Australian Government
Department of Immigration and Citizenship

About the research

Long-term physical implications of net overseas migration: Australia in 2050

Dr Jonathan Sobels, Professor Sue Richardson, Dr Graham Turner (CSIRO), Associate Professor Alaric Maude, Dr Yan Tan, Professor Andrew Beer, Dr Zhang Wei

This research set out to examine the nature of the relationship between population growth driven by particular long term average levels of net overseas migration (NOM), the implications on Australia's natural and built physical environment over the next fifty years, and relevant policy considerations. The research was commissioned to complement research on the impact of migration on future economic and labour force growth ('Demographic and labour supply futures for Australia', Professor Peter McDonald & Jeromey Temple, Australian Demographic & Social Research Institute, Australian National University, July 2010).

This research offers the benefit of varied perspectives from a range of disciplines and methodological approaches. One of the approaches was to deploy the Australian Stocks and Flows Framework (ASFF), a physical model of the environment and the economy. The utility of this model is highly contested by experts, and findings resulting from this modelling should be interpreted with caution. Reviews of this modelling are available on the Department of Immigration and Citizenship's website.

Key messages

Scale and location are crucial to understanding physical implications of population change. The focus of concern for managing the physical implications of NOM should be on particular locations at the regional/local level as the impact of population/NOM dynamics is more critical for some locations than others.

In general, and having regard to the highly contested reliability of the ASFF, the macro-scale modelling found that higher levels of NOM impose greater adverse impacts on the quality of our natural and built environments, other things being equal.

Future research should focus on identifying ways of improving the adaptive efficiency of regions of Australia in which increases in NOM are most likely to take place. Any quantitative modelling used in such research should include to the extent possible prices, and have regard to the role of positive and negative feedback processes, risk and uncertainty in the Australian economy, the interconnectivity of the Australian economy with the rest of the world, and include considerations such as the role of terms of trade, exchange rates and foreign debt in the Australian economy.

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Research into the Long-Term Physical Implications of Net Overseas Migration

Australia in 2050

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Dr. Jonathan D. Sobels

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Executive Summary

This report set out to establish the impact of various levels of Net Overseas Migration on Australia's natural assets and built environment. The time frame was from the present (2010) to mid-century. The work was commissioned by the Australian Department of Immigration and Citizenship (DIAC).

Net overseas migration (NOM) is the difference between those leaving Australia permanently or for 12 months or longer (long-term) and those arriving permanently or long–term. It includes the inflow and outflow of the large volumes of international students and business-sponsored temporary workers. Natural assets studied include water quantity, water quality, oil resources, land use and land use change, food production, air pollution, waste assimilation and biodiversity. The built environment includes energy supply, greenhouse gas emissions, traffic congestion and transportation infrastructure.

This study addressed four Key Questions:

1: What is the nature of the relationship between population growth driven by particular long term average levels of NOM, and the implications of each average level of NOM on Australia's Natural and Built Physical Environment.

2: What are the implications of each average level of NOM on Australia's Natural and Built Physical Environment over the next fifty years?

3: What key considerations, concerns and constraints should the proposed long term immigration planning framework take into account in terms of the interactions between NOM and the optimal development and sustainability of Australia's Natural and Built Physical Environment?

4: In relation to each average level of NOM, what measures may be considered by the Australian government to counterbalance the negative impacts, or to optimise the positive impacts, on Australia's Natural and Built Physical Environment?

This report adopts a multi-level strategy for the calculation of the impact of NOM on Australia's physical environments, both natural and built. We explore the issues at multiple scales, with particular spatial references, analysed by three methodologies. We do this because there is no single analytical or empirical approach that can yet be relied on to estimate the impacts of interest and to look forward 40 years. To focus on any one dimension or component of the strategy is to miss the point of the exercise. To understand the interaction of increased migration/ population with the physical environment requires analysis of meso-level empirical data and micro-level behaviours, in equal measure, with modelling at the macro-scale.

We discuss factors that influence outcomes associated with different NOM levels in terms of complexity, interdependence, uncertainty and conflict. The adoption of three methodologies allowed the findings to be compared and contrasted such that commonalities reinforce the validity of the findings of any one of the methodologies.

The three approaches applied at different geographic scales were: modelling natural environment stocks and flows at the macro-scale; empirical data collection and analysis of specific locations at the meso-scale; and a series of essays synthesising literature at the micro-scale. Where comparisons were available across scales, results from the three methods were found to be consistent and therefore, robust.

We emphasize that the issues that we are investigating are a complex combination of physical, economic, social and policy relationships. The current state of knowledge does not allow us to fully understand any one of these, let alone all in combination. The challenge is that much greater when we seek to project relationships and outcomes 40 years into the future. This is one reason for not relying on a single type of analysis. Our findings should be understood as thoughtful, well-informed, judgements that are based on original analytical work, insights from the literature, and detailed place-based case studies. Their contribution is to highlight the likely environmental pressure points that a growing population will generate, and any migrant-specific dimensions to these. We hope that our methods and findings make a valuable contribution to a continuing debate about the interactions between migration, population and the environment. They will not be the last word.

A helpful context for the key findings is provided in an address given in 2009 by the Secretary to the Treasury, Dr Ken Henry

> --- we are now projecting an increase of 13 million people, or around 60 per cent, over the next 40 years. A population expansion of this order has a host of implications for the Australian economy and society; and it raises a number of profound issues for economic policy.
>
> Where will these 13 million people live – in our current major cities and regional centres or in cities we haven't yet even started to build? –
>
> How will Sydney cope with a 54 per cent increase in its population, Melbourne a 74 per cent increase and Brisbane a 106 per cent increase? Surely not by continuing to expand their geographic footprints at the same rate as in the past several decades. Surely not by loading more cars and trucks onto road networks that can't cope with today's traffic.
> However our cities do cope, they will have to find ways of securing a sustainably higher level of investment in public infrastructure.
>
> What sorts of jobs will this larger population want? ---How will the location of the jobs be reconciled with preferences about where people want to live?
>
> Are Australia's natural resource endowments, including water, capable of sustaining a population of 35 million? What are the implications for environmental amenity of this sort of population growth? Must it mean an even greater loss of biodiversity – difficult as that might be to imagine, given our history of species extermination?
>
> We don't know the answers to these questions, even though all of us would have opinions.

This report deals with the physical world within which the impact of higher net overseas migration is felt. Our response to the brief covers the major issues of concern to the Secretary of the Treasury. Our key findings are relevant to the Department of Immigration and Citizenship as sponsor of the study, the Department of the Treasury and the new portfolio of the Minister for Population. Our findings represent a step towards a greater understanding of immigration and population impact on the natural and built world.

Our key conclusions are:

1. In general, the macro-scale modelling found that higher levels of NOM impose greater adverse impacts on the quality of our natural and built environments. Key impacts are outlined below. The modelling demonstrates an approximately linear correlation between the NOM level and the magnitude of many impacts at any given year. This does not imply cause and effect relationships due to the complexity of the physical relationships and independent social variables that are involved in our social and economic systems. In particular, other variables such as individual affluence expressed as per capita consumption, industrial activity and technological efficiency play a role in the extent of the impacts; none were without negative consequences.

2. The meso-scale analysis established that migrants are essentially similar to Australian residents in adopting Australian consumption patterns and lifestyles except that they congregate in particular locations, especially within Sydney, Melbourne and Perth. This geographical concentration substantially increases their environmental impact.

3. Decreased urban water supply is a significant environmental constraint exacerbated by higher levels of NOM. Modelling shows the vulnerability of Sydney, Melbourne, Brisbane and Perth to deficits in water supply, on a NOM strategy of 260,000 pa.: a view strongly supported by empirical review of State Government reports. The effect on water infrastructure investment of the most recent drought and entry to a drier, hotter climatic phase since the 1990s was substantial. State Governments were compelled to review future strategies and implement infrastructure spending of billions of dollars. It remains moot whether this increased capacity for our cities will cope in the next drought, given that they will have substantially larger populations nudging absolute water demand ever higher, even with improved water use efficiencies from behavioural and technological solutions.

4. Only NOM levels of 50,000 pa or less result in Melbourne and Sydney maintaining a small surplus of net surface supply over demand on average out to 2050, assuming current climate conditions persist. Potential options to alleviate water stress at high NOM levels over the longer term may be hard to find.

5. Oil is a physical resource in a critical state of supply, which macro-scale modelling reveals to be particularly grim for transport fuel. Domestic production of oil could diminish quickly within the next 1–2 decades, independent of, i.e., at similar rates for, all NOM levels. In contrast, demand for oil increases steadily over time and at faster rates for higher NOM levels. Demand for oil reaches about double recent volumes by 2050 for a NOM of 260,000 pa. NOM levels of 50,000 pa or less result in demand remaining

marginally below recent volumes. This reduction reflects increases in vehicle fuel efficiency countering most of the effects of increased affluence and consumption.

6. Analysis of any potential resolution of an impending gap between demand and supply of oil—or the implications of not resolving the gap—is complex, fraught with uncertainties and is beyond any predictive modelling. It is unclear, for example, what volume of foreign oil might be available for import to Australia and at what price. Substitution of conventional oil by a range of alternative transport fuels, or wider use of public transit and modal shifts present other options for maintaining transport services. Issues of timely infrastructure development, as identified in the meso-scale reviews, and of increased pressure on other environmental resources arise with such options.

7. The micro-scale analysis revealed that increased traffic congestion caused by higher levels of NOM is estimated to reduce people's subjective well-being by up to 10% of their income. Our conjecture is that this has important implications for employment location and housing (re) development, since congestion perceived at this level alters people's preferences. Their response is to adapt to the unreasonable time and distance required to travel to work by moving to other jobs and locations. Melbourne has maintained a relatively constant average commuting time to work of 20 minutes over the last two decades demonstrating an adaptive capacity in the people of Melbourne.

8. Assuming that critical oil and water resource issues are addressed to support ongoing economic activity, greenhouse gas (GHG) emissions are expected to grow to several times current levels by 2050 unless substantial and rapid mitigation activities are implemented. The level of emissions is sensitive to levels of NOM, and grow in an accelerating manner with time. By mid-century, GHG emissions from fuel combustion were modelled to increase by about 60% above contemporary levels for a zero NOM level, and by 170%, and 200% for a NOM of 180,000 and 260,000 p.a. respectively.

9. The growth in GHG emissions is not as rapid as the modelled economic growth, calculated as GDP in the macro-scale modelling. This *relative* decoupling of the economy from emissions results in the aggregate carbon intensity (tonnes of CO2 emitted per dollar of GDP) decreasing by approximately 50% by 2050. This is facilitated by increases in efficiencies and structural changes in the economy, but overall economic growth results in higher *absolute* GHG emissions.

10. Accompanying this overall economic growth are additional pressures at the meso- or regional scale. Urban expansion occurs for all NOM levels in the modelling, with total urban area increasing about 50% in 2050 for zero NOM in a slightly saturating trend over time. For a NOM of 260,000 pa accelerating expansion results in an increase of about 150%.

Implications of such urban growth include the loss of horticultural production from peri-urban areas which will reduce access to high quality fresh food especially vegetables and increase the vulnerability of food supply for consumers. Sydney is the city most at risk from losing access to fresh foods due to urban expansion into productive agricultural land. This may exacerbate other food security issues based on increased demand for fertilisers (for both nitrogen and phosphorus), water availability, climate change impacts, and disruption of distribution due to oil constraints.

Assuming that additional land for urban growth is released, or that more compact urban form is adopted, there is an on-going demand for building and dwelling construction. It appears that much of the decision making about resource consumption and waste disposal is made at the household scale, so it is important for policy to understand the links between the growth in population and the growth in the number of households. The demand for buildings increases with higher NOM levels. The growth in construction does not scale linearly with time, but demonstrates dynamics associated with population demographics and building vintage, such as reduced occupancy per dwelling and smaller households. Related to this, demolition waste was modelled to increase by at least a factor of two by mid-century. The meso-scale analysis identified additional waste streams caused by high migration inflows to be especially problematic for Sydney, which has no future landfill sites identified within the Sydney Basin, and will use up its landfill air-space within 10 years.

From the combined analysis, the magnitude of the impacts at all NOM levels suggests that unless substantial and timely actions are taken to address these impacts, some impacts have the potential to disrupt Australia's economy and society. Crucially, but not part of this study, will be the roles of institutions and governance in the establishment of the frameworks within which adaptation and mitigation can occur. An example is the case of transport infrastructure overhaul for Western Sydney to reduce the social and environmental impacts of congestion. This will affect the location of employment and homes and perceptions of 'liveability' in Western Sydney for the next 30 years.

The case for judicious action arises due to the cumulative nature of many of the impacts for most NOM levels, that is, impacts on the natural and built environmental increase steadily or accelerate modestly with time. Small differences now in the effects of different levels of NOM on various natural and built assets in many cases accumulate to large differences 10, 20 or more years down the track.

Introduction

Context

Our report explores the empirical reality and modelling of people's interactions with their physical environment in Australia. The task set by the Department of Immigration and Citizenship (DIAC) was to explore how different levels of Net Overseas Migration (NOM) were likely to affect our physical natural and built environment over the years to 2050. Over this period, the slow-moving stock of increasing population will interact with the faster cycles of variations of immigration, and the production and consumption of goods and services.

Net Overseas Migration is the number of arrivals of people who intend to reside in Australia for 12 months or more, less the number of departures of people who intend to be away from Australia for 12months or more. It includes temporary but long stay immigrants, such as students and 457 visa holders.

Our study is a logical segue from the conclusions drawn by McDonald and Temple's paper commissioned previously by DIAC to research the 'interrelationship between Australia's projected population directions and its long-term future labour supply, with particular emphasis on the role of migration' (McDonald and Temple 2008:2). Using an economic model designed by the Productivity Commission the authors 'tested the relationship between immigration on one hand and demographic, labour force and economic growth on the other hand' (McDonald and Temple 2008:9). Of the three model outputs, viz., demographic estimates, labour force estimates and GDP per capita and growth in GDP per capita, the latter was perhaps most instructive. They used NOM levels of 0 pa., 100,000 pa. (long-term historical average NOM), 180,000 pa., 190,000 pa., 200,000 pa., 210,000 pa, 220,000 pa., 230,000 pa., 240,000 pa., 250,000 pa. and 260,000 pa. They concluded that the optimal economic benefit was likely to be achieved with a NOM level of 180,000 pa. beyond which improvement in economic circumstances was incremental.

They were however mindful of the broader context within which the economic outputs are situated: 'Australia needs to be very cautious about expanding its population at a rate that is beyond the capacity of housing, infrastructure and the environment to absorb population growth' (McDonald and Temple 2008:5). Our report was commissioned explicitly to expand knowledge of 'infrastructure and the [natural] environment'. We did this by identifying and examining possible pathways by which population increase interacts directly and indirectly across different scales, locations, institutions and governance with the physical assets of our Australian environment. We also attempted to characterise those basic rules and assumptions that serve to underpin policy and future development processes, such that our conclusions would lead to a logic which could justify a broad social platform for the use and creation of physical assets over time. That is, we do not attempt to predict or pick winners by sector or technology as the particular shape of the future, but rather identify the framework within which change can be managed. We will:

1. Articulate the objective of the research and research questions

2. Conceptualise population as one factor among others when considering physical asset implications of NOM

3. Describe and provide the rationale and argue the case for the inter-disciplinary and multi-method approach that we adopted.

4. Present the conclusions from each of the chapters, prefaced by a description of each approach and perspective

5. Present the overall conclusions

6. Present the implications for a long term immigration planning framework

The objective of the research and research questions

The key result of the project was to obtain a considered, defensible, well researched and evidence-based understanding of the impact of a range of NOM on Australia's natural and built physical assets from the present to mid-century. To meet this objective, our report addresses the following questions:

1. The nature of the relationship between each level of NOM and the implications for Australia's physical assets

2. The implications of time for each NOM level on Australia's physical assets

3. Based on these interactions at various NOM levels over time, what considerations, concerns and constraints should the proposed long term immigration planning framework take into account?

4. What measures should be considered by the Australian government to mitigate negative impacts or optimise positive impacts?

The objectives of the Department of Immigration And Citizenship (DIAC) as stated in Attachment A to the Request for Proposal were that:

> "DIAC now wishes to use the various Net Overseas Migration (NOM) levels researched by Professor Peter McDonald, including the 180,000 threshold identified as optimal for the economy and labour force, and analyse the likely impact on the natural and built physical environment, including infrastructure provision and urban and regional development. The research will consider both negative and positive impacts and consider measures that will counterbalance or optimise these impacts. DIAC will use the findings from the two studies to undertake a cost/benefit analysis of the various NOM levels".
> In the context of this Research Brief, reference to "Australia's Natural and Built Physical Environment" includes Australia's:

1. natural environment;

2. influence on climate change;

3. urban development, including housing;

4. regional development;

5. Infrastructure provision, including transport, water, power generation, and

6. environmental "carrying capacity".

The brief also states:

> "In addition, there is a range of views as to the impact of NOM on our urban and regional development and infrastructure provision. Some have argued that NOM contributes to the labour force and the economic and fiscal strength we will require to build the infrastructure that will assist in mitigating climate change and improving environmental and urban amenity more generally.
>
> Others argue that population growth through NOM adds more to demand for infrastructure, services and resources than to supply, with consequent negative effects for the quality of urban life, for example because of congestion and overloading of transport infrastructure".

We interpret this to mean that we should only discuss infrastructure in relation to its impacts on the quality of urban life, not in terms of the cost of providing it.

Methodological Approach

We drew on the complementary perspective of several disciplines, because no one discipline currently conceptualises or embodies all levels of data or the complexity of dynamic, non-linear, probabilistic relationships. Our methodological approaches were chosen to incorporate data from the broad macro-scale to the regional or meso-scale and the local or micro-scale. Principally we conducted:

- Literature reviews of conceptual frameworks that have been or are currently in use that describe the interactions of population growth and the physical environment;

- Literature review of consumption as a key independent variable in the impact of population growth n the physical environment;

- Quantitative modelling primarily at the gross national level to establish possible points of tension in future scenarios of population growth in terms of independent variables such as oil and energy supply or regional impacts of water supply;

- Qualitative location-based profiling justified by a spatial distribution analysis to establish linkages between independent variables such as geographic location, institutions and governance and population growth at the micro and regional scales where direct interactions can be observed; and

- A series of studies synthesising effect of population growth symptoms using concepts of liveability and quality of life in order to assess micro-scale interactions between people and their physical environment. Congestion was a prominent consideration in this synthesis.

Where possible we distinguish between population growth that occurs as a result of net migration, and population growth from all sources. There is a dearth of literature and data on the distinctive impacts of migrants, so we often resort to the latter. In this we are reassured by the evidence we produce that migrants are much like other Australians in their consumption behaviours (and hence in an important aspect of their environmental impact).

We applied three methods to evaluate the three scales of information, that is, as 'populations' become 'people' and communities which become households and 'individuals'. The methods examined different levels of uncertainty, interdependence and conflict in the data available. The issues we dealt with are complex. We chose the CSIRO's Australian Stocks and Flows Framework (ASFF) to address the macro-scale.

At the same time we embraced the need for data and theoretical development from the biophysical locations of NOM. We sought data at the local and regional level to uncover the actual, physical relationships between people, settlements and the environment.

Macro-level scale quantitative modelling

We support the view of Engineers Australia that an examination of the impacts of migration:

> "--would be incomplete without a robust consideration of the population scale implications of relatively large migration intakes. This requires a different, but potentially complementary, approach to modelling… There is no merit in unbounded support for any particular analytical technique. Support for a different approach here is a horses for courses argument to ensure all consequences of population growth are considered (The Engineers Australia Submission to the Productivity Commission on the Economic Impacts of Migration and Population Growth (2005) p. 9).

The rationale for the ASFF is presented below by its current developer, Dr Graham Turner:

> An accurate assessment of a nation's future environmental condition requires far greater richness than simple equations or qualitative arguments offer. The Australian Stocks and Flows Framework (ASFF) developed by CSIRO Sustainable Ecosystems makes a serious attempt to quantify the complexity through the incorporation of some 800 multi-dimensional variables which represent explicit physical activities. For example, the ASFF breaks out population in terms of age-cohort demographics, household size and locations. Lifestyle related parameters such as various product consumption rates per capita, transport mode shares and household characteristics collectively represent affluence. Economic throughput is modelled in detail, and incorporates technological efficiency parameters, substitution options (e.g., different fuels) and stock dynamics to simulate infrastructure turnover.
>
> The spatial and temporal extent and detail of the model analysis is determined by the specific environmental/resource issues, such as food or water security. Population dynamics and most infrastructure developments occur over decades; consequently the simulations must extend to at least the middle of the century. Food production and water resources in particular require sufficient spatial detail to differentiate regional characteristics. Nevertheless, the reality of our

economic system is that each region is highly dependent on others throughout Australia (Lennox and Turner 2005).

Assessing *absolute* sustainability therefore requires a national perspective, since different locations and sectors of the economy are strongly linked by physical transactions. This means that if a crisis occurs in one area or sector it will impact others, most likely in an adverse way. Consequently, it is necessary to consider the full system and not base sustainability assessment solely on separate parts as if they were independent. This system perspective is provided by the ASFF modelling, with its coverage across the national economy and environment.

Meso-scale quantitative data and micro-scale qualitative synthesis

However, even a model as sophisticated as the ASFF model with its 800 sub-sets of data, numerous feedback loops and with a degree of regional expression can only ever approximate reality. It is based on assumptions that operate at a macro scale which tend to average out the 'outliers' – both positive and negative - associated with the uneven, 'lumpy' distribution of physical environmental assets and human activity in the bio-physical world. According to the literature review, the meso or regional scale is where some population pressures affect the natural and built environments and the micro-scale where the concept of well-being becomes an important factor in how we define net benefits from change.

In this report we provide a local and regional version of sustainability as a 'bottom-up' process to complement the national modelling. We intend that the three approaches will enable a triangulation effect, where each provides supporting evidence for the other, or not, as the case may be.

Since environmental impacts of increased population and the possible institutional responses occur across geographic scales we have combined detailed national and regional modelling with more locally based case-study assessments. We opted to examine locations at a regional (eg. a Capital City) or even more local scale (eg. Western Sydney Regional Organisation of Councils, WSROC). We did this for the richness that such detail adds to our understanding of the people – environment relationship. The physical variables we consider in this study are the natural assets of water, land, food, biodiversity, vegetation, air, greenhouse gas emissions and waste disposal; and built assets of our cities, in particular, congestion, transportation and energy supply. Speculation on future technology was outside our brief but governance and its subset, urban planning, emerged as important variables of the performance of governments as detailed in public documents in relation to population and related physical asset management.

The ASFF acknowledges the social dimension of how we appropriate natural assets for our consumption at the macro level. But regional and local communities perceive issues and want solutions implemented at their meso and micro scale. We require an understanding of social institutions in the broadest sense, in order to make and implement decisions about population growth and consumption which have implications for change at the national, regional and local level over the next 30 to 40 years.

How we defined our preferred population – environment concept

One of the key outcomes of the literature reviews was a concept of what it was that we thought were the 'problems' that arise from population growth. We needed to be able to answer questions about where current knowledge stood and what was needed to make progress theoretically and empirically. The nub of this thinking process was to understand how the notion of an 'environmental impact or problem' in relation to population was raised, by whom, and with what assumptions and logic and data. The next section summarises our process and conclusions.

Concepts in Current Use

The use of analogous or metaphorical terms indicates the difficulty with which people generally understand the interdependence of our physical system. Instead we hope to present a framework of factors to explore how population affects the environment and, therefore, to attempt to identify a perception of population growth that we feel will be regarded as useful for government policy making.

'Sustainability' and sustainable development are terms used widely in academic publications and the popular press to describe scenarios where human activities and systems are organised so as to permit their continuity beyond the short term and not result in catastrophic failure of the resource base or generate waste streams that cannot be assimilated by the natural environment. The Council Of Australian Governments (COAG) meeting of 1992 introduced Ecological Sustainable Development as a key conceptual base to which all government policy and legislation should respond. Unfortunately, it is a debased phrase because of its frequent application without appropriate riders to define its contextual assumptions, which therefore results in ambiguous interpretation. Butler (2003) sums up the position thus:

> Like many useful concepts 'sustainability' can be criticised as fluid, fuzzy and subjective. Clearly, this term is now part of the vernacular. A succinct (though circular) definition for sustainability is 'that which can be sustained'. This definition is not entirely tongue in cheek – it also reflects an exasperation with the hijacking (or at least distracting) of what many think should be an urgent debate by overly semantic approaches. (Butler 2003 p14)

More recently however is the academic and private sector discussion about a more rigorous and robust definition of sustainability, one that refers to: the conservation of energy and matter; the tendency for energy and matter to dissipate; how the value of matter arises from its concentration; and, the key role of photosynthesis in transforming the Sun's energy into matter and energy for Earth's biological systems (Robert et al 2002). That is, a sustainable policy or program will not place the natural environment under more systematic stress from concentrations of substances extracted from the Earth's crust, concentrations of substances produced by society, degradation by physical means, and that through such a policy or program, does not subject people to conditions that systematically undermine their capacity to meet their needs (The Natural Step, 2010).

There are no measures attached directly to sustainability, relying instead on other concepts and 'measures' to establish a quantitative value. The concept of carrying capacity is or was initially used in this way. It is, however, of declining relevance in an urbanised, services dominated, trading economy, and is only supported by a few scientists. Indeed, it is contingent on the activity of the very people in the particular environment it is trying to assess for the possible number of people that can be sustained. For example, domestic shortages of non-renewable resources can be overcome by trade, technology and substitution. That is, our world is so interdependent through trade between regions that substitution for a lack of local produced goods and some services can be purchased from further afield.

> Both globally and locally, other authors have implied the usefulness of the concept of optimal population (Daily et al., 1994; Jones and Pearson, 1995; Pimentel et al., 1999; Willey, 2000). Arrow et al. (1995) wrote: 'Carrying capacities are contingent on technology, preferences, and the structure of production and consumption'. Though arguing that 'a single number for [human carrying capacity] would be meaningless', they point out that human appropriation of the products of photosynthesis is about 40% (Vitousek et al., 1986; Rojstaczer et al., 2001), implying that limits to this human impact must be approaching. (Butler 2003 p19)

Calculation of a carrying capacity for a particular region becomes something of a reductionist exercise which requires caveats in terms of context and assumptions about data, technology and behaviour. It does support improved awareness of environmental impact amongst people more generally, so can have an impact on consumption, but one needs to be aware of the assumptions built into the calculations.

This is not a recent situation. With a sense of déjà vu we note the following comments from the National Population Inquiry (1971-1975) which raised the same issues that inform the concept of carrying capacity that we confront in this study in 2010. For example, there were the huge inflows of capital for mineral extraction for export; increasing water pollution, and deteriorating coastal and peri-urban environments from an increasingly affluent, consumerist and growing population. There was a call for Australia to move to a zero growth scenario, with all possible speed. (National Population Inquiry 1975, p. 211)

This account shows a shift in thought about Australia's population size away from the focus on carrying capacity to concerns about the effects of a growing population and increasing consumption on environmental quality and 'sustainability'. Yet we are only just beginning to seriously question growth as a population and economic strategy in the wake of the Global Financial Crisis. .

As a consequence of the misuse of these terms an expectation exists that we can calculate an optimal population for Australia. Because of the complexity of our trade in goods and services and the continual evolution of technology and behaviours, there is no optimal sustainable population number or an optimal carrying capacity. A more considered use of these terms would be beneficial to the population – environment debate.

'Ecological Footprint'

Another method of examining the possible connections between population, consumption and environment reviewed by Curran and de Sherbinin (2004) is that of the 'ecological footprint' first proposed by Rees (1992) and Wackernagel and Rees (1996). The ecological footprint is a number that represents the area of biological activity in hectares that is needed to supply the natural assets for consumption, absorb the waste streams and host the infrastructure of human organisations. Although intuitively appealing and a useful springboard for research it does not account for the efficiency of natural resource use. It also fails to properly account for the relative effectiveness with which afforestation/ revegetation is achieved in reality, and its aggregate outputs are dominated by the land energy component (Limnios etal 2009, p. 2526). The ecological footprint approach does not appear useful if one wants to compare and contrast the costs of human activity at different scales of aggregation, that is, individuals to households to communities to regions and beyond. The scale of data available is a primary limit to its application; most data is at the national and global levels which obscure more immediate, spatial relationships.

These are the key popularised approaches to raising awareness and deriving a measure for individual or global impacts of population and consumption. For a more nuanced understanding to guide our preferred population – environment concept, we next turned to the literature review of academic debate about what constitutes the environmental impacts of population growth.

Evolution of the Academic Debate between Population Growth and the Environment

The evolution of the academic debate about the nexus between population and the bio-physical environment suggests the prominence of the positivist framework for research and its reductionist methods. That is, positivist as in measurement of data that is not connected to subjective assessment, and reductionist as in measuring and analysing a factor in isolation from its context. For example, some authors argue that only the impacts of population growth that are directly observable, such as urban land, water and air pollution, should be counted. In other words, developing a sufficiently rigorous picture of cause and effect relationships can be achieved by isolating individual physical factors and measuring them. What this completely misses is the larger picture of the systems within which these factors operate, their history, location, scale, social institutions and governance. Who makes the decisions, who implements the decisions, whose knowledge is regarded as valid, are all necessary inclusions if one is to understand how population growth intersects with the physical environment.

We read of developments in the debate that suggest that any environmental impact that could be reduced through better management and planning is not caused by population growth (ATSE 2000; ATSE 2007) Again, such studies attempt to contain the complexity of the real world in terms of human agency: the only 'problems' we face are those which we can fix.

Others (Hamilton 2002; Jones, 2001) argue that Australia has largely failed to achieve significant improvements in environmental management, and that the effects of population growth should be assessed on the assumption that future improvement will be limited. Again, this view is constrained by reference to past achievements based on a particular set of evaluation criteria and assumptions about the future. If we are to measure achievement, the range of criteria needs to be sufficiently broad so as to allow consideration of the numerous levels of scale both geographic and temporal, and the extent of linkages that exist in any physical system of nature. Again, who says that what we have achieved so far is failure? We need to have a base line of information against which to measure our progress and not just a base line of someone's expectations and assumptions. At present much of the information we need at the local level is not collected and only macro-scale models are available for guidance.

It appears that much of the research in this field has shied away from attempting to evaluate the population 'problem' in all its complexity. Research has focused on particular sections of the broader debate, in part because of limited resources, with the consequence that linkages tend not to be made across conceptual and institutional boundaries. There is a need, however, to confront the enormous complexity of our organisation as a species and our interactions with the physical world in order to make better decisions which involve reducing unexpected, undesirable outcomes. A tall order when policy settings now will generate outcomes not evident for 30 to 40 years.

Econometric models are optimistic about improved environmental and resource management from increasing wealth generated by an increasing migrant intake. These models suggest that our societies are resilient in part because of high levels of innovation and the capacity to adapt; the thesis of economic adaptive efficiency. This theory of North (1993) suggests that Australia is well served by institutions that allow for change to be productive and positive. By comparison, environmental and social scientists urge caution across the board based on ecological principles of species survival and suggest that our populations are vulnerable to perturbations in our physical environment.

But perhaps a better way to approach the contested realm of population –environment nexus is to take a long bow from Foucault and his essays on power: not to attempt precise definitions at all but rather observe how and where the concepts find their expression, and to explore that set of circumstances. In a sense that is our theoretical base for the following section.

We also found that our views on a methodology for examining how population and environment relate to each other resonated with those proposed by Dovers et al (1992) His essential ecological proposition was that:

> At any given time and place, an increase in the human population will be at the expense of other species, and will result in environmental changes. In the present day, these changes will typically be deleterious. (p.25)

He goes on to emphasise that in order to evaluate the impacts of population growth, we need information about the nature of the population and its consumption behaviours, the institutional settings and governance of that population, and the location and scale effects on the target population. This view is particularly appealing because it considers the real world of action and response in a broader more holistic context and is a view we have followed in structuring this study. The (triple!) bottom line is that the impacts of rapid population change are inextricably tied up with consumption behaviour by migrants and by households, location and scale, governance and institutions.

Examination of Independent Variables and the Project Brief

The next section elaborates on these key factors that are in play with population growth in relationships with our physical environment. Our view follows that of Systems Theory (Ison et al 2000) where the attribution of the effects of population growth is considered to be about the context, the relationships, the complexity, uncertainty, conflict and, in particular, interdependence that characterises research into environmental management and other complex situations where no simple answer will suffice. It is a framework that allows reflection rather than conflict, for example, when arguing about the semantics of what constitutes an 'environmental problem'.

While population growth is a key factor in determining the rate and direction of gross human/ environment interactions, other independent variables affect the location, intensity, characteristics and implications of population growth on the environment. Population cannot be 'managed' in isolation or its effects 'modelled' without consideration of the local and regional permutations which determine the real and long-term effects of a population policy on the bio-physical environment. These variables operate at various scales, at particular bio-physical locations, and their current institutions and governance have evolved over time (so-called 'path dependence'). There are also broad shifts in the attitudes and behaviours of consumption to take into account. In fact, the proposition that any one of the key independent factors can be applied or evaluated independently of the others is to miss the crucial fact of *inter*dependence between them all.

The time span over which population extends its affects creates great uncertainty for planning and planners. The range of independent variables and their interactions introduced in this report similarly invoke uncertainty about actions taken and reactions that happen. We invoke models or presage scenarios in attempts at simplification for understanding but don't know what the outcomes will be once resources are allocated. This study is an attempt to bring together disparate knowledge that represents the complexity of the physical world and our relationships with it: To provide a window through which to see (a few of the many) conflicts and their possible resolution.

The priority of this study was to investigate the impacts of population growth on the physical natural and built environments, now and out to 2050. We have noted that institutions and governance emerged from both the literature and our studies as key independent variables that have a transforming effect on population-environment processes and outcomes. But the scope of this study did not allow us to explore this important area more fully at this time.

We did, however, pursue consumption as we were charged to examine migrant patterns of consumptive behaviour. The literature led us to consider that the most appropriate scale at which to measure consumption was the household. Unfortunately, the data available on migrants was from a random sample of all migrants across Australia and not limited to our geographical locations.

Institutions and Governance

The impacts of a settlement on its natural and built environment are shaped by the level of infrastructure spending and the regulatory and market environment that affects employment and consumption patterns. These are influences and constraints on our behaviour, the rules by which we must live in order to function as a multitude of collaborating communities. Governance is important for the effectiveness with which the community's pooled resources, mainly taxation, are applied. It is frequently judged by the equity of distribution, the timeliness and appropriateness of its infrastructure developments, and the general health, education, and protection of its constituents. Migration is an important national concern that generates regional and local consequences for all of these elements at all levels of government.

Not only are there the formal rules of governance but also the informal norms of behaviour that are generally accepted as contributing to a stable community. Both forms of rules beget roles, of which we expect certain behaviours and outcomes. These are the institutions of our communities that provide the foil and support to governance. Both are concerned with decision making and the allocation of resources; both are part of an examination of the population growth dilemma. It is the attitudes and subsequent behaviours of individuals and organisations that have a large influence on resource consumption practices and waste streams and, which, thereby affect the dynamic relationships between population and environment at the local and regional levels over time. To borrow from Nobel Prize Economics Laureate-winner Douglass North, it is the efficiency with which a community adapts over time rather than its capacity to allocate resources in the short term that

> "is the key to long run growth. Successful political/economic systems have evolved flexible institutional structures that can survive the shocks and changes that are a part of successful evolution. But these systems have been a product of long gestation. We do not know how to create adaptive efficiency in the short run"(North 1993).

Infrastructure policies that provide rail for public transport will, for example, result in significantly less CO2 pollution – and reduced air pollution-- than policies that provide motorways. Similarly, regulatory frameworks that emphasise urban infill and urban consolidation in some cases result in a smaller environmental footprint when compared with broadacre residential development. Critically, these are elements of resource consumption over which governments at various levels are able to exert considerable control or influence. A focus on urban development and the consumption of resources within urban settings is critical, given that more than 80 per cent of immigrant arrivals settle in the major capitals.

Net Overseas Migration (NOM) is a key variable in this study because the Commonwealth Government can control the levels to make short-term changes to the flows of population into Australia and hence warrants investigation (Figure C1). The other two factors that determine population size are fertility rates and death rates which are much less amenable to short term manipulation. However once in Australia new migrants can settle where they prefer, although incentive plans are in effect to encourage migrants to settle away from the major cities in particular. These incentives are driven by all levels of government for their own particular needs, for example, workers in agriculture, nursing, mining and small business in order to retain or maintain local institutions such as schools or bank branches or government offices in regional towns. Some of their influence on our physical environment is therefore going to be 'lumpy', determined by the variables of the place and time and community in which they choose to settle, while others will add to national (and international) pressures.

Location

The location of our population within the biophysical environment is an independent variable that exerts a powerful influence over the scale and type of organisation of our communities and the nature of aggregation into settlements. As social actors we are not atomistic but thoroughly networked in a soup of relationships and transactions, otherwise known as social cohesion and social capital. That is why migrants tend to congregate; it is why and how our communities form and evolve. Employment, for example, is a crucial aspect of where populations grow. There is a physical space that has to be occupied, somewhere. The occupation of physical space means there is a specific local relationship between the built environment, our occupation of that place, and the natural assets of that place. Our needs for food, water, shelter; then transport, communication and jobs; all occur in a place comprised of soil, water, vegetation, terrain and various temporal flows associated with seasons and climate. Our relative wealth and consumptive behaviour determines what products and services we generate from our immediate surroundings and what comes from beyond our region.

The access we have to these assets determines how many of us can survive in a given location, depending on variables like technology and governance and institutions. Our access to trade and new economic opportunities (Adelaide) or solutions to other problems (Sydney had a safe harbour) are historical decisions on settlement which determine why our cities are located where they are. But the impact of population growth carries with it the physical context of location that shapes the physical development of the settlement and therefore the impact on the natural and built environments.

We decided on a significant effort to gather regional and local information about the physical environments of the major concentrations of migrant settlement. As Curran and de Sherbinin (2004) citing Walsh et al (1999) found, *the more local the social and spatial scale the more likely … to find population and environment links.*

We believe it is important to aggregate the data of individuals' lives to scales that generate an understanding of the cumulative impacts of a population in a given location at a given time in their history. Our attention is drawn to the local and regional scales of our lived experience, where the various independent factors act on us and on our physical assets. Modelling at the macro scale, that is, at the national or global scales, does not reveal this information

One of the very few studies that has followed this approach was that of Cardew and Fanning (1996), in which the authors used a study of the Wollongong Statistical District to explore the links between population, economy and environment. In their study, Cardew and Fanning described a regional profile of the Wollongong District including the extant natural assets, history of settlement, known impacts of urban growth on the Wollongong environment, current environmental issues and prognoses for the future. Once described, the regional profile provided the data for a policy framework that could be used to analyse the interactions between environment, population and economy.

Our study caters for the gross geography of population distribution, especially the influence of historical and institutional factors. For example, 80% of post-World War II immigrants have settled in towns of at least 100,000 people and over 50% of these migrants have settled in

Sydney and Melbourne (Hugo 2008). Because many of these settlers are 'chain' migrants, that is they have familial connections; they also tend to live close to one another within these cities (Hugo 2008).

It is not possible to know what future net overseas migration will look like since the forces that create immigration and emigration are dynamic and often beyond the immediate control of government. The best we can do is to understand the characteristics of recent migrants on those dimensions that are relevant to their impact on the natural and built environment. Many of these are persistent, and not very sensitive to the exact origins of the migrants, or their type of visa. The next section therefore deals with the nature of consumption of migrants and reflects on the importance of measuring consumption at the household level, rather than per person.

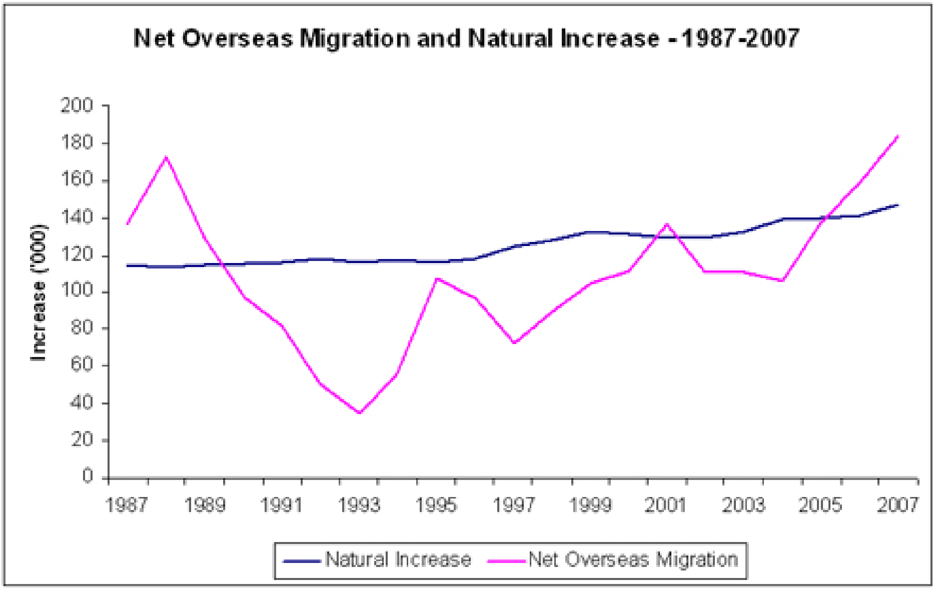
Box 01

NOM is concentrated in specific locations

We found that 80% of NOM are concentrated in 300 Statistical Local Areas (SLAs): that is, 20% of the SLAs contain 80% of the migrants. Of these, the top 30 SLAs are all located in the metropolitan areas of Sydney, Melbourne, and Perth (Figure C2). The top 10 SLAs in 2006 where 10% of the overseas-born people resided include: Canterbury, Fairfield-East, Randwick, Brimbank-Sunshine, Rockdale, Greater Dandenong, Ryde, Liverpool-East, Stirling-Central, and Holroyd.

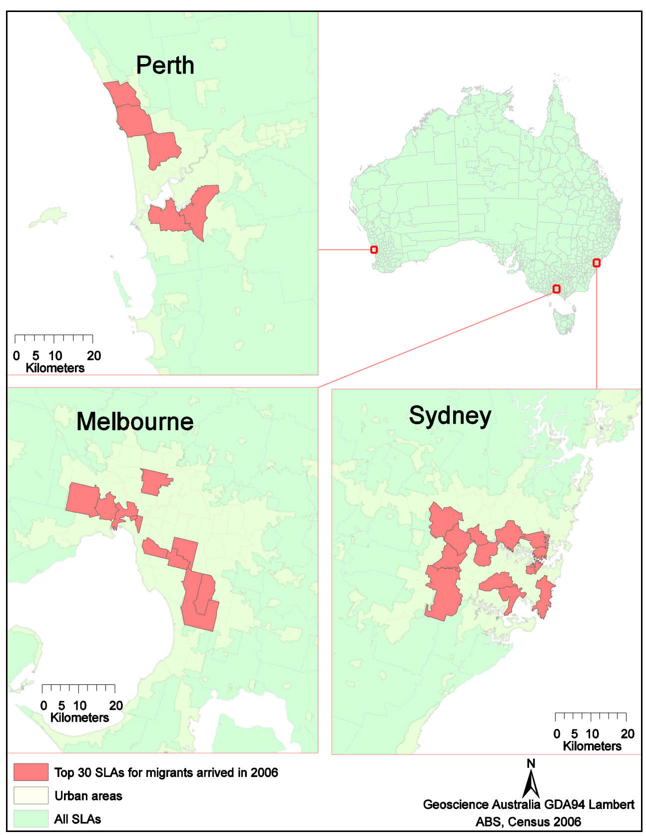
This aggregated pattern of distribution would suggest that their impact on urban infrastructure and natural assets is more likely to be concentrated and for some groups, involves recycling of older physical stocks of urban infrastructure. Once we understood where migrants chose to settle we needed to understand how this diverse section of the population lived: what sort of lifestyle and consumption practices did they have.

Figure C1: Net overseas migration and natural increase – 1987-2007



Sour
ce: Fact Sheet 15, Department of Immigration and Citizenship

Figure C2.: Top 30 SLAs for migrants arrived in Australia in 2006, at SLA level



Consumption by Migrants

To compare consumption between migrants and Australian-born people we need to have information on how Australians more broadly behaved as consumers. What we found from a review of the literature was the primacy of the household as the unit of consumption rather than individuals. This has important implications for the consumption of food, water, energy, transport, jobs, and the many services such as health and education. The fall in household size means that we found that we need more houses per head of population than we did 10 or 20 years ago.

With the importance of consumption highlighted in understanding human impacts, the next section of this report examined data on migrants' consumption intentions and behaviours from the survey of Household Income and Labour Dynamics in Australia (HILDA), Australia's first large-scale national household longitudinal survey.

Begun in 2001 it has been collected from a random sample of people each year from across Australia and is therefore not spatially specific. The implication is that we don't know which migrants from which locations and who consume in a particular way, completed the survey. We cannot be certain that the survey findings either exactly or approximately correspond to the spatial focus of this study. Its main conclusions, however, were applied to our analysis as the best information available.

The important finding is that the consumption preferences and behaviours of non-English speaking migrants demonstrated in the results of the 2007-2008 HILDA surveys actually show few differences with the broader Australian and English-speaking migrants. Not only are expenditures of a similar level, trends in spending are similar. The only exceptions to this general view are the slightly increased expenditures by this group of migrants on groceries, eating out and use of public transportation and taxis.

We also undertook a review of the data from a new survey. For the first time in 2007-08 financial year, the Australian Bureau of Statistics (ABS) conducted an Environmental Views and Behaviour survey in Australia The survey enabled us to gain some understanding of the factors that influence people's participation in environmental activities, and energy and water conservation practices in particular. Again this was not spatially specific data.

The key conclusions were that:

- Personal water use declined slightly more amongst migrants because of *lifestyle changes*;
- People born overseas purchased slightly more refrigerators and washing machines than native-born Australians;
- People born overseas who increased personal electricity use in 2007-08 did so more because of weather conditions than lifestyle changes when compared to native-born Australian respondents; and

- Migrants appear more concerned about saving energy than are their Australian counterparts.

Box 02:
Migrant consumption behaviour mirrors native Australian patterns

We therefore believe that it is reasonable to assume that migrants adopt similar consumption patterns of natural resources and generate similar waste streams as the broad Australian community. The implication is that we can use data about consumption by the general populace and apply it to migrant impacts. In saying this, we note that we have no specific information about the consumption behaviours of the growing number of long-term temporary migrants. Most are students or 457 visa holders. They may well behave differently. We cannot know, or make adjustments for, the composition of the migrant flow over the next four decades.

The next section builds on the conclusion that migrant consumption behaviours are within the normal variation of the rest of the Australian population. That is, what we find for the population generally applies to migrants as well.

Consumption by the Household

One of the key development in understanding people's environmental impacts was the emergence of the household[1] as a unit of analysis. The importance of the household was presaged by Dovers (1992) and reinforced by (among others) Curran and de Sherbinin (2004). The latter suggested that national level per capita numbers were but averages of substantial variation within the populations of interest and so were of little utility for policy. Significantly, household characteristics made a major contribution to this variability. Citing evidence from O'Neill, MacKeller, and Lutz (2001) and Lutzenhiser, (1997) respectively, Curran and de Sherbinin state that:

> [C]hanges in the number of households are a better predictor of greenhouse gas emissions than overall population growth… and
> [R]esearch in California found that energy consumption for a one person household was only half that of four and five person households. (Curran and de Sherbinin, p.111)

Further, replacing per capita with per household measures in an I = HxAxT variation of the I = PxAxT model (Ehrlich and Ehrlich 1974) (see Box 3) results in significant differences for developed countries but not developing countries.

> … when population growth is measured using households, its contribution towards energy consumption is 76% (income and technology contributing only 24%) in developed countries. When using a per capita measure in the model, the contribution of population growth towards

[1] An interesting side line: the etymology of the word 'economy' is from the Ancient Greek oikonomia – Latin as *oeconomia*, meaning 'household', 'management of the household'

changing energy consumption falls to 33% in developed countries… (MacKellar et al 1995 p. 860)

Spangenberg and Lorek (2002) identified the three key areas of household consumption as construction and housing, food and nutrition and transport and mobility. Together these areas account for 70% of an economy's material extraction and energy consumption. Bin and Dowlatabadi (2005) showed that when using a Consumer Lifestyle Approach – a form of Life-Cycle Analysis – *more than 80% of energy used and CO_2 emitted in the US are a consequence of consumer demand.* The nature of the analyses used includes both direct and indirect energy demands of the household's consumption for home *and* travel. Our consumption of energy, materials, infrastructure and time for travel is increasing because of this 'lifestyle' choice (p. 113).

The concept of lifestyle plays a role in the connections between population and consumption. Curran and de Sherbinin (2004) suggest that it is a fuzzy concept that helps researchers to understand how the construction of one's identity can be a factor in setting preferences for consumption. Likewise, the feedback that people get from the consequences of their behaviours, set in motion by their preferences, will influence their identity and future actions. This has direct relevance because this project is focused on migrants who by definition, in coming to Australia, will have different preferences and behaviours inculcated from different social settings. How much change in behaviour is required, or accomplished after they settle in Australia is uncertain. The following section reveals some of the lifestyle preferences of migrants, generally, from the survey of Household Income and Labour Dynamics in Australia (HILDA), Australia's first large-scale national household longitudinal survey. Commenced in 2001, HILDA tracks household background, household formation, housing, education, preferences and expenditures including behaviours related to natural resource use.

Box 03:

Paul and Anne Ehrlich's I=PAT model

The widely cited IPAT formulation—in which environmental impacts (I) are the product of population (P), affluence (A), and technology (T)—is implicitly framed in neo-Malthusian terms although not all research using the identity is Malthusian in approach. IPAT itself has been criticized because it does not account for interactions among the terms (e.g., increasing affluence can lead to more efficient technologies); it omits explicit reference to important variables such as culture and institutions (e.g., social organization); impact is not linearly related to the right side variables (there can be important thresholds); and it can simply lead to wrong conclusions. (de Sherbinin et al 2007, p. 348).

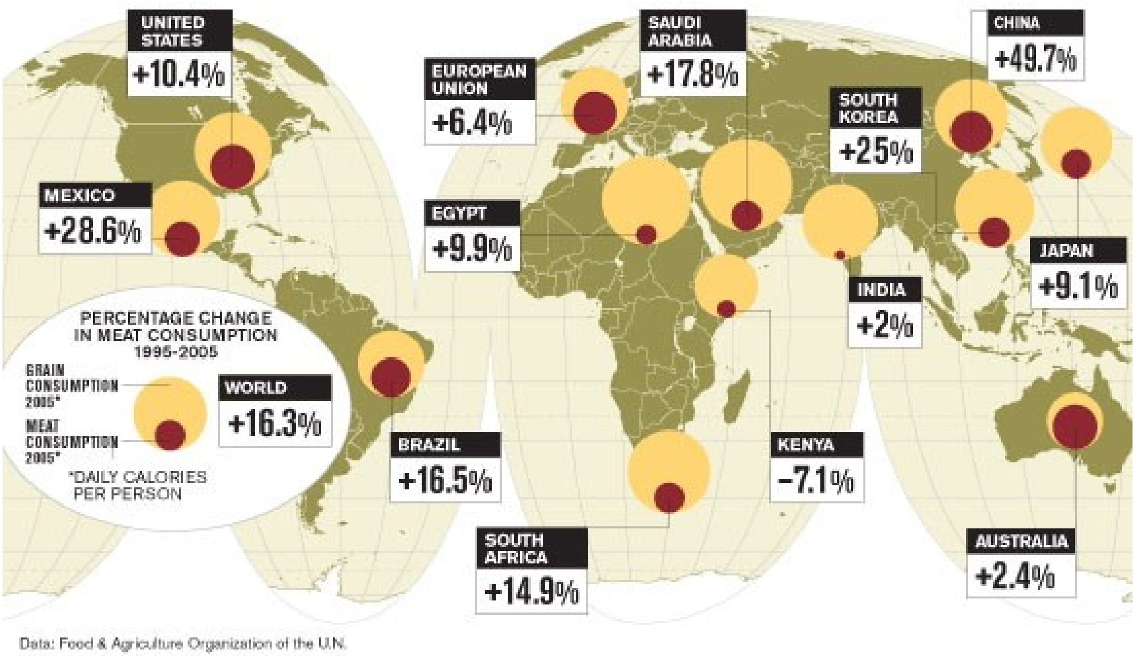
Within these caveats, however, the IPAT formula is still one of the most useful in constructing scenarios, such as those in the IPCC 2000 report, pp. 83-84. It is the 'master equation' in the field of industrial ecology and allows exploration of factors that influence human and environmental well-being at a macro scale (Goklany 2009).

The household diet has a major cumulative impact on the environment. Residents of developed countries like Australia consume significantly more meat and dairy products than their counterparts in India or China, although the gap is closing (FAO 2007). The production of animal protein uses more water, energy and inputs than plant protein from cereal and pulse crops. The use of extrinsic inputs such as water, transformed feedstuffs, nitrogenous fertiliser, drenches, capital-intensive machinery and fossil fuels exacerbate the gap in inputs between plant based diets and the production of animal protein foods.

> Worldwide, an estimated 2 billion people live primarily on a meat-based diet, while an estimated 4 billion live primarily on a plant-based diet. The US food production system uses about 50% of the total US land area, 80% of the fresh water, and 17% of the fossil energy used in the country. The heavy dependence on fossil energy suggests that the US food system, whether meat-based or plant-based, is not sustainable. (Pimental & Pimental 2003, Abstract)

A recent review by the Johns Hopkins Centre for a Livable (sic) Future (2009) found that: in the US it takes about 13 kcals of fossil fuel energy to produce one kcal of food and 25 kcals to produce one kcal of meat; up to a third of total food energy inputs went into the production of food of a low nutritional value such as sweets, snack food and drinks; that (fresh?) produce sourced 'conventionally' travelled 35 times further than locally sourced food; and that over 25% of food in the USA goes to waste.

Figure C3 Percentage Change in Meat Consumption 1995-2005



Source FAO

Box 04:

Household is the key unit of consumption

We can conclude that the household is a crucial unit of analysis. This finding substantially increases the need to collect and examine local and regional level data about households in order to study population growth effects on the built and natural environments. It appears that much of the decision making about resource consumption and waste disposal is made at this scale, so understanding this relationship is crucial to policy construction about the broader concept of population growth. It further emphasises the importance of location as a significant variable that influences the impacts of population growth on our environments. For example, Where are new houses being constructed? What is the difference between infill or green-field development? Where are new jobs being created? What public transport exists? What is my access to services – health, education, recreation? All these are a factor of and influenced by location. Population growth is a local and regional phenomenon.

References

ATSE (Australian Academy of Technological Sciences and Engineering) 2000, Population futures (http://www.atse.org.au/uploads/Population_Futures.pdf);

ATSE 2007, 30/50: The technological implications of an Australian population of 30 million by 2050 (http://www.atse.org.au/uploads/ATSEScanlon.pdf).

Bin, S., & Dowlatabadi, H. 2005. Consumer lifestyle approach to US energy use and the related CO2 emissions. Energy Policy, 33(2), pp. 197–208.

Butler, C.D. 2003, Population and environment in Australia: 2003. A report commissioned by the Population and Environment Research Fund Committee of the Australian Academy of Science. http://www.science.org.au/events/fenner/pdfs/populationandenvironment.pdf

Cardew R. and Fanning, P. 1996 Population-economy-environment relationships in the Wollongong region : a framework for analysis and policy development. AGPS: Canberra

Curran S. and de Sherbinin A. 2004. Completing the Picture: The Challenges of Bringing 'Consumption' into the Population-Environment Equation, Population and Environment 26 (2) pp. 107-131

DEC NSW Dept. of Environment and Conservation 2004. The Environment and Ethnic Communities in 2004, DEC Social Research Series. NSW Government.

de Sherbinin, A., Carr, D., Cassels, S. and Jiang L. 2007 Population and Environment Annual Review of Environmental. Resources 32:345–73

Dovers, S. & Australian Bureau of Immigration Research. 1992, Population growth and Australian regional environments Australian Govt. Pub. Service: Canberra

Dovers, S., Norton, T., Hughes, I. and Day, L. 1992, Population growth and Australian regional environments, Australian Government Publishing Service, Canberra.

Ehrlich P.R. and Ehrlich A.H. 1974 The End of Affluence: A Blueprint for Your Future. Ballantine Books: New York

Engineers Australia 2005 Submission to the Productivity Commission on the Economic Impacts of Migration and Population Growth. Engineers Australia

Hamilton, C. 2002, 'Population growth and environmental quality: are they compatible?', People and Place, vol. 10, no. 2, pp. 1-5

Hugo, G. (2008) Future Urban Population and Settlement Transitions, in P.W. Newton (ed.), Transitions: Pathways Towards Sustainable Urban Development in Australia, CSIRO Publishing, pp. 149-170.

Ison, R.L., High, C., Blackmore, C.P. & Cerf, M. 2000. Theoretical frameworks for learning-based approaches to change in industrialised-country agricultures In LEARN. eds. Cow up a Tree. Knowing and Learning for Change in Agriculture. Case Studies from Industrialised Countries. INRA (Institut National de la Recherche Agronomique) Editions, Paris. pp. 31-54. ISBN: 2 7380 0929 8

Jones, A. 2001, 'The Business Council of Australia's case for population growth: an ecological critique', People and Place, vol. 9, no. 2, pp 49-57

Lennox, J. A., G. Turner, et al. (2005). "Modelling Australian basic industries in the Australian Stocks and Flows Framework." Journal of Industrial Ecology 8(4): 101-120.

Limnios, E.A.M., Ghadouani, A., Schilizzi, S.G,M. And Mazzarol, T. 2009. Giving the consumer the choice: A methodology for Product Ecological Footprint calculation, Ecological Economics 68, pp. 2525–2534.

Lutzenheiser, L. 1997. Social structure, culture, and technology: Modeling the driving forces of household energy consumption. In P. C. Stern, T. Dietz, V. W. Ruttan, R. H. Socolow, & J. L. Sweeney (Eds.), Environmentally significant consumption: Research directions. 129 Washington, DC: National Academy Press (available at http://books.nap.edu/books/0309055989/html/index.html).

McDonald, P. and Temple J. 2008. Demographic and Labour Supply Futures for Australia. Canberra, Australian Demographic and Social Research Institute, Australian National University.

MacKellar, F. L., Lutz, W., Prinz, C., & Goujon, A. 1995. Population, Households, and CO2 emissions. Population and Development Review, 21(4), 849–865.

National Population Inquiry 1975, Population and Australia: a demographic analysis and projection, Australian Government Publishing Service, Canberra.

North, D. 1993 Economic Performance Through Time. In Nobel Lectures, Economics 1991-1995, Editor Torsten Persson, World Scientific Publishing Co., Singapore, 1997. Accessed on 5th May 2010 at http://nobelprize.org/nobel_prizes/economics/laureates/1993/north-lecture.html

O'Neill, B., MacKellar, F. L., & Lutz, W. 2001. Population and Climate Change. New York: Cambridge University Press.

Rees, W.E., 1992. Ecologicial Footprints and appropriated carrying capacity: What urban economics leaves out. Environmental Urbanism, 4, 121–130

Spangenberg, J., and Lorek, S. 2002. Environmentally sustainable household consumption: From aggregate environmental pressures to priority fields of action. Ecological Economics, 43, pp. 127–140.

Wackernagel, M. and Rees, W. 1996. Our ecological footprint – reducing human impact on the Earth. Environment and Urbanization 8 (2), 216-216.

Walsh, S. J., Welsh, W. F., Evans, T. P., Entwisle, B., & Rindfuss, R. R. (1999). Scale dependent relationships between population and environment in Northeastern Thailand. Photogrammetric Engineering and Remote Sensing, 65(1), 97–105.

Population growth and the natural and built physical environment of Australia: a literature review

Summary

The report first introduces a literature review of the population – environment nexus going back to the 1920s. A number of conclusions were drawn about the role of population growth, including that related to immigration, on the environment in Australia, and these conclusions are presented below:

1. The concept of 'carrying capacity' used in early studies is of declining relevance in an urbanised, services dominated, trading economy, and is only supported by a few scientists (e.g. Butler 2003). For example, domestic shortages of non-renewable resources can be overcome by trade, technology and substitution. In relation to energy resources, however, there are concerns over the supply and cost of transport fuel by or before 2050, and over the adequacy of Australia's coal and natural gas resources at the current high rates of export (Bartlett 2006). In relation to renewable resources all recent studies suggested that food production and water supply will not be constraints on populations of up to 32 million. More recent experiences during the drought demonstrated that water supply is an absolute constraint on population growth in most capital cities. The loss of good agricultural land to urban expansion will also add to the costs of food production and distribution in the future.

2. Recent studies focus more on attempts to determine the effects of population growth on specific aspects of environmental quality and quality of life, such as urban air pollution, congestion, and loss of agricultural and recreational land. Some involve modelling of a large number of variables, and some are at a regional rather than national level (Harding 1995).

3. The main impacts of immigration on Australia's natural and built environment are:

    a. loss of agricultural land through urban expansion

    b. increased greenhouse gas emissions

    c. increased urban land, water and air pollution

    d. pressures on coastal areas

    e. increased pressure on fish stocks

    f. loss of recreational space

    g. increases in traffic congestion and travel time

Modest threats to health should perhaps be added to this list as the outcome of worse environmental conditions.

4. There are particular concerns that population growth will make it substantially more difficult for Australia to meet greenhouse gas emission targets, and that migration to Australia raises global greenhouse gas emissions as migrants adopt the high energy consumption patterns of the Australian population. (Birrell and Healy 2008; Hamilton and Turton 1999)

5. There is disagreement over how to determine if an environmental problem is caused by population growth. Some argue that only impacts that are directly caused by population growth, such as urban land, water and air pollution, should be counted. Others contend that impacts that are somewhat indirect, such as land degradation caused by export production that is needed to pay for imports for a largely urban population, should also be included. The extent to which agricultural exports are in fact influenced by the level of imports needs to be considered in the present study.[2]

6. Some studies regard any environmental impact that could be reduced through better management and planning as not caused by population growth. Others argue that because Australia has largely failed to achieve significant improvements in environmental management, the effects of population growth should be assessed on the assumption that future improvement will be limited. One view is that immigration should not be increased until governments have established adequate policies to manage the environmental impacts of immigration. There is a significant division on this issue between economists, who tend to be optimistic about improved environmental and resource management, and environmental scientists and some other social scientists, who tend to be pessimistic.

7. A consequence of the previous point is that an evaluation of the effects of immigration on the Australian environment must take account of a range of institutional and cultural factors.

8. There is a strong consensus that consumption habits and methods of production are bigger causes of environmental degradation than the size of the population per se.

9. The main policy advocated to manage the environmental impacts of immigration, and population growth generally, is appropriate market pricing of environmental goods, but this must be accompanied by appropriate planning and regulation, and the allocation of funding.

10. The environmental pressures created by migration are a consequence of where migrants settle in Australia, which is largely in the capital cities and particularly in suburban locations in Sydney, Melbourne and Perth.

[2] This is part of the Australian Stocks and Flows Framework (ASFF) modelling conducted by Dr Graham Turner later in this report.

11. Migrants also add to the demand for land and housing in the suburbs, and therefore to the cost of supplying suburban infrastructure in the outer suburbs and maintaining or replacing it in the existing suburbs. There are a number of ways to reduce these costs that might have more effect than slowing immigration. However, there is disagreement over whether migrant housing demand has helped to raise the price of housing (compare Fincher 1991 with Burnley, Murphy and Fagan 1996).

12. There is very little research on the role of the composition of the migrant intake on their environmental impacts.

13. There is a suggestion that immigration to the larger capital cities may contribute to the out-migration from those cities, which would reduce the urban environmental and infrastructure impact of immigration but cause a welfare loss to the Australians who move for this reason.

14. Several studies note the role of tourists and other short-term visitors in adding to the pressure of population on the Australian environment.

15. There are sometimes strong disagreements between disciplines, particularly between economists and environmental scientists, and there is no clear way to resolve these differences. These disagreements are over both the role of population growth in environmental degradation, and over the policies advocated to manage degradation.

16. Modelling is supported as the best way to deal with the complexity of population-environment relationships, but there are disagreements over the variables to include. Modelling also needs to be carried out at a regional level to cope with the large variation across Australia in population-environment relationships.

17. The concept of sustainability offers one framework for evaluating population-environment relations, but it is a difficult one to work with.

Introduction

There has been a longstanding debate in Australia on the relationships between population growth and the natural and built physical environment, a debate that has been inextricably linked with the issue of immigration. For much of the Twentieth Century this debate was over the population that the environmental resources of the nation could support, and therefore over the level of immigration that should be aimed for. In the 1970s the debate shifted to concerns over the negative impacts of population growth on the Australian environment and to issues of environmental sustainability. In the 1990s the urban infrastructure implications of immigration, and questions about the quality of life in Australia’s rapidly growing cities, became additional matters of public discussion. This chapter reviews the literature on these debates to see what conclusions can be drawn from them that might inform this report.

In the early decades of the century British and Australian governments and a number of populist writers promoted migration to Australia to develop its resources and populate its supposedly empty land, and they spoke of future populations of from 100 to 300 million people. Their arguments were based on comparisons with the United States and Europe, and they viewed land simply in terms of its area, not in terms of its productivity. The image promoted by the optimists, or 'boosters' as they were termed, was of an 'Australia Unlimited', waiting to be developed by British-Australian pioneering spirit and ingenuity. For example, they believed that the arid areas of Australia could be made productive with underground water, and that drought was only an accidental happening.

1920s and 1930s: Griffith Taylor

A major critic of this position was Griffith Taylor, the founder of Australia's first university department of geography (at Sydney University in 1921). Taylor argued that much of Australia *was* a desert, and also that the tropical areas were unsuited to dense settlement by Europeans. He mapped the arid zones, made climatic comparisons with Mexico, North Africa, Persia and the Indian subcontinent rather than with Europe and the USA, and argued that on the basis of these comparisons the limits of settlement had already been reached. He also stressed the need to concentrate development in the better-watered areas of the continent. In 1921, on the basis of latitudinal comparisons and inventories of regional resources, he proposed that the continent could support a maximum of 20 million, although he did also suggest a higher figure of about 60 million. This last estimate was based on a large industrial population on the coalfields and a standard of living comparable to Europe, and Taylor later reduced this number to 20 million if the desired standard of living was that of the United States. Griffith Taylor's estimates of Australia's population carrying capacity were therefore based on the potential for agricultural settlement and industrial development based on coal. Rainfall, water, soils and the climate of the tropics were the main limiting factors.

Griffith Taylor was criticised by politicians and the media for being unpatriotic, and his textbook on Australia was banned by the West Australian Department of Education in 1921 for stating that much of WA was a desert. Today his views of the environmental limitations of much of the continent are more widely accepted, although he was wrong about the possibilities of European settlement in Northern Australia. But in the 1920s his arguments could not be accepted in a country obsessed with a British imperial mission to settle and develop the continent. Some people, however, did listen to him, and in the context of this project it is worth noting that his methods of analysis were praised in a report to the Commonwealth Development and Migration Commission, the organisation then responsible for advising on settlement and population policy. (Powell 1992; Strange and Bashford 2008)

Taylor was not the only person making estimates of Australia's carrying capacity at this time. In the 1920s both Huntington, an American, and Barkley, an Australian, followed Taylor's method of basing their estimates on the population densities of climatically comparable regions in other parts of the world, and calculated carrying capacities of 15-20 million and 30 million respectively. In the 1930s Mullet and Wadham, on the basis of their calculations of the food production capacity of the land, concluded that a population of between 40 and 50 million could be supported (National Population Inquiry 1975, pp. 179-191).

In the 1920s and 1930s another approach to debate about the size of the Australian population, adopted by some economists, was to attempt to determine an 'optimum' population, described as the population at which per capita real incomes would be maximised. These estimates were largely based on the capacity of rural production and the constraints of diminishing returns to land. In 1928 Benham, for example, suggested that a population of between 10 and 15 million people would yield the highest productivity per head (National Population Inquiry 1975, p. 181).

1970s

Population limits and environmental pressures were not matters of much public debate during the 1930s to 1960s, through periods of both low and high immigration, but interest returned in the late 1960s, perhaps as a reaction to the rapid and sustained population growth of the postwar period. The National Population Inquiry, which commenced its work in 1971 and reported in 1975, described the emergence at this time of new challenges to the policy of population growth through immigration as follows:

> Meanwhile concerns of other kinds were mounting: the danger of depleting mineral reserves following the tremendous expansion of both Australian and overseas investment in the extraction and export of a wide range of mineral ores (iron, bauxite, uranium, coal); the increasing pollution engendered by industrial concentration and population growth in major capital cities; fear of environmental deterioration of coastal playgrounds, estuaries, and native forests by excessive development and their uncontrolled use by a growing and increasingly affluent population; increasing awareness of the impact of exponential growth, particularly with regard to the human situation, and the need for Australia to join with the rest of the world in encouraging the move to a zero growth situation with all possible speed. A trend towards higher levels of inflation in the late 'sixties and into the seventies was also seen by some to be directly associated with excess demand generated by the increasing volume of sponsored immigration. (National Population Inquiry 1975, p. 211)

This account shows a shift in thought about Australia's population size away from the earlier focus on carrying capacity to concerns about the effects of a growing population on environmental quality and sustainability. The National Population Inquiry also noted that attempts to estimate an economic 'optimum' population had been abandoned, and offered the following explanation:

> One basic reason is the recognised incapacity of social or physical sciences to predict technological changes or changes in the availability of resources. A second reason is the growing recognition of the relevance of a wide range of human activities, generally subsumed within the generic title of 'quality of', to an index of optimum human welfare. Once the concept of the optimum is so widened, the task of defining an index which has universal application has proved, so far, beyond the range of human ingenuity. (National Population Inquiry 1975, p. 227)

The National Population Inquiry did not express any concern over the role of population growth in environmental degradation. After a review of physical and resource constraints the Inquiry concluded:

> None of the figures of carrying capacity in relation to land, minerals, energy and water is presented to determine an ideal or desirable population size. Nor indeed are the figures given very meaningful if interpreted only in relation to each single resource. Resources are only useful if there is a demand for them and in the Australian situation the level of demand will be determined by overseas as well as internal market situations. The population required to exploit these resources will also depend largely upon national economic policies, such as whether to process the resources in Australia or simply to export the raw materials. The conclusion relevant to this

> study which seems to follow from the kind of analysis undertaken is that resources are not likely to impose an early ceiling upon the population that can be carried at existing levels of living. A minimum level might be three times the present population; the maximum might well be several times greater, depending upon such factors as technological developments, expanding markets, and increased availability of resources compared with the present state of knowledge. (National Population Inquiry 1975, p. 724)

The Inquiry also briefly reviewed the issue of environmental quality. It concluded that population growth within the projections made by the Inquiry could be managed without 'serious environmental deterioration', and that *'[l]ocation, technology, the industrial base and transportation raise more fundamental issues than feasible changes in population growth rates'* (National Population Inquiry 1975, p. 714). The Inquiry Chair, Professor Borrie, is reported as later stating that '*there was no reason to think that Australia could not support 50 or 60 million people comfortably'* (House of Representatives Standing Committee on Long Term Strategies 1994, p. 17).

The Australian Institute of Political Science held a Summer School in 1971 on population and immigration, and published the proceedings as a book (Australian Institute of Political Science 1971). Fenner, a biologist, pointed to pressures on resources, especially water, and to the growing pollution produced by an industrial economy. He argued for a lower rate of population growth to enable the country to improve the quality of the social and physical environment, and for the eventual stabilisation of the population by at least 2071. A commentator suggested that this approach ignored the roles of technology and markets in overcoming resource shortages. The commentator argued that slowing population growth was not an effective way to address environmental problems, and advocated economic and administrative means of changing environmental behaviour. Neutze, an economist, outlined the effects of population growth on the quality of life in the major cities under the headings of accessibility, the social environment and congestion, and advocated slower urban growth distributed over a larger number of cities. Commentators pointed to other ways in which the problems of large cities might be managed.

Later in the 1970s a geographer, Ian Douglas, returned to Griffith Taylor's theme and argued that the limitations to the population that Australia could sensibly support were related to the supply of land close to the coast and with relatively reliable water and reasonably fertile soil. This was the type of land that was valued in Australia, and it was scarce. It was now in demand not only for agriculture and food production, but also for forestry, urban settlement, industrial development, mining, waste disposal and recreation. In addition, he pointed to the accompanying problems of coastal erosion and pollution. (Douglas 1977)

Other estimates in the 1970s were based on food production. For example, Gifford and his colleagues, using data from the 1960s, calculated that Australia's potential food production, combined with assumptions about agricultural technology, diets and standards of living, could feed a resident population of about 30 million if 50 per cent of food protein produced was exported, and up to 80 million with a lower protein consumption and no agricultural exports. These calculations were revised nearly 20 years later, producing estimates of 'supportable' populations of from 96 to 206 million people (Henry and Godden 1995). The authors of the revised estimates concluded that:

> The dramatic differences between the population estimates of the earlier and current studies is good evidence that the specified procedures are simply incapable of being used to infer anything meaningful for population policy (Henry and Godden 1995, p. 103).

An economic analysis of immigration, population growth and the environment (1990)

By the 1980s the rapid post-war growth of the Australian population, based on both high fertility and high immigration, had begun to stimulate renewed debate over the long term future size of the population and the environmental consequences of population growth. The Bureau of Immigration Research was established in 1989, and commissioned a number of reports on these issues from different disciplinary perspectives. One was by a group of economists, who produced a closely argued and theoretically-based analysis of a range of issues, as well as a critique of previous studies (Clarke et al 1990). They argued that many of the claims about the extent of environmental degradation had been exaggerated, and had not been caused by population growth. They contended that:

> More importantly, regardless of the alleged extent of environmental or resource problems facing Australia, the key question facing Australian policy makers is the extent to which these problems should be tackled through immigration policies. A major conclusion of this report is that Australians will in general be better off using resource management policies targeted to deal with specific resource and environmental concerns rather than using immigration policies. These preferred policies for the most part involve implementing the standard types of efficient pricing rules that have been discussed at length in the economics literature. (Clarke et al 1990 pp. ix-x)

However, they cautioned that:

> Our view is that while there have been changes in Australia toward more efficient incentive-based controls, and more are planned, overseas experience suggests that progress is likely to be slow unless a firm commitment to rational resource policies develops. (Clarke et al 1990 p. x)
>
> At the same time it should be noted that if the environmental policies preferred by economists on efficiency grounds are not implemented, because of, for example, prohibitively high enforcement costs or unacceptable distributional consequences, other 'second-best' policy instruments should be considered jointly with immigration policy. That is to say, it will usually be preferable to implement a 'second-best' policy of non-price environmental regulation rather than restrict immigration unnecessarily to protect the environment. For example, it may make more economic sense to subsidise public transport more heavily if governments are unable or unwilling to make motorists pay the marginal social costs of pollution and congestion arising from driving in inner-city areas, rather than curb immigration. (Clarke et al 1990 p. xi)

Another caution related to the possibility of irreversible environmental changes.

> Caution is needed in making decisions to the extent that there are irreversible consequences of immigration with currently uncertain costs. The most significant irreversibilities are biological: the threat to lives from toxic pollution, the adverse effects on native species of the possible introduction of overseas species, and the extinction of species due to loss of wilderness areas. Immigration itself is largely an irreversible decision. The implication is that caution needs to be built into either or both immigration policy and resource and environmental policy. It may be worthwhile to postpone an irreversible decision if the economic consequences will be known with greater certainty in the future. (pp. 86-87)

Ruth Fincher (1991)

Another Bureau of Immigration Research report was by geographer Ruth Fincher into the links between immigration and the condition of Australia's urban and non-urban environments. Her report briefly reviewed the past history of the debate and her conclusions are reproduced below:

> 1. The population's effects on urban environments are not straightforward because a larger, wealthier population may demand better environmental quality, and will have the capacity to pay for the technology required to achieve that quality. On the other hand, the political will to act on such demands, and to pay for them, may not always be present and then environmental degradation in cities may result from congestion costs, waste disposal, etc. The consumption habits of existing residents, and the production processes of existing enterprises or institutions, crucially influence the effects of population numbers on environments. Changes in these can offset quite large increases in population numbers.
>
> 2. Domestic population growth may cause congestion of recreation or wilderness areas. This can be managed, and indeed new recreation and wilderness areas can be (respectively) developed and identified. It also needs to be emphasised that the development of our tourist industry is partly driven by the demands of overseas residents and the investment of foreign capital, as our agricultural industry has been. The demands of overseas, would-be tourists and business people are transforming many of our recreation and wilderness sites, as much as are the demands of the domestic population.
>
> 3. Claims of direct or simple links between population numbers and agricultural sustainability, or the land degradation which prevents agricultural sustainability, are often far too simplistic. Land degradation in Australia is the product of damaging farming practices which have occurred through the past 100 years, and have been responses to the demands of export markets and foreign investors as well as to calls on local farmers to feed the Australian people. Large population size was not, and is not, the cause of this situation—in fact it has been argued that population levels were, in the past, too low and that inappropriate farming methods developed in part to compensate for this. (Fincher 1991, pp. x-xi)

Population growth and Australian regional environments (1992)

Another report commissioned by the Bureau of Immigration Research was produced by a team of social scientists with considerable ecological expertise (Stephen Dovers, Tony Norton and Ian Hughes) and a demographer (Lincoln Day). It brought the discussion of population-environment issues down to a regional level, with case studies of the Canberra, Illawarra and Alice Springs regions. Among a number of valuable insights, the main contributions of the report to the present study are:

- The inclusion of tourists as a component of the population impacting on the Australian environment and infrastructure.

- The necessity of adopting a regional and local approach to population-environment issues, because of the enormous variation between places in both the environment and the population pressures on it.

- The need to evaluate the integrative and cumulative nature of environmental impacts, rather than looking at each impact in isolation.

- Awareness of the way that environmental degradation can reach a threshold at which point the system collapses or changes quickly, rather than continuing to change in a linear pattern.

- Arguments about the management of environmental impacts must '… address the political, institutional, economic and technological capabilities required.'

- Assessments of environmental capacities must take account of the variability of the Australian environment over space and time.

- The need to find a framework for analysing population-environment issues.

The framework adopted by the authors is based on the concept of sustainability, but they admit that this framework is difficult to apply because of the number of variables involved in population-environment relations, and the interactions between them. They present a model which identifies the elements of both the biosphere and society that are involved in population-environment relations, and which includes the institutional and cultural arrangements that influence the impact of a population on the environment, and the ability to manage that impact.

Population Issues Committee: Population issues and Australia's future (1992)

In the early 1990s a report was produced by the Population Issues Committee of the National Population Council, which had been asked by the Prime Minister to examine the major issues that could arise from the increase in Australia's population. In their chapter on 'Population impacts: ecological integrity', the Committee made the following comments (Population Issues Committee 1992):

> Australians are well-endowed with natural resources, which support a large number of people outside the continent.
>
> On the other hand, arable land is scarce, water supply is very variable, there is a serious mismatch between the distributions of water and people, soils are thin and easily depleted, much of the land is seriously degraded, and Australia has a high proportion of threatened species.
>
> Degradation of land is not related to the size of the Australian population but to agricultural and mining production for export markets to meet the demands of the global population. However, the environmental pressures from forestry, fisheries and tourism, and from domestically-oriented manufacturing and service industries, will increase with population growth.
>
> The productivity of resource use will have to increase at a higher rate than has been achieved in the past if the absolute level of resource use (and therefore the pressure on the environment) is to be prevented from rising. Alternatively, there will have to be a major transformation of the

economy towards less intensive industries if Australia is not to draw on its stock of natural capital.

Resource shortages resulting from depletion will not be a major problem.

Population growth has a major impact on ecological processes and systems, natural capital as an amenity, the ability of environmental processes to absorb wastes, and biological diversity. In none of these are the environmental effects of population growth reflected in market prices.

Market pricing can play an important role in conservation and the socially efficient use of scarce resources.

Australia's population concentration into large, low density cities has led to air and water pollution and consequent public health problems, and to marine pollution, the loss of bushland and wetlands, reduced housing affordability and a declining quality of life.

Population growth plays a major role in greenhouse gas emissions.

There was a need for improved management of urban environmental amenity.

Environmental problems should be addressed directly through better management, rather than through cuts in population.

Australian Academy of Science Symposium (1994)

In 1994 the Australian Academy of the Sciences held a symposium on the future population of Australia with the title *Population 2040: Australia's choice*. The opening paper by Jonathan Stone noted that while there was growing concern over the impact of people on the Australian environment, since the 1940s there had been little debate over the role of population growth and immigration in this impact. A paper by Cocks and Foran examined ways of framing and answering questions about the desirability of future target population sizes. They contended that approaches based on resource limitations or carrying capacity would not produce defensible population targets, and suggested re-phrasing the population question as an examination of the effects of population growth on a range of measures of quality of life, through analytical modelling. This methodology was being developed at the CSIRO and was eventually used to produce the report *Future Dilemmas* discussed later in this section. They identified a number of possible indicators of quality of life, but noted that some are difficult to measure, and all face the problem that there are no standards to use to determine when an indicator has crossed an acceptability threshold. It was also difficult to separate the role of population growth from other factors that contribute to changes in the indicators.

Another paper by Kalma and Fleming drew attention to the value of using the concepts of urban metabolism and ecological footprint to examine the environmental implications of urban growth, and particularly the impacts of cities on regions well beyond the urban area. However, they rejected the view that immigration was the main cause of the environmental problems created by cities, and instead suggested that these were the result of the ever-increasing per capita consumption of resources, 'the absence of integrated planning, the need to adapt cities to the Australian environment and a lack of insight in the total product of urban development' (Kalma and Fleming 1995, p. 110).

A joint statement by the Population 2040 Working Party included the following paragraph:

> If our population reaches the high end of the feasible range (37 million) the quality of life of all Australians will be lowered by the degradation of water, soil, energy and biological resources. Cities such as Sydney and Melbourne will double or triple in size, multiplying their current infrastructure problems and their impact on the surrounding regions of the continent. Alternatively, new cities of their present size and impact will have to be sited, built and serviced. Moreover, this large population would continue to grow for decades after 2040, and the quality of Australian life would continue to fall. (Australian Academy of Science 1995, p. 136)

In a submission to the House of Representatives Inquiry discussed below the Working Party drew attention to the growing knowledge of the environmental problems caused by population increase, and outlined the fragility and low productivity of Australia's land and water resources. The submission went on to state:

> Accepting the argument set out above—that the range of next-century outcomes is sensitive to policies set today—much debate is needed to identify policies which are both responsible and feasible. No simple analysis is available which will set the optimum population of Australia; that optimum is essentially a communal decision, to be set by the values the community places on such diverse factors as individual affluence, acceptable levels of crowding and pollution, and of security from crisis in the supply of food and fuel, and the degree to which individuals will accept community goals.
>
> The analysis of limiting factors (water, arable land, marine resources, minerals), for example, has not provided a clear estimate of Australia's carrying capacity. The substitution of one commodity for another, of one technology for another, has proved capable of overcoming many limits foreseen by analysts since Malthus. And the analysis of limiting factors has difficulty dealing with factors such as wilderness, recreation areas and pollution-free air and water. Wilderness, for example, may be regarded with fear in one generation, and with reverence in the next. Recreation areas and clean beaches are (arguably) essential for high-quality life, but not for survival. The limits to population set by resources cannot be defined without dealing with the issue of the quality of life.
>
> The coming debate over the population of Australia is likely therefore to involve an analysis of the quality of life, the modelling of a lifestyle acceptable to the Australian community, and the matching of the lifestyle to its acceptable cost. Only from such debates can a consensus emerge of the population appropriate for Australia. Given, however, the major unresolved ecological problems already created by the human population of Australia, it is essential that, while such debates run their course, Australia follow a cautious policy on population, and adopt policies which minimise population growth. (Australian Academy of Science 1995, pp. 142-143)

The Committee did not consider, or make recommendations about, appropriate levels of population growth and size, or of the level of immigration, and the report contains no discussion of carrying capacity or supportable population. However, these were the subject of a Commonwealth House of Representatives Standing Committee report in 1994.

House of Representatives Standing Committee for Long Term Strategies: Australia's population 'carrying capacity' (1994)

The Standing Committee's report contained a discussion of the concept of human 'carrying capacity', and gives it a much wider definition than the number of people that can be supported by the environment at some specific standard of living by including economic and socio-cultural factors in addition to environmental ones. It pointed out that in an economy engaged in international trade the population that can be supported is not limited to the number of people that can be fed from domestic production. The Standing Committee also stated that it was troubled by many submissions in which:

> The almost universal explanation offered for contamination of river systems, for problems of waste disposal, and for excessive water use is identified as population growth alone, without any attempt to suggest more appropriate land management, developing new techniques in waste disposal and treating pristine water as a premium product (Australia. Parliament. House of Representatives Standing Committee for Long Term Strategies 1994, p. 19).

The Standing Committee received submissions that argued for populations ranging from 1 million to 100 million. It commented that the arguments in the submissions 'have not been developed systematically and are supported by limited and patchy data only'. The Committee concluded 'it would not be possible from the material available to the Committee to develop cases for or against populations of different sizes and different rates of change …' (Australia. Parliament. House of Representatives Standing Committee for Long Term Strategies 1994, p. 112). The Committee argued that:

> Ultimately, Australia's 'carrying capacity' is a function of choices, not environmental constraints, for example, whether to consume at present levels or at reduced levels per head, whether to develop output increasing or cost reducing technology (Australia. Parliament. House of Representatives Standing Committee for Long Term Strategies 1994, p. 42).

The Committee rejected the view that Australia was close to its maximum population already, and called for ongoing debate over a range of scenarios.

In a review of the report Mercer (1995, p. 25) criticised 'its unbalanced focus on the land and water problems of thinly-populated rural Australia by comparison with the country's rapidly expanding urban regions. It is in the latter that population growth is having its most direct and dramatic impact.' He also comments (p. 27) that the Committee's argument that superior social organisation can minimise environmental impacts '… implies a powerful role for the state ('political will'), strict planning laws and a high level of national consensus about what needs to be done. In no sense does deregulated Australia fit this model.'

Ecologically sustainable development (1990s)

In the 1990s nine national government-sponsored working groups reported on ecologically sustainable development. According to Cocks (1996, pp. 6-7), they identified a number of crucial elements of a population policy consistent with ecologically sustainable development (ESD). These included:

- The policy should provide clear statements of long-term population size and growth rate objectives, including the possibility of zero or negative population growth, based on the best understanding of the economic, environmental, social and cultural impacts of population growth. Such statements can then provide an appropriate basis on which an immigration policy can be formulated that promotes the achievement of ecologically sustainable development.

- The policy should consider the impact of various economic, environmental, social and cultural forces on the distribution of population, especially in the urban and regional development contexts.

- The policy should emphasise that the skills base of the population is more relevant to Australia's economic prospects than simple population size.

- Given the many uncertainties involved, especially over the impacts of population on ecological systems, the policy should adopt a precautionary approach to population issues. Such an approach is also warranted in the light of the time-lags between population growth and its resultant effects.

Cocks records that the recommendation for studying the links between ESD and population was one of the few recommendations out of the hundreds in the ESD Working Group reports to be explicitly rejected by the government.

Doug Cocks: People policy (1996)

Doug Cocks was an advisor to the 1994 House of Representatives Standing Committee Inquiry reviewed above, and he drew on this experience, and the submissions to the Inquiry, in a wide-ranging book on population policy (Cocks 1996). His conclusions relating to resource availability and the effects of population growth on the environment were:

> With present international trade and factor substitution possibilities, it is not defensible to argue that any particular natural resource such as water or mercury is so limited in Australia that doubling (say) the population over coming decades is impossible. Certainly the real marginal cost of supplying some important goods (clean domestic water, for example) will rise with population growth, and positional goods like wilderness will have to be rationed. But, while Australia might become a less pleasant country in which to live, there is no foreseeable combination of material shortages that would make Australia uninhabitable for 36 million people in 2045, a not implausible demographic scenario.
>
> Coming up with a working judgement of Australia's long-term maximum well-fed locally-fed population requires balancing several poorly known, unknown and intangible factors including future climatic conditions; future technological advances; future land availability; and future political priority given to food production.
>
> And then there is the prospect of future resource base deterioration: for instance, do we assume that problems like erosion, soil acidification, soil salinisation are solved or not solved when making such a calculation? Without being able to formally justify the figure, I would be very uneasy with any estimate much above twice the present population, say 36 million people. This is not greatly different from the number currently being fed by Australian farmers.

> Significant population growth stands to produce a significant increase in the present moderate probability that, even without such growth, a range of urban environmental (e.g. pollution, congestion, services, amenity) and social (e.g. personal relationships and freedoms) quality of life indicators will deteriorate markedly for most Australians.
>
> I would be less inclined to make this my most important reason for favouring population stabilisation if I could see real evidence that Australian society is, or is likely to begin, deliberately and comprehensively tackling urban quality of life problems in other ways such as decentralisation, functional urban design, consumer education, economic incentives for reducing externalities and the adoption of materially efficient technologies. Appropriate complementary policies and programs must be in place before any reassessment of this position seems warranted. Significant population growth stands to produce a significant increase in the present moderate to high probability that, even without such growth, the real per capita cost of providing Australians with many goods and services based on natural resources (e.g. food, water, biodiversity, residue sinks, amenity resources) will increase markedly and inequitably. (Cocks 1996, pp. 85, 102, 182-183)

A short statement of Doug Cocks' assessments is in Cocks (1998).

Immigration and urban infrastructure and housing (1996)

Another of the studies commissioned by the Bureau of Immigration Research in the 1990s appeared as a book (Burnley, Murphy and Fagan 1996). It synthesised a large volume of previous research on the settlement of migrant and their effects on urban infrastructure, housing, the urban environment, urban labour markets and regional development, and added new research.

