. Econtech’s modelling does not address this difficult topic, but rather takes a neutral position on the basis that one can point to economies of scale in some areas (e.g. communications networks) and diseconomies in other areas (e.g. a fragile natural environment that can be degraded by economic activity).

Both economies and diseconomies of scale need to be considered as part of any balanced consideration of the issue of economies/diseconomies of scale. Indeed, one reason for Australia’s large-scale post-war migration program was a belief that there was a need to boost Australia’s population to generate a local market that was large enough to take advantage of economies of scale for a manufacturing industry that was protected from import competition.

Foran and Poldy ignore economies of scale, including in communications networks, and instead focus purely on diseconomies of scale. This exclusive focus on diseconomies of scale loads the deck against the migration program and is a fourth limitation of the CSIRO model.

Foran and Poldy focus both on depletion of reserves of natural resources such as natural gas and oil, as well as degradation of water, air and land quality.

Their focus on reserves of natural resources recalls the Club of Rome projections of thirty years ago. One accurate projection of the Club of Rome was that the population of the world would be around 6 billion at the turn of the century. Most projections of what this would mean, especially for reserves of natural resources, were completely astray.

World reserves of natural gas were projected to be exhausted about 10 year ago and reserves of aluminium about now. This led Paul Ehrlich to contend that prices of many natural resources would skyrocket. Julian Simon challenged this and bet that any $1000 shopping basket of raw materials of Ehrlich's choosing would be less expensive by 1990. The loser was to pay the winner the difference. In 1990 Ehrlich had to pay Simon $576.01.

What has happened before the Club of Rome produced its projections and has happened since is that real prices of natural resources have tended to fall. When scarcity has threatened, the resulting price rises have stimulated more efficient use of the resource as well as increased exploration leading to increases in proven reserves. Further, continuing improvements in mineral exploration and extraction technology have kept real prices low.

The CSIRO model does not include prices and therefore is missing the main feedback mechanisms whereby, through price rises, an emerging scarcity of reserves can be overcome through increased exploration activity and more efficient resource use. This omission leads to unduly pessimistic projections of Australian reserves, which is a fifth limitation of the CSIRO model.

In any case, given that natural resources such as gas and oil are tradeable, the more important issue is world reserves, not the Australian reserves that are tracked in the CSIRO model. The assumed changes in migration flows from other countries to Australia will not greatly impact on world reserves of gas and oil, since people will consume from these reserves wherever they live, although possibly at different rates.

The same point holds for Foran and Poldy's modelling of a connection between Australia's migration program and Australian greenhouse gas emissions. Greenhouse gas emissions are a global issue, and so in modelling the migration program one should only take into account the net difference in emissions from someone living in Australia rather than another country. Foran and Poldy do not do this, which is a sixth limitation of their model.

The more interesting side of the CSIRO model is in its modelling of urban air quality, water quality and land quality. However, again it is a stretch to view these environmental issues as being mainly the concern of migration policy.

Foran and Poldy generate their scenarios based on the possible extremes of net migration. More realistic scenarios for annual net migration would be 60, 90 or 120 thousand leading to an Australian population in 2050 of 24, 26 or 28 million. These fairly narrow variations in population outcomes would lead to similarly narrow variations in environmental outcomes.

Of much greater consequence for environmental outcomes are environmental policies themselves. For example, the shift to lead free petrol and the looming shift to clean diesel have major implications for urban air quality. Examining these sorts of issues is where one might expect the CSIRO model to come into its own.

However, where environmental policies are market based, as is increasingly the case, the CSIRO model is again not much help, which is a seventh limitation of the CSIRO model. A model that omits prices, and consumer and producer responses to price changes, cannot contribute much to analysis of the effects of policies that operate by raising prices where there are negative externalities and reducing prices where there are positive externalities.

At a broader level, the population debate is always evolving and increasingly is focussing on emerging problems for developed countries arising from prolonged low fertility. While the collapse in fertility maintained since the 1970s is no doubt primarily due to the introduction of the contraceptive pill and the feminisation of the workforce, the false alarms of the Club of Rome, with its claim that responsible couples should limit themselves to two children, is no doubt an unwanted contributor.

Developed countries now have to develop policies to deal with populations that are projected to age rapidly in the next few decades and then start declining. This shift in policy focus may make the CSIRO model, with its negative message about population and economic activity, increasingly less relevant.

As members of the External Reference Group, fellow economist Professor Mark Wooden and I have made these points throughout the course of the project but note that the current CSIRO model is currently unable to incorporate the economic perspective as outlined above. This area of research straddles the physical and social sciences, and the obvious way to address the seven limitations of the CSIRO model that are identified in this note would be a multi-disciplinary approach in which physical and social scientists work side-by-side. Such an approach has already been followed elsewhere in modelling policies affecting global greenhouse gas emissions.

Chris Murphy
Mark Wooden

Creating the link between people and their environment – or how does demography get a look in?

Our discussions above about 'issue' sub-models and the problems of joining soft systems to hard systems describe to some extent how demography is treated in the framework. It remains here to consolidate that argument with particular reference to demography.

A useful place to start is to note that the whole framework is an extension of demographic thinking, since it is based on the idea that the purpose of economic activity is to meet the needs (and wants) of people. People need houses, food, transport, and so on. Houses require bricks, timber, glass, and so forth. Food implies crops, animals, tractors, etc. As we unfold this logic, we eventually get to land degradation, water consumption, pollution, resource depletion, and other mainstays of the sustainable development debate. Thus the framework has clear physical links and a direction in which we do all the accounting.

But demography is more than accounting identities and projection models, which are essentially simple arithmetic constructions. It also includes understanding and explaining the values of fertility, mortality and so on. In other words, like all disciplines, it is embedded in theory, such as demographic transition theory. This aspect of the discipline describes choice and behaviour, which are left in control space along with similar parts of economics and sociology - i.e. the values are set exogenously after consultation – or instruction – from the client.

Similarly, the feedback link from the environment to fertility and mortality is in control space and is not modelled.

How does the model deal with the essentially spatial notions implicit in the concepts of sustainable development – or how does ecology get a look in?

There are two traditions in ecology that might be drawn into the framework (Bradbury et al., 1996). In the event, only one really is. In this section we will examine if this is a reasonable thing to do.

The first, and oldest, tradition is that of natural history leavened with the theory of evolution (Hutchinson, 1965) and is called population dynamics. It talks about populations of organisms and their distribution in space. It is concerned with the origins, lives and fates of individuals and populations. It is also intensely interested in how the higher structures of the natural world – communities and ecosystems – emerge from the lower structures – individuals and populations – through ecological interactions – predation, competition and symbiosis – and how these structures then become evolutionarily coercive. We might call this the biodiversity view.

The second tradition is called trophodynamics (Morowitz, 1968). It looks at the problems of ecology from the point of view of flows of materials and energy. It has always been intimately associated with systems analytic approaches to biology and provides powerful descriptions of ecosystems as systems of stocks and flows. But it has a major drawback in that it does not recognise the primary locus of evolutionary action – the species – and so finds it hard to provide an evolutionary perspective. We might call this, in contrast, the biomass view.

It does not really matter in a trophodynamics analysis that the entities have an evolutionary history, while it is the thing that matters most in a population dynamics analysis.

Population dynamics is very similar to much human demographic analysis. Indeed, some of the first mathematical formulations of population growth were used in both ecology and demography with great effect (Pearl, 1925). So we might expect the model to use population dynamics calculators in its ecological parts – agriculture, fisheries and forestry – just as it has used demography calculators in its human population parts. That this is not so is due to the biodiversity problem: while it is feasible to calculate the population dynamics for one species – *Homo sapiens* – for which we have a lot of life history data, it is not feasible to do such calculations for each of the thousands of species in any real ecosystem for which we have very little data.

The model thus resorts to a trophodynamics approach, not so much because of its implicit stocks and flows structure, but because it is aggregated in a way that allows us to make progress. It is not a pure trophodynamics approach however. We see, in the equations that govern the growth of the stocks, echoes of population dynamics equations.

The thing we do not see, and the thing that has the potential to reduce our understanding of the contribution of biology to the model, is the spatial graininess or heterogeneity of the biological processes. The aggregation of species and the focus on biomass that are direct consequence of making the model tractable (rather than being consequences of the approach) reduce perforce the heterogeneity that is both a feature of the ecosystem and an important factor in its dynamics. That factor is lost to us.

To the extent that sustainable development is about the harmonisation of the biophysical systems of the natural world with the socio-economic structures of man, then it is about processes and structures operating at various spatial and temporal scales. Spatiality is thus as important as dynamics for our understanding. If spatiality is to be reinserted as a coercive factor with the dynamics in the system, it must be done somehow in the control space.

The spatial dimension

Australia is a country of continental dimensions and its metropolitan-hinterland relationships of the traditional kind have spread over hundreds of linear kilometres in each direction within the country in the case of each mainland state capital city.

The climatic variations and biotic and soil condition contrasts on a continental scale and from the deep interior of each state to the coasts mean that there are major environmental gradations and variations.

Considering metropolitan and non-metropolitan spatial entities is not really sufficient for understanding the nature of likely human and economic impacts on this great diversity of environments. For instance, in considering the “ecological footprints” of large cities, are the impacts greater where there has been migration away from the cities to the coastal zones- particularly the belt south from Hervey Bay in Queensland to the Bass Strait coast in Victoria, coastal areas southeast of Adelaide and the south west of Western Australia?

Are the environmental impacts worse in the relatively more watered non-metropolitan coastal areas, or in inland dry zone farming areas, in semi -arid grazing areas or in deserts- the inland areas being far less populated by humans? Is the nature of the material economy fundamentally different between the metropolis, the high amenity non-metropolitan coastal areas or the inland? Does the lateral expansion of the metropolis create more environmental damage than other forms of urbanisation and consumption in the coastal zone?

To answer these and related questions, analytical modelling of the multi-regional kind should be undertaken, with at least the following components: the metropolis and its perimetropolitan zone; urbanising areas in other parts of coastal Australia, and changes in inland areas. That is, a minimum of a three region model for each state, and taking account of the eccentric locations and their possible differential impacts of some cities like Brisbane. Such modelling should include stocks and flows, and alternating growth scenarios within each type of region.

Ian Burnley

How does the model deal with innovation and change, both technological and social – or how does 'Factor 4' thinking get a look in?

As much as everyone agrees that scientific breakthroughs and technological innovation are major drivers of societal change, no one has a good theoretical basis for predicting either the long-term direction of science and technology or its impact on society. Almost the opposite is the case, with eminent scientists and technologists like Lord Kelvin and Thomas Watson making spectacularly wrong predictions about the fate of the solar system and the need for computers respectively. For deep reasons to do with the nature of complex systems, we just cannot pick winners in science and technology.

The CSIRO modellers rightly avoid such traps. However, there is a sense that short-term incremental change can be brought within the scope of the project. One way to do this is to develop scenarios that mimic the potential impact of so-called 'Factor 4' technologies (von Weizsacker et al. 1997). This is essentially a call for a new set of technologies. Because the inputs and outputs of these technologies are specified – broadly half the resources as inputs, with twice the efficiency of processing resulting in quadrupled outputs – even if we do not know what the technologies actually are, they can be incorporated into the framework as a feasible scenario, after making some further assumptions to ensure that they are scientifically 'lawful'.

Thus the framework can do useful work to decide, in the first place, if various Factor 4 strategies are feasible, and then, if so, it can work through the consequences of such technologies for the whole framework as for any other scenario, by creating and exploring dilemmas. And, as with the other scenarios, resolving the dilemmas, deciding whether or not to embrace Factor 4 or other innovation strategies, and developing public policy to introduce the innovations are all activities to be handled in control space.

There are a vast number of possible permutations and combinations of different feasible Factor 4 technologies in such a well-specified framework as the present one. The CSIRO modellers have wisely chosen to describe the potential for using the framework in this way through only a few examples. They describe the consequences for the whole framework of halving the material and energy inputs to a group of important components in construction and transport – broadly, the manufacture and maintenance of buildings and vehicles.

However, we need to keep clear in our minds that the projection of these incremental, short-term changes, even if carried out over long time scales, is not the same as predicting the impact of future scientific and technological innovation on society. These future innovations will undoubtedly create dilemmas for society that, in their novelty, are unaccounted for in anyone's scenarios.

A technology analyst's perspective

Management of flows, through appropriate policy formulation, will clearly remain a critical area for government attention and action. In fact the positive environmental effects of reducing the energy and materials intensity of the economy, demonstrated by the two sub-scenarios in the study (buildings and transport) will probably drive government towards a policy stance of 'architect' rather than 'observer'.

However, even if this is not driven by local community concern and public values, it seems bound to be an outcome of economic survival in a global market. Many of Australia's trading partners in the OECD are taking a much more interventionist approach to industry and environmental policy, seeking to stimulate infrastructural change and technical innovation, to de-link economic growth from resource consumption. In these countries, combinations of resource taxes, procurement programs, targeted public R&D funds, information systems, standards and regulations, are being used to stimulate a progressive dematerialisation of production and consumption.

New systems of pollution and waste prevention, eco-products and services, and intelligent transport logistics and distribution systems, are the intended outcomes of such a policy framework, which assumes that it is possible to achieve 'win-win' economic and environmental outcomes through innovation. Resource efficient goods and services are seen as critical to reducing 'over-consumption' in developed countries (the Rio and Johannesburg agreements) and for development in countries which are resource and infrastructure poor.

Government attention to effectively managing resource flows (in the EU for example), has seen the growth of research organisations able to model the resource economy and support policy formulation by life-cycle thinking. The result of this shift in thinking is evident in the submissions from international business organisations to the World Summit for Sustainable Development in August 2002. In the face of such hand-on (industry and government) management approaches, a hands off 'leave it to the market' stance would simply run the risk that the Australian economy, infrastructure and technical development, would settle into a backwater, increasingly isolated from the new dynamics of the global economy.

Chris Ryan

CONCLUSION

What emerges from the study?

A key argument for modelling the whole system rather than its parts is that it is supposed to reveal something more than what is revealed by a set of models of the parts – the whole is believed to be more than the sum of the parts. Thus ‘whole system’ modellers look for ‘emergence’ – the generation of processes and structures that would not be seen at the level of partial models (Holland, 1998).

But what is the whole we wish to consider? Any reading of the CSIRO study confirms that the model itself is always seen in a larger context. There is a strong sense that the stakeholder workshops are an integral part of the process. There is also a sense that the model’s users are also part of a whole system. This last point is made quite forcefully in the overall modelling strategy – the model (in the narrow sense) produces dilemmas or tensions that cannot be resolved within it. Instead, we seek resolution in a more embracing context where the users of the model – such as policy makers – can offer potential solutions whose efficacy can then be examined within the model. Thus, users and model are in a feedback loop, and together form a larger system out of which we might expect ‘emergent behaviours’.

In a sense, users and model now become partners in a broader endeavour, and their previous roles as, respectively, subject and object become blurred. The boundaries between them are open, as are the boundaries between the disciplines within the model itself (Sherman and Schultz 1998). This openness is one of the particular strengths of the approach.

Thus, it is with this larger idea of emergence that we make our observations.

Perhaps the most striking, and first, thing to emerge from the study is the sheer diversity and intricacy of the interactions that make up the whole system. When viewed as a whole, and informed by the tremendously detailed workshop reports, we are see a new picture of Australia, one in which there is both ‘devil in the detail’ and some long-term strong processes driving the system. We see primary, secondary, tertiary and quaternary drivers – some direct, some indirect, some immediate, some greatly lagged – influencing the system of the human population and its environment.

This complexity just cannot be seen with single-issue models, and so this feature alone is a strong justification for the approach, even in the absence of more detailed analysis. It can be used as a reality check for disciplinary models, helping them acknowledge the richer world in which they exist.

However the richness of the system has greater uses than this. It is the primary source of a new understanding of the system being revealed by the study.

The study shows that we need to understand and manage both the stocks and the flows in the system, but that, by and large, we traditionally tend to focus on the flows. Stocks, as extremely slow moving variables in the system, may seem to be us, with our short time horizons, to be constants in the system, in contrast to the fast moving flows. But stocks have tremendous potential to modulate system behaviour over the longer haul, and indeed, drive the system in unexpected and sometimes undesirable directions. We see this in the present study in the way technology can ‘saturate’, resulting in environmental variables coming to drive some outcomes, and in the knock-on effects of resource stocks becoming constrained.

This attention to stocks as well as flows provides both a rationale for an expanded role for public policy and a setting within which the resulting tensions or dilemmas may be handled.

The distinction, in the study, between stocks and flows mirrors a distinction in our society between the concerns of public policy and the market. There is a sense in which the management of flows – fast moving variables in the system – is one of the key concerns of the market economy. There is also a recognition by government that it should get out of the business of the management of flows and ‘leave it to the market’. This is reinforced if one observes that, in recent years, government has not only deregulated many of the markets it once managed (electricity, water, dairy and so on), it has also attempted to create new (deregulated) markets for previously unregulated and unexploited flows (carbon credits, salinity credits and so on).

The CSIRO report implicitly suggests and justifies a new role for public policy, even as public policy passes the management of flows to the market. This new role is the management of stocks, and this discovery is the second key thing to emerge from the study. The study shows emphatically that the stocks have time scales of decades or centuries, far beyond the concerns of the market, but it also shows that the management of stocks is as important, and probably more important than managing flows in resolving the dilemmas generated by the model.

The existence of the dilemmas is the last important feature to emerge from the study. The report identifies six dilemmas that cannot be resolved within the model. They each require policy intervention. Each of the dilemmas is important, involving major components of the system, and having strong effects on the behaviour of the whole system. The report shows that, while it may be possible to solve any single dilemma with concerted national action over a generation or two, in reality solutions will need to be sought for more than one dilemma at a time. Because dilemmas interact, the complexity of the problem will grow as more dilemmas are considered. The report offers no solution to this problem, instead only identifying it, and noting the importance of a whole-system approach to deeper understanding. It also notes that public debate is required to further bound the range of each dilemma.

Are the report’s conclusions robust?

We need to consider two different aspects of robustness in examining this issue. The first has to do with the structure of the model itself – its grounding in physical reality, and its superstructure of progressively ‘softer’ sciences – with attendant questions about the robustness of the different components and their dependence on different disciplines with different conceptions of robustness. The second has to do with the use of the model to generate scenarios – with attendant questions about the robustness of the scenarios.

We may conceive of the model more or less as a hierarchy of calculators, each itself a model of some particular bit of the system. But we should not confuse this hierarchy with the implied scientific hierarchy above of natural sciences through to social sciences. In the individual calculators, soft and hard sciences are mixed up. Depending on the purpose of a calculator, it may derive its data and relationships from several disciplines.

Despite this mix of hard and soft science, three features of the modelling protocol ensure a high level of scientific rigour. In the first place, the whole model is highly empiric. It is based on actual data and known relationships over a long ‘training set’, which in the present case is the last 50 years. The model is grounded in this ‘training set’ by ‘hindcasting’: key individual calculators are progressively tuned and refined until they are able to ‘predict’ the known history accurately. Secondly, the model seeks to represent ‘only’ physical reality, for which the modellers use the term ‘the physical economy’. This means that they only accept into the model those variables and processes that can be represented scientifically – they must be able to be measured in standard SI units – and hence are part of the real or material world. This is not to say that non-material variables, such as money, are not important to the way the world works. It argues instead that, because such non-material variables, if they are important, would have effects in the physical economy, their effects can be represented appropriately in the model. The last feature of the modelling protocol contributing to rigour is its 'lawfulness': the relationships between the variables follow known scientific laws. Thus, for example, matter and energy are conserved as required by physical law, and calculators may only interact in lawful and not arbitrary ways.

The effect of this rigour permeates the whole model and allows us to say that, if we accept that the calculators have captured the physical reality of their part of the world, then we should accept that the results the calculators produce will represent the path that their part of the world will take. The degree to which this is not true will be due solely to the degree to which we have not captured the physical reality and not to any other extraneous factor, such as the adequacy of any underlying theory. Empirical, physical modelling thus comes with an important intrinsic source of rigour: the 'truth' of the model comes from only one source – the data – and it is a source that may be progressively and rationally refined.

We may conclude that, as a modelling protocol, the CSIRO study is highly robust.

The matter of the use of that protocol for the development of scenarios demands its own analysis, even though the present study tends to confound them by assuming that the protocol is usually used for scenaric work.

We have discussed above the important differences between predictions and scenarios. And it is in the light of these differences that these comments on the robustness of the scenarios need to be understood. The two key points that bear on such robustness are the existence of dilemmas and their nature.

The first point is easy: dilemmas or tensions manifestly exist in the real world. It is our common human experience that issues continually arise within a frame of reference that can only be resolved by resort to a larger, more embracing frame of reference. This is a fundamental feature of all complex systems from social systems to mathematics (Gödel, 1931). It gives us some comfort that the study generates dilemmas. Indeed, it would be alarming if it did not. In this sense, the study is robust.