Their conclusions on infrastructure and services are:

> While immigration does contribute to metropolitan growth, it does not follow that it causes the problems of inadequate provision of infrastructure and services that are found particularly in the outer suburbs. These are the result of an inadequate flow of funding to the jurisdictions responsible for providing this infrastructure and services.
>
> If, at the national level, the long-run benefits of immigration exceed its costs, as is generally regarded to be the case, and if financial flows from Commonwealth to State and Local Governments properly reflect demand pressures arising from immigration, there should not be a problem. (Burnley, Murphy and Fagan 1996, pp. 69-70)

On housing they conclude:

> Immigration seems unquestionably to be associated — on theoretical and empirical grounds — with short and long term inflation in housing prices in Australian cities. In the short run the unpredictability of immigration levels means that supply constraints emerge in markets for housing allotments and dwellings. Price inflation during periods of high immigration is, however, also associated with the state of the national economy which simultaneously influences the propensity of people to migrate to Australia. Paths of causality are therefore blurred. In the long run, other things being equal, larger cities have higher prices for their established housing. Because immigration substantially drives population growth in Australia's largest cities, especially now in Sydney, it also logically drives price increases in the long run. The situation is

> exacerbated in Sydney because costs of land development at the edge of the city are higher than in other cities. The evidence is that affordability of housing is lower in Sydney and that people must either be prepared to spend a higher proportion of their income on housing or else compensate by living at higher densities or by relocating to other parts of Australia. It should be noted that in the long run, higher prices in Sydney result in greater asset accumulation, since capital gains are largely untaxed. (Burnley, Murphy and Fagan 1996, pp. 89-90)

On whether immigration should be reduced as a way of managing the environmental problems of cities they argue:

> If human behaviour and urban form remain constant then slowing rates of population growth in cities, even curtailing growth completely, will contribute to their ecological sustainability. But questions of how to achieve such objectives arise. So too do questions of the relative effectiveness of population control, compared with controls over urban form and environmentally damaging behaviour.
>
> From a purely technical viewpoint, reducing immigration to achieve sustainable cities is a second best option. First of all, if immigration is halted this will not stop population growth overnight. This is partly because any population holds the potential to grow from natural increase. In the case of Sydney, it has been noted that when population growth from immigration is high more people leave to live in other parts of Australia. Conversely, when immigration is low the outflow of people from Sydney declines. The implication of this relationship is that if immigration is reduced the effect on Sydney's population growth will be much less than proportional. A second reason why controls over population growth are a second best option for dealing with environmental problems is that such a strategy will only defer attacks on the more fundamental issue of environmentally damaging behaviour.
>
> Unquestionably there are significant environmental problems in Australian cities and, other things being equal, the larger the population of a city the greater will be the pressures on the natural environment. But population levels and rates of growth are merely part of a complex set of forces influencing environmental quality, and control of population is not self-evidently the sole or the most effective way to go.
>
> The technical principles of achieving ecologically sustainable cities are thus well established. One of the problems in implementing these principles is, however, that urban managers and politicians typically lack economic literacy as opposed to physical planning and civil engineering skills. They thus typically conceive of urban environmental management, and urban planning generally, as an exercise in setting regulations, in public education, and in improved coordination between State and Local government agencies. While those approaches are essential, market forces strongly limit their effectiveness while simultaneously pointing the way to the most direct and effective means for policy implementation.
>
> Externality pricing, and more generally cost-recovery pricing for urban infrastructure, are clearly the linchpins of ecologically sustainable cities. Properly conceptualised and implemented, their use is capable of defusing conflicting social justice, environmentalist and ethnic agenda. (Burnley, Murphy and Fagan 1996, pp. 108-110)

ATSE: Population futures (2000)

In 2000 the Australian Academy of Technological Sciences and Engineering (ATSE) released a report on Australia's population futures for the Business Council of Australia, a longstanding advocate of population growth and immigration. The report classified environmental problems according to their link with population growth. The four which had a strong link to population growth (i.e. there was likely to be a clear and significant worsening with larger populations) were:

- the pollution of land and groundwater
- the pollution of coastal waters, rivers and lakes near major urban centres
- the depletion of freshwater stocks near large urban areas, and
- urban air pollution.

The ATSE report also argued that these problems were not just the result of population numbers, but also of the structure and functioning of Australia's cities, and particularly urban sprawl and consequent car dependency; the high level of resource use and waste production by world standards; and the low stocks of fresh water near the major population centres because of Australia's dry climate. The report went on to contend that the application of a range of technological, behavioural, pricing and settlement planning strategies could improve environmental outcomes even with significant population growth.

The ATSE report identified nine issues with only a tenuous link with population growth (i.e. a degree of worsening could be expected, but not a 'clear and significant worsening'). One was greenhouse gas emissions, because in the words of the report:

> … any increase in greenhouse gases from an enlarged population in Australia could be small on a global scale, might be off-set by greenhouse reductions in other nations (assuming immigration) and, importantly, would probably be caused by economic and transport patterns (as opposed to population per se).

Another was the loss of biodiversity, because this was caused by land clearing for agriculture, and agriculture was not directly linked to the size of the population within Australia. The report noted, as had many other studies, that much of the damage to land was done when Australia's population was much smaller.

The eight environmental issues that the report argued had no link with population growth (i.e. there was no reasonable possibility that an enlarged population could directly cause a significant worsening in the issue) included:

- the degradation of soils through salinity, acidification and erosion, which the ATSE report contended was the result of inappropriate land management practices.
- the degradation of rivers and lakes in rural areas, which the report argued was caused by irrigation for agricultural production, not directly by population, and as much of this production was for export it would not be affected by population growth.

The ATSE report was the subject of an ecological critique by Jones (2001). He argued that the judgement of what was 'strong' and what was 'tenuous' was too subjective, that the cumulative effect of a number of 'tenuous' issues could be substantial, and that the report downplayed the role of population if it is indirect, as in the case of irrigation to produce agricultural exports. Exports were needed to pay for imports, and demand for imports increased with population growth. He further suggested that the argument that much of the environmental damage caused by land clearing and habitat loss had occurred in the past when the population was much smaller ignored the very high rate of land clearing over the last 50 years. He also dismissed the claim that population growth was not responsible for environmental problems if it could be shown that better management could reduce or remove these problems, arguing that population growth did place additional pressures on the environment, regardless of whether these pressures could be managed. In his view, both population stabilisation and better management were needed to address Australia's environmental issues. Furthermore, belief in better management as the answer was an act of faith that ignored the financial, social and political obstacles that had limited the adoption of better management practices in the past.

Hamilton (2002) did not address the ATSE report, but implicitly argued against its conclusions on the 'tenuous' link between population growth and greenhouse gas emissions. He contended that growth in population would directly increase energy used in households, travel by car, and air travel. Population growth would also increase the size of the economy, and through this indirectly increase energy use in the services sector, manufacturing for the domestic market, construction, road freight and rail freight. Hamilton also highlighted the role of population growth in the degradation of coastal ecosystems, an issue ignored in the ATSE report. He argued that people who move to settle in Australia's coastal environments, and those who holiday in them, were putting extreme pressures on these environments. The consequences were coastal and beach erosion, degraded water quality, loss of aquatic habitats, sedimentation, loss of familiar landscapes and seascapes, loss of productive farmland, and degradation of the environmental quality and amenity that attracted people to settle or holiday along the coast in the first place.

Yencken and Wilkinson: Resetting the compass (2000)

Yencken and Wilkinson wrote a comprehensive review of environmental sustainability issues in Australia. In a section on pressures on the environment they included a discussion of the role of population, and made the following comments:

> Increases in population must have an impact on the environment unless there is a compensating drop in consumption and/or an increase in technological efficiency which in combination lead to no net increase in energy and material use or waste output. There is no immediate prospect of a reduction in consumption patterns in Australia and it is doubtful that we are achieving improvements in technological efficiency at the rate required to compensate for the impact of additional people. If we take into the account the projections now coming from many quarters and cited in Chapters 2 and 4, that very large reductions in material and energy use are required simply to put the existing energy and material use in developed countries such as Australia onto a sustainable footing before we even consider the impacts of additional people, it is apparent that we have to take the question of the environmental impact of population growth seriously. There will be overall impacts which relate to increases in energy and material use and the wastes associated with additional resource use.

There are also likely to be specific environmental pressures on the Australian environment. They include pressures from:

- ***greater concentrations of people along the coastline especially the eastern and south-eastern coastline***. The additional pressures on the coastline will be from many sources: increased permanent settlement, holiday houses and internal tourism. These pressures fall on a very sensitive zone. Some of Australia's richest and most complex ecosystems are found on the eastern and south-eastern seaboard, the area to which settlement and recreational activity has been most strongly attracted. We have not managed our coastline very well as numerous inquiries such as the Resource Assessment Commission's Inquiry and Report testify. There are few signs of major improvements to the management of the impacts of existing populations.

- **increases in the size of our cities and towns**. Increase in size of the major metropolises will likely increase car dependency and oil use and their emissions. There will also be impacts on the hinterlands of our settlements.

- **increased pressures on the land from the need to feed and support additional people**. This increased pressure on agricultural lands will come from the need to provide for the additional population and the pressure to increase agricultural exports for balance of payment reasons. (Yencken and Wilkinson 2000, p. 40)

CSIRO Sustainable Ecosystems, Future Dilemmas (2002)

A report on options to 2050 for Australia's population, technology, resources and environment was commissioned by the Commonwealth Department of Immigration and Multicultural and Indigenous Affairs. It was produced by a team at CSIRO Sustainable Ecosystems led by Barney Foran and Franzi Poldi and created considerable controversy when it was released, with attacks from economists, environmentalists and the conservative press (Foran 2003).

The report explored the effects on infrastructure, resources and the environment of three different population scenarios out to the year 2050. These projected the population at 2050 to be 20, 25 and 32 million, using net migration rates of 0, 70,000 persons per year, and 0.67% of the current population in each year. The report identified four types, or drivers, of population-environment relationships. These were:

- Primary (or first order) drivers [of the effects of population growth on the environment] are linked directly to individuals who require food; households who require houses, cars, newspapers, televisions and refrigerators; and communities who require schools, hospitals, public transport and sporting ovals.

- The secondary (or second order) drivers of [the effects of population growth on the environment] 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. For example, while everyone needs a house (a primary driver) affluence might lead to the construction of a larger house (a secondary driver). Scale issues are those that relate to threshold effects such as the presence of international airports, convention centres and five star hotels that expand opportunities for industries such as tourism and thereby stimulate transactions in the physical economy.

- The tertiary (or third order) drivers of [the effects of population growth on the environment] 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. These rising level of imports are linked to consumption growth on a per capita or per household basis. They have to be paid for by exporting commodities such as coal, aluminium and wheat and importing international tourists. Traditionally, the national population debate ignores this tertiary driver of population effect.

- The quaternary (or fourth order) drivers of [the effects of population growth on the environment] 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. (Foran and Poldy 2002, pp. 19-20)

The CSIRO report then identified several future resource and environmental issues, based on physical modelling of a very large number of demographic, resource and environmental variables. The modelling estimated the physical outcomes of different population scenarios, and was also used to calculate the extent of change needed to prevent resource and environmental problems.[3] The main issues identified were:

- The only food issue related to a likely decline in fish stocks, and otherwise domestic food production was projected to be adequate under all population scenarios to 2050 and beyond, although increased consumption could reduce exports and consequently affect international trade balances.

- The longevity of the nations' infrastructure will make it difficult to achieve the widespread adoption of new technology that would reduce resource use or waste generation.

- Stocks of oil could become a constraint on transport unless there is a major transition to a new energy economy.

- Population growth combined with rising incomes and standards of living will increase the demand for houses, other buildings, cars and roads, mainly in urban Australia, and therefore increase resource consumption and waste production.

- Population growth will increase greenhouse gas emissions.

- Increased urban air pollution is likely in Sydney, and possibly in Brisbane and Perth.

[3] For a description of the model see Foran and Poldy 2001.

The study did not link the problems of agricultural land degradation, loss of biodiversity and the declining water quality of inland rivers directly to the primary population effect. Rather these were indirectly related to population through the use of water for domestic food consumption and the need to earn export income to pay for imported consumer goods. For example, while the direct use of water by Australian households was projected to range from only 12-20 per cent of total water use in 2050, over 80 per cent of total water use could be attributed to households through the combination of the primary, secondary and tertiary drivers. The study found that water availability was not likely to be a constraining factor under any of the population scenarios, except perhaps in Sydney and Melbourne by 2100, provided that major changes in water management occurred over the next 50 years.

The report concluded with a review of six dilemmas or challenges which linked population policy, population ageing, physical trade, material flows, greenhouse emissions, natural resource depletion and environmental quality. It explored the policy options for solving each dilemma, and noted that, as they interact with each other, solutions may require substantial structural and social change. In a separate publication the lead authors of the report argued that:

> Technology alone will not moderate the environmental outcomes of whatever population size unless in parallel there is a substantial reduction in the material and energy content of the daily lifestyles of each and every Australian (Foran and Poldy 2003, p. 13).

The CSIRO's report was reviewed by an External Reference Group who, while satisfied that the results of study were robust and defensible, contended that:

- The model was a physical model of stocks and flows and did not include prices. Consequently the report ignored the impact of rising prices on the balance between supply and demand through, for example, technological innovation, substitution or exploration for new resources. The result was an unduly pessimistic view of reserves.
- The model ignored the potential role of market-based environmental policies.
- The model ignored the benefits of the economies of scale, such as shared infrastructure, that would result from population growth.
- The scale of the analysis, in which states are divided into metropolitan and non-metropolitan areas, was too coarse.
- The population problem is about the effects of ageing and low fertility on government budgets, not about migration.
- Environmental problems should be primarily addressed through environmental policies, not through migration policies, which should primarily target the performance of the Australian labour market.

Foran wrote a vigorous response to these and other criticisms of *Future Dilemmas* in an article in *People and Place* (Foran 2003). Despite these criticisms, there seemed to be agreement on a middle of the road scenario, in which net migration of 60,000 to 120,000 a year, mainly focused on skills, would result in a total population of 24-28 million in 2050.

The 2002 Australian Population Summit

The National Population Summit held in Melbourne in 2002 brought together speakers on the economic, environmental, social and cultural aspects of population policy. The papers presented were subsequently published as a book (Vizard, Martin and Watts 2003), but most of the speakers on the environment reviewed work that has already been discussed above. Withers, in concluding the book on the Summit, wrote:

> The view that cities come under considerable pressure from population growth in relation to environmental amenity is broadly accepted. Air and water pollution, waste disposal, congestion, loss of recreation areas and the like are seen as genuine problems requiring address in this arena. There is stout resistance to the idea that rural and regional environmental concerns should be attributed to domestic population growth, however. These derive from global markets. (Vizard, Martin and Watts 2003, pp. 258-259)

2004 Fenner Conference on the Environment

The Australian Academy of Science held a conference on 'Understanding the population-environment debate: bridging the disciplinary divides' in May 2004 (http://www.science.org.au/events/fenner/index.html). This was preceded by an online conference that started with a commissioned report by Colin Butler (Butler 2003), followed by responses from 14 scholars from a range of disciplines and comments from the general public. The conference focused on whether there was a gap between environmental scientists and social scientists in their approach to the relationships between population and the environment, and if there was, how this gap could be bridged. The 2004 meeting did not reach any formal conclusions, but the papers presented and available on the website provide a valuable range of views. They also illustrate the division between those who see the economy and the environment belonging to separate boxes, and those who see the economy as nested within the environment and subject to the limitations that the environment may set.

Comments made by participants that may add to this study include:

- Stephen Dovers' argument that pro-population growth and anti-population growth advocates only perceived one set of causes for environmental problems, but different sets, and therefore advocated one only one set of policies to deal with these problems, but again different sets, rather than a complex mix of policies (Dovers 2004).

- Katherine Betts' comments on the reasons for the positions (or lack of a position) of lobby groups on the population growth debate (Betts 2004).

- Glenn Withers' argument that complementary policies in education, infrastructure and the environment are required before governments raise the level of immigration (Withers 2004).

- Tony McMichael's contention that '… the population-environment debate in Australia and elsewhere should emphasise human experiential consequences, especially health. A prime reason for seeking sustainable social and environmental conditions is ultimately to achieve safety, health and survival (McMichael 2004).

- Ruth Fincher's belief that the central research question in the population-environment debate '… is at once too general, too simple and too binary' (Fincher 2004).

ATSE: The technological implications of an Australian population of 30 million by 2050 (2007)

In 2007 the Australian Academy of Technological Sciences and Engineering (ATSE), commissioned by the Scanlon Foundation, produced a second report on the resource, infrastructure and environmental implications of population growth (Australian Academy of Technological Sciences and Engineering 2007). The report assessed the consequences of a population of 30 million by 2050 through an examination of climate change, water, energy, transport, waste management and social infrastructure, and the planning and investment issues involved in accommodating a larger population. Its conclusions were similar to the 2000 ATSE report, and were that while some environmental problems, such as depletion of arable land, poor waste disposal, water availability and water and air pollution were directly related to population growth, others were not, but were more broadly related to deficiencies in the planning and management of Australia's urban areas, regions, catchments and natural resources. The report concluded that there were no inherent physical, resource or technological barriers to the accommodation of a population of 30 million, but long-term planning was essential to ensure the timely and orderly provision of needed infrastructure, and leadership from governments was essential in setting clear policy directions. Environmental impacts should be addressed through technological development, lifestyle changes, market instruments, policy and regulation responses and education.

The next section of the report deals with the measurement of consumption by migrants and its interplay with the environment and health. It provides a viewpoint on migrant preferences and behaviours in their use of natural assets and produced goods.

References

Australia. Parliament. House of Representatives Standing Committee for Long Term Strategies 1994, *Australia's population 'carrying capacity': one nation – two ecologies*, Australian Government Publishing Service, Canberra.

Australian Academy of Science 1995, *Population 2040 Australia's choice: proceedings of the Symposium of the 1994 Annual general meeting of the Australian Academy of Science*, Australian Academy of Science, Canberra.

Australian Academy of Technological Sciences and Engineering 2000, *Population futures* (http://www.atse.org.au/uploads/Population_Futures.pdf)

Australian Academy of Technological Sciences and Engineering 2007, *30/50: The technological implications of an Australian population of 30 million by 2050* (http://www.atse.org.au/uploads/ATSEScanlon.pdf).

Australian Institute of Political Science 1971, *How many Australians? immigration and growth; proceedings of the 37th Summer School*, Angus and Robertson, Sydney.

Bartlett, A.A. 2006, 'A depletion protocol for non-renewable natural resources: Australia as an example', *Natural Resources Research*, vol. 15, no. 3, pp. 151-164.

Betts, K. *A response*. (http://www.science.org.au/events/fenner/pdfs/KatharineBettsResponse.pdf).

Betts, K. and Gilding, M. 2006, 'The growth lobby and Australia's immigration policy', *People and Place*, vol. 14, no. 4, pp. 40-52.

Birrell, B. and Healy, E. 2008, 'Labor's greenhouse aspirations', *People and Place*, vol. 16, no. 2, pp. 1-15.

Burnley, I., Murphy, P. and Fagan, B. 1997, *Immigration and Australian cities*, Federation Press, Leichhardt.

Butler, C.D. 2003, *Population and environment in Australia: 2003*. A report commissioned by the Population and Environment Research Fund Committee of the Australian Academy of Science. (http://www.science.org.au/events/fenner/pdfs/populationandenvironment.pdf)

Clarke, H.R., Chisholm. A.H., Edwards, G.W. and Kennedy, J.O.S. 1990, *Immigration, population growth and the environment*, Australian Government Publishing Service, Canberra.

Chisholm, A. 1999, 'Land, resources and the idea of carrying capacity', *Business Council of Australia Papers*, vol. 1, no. 2, pp. 19-26.

Cocks, D. 1996, *People policy: Australia's population choices*, University of New South Wales Press, Sydney.

Cocks, D. 1998, *Population-immigration policy in Australia* (article to be published in *Encyclopaedia of World Ecology*). (http://www.labshop.com.au/dougcocks/abernethyfinal.htm).

Douglas, I. 1977, 'Frontiers of settlement in Australia—Fifty years on', *Australian Geographer*, vol. 13, no. 5, pp. 297-306.

Dovers, S., Norton, T., Hughes, I. and Day, L. 1992, *Population growth and Australian regional environments*, Australian Government Publishing Service, Canberra.

Dovers, S. 2004, *How might we think about population-environment more effectively*. (http://www.science.org.au/events/fenner/pdfs/SteveDoversResponse.pdf)

Fincher, R. 1991, *Immigration, urban infrastructure and the environment*, Australian Government Publishing Service, Canberra.

Fincher, R. 2004, *Geography and the population-environment debate*. (http://www.science.org.au/events/fenner/fincher.htm).

Foran, B. 2003, 'Future Dilemmas: a reply to the critics', *People and Place*, vol. 11, no. 4, pp. 2-15.

Foran, B. and Poldy, F. 2001, 'Modelling physical realities: designing and testing future options to 2050 and beyond', in Venning, J. and Higgins, J. (eds), *Towards sustainability: emerging systems for informing sustainable development*, UNSW Press, Sydney, pp. 165-195.

Foran, B. and Gurran, N. 2008, 'Population', in Lindenmayer, D., Dovers, S, Olson, M.H. and Morton, S. (eds), *Ten commitments: reshaping the lucky country's environment*, CSIRO Publishing, Collingwood.

Foran, B. and Poldy, F. 2002, *Dilemmas distilled: a summary and guide to the CSIRO technical report.* Report to the Department of Immigration and Multicultural Affairs, CSIRO Sustainable Ecosystems, Canberra (http://www.cse.csiro.au/futuredilemmas).

Foran, B. and Poldy, F. 2003, 'Between a rock and a hard place: Australia's population options to 2050 and beyond', *People and Place*, vol. 11, no. 1, pp. 1-15.

Hamilton, C. 2002, 'Population growth and environmental quality: are they compatible?', *People and Place*, vol. 10, no. 2, pp. 1-5.

Hamilton, C. and Turton, H. 1999, 'Population policy and environmental degradation: sources and trends in greenhouse gas emissions', *People and Place*, vol. 7, no. 4, pp. 42-62.

Harding, R. 1995, 'The debate on population and the environment: Australia in the global context', *Journal of the Australian Population Association*, vol. 12, no. 2, pp. 165-195.

Henry, L.A. and Godden, D.P. 1995, 'A note on estimating Australia's sustainable population', *Review of Marketing and Agricultural Economics*, vol. 63, no. 1, pp. 97-103.

Jones, A. 2001, 'The Business Council of Australia's case for population growth: an ecological critique', *People and Place*, vol. 9, no. 2, pp 49-57.

Kalma, J.D. and Fleming, P.M. 1995, 'The resource needs of our cities and the population debate', in Australian Academy of Science 1995, *Population 2040 Australia's choice: proceedings of the Symposium of the 1994 Annual general meeting of the Australian Academy of Science*, Australian Academy of Science, Canberra, pp. 79-114.

McMichael, T. 2004, *Population, environment and human health: the role of epidemiological research*. (http://www.science.org.au/events/fenner/mcmichael.htm).

Mercer, D. 1995, 'Australia's population carrying capacity'. One nation – two ecologies. A review and assessment', *People and Place*, vol. 3, no. 1, pp. 23-28.

National Population Inquiry 1975, *Population and Australia: a demographic analysis and projection*, Australian Government Publishing Service, Canberra.

Population Issues Committee, National Population Council 1992, *Population issues and Australia's future: environment, economy and society*, Australian Government Publishing Service, Canberra.

Powell, J.M. 1992, *Griffith Taylor and "Australia Unlimited"*, The John Murtagh Macrossan Memorial Lecture, University of Queensland Press, St Lucia.

Strange, C. and Bashford, A. 2008, *Griffith Taylor: visionary environmentalist explorer*, National Library of Australia, Canberra.

Vizard, S., Martin, H.J. and Watts, T. (eds) 2003, *Australia's population challenge*, Penguin Books, Camberwell.

Withers, G. 2004, *Is the dismal science changing?* (http://www.science.org.au/events/fenner/withers.htm).

Yencken, D. and Wilkinson, D. 2000, *Resetting the compass: Australia's journey towards sustainability*, CSIRO Publishing, Collingwood.

Household-level Consumption

Summary

A further insight was gained from a review of literature regarding consumption as a key element in understanding the population impacts of migrants. The main conclusion was that household expenditure was the best indicator of consumption across a population. With the importance of consumption highlighted in understanding human impacts, the next section of this report examined data on migrants' consumption intentions and behaviours from the survey of Household Income and Labour Dynamics in Australia (HILDA), Australia's first large-scale national household longitudinal survey. Begun in 2001 it has been collected from a random sample of people each year from across Australia and is therefore not spatially specific. Its main conclusions however were applied to our analysis of the impact of migrant population increase on the physical assets of Australia. The key conclusions were that

> *The preferences and behaviours of non-English speaking migrants demonstrated in the results of the 2007-2008 HILDA surveys actually show few differences with the broader Australian and English-speaking migrants. Not only are expenditures of a similar level, trends in spending are similar. The only exceptions to this general view are the slightly increased expenditures by this group of migrants on groceries, eating out and use of public transportation and taxis.*

We also undertook a review of the data from a new survey. For the first time in 2007-08 financial year, the Australian Bureau of Statistics (ABS) conducted an Environmental Views and Behaviour survey in Australia The survey enabled us to gain some understanding of the factors that influence people's participation in environmental activities, and energy and water conservation practices in particular. Again this was not spatially specific data.

The key conclusions were that:

- Personal water use declined slightly more amongst migrants because of *lifestyle changes*;
- People born overseas purchased slightly more refrigerators and washing machines than native-born Australians;
- People born overseas who increased personal electricity use in 2007-08 did so more because of weather conditions than lifestyle changes when compared to native-born Australian respondents; and
- Migrants appear more concerned about saving energy than are their Australian counterparts!

We therefore chose to assume that migrants adopt similar consumption patterns of natural resources and generate similar waste streams as the broad Australian community. In saying this, we note that we have no specific information about the consumption behaviours of the growing number of long-term temporary migrants. Most are students or 457 visa holders. They may well behave differently.

Consumption pattern: Analysis of HILDA survey data

The survey of Household Income and Labour Dynamics in Australia (HILDA) is Australia's first large-scale national household longitudinal survey, with wave 1 conducted in 2001, currently 7 waves available. The HILDA is a broad social and economic survey covering household background, household formation, housing, education, social factors, and many other variables. Since 2005 (wave 5), the survey has collected information on *household-level expenditure*. Such information include annualised expenditure on items such as groceries, public transport and taxis, meals eaten out, motor vehicle fuel, electricity/ gas/ other heating fuel bills, motor vehicle repairs/ maintenance, and purchase of new/ used motor vehicles, motorbikes or other vehicles. These information enable us to examine whether there is any similarity or difference in the pattern of consumption between households of people born in Australia and households of immigrants (distinguishing by main English-speaking and non-English speaking), and how the consumption pattern changes over time. The consumption of a household is measured by dollars per annum.

Purchasing '*groceries*' is one of the major items in a household's annual consumption. As shown in Fig. 1(a), people with non-English speaking background, their average household expenditure on groceries maintained a relatively high, and stable, level from 2005 to 2007, compared to the expenditure of households of people with main-English speaking background or people born in Australia. For the two groups of people (English-speaking, Australia-born), their expenditure presented a growing trend over the same period.

'*Purchasing, repairing and maintaining motor, motorbikes or other vehicles*' is another big item of consumption for these three categories of households of people: Australian-born, English-speaking, and non-English speaking. Australia-born people's households had higher expenditure than the two groups of immigrants' households (Fig. 1 (b)). Non-English speaking households spent the least amongst the three groups, and their expenditure ($3,756) in 2007 was less than that in 2006 ($4,085).

The pattern of expenditure on '*motor vehicle fuel*' for the three categories of households looks similar (Fig. 1 (c)). The peak expenditure on fuel occurred in 2006 due to the substantially increased price for petroleum and gas in that year.

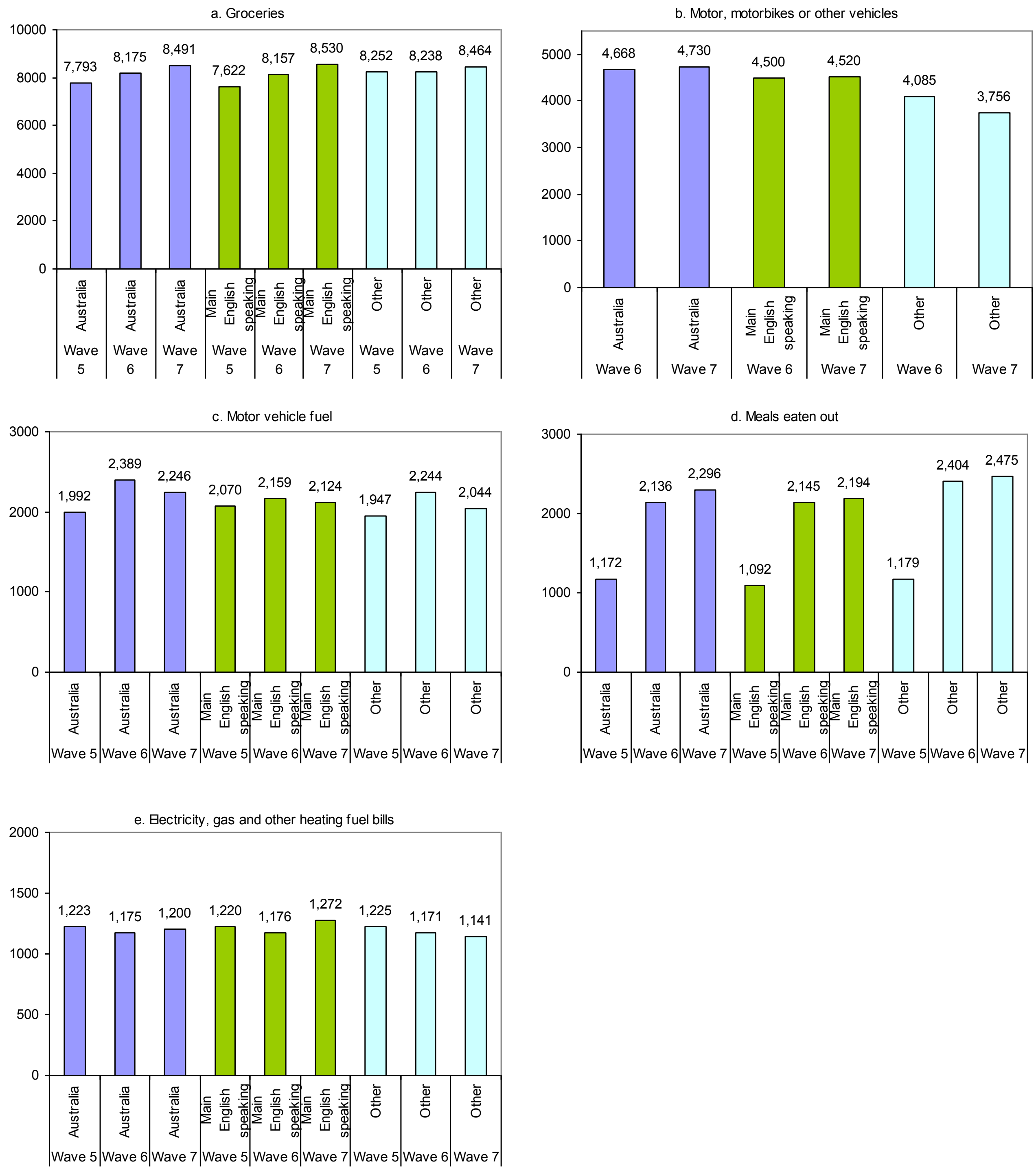
Expenditure on '*meals eaten outside*' in 2006 and 2007 almost doubled the level in 2005, for all the three categories of households, as is apparent in Fig. 1 (d). The substantial increase in expense on this item was closely associated with fast growing food prices in Australia due to drought, mainly, in 2006. There is a striking finding of that non-English speaking people spent more money to eat outside than Australia-born or English-speaking immigrants did. Cultural difference between non-English speaking and English-speaking migrants and the main stream population in Australia is possibly a causal factor.

For the three categories of households, their expenditure on '*energy*' (i.e., electricity, gas and other heating fuel) did not have much difference or varied significantly over the past 3-year period. For non-English speaking people, on average, their households used less energy than the other two groups (Fig. 1 (e)).

Expenditure on '*public transport and taxis*' varies significantly among the three groups of people (Fig. D1f). For non-English speaking people, although their average expenditure on this item presented a declining trend in recent 3 years, their expenditure was much higher than that of Australia-born people or main English-speaking immigrants. This suggests that public transport is an important means used by non-English speaking people when they need transportation to work, study, travel, or do other businesses. English-speaking migrants spent slightly higher expenditure on public transport than people born in Australia.

The HILDA survey has also collected information about '*household-level rent repayments per month*'. As shown in Fig. D2, on average, both non-English speaking and main-English speaking immigrants spent more money to rent residential houses, apartments or flat units than people born in Australia. For each of the three household categories, their average monthly expenditure on rent repayments kept rising from 2001 to 2007. But the gap between their rent repayments was narrowed down over time. For example, the gap of monthly average rent repayments between non-English speaking people's households and Australia-born people's households was $79.60 in 2001. This figure was reduced to $17.60 by 2007.

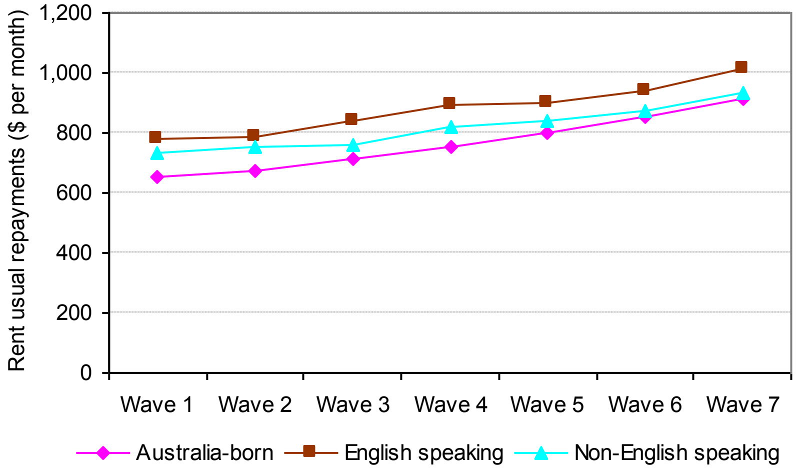
Figure D1 Average consumption of households ($ per annum): immigrants vs. people born in Australia, 2005-07



Data source: Household Income and Labour Dynamics in Australia (HILDA) survey, waves 5, 6, and 7.
Note: The estimated average consumption figures are based on the sample size of households surveyed in waves 5, 6, and 7. For people born in Australia, the sample size is 5,548, 5,472, and 5,360, in waves 5, 6, and 7 respectively. For main-English-speaking immigrants' households, the sample size is 810, 783,

and 733, respectively. For non-English-speaking immigrants' households, the sample size is 754, 727, and 698, respectively.

Figure D2: Average rent usual repayments of households ($ per month): immigrants vs. people born in Australia



Data source: Household Income and Labour Dynamics in Australia (HILDA) survey, waves from 1 to 7.

Behavioural factors influencing consumption: Analysis of ABS survey data

During the 2007-08 financial year, in the first time, the Australian Bureau of Statistics (ABS) conducted an Environmental Views and Behaviour survey in Australia. As a supplement to the ABS monthly Labour Force Survey (LFS), this survey collected information about environmental views and behaviours from the Multipurpose Household Survey (MPHS). This survey has a valid random sample size of 13,527 people from 15,800 private dwellings. It collected information on people's views and practices on environmental issues, for people aged 18 years and over. The survey provides information on environmental concerns, personal energy and water use, waste collection and disposal and environmental involvement. The survey information enable us to gain some understanding of the factors that influence people's participation in environmental activities, and energy and water conservation practices in particular.

Electricity use

In the MPHS, people, distinguishing by born in Australia and born overseas, were asked the question whether they take steps to limit use of personal electricity (ABS, 2009). There was virtually no difference in proportional terms of the two groups of people who answered that they 'take steps' or 'do not take steps' to limit personal electricity use. For instance, 87.8% of immigrants responded that they 'take steps' while 12.2% of immigrants 'do not take steps'. This was compared to 87.9% of Australian-born residents 'take steps' while 12.1% of them 'do not take steps'.

Table D1 shows the reasons why some people did not take steps to limit energy use. Similar reasons include that both groups of people perceived that taking action to limit energy use was 'inconvenient' and 'time consuming'. However they indicate other reasons which are quite different. For example, a higher proportion of immigrants (40.5%) than that of Australia-born people (30.4%) pointed out the reason of 'electricity consumption already low enough'. A greater proportion of immigrants (8.7%) than Australian born residents (4.4%) said that they 'lack of knowledge or did not know what to do'. Compared to immigrants, people born in Australia were more likely not to take action to reduce energy consumption for the reasons that they: 'have not thought about saving electricity' (29.6%); 'do not care how much electricity is used' (13.2%); 'limit electricity consumption is not a priority' (9.9%); and 'comfort' (7.2%).

Australia is a country where climate change will tremendously affect its physical environment and economy in next 20 to 50 years (Garnaut, 2008). Research suggests that industries with high power and resource usage, or those directly involved in the energy supply chain, are most likely to be negatively affected by climate change (ACTU and ACF, 2008; Bill et al, 2008; Hetherington, 2008). With the likely implementation of carbon emission trading scheme in the near future, the cost of energy use of all Australian households will rise. People's consumption behaviour will be challenged by the fact of climate change and the concomitant economic transition towards a 'low-carbon' economy.

Table D1: Reasons why people do not take steps to limit energy use: immigrants vs. Australia-born people, 2007-08

Country of birth	Born in Australia	Born overseas
Electricity consumption already low enough	30.4	40.5
Have not thought about saving electricity	29.6	21.8
Do not care how much electricity is used	13.2	10.5
Inconvenient	10.0	10.4
Limiting electricity consumption not a priority	9.9	7.1
Comfort	7.2	4.8
Lack of knowledge/did not know what to do	4.4	8.7
Time consuming	3.0	2.2
Other	4.6	1.7

Data source: ABS. 2009. cat. No. 4626.0.55.001 Environmental Views and Behaviour, 2007-08 (2nd issue), Table 12.

Table D2 lists the multiple reasons why people, disaggregated by two groups – living in 'capital cities' and 'living in the rest of State/ Territory' – did not take steps to limit use in energy consumption. About one-third of both groups thought this was because of 'electricity consumption already low enough'. People residing in the rest of State/ Territory were more likely to say that they 'have not thought about saving electricity' (28.7%) than those living in capital cities (26.7%). In comparison, there was a higher likelihood for people living in capital cities not to take steps to limit energy use for the reasons of inconvenience, time consuming, comfort, or lacking knowledge or not knowing what to do.

Table D2: Reasons why people do not take steps to limit use: people living in capital cities vs. living in rest of State/Territory, 2007-08

	Capital cities	Balance of State/Territory	Australia
Electricity consumption already low enough	33.1	33.6	33.3
Have not thought about saving electricity	26.7	28.7	27.4
Do not care how much electricity is used	13.1	11.2	12.4
Inconvenient	10.7	9.0	10.1
Limiting electricity consumption not a priority	8.8	9.7	9.1
Comfort	7.3	5.1	6.5
Lack of knowledge/did not know what to do	6.1	4.8	5.6
Time consuming	3.5	1.5	2.8
Other	3.1	5.1	3.8

Data source: ABS. 2009. cat. No. 4626.0.55.001 Environmental Views and Behaviour, 2007-08, Table 10.

At the individual level of consumption, about 45% of both groups reported that their personal use of electricity remained unchanged during the financial year 2007-08. A slightly higher proportion (47.6%) of Australia-born people stated that the amount of their energy use decreased, compared to 45.7% of immigrants reduced energy consumption. A small, but a relatively higher, proportion of immigrants (7.3%) increased use of energy (Table D3).

Table D3: Change in personal electricity use: immigrants vs. Australia-born people, 2007-08

Country of birth	Born in Australia	Born overseas
Use increased	6.7	7.3
Use decreased	47.6	45.7
Stayed the same	44.8	44.7
Did not know	1.0	2.3
Total	100	100

Data source: ABS. 2009. cat. No. 4626.0.55.001 Environmental Views and Behaviour, 2007-08, Table 14.

Three are three reasons that both groups of people who increased use in electricity considered as the main reasons. These are: 'life style changes', 'acquired additional electricity appliances', and 'weather conditions' (Table D4). A higher proportion of Australia-born citizens (36.4%) than immigrants (30.6%) thought that 'lifestyle changes' played an important role. A greater proportion of immigrants (29.4%) than people born in Australia considered 'weather conditions' as the third important factor which resulted in an increase in electricity consumption. Again, these reasons have important policy implications for the government, energy industry, environmental sectors, and other related agencies. Ageing population, immigration, and climate change are big challenges that Australian people will face in this century. People's changing lifestyle, changing weather conditions, and thus needs to meet such changes will continue to shape their energy consumption behaviour in next years.

Table D4: Reasons why personal electricity use increased: immigrants vs. Australia-born people, 2007-08

Country of birth	Born in Australia	Born overseas
Lifestyle changes	36.4	30.6
Acquired additional electrical appliances	30.9	29.7
Weather conditions	17.2	29.4
Lived in different dwelling	12.3	9.6
Health reasons	3.8	4.4
Other	8.1	6.0
Did not know	3.9	4.0

Data source: ABS. 2009. cat. No. 4626.0.55.001 Environmental Views and Behaviour, 2007-08, Table 16.

'Trying to conserve energy' was a main reason for people to reduce use in energy in 2007-08 (Table D5). Another three important reasons responsible for reduced use in energy include: 'purchased/ used energy efficient electrical appliances', 'lifestyle changes', and 'cost saving'. The pattern of various reasons did not vary significantly between the two populations. Washing machine, refrigerator, and air conditioner were the major appliances that both immigrants and Australia-born residents bought in the last 12 months prior to the 2007-08 survey (Table D6). A greater proportion of immigrants than Australia-born people chose to buy washing machines and refrigerators. In contrast, people born in Australia have a more preference to purchase other categories of appliances such as air conditioners, dish washers, and clothes driers.

Table D5: Reasons why personal electricity use decreased: immigrants vs. Australia-born people, 2007-08

Country of birth	Born in Australia	Born overseas
Tried to conserve energy	79.4	80.4
Purchased/used energy efficient electrical appliances	24.6	23.1
Lifestyle changes	23.1	20.6
Cost saving	20.8	21.5
Got rid of old electrical appliances	10.1	7.8
More use of other sources of energy instead	7.7	6.3
Lived in different dwelling	4.2	2.3
Other	2.5	2.0
Did not know	0.3	0.3

Data source: ABS. 2009. cat. No. 4626.0.55.001 Environmental Views and Behaviour, 2007-08 (2nd issue), Table 18.

Table D6: Selected 2007-08appliances bought in the last 12 months: immigrants vs. Australia-born people, 2007-08

Country of birth	Born in Australia	Born overseas
Washing machine	39.6	44.7
Refrigerator	35.5	44.2
Air conditioner	25.4	23.9
Dishwasher	16.6	16.6
Clothes dryer	15.1	11.0
Separate freezer	12.8	12.4

Data source: ABS. 2009. cat. No. 4626.0.55.001 Environmental Views and Behaviour, 2007-08 (2nd issue), Table 22.

Water use

More than half of the surveyed immigrants and Australia-born citizens stated that they reduced use of water, while about 40% of these two groups of people maintained water use level unchanged in 2007-08 (Table D7). Only a small proportion of immigrants (4.6%) and Australia-born residents (4.1%) reported that their use of water was increased over the same time.

Table D7 Change in personal water use in 2007-08: immigrants vs. Australia-born people

Country of birth	Born in Australia	Born overseas
Use increased	4.1	4.6
Use decreased	56.1	53.0
Stayed the same	39.0	40.8
Did not know	0.8	1.5
Total	100	100

Data source: ABS. 2009. cat. No. 4626.0.55.001 Environmental Views and Behaviour, 2007-08 (2nd issue), Table 36.

'Lifestyle changes' was considered, by both immigrants and people born in Australia, as a primary reason why they reduced water use. This was particular the case for immigrants, with 41.8% of them choosing it to be a main reason (Table D8). A slightly higher proportion of people born in Australia (23.8%) than immigrants (20.8%) increased use of water for the reason of 'increased water needs in garden'. In contrast, about one in five of immigrants (21.6%) increased water use for a reason of 'doing more household tasks that use water'. This was compared to 19.8% of people born in the country selected this factor as a reason for their increased use of water.

Table D8: Reasons why personal water use decreased in 2007-08: immigrants vs. Australia-born people

Country of birth	Born in Australia	Born overseas
Lifestyle changes	34.1	41.8
Increased water needs in garden	23.8	20.8
Doing more household tasks that use water	19.8	21.6
Lived in different dwelling	15.0	13.5
Acquired additional water-using appliances	9.5	11.3
Other	7.3	3

Data source: ABS. 2009. Cat. No. 4626.0.55.001 Environmental Views and Behaviour, 2007-08 (2nd issue), Table 38.

More than three quarters of both immigrants and people born in Australia took action to conserve water at home, resulting in declining use of water (Table D9). Reduced water use of both groups of people was also related to other important factors, such as 'water restrictions imposed', 'used recycled or grey water', 'lifestyle changes', 'used tank water instead of mains', and 'water saving devices used'.

Table D9: Reasons why personal water use decreased in 2007-08: immigrants vs. Australia-born people

Country of birth	Born in Australia	Born overseas
Tried to conserve water at home	75.4	78.9
Water restrictions imposed/ increased	42.2	40.6
Used recycled or grey water	21.3	21.7
Lifestyle changes	20.6	19.5
Used tank water instead of mains	14.0	12.4
Water saving devices purchased/used	13.5	13.0
Water efficient appliances purchased/used	9.6	9.1
Lived in different dwelling	3.1	3.1
Other	1.8	1.4

Data source: ABS. 2009. cat. No. 4626.0.55.001 Environmental Views and Behaviour, 2007-08 (2nd issue), Table 40.

Due to restricted use of water, a range of activities that need to use water were limited. The main activities, for both groups of people, include: 'watering the garden', 'washing vehicles', 'taking shower/ bath', 'cleaning outdoor areas', 'washing cloths' and 'washing dishes'. Patterns of their restricted activities did not show significant difference between the two populations (Table D10).

Table D10: Activities that were affected by water restrictions: immigrants vs. Australia-born people

Country of birth	Born in Australia	Born overseas
Watering the garden	81.7	79.0
Washing vehicles	61.5	57.2
Taking shower/bath	37.8	34.0
Cleaning outdoor areas	24.1	24.1
Washing clothes	16.1	19.6
Washing dishes	12.2	12.9
Using swimming pool	6.6	4.3
Children not playing with water outside	0.3	0
Other	2.2	1.5

Data source: ABS. 2009. cat. No. 4626.0.55.001 Environmental Views and Behaviour, 2007-08 (2nd issue), Table 46.

References:

ABS. 2009. cat. No. 4626.0.55.001 *Environmental Views and Behaviour*, 2007-08 (2nd issue).

ACTU and ACF. 2008. *Green Gold rush.* Australian Conservation Foundation and the Australian Council of Trade Unions, Melbourne.

Bill, A., Mitchell, W., Welters, R. 2008. *A just transition to a renewable energy economy in the Hunter region*, Australia. CofFEE, Newcastle.

Garnaut, R. 2008. *Climate change review: Final Report to the Commonwealth, State and Territory Governments of Australia*. September. Garnaut Climate Change Review, Melbourne.

Hetherington, D. 2008. *The full-cost economics of climate change: Aluminium: a case study*. Per Capita, Melbourne. July.

Analysis

The preferences and behaviours of non-English speaking migrants demonstrated in the results of the 2007-2008 HILDA surveys actually show few differences with the broader Australian and English-speaking migrants. Not only are expenditures of a similar level, trends in spending are similar. The only exceptions to this general view are the slightly increased expenditures by this group of migrants on groceries, eating out and use of public transportation and taxis.

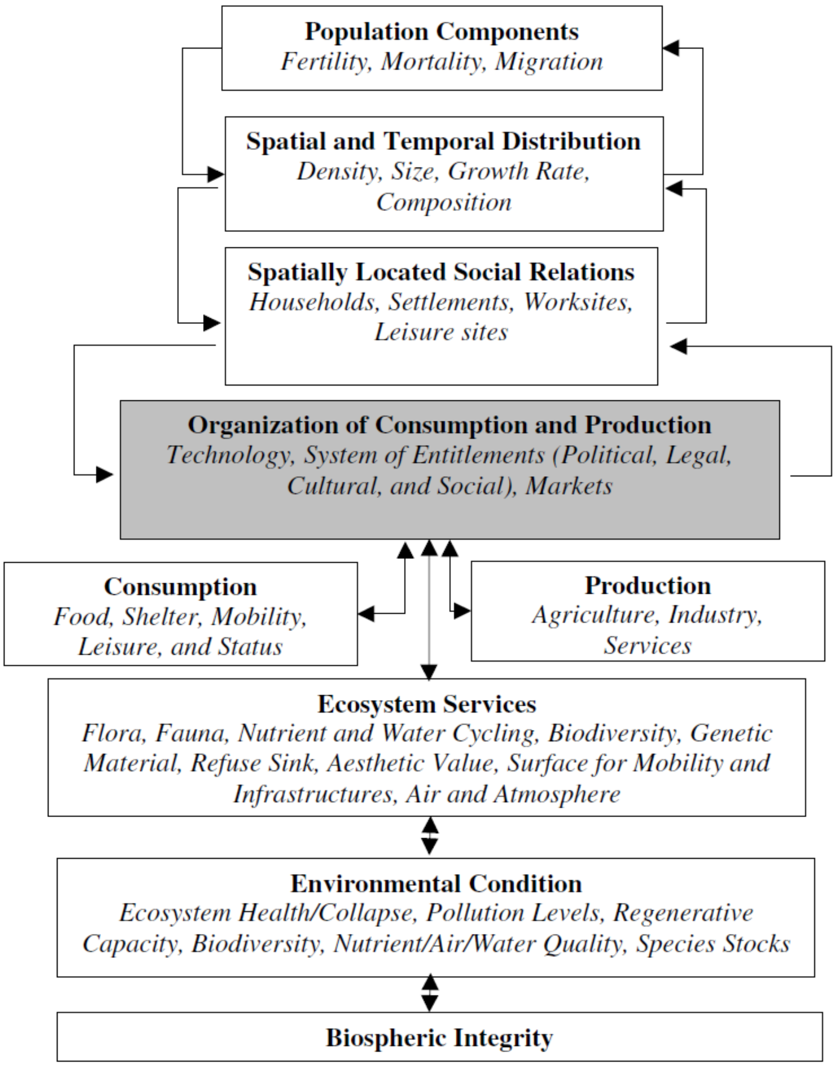
There are questions as to whether local geography might come into play, however, this data is the best available from which to determine if consumption patterns of migrants vary significantly from the broader Australian population. That is, when assessing the impact of increasing numbers of migrants as part of our population mix into the future, on the capacity of our natural assets to support them, we can only assume that migrants (NOM) will adopt similar attitudes and behaviours of their new countrymen. Meaning: that the natural assets needed to provide livelihoods and lifestyles to migrants in terms of water, energy, transportation, food, air, communication and effective waste disposal can be assumed to be consumed or saved at a similar rate on a per household basis as the rest of the population. For example, personal water use declined slightly more amongst migrants because of *lifestyle changes* (Table 8); people born overseas purchased slightly more fridges and washing machines than native-born Australians (Table 6); people born overseas who increased personal electricity use in 2007-08 did so more because of weather conditions than lifestyle changes when compared to native-born Australian respondents (Table 4); and Table 1 suggests that migrants are more concerned about saving energy than are their Australian counterparts! We therefore choose to assume that migrants adopt the consumptive patterns of natural resources that are shared by the broad Australian community. This report suggests however that local variation could still be important should this data be available or collected in the future.

For example, the Environment and NSW Ethnic Communities survey of 2004 following the community-wide DEC survey ‘Who Cares about the Environment’ (2003) found that people from overseas valued ‘environment’ almost as much as ‘family’ in importance and 80% were concerned about environmental problems. Indeed there was a significant increase in people from non-English speaking backgrounds (NESB) who rated ‘environment’ as ‘very important’ in the Ethnic Communities Survey compared to the DEC (2003) survey. Environment and water issues together, ranked third in importance for government attention, after health and education. There was a decline in the number of people who responded as ‘unsure’ or ‘don’t know’, indicating greater awareness and possibly a better informed public. Finally, migrant respondents ‘often acted’ to reduce water and energy use, ‘often’ recycle paper and tend to ‘reuse’ articles rather than disposing of them.

Curran and de Sherbinin cited Walsh, Welsh, Evans, Entwisle, and Rindfuss (1999) who found that *the more local the social and spatial scale the more likely they are to find population and environment links (Figure ?).* By implication it is harder to establish such links at increasing scales of data. A future project is to clarify the links between the different scales of analysis.

The next section uses ARC GIS v 9.3 to map C-Data from the ABS of the location of immigration settlement in Australia and provides the spatial variability rationale for examining Sydney Melbourne and Perth at higher levels of detail.

Figure: D3 A Population – Environment – Consumption Conceptual Framework



Source: Curran and de Sherbinin 2004, p. 123

References

Bin, S., & Dowlatabadi, H. 2005. Consumer lifestyle approach to US energy use and the related CO2 emissions. *Energy Policy*, **33**(2), pp. 197–208.

Butler, C.D. 2003. *Population and Environment in Australia: 2003,* A report commissioned by the Population and Environment Research Fund Committee of the Australian Academy of Science: Canberra.

Curran S. and de Sherbinin A. 2004. Completing the Picture: The Challenges of Bringing 'Consumption' into the Population-Environment Equation, *Population and Environment* 26 (2) pp. 107-131

DEC NSW Dept. of Environment and Conservation 2004. *The Environment and Ethnic Communities in 2004,* DEC Social Research Series. NSW Government.

Dovers, S. & Australian Bureau of Immigration Research. 1992, *Population growth and Australian regional environments* Australian Govt. Pub. Service: Canberra

Entwisle, B. and Stern, P.C. (Eds), 2005. *Population, Land Use, and Environment: Research Directions*, National Research Council National Academies Press: Washington

Johns Hopkins Centre for a Livable Future 2009. *What You Eat Affects Climate Change*. Fact Sheet. Accessed 13 November 2009 www.jhsph.edu/clf

Lutzenheiser, L. 1997. Social structure, culture, and technology: Modeling the driving forces of household energy consumption. In P. C. Stern, T. Dietz, V. W. Ruttan, R. H. Socolow, & J. L. Sweeney (Eds.), *Environmentally significant consumption: Research directions*. 129 Washington, DC: National Academy Press (available at http://books.nap.edu/books/0309055989/html/index.html).

O'Neill, B., MacKellar, F. L., & Lutz, W. 2001. *Population and Climate Change*. New York: Cambridge University Press.

Pimental, D. and Pimental M. 2003. Sustainability of meat-based and plant-based diets and the environment, *American Journal of Clinical Nutrition*, **78**, (3), pp. 660S-663S

Rees, W.E., 1992. Ecologicial Footprints and appropriated carrying capacity: What urban economics leaves out. *Environmental Urbanism*, **4**, 121–130

Spangenberg, J., and Lorek, S. 2002. Environmentally sustainable household consumption: From aggregate environmental pressures to priority fields of action. *Ecological Economics*, **43**, pp. 127–140.

Wackernagel, M. and Rees, W. 1996. Our ecological footprint – reducing human impact on the Earth. *Environment and Urbanization* **8** (2), 216-216.

Limnios, E.A.M., Ghadouani, A., Schilizzi, S.G,M. And Mazzarol, T. 2009. Giving the consumer the choice: A methodology for Product Ecological Footprint calculation, *Ecological Economics* **68**, pp. 2525–2534.

Distribution of Australia's Migrants

Summary

The report next considered where migrants have actually settled in Australia. We found that Australia's overseas-born people are unevenly distributed, with 80% of them are concentrated in 300 Statistical Local Areas (SLAs): 20% of the SLAs contain 80% of the migrants. Of these, the top 30 SLAs are all located in the metropolitan areas of Sydney, Melbourne, and Perth. The top 10 SLAs where 10% of the overseas-born people resided include: Canterbury, Fairfield-East, Randwick, Brimbank-Sunshine, Rockdale, Greater Dandenong, Ryde, Liverpool-East, Stirling-Central, and Holroyd.

Distribution of Australia's Migrants in Census 2006

According to the 2006 Census, the population that were born overseas amounted to some 4.4 million, accounting for 22% of the total population in Australia. The three largest overseas-born groups are those born in the UK (23.5% of all overseas-born), New Zealand (8.8%), and China (4.7%). Around 2.1 million of the overseas-born population were born in Europe. However, only 8% of these were recent arrivals (arrived in 2001 or later). Of the 1.2 million Australian residents born in Asia, 27% were recent arrivals.

Western Australia had the highest proportion of its total population born overseas (27%) and Tasmania the lowest (11%). Sydney was the capital city with the highest proportion (about one-third) of its population being born overseas. Hobart had the lowest proportion (12%) born overseas.

Australia's overseas-born people are unevenly distributed, as shown in Fig. E1. Eighty percent of them are concentrated in 300 Statistical Local Areas (SLAs), as shaded in red colour in Fig.1. (Note that the geographical landscape of the country is divided into 1,418 SLAs.) Of these, the top 30 SLAs are all located in the great metropolitan areas of Sydney, Melbourne, and Perth (Fig. E2). The top 10 SLAs where 10% of the overseas-born people resided include: Canterbury, Fairfield-East, Randwick, Brimbank-Sunshine, Rockdale, Gr. Dandenong, Ryde, Liverpool-East, Stirling-Central, and Holroyd.

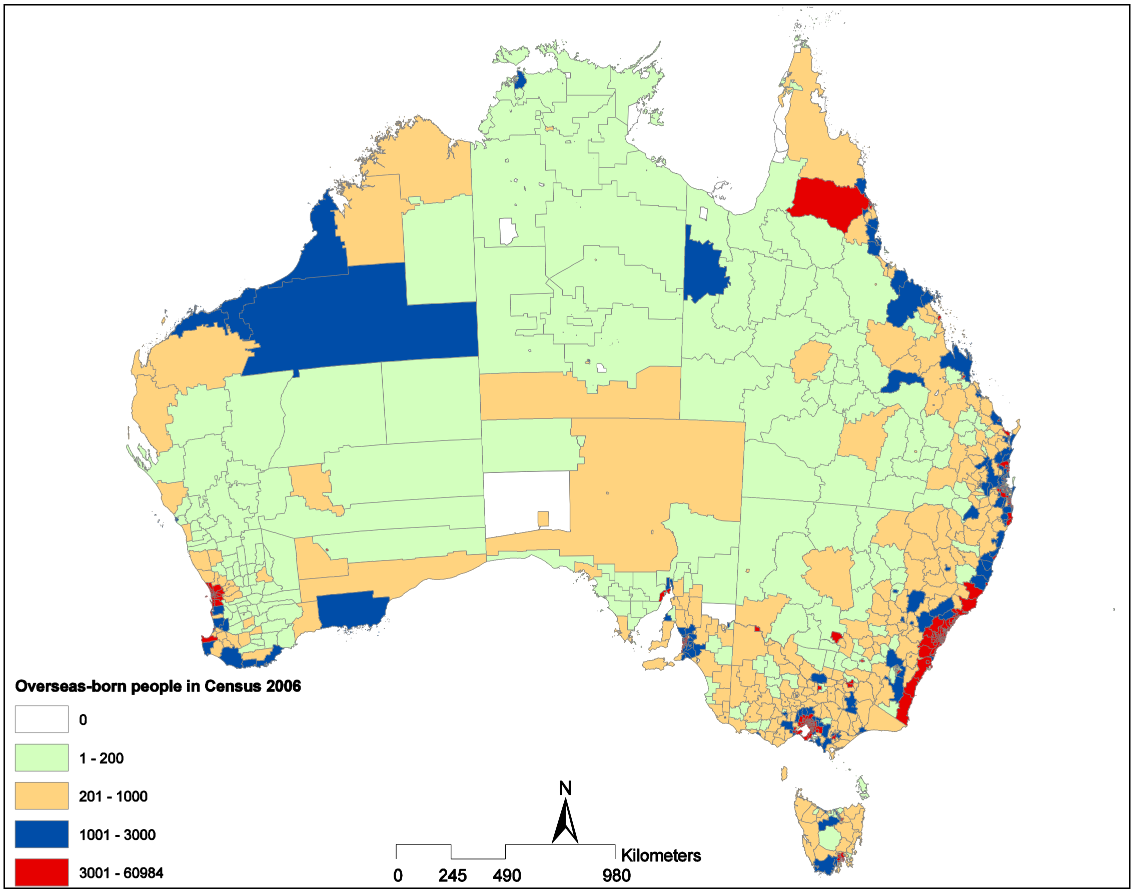
The number of immigrants who arrived in Australia in 2006 (i.e., within 1-year period of residence) totalled 110,273 persons. While they were distributed throughout over half of the national territory, the majority (80%) of them were distributed in 260 SLAs, shown in red and blue shaded areas in Fig. E3. There are two striking features about the distribution of this group of immigrants. One is the high concentration of their resettlements. The metropolitan areas in Sydney, Melbourne, and Perth are their major destinations (Fig. E4). About 12% of this group of migrants were concentrated in 10 SLAs: Melbourne, Randwick, Parramatta-Inner, Canterbury, Canning, Monash-Southwest, Ryde, Auburn, Sydney-West, and Sydney-Inner. The other feature is that there is a clear trend in moving to the regional areas, shaded in blue as shown in Fig. 3. For instance, Adelaide ranks 25 of top 30 SLAs where the new immigrants chose to live. Other typical regional areas also include the agricultural or mining industry regions such as south Perth, west WA, and northwest Qld.

The number of migrants who arrived in Australia in 2001 (i.e., within 5-year period settling in Australia) totalled 106,443 persons. The majority (80%) of them were distributed in 248 SLAs, as shown in red and blue shaded areas in Fig. E7. The largest 30 SLAs are also concentrated in three states —– NSW, Vic, and WA (Fig. E8). The top 10 SLAs are *all* located in the metropolitan areas of Sydney. They are: Canterbury, Randwick, Auburn, Holroyd, Fairfield-East, Liverpool-East, Ryde, Warringah, Parramatta-Inner, and Blacktown. These 10 regions accommodated 12.1% of the total migrants arriving in 2001. This suggests a further concentrating process of migrants, moving towards NSW, and Sydney in particular. For example, in the document 'A Life Devoid of Meaning' (WSROC 2003), Over 50% of Temporary Protection Visa (TPV) holders (at least 3000 individuals) now live in the Western Sydney Area where they are in proximity to their ethnic communities. Parramatta is the regional centre for services to migrants for surrounding LGAs (TableE1):

Table E1: Migrant Arrivals in Western Sydney LGAs 2000-03

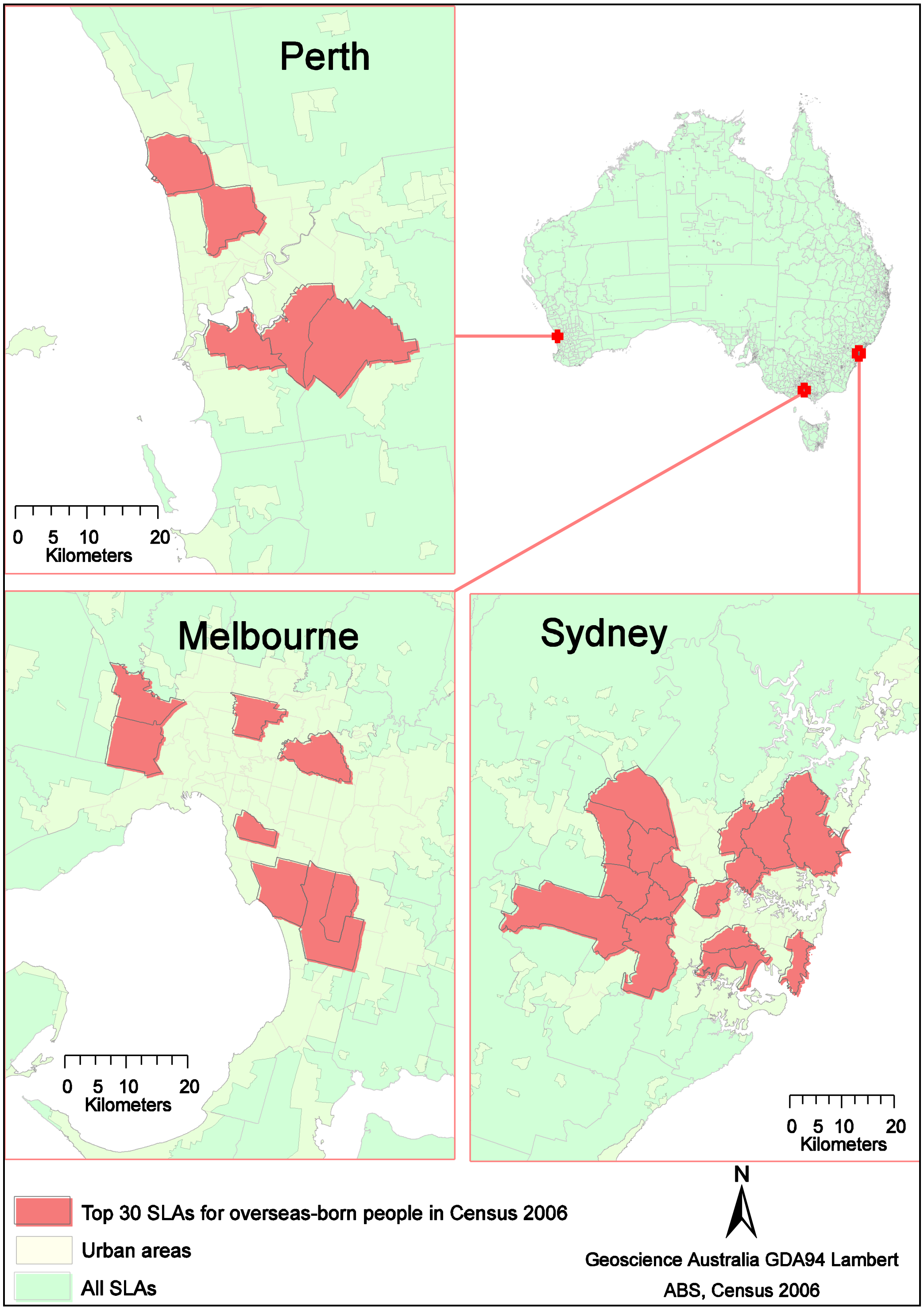
		LGA				
Migrant type		**Auburn**	**Baulkham Hills**	**Blacktown**	**Holroyd**	**Parramatta**
Humanitarian		961	202	1091	562	675
Non-Humanitarian	Family	1335	706	1622	1014	1583
	Skilled	600	1464	1769	882	1395
	Special/other	6	5	3	6	8
Total		2902	2377	4485	2464	3661

Figure E1: Distribution of Australia's population who were born overseas, at SLA level, 2006



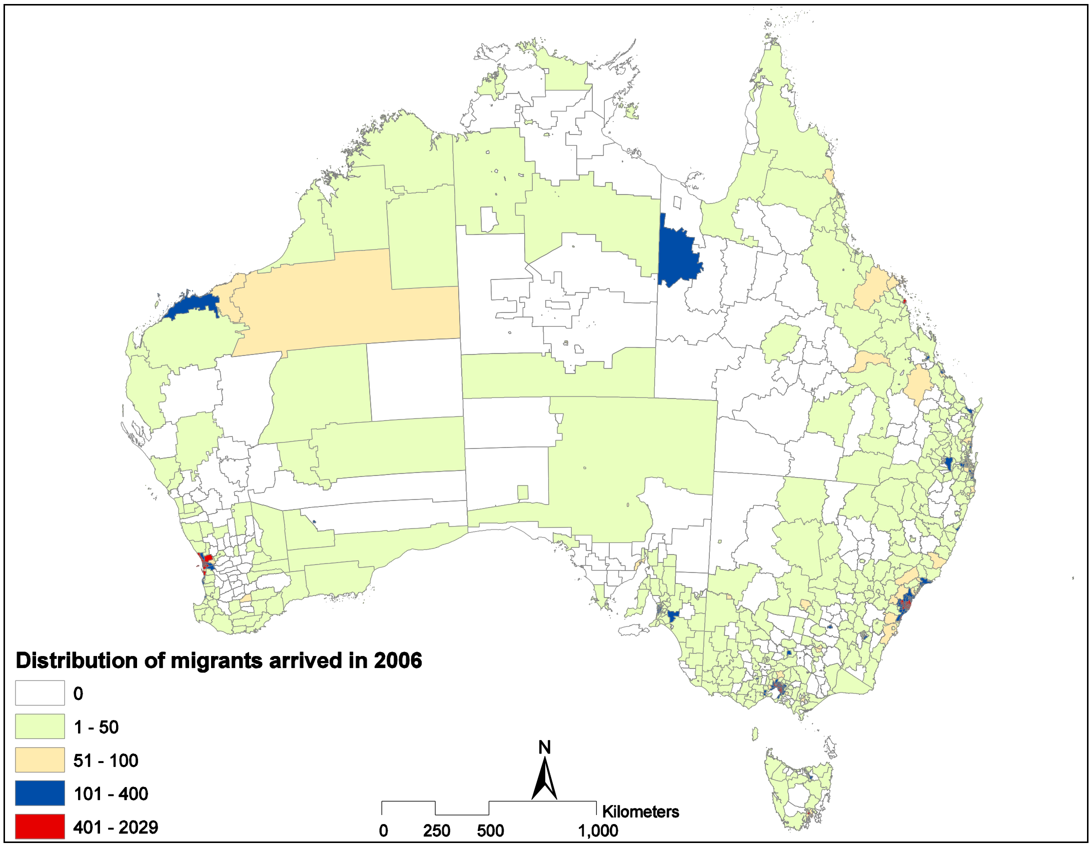
Source: Constructed by the author from Census 2006.

Figure E2: Top 30 SLAs for all people who were born overseas, at SLA level, 2006



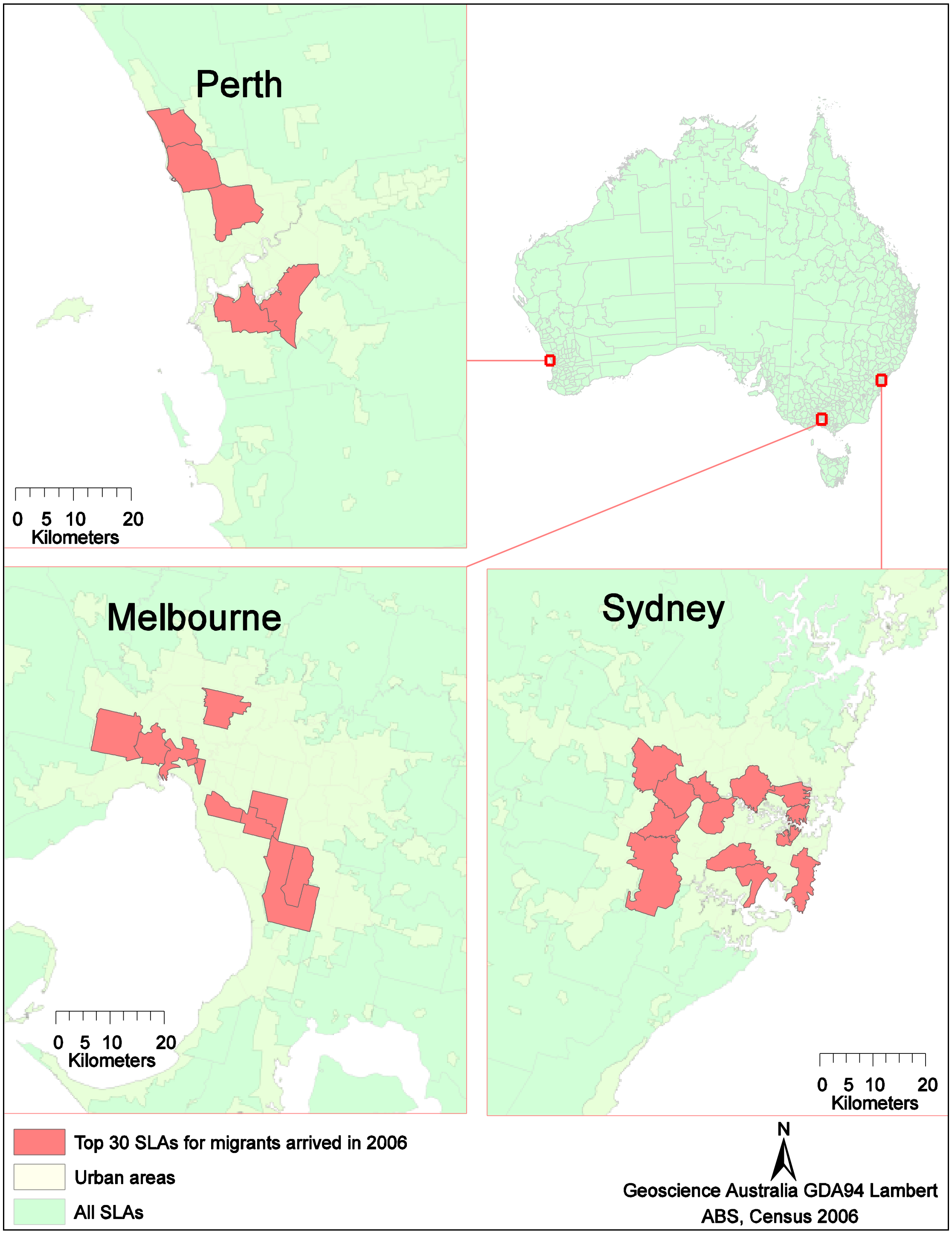
Source: Constructed by the author from Census 2006.

Figure E3: Distribution of migrants who arrived in Australia in 2006, at SLA level



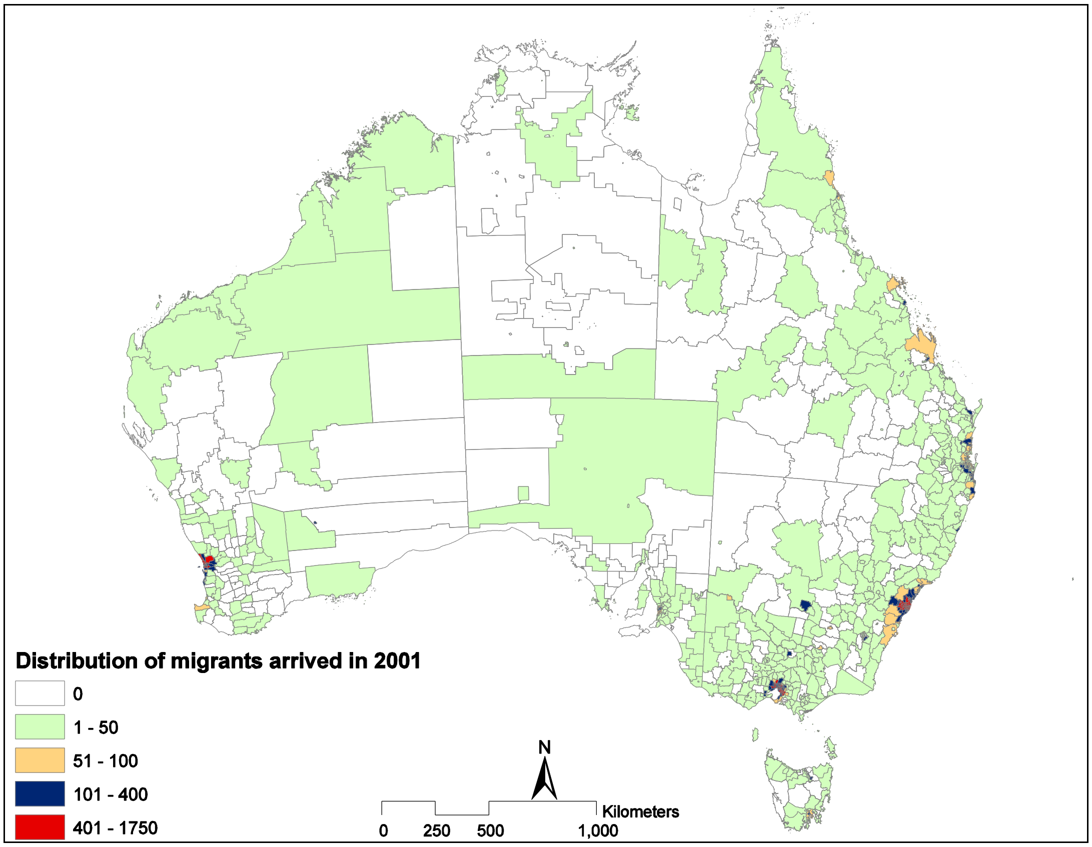
Source: Constructed by the author from Census 2006.

Figure E4: Top 30 SLAs for migrants who arrived in Australia in 2006



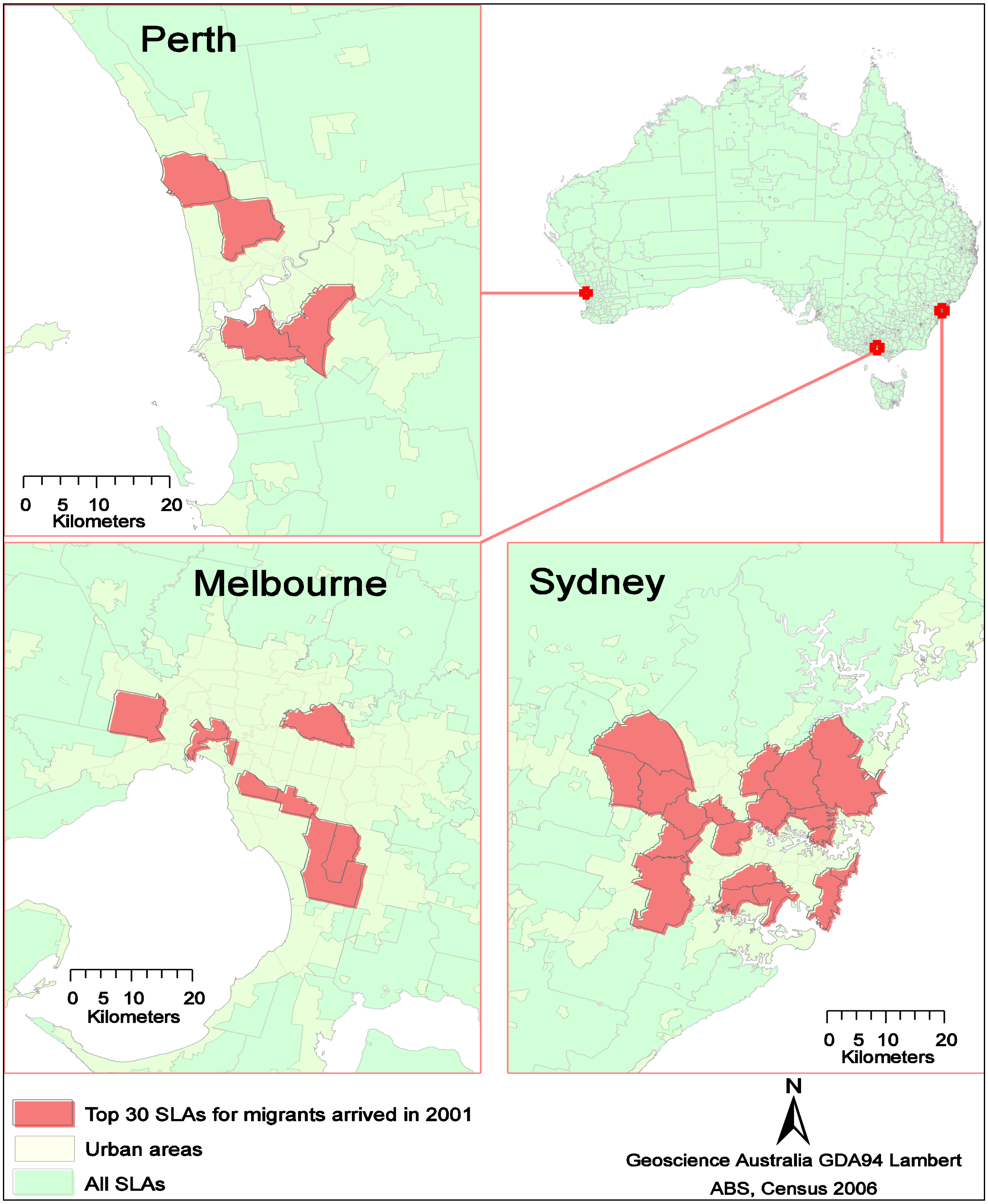
Source: Constructed by the author from Census 2006.

Figure E5: Distribution of migrants who arrived in Australia in 2001, at SLA level



Source: Constructed by the author from Census 2006.

Figure E6: Top 30 SLAs for migrants who arrived in Australia in 2001



Source: Constructed by the author from Census 2006

Temporary Net Migration

Net overseas migration (NOM)

Net overseas migration (NOM)[4] is defined by the ABS as "the difference between the number of incoming travellers who stay in Australia for 12 months or more and are added to the population and the number of outgoing travellers who leave Australia for 12 months or more and are subtracted from the population".

Almost one quarter of the current Australian population was born overseas and net migration into Australia totalled over five million over the past century. NOM is currently a major driver of the movements in the estimated resident population (ERP), accounting for around half of population growth at the national level. NOM is also a volatile phenomenon, with a wide range of demographic, social, economic and political determinants and consequences. In recent years many factors have presented challenges in accurately deriving estimates of NOM (ABS, 2006), including:

- increasing volumes of international movements across Australia's borders;
- changes to the composition of international visitors and their duration of stay behaviour;
- international travel patterns of Australian residents (including duration of absence and frequency of travel);
- operational changes to more efficiently process international travellers' information.

Specifically, NOM consists of three components of people movements as follows (McDonald and Kippen, 2002, p.4).

A. Net permanent overseas migration, defined as:

- arrivals in Australia of new permanent settlers, *minus*
- permanent departures of permanent residents of Australia

B. Net long-term movement of Australian permanent residents, defined as:

- arrivals of permanent residents of Australia who have been absent for 12 months or more, *minus*
- departures of permanent residents of Australia for a period of 12 months or more

[4] Prior to 1 July 2006, NOM estimation methods used a 12/12 rule to determine if a traveller contributed to ERP. This meant that in order for a person to contribute to NOM they must stay in or be absent from Australia for a continuous period of 12 out of 12 months. From September quarter 2006 onwards a new method for calculating NOM is used. The key change is the introduction of a 12/16 rule, which requires a person to be in or absent from Australia for 12 months within a 16 month period, for determining a person's residency in Australia.

C. Net long-term movement of visitors, defined as:

- arrivals of visitors for a period of 12 months or more, *minus*
- departures of visitors who have been in Australia for 12 months or more.

Net overseas migration[5] has been significant and has generally grown over the last 50 years (Fig. E7). This has caused impacts on Australia's population numbers. The question then arises about the *future* prospects for net migration and the extent to which it could impose effects on the physical and built environment over the next 40 years. At least in the short term, the Australian Government can largely determine the size of net migration inflows by altering quotas. Accordingly, of all the factors affecting population size, net migration rates might be seen as the most policy malleable (political economy considerations aside).

Net migration now plays a more important role than natural increase in national population growth in high-income countries including Australia. Australia's population has two outstanding features: a high degree of concentration of the population into a few large cities, and the significance of international migration in shaping national population growth, composition and distribution. Seventy six percent of the national population lives on the 0.33% of the land, which has a population density of 100 or more people per km^2. Over 40% of the national population are an immigrant or the child of an immigrant, and more than half of post-war population growth is due to immigration. Without post-war migration the national population would be 12 million in 2009 rather than the present 22 million. These two features have been strongly linked during the post-war period because immigrants have shown an increasing tendency to settle in large cities, especially Sydney and Melbourne, which had 34.1% of the Australia-born population but 53.1% of the foreign-born in 2006.

Australia's international migration has experienced a paradigmatic shift since the mid-1990s in response to globalisation and other developments within and outside Australia (Hugo, 1999, 2004). First, Australian immigration policy for the first 4 post-war decades focussed almost exclusively on permanent settlement and avoided temporary worker migration. This policy was reversed in the mid-1990s which saw the expansion of a range of types of temporary skilled worker migration (Hugo, 2006). The second major change was the introduction in 1996-97 of the State Specific and Regional Migration (SSRM) visa categories.

Table 1 shows that the proportion of newly arrived immigrants who settled in Australia's capital cities fell from 86.3% in 1991-96 period to 83.9% in 2001-06. While newly arrived

[5] *Note:* From July 1925, only long-term and permanent arrivals and departures were counted in NOM. From 1976 an adjustment was made for the fact that changes to travel intentions from short term to permanent or long-term and vice versa occur (category jumping). Due to problems identified in the processing of information on traveller intentions, adjustments for category jumping were dropped by the ABS in September 1997 pending a review of the method, but were re-introduced several years later. The data therefore reflect somewhat different measures of NOM over this long period. The time series since 2006 are compiled using an improved methodology that is not comparable with NOM estimates from earlier periods. NOM estimates for 2007 onwards are preliminary.

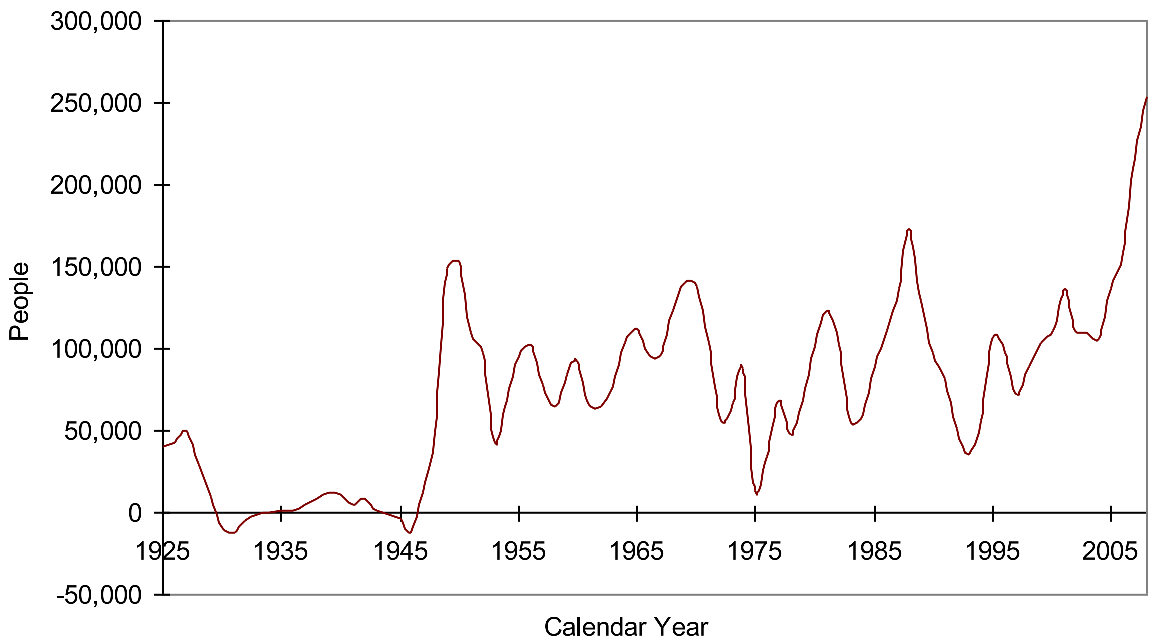
migrants overwhelmingly still settle in the nation's major cities, this was the first time in the post-war era that this proportion declined. Moreover, in Sydney (the main destination of immigrants) the proportion settling fell from 37.5% to 30.6% between the last two inter-censal periods. Since Sydney has only 20.7% of the national population, it is still receiving a disproportionate share of the immigrant intake, but a change has occurred (Hugo, 2008).

Table E2: Australia: percentage of immigrants arriving in five years prior to the Census settling in capital cities and rest of State, 1991-2006.

Years	Capital cities	Rest of State	Sydney
1991-96	86.3	13.7	37.5
1996-2001	85.5	14.5	37.3
2001-06	83.9	16.1	30.6

Source: ABS Population Censuses of 1996, 2001, 2006.

Figure E7: Net overseas migration, 1925-2008



Data sources: ABS (Australian Historical Population Statistics, Cat. no. 3105.0.65.001 and Australian Demographic Statistics, Cat. no. 3101.0 for latest years).

Long-term movement of visitors

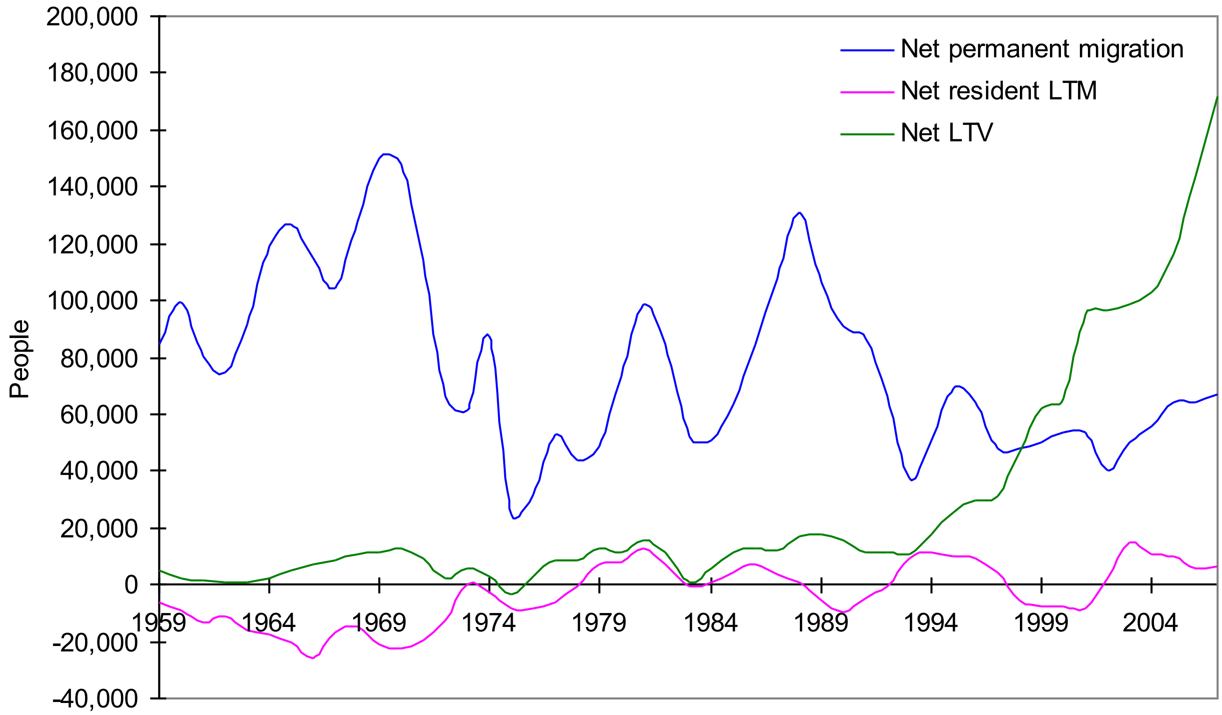
It is necessary to take into account the impacts of not only the permanent overseas migration but also long-term (1 year or longer) temporary migration in Australia's NOM projections. There is a trend in growing numbers of people coming to and living in Australia as long-term residents. This group of migrants has a specific feature that differs from the group of permanent overseas migrants. Temporary migrants may have a zero effective birth rate because any births they have will leave with them, but they are subjected to Australian rates of mortality while in Australia.