The nature of the dilemmas is trickier. The actual dilemmas arise in the model as a consequence of the working through of the scenarios, and we have argued that the scenarios should not be held to be true, in the sense that we expect explanations or predictions to be true. We ask no more of the scenarios than that they should be plausible and interesting: plausible in the sense of being a story that is continuous with the real 'story so far'; and interesting in the sense that, of all possible scenarios, the ones we choose have resonance with our concerns. We assume that, given the modelling protocol, scenarios will always be feasible, that is scientifically lawful. So it is not immediately clear how we should judge the robustness of some particular dilemma arising from some scenario.

Perhaps the best we can say is that the scenarios inherit their robustness from the modelling protocol, and the dilemmas inherit theirs from the scenarios. This line of argument leads us to suggest that while a particular dilemma may not be 'real', because it is robust and its antecedent scenario is both plausible and robust, then the dilemma surely resides in the neighbourhood of a real dilemma. We would be wise to take it seriously.

What are the report's implications?

Most research studies conclude with the mantra 'more research is needed'. This is also the case here. But this report offers us more than such an introverted implication. It offers a nested set of implications, deriving from the whole project, the model itself, the scenarios and the dilemmas.

Consideration of the whole project leads to the implication that it is feasible to analyse complex policy problems holistically rather than in a reductionist way. That is, we are not confined to thinking of such complex problems in a compartmentalised way. We are not forced, by a lack of tools or imagination, to analyse, say the demography, the ecology and the economics separately, and later merge them at the policy table in some *ad hoc* integrative way. We may, of course, choose to analyse our complex problems in discrete partitions, but the strong point made by the project is that we are no longer forced to. We have a choice.

An important corollary of this is that the object that goes to the policy table is, in a sense, balanced. The different disciplines make their contributions more or less equally in the policy-neutral and discipline-neutral language of physical reality, and none is 'subservient' to the other.

The model itself reveals that both stocks and flows contribute to the system's behaviour. The strong implication is that we are much better at managing the flows than stocks, in part because of the great difference in their time scales (days and weeks *vs* decades and centuries), in part because we usually think of stocks as a system constant rather than variable, and in part because we have tools to manage flows – the market – but none to manage stocks. We tend to do what we can do.

This implication has an important corollary too: as public policy relinquishes its interest in the direct management of flows (through deregulation and freeing of markets), it should envisage an emerging role in the management of stocks. Government needs to enhance its capacity to have long views of the system.

The scenarios, as argued above, are plausible stories about possible futures. They were chosen because they each represent the particular concerns of different protagonists in the public policy debate on Australia's future population. The model demonstrates that no scenario is an unalloyed good – a clear and unrestricted path to the future. Instead it shows that each creates tensions that need resolution at the policy table. A moment's reflection suggests that this is good common sense – we would be alarmed and suspicious, knowing what we do about the way the world works, if there appeared to be some 'Yellow Brick Road' to the future.

The strong implication of the scenarios is that the future involves dilemmas, no matter which path we take. But the corollary of the implication that there are choices among dilemmas is that we actually have a choice. The future is not determined.

When we consider the dilemmas or tensions, we immediately observe that the system has emergent properties, as discussed above. This observation is not available to disciplinary analysis. This adds to our implication above – the feasibility of holistic analysis – the further implication of its necessity if we wish to understand the whole system. This necessity is compounded when we consider, as discussed in the report, the need to resolve dilemmas in parallel.

The dilemmas create a final implication. While they cannot be more 'real' than the scenarios from which they unfold, they strongly imply the existence of real dilemmas in their neighbourhood, because of the way in which they inherit their 'reality' from the model itself. They merit further research.

REFERENCES

Bradbury RH (1997). On (holistic) modelling, Pages 21 - 27 *in* RK Munro, and LM Leslie (eds.) *Climate Prediction for Agricultural and Resource Management*. Bureau of Resource Sciences, Canberra.

Bradbury RH (1999). Just what is science anyway? Nature and Resources 35,9- 11.

Bradbury RH van der Laan JD and Green DG (1996). The idea of complexity in ecology. Senckenbergiana Maritima 27,89-96.

Gault FD Hamilton KE, Hoffman RB and McInnis BC (1987). The design approach to socio-economic modelling. Futures February, 3-25.

Gödel K (1931). Über Formal Unentscheidbare Sätze der Principia Mathematica und Verwandter Systeme, 1. Monatshefte für Mathematik und Physik 38,173-198.

Hogeweg P and Hesper B (1985). Interesting events and distributed systems. SCS Multiconference on Distributed Simulation.

Holland JH (1998). *Emergence: From Chaos to Order.* Oxford, Oxford University Press.

Hutchinson GE (1965). *The Ecological Theatre and the Evolutionary Play*. New Haven, Yale University Press.

Leontief W (1966). *Input-output Economics*. New York, University Press.

Lutz W (1996). *The Future Population of the World: What Can We Assume Today*? London, Earthscan.

Meadows DH Meadows DL Randers J. and Behrens WW (1972). *The Limits to Growth*. New York, Universe Books.

Morowitz HJ (1968). *Energy Flow in Biology*. New York, Academic Press.

Pearl R (1925). *The Biology of Population Growth*. New York, Knopf.

Pielou EC (1981). The usefulness of ecological models: A stocktaking. Quarterly Review of Biology 56,17-31.

Reder MW (1999). *Economics: The Culture of a Controversial Science*. Chicago, University of Chicago Press.

Sherman H and Schultz R (1998). *Open boundaries: Creating Business Innovation through Complexity.* New York, Perseus Books.

von Weizacker E Lovins AB and Lovins LH (1997). *Factor 4: Doubling Wealth - Halving Resource Use.* Sydney, Allen and Unwin.

West BJ (1985). *An essay on the Importance of Being Nonlinear*. Berlin, Springer-Verlag.

Wolfram S (1984). Cellular automata as models of complexity. Nature 311:419-424.

Appendix 1
Brief description of the base case scenario

ABSTRACT

In this section 20 issues are used to describe a range of settings in the base case scenario. They are (1) Population (2) Tourism (3) Building Space (4) Building Operations (5) Freight Transport (6) Passenger Transport (7) Cars (8) Roads (9) Manufacturing (10) Consumption and Recycling (11) Materials and Energy (12) Crops and Animals (13) Forestry (14) Fishing (15) Mining (16) Water (17) Land (18) Air Resources (19) Trade (20) Labour

1. Population

Description

The Australian population in the ASFF model is determined by immigration and emigration, and birth and death rates. These factors are broken down by gender and age, among other things. Details of the geographic distribution of population are also included, so internal travel and migration is factored in, allowing rural-city and state populations to be simulated.

Some aspects of the physical economy such as requirements on buildings are determined directly from the population (others are more indirect and are accounted for in other sectors of the model). In particular, the participation rates in primary, secondary and tertiary eduction and birth rates (e.g., mini baby booms) drive the demand for associated infrastructure. Similarly, the need for health care buildings is driven by illness rates. Aging population plays a role in household size.

Consumption of food and other items such as paper, textiles, plastics and chemicals is calculated directly by linkage to population number and location.

Rationale for the base case settings

The level of net immigration has been chosen as 70,000 persons annually. Not only is this figure consistent with historically averaged records (noting there have been substantial variations in the net rate), but also it results in moderate growth of the Australian population over the complete simulation period. Other factors such as fertility and life expectancy have been made consistent with historical trends and set the background against which immigration is the major cause of population increase.

Major Outcomes

There is strong growth in the Australian population for several decades, peaking in about 2070 and subsequently reducing marginally. The population ages over time.

		1996	2050
total population	(millions)	18.4	25.1
Sydney	(millions)	3.9	5.3
Melbourne	(millions)	3.3	4.4
Brisbane	(millions)	1.5	2.6
labour force	(millions)	9.2	11.4
number of households	(millions)	6.7	10.8
proportion of population over 65 years old		12%	25%

.

Base Case Settings

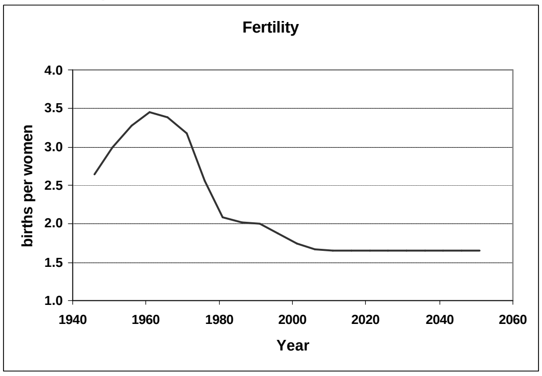


Fig. 1.1 Total period fertility

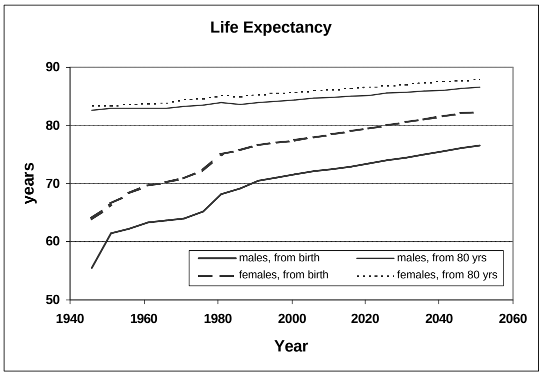


Fig. 1.2 Life expectancy: from birth and from 80 years

.

factor	assumptions			
• population dynamics				
net immigration rate	constant:	70,000 p.a.		
fertility	number of children per woman reduces (and then remains constant)	from 1.74	in 2001	
		to 1.65	in 2011 and beyond	
life expectancy	increases by 1 year per decade of simulation time to 2050 and then constant			
	males:	77 years	in 2061	
	females:	83 years	in 2061	
• characteristics				
internal migration	propensity constant over time: turnover of ACT and NT stays high			
	destinations constant over time: NSW, Qld then Vic are dominant destinations			
urban-rural split				
labour participation	average drops over time (according to ABS Projections to 2016):	64%	in 1996	
		52%	in 2061 & beyond	
	male participation	average + 5%		
	female participation	average - 5%		
food consumption	total (by mass) increases	3.5%		
other consumables	total (by mass) increases	3.5%	by 2066	

Caveats and uncertainties

- Advances in health technology and health care could see life expectancies increase dramatically e.g., living 30 years longer by 2050. The consequences of this across all sectors of the physical economy would be dramatic.
- Internal migration trends are very uncertain—states like Victoria that have previously lost people to Queensland but may start to grow again. When combined with the growth of urban development beyond the traditional city boundaries into coastal areas there will be significant impact on ecosystems.
- A description of marital status may be useful—in particular, divorce are a key driver of household formation rates as well as age and sex.

References

1. ABS "Population Growth and Components of Growth" in Population theme of Australian Statistical Profile: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/fe3cc96b0647ba20ca2568a900154971!OpenDocument

2. Tourism and Travel

Description

Tourism and travel creates requirements for food (in terms of what is consumed and the restaurant space needed), accommodation, transport (cars including car hire, air, bus and rail) and other services. These demands come from both domestic and international travellers, whose differing characteristics are captured through rates of travel and usage, and are combined with the number of travellers to determine overall requirement. Country of origin and purpose of visit can also be considered.

The requirements add to those of the domestic population—in the base case scenario trends in restaurant and accommodation requirements differ substantially due to differences in use by travellers and the domestic population. These higher level demands feed into subsequent sectors of the physical economy to determine, for example, fuel and infrastructure use.

Travel also has a substantial impact on the balance of (trade) payments. Simple estimates of spending in today's nominal dollars are made for both inbound international travellers and Australian travellers going overseas.

Rationale for the base case settings

An optimistic growth in the number of inbound tourists is assumed to be sustainable for the time period of the base case scenario. This is based on industry expectations of full economic recovery and growth in Asian nations, resulting in more tourists from the Asian region (top five in 2056: Indonesia, New Zealand, China, Malaysia and Korea; compared with in 1991: Japan, New Zealand, UK/Ireland, USA). Complementing this growth, other settings reflect greater disposable income at the expense of leisure time.

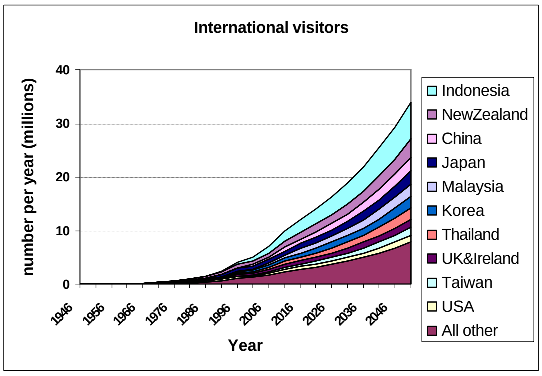
Major Outcomes

The demands on the tourism industry grow rapidly (e.g., driving building construction for accommodation) as the requirements of international tourists over-takes that of domestic travellers. Tourist spending increases, and the tourism component of the trade balance reverses in Australia's favour.

		1996	2050
total number of inbound tourists	(millions)	4.2	34
total number of inbound tourist days	(millions)	84	552
total number of tourist nights	(millions)	179	600
proportion of tourist nights for domestic travellers		84%	69%

.

Base Case Settings



International visitor numbers, by country of origin

factor	assumptions		
• international visitors			
visitors per year	growth rates produce a 10-fold increase in numbers by 2066:		
	growth rate per year (compounding):	7%	to 2009
		decrease to 3%	by 2016
		3%	after 2016
length of stay	varies considerably by country of origin, purpose of visit, and age of visitor		
	average	27 days	in 1991
		16 days	by 2021 and after
spending rate	constant over time, but varies markedly by country, travel purpose and traveller age		
	minimum: aged Phillipinos on holiday	$1.30 / day	
	maximum: aged Japanese travellers	$1140 / day	
	average	$62 / day	
food consumption	as for domestic population		
transport modes	more air travel at the expense of bus and rail		
	air	47–59%	1996–2050
	bus	48–39%	
	rail	5–2%	
• domestic travel			
transport modes	inter-city: mostly by car (decreasing over time), remainder as for international travellers		
	proportion of travel by car	61–52%	1996–2050
• Australian overseas travel			
rate of overseas trips	increases but levels off a decade or so after 2050		
	trips per person per year	0.15–0.29	1996–2050
spending rate		$100	per day per person
length of stay		40–34	1996–2050

.

Caveats and uncertainties

- Trade balance payments are naturally limited by uncertainties over exchange rates. Additionally, the treatment of airfare payments for inbound and outbound travellers needs to be consistent.
- Information on the distance travelled by international visitors per day is not directly available and has been imprecisely derived from other data.
- Currently there is no connection between tourism and land resources to account for national park as attractions.
- Students are not disaggregated despite expectations that these (will) form a substantial proportion of inbound travellers, and have different behaviour to other tourists.

REFERENCES

- ABS: collection of pages on Tourism, under Australian Statistical Profile: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2!OpenView&Start=1&Count=1500&Expand=26#26
- Bureau of Tourism Research Monitor of Tourist Activity: CD-MOTA.
- Foran, Cumpston and Bartram (2000)…
- Benghezal, Foran and Baker (2000)…

3. Building Space

Description

The number, size and type of buildings are driven directly by demographics as well as requirements for international visitors. Both dwellings for the domestic population and non-dwellings are considered: hotel/motels; restaurants; retail/wholesale space; education; health care; office; and institutional buildings. Dwellings are largely either single detached units or units that incorporate higher density multiple households. Buildings associated with manufacturing and processing such as factories are treated elsewhere since the number of people does not directly determine the number of these buildings.

Construction of buildings requires significant amounts of material and energy. Therefore the age and lifetime of the buildings is an important characteristic in these calculations. The demolition of old buildings is tracked for subsequent accounting of demands on recycling and energy.

Maintenance, operation and content of buildings are specified on a square metre of floor space basis and vary by building type. These are dealt with separately in the following section.

Rationale for the base case settings

The size of dwellings continues to increase over time, reflecting the increasing affluence of the population as the economy grows. At the same time multiple dwellings become more popular due to constraints on the expansion of city limits and greater acceptance of high density housing in cities. No substantially new construction techniques or materials are introduced, rather there are continual improvements to current practices.

Major Outcomes

Dwellings are by far the most dominant form of building space, making up approximately 84% of the total floor space, (constant over time). Most of this is as single dwellings: 83% in 1996, dropping to 77% by 2050 as more people use multiple dwellings in high density city development.

		1996	2050
total building floor space	(billion m^2)	1.0	2.0
total dwelling floor space	(billion m^2)	0.8	1.7

.

Base Case Settings

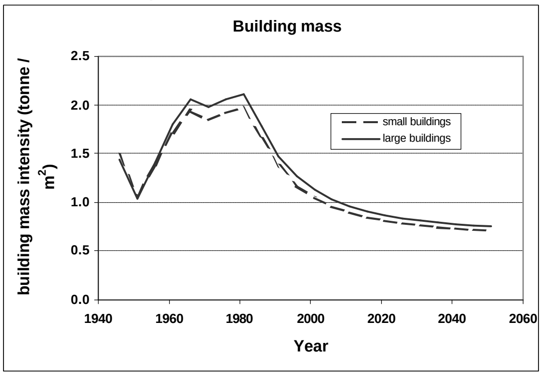


Fig. 3.1 Building mass per unit floor space

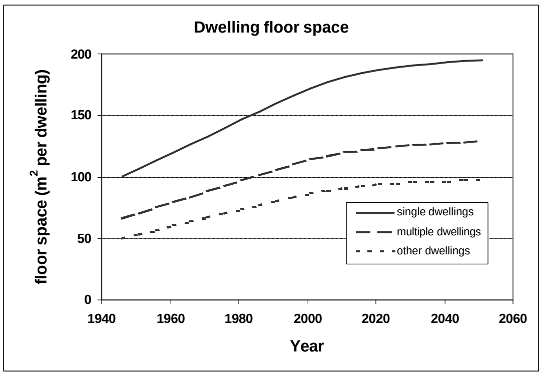


Fig. 3.2 Floor space for urban dwellings

factor	assumptions		
• dwellings			
single vs multiple	more single dwellings than multiple, but the balance becomes more even		
	ratio of single : multiple dwellings in 2050	78:22	for Melbourne
	(other cities between these extremes)	51:49	for Canberra, Darwin
floor space	historical increase of approx. 10-15 m^2 per decade levels off several decades after 2050:		
	single dwelling	197 m^2	(75% lower in rural areas)
	multiple dwelling (area for household unit)	130 m^2	
composition	concrete	79%	constant over time
	bricks (clay)	13%	
	wood and gypsum	7%	
mass	decreases marginally	0.7	tonne / m^2
demolition	for each future year the age related demolition rate increases:		
	no demolition for buildings up to 20 years	0%	
	at 100 year age	2%	per year in 1991
		20%	per year in 2101
• other buildings			
floor space	varies by type of building	from 0.33 m^2/person	to 15 m^2/person
composition (large buildings)	concrete	86%	constant over time
	bricks	8%	
	iron/steel, gypsum & wood	5%	
mass	decreases marginally	0.7	tonne / m^2
demolition	age related demolition rates stay constant in future years		
	no demolition for buildings up to 20 years	0%	
	for ages 65 to 105 years (or 200 for institutions)	20%	per year

.

Caveats and uncertainties

- Since historical demolition rates were not available directly they have been calculated from the historical stock and new construction data. To account for old buildings at the start of the simulation it was necessary to project demolition rates back to 1896.
- The proportion of concrete compared with clay (bricks) used in the construction of dwellings appears to be rather high—wall construction should mostly be bricks and the mass should roughly match that of the foundation, assuming similar density.

References

- ABS “Types of dwellings” in Housing theme of Australian Statistical Profile: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/a82ebf34b536d7dbca2568a900154a61!OpenDocument
- ABS: Australian Social Trends (4102.0).
- http://www.ahuri.csiro.au/index.htm

.

4. Building Operations

Description

The on-going use of dwellings and non-dwelling buildings involves the use of energy (mainly heating, cooling and electrical equipment), water and materials (for maintenance and daily operations). The contents of buildings such as furniture, fittings and equipment must also be replaced over time as they age.

Rationale for the base case settings

Minor improvements in energy efficiency are expected due to refinements in building design and construction and adoption of better heating and cooling systems. Energy use overall will increase, accompanied by a move away from oil to gas and continued use of electricity, due to resource pressures on oil and the convenience of electricity supply. The most substantial quantitative changes may be seen in the quantity of operating materials and contents, particularly with the introduction of more plastic based products.

Major Outcomes

Energy use doubles in the period 1996 to 2050. This is largely driven by dwellings (despite having the lowest energy use per unit floor space) and retail buildings, and mostly supplied as electricity and gas (58% & 40% respectively—the high proportion by gas reflects the dominating influence of dwellings). Similarly, water use is driven by dwelling requirements: 67% of the total in 1996 increasing to 75% in 2050.

		1996	2050
total energy use	peta Joule / yr	443	930
total water use	1000 GL / yr	0.7	1.8

.