There is a shift in Australia's migration entry from permanent settlers to long-term visitors (Figure E8). This will have some implications. One of our concerns in this project is whether or not permanent residents and temporary residents should be treated as two separate populations in the assumptions about future migration projections, which will be an endogenous input in the inflow-outflow models for the physical and build environmental impacts. Accordingly, a future challenge of this project is how to factor this group of temporary migrants when evaluating their impacts on Australia's physical and built environment, such as housing, transport, water, and energy supply.

The analysis that we have done of the expenditure patterns of migrants is based on data from the Household Income and Labour Dynamics (HILDA) survey. This survey provides information on country of birth and on income and various items of expenditure. Our analysis shows that the expenditure patterns of migrants do not differ much from those of the native born, and this finding is incorporated into the modelling of the impact of different levels of NOM.

But there is a caveat. HILDA is a longitudinal survey that follows over time a random sample of people who were resident in Australia in 2001. It therefore does not capture the temporary component of NOM. As we show in Figures 8 and 11, temporary migrants (especially 457 visa holders and students) are the group that has grown most rapidly in recent years: they are now a large part of NOM. It is likely that they have distinctive expenditure patterns, if only because many are young and are students. We have no information on these patterns, and can only advise the reader of this imprecision in our modelling. This caveat also applies to our investigation of the local and regional impacts of migration with an assumption that the majority of migrants recorded for CBD LGAs are going to be students located close to major tertiary education centres.

Figure E8: Components of net overseas migration, 1959-2007



Data source: ABS (Australian Historical Population Statistics, table 10.1, Cat. no. 3105.0.65.001).
Note: LTV denotes long-term visitors and LTM denotes long-term migrants of Australian residents.

Fig. E9 details the patters of arrivals and departures for each category of migrant movements in 2008. The NOM amounted to 312,448 persons, with 634,065 arrivals and 321,617 departures. Temporary migrants (comprising overseas students, Temporary Business 457 visa holders, Working Holiday Maker (WHM) visa holders) took the biggest share (49.5%) in the total arrivals. Other three groups of migrants — Australian residents, settler migrants (who held family, skill, or humanitarian permanent visas), and New Zealand citizens — made up 23.2%, 19.4%, and 7.9% of the total arrivals, respectively. The majority (71.4%) of the total departures were Australian citizens (including other and not stated people). More than a quarter (27%) of people who left Australia were temporary migrants, while NZ residents accounted for 1.6% of the total departures in 2008.

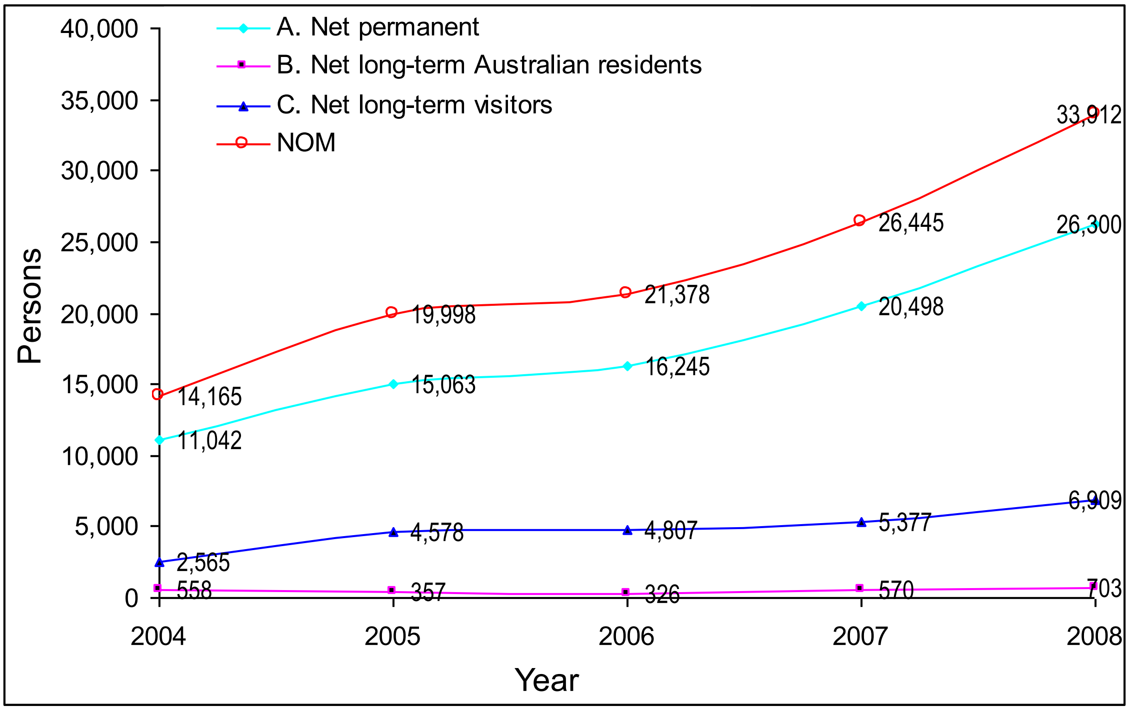
Figure E9: Permanent and long-term arrivals and departures, by visa and traveller type, 2008

Data source: DIAC unpublished data, as requested.

An example: permanent and net long-term migration from New Zealand, 2004-08

The stock of net long-term visitors from NZ increased faster than the net permanent residents from this country over the 4-year period to 2007-08, by 169% and 138% respectively (Fig. E10). During this period, Movement B (net long-term Australian resident migration) has fluctuated around 500 persons. Thus, the total of the three movements was dominated by net permanent migration (Movement A), followed by net long-term visitors (Movement C).

Figure E10: Net permanent and long-term migration of people from New Zealand, 2003-07



Data source: DIAC unpublished data, as requested.

Overseas students in Australia, 2008-09

The biggest component of the long-term temporary migrants in Australia is overseas students. The recent data on the stock of overseas students, as observed at the end of March across the years 2008 and 2009, show an increased number of this group of migrants. It stood at 400,802 students by the end of March 2009. The pattern of their distributions across States/ Territories over the 1-year period remains almost unchanged. More than three quarters of them (77.7% in March 2008, 78.3% in March 2009) reported to be residing in NSW, Vic, and Qld (Table E3).

Table E3: Distribution of overseas students in Australia, by State, 2008-09

State of Intended Residence	31 Mar. 2008	31 Mar. 2009	% of Total in 2008	% of Total in 2009
NSW	113,896	138,876	34.8	34.6
Vic	96,727	119,855	29.6	29.9
Qld	43,548	54,920	13.3	13.7
WA	21,809	26,869	6.7	6.7
SA	16,186	19,509	4.9	4.9
ACT	5,468	6,297	1.7	1.6
Tas	2,755	3,205	0.8	0.8
NT	481	617	0.1	0.2
Other & not stated	26,318	30,654	8.0	7.6
Total	**327,188**	**400,802**	**100.0**	**100.0**

Data source: DIAC unpublished data.
Note: State/territory is that of intended residence as given on the incoming passenger card on the most recent arrival prior to reference date and may not be that of actual residence.

References

ABS. 2006. Information Paper: *Improved Methods for Estimating Net Overseas Migration*. cat. No. 3107.0.55.003. Released on 2 October, Canberra.

McDonald, P., Kippen, R. 2002. *The impact of long-term visitors on projections of Australia's population*. Prepared for the Department of Immigration and Multicultural and Indigenous Affairs. Australian Centre for Population Research, Australian National University. May.

Key Questions – Findings

The study was split into four sections to present information related to demographics and consumption, macro-scale modelling of stocks and flows, meso-scale empirical data of the physical environment based on location, and micro-scale essays about evaluating the impacts of individual lives (Table F1). The following sections present our findings according to the key questions.

Table F1: Key Questions

Key Question	Methodology
1: What is the nature of the relationship between population growth driven by particular long term average levels of NOM, and the implications of each average level of NOM on Australia's Natural and Built Physical Environment. **2: What are the implications of each average level of NOM on Australia's Natural and Built Physical Environment over the next fifty years?**	**Macro-scale modelling of stocks and flows – ASFF**
3: What key considerations, concerns and constraints should the proposed long term immigration planning framework take into account in terms of the interactions between NOM and the optimal development and sustainability of Australia's Natural and Built Physical Environment?	**Empirical information of physical environment by location** **Synthesis of information on micro-scale effects**
4: In relation to each average level of NOM, what measures may be considered by the Australian government to counterbalance the negative impacts, or to optimise the positive impacts, on Australia's Natural and Built Physical Environment?	**Scenarios based on analysis of information collected**

Key Research Question 1:

What is the nature of the relationship between population growth driven by particular long term average levels of NOM, and the implications of each average level of NOM on Australia's Natural and Built Physical Environment.

Key Research Question 2:

What are the implications of each average level of NOM on Australia's Natural and Built Physical Environment over the next fifty years?

Introduction and Background

This study was initiated to understand better the implications of various immigration rates on the natural and built environment. Previous analysis based on demographic and economic modelling was undertaken for DIAC (McDonald and Temple 2008), and identified net overseas migration (NOM) of at least 180,000 p.a. as producing optimum GDP per capita growth. That analysis used the Productivity Commission's MoDEM model, which does not incorporate environmental or resource factors. In order to understand the aggregate Australian resource and environmental implications, CSIRO's model of the Australian physical economy (the Australian Stocks and Flows Framework) was employed.

The Australian Stocks and Flows Framework (ASFF) is a comprehensive and detailed simulation of the physical processes throughout the economy and environment of Australia (Table F2). The ASFF is calibrated with decades of historical data (which it reproduces), and simulates multiple scenarios over the decades of the current century. A full description of the ASFF is available in (Poldy, Foran et al. 2000), and concise descriptions in (Turner, Hoffman et al. 2009; Turner, Hoffman et al. 2010). A short technical description is provided in Appendix B.

This report presents the results of the ASFF modelling of various NOM levels. It describes:

- how the modelling was undertaken;
- what assumptions were employed; and
- results and discussion of the ASFF outputs.

Table F2: Outputs of Environmental Analysis from ASFF Model

Output	Sectoral or other breakdown	Spatial detail	Notes	Temporal extent
Water Consumption	Major sector (8)	Water Regions (77)		from recent years, covering multiple decades: 2006 — 2051 (in 5 year steps)
Water Supply	Aggregate of surface and groundwater	Water Regions (77)		
Area of Arable Land	Dryland and irrigated; Major crop type and pasture	Statistical Divisions (58)	may include status of land productivity	
Food Consumption	Major food groups (12)	State and Capital City (16)	in 'farm gate' terms, not processed food	
Food Production	Major food groups (12)	Statistical Divisions (58)	may include fish stocks	
Greenhouse Gas Emissions	Major fuel-based sectors (10)	National (& potential for State disaggregation)	may include estimate associated with land-use change	
Urban Population	Five-year age cohorts (20)	Capital City (8)		
Households and Dwellings	Single and multiple dwelling types	State and Capital City (16)	number and sizes of households, leading to need for housing of different types	
Solid Waste Production	Major materials (up to 40)	National	includes provision for recycling	
Mineral Production	Major minerals (10)	National	includes energy resources	
Mineral Consumption	Major minerals (10)	National		
Electricity Generation	Fuel-based and renewable	National (and potential for State/Capital City disaggregation)		
Energy Consumption	Fuels and electricity; residential and non-residential	National (and potential for State/Capital City disaggregation)		
Employment	Major sector (8)	National	without occupational breakdown	

(Numbers in parenthesis are generally approximate)

Modelling Environmental Implications

A framework for evaluating impacts of immigration

To examine the effects of immigration on the Australian environment and its resources it is necessary to understand that population is only one factor. The "IPAT" equation introduced by Ehrlich and Holdren in the 1970s conceptually summarises that environmental impacts are determined by population size (capita), affluence (products or services per capita) and economic throughput (resources or wastes per product or service) multiplied together[6] (see e.g., (Lutz, Prskawetz et al. 2002)).

An accurate assessment of a nation's future environmental condition, however, requires far greater richness to be incorporated in each of these summary factors. This is achieved in the analysis presented here by using a detailed biophysical model of the Australian economic activity and its interaction with the environment, namely the Australian Stocks and Flows Framework (ASFF) (in which some 800 multi-dimensional variables in this version represent explicitly the different physical activities).

The ASFF categorises population in terms of age-cohort demographics, household size and locations. Lifestyle related parameters such as various product consumption rates per capita, transport mode shares and household characteristics collectively represent affluence. Economic throughput is modelled in detail in the ASFF, and incorporates technological efficiency parameters, substitution options (e.g., different fuels) and stock dynamics to simulate infrastructure turnover for example.

The spatial and temporal extent and detail of our analysis is determined by the specific environmental/resource issues, such as food or water security. Population dynamics and most infrastructure developments occur over decades; consequently our simulations must extend to at least the middle of the century. Food production and water resources in particular require sufficient spatial detail to differentiate regional characteristics. Likewise, regional/local communities perceive issues and want solutions implemented at their scale. Nevertheless, the reality of our economic system is that each region is highly dependent on others throughout Australia (Lennox and Turner 2005).

Assessing absolute sustainability therefore requires a national perspective, since different locations and sectors of the economy are strongly linked. This means that if a crisis occurs in one area or sector it will impact others, most likely in an adverse way. Consequently, it is necessary to consider the full system and not base sustainability assessment solely on separate parts as if they were independent. This system perspective is provided by the ASFF modelling, with its coverage across the national economy and environment.

In addition, since environmental impacts occur through absolute quantities such as greenhouse gas volumes, relative indicators such as per capita measures are not relevant to assessing environmental impact. This contrasts somewhat with the situation for economic indicators, such as the population's wealth commonly represented by GDP per capita.

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[6] I = PAT or impacts equal population times affluence times throughput, or capita x products/capita x resources or wastes/product = resources or wastes.

Modelling process for creating immigration scenarios

The modelling of environmental implications of different levels of NOM was undertaken using the ASFF. Several stages were required to produce the scenario outputs. As summarised here, this involved the simulation and use of macro-economic indicators (employment, GDP and national trade balance) to create scenarios that observe standard economic objectives. At the end of this section, we address the common and misplaced criticism that prices are missing from the ASFF modelling.

In order to create scenarios in the ASFF, it is necessary to set the values for several hundred input variables. These variables cover behavioural factors (e.g., per capita consumption, travel mode share), and technological and engineering factors (e.g., engine efficiencies, infrastructure lifetimes). The general process starts with the reproduction of the demographic and labour productivity settings of the previous study (McDonald and Temple 2008). Then both production (primary and secondary industry output) and final demand consumption are adjusted to maintain a target unemployment rate and a target trade balance (relative to GDP). Other physical details are set accordingly, such as freight volume. Subsequently, if environmental and resource problems have occurred in the scenario, alternative settings can be tried to alleviate the problems. An outline of the process used is as follows (more details are provided in the Appendix):

1. GENERAL — initially project forward the future values of ASFF inputs, in keeping with past historical trends or context;
2. DEMOGRAPHICS — replicate the demographic settings of (McDonald and Temple 2008) for a particular NOM scenario;
    - geographic location by state and capital city aligned with recent census data
3. PRODUCTIVITY — set changes to labour productivity (typically annual compounding increases approximately matching those of (McDonald and Temple 2008));
    - typically a consequence of these conditions is large unemployment, and excessive foreign debt or surplus, which are resolved in the following steps;
4. UNEMPLOYMENT — a feedback algorithm adjusts domestic consumption rates to maintain a desired level of unemployment, allowing for service workers supporting economic activity;
5. FOREIGN DEBT/SURPLUS — a feedback algorithm maintains the net foreign debt (or surplus) at a realistic level relative to GDP by adjusting exports (via changes to primary and secondary production), imports, international travel rates (outbound Australians and inbound visitors), and investment "invisibles";
6. PHYSICAL PRODUCTION — complete detailed physical balances, including:
    - ensuring non-traded commodities are produced to meet domestic requirements only (principally construction materials);
    - adjusting freight volume to transport the goods and commodities produced; and

- increase discovery of most minerals and fuels in line with production requirements for combined export and domestic use (the key exception is planned production of oil, which is set according to Geoscience Australia forecasts);

7. CONSISTENCY — repeat steps 4–6 as necessary to establish initial scenarios where the economic and physical conditions above are satisfied simultaneously. In particular, when the net foreign debt is established by feedback (step 5), the unemployment rate is marginally altered due to the changes in economic activity. It is then necessary to re-establish the unemployment rate via the feedback that uses consumption rates (i.e., using step 4 again). This perturbs the net foreign debt (and the ratio to GDP), so that this must be re-established (using step 5 again). These iterations of the feedbacks are repeated until the calculations settle on relatively stable values; in practice this process required two iterations of both feedback calculations.

8. ENVIRONMENTAL CONSTRAINTS — observe any environmental problems that may have occurred in the initial scenarios, and potentially alleviate these with alternative input settings.

The process above establishes initial scenarios for different NOM, such that standard macro-economic objectives are observed i.e., healthy levels of trade and employment. It does not ensure that environmental or other physical necessities or environmental objectives are automatically met. For example, it is possible that water resources are over-exploited (beyond that available), or that pollution targets are exceeded. If this happens, it is necessary to identify the factors leading to such tensions by following the physical causations in the ASFF. Subsequently, the scenarios can be refined by adjusting key factors to attempt to ameliorate the tensions. This may require some repeat of the earlier steps in creating scenarios to achieve target trade and employment rates.

An important example of alleviating a tension is the simulation of a switch from oil to gas (when used in energy-based processes). Australian production of oil appears to have peaked, potentially in keeping with global constraints due to Peak Oil (which is now widely recognised, including recently by the IEA). Without any other change made in the ASFF under declining domestic oil production, sufficient oil will be imported to Australia in order to meet the domestic deficit. This can be viewed as a tension, particularly when there is significant uncertainty about the price or availability of oil on the international market. Various alternative scenarios can be created to alleviate this tension. One possibility is for natural gas to be substituted for oil; the transition away from oil can be simulated for oil used as a fuel—oil may still be required as a material feedstock (e.g., bitumen, lubricants and organic chemicals).

Where are the prices? Indeed!

Although the modelling process described above ensures that key macro-economic objectives are maintained in the ASFF scenarios, some economists are likely to ask "where are the prices?" (i.e., economic behaviour equating supply and demand). In response, it is fair to ask: indeed, where *are* the prices?

The ASFF generally does not incorporate prices[7] internally, or more specifically, the response of the economy to scarcity in resources (or similar changes). The general approach in the past, has

[7] In principle, prices and salaries have been included to estimate the trade balance and GDP.

been to treat the scenarios as exploratory, so that scarcity or other tensions are highlighted. Subsequently alternative scenarios are created to alleviate the tensions.

Ongoing research, separate from this study, is investigating the linking of the ASFF with economic modelling (see for example, early results in (Turner and Baynes 2010; Turner, Keen et al. 2010))[8]. The general concept is that the economic modelling initially prescribes the structure, consumption, growth, etc. of the economy, and these factors determine the input variables of the ASFF. Physical constraints that may arise in the ASFF scenarios should then be inputs fed back to the economic modelling. The process is repeated until the scenarios converge to a solution, assuming they do.

If this process is possible it would imply that the (relative) price of oil or water or many other critical resources and factors of production would be known long into the future. We do not judge here whether or not this is likely.

To date however, it has most clearly not been possible to predict prices with the accuracy of size or timing required to treat these as reliable variables for model input. Two salient contemporary examples illustrate this. First, despite the long-held physical evidence of a looming peak in oil production, the dramatic rise in oil price in recent years was not estimated or anticipated in economic analysis with any accuracy. Similarly, standard economics did not provide estimates of the dramatic rise and rapid decline in UK and US housing prices associated with the speculative asset market and subsequent Global Financial Crisis. This is despite clear evidence of excessive national debt levels. These failings aside, any research attempting to bring prices to bear on the physical modelling in the ASFF would certainly be interesting. For now, future prices and economic responses are not available to this analysis.

In the meantime, it is sufficient to use the historical trends in the ASFF (which of course *embody* past price signals) to initially inform possible settings of inputs to the ASFF for creating scenarios. These settings can and are changed by a variety of means. Substantial use has been made of technical information and expert knowledge (Conroy, Foran et al. 2000). Additionally, as described above, feedback loops are employed to change inputs on the basis of the ASFF outputs, with the aim of satisfying macro-level economic objectives relating to employment and trade.

Interpretations of this analysis

The modelled scenarios should not be misconstrued as predictions, but rather what would happen to the environment and physical resources given the assumptions made and feedbacks used. The scenarios in this analysis do not employ prices or other economic signals to model how the economy might respond to the environmental implications, since reliable estimates of these prices and responses over multiple decades were not available. Nevertheless, this analysis has employed complex feedback mechanisms in order to achieve common economic goals (healthy unemployment and trade balance levels). It may be possible in principle, for instance, to produce similar economic goals with somewhat different structure to the economy. The scope of this study did not permit this to be explored. The scenario outputs should not therefore be viewed as predictions, but as a means to develop better understanding of the physical implications of policy options.

[8] Offers or suggestions of access to alternative economic models of suitable scale and coverage are invited to enable us to extend this research.

There are also caveats related to the precision associated with modelling features. One relates to the five year time-step that is generally used in the ASFF (which is being updated to one year steps in a new version of the ASFF). This aggregates or smooths over annual or other rapid variations, and focuses on the longer term developments.

Another limitation to the precision of the outputs relates to the feedback mechanisms described above. These feedbacks attempt to reach specified goals (e.g., an unemployment level) within some level of tolerance. This tolerance was typically set to 5% of the specified goal. Therefore, different NOM scenarios do not have identical levels of unemployment or trade balance. Consequently, there is some variation in the scenario outputs (and inputs) that result from these differences.

Despite these caveats, scenario outcomes appear to be generally robust to changes in settings that are within the level of precision that has been achieved in this study. We can expect to find similar trends and levels for outputs if marginal changes occur in the creation of scenarios. The scenario outputs are likely to be generally reproducible, even in the absence of prices, since the activity in the simulated economy is largely driven by the requirement to satisfy domestic demand and trade volumes.

Key Assumptions and Settings in the Scenarios

There are a number of key assumptions that, by necessity of any modelling exercise, are embodied in the scenarios. The assumptions do not reflect any particular stance, but are provided as starting points for discussion and exploration. A description of the key assumptions is provided below; all assumptions can be viewed transparently in the model. Assumptions can be changed to simulate alternative points of view, or varied to explore the sensitivity of outcomes to changes in economic factors.

For this work, explicit assumptions were made in the areas of:

- migration and demographics;
- labour productivity;
- technological progress;
- unemployment (and economic growth);
- trade balance;
- structure of the economy;
- mining – mineral/fuel production; and
- climatic conditions.

Migration and demographics

A range of values for net overseas migration (NOM) was used in the scenarios (0, 100,000, 150,000, 180,000, 230,000, and 260,000 p.a.) specified by DIAC to match the modelling of (McDonald and Temple 2008), which used the Productivity Commission's MoDEM model. Fertility and mortality rates were set to reproduce the birth and death rates of the MoDEM model. Age distributions were also obtained from MoDEM.

Immigrants were assumed to have the same behaviour (e.g., consumption habits, service requirements, transport mode share) as the resident population. This is supported by NILS data analysis.

In terms of geographical location, immigrants and the resident population were distributed to States[9] and then into the capital cities according to ABS data. The most recent trends were maintained throughout the scenarios.

Labour productivity

The productivity of the workforce was increased using a compounding growth rate given by the previous demographic/economic study (McDonald and Temple 2008). In the scenarios examining environmental implications, a background growth rate of 1.5% pa was taken from (McDonald and Temple 2008). The growth rate is applied to each of the labour sectors in the ASFF, including for those service workers supporting economic activity.

Technological progress in material and energy use

In general, efficiency of material and energy use in a variety of economic activities in the ASFF were increased over time. Efficiencies increase initially at a rate determined by historical trends, and then saturate toward a steady value. Details of specific trends are available in the Appendix of (Foran and Poldy 2002). These efficiencies gains may result from different drivers, such as economies of scale or the introduction of improved processes.

Unemployment

A target rate of 3.8% (±0.2%) unemployment was used. This represents a level achieved in recent Australian economic performance, and a level that might generally be considered to be healthy i.e., not too low and not too high. The level of (un)employment is a result of the population size, its age profile, the participation rate, labour productivity, and the various economic activities requiring labour. If no other change is made to the ASFF inputs, then increased productivity (labour input per unit output and other efficiencies) leads to increased unemployment due to the simple fact that the same economic output can be achieved with fewer workers. With the productivity growth assumed above, mass unemployment of the order of 50% occurs after several decades.

To achieve a stable unemployment level and replicate past economic conditions, the background scenarios incorporate re-employment of displaced labour through increased economic activity. It was assumed that the trends in labour participation rates are not changed from their background settings[10]. McDonald and Temple found that changes to participation rates had a relatively minor effect on GDP per capita. Consequently, in the background scenarios, final demand consumption was increased (or decreased) in order to lower (or raise) the unemployment rate. The modelling calculations allow for service workers supporting the physically productive sectors of the economy. The number of service workers was assumed to be proportional to the various stocks of physical capital used. The level of unemployment achieved in each scenario is illustrated in Figure F1.

[9] Including Territories.

[10] For most age brackets, male labour productivity rates decline modestly, while several of the female age brackets increase towards a convergence with the male levels.

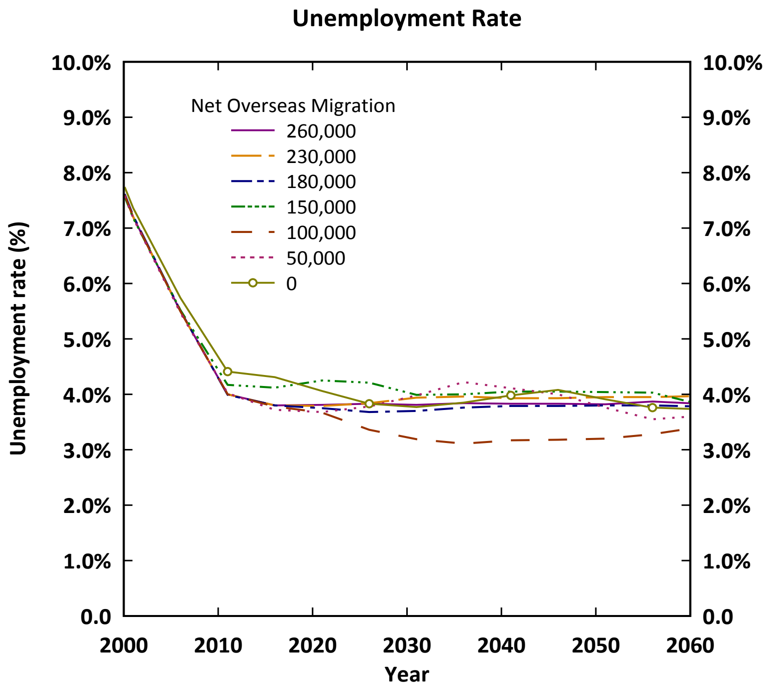


Figure F1. Aggregate unemployment rate achieved in the scenarios.

Trade Balance

A net foreign debt (NFD) relative to GDP of 52% was used as a target. NFD relative to GDP has increased over recent decades, to 52% in 2006 (Kryger 2009). High rates of debt (and surplus) are considered to be contrary to a stable national economy. In one measure of the economy, the net foreign debt is compared with the nation's GDP in order to judge whether an economy is overstretched to pay its international debt. This has been adopted in this study.

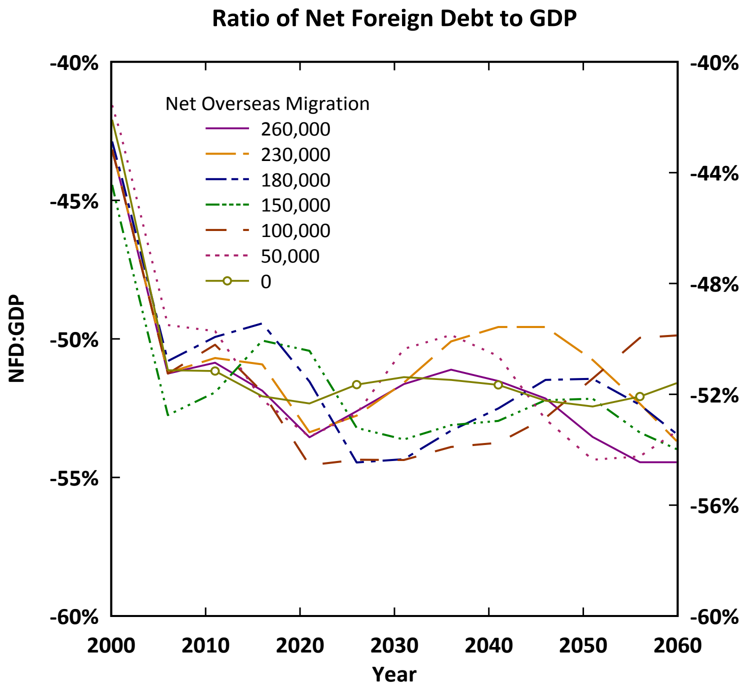


Figure F2. Net foreign debt as a percentage of GDP.

The net foreign balance in the ASFF was adjusted by changes to exports and imports, and international travel (inbound visitors, and outbound Australians), and investment. It is possible to achieve the same NFD through different combinations of changes to exports, imports and investment; however, this study (to date) has not explored this sensitivity. Adjustments to exports were made by altering activity in both primary and secondary industry, after allowing for domestic requirements to be met from these industries (where Australian exports are a large fraction of Australian production). International travel and investment were adjusted by the same proportion as exports. Imports were adjusted by changing the fraction (between 0 and 1) of the domestic demand for goods/commodities that is obtained from overseas. These changes also alter GDP, so that an iterative feedback calculation is necessary to achieve the specified NFD:GDP ratio (shown in Figure F2).
This process provides a more objective means of establishing import and export behaviour when economic modelling of international trade is not available (or not within the study scope).
The scenarios achieve similar levels of NFD:GDP, within about 5% of the target rate of -52% (Figure F2). The oscillations evident in each scenario arise from complex iterations among different dynamic processes. These include the lifetime of infrastructure and physical capital; and the effect of international interest payments to be made on the level of international debt.

Mining – mineral/fuel production

Guidance on the discovery and production of minerals and fuels was taken from Geoscience Australia publications. For the majority of minerals, it was assumed that further discoveries would occur in line with production requirements driven by export and domestic demand. There may be exceptions to this assumption.

In particular, domestic production of oil is forecast by Geoscience Australia to fall over coming decades (GA 2009). This forecast includes provision for currently undiscovered resources to be found and developed. In the ASFF scenarios, the addition to oil resources is double the GA forecast, since this forecast was only given to 2025 and the yearly profile follows the first half of a bell-shaped curve (implying that the other half of the resource may be produced beyond 2025). The 50% probability forecasts were used in the ASFF scenarios.

In the primary or initial scenarios, any deficit in domestic oil supply (i.e., not meeting domestic oil demand) is met through imports. This clearly raises questions about the availability of oil on the international market, and at what price. Being able to answer these questions is beyond the scope of this study. In these initial scenarios, the import of oil is therefore presented as a tension. This tension can be addressed by a number of strategies, or could trigger responses in the economy. Such changes can form sub-scenarios.

For instance, in the sub-scenarios that simulate a transition from oil to gas (for use as fuel), it is implicitly assumed that global production of oil also peaks and becomes economically unavailable. At this stage in this study, the transition to gas is only simulated in terms of the energy and mass balance of the feedstock, leading to changes in resource stocks and trade balance. Other issues to be simulated include the introduction of suitable types of vehicle engines and refuelling stations.

Other alternatives to dependence on foreign oil should also be investigated. These could include transition to other vehicle engine types such as electric and hydrogen based engines. There is also the potential mode shift in passenger and freight transport, say to rail for example.

Structure of the economy

No explicitly assumptions were made about changes to the structure of the Australian economy. Changes do occur however, due to the assumptions and modelling process described above.

Climatic conditions

Ongoing changes to climatic conditions were not incorporated in the scenarios. Some of the inputs that could be changed, with suitable advice and analysis, to simulate impacts of climate change include: rainfall, evapo-transpiration (ET), crop and livestock yields, tree growth rates, fire rotation rate, infrastructure degradation, and building space conditioning.

For water accounting in the present scenarios, rainfall and ET rates were held constant at recent levels. These levels were determined by linear regression through the past 15 years of basin level data (Raupach, Briggs et al. 2008; Raupach, Briggs et al. 2009). The water resource projections therefore embody a change in average climatic conditions away from a longer term historical average, where such a difference exists. Yearly variation in rainfall was not included in the scenarios, since average flows determine the long-term resource use. Large yearly variations that are typical to Australian rainfall do impact on short term operational management of water, which has relied heavily on dams with capacity to store several years of water use. This operational aspect is not a current feature of the ASFF analysis. These assumptions mean that modelling produces a relatively optimistic account of the impact of NOM on water stress.

Scenario Results and Discussion of the Implications

The results presented here are the outcome of the modelling process and assumptions that have been described above. These scenario outputs do not incorporate additional attempts to alleviate any problems in resources or the natural/built environment. Generally, each graph compares the outcomes of different net overseas migration (NOM).

Demographics

There are substantial differences in the size of the national population under the range of NOM scenarios modelled (Figure F3). The only scenario which sees a reduction in population, within the mid-century timeframe, is the zero NOM. Population stabilises by 2060 for 50,000 pa NOM, and increases continuously for all higher NOM.
The different population scenarios naturally translate into the populations of capital cities, assuming continuing trends in the proportions of people living in cities (Figure F4). Consequently, there are significantly different implications for the management of these large urban areas.
For instance, a fall in capital city population under the 0 NOM scenario raises the question of what, if anything, would happen to the excess infrastructure in the cities? Alternatively, under such a NOM scenario, would the cities maintain their population rather than decrease? In this case, the rural population would fall even faster, possibly with implications for the viability of rural towns and even agricultural production.
Despite the fall in capital city population in the 0 NOM scenario, land areas do not follow suit. Instead, urban areas grow continuously for each population scenario, as shown in the section on the Built Environment.

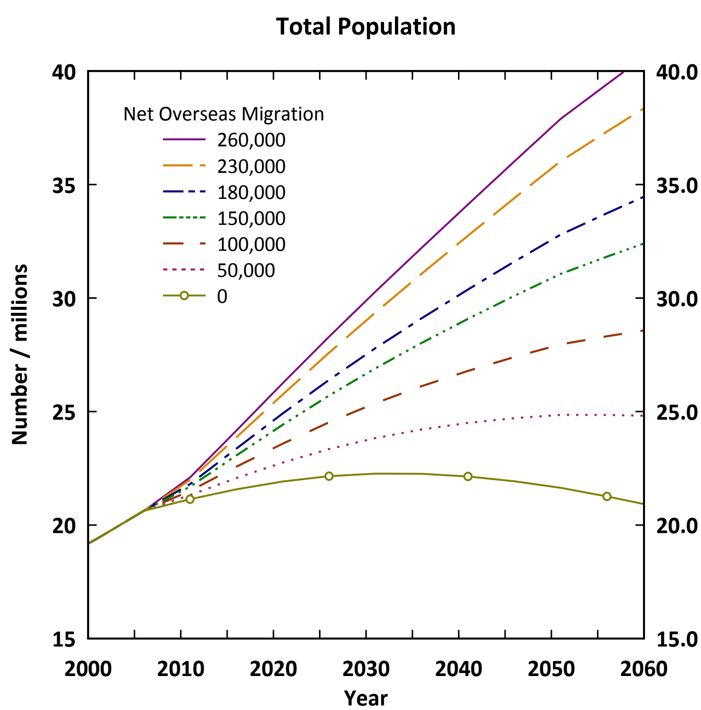
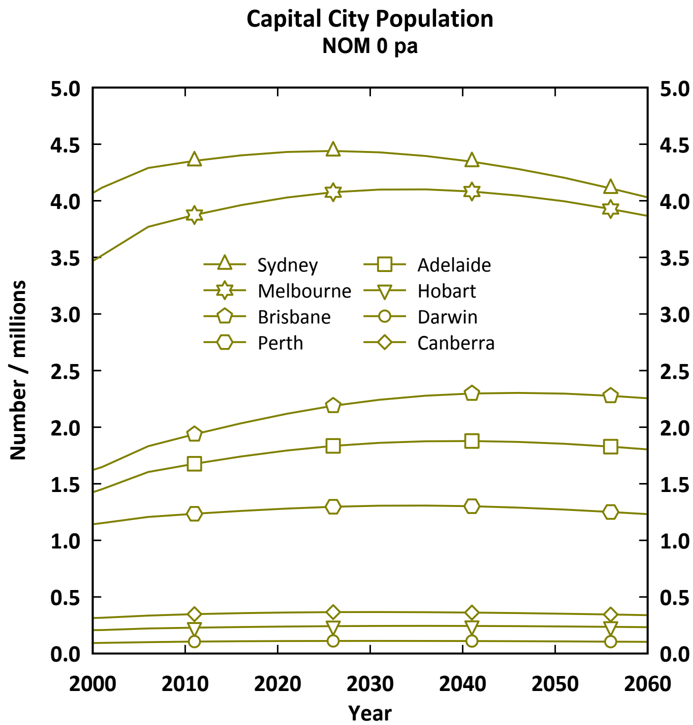


Figure F3. National population under the various scenarios of Net Overseas Migration.



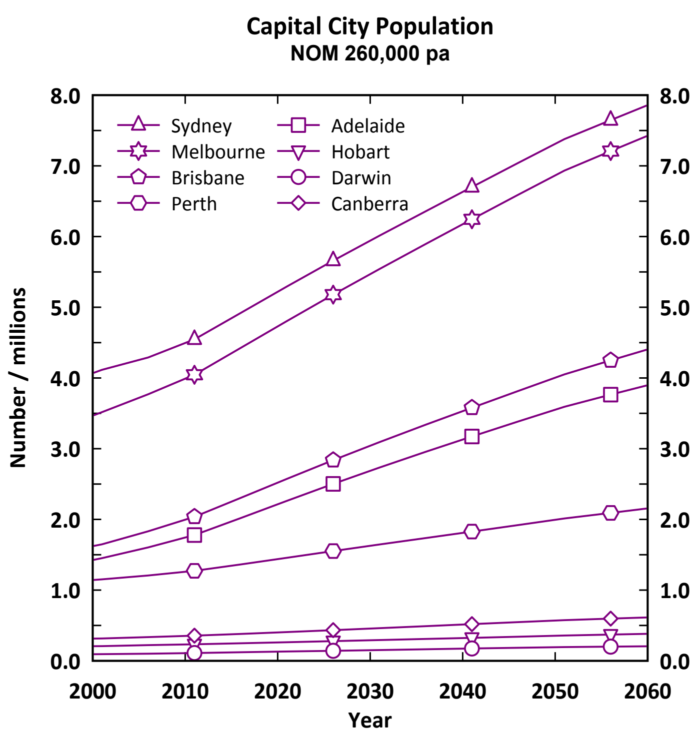


Figure F4. Population of the capital cities, for the high (bottom, 260 kpa NOM) and low (top, 0 pa NOM) scenarios. Note change of scale between graphs.

Economic outcomes

This section examines some aggregate economic outcomes from the scenarios, such as GDP, consumption and structure of the labour force. As shown above the scenarios all result in a steady unemployment rate (Figure F1) and steady levels of net foreign debt relative to GDP (Figure F2), because these were conditions imposed on the scenarios—other factors were adjusted in a feedback process to ensure good employment and trade results.

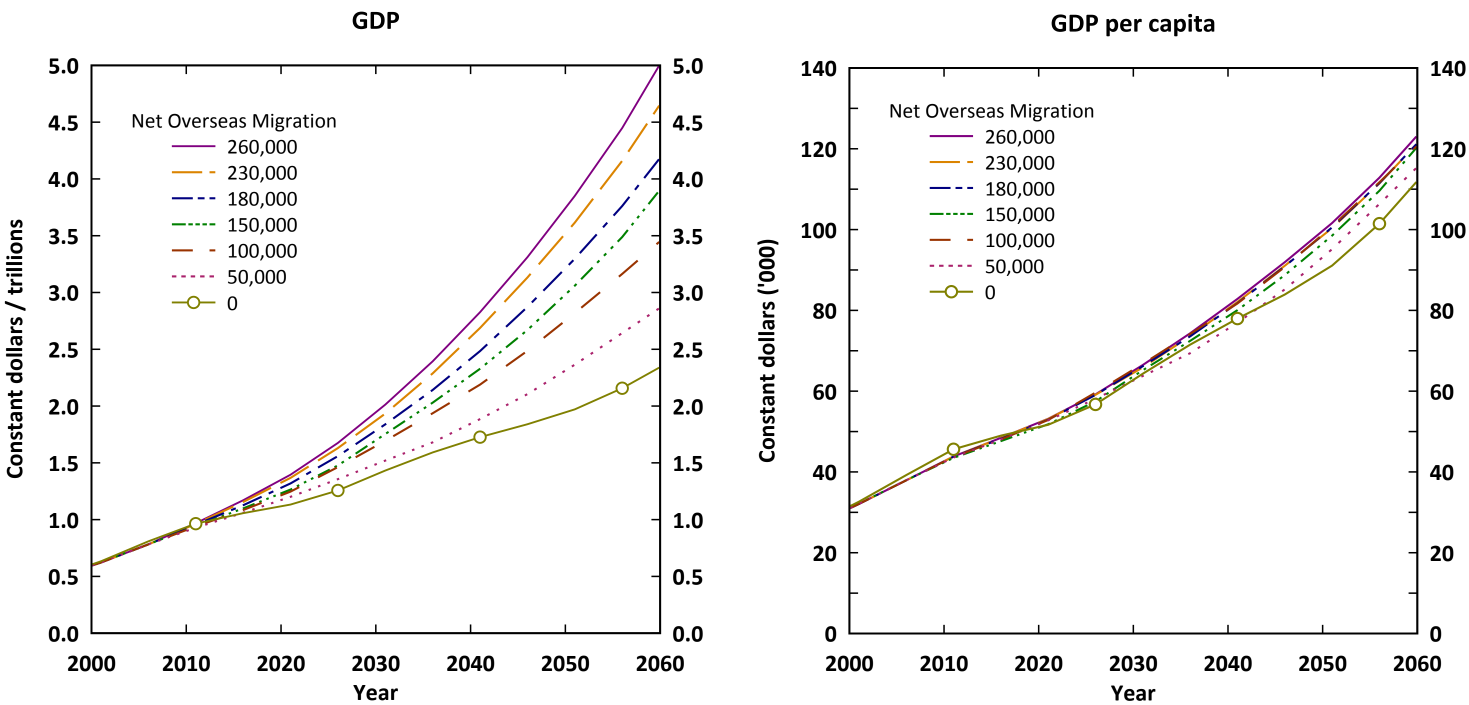


Figure F5. Gross Domestic Product (left, GDP) and a measure of per capita wealth (right, GDP per capita).

Economic growth is clearly evident for all NOM and population scenarios. This assumes that the environmental and resource issues identified below are adequately addressed, an aspect which is explored further in Section 6. The modelling produces growth in GDP for each level of NOM, even for zero NOM. This growth is necessary in order to provide employment (for the increasingly productive workforce). The growth in GDP is higher for increasing NOM, with zero NOM approximately doubling GDP by 2050 compared with a quadrupling for a NOM of 260,000 pa (Figure F5). Similarly, per capita wealth increases in all scenarios (Figure F5). Importantly, there is only a marginal difference in per capita wealth between the scenarios, and that difference only tends to appear after about 2040. For instance:

- by mid-century Australian per capita wealth relative to current levels would be 2.3 times higher under a NOM of 260,000 pa, compared with 2.0 times for a zero NOM; alternatively

- by mid-century the 22 million Australians resulting from zero NOM would achieve the same per capita wealth some 6 years later compared with the 38 million resulting from a NOM of 260,000 pa.

These results compare favourably with previous economic modelling (using the Productivity Commission's MoDEM model (PC 2006; McDonald and Temple 2008)) used to examine the effects of NOM, as shown in the Appendix A.
Labour force structure is considerably different under the alternative NOM scenarios (Figure F6). Economic structure and environmental impacts are influenced by Australian trade conditions. Generally for any NOM level, both exports of primary materials and imports of goods increase somewhat until about 2030. After this date, the trends reverse, though Australia remains a net exporter of primary materials and a net importer of goods for most NOM levels. These changes occur for each NOM, though lower levels of NOM result in higher exports as well as higher imports at the end of the scenario period.

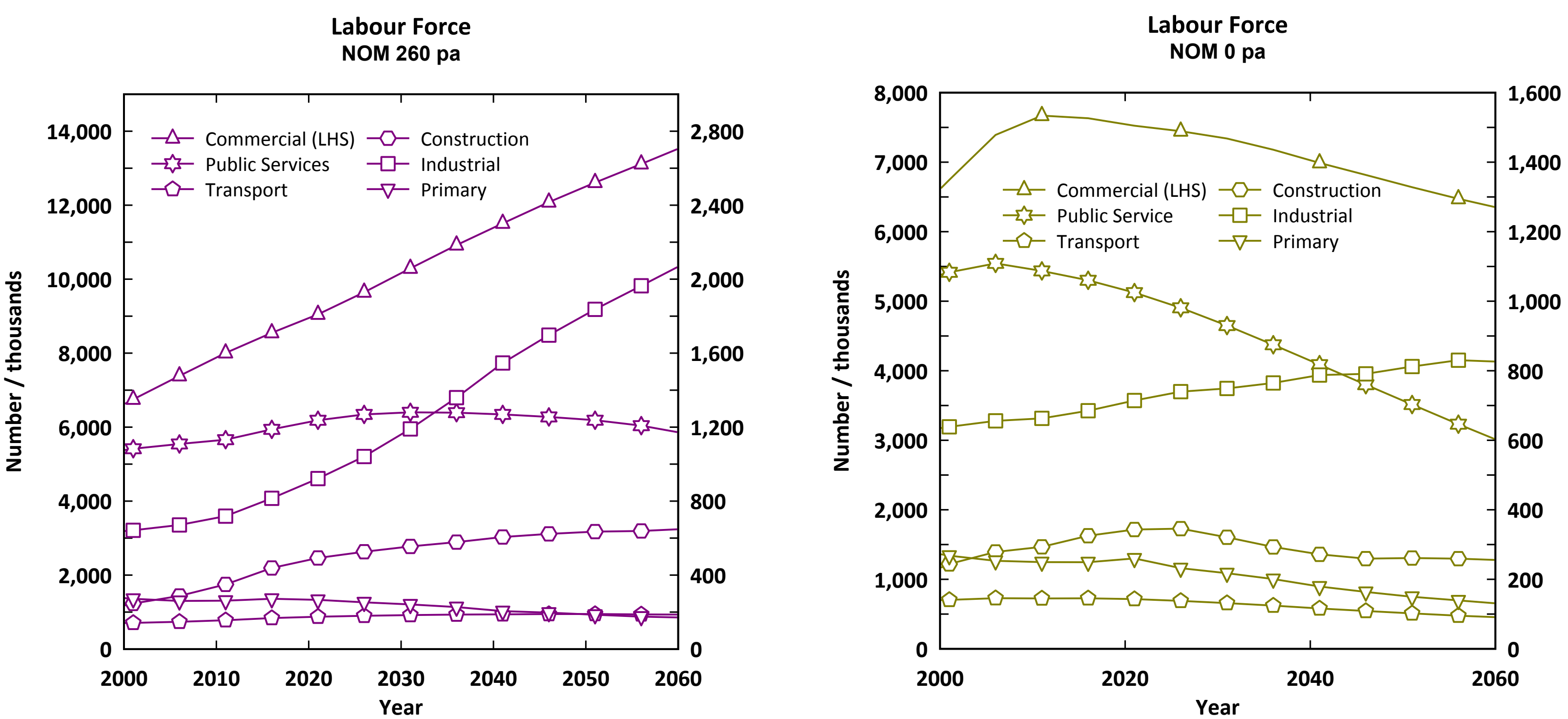
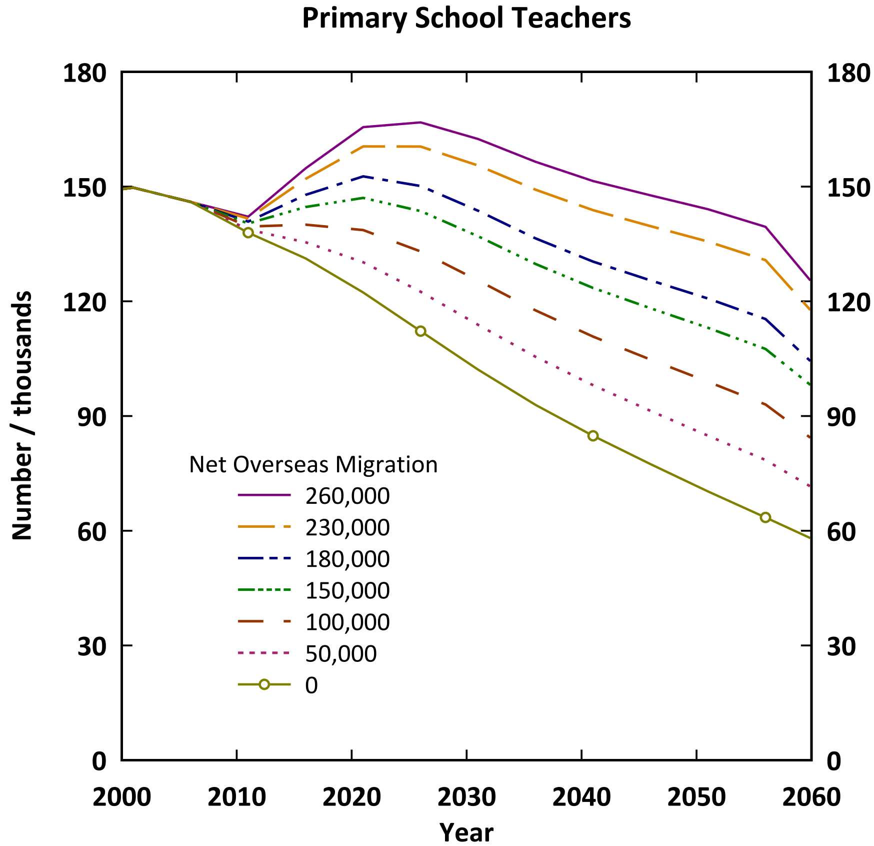
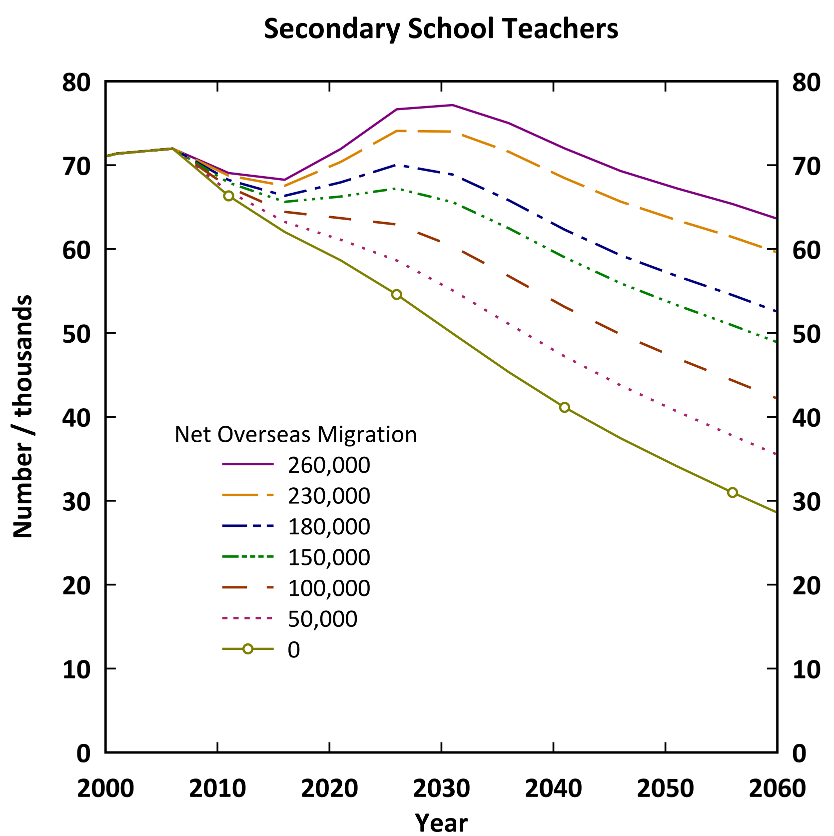


Figure F6. Numbers of workers in aggregate employment sectors for 260,000 pa NOM (left) and zero NOM (right);

(*in both graphs 'commercial' workers are plotted on the left axis, while all others are plotted on the right axis)*


Primary School Teachers
Number / thousands
Year
Net Overseas Migration
260,000
230,000
180,000
150,000
100,000
50,000
0
180
150
120
90
60
30
0
2000
2010
2020
2030
2040
2050
2060


Secondary School Teachers
Number / thousands
Year
Net Overseas Migration
260,000
230,000
180,000
150,000
100,000
50,000
0
80
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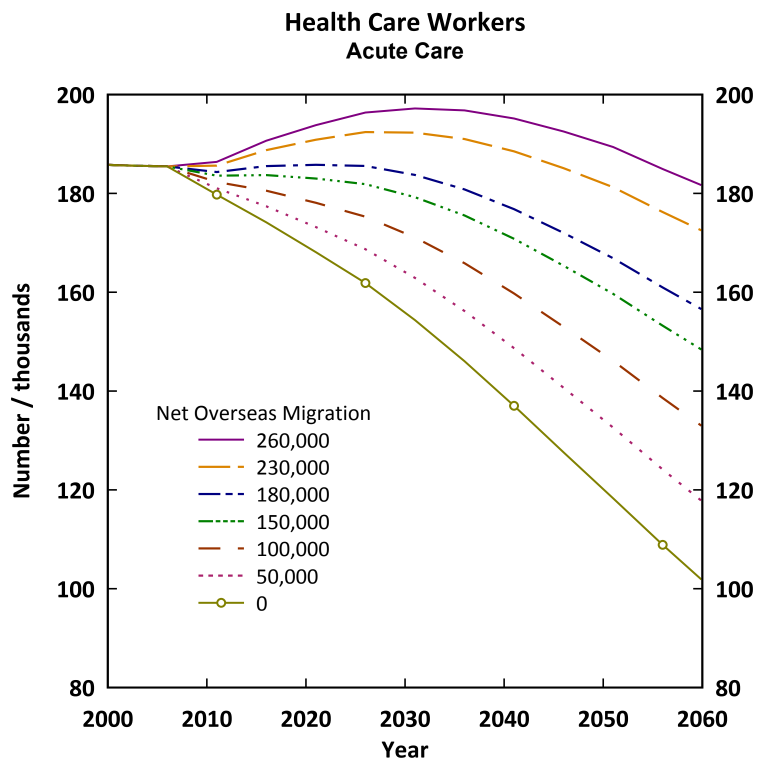


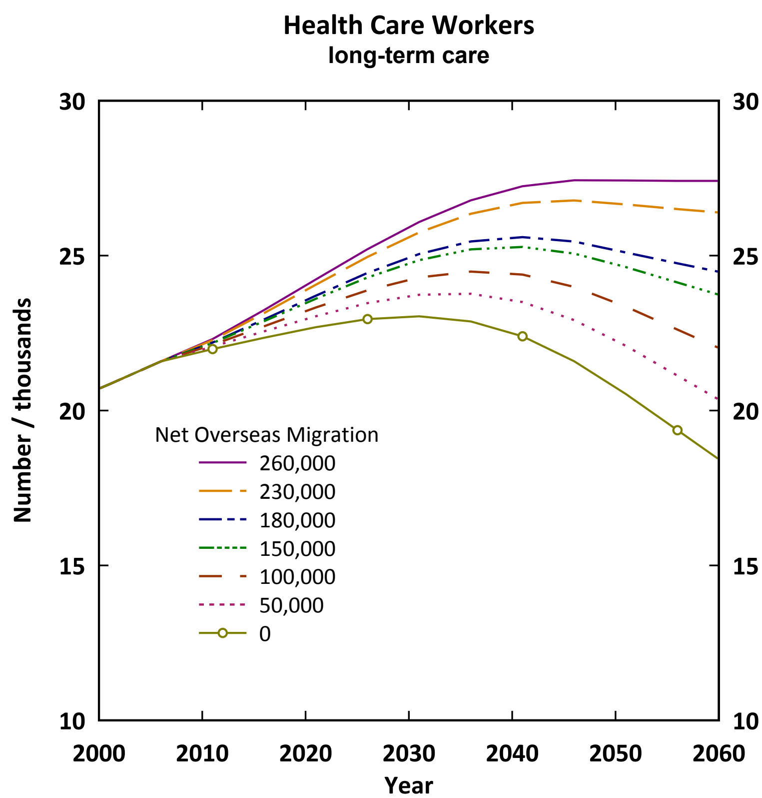


Figure F7. Dynamics of employment in selected services for the various NOM scenarios.

In terms of labour force breakdown, the Australian economic structure is not strongly affected by the different NOM levels. Service workers continue to dominate the labour force. The most dramatic change is the increasing share of manufacturing workers, and this trend is stronger at higher NOM. In contrast, primary industry workers form a decreasing share of the workforce, a trend which is strengthened with higher NOM. These changes take place through the feedback dynamics that aim to stabilise NFD:GDP at its recent level. For example, greater domestic production of manufactured goods results in lower import volumes, which helps to constrain the international trade debt. Increasing exports also contribute, though the lower unit prices of commodity prices compared with prices for manufactured goods means that proportionally smaller volume changes of these goods is required to achieve the same effect on trade balance.

Although demand for public services such as health and education are driven primarily by demographic dynamics, there are significant differences in the resulting requirement of workers in these sectors (Figure F7). The simulations in this study have not factored in potential influences such as changing rates of morbidity and mortality based on changes to food consumption and diet.

Lifestyle

The proximate reason for the economic growth evident in each scenario is increased final consumption. An example of this is the growth in the number of vehicles per household and the size of dwellings (Figure F8). Consumption of other goods increases in a similar manner. This includes for example, food consumed per capita and amount of household contents. Increased consumption is driven by the requirement to maintain unemployment at low levels (Figure F1). In general, consumption rates increase over the years, but not in a simple linear manner. Also as a rule, consumption rates are similar across the population scenarios until after about 2040, when higher consumption rates apply to higher NOM levels (Figure F8).
While the propensity for travel is adjusted like other consumption factors, the rate of outbound travel does not continue to increase through the years of the scenario simulations (Figure F9). The international travel propensity is also adjusted in the process of maintaining a steady net foreign debt relative to GDP. As a result of the combined effects, outbound travel rates increase initially and then fall steadily. Also in contrast with other consumption factors, the travel rate is higher for lower NOM scenarios and remains at higher values for longer into the scenario period.

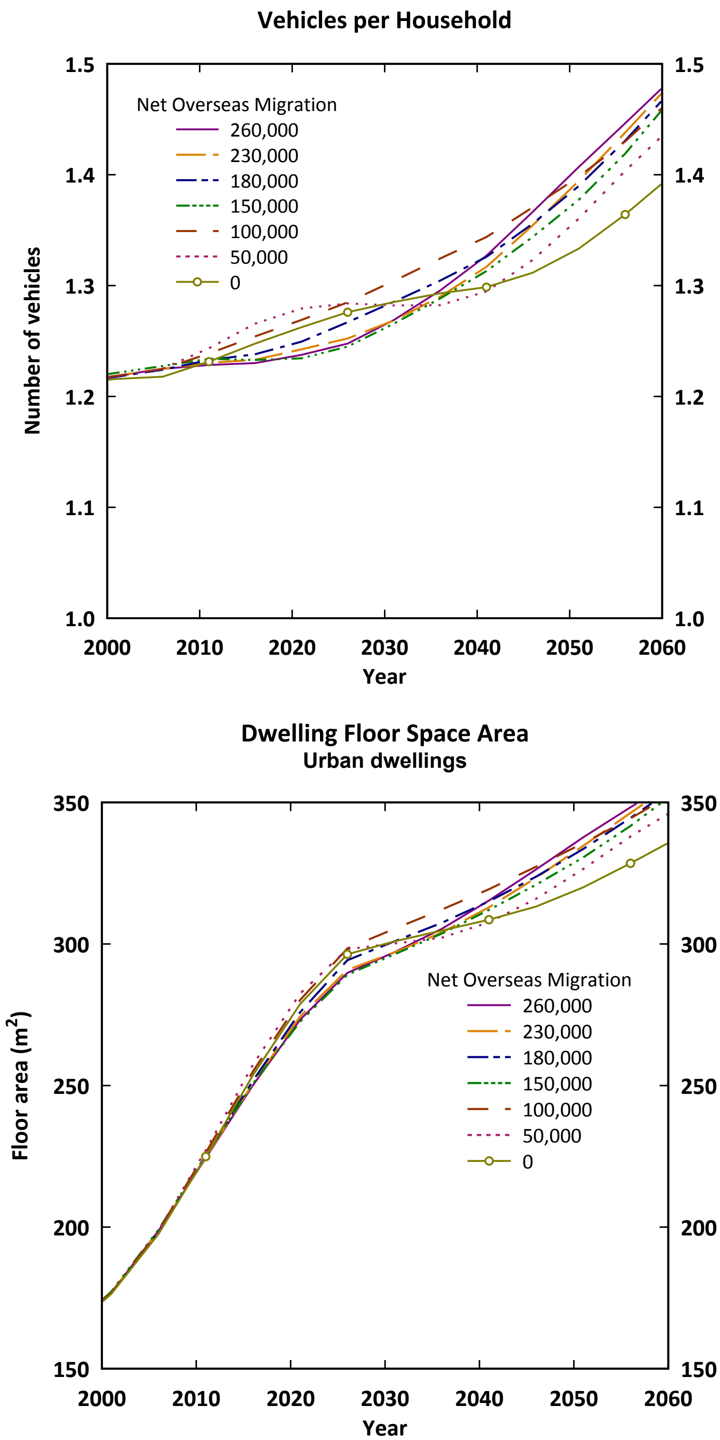


Figure F8. Number of cars owned by households (top) and size of dwellings (bottom), illustrating the increase in consumption required to prevent unemployment from rising.

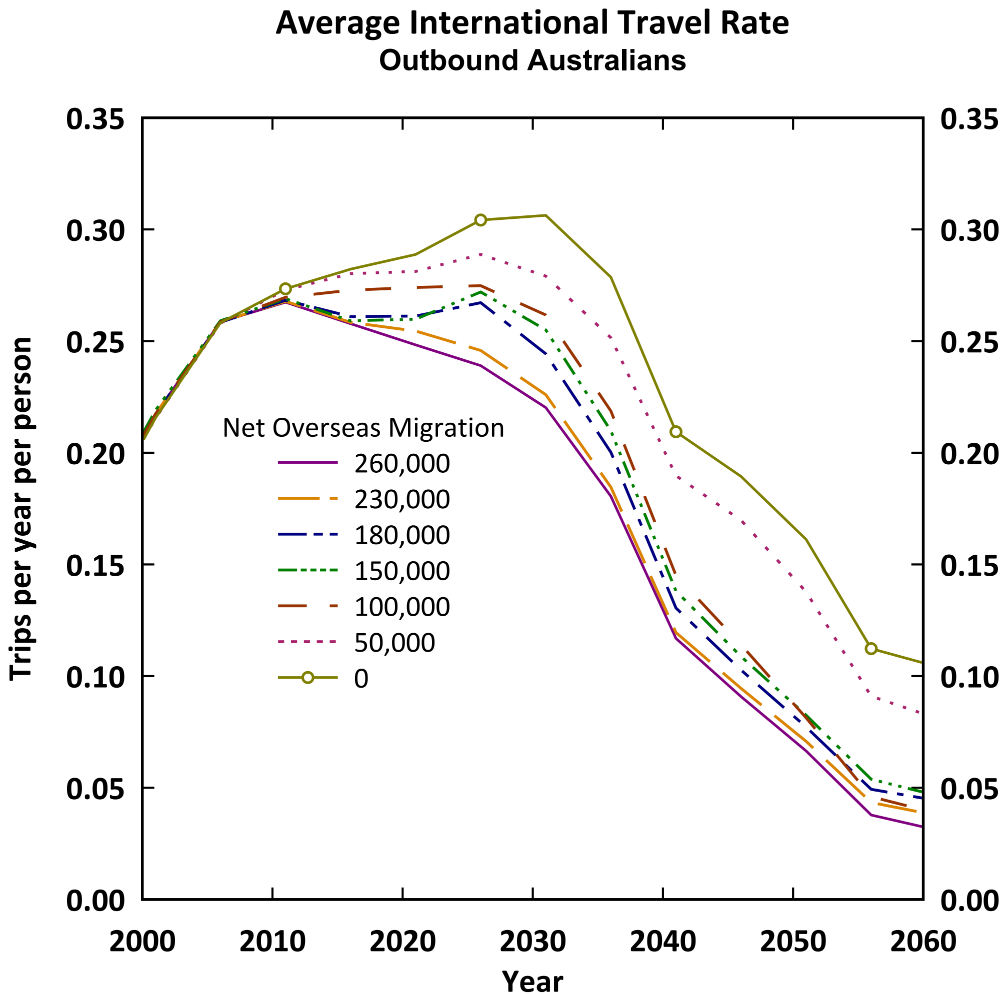


Figure F9. Average rate of international trips taken by Australians.

Water

Total water use (Figure F10) increases initially in all NOM scenarios, but begins to diverge from about 2020 onward in the alternative scenarios. For lower population scenarios, water use remains relatively stable for the remainder of the simulation. As NOM rates and population increase, so too does water use in the later decades. In the 260,000 pa NOM case, water use increases almost linearly over time, more than doubling by mid-century.
These simulation outputs represent the requirement for water, which result from the economic conditions created in the scenarios. This requirement may not necessarily be met. As described in the 'Modelling Environmental Implications' section, the initial scenarios may result in resource or environmental impacts which involve tensions between requirements and provisions. This is the case for water, as shown below, where there is insufficient water available to satisfy demand. There are many potential options for attempting to resolve such tensions.

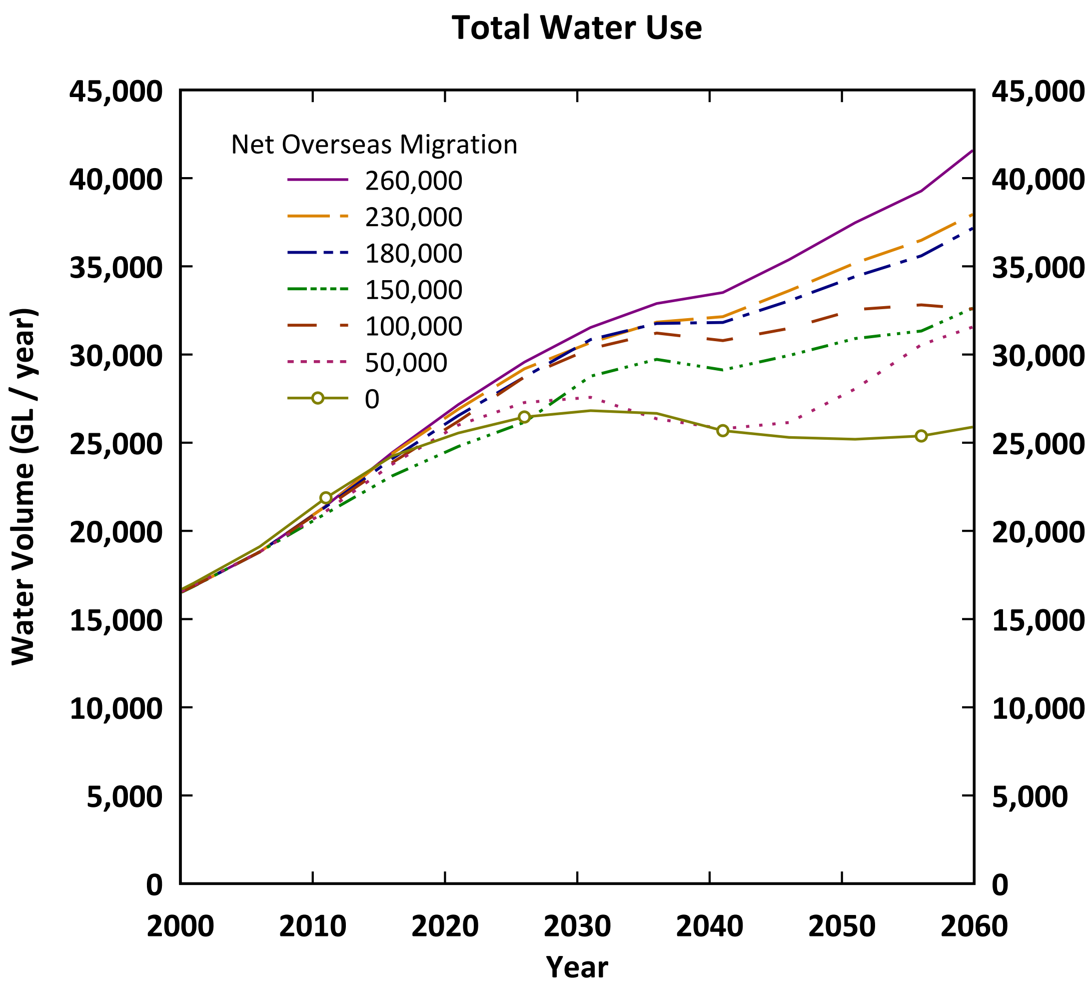


Figure F10. Water use aggregated over all sectors and end-uses.

In all scenarios, water consumption in the agricultural sector remains the dominant water use throughout the scenario period (Figure F11). However, agricultural share of water use diminishes significantly after about 2030 due to the continuous increase in water use by residential, commercial and industrial sectors. This trend is emphasized with higher NOM rates, to the extent that non-agricultural water use overtakes agricultural water use by mid-century. The consumption of water in urban areas accelerates over time, especially for NOM greater than 50 kpa, and for high NOM levels it even approaches the volume of water consumed in agriculture by mid-century (Figure F11). The latter peaks in about 2030 (following the dynamics of primary industry described earlier), while urban water use follows city expansion driven by both population growth and higher consumption lifestyles. While these scenarios have not simulated water conservation initiatives or efficiencies, some of which have been introduced in recent years, the scale of the task to limit increased water use is evident from Figure F11. If future urban water use were to be maintained at contemporary levels, the savings necessary in the future must be at least the same magnitude as the current volume of water use (as seen in the zero NOM scenario where urban water use could double). Higher NOM magnifies this task up to a factor of about four.

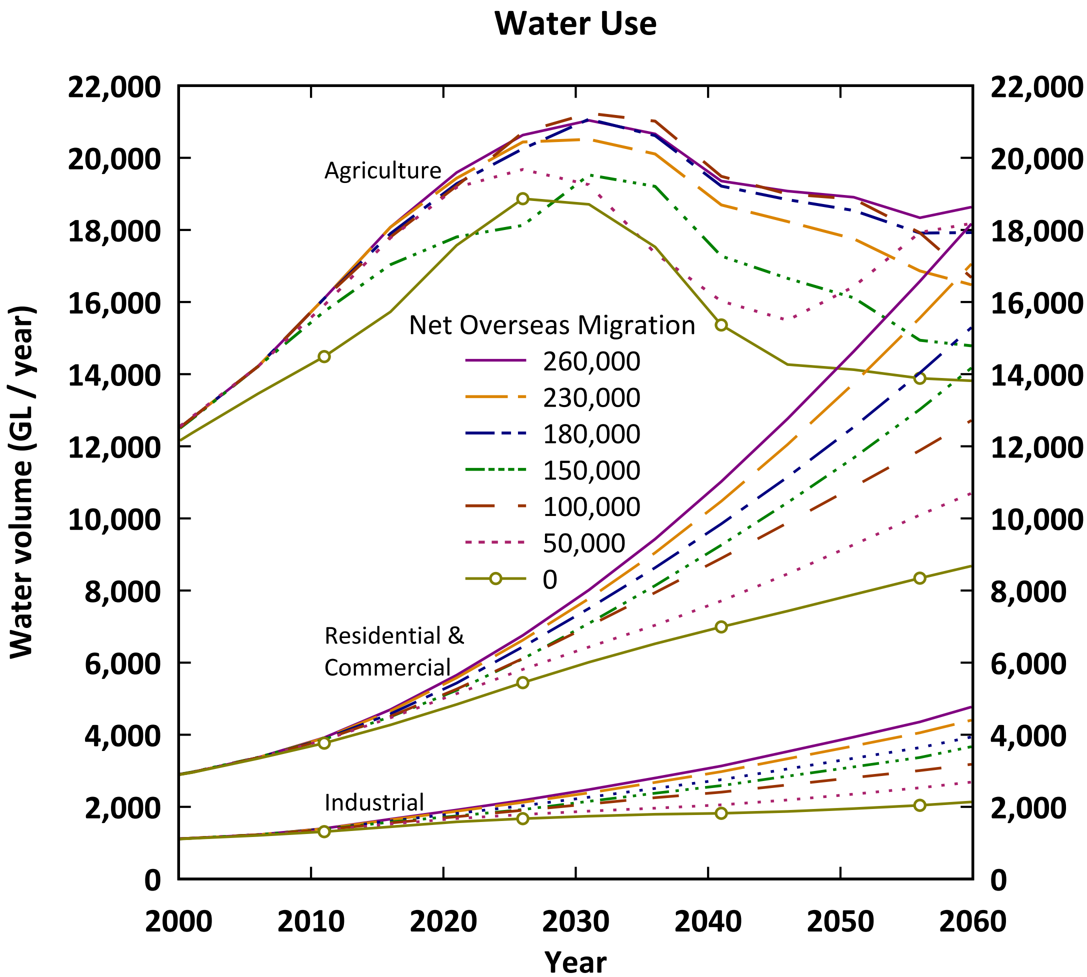


Figure F11. Water use split into three aggregate sectoral uses.

Since the availability and public acceptance of such substantial, continuous and accelerating water conservation and efficiencies measures may be brought into question, the other side of the water balance equation must be examined, i.e., water availability. The potential for surface water catchments, as mostly used in the past, to meet the growing demand for water is examined below. If this is insufficient, other options such as inter-region water transfer or desalination can also be explored.

Net unused surface water (availability less consumption) in river regions for major cities, and MDB

The following graphs show net unused surface water flows out of water regions i.e., the flow of unused water, which is the input surface flow less the water used in the region (plus return flows). Some modelling features require explanation before interpreting the graphs. The precipitation, evapo-transpiration, and groundwater flows have been calculated on a yearly basis, while water use (and land use) is based on a five yearly step in the simulations. The calculations also don't incorporate any storage effects. Storage is of course an important part of water management, but it is essentially an operational or short term feature (since storages are limited e.g., 3 years typically for capital city reservoirs). The long-term trends are ultimately not affected by storage details.

Consequently, the apparent zeroes in the historical data series do not indicate that the unused water flow ceased in those years. This is just an artefact of the different time steps and lack of storage in the modelling. Storage was used in those dry years to deliver water. Since annual variation was not simulated in the scenarios, the scenario curves implicitly present some averaging that inherently accounts for storage. In other words, persistent values below zero (i.e., persisting for longer than the years of storage capacity, typically 3 years) imply that water demand has outstripped supply.

Also, there are return flows from the water discharged after use. This has been included in the following analysis (as an addition to water available) to establish an estimate of remaining environmental flows. If these flows are not reused, then they would contribute to environmental flows, though they may carry nutrients and other contaminants. Alternatively, this water may have potential repeated use, depending on the degree of contamination and any subsequent treatment and suitable use. Nevertheless, the critical need for clean water and a degree of uncertainty about reuse options means that including return flows may over-estimate water availability for urban water use.

Yearly variation is not present in the scenario simulations, in order to more clearly show the average trend. Clearly variations are also an important feature of operational water management, generally managed via storage facilities. Such variation and storage can be incorporated in the modelling (see e.g., (Kenway, Turner et al. 2008; Turner, Baynes et al. 2010)), but it does not add greatly to the strategic long-term analysis as described above.

Therefore, the scenario simulations presented below of unused surface water highlight when water resources may be insufficient to support critical water use in the regions and cities shown. This occurs when the net surface water flow remains at zero for extended periods.

The modelling has indicated that water stress is a key issue potentially facing many parts of Australia if recent climatic conditions persist (i.e., without further changes due to climate change). A number of capital cities appear to be vulnerable. Of the capital cities, the calculations show that only Hobart and Darwin have secure water supply for all NOM rates through the coming decades.

Melbourne and Sydney appear to have a little more leeway, though this depends on the level of NOM. Both Melbourne (Figure F12) and Sydney (Figure F13) have on average more surface water resource than demand for zero NOM, at least until 2060 or beyond. Above a NOM of 100 kpa however, net water supply enters a deficit at about 2035. At high NOM levels, e.g., 260 kpa, the deficit in Melbourne or Sydney is some 1–2,000 GL/a by mid-century.

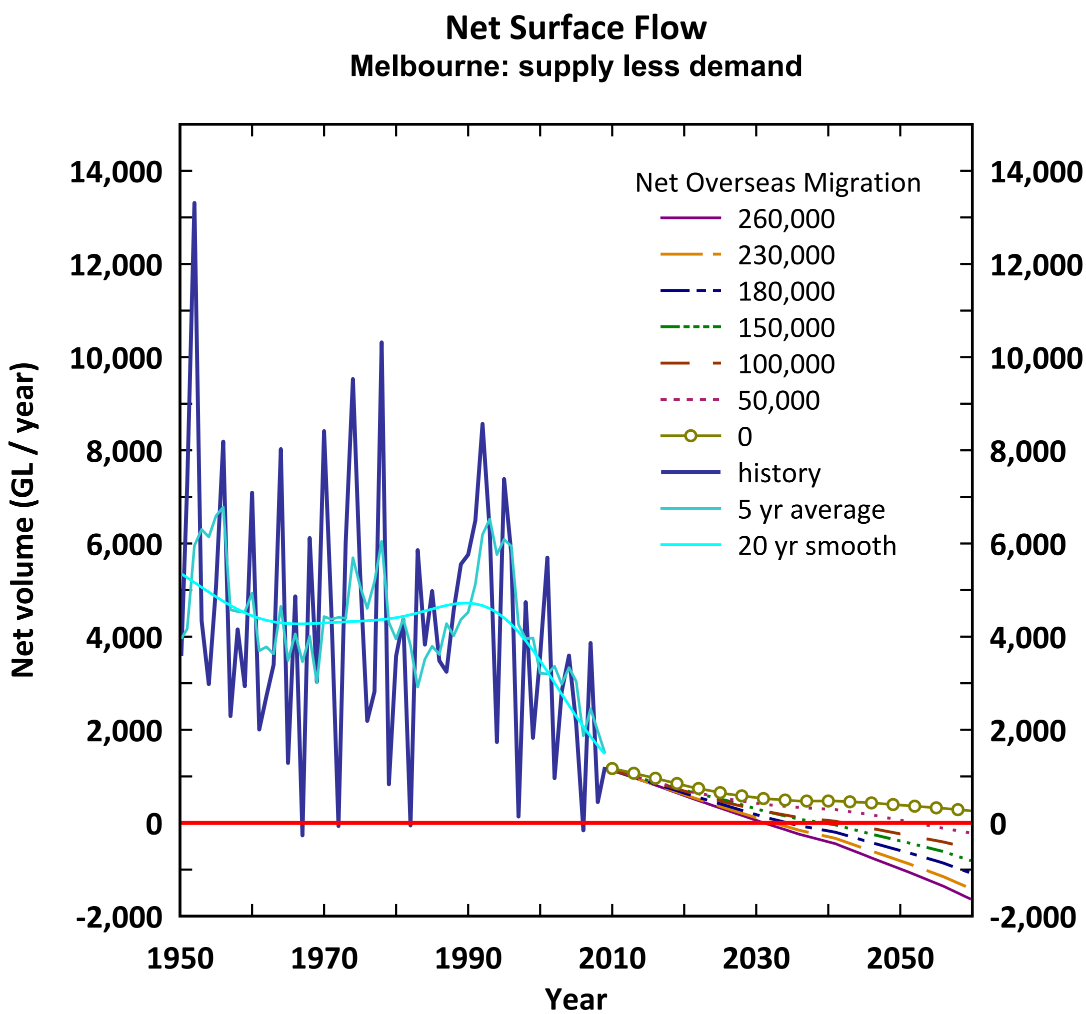


Figure F12. Remaining surface water (or environmental flows) after use for the river catchments containing Melbourne.

(Historical data incorporated in the simulation is shown for 1950-2009, and a 5 year prior moving average and a 20 year smoothing applied to this data.)

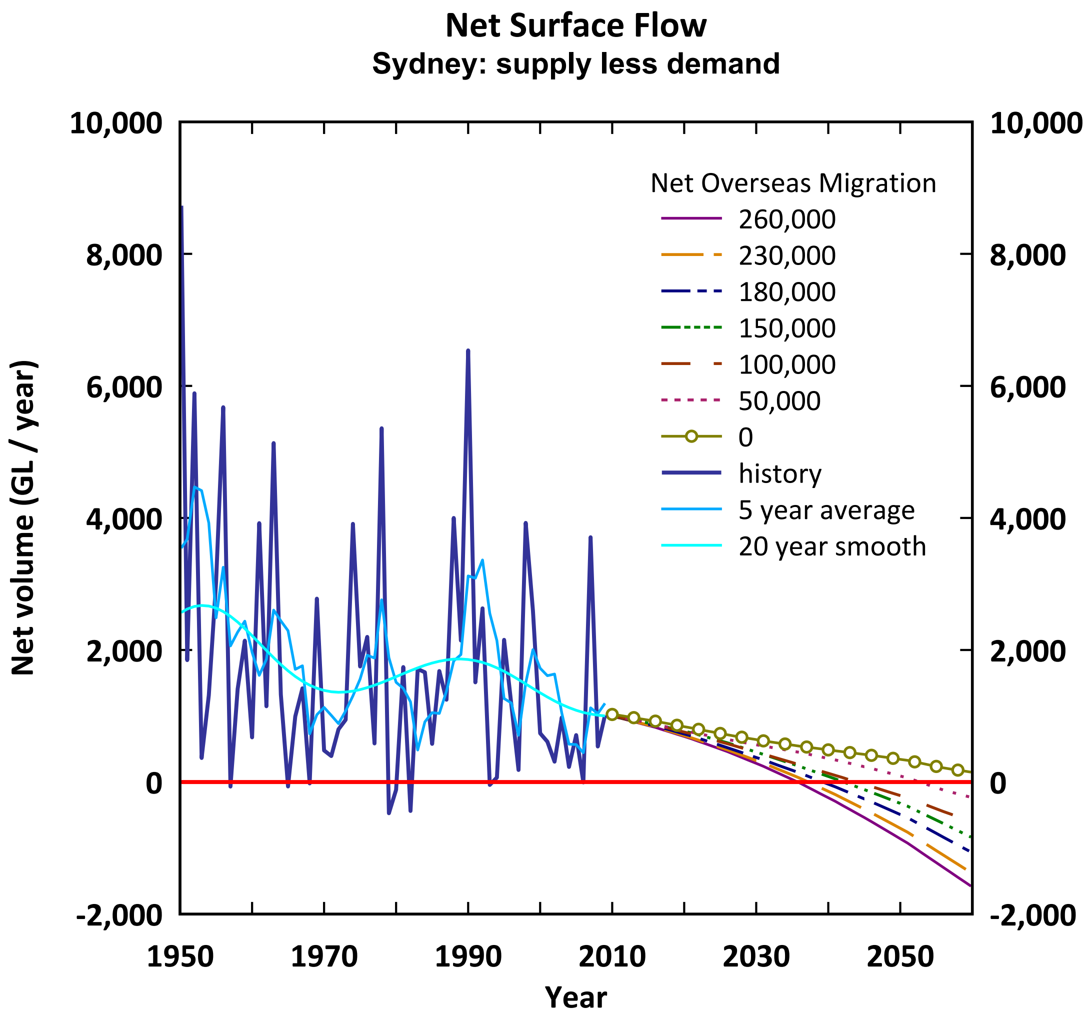


Figure F13. Remaining surface water (or environmental flows) after use for the river catchment containing Sydney.

(Historical data incorporated in the simulation is shown for 1950-2009, and a 5 year prior moving average and a 20 year smoothing applied to this data.)

The situation for Brisbane (and possibly Perth[11]) appears far more constrained, with the simulations indicating surface water deficits within a decade. This reflects the substantial reductions in inflows that have occurred recently around these cities. Consequently, the date when an ongoing water deficit occurs is very sensitive to assumptions or simulations of future climatic conditions.

Adelaide is able to maintain a positive surface water balance for all NOM rates, by virtue of water transfers from the Murray River. As the following shows, this flow cannot be guaranteed, so Adelaide's water security is also in doubt. These outcomes do not incorporate (further) climate change, which generally would exacerbate the outcomes.

[11] The water accounting focused on surface and should be extended to include groundwater flows, which are particularly important for Perth.

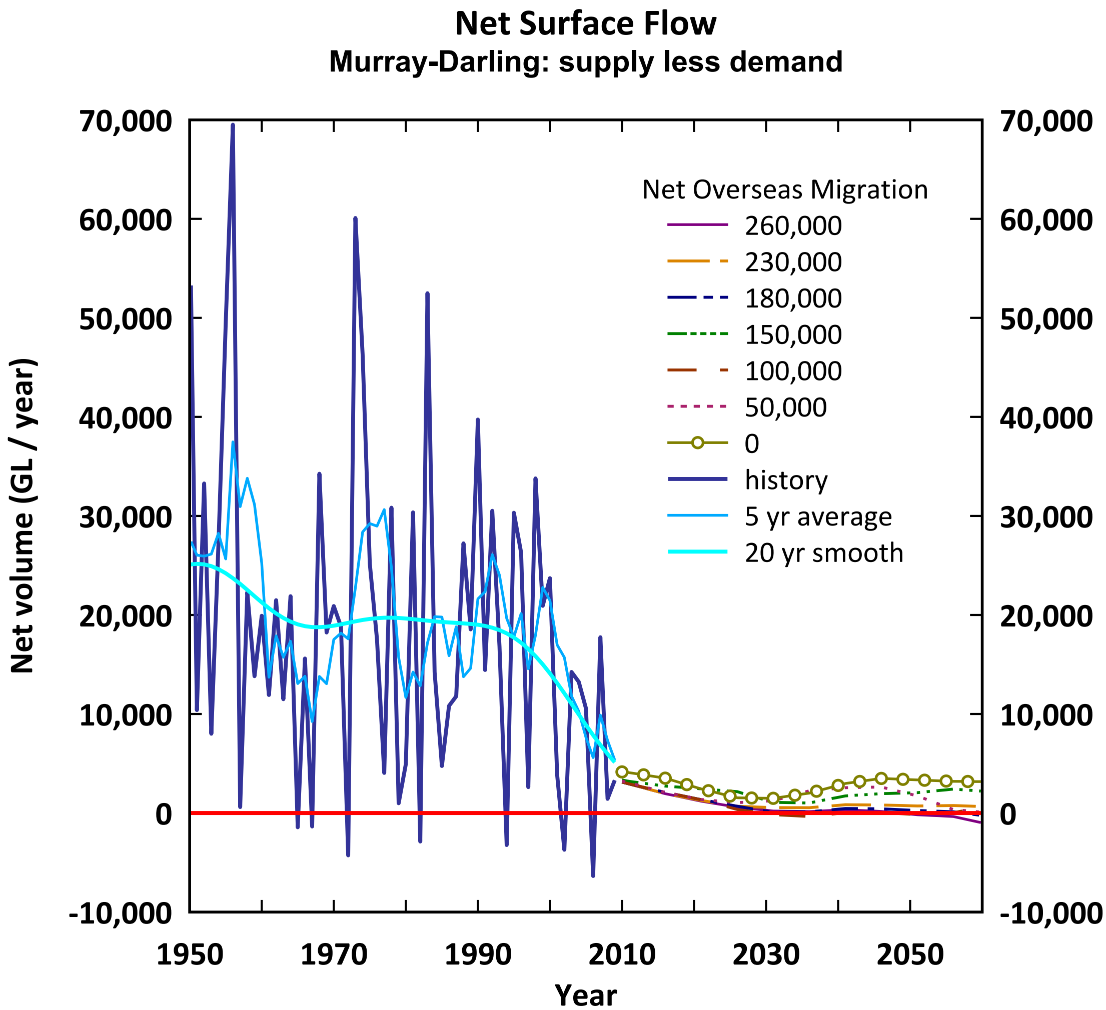


Figure F14. Remaining surface water (or environmental flows) after use in the Murray-Darling Basin.

(Historical data incorporated in the simulation is shown for 1950-2009, and a 5 year prior moving average and a 20 year smoothing applied to this data.)

Average flows of the Murray River at the river mouth remain significantly low for all rates of NOM (Figure F14), and in some cases the net water balance is reduced to zero. The Murray-Darling Basin, as Australian's major food bowl, manages to maintain on average a minor net surplus up to 2,000 GL/a surface water for NOM levels up to 150 kpa; at higher NOM the net surface flow approaches zero from 2030 onwards. The assumption that Adelaide continues to extract from the Murray, means Adelaide is able to avoid a water deficit on average, though large variations typical of Australian climatic conditions would jeopardise this in some years. Factoring in large annual variations is likely to mean that the flow ceases at the river mouth in some years for any of the NOM scenarios.

These outcomes reflect not only the prevailing water input conditions which are set at recent levels, but also the water used in agriculture. Since water use in agricultural production tends to saturate and fall from about 2030 onward (due to the process of adjustment of primary

production to maintain a steady trade balance), the Murray flow does not contract further and enter a deficit.
As is common for other environmental stresses, somewhat different outcomes may eventuate depending on a range of factors that require further investigation. The recent dry climatic conditions may ease somewhat, reflecting cyclic climate variations. The balance of scientific evidence indicates that further climate change may however lead to longer term reductions in rainfall and runoff. Water conservation and efficiency practices may be enhanced, and denser urban form could reduce outdoor watering. Alternative water supply may be obtained via inter-region transfers or desalination.