Base Case Settings

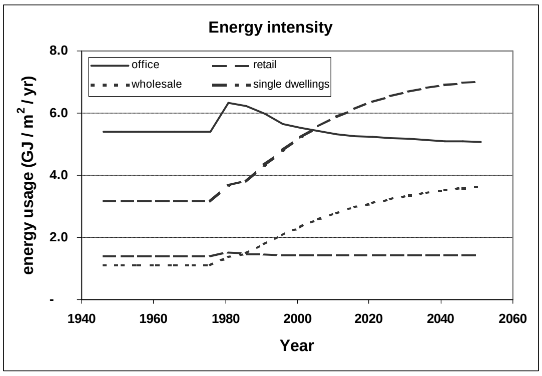


Fig. 4.1 Energy usage for important building types

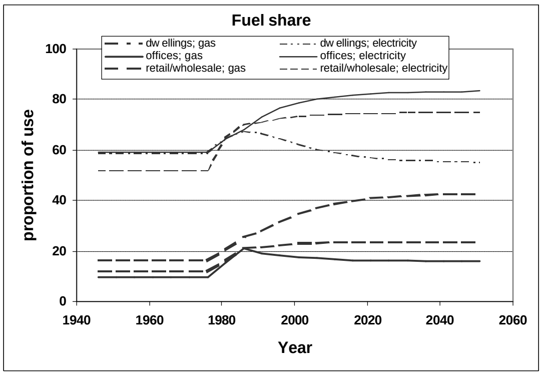


Fig. 4.2 Fuel share for electricity and gas

.
.
.
.
.
.
.
.
.
.
.

factor	assumptions			
• inputs				
operating goods	quantity and variation independent of building type			
	amount decreases and levels off:		–33 %	from 1996 to 2050
	for 100 m^2 building space		11 kg / yr	in 2050
maintenance	amount decreases and levels off:			
	–39 %		from 1996	to 2050
	concrete for 100 m^2 building space		0.67 tonne / yr	in 2050
water use	constant over time, but varies by location and building type:			
	maximum use occurs in dwellings in Darwin:		1.05 ML / yr	for 100 m^2 building space
	minimum use occurs in Victorian rural dwellings:		12 kL / yr	
energy use	independent of location, but varies over time and by building type		1996 to 2050 change	in 2050 GJ /100 m^2/ yr
	retail	increases and levels off	+47%	141
	wholesale		+74%	72
	other non-dwelling	decreases and levels off	–10%	71–101
	dwellings	constant over time	0%	29
fuel share	mostly electricity, then gas, then oil		electricity	gas
	retail/wholesale	increasing electricity	+3.5%	
		by 2050:	75%	24%
	other non-dwelling	increasing electricity	+8.8%	
		by 2050:	83%	16%
	dwellings	decreasing electricity	–14%	
		by 2050:	55%	43%
energy efficiency	electricity	constant over time:	100%	
	gas & oil	increase and level off:	from ~68%	to ~75%
contents	total weight decreases and levels off, approx:		–33%	from 1996 to 2050
	total weight approx (independent of building type)		12 tonne / 100 m^2	in 2050

Caveats and uncertainties

- Disaggregation of some building types (particularly low and high density housing) may allow better representation of water, energy and material use.
- The use of wood for heating in dwellings may be under-estimated due to self-gathering of wood which is not recorded.
- Domestic energy use may increase if more people work from home, and increasing affluence translates into more space heating and cooling. The combination of affluence and work pressures may result in increasing adoption of labour saving devices, which use more energy.

References

- ABS "Energy End Use in Australia"; Energy theme in Australian Statistical Profile: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/e861484b4031ee3dca2568a900154a0d!OpenDocument
- 'Unravelling the "Australian housing solution": the post-war years'; M. Berry, Housing Theory and Society, vol 16 (3), pp. 105–123, 1999.

- Australian Greenhouse Office; domestic housings; Australian Greenhouse Office; commercial buildings.

5. Freight Transport including Urban Delivery

.

Description

The movement of materials, goods and commodities is an important function of Australia's physical economy due to the geographically dispersed nature of this material intensive economy. As a result, freight transport is a significant contributor to Australian energy use and emissions to the atmosphere. Movement of goods and commodities within city areas (urban delivery) is considered separately from all other freight haulage, and the demand is related to the non-dwelling building space occupied.

For all freight, the size of the various fleets are linked directly to the demand for haulage, taking account of efficiencies in loading, distances travelled and the different modes available (trucks, rail and shipping—air freight is not considered since the volume is negligible in comparison to other modes). Demands for other materials and energy are created through the maintenance, operation and aging of the various fleets.

Rationale for the base case settings

Despite a focus on moving to high value-added industries and more sophisticated technologies, there has been considerable increase in materials flows and activity of the primary production sector. Consequently the haulage task has increased substantially. For example, average total growth rates of roughly 5% p.a. have led to a four-fold increase in the haulage of articulated trucks in the last two decades preceding the simulation.

Major Outcomes

Total emissions of CO_2 increase three fold between 1996 and 2050, mostly due to light trucks in urban delivery (56%) and articulated trucks in long haul freight (38%). Total fuel consumption increases by a factor of 2.7, with light trucks dominating (60% in 2050).

	1996	2050
Total CO_2 emissions (million tonne/yr)	23	68
Total energy consumption (peta Joules / yr)	320	870

.

Base Case Settings

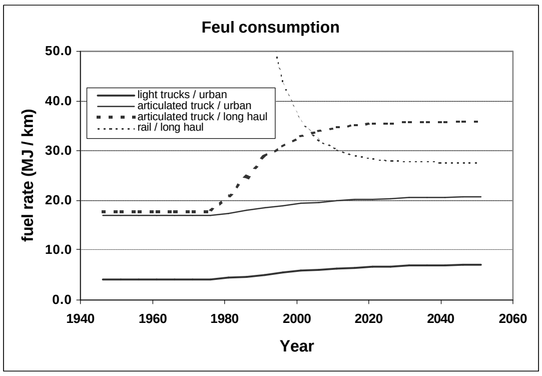


Fig. 5.1 Fuel consumption for selected freight vehicles

.
.
.

factor	assumptions		
• freight outside urban areas			
haulage task (bulk + non-bulk total)	roughly linear growth (mostly in bulk transport) to 2050	increase relative to 1996:	tonne x km / yr haulage in 2050 (in billions)
	road—rigid truck (no bulk freight)	1.2	13
	road—articulated truck	1.9	108
	shipping	2.3	234
	rail	2.7	282
load factors (efficiency)	road—rigid truck	60%	
	road—articulated truck	70%	
	shipping	70%	
	rail	50%	
energy intensity	road	constant	
	shipping	constant	
	rail	–36%	by 2050 rel to 1996
• urban delivery			
vehicles needed	mostly light trucks (rigid trucks make up less than 10% of the total)		
	numbers increase (by 38% relative to 1996) and level off		
		vehicles per 100 sq m	
	retail/wholesale	2.9	in 2050
	5 x less for offices		
	10 x less for institutions & "acute chronic" facilities		
fuel consumption	light trucks, similar to cars		
	increases and levels off 28% higher relative to 1996	7.0 MJ/km	in 2050

.

Caveats and uncertainties

- Since the (non-urban) freight task is specified in the control settings and not generated within the framework, the extent of the task must be reconciled with the output of the sectors whose products require haulage.
- Some differentiation of shipping freight into that undertaken by Australian owned ships and those under foreign flags may have an effect on balance of payments and operational inputs.

References

- ABS: "Use of Motor Vehicles"; in Transport theme of the Australian Statistical Profile http://www.abs.gov.au/ausstats/abs%40.nsf/94713ad445ff1425ca25682000192af2/6499c5d70e00e881ca2568a900154b1e!OpenDocument
- "RoadsFacts '96: An Overview of Australia's Road System and Its Use"; AustRoads, Sydney, 1997. (Available through the Department of Transport and Regional Services web site: http://www.dot.gov.au/land/road/roadfacts.htm)

6. Non-urban Passenger and Urban Public Transport

Description

The movement of people within Australia incorporates urban public transport (for commuting to work and other travel activities) and travel beyond and between cities. In total, several modes of transport are used, namely car, air, bus and rail. For urban public transport, rail incorporates tram and light train networks (and transport by air is irrelevant). Details on the contribution of cars for all types of passenger travel are picked up in the next section.

Both the domestic population and number of inbound international travellers determine the number of aircraft, buses, trains and trams needed (for urban public transport the numbers are allocated to capital cities). These stocks are replaced as they age, consequently driving further material and energy use. Operating these fleets uses fuels and other materials, as well as producing emissions to the atmosphere.

Rationale for the base case settings

While some improvement in the fuel efficiency and emission characteristics of aircraft and buses is anticipated, there are no dramatic events (such as oil shocks) or introduction of new technologies that result in substantially improved fuel use and reduced environmental loadings. The low exploitation of public transport (particularly for commuting) relative to Australian's dependence on personal cars reflects a level of investment in mass public transport systems that has fallen behind population growth, the structure of Australian cities, and the resistance of the public to mass transport.

Major Outcomes

Fuel consumption and emissions to the atmosphere increase substantially, largely driven by the increasing number of foreign visitors and their considerable use of air and bus transport. (Urban public transport is about 10% of the total.) Fuel use in passenger transport is about 2–3 times less than in freight transport, and grows at a slightly lower rate.

	1996	2050
Total CO_2 emissions (million tonne/yr)		~15
Total energy consumption (peta Joules / yr)	143	296

.

Base Case Settings

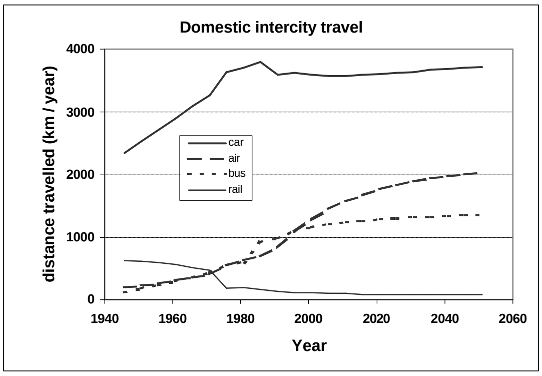


Fig. 6.1 Intercity travel by different modes

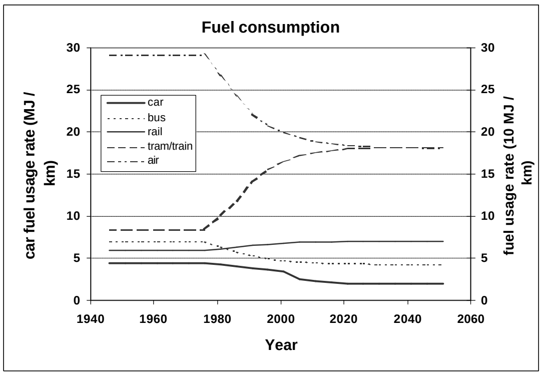


Fig. 6.2 Petroleum consumption by different vehicles

factor	assumptions					
• between and outside cities						
passenger km						
domestic travellers	increases (~ 25% rel. 1996) and levels off several decades after 2050		5900 km / year / person			in 1996
			7200 km / year / person			in 2050
international visitors	increases (~ 69% rel. 1996) and levels off shortly after 2050		55 km / day / person			in 1996
			93 km / day / person			in 2050
share of transport type		cars	air	bus	rail	
domestic travellers	dominated by cars	61%	18%	19%	2%	in 1996
	but with a move toward air	52%	28%	19%	1%	in 2050
international visitors	mainly air and bus	5%	45%	46%	4%	in 1996
	increasing air	3%	58%	38%	2%	in 2050
fuel consumption	reducing consumption on air and bus transport, levelling off		air	bus	rail	
	in 2050		181	43	70	MJ / km
	changes relative to 1996		–14%	–14%	+4%	
• urban public transport						
labour force commuting	small increase in proportion		79%			in 1996
			88%			in 2050 & beyond
commuters driving cars	small increase in proportion		84%			in 1996
			87%			in 2050 & beyond
commuting distance	increases and levels off several decades after 2050 for all cities		+7%	15 km		for Darwin in 2050
			+35%	35 km		for Brisbane
			+25%	47 km		for Sydney
			bus	train/tram		
choice of mass transport	bus travel predominates over trains/trams, with marginal increase to buses over time		92%	8%		in 2050 (Melbourne – lowest use of buses)
fuel consumption	energy use decreases for buses but increases for trains/trams (which use 10x more energy)		4.6 –17%	443 +37%		MJ / km; in 2050 (rel to 1996)
emissions	decrease marginally for buses but increase for trains/trams		0.12 –6%	13. +34%		tonne CO_2 / 1000km; in 2050 (rel. '96)
passenger load	approx. equal for buses and trains/trams		~15			

.

Caveats and uncertainties

- Congestion limits on roads as city population grows may apply a downward pressure on the proportion of commuters using cars, or limit the travel time/distance.
- Working from home could reduce the proportion of the labour force commuting by 5–15%.
- Increasing urban density may play a role in transport characteristics along with urban population.
- Increasing affluence and business activity may increase holiday travel and business trips.

References

- ABS: "Use of Motor Vehicles"; in Transport theme of the Australian Statistical Profile http://www.abs.gov.au/ausstats/abs%40.nsf/94713ad445ff1425ca25682000192af2/6499c5d70e00e881ca2568a900154b1e!OpenDocument

7. Cars

Description

Across all transport elements in Australia cars are the major source of personal mobility as well as energy consumption and emissions to the atmosphere. The majority of kilometres travelled, whether in cities or between them, are made in cars. The total stock of cars comprises those owned by individuals for personal use and commuting (which are associated with households) and fleets such as taxis, car hire, commercial and company cars. Some of the cars in these fleets are used for personal transport, some by international travellers and the rest by service workers.

The replacement of ageing cars is an important factor within Australia's physical economy since the stock of cars vastly out-numbers the vehicles of other transport modes.

Rationale for the base case settings

Improvements in current engine technology are expected to result in some reduction in fuel (petroleum) consumption rates and consequently emissions to the atmosphere. This reflects a future without shock events such as an oil crisis, as well as minimal change to the buying or driving behaviour of people. Although increasing affluence means that there will be more cars per person, the decreasing number of people per household and logistic constraints (such as garaging space) limit the number of cars per household (to about 1.2 on average).

Major Outcomes

Despite increasing numbers and use of cars, fuel consumption gradually decreases due to increasing engine efficiency. Emissions to the atmosphere increase initially but drop over the long term to 2050.

	1996	2050
Total number of cars (millions)	9	14
Total CO_2 emissions (million tonne/yr)	37	40
Total energy consumption (peta Joules / yr)	530	410

.

Base Case Settings

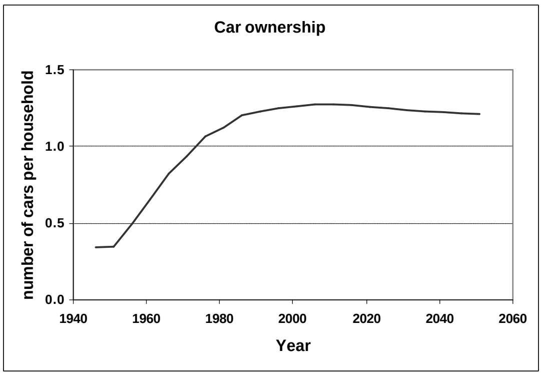


Fig. 7.1 Personal car ownership

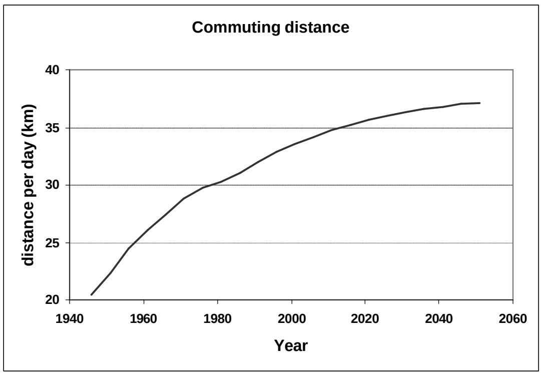


Fig. 7.2 Average commuting trip length in cities

.
.
.
.
.

.

factor	assumptions		
• car stocks			
ageing and replacement rates	cars for personal use are kept longer due to construction for longer life	car age in years	
	average age	10.5 yrs	in 1996
		13.8 yrs	in 2050
	1 in 5 probability of replacement (in the next 5 yrs)	10–15 yrs old	in 1996
		20–25 yrs old	in 2050
cars per household	following past increase (which has been diminishing), numbers per household reduce marginally to a constant average of 1210 cars per 1000 households		
• car operations			
fuel consumption rate	decreases rapidly over the next couple of decades, then levels off (equivalent to 6.6 l/km)	3.6 MJ/km	in 1996
		2.1 MJ/km	in 2020 and beyond
yearly car distance	personal use	9,700 km / yr	constant over time
	commuting distance increases 12% and levels off	37 km / day	in 2050
	fleet cars	29,100 km / yr	constant over time
operating materials	increases by 50% and levels off	3 kg / yr / vehicle	in 2050

.

Caveats and uncertainties

- Congestion limits on roads as city population grows may apply a downward pressure on the use of cars for commuting.
- The distance travelled per person in cities should be the lowest for Sydney and Melbourne (not the highest) due to the population density of these cities, not the size of the population.
- "Re-bound" effects in behavioural aspects can offset technological gains. For example, more people may acquire cars that use more fuel (e.g., 4WDs) when better engine performance or lighter structural materials lower the overall fuel consumption rate of all cars.
- Possible dramatic changes to fuel consumption and vehicle stocks could occur if hybrid vehicles (e.g., CSIRO Axess car) or hypercars (e.g., small and light vehicles such as the Amory Lovins' hypercar) are successfully introduced. Some pressure for such change may come from government regulations for new cars to meet Euro standards early in the 21st century.

References

- ABS: "Use of Motor Vehicles"; in Transport theme of the Australian Statistical Profile http://www.abs.gov.au/ausstats/abs%40.nsf/94713ad445ff1425ca25682000192af2/6499c5d70e00e881ca2568a900154b1e!OpenDocument
- "RoadsFacts '96: An Overview of Australia's Road System and Its Use"; AustRoads, Sydney, 1997. (Available through the Department of Transport and Regional Services web site: http://www.dot.gov.au/land/road/roadfacts.htm)
- hypercar web site or: "Natural Capitalism", Hawken, Lovins & Lovins (1999).
- Brian Fleay: oil & transport ("Age of decline of oil")
- Australian Motor Vehicle Manufacturers web site.
- Peter Newman and Geoff Kenworthy
- Petroleum Institute of Australia

8. Roads

.

Description

Roads are a major element of infrastructure in Australia given the size of the continent, the separation of major population centres, the dominant role of cars and trucks for transport, and the continuing importance of primary production. There are close to 20,000 km of national highway and many 100,000 km of other roads. Roads are classified here as sealed or unsealed, and main or local. Additionally, the quantity of urban roads is linked to city population size while the stock of roads in rural areas is determined by exogenous factors such as political and social influences.

In addition to construction of new roads, other operations include the conversion (reconstruction) of existing roads to an upgraded status (e.g., unsealed to sealed) and maintenance activities. Substantial quantities of materials (mainly sand, gravel and crushed stone) are involved in the construction operations. The labour force required for road construction is relatively small (roughly 5% of the total) compared with that for building construction.

Rationale for the base case settings

Total road length is approximately constant over time, reflecting the improvement of the existing road system as unsealed roads are upgraded to sealed roads. Unsealed rural roads constitute about 65% of the total road length. The improvement in quality (including the widening) of roads is the cause for increasing quantities of the major materials.

Major Outcomes

Quantities of major materials peak in about 2030 and then decrease in a non-linear fashion; relative to 1996 use of sand remains high while crushed stone is reduced. This is eventually linked to the stablising population, which is concentrating in urban areas.

Major materials, million tonne / yr	1996	2050
crushed stone	78	72
sand	19	31

.

Base Case Settings

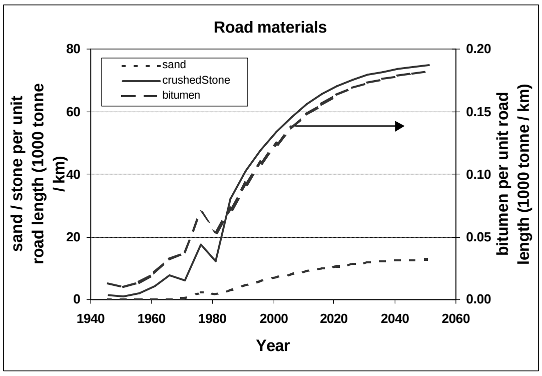


Fig. 8.1 Materials for construction of sealed rural ("local") roads

.

factor	assumptions		
• urban roads			
construction rate	average rate generally decreases by about 20% rel. to 1996 for most cities (construction of unsealed roads is negligible in comparison)		
	sealed roads	km / yr / million people	in 2050
	maximum rate is in Darwin (and increases by ~70% rel to 1996 for main roads)	2700	main roads
		1200	local roads
	minimum rate is in Canberra	100	main roads
		400	local roads
reconstruction rate	constant for local & main roads, sealed & unsealed (double the rate of rural roads)	0.4% / yr	constant over time
• rural roads			
roads required	National totals		
	local roads—mostly unsealed (and total distance much greater than main roads)		
		1000's km	
	unsealed	513	constant over time
	sealed	121	
	main roads—negligible change in sealed roads, 17% decrease (rel. to 1996) in unsealed roads		
	unsealed	13	in 2050
	sealed	89	
reconstruction rate	constant for local & main roads, sealed & unsealed	0.2% / yr	constant over time
• inputs			
materials	trends are duplicated for all road types, but quantities differ		
	for local, unsealed rural roads		
	sand, increases by 125% rel to 1996	12,700 t / km	in 2050
	crushed stone, increases by 57% rel. to 1996	18,700 t / km	in 2050

Caveats and uncertainties

- The widening of roads, particularly the use of multiple lanes, is not captured by measuring road quantities in kilometres and could influence the amount of materials incorporated in construction.
- Reclassification of roads in historical data may account for a counter-intuitive reduction in the total length of roads. For example, stock routes may be downgraded to 4WD tracks.

References

- ABS: "Length of the Road System"; in Transport theme of the Australian Statistical Profile: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/437f171ae2273e90ca2568a900154b1b!OpenDocument
- ABS: "Special Article: Roads: The Beginning and Now"; in Transport theme of the Australian Statistical Profile: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/7b43de05d56bff2eca2569260020890d!OpenDocument
- "RoadsFacts '96: An Overview of Australia's Road System and Its Use"; AustRoads, Sydney, 1997. (Available through the Department of Transport and Regional Services web site: http://www.dot.gov.au/land/road/roadfacts.htm)

9. Processing and Assembly (including food)

Description

Processing and Assembly is concerned with the manufacture of goods and artefacts to meet people's needs for food, consumables, buildings, transport and services. These goods are formed from secondary or manufactured materials (see Material and Energy Transformations later), which are themselves converted from primary materials produced in agriculture, forestry, fishing and mining. Examples of these goods include furniture, office equipment, transport vehicles, primary production machinery, food consumables and chemicals. Some of the goods needed are imported and some are produced in Australia for export, with subsequent effects on the international trade balance. Generally, domestic production is determined by the difference between the amount of goods required (including those for export) and the amount imported to Australia.

Input materials, energy and labour requirements are determined after consolidating the need for the various goods and artefacts, including packaging for some goods. The conversion process requires production plants, which must be replaced over time according to the demand for the products and the lifetime of the plants. This creates requirements for construction materials. Emissions to the atmosphere from the factories also result from the production process.

Rationale for the base case settings

The settings reflect an active and expanding manufacturing sector that is based on traditional techniques and energy sources. Further automation of the manufacturing processes results in lower labour requirements at the expense of increasing energy use. Australia remains considerably reliant on import of elaborately transformed goods, while increasing exports of some products to satisfy the requirements of growing world population and affluence (particularly in the Asian region).

Major Outcomes

Energy and water inputs and emissions increase substantially—largely associated with the export of goods, of which "furniture" contributes about half.

	1996	2050
energy consumption (peta joules / yr) goods	57	220
food	67	101
water consumption (GL / yr) goods	197	409
food	160	236

.

Base Case Settings

factor	assumptions		
• import / export			
new vehicles	imported proportion (of vehicles required) generally constant over time: 10–100%; except for light trucks, cars, milk machines, and harvesters:		
	light trucks & cars, increasing imports level off:	23%–37%	1996–2050
	exported vehicle numbers dominated by cars, increasing continuously over time:		
	car numbers exported	17,000–61,000 / yr	1996–2050
	proportion of domestic production	4.8%–16%	
final demand goods	imported proportion (of required goods) constant over time:		
	office equipment	80%	
	furniture	10%	

	exports increase substantially and continuously over time:		
	total	0.1–7.1 Mt / yr	1996–2050
	furniture dominates:	42% of total	in 2050
operating goods			
food	imported proportion (of food required) constant over time; top three proportions (rest are below 50%):		
	phosphate	99%	
	gold	68%	
	tunas	57%	
• manufacturing plants			
energy use	same for all goods— large increase over time (~54%) levelling off by 2100		
		6.5–9.7 GJ / t	1996–2050
	mostly supplied as electricity then gas:	72% & 27%	~constant over time
water use	constant over time, varies from 20 to 48 t water per t good		
labour force	same for all goods—decreasing numbers required, levels off by 2100		
	amount of good produced per person:	65–214 kt / yr	1996–2050
• packaging			
goods packaging	same for all goods—mainly wood, paper and plastics:		
	wood, decreasing and levelling off by 2100	44–49%	1996–2050
	paper, decreasing and levelling off by 2100	36–31%	
	plastics, increasing and levelling off by 2100	19–28%	
	amount relative to good (by weight):	0.4–0.6%	
food packaging	same for all food types—mainly paper (~70%) and plastics (~26%) constant over time		
	amount relative to food (by weight):	4.4–4.8%	1996–2050
• food processing			
energy use	same for all food types		
	moderate increase over time:	1.3–1.4 GJ / t	1996–2050
	mostly supplied as electricity then gas:	56% & 26%	constant over time
water use	same for all food types and constant over time	6.5 t water / t	constant over time
labour force	same for all food types; decreasing numbers required, levels off by 2100		
	amount of food processed per person:	0.9–2.1 Mt / yr	1996–2050

Caveats and uncertainties

- Significant changes could be made by economic pressures and national policies to shift the emphasis from manufacturing low value-added products to either innovative and elaborately transformed items or information and service related economies.
- Trading success on world markets could change the import-export balance.
- Under national and global policies, some manufacturing techniques could be replaced by cleaner technology and the concepts of industrial ecology and zero emissions manufacturing.

.

References

- ABS “Manufacturing” theme in Australian Statistical Profile: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2!OpenView&Start=1&Count=1500&Expand=23#23

- Survey of Australian Manufactures, The Australian Industry Group, Yr 2000 results: http://www.aigroup.asn.au/

10. Consumption and Recycling

Description

In addition to the food consumed by the domestic population and tourists, other products are used up by the domestic population (defined on a per capita basis). These consumables are paper, plastic, textile, chemical (organic or non-organic) or pharmaceutical products.

Landfill and recycled materials like paper, glass, many metals, plastics and rubber come from the discarded vehicles, goods and packaging, building materials and contents, and processing plant materials. Some fraction of the component materials of these discards goes straight to landfills. The remainder is either recycled or stockpiled for recycling.

The recycling process requires plants that must be replaced over time according to the throughput of materials and the lifetime of these plants. These operations require energy and water and a small workforce, and produce emissions.

Rationale for the base case settings

The treatment of the recycling industry remains embryonic and handles only paper and textiles. Per capita consumption of food and other items increases somewhat as spending increases as people become more affluent.

Major Outcomes

Landfills grow continuously (exponentially for several decades, then linearly) largely from building waste (concrete contributes about 60% of the total mass). Material stockpiled is mostly (~roughly 90%) iron and steel from vehicle discards. Paper makes up about 70% of the material recycled.

Totals		1996	2050
food consumed	(million t / yr)	25	37
accumulated landfill mass	(million t)	1100	4100
accumulated stock of recyclable material	(million t)	48	130
material recycled (summed over all years)	(million t)	8	49
energy used	(peta J / yr)	77	114

.

Base Case Settings

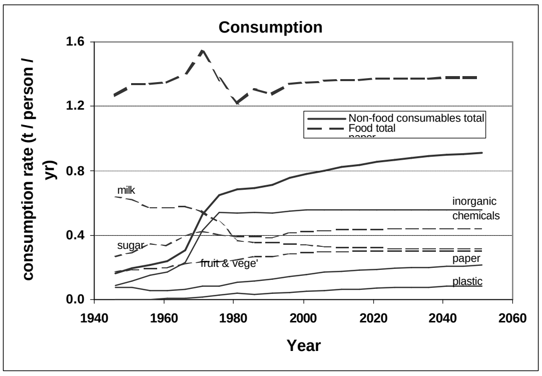


Fig. 10.1 Consumption rates for major categories

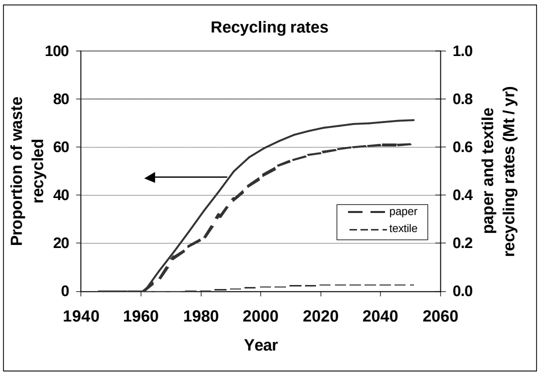


Fig. 10.2 Recycling rates

factor	assumptions			
• recycling rate		% to recycling	planned rate (kt / yr)	
packaging	paper	56–71%	440–612	1996–2050
	and textiles		16–31	
vehicles	ferrous metals	0	164–245	
	aluminium		8.5–14	
	other metals		9.3–13	
goods	all materials (incl building contents)	0	0	
building materials	all materials	0	0	
building contents	all materials	0	0	
processing plants	all materials	0	0	
• recycling operations				
energy use	same for all materials recycled	44 GJ / t		constant over time
water use		36 kL / t		
emissions		0		
• consumables				
food	total consumption increases slightly (2%); more sugar, less milk; more poultry, less beef		1.4 t / pers / yr	in 2050
	sugar : milk : fruit&vege' : all other		32 : 23 : 23 : 22	
other items	total consumption increases (21% by 2050 rel to 1996): more paper, plastic & textiles			
			0.9 t / pers / yr	in 2050
	inorganic chemicals : paper : plastics: textiles		73 : 19 : 6 : 2	in 1996
			61 : 23 : 9 : 7	in 2050

.

Caveats and uncertainties

- Decay of paper in landfills (not included at this stage) will reduce the volume of the cumulative landfill required, and could provide energy through production of methane or be included as greenhouse emissions.
- Landfill volume may be under-estimated without the inclusion of organic matter (household garden waste).
- Collection of material (particularly post-consumer waste) is very transport intensive and could impact on energy and emission futures.
- Aluminium should be included in packaging recycling.

.

References

- ABS "Hazardous Waste out with Garbage"; Media Release with "Environment Issues, People's Views and Practices" 4602.0: http://www.abs.gov.au/ausstats/abs%40.nsf/5e3ac7411e37881aca2568b0007afd16/5faca4a00dbe92f5ca2568a900136206!OpenDocument&Highlight=0,recycling
- ABS "Diet and Nutrition" in Health theme of Australia Now Statistical Profile: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/85783d365a077166ca2568a900154a42!OpenDocument
- Recyclers Association / big companies: BFI, VISY, SIMSMETAL
- Local government re garbage & landfill, e.g., ACTEW per capita data

11. Materials and Energy Transformation

Description

The transformation of raw materials and energy into intermediate goods (and secondary energy forms) is the foundation of the physical economy. The demand for these materials and energy inputs is driven by upstream sectors that are either linked to population e.g., building operations or associated with primary industry e.g., mining. In contrast to the processing and assembly of goods such as machinery and furniture, which are delivered to particular sectors of the economy, the output of the basic material and energy transformations, e.g., paper, concrete or electricity, are available for the whole economy. This includes the international trade of these outputs; energy is traded in the form of materials. The inputs to the material and energy transformation processes are primary materials (water, air and products from agriculture, forestry, fishing and mining), other basic materials (such as cement for the production of concrete) and recycled materials. The total mass of the inputs must always be greater than (or equal to) the mass of the outputs.

Energy is provided to the economy either as electricity or as fuels. A wide range of processes, using fuels or renewable sources, generates electricity. The transformation process requires production plants, which must be replaced over time according to the requirement for energy and materials and the lifetime of the plants. New plants may be built if the existing productive capacity cannot meet the total material or energy need. This construction is prioritised and creates additional requirements for materials and energy. Emissions to the atmosphere from the plants also result from the transformation process.

Rationale for the base case settings

The settings reflect current techniques and energy sources. There are improvements to the efficiency of generating and supplying energy. Renewable energy sources provide a minor contribution currently, and an assumption is made that petroleum resources remain relatively available and cheap. Without changes to the processes in the manufacturing sector, no new basic and primary materials are introduced, although this sector will be broadened and deepened in a revamped model.

Major Outcomes

Total energy consumption is about 50% higher in 2050, with most use in the form of petroleum products (used largely for transport of people and domestic freight). The use of electricity and natural gas increases in absolute and relative terms—both energy sources for buildings.

		1996	2050
energy generation	(peta joules / yr)	3,970	6,990

.

Base Case Settings

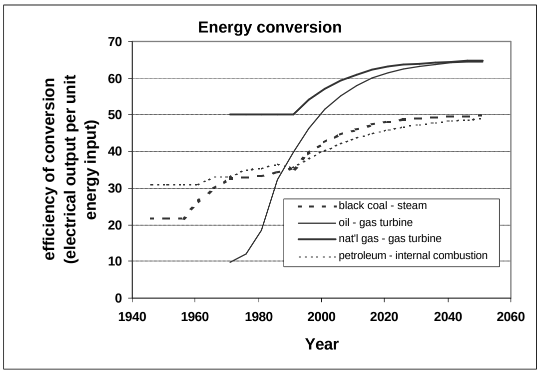


Fig. 11.1 Efficiency of energy conversion to electricity for selected processes

.

factor	assumptions		
• energy production/conversion			
conversion efficiency (to electricity)	improvements to conversion efficiency level off by 2040–2060		
	most efficient: natural gas/oil for turbines	65%	in 2050
	less efficient: brown coal for steam	45%	
electrical losses	transmission losses & generation losses	10%	
• material transformation			
energy use	constant over time based on 1996 figures		
	highest use per tonne: gold / silver processing	250 GJ / t	50% by black coal
	low use per tonne: pharmaceutical products	0.17 GJ / t	
material input	constant over time based on 1996 figures (including primary materials)		
• production of new plants			
priority for more capacity	new electricity plants are largely (factor of ~10x) coal-fired steam driven, based in non-urban areas of the Eastern states		
• plant operation			
water use	constant over time based on 1996 figures		
	paper production	23 kL / t	material production
	production of clothing materials	13 kL / t	
	highest rate: nuclear plants	1.5 kL / GJ	electricity generation
	steam plants	0.37 kL / GJ	
emissions	constant over time—		
import / export			
material exports	remain constant over time based on 1996 figures		
	wood	2.3 mt / yr	(top three, by mass)
	petroleum	2.2 mt / yr	
	iron and steel	1.2 mt / yr	
material imports	proportion of domestic requirements remains approximately constant over time (1996 figures); top three proportions: briquettes, pharmaceuticals, copper		

Caveats and uncertainties

- Markedly different energy processes such as nuclear fission and fusion have the potential to dramatically change the energy supply and waste issues. However, some processes may not be introduced for decades because they are either uneconomic currently or require substantial development efforts.

- Spatial analysis of energy plants and delivery throughout Australia is important given transmission losses and transport costs (including fuel). Distributed micro power systems such as photovoltaics and home based fuel cells could revolutionise power generation as could the implementation of a 'factor 4' economy.

References

ABS "Manufacturing" theme in Australian Statistical Profile:
http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2!OpenView&Start=1&Count=1500&Expand=23#23
http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/31469114e4fcfa12ca2568a9001549e3!OpenDocument
ABS "Energy Resources" and "Electricity and Gas Operations" in Energy theme of the Australian Statistical Profile:
http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/9db8341df368a561ca2568a900154a0b!OpenDocument.

12. Crops and Animals

Description

Crops and livestock are harvested for the production of food for domestic consumption, export, and input to other primary production e.g., cotton. The capacity for the Australian landmass across 58 statistical divisions to support crops is determined by a set of factors with positive and negative effects on productivity. Yield may be increased through fertilisation, irrigation or plant genetics. Environmental degradation may have the opposite effect through soil acidity, dryland salinity, irrigated land salinity and soil structure decline.

Animal products include edible commodities, such as beef, poultry and milk, and inedible products, namely wool and skins. These are all determined from the production capacity per animal.

Population size is not a direct driver of crop and animal production since Australia produces substantially more than can feasibly be consumed domestically. The excess goes to exports, which therefore contributes to the trade balance and subsequently is related to population through other lifestyle demands.

Rationale for the base case settings

Control variables have been set to expand agricultural output in a regime that is consistent with expansion and growth of the economy. Crop and animal production is expanded in line with assumed industry aspirations and constrained by national environmental issues.

Major Outcomes

Production of seed crops increases by 41% between 1996 and 2050, although there are regions that experience decreased productivity. Production of animal products is dominated (in terms of weight) by milk, increasing by a factor of 3 by 2050. Water use increases dramatically, with crops dominating over livestock. This is the major component of total water use within the physical economy.

Totals		1996	2050
seed crop production	(Mt / yr)	1.17	1.65
milk production	(Mt / yr)	37	110
water use for crops	(peta L / yr)	7.0	20.5
water use for livestock	(peta L / yr)	5.8	12.3

.

Base Case Settings

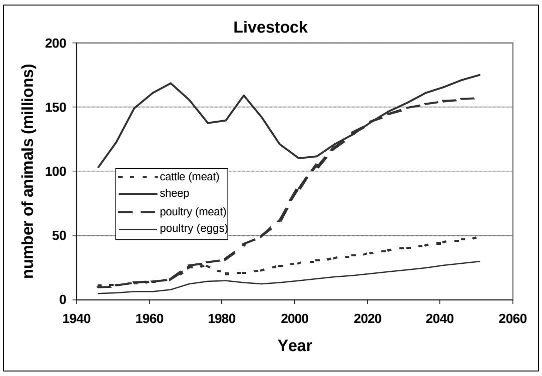


Fig. 12.1 Numbers of livestock.

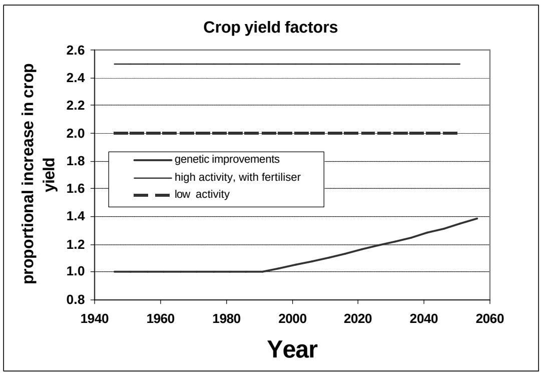


Fig. 12.2 Improvement in crop yield due to genetic factors and irrigation.

.

factor	assumption		
• crops			
arable land change	new arable land varies by statistical division and over time in a complex manner:		
	generally the annual additions increase rapidly (up to about 2030):		
	maximum addition	66,000 h / yr	Midlands, WA
fertiliser use	varies by statistical division; all increase over time, levelling off several decades after 2050		
	maximum rate: Central West Qld	7.8 t / hect	in 2050
	increases by	59%	rel to 1996
	minimum rate: Eyre, SA	0.47 t / hect	in 2050
	increases by	31%	rel to 1996
water use	constant over time and independent of statistical division, varies by crop type		
	cotton	5.34 ML / hect / yr	maximum
	e.g., legumes, oil crops, nuts	32.0 kL / hect / yr	minimum
crop yield	genetic improvement identical for all crops and independent of region		
	proportional change in crop yield increases over time	103–135% rel to 1991	for 1996–2050
	relative yield response to irrigation: constant over time, independent of crop type and region		
	high activity cropping with fertilization	250%	constant over time
	low activity cropping	200%	
• livestock			
total numbers	increase over time for all livestock	millions	
	sheep; remain as the dominant stock number	121–175	1996–2050
	poultry (meat); increase rapidly then levels off	62–156	
	cattle (meat); increase linearly: 100,000 p.a.	26–49	
water use	constant over time, varies by animal type		
	diary cattle	1.1 ML / animal / yr	maximum
	meat cattle	104 kL / animal / yr	
	others are order(s) of magnitude less		

Caveats and uncertainties

- The scale of tree planting being contemplated may negatively affect land use, possibly placing higher biological demand on water resources.
- Increasing energy prices may have pervasive and strong effects on agriculture, but the dynamics are not clear.
- Comparison of the relative functional status (or degradation status) of land is limited due to the lack of reliable data on the "original" functional status before development.
- Small scale effects such as intensive irrigation are averaged over larger statistical divisions.
- The threshold levels at which land is judged to be unproductive and consequently "retired" are yet to be incorporated in the grounding of the model.

References

- Sustainable management of Australia's land, forest and woodland resources; "Topics of interest"; Environment; Themes; ABS home page: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/1b1970dd4aedc37cca2568a9001549ba!OpenDocument
- "Land use classification", Bureau of Rural Sciences: http://www.brs.gov.au/land&water/landuse/landuse.html
- CIE-LWRRDC report.