Food & fibre

For the majority of agricultural products Australia remains a net exporter of food commodities for all of the NOM scenarios (see for example cereals in Figure 15). In some commodities for which production is already close to domestic requirements, such as nuts and fruits, imports may be used to complement domestic production in satisfying Australian food requirements. In these cases, higher NOM scenarios result in an increase in imports at earlier years.
For many food categories (excluding seafood), Australia remains a net exporter of food for most of this half-century, though not necessarily at high volumes. This status varies according to the NOM level. In the case of zero NOM, essentially all categories of agricultural production produce a net excess over domestic consumption, allowing exports to be produced.
Where exports are large, particularly wheat, sugar and beef, the NOM effects are minimal and exports peak at similar levels at about 2030 and then decline. In other food types, however, Australia becomes a net importer by mid-century or earlier. This is particularly evident in the case of fruit, nuts, oil crops and pig-meat for all but the lowest NOM levels. As an approximate guide, each 50 kpa increase in NOM advances the date when Australia becomes a net importer by about 5 years. Even for dairy, lamb and vegetable categories, net imports are required by 2050 for the 260 kpa NOM level.
Underlying these outcomes are several factors. Recent trends in per capita consumption of the food categories were projected into the scenarios. A transition to more nutritious diets could decrease food security in some categories (e.g., fruit and vegetables) and increase it others. In terms of production, crop yields were assumed to increase steadily by about 20% over the coming four decades through genetic improvements and other agricultural techniques. The application of fertilisers and other amendments also improves yield. Land degradation on the other hand reduces productivity non-linearly for most crop activity, when older parcels of land remain in production. Climate change is expected to have positive and negative effects, but these have not been modelled in this analysis.
Ultimate food security, however, goes beyond these direct production elements. Should critical inputs such as nitrogen and phosphorus fertilisers (which are required at higher volumes over time for all NOM levels) become harder to acquire on international markets, then production will be more expensive and potentially reduced. Additionally, a large majority of Australian food is freighted across the country, much of it by road. Constraints in oil could impact food security for different areas and demographics through transport related price rises and possible disruptions of supply. This modelling did not explore the food security implications of potential fertiliser or transport fuel constraints.

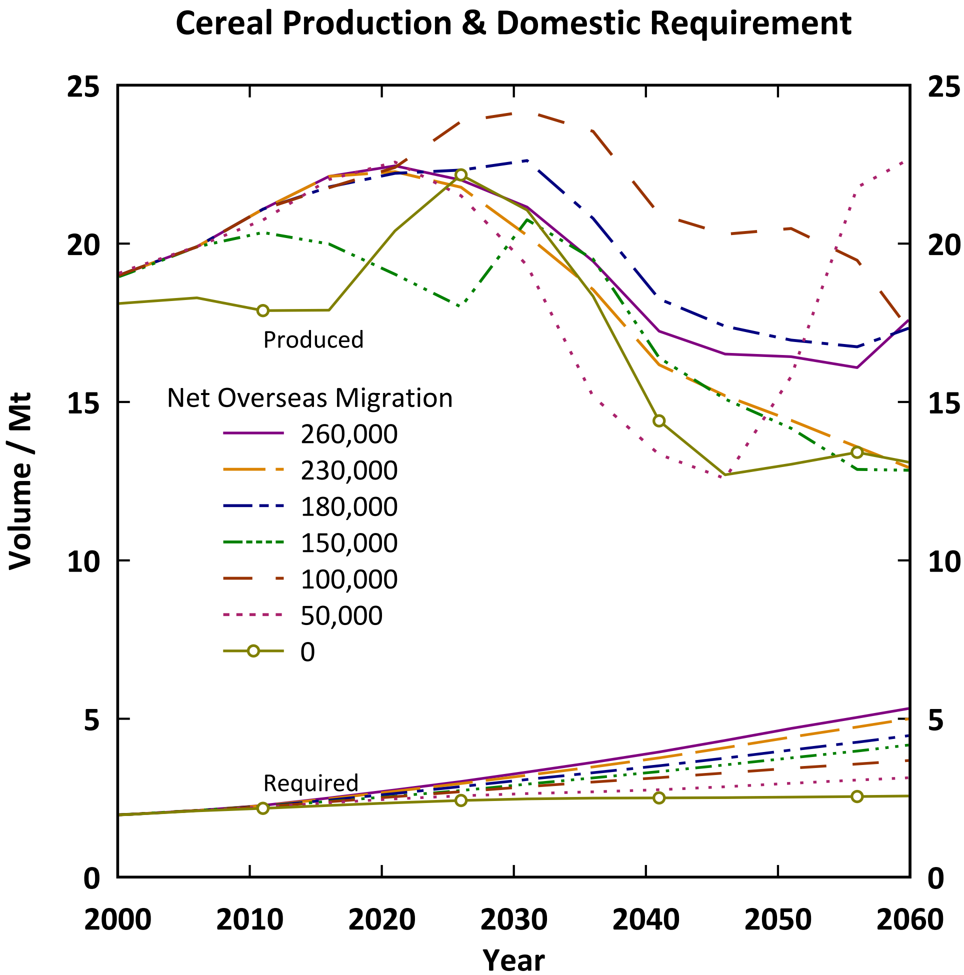


Figure F15. Comparison of production (after allowing for animal feed and seed) and domestic food requirement of cereal grains within Australia. The gap between the production and requirement is the volume exported.

Overall, agricultural production is simulated to increase somewhat toward 2030, and then decline, as shown for cereal grains. As a result the amount of agricultural land stays relatively steady, with occasional retirements of land (assumed to be from the oldest vintages) and additions of new land. Consequently, the vintaged stock of agricultural land continues to age (Dunlop, Turner et al. 2002; Dunlop and Turner 2003). This leads to further decline in the land productivity for cropping (Figure 16), reducing to about 60% of its original state for a zero NOM scenario, and decreasing to about 45% for high (230,000 pa or more) NOM scenarios. These losses are offset to some degree by increases in yields due to better farming techniques, genetic improvements, and the use of fertilisers and conditioners.

Use of fertilisers therefore increases for all NOM scenarios (Figure 17). This increase of about 50–60% mostly occurs over the two decades to 2030, after which total volume of fertilisers approximately plateau.

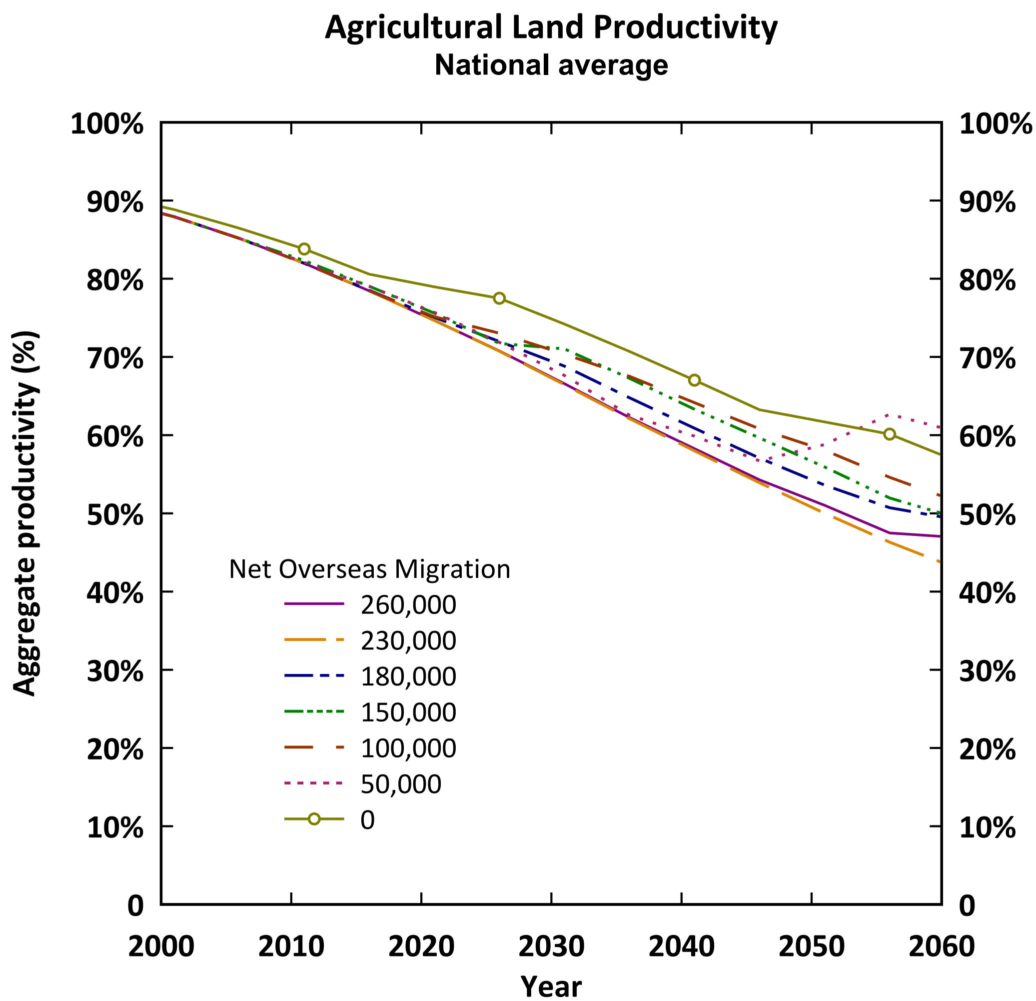


Figure F16. Relative productivity of agricultural crop and pasture land. This relative loss of productivity occurs with aging of the land stock. Farming techniques, genetic improvements and use of amendments can improve yield.

Currently, a substantial fraction of fertilisers used are imported into Australia, particularly in the case of phosphorus. If concerns about the potential for production of (high grade) phosphate rock peaking in about 2030 (Cordell, Drangert et al. 2009) are realised, then the security of production of food in Australia (and imported from overseas) is in question. Additionally, nitrogen fertilisers are based on the Haber-Bosch processes using natural gas as the main feedstock. Pressure on access to natural gas is likely to increase as production of domestic and global oil declines. This may lead to constraints in supply of nitrogen fertilisers and/or price increases. This situation was evident in the recent years preceding the global financial crisis when oil and gas pressures increased markedly.

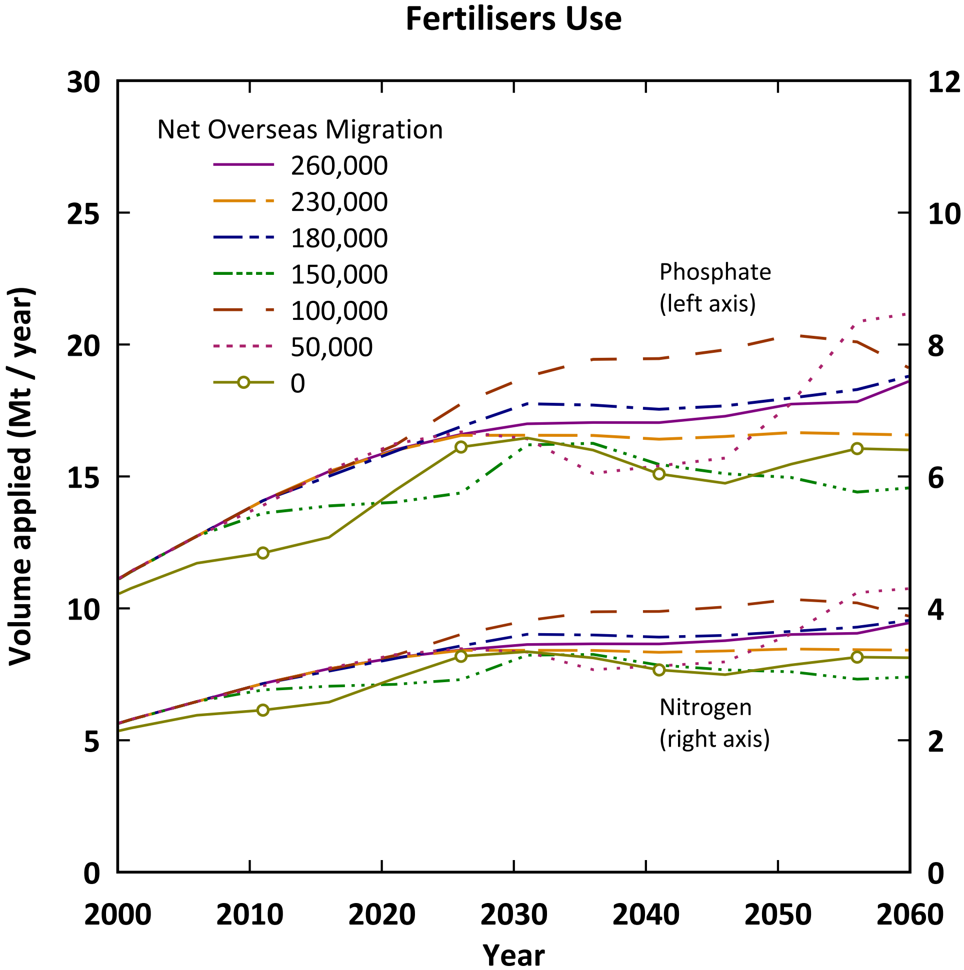


Figure F17. Use of critical fertilisers for agricultural production.

Absolute security of food supply to all Australians is not guaranteed given:

- potential constraints on nitrogen and phosphorus fertilisers;
- water availability issues even without further climate change;
- potential for increasing deleterious impacts of climate change (Howden and Crimp 2005; Howden, Crimp et al. 2020).

Factors that also increase the pressure on supplying food to the Australia population include:

- potential disruptions in freight movements due to constraints on oil as a transport fuel;
- increasing per capita consumption of food;
- population increases in the majority of the NOM scenarios.

Mineral and fuel resources

Minerals in Australia are generally considered to be in abundant supply. Estimating the resource of minerals is a difficult task, so that figures of economically recoverable resources and the larger pool of total resources change with exploration, discoveries and improvements in extraction processes. This has led to the view that new resources will be found and developed as existing ones decline in their rate of production. Past experience supports this view to some extent for many minerals, and this study has adopted this view. However, more detailed analysis is required to account for the likelihood that new discoveries tend to be of lower grade ores (Mudd 2007). This could lead to more intense use of inputs such as energy and water, and the potential for increased toxic outputs. These issues have not been investigated in this work, though the simulation has the potential for this.

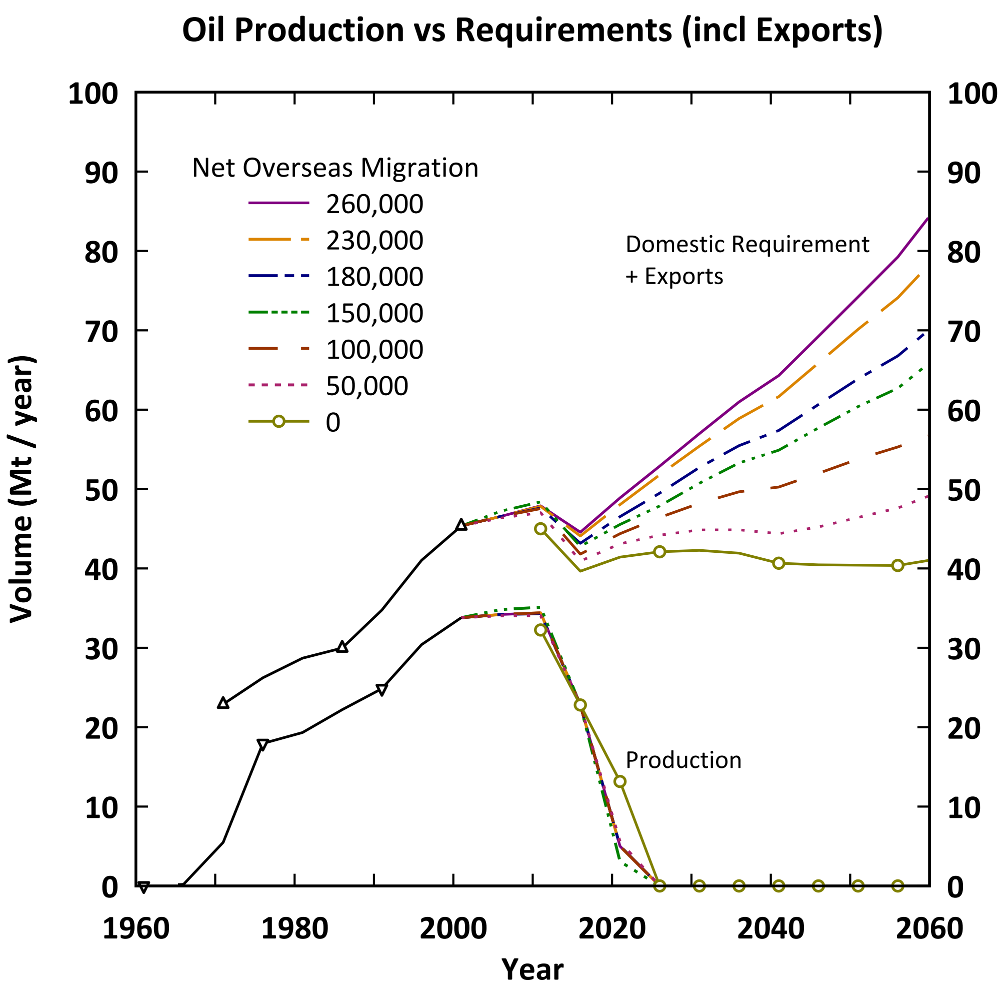


Figure F18. Comparison of Australian production of oil with the total of domestic consumption and exports. The gap between requirements (plus exports) and production must be satisfied by imports, or some other means.

However, the resource situation is different for oil. Until very recently only a few commentators were advising that physical production of oil may be approaching a peak. It seems that recent constraints on global oil supply means that normally conservative organisations like the IEA recognise the issue of "peak oil" (the peaking and subsequent decline of production rates), though there remain a wide range of estimates of when or if peak oil occurs (Sorrell, Miller et al. 2010). Geoscience Australia now publish forecasts that include a reduction in Australia's production of oil, and a forecast for the addition of further, as yet undiscovered, resources. These forecasts[12] have been used in this study.

[12] '50% probability' i.e., production is just as likely to be lower or higher than the forecast.

Potentially the most immediate resource challenge evident from the scenario simulations is an impending drop in the production of oil for use as transport fuel. In contrast with the past four decades when Australia produced the majority of its net oil requirements, domestic production is likely to fall rapidly over coming decades (GA 2006; GA 2009). Based on these forecasts, a rapid decline in oil production occurs for all NOM scenarios (Figure 18). It appears that production is likely to be critically low between 2020 and 2030. A similar outcome was simulated in independent research that employed macro-economic modelling based on embedded energy analysis (Foran 2009).

This contrasts with domestic requirements for oil, which vary strongly with NOM level. Requirements for oil are approximately stable for zero NOM, but increase steadily over time for NOM levels above 50,000 pa, with the rate of increase being approximately in proportion with the NOM level. The stable or growing requirement for oil is partially driven by population growth and increasing household mobility, and obviously assumes that transport fuel remain oil-based. Freight movement grows in proportion with the volume of goods and commodities produced. Consequently, freight movements stabilise after about 2020 for low NOM levels (zero and 50 kpa), while all other NOM levels require steadily increasing freight volumes at higher rates for higher NOM. The overall growth in requirement for oil is moderated by improvements in car fuel efficiency incorporated in the modelling.

Consequently, the deficit between requirement and production means the volume of oil to be imported would approximately triple contemporary volumes for zero NOM, and be about six-fold higher for a NOM of 260 kpa in 2050. This modelling assumes that foreign oil is available, and at economically reasonable prices[13]; both assumptions appear questionable from recent global events and forecasts.

Even if more optimistic forecasts of discovery and production are used, the scale of growth in consumption leaves a large gap to be filled. This places Australia in a position of reliance on access to international oil, which may have serious implications for Australian economic stability, given oil price increases and fluctuations in recent years on the international market. Furthermore, Australia is unlikely to be insulated from global impacts of oil constraints, which could be substantial (Friedrichs 2010; Owen, Inderwildi et al. 2010).

Given the overwhelming dependence of personal mobility and freight on oil-based transport, Australia's economy (and the global economy) cannot function smoothly unless rapid changes occur. A range of alternatives should be explored to address the issue of oil scarcity. Since the scenarios already include a significant increase in the fuel consumption efficiency of cars, other options should also be developed, such as substitution of oil by other fuels, such as compressed natural gas, and a transition to other vehicle types, such as electric cars.

Greenhouse Gas Emissions

All levels of NOM result in growth in aggregate CO_2 emissions from burning fossil fuels, and the emissions increase with NOM. Zero NOM produces a 60% increase on 2000 levels by mid-century (to reach about 500 Mt/a), while emissions are tripled under 260 kpa NOM (reaching about 1000 Mt/a) (Figure 19).

Contributions to this growth occur in all major sectors, predominantly in electricity generation, manufacturing, and transport. The portfolio of power generation was based on the current mix,

[13] The relative price of oil remained unchanged in the modelling, but this can be changed with suitable economic advice.

with black and brown coal-fired plant remaining dominant. Generator efficiency was increased over time to saturate at thermodynamic limits for these technologies by mid-century. In keeping with national accounting conventions, the calculation of CO_2 emissions are not offset by the reduced emissions in the birth countries of migrants. To do so in a consistent framework would also require benefits of migrants, such as economic contributions, to be offset as well.
Other greenhouse gas contributions were not calculated in this analysis, but the underlying activity indicates some increase in emissions, with an offset due to forestry. Fugitive emissions from mining would increase with NOM and over time due to trade dependencies (though emissions would stabilise after about 2030 for zero and 50 kpa NOM). Agricultural emissions due to fertiliser use may saturate about 30% higher by 2030, while emissions associated with livestock would peak at a similar scale and time, but then decrease toward contemporary levels; generally higher NOM results in somewhat higher livestock emissions. Forestry activity is identical for each NOM, and sequestration of carbon increases over several decades to reach an average level that is about 15% of the emissions from fuel combustion.

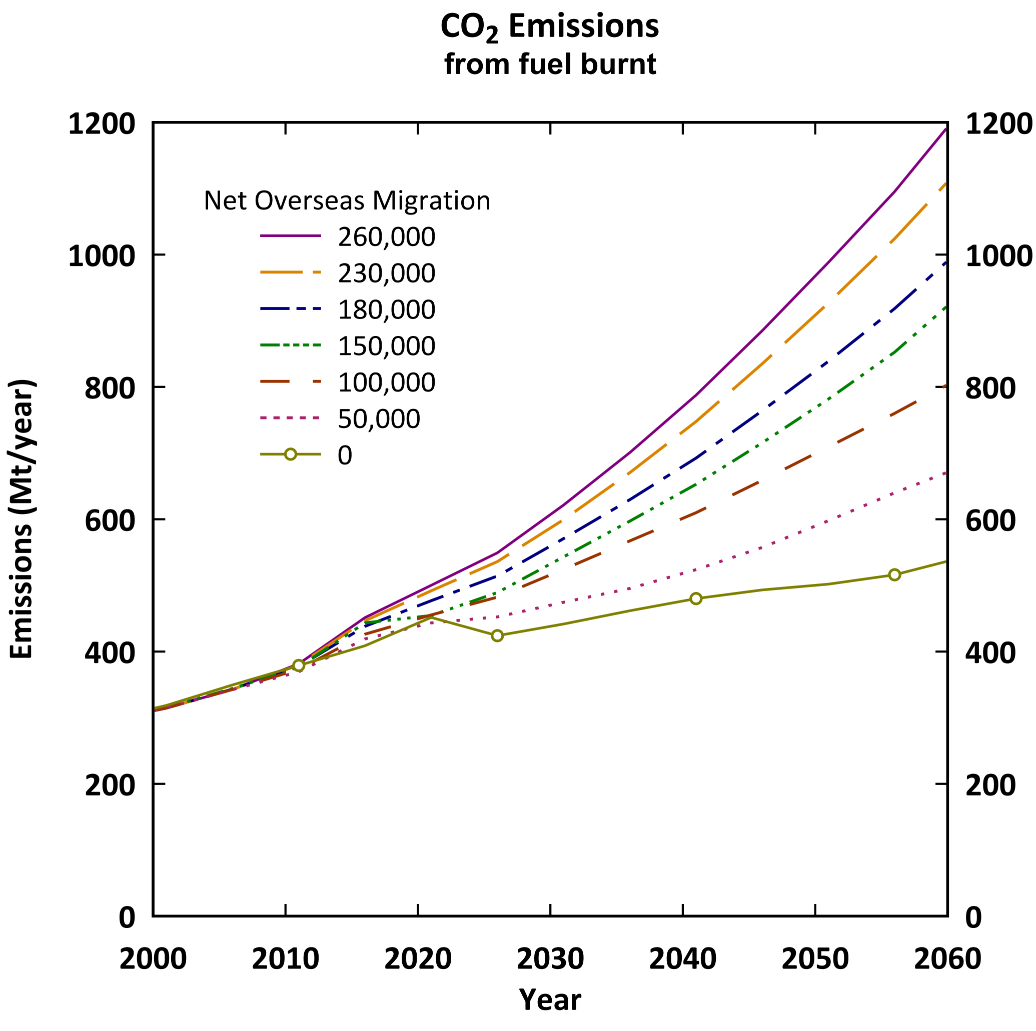


Figure F19. Emissions of the greenhouse gas CO2 as a result of fuel use.

Such increases in emissions have significant implications for achieving proposed greenhouse gas emission reduction targets to stabilised atmospheric concentrations. For example, to achieve a target in 2050 of 60% reduction of 2000 levels, requires emissions from fuel combustion for 180 kpa NOM to be cut in 2050 by about 710 Mt/a, which is equivalent to a reduction of 85% of the unmitigated levels in 2050 (and the cut is about double contemporary volumes). The corresponding tasks for zero NOM are about half the magnitude: a 60% reduction target is about 380 Mt/a, equivalent to 75% reduction of unmitigated levels in 2050.

Future impacts of climate change on the Australian economy and environment have not been included in the modelled scenarios. Subsequent estimates can be made, associated with unmitigated or alternative trajectories of greenhouse gas emissions, assuming that Australia's contributions reflect global trajectories. Nevertheless, if emissions were to increase largely unmitigated in Australia and globally, then scientific projections indicate that impacts already being experienced (CSIRO-BOM 2010) would be significantly more severe and/or frequent.

Built environment

The (aggregate) land area of the capital cities increases over the course of the scenarios by about 50% to 150% for zero NOM to 260,000 NOM respectively (Figure 20). This is a more rapid increase than the corresponding total population figures. And for the zero NOM case, the increase in urban area contrasts with the stabilisation and slight fall in total population. There are a number of factors in the simulations that influence the size of the urban area (and related infrastructure), in combination with sheer population numbers. These include household size in association with age profile demographics, numbers of dwellings per household, urban form and floor space of dwellings. In the scenarios developed here, the strongest drivers of urban area are dwellings per household and floor space of those dwellings. These factors are linked to economic growth and the macro objective of maintaining a specified unemployment level.

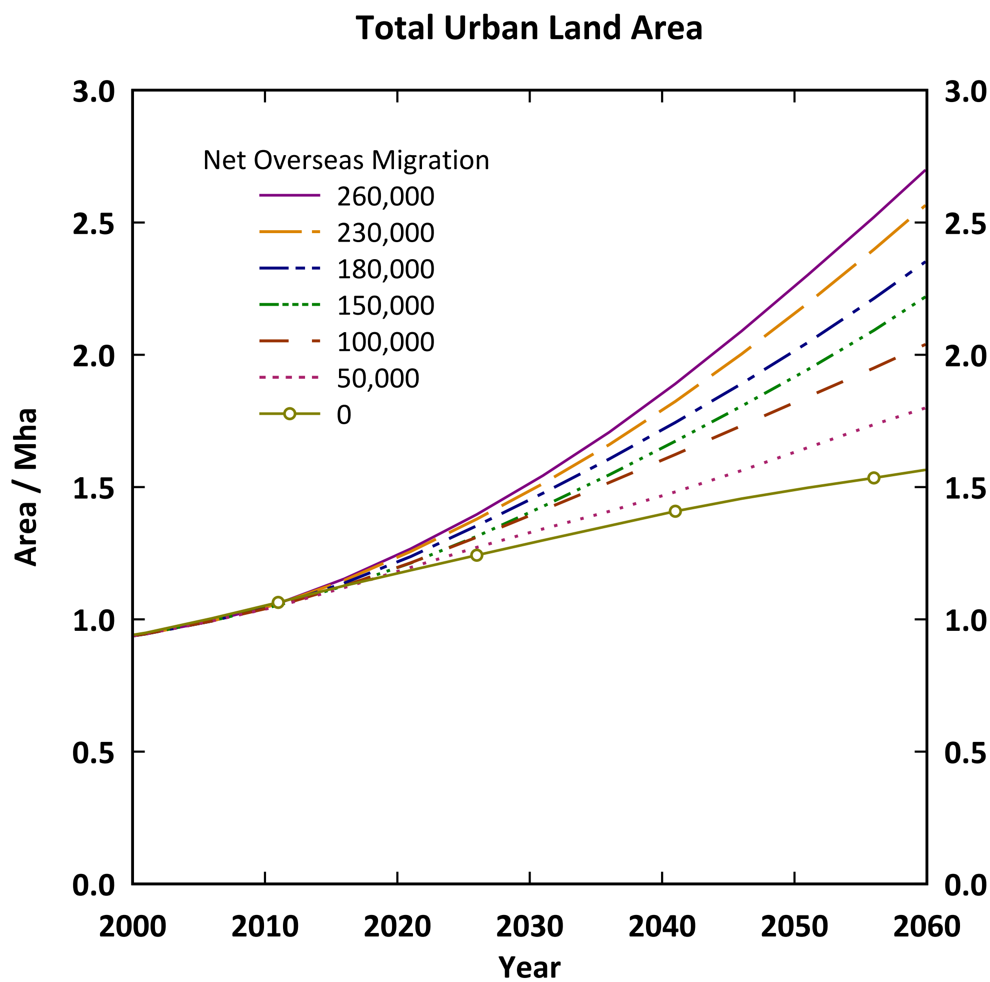


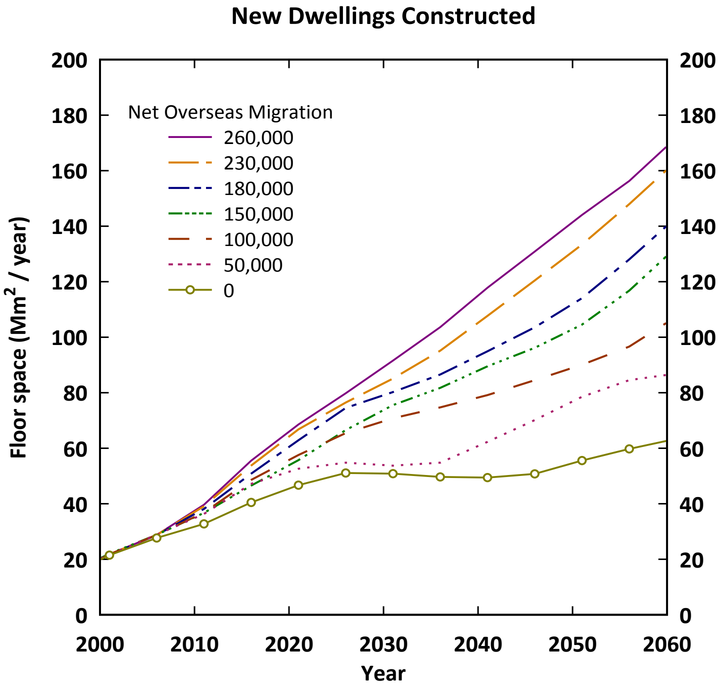
Figure F20. Total urban land area aggregated across the capital cities.

This urban growth naturally increases the rate of construction of housing (Figure 21), which increases faster than the construction of non-dwelling buildings. Nevertheless, growth in all construction is simulated to continue in a more or less linear fashion over the extent of the scenarios.

Expansion of urban areas raises issues such as likely increases in traffic congestion, city airshed pollution, and competition for land as a resource. The latter is an important issue since peripheral land of a number of capital cities has been relatively productive agriculture land, which can supply fresh food to the local area with lower freight requirements. Some indication of this competition is evident in Figure 22.

Under the high NOM rate of 260,000 pa, the urban area of both Sydney and Melbourne occupies more than half the Statistical Division by 2060. More than 430,000 ha of land is transferred to urban use in each city. The urban expansion is significantly more moderate for a zero NOM, but still occurs. While this study did not utilise the full simulation capacity to directly substitute urban development for agricultural land, it is evident that substantial areas are potentially to be lost from food production.

In strong connection with the built environment is the issue of waste management. Cumulative landfill increases rapidly irrespective of the NOM rate (Figure 23). By mid-century there could be another 2.5 landfills for each of those that exist now. Much of the waste stream is dominated by concrete from the demolition of old buildings. Up to 2030 this waste stream increases at the same rate for all NOM scenarios, slowing after this in the zero NOM scenario to about half the rate of the high NOM scenarios.



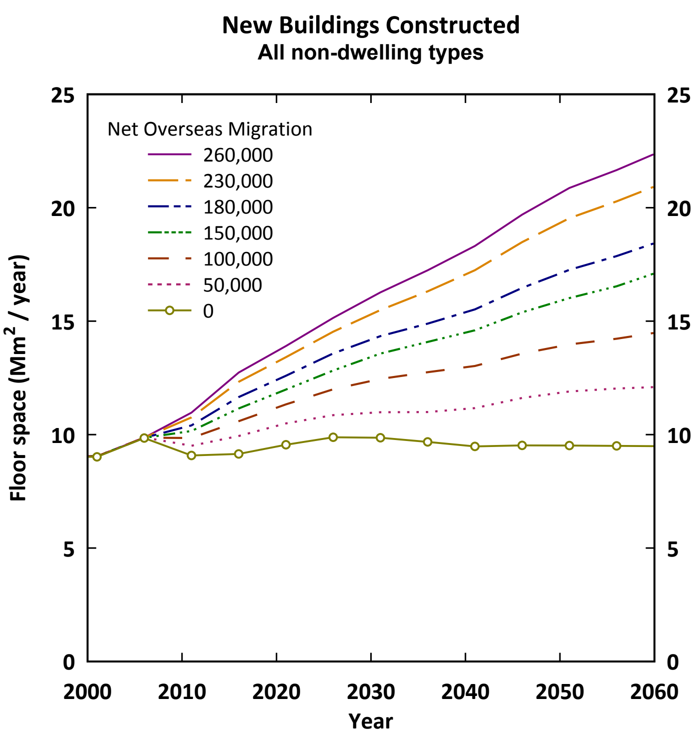


Figure F21. Construction of dwellings (top graph, aggregating over dwelling types), and all other buildings (bottom graph, aggregating over different commercial and institutional buildings).

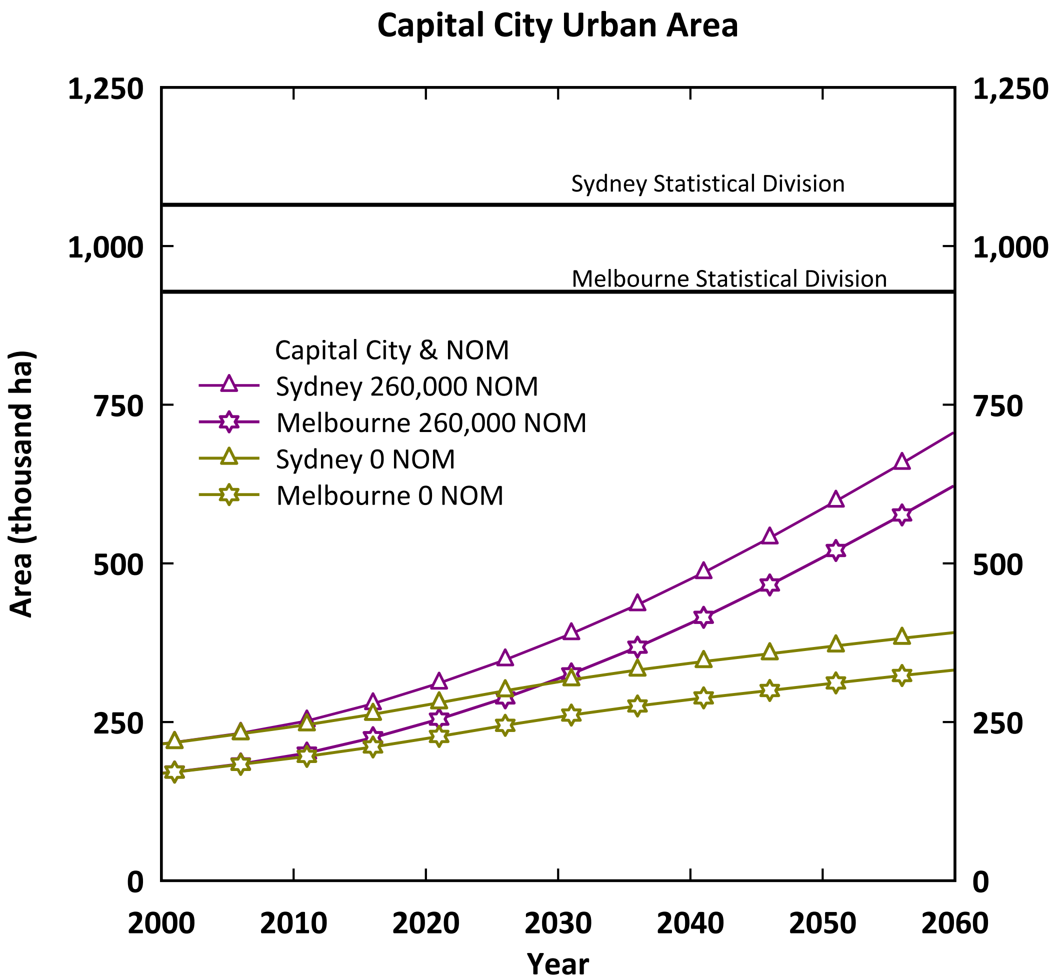
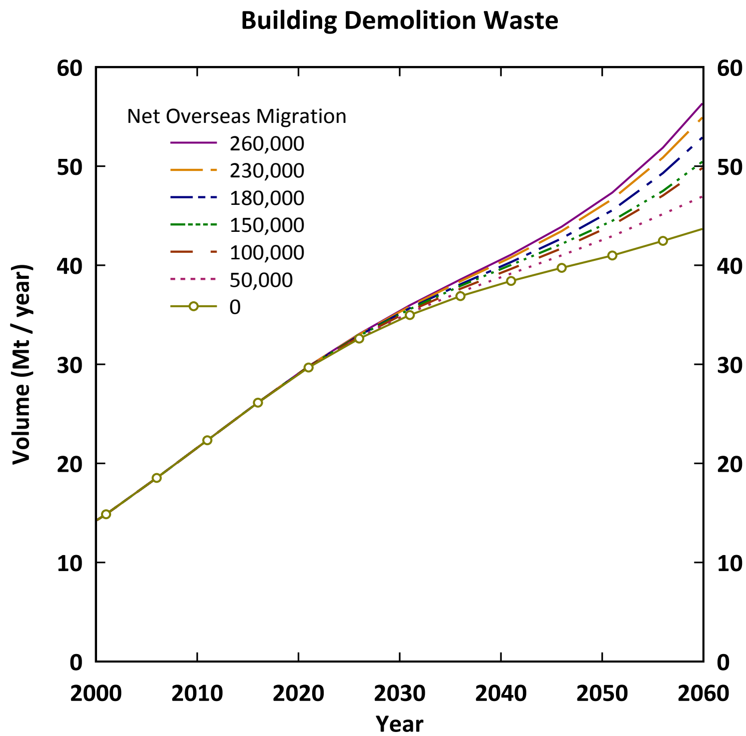


Figure F22. Growth of capital cities relative to the area of their Statistical Division.



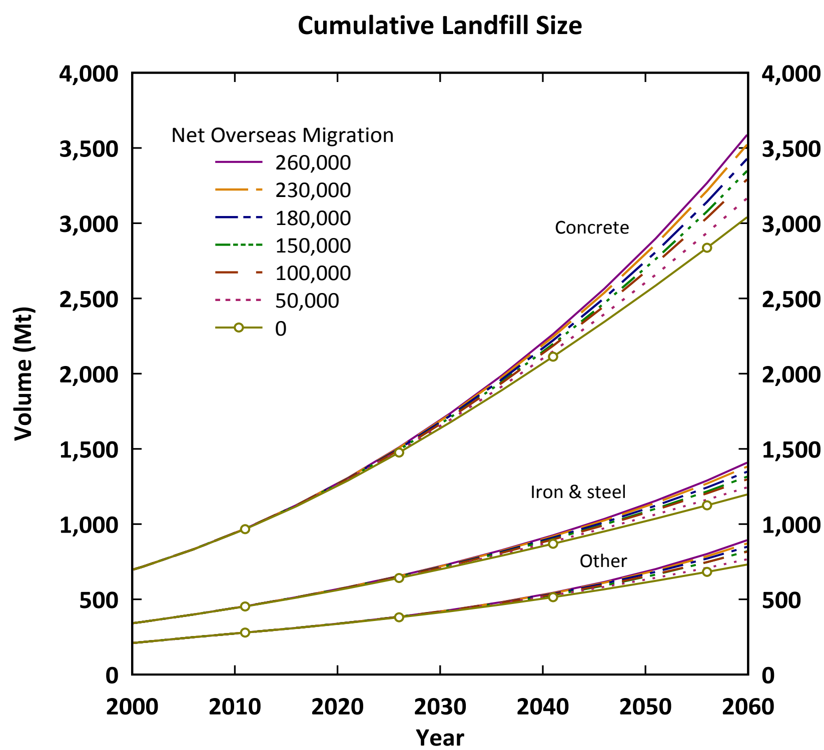


Figure F23. Volume of waste produced annually from building demolition (left), and the cumulative amount of waste in landfill (right, which excludes the recycled waste stream).

Key Research Question 3:

What key considerations, concerns and constraints should the proposed long term immigration planning framework take into account in terms of the interactions between NOM and the optimal development and sustainability of Australia's Natural and Built Physical Environment?

Introduction

The next section of the report surveyed publicly available material to discover what, if any, were the relationships between where migrants settled and their impact on the natural and built assets of those locations. Curran and de Sherbinin (2004) cited Walsh et al (1999) who found that *the more local the social and spatial scale the more likely they are to find population and environment links.* By implication it is harder to establish such links at increasing scales of data. The Engineers Australia Submission to the Productivity Commission on the Economic Impacts of Migration and Population Growth (2005) compared three economic models[14]. The paper made two important distinctions. First, that existing macro-economic models are not well suited to long term forecasting because of their incapacity to account for the scale effects of large changes in population on their models. And second, that a complementary approach to econometric modelling is required to explore the implications of mitigation and adaptation policy responses to climate change – water and food security, and a low-carbon future – energy security and liveability in Australia.

A set of natural and built physical assets were reviewed, i.e. Land Use and Food Supply, Water Supply, Water Quality, Air Pollution, Traffic Congestion and Transport Infrastructure, Energy Supply and Consumption, Greenhouse Gas Emissions, Waste Assimilation and Biodiversity. We reviewed these assets for Sydney, in particular Western Sydney with its high proportion of migrant settlement, Melbourne and, to a lesser extent, Perth.

Land and food

Sydney

A summary statement by the Metropolitan Strategy 2005 (NSW Dept of Planning) about the current state of Sydney's consumption of water and energy, production of air pollutants, waste streams and greenhouse gases, and the use of transport went as follows:

- Water consumption is increasing, and Sydneysiders are using more water than our dams can sustainably supply.
- Energy consumption is increasing (by 2.8 per cent per annum over recent years) with increases in peak electricity demands resulting in high costs to maintain and govern the NSW electricity network.
- Australia has the highest per capita greenhouse gas emission rate of any developed nation, with each person in Sydney creating 27.2 tonnes of carbon dioxide each

[14] Econtech Pty Ltd, Access Economics Pty Ltd. and Productivity Commission

year. Australian emissions are almost 30 per cent higher than American and 50 per cent higher than the average figure for industrialised countries.

- People in Sydney are travelling further and more often in their cars with VKT (vehicle kilometres travelled) increasing at double the population rate.
- Sydney disposes 1.1 tonnes of waste per person to landfill each year. This makes us per capita one of the world's worst generators of waste, ranking the second highest of OECD countries.

In 2005 these statements suggested a city which was not coping with the consumptive behaviour of its existing population let alone what the future might hold from certain population increase. The Strategy goes on:

- Even if we have zero population growth over that time, (i.e. our births and migration equal deaths) we would still require 190,000 new homes in Sydney to respond to demographic changes where fewer people are living in each home.
- Demographic forces independent of population growth are therefore driving increased consumption of natural assets of land and air and water, as well as the natural assets required to provide building materials, appliances and motor vehicles, and provision of services. Even if an attempt was made to re-direct 50% of new arrivals away from Sydney over the next 25 years to the 19 regional and coastal centres in NSW, this would 'only put back Sydney's growth by six years'.

In order to cope with an anticipated extra one million or more people in 25 years the NSW Dept of Planning estimates that it will require '640,000 new homes, 500,000 more jobs, 7,500 hectares of extra industrial land, and 10.5 million square metres of additional commercial and retail floor space'. Approximately another two and a half million more people are expected to live in Sydney in the following 20 years to 2056 (ABS 2009), due in large part to net overseas migration.

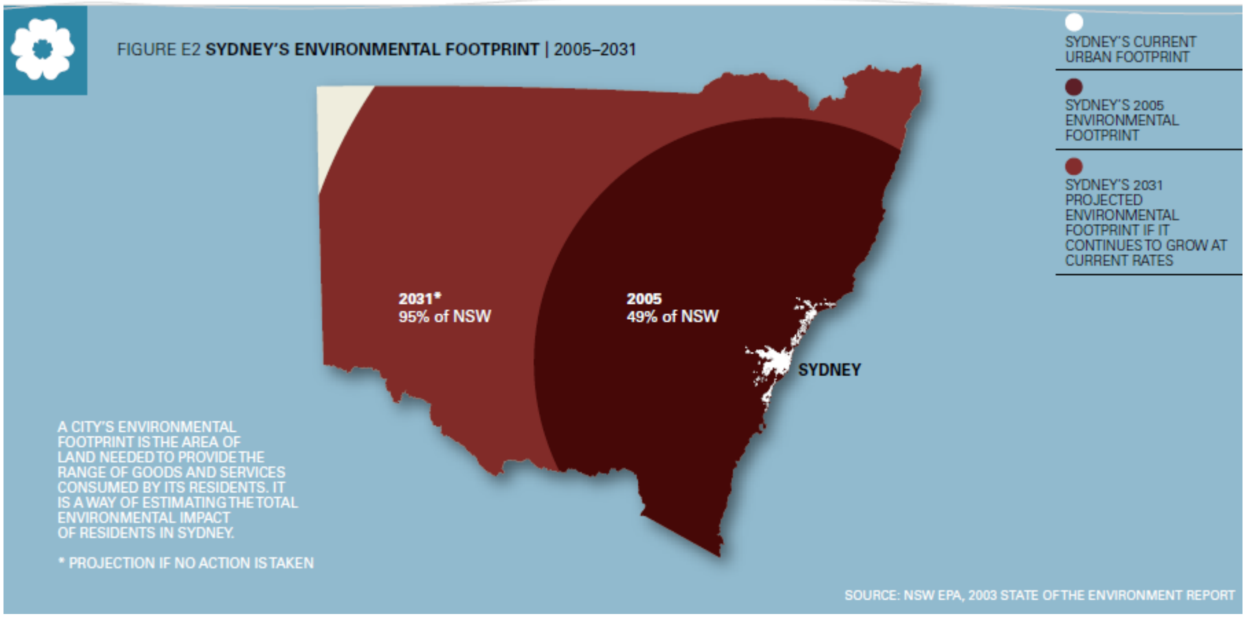
Figure G1: Sydney's 'Green' landscape

Source: http://www.metrostrategy.nsw.gov.au/dev/uploads/paper/introduction/index.html

Sydney's remnant, patchwork of native vegetation within and adjacent to the metropolis is represented in Figure G1. What Sydney-siders consume in terms of actual land required according to supply the current population, known as an environmental footprint, as represented in Figure G2. It also predicts what this same calculation might look like in 20 years time, in 2031.

Essentially, Figure G2 tells us that Sydney requires substantial intrastate, interstate and international trade now to survive. This means that Sydney must invest to ensure it has an infrastructure in the future that provides efficient access for equitable distribution of goods and services, especially food and water. Of note is the fast emerging international issue of food security. It is not an isolated episode somewhere overseas but also occurs in Australia. As a community we would be wise to ensure that all Australians have access to sufficient food. For example, in 2003 a report from the NSW Chief Health Officer indicated that "6.1% of people in NSW reported that they had experienced food insecurity in the last 12 months, in that they had run out of food and could not afford to buy more" (New South Wales Chief Health Officer 2004, p.2).

Figure G2: Sydney's environmental footprint



Source: NSW Dept of Planning 2005

By 2008 the situation was a little better but still an average of 5.1% across ages and gender (NSW Department of Health, 2008). The term food security refers to the ability of all people to regularly access healthy, affordable, culturally appropriate and safe food without the use of emergency food relief. Food security is achieved when there is adequate food supply in the community and households have the necessary resources to acquire and use that food (New South Wales Chief Health Officer 2004 cited in NSW Dept of Health 2008).

The Metropolitan Plan (2007) makes the point that the 'Beautiful waterways and clean beaches are central to maintaining Sydney's enviable lifestyle'. We must be cognisant that a substantial proportion of Sydney's water supply comes from the Hawkesbury–Nepean system. About one million people currently live in this catchment as part of the western, north-western, and south-western suburbs of Sydney. A large concentration of overseas migrants settle in Sydney's western suburbs. Without wishing to second guess the government author's intentions, perhaps it is more to the point that the 'Plan highlights the substantial proportion of the livelihoods of the people of western Sydney which are derived from (a healthy) Hawkesbury–Nepean River. The estimate was that 70 % of the goods and services produced in NSW are dependent on this river system, including:

> … the second largest commercial coastal fishery of prawns, oysters and fish in NSW, with a wholesale value of $6.3 million annually … [and] … tourist expenditure valued at around $1 billion annually.

Indeed, fishing is an example of the role of trade, where NSW imports 75% of its seafood yet the nation exports 50,000 tonnes of high value seafood. However by 2056 national demand could be as high as 630,000 tonnes, a 60% increase on current consumption which already relies on imports for 51% of our total consumption.

The following quotations from a story by Debra Jopson (Sydney Morning Herald, October 22 2009) from a seminar on food security organised by the NSW Dept. of Industry and Investment suggest how insecure our access to seafood may become:

> Australia should not rely so heavily on imports and wild catch and make farming fish a stronger policy priority, Dr Allan said. We are eating hoki, hake, Nile perch, catfish and snapper from elsewhere as the nation exports 50,000 tonnes of "high-value" seafood annually.
> "The sad thing about that is we are very vulnerable to price changes and other trends in other countries," he said at the seminar, organised by the NSW Department of Industry and Investment to chew over how secure we can feel about our food supply. Almost one-third of the world's fisheries are in collapse, but the globe needs to double the ocean harvest to keep up with food demand, Julian Cribb, Adjunct Professor of science communication at the University of Technology, Sydney, told the seminar.

Existing agricultural production within the Sydney Basin contributes about one billion dollars to the farmers and $4.5 billion in multiplier effects to the State economy (Gillespie & Mason 2003 as cited in Sydney Food Fairness Alliance and Food Fairness Illawarra, Version 1: December 2006). This represents about 12% farm gate value of NSW primary production from 1% of its land area. The State Metropolitan Plan notes that:

> There are approximately 13,000 people employed in the agricultural, forestry, fishing and mining industry in the Sydney region; … at least 8,000 full time on farm jobs in the Sydney region; …[and] … The value of mineral production in the Sydney region for 2003–04 is estimated at over $1.2 billion.

The 'Plan also notes that there are serious conflicts arising in competing land uses:

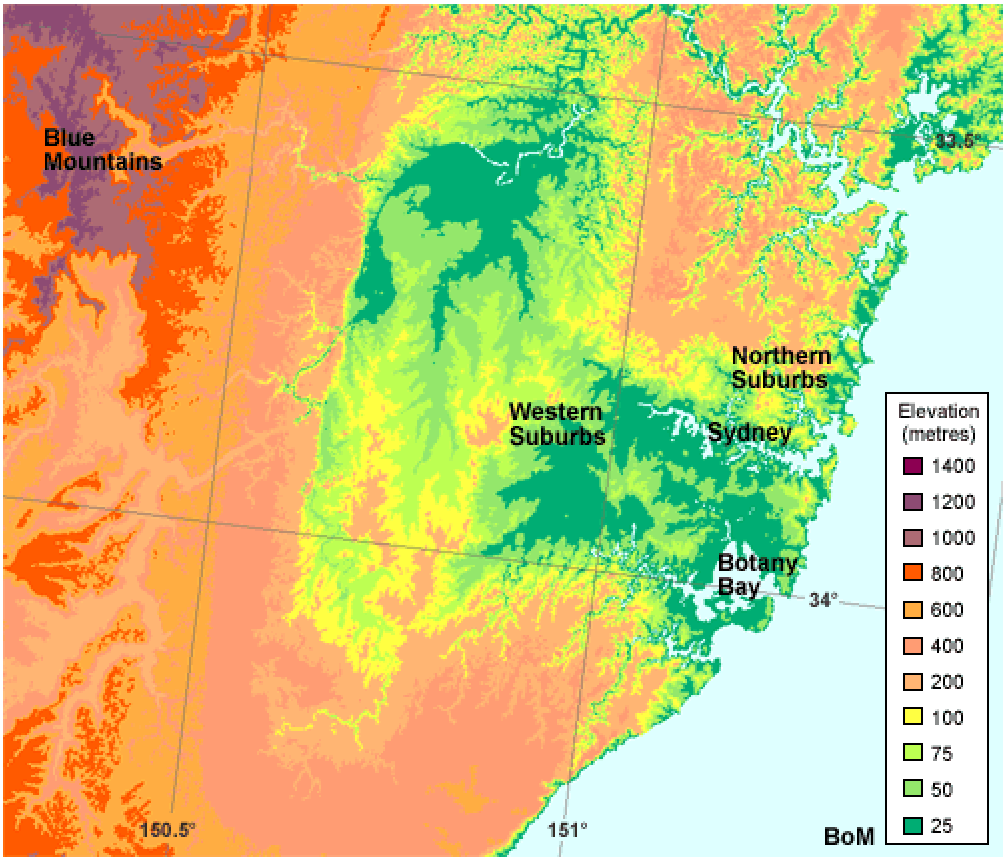
> … Uncertainty about future land uses, like agricultural activities, has led to land speculation in rural areas, raising land values and investment uncertainty. …Subdivision of rural and resource land has led to land use conflicts.

In quotations from news stories accompanying the text are examples of the conflict and issues raised by the Sydney Metropolitan Plan in terms of natural asset use and the looming impact of population growth. Essentially there is one group who represent the farmers, principally the vegetable growers in the Sydney basin, who provide access for consumers to safe, nutritious and affordable fresh produce at low cost. Such a food supply adds to the well-being of a community. By comparison, other stakeholders including developers responding to calls for more land to be released have a - not unexpected – different perspective. '*Grow suburbs, not vegies'* was one headline. The growth and development people look to technology to offer an alternative, for example, in the application of capital-intensive computer-controlled glasshouses using hydroponics technology and large transport hubs to organise food distribution by road to Sydney from production beyond the Sydney Basin.

The impact of new suburbs on immigrants and peri-urban food production

The impact of increasing urbanisation in the Western Sydney Basin ranges across three competing land uses: a) 'urban uses such as residential, open space, employment and transport lands; b) primary industries; and c) land set aside for conservation such as flood plains, biodiversity conservation reserves, scenic landscapes and national parks' (NSW Dept of Planning 2005).

Figure G3: The Sydney 'Basin': How sprawl is limited by topography



Increasing urbanisation of land for primary industry appears to affect migrant settlers disproportionately. James (2008) reported that:

> [Approximately] 80% of market gardeners in the Sydney Basin are from non-English-speaking backgrounds (NESB), and this area is no exception, with farmers from Chinese, Lebanese, Italian, Maltese, Vietnamese and Cambodian backgrounds. The majority of these are first or second generation migrants with varying degrees of English who have used market gardening as a means to support their families and build a life for themselves in a new country.

Within the proposed population growth areas (see Figure G6) Parker (2006) found that of the 90% of the vegetable growers who produced 90% of Sydney's fresh vegetables, 40% had market gardens located in the designated urban growth areas with no apparent strategies for their relocation.

The peri-urban and urban farms are important for two reasons. One reason is economic value. Of the $1 billion farm gate production value, vegetables accounted for $250 million pa, poultry $278 million pa (both worth 40% of NSW production), and cut flowers $185 million pa. They are also involved in the turf industry. A second reason is settlement patterns. Parker (2006) goes on to describe the role of market gardens in the establishment of livelihoods by successive waves of immigrants. Each wave began cultivating particular crops of fresh vegetables with which they were familiar, for which their own communities were a captive market. They were able to establish a capital base working in factories, restaurants, driving taxis, etc. before working on farms and purchasing their own land. Motivation for this course of action includes 'being their own boss', avoiding or reacting to situations where language barriers were a problem in earning an income, and to avoid being on government social security. The latest wave of immigrants are Africans working as casual labourers.

Perhaps a third reason is also worth considering. Food security relies on a global system of interdependent financial and produce markets and transportation. Food security also relies upon a constant availability of food. So-called global cities have demonstrated that they are vulnerable to financial shocks. Failure of staple crops to supply world trade and the resultant rapid increase in price caused food riots in 2008. A city which relies substantially upon imported food will need to take steps in terms of risk management to ensure future supply.

A summary of the features and advantages of peri-urban farms in Sydney illustrated in Table G1 demonstrates the importance of this sector for immigrant settlement pathways and the added value provided to Sydney's economy and resilience to external shocks, be they financial or related to trade in food.

However, some of this argument has been made before:

> "The county is small in area and not particularly rich from the growing point of view, yet in 1947 it produced three quarters of the State's lettuces, half of the spinach, a third of the cabbages and a quarter of the beans; seventy percent of the State's poultry farms were in the county and more than eighteen percent of Sydney's milk came from the County; the preservation of the farms and market gardens therefore is of considerable importance for the well-being of Sydney as well as for the economy of the State". (Denis Winston, Sydney's Great Experiment – the Progress of Cumberland County Plan, **1957)** Source: Elton Consulting 2009.

In the fifty years since this statement, it appears that trade and food distribution systems have ensured that Sydney people were not affected by the steady urbanisation of the horticultural production of the Sydney Basin. The question to be asked is whether the threat to almost eliminate food production from the Sydney Basin will have an impact on the people of a larger Sydney. Perhaps the consequence is in the increased risk of failure as the food system becomes more vulnerable without a local source of supply. It also raises the question of the adaptation by migrants to settlement in Australia without the option of market gardening in Sydney.

Table G1: Sydney Basin Agriculture

The Sydney Basin provides...	The Sydney Basin contributes to...
90 per cent of Sydney's perishable vegetables	The security of Sydney and NSW's food supply
Almost 100 per cent of the state's Asian vegetables	A sustainable and healthy city
80 per cent of the fresh mushroom supply	A viable local economy
Most of Sydney's cherry tomatoes, snow peas, snake beans, Lebanese cucumbers, fresh tomatoes, spring onions, shallots	The economic and social livelihoods of farming communities and workers in agricultural processing and marketing
33 per cent of NSW's poultry production	The survival of small, often family-owned farms which are often more productive than large corporate farms (Food First)
	The maintenance of productive, natural resources

Productive small farms...	Sydney agricultural livelihoods...
Farm ownership: mostly family owned and operated (Parker 2004)	Sydney Basin agriculture is the largest industry in Western Sydney, employing around 12,000 people
Average size: 40ha, compared to 1454ha for the state (Sinclair 2004)	At least 30 per cent of the workforce come from culturally and linguistically diverse backgrounds, with around 90 per cent of those in the vegetable industry (Sinclair et al 2004)
Average return per hectare to Sydney Basin farmers: $5433 Average return for NSW: $136 per hectare (1997 ABS Agriculture, NSW Agriculture 2003, p1)	For every million dollars of agricultural output, 22 agricultural jobs and 65 additional jobs linked to the sector are created (Australian Farm Institute report, March 2005)

Source: Sydney Food Fairness Alliance, Newsletter 1: December 2006

The State Metropolitan Plan has defined the growth regions of the next 30 years in order to:

> provide certainty for other non–urban land uses and in turn provide incentives for local rural industries to reinvest in their businesses and infrastructure, keeping jobs in the area and minimising negative environmental impacts from ageing infrastructure.

I am not sure this aim allows for any flexibility in the way in which land use is re-allocated. There is growing awareness of the values associated with a more diverse urban landscape. Quotations from recent media articles make the point that urban expansion comes at a significant cost.

> The 603 hectares devoted to vegetables in the south-west and north-west growth areas, about 52 per cent of Sydney's farms, are likely to disappear, the researchers say. In addition, the area devoted to greenhouse vegetables could decline by as much as 60 per cent when these areas are developed… Some communities, such as the Cambodian growers who farm rented land, may have to disperse or cease production, they warn.

The Sydney turf industry has about 1800 hectares planted in grass for lawns and parks, an area similar to the land used for outdoor vegetable crops;

> Many of these turf farmers are ex-vegetable farmers who, if given the appropriate incentives, could easily switch back to growing vegetables, the report says (Debra Jopson SMH 12 October 2009).
>
> We should be consolidating in the centre of Sydney- we haven't exhausted that potential yet," he said. "We should be developing a sister Sydney somewhere near by which can take an increased population - where we can move some industry to it. We need to have market gardens and we need to have them close to the city; we should not be getting rid of those facilities (Olivia Collings Architecture & Design, 12th October 2009).

On the other hand the real estate developers have a substantial stake in the implementation of the State Metropolitan Plan growth areas.

Preserving the farms on Sydney's fringe in the name of agricultural self-sufficiency will cripple the city's growth, putting extra pressure on renters and home owners, a property developers' lobby group says.

> The costs of that are further restrictions on our supply of new housing. Sydney has already seen over the past 10 years what happens when you don't allow for adequate growth outward. Rents have gone up by 22 per cent in the past two years for three-bedroom houses, said Aaron Gadiel, chief executive officer of the Urban Taskforce.
> Some farmland is set to accommodate industrial centres providing employment, said Mr Gadiel. "Should we … deprive ourselves of housing and job creating industries to prop up an industry which is not economically viable? he asked. (Debra Jopson, SMH October 13, 2009

Finally, the State have gazetted the development of 5,280 ha in West Sydney as Parklands, in part, because of the higher indicative average temperatures of inland developed Sydney versus the coast will necessitate open green space to mediate the 'urban heat island' effect.

Figure G4: Urban encroachment

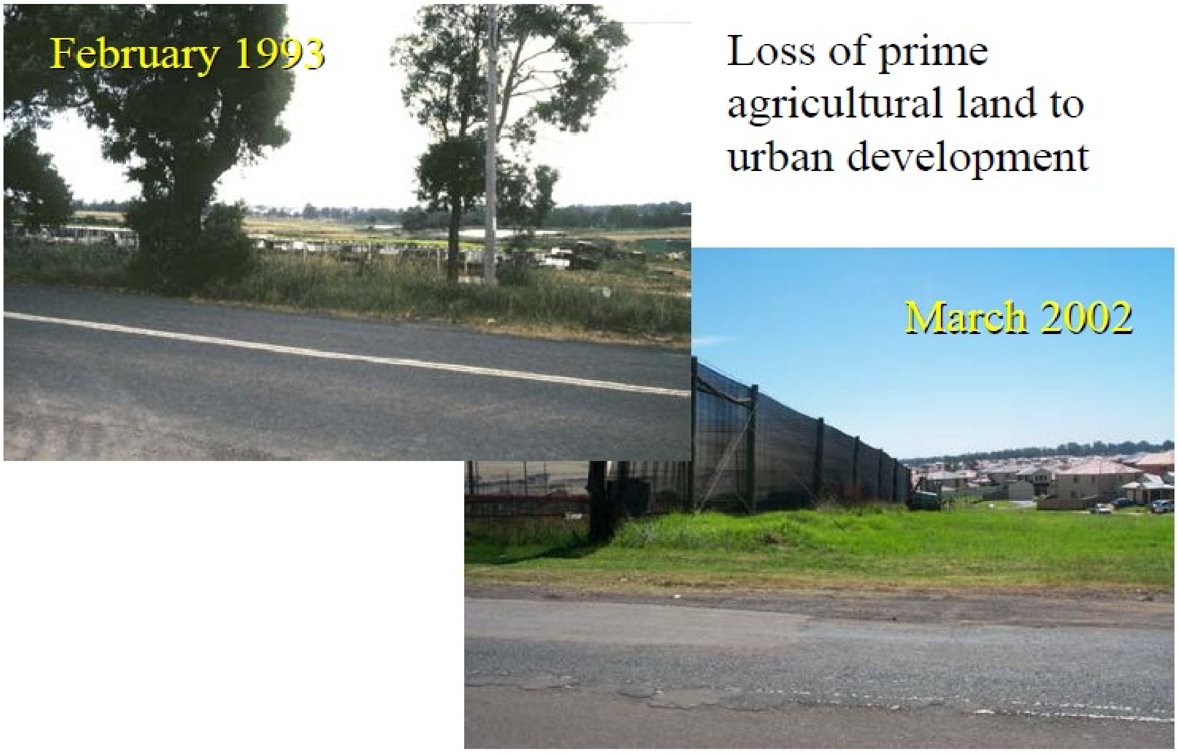


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Figure G5: Gravel mining replaces agriculture

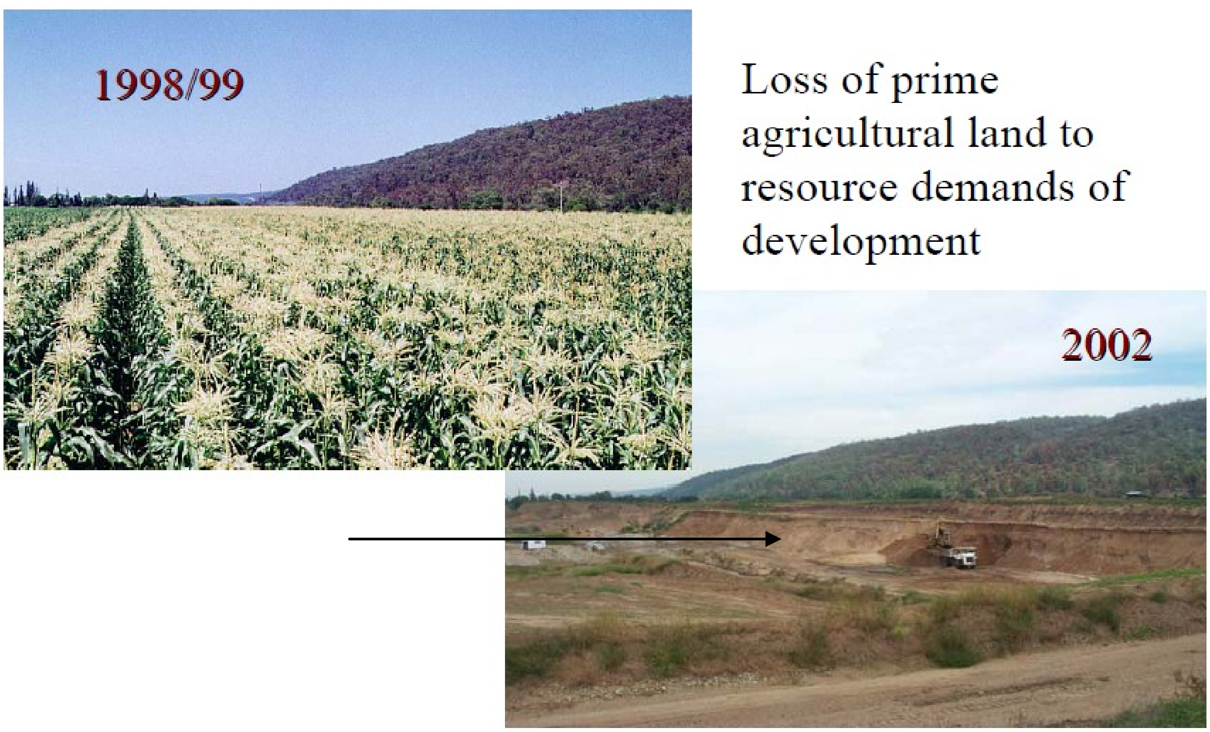
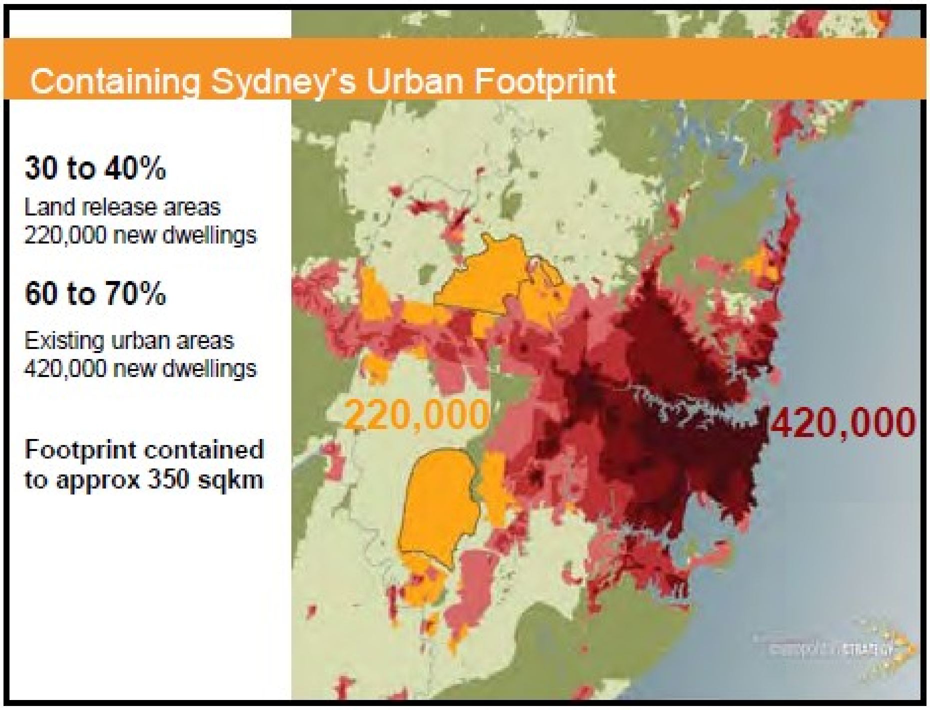
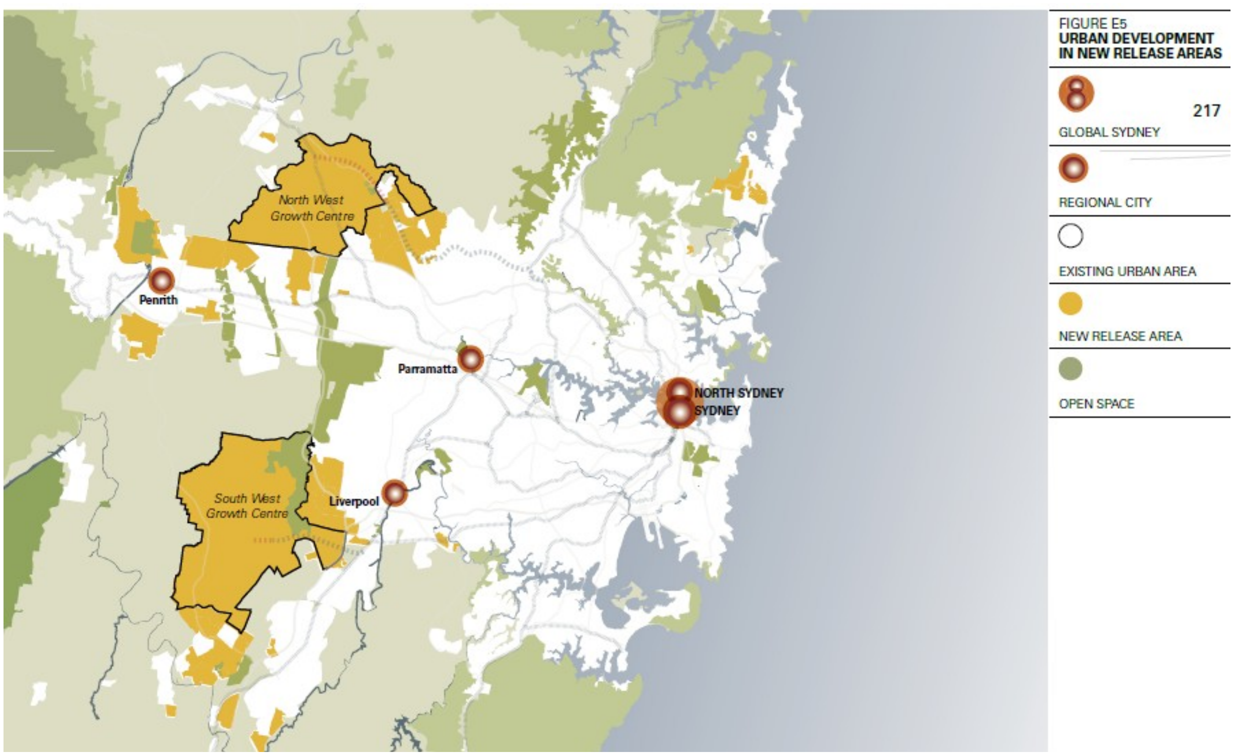


Figure G6: Containing Sydney's Urban Footprint



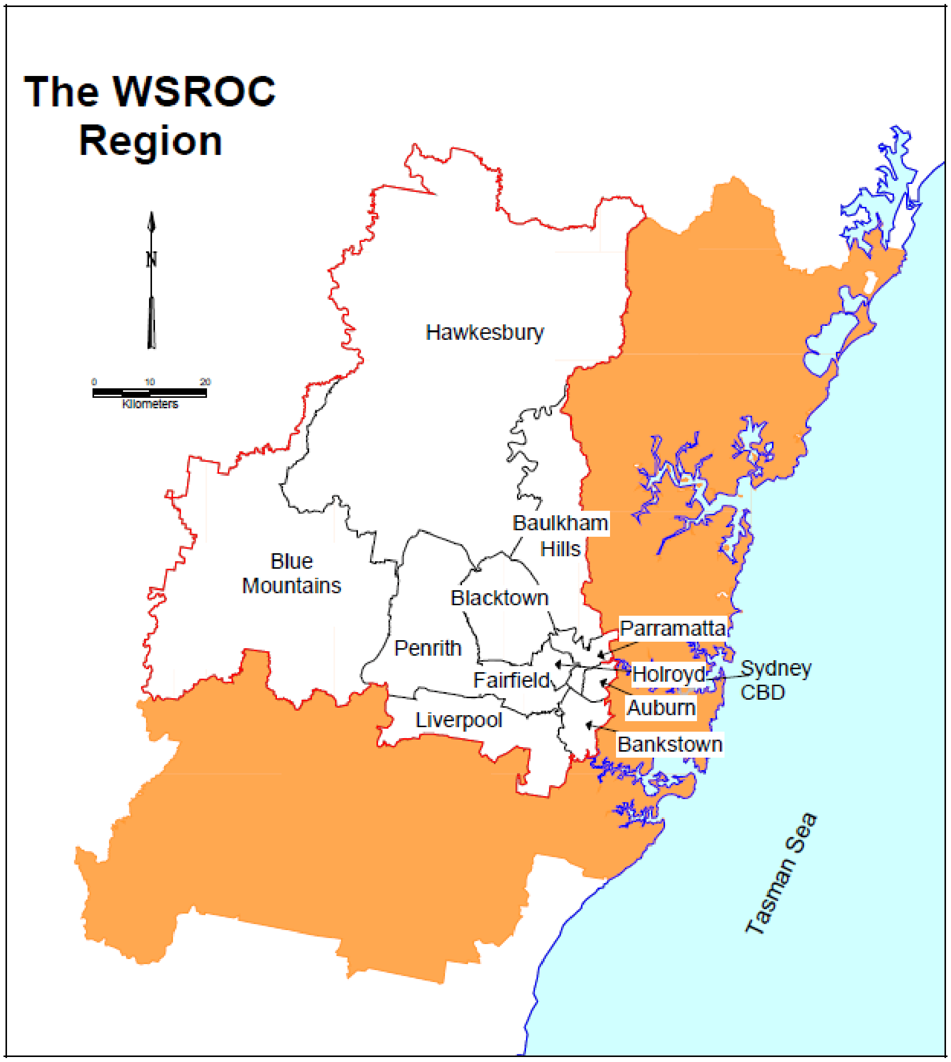
Source: Elton Consulting, 2009

Figure G7: Planned Growth Centres for Sydney



Source: NSW Dept of Planning 2005

Figure G8: WSROC LGA Members



References

Jopson, D. (22/10/2009) Here's the catch: we love seafood to death, *Sydney Morning Herald*.

Jopson, D. (13/10/2009) Grow suburbs, not vegies: developers, *Sydney Morning Herald*.

Jopson, D. (12/10/2009) Suburbs will swallow Sydney's market gardens, *Sydney Morning Herald*.

Jopson, D. (22/09/2009) Local food gobbled up by Sydney's urban sprawl, *Sydney Morning Herald*.

Elton Consulting, 2009. *Sydney's Agriculture Forum Final Report.* for the NSW Department of Primary Industry.

James, S. 2008. *Market gardens and McMansions*: *Contesting the concept of 'growth' on Sydney's peri-urban fringe* Online Proceedings of 'Sustaining Culture' (2008) Annual Conference of the Cultural Studies Association of Australia (CSAA) UniSA, Adelaide December 6-8, 2007. Accessed 09/11/2009 http://unisa.edu.au/com/csaa/onlineproceedings.htm

Knowd, I., Mason, D. and Docking, A. 2007. Urban Agriculture: The New Frontier, *City Structure* 23, pp. 1-22

NSW Department of Health 2008. New South Wales Population Health Survey 2008 (HOIST). Centre for Epidemiology and Research. Accessed 09/11/2009 http://www.health.nsw.gov.au/PublicHealth/surveys/hsa/08/i_food/i_food_bar.asp

NSW Department of Health, 2008. NSW Dept of Planning, 2007. *The Metropolitan Strategy: West Central Subregion.*. Government of New South Wales.

NSW Dept of Planning, 2005. *The Metropolitan Strategy*. Government of New South Wales

Olivia Collings 12/10/2009 McMansions no substitute for vegetables: architect, Architecture & Design http://www.architectureanddesign.com.au/article/McMansions-no-substitute-for-vegetables-architect/501736.aspx Accessed 12/10/09

Parker, F., 2007. *Making peri-urban farmers on the fringe matter*, State of Australian Cities Conference, Adelaide, November.

Parker F. and Jarecki S., 2003: *Transitions at the Rural/Urban Interface: "Moving In", Moving Out" and "Staying Put"*. State of Australian Cities Conference, Parramatta, Sydney Australia.

Paul Bibby 07/11/2009 Western Sydney faces water crisis, scientists warn, Sydney Morning Herald

Sinclair, I., Docking, A., Parker, F., Jarecki, S., and Saville, L., 2004. *From the Outside Looking In – the Future of Sydney's Rural Land Issues.* UWS: Sydney.

Sydney Food Fairness Alliance, 2008. *Public Submission to ACCC Grocery Inquiry*. SFFA.

Sydney Food Fairness Alliance, 2006. *Sydney Basin Agriculture: Local Food, Local Economy.* Newsletter # 1, SFFA.

WSROC, 2008. *Submission to the National Infrastructure Audit,* Western Sydney Regional Organisation of Councils Inc.

Melbourne

Melbourne's population could reach 5 million people by 2030 or earlier (DPCD 2008). Coupled with a trend to larger houses with fewer inhabitants in low density development means that pressures on land and vegetation, water, and biodiversity will increase from wastes, extraction of building materials, supply of energy, water, communications, transport, social amenities and consumption of goods. The metropolitan area of Melbourne doubled between 1971 and 2004 to around 210,000 hectares. Current expansion is taking place to the south east (Casey-Cardinia LGAs), north (Whittlesea, Hume), west (Melton-Caroline Springs) and south west (Wyndham). The associated formal urban growth boundary was extended in 2003, 1,610 ha added, and in 2005, 11,132 ha added.

The intent in the *Melbourne 2030* planning document of 2005 was to limit expansion to ensure that natural assets were maintained in so-called 'Green Wedges' on the urban fringe of the city. This was to prevent, for example, the significant loss in 2005 of native grasslands in the north west of the city due to urban development and a mis-match between LGA planning and native vegetation plans of the Port Phillip and Westernport (PPW) Catchment Management Authority (CMA).

The 'Green Wedges' arose in 1971 in a planning blueprint by the Board of Works under Sir Rupert Hamer when he was Minister for Local Government. The idea was to provide a home for "most of the areas of significant landscape, historic scientific interest, the major areas supporting significant bird, animal and plant life, the major agricultural resources and water catchments", as quoted by the Age newspaper article, June 9, 2009. So the idea of urban containment is not new. What is new is that the expanded Urban Growth Boundary (UGB) announced in 2005 has already been gazumped by an intention to release another 51, 393 ha of land for urban development, most beyond the existing UGB; and most within designated 'Green Wedge' areas. The Green Wedge areas cover about 650,000 ha.

The city requires approximately 628,000 new homes to cater for the sharp increase in population expected over the next 20 years and the new growth areas need to accommodate 47% or 284,000 of these (DPCD 2008). Originally, the UGB aimed to ensure that urban development of outer areas occurred around mixed-use activity centres (for jobs, transportation, community services, so less energy is consumed and greenhouse gases exhaled) that would account for 41% of new housing development, up from 24% in 2001.

On the face of it Melbourne has similar issues to Sydney of changing land use and the apparent primacy of urban expansion. Two particular sectors that could be adversely affected by the recent plans are the preservation of biodiversity (covered in a later section) and agricultural production, especially fresh produce.

Farm-gate pricing in 2001 valued the gross food production from around Melbourne at $890 million using ABS Australian average prices, which underestimated the actual value of production by a possible factor of 2 (DPI 2008). However, the true value of food to Melbourne is perhaps better measured by its role across nine industry sectors (ANZSIC classification): agriculture, manufacturing, electricity, gas and water, wholesale distribution, retail sales, accommodation, cafes and restaurants, transport, property and business and health and community. In March 2009 the Victorian Local Governance Association (VLGA) released the SGS Economics and Planning Pty. Ltd. (SGS) report 'Economic Significance of the Food Sector'. Using a 'Satellite Accounting Method' available within the National Accounts Framework and a range of ABS data sources SGS calculated that in 2007-08 the Food Sector in Melbourne represented 12.3% Gross Value-Added to Melbourne's economy or $21.2 billion and employed 210,000 people. Ten years ago (1998-99) the Food Sector in Melbourne accounted for 13.5% of Melbourne's Gross value added. The lower recent value is attributed to '*a steady decline in agricultural production within the [Melbourne Statistical District] MSD. This is related to agricultural land being converted to residential or employment land*' (VLGA, 2008, p.7).

Figure G9: Melbourne 'Green Wedges'

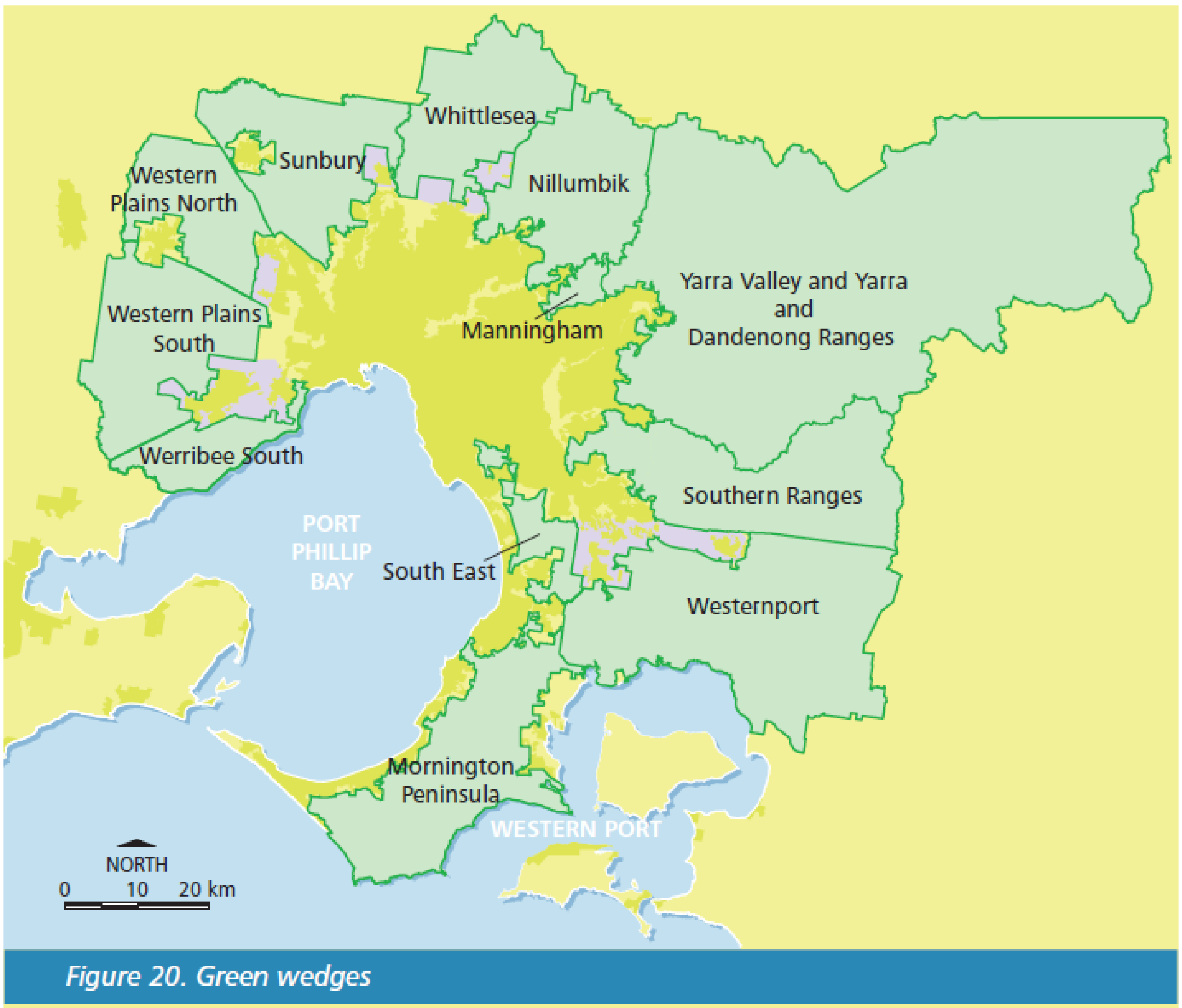


Figure 20. Green wedges

In October 2009 the VLGA report 'Integrating Land Use Planning and Community Food Security' (funded by VicHealth) discussed the issue of food insecurity from the perspective of the steady decline of agricultural production close to Melbourne. The study sought to link the loss of peri-urban agricultural production with food security, land use planning, health and jobs. Its outcomes included:

1. A heightened awareness and understanding of the links between land use planning and community food security and the potential for a more integrated approach is needed.

2. A heightened awareness and understanding in the community at all levels and sectors [is needed] that food in all its dimensions, health, land use planning and jobs are linked and that a continuing failure to make that link is a recurring cost to government, communities, families and individuals...

3. A greater realisation is needed at the state level that concerted action is required to address and own a suite of issues around community food security that can also be linked to the continuing action of local governments.

Among its recommendations were:

1. A state government department needs to be assigned responsibility for community food security. A unit needs to be established within that department to provide a focus for research, policy and a suite of programs to address community food security and to liaise with other relevant departments, agencies and local governments to document the relationships between food, health, land use planning and jobs.

2 That the State's land use planning system be amended to include:

- Increased focus on health and community food security, primarily through amendments to the Planning and Environment Act so as to specifically include health outcomes in the objectives. This would be facilitated if the reference to objectives Response Paper prepared by the Department of Planning and Community Development is taken through to legislative changes. There is concern in some quarters that 'food security' is not explicitly referred to and that the reference to health is ambiguous.

- Additions in the State Planning Policy Framework (SPPF) so as to link the retention of productive agricultural land to community food security.

- Requirements that the SPPF the design of urban areas require the retention of productive agricultural land, and specifically support the provision of local food systems and supplies.

- A new zone be introduced in the Victoria Planning Provisions that specifically provides for urban agriculture (VLGA 2009).

It is worth noting at this juncture that biodiversity legislation is far more prescriptive in relation to (urban) development and regulation than food production appears to be.

Melbourne reflects the Sydney experience that there are also people who go hungry. One example from an LGA in Melbourne that was home to a substantial proportion of NOM - the City of Moreland - found from its Household Food Security Survey conducted in 2007 (Merri 2009) that 7.8% - 10,500 people - had run out of food at some time in the last year. The study did not interview or count dependents, so the total of people who went hungry could be potentially doubled. The Victorian average was 6%. Moreland residents are a diverse group; 28% are from non-English speaking backgrounds in a total of 32% born overseas. The LGA was assessed as a region of significant socio-economic disadvantage with high unemployment, limited education and skills attainment, low incomes, poor English and a large population of elderly people (Merri 2009). Food pricing, access to food, and the implications of poor diet conspire to reduce food security in the Moreland LGA. Increasing the population load in such an area already at medium density per hectare, without alternative food supply strategies would likely increase food insecurity and associated social problems. The drought and oil price rise were primary drivers of increased food prices of 5.7% between April 2007-08. Inflation was at 4.2%. However, fresh food staples such vegetables increased by 9.7% and milk by 11.6% (VLGA 2009). Given that there are a large number of vegetable growers located in or near the Melbourne urban areas, the Merri report suggested that:

> Localising the food system and reducing the environmental impact of food supply may help to stem the increase in food prices. Growing food in Moreland and establishing relationships with farmers in Victoria to provide food at the farm gate or to engage in farmer's markets are both options that could be investigated.

Figure G10 below shows where agriculture is currently situated near Melbourne. The two areas of high value agriculture at risk are Pakenham (Casey and Cardinia LGAs) in the south east and Werribee in the south west. The determination to expand suburbs onto agricultural land in Green Wedge areas was justified as follows (DPCD 2009):

> An important issue is the existing and potential high agricultural productivity of much of the land in this [Casey-Cardinia] Investigation Area. The presence of good soils, access to water and markets provides a competitive advantage for agricultural production, particularly high value market gardening. The agricultural and economic advantages of this relatively limited area must be weighed up against the advantages of extending urban development into this area.
> As indicated in Melbourne @ 5 million, there is demand for more developable land to manage Melbourne's outward growth. In the south-east the range of constraints are such that the land in this Investigation Area provides the most sustainable outcome for urban development; being relatively close to public transport, community services and jobs.
> On balance this review favours extending urban development into this Investigation Area because of the metropolitan-wide settlement advantages this brings…

In its conclusion the DPCD report includes the parameters: The preservation and provision of appropriate habitat linkage to support the Southern Brown bandicoot; [and] Landscape and cultural heritage values. It makes no mention of agriculture.

Once this area of Casey-Cardinia Green Wedge is built on, no further development is (currently) contemplated for the south-east of Melbourne. Instead, the focus will be on the northern and western areas of Melbourne. The Green Wedge area of interest is the retention of horticultural production along the Lerderberg River adjacent to expanding urban development in Bacchus Marsh on the outskirts of Melbourne to the north west.

Of relevance to the issue of water supply and what a drying weather pattern portends is the following news article from ABC News Online today, 8th February 2010.