13. Forestry

Description

Forestry involves the production of round wood and pulpwood from plantation and native forests in a range of ecological regions such as tropical rainforest, ash forests of the south-east and native pine. A series of management regimes are used, such as clear cut, selective cut and primary reserves. The volume of felled timber is driven by trade requirements, not by population needs, but the actual volume achieved (greater or less than the planned figure) is influenced by forest growth histories. Other factors also determine the dynamic inventory of trees, including forest fire, tree mortality and urban encroachment. Forests regenerate through either self-seeding or planting operations.

Logging trucks, cutting machines and other machines are used in forestry operations, requiring fuel and labour. The stock of machines is replaced over time, partially driven by the requirements for timber production. Other labour is required for planting of forests.

Rationale for base case settings

Planned production of wood—particularly pulpwood—is assumed to increase substantially due to sustained overseas demands for paper based products. However, the production rate is constrained by low land quality throughout Australia and competition for land use from agriculture.

Major Outcomes

CO_2 is removed from the atmosphere due to forest growth; the net deletion rate is highly variable over time, but generally decreases—beyond 2050 the average rate is approximately 150 Mt/yr. Managed forests contribute the majority of the total wood production, mainly from pine forests.

		1996	2050
total wood production			
from managed forests	(million m^3 / yr)	3.7	7.0
CO_2 net **deletion**	(million m^3 / yr)	~10	~50

.

Base Case Settings

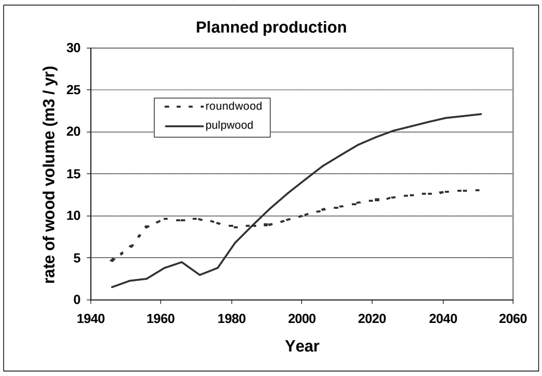


Fig. 13.1 Total of the planned wood production rate. Fig. 13.2

.

factor	assumptions		
• tree characteristics			
tree growth	managed forests have rapid growth, for all forest types		
	max volume per tree	2.5 m^3	by 100 years
	maximum volume but slowest growth occurs in Northern dry forests (except managed)		
	max volume per tree	6.7 m^3	by 380 years
	Native pine has minimum volume and growth		
	max volume per tree	0.9 m^3	by 320 years
mortality rate	minor variations for different forest types and management regimes		
	lowest survival probability	10–50% (over 5 yrs)	at 5–10 years
• forest growth			
fire rates	proportion of forests lost by fire—constant frequency over time		
	managed forests	0.3% /yr	constant over time
	several Eucalypt forest have highest rate	2.0% / yr	
regeneration	forest density (for mature trees)	trees / hectare	
	managed forests	100–725	
	minimum: dry Eucalypts of SE forests	12	
	maximum: ash forests of the SE	870	
• forestry operations			
planned production	production only from selected regions and forest types; increase and level off by ~2050		
	roundwood from managed Pinus radiata	1.4 million m^3 / yr	
forest land change	managed forests constitute the only land added to or deleted from forests		
fuel use	continuously decreasing fuel consumption	–16% (rel 1996)	in 2050
		1 TJ / vehicle / yr	

.

Caveats and uncertainties

- The action of forests as sinks of CO_2 and the emission of CO_2 from forestry operations (e.g., burning) should be implemented to add to totals from other sectors of the economy. This will contribute to the mechanism for tracking national carbon sequestration targets.
- Changes are likely to the type and ownership of forests, with a move to more plantations rather than native forests and a greater proportion being privately owned. Consequently inputs such as fertilizers may increase and management regimes change.
- Forest impacts on water resources are unclear. Water use may change with increasing areas of private plantations, but this will be constrained by the application of water licensing. Effects to be considered include transpiration of water from the forest cover, reduction of run-off to waterways, and lowering of water table levels.
- First and second thinning of clear cut forests delivers some 30% of wood produced and should be included, while removing the selective cut after clear cut management regime.

References

- ABS "Forest Estate" and "Wood and Paper Products" in Forestry and Fisheries theme of the Australia Now Statistical Profile: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/9147dc7ea63e9903ca2568a9001549a6!OpenDocument http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/f79d1ef67124e296ca2568a900154a01!OpenDocument
- "Australia's State of the Forest Report 1998", Bureau of Resource Science.
- BRS "Forest Information": http://www.brs.gov.au/nfi/forestinfo/info.html

14. Fisheries

Description

Fish for consumption is harvested from both wild fisheries and fish farming operations, these being treated separately in the model. The stock levels of wild fish species are determined by the catch rate of a fishery and the pseudo-biological parameters of the species that describe its growth (or recovery) rate and a virgin (maximum) biomass. These parameters are used in a simple “logistic growth model that captures adequately the dynamics of species population in response to exploitation.

The fishing effort to produce the catch takes account of increasing difficulty as stock levels decrease. This effort is measured in terms of the size of the fishery fleet and the labour, materials and energy required. Attempts to fish at rates that are driven only by the demand for consumption without recognition of the stock levels can result in depleted fish stocks and collapse of fisheries. Consideration is also given to foreign fishing, which can reduce the stock levels without contributing to domestic consumption.

In contrast with wild fisheries, fish farming (or aquaculture) is assumed to produce sufficient quantities to meet consumption demand. Although no dynamics are involved, the labour, material and energy inputs are tracked.

Rationale for base case settings

Key control variables for fisheries have been set to produce as much of Australian domestic requirements for fisheries product while remaining consistent with realistic catch limits. These limits are set by the relatively low productivity of the Australian marine environment and the requirement for export income, which is driven by the high price of fish such as tuna, prawns, lobsters, abalone and pearls. Aquaculture development is set to supply as much of the shortfall as is physically feasible given the limits on suitable aquaculture sites and uncertainties on future costs and returns. Where appropriate the production levels of each fishery are set to coincide with policy issues such as 'fisheries management plans' and 'total allowable catch' concepts.

Major Outcomes

A number of key fisheries decline but closely managed fisheries (.e.g, lobsters, prawns, etc.) are maintained.

Totals catch (kt / yr)	1996–2050
marine fish (other than tuna)	84
crustaceans	62
tuna	1.0

.

Base Case Settings

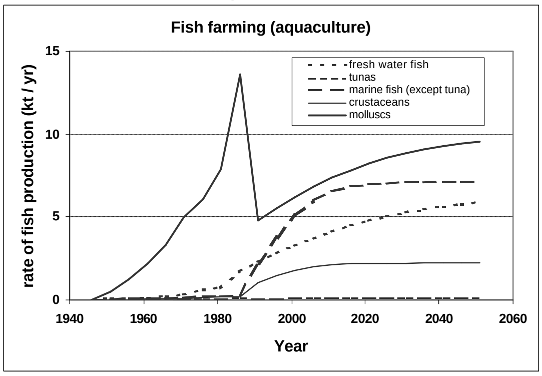


Fig. 14.1 Rate of fish production from aquaculture

factors		assumptions			
• Wild fisheries					
	catch rate	80% of the estimated maximum sustainable yield for each species			
	requested catch p.a.	constant over time, but varies by "fish kind"			
		marine fish (other than tuna)	84	kt / yr	
		crustaceans	62		
		molluscs	18		
		tunas	1.0		
		fresh water fish	5.1		
	energy use	constant per day per boat, varies for boat types	~1-5	GJ	
• Aquaculture					
	production rate	increases by different rates:	production reaches approx.		
		molluscs	10	kt/yr	
		marine fish	7	kt/yr	
		fresh water fish	6	kt/yr	
		crustacean	2	kt/yr	
	energy use	decreases by 36% to stabilise several decades after 2050			
		per tonne fish produced, varies by type	~0.5-4	GJ/t	

Caveats and uncertainties

- While using a logistics model for fish stocks appears adequate, there can be substantial sensitivities to some parameters (this can be true of other models). For example, changes of less than 1% to the virgin biomass can result in marked recovery of a species that has been fished to very low levels.
- Progressive depletion of fish or fish stocks tends to be more catastrophic in the ASFF model due to limitations in the modelling of the dependence of fishing effect on stock numbers. Consequently, fisheries turn off and on more dramatically or discretely than in reality.
- Foreign fishing can have a profound effect on particular "domestic" ocean fish populations.
- Achieving oxygenated and clean flowing water for aquaculture may limit the extent to which this industry grows and can therefore supplement wild fish harvest.

References

- 4607.0 Fish Account, Australia; under "Environment"; under "Themes": http://www.abs.gov.au/Ausstats/ABS%40.nsf/e8ae5488b598839cca25682000131612/4f2fce9d56c2fca2ca2568a9001393dd!OpenDocument
- BRS, Working Paper No. WP/14/91, Twenty-five years of Australian Fisheries Statistics, (1991).
- BRS/FRDC, Australian Fisheries Resources, P.J. Kailola et al., (1993).
- ABS, Fish Account Australia 1997, (1999).
- ABARE, *Australian Fisheries Statistics* 1991, 1992, 1994, 1997, 1998, 1999
- ABARE Research Report 97.3 for the Fisheries Resource Research Fund, Australian Aquaculture: Industry Profiles for Selected Species, 1997.
- Fisheries Research and Development Corporation, National Seafood Consumption Study, August 1992.

15. Mining

Description

Mining involves the extraction of minerals, ores, energy materials and other materials (e.g., construction materials and fertilizers). These are fed into various sectors of the physical economy, including international trade, but particularly for the transformation of these base materials into intermediate materials and energy supply. Australia is a major supplier of bauxite and iron ore.

The amount of material extracted depends on the measured resources (previously known as current reserves), and how it compares with the planned production rate. The measured resources increase over time as exploration reveals more of the "indicated" resources (previously known as inferred and undiscovered resources), which also increases over time as new estimates are made. As more resources are used production becomes more difficult (in terms of energy required, for example), although production is not curtailed (except for oil and gas in the base case scenario) by the availability of resources.

New mining equipment is introduced to accommodate increases in planned production or replace aging stock. Mining operations require energy, materials, water and labour inputs; and contribute emissions to the atmosphere.

Rationale for base case settings

Industry expectations are for requirements for most metal and mineral commodities to grow at between 1.5% and 3% p.a. out to 2030 and beyond. Planned oil production follows the BRS median projection to 2010 and then continues with a linear extrapolation of the downward trend. Similarly, planned production of natural gas follows the AGA projections to 2030, then continues this trend with declining growth as for other minerals.

Major Outcomes

Of the primary industries, mining uses the most energy, although it is relatively small compared with consumption in transport. Domestic production of oil and gas is limited by constraints on the resource base.

major mineral production rate		1996	2050
black coal	(Gt / yr)	0.23	1.24
iron ore	(Gt / yr)	0.17	0.28
construction materials	(Gt / yr)	0.16	0.17

Base Case Settings

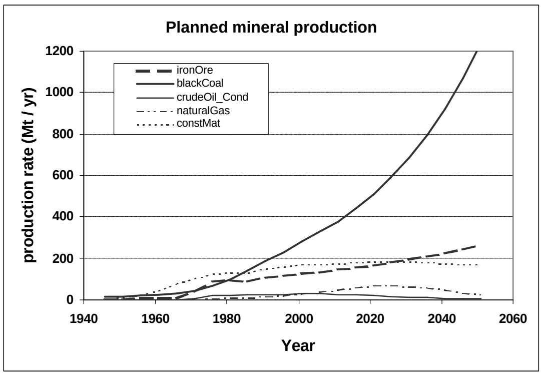


Fig. 15.1 Planned production for selected minerals.

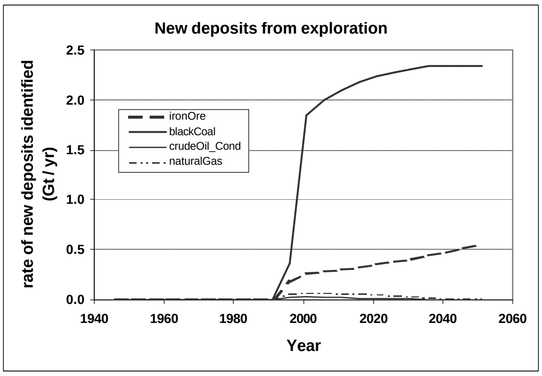


Fig. 15.2 New deposits identified from exploration, to be added to measured resources

factor	assumptions		
• resources			
annual additions	except for oil and gas, amounts increase and levelling off; top three:		
	black coal	2.3 Gt / yr	constant after 2000
	iron ore	0.17–0.55 Gt / yr	1996–2050; constant after 2050
	bauxite	0.04–0.10 Gt / yr	
	oil and gas peak in 2001 and then decrease approx linearly, based on AGSO median assessment		
	oil	26–1.4 Mt / yr	2001–2050
	natural gas	65–2.6 Mt / yr	
new deposits identified	mostly identical to “annual additions” except for:		
	black coal	2.3 Gt / yr	after 2035
	natural gas	~2 x annual additions	
• production / extraction			
planned production	generally increase over time, but not uniformly		
	black coal, increases continuously until about 2060	0.23–1.2 Gt / yr	1996–2050
	oil (peaks in 2006)	24–2.9 Mt / yr	
	natural gas (peaks in 2025)	22–26 Mt / yr	
extraction difficulty	extraction gets exponentially more difficult as total production approaches the (total of) resources ever found applies to all inputs and for all materials	difficulty factor	total production / resources ever found
		1	0–20%
		2	60%
		4	81%
		8	91%
• operations			
energy use	for all materials, consumption rates (J per unit material) of new equipment decrease by 34% (1996–2050) and level off		
	diamonds	540 GJ / t	in 2050
	gold	42 GJ / t	
	black coal	84 MJ / t	
water	constant over time for all materials		
	bauxite	2.5 kL / t	(max water rate)
	black coal	400 L / t	
	iron ore	150 L / t	(min water rate)

Caveats and uncertainties

- Access to land may be difficult due to Native Title claims and environmental restrictions in wilderness areas or national parks. This could stimulate substitution of other minerals (e.g., manganese for nickel) or imports from overseas.
- Substantial effects would follow major events such as oil shocks and wars.
- New exploration techniques and better geological knowledge may extend the estimates of resources by permitting depths greater than 100–200 metres to be explored
- Recovery of urban metal wastes combined with the increasing capital cost of mining operations could depress mining activity for some metals such as lead.

References

- ABS “Mining” theme in the Australia Now Statistical Profile: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2!OpenView&Start=1&Count=1500&Expand=21#21
- Fact Sheets on Minerals, in Department of Industry, Science and Resources web site; produced by AGSO and the Mineral Council of Australia: http://www.isr.gov.au/resources/minerals/index.html

- Oil and Gas Resources of Australia 1998, BRS 1998.
- Gas Supply and Demand Study 1997, AGA 1998.

16. Water

Description

Australia's water use is increasing, with a growth in water use from 16,000 to 22,000 gigalitres over the period 1983-4 to 1995-6, mostly through irrigation for agriculture (~80%). The stock of water is distributed between soil water (available for crops and vegetation), surface water (rivers, dams, lakes, etc.) and aquifers (sub-surface bodies of water)—the sea is not used as a water stock although there is discharge to the sea. Water transfers between these stocks but levels are also changed through natural processes (rain, evapotranspiration and evaporation) as well as through use in the physical economy (agriculture, mining, material and energy transformation, goods and food processing, recycling and buildings).

Water use and movements are mapped into the ten water divisions (and their regions) based on groups of river basins (as used in the DPIE "Review of Australia's Water Resources and Water Use"). Regions receive water from upstream regions, and movement occurs through man-made transfers such as pipe-lines of hydro-electric schemes.

Rationale for base case settings

Climatic changes have been assumed to be sufficiently small that there are no changes to the environmental parameters such as rainfall and evaporation rates. Variability in these parameters, which is a key feature of Australia's environment, are averaged out by the 5 year time step.

Major Outcomes

Total water consumption increases approximately linearly to about 2030 when the rate begins to level off. The 2050 water consumption is 2.3 times that in 1996. The vast majority of water is used for agriculture: in 2050, 48% goes to crops, 30% for animals, and 14% into buildings.

	1996	2050
total water use (GL / yr)	22,000	50,000

.

Base Case Settings

factor	assumptions		
• man-made aspects			
discharge	proportion of water use discharged is constant over time, and independent of location		
	buildings & animal sectors	90%	
	goods assembly & recycling	80%	
	food processing, material/energy, & mining	70%	
	crops	55%	
	distribution is shared evenly over water regions in each city and rural area		
	all (non-sea) discharge goes to surface water		
sourcing	from either surface water or aquifer, constant over time		
	independent of sector using the water except generally crops & animals are different from all other sectors		
	proportion varies markedly depending on water region—some only aquifer or surface water, others are a mixture		
transfers			
• environmental aspects			
rainfall	constant over time, varies by water region		
	maximum:	1550 mm / yr	Gordon, Tas.
	minimum:	275 mm / yr	Western Plateau
	most rain goes directly to soil water	90:10	ground : surface

evaporation	constant over time, only from surface water, varies by water division (per m^2 of surface water)		
	maximum:	3500 mm / yr	Western Plateau
	miniumum:	1000 mm / yr	Tasmania
evapotranspiration	constant over time, only from soil water, no variation by water region		
	fraction of soil water lost	~2% / yr	
transfer between water stocks	constant over time, minor variations in some water regions; main flows are:		
	ground to surface water	2.6 ?? / yr	
	aquifer to ground	0.7 ?? / yr	
	surface to ground	0.6 ?? / yr	
regional transfers	constant over time, substantial variations across water regions; most flow to the sea		
	maximum:	36 TL / yr	

.

.

.

.

.

.

.

Caveats and uncertainties

- Water quality is not represented. Incorporating water quality will have health and infrastructure implications. It is possible to use technology (e.g., desalination through a heat process) to produce water with nil contaminations or to introduce water reuse, with subsequent material and energy (and cost) implications.
- Water infrastructure such as dams, sewage and fresh water systems are not treated. The aging of Australia's water infrastructure is contributing to water loss (e.g., 30–45% loss in urban distribution), and the infrastructure will need increasing maintenance and replacement to extend the service life another 40 years.
- Climate and variability change may affect many of the environmental parameters, in non-uniform ways across Australia.
- Environmental initiatives such as tree-planting (for carbon sequestration) and dryland salinity control may dry up catchments, reduce water flows and increase water quality problems.
- The most significant water stock over the long term is the quantity of water stored in Australia's aquifer fields.

References

- ABS "Sustainable Management of Australia's Rivers, Inland Water and Ground Water", in Environment theme in the Australia Now Statistical Profile: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/22fb7d45f5ece3cfca2568a9001549b7!OpenDocument
- ABS publication: 4610.0 Water Account for Australia 1993-94 to 1996-97: http://www.abs.gov.au/ausstats/abs%40.nsf/5e3ac7411e37881aca2568b0007afd16/a7f8ae8188119911ca2568d40004eaf7!OpenDocument.

17. Land

Description

Competition for land resources comes from a wide variety of sources. Changes related to urban areas involve urban encroachment in the form of building and road construction, as well as demolition of buildings. The majority of land use (in terms of land area) however, is for agriculture (for crops and livestock grazing) and forestry. These sectors (described in detail elsewhere) include land to be rested or made available for alternative uses e.g., some poor grazing country may be used for forestry.

Rationale for base case settings

The net area of arable and forest land is assumed to increase to provide for expanding agricultural and forestry output. Increases are most dramatic in the near term, but the growth rate declines thereafter due to environmental constraints such as land degradation and provision of conservation areas. Urban areas also increase because of population growth, and not from expansion of building areas. On average the footprint of buildings does not change over time—higher density housing in the heart of cities is balanced by the expansion of housing developments on the outskirts associated with increasing numbers of affluent people wanting their own home.

Major Outcomes

In 1996 the area of land used productively (arable, forest and urban land) is about 10% of Australia's land mass (769 million hectares). Although this is small proportion, there are substantial relative increases by 2050 in arable land and urban areas, increasing with an additional 42% (of the 1996 areas).

proportion of Australia's land mass	1996	2050
arable land	4.3%	6.1%
forest	5.8%	6.0%
urban	0.12%	0.17%

.