Vegetable producers may be forced out of their livelihoods on the north-west outskirts of Melbourne due to an irrigation water shortage. The flow-on effects include but are not limited to unemployment, less reliable fresh food supply, business bankruptcies, movement of people to new locations, loss of skills from the region, loss of families and breakdown of social networks;

> Vegetable growers at Bacchus Marsh, north west of Melbourne, fear they will go broke if the State Government does not secure an emergency water supply.
> About 600 people are employed by the town's vegetable industry, which generates more than $100 million a year.
> The Moorabool Council met the Water Minister Tim Holding last week, in a bid to encourage the Government to help the irrigators.
> Lettuce farmer Andrew Closter says his water supply dried up at the weekend and his business will not survive much longer.
> "If you were to stop paying your home loan repayments, how long would the bank give you in your home before they told you to get out of their house," he asked.
> "To be in the position that we are as high yield high value growers you must spend a lot of money."

Figure G10: Significant agricultural resources

Figure 33. Significant agricultural resources

Source: Department of Infrastructure, Department of Natural Resources and Environment, 2001

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References

ABC News Online Today, 8th February 2010 http://www.abc.net.au/news/stories/2010/02/08/2813385.htm , Accessed 8th February 2010

Department of Infrastructure 2002 Melbourne 2030 Planning for Sustainable Growth Government of Victoria

DPCD (Department of Planning and Community Development), 2009. Delivering Melbourne's newest sustainable communities. Government of Victoria

DPCD, 2008. Planning for All of Melbourne: The Victorian Government 's Response to the Audit Expert Group's Report. Government of Victoria.

DPCD, 2008. Melbourne @ 5 Million. Government of Victoria

Department of Premier and Cabinet 2004 Beyond Five Million: The Victorian Government's Population Policy Government of Victoria.

Perth

The following is a brief overview of the 'undesirable trends' of the effects the people of Perth are having on their environment and comes from the Sustainable Environment information sheet of the '*Network city: community planning strategy for Perth and Peel*' published by the WA Planning Commission (WAPC) 2004:

- a winter rainfall decline in the southwest over the past 25 years of 15 to 20 per cent;
- an increase in eutrophication of the Swan- Canning Rivers, resulting in algal blooms in the lower reaches of these rivers;
- a loss of wetlands, estimated to be upwards of 80 per cent on the Swan Coastal Plain;
- a decline in fringing vegetation due to clearing for agriculture and urbanisation – in one survey from Gingin to Mandurah, it was estimated that 52 per cent of rivers and 66 per cent of the creeks have lost half their native foreshore vegetation;
- a loss of native bushland, with approximately 28 per cent remaining in the Perth metropolitan region;
- concerns about photochemical smog and particulate haze - ozone exceeds national environment protection measure values at times, while particulates can cause human health problems;

- wastewater leaving outfalls and entering the marine environment - the volume of this wastewater is predicted to treble by the year 2040;
- additional water resources needed for the growing population - an additional 120 million kilolitres is needed by 2010, and a further 110 million later (vs the current demand of 290 million); and,
- a need to reduce the amount of solid waste being disposed in Perth metropolitan landfills, as the total quantity will increase without due diligence - it was 2 735 191 tonnes in 2000, increasing from 1 362 797 tonnes in 1991.

This is a very similar picture to the environments of Sydney and Melbourne but there are important differences. In particular, there are differences in the nature of Perth's water supply, its recent transport infrastructure developments and its waste disposal options. It is also subject to a rather different economic framework that has severe negative effects on housing affordability in particular. Perth has the second highest proportion of Australian capital cities with people born overseas at 31.3% or 475,000 but the vast majority of whom (30%) are from the UK. The next four nations that contribute the most immigrants are New Zealand, Scotland, Malaysia and South Africa. These English speaking migrants are highly likely to rapidly adopt Australian norms of consumption and lifestyle.

(**Note**: Much of the material in this report that describes the natural and built assets of Perth comes from the publication *Boomtown: 2050* by Professor Richard Weller of the University of WA. It was published in 2009 and contains a substantial recent summary of many aspects of Perth's built and natural assets).

Perth has approximately 180,000 hectares of land available for urban development including land already zoned that might otherwise have been excluded under more recent guidelines due to its coverage of vegetation. The suburban area is over 100,000 ha spread along the coastal plain for 120 km between Gin Gin and Mandurah.

Food production is an important land use in the vicinity of the Perth metro area comprising 6% of the farmland in the South West region (see also Figure G11). The range of production by area occupied includes beef production (48%), wool (21%), grains and pulses (7.5%), dairy (5%), vegetables (1.5%), fruit (1.4%), grapes – wine and table (0.7%), nurseries, turf and cut flowers (0.6%), intensive meat (0.4%), honey (0.2%) and eggs (0.1%). According to Kininmonth (2000) cited in Weller 2009:

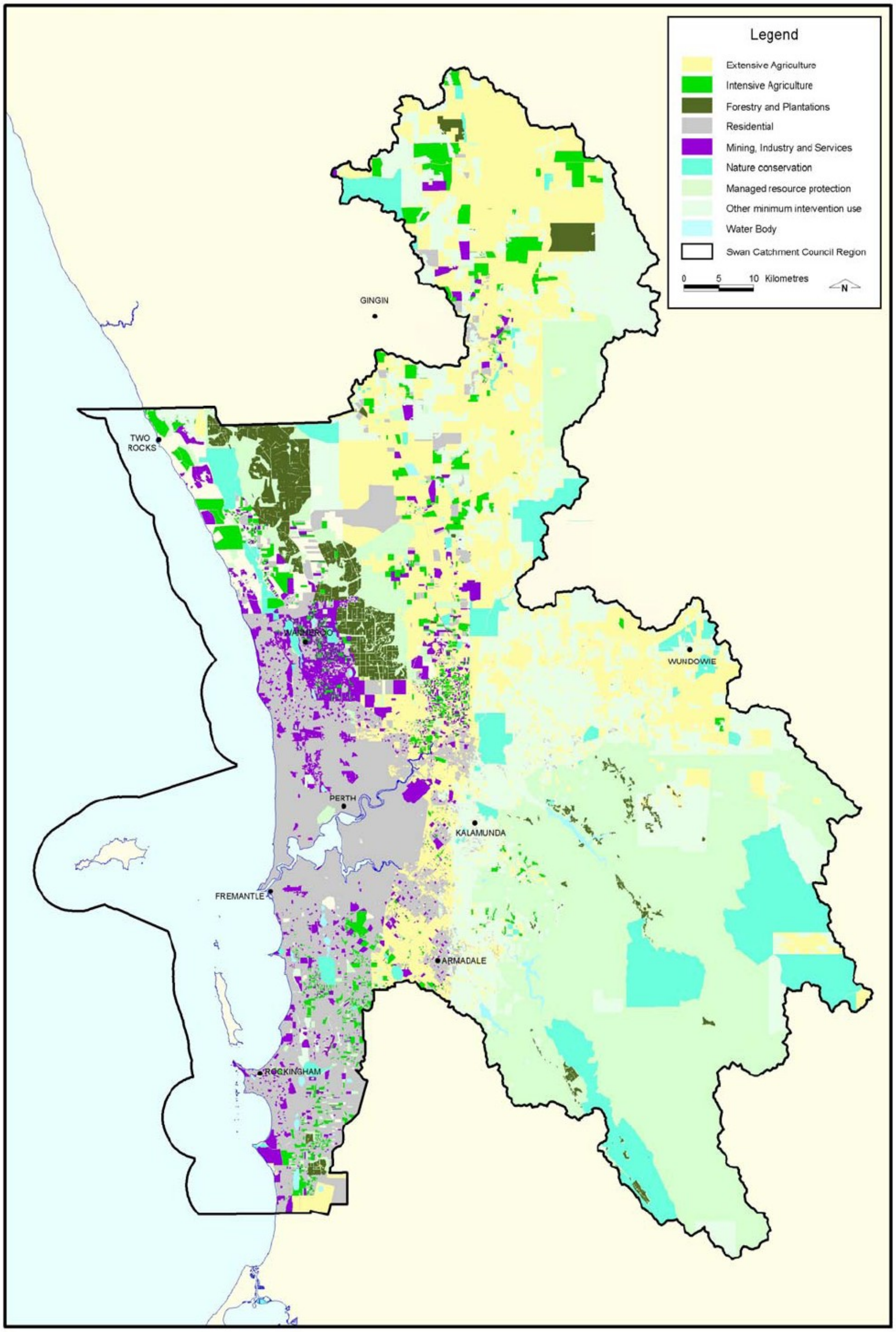
Land use planning processes have not considered the strategic importance of agricultural land in the Perth region and have tended to follow the market rationalist view driven by urban property development processes… New integrated approaches to land use planning for these areas should be investigated that have regard to the possibility of multiple land use objectives.

There appear to be large areas of land available for urban development that is cleared of its original vegetation and a change in land use will not be at the expense of biodiversity or other ecological services.

Table G2: Primary cause and effect of pressure on land as a natural resource asset (SoE 2007)

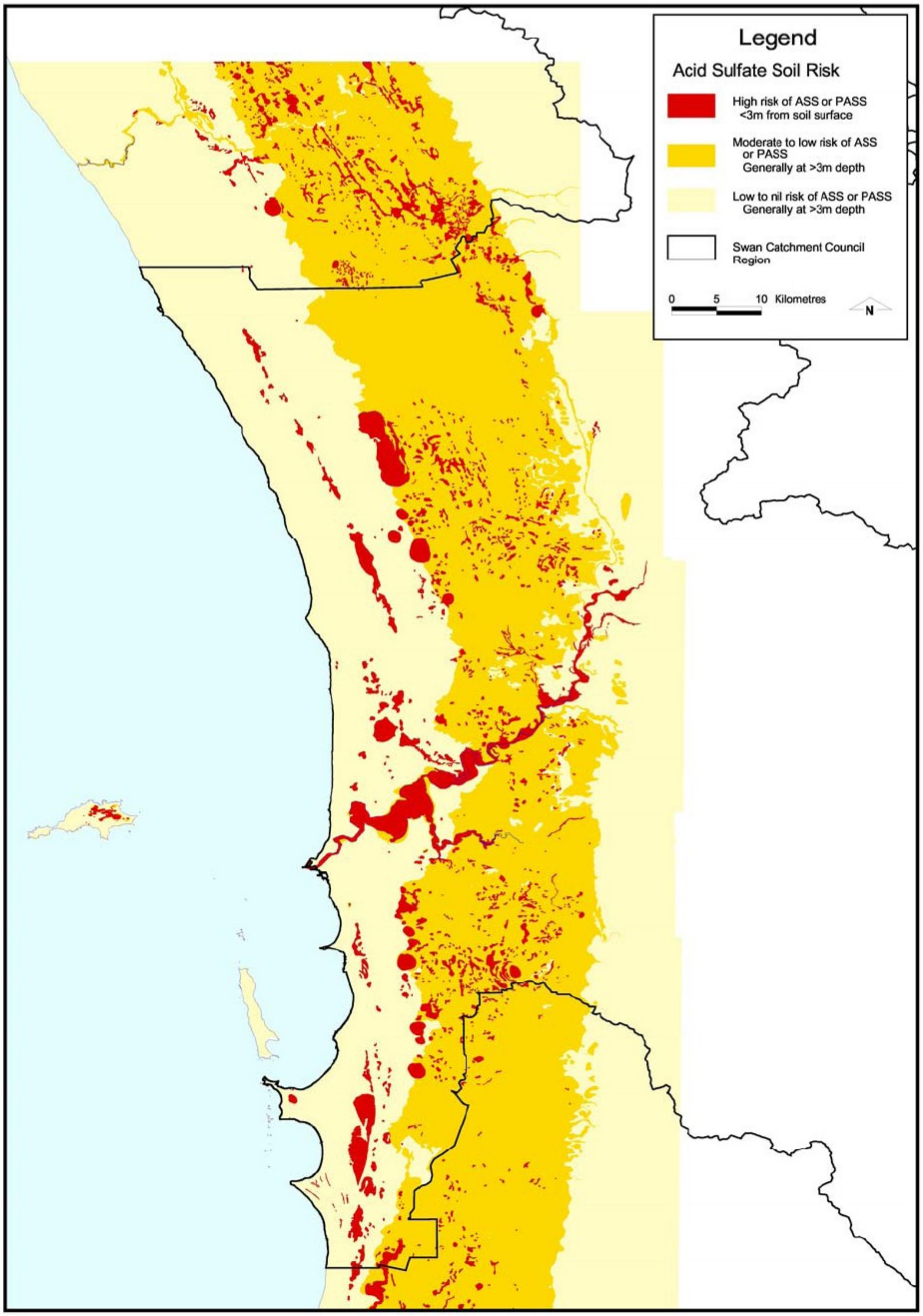
Cause	Effect
Increasing population and urban growth	Land use conflict and subsequent risk to asset base and landforms • pests and diseases • weeds • vegetation clearing • water use issues • nutrient export • salinity • acid sulphate soils • contaminants • drainage • erosion • hydrological change • drainage management and water sensitive design requirements • gross pollutants Fragmentation of natural resources and management leading to: • loss of connectivity between natural resources e.g. biodiversity corridors • loss of critical mass e.g. farmland, native vegetation/biodiversity • increased risk of conflict e.g. between agriculture and lifestyle uses • increased management costs ie due to more landholders/land managers • increased problems with biosecurity e.g. increased risk of exotic pests and diseases being introduced from urban areas
Incompatible land management practices	General environmental degradation • nutrient export • salinity • acid sulphate soils (Figure G12) • contaminants • drainage • erosion • hydrological change • pests and diseases • weeds • vegetation clearing • water use issues

Figure G11: Land use in the Perth Region, Swan Council catchment



Key: Grey – Urban; Olive – Forest (Pine); Purple – Mining Industry and services; Lime Green – Horticulture; Blue – Nature conservation; Yellow – Grazing, crops; Light Blue – Protected water catchment zone

Figure G12: Perth Region acid sulphate soil risk



References

EPA (Environment Protection Authority WA) 2007, *State of the Environment Report, 2007*. Government of Western Australia.

WAPC, (WA Planning Commission) 2004, *Network city: community planning strategy for Perth and Peel*. Government of Western Australia.

Weller, R. 2009, *Boomtown 2050*, UWAP: Crawley, WA.

Water supply

The following Table (G3) presents most graphically the near future scenario for total Australian water supply as a national compilation of the major urban centres, from the Water Services Association of Australia (WSAA) Position Paper No. 01, *Testing the Water*, October 2005 (Urban water in our growing cities: the risks, challenges, innovation and planning, p. 25). A shortfall of almost 1,200 GL per annum was forecast unless alternative water resource strategies were effectively implemented by 2030. This also assumed that the ABS ‘high’ population growth scenario was used in the assumptions. However, current population growth exceeds the 2008 ABS ‘high’ growth scenario.

The risks to adequate water supply for urban Australians perceived by WSAA include:

- Population increase generally but more particularly, the influence of Commonwealth net migration policies because of the regional concentration of NOM;
- Water catchments yield less water due to continuing or more frequent droughts;
- Increases may be required for environmental flows as suggested by scientists and agreed to by public decisions;
- Any new water assets will be subject to increasingly stringent environmental assessment, especially given that catchments are currently over-allocated;
- And the mechanisms to redress this imbalance are being hampered by interstate political rivalries;
- Desalination plants are likely to continue to be problematic given their high capital costs of construction, the high energy costs to run them, and the disposal options for the brine by-product;

Table G3: The urban water balance sheet

Table 7: The urban water balance sheet

	Population	Available Water	Consumption	Total
Current				
Population of Australian capital cities (plus Gold Coast and Lower Hunter region)	12.8 million			
Yield		2175 GL		
Unrestricted Consumption			2063 (GL)	
Existing surplus				**111 (GL)**
Future – 2030				
Population	17.3 million			
Yield (25% reduction to account for potential climate change impacts)		1631 GL		
Consumption based on 2004 per capita			2811 (GL)	
Water Deficit				**1180 GL**
Measures identified in urban water resource strategies				
New sources of water		684 GL		496 GL deficit
Alternative sources of water		195 GL		301 GL deficit
Water efficiency measures			- 326 GL	
Total		**2510 GL**	**2485 GL**	**25 GL**

Based on WSAA*facts* 2004

- Public confidence is low in piping recycled water from sewage treatment or stormwater aquifer storage into potable water supplies. It would only take a single incident of contamination to result in this option being abandoned;
- The complicated picture of factors affecting consumption means that there is a healthy risk of so-called 'bounce-back' or increased use of water by people who are increasingly affluent and for whom water is a small cost;
- Should rainfall return to longer-term averages (if they do in the next generation!) people might also feel that their water-saving behaviours need not be continued;
- The fact of population increase means substantial investment in new housing in greenfield sites which will increase consumption per capita and per household; and
- The demographic transition to fewer people per household also means that more dwellings will be required, increasing overall water demand. (WSAA 2005).

Water supply infrastructure is also tied directly to energy consumption, a relationship made obvious by the installation of desalination plants that demand large inputs of energy and which therefore produce large amounts of greenhouse emissions. However, a study commissioned by

WSAA and carried out by CSIRO in 2008 entitled 'Energy Use in the Provision and Consumption of Urban Water in Australia and New Zealand' found that:

> if the amount of energy consumed by households to heat water could be reduced by 20% either by using less hot water (by installing water efficient shower heads and changing to water efficient washing machines) or increasing the efficiency of the means by which the water is heated (gas instead of electricity or turning down the temperature by just a few degrees), the greenhouse gas footprint of the urban water industry could be completely eliminated.

Given that migrants tend to follow similar consumption patterns to Australian–born households, it follows that improvements in household energy use can have surprising outcomes that illustrate the interdependence of natural assets and the 'law of unintended consequences'.

Sydney

When Sydney's 11 dams are at 60% capacity they can supply Sydney's water needs for four years. By comparison with other international capitals, Tokyo has six weeks of zero-inflow supply and London, 10 weeks (NSW Dept of Water & Energy 2009). The key to understanding water supply for Sydney's growing population is the already variable rainfall pattern which is likely to become more volatile as average temperatures increase with global warming. The recent drought has forced the NSW Office of Water to bring forward plans to build a desalination plant which will supply about 15% of total potable water needs from late in 2009. A policy of *Dams, Recycling, Desalination and Water Efficiency* is now in place to mitigate the risk of failure of future rainfall in the dams' catchment areas and to cater for a population of over six million people by 2030 (Figure G17).

The Metropolitan Water Plan 2008 Progress Report (NSW Dept of Water & Energy 2009) suggests that *by using water wisely, whether it comes from rivers and dams, the desalination plant or from water recycling initiatives, Sydney will have enough water to meet the needs of its growing population*. The confidence in this assertion is derived from the historical fact that the city used the same total amount of water in 2008 as it did in the 1970s, during which time the population increased by 1.3 million people. The reduction in water use per person of 40% since 1991 was achieved through water efficiency measures and price increases (NSW Dept of Water & Energy 2009).

Recent research has focused on both consumptive practices and increasing the range of options to increase the supply of fresh water, among them the Independent Pricing and Regulatory Tribunal (IPART) in NSW and academic studies (Figures G13; Table G4).

IPART found that it was the household's (and associated factors) consumption rather than the individual per se that predicted water consumption. For example,

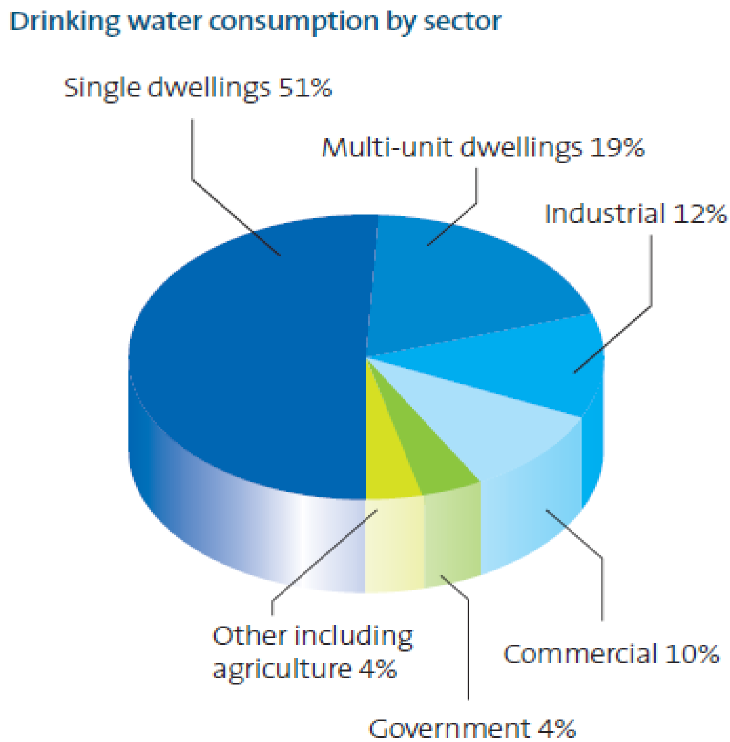
> on average, households in separate houses consumed most water: 304 kl per year compared with 211kl for those in semi-detached dwellings, 192kl for those in low rise flats, flats in a block of less than four storeys, and 148kl for those households in high rise flats, flats in a block of 4 or more storeys.

However, once the size of the households was taken into account IPART found that the type of occupancy – owned, mortgaged, rented privately or in public housing - became more informative, and: *the type of dwelling was not the most important factor in determining water consumption*.

A large study by Troy *et al.* (2001) examined consumption in approximately 25,000 households in a stratified random sample of 140 Census Districts (CDs) across Sydney. The households were selected on the basis of their type, geographical location and socio-economic status. Their results of per capita as opposed to per household consumption were very similar to the IPART study. Two key conclusions resulted: a) that tenants tend to use more water than owners on a per capita basis; and b) the higher the value of land, the higher consumption of water. But there was no straightforward relationship established between dwelling type and water consumption.

In terms of per household consumption of water the Troy *et al*. study found that, in 2001, separate houses used 310 kl per year, semi detached dwellings 235 kl per year and flats 195 kl per year, virtually identical if slightly higher than the IPART data from two years later. As water consumption is measured by the household rather than per capita, and the demographic trend is for more dwellings to house the same number of people because households are getting smaller, we may find that reducing water use, without further behavioural adoption or technical innovation, becomes stalled and may even increase in absolute terms as well as per household. There is a limit to which water conservation measures can be effective.

Figure G13: Sydney Drinking Water by Sector



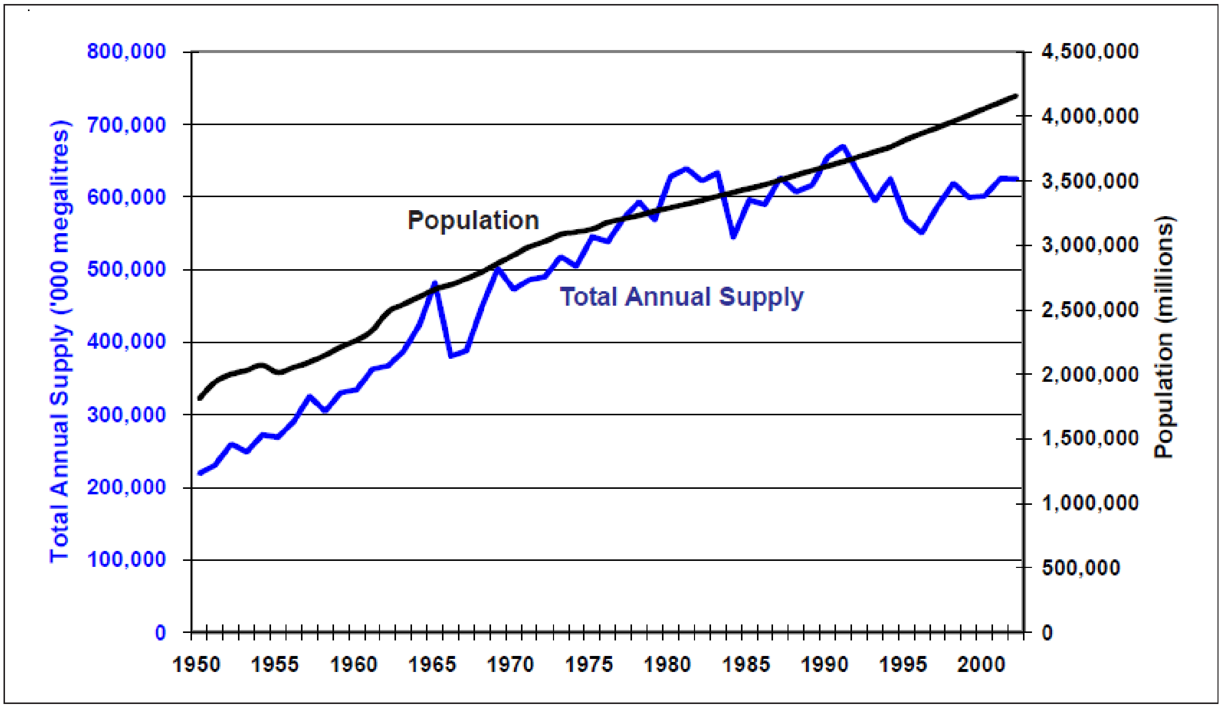
Source: NSW Dept. of Water and Energy 2009

Table G4: Per capita water consumption survey results

Survey (year)	Per capita Water Consumption, Sydney
IPART (2003)	92 kl
ABS (2004)	101 kl
Troy et al (2001)	98 kl
Eardley et al (2005)	71 kl

Unfortunately (or perhaps sensibly?) the Dept. of Water and Energy only projects supply and demand out to 2015, by which time recycling is expected to contribute 12% of annual water needs; desalination to contribute 15% (with plans in place to double capacity should that be needed); and water efficiency measures to save 24%, a total of 51% of anticipated demand supplied from alternative sources: Households consume around 70% of total water demand (see Figure G13).

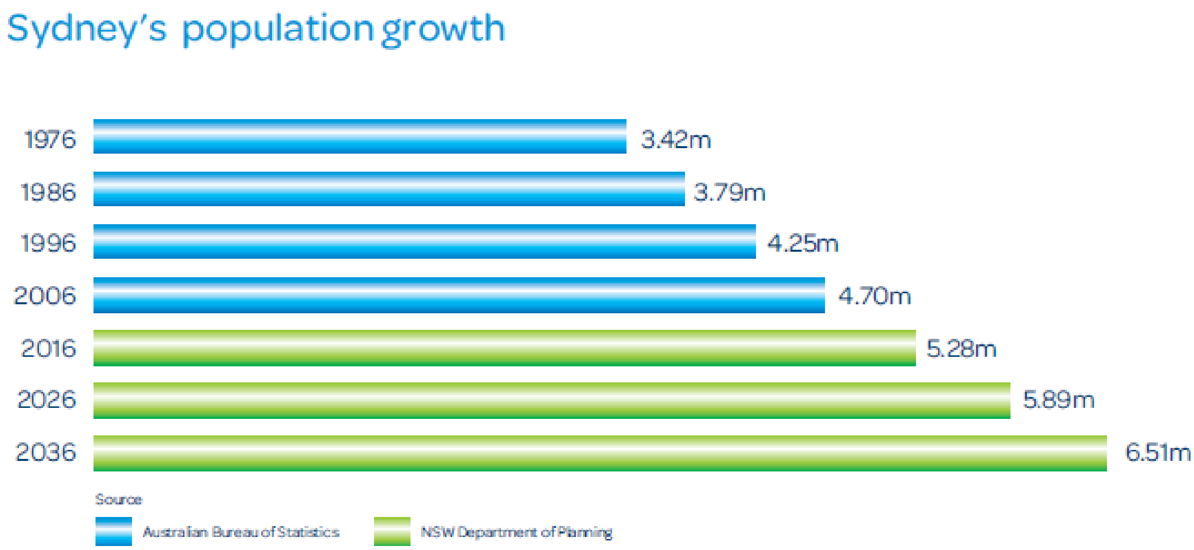
Figure G14: Sydney water supplied versus population increase



Source: WSAA 2005

What happens if the population projections beyond 2015 are considered? With alternative sources of water providing 51% of an estimated supply of 575 GL pa in 2015 and an estimated population of 5.28 million people in 2016 consuming 542 GL (2015 figure), the dams must supply 282 GL pa. (Figures G14, G15).

Figure G15: Sydney's Populations Growth



Source: Dept of Water & Energy 2009

If we assume that supply from dams is compromised by more frequent droughts and the increased evapotranspiration from higher temperatures caused by climate change, and that no further dams will be built (NSW Dept of Water & Energy, 2009); that the desalination capacity is doubled to 180 GL per annum by 2036; and that estimated consumption of ~103 GL per million people per annum is maintained pro rata as a basis for calculating the savings from recycling and water efficiency actions; then supply will just cover anticipated demand from population growth. Although the supply side of water is more diverse than at present there would appear to be a need for the desalination plant to be doubled in size sooner rather than later. Otherwise one is hoping for significantly better water use efficiencies through behavioural change and adoption of technology, but which, to repeat the assertion above about improving household use of water, will meet a finite limit (Table G5).

Table G5: Alternative Water Sources, Sydney to 2036

Year	Pop.	Estimated [1] Consumption	Water from Dams	Desalination[3]	Alternative Sources[2]	Total Est. Supply
2015/16	5.28m	542 GL	282 GL	90 GL	203 GL	575 GL
2026	5.89m	607 GL	282 GL	90 GL	219 GL	611 GL
2036	6.51m	671 GL	282 GL	180 GL	242 GL	704 GL

Notes:
1. *Estimated Consumption is calculated pro rata from 2016 population*
2. *Alternative Sources are calculated pro rata from 2015 estimates*
3. *Production of up to 250 million litres per day , doubling to 500 million litres per day*

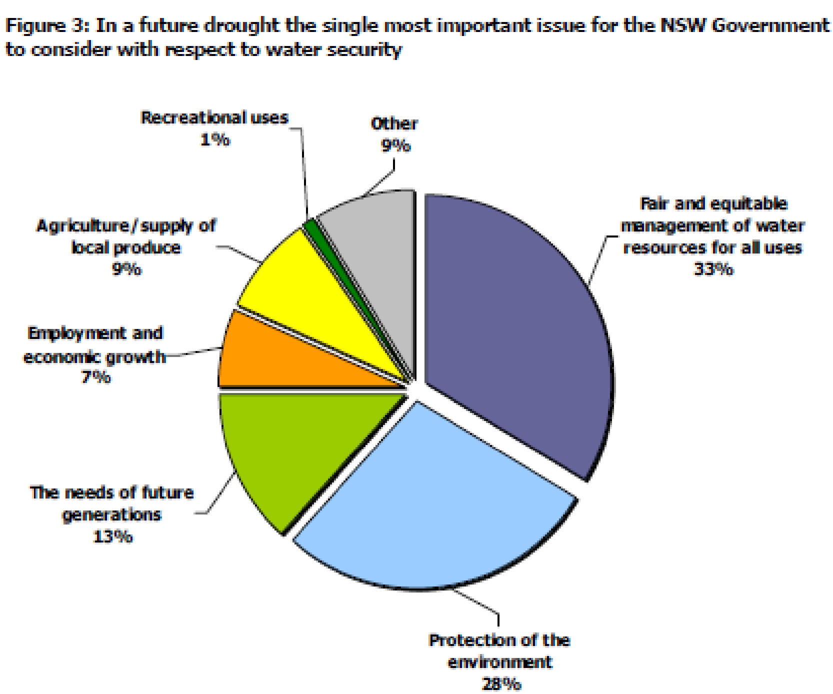
A review of the Metropolitan Water Plan conducted in 2009 by Elton Consulting focused on community feedback (see Figure G16). They found a high degree of correlation between different data sources regarding the preferences of residents for long-term water security in Sydney. The main priorities were summarised as: *Safe and dependable supply for residential needs; Needs of future generations considered; and Environments should receive sufficient water to stay healthy.* Importantly, the respondents desired to *balance these values without the need for significant trade-offs*. The respondents supported the need for collective action in using water more wisely as long as government was part of the mix, through leadership that supported water affordability especially for low income households (Elton 2009, p.2).

Therefore the Government and people of Sydney appear to be optimistic about the future reliability of supply of high quality water for consumption and maintenance/ improvement of riverine environments. They are also concerned about governance and equity of water resources, in the way that water will be allocated in the expectation of future severe droughts and significant increases in demand from population growth.

The Business Council of Australia in 2006 published a study that was also positive about the quantity of water that was available to satisfy all demand now and in the future, but for a lack of government action in infrastructure and markets (BCA 2006, p.i). However, most recent Dept of Water and Energy reports have commitments to remedy the perceived short-comings registered by the BCA report:

> Unavoidable water scarcity is one of Australia's great myths. This myth has enabled Governments to avoid or neglect practical solutions to the problem. Australia's water problems are a direct result of a poorly planned and managed water system that has conspired to turn a sufficient supply of water at the source to scarcity for end-users. Water management practices have turned sufficiency into scarcity… (BCA 2006, p.i)

Figure G16: Community attitudes to Government action on water security



Source: Elton Consulting 2009

Figure G17: Sydney's Drinking Water Catchments

Source: Sydney Catchment Authority

Western Sydney

The CRC for Irrigation Futures Western Sydney initiative - Water and Irrigation Strategy Enhancement through Regional Partnership in Western Sydney (WISER) - focuses on the peri-urban western region of Sydney along the South Creek catchment (Figure G18). This catchment is the focal region for the expansion of Sydney's population by about 220,000 new dwellings for around 500,000 people on 350 square kilometres, split into a pair of north-west and south-west areas (Table G7). The catchment itself is only 692 square kilometres across eight local councils; the areas designated for development will replace pasture and horticultural land uses. Development will place regional pressure on the water resources, ecosystems, rural production and environmental services currently provided. The development will substantially alter the hydrological balance of the catchment, especially because of the area of hard surfaces producing storm water runoff and pollution and preventing accession of rainfall to groundwater along the alluvial soils.

Coincidentally, this urban development is roughly equal to the inputs required to house the population growth that will occur even with zero immigration for the next 25 years, assuming that the net fertility rate remains at or around its current 2009 value of 1.9.

Media reports of the WISER study results suggest that there will be a serious regional impact on water ecosystems and land uses in western Sydney. The Government on the other hand rejects this assessment by: a) saying that the Water Plan projections took population and climate change into account; and b) that recycling schemes and water efficient devices will provide 12% and 24% of Sydney's water needs by 2015. In support of this contention that a combination of adoption of water efficient devices and water sensitive urban design will provide 36% of Sydney's water is data from Parramatta Council, which reported reduced consumption in 2008 of 5% to 25% in residential usage between 2005/ 06 to 2007/ 08. Interestingly this LGA contains a high proportion of migrants.

From the Sydney Morning Herald November 7 2009:

> But scientists working for the water strategy group WISER say there will be only just enough water for drinking and bathing, leaving little for the region's market gardens, playing fields, and the Hawkesbury-Nepean River system.
>
> This would have serious consequences for health and quality of life in the region, the scientists say, and the Government needs to reconsider the release of land for housing or dramatically increase water harvesting and recycling.
>
> "Having healthy rivers, locally grown food, useable playing fields - these things are vital to people's happiness and they must be part of the thinking when we make plans for Sydney's future," said Associate Professor Basant Maheshwari, from the University of Western Sydney's School of Natural Sciences. "One of the solutions is to draw back on the expansion into western Sydney and consider that people will have to live elsewhere."
>
> "In 2031 the population of the South Creek Catchment will be using 91 gigalitres of drinking quality water each year instead of 41 gigalitres as they are now, and 16 gigalitres of non-potable water instead of 12," Dr Maheshwari said.

"If you extrapolate that across the region, there will only be just enough available for general domestic use and very little for agriculture and other outdoor uses such as parks and playing fields."

There would be an increasing reliance on water from the Hawkesbury Nepean River which would suffer seriously as a result, Dr Maheshwari said.

"The Hawkesbury-Nepean is already suffering from serious degradation. The impact of 600,000 more people could create permanent damage to the ecosystem and limit any future use of the system." (Paul Bibby SMH, November 7, 2009

Table G6: Water Consumption in Parramatta LGA 2006 to 2008

Property Types	**Total Megalitres**		
	2005/06	**2006/07**	**2007/08**
Residential (in. single, dual occupancy dwellings, residential strata units)	11,611	11,759	11,168
Industrial	3,732	3,827	3,547
Commercial properties (inc. Clubs, Hotels, other commercial)	2,252	2,225	1,902
Miscellaneous Non-Residential (inc. non-residential developments, vacant land, standpipes)	736	626	466
Medical facilities (Public and Private Hospitals only)	512	627	618
Commercial services (inc. baby health centres, Libraries, Community Halls, amenity blocks, Aboriginal land, Guide and Scout Halls, Public Reserves)	389	416	370
Educational institutions (Public and Private)	142	160	139
Mixed development (Residential /Commercial)	110	122	148

Source: State of the City Report, 2009, p. 16

Figure G18: South Creek Catchment

Source: WISER 2009

Table G7: Increased population planned for South Creek Catchment

Year	Homes	People
2009	130,000 homes	400,000 people
2030	180,000 *new* homes	500,000 *more* people

Source: WISER 2009

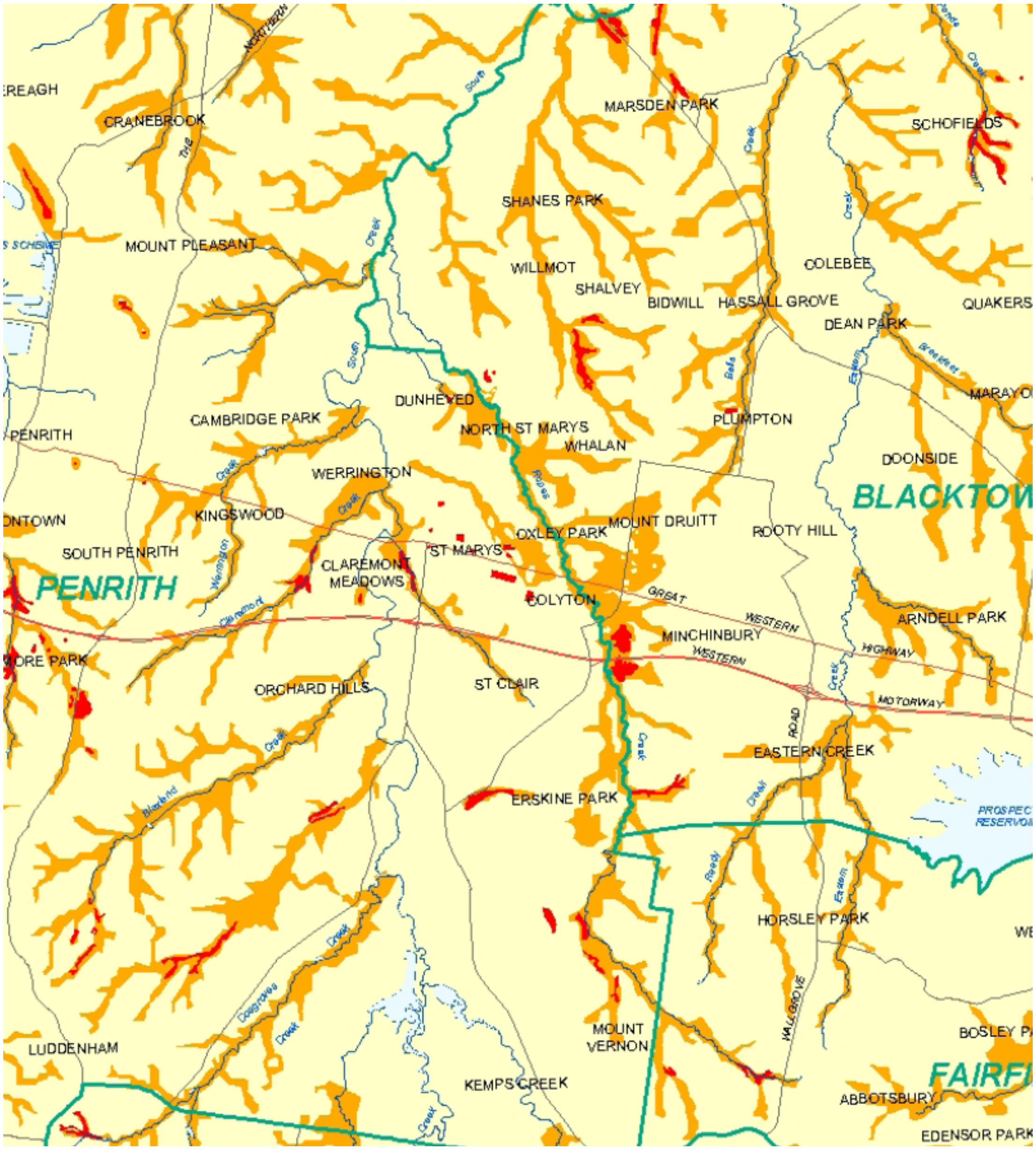
Salinity in Western Sydney

Of some concern to the urbanisation of Western Sydney is the presence of saline groundwater and geology in the South Creek Catchment (see Figures G18, G19; Table G7). The Wianamatta Shales and soils derived from there contain elevated levels of salts as the layers formed undersea. Some 5% (4200 ha) of the South Creek Catchment is affected and 20% (19,000 ha) is susceptible. Management plans are in place but as the fifth most important environmental issue of the region, salinity can be exacerbated by inappropriate buildings, roads, artificial lakes and storm water drains which increase local soil water logging and poor drainage.

Salt is a significant problem for water courses because it is easily mobilised by land use changes such as urban development. Salinity affects the quality of water resources for use in agriculture and urban and industrial applications. Salt is also a significant problem for the integrity of bricks, mortar and concrete; damp courses are a must and construction that interferes with groundwater drainage in the B-horizon especially increases the risks of salinity occurring. Often associated with soil salinity is sodicity, a condition of soil chemistry that means it erodes easily.

Again, removal of surface vegetation and disturbance of the B-horizon through construction can expose and erode these soils resulting in damage to infrastructure and poorer quality water.

Figure G19: Snapshot: Localities in part of the Northern Growth Area showing current (red) and potential (cacky orange) salinity



References

Paul Bibby, 2009 Sydney Morning Herald, November 7

Parramatta City Council 2008 State of the City Report, p. 16.Singh, R., Nawarathna, B., Simmons, B., Maheshwari, B. and Malano, H.M. 2009 Understanding the Water Cycle of the South Creek Catchment in Western Sydney, Technical Report 5/09, CRC Irrigation Futures

Melbourne

In the report by the Environment and Natural Resources Committee Inquiry, 2009 (ENRCI) *Melbourne's Future Water Supply*, is described as a 'once through system', meaning that once used, water is 'discarded'. Although annual water demand has come down from around 479 GL during the 1990s to 431 GL in the last decade during a period of population growth, water supply is still about 40% dependent on rainfall, after recycled water (14%), groundwater (2%) and the desalination plant at full capacity of 150 GL (33%) are taken into account. The strong suggestion of the report is that Melbourne needs to consider raising its re-use options because with population increase and climate change to a drier, hotter weather pattern, Melbourne may experience an annual shortfall of between 210 GL to 302 GL by 2055, depending on the model used.

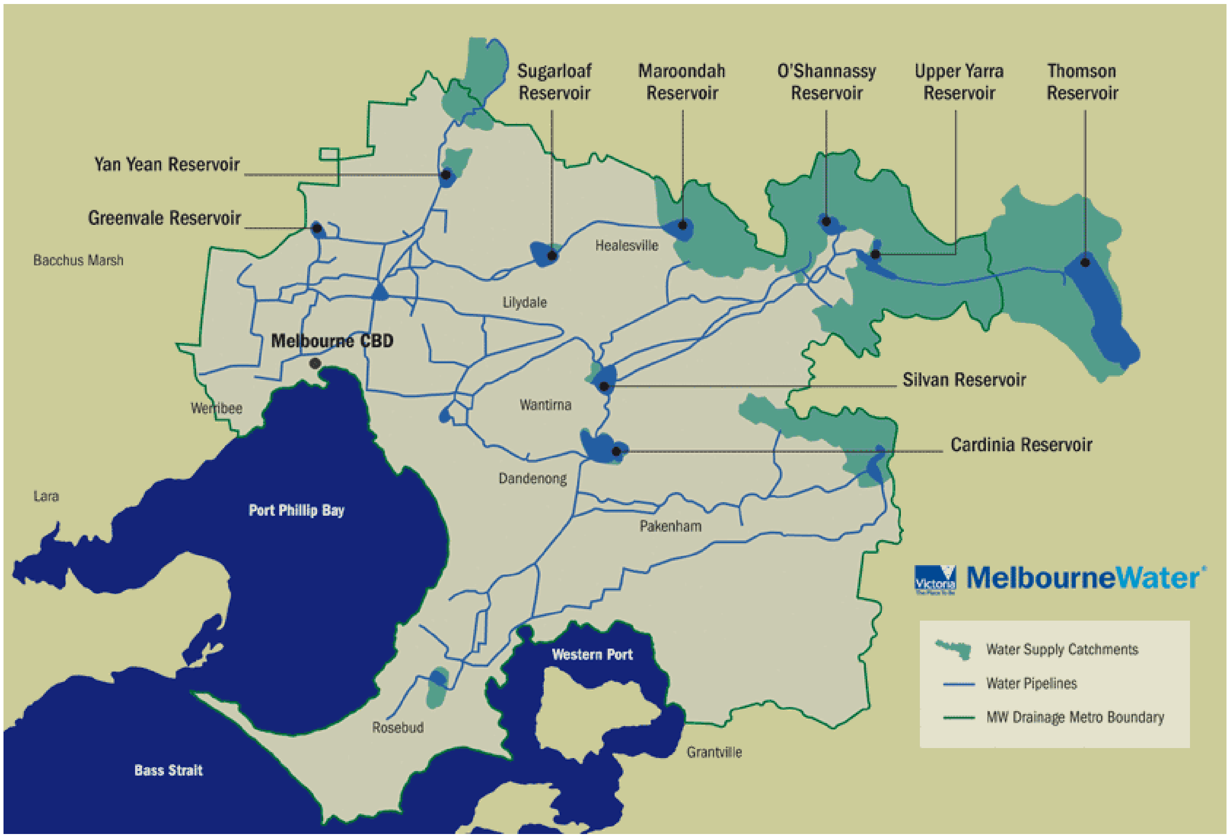
The Parliamentary Committee therefore recommended that Melbourne Water aim to recycle 50% of sewage by 2012 and 70% by 2015 for recycled water. These targets are not that radical: the upgrade to the Eastern Treatment Plant to be completed by 2012 will deliver approximately 110 -130 GL of recycled water per annum. This upgrade is part of the Government's infrastructure plans laid out in *Our Water Our Future – the Next Stage of the Government's Water Plan* from June 2007. Projects worth $4.9 billion should deliver an extra 240 GL of potable water supply by 2012. The Sugarloaf Pipeline from the Goulburn-Broken system and the recommissioning of the Tarago Dam are completed (Melbourne Water 2008). Additionally, an area the ENRCI recommended be investigated is to harvest stormwater from the urban catchment. Not only will this reduce pollution of Port Phillip Bay and the urban streams but it could potentially deliver 35% of potable demand to the city. Additionally, an area the ENRCI recommended be investigated is to harvest stormwater from the urban catchment as an estimated 400–550 gigalitres runs off Melbourne's urban catchment annually'.

Finally, the Committee suggested that Indirect Potable Reuse (IPR) was an option for Melbourne. According to CSIRO submissions there was no technical or health impediment to an adoption of this approach to water recycling, but the Committee did not endorse implementation at this time.

Modelling by Melbourne Water in 2008 (DSE 2008) concluded that Melbourne required a desalination plant to be built as soon as possible to supply 150M L per annum. In concert with continued programs to reduce per capita consumption, this quantity might allow storages of rainfall to begin to accumulate water even with a drying weather pattern. Trigger points for restrictions on water use - where the water levels in storages fall below certain values – would therefore take longer to eventuate. Melbourne has reduced its consumption of water by 26% since 2000-01, to 370 GL in 2007-08. It is worth noting that the average inflow to Melbourne reservoirs 1997 to 2008 was 377 GL versus a long term average of 590 GL per annum.

In terms of climate change (Table G8) the scenarios posit higher temperatures resulting in higher evaporation from storages, less rainfall and concomitant reduced streamflow and yield. The bushfires of February 2009 that burnt 30% of the catchment areas for Melbourne's storages will reduce runoff from about 2020 as vegetation begins to regrow. Large scale forest regrowth uses more water – more rainfall - than mature stands therefore reducing inflows in our current drying weather cycle. The impact on water inflows of regrowing forest especially can be expected to last to 2100 (Figures G22 and G23).

Figure G20: Melbourne's Water Supply

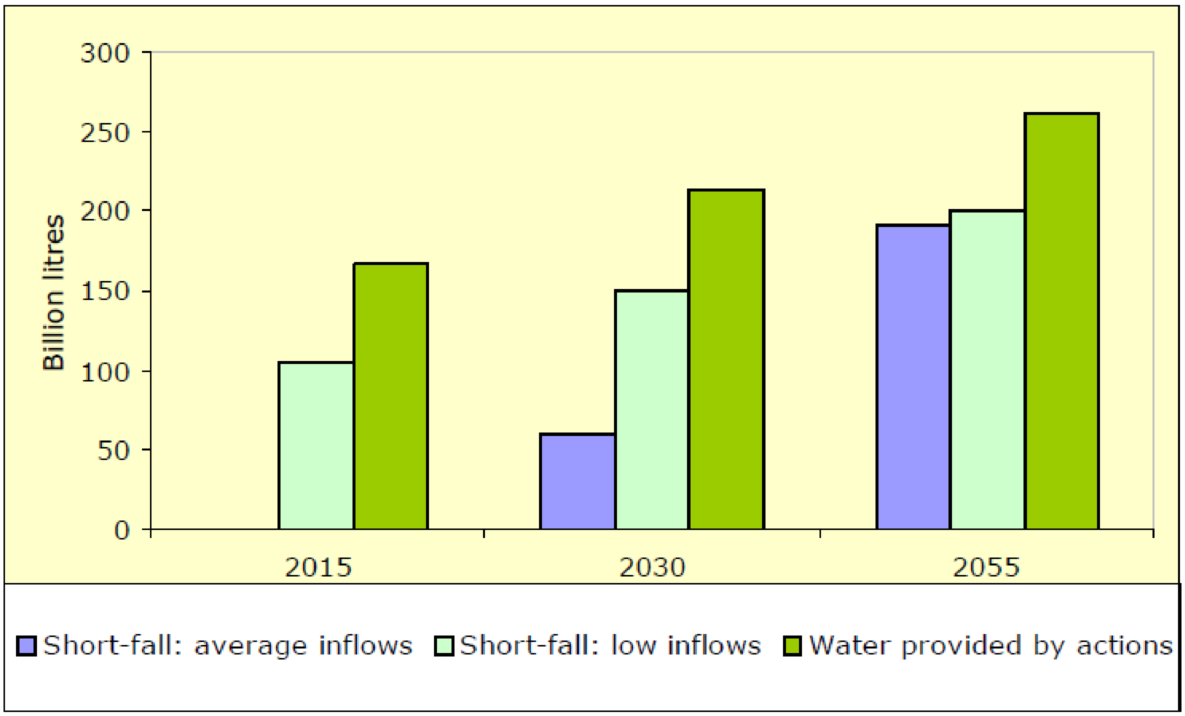


Source: Melbourne Water cited in DSE 2008

The report 'Augmentation of the Melbourne Water Supply System: Analysis of Potential System Behaviour' (DSE 2008) concludes there is a substantial uncertainty about the likelihood that rainfall in the future will fill the dams. The DSE authors are not confident that water use behaviours and demand management (increasing the cost) will be sufficient, although they will be an important contribution to more effective use of water. The report reached the same conclusion as the other capital cities: the need for desalination plants to capture water independently of rainfall. Melbourne Water concluded that without the Wonthaggi Desalination Plant the city could not sustain water supply if the current trend in dry weather continued. At 150 GL per annum, the capacity of the new desalination plant, Melbourne should be able to escape the need for water restrictions at least in the near term (Figure G21). However, the report suggests the need for the capacity of the desalination plant to be increased to 200 GL per annum, such is the uncertainty of rainfall and the certainty of rapidly increased population. Demand management – price, behaviours, and technology - will need constant monitoring and even better, prevention of extra demand could be achieved through mandated planning regulations for water sensitive design of urban landscapes and the built environs.

The dams that capture runoff for Melbourne's water have a capacity of 1,810 GL (Figure G20). By June 2009 the levels were down to 26% or 471 GL and in November 2009, 21%, a fall of 100 GL per annum since 1997. The so-called 'drought reserve' reservoir – the Thomson Reservoir – which has a capacity of 60% of the total water capacity, was at 16% (173 GL) in mid-2009.

Figure G21: Increasing population, reduced inflows, the water made available by current spending on infrastructure.



Source: DSE 2006

Table G8: Climate Change Predictions for Melbourne

	2020	**2050**
Temperature	0.30 C to 1.0 0C (mid range 0.50C)	0.60C to 2.50C (mid range 1.40C)
Evaporation	1% to 7% (mid range 3%)	3% to 18% (mid range 8%)
Rainfall	-5% to-0% (mid range-2%)	-13% to 1% (mid range -4%)
Streamflow	-3% to-11% (mid range-7%)	-7% to-35% (mid range -18%)
Yield	-4% to-15% (mid range-8%)	-10% to-40% (mid range -20%)

Source: Melbourne Water

In 2008-09 Melbourne Water, the Government wholesaler of water in Victoria, supplied 371 GL of drinking water, slightly less (2.6%) than 2007-08 and 16% less than 2005-06 through water restrictions and other measures. In terms of waste treatment, 261 GL of sewage was processed but importantly 23% of this was recycled.

Figure G22: 2009 Victorian bushfire burnt areas and water supply catchments

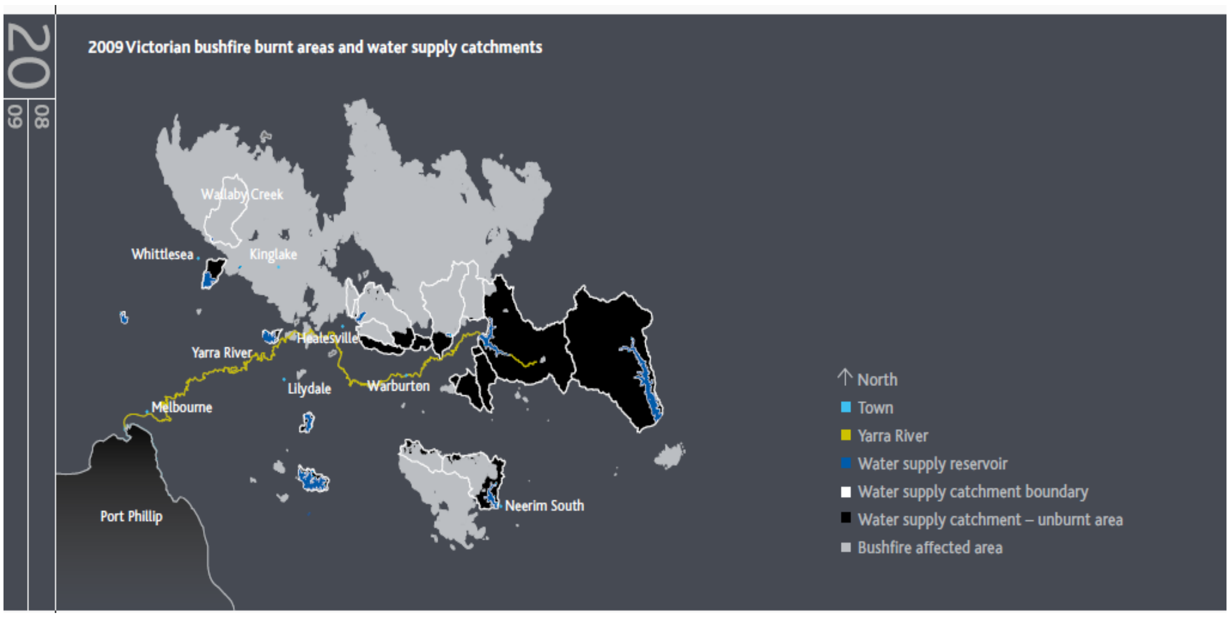


Figure G23: Impact of bushfires on Melbourne Water's Catchments

Impact of bushfires on Melbourne Water's catchments

Catchment	Fire affected	Area burnt estimate	Share of total reservoir inflow
Reservoirs with catchment			
Thomson	No	None	36%
Upper Yarra	Yes	About 2% burnt	19%
Maroondah	Yes	About 75% burnt	12%
O'Shannassy	Yes	About 93% burnt	12%
Yan Yean	No	None	2% (not in supply)
Tarago	Yes	About 50% burnt	Nil (not used for Melbourne's water supply at time of bushfires)
Reservoirs with no catchment			
Cardinia	No	N/A (no catchment)	Nil
Sugarloaf	No	N/A (no catchment)	12%*
Greenvale	No	N/A (no catchment)	Nil
Silvan	No	N/A (no catchment)	7%**
Small catchments			
Graceburn Creek	Yes	About 100% burnt	Run-off to Maroondah Reservoir
Wallaby Creek	Yes	About 100% burnt	Run-off to Yan Yean Reservoir
Armstrong Creek	Yes	About 100% burnt	Run-off to Silvan Reservoir
Coranderrk Creek	Yes	Less than 2% burnt	Run-off to Silvan Reservoir
McMahons Creek	No	None	Run-off to Silvan Reservoir
Starvation Creek	No	None	Run-off to Silvan Reservoir

Percentages are calculated from the annual average inflow (run-off) into our reservoirs from 1997-2008.
* Sugarloaf inflow is from the Maroondah aqueduct and Yarra River.
** Silvan inflow is from small catchments (see above). This accounts for 7% of our total reservoir inflow.

Consumption of water by Melburnians has reduced following positive responses to behavioural change programs initiated by the Government and water restrictions. The following figures portray the timing of regulatory water use imposition against water supply and below, the pattern of use in daily consumption during the period of the *Target 155* program (Figure G24). The third Figure (G29) shows Melbourne's recent average daily water use from the 1990s.

According to the *Water Supply – Demand Strategy for Melbourne 2006 to 2055,* Melbourne consumes 59% of water in homes, about 30% in business and the remainder (11%) is so-called 'non-revenue water' made up of mains leaks, inaccurate meters and fire-fighting. Domestic water consumption patterns for Melbourne were recently measured by Yarra Valley Water 2005: *80% is used internally in the kitchen, bathroom and laundry and 20% is used externally on gardens and car washing. Showers (30%) and washing machines (14%) are the highest uses of water inside homes.*

Figure G24: Water in storage Melbourne

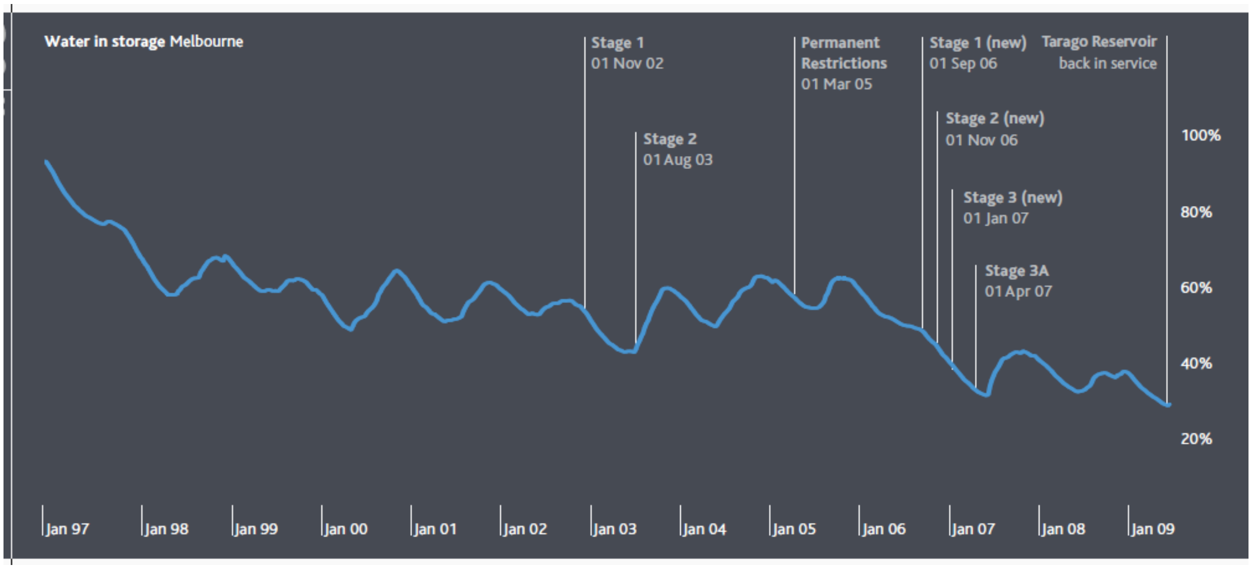


Figure G25: Current residential consumption

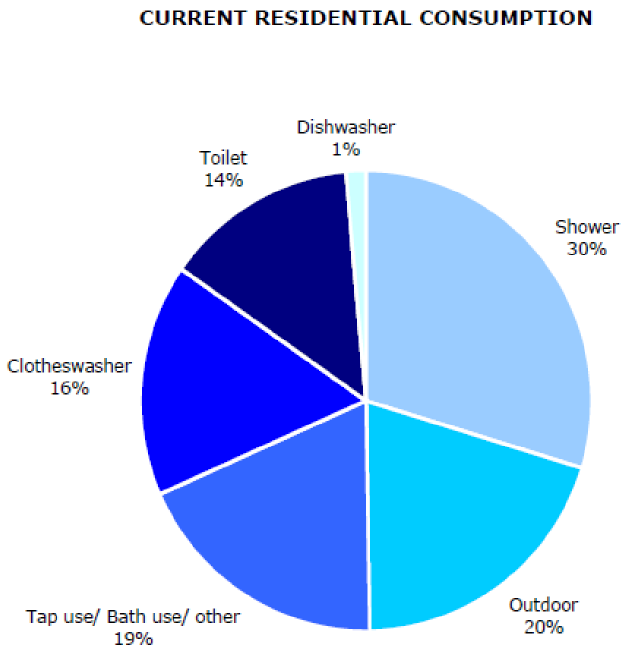


Figure G26: Average daily consumption

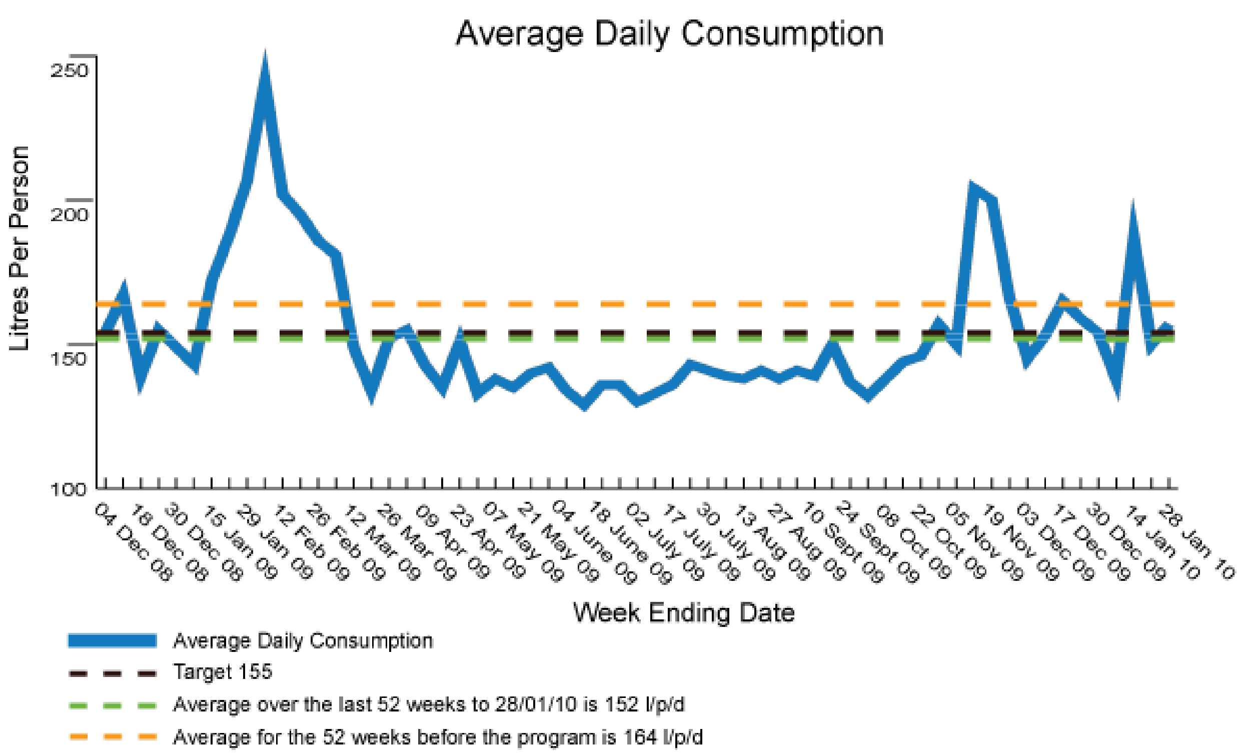


Figure G27: Daily water use in Melbourne

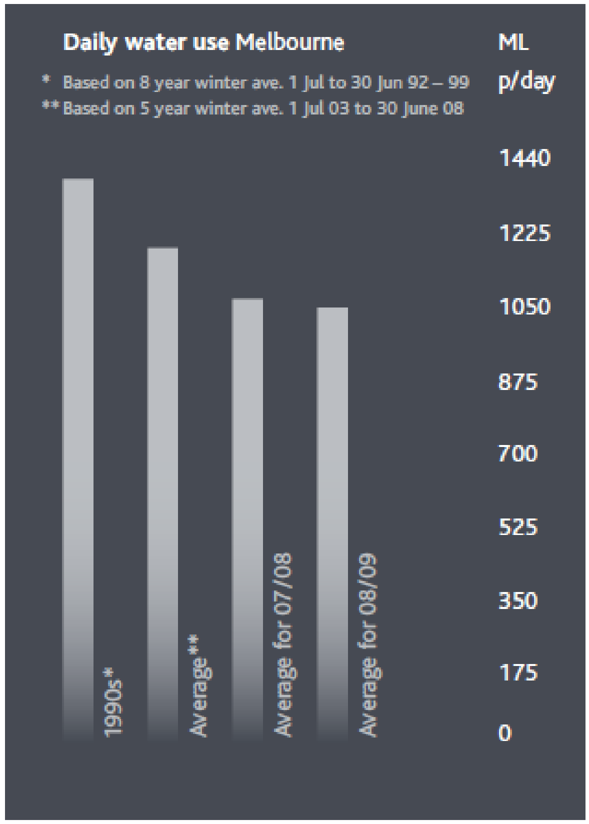


Figure G28: Historical average inflows to storage

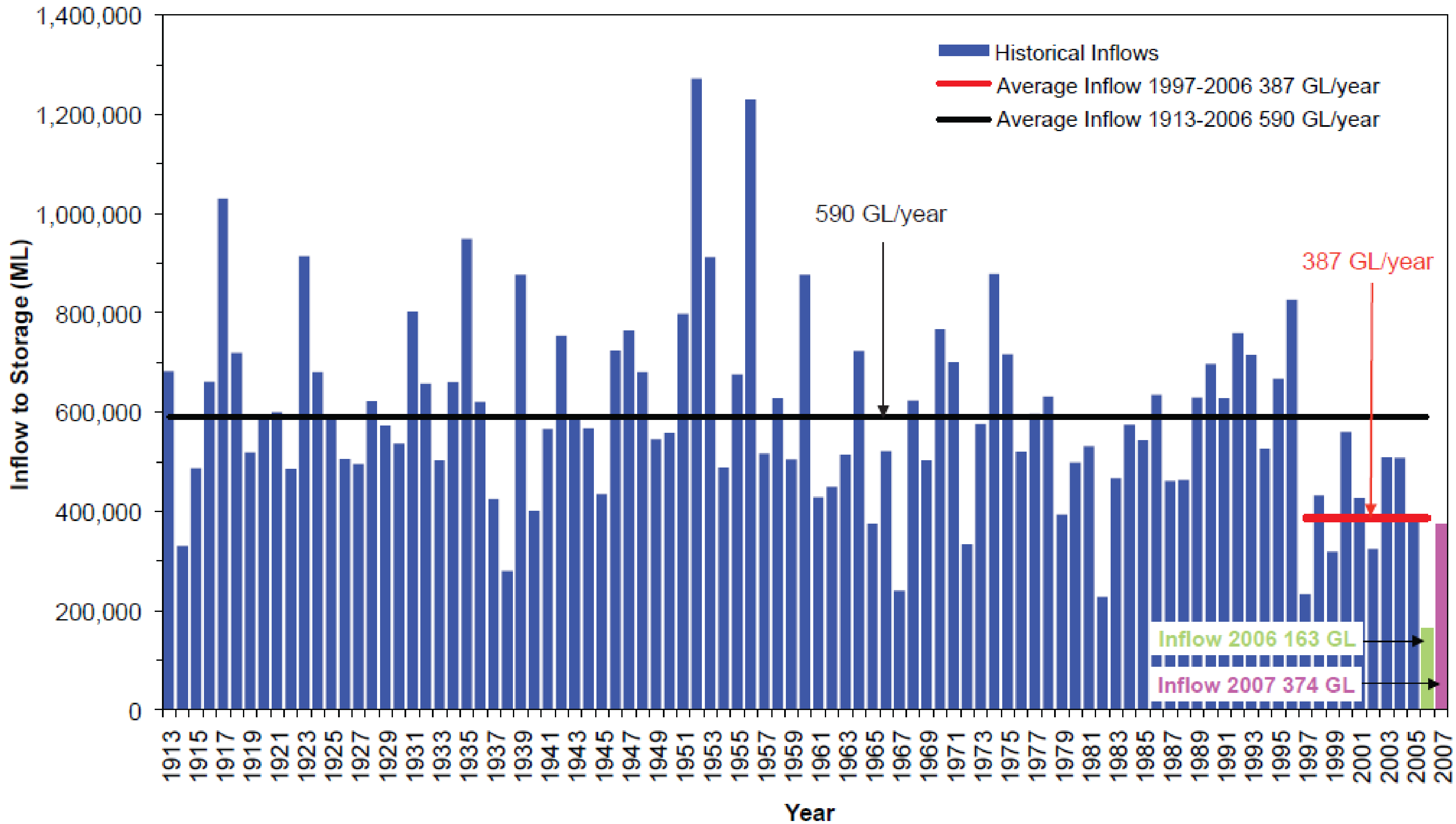
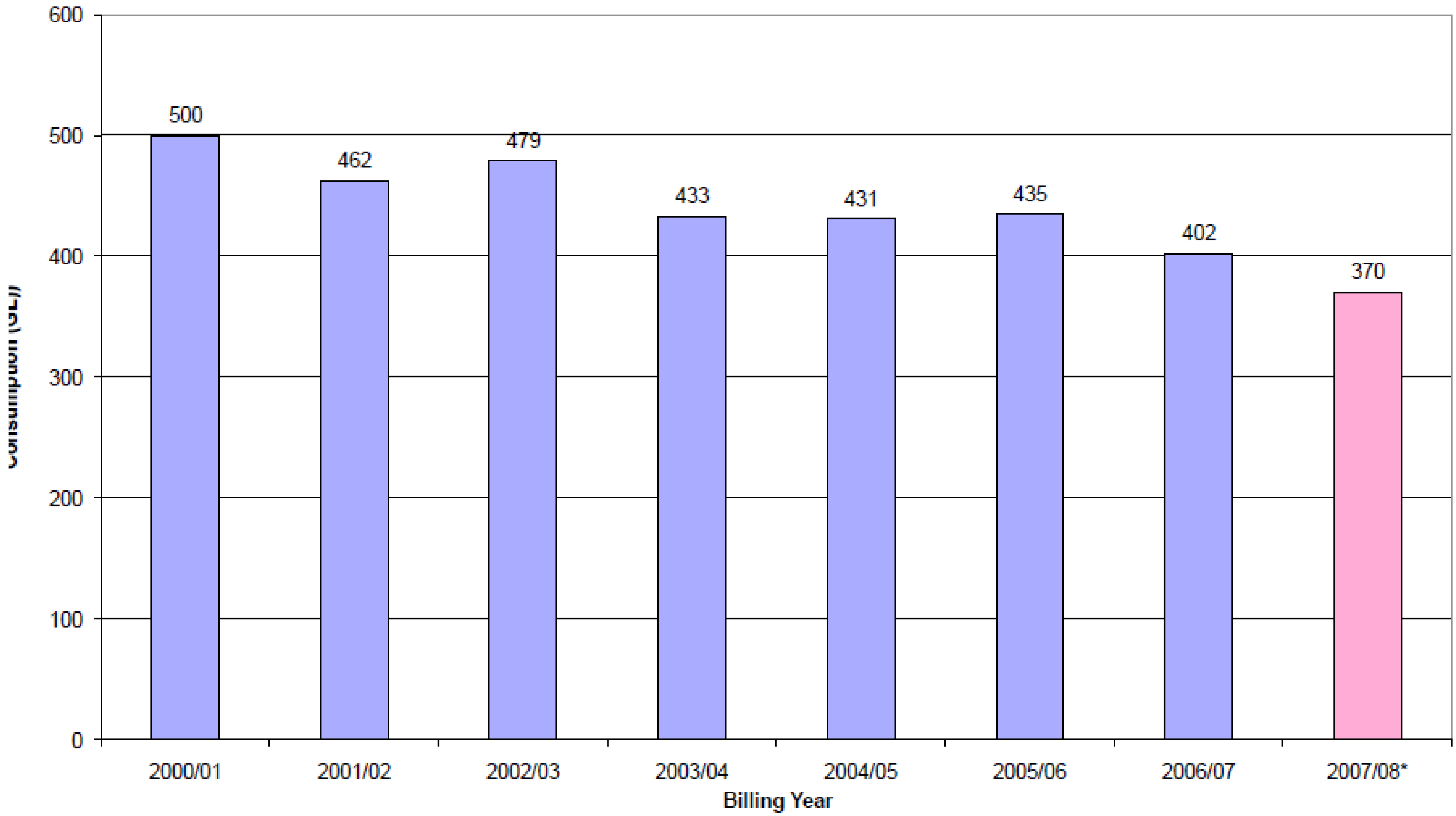


Figure G29: Melbourne water consumption since 2000



* projected consumption based on actual data to 31 December 2007

References

(ENRCI) Environment and Natural Resources Committee Inquiry, 2009. *Melbourne's Future Water Supply Report.* Parliamentary Paper No. 174 Session 2006-2009. Parliament of Victoria.

DSE, 2008. *Augmentation of the Melbourne Water Supply System Analysis of Potential System Behaviour*. Government of Victoria.

DSE, 2007. *Our Water Our Future: The Next Stage of the Government's Water Plan.* Government of Victoria.

DSE, 2006. *Water Supply – Demand Strategy for Melbourne 2006 to 2055*. Government of Victoria.

Melbourne Water, 2009. *Sustainability Report 2008-09*. Government of Victoria.

Perth

Perth draws its water supply primarily from the Gnangara Mound and Jandakot Mound, shallow aquifers recharged by the Darling Ranges to the east of the city (see Figure G30). The former extends north from the Swan River to Gin Gin underneath the costal plain that Perth is built upon for 2,115 square kilometres. The latter extends from the Swan River south to the Serpentine River and covers an area of approximately 760 square kilometres. Surveys' suggest the aquifers capacities are 18,800 GL and 4,200 GL respectively. These shallow aquifers are underlain by the deep confined aquifer known as Yarragadee.

Both sets of aquifers are accessible and used by individuals and industry to the tune of 370 GL per annum (see Figure G31). Beside this essentially private supply is a public supply from reservoirs and the new desalination plant for a demand of 268 GL per annum. Total use per annum: 638 GL. Average use per person: 147 KL.

Figure G30: Groundwater tables of the Perth region

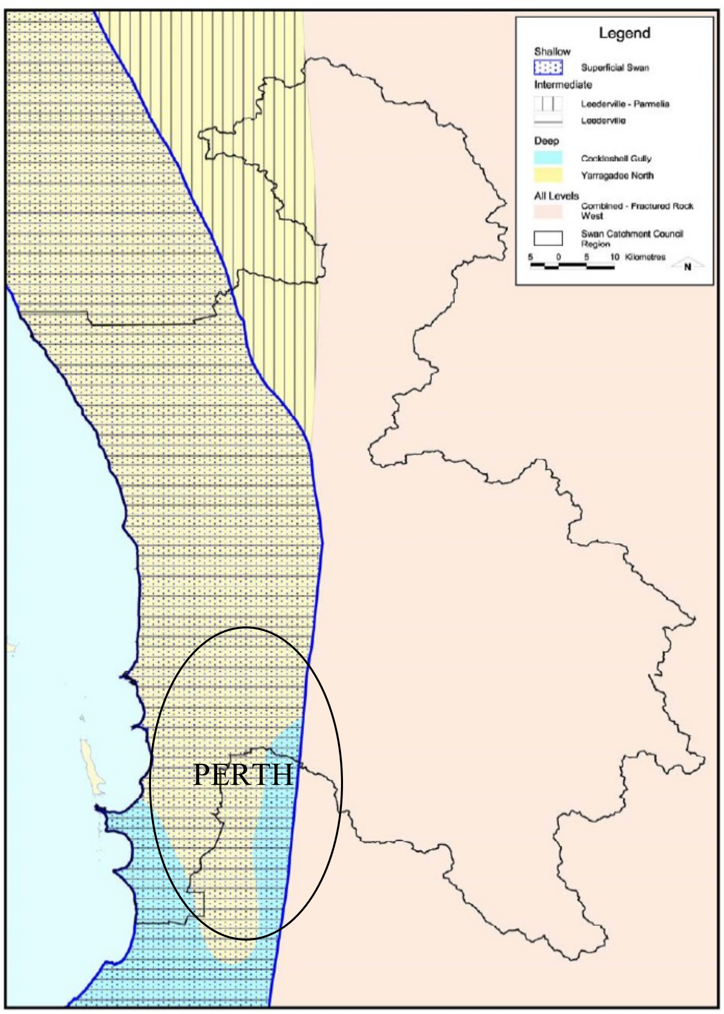
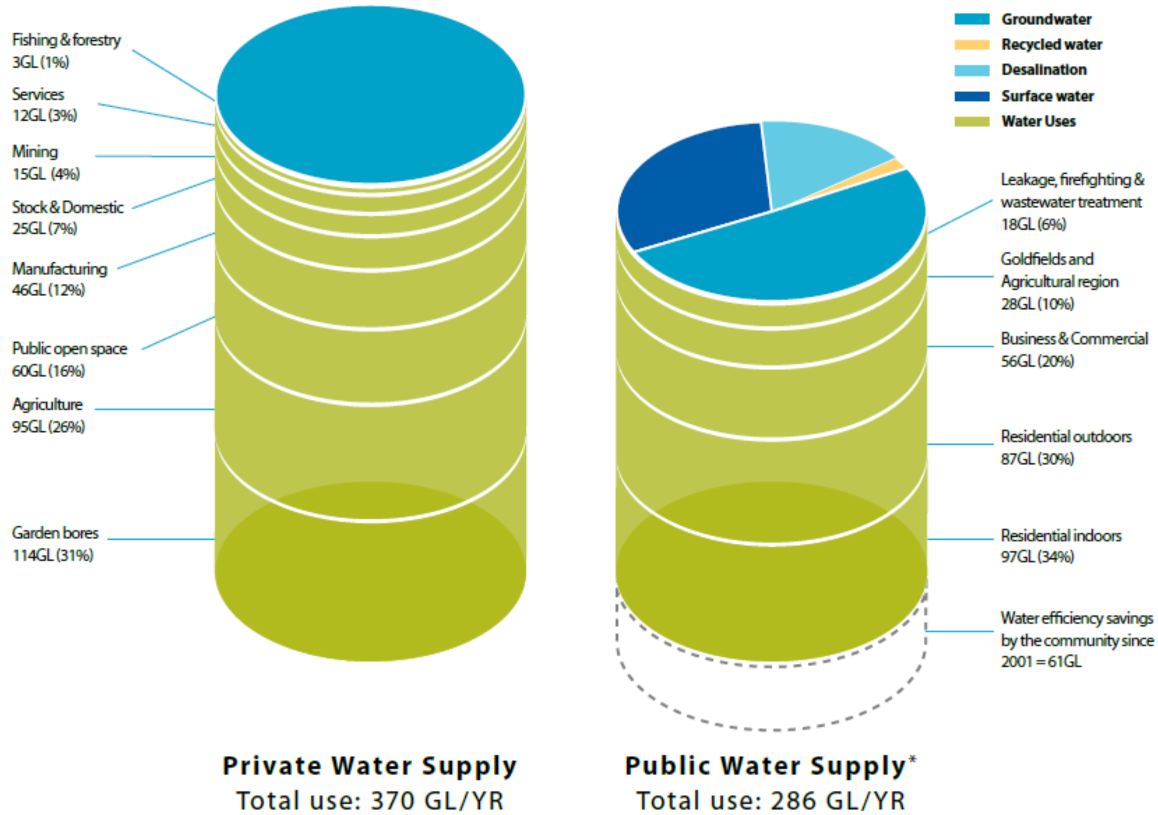


Figure G31 : Estimated total water sources and use in Perth and surrounding areas in 2008

Estimated total water sources and use in Perth and surrounding areas in 2008 *(figure 5)*
(Gigalitres per year)



Unfortunately the population estimates in Table G9 are now superseded and I draw your attention to a more recent interpretation of the data in Table G11.

Table G9: Population forecasts to 2060

Population forecasts to 2060 *(table 3)*

Year	2010	2020	2030	2040	2050	2060
Perth population	1,640,000	1,910,000	2,180,000	2,420,000	2,660,000	2,900,000
Mandurah population	80,000	105,000	130,000	155,000	180,000	205,000
Total population	1,720,000	2,015,000	2,310,000	2,575,000	2,840,000	3,105,000

That is, the latest ABS data from late 2009 suggests that Perth will reach 4.2 million people in 2056, an extra 30% more people than modelled 12 months previously (Table G9). If one models the population growth by decade on a pro-rata basis to reach this population in about 2056, the supply-demand gap for water supply can be calculated around the same assumptions of rainfall, improved water use efficiency and new sources of supply.

Table G10 below demonstrates that after progressive improvement in water use efficiency to 25% per person by 2060, and the doubling of desalination capacity to 95 GL per annum in 2020, Perth will need to plan for the supply of around 115 GL pa extra supply in 20 years time in 2030 and more than 250 GL pa by the next 20 years after that to satisfy demand in 2056. The prime cause is the drying climate which will reduce groundwater accessions and surface run-off accumulation in dams from 145 GL pa to 30 GL pa, and 90 GL pa to 25 GL pa, respectively, a total loss of rain fed water supply of 180 GL per annum (Figures 36 -38).

The deficit in current planning for 2030 is therefore of the order of 15 GL pa to 45 GL pa. based on 'Water Forever' Water Corporation October 2009 calculations for the Integrated Water Supply Scheme water supply grid.

Table G10: Expected contribution from existing sources to 2060

Expected contribution from existing sources to 2060 *(table 2)*

Expected contribution from existing sources (GL / year)	2008	2020	2030	2060
Desalination sources	45	95	95	95
Surface water sources	90	85	75	25
Groundwater sources	145	110	90	30
Total	280	290	260	150

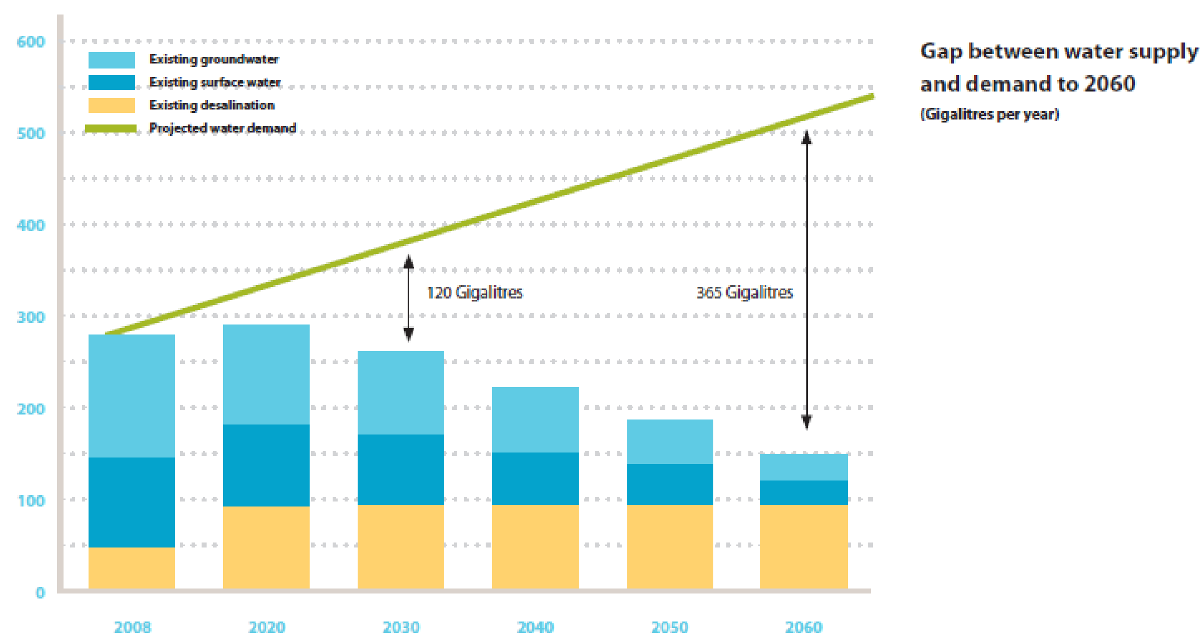
New sources being investigated include waste water recycling, aquifer storage and recharge, more desalination plants, thinning forest cover in catchment zones and water trading.

Table G11: Re calibrated water supply deficiency with updated population estimates

Year	2010	2020	2030	2040	2050	2060
Perth and Mandurah Total *Population*	2,236,000	2,619,500	3,003,000	3,347,000	3,692,000	4,036,000
Water Use per Person *KL*	145	135	125	120	115	110
Total Water Use *GL*	324.2	353.65	375.4	401.6	424.6	444.0
Water Efficiency Savings *GL*	6.5	32.5	65	97	130	169
Probable Water Supply *GL*	280	290	260	225	180	150
New Water Supply Needed in *GL*	44.2	63.6	115.4	176.6	244.6	294.0
Total Supply Gap	50.7	96.1	180.4	273.6	374.6	463.0

The Total Supply Gap in Table G11 provides a statement of the increased deficit that Perth's increased population will cause decade by decade. It updates the volumes calculated for Figure G32 below, which included the savings from improved water use efficiency.

Figure G32: Gap between water supply and demand to 2060



The key point about lower rainfall especially in a warming climate is the translation into surface storage. A 10% fall in rainfall produces a 50% decline in runoff because of the sandy nature of the soils and ancient geology of south west WA. Given recent years have experienced a 20% fall in rainfall leaves very little for dams to collect unless fed by groundwater (Figures G33, G34 and G35) (ATSE 2002).