Base Case Settings

factor	assumptions			
• urban land use				
building footprint	constant over time and independent of city location			
		ratio of land required to building area	4	
road footprint	varies by city, but not dependent on time			
		area for main roads relative to local roads	150%	
	area per metre of road length	max. footprint	15.3 m^2 / m	Perth
		min. footprint	6.7 m^2 / m	Adelaide
other urban use	other urban land use (rel. to building area) is constant over time, and varies by city			
		max. ratio	63%	Perth
			22%	Sydney, Melb.
		min. ratio	17%	Hobart, Darwin
• non-urban use				
forest land change	the distribution over statistical divisions of forest land deletions is constant over time, but varies by forest ecological type (so 100% for ecological types exclusive to a statistical division)			
	new forest land is created from land previously used for agriculture			
arable land change	new arable land varies by statistical division and over time in a complex manner:			
	generally the annual additions increase rapidly (up to about 2030):			

	maximum addition	66,000 h / yr	Midlands, WA
	then growth in arable land diminishes over time:		
	rate decreases by	~70–80%	by 2050 rel 1996
other use	deletions constant over time, mostly zero except near cities and some SA regions		
	cities	< 1,000 h / yr	
	maximum	4,800 h / yr	(Yorke Lower)

.

.

.

.

.

.

.

Caveats and uncertainties

- The proportions and geographic distribution of land use will be affected by possible climate change and developing land degradation. Climatic change could see the rainfall distribution change sufficiently that some areas become more productive while others become unviable for agriculture or even forestry. Land degradation is another driver that will develop over the long term according to policies put into practice in the past and near term.
- The choice of land use will also be influenced by the population growth rate of major trading partners. Since the vast majority of our raw material and food production is driven by export requirements, major changes to land use could occur if there are surprise variations in international trading practices or the global population (possibly brought about by major wars or epidemics).
- The possible introduction of large scale irrigation for cropping in northern Australia has the potential to dramatically increase agricultural land use, although there will be considerable issues associated with water use (e.g., water access and quality, land degradation).

References

- ABS "Land used for agriculture" in Agriculture theme of Australia Now Statistical Profile: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/ae5478f08dfe92fcca2568a9001549eb!OpenDocument
- "Land cover changes", Bureau of Rural Sciences http://www.brs.gov.au/land&water/landcov/index.html

18. Air Resources

Description

Air pollution is created from the emissions to the atmosphere from transportation (of people and freight/goods), processing and other forms of energy use. Australia has a relatively high production of CO_2 per capita (e.g., greater than the US) due to our dependence on coal for energy supply and the reliance on transport between widely spaced cities. Air pollution in the city air sheds can be quite visible at times and have considerable and relatively short-term impacts. Other emissions such as the Greenhouse gas CO_2 may have global long-term impacts on the environment, with flow-on effects (to the agricultural sector in particular) and feedback (e.g., increased use of air conditioning in buildings). Additionally, international protocols for controlling the emissions of Greenhouse gases have substantial ramifications for the physical economy.

Rationale for base case settings

Since the emissions to the atmosphere are generated in the relevant sector of the physical economy and consolidated in this issue, there are few settings to be made for this aspect of the physical economy. Emissions per unit output generally decrease over time due to the introduction of better technology, largely in response to regulations but also via greater energy efficiency.

Major Outcomes

Most growth in emissions is linked to the provision of energy services (electricity and gas) and consumer items (tourism, food, furnishings, etc.) to a strongly growing population.

		1996	2050
CO2 emissions	(million t / yr)	350	850

.

Base Case Settings

factor	assumptions		
• energy			
energy use emissions	volumes per unit energy used are constant over time, depending on the fuel source, the sector use and vary slightly by location		
	CO_2 from:	kg / GJ	
	black coal	84–103	range of values
	petroleum	60–70	
	natural gas	50–55	
• transport			
transport emissions		t CO_2 / 1000 km	
	air	14.2–12.3	1996–2050
	train/trams (urban)	10.0–13.4	
	rail (inter city)	4.2–4.5	
	articulated truck	3.4–4.4	
	rail (freight)	2.6–1.1	
	bus (inter city)	1.1–1.0	
	light truck	0.4–0.5	
	cars	0.3–0.2	
	bus (urban)	0.1	
urban emissions of inter-city transport	proportion of emissions into cities is constant over time, independent of location		
	air	30%	
	trucks and ships	10%	
	bus, trucks (articulated) and rail	5%	
• processing—direct emissions			

food processing	constant over time and for all food types	1.0 kg / kg food	*check*
	goods processing, energy conversion, recycling	0	

.

.

.

.

.

.

.

Caveats and uncertainties

- Although a comprehensive account has been made of CO_2 emissions, full carbon sequestration requires land clearing and forestry operations to be included as sources and sinks. However, these processes may make limited contribution to moderating the effects of the emissions.
- (Most?) Ozone depleting gases are not included. Although volumes of these gas emissions are relatively small in comparison with the major Greenhouse gases, the effect on atmospheric ozone is substantial because of the reactivity and longevity of these gases. However, in the time frame of the projections made, ozone depleting gases may be effectively eliminated through legislative action.

References

- ABS "Greenhouse gas emissions and climate change" in the Environment theme of the Australia Now Statistical Profile: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/a817900a559dc659ca2568a9001549b9!OpenDocument
- "Climate Change: Australia's Second National Report under the United Nations Framework Convention on Climate Change", Nov 1997, Australian Greenhouse Office; access through the AGO web site: http://www.greenhouse.gov.au/policy/analysis_projections.html
- The National Pollutant Database, available through the Environment Australia web site: http://www.environment.gov.au/epg/npi/database/index.html?Ok=OK

19. Trade

Description

The import and export of goods and commodities is an important element of the physical economy—much of the primary production in Australia is driven by export potentials (in addition to satisfying the needs of the domestic population) and significant quantities of elaborately transformed goods are imported. The level of trade is largely determined external to the Australian physical economy (i.e., as an independent input), although the import of depleted national resources is driven by the needs of the domestic population. The dollar value of exports and imports provides an external constraint to unhindered international trade through the trade balance and accumulating international debt. The trade balance includes the contribution from "invisibles" and from tourists spending in Australia and Australian's spending overseas.

Rationale for base case settings

This scenario assumes that Australian agriculture, mining and manufacturing will continue to compete at a reasonable level, innovating and adapting in response to the global market place. This may include adopting similar lifecycle and product stewardship regulations and technologies as other nations. The settings reflect a doubling (or greater) of physical production in many of our commodities over one human generation, most of which goes to exports.

Major Outcomes

Despite Australia's "resource rich" reputation, several primary materials require greater import in 2050 than planned, including round-wood, seafood (especially tuna), oil (95% of requirement) and natural gas (27% of requirement).

		1996	2050
import of oil	(million t / yr)	11	51
import of natural gas	(million t / yr)	0	9.7

.

Base Case Settings

factor	assumptions		
• primary materials and energy			
planned import of materials	proportions of domestic requirement are constant over time (set at 1996 levels)		
	phosphate	99%	top three by %
	gold ore	68%	
	tuna	57%	
	e.g., roundwood, nuts, seafood, crude oil, diamonds	>20%	
material exports	remain constant over time based on 1996 figures		
	wood	2.3 mt / yr	top three by mass
	petroleum	2.2 mt / yr	
	iron and steel	1.2 mt / yr	
secondary energy	not transferred into or out of Australia		
• elaborately transformed goods			
vehicles imported	proportions of domestic requirement are constant over time		
	most vehicles fully imported	100%	of requirement
	cars & light trucks	23%	
	urban trains & trams	20%	
vehicle exports	no exports except cars, tractors and harvestors, increasing continuously with time (~1–3% of domestic production)		
	cars	17–61,000 / y	1996–2050

	tractors and harvestors	0.9–3,000 / yr	
final demand goods imported	proportions of domestic requirement are constant over time		
	communications and office equipment	80%	of requirement
final demand goods exported	increase continuously over time from small base, for all goods		
	furniture (max in absolute and relative terms)	0–2.9 mt / yr	1996–2050
	% of domestic production of furniture	0–72%	
• prices			
materials	constant over time for all materials, based on 1996 figures—most imports equal or cheaper than exports (except salt (200% of export price) and gypsum (173% of export price))		
		export $ / t	import $ / export $
	phosphate	19	100%
	gold ore	18,000,000	21%
	tuna	3,000	28%
	wood	220	25%
	petroleum	400	100%
	iron ore	26	7%
elaborately transformed goods	constant over time for all vehicles, based on 1996 figures	export $	import $ / export $
	cars	21,000	100%
	light trucks	110,000	26%
	furniture	2,900 / t	100%
	communications + office equipment	29,000 / t	100%
interest rate for international debt	for 5 year period	28%	

.

.

.

.

.

.

.

Caveats and uncertainties

- There is substantial uncertainty regarding the price of exports and imports, and the interest rate associated with Australia's international debt. Variations are likely, but it is the long-term movement in these parameters that will impact the trade balance.
- Growth in trade exports may not remain as healthy as set in this scenario, which would have significant impacts on the resources used. Trade wars, collapse of major economies and wide-scale military conflicts could all have an impact.

References

- ABS "International Trade in Goods and Services (balance of payments basis)" in International Accounts and Trade theme of the Australia Now Statistical Profile: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/17cc02d909410fe1ca2568a900154af8!OpenDocument
- "Composition of Trade, Australia 1999", Department of Foreign Affairs and Trade, May 2000. Extract and other publications available at the AusTrade (DFAT) web site: http://www.dfat.gov.au/publications/statistics.html

20. Labour

Description

The proportion of the (civilian) population that is available to participate in work dictates the total size of the Australian labour force (which includes those unemployed); for males, the participation rate has been falling over time, while the participation rate for females has increased dramatically over the last half century although it remained lower than for males.

Correspondingly, the labour employed in each sector of the physical economy is driven by the activity in that sector (itself driven by the requirements of the population) and the productivity of the workers directly associated with the output of the sector. Additionally, a proportion of the population is involved in providing either support (e.g., management and administration) to these sectors, or service activities to the general population (e.g., financial services). Similarly, a separate proportion of the population provides Defence of the nation.

The total civilian labour force employed is a consolidation across the various sectors and service components—and since this number is less than those available for work (the labour force) the difference is the number of people that are unemployed.

Rationale for base case settings

An acceptable level of unemployment in a growing first world (industrialised) economy is about 6%. Ultimately, productivity of the labour force increases—through technological innovation—driven by two competing pressures. Firstly, increasing affluence per capita and alternatives or adjuncts to work (such as further education) result in lower overall labour participation rates. However, at the same time a growing population and economy requires greater sector output.

Major Outcomes

The labour force increases by 24% from 1996 to 2050, but then is approximately constant after 2050. On top of this level variations of 100,000 occur on a period of about 30 years due to "baby-boom" population dynamics. (The overall labour participation rate of females drops after 2006—despite the general increase over time in participation rate (by age) of females—because of a relatively large increase in the population over 65, who don't make a large contribution to the labour force.)

		1996	2050
labour force available	(millions)	9.2	11.4
labour force employed	(millions)	8.5	10.7
office workers employed	(% of labour force employed)	44%	66%

.

Base Case Settings

factor	assumptions			
• participation rates				
Defence	participation remains highest in the 25–29 age group; more females joining and less males			
			in 2050	
	males	participation rate	1.8%	of 25–29 bracket
		change in participation rate	–25%	rel. to 1996
	females	participation rate	0.9%	of 25–29 bracket
		change in participation rate	+210%	rel. to 1996
Civilian labour force	in line with ABS projections			
	males	overall participation rate	76%–59%	1996–2050
	proportion participating falls (except those over 65)		~85%	for X-Y yrs
	females	overall participation rate	55–48%	1996–2050
		proportion by age increases marginally	~78%	for X-Y yrs

• labour productivities			
occupational services	number of people based on a proportion of the total population		
		per 1000	
	Financial, Insurance, Business & Property service	60–65	1996–2050
	Community service, Health, Education, Restaurant	47–44	
	Construction and Trades	13–35	
	Total of all services	200–240	
other			
	Processing and Assembly	78–24 person / kt / yr output	1996–2050

.

.

.

.

.

Caveats and uncertainties

- The desired sector activity and output may not be achieved when skilled labour is not available and if it is not possible or economically attractive to increase the productivity of the work force. In other words an alternative for managing discrepancies between the labour force available and that needed is to reduce sector activity. Further, uncreasing pressure will be placed on the productivity of the labour force if there are further reductions in the standard hours worked per week.
- Labour requirements will be affected significantly if international trade barriers are re-established, e.g., between Europe, USA and Japan. Similarly, disease epidemics could have unpredictable effects on the composition of the work force and population, particularly if young people or fertile women are susceptible.
- Since service workers form the bulk of the labour force, and their numbers drive significant construction of buildings and are linked to much of the transport use, it is important to derive more accurate representations for the service sector.
- A movement from an industrial or primary production based economy to one based on value-adding and knowledge based services could alter employment dynamics.
- There is scope for describing the labour force in terms of skills (as opposed to occupation) to incorporate education and training processes as workers transfer between occupations, and to account for loss or gain of a skill base due to international migration.

References

- ABS “Employment”; in the Labour theme of the Australia Now Statistical Profile: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/347f52fdd7db4d82ca2568a900154970!OpenDocument
- ABS “Feature Article - Labour force projections: 1999-2016 (Oct, 1999)”; in the Labour theme of the Australia Now Statistical Profile: http://www.abs.gov.au/Ausstats/ABS%40.nsf/94713ad445ff1425ca25682000192af2/4e65f9020e6050baca2568a900154b7a!OpenDocument

Appendix 2
Resolution of Differences Between CSIRO and ABS Population Projections

ABSTRACT

Supplementary analyses were required by DIMA to explain the differences between CSIRO and ABS population projections apparently based on the same input assumptions. The key finding of this review is that, while the CSIRO and ABS assumptions both reflect the total net immigration levels specified by DIMA, different age and gender distributions of net immigration were used. In the ABS implementation, about 25% of net immigration is made up of long-term (as opposed to permanent) migrants who contribute little to overall population growth. Long-term migrants are primarily young people (students and business workers) who arrive and depart in the 18-27 year old age bracket before females reach full reproductive activity. In the CSIRO implementation, net immigration is determined from separate assumptions about immigration and emigration. These CSIRO assumptions are based on historical data adjusted to ensure that the demographic accounting identities are satisfied throughout the period 1941 to 1996. A key feature of the CSIRO age distributions is the net outflow of older people balanced by an inflow of younger people in the fertile age range. The net outcome of these differences is a higher population growth rate in the CSIRO scenarios. The differences compound over the time scale of the scenarios to produce the observed differences in projected populations.

The population size for the zero, base case and 0.67%pa scenarios projected by the ABS is 19.45m, 24.18m and 30.47m at 2050. The comparable results projected by CSIRO are 20.65m, 25.09m and 32.24m. The differences of 1.2m, 0.9m and 1.8m in 50 years time could be important and represent differences of 5.8%, 3.6% and 5.5% for the zero, base case and 0.67%pa scenarios respectively. When the implementation of the assumptions was brought into confluence (in a computational sense in the zero scenario), the difference at 2050 was 0.4m (2.1%) and 0.6m at 2100 (4.3%). In an overall sense both CSIRO and ABS view these relatively close agreements as a good outcome given the large number of different assumptions and implementation modes that could be used in national demographic projections. By 2100 the difference between CSIRO and ABS are larger, particularly in the 0.67%pa scenario.

The findings of this review highlight the importance of matching the level of detail of analysis to the goals of the project. If close agreement with particular projections is required, then scenarios need to be specified with the corresponding precision. In the present case, this would have involved a much more detailed specification of the nature and age distribution of migrants than was included in the project brief. CSIRO considers that this would not have been appropriate for the very much broader goals of this project. Indeed, the team considers that DIMA's original specification of scenarios in terms of total levels of net migration was well matched to the project goals of understanding the overall consequences to the physical economy of substantially different population policies.

Given the analyses undertaken in this report, the CSIRO analysis team is happy that the results of their demographic projections are reasonably robust and can withstand scrutiny. As ever, there is room for more detailed analysis to examine some of the issues highlighted throughout this report. This should be undertaken by experts in human demography.

INTRODUCTION

During the vetting of the second draft of this report, the Department of Immigration and Multicultural Affairs raised concerns that population projections by CSIRO and the Australian

Bureau of Statistics were producing different results. The differences are shown in Table A2.1 below.

Table A2.1. Comparison of CSIRO and ABS population projections at 2050 and 2100 (millions).

Scenario	2050			2100		
	CSIRO	ABS	% diff	CSIRO	ABS	% diff
DIMA-0	20.65	19.45	5.8	16.81	13.88	17.4
DIMA-0 (1)	19.87	19.45	2.1	14.51	13.88	4.3
DIMA-70	25.09	24.18	3.6	25.50	23.55	7.6
DIMA-0.67%	32.24	30.47	5.5	50.19	41.34	17.6

o CSIRO adopts ABS implementation of zero net immigration - i.e. zero net immigration at all ages

At 2050 the CSIRO projections were higher than the ABS projections by 1.2, 0.9 and 1.8 million persons for the zero, base case and 0.67%pa scenarios respectively. In percentage terms the CSIRO results are between 3.6% and 5.8% higher. By 2100 the differences between the projections have widened considerably to be between 2.0 and 8.9 million and from 4.3% to 17.6%. During the course of the investigations it was possible to implement the ABS assumptions for the zero scenario reasonably closely within the CSIRO model and these results are also presented in Table A2.1. This gave much closer agreement with a difference of 0.4 million (2.1%) at 2050 and 0.6 million (4.3%) at 2100. This showed that the modelling code for both projections was reasonably compatible allowing for differences in original data and ways in which particular assumptions were implemented.

If the modelling code was performing similarly, then the implementation of the driving assumptions for each population scenario was likely to be the cause of the differences between modelling outputs.

This Appendix to the main report explores these issues and highlights the differences in the detailed implementation of the same overall scenario assumptions. The conclusion is that, if precise agreement among projections is required, the details of the implementation matter and need to be specified explicitly. For the purposes of this report, the major differences between scenarios as they develop over time are more important than the smaller differences due to alternative implementations, both of which are defensible. The CSIRO analysis team is satisfied with their results and that the guiding principles of the project brief have been adhered to. There is a case to consider further development of demographic projection methods in Australia in the light of this analysis and to develop better integrated data sets that underpin them.

METHODS

The result comparison developed through five stages as follows:

- Firstly, a thorough examination was undertaken of the control variables and the output data for the demographic calculator within the Australian Stocks and Flow Framework, the CSIRO physical modelling tool. In addition the CSIRO team reviewed the published demographic projections particularly by the ABS and the ANU, to see if the CSIRO results were strange in any way, or lay outside the normal boundaries of reality and compliance.

- Secondly, meetings were held with the ANU (by phone) and with the ABS (face to face) to understand how their population projections were implemented. The first outcome of these meetings was that both ABS and ANU generally ran models with a one year time step and they adjust the levels and age distributions of net migration directly to meet the scenario specifications. By comparison, in the CSIRO approach, the model is run with a five year time step and the level and age distribution of net migration is determined indirectly from independent assumptions about immigration and emigration. This was later found to be a key difference in the methods.

- Thirdly, the datasets that quantitatively described the ABS input assumptions and output results were obtained from the ABS and this process was facilitated by DIMA staff.
- Fourthly, a wide range of data exploration approaches and modes of presentation were used to help understand the differences between the projection out comes.
- Fifthly, this report was prepared and it was circulated as a first draft stage to both the ABS and DIMA and this second draft was included as Appendix 2 in the final report to DIMA.

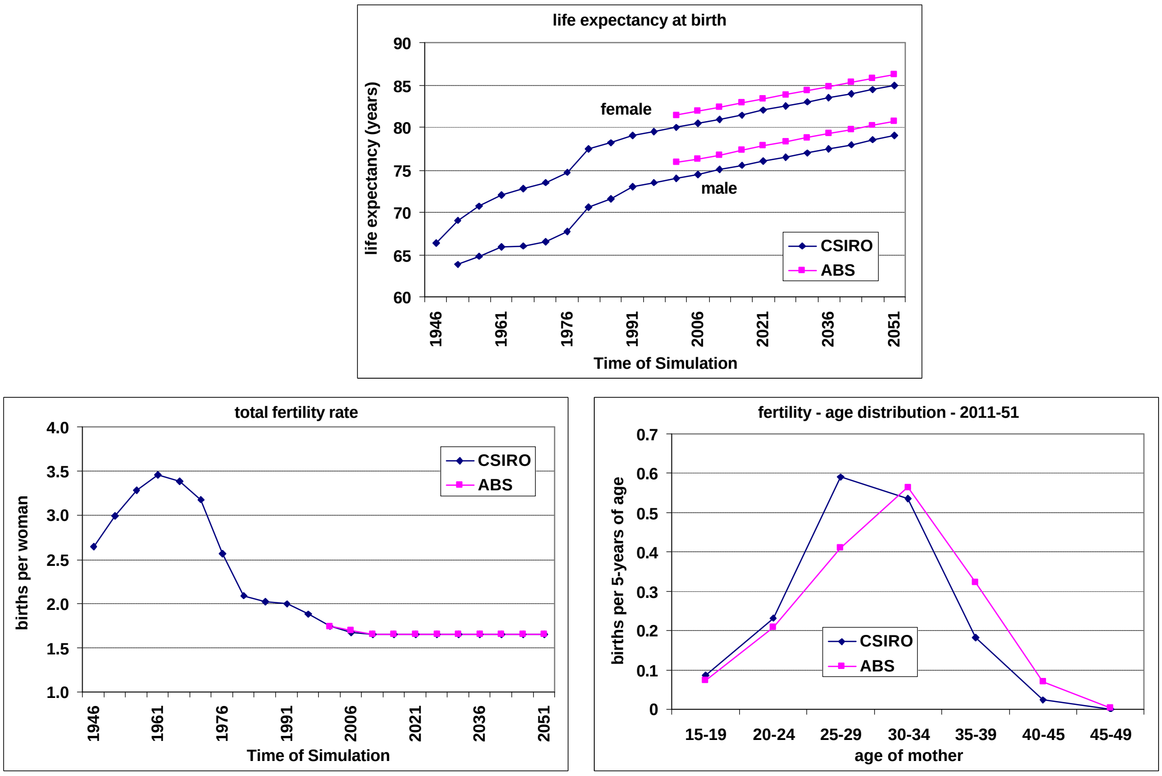


Figure A2.1. A comparison between the main control variables used by CSIRO and ABS for the demographic projections (top) life expectancy at birth, (bottom left) total fertility rate, (bottom right) age distribution of births.

RESULTS AND DISCUSSION

Birth rates and death rates

The ABS mortality assumptions lead to slightly higher life expectancies at birth than those of CSIRO. The scenario specifications for mortality were that life expectancy at birth should increase by one year per decade. Both sets of assumptions reflect this. The difference in starting point arises because, as discussed below, the CSIRO assumptions are derived from data which have been adjusted to satisfy the demographic accounting identities over the historical period. However, it should be noted that, other things being equal, this difference in mortality assumptions would tend to increase ABS population estimates in comparison with those of CSIRO, not decrease them as has been found. There is no difference between the total fertility rates assumed by the ABS and CSIRO.

There is a difference between the age specific fertility rates with the peak for the CSIRO assumptions in the late 20s and for the ABS in the early 30s. This should not make much difference if it is applied to reasonably smooth demographic age structures of females in that the same number of children will still be born for each female of reproductive age. However, the higher age of the ABS peak is significant when it is combined with the age distribution of net immigration. As shown in the next section, the ABS assumption is that net immigration is dominated by (younger) long-term migrants whose ages while in Australia are somewhat below the age of peak fertility.

ABS net immigration assumptions - one year cohorts

The age and gender distributions of the net immigration are shown for the base case (Figure A2.2) and for the 0.67%pa scenario (Figure A2.3). For the zero scenario, the ABS assumed zero net immigration for all ages and both genders.

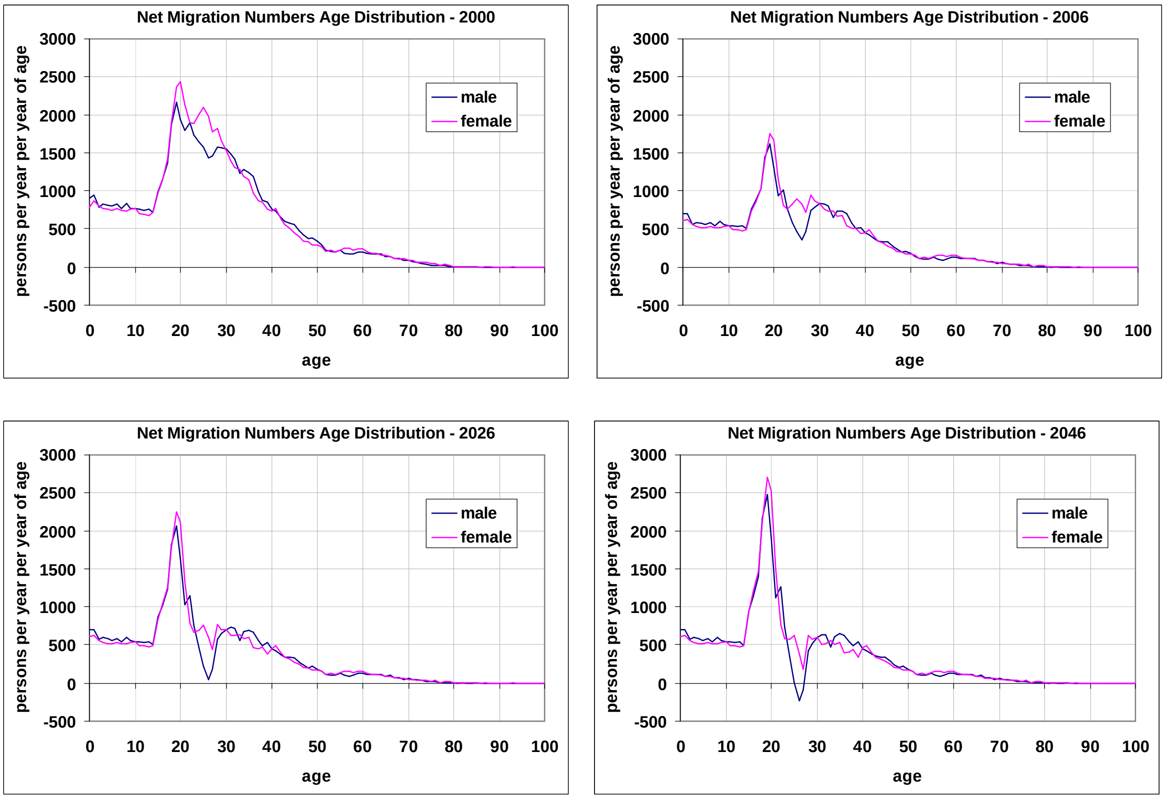


Figure A2.2. A comparison between the 'one year cohort' demographic structure of males and females for the ABS implementation of the base case scenario driven by net overseas migration rates of 70,000 persons per year. The four graphs show the distribution for the years 2000, 2006, 2026 and 2046.

Both sets of graphs show distributions characterised by distinct peaks where the long-term migration of students and business workers is overlaid on the broader permanent net migration component. Long term migration contributes about 25% of total net immigration. Long-term (as opposed to permanent) migrants tend to be young people in the age range late teens to late twenties. Their arrivals correspond to the peaks at 18-20 years and their departures to the troughs at 26-27 years. Long-term migrants make a contribution to net immigration as long as arrivals exceed departures. This is the case while the overall flow is increasing because, in any year, the number of departures corresponds to the smaller number of arrivals at an earlier time i.e. there is a lag period.

In the scenarios, adjustment of total net immigration to the specified level (constant 70,000 persons per year or 0.67% of the population per year) is achieved by separately adjusting the net levels of long-term and permanent migration. In the 70,000 scenario, permanent migration is held constant while long-term migration (in and out) continues to grow although net long-term migration is held constant (at 18,000 of the total 70,000 persons per year). In the 0.67% scenario, both components grow over the period 2006-46. See also Figure A2.4

These assumptions imply that the 25% of net migration represented by long-term migrants are present in Australia mainly in the age range 18-27 years which, as we have seen, is below the age of peak fertility. They therefore contribute relatively little to the long-term reproductive potential of the simulated Australian population. This feature is one component contributing to the difference between the CSIRO and ABS population projections.

The other main component is a difference in the assumptions about the movements of older people. As can be seen in these figures, the ABS assumption is that (with the minor exception of 26 year old males) net immigration is positive at all ages. In particular, it is positive for ages over 60. This is in contrast to the CSIRO assumptions.

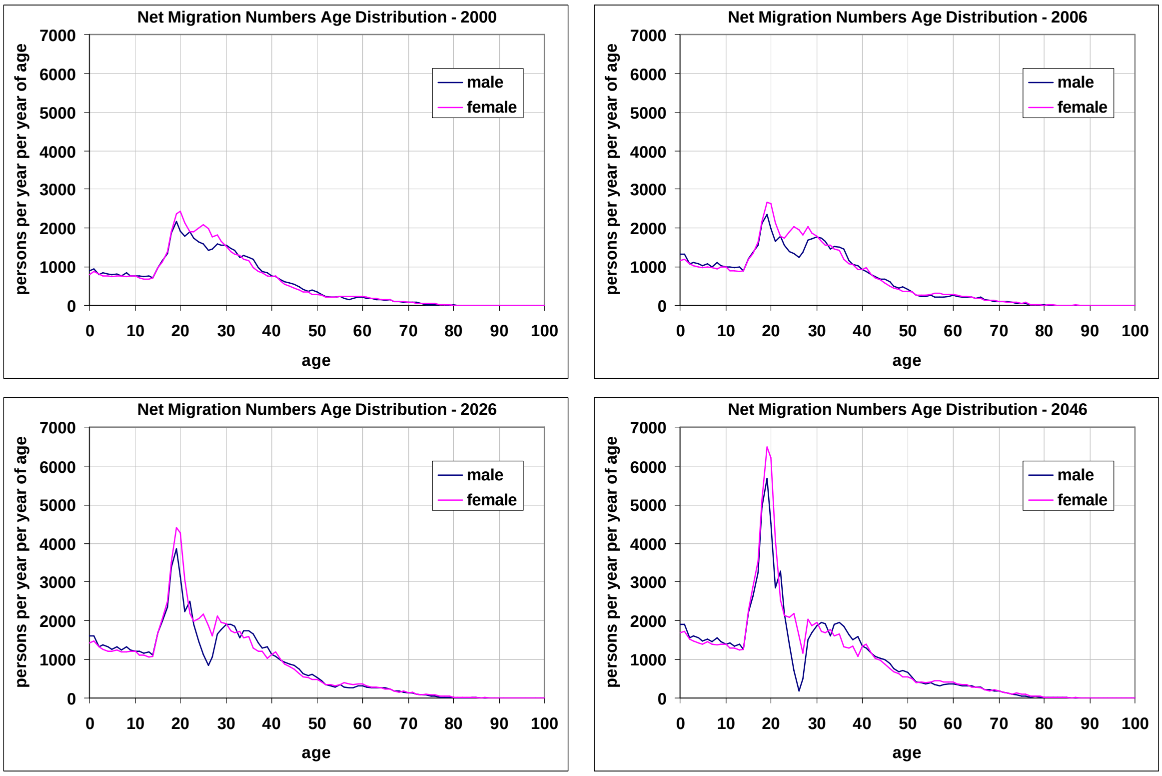


Figure A2.3. A comparison between the 'one year cohort' demographic structure of males and females for the ABS implementation of the 0.67%pa scenario driven by net overseas migration rates of 0.67% of yearly population. The four graphs show the distribution for the years 2000, 2006, 2026 and 2046.

ABS net immigration assumptions - five year cohorts

In Figure A2.4 the net immigration distributions are presented in five-year cohorts and the genders combined to allow easier comparison with the CSIRO assumption where the modelling uses a five year time step. The spikes and the troughs corresponding to long-term migration are still evident in this presentation although not as pronounced as in Figures A2.2 and A2.3. Again we should note that the distributions are positive at all ages.

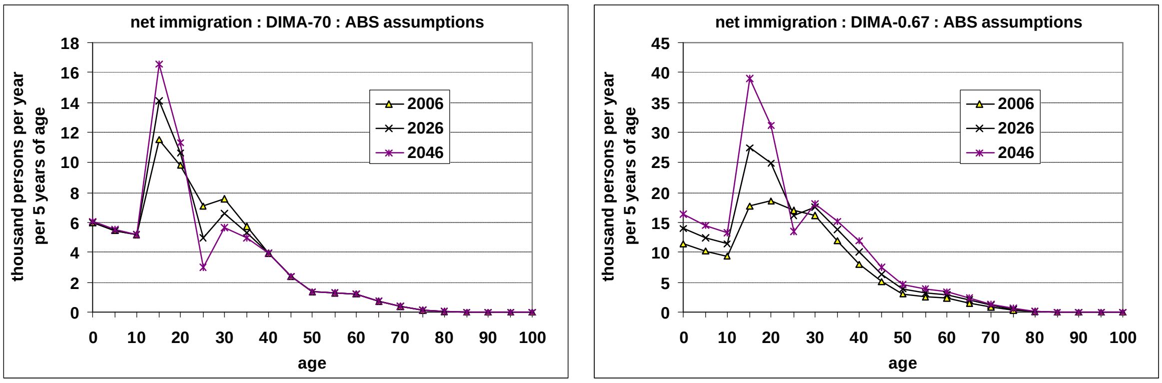


Figure A2.4. A reformatting of the ABS one-year cohorts to five-year cohorts to enable easier comparison with he CSIRO assumptions. The graphs show the distribution for the years 2006, 2026 and 2046 for the base case (left graph) and 0.67%pa scenarios. Note that the y scales are different.

CSIRO immigration and emigration assumptions

Net immigration is the result of separate processes of immigration and emigration. There are no motivational factors leading to characteristic distributions of net immigration as such. Rather, the motivational factors for immigration and emigration operate independently to give characteristic distributions for each component. The level and the age and gender distributions of net immigration are then obtained simply as the algebraic sum of immigration and emigration.

The CSIRO assumptions for the age and gender distribution of net immigration are therefore derived from explicit assumptions about immigration and emigration. These are shown in Figure A2.5.

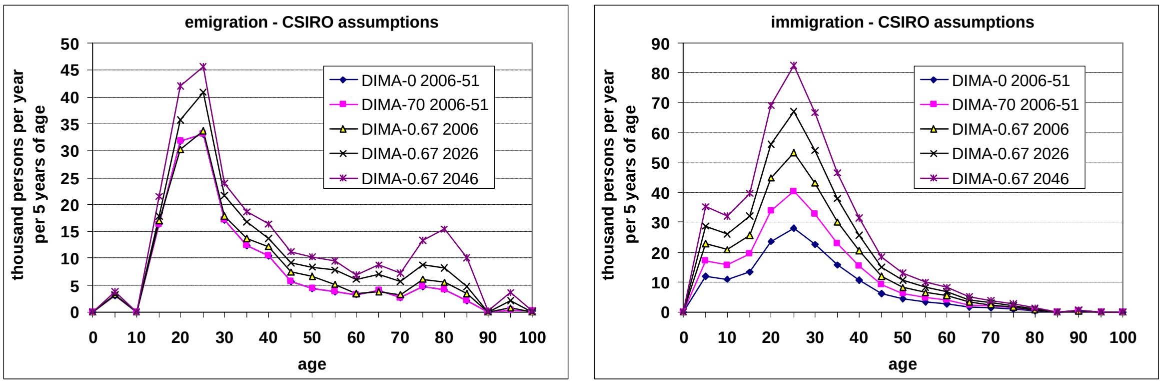


Figure A2.5. The emigration (left graph) and immigration (right graph) assumptions used in the CSIRO implementation of specified levels of net immigration. One graph is shown for the zero and base case scenarios while the year 2006, 2026 and 2046 are shown for the 0.67%pa scenario. Note different y-axis scales.

Emigration has its source in the Australian population and its characteristics should therefore reflect the changing structure of the population. This is taken into account in the CSIRO assumptions where the level and the age and gender distribution of emigration are determined by applying a constant propensity to emigrate (the probability that a person of a particular age and gender will choose to emigrate) to the evolving population. The main features of the propensity to emigrate are a strong peak for people in their 20s and a lesser one for people in their 70s. Because of the ageing of the Australian population the proportion of emigration in the older group grows with the passage of time.

Immigration has its source outside Australia and its age and gender distribution is assumed to be independent of Australian conditions and is therefore kept constant. The distribution has a strong peak for people in their 20s and declines continuously to greater ages. The level of immigration, on the other hand, is a policy variable under Australian control. In the scenarios, the specified level of total net immigration is achieved by adjusting the immigration level after emigration has been determined as described above.

Comparing CSIRO and ABS assumptions in net immigration terms

This section converts the CSIRO assumptions for immigration and emigration into net immigration terms and compares them to the ABS assumptions for each scenario. The comparison is shown in Figure A2.6 below, where the CSIRO curves are the net effect of subtracting the left hand graph (emigration) from the right hand graph (immigration) in Figure A2.5. The ABS curves are obtained from Figure A2.4. For the zero scenario, the ABS distribution is flat, corresponding to the ABS assumption of zero net immigration for all ages and both genders. The CSIRO assumption for zero net immigration is the result of combining equal numbers of immigrants and emigrants. However, because immigrants and emigrants have different age distributions, the resulting distribution is not zero at all ages even though total net immigration is zero.

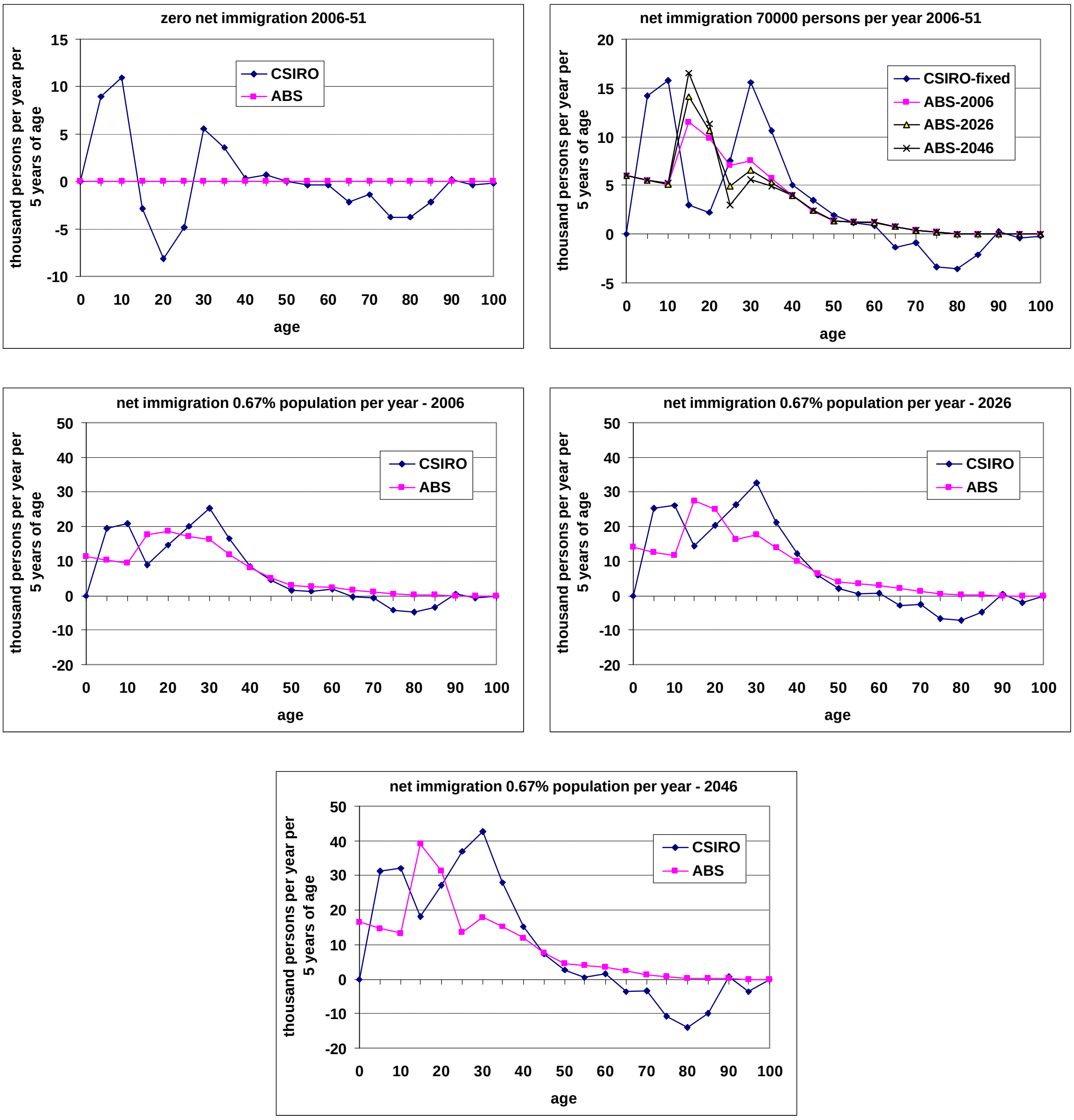


Figure A2.6. A comparison of the net immigration rates implemented by ABS and CSIRO for the zero (top left), base case (top right) and 0.67%pa scenario (bottom three graphs for the years 2006, 2026 and 2046).

A similar picture is shown for the base case scenario for the CSIRO assumptions except that the whole relationship has moved into surplus for the younger age groups and a trough remains for the post sixties cohorts. For the ABS scenarios net immigration is shown for the three years 2006, 2026 and 2046. These show increasing peaks and troughs through time, reflecting the assumption of increasing long-term migration. The same differences in cohort distribution are shown in the three graphs that describe the 0.67%pa scenario.

The most important difference between the CSIRO and ABS assumptions for these scenarios is the negative net immigration (i.e. net emigration) of people over 60 in the CSIRO scenarios. We have already noted that this is not the case in the ABS scenarios. A rationale for this older emigration could be the return after retirement of former immigrants to their countries of origin. The demographic effect of this is that older women are replaced by younger women near their peak of fertility, and this leads to a greater rate of population growth in the CSIRO scenarios.