Figure G33: Historical rainfall patterns at Jarrahdale

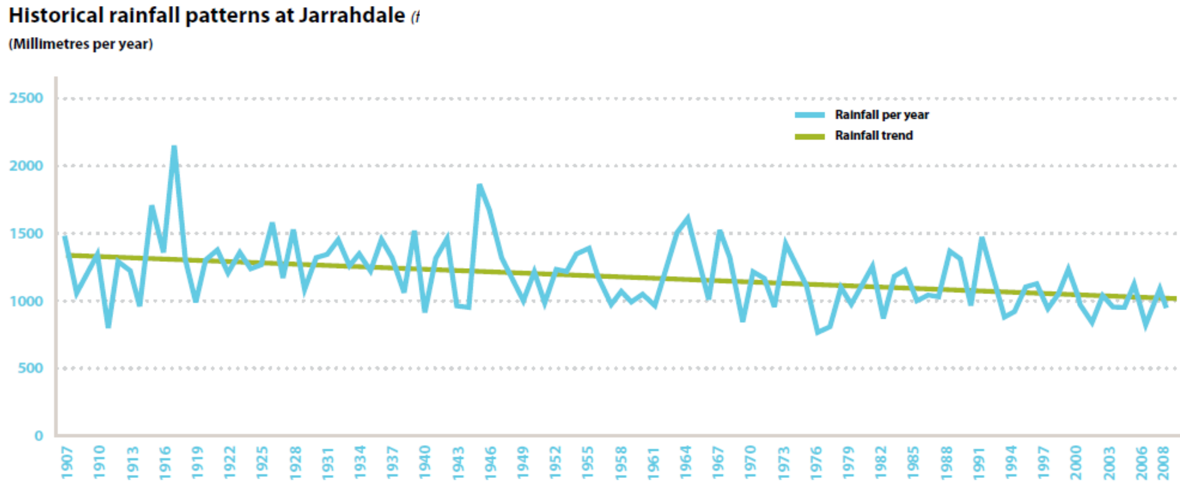


Figure G34: Historical annual streamflows into Perth dams

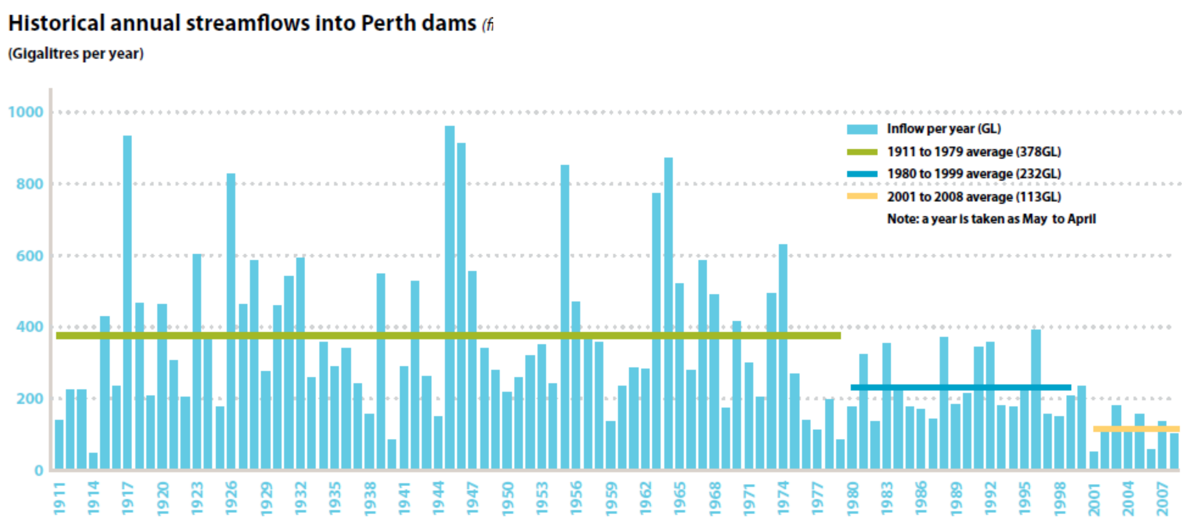


Figure G35: Historical streamflows 1950-2008 with projected streamflows from 2009

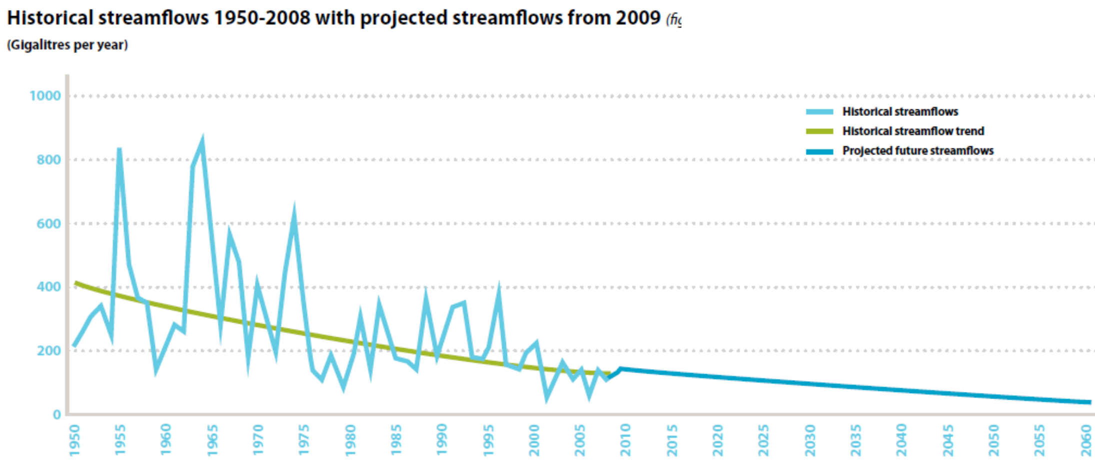


Figure G36: Groundwater depletion, relative to 1979 level

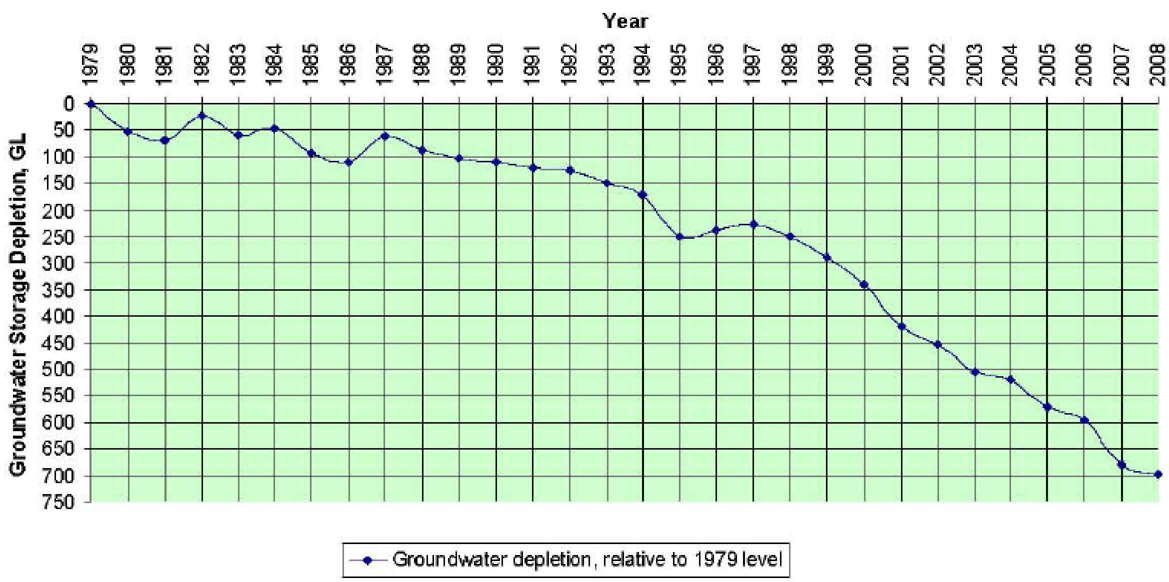


Table G12: Meeting the supply demand gap to 2060

Meeting the supply demand gap to 2060 (i

	2010	2020	2030	2040	2050	2060
Water use (KL per person)	145	135	125	120	115	110
Water efficiency savings (GL)	5	25	50 (15%)	75	100	130 (25%)
New water sources required (GL)	0	15	70	125	185	235
Meeting the supply - demand gap (GL)	5	40	120	200	285	365

Figure G37: Groundwater resources of the Swan Coastal Plain, Perth

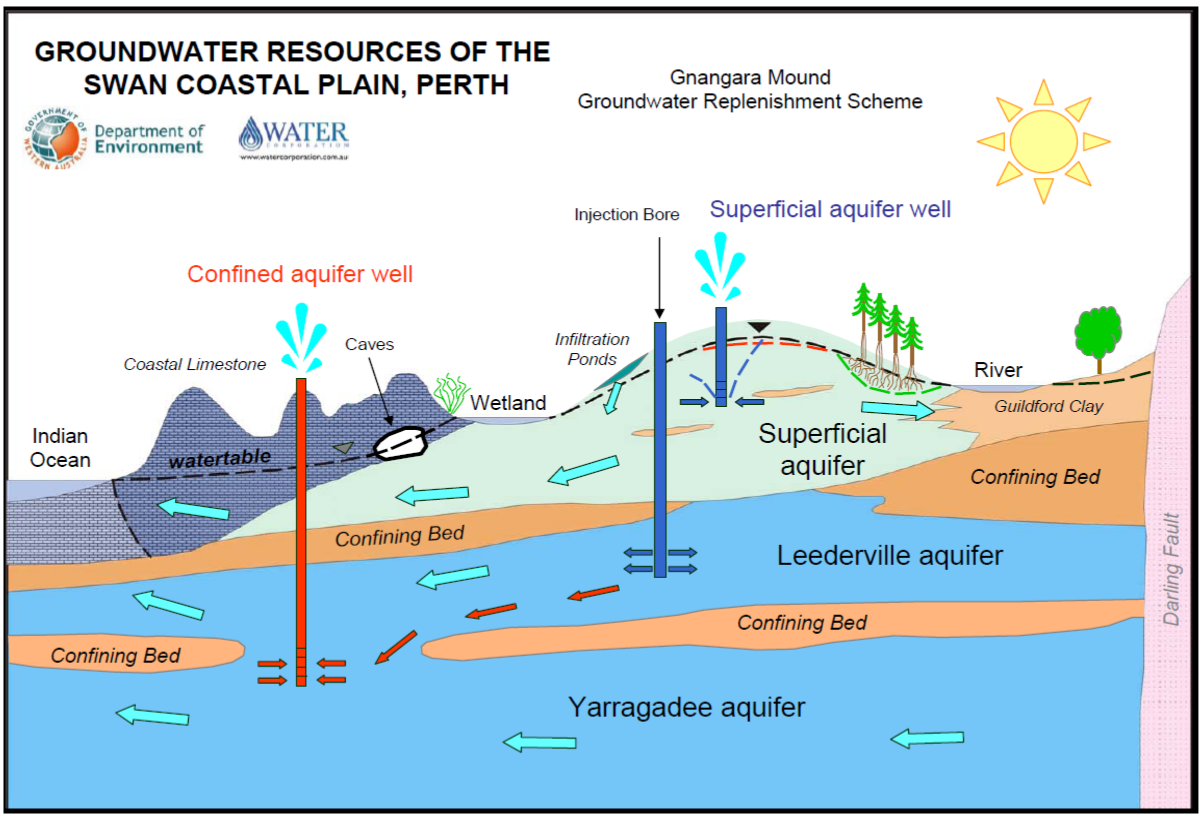


Figure G38: Future water source options

References

ATSE (Australian Academy of Technology Science and Engineering) 2002, Perth's water balance -the way forward. ATSE:Canberra

Department of Water, 2009, *Perth-Peel Regional water plan 2010–2030: Responding to our drying climate* Draft for public comment. Government of Western Australia

Water Corporation, 2009, *Water Forever: Towards Climate Resilience.* Government of Western Australia

Water Corporation, 2009, *Directions For Our Water Future :Draft Plan*. Government of Western Australia.

Water Corporation, 2008, *Water Balance Analysis for the Gnangara Mound under Corporation abstraction scenarios of 105, 135 and 165 GL/a*. Government of Western Australia.

Water quality

Sydney

Migrant populations in Greater Sydney are concentrated in western Sydney LGAs. Major urban centres including Parramatta, Penrith, and Liverpool together comprise the third largest urban region of Australia. These centres are established on rivers for which water pollution from the urban surfaces and sewers, and the peri-urban agricultural waste streams are an *a priori* concern for future population increase in the west of Sydney.

> Schueler (1994) determined the threshold of impervious surfaces to support natural waterway systems to be 25%. Above this benchmark stream processes such as channel stability, water quality and biodiversity were seen to be in an unstable or poor condition. Most of the catchments in Blacktown are above the 25% threshold and with continued urbanisation, this figure would be expected to increase.

Tables G13 and G14 demonstrate the high pollutant loads of sediment, oil and grease, metals, nutrients, organic material and detergents that stormwater empties from different land use types into the streams of Western Sydney in 2002.

Table G13: Annual stormwater pollutant loading rates for western Sydney, 2002

Land use	Coarse sediment		Organic matter		Litter		Total phosphorus	Total nitrogen
	kg/ha/yr	m^3/ha/yr	kg/ha/yr	m^3/ha/yr	kg/ha/yr	m^3/ha/yr	kg/ha/yr	kg/ha/yr
Residential	500	0.33	100	0.25	15	0.05	0.8	4.8
Commercial	900	0.6	80	0.2	135	0.45	1.6	8.1
Industrial	900	0.6	72	0.18	105	0.35	1.7	9.5

Source: Sainty and Assoc. for Parramatta City Council, 2002

A more detailed study of the sites which generate particular pollutants is shown in Table G15 for Parramatta LGA. The median 2004 Signal Score (a pollution index) for Parramatta LGA streams was 3.27 – **Severely** polluted (Table G16 below). Taken together with the information on Blacktown LGA's impervious areas in its sub-catchments and pollutants in its streams, (Table G14; Figures G40-G43), briefly illustrates both the severity and pervasiveness of the impact on water quality from land use change, i.e. urban development in Western Sydney. Population increase is more likely than not going to continue to cause substantial loss of biodiversity and water quality to the streams in the Western Sydney area. Population increase that does not do this will require much smarter planning than what has gone before.

Table G14: Catchment and impervious area

Catchment	Total area (ha)	Impervious area (ha)	Impervious area as % of Catchment Total area (ha)
Angus	635.4	362.5	58%
Lalor	496	287.4	60%
Bells	1378	506.9	37%
Little	1772	568.8	32%
Blacktown	814.5	468.7	58%
Marsden	870	105.8	13%
Breakfast	2248	1377.4	62%
Minchinbury	232	74.1	28%
Bungarribee	679.3	382.1	59%
Quakers	809	471.0	61%
Caddies	227.5	66.4	29%
Reedy	128.5	1.4	5%
Eastern	3622	2098.8	60%
Ropes	1628	646.2	49%
Eskdale	314	141.2	54%
Second Ponds	729	102.5	15%
First Ponds	1159	228.9	20%
South	2.9	0.1	5%
Grantham	283.5	146.1	53%
Stoney	511	49.7	10%
Greystanes	337	172.9	51%
Toongabbie	157	123.2	78%
Total (ha)	19033.6 ha	8381.7 ha	44%

The following graphs dramatically illustrate the actual water pollution in Blacktown streams compared to what once existed before urbanisation. Nitrogen and Phosphorus lead to eutrophication or loss of oxygen in the streams causing whole food chains of fish and invertebrates to die. The nutrients cause algal blooms in warm shallow water bodies in summer, which use up the dissolved oxygen in their decomposition. Total dissolved solids from erosion and stormwater increase turbidity and poison hazard for living organisms in the water, or those who/ which might depend on the water and its quality for other services, such as drinking!

Figure G39: Imperviousness of sub catchments within LGA

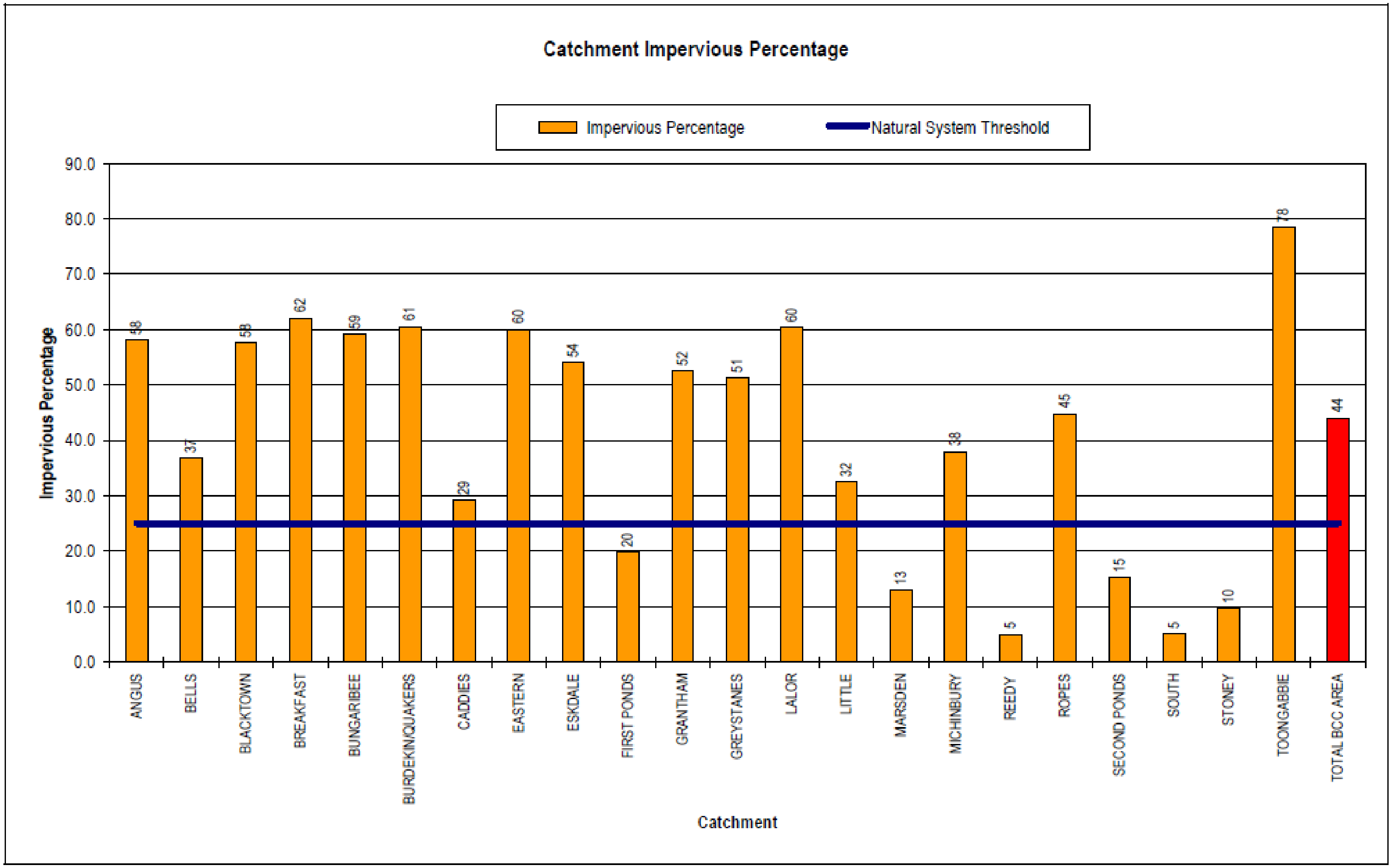


Figure 7 - Imperviousness of sub catchments within LGA

Figure G40: Total Nitrogen (TN) Export Loads (kg/ha/yr)

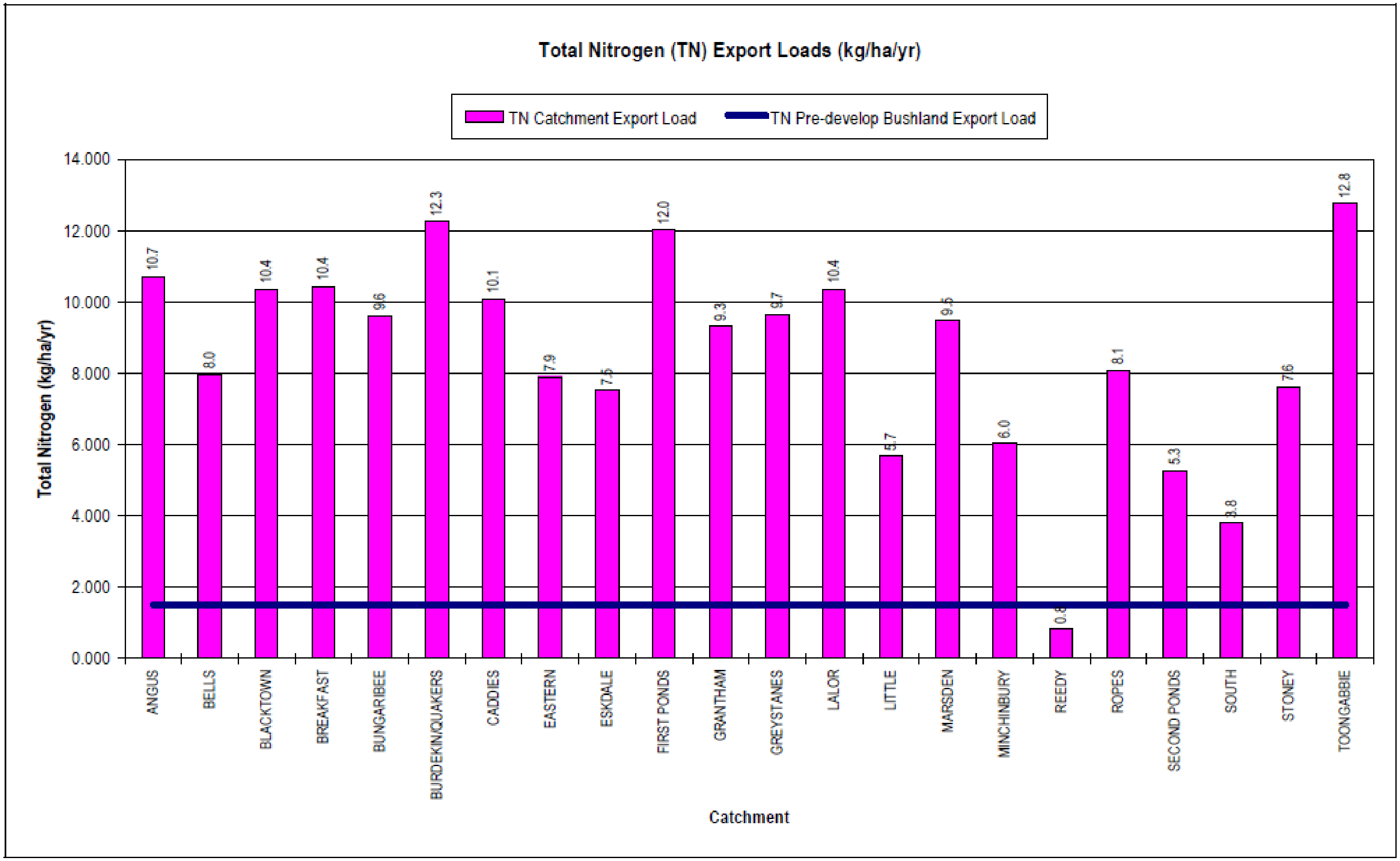


Figure 9 - Comparison of total nitrogen for catchments

Figure G41: Comparison of total phosphorous for catchments

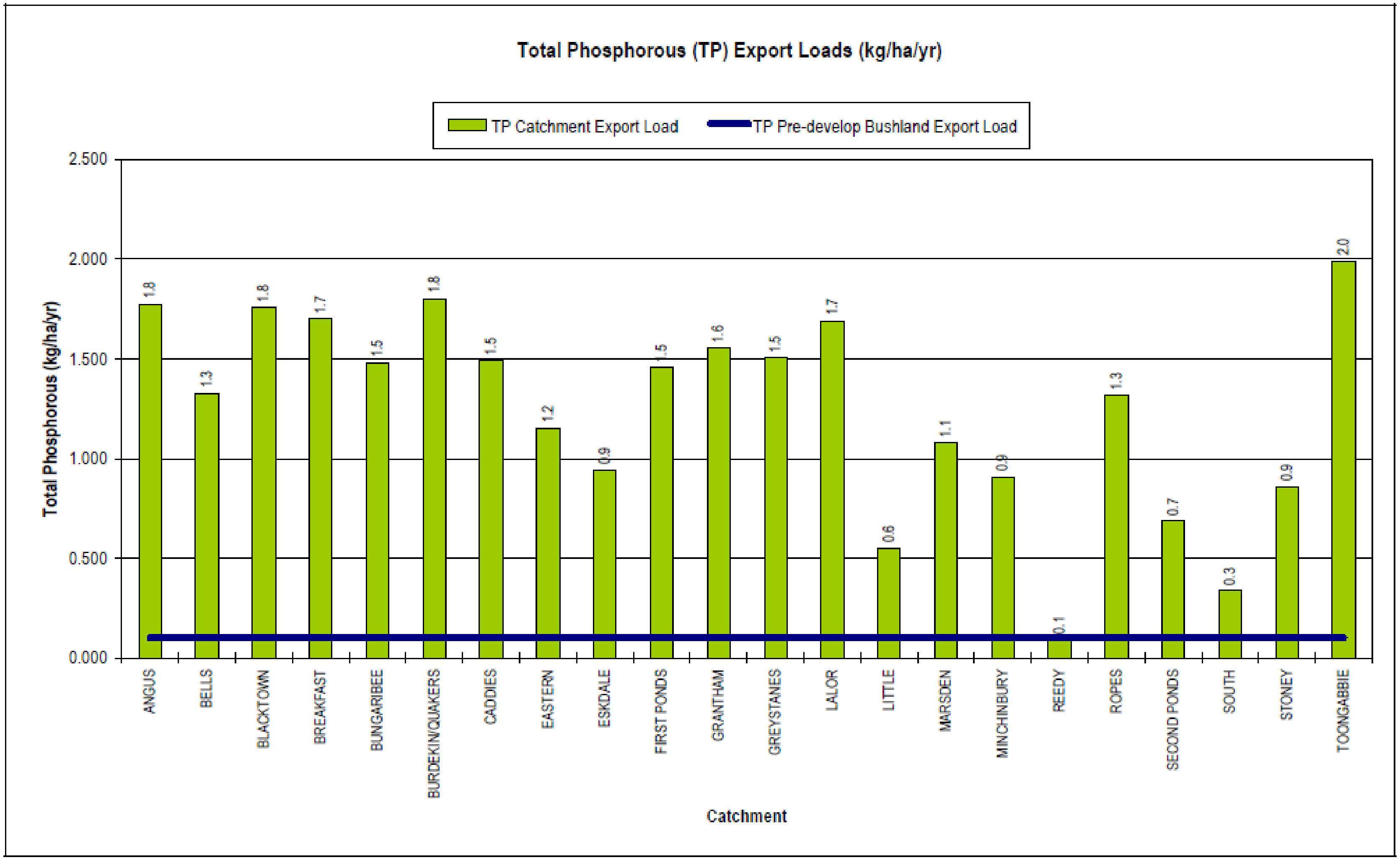


Figure 10 - Comparison of total phosphorous for catchments

Figure G42: Comparison of total suspended solids for catchments

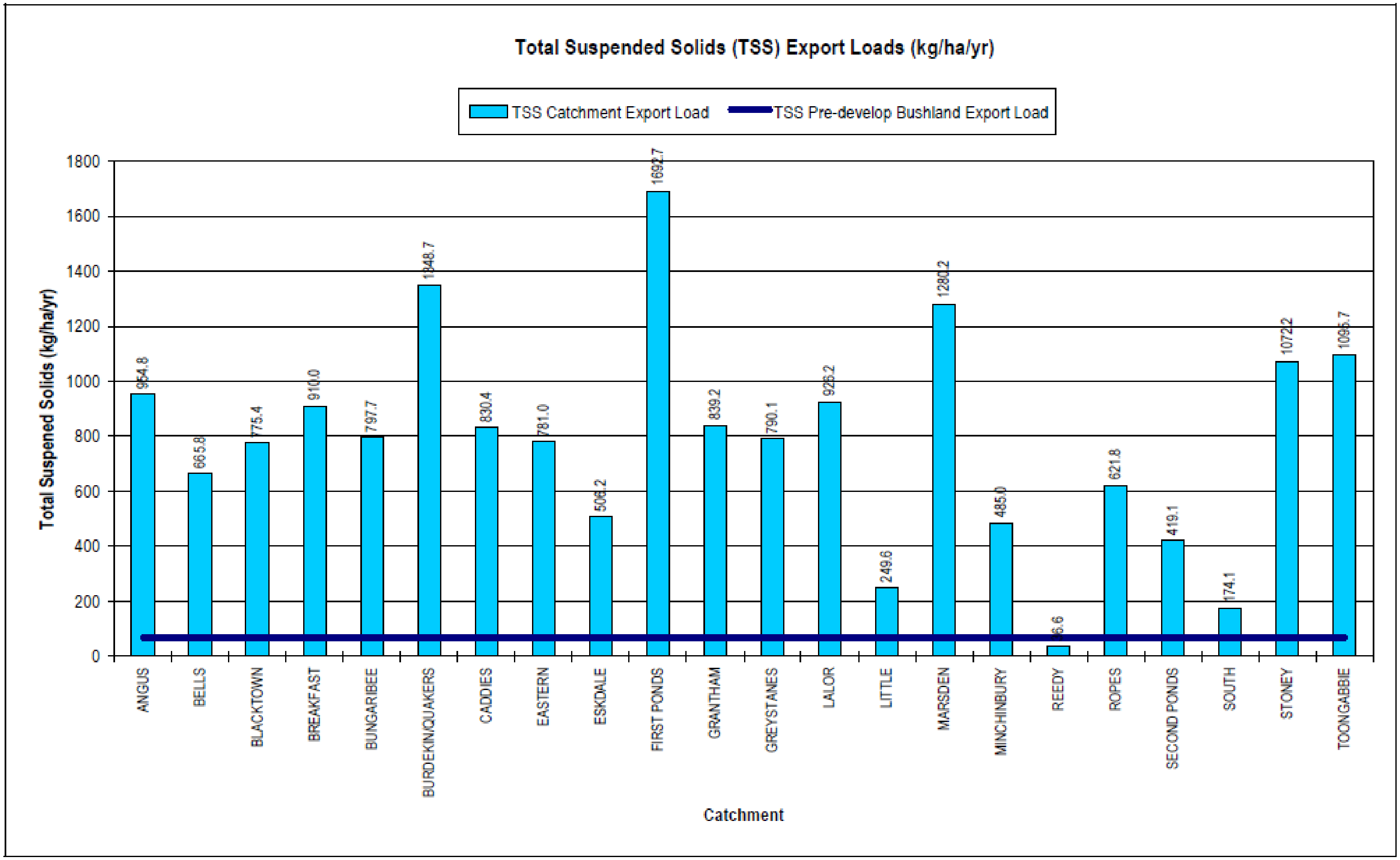


Figure 11 - Comparison of total suspended solids for catchments

Table G15 below is data from the Parramatta LGA and describes the pollutants that enter local streams from storm water. The Table G16 following describes the relative condition of the Parramatta streams in terms of pollution loads. Most are in very poor condition because of land use change associated with urbanisation in their catchments.

Table G15: Land use and major stormwater pollutant type 2002

Land Use	Litter	Oil & Grease	Metals	Organic	Sediment	Detergents	Nutrients	Bacteria
Roads	*	*	*		*			
Motor vehicle sales and repairs		*	*		*	*		
Unsealed car parks		*	*		*			
Sealed car parks		*	*					
Pedestrian thoroughfares	*	*						
Transport nodes	*	*	*		*	*	*	
Retail space	*	*	*			*		
Office / business	*	*	*		*	*		
Food premises	*	*	*	*		*	*	
Parks and open space	*		*	*	*		*	*
Street trees/ landscaping	*		*	*	*		*	
Temporary construction sites	*	*	*		*		*	
Pubs and hotels	*	*	*			*	*	

Source: Sainty and Assoc. for Parramatta City Council, 2002

Table G16: Condition of streams in Parramatta LGA

Creek	***2003 Signal Score***	***2004 Signal Score***	***Water Quality Condition***
Lake Parramatta	-	6.06	*Healthy* Habitat
Toongabbie Ck	2.6	5.57	*Mild* Pollution
Quarry/Toongabbie Cks	2.43	5.2	*Mild* Pollution
Coopers Ck	2.5	5.08	*Mild* Pollution
Toongabbie Ck	2.16	4.21	*Moderate* Pollution
Devlins Ck	2.16	4.07	*Moderate* Pollution
Duck River	-	3.75	***Severely*** Polluted
Subiaco/Bishop Ck	3.7	3.67	***Severely*** Polluted
Domain Ck	-	3.64	***Severely*** Polluted
Hunts Ck	-	3.27	***Severely*** Polluted
Vineyard Ck	3.6	3.12	***Severely*** Polluted
Ponds Ck	4.4	3	***Severely*** Polluted
Terrys Ck	3	-	***Severely*** Polluted
Duck River	-	2.94	***Severely*** Polluted
Ponds Ck	3.6	2.85	***Severely*** Polluted
Finlaysons Ck	2.57	2.85	***Severely*** Polluted
Vineyard Ck	-	2.82	***Severely*** Polluted
Ponds Ck	2.6	-	***Severely*** Polluted
Quarry Branch	2.16	2.1	***Severely*** Polluted
Vineyard Ck	2.6	2	***Severely*** Polluted
Brickfield Ck	1.8	-	***Severely*** Polluted
Pendle Ck	2.75	1.56	***Severely*** Polluted

Source: State of the City Report, 2009, p. 8

References

Parramatta City Council, 2009, Parramatta Twenty25 State of the City Report.. March

Sainty and Associates 2002, Parramatta CBD Stormwater Management Plan. June.

Schueler, T.R. (1994) The Importance of Imperviousness. Watershed Protection Techniques, **1** (3).

Melbourne

The State of the Environment Report for 2008 for Victoria reporting on the quality of inland waters reiterates the same raft of issues for Melbourne as occurs in Sydney. Urban development adversely affects stream morphology and water quality (Figure G44). Only about 22% of streams remain without substantial engineering alteration of their flow regimes, if they survive as streams at all (Figure G45). The local streams have to cope with higher velocities and volumes of surface runoff in a short time span resulting in greater erosion of channels. The urban catchment area of the Port Philip and Westernport Catchment Management Authority (PPWCMA) contributes 50% of the nitrogen pollution, which may result in approximately 260 tonnes of nitrogen per annum by 2030. Primarily a consequence of stormwater flushing the impervious surfaces of a city, pollutants are delivered directly to the coastal environment, again large loads in a short time span producing peaks of pollution that the marine environment must somehow deal with. The range of pollutants is the same as Sydney – increased sediment (Figure 43), nitrogen, phosphorous, heavy metals, hydrocarbons and faecal coliforms. In addition, similar to Sydney are the point sources of pollution, including sewage outlets, intensive animal farms (piggeries, feedlots, dairies) and some irrigated properties. Melbourne Water has increased the volume of sediment and litter retrieved from storm water drains and creeks such that stormwater reaching Port Phillip Bay contains less nutrient and sediment pollution.

Figure G43: Urban expansion and decreasing water quality

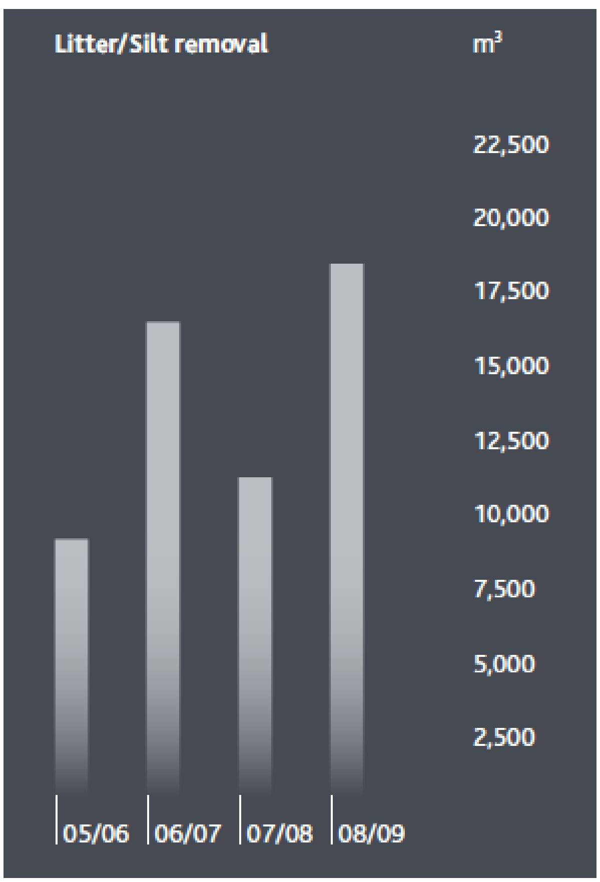
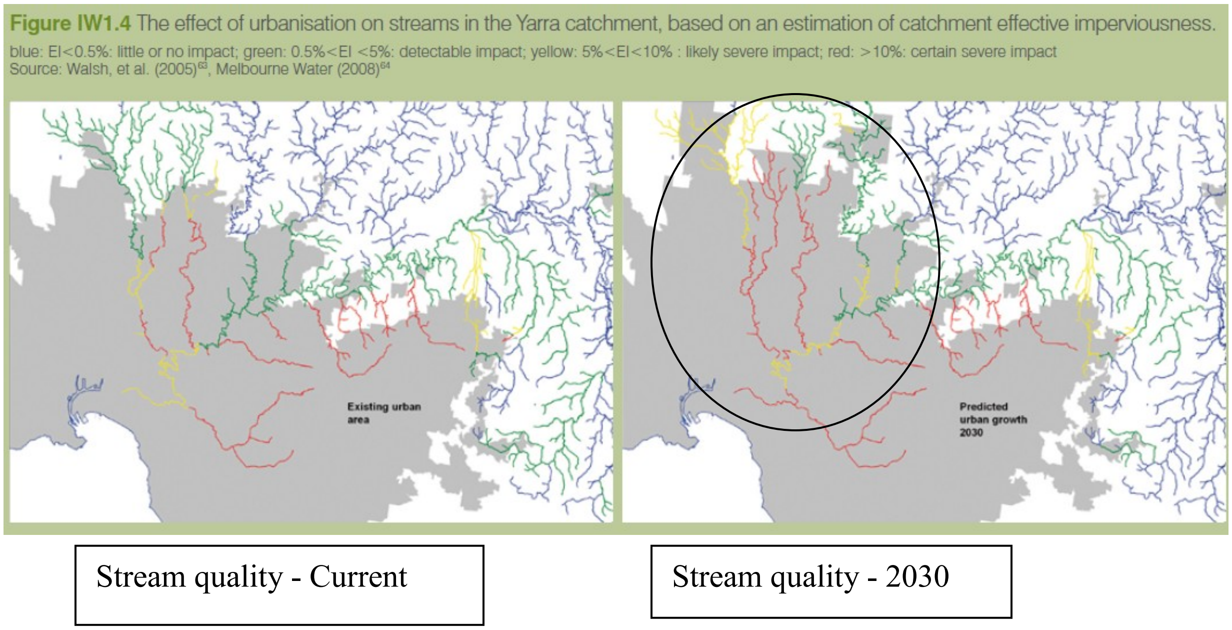


Figure G44: The effect of urbanisation on streams in the Yarra catchment, based on an estimation of catchment effective imperviousness

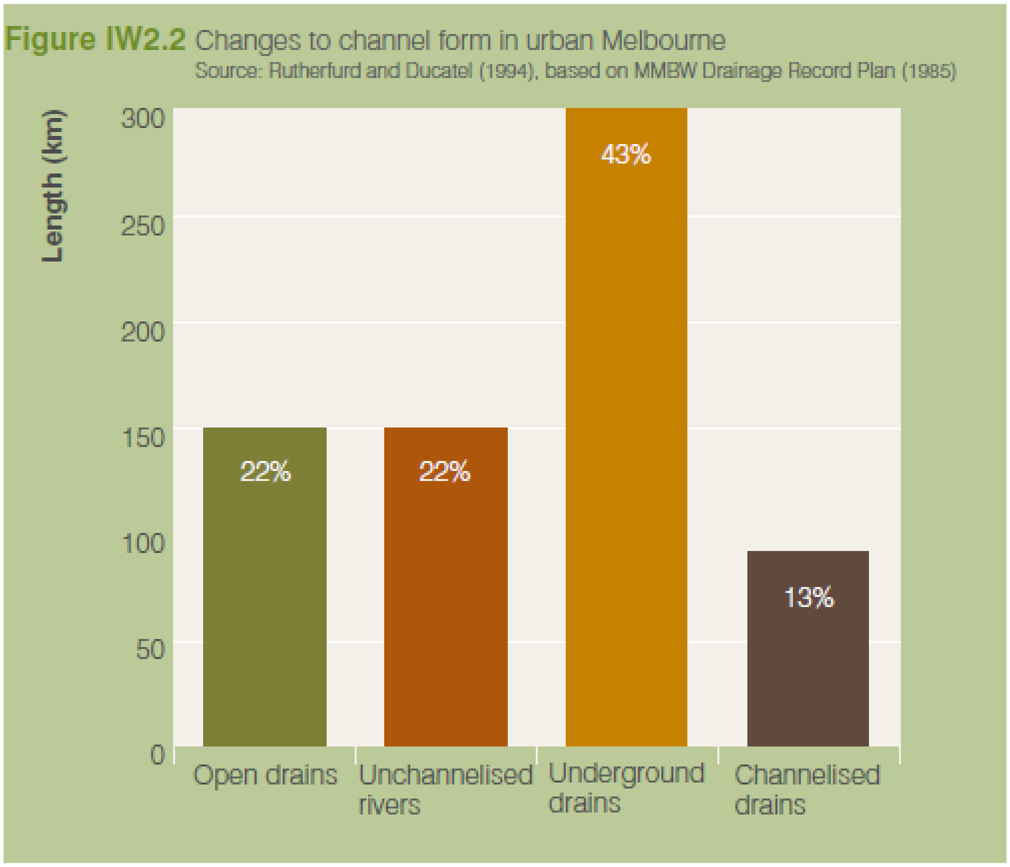


Source: SoE, 2008

There are four catchments that prescribe the Melbourne metropolitan location, the Upper Western (Maribyrnong River) and Western (Werribee River), Yarra (Yarra River), Dandenong and Westernport catchments (Figure G49). Taking the latter first, Westernport catchments are characterised by healthy upstream reaches. However, where road building, urban settlement and irrigation have developed, water quality is very poor and there is pressure on habitat for 14 species of native fish, 11 species of native frogs, platypus and a variety of native plants. This is a similar scenario for the Dandenong catchment, which has undergone extensive engineering converting natural waterways to drains. By contrast, the upper Yarra catchment is one of perhaps five catchments in the world that have been protected from any sort of human interference for more than 100 years. The 157,000 hectares contained therein nominally provides 90% of Melbourne's drinking water. However, once the river meets the urban environment the same sort of pollution problems and water engineering approaches occur (ie. creeks concreted, directed into underground drains etc.). Finally, increasing sewerage services in the west and north-west of the city have reduced the diffuse and point sources of pollution of the Maribyrnong River which overall is in moderate condition. It is however one of two key areas nominated for the next phase of urban expansion.

Worth focusing on briefly is the extent to which the Merri Creek growth area nominated for urban expansion in the north-west of the city has two potential concerns. The first is the poor quality of stream condition and water quality already extant. The second, covered in more detail below relates to the expansion into remnant native grasslands. On present planning management, both environmental circumstances are unlikely to be improved by urban expansion.

Figure G45: The transformation of creeks and streams by urban development



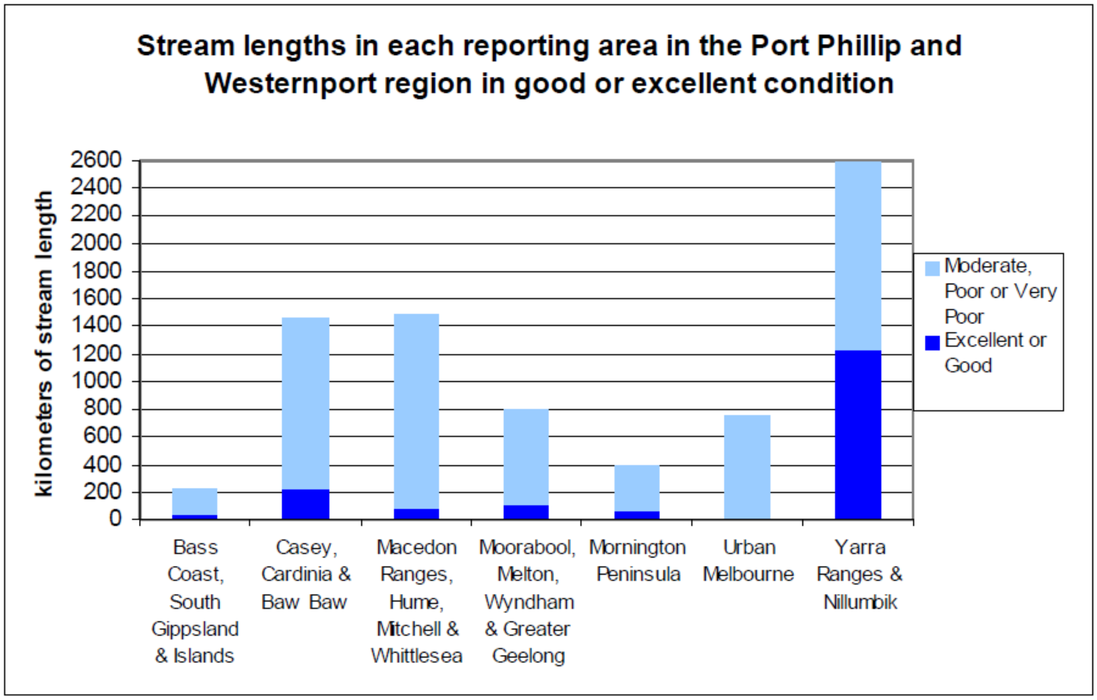
Source: SoE, 2008

The monitoring of water quality specifically and not just the stream condition has found that, in general, and where sufficient length of data records allow, the trends are a positive improvement in urban Melbourne from early 1990s records (Figures G46-49). In particular the reduced nutrient levels and suspended sediments have improved. This would suggest that poor water quality in an urban setting can be reversed to the obvious environmental and biodiversity benefits. The CMA is aiming to have all streams comply with State Environmental Protection Policy (SEPP) guidelines by 2030. At a time of increasing population growth, this goal presents major challenges (PPW CMA 2007); for example, Urban Melbourne only satisfies 35% of the guidelines but is moving in the right direction.

In addition to the impact of population increase in west Melbourne on surface waters and grasslands is the declining water level and water quality in the Deutgam aquifer that underpins the local Werribee vegetable industry, south west of Melbourne. Monitoring of this aquifer over the last eight years has shown increasing salinity. It is believed that because the aquifer is adjacent to Port Philip Bay, intrusion by sea water occurs when water levels are too low; a consequence of over-drawing by irrigators.

Figure G46: River and stream lengths in each reporting area in good or excellent condition

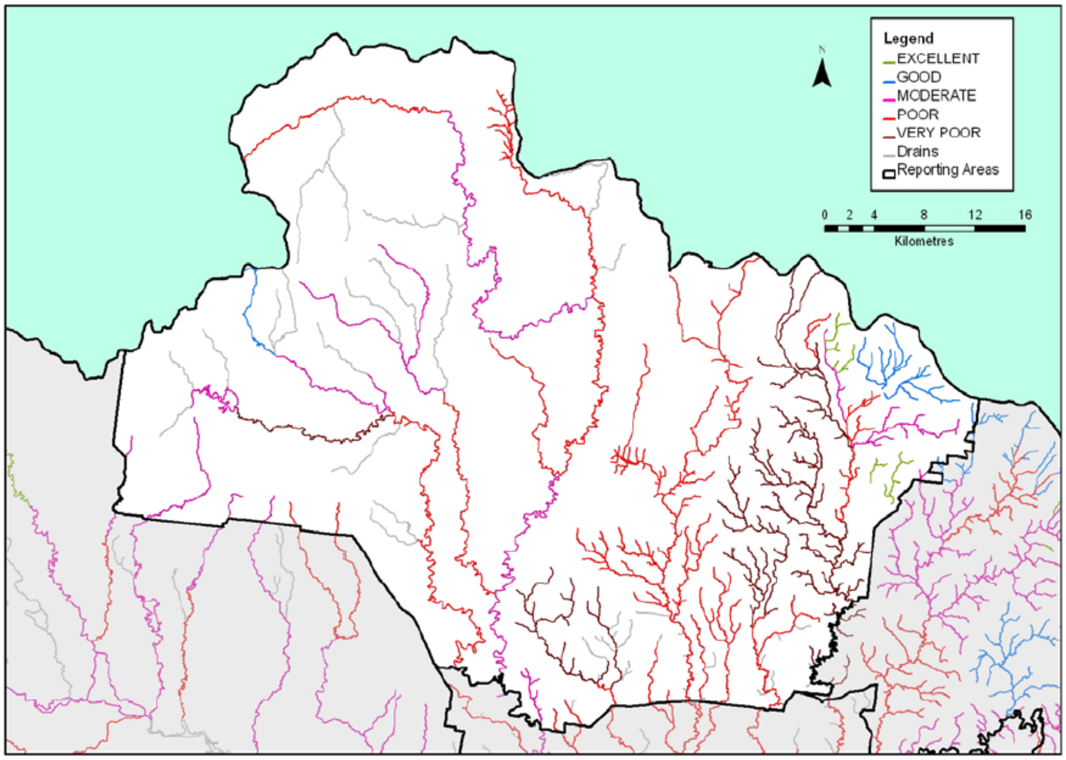
River and stream lengths in good or excellent condition



River and stream lengths in each reporting area in good or excellent condition.
Source: Index of Stream Condition survey 2004.

Source: Index of stream condition survey, DSE, 2004

Figure G47: Stream condition in the Macedon Ranges, Hume, Mitchell and Whittlesea reporting area



Stream condition in the Macedon Ranges, Hume, Mitchell and Whittlesea reporting area.

Figure G48: Water quality trends by parameter

Reporting area	Water quality parameters										
	DO	EC	pH	Turbidity	TP	TN	E. coli	TSS	Lead	Zinc	Overall trend
Mornington Peninsula	↓	-	?	↓	-	↓	-	↓	?	-	↓
Urban Melbourne	↓	↑	↑	↑	↑	↑	↑	↑	-	-	↑
Yarra Ranges & Nillumbik	↓	↓	↓	↑	↑	↓	↑	↑	↑	↓	-
Casey Cardinia & Baw Baw	↓	↓	?	↓	↓	↓	↑	↓	-	↓	↓
Macedon Ranges, Hume, Mitchell & Whittlesea	Insufficient data										
Moorabool, Melton, Wyndham & Greater Geelong	No data										
Bass Coast Sth Gippsland & Islands	No data										

Water quality trends by parameter in reporting areas

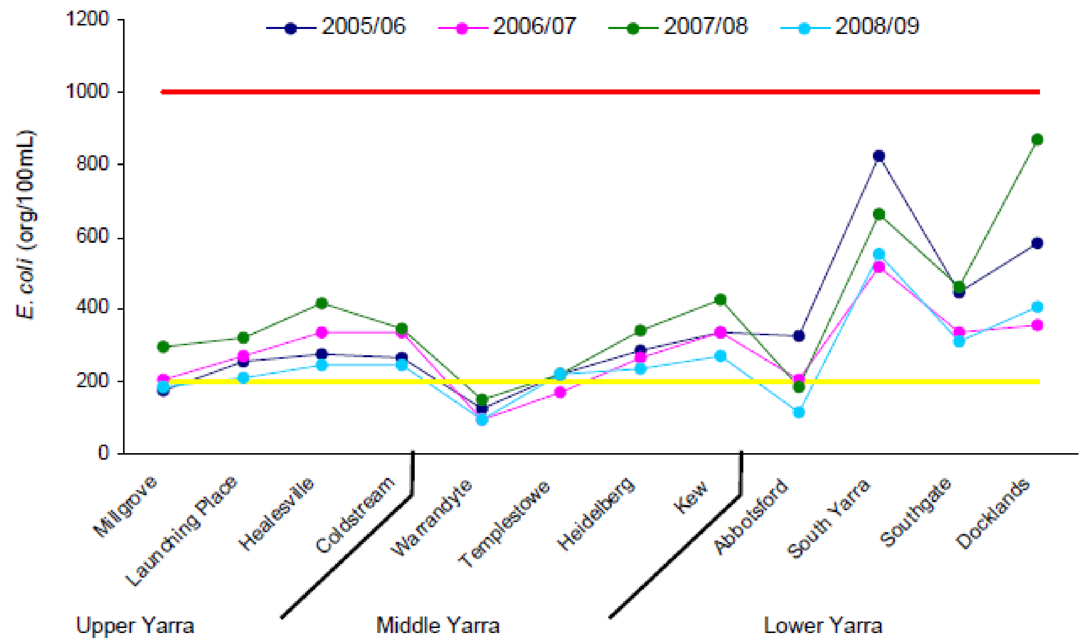
Keys

Symbol	Trend
↓	Declining conditions
↑	Improving conditions
-	stable trend or non-signifi data
?	Unknown

Explanation of terms

DO	Dissolved Oxygen
EC	Electrical conductivity (a measure of salinity
pH	Measure of acidity or alkalinity
Turbidity	Cloudiness
TP	Total Phosphorus – an algal nutrient in fresh waters
TN	Total Nitrogen – an algal nutrient in marine waters
E coli	Bacteria
TSS	Total suspended solids
Lead & Zinc	Metal contaminants

Figure G49: Annual geometric means of *E.coli*



Annual geometric means of *E. coli* for 2005-06, 2006-07, 2007-08 and 2008-09 at sites along the Yarra. Yellow line – SEPP primary contact objective. Red line – SEPP secondary contact objective.

Source EPA 2009
EPA (Environmental Protection Authority, Victoria) 2009. Yarra Watch 2007-2009. Publication 1300. Government of Victoria.

References

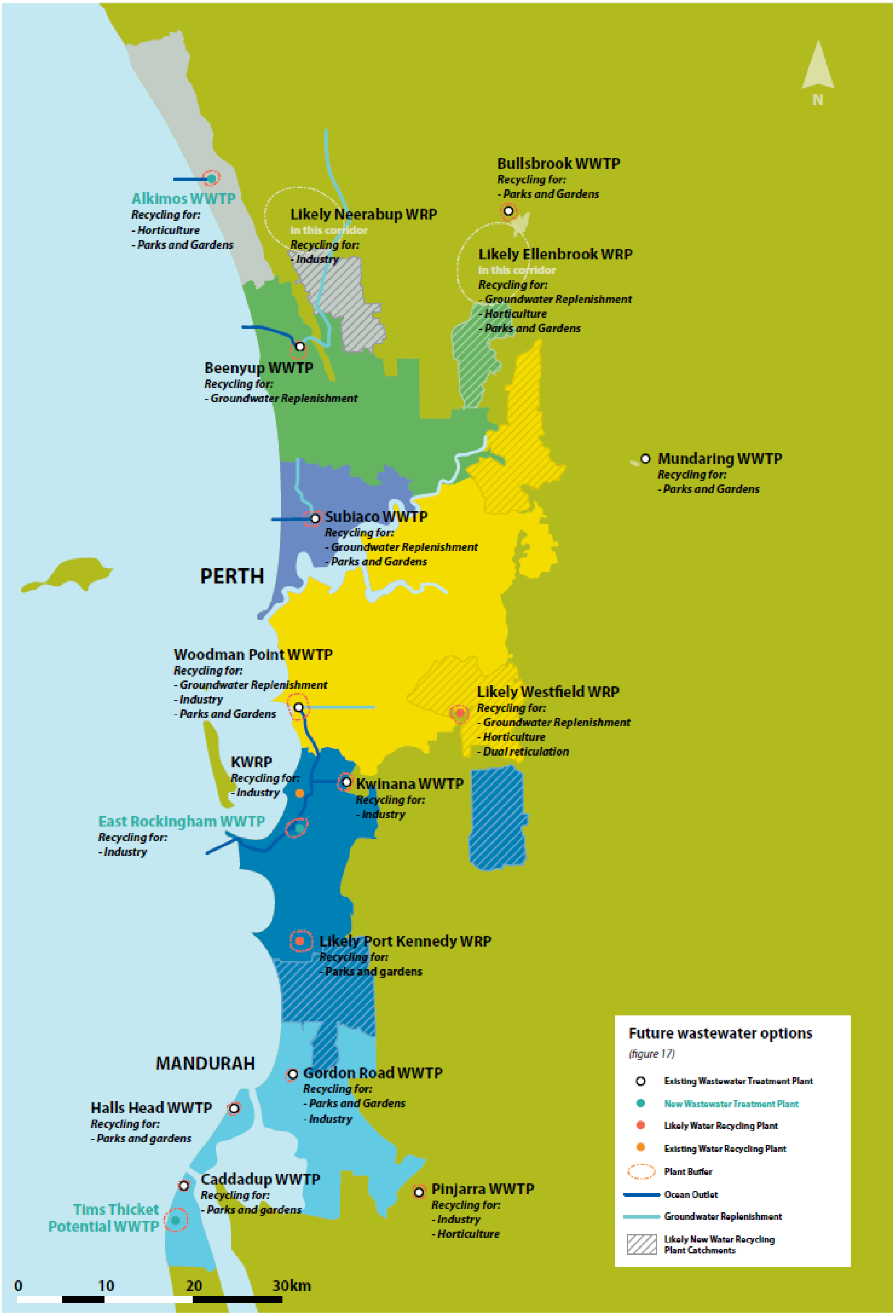
EPA (Environmental Protection Authority), 2009, State of the Environment Report 2009, Government of Victoria

DSE (Department of Sustainability and Environment) 2005, Index of Stream Condition. Government of Victoria.

Perth

In 2006-07 the Water Corporation estimated that about 300 ML of raw wastewater is collected from households, businesses and industry and transported via a network of 9000 km of pipes to treatment plants (Figure G50). In 1994 some 25% of Perth's houses used a septic tank. Because of the leakage from these units into the shallow unconfined water tables of the Perth Coastal Plain, the groundwater carried a diffuse pollution load of nitrogen and phosphorus to the Swan River estuary. A subsequent program to sewer these properties will, when completed, service 100,000 more residences. By comparison, other capital cities might have around 4% of properties on septic tanks. By January 2010, 88,000 homes had been connected (WALGA 2010).

Figure G50: Future wastewater options



Eutrophication is a significant problem in the Swan estuary of Perth. The soils of Perth are sandy, highly porous and low in nutrients. In addition to septic tank seepage, gardeners and farmers add nitrogen and phosphorus for plants to grow. Unfortunately, much of the nutrients percolate through the soil to the groundwater where they end up in the rivers. The results are algal blooms which cause fish deaths and mussel contamination and reduce the amenity value of the water. Small lakes in the Perth urban area such as Lake Monger have recorded phosphorus levels of 0.8 mg/L, well above the ANZECC guideline level for estuaries in the South West of 0.3 mg/L.

Urban development around Mandurah could increase the nutrient load by four times in the Peel-Harvey inlet south of Perth. This is particularly problematic since nutrient loading of groundwater used for drinking can make the water subject to nitrate toxicity.

Continuing eutrophication events are expected which introduces health consequences since midge and mosquito populations thrive in such circumstances, increasing the incidence of viral borne diseases such as Ross River Virus.

References

ATSE (Australian Academy of Technology Science and Engineering) 2002, Perth's water balance -the way forward. ATSE:Canberra

EPA (Environmental Protection Authority), 2007, State of the Environment Report 2007, Government of Western Australia

Waste assimilation

Australians divert on average 52% of their wastes away from land-fill via some form of recycling. Per capita we generated an average of 2080 kg (or just over 2 tonnes) of waste in 2006-07 of which 1080 kg was recycled. This rate of recycling has increased substantially from 6% diversion from land-fill in 1997-98 to 46% in 2002-03. However, total waste generated since 2002-03 has increased by 31% whilst population grew 5.6%. Allowing for improved measurement and recording of waste management during this time, the increase of waste per person is still considerable and would appear to coincide with a significant rise in durable goods ownership and packaging to product ratios (ABS 2007). Table G17 displays how the most recent average is broken down by State and Territory. Of note is the divergent success rate of the different jurisdictions, from 33% (WA) to 75% (ACT), again emphasising the importance of place when disaggregating national average figures for use in policy and planning.

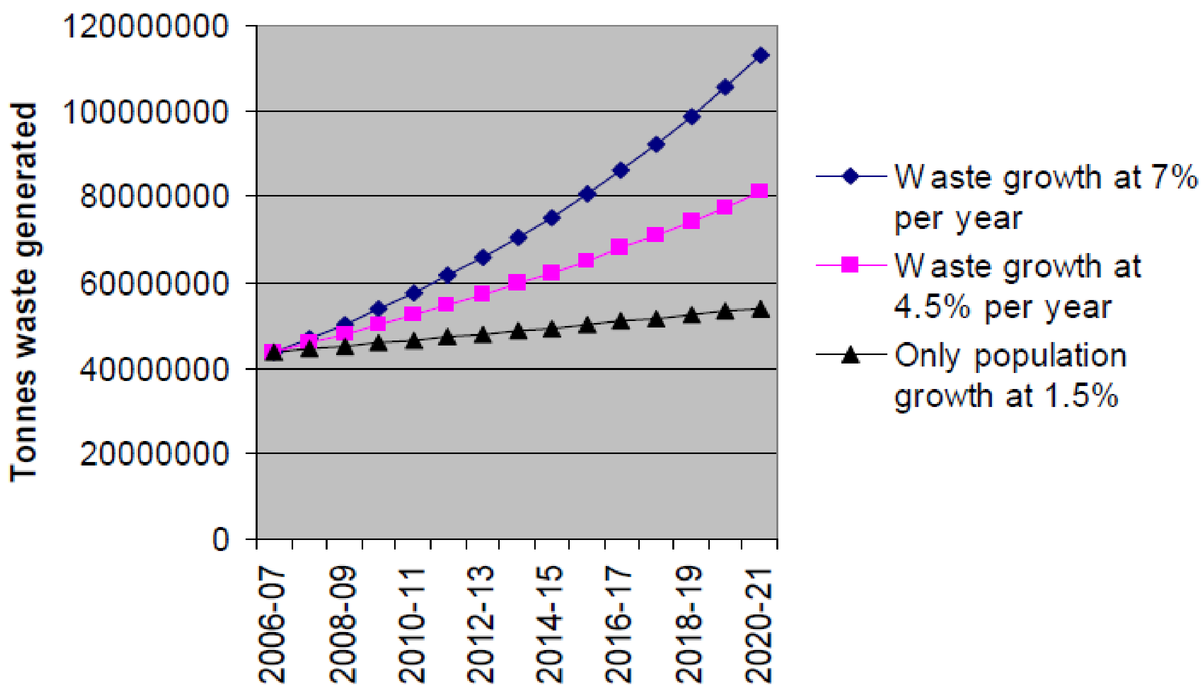
Table G17: Per capita waste generation, recycling and landfill disposal, 2006–07

State / territory	Total waste generated	Disposed to Landfill	Recycled/ Diverted	Diversion rate %	% of total population	% of land area
	Kilograms per person					
NSW	2230	1070	1160	52%	37%	10.41%
Vic	1980	750	1220	62%	28%	2.96%
Qld	1930	1030	900	47%	20%	22.50%
WA	2490	1680	810	33%	10%	32.89%
SA	2090	720	1370	66%	8%	12.79%
ACT	2310	580	1730	75%	2%	0.03%
Tas	-	-	-	-	2%	0.89%
NT	-	-	-	-	1%	17.54%
Total	2080	1000	1080	52%		

Of particular relevance to this report is the Environmental Protection and Heritage Council's (EPHC 2009) projected volume of waste potentially being generated each year by Australians in 2020-21. Making an assumption about growth rates in population of 1.5% per annum (the rate from 2007-09), maintaining the recycling rate of 52%, and continuing the recent growth in waste between 2002-03 and 2006-07 of 7% per annum, total waste in the year 2020-21 alone will be about 112 million tonnes, an increase of 255% in 14 years! If, instead, we assume an annual rate of waste generation of 4.5% that acknowledges waste avoidance, cleaner production and new recycling technologies being widely adopted, the total comes in just over 81 million tonnes, itself an increase of 85% over 2006-07 data of a total of 43.8 million tonnes (Figure 51). At an estimated Australian population of, say, 25.6 million in 2020 -21 (ABS 2009), and an annual increase in waste generation of 4.5%, the average per capita waste load in 2021 increases to 3.16 tonnes, an increase of 52% over the 2006 level of 2.08 tonnes per person, for a population increase of 21%.

The next question is whether we have the spaces available to accommodate landfill without increasing pressure on the natural assets of soil, water quality, biodiversity and productive land uses. The EPHC 2009 Report (p.7) states that '*Australia has sufficient, unused physical landfill capacity in most of the larger urban centre but this may be constrained by social and environmental factors'*. This suggests that the guaranteed increase in Australia's population and its concentration in urban centres will not necessarily run into problems associated with disposal of wastes from our lifestyle and level of population taking the country as a whole. There are however significant differences when regional data is examined.

Figure G51: Comparative waste generation 2006-07 to 2020-21



Problems associated with landfill include the 'Not In My Back Yard' – NIMBY – perception. That is, people who live close to a landfill site find that their location has reduced value in terms of real estate and amenity. Secondly, the true or life cycle costs of waste disposal are not reflected in the prices people must pay through council rates or fees to use landfill or to construct new landfill to dispose of rubbish. This low price means that landfill is a less costly option than recycling, waste processing or waste minimisation activities, which in turn reduces the viability of new 'green jobs' and industries that could otherwise be options for disposal.

References

ABS (2009) Population Projections, Australia, 2006 to 2101, Bulletin 3222.0, Australian Bureau of Statistics: Canberra

ABS (2007) Australia's Environment: Issues and Trends 2007, Catalogue no. 4613.0, Australian Bureau of Statistics: Canberra

Environment Protection and Heritage Council (EPHC) (2009) National Waste Overview, 2009. Commonwealth of Australia: Canberra

Sydney

In 2000 Sydney had virtually run out of putrescible landfill capacity (Wright 2000). There is now only Eastern Creek and Lucas Heights landfill sites within the Sydney Basin with a capacity of about 20 million tonnes, filling at 2 million tonnes per annum. They will be filled by 2016 unless diversion (recycling) rates increase substantially. About 240,000 tonnes per annum of putrescible waste is already diverted to landfill outside the Sydney Basin, collected at Auburn Waste Transfer facility for transport by train to the de-commissioned Woodlawn open-cut mine site at Goulburn south west of Sydney. Even with its present population Sydney has effectively run out of options for cheap waste disposal in landfill. The variety of alternative waste treatment technologies that are in place will shortly become 'economic' options as the landfill option increases in price and therefore markets for their product lines such as compost, recyclable raw materials and energy will become more attractive.

Although Sydney has two new technology resource recovery plants operating and a steady reduction in waste to landfill per capita, there still is an absolute increase in volume of waste destined for landfill. With an expected increase in population of at least 500,000 in the North-west and South-west growth zones by 2020, the existing options for local waste disposal appear to have been used up. The alternative is more expensive transport of waste outside the Sydney Basin via Transfer Facilities that collect waste to enable bulk transfer.

Melbourne

Melbourne has enough putrescible landfill capacity for at least 50 years at current disposal rates in three locations in the north-west part of the metropolitan area. The city has a policy to minimise the number of landfill sites and by 2018 36% will be closed.

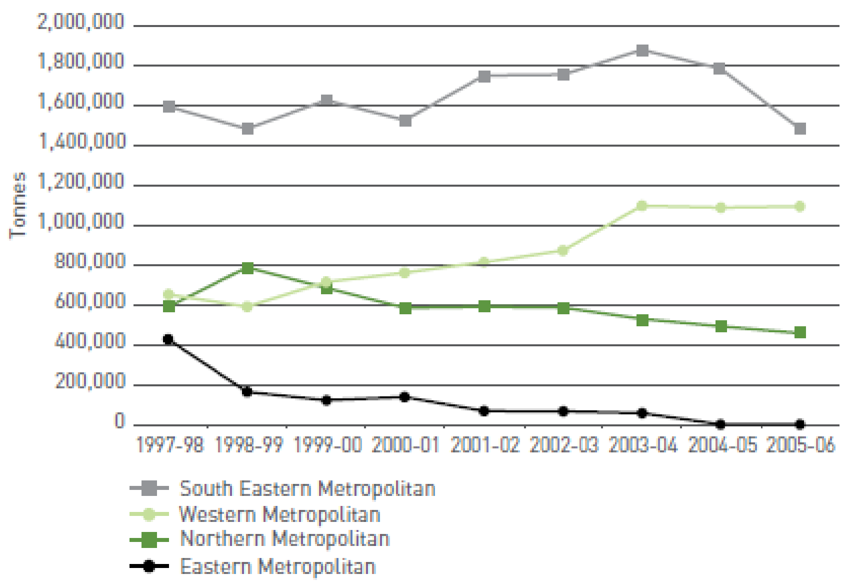
Recent history shows that the volumes of waste delivered to landfill have declined somewhat in three of the four regions of Melbourne, south east, east, and north, but west has increased its landfill disposal (Figure G52). The increase in disposal to western landfill sites is due to transport of waste from eastern suburbs across Melbourne. The disposal volumes to eastern and south eastern landfill sites are declining due to landfill closures but the south-east has current and alternative sites for both putrescible and solid inert wastes that meet foreseeable needs. Over the next ten years this trend will continue. No new sites are available in the region that meets the stringent standards set by the Victorian Environmental Protection Agency (EPA).

Melbourne is fortunate to have quarries being excavated for building and construction materials at six times the current landfill rate and so has a continuing supply of possible sites into the foreseeable future.

Melbourne's rate of disposal to landfill has remained relatively constant in spite of an increasing population over the period since 1997 (Figure G52). This suggests that people are increasing the rate at which they recycle more materials. In 2006-07 the amount disposed to landfill was 2.9 million cubic metres. The airspace or capacity in the south and east was 30.4 million cubic metres and for the north and west, 128.7 million cubic metres. The 'Metropolitan Waste and Resource Recovery Strategic Plan' also records that the Maddingley Brown Coal mine site in Moorabool shire adjacent to Melbourne accepts 'large volumes' of solid inert wastes from metropolitan Melbourne.

Projections of waste to landfill assumed that by 2014 the new technologies for extracting resources from wastes were operational and their impact would reduce overall waste disposal to landfill to 63% of the 2005-06 levels. They also assumed that population would increase according to the latest ABS scenarios to 2030 (i.e. around 5.2 million people).

Figure G52: Recent landfill disposal volumes per annum



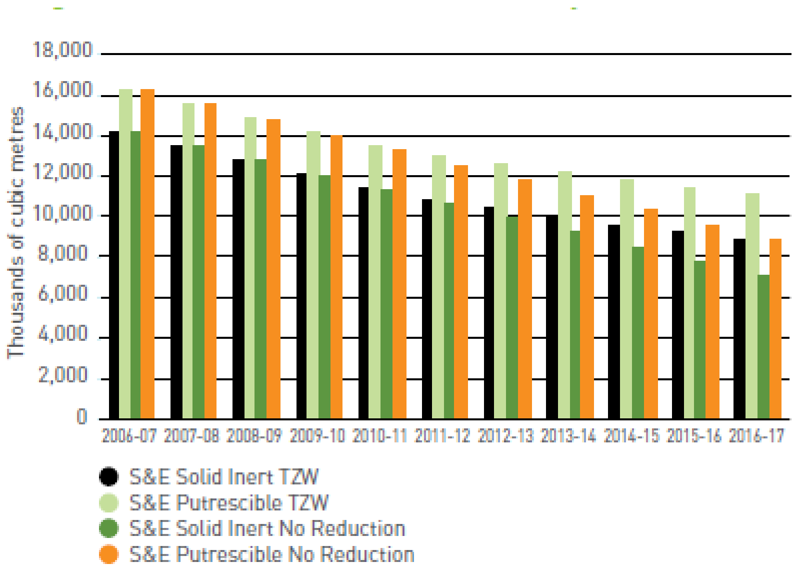
Source: DSE 2009

Figure G53 shows that the projected landfill capacity of south and east sites to 2017 will be less rapidly used up if the Towards Zero Waste (TWZ) government strategy achieves its objectives of increased recycling. In the graph, the higher the bar, the more 'air' capacity that remains, especially after 2014.

There is therefore a substantial opportunity for Melbourne to begin to stabilise its population, implement behaviour change with recycling and resource recovery with technology, and affect the extent to which packaging is minimised so that by 2050 or beyond, Melbourne can achieve a 'steady state' in the relationship between a stable population and its waste streams.

Melbourne is poised to reduce per capita waste generation, increase resources obtained from waste streams and yet has an abundance of sites for landfill able to cope with a scenario population of five million people and beyond in the next 40 years.

Figure G53: South and east landfill availability



References

DSE (Dept of Sustainability and Environment) 2009. *Metropolitan Waste and Resource Recovery Strategic Plan*. Government of Victoria.

Perth

The recycling industry in Perth has increased its volumes in the last three years (Tables G18-G20). However it ranks well behind the other capital cities in terms of its diversion and recycling of wastes from landfill. Table G18 shows that Perth diverts half as much waste from landfill per capita as does Melbourne or Adelaide which have much larger or similar populations and similar extensive urban areas.

Tables G21-23 show how Perth's waste is generated and what proportions go to landfill recently and in 2006/07. Table G21 subdivides this waste profile into sub-regions of the Perth metropolitan area, by capita and household showing some remarkable differences at the local level. Further evidence of landfill potential is shown in Table G22 and Figures G55, G56 and G58. Per capita waste disposal patterns over recent history in Perth are represented in Figure G57, which indicate that increasing efficiencies in disposal per capita are keeping pace with increasing population such that total volumes to landfill are not increasing at a rate greater than population increase.

Perth also diverts a substantial proportion of its recyclable material interstate and overseas (Figure G54) because the local economies of scale do not match the aim of establishing local industries based on recycling wastes. This reality might also explain in part why the recycling rate is much lower than comparable Australian cities.

Table G18: Waste generation and destination per capita, WA, 2006-07

State / territory	Total waste generated	Disposed to Landfill	Recycled / Diverted	Diversion rate %	% of total population	% of land area
	Kilograms per person					
WA	2490 kg	1680 kg	810 kg	33%	10%	32.89%

Table G19: Total volumes of materials delivered to landfill, by material type, WA, 2006-07

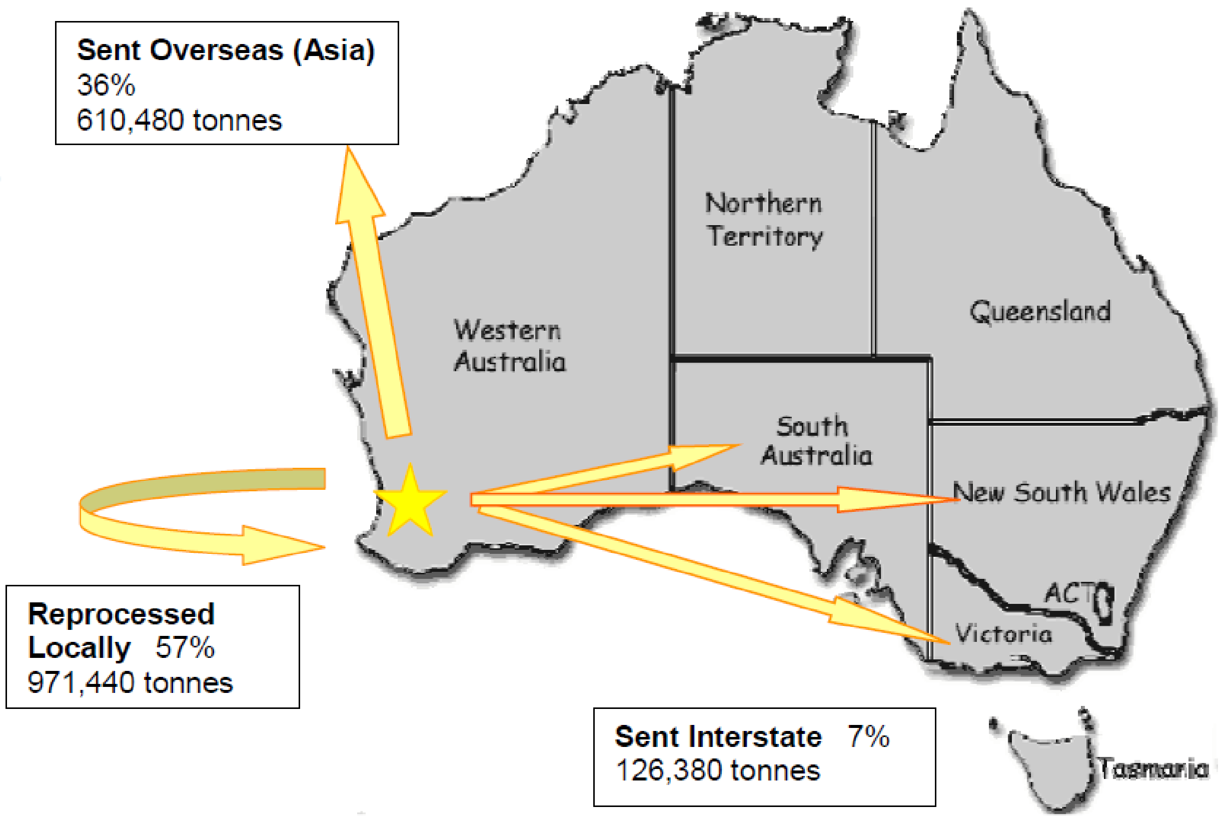
Material Type	2004/05	2005/06	2006/07	% Change
Organics	539,360	578,630	531,340	-8
Metal	276,500	428,860	501,300	17
C&D	333,870	364,370	403,870	11
Paper	185,820	207,690	225,760	9
Glass	18,000	18,000	20,800	16
Plastic	7,130	13,360	18,130	36
Rubber	1,900	5,000	5,550	11
Textiles	1,240	1,560	1,550	-1
Total	**1,363,820**	**1,617,470**	**1,708,300**	**6**

Note: Data from 2005/06 report has been amended to reflect more accurate tonnage recovery

Table G20: Volumes of materials delivered to landfill, by sector, WA, 2006-07

Source Sector	Tonnes
Commercial and Industrial	890,560
Construction and Demolition	409,350
Municipal	408,390
Total	**1,708,300**

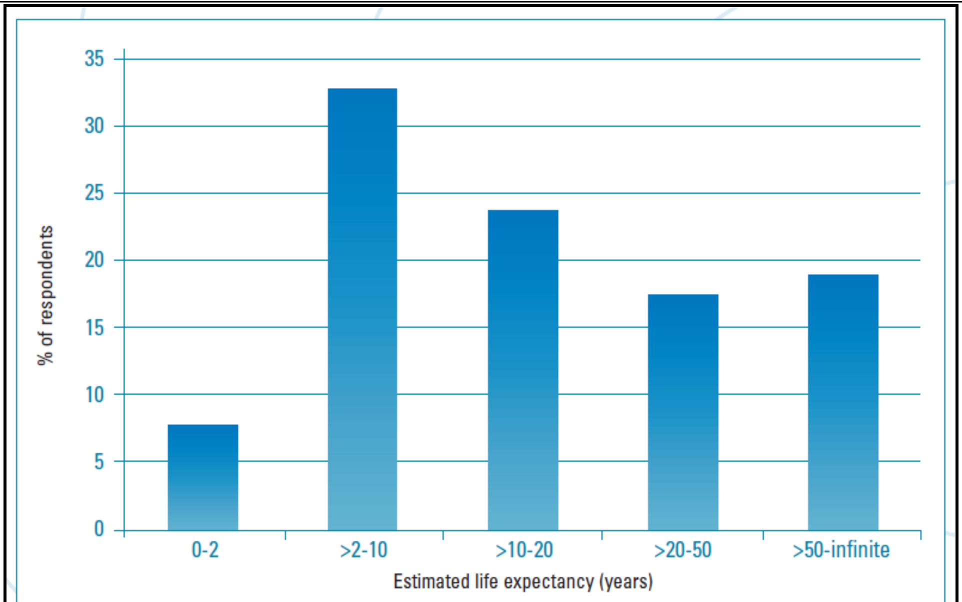
Figure G54: Destination of part of Perth's waste streams, 2006-07



0-2 years	8 %
>2-10 years	33 %
11-20 years	24 %
21-50 years	17 %
>50 infinite	*19 %

**13 (out of 27) of the facilities in the over 50 year category (or indefinite) were transfer stations.*

Figure G55: Estimated life expectancy for landfills and transfer stations



: Estimated life expectancy for landfills and transfer stations

Figure G56: Waste Landfill, Perth Metropolitan Region

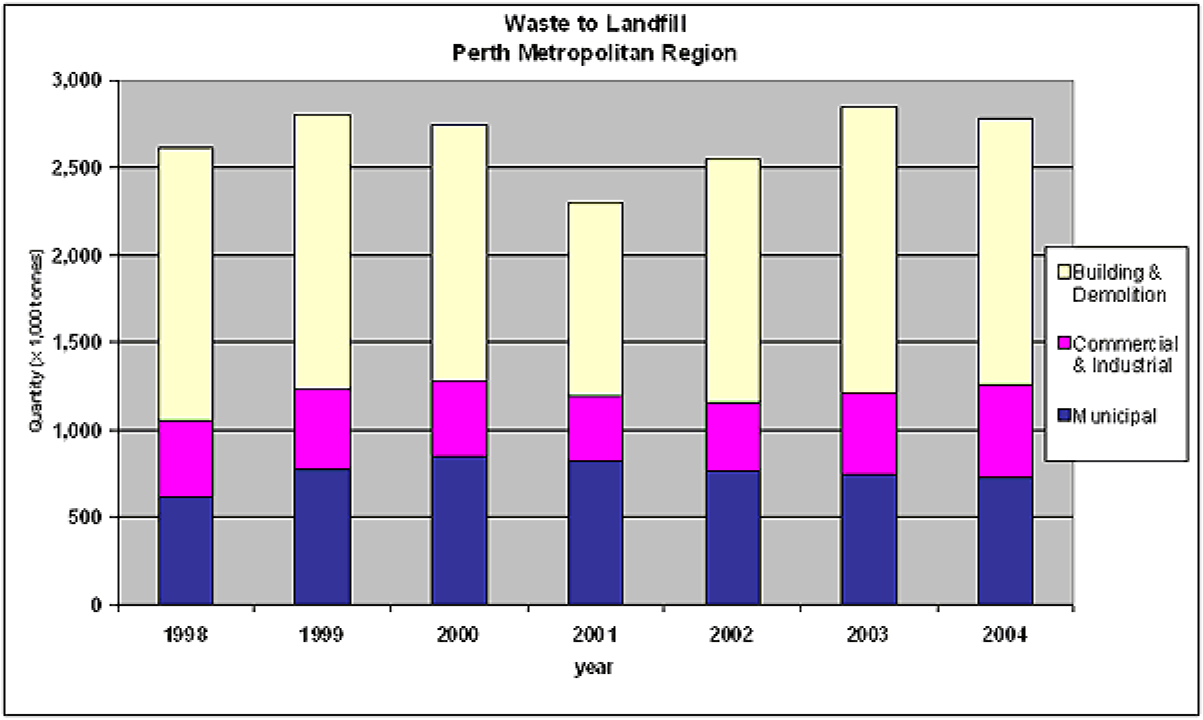


Figure G57: Waste disposed per capita Perth metropolitan region

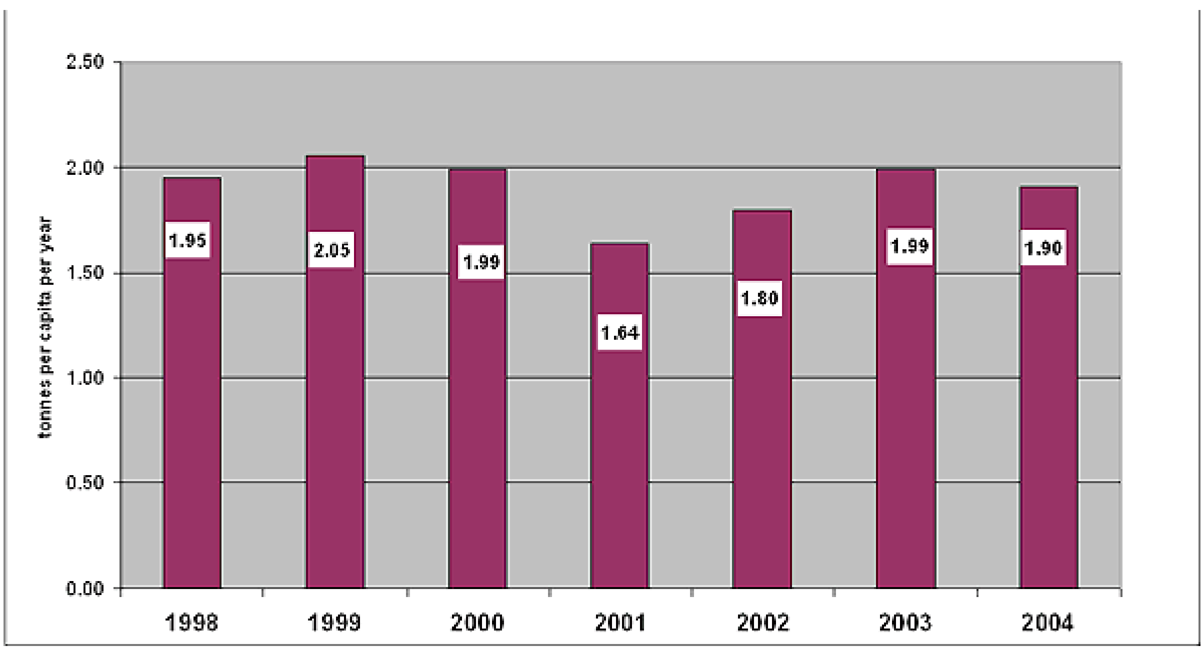
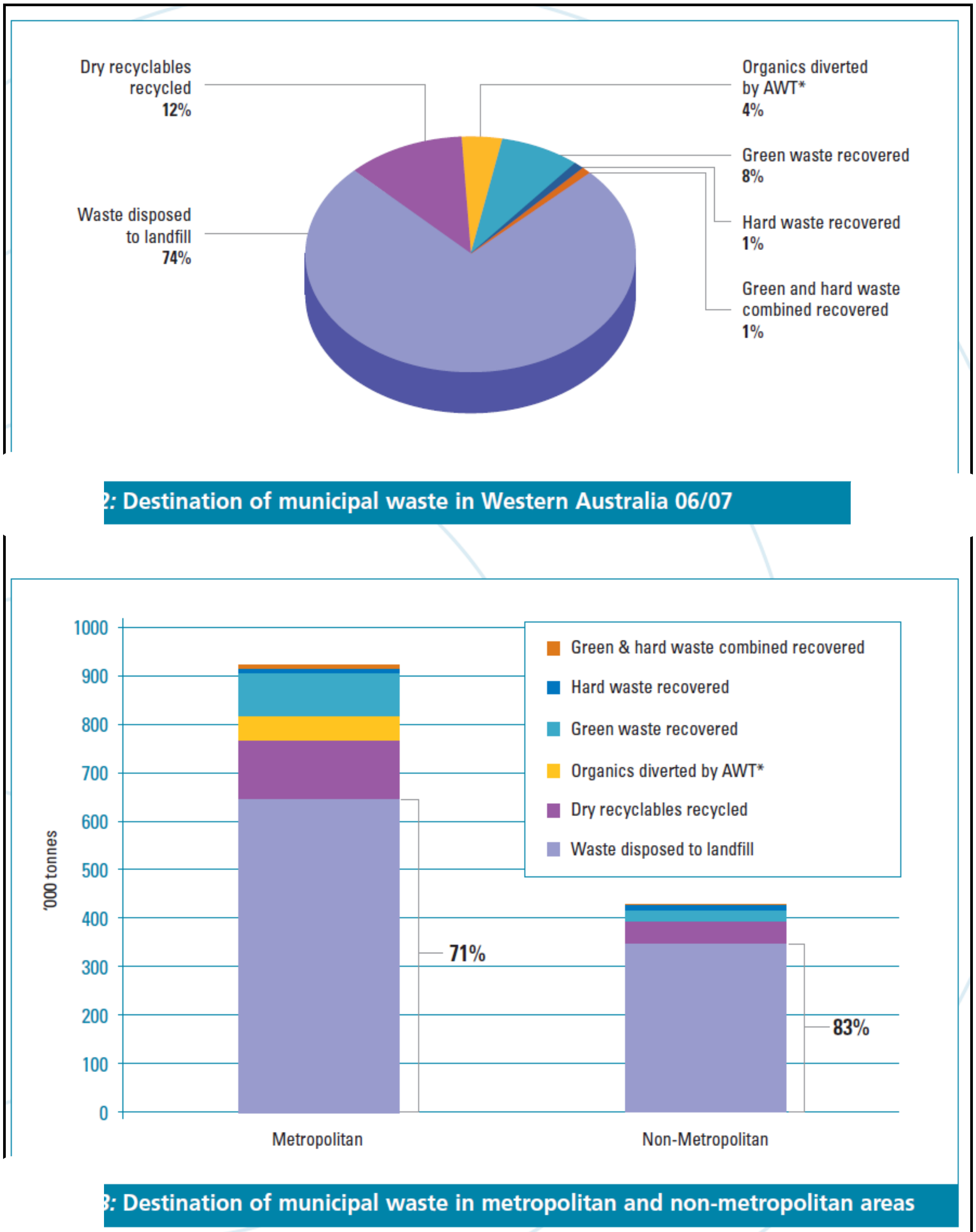


Figure G58: Destination of municipal waste in Western Australia 06/07



References

WALGA (WA Local Government Association) 2010, *2010/11 Pre-budget Submission to the State Government.* WA Local Government Association.

Biodiversity

Sydney

Allied to its location – temperate coastal, floodplain, mountain escarpment – and climate, the Sydney Basin is noted as one of the more biologically diverse regions of Australia. It is, however, badly fragmented. The question arises: Can future planning of urban growth because of inevitable population growth preserve areas of diversity; indeed seek to improve their quality? The Metropolitan Plan says that:

> Sydney can grow while protecting biodiversity values. This Strategy complements existing mechanisms to protect biodiversity by minimising the urban footprint and concentrating future growth in existing urban areas around centres and corridors, thereby avoiding regionally and state significant habitats.

Climate change impacts aside, the proof, as they say, will be in the pudding. The history of landscape and habitat nurture in the Sydney Basin is at odds with such sentiments.

If we do include climate change models, according to the CSIRO study 'Climate Change in the Sydney Metropolitan Catchments' (2007) *149 species, nine populations and 21 ecological communities (i.e., collections of species or habitat) in the Sydney Metropolitan Catchments are classified as threatened or endangered (DEC, 2006).* Essentially this situation is a product of *historical land clearing and alterations of river flows and water extraction*. Climate change and increasing urbanisation, however, are likely to have a further, deleterious impact on these species. Given the importance of the Hawkesbury-Nepean catchment to Sydney's survival, similar impacts should also be expected to affect *the 245 species, ten populations and 32 ecological communities (i.e., collections of species or habitat)* that are currently listed there as endangered or threatened.

In the western suburbs of Sydney, the Parramatta Council, which features as one of the LGAs with a high proportion of NOM, have described the pressures from urban settlement on biodiversity in their area.

> The remaining bushland in Parramatta is accordingly a patchwork of largely unconnected reserves. In all, Council manages 326 hectares of remnant vegetation including wetlands, 158 hectares of remnant canopy trees and 11 different vegetation or ecological communities (eight of State or national significance).

Terrestrial and aquatic biodiversity have both been severely impacted by stormwater volume and quality (including sewerage, fertilisers and industrial pollution). Human impacts in the Local Government Area are on the increase, ranging from the inroads of mountain bikes and over usage of limited natural bushland resources. On a more positive note, dumping appears to be on the decrease due to education programs and Council's green waste service. (Parramatta City Council 2008 p.135)

Worth noting is this comment from the Sydney Catchment Authority Special Areas Strategic Plan of Management (SASPoM) 2007: *Urban growth in south-western Sydney is contributing to increased urban land use in the water supply catchments, and increased potential for adverse impacts on* *water quality and natural values*. They note the fragmentation of areas adjacent to the catchment reserves by transport corridors and the severe impact of the recent drought on water flows and ecological processes in these Special Areas. They plan to increase the amount of monitoring in these areas to prepare for the impacts of population and climate change.

References

ABS, 2009. Australian Social Trends. Bulletin 4102. Commonwealth Government: Canberra.