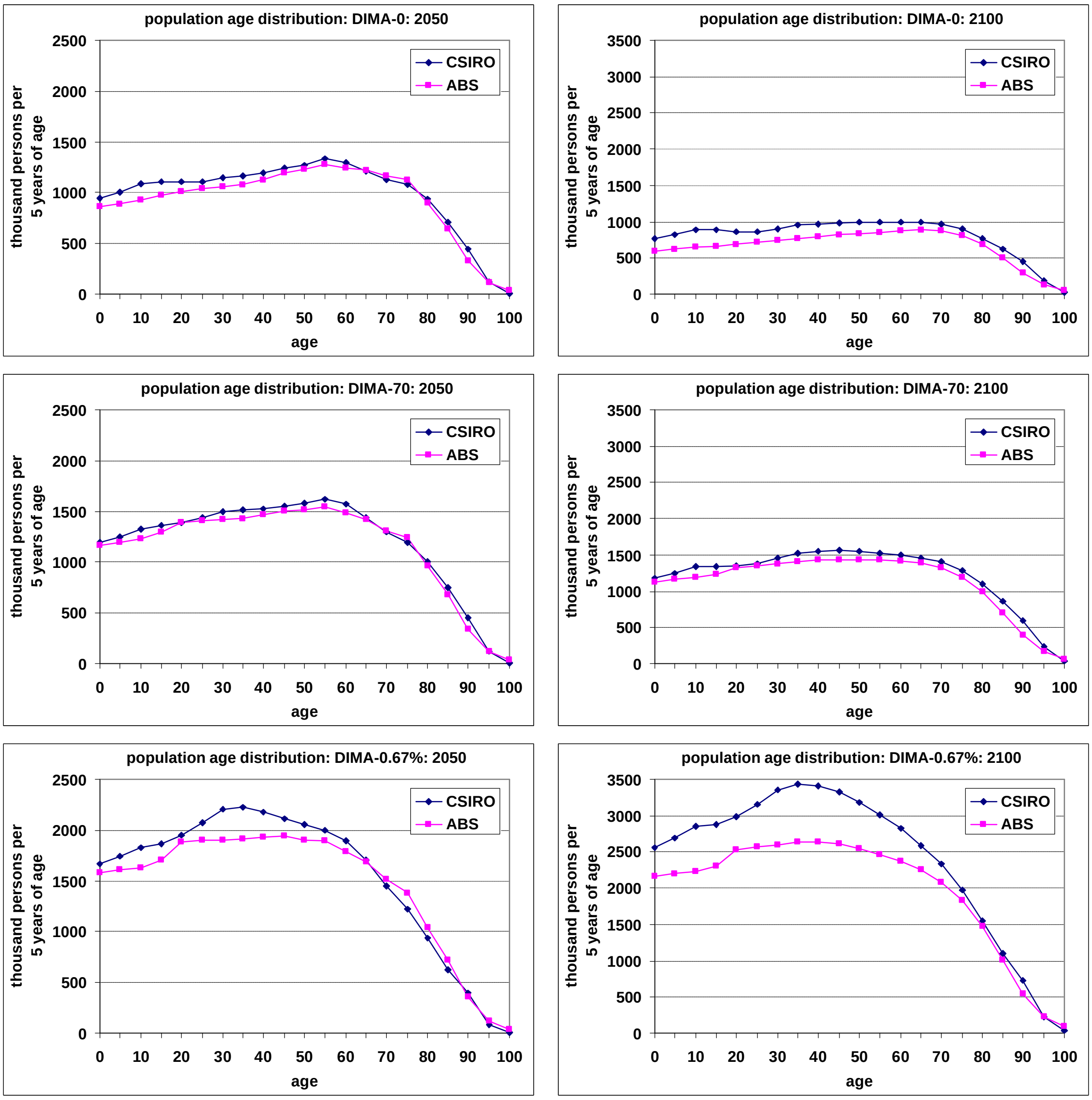


Figure A2.6. A comparison of the age structures (male and female combined) for the years 2050 (left) and 2100 (right) for the zero population scenario (top), the base case population scenario (middle) and the 0.67%pa scenario (bottom).

.

Comparing population distributions at 2050 and 2100

Figure A2.6 compares the distributions of age classes (male and female combined) for the CSIRO and ABS implementation of the scenarios for the years 2050 and 2100. The main point of this approach is to ensure that there are not any bumps and troughs in the distributions that cannot be explained. This was one avenue of exploration to make sure that the slight difference in mortality assumptions did not result in any build up of number in older age cohorts.

The main difference for the zero scenario is higher numbers of younger age cohorts that reflect the higher reproductive potential of this scenario as both teenagers and their parents flow inwards to balance those that leave. The picture shown by this scenario implementation is still one of population decline but a decline that does not accelerate at the same rate as the ABS scenario. The potential for a continuing flow of immigrant families, however small, to partially sustain the reproductive potential is thus important over timeframes of 100 years and four human generations.

For the base case scenario the distributions match more closely. The CSIRO line for the 2050 distribution tracks above the ABS line up to the 60-year old cohort and then is essentially the same. For the 2100 distribution, the CSIRO line tracks higher for the entire distribution reflecting the extra two million people projected by the CSIRO approach.

For the 0.67%pa scenario there are substantial differences in size and distribution, again reflecting the higher total numbers simulated by the CSIRO implementation of the scenario. The 'demographic bump' described in Chapter 7, which produces a number of dynamics in different aspects of Australia's physical economy is clearly shown in the CSIRO line and this compares to a relatively flat distribution in the ABS line. These differences are caused by subtle implementations of the young female effect by both CSIRO and the ABS. The CSIRO approach perhaps causes a slight enhancement of the young-female effect and the ABS approach tends to partially constrain the effect. Once again it is obvious that over four human generations, the effect can be substantial.

Matching the assumptions in the zero scenario

Different implementations of the migration assumptions are the main cause of the differences in the results. This can be shown most easily with the DIMA-0 scenario. As shown above, ABS assumes zero net immigration for all ages and both genders while CSIRO assumes overall zero net immigration resulting from non-zero immigration and emigration in different age classes. Figure A2.7 repeats the DIMA-0 population age distributions for 2050 and 2100 shown at a different scale at the top of Figure A2.6.

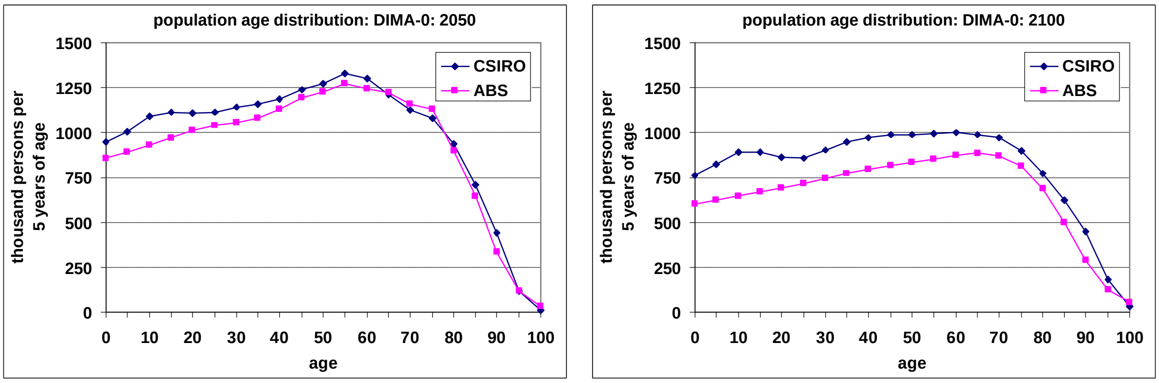


Figure A2.7. A comparison of the age structures (male and female combined) for the years 2050 (left) and 2100 (right) for the zero population scenario driven by different implementations of the net immigration rate by CSIRO and ABS.

The differences are mainly due to CSIRO's assumption that zero net immigration can result from younger immigration balancing older emigration. The differences almost disappear if CSIRO adopts the ABS assumption of zero net immigration at all ages (Figure A2.8). There remain slight differences between the CSIRO and ABS lines and precise explanations of these are difficult to find without more investigation. Some of it could be due to differences in initial starting conditions and the transition pathway from the current size and structure of population stocks and flows to the situation intended under the zero scenario that is being implemented.

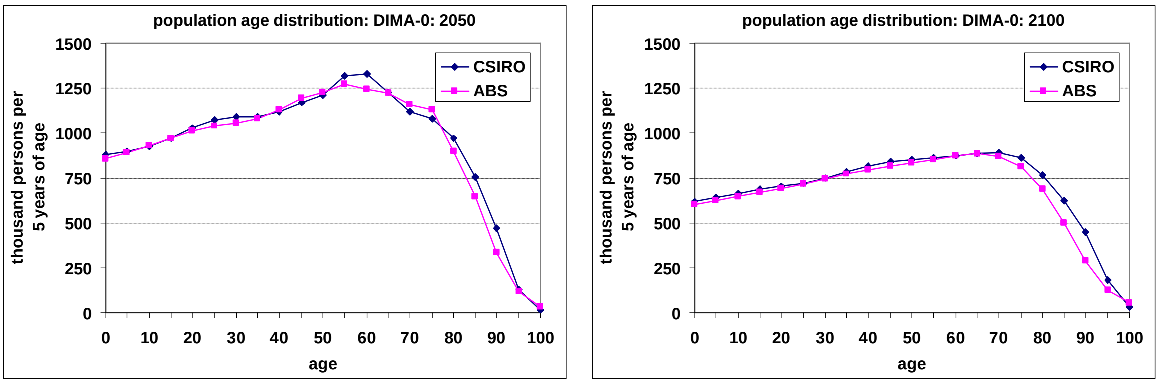


Figure A2.8. A comparison of the age structures (male and female combined) for the years 2050 (left) and 2100 (right) for the zero population scenario driven by similar implementations of the net immigration rate by CSIRO and ABS.

Historical data and calibration (grounding the ASFF model)

Demographic data come from a number of sources with different levels of reliability. Very roughly, we would expect births and deaths to be most reliable, then census data, and lastly migration data. Naturally, we do our best to use the best data available.

Demography is an accounting process. People are born and they die, they arrive and depart, and they age. There are no other processes. Together these processes establish a set of accounting identities which should be satisfied at all times. These identities are the bases of models used for demographic projections. Starting from the current population, and making assumptions about fertility, mortality and migration, we can calculate births, deaths, population numbers and age distributions. Because of the way the models are set up, the demographic identities are automatically satisfied for projections.

But this is not generally true for historical data. Time series of demographic variables are generally best estimates as obtained from the sources of the data. As such, they are subject to varying levels of error and will not, in general, satisfy the accounting identities. In other words, running the demographic models with historical input will not in general give the historical output as represented by published time series.

We have taken the view that internal consistency is important. It is part of our understanding of reality. The other part is provided by the values of variables as observed (but subject to error). We attempt to reconcile the two by running our models over the entire historical period. If there are discrepancies (i.e. if historical input does not give the historical output) then something has to be changed. In other disciplines, changes might be required to the models themselves. But in demography we are confident of the accounting identities, and discrepancies are much more likely to be due to errors in the data. We therefore make the adjustments to the data - taking account of the hierarchy of confidence in their reliability. Because migration data are more likely to be subject to error than the other data, most of the adjustment is made to the migration data which is estimated as a residual. A smaller adjustment is made to fertility. The procedure is as follows:

- get historical time series
    - population by age and gender;
    - age specific fertility;
    - age and gender specific mortality;
    - total net immigration;
    - assume fraction of total net immigration in first age class (0-4 years) ;
- step through the historical period re-estimating fertility and net migration so that the demographic accounting identities give the observed population change (by age and gender) between successive observations
    - determine target births and gender share from the first age class of target population;
    - revise target births by assumed net immigration in the first age class;
    - estimate this period's population from last period's population assuming observed fertility, gender share and mortality - with zero migration;
    - estimate this period's births from the first age class of the estimated population;
    - scale this period's observed fertility by the ratio of (revised) target births to estimated births;
    - re-estimate this period's population as before but using scaled fertility
        : differences between the new estimated population and the target population are assumed to be accounted for by net immigration (set by assumption for the first age class)
- subsequently, adjust historical time series for immigration and emigration to be consistent with the net immigration.

This procedure preserves the observed values of population and mortality and adjusts fertility and net immigration to ensure that the demographic accounting identities are satisfied at all times. Other internally consistent schemes could have been used. Indeed, it could be asked why, if births are among the more reliable data, we have chosen to adjust fertility. Part of the reason is that it is easier, because in any time period fertility has its impact only on the first age class. The other part of the reason is that, unlike births, fertility is not primary data. Fertility is not observed directly but, in the simplest case, as the ratio of births to female population of childbearing age. Fertility time series are not, therefore as reliable as births because, at the least, they include the uncertainties associated with population data - plus the impact of any other assumptions in the estimating procedure. Similar considerations apply to mortality - leading to the conclusion that, ideally, we would work with population, births and deaths rather than population fertility and mortality.

The above process is used in all 32 calculators within the Australian Stocks and Flows model.

CONCLUSIONS

Overall conclusions

The overall conclusion is that the ABS and CSIRO modelling approaches produce close agreement if the same assumptions are made. This was shown for the zero population scenario where it was relatively easy to mimic the net immigration assumptions used by the ABS and ANU demography groups. The CSIRO result of 19.87m was within 2% of the ABS result of 19.45m for the year 2050.

The principal reason for the different results is that, while CSIRO and ABS adopt the same specified total net immigration levels, they implement the migration process in different ways. In particular, their assumptions about the age distributions of net immigration are different. There are two components to these differences and each leads to higher rates of population growth in the CSIRO scenarios.

The ABS assumptions are dominated by long-term (as opposed to permanent) migration of young people whose ages, while they are in Australia, are in the range 18-27 years, which is substantially before the ages of peak fertility. This component of net immigration therefore contributes relatively little to long-term population growth in the ABS scenarios.

The CSIRO derives net immigration from separate assumptions about immigration and emigration which, while they meet the specified level of total net immigration, involve a net outflow (emigration) of people over 60 balanced by a greater net inflow (immigration) of younger people. This process tends to increase population growth in the CSIRO scenarios because it replaces older women by younger women at the peak of their fertility.

Given the data complexity issues the CSIRO perspective on the differences that have been examined is as follows:

- The modelling methods have produced results within 2% of each other when approximately the same assumptions can be numerically implemented

- The CSIRO method has a reasonably robust approach to the reconciliation of the nation's historical demographic structures and the separation of immigration and emigration flows which produce important analytical flow-on effects over four human generations.

- The ABS approach appears to have a specific and logical implementation for the separation of long-term and permanent immigrants. This removes an important component of females of peak reproductive age and the compounding effect of this leads to lower population projections at 2050 and larger differences at 2100 when compared to the CSIRO projections.

- The highly specific nature of the long-term, versus the permanent immigration flows was not specified in the original project brief where the main focus was net overseas migration. In retrospect it could be seen that these investigations have stimulated some analytical focus on the importance of this issue.

- Given all of the above, the CSIRO implementation of the population scenarios is judged to be robust and defensible. However, there is good cause for further analysis of these issues to be conducted by experts in demography should a more transparent population projection be required for national policy development.

Understanding current data and future trends

Given the possible importance of these population projections in policy terms, a key point emerging from the CSIRO analyses is the requirement to have access to long-term original data. Much of the information and data used in all national analysis is of a derived type e.g. the birth rates rather than the actual births at a finer spatial scale than national statistics. In this case the original data on births and deaths is reasonably robust and accurate. These data could provide a tight boundary and reality check in the data reconciliation procedures that contribute to the process of model grounding used by the CSIRO approach. Given the focus of this particular analysis, data from longitudinal surveys on the behaviour and dynamics of long-term immigrants would be useful.

In the ABS implementation of the population projections, the spike and trough of long-term migrants and the differential between males and females should be examined in a long-term context in much the same way as a good theoretical background to human fertility has been developed by examining the demographic transition in other countries. The observed data for the year 2000 describes a current demographic structure. To project an ever enlarging spike and trough through a demographic analysis is a reasonable approach, but could merit further examination. In particular the compounding effect through generations, for females of reproductive age and subsequent numbers of births, is a key feature of the differences between the CSIRO and ABS results.

Policy implications

That the reconciliation of the ABS and CSIRO population projections had to be undertaken possibly provides a number of rewards in overall policy terms in that it may help refine important quantitative issues that have remained hidden or unclear to date. In an overall population policy sense there are four issues from the CSIRO 'physical economy' viewpoint or paradigm as follows:

- That current population policy is directed towards the management of flows (current rates of immigration and emigration) rather than stocks (a long-term transparent goal of population size and structure) is an issue that pervades all modern economies. This is perhaps just a philosophical point but one that emerges in many parts of this study. In the real cut and thrust of politics and policy development though, it is perhaps a moot point. If Australia had a population target there would be much analysis and discussion about how to get there. At the moment without a defined stocks policy, the discussion is about flows and what they mean in terms of eventual stocks. The saving grace is that a considerable amount of quantitative analysis and policy is based on relatively robust numeracy, even if it does throw up the type of quandary explored in this section.

- For both the industry and environment stakeholders in national population policy there are some mixed messages in the analytical outcomes of the two analyses. If the lower numbers are accepted as more realistic, then for business interests the churn of long-term immigration (mainly students and business managers) offers opportunities for commerce but may not provide the long-term consumer whom they would like to provide for during their full lifecycle. If the long-term component leave before household formation and possible family activities, then industrial sectors that supply houses, whitegoods and furnishings may lose the business rewards that they expected from national population policy. On the other hand, the nation does not have to provide for their primary and secondary education and it does not have to look after them in their old age. The environmental stakeholders might claim that this component of the immigration intake requires most normal consumption items thereby adding to material and energy flows. However there is no long-term environmental concern engendered in this group, and they may not be available to re-invest their superannuation funds in long-term natural capital, or in the social capital required to build a happy and prosperous lifestyle. One wild card to consider is whether the long-term component would achieve the levels proposed in the ABS assumptions if global shocks were to occur such as higher oil prices, economic meltdowns in source countries, if Australia became a multinational branch office and if the communications revolution meant that prospective long-term immigrants could remain in their own countries, and still receive the services required from Australian business and education.

- This excursion into assumptions, data and analytical methods seems to enforce the trend that public policy must increasingly focus on finer levels of detail. This will require that policy analysts in national service will increasingly be required to have reasonable competence in analytical and modelling methods that underpin their policy development process. In this context there is a reasonable argument for maintaining high quality and reputable capability within policy groups so that issues and analysis can evolve in tandem. This may conflict with current outsourcing trends. The increased analytical endeavour must be balanced against a requirement that analysts keep their world view intact and in sympathy with the requirements of their minister. To be guarded against is the seductive pleasure of deep numeracy from which little real policy advantage can be gleaned i.e. the trees versus the forest analogy.

- A busy policy advisor with an agnostic view of this data inquisition by might wonder whether the world view of the organisation dictates the way in which the population scenarios are presented. Between these two sets of population projections are two important insights. The first is that out to 2050 both sets of projections agree reasonably well, especially given the potential complexity of model implementation and the assumptions used. The second is that the absolute numbers of females of reproductive age, even with a declining birthrate, can still make a substantial contribution to population maintenance or growth, across four human generations. Better data and more policy focus on this area may be justified.

SUMMARY OF ASSUMPTIONS

Comparison of CSIRO and ABS assumptions

Table A2.2. A comparison of the implementation of the demographic assumption by CSIRO and ABS

Parameter	CSIRO	ABS
Fertility		
total fertility rate	1.65 from 2011	1.65 from 2011
fertility age distribution	peaks at 25-29	peaks at 30-34
Mortality		
life expectancy at birth	increase 1 year each decade to 2061 then constant male: 74.0 - 79.0 (2001-51) female: 80.0 - 85.0 (2001-51)	increase 1 year each decade to 2051 (then fixed at as at 2051) male: 75.9 - 80.8 (2001-51) female: 81.4 - 86.3 (2001-51)
Migration	net immigration based on assumptions about immigration and emigration	net immigration assumptions provided - assumptions about immigration and emigration not explicit (but do not use emigration propensity)
immigration	1991 age x gender distribution scaled as required 3% over 65 yrs	not explicit
emigration	DIMA-0 and DIMA-70: 1991 emigration held constant DIMA-0.67%: 1991 emigration propensity held constant. Emigration determined from emigration propensity and evolving	not explicit

	population 11-21% over 65 yrs	
net immigration	immigration - emigration immigration scaled to give required total net immigration. negative for cohorts over 65 yrs	While migration is still dominated by the permanent component, yearly flows have a significant proportion of long-term migrants - this gives large peak at 15-20 yrs and trough at 25-29 yrs. positive for all 5 yr cohorts