Armstrong, H. 2009. *New Forms of Green for Mega-Cities: Peri- and Inter-urban Agricultural Space.* Accessed 09/11/2009 www.aila.org.au/lapapers/conferences/2004R/.../Armstrong.pdf

NSW Dept of Planning 2005. *The Metropolitan Strategy*. NSW Government: Sydney. Accessed 07/08/09 http://www.metrostrategy.nsw.gov.au/dev/uploads/paper/introduction/index.html

NSW Department of Water and Energy 2009. *Metropolitan Water Plan 2008 Progress Report*. NSW Government: Sydney

Randolph, B and Troy, P 2008. Attitudes to conservation and water consumption, *Environmental Science & Policy* **11** pp. 441-445

Randolph, B., Holloway, D., Pullen, S. and Troy, P. 2007. *The Environmental Impacts of Residential Development: Case Studies of 12 Estates in Sydney* City Futures Research Centre: Sydney

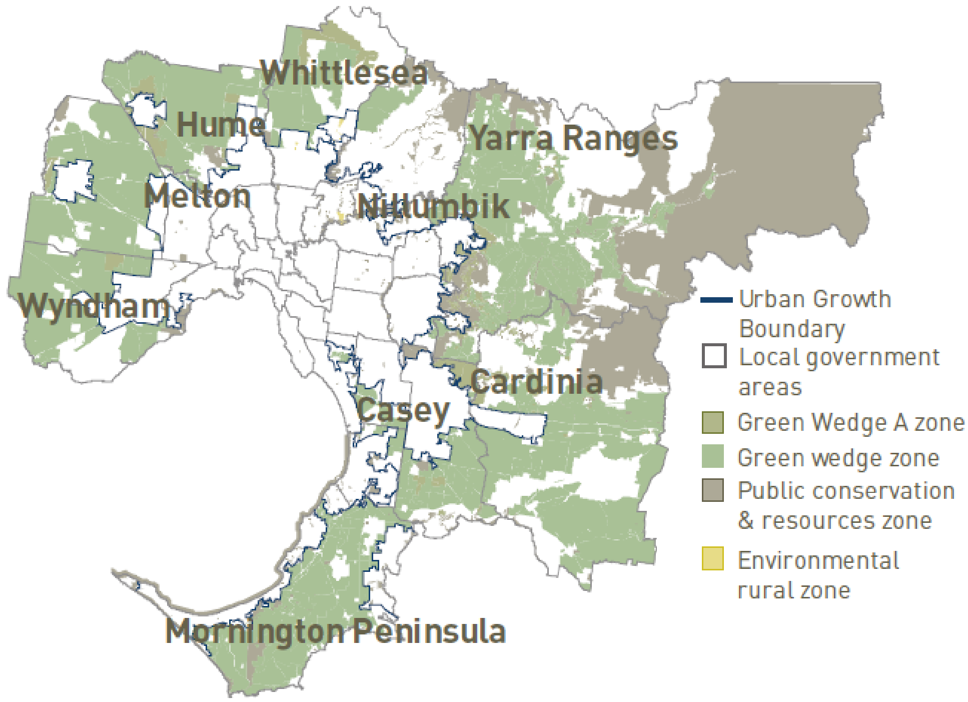
Melbourne

The State of the Environment Report, 2008 (DSE 2008) for Victoria states that the:

'Development of Melbourne, its suburbs and peri-urban regions have placed extreme pressure on the native vegetation of the Port Phillip region. Only one-third of the original vegetation of the Port Phillip region remains and much of this is located in protected water catchment areas outside the city. Natural ecosystems within the Urban Melbourne reporting area (the city and inner suburbs) of the Port Phillip and Western Port CMA have been permanently altered and only 5% of the original vegetation remains'.

Surveys have, so far, counted 296 threatened flora and 128 threatened fauna species around Melbourne. Of these, 95 are listed under the Victorian *Flora and Fauna Guarantee Act (1988)* and 49 are listed under Commonwealth legislation, the *Environment Protection and Biodiversity Act, (1999)*. Figure 59 shows the extent to which Green Wedge Zones and Public Conservation Zones surround Melbourne and Figure 60, more specific areas of environmental importance. A map of threats and environmental condition for Greater Melbourne and surrounds is shown in Figure 61. In particular, Figure 60a provides detail of the Mornington and Westernport Biosphere Reserve established on the outskirts of Melbourne's south-east suburbs. This is especially useful as an alternative governance regime wherein people's built environment is specifically managed to co-exist with their natural environment.

Figure G59: Percentage of local government area in the 4 conservation zones



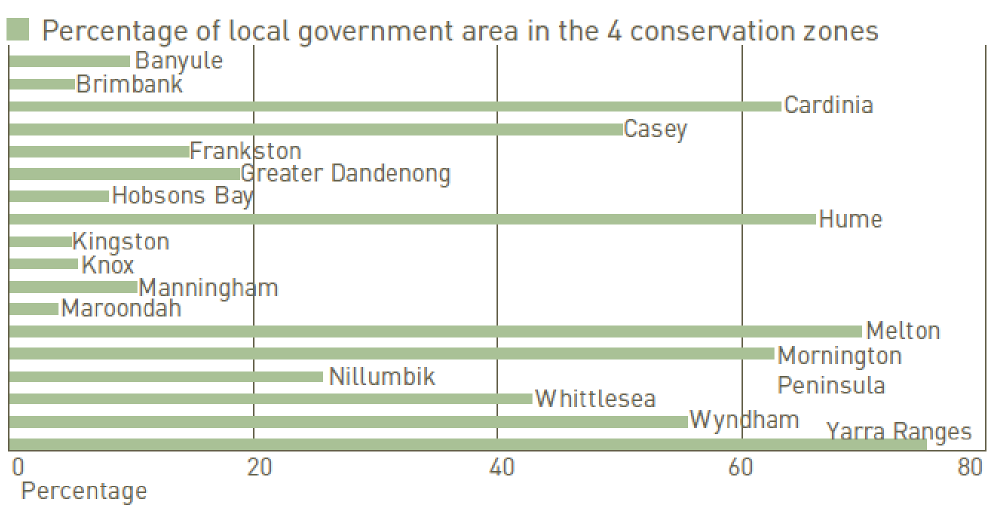


Figure G60: Significant environmental resources and constraints

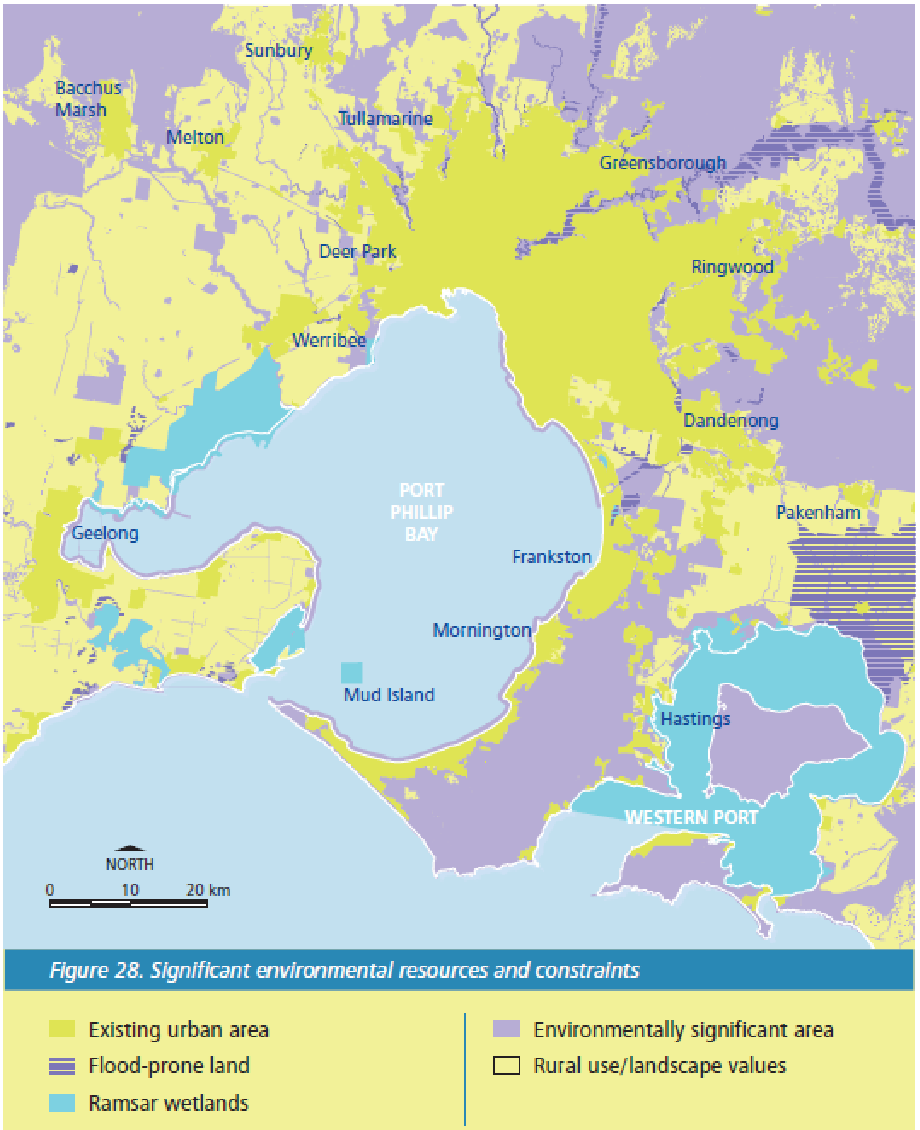
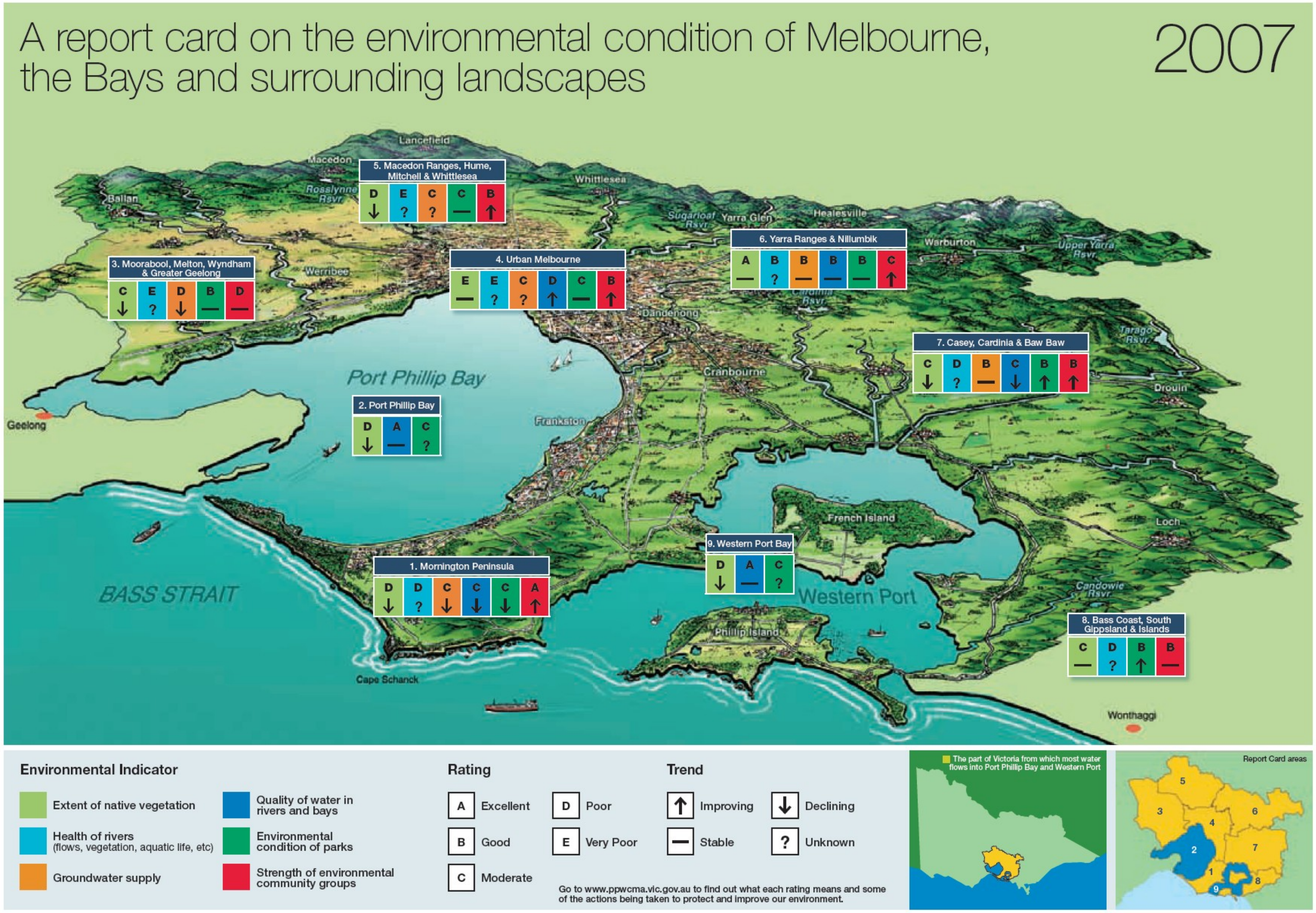


Figure 28. Significant environmental resources and constraints

Source: Department of Infrastructure, Department of Natural Resources and Environment, 2001

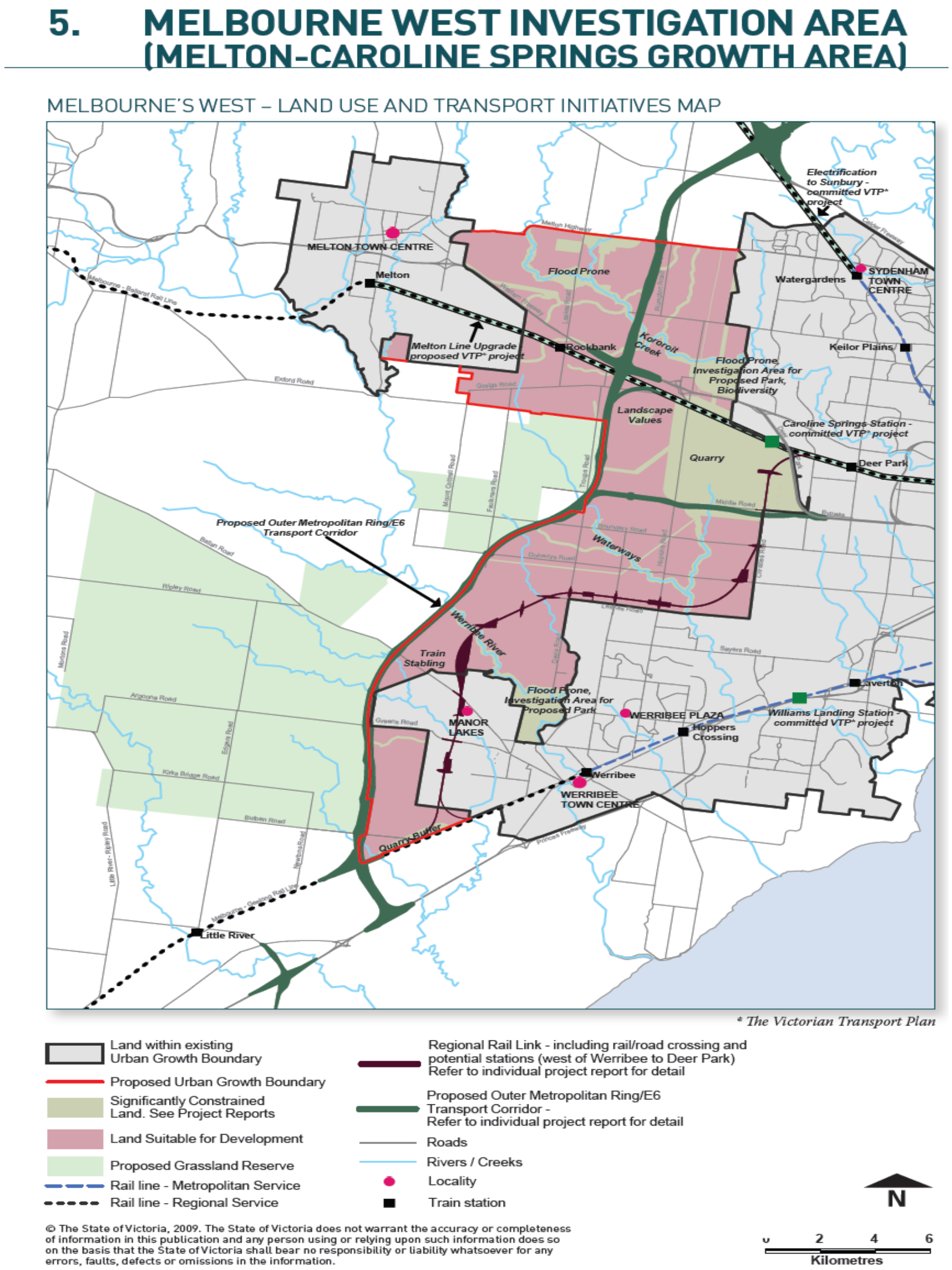
Figure G60a: Mornington Peninsula Western Port Biosphere

Figure G61: A report card on the environment condition of Melbourne, the Bays and surrounding landscapes



There is also continuing concern over the loss of native grasslands in the north and west areas of greater Melbourne, and another 92 species of conservation concern. The native grasslands used to cover about 870,000 ha before clearing for agriculture and settlements occurred, making the remnant patches one of the most threatened species communities in Australia. The Melbourne West Investigation Area includes a declining trend in the extent of biodiversity in the landscape where new urban expansion is planned. However the map below (Figure G62) shows the intent to provide a contiguous block of habitat for the flora and fauna of the endangered native grasslands ecosystem, now just 5% of its pre-European extent in Western Victoria. The map also shows the extent to which other landscape values limit the areas where urban expansion in all its components – transport, services, jobs, housing and recreation – can be located.

Figure G62: Melbourne West investigation area (Melton-Caroline Springs growth area)



Perth

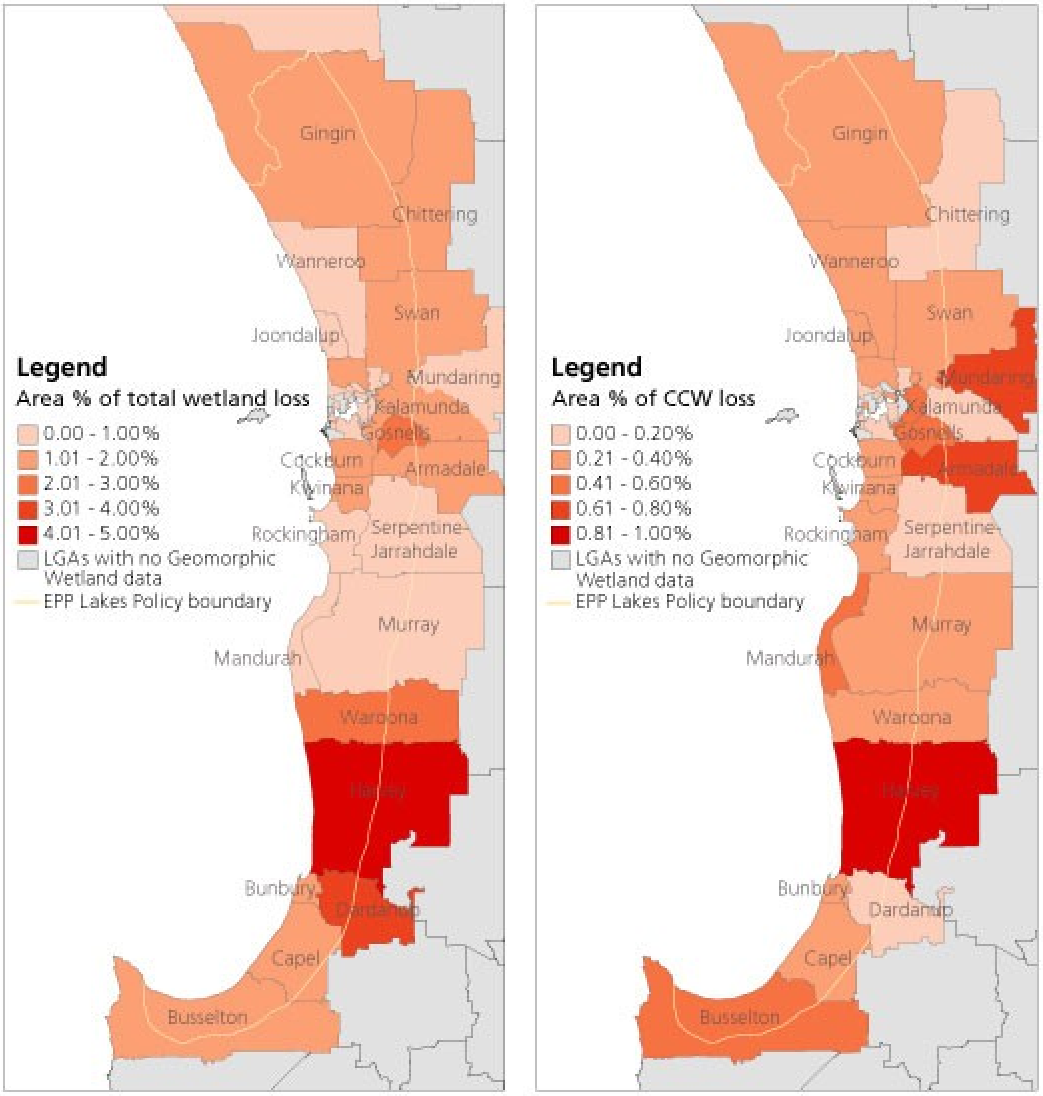
The South West region of WA is one of a very few (34) global locations known as 'Biodiversity Hotspots', so called because they represent concentrations of a large number of species. In the 26 bio-geographic regions there are more than 11,500 higher order plant taxa and 4,446 vertebrate animal taxa, some of which form the highest proportion of rare and endangered species in a single region in Australia (WALGA 2010b) Of the 8,000 vascular plants that are known to occur in this region, 1,500 (19%) are found within the Perth Metropolitan area.

Perth is home to over 70 species of reptile, mostly lizards, which is the most for a large city anywhere in the world. Interestingly there is still enough habitat to support kangaroos, wallabies, water rats, bats and possums. However, the rate of clearance has increased recently, from an average of 900 ha of native vegetation per annum (1998 – 2004) to 15,000 ha in 2005-06 alone. The majority of this clearance is for new suburban development. In 2001 the Perth Metro region contained 266,000 ha of native vegetation of which 191,000 ha is protected from development. Similarly, private land contains 58,000 ha of native vegetation of which only 12% or 6,960 ha is zoned for urban expansion (Weller 2009).

Approximately 80% of the Perth region wetlands have been lost to the city leaving a series of remnants that total 80,000 ha in 2001 (see Figure G63). Some of these wetlands are categorised as suitable for development depending on their state of degradation. Approximately 1,500 ha are being drained or developed each year (SoE 2007). There is still some native riparian vegetation of about 10,000 ha. A plan to link remnant habitats by 500 metre-wide strips of revegetation and fenced-off areas is currently underway by the Perth Biodiversity Project.

Degradation includes *altered catchment water balances, drainage, development, salinity, acidity, pollutant discharge, dieback, weed encroachment and insensitive fire management* (SoE 2007). The impact of urbanisation includes *areas where wetlands have been excluded from conservation by poor town planning, excessive clearing has been allowed, or there has been inadequate buffer distances, poor drainage planning or stormwater management. Remaining wetlands in major urban and regional centres undergoing growth are facing significant developmental pressures due to increasing land values and the need to enhance supporting infrastructure (e.g. roads, railways, pipelines)* (SoE 2007). Some landowners are unaware that ephemeral wetlands count as much as permanently filled swamps.

Figure G63: Percentage of wetland loss, Perth Costal Plain



In terms of the impact of extraction of groundwater from the Gnangara Mound, a Water Corporation study in 2005 found that there was virtually no change to the existing risks to wetland or phreatophytic species dependent on groundwater ecosystems, with either greater or reduced extraction volumes.

Air quality

Sydney

The South-Western region of the Sydney Basin is more affected by air pollution than other parts of Sydney. According to the WSROC Submission on the Impacts of Air Pollution on Health in the Sydney Basin (WSROC 2006), *[t]ypical of these conditions is the development of local winds in response to terrain features. In particular, the Blacktown ridge separates the Hawkesbury basin from the eastern half of Sydney. At various times during the day, air pollutants may become trapped within the Hawkesbury Basin.*

Table G23 below provides evidence of the complaints received about air pollution by the EPA in 1998-99. The LGAs listed are locations with high ratios of people born overseas.

Table G23: Complaints to the EPA Pollution Line regarding air quality in Western Sydney 1998/1999.

Council Area	No. of complaints	Total pollution complaints	Air quality complaints as a % of total
Baulkham Hills	92	167	6%
Blacktown	87	168	52%
Hawkesbury	202	281	72%
Penrith	34	120	28%

The two main pollutants are photochemical smog and brown haze. Cars are the main source of pollutants, with the number of cars exceeding population growth. The majority of car journeys are within the Western Sydney area for both employment and leisure (WSROC 2006):

> Currently Australian cities and in particular the fringes of these cities are highly car and oil dependent. In Western Sydney the private motor car is used for the vast majority of trips, 76% for work and 71% for all trip purposes. While Sydney's annual total vehicle VKT increased on average 2.3% each year from 1991 onwards, the patterns were geographically uneven – with a 23% increase in outer and south-west Sydney compared with a 10% decline in inner and eastern Sydney.

This area of Sydney has experienced substantial population growth and greenfield development without adequate provision of public or mass transit facilities. Increased health problems are therefore indicated for this region:

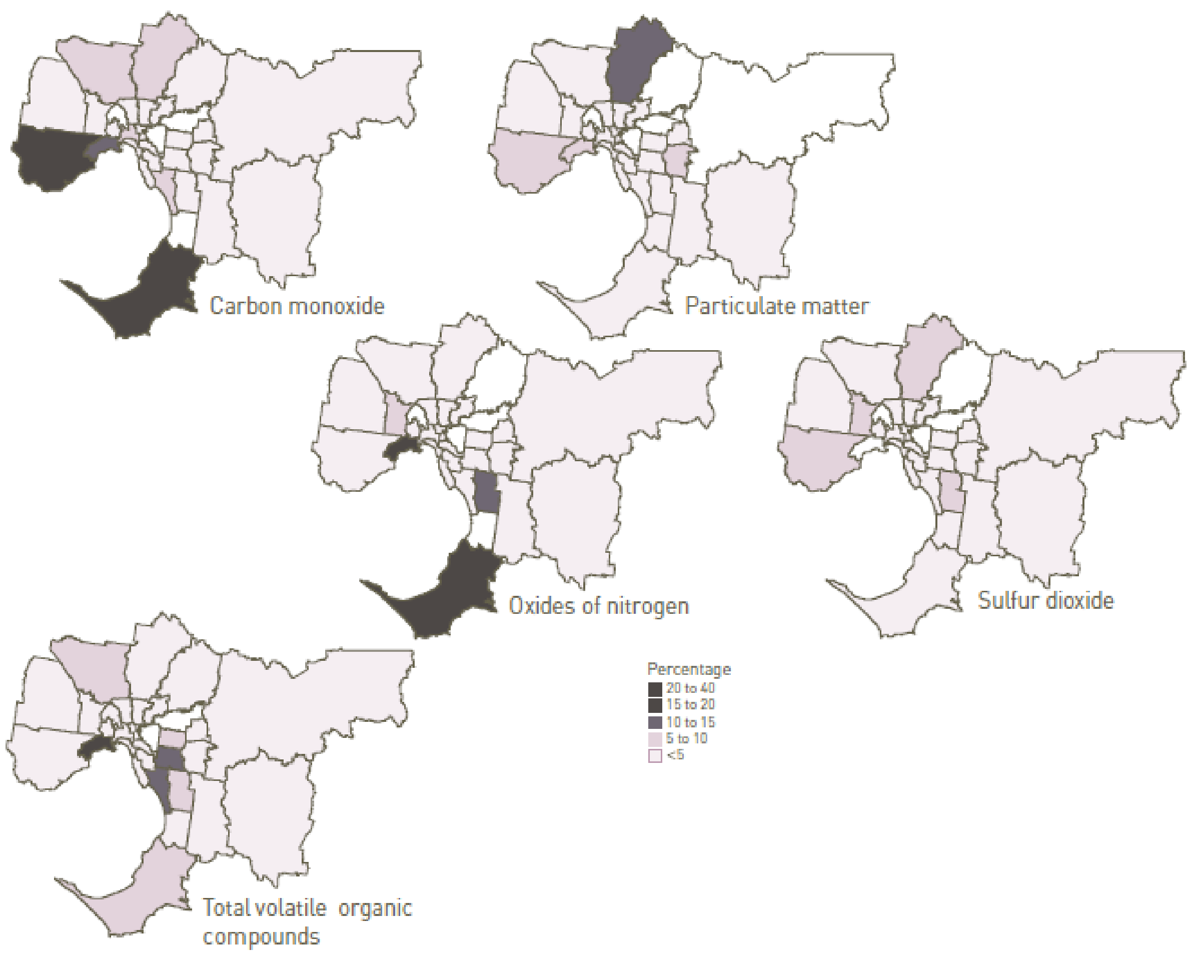
> NSW Health have advised the DEC that elevated levels of ozone are associated with increases in mortality, hospital admissions, respiratory symptoms and decreases in lung Some sub-groups are particularly susceptible, such as asthmatics.

Melbourne

According to the Victorian EPA the two main air pollutants in Melbourne are particulates and ozone in smog. Sources of these pollutants in urban areas are vehicles, industry and wood combustion heaters in winter. The distribution of air pollution geographically follows a local eddy produced by winds from the west and south being blocked by the hills to the north and east of the city. Pollutants emitted from industrial plants primarily in the west are carried east and then south over more populated regions. The afternoon sea breeze will also carry pollutants back over the city to the north that may have been emitted by vehicles in the morning, transformed by interaction with sunlight and returned to the city in the late afternoon.

Melbourne abuts forested landscapes of catastrophic fire danger in summer to which recent events in 2009 and 2006 will testify. Bushfires produce very large quantities of particulates which are responsible for the majority of air pollution events recorded in excess of healthy levels. Otherwise, in winter, wood fires can contribute up to 60% of particulate matter. Vehicles contribute (2004 data) 83% of carbon monoxide, 41% of hydrocarbons and 63% of nitrogen oxides into Melbourne's air. Other indicators of air pollution include sulphur dioxide and total volatile organic compounds. The map below (Figure G64) shows how these substances are distributed around the Melbourne airshed.

Figure G64: Distribution of selected emissions as percentage of Melbourne's total (2004)



Source: DPCD 2006

In a comparison of Melbourne's particulate air pollution with cities internationally and locally (see Figure G65) the EPA Report 'Victoria's Air Quality – 2006' (EPA 2007) found that

Melbourne's particulate pollution was: similar to Sydney and Brisbane; lower than US cities Los Angeles, Phoenix and Minneapolis (but note that US data excludes extreme events such as bushfires); and lower than London, Berlin, and Lisbon (see Table G24 below for population comparisons).

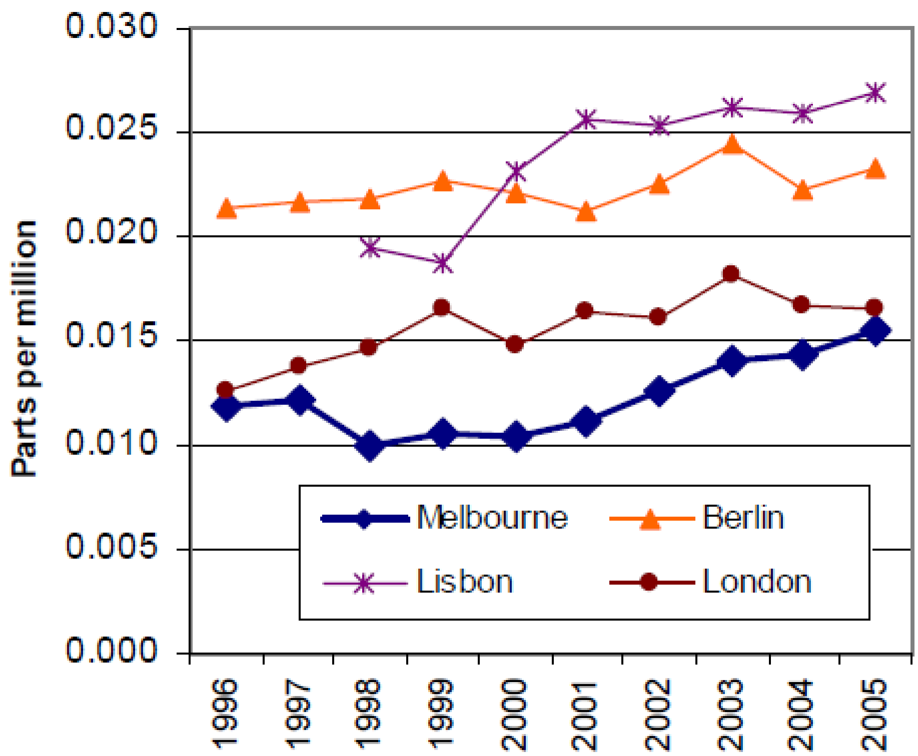
Furthermore, in a similar comparison for ozone (smog) pollution (Figures G62 and G63), the report found that Melbourne's ozone pollution was: generally lower than Sydney and Brisbane; equivalent at peak levels to Minneapolis but lower than Los Angeles or Phoenix; and better or about the same as its European comparators.

The final Figure (G64) in this series shows the impact of different sources of particulate matter on air pollution readings across Melbourne in 2006. In particular, the impact of large bushfires is clearly evident.

Table G24: Comparison cities

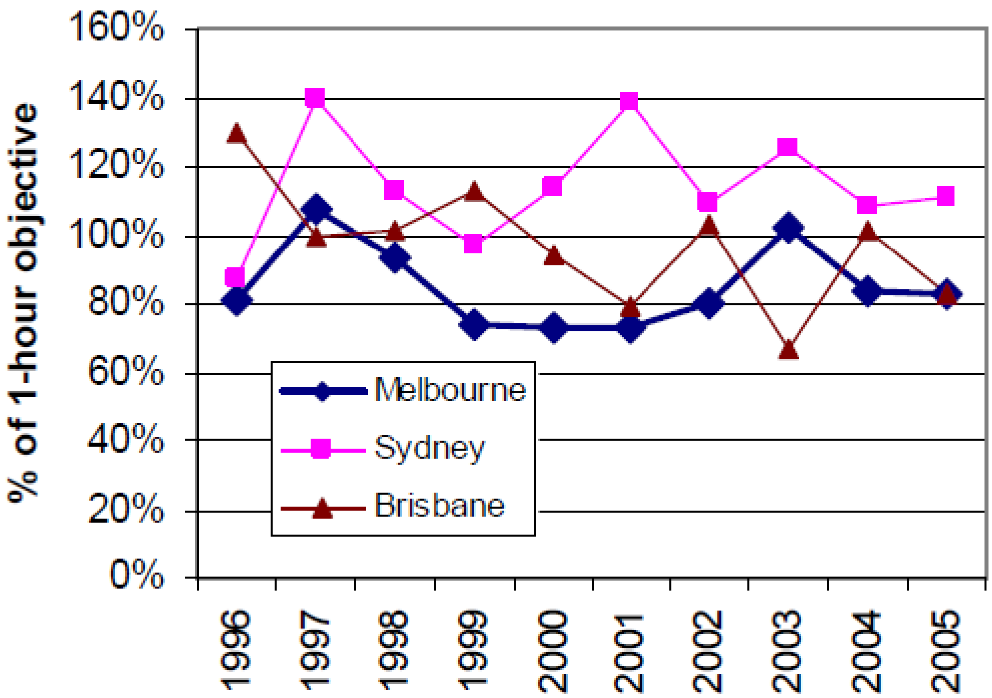
City	Population
Australian Cities	
Melbourne	3.7 million
Sydney	4.3 million
Brisbane	1.8 million
US Cities	
Los Angeles, California	9.5 million
Greater Phoenix, Arizona	4.0 million
Greater Minneapolis, Minnesota	3.2 million
European Cities	
Greater London, England	7.5 million
Berlin, Germany	4.2 million
Lisbon, Portugal	2.9 million

Figure G65: Particulate pollution comparison with overseas cities



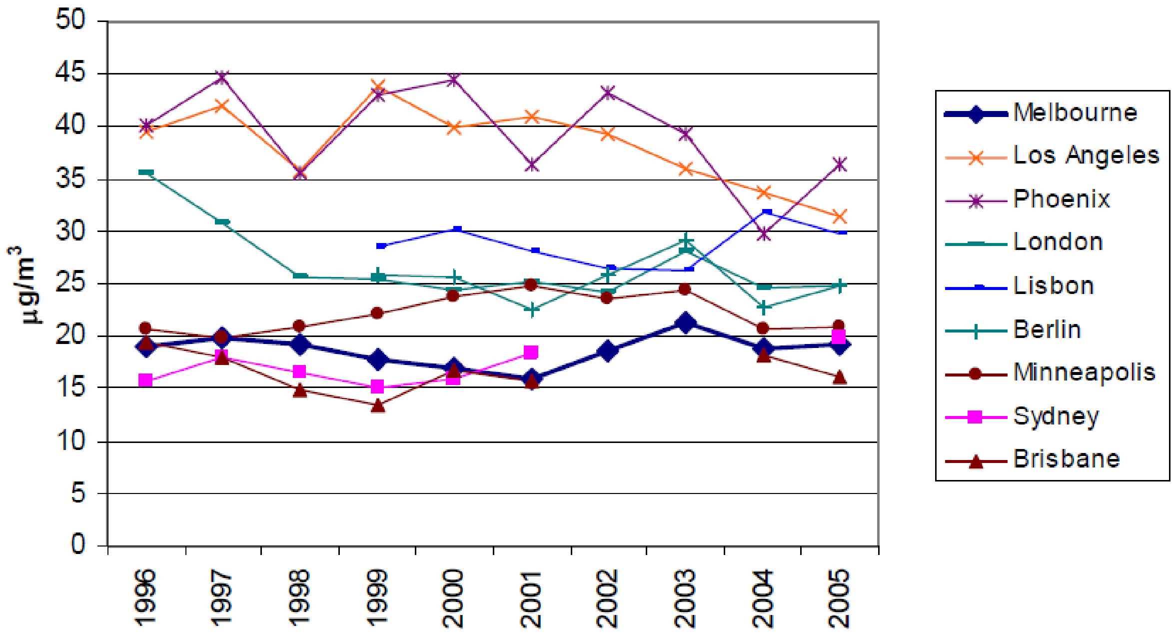
Source: EPA 2007

Figure G66: Ozone pollution comparison



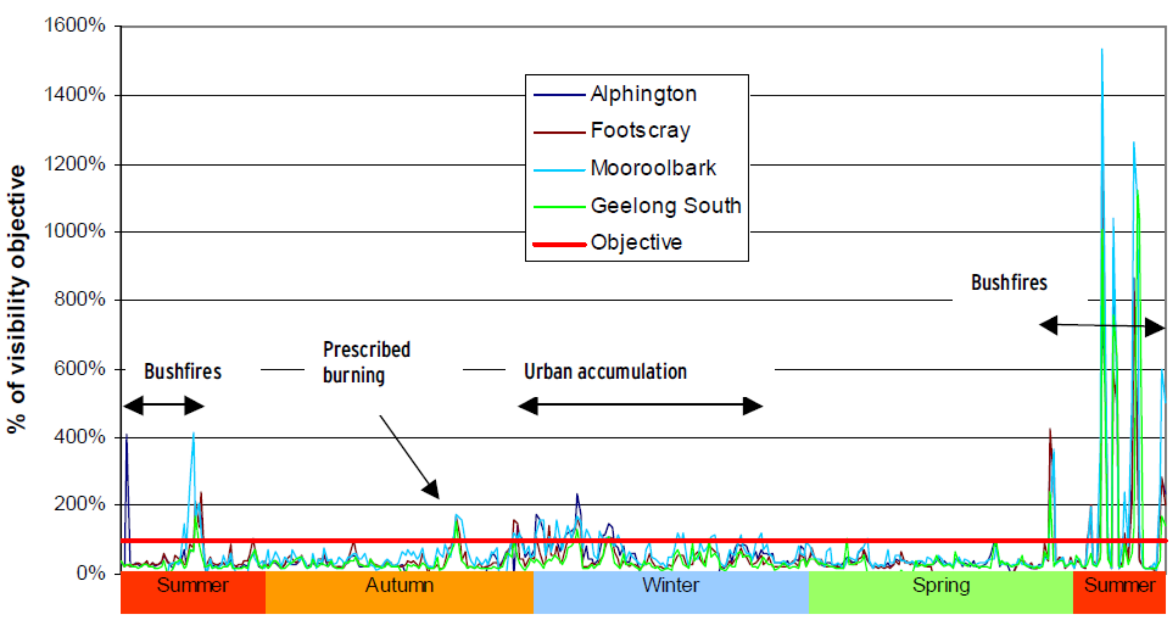
Source: EPA 2007

Figure G67: Ozone pollution comparison



Source: EPA 2007

Figure G68: Visibility as measured by daily maximum airborne particle index at selected stations in 2006



Visibility, as measured by daily maximum airborne particle index at selected stations in 2006

Reference

EPA (Victorian Environment Protection Authority) 2007, *Victoria's Air Quality – 2006*, Publication 1140. Government of Victoria.

Perth

Perth's air shed is perceived to be of 'good quality' by residents and experts alike (EPA 2007). The overall changes reflect a positive impact on air pollution sources bearing in mind the substantial increase in Perth's population over this period (see Table G25).

Table G25: Main air pollutant trends

Pollutant	1992-93 to 1998-99	2000 to 2006 Trends
NOx	↓ 28%	Steady/slightly improving
Particulates	↓ 58%	PM 10 steady; PM 2.5 deceasing average per annum; peak values steady
SO_2	↓ 3.6%	Generally steady
CO	↓ 1%	Improving
Total Organic Compounds	↓ 14%	
Lead	↓ 88%	Improving
Ozone (smog)		Steady/slightly improving

However, the impact of a rapid increase in Perth's population, land clearing, a drying south west and more frequent fires and dust storms suggests that air pollution may become more of a problem in the near future. The sources and categories for the 1990s comparisons are illustrated in Table G26.

Table G26: Change in annual estimated emissions in the Perth airshed between 1992-93 and 1998-99.

	Oxides of nitrogen (NO_x)	Particulates (PM_{10})	Sulfur dioxide (SO_2)	Carbon monoxide (CO)	Total reactive organic compounds (ROCs)	Lead
Motor vehicles (on road)	22%	18%	36%	-2.3%	-27%	-88%
Industrial and commercial sources	28%	262%[a]	-6.1%	81%	-52%	
Biogenic and natural sources	0%				0%	
Area-based sources (not included elsewhere)	169%	0.5%	514%	-2.2%	13%	
Total	28%	52%	4%	-1%	-14%	-88%

The actual graphs for particulates matter (PM) measured in the 2000s are provided below. Both are subject to significant temporal variation so care should be used in making definitive statements; but it does appear that particulates are decreasing, especially PM2.5. Where exceedances have occurred for PM10 there was a bushfire or controlled burn that was the source of the particulates.

Figure G69: PM measured in 2000s – PM10

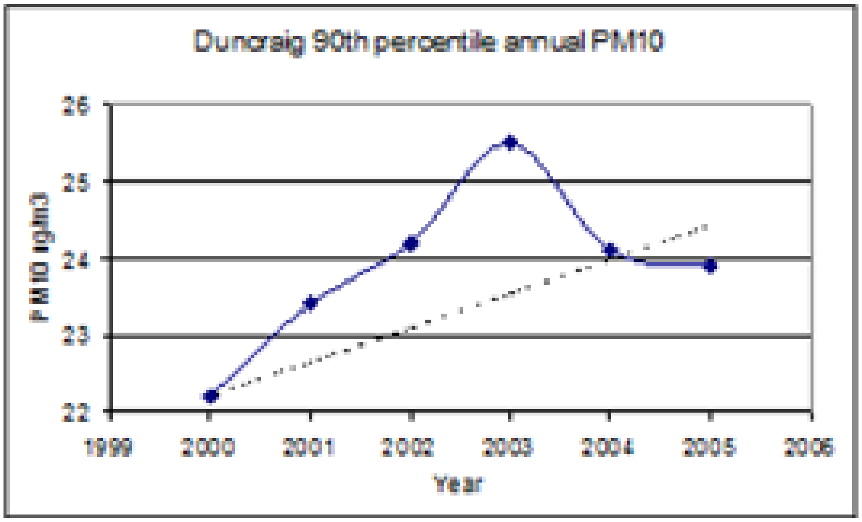
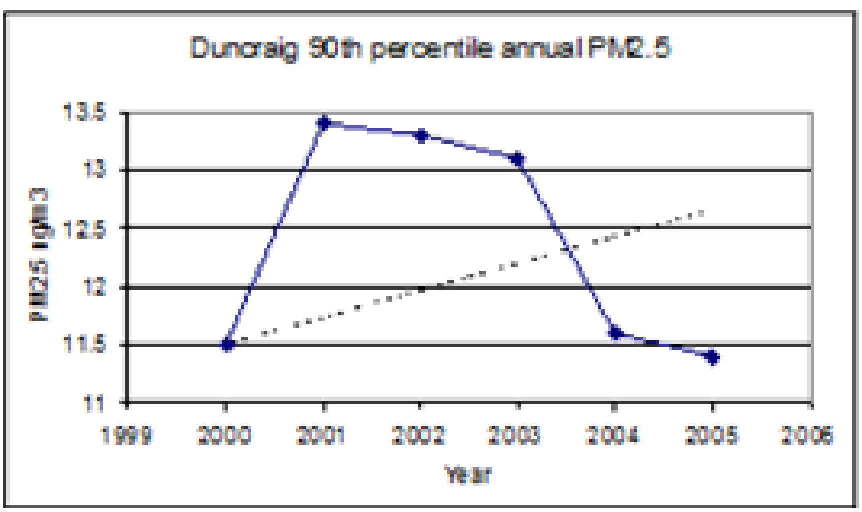


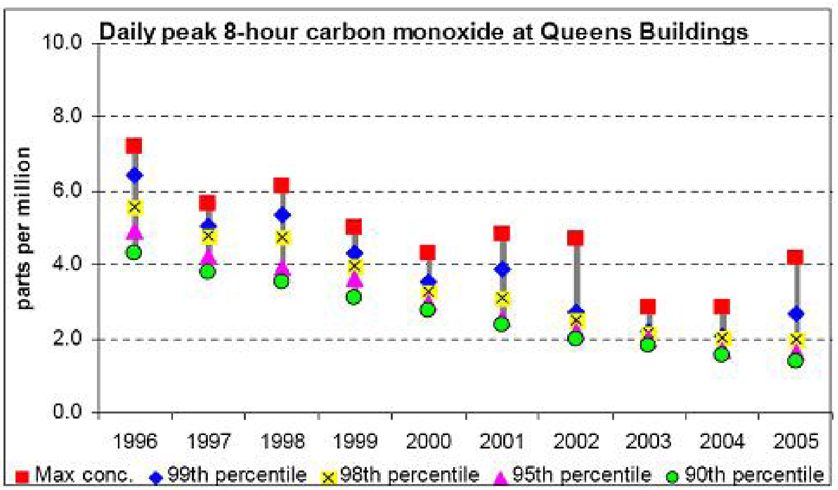
Figure G70: PM measured in 2000s – PM2.5



Source: EPA, 2007

The clean up of car exhaust by the introduction of unleaded petrol appears to be reducing the incidence of carbon monoxide in the CBD over the period despite quite substantial increases in vehicle ownership and congestion in the CBD (Figure G71) (SoE 2007).

Figure G71: Daily peak 8-hour carbon monoxide at Queens Buildings



Source EPA 2007

References

EPA (Environmental Protection Authority), 2007 *Perth Air Quality Management Plan: Five-Year Review*. Government of Western Australia.

Traffic congestion and transport infrastructure issues

Sydney

Glazebrook's (2009b) Transport Plan for Sydney 2030 describes the current situation of motorised vehicle movement in Sydney. The following are excerpts from the Summary document:

- Sydneysiders make 15.5 million trips on an average weekday, at a rate of 3.8 trips per person. On weekends, there are 13.4 million trips, at a rate of 3.3 trips per person. Only a quarter of all trips are work related. The majority are for activities such as shopping, recreation, and personal business. On weekends, almost half of all trips are for social and recreational purposes.

- Despite the diversity of travel purposes, and origins and destinations for trips, many trips are short local trips. Half the trips made each day in Sydney are less than five kilometres, with the majority of these trips made by car.

- There are regional differences in the way people travel. The further people live from the CBD, the longer their trips tend to be, the greater the reliance on car travel and the less likely they are to walk or ride a bicycle. In eastern Sydney, almost 30 per cent of all weekday trips are made by walking or cycling, while in north western and south western Sydney, only 11 per cent of trips are made by walking or cycling.

- Vehicle kilometres travelled (VKT) has increased faster than population growth. In the last 20 years, Sydney's population grew by 21 per cent, the number of car trips by 41 per cent and the number of cars by 58 per cent. Between 1991 and 2001, population grew by 1.3 per cent per year, while car trips increased by 1.8 per cent per year and vehicle kilometres travelled increased by 2.3 per cent per year.

- Sydney has the highest use of public transport of all Australian capital cities. In Sydney, over one in five people use public transport to get to work (22 per cent), compared to less than 13 per cent in Melbourne and Brisbane.

- The majority of Sydney's freight is moved by road (86 per cent) with the proportion of freight carried by road increasing over time at the expense of alternative modes including rail. (Reflected in increased energy intensity of tonnes per km travelled: next section)

- Mode choice by shippers is influenced by several factors including reliability. The shared use of rail infrastructure including train paths and the Government policy of priority to passenger trains reduces rail freight operations to off–peak periods. In turn, this restricts frequency and reliability of rail freight services.

- Road freight operators also are experiencing heavier levels of congestion. With the cost of congestion estimated to increase, the efficiency of road freight operations will become increasingly difficult to enhance. As such, there is a clear need to encourage the greater use of rail, and where rail is not an option, to promote greater efficiency of road freight movements.

- Freight trip generation is highest in areas that have high numbers of industrial sites and warehouses. The significant remnants of industrial and warehousing activities located near Port Botany reflect the historic growth of the Port. However, these activities have spread across Sydney, concentrated reasonably adjacent to the M4 and M5 Motorways in suburbs including Bankstown, Silverwater, Fairfield, Wetherill Park, Ingleburn and Minto.

- Freight activity is likely to intensify in Western Sydney. The availability of industrial land in outer Western and South Western Sydney, coupled with the imminent opening of the M7 Motorway, has resulted in considerable industrial activity within the motorway corridor, particularly near the junction of the M4 and M7 Motorways.

- Some 90 per cent of the goods originating from Port Botany are destined to locations in Western Sydney. The more efficient movement of these goods and commodities is a priority.

Part of Sydney's problems of congestion is the result of cancelled or unviable infrastructure projects. Reasons for poor performance of completed projects includes *inappropriate pricing decisions (Airport line), non-optimal alignments (Olympic Rail Line, Epping-Chatswood Line), poor service provision (Parramatta Y-Link), or cost over-runs (Clearways).* Virtually no substantial improvement in transportation via train or light rail has occurred in Sydney since the 1930s, or about the time the Sydney Harbour Bridge was built.

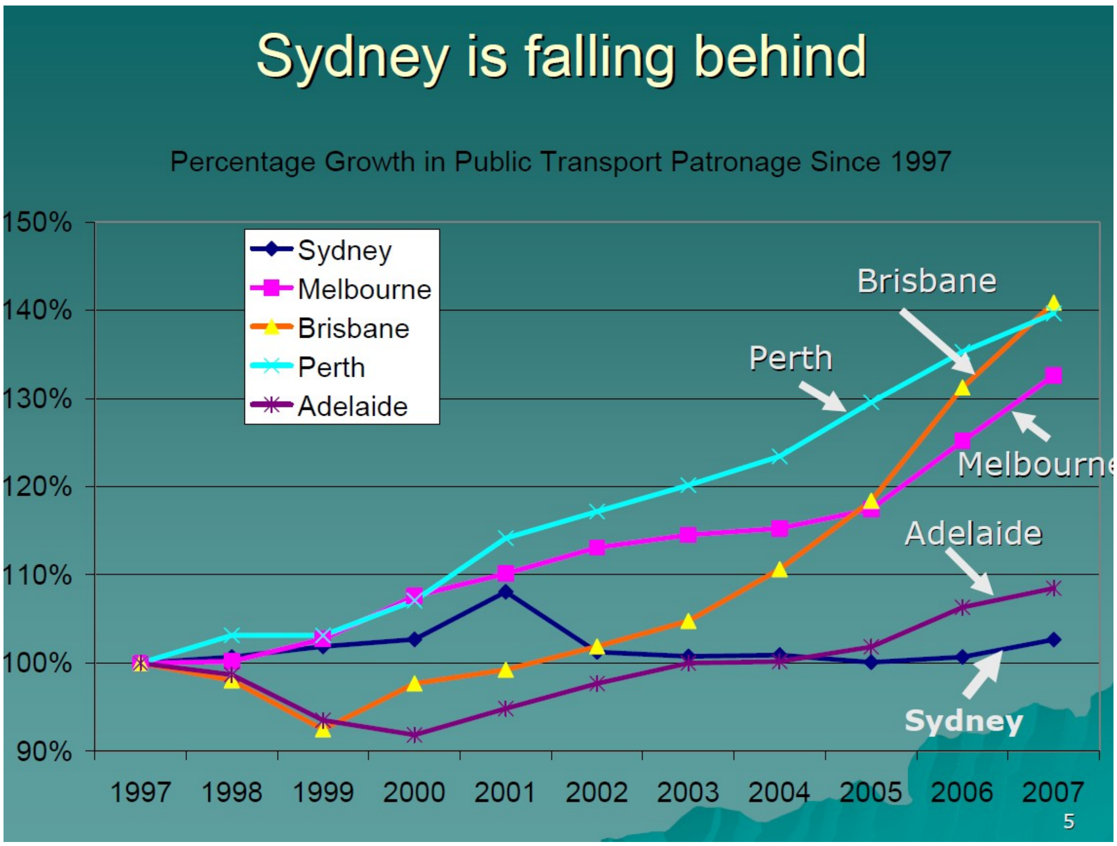
> The rail network in Western Sydney has not been significantly expanded since the 1930s when the region's population was less than a fifth of what it is today. The result is that urban expansion is pushing residential growth further and further away from the existing rail network, increasing dependence on private cars and buses. Yet there has been little integration between the rail and private bus networks; the use of local buses as feeders to the higher capacity rail systems has been underdeveloped and, in many instances is no longer relevant to people's transport needs. Travel between outer suburbs is very difficult and results in high car dependence for cross-suburban trips.

In terms of patronage of public transport, Sydney shifts more than one million people per day or 22% of workers commute using public transport versus less than 13% in Melbourne and Brisbane (Dept. of Planning 2005). However, the percentage growth in patronage since 1997 of about 5% is well behind that of Melbourne, Perth or Brisbane at between 30%-40% increase (Figure G76).

The Western Sydney Regional Organisation of Council's (WSROC) 2009 Response to the 'Inquiry into the investment of Commonwealth and State funds in public passenger infrastructure and services' suggested that the reason for poor patronage involved a failure to provide a reliable service and that governance was so splintered as to make coordination unlikely or at best uneven;

> Public transport is underutilised and has not sufficiently reduced motor vehicle reliance as it is not accessible and has had a long history of operational and patronage problems. Sydney's public transport is split between State Rail, Sydney Transit which operates buses in the central and eastern suburbs and a number of loosely co-ordinated private operators throughout the western region.

Figure G72: Percentage growth in public transport patronage since 1997



Source: Glazebrook 2009a

In terms of where you live and your choice of mode of travel, Glazebrook (2009a) suggests that increasing the density of settlement to 60 or more people per hectare increases the proportion of trips made on public transport to work, as does location within 20 km of a CBD. This might also apply if an alternative major employment centre was located within a commute of 20 km in the sub-urban region. It is interesting to note at this point that in the earlier discussion on household consumption of water, energy and communications in medium density infill development in existing suburbs, increasing the density of people to beyond 50 per ha made the cost of augmenting the stuff of established services – pipes, conduits, wiring cables, mains – more expensive than the cost in greenfield suburbs. Hence, there is a possible need to consider a trade-off on density depending on circumstances or planning objectives.

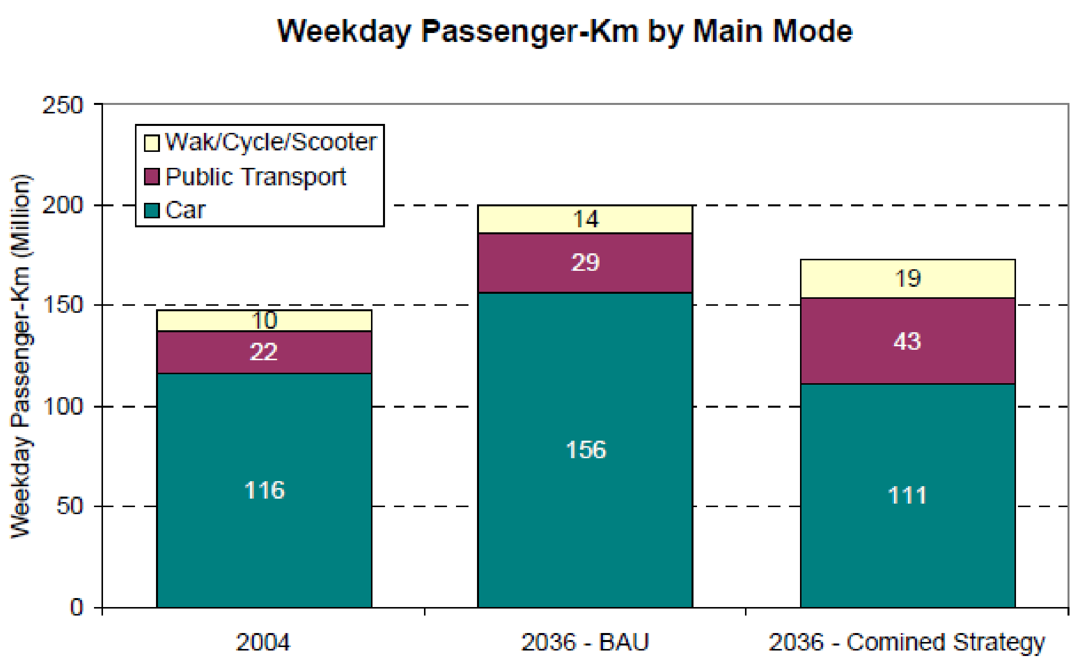
The number one aim from the 2030 Transport Plan was to 'reduce population growth to 30%'. This is a significant statement because it acknowledges the fact that current and near future likely transport does not cope / will not cope with an accelerating population in Sydney. Managing how many people live and where is the key element in planning transport, the built environment, GHG emissions, health outcomes and access to employment.

The remaining objectives were:

1. Reduce the total amount of travel per capita by 10%
2. Double public transport use (pass-kms) in Sydney
3. Double walking and cycling
4. Reduce car share of travel (pass-kms) from 80% to 64%
5. Reduce fuel consumption and emissions per car-km by 50%
6. Switch to 100% green power for all electric rail transport

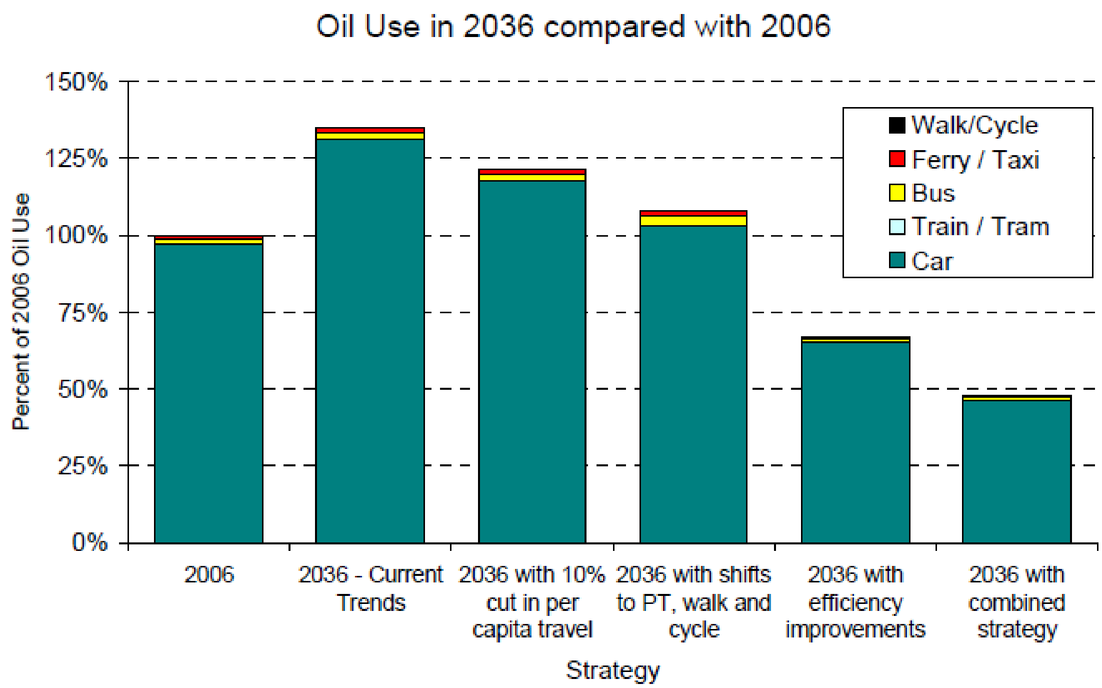
The following three Figures (G73; G74; G75) display the anticipated outcomes of the effective implementation of these seven objectives (i.e. reduced car use, increased public transport patronage and around 50% less oil used and GHG exhaled in transporting people and goods around Sydney);

Figure G73: Weekday passenger – Km by main mode



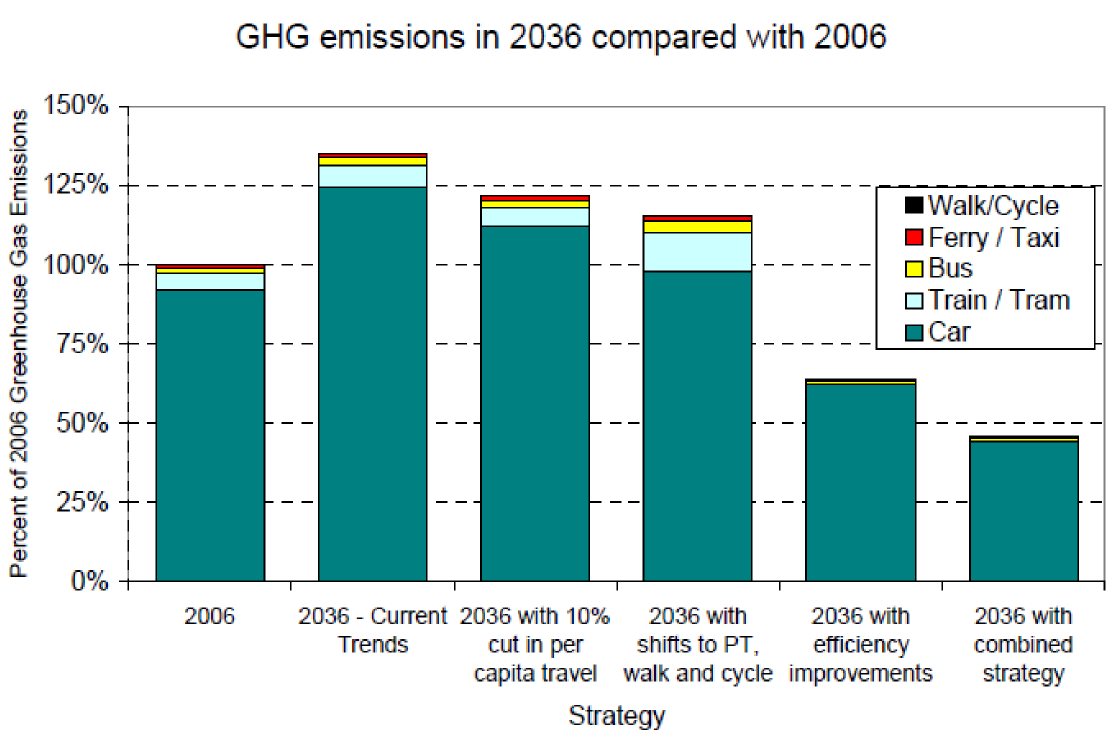
Source: Glazebrook 2009a

Figure G74: Oil use in 2036 compared with 2006



Source: Glazebrook 2009a

Figure G75: GHG emissions in 2036 compared with 2006



Source: Glazebrook 2009a

The true cost of motor vehicle use in Sydney, that is the cost with all externalities included is presented in Table G27 below;

Table G27: Estimated costs of cars in Sydney for urban use (2006)

Estimated Costs of Cars in Sydney for Urban Use (2006).

COMPONENT	$ million	$ / Veh-km	$ / Pass-km	% of Total
Petrol/ fuel (at $1.40 / litre)	$5,886	$0.18	$0.12	14.3%
Tolls	$319	$0.01	$0.01	0.8%
Paid Parking	$309	$0.01	$0.01	0.8%
Private Out-of-Pocket	**$6,515**	**$0.20**	**$0.14**	**15.9%**
Other User Costs *	$16,370	$0.50	$0.34	39.9%
Total User Costs	**$22,885**	**$0.70**	**$0.48**	**55.8%**
Congestion	$9,597	$0.29	$0.20	23.4%
Accidents	$3,072	$0.09	$0.06	7.5%
Greenhouse Gas Emissions	$118	$0.00	$0.00	0.3%
Air Pollution	$972	$0.03	$0.02	2.4%
RTA Subsidies	$589	$0.02	$0.01	1.4%
Unpaid Parking	$2,803	$0.09	$0.06	6.8%
Noise, Water Pollution, Other	$1,001	$0.02	$0.02	2.4%
Total External Costs	**$18,152**	$0.55	**$0.38**	**44.2%**
Total Costs	**$41,037**	**$1.25**	**$0.86**	**100.0%**

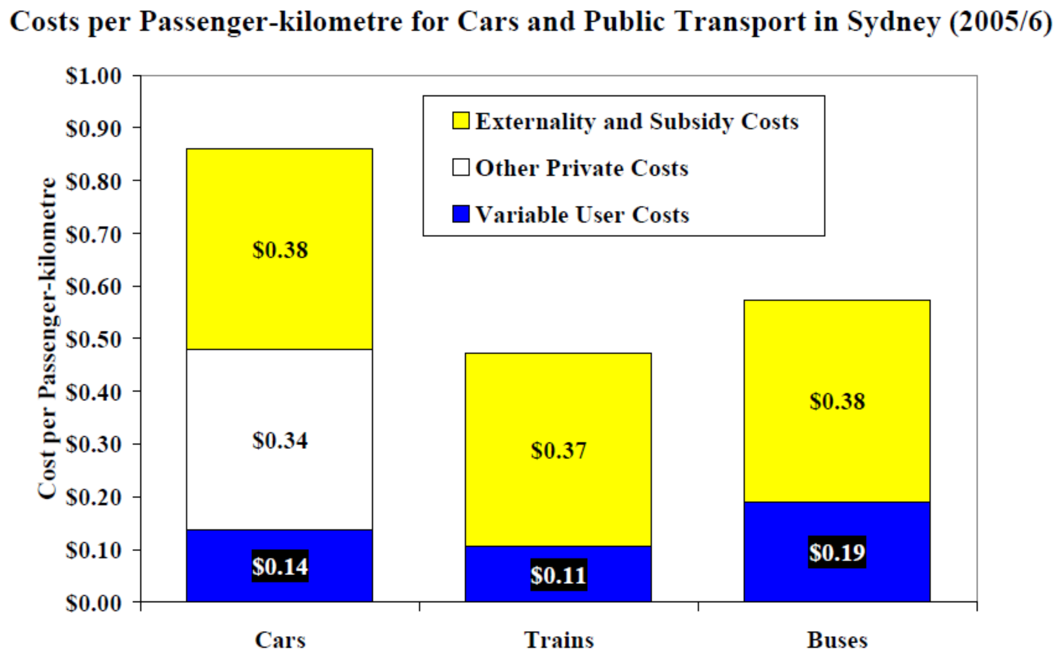
*Source: Glazebrook (2009) * Depreciation, registration, insurance, maintenance.*

Comparing the different transport modes using 2006 figures and including the externalities we find that cars cost 86c per passenger-km, rail costs 47c per passenger-km and buses cost 57c per passenger km (Figure G76). Considering that expenditure on public transport in 2006 was approximately $3.5 billion including externalities and fares paid, and cars cost $41 billion to run, it would appear that substantial gains could accrue to individuals if more of them used the more cost effective mode.

However, Sydney's public transport infrastructure has proven to be unreliable, difficult to get on, and its governance ineffective; a result of splintered responsibility and inadequate resources split between State, and Local Government and private operators. The consequence is that the transport organisations are without the capacity in terms of power to make appropriate long term investments;

> Public transport is underutilised and has not sufficiently reduced motor vehicle reliance as it is not accessible and has had a long history of operational and patronage problems. Sydney's public transport is split between State Rail, Sydney Transit which operates buses in the central and eastern suburbs and a number of loosely co-ordinated private operators throughout the western region.

Figure G76 : Costs per passenger – kilometre for cars and public transport in Sydney (2005/6)



Source: Glazebrook (2009). Note "operator" costs are covered by fares plus direct subsidies to the operator. In addition there are other subsidies to the RTA for construction of buslanes, T-Ways etc.

In summary, Glazebrook (2009a) makes the following remarks about the current inability of Sydney as a whole to cope with a rapid increase in population whether of immigrant or local origin. Sydney is more vulnerable to shocks from oil price rise and the carbon tax or CPRS when implemented (emphases in original):

> Sydney thus has an inefficient and unsustainable transport system. But Sydney is also very vulnerable to future oil price rises and to measures to reduce greenhouse gases.
> The overall 30 year plan is designed to restore some balance by allowing a doubling of public transport patronage. It is estimated to cost $40 billion over and above the $90 billion which maintenance of the current spending level to 2036 would entail.
> This may seem a large amount, but in fact it would require allocation of resources equivalent to **only 6% of our current direct car-related expenditures** and would lead to substantial long term financial as well as environmental and health savings. As indicated in Chapter 2, "business as usual" will see vehicle kilometres of travel rise by at least 30% by 2036, whereas the 30 year plan will hold VKT at current levels.
> The 30 year plan would result in a **saving of at least $100 billion in directs costs to motorists**, with additional savings in external costs. In particular in the absence of this plan, congestion and greenhouse gas emission costs are likely to increase rapidly as we properly price in the costs of climate change, whilst fuel bills are also likely to rise steeply in future.

The next section explores the level of organisation below that of Greater Sydney to the LGA regional organisation of Western Sydney and the Western Sydney Regional Organisation of Councils (WSROC).

Western Sydney

In 2008 WSROC made a submission to Infrastructure Australia regarding… infrastructure. Their key message was that in general, people did not live close to their places of employment, thus necessitating more travel than is desirable for quality of life, energy intensity and pollution. The submission records that:

> The functionality of Sydney as a global city is presently threatened by congestion. There is a serious imbalance between the geographic location of employment opportunities and where people live, necessitating significant travel with an inadequate transport infrastructure. Historically the rail and road networks feed from mostly radially to and from the centre of the CBD of Sydney. Progressively these main arterial road and rail links, and the main through-Sydney-traffic and radial-ring road traffic roads around the city have become increasingly bottlenecked.

The 2030 Transport Plan plotted access to transportation and employment (Figure G77) and the overall structure upon which routes are being planned is represented by the 'double cobweb' design (Figure G82). This neatly describes the perspective of WSROC as a separate economic region; as the secondary centre or 'web' of the urban form of Sydney (Figure G78).

Figure G77: Key land use patterns and transport accessibility in Sydney

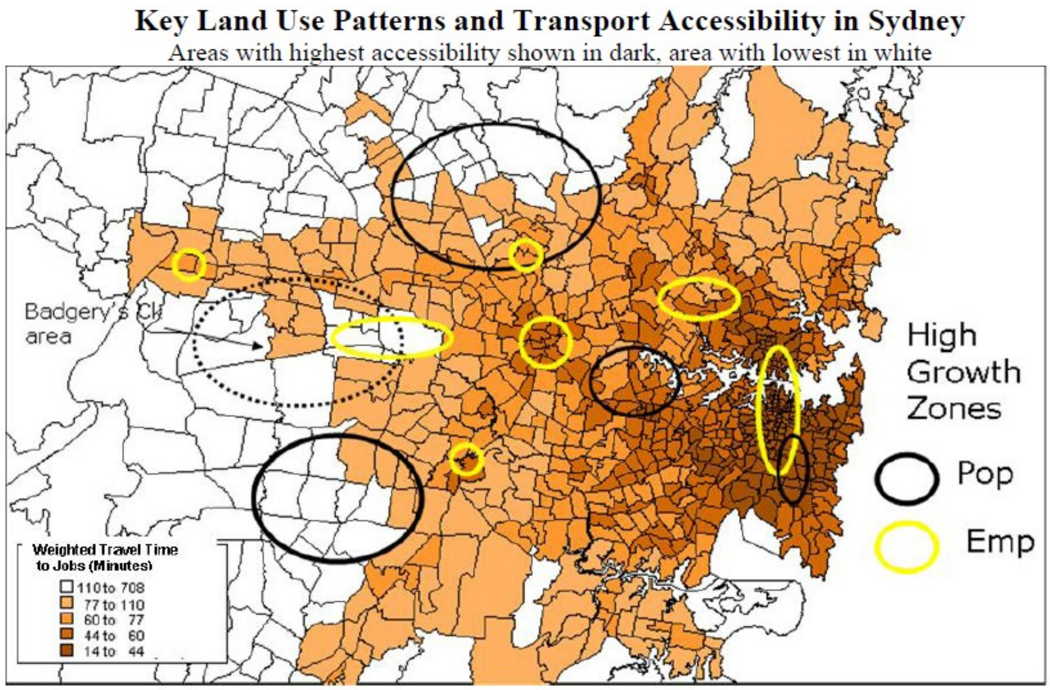
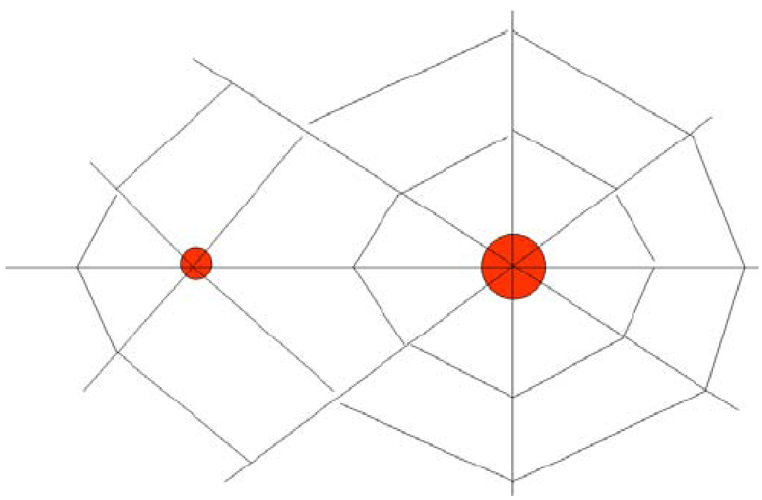


Figure G78: Double "cob-web" design for Sydney's strategic transport network



The economic productivity of Western Sydney is measured by the number of actively trading businesses – 151,000 which employ 890,000 people (Sydney 2.2. million), with a Gross Regional Product of $76 billion (NSW $335 billion). Importantly, Western Sydney is the main location of manufacturing industries in NSW with an output valued at $14.4 billion or 38% of NSW total manufacturing output. The head offices of some 30% of Australia's Top 100 companies are located in the region and 20% of the Top 500 companies have plants there.

Given this concentration of manufacturing it is not surprising that 80% of Sydney's shipping freight is transferred between Western Sydney and Botany Bay, and the region is the key logistics hub for the eastern seaboard of Australia. The logistics road transport industry expects turnover to double in the next 20 years.

The region must find work for an expected 280,000 people during the next growth phase in the north-west and south-west urban growth areas as approximately 600,000 people move into the region over the next 20 years.

In WSROC's submission to the National Infrastructure Audit October, 2008, the organisation detailed the uncoupling between population growth, increasing public transport use, crowding on public transport and yet increase in overall numbers of motor vehicles on the roads:

> CityRail statistics indicate that demand on most rail lines in Western Sydney is now exceeding train capacity, especially during peak hour. Despite the increase in train travel, however, recent journey to work and other travel statistics indicate that motor vehicle use is increasing much faster than public transport patronage with resulting pressure on the region's road network. Even if additional roads are constructed and motorways widened, this pattern is likely to continue, leading to unacceptable levels of congestion.

Part of the disconnect is that as soon as new capacity is added to the road network the increasing population fills it up. Employment growth within the region is not keeping pace with population growth in absolute terms nor in matching the type of jobs available to workers skills. This means that more people are travelling outside the region for work for which they are using private vehicles;

> Research recently completed for WSROC indicates that after a period of sustained growth, employment "containment" – the proportion of the region's workforce employed within the region – has remained static since the early 1990s. In other words, employment growth is only keeping pace with population growth.
> This research also strongly suggests that whilst it continues to grow, the region's economic structure has not evolved fast enough in the face of changes in the national economy. This means that in future all levels of Government will have to make a range of strategic interventions to generate the 250,000 additional jobs required within the region just to continue maintenance of the current level of containment. Even if this level of containment is achieved, the region's transport infrastructure will still have to cope with an additional 120,000 journeys to jobs outside the region.

The strong Australian dollar currently shields motorists from more severe price increases for petrol. However, the prospect of more people travelling by car for work and leisure suggests increased vulnerability for people in Western Sydney. This highlights again the heterogeneous nature of large urban places and the need to be attentive to these differences in policy development:

> A research paper issued by the Urban Research Program, Griffith University entitled Oil Vulnerability in the Australian City (Dodson and Sipe 2005), has assessed the resilience or vulnerability of urban communities to increased fuel prices and how the socio-economic impacts will spread across different localities. Their research highlighted the fact that localities situated in the middle and outer suburbs of GWS [Greater Western Sydney] are most vulnerable to the socio-

> economic impact of oil price rises. The authors called for new policies emphasising the need for public transport services to address the impacts of oil price rises.
> Further research by the same authors has recently pointed to the spread of the crisis creeping inwards from the urban fringes. They noted "a highly regressive pattern in which the impacts of higher fuel costs and increased interest rates fall on those with least capacity to absorb these impacts. Worse, the deficits in urban infrastructure and services meant the more vulnerable households had less ability to adapt to higher fuel costs by taking public transport.

Research conducted by the University of Western Sydney also shows that transport disadvantaged CDs [Census Districts] cover over half (53.8%) of the Sydney Urban Area. Just over a third (34.4%) of the Sydney urban region live in these areas (1.2 million people) and 58.2% of the people living in transport disadvantaged areas were located in Western Sydney – some 700,000 people. The report identifies older people and people with a disability as among some of the groups most at risk in Western Sydney.

In WSROC's 2009 Response to the 'Inquiry into the investment of Commonwealth and State funds in public passenger infrastructure and services', the organisation detailed current congestion and transport failures for Western Sydney:

> Over many years urban release has been taking place on a massive scale in Western Sydney. The land was cheap due to poor accessibility and a lack of services and facilities. Low-income families moving into the area had no choice but to rely on the car as there were few public transport services and even basic facilities were either dispersed or available only in distant centres. The need for a second car (or a third) is now firmly entrenched in the minds of the population, with the result that high levels of car ownership are exacerbating income deprivation in many areas.
> Travel times by public transport for non-work purposes varied across Greater Western Sydney LGAs, with times of up to 10 and 20 minutes greater than the Sydney average. Average travel times for commuting trips by both car and public transport for Greater Western Sydney residents were generally longer than for the rest of the Sydney SD. Car commuting trips in the morning peak are up to 17 minutes longer in many areas. Travel times by public transport for non-work purposes varied across the region with times of up to 10 and 20 minutes greater than the Sydney average (in areas such as Baulkham Hills, Blacktown, Campbelltown and Hawkesbury).
> The high volume of traffic within the region, with a mix of private and public passenger, freight and commercial vehicle travel, places pressure on the sparse arterial road network. During the morning peak (7am to 9am), more than 1,800 vehicles per hour travel on many arterial roads throughout Greater Western Sydney. Many other roads also experience traffic volumes of 800 to 1,800 vehicles, even though they were not originally designed for such levels. The problem of high volumes on roads built for lower capacities is exacerbated by poor connectivity with other local roads and, prior to the opening of the Westlink M7, a lack of north-south regional links. Often the result is severe congestion which also contributes significantly to air pollution.

If, as Glazebrook suggests, it takes 30 years to install a world class transport system, by the time Sydney is supplied with one, it will have been overtaken by the population increase expressed in residential and business urban expansion.

Melbourne

Melbourne has done a little better than Sydney in its provision of public transport infrastructure. However, the most recent rail development goes back 30 years to the City Loop underground service completed in 1985 along with track duplication and electrification. The tram networks have been extended but only modestly. In addition, buses are the only public transport option for most of the middle and outer suburbs. Approximately 84% of Melburnians live within 400 metres of a bus route, 15% live within 400 metres of a tram route and 23% live within 800 metres of a railway station (VCEC 2006). By contrast, a substantial proportion of transport money has been directed into new public-private partnerships for freeways that pay tolls.

Around 250 bus routes serve metropolitan Melbourne, transporting approximately 85 million passengers each year. The recent tram route extensions now make the Melbourne tram system the largest operational track in the world, carrying 150 million passengers in 2006-07. Further to this, Melbourne trains carry around 200 million passengers each year.

Unfortunately, these services are showing symptoms of congestion including overcrowding and less reliable services. According to VCEC (2006) the increasing population will drive greater travel demands; *'overall travel demand in Melbourne will grow by 34 per cent between 2006 and 2031, with the strongest growth occurring in the inner city and in the west and south of the city'* (see Table G28).

Table G28: Trip demand summary, all day, 2006 and 2031

Road Name	Location	Current Volume (2006)	Predicted Growth	Predicted Volume 2031
Western Ring Road	South of Deer Park Bypass	113,000	33%	150,700
Princes Hwy West	West of Western Ring Road	141,000	38%	194,300
Geelong Road	East of Francis Street	42,000	91%	80,200
Calder Freeway	West of Western Ring Road	87,000	47%	128,100
West Gate Freeway	West Gate Bridge	165,000	41%	235,000
Monash Freeway	East of Toorak Road	150,000	42%	213,500

Source: EWLNA (Veitch Lister)

According to the Victorian Commissioner for Environmental Sustainability (CES):

> It should be acknowledged that congestion is a sign of economic success, that some congestion is unavoidable and that cities can – and should – tolerate a level of congestion because it contributes to reducing the growth in demand for motor vehicle travel.

The response to this is both yes and no. Yes: Congestion can be defined as slower than expected or average traffic flow times that generate some unreliable travel times, and which tends to occur at limited peak times on maybe 20% of (Melbourne's) roads. When we talk about cars, vans, trucks, buses and trams sharing the roads, provided drivers' expectations – particularly about reliability of the trip time – are satisfied, then some congestion would appear to be tolerable (Eddington 2008). No: When our expectations get to a point where work, school or other constraints impose timelines that cannot be satisfied by 'business as usual' practices due to the overall time taken, timing of the activity related to the trip, and the impact on our health and productivity, then congestion becomes a problem.

Eddington (2008) concludes that *many roads that are currently at or approaching capacity will become more and more congested over the next two decades* (see Figure G79). This is the case even though the total carrying capacity of Melbourne's roads are in excess of total vehicle traffic: it is the peaks – high frequencies at particular times in particular locations - that need to be serviced, since it is these peaks that generate the perceptions of congestion because this is when most people use the roads. The form of Australian cities was set by suburban expansion caused by the coincidental arrival of large numbers of migrants and the increasingly affordable motor car. The appearance of congestion may indicate a lack of holistic urban planning, a lack of actual construction and/ or a lack of appropriate price signals to drivers through the expenditure on making roads to the detriment of public transport.

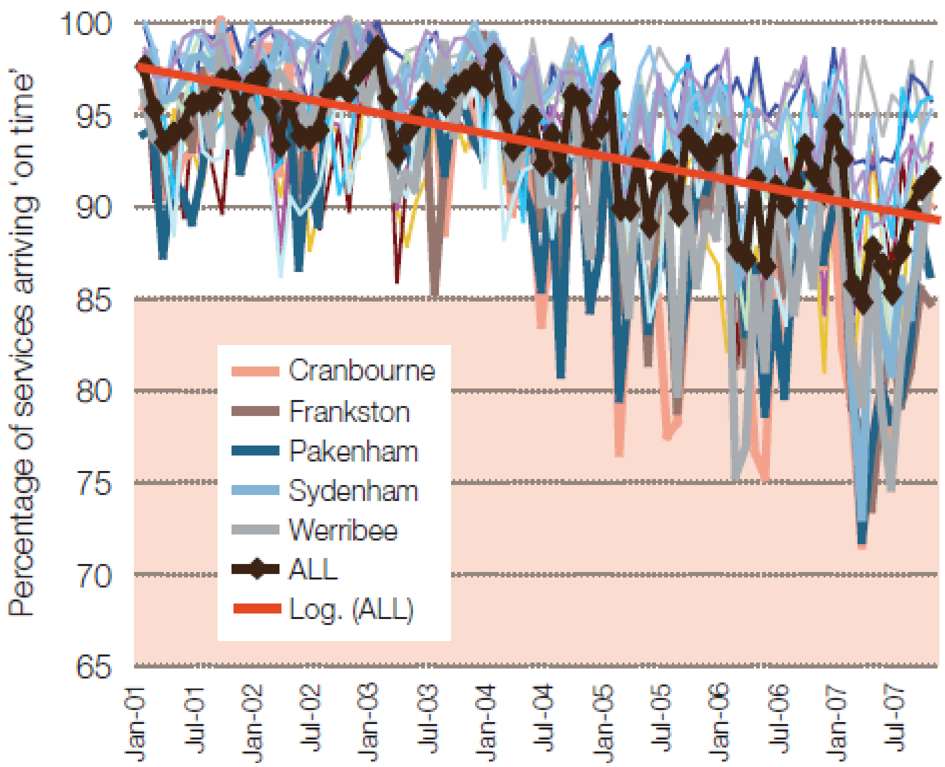
Figure G79: 2006 morning peak congestion, Metropolitan wide

Source: VicRoads

Economic estimates of the cost of congestion vary. BTRE (2007) estimates the cost to be around $3 billion in 2005 and double that by 2020. The Victorian Competition Efficiency Commission (VCEC) projected costs between $1.3 billion to $2.6 billion. The costs of not dealing with congestion appear to be far worse than spending money now on physical and behavioural changes. All three reports, Eddington (2008), BTRE (2007) and VCEC (2006) discuss a range of Government interventions that together will prevent congestion increasing exponentially. Without intervention this rate of increase in congestion is probable, given: overseas experience;

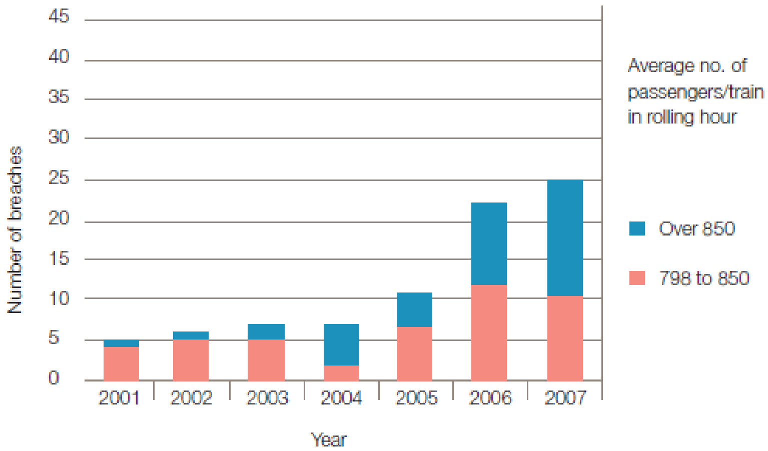
that current roads have reached capacity; the population of Melbourne is increasing rapidly; economic activity is increasing; wealth is increasing; and public transport is beginning to get slower and more unreliable (see Figures G80 &G81). Interestingly the 2004 bar is evidence of the increased use of public transport during the Commonwealth Games which substantially restricted access to the city. There is a carry-over effect still visible as patronage has continued to rise on trains and trams since that event. In essence it was a brilliant opportunity to study what people would do if vehicle access to the CBD was cut off at short notice and with a rationale that people would accept.

Figure G80: Reliability of morning peak services, 2001 - 2007



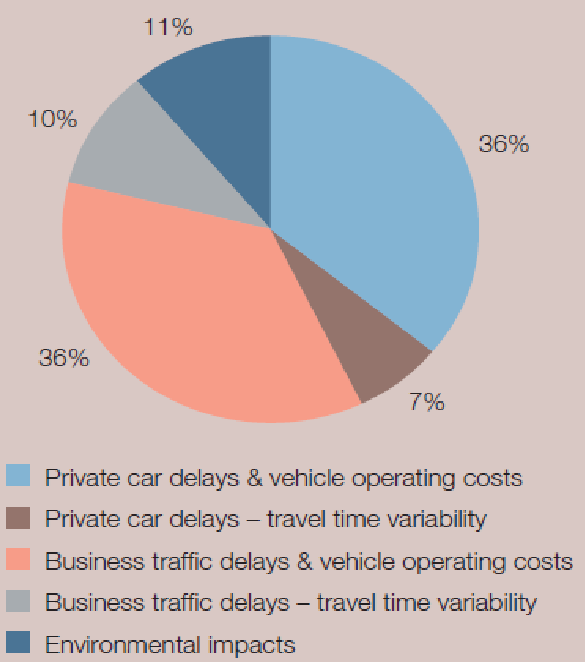
Source: Public Transport Division, DOI

Figure G81: Train overcrowding – load breaches on morning peak period trains, 2001 - 2007



Source: PTD and EWLNA. (Figures are average annual growth. Projections assume a high initial growth rate, tapering off over time.)

Figure G82: Breakdown of the costs of congestion in Melbourne, 2005



Source: VCEC (2006) – based on BITRE analysis

To alleviate congestion essentially caused by too many cars (Figure G82), the VCEC (2006) found that improvements to public transport and programs to increase patronage of public transport had at best minor impacts on total road traffic volumes; with a reduction of between

5% - 15%. However, when linked with active pricing measures to make it more expensive to drive into certain parts of the city and/ or at certain times, the combination appeared to have more impact on total traffic volumes.

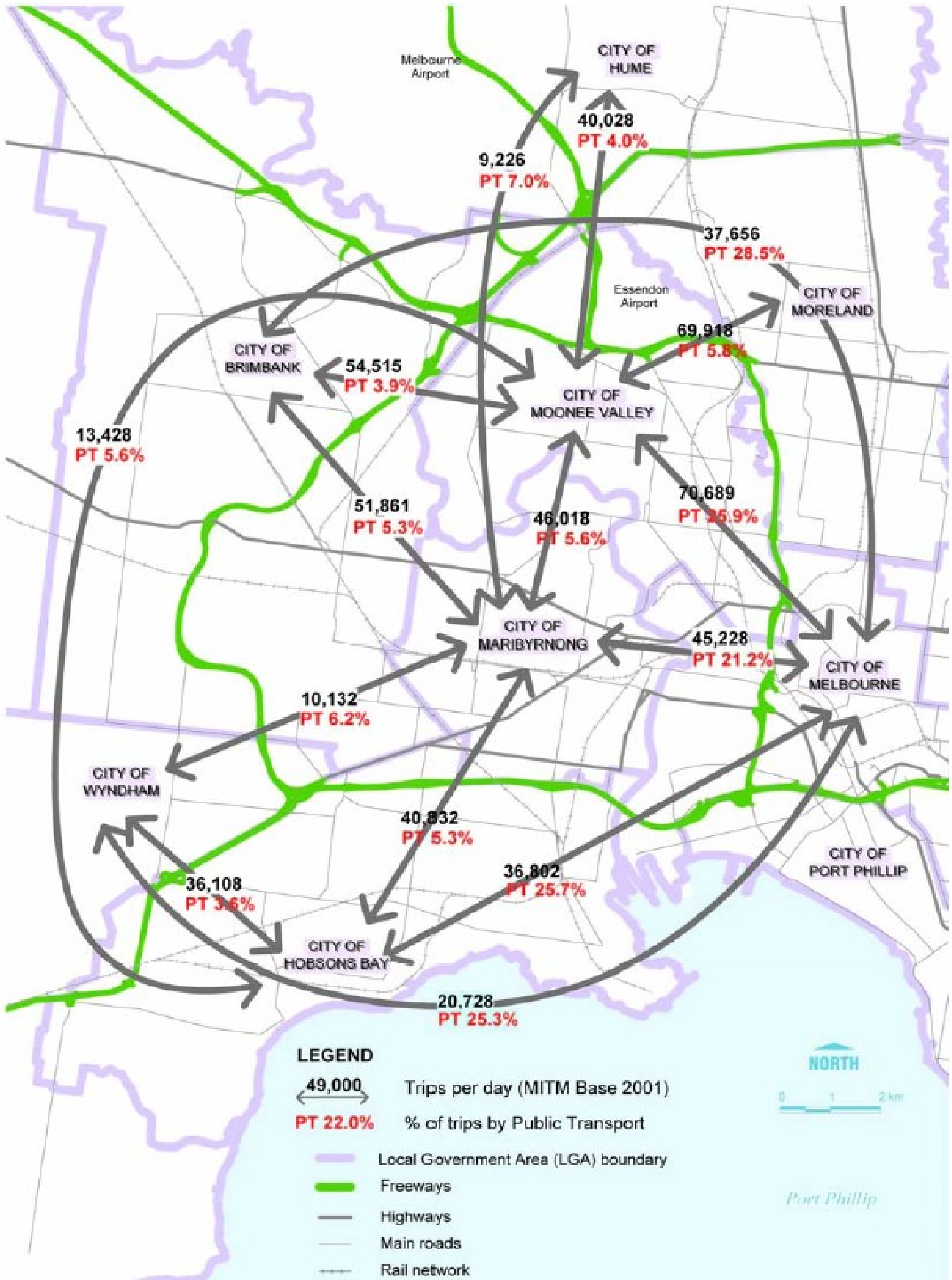
Total traffic volumes in Melbourne (DOT 2009) are made up of about 14 million trips per weekday of which about 30% occur in peak times. Individual trips completed by car amount to 78% of the total; by public transport – 7%; and by walking or cycling – 15%. Of the trips specifically to work, 14.5% were made by public transport and 77% by car. Some 90% of trips begin and end within the LGA or adjacent LGA to the home and up to 35% of people live in the same LGA as their work address (VCEC 2006). Additionally, from the literature reviewed over the past 100 years it appears that the average journey-to-work time has remained around 20 minutes, a finding borne out by overseas evidence:

> The experience of stable journey-to-work times is not limited to Australian cities, or to cities with similar physical and travel characteristics. Kenworthy and Laube (1999, p. 612) have found that journey-to-work times are stable in North American, European and Asian cities at 26, 28 and 33 minutes respectively (VCEC 2006 p. 46)

This remarkable facet of transport history suggests that despite a radical change in the size and character of Melbourne in 100 years, people have purposefully located themselves within this commuting distance/ time of their workplace (Figure G85). This was made possible due to increased speeds of transportation (VDEC 2006).

In the Western Melbourne LGAs of Maribyrnong and Brimbank, in which migrants are over-represented, most travel occurs locally (Figure G83). However, this region is also subject to a substantial increase in freight trips and congestion as industry becomes more concentrated in these areas. Indeed western Melbourne is the largest centre for freight operations in Australia contributing $21 billion to the Victorian economy. This means a substantial amount of trucks and vans on the roads of western Melbourne, trying to get into the CBD and beyond to locations in the east and south-east of the city. Vans are the fastest growing segment of the traffic flow (as in Sydney) comprising 15% of all motorised vehicles (Figure G84).

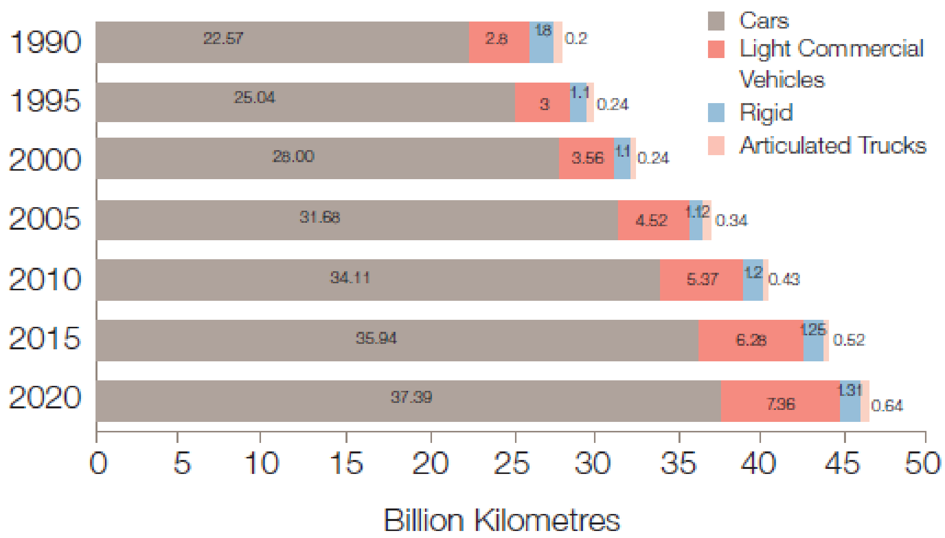
Figure G83: Trip patterns in inner west Melbourne



Notes: PT denotes public transport (train, tram or bus). MITM denotes Melbourne Integrated Transport Model.

Source: DOI for the Commission

Figure G84: Contribution to Melbourne traffic (1990 to 2020)



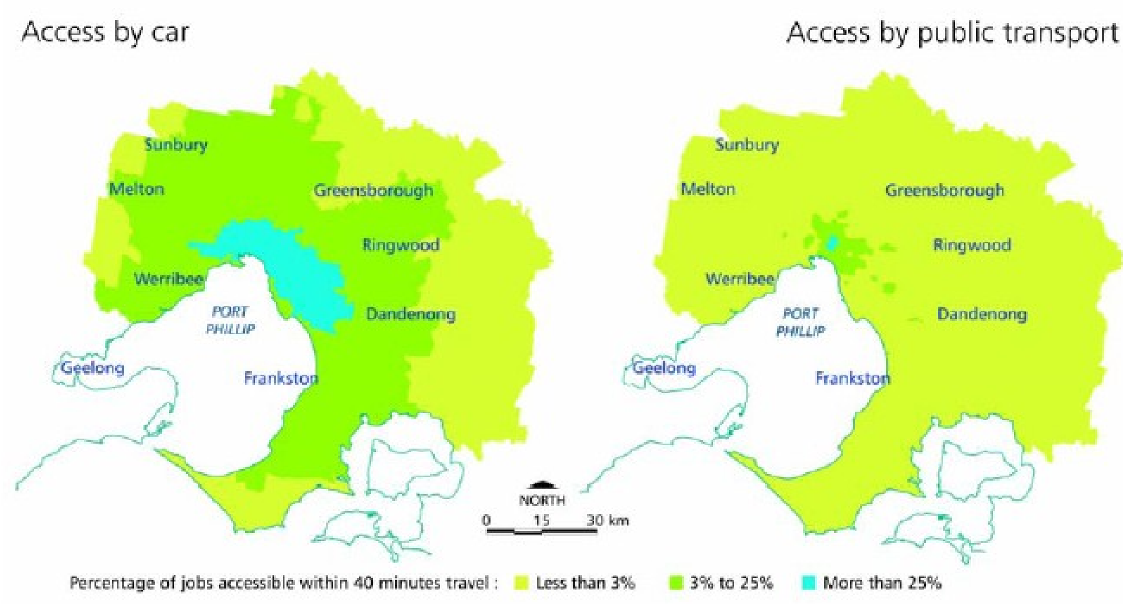
Source: BITRE (2004)

Table G29: Commercial vehicle traffic by route

Route	Commercial vehicle growth
West Gate Bridge	55%
Princes Freeway (west of the Western Ring Road)	98%
Princes Highway (Geelong Road) in the west	200%
Princes Highway (Smithfield Road)	61%
Dynon Road over the Maribyrnong River	37%
Footscray Road over the Maribyrnong River	68%
CityLink / Monash Freeway	53%
Alexandra Parade	23%

Source: EWLNA (Veitch Lister)

Figure G85: Jobs within 40 minutes of travel by car and public transport



Source: DSE 2002, p. 7.

Eddington's 2008 EWLNA Report makes two recommendations about transport and GHG:

- That replacing cars with public transport at peak times will make the most effective contribution to reducing GHG emissions from cars in Melbourne; and
- Peak oil will not change people's desire for personal mobility in the most flexible form. A high price for oil will increase the acceptance of renewable fuelled cars and a transition to a public transport system that had better be ready for the increased patronage. *But motor vehicles will still exist – and in greater numbers as the population grows: they just may not be running on petrol*

The Department of Transport (DOT) (2009) examined future scenarios for Melbourne in 2031 based on a range of urban forms which had determinants subject to policy manipulation. Their basic premise was that:

> When viewed alongside the industry, demographic and work changes taking place across Melbourne, these changes suggest that future travel demand in Melbourne is likely to involve more short trips, more linked trips, more door-to-door travel, and travel to and from a more dispersed range of origins and destinations.

The 2031 Scenario Results DOT (2009)

An important component of the study was the modelling of a series of possible future scenarios for Melbourne in 2031. In summary, this scenario modelling produced the following results:

- The Non-intervention and Base Case 2031 scenarios produced the worst outcome for transport energy and GHG emissions
- The Activity Centre/Growth Areas Plus scenario performed little better, on account of the dispersed patterns of population and employment (and associated travel patterns and higher VKTs) resulting, in large part, from residential growth on the urban fringe
- The Activity Centre Scenario performed better than the Activity Centre /Growth Areas Plus Scenario, indicating (as above) the impact of Growth Area development on transport energy and GHG emissions (even at higher densities than presently)
- The Inner City scenario produced the best results of all the scenarios, followed by the Super CBD scenarios, largely on account of their high Public Transport mode share, particularly for tram and train
- In the Inner City and Super CBD scenarios, the energy benefits were more significant than the GHG benefits, indicating that there is scope for further reduction in GHG emissions if more renewable energy sources become available to power trams and trains
- GHG emission levels are higher in the Super CBD scenarios than in the Polycentric scenarios, largely because of the lengthier commuting distances (VKT) for those continuing to reside in outer metropolitan areas
- The Polycentric scenarios showed solid GHG emissions and energy reductions, with low-ish VKTs and some mode shift to buses
- The Polycentric scenarios performed better than the AC and AC/Growth Areas Plus scenarios, indicating that there are benefits to be had from focusing urban growth into a small number of select Activity Centres across metropolitan Melbourne
- That the Super CBD parking variant showed a marked improvement over the Super CBD scenario indicates that pricing of private car use, at least in terms of parking, can be effective in promoting mode shift and thus reducing transport energy use and GHG emissions.

By way of explanation of these findings, it appears that those scenarios which showed the greatest value in improved energy use efficiency with regards to transport or lowering the VKT by car were related to locations of higher population and employment density, the inner metro tram network and the metro rail network.

In terms of energy efficiency, the Inner City Scenario and Polycentric City Outer Centres Scenario performed best, that is they contained the most transport zones with the highest range of energy efficiency, measured as 2,500 to 20,000 MJ per 1000 trips.

In terms of GHG emissions efficiency, the Inner City Scenario and Polycentric City Middle Centres Scenario measured as 400 to 1,200 kg-CO2-e per 1000 trips.

The urban form that would follow this scenario and which promises the most value in reducing car dependence and GHG emissions is one that requires significant expansion through inner city infill and around middle-metro to outer-metro activity centres, making the city develop as a more compact and at the same time polycentric city.

As DOT (2009) conclude:

> [T]he modelling revealed (1) that urban development occurring in a small number of larger Activity Centres will tend to produce significantly better outcomes in terms of transport energy and GHG emissions than development dispersed in a larger number of smaller centres, and that (2) development focused on major transport nodes (with well-serviced local Public Transport catchments) will produce better outcomes than development occurring in a more linear fashion along major transport corridors.

Figure G86: Polycentric City: middle centres scenario vs base case: % change in new population distribution by travel zone 2031

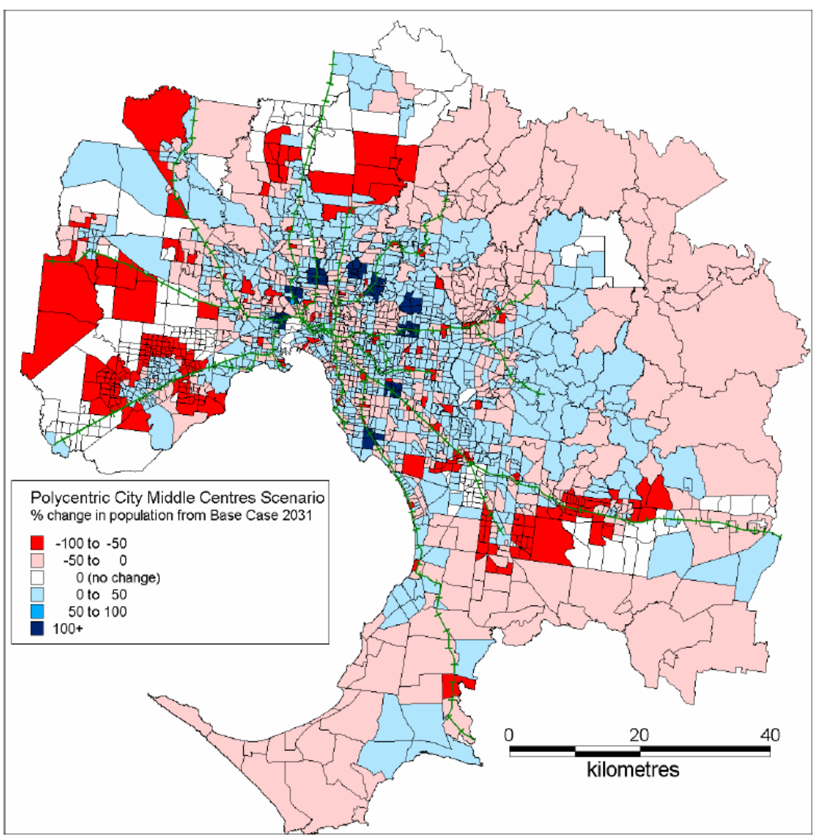
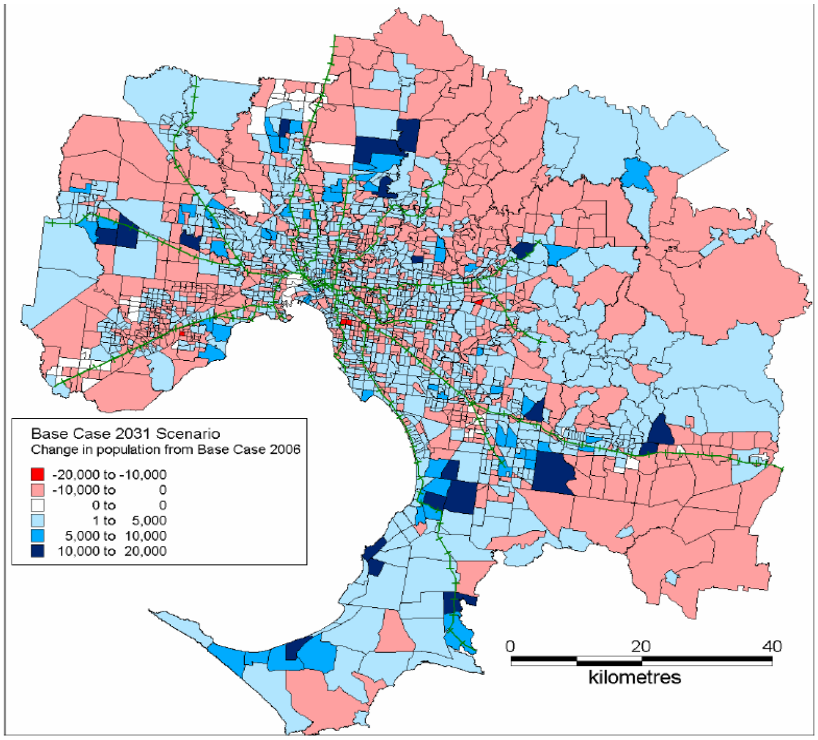


Figure G87: Current trend/base case scenario: New population travel zone, 2006 - 2031



Comparing Figures G86 and G87 shows that by adopting the Polycentric Middle Centres scenario, Melbourne will place much less stress on its urban fringe expansion west, north west and south east (red polygons). Apart from its public transport, energy, liveability and employment benefits, the Polycentric Middle Centres scenario releases the pressure on the western native grasslands biodiversity and the production of food in the south east.

References

CES (Commissioner for Environmental Sustainability) 2007, *Creating a City that Works: Opportunities and solutions for a more sustainable Melbourne.* Commissioner for Environmental Sustainability: Melbourne.

DOT (Department of Transport) 2009, *Macro-Urban Form, Transport Energy Use and Greenhouse Gas Emissions: An Investigation for Melbourne*. Government of Victoria.

Eddington, R. 2008, *East West Links Needs Assessment*: Report to the Government of Victoria.

VCEC (Victorian Competition and Efficiency Commission) 2006, *Making the right choices: Options for managing transport congestion, Final Report.* Government of Victoria.

Perth

…there is a need for a more comprehensive congestion management strategy; one that does not rely solely on building or widening roads. The result of the strategy would be less driving

per person and more people using public transport, walking and cycling; together with better freight logistics. In short, moving from congestion coping to congestion management.

(*DPI 2005, p.iii, emphasis in original).*

The quotation above is from the final report of the Local Impacts Committee (LIC) 'Review of Major Roads in the South West Metropolitan Corridor' prepared by the Department of Planning and Infrastructure (DPI) with a view to planning the most efficient routes for freight transport to and from the Port of Fremantle. Existing problems were described via a survey of residents and businesses along the current freight routes in 2003. The results are presented in Figures G88 - G90:

Figure G88: Adverse impacts of freight transport on key urban transport routes

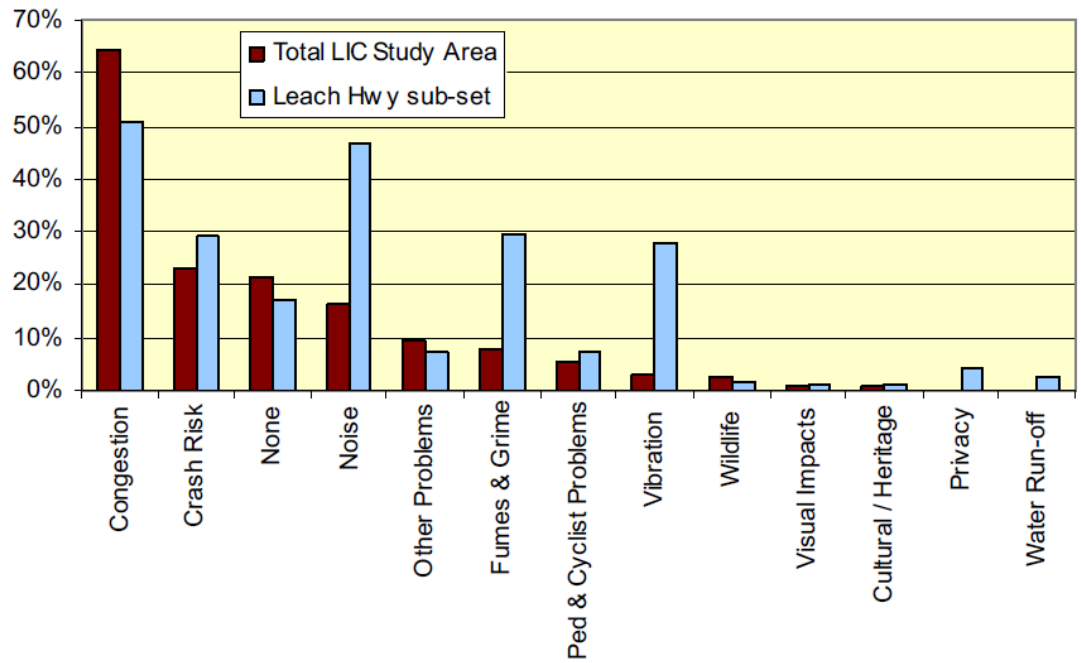


Figure G89: Composite map – existing worst problem locations

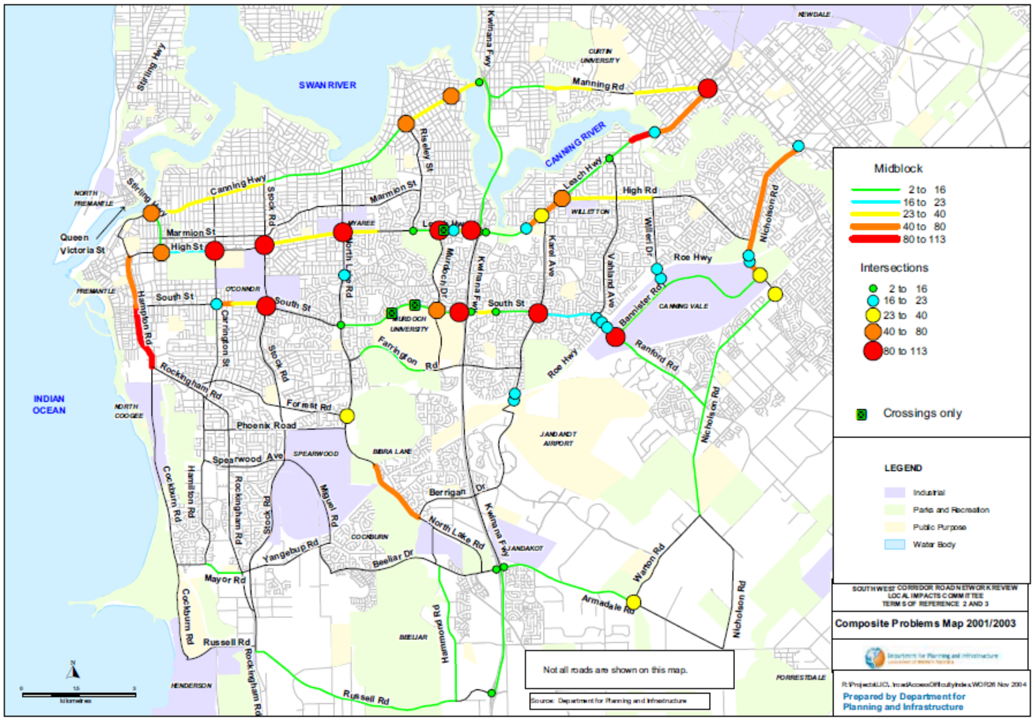
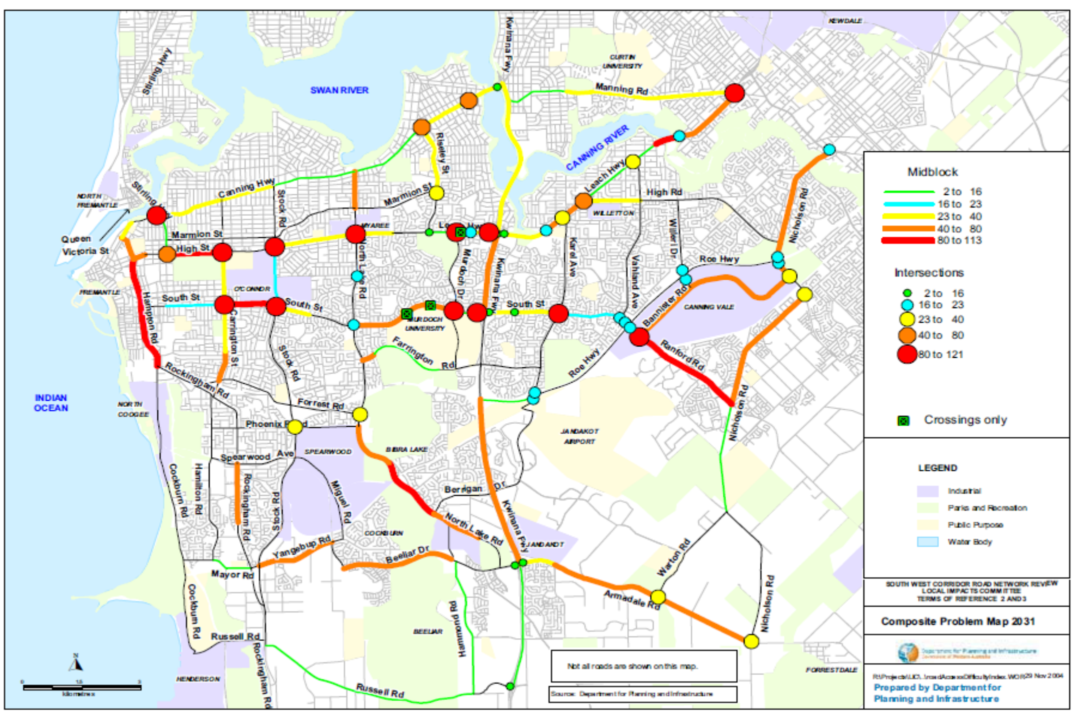


Figure G90: Composite map – estimated 2031 worst problem locations

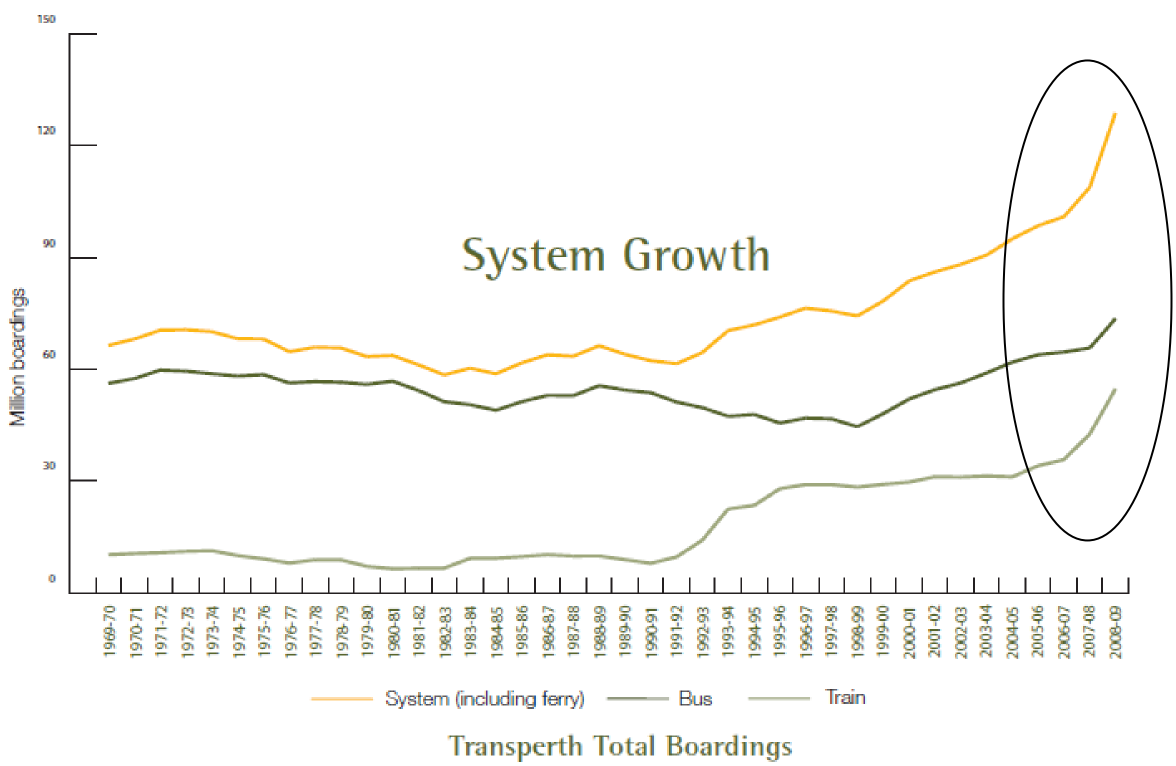


Recommendations from the Final LIC Report included projects to:

> … reduce the impact of freight and general traffic on local communities. In particular, the recommended projects will improve the safety of pedestrians at key intersections, improve road safety for motorists, reduce traffic noise for the most vulnerable communities and improve water quality in wetlands and river systems (by ensuring polluted water does not enter from the road). However, the package of recommended projects will not solve all the social and environmental problems that have accumulated over the road network. The LIC recommend an enhancement strategy, designed to retro-fit social and environmental improvements to protect local communities.
> Referring to the Austroads monitoring of urban travel times, the Engineers Australia Western Australian Infrastructure Report Card for 2005 stated:
> When considered in light of the increasing number of vehicles on the road network, travel times in peak periods have remained relatively stable over the period of 1998 to 2003 and are lower than NSW and Victoria which are commonly viewed as having congestion issues. (Engineers Australia 2005).

In its public transport Perth is very well positioned with significant investment in infrastructure in the 2000s producing outstanding patronage results as shown in Figure G91:

Figure G91: Transperth total boardings

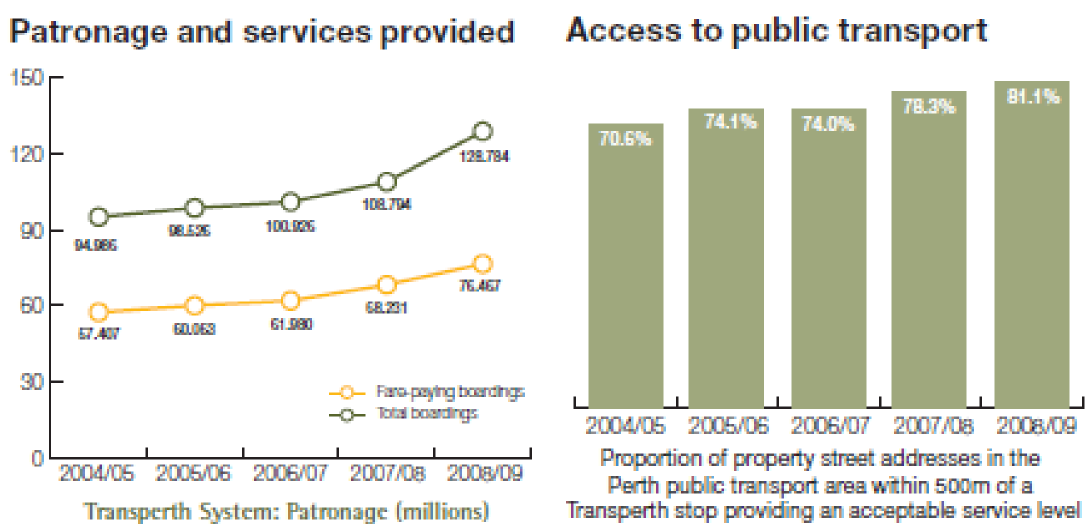


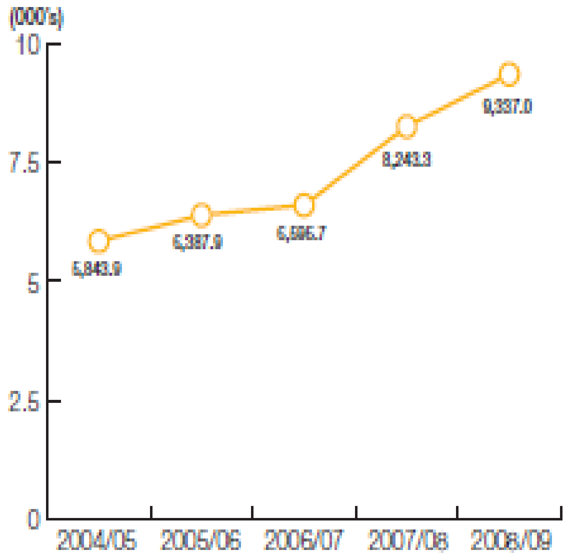
A range of Figures (Figure G92) below provide evidence of the results in more detail. Not only has the total patronage increased but so too has the extent of the rail and bus systems such that over 81% of all Perth residents are within 500 metres of a Transperth stop (without knowing if this computed on a GIS 'as the crow flies' or actual footpath walking distance). Reliability for trains has returned to 2004-05 levels (almost 95%) but for a vastly extended system some 60% greater than in 2004-05. The Total Passenger Place Kilometres figure is a measure of the number of patrons by their trip length. In 2007-08 this figure jumped 25% to 8,243.3 million km up from 6,595.7 million km. Last financial year (2008-09) the increase was 13% to 9,337.0 km.

In its 2008-09 Annual Report the Public Transport Authority acknowledges that…

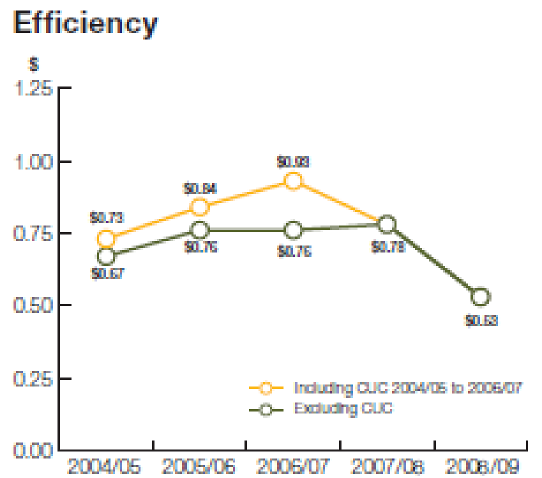
> while the population base will increase by 33 per cent over that period, demand for public transport is expected to double. We also know that WA is in the enviable position of being able to expand the passenger capacity of our rail network – which will continue to provide the major spine of our mass transit system – by 100-150 per cent without the need for major new infrastructure other than rolling stock.

Figure G92: Evidence of successful transfer to public transport.

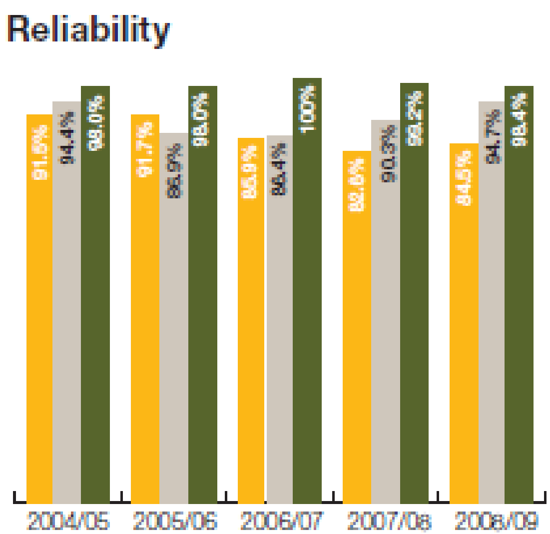




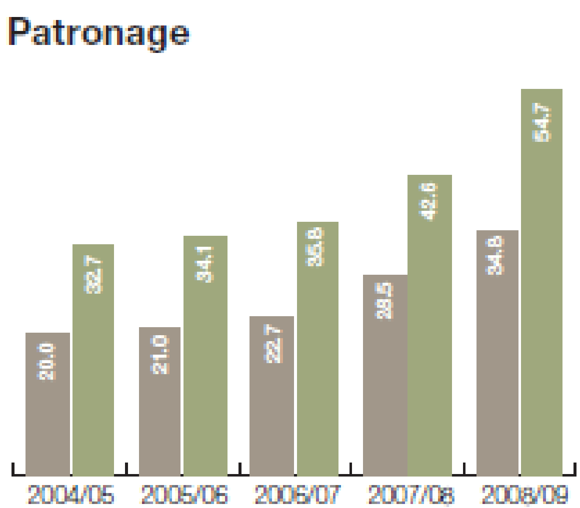
Transperth System:
Passenger place kilometres (millions)



Transperth System: Total cost per passenger kilometre
Passenger kilometres: 2007/08 based on average trip length derived from the zonal distribution of tickets; 2008/09 average trip length based on SmartRider tag-on/tag-off data
CUC: Capital User Charge (now abolished)



Transperth: Service reliability by mode
Proportion of services meeting on-time targets
Bus Train Ferry



Transperth Trains: Patronage (millions)
Fare-paying boardings Total boardings

Tranperth's bus fleet at the end of 2008-09 was taking advantage of the city's access to natural gas by operating 444 Compressed Natural Gas (CNG) buses out of a total of 1134 buses, with a further order for 80 more CNG buses in 2009-10 and 74 in 2010-11. Despite the impressive results of increasing patronage of public transport, the PTA warn that:... *congestion, particularly during peak periods, and the lack of significant bus priority measures on major roads in Perth, will continue to impact on service reliability and may affect patronage*

References

DPI (Department of Planning and Infrastructure) 2005, *South West Corridor Road Network Review : Final Report,* Government of Western Australia.

Engineers Australia, 2005, *Western Australian Infrastructure Report Card for 2005* Engineers Australia: Perth.

PTA (Public Transport Authority) 2009, *Annual Report 2008-09,* Government of Western Australia.

Energy Supply and Consumption

Australia

The Australian energy supply system is comprised of three networks of which the Eastern Australian Network (Figure G93) is of particular interest in this report. Because the Network is operated as a 'spot price' grid that links all major population centres in Eastern Australia there is not the same degree of local or regional difference in power supply compared to, say, water supply. The wholesale market is operated by the Australian Energy Market operator (AEMO), which 'sells' electricity to retailers in a virtual spot price market determined every 30 minutes. Generators produce power according to the demand of the spot price and base load required which is 'purchased' by AEMO and placed in a physical 'pool' of energy available.

Each year AEMO (and its predecessor NEMMCO) make forecasts of power supply required in ten years time. In a paper by Sligar and Vassallo (2009) on the emerging gap between current supply and possible power needs in 2050, they suggest that:

> The price of power will rise, some coal fired power stations and aluminium refineries will close, new generating technologies will be essential… the 2050 power supply system will need to be very different indeed.

The present situation of increasing demand of 1.7% per annum requires about 500 MW of additional generator capacity per annum. The cause is increasing population and expansion of urban areas. There are about 50 coal fired electricity plants installed of 300-750 MW each, transmission infrastructure network stretching over 4,500 km, and centres where the load is distributed in cities and aluminium plants (Sligar and Vassallo 2009). The total grid connected generation capacity in Australia is 48,500 MW. The total power generated in 2007–08 was 228 TWh for 9.9 million customers (IES 2008).

The price of electricity is increasing because of the export price of black coal. It will also be affected by whatever carbon tax or carbon reduction scheme is implemented by the Commonwealth Government, to the extent that some plants may close due to the financial stress. Altogether, some 15% to 20% of coal-fired power plants may close due to the combined effects of the CPRS and Government mandate to have 20% of power produced by renewable sources by 2020 (Sligar and Vassallo 2009).

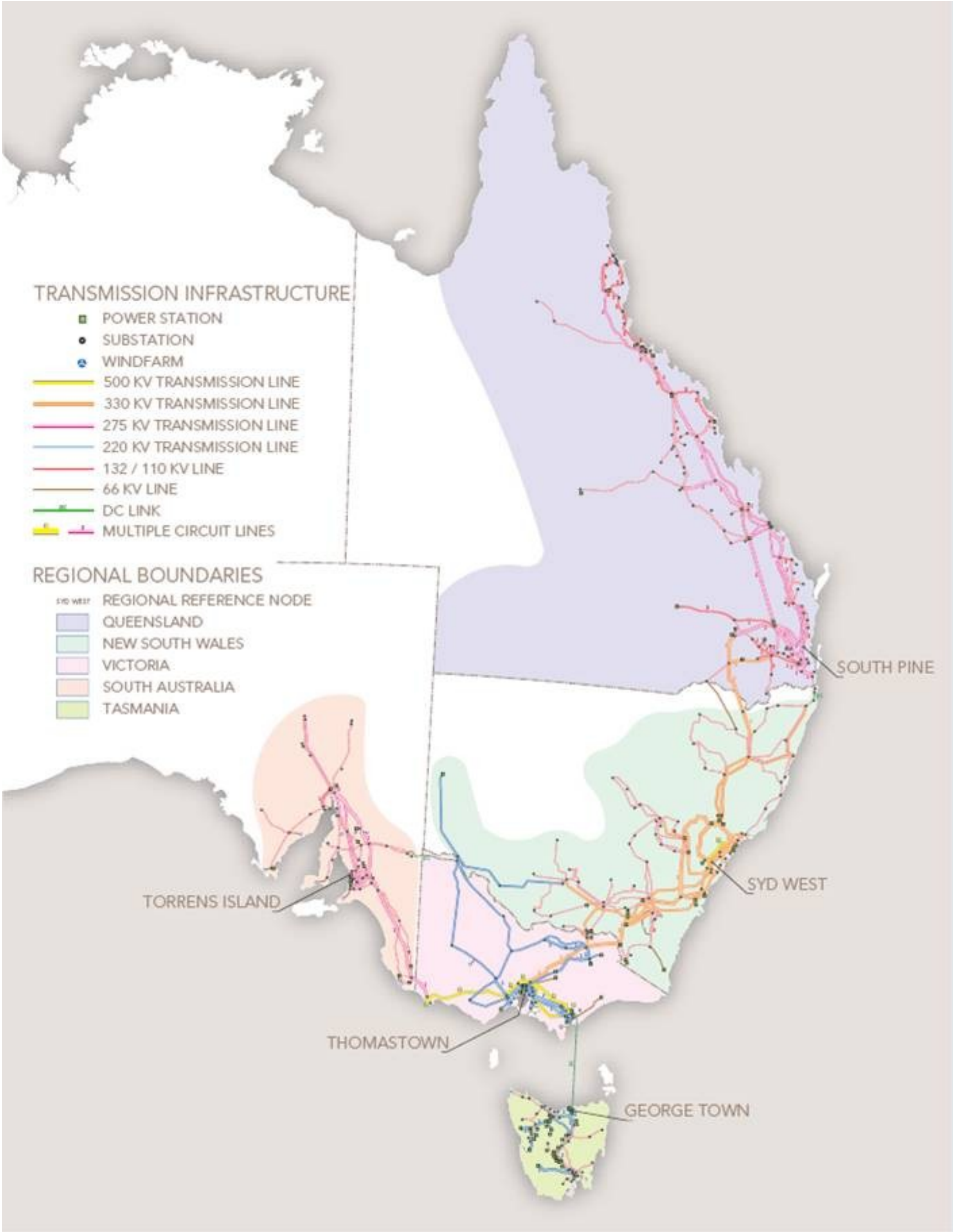
The security of power supply may be further stretched because aluminium plants such as Alcoa in Geelong and Portland, Victoria, which act as load distribution points were built at about the same time as some of the key power plants. They share the same life spans and are likely to be closed or replaced at the same time, therefore resulting in stranded assets in generation and transmission of power.

Looking into a crystal ball, the future of power generation in 2050 might look like this according to Sligar and Vassollo (2009) (See also Figure G108 in Greenhouse Chapter):

> Looking at 2050 there will be limited and expensive fossil fuels available in power stations with CCS [Carbon Capture and Storage]. The remaining electricity will be

supplied by many (thousands) small 2-10 MW wind/solar generators and some larger geothermal units. Nuclear will play a role but we are far behind in developing this potential. The power system will have a higher level of losses compared with now, because all the small units generate at about 600v rather than 25kV and require additional transformer stage to feed the system. The power system will also probably have a reduced level of security because of less firm load centres.

Figure G93: Eastern Australia's Electricity Network AEMO July 2009



Source: http://www.warren.usyd.edu.au/bulletin/NO60/Network.jpg

Residential

The Australian Bureau of Agricultural and Resource Economics (ABARE) examined the composition of energy consumption in Australia in a 2009 report (Sandu and Petchey 2009). In the following two sections, the energy consumed by residential and transport sectors is examined. These are the two sectors most closely associated with increasing population growth in our cities. In the first section on residential consumption (see Figures G98, G99 and G100) the ABARE study identified the following key points:

1. *In 2006-07, the residential sector accounted for around 12 per cent of final energy use in Australia.*
2. *Space heating and water heating dominated energy use in the sector, contributing to more than 60 per cent of residential sector energy consumption.*
3. *Energy consumption in the residential sector grew by 34 per cent (106 petajoules), from 313 petajoules in 1989-90 to 419 petajoules in 2006-07. The largest increase occurred in the use of household appliances.*
4. *Over the same period, Australia's population rose by 23.5 per cent to 21 million. The increase in population alone would have resulted in energy consumption increasing by 79 petajoules (activity effect).*
5. *A reduction in household occupancy and an increase in both house size and ownership of appliances (structural effect) are estimated to have led to an increase in energy consumption of 84 petajoules.*
6. *The efficiency effect in the residential sector resulted in a reduction in energy use of 0.9 per cent a year. This is equivalent to energy savings of 57 petajoules.*
7. *There are a number of factors which may have affected energy intensity trends in the residential sector, including disposable income, energy prices and government policies.*

Of relevance to the behavioural changes that people have made to their energy use is illustrated in Figure G99 which shows that space heating was reduced by almost 60 petajoules, water heating by 16 petajoules and fridge use by almost 10 petajoules between 1989-90 and 2006-07. Increases were recorded in standby power and IT equipment reflecting the purchase of new consumer electronics by large numbers of people.

Figure G94: Composition and growth in energy consumption in the residential sector

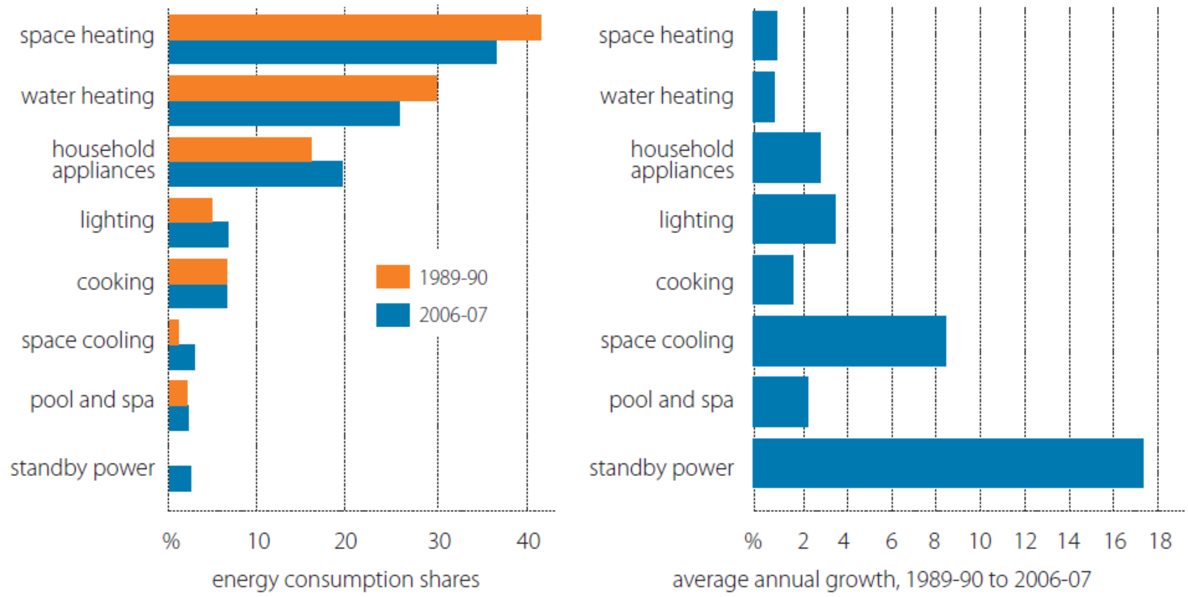


Figure G95: Summary of changes in energy consumption because of the efficiency effect in the residential sector by end use

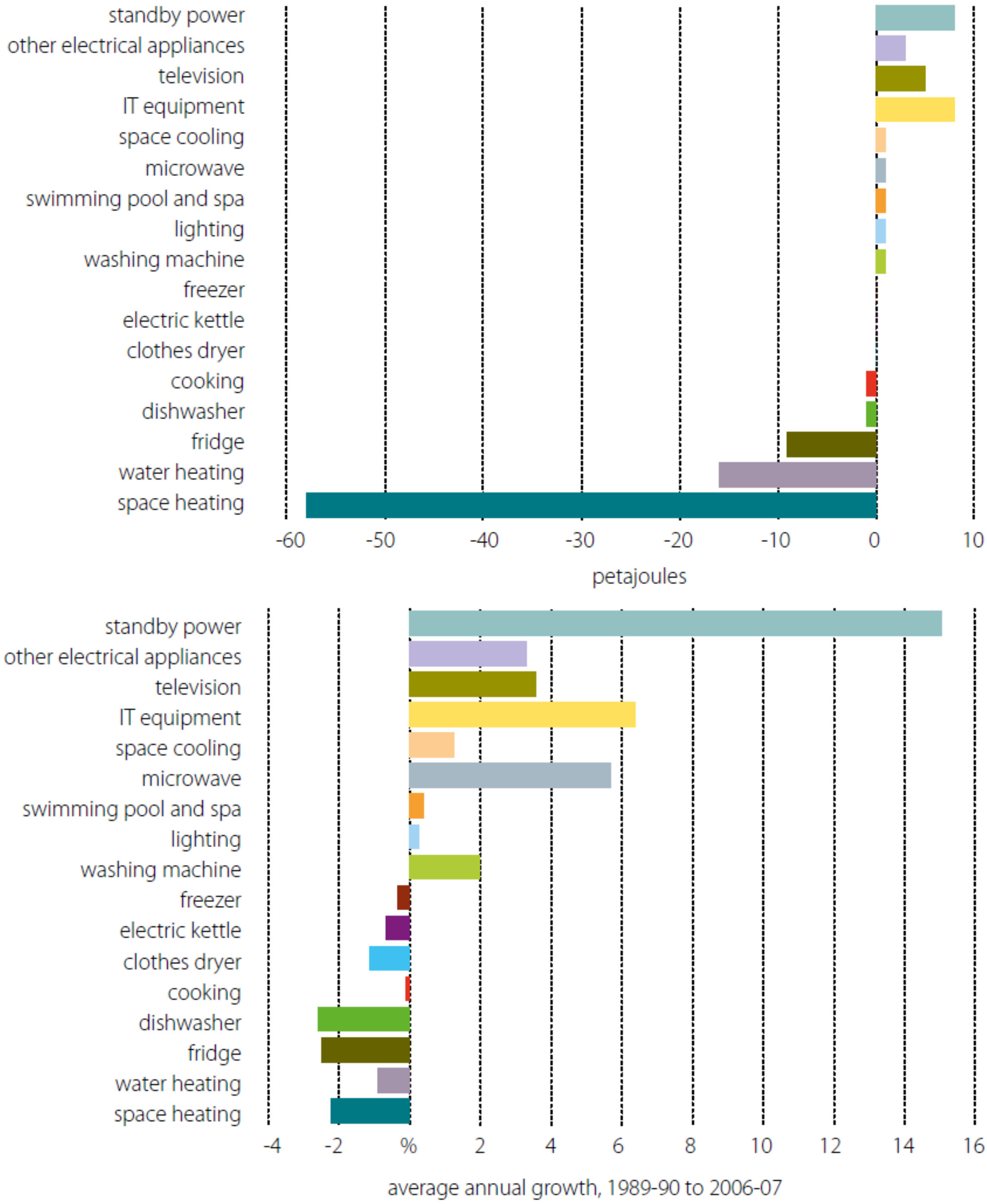
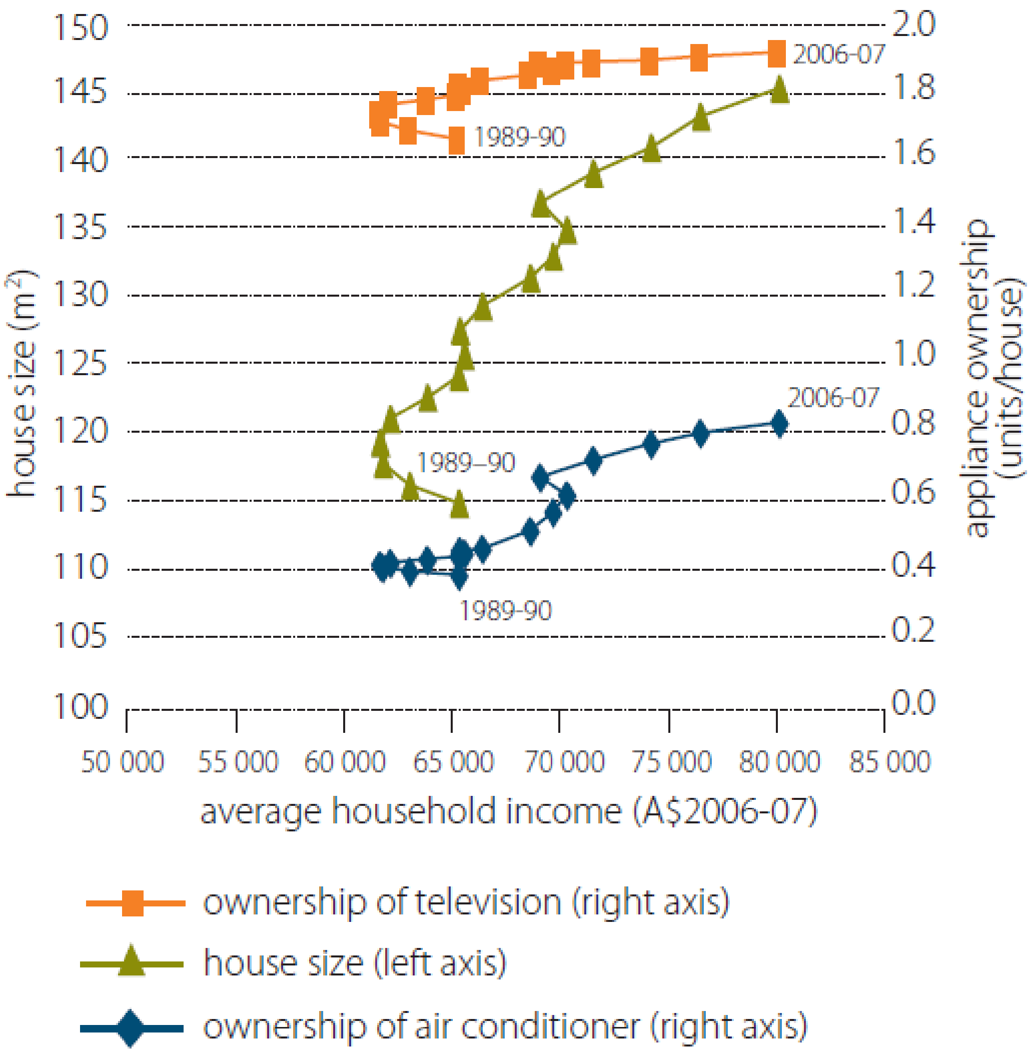


Figure G96: Appliances ownership, house size



Sources: ABS 2008b, 2009a and 2009b and EES 2008.

Transport

In the second sector report ABARE made the following key points:

1. *In 2006-07, the transport sector accounted for 34 per cent of final energy use in Australia. Around 60 per cent of energy consumed in the transport sector is associated with the movement of passengers and the rest with the movement of freight.*

2. *Transport energy consumption grew at an average rate of 1.6 per cent a year, from 911 petajoules in 1989-90 to 1194 petajoules in 2006-07. Passenger transport energy consumption grew at an average annual rate of 1.3 per cent, from 591 petajoules in 1989-90 to 739 petajoules in 2006-07, while energy use in freight transport grew at an average rate of 2.1 per cent a year, from 319 petajoules in 1989-90 to 455 petajoules in 2006-07.*

3. *The activity effect resulted in transport energy consumption increasing by 441 petajoules (to 1352 petajoules) over the period 1989-90 to 2006-07, with passenger travel contributing 198 petajoules and freight contributing 243 petajoules.*

4. *Shifts within the passenger and freight transport sectors from less energy-intensive to more energy intensive modes (structural effect) are estimated to have led to an increase in energy consumption of 8 petajoules. The freight transport sector contributed to an increase of 11 petajoules, while shifts within the passenger transport sector offset this by 3 petajoules.*

5. *The efficiency effect in the passenger and freight transport sectors resulted in annual reduction in energy use of 0.4 and 1.8 per cent, respectively. This is estimated to have led to energy savings of 48 petajoules and 118 petajoules for passenger and freight transport, respectively, which is a total energy saving of 166 petajoules.*

6. *There are a number of factors which may have affected energy intensity trends in the transport sector, including energy prices, income, technological development and government policies.*

Of particular note in the transport sector is firstly the increase of MJ per passenger kilometre in cars and buses (Figure G98), indicating perhaps more single occupant trips and less patronage respectively. This is borne out by Figure G99 where we own more cars but use the bus less often. About 1997, when GDP per capita reached $38,000 it appears more people could, or chose to, afford a vehicle instead taking public transport (see Figure G99). The graph may also indicate the influence of urban sprawl without adequate public transportation which requires households to use a car. The composite measures of efficiency take into account the fuel efficiency of a vehicle, but if fewer people are in the car, the energy intensity will increase. This is also applicable for buses.

By contrast, domestic aviation almost doubled its share of the energy budget from 1989-90 but was able to deliver energy efficiency gains through more ‘bums on seats’ per kilometre flown and more efficient use of fuel per passenger kilometre compared to cars (see Figures G100 and G101). Aviation went from 4% of total domestic travel to a 16% share in 2006-07 and was largely responsible for the efficiency gains by the passenger transportation sector. Cars actually declined in proportion from 90% to 80% of energy consumed since 1989-90.

Figure G97 Composition and growth in energy consumption in passenger transportation

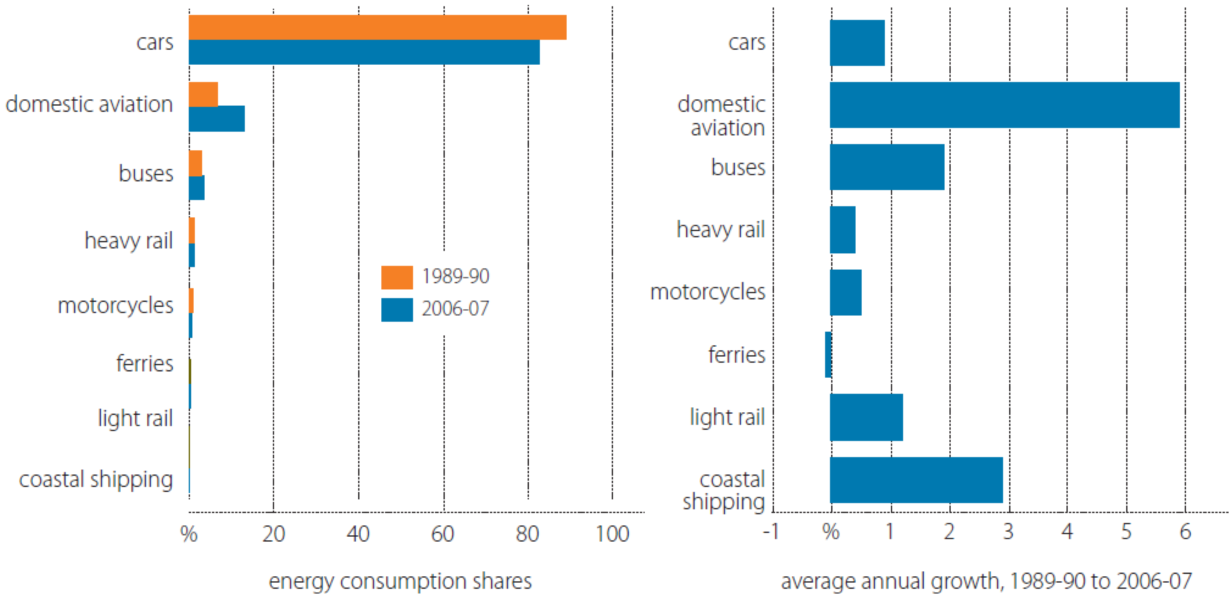


Figure G98: Summary of energy intensity indicators in passenger transportation

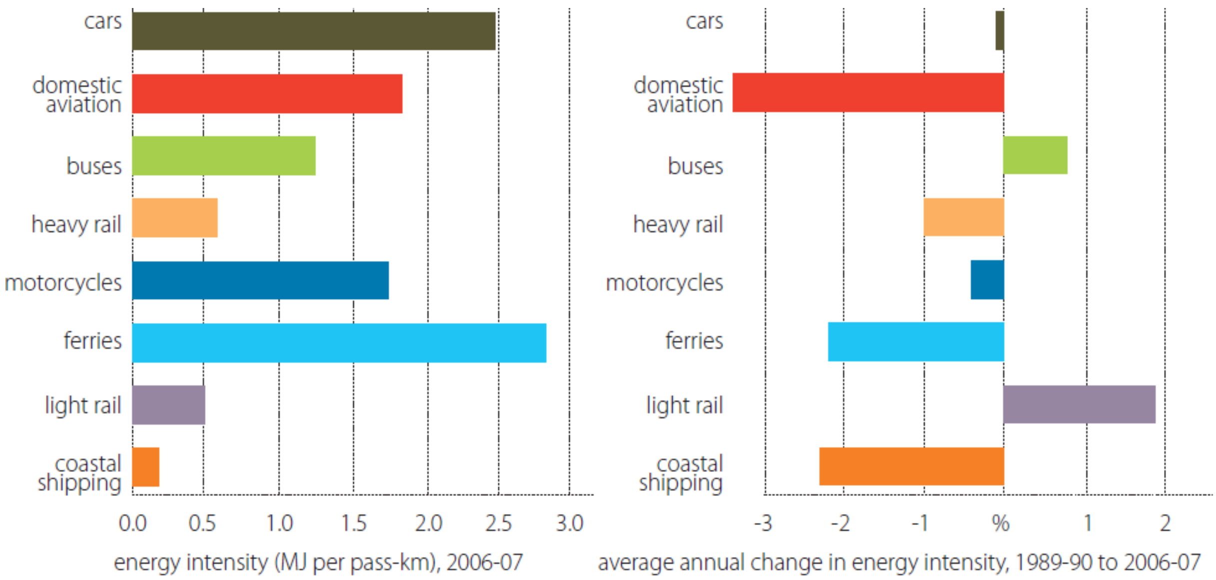
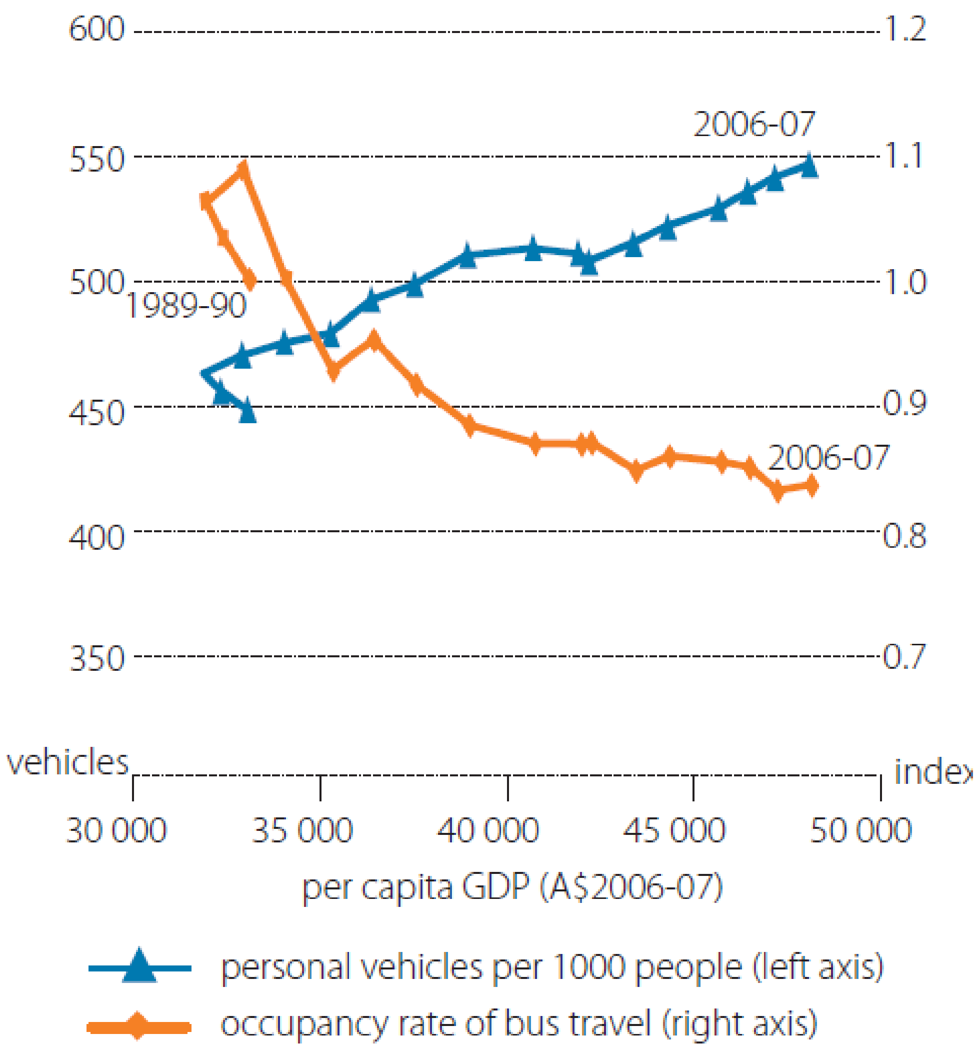


Figure G99: Ownership of personal vehicles, public bus usage and per capita income, 1989-90 to 2006-07



Sources: ABARE estimates using data from ABS (2009a, 2009b, various) and Apelbaum 2008.

Secondly, the increase in MJ per tonne kilometre for light commercial vehicles (Figures G102 and G101), likely due to increasing numbers of delivery vehicles on the roads as retailers, aim to hold less stock on hand to improve financial efficiency. They therefore needed more frequent supply trips from the wholesaler. There was also a shift towards greater use of logistic transfer hubs, improved rail infrastructure and simple growth in demand for goods.

Figure G100: Composition and growth in energy consumption in freight transportation

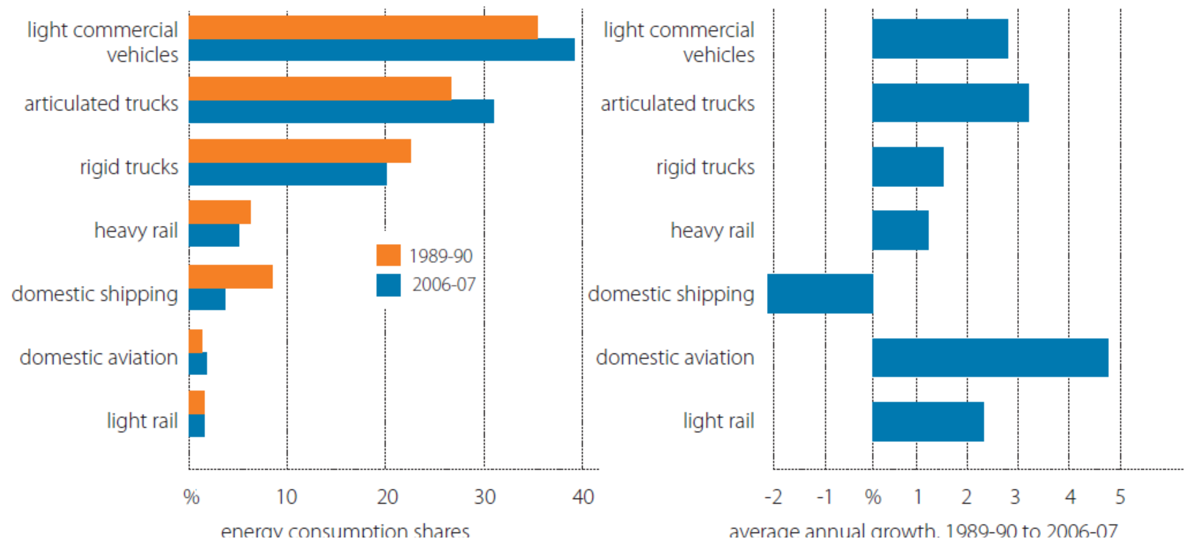
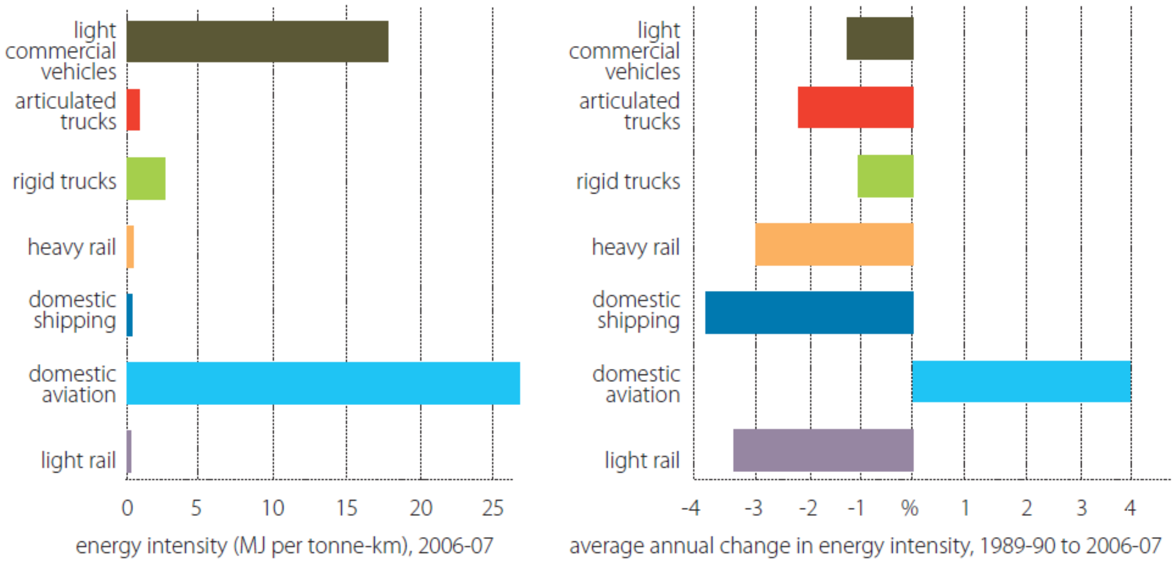
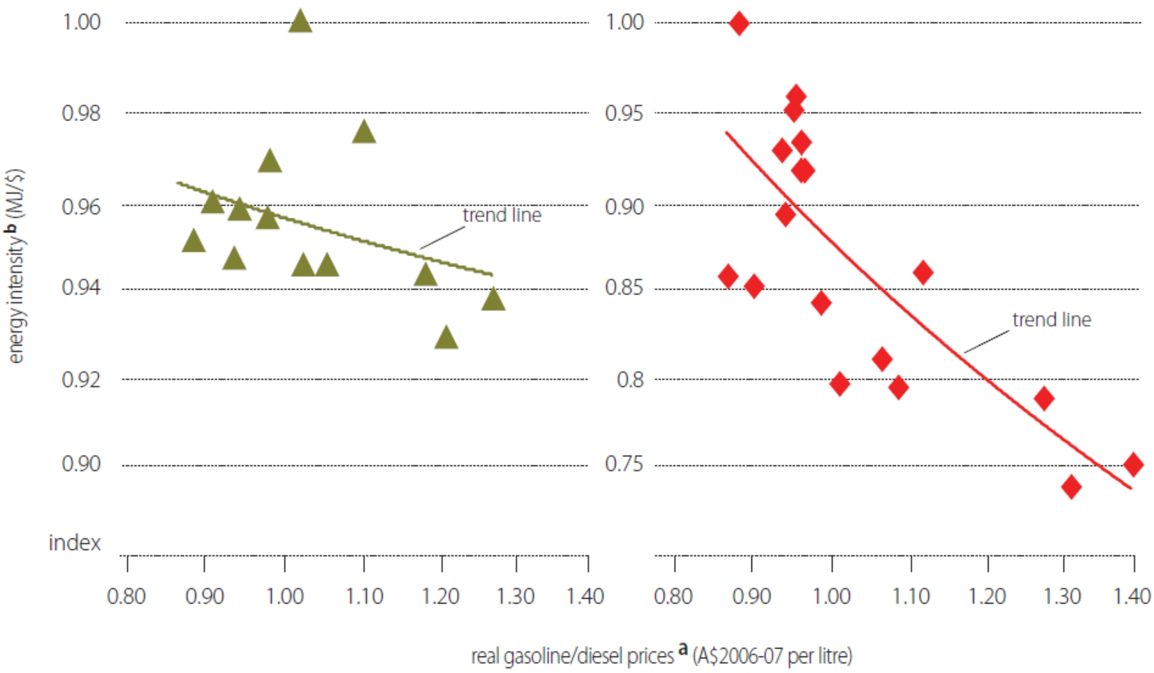


Figure G101: Summary of energy intensity indicators in freight transportation



Finally the impact of energy price on energy intensity is problematic. On the one hand Figure G102 shows a general decline in energy intensity when energy prices increase. That is, people make fewer trips from doing more in each trip or carry more people per trip. Similarly, the freight sector carries more goods each trip perhaps by consolidating the number of trips and/ or driving more slowly so as to use less fuel.

Figure G102: Energy prices and energy intensity in the transport sector, 1989-90 to 2006-07



Sources: **a** IEA (various) **b** Result from this study

References

IES (International Electricity Summit) 2008, *Roadmap for a Low-Carbon Power Sector by 2050*. International Electricty Summit Atlanta Georgia October.

Sligar, J. and Vassallo, A. 2009 Emerging gap between current power supply system and needs of 2050. *Engineering the Future e-Bulletin* 60 November.

Sandu, S and Petchey, R 2009, End use energy intensity in the Australian economy, ABARE research report 09.17, Canberra, November.

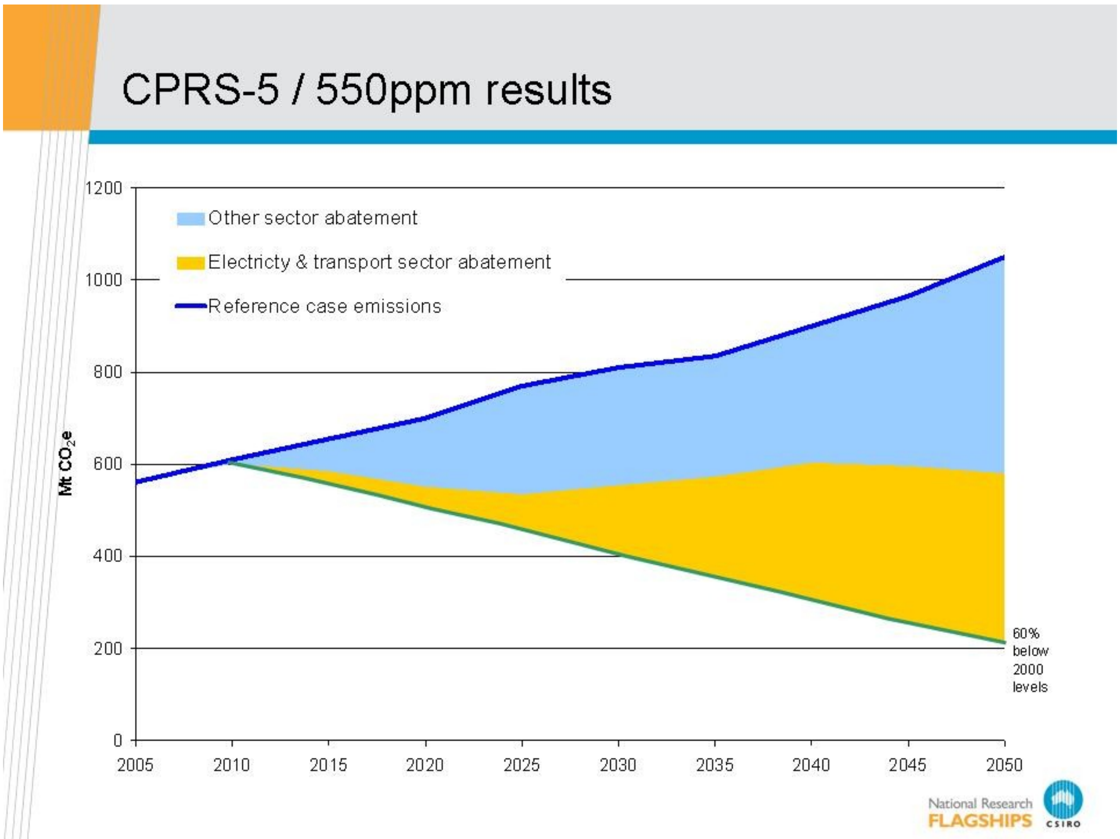
Wright, J. 2009, The contribution of renewables in Australia's future energy mix, *Australian Academy of Science Lecture Series*, August.

Greenhouse gas emissions

Each LGA in Australia has a Greenhouse Gas (GHG) abatement plan at least for their own operations let alone what each of their constituents is doing with energy efficiency and low carbon adaptive behaviours. However, the profile of GHG in Australia more generally is driven by the amount of energy required by an increasing population, given that it is the energy generation sector that contributes between 40% -50% of total Australian GHG and that the energy supply is linked in expansive networks that account for regional and local differences. The rest of the GHG are generated by forestry, land use changes (eg. urban expansion), fugitive emissions (eg. methane from landfill), agricultural operations, and non-electricity steel, cement and chemicals manufacture.

Figure G103 below shows the extent to which abatement in GHG emissions will be required from the two sectors – electricity generation and the rest of the economy – in order to meet the Government's Carbon Pollution Recovery Scheme (CPRS) objective of 5% reduction on 2000 levels of GHG.

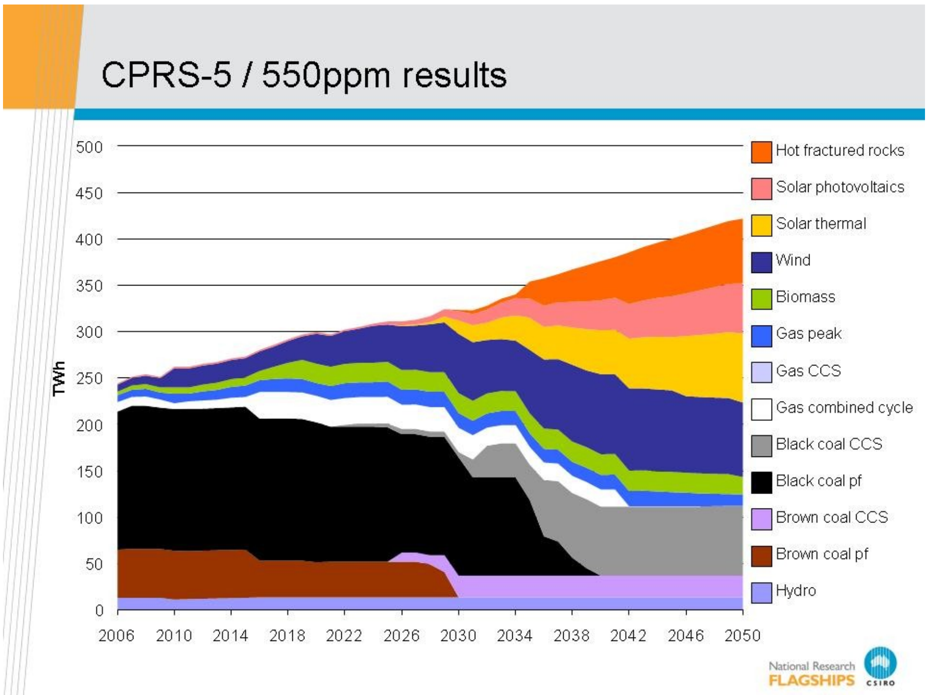
Figure G103: Projected abatement for transport and electricity sector



The role of renewable energy sources is also crucial. Dr John Wright, currently an advisor to CSIRO's Sustainable Energy Partnerships, suggests that once we hit 2020, important because the Government has put in place a mandated target of 20% of our total energy to be derived from sources by 2020, *once you have achieved your 2020* *targets, you have curled over your greenhouse gas emissions, it is starting on the downhill slope and it should get a lot easier once we start on the downhill slope.*

Eventually by 2050 the make-up of our electricity generation will look something like Figure G104 below. The demand for energy keeps increasing with increasing population but the proportion of energy production that exhales carbon keeps on reducing; The Figure contains energy contributions from coal plants fitted with carbon capture and storage technology but not energy from either nuclear plants due to political difficulties with its introduction, or wave power given the existence of alternatives and development timetables.

Figure G104: Scenario for energy sources



References

Wright, J. 2009, The contribution of renewables in Australia's future energy mix, *Australian Academy of Science Lecture Series*, August 2009

A select synthesis of micro-scale impacts of NOM

Summary

To examine the contribution of NOM to the range of independent variables at the micro-scale a series of four essays were written that synthesised our exiting knowledge about aspects of the costs of additional NOM on our physical environments: the costs of migrant ownership of a motor vehicle, the cost of congestion, the social costs of carbon, and a subjective assessment of liveability.

Table H1 provides a snapshot of the conclusions from the four essays and three of the environmental impacts measured in this report. Urban traffic congestion has the greatest social costs, and because overseas migration is responsible for over half of the population growth of Sydney, Melbourne and Perth, it is a major contributor to the increase in these costs. Air quality and associated impacts have the least costs and are the easiest of the three to manage with improved technology, so they should not be regarded as a major issue, except perhaps in Sydney because of that city's higher population and traffic density, and the particular atmospheric conditions of the Sydney airshed.

Table H1 Annual social environmental costs per migrant, 2006-2056, without mitigation ($, in 2000 values)

Type of cost	2006	2026	2056
Annual vehicle social environmental costs	$261	$282	$282
Annual social costs of traffic congestion for private vehicle travel, Sydney	$1527	$2410	na
Annual social costs of traffic congestion for private vehicle travel, Melbourne	$1731	$2398	na
Annual social costs of traffic congestion for private vehicle travel, Brisbane	$949	$2164	na
Annual social costs of traffic congestion for private vehicle travel, Perth	$897	$2022	na
Annual social cost of carbon per migrant	$624	$928	$1681

Traffic congestion and carbon emissions are major issues, and will also be very difficult to manage, and the social costs of traffic congestion are already being experienced. Sydney, as expected, has the highest costs of congestion, but the estimates suggest rapid growth in these costs in Melbourne, Brisbane and Perth.

Brief summaries of the four essays follow:

The first essay on liveability was a response to the project brief: 'While starting from a quantitative basis, the report must also develop a qualitative assessment of

particular levels of NOM on "liveability" and quality of life, for example in Australia's cities ….' In summary, the findings of this essay were that:

- Economic analysis of subjective well-being can provide quantitative assessments of liveability and quality of life.
- The quality of urban areas, as measured by factors such as good infrastructure and services, safety, good social relationships and an unpolluted and attractive environment, contributes in a small but significant way to people's subjective well-being.
- If the growth of Australia's cities to the sizes projected in this report leads to higher levels of air and water pollution, noisier cities, increasing congestion and longer commuting times, subjective well-being will be reduced. [The risk of environmental degradation in the cities will be assessed elsewhere in this report] The degree of this reduction cannot be calculated, but based on the studies above it could be the equivalent of perhaps ten per cent of individual income.
- Higher population densities, which are an inevitable outcome of urban population growth and an essential way of coping with this growth, need not produce a decline in subjective well-being. This will only be achieved, though, if higher density areas have the attributes of good public transport, a range and variety of leisure, entertainment and cultural facilities, and a stimulating life style that compensate for some of the negative aspects of higher density areas. In addition, residents' life satisfaction will be increased if the negatives of higher density areas, such as noise and air pollution, can be reduced.
- Careful planning is also needed on the expanding fringes of Australia's major cities, to ensure that urban growth does not produce a decline in subjective well-being.
- Policy should seek to avoid concentrations of migrants from non-English-speaking countries, if the finding of the study by Shields, Wheatley Price and Wooden (2009) is correct and the objective is to maximise the welfare of the resident population.
- Generational shifts in the Australian population are likely to increase the influence of environmental conditions on people's subjective well-being, and produce stronger demands for governments to improve the environmental sustainability of the cities.

The second study on the social cost of carbon, was, essentially a proxy for a consideration of Greenhouse Gas contribution by NOM taken out of any specific location context. There are several ways of attributing a cost or price to emissions of carbon by an individual such as a migrant (Minh 2009). Perhaps the most appropriate for the purpose of this report is the social cost of carbon (SCC). This is defined by the International Panel on Climate Change (Parry et al. 2007, p. 881) as the value of the climate change impacts from an additional 1 tonne of carbon emitted today as CO_2, aggregated over time and discounted back to the present day. As an example of the use of the SCC in government planning, in 2002 the UK Government recommended an illustrative marginal global SCC estimate of £70/ tonne of carbon (tC), rising at £1/ tC per year from the year 2000, for use in policy appraisal across Government (Watkiss and Downing 2008, p. 86).

Estimating a SCC is very difficult and the results have a considerable degree of uncertainty. As Tol (2008a) comments: "[c]limate change is the mother of all externalities, larger, more complex, and more uncertain than any other environmental problem". First, most of the future costs that are aggregated into the SSC are difficult to estimate accurately, especially those that have no market value. Second, estimates differ according to the impacts that are included (for example, whether extreme events and biodiversity losses are estimated). Third, experts differ over the discount rate to use to adjust future costs back to present values, and over whether the rate should be constant or declining. Most of the cost impacts of climate change are in the future, so the discount rate has a large impact on estimates, and high rates produce low estimates. Most studies prefer standard discount rates. However, some argue that this undervalues the interests and welfare of future generations and conflicts with the principle of inter-generational equity, and that the discount rate should be near or at zero. The Stern Report, for example, used a low discount rate and therefore produced a high SCC. Fourth, studies differ in the length of time considered. Because climate change impacts are likely to increase over time, the longer the time span, the higher the SCC. Fifth, studies use different ways of weighting the impacts in different countries, as estimates of SCC are typically global estimates on the grounds that the impacts of climate change, and the benefits of climate change mitigation, are global. Sixth, estimates vary according to the assumptions made about future temperature levels (Anthoff, Hepburn and Tol 2009; Dietz 2007; Guo et al. 2005; Hope and Newbery 2006; Pearce 2003; Watkiss and Downing 2008).

The final calculation yielded the following table H2:

Table H2 Social Cost of Carbon per Migrant

Year	SCC/t CO2 (A$ in 2000 values)	SCC per migrant, without mitigation (A$ in 2000 values)	SCC per migrant, with mitigation (A$ in 2000 values)
2000	$42.00	$554.40	$554.40
2006	$47.30	$624.30	$624.30
2026	$70.30	$927.70	$566.60
2056	$127.30	$1,680.50	$130.10

Comment: These figures do not take into account the children and grandchildren of migrants. They could be increased by adding the per capita output attributed to children expected to be born to a migrant. This is a process that has not been attempted in this report.

The third study of NOM at a micro-level examined congestion, i.e. what happens when population growth increases the number of motor vehicle owners and the demand for other forms of road transport, and increases traffic congestion in the cities in the absence of any measures to manage this growth. The Bureau of Transport and Regional Economics identifies the following costs associated with increased congestion:

- longer average journey times because of interruptions to traffic flow
- more uncertain travel times, leading to travellers having to allow for a greater amount of travel time than previously
- increased vehicle operating costs primarily because of higher fuel consumption, and
- poorer air quality because of increased emissions of pollutants (BTRE 2007, p. 77).

BTRE has estimated the social costs of traffic congestion resulting from these factors for each Australian city, and projected these to 2020. Their estimates are of how much total costs (for time lost and other wasted resources) could be reduced if traffic volumes were reduced to the economically optimal level, which they define as 'the level of traffic beyond which the full social costs of any further travel would outweigh the benefits of that extra travel' (BTRE 2007, p. 78). This is described as the avoidable cost of traffic congestion. The estimates are not based on a comparison with a situation of freely-flowing traffic, which BTRE describes as unrealistic.

BTRE projects that the total social costs of congestion in Sydney will rise from \$3.5 billion in 2005 to \$7.8 billion in 2020, in Melbourne from \$3.0 billion to \$6.1 billion, in Brisbane from \$1.2 billion to \$3.0 billion and in Perth from \$0.9 billion to \$2.1 billion (BTRE 2007, p. 107).

The contribution of overseas migration to these costs can be very approximately estimated from the data in the BTRE report. The annual increase in the social costs of congestion for private vehicle travel in 2006 in Sydney attributable to population growth rather than income growth is estimated at \$1527 (in 2000 values) per person added to the population of Sydney that year. The data on growth in population is the same as used by the BTRE in their projections. To calculate the corresponding figure for 2026 the BTRE estimate of the social costs of congestion in 2020 is projected forward to 2026 at the average rate of growth of these costs before 2020. BTRE expects that all of the increase in car traffic after 2020 will be caused by population growth rather than by a combination of population growth and higher incomes, so all of the increase in congestion costs in 2026 has been attributed to population growth. Projecting the BTRE figures, which end in 2020, forward to 2056 to produce an estimate for that year is not considered advisable.

Table H3 shows the annual social cost of traffic congestion for Sydney, Melbourne, Brisbane and Perth. The estimates do not include business vehicle use, which is projected to contribute 22 per cent more than private vehicle use to the total social costs of congestion in 2020 in the BTRE study. Population growth resulting from migration must have some effect on growth in business vehicle use, so the estimates in the table are conservative.

Data on the possible effects of mitigation measures on the social costs of congestion are limited, and difficult to use to adjust the estimates in the table. BTRE estimates that aggregate congestion costs could be reduced by approximately 27 per cent by 2020 if 12 per cent of urban travel could be switched from cars to other modes (BTRE 2007, p. 119). This estimate is based on the assumption of no increase in transport infrastructure. In earlier work the Bureau examined the potential effects of variable congestion charges in the metropolitan areas. They estimated that the likely effects of levying such charges in the eight State and Territory capitals would be to:

- decrease total metropolitan vehicle kilometres travelled in 2020 by around 14 per cent below the level projected in the base case (where it is assumed that bus travel increases by 30 per cent);
- decrease average fuel intensity (L/100km) across metropolitan Australia in 2020 by around 7 per cent; and thus
- decrease total metropolitan fuel use in 2020 by around 20 per cent.

These estimates do not suggest that the costs of congestion in 2026 can be reduced by more than about a quarter unless there is a major increase in public transport infrastructure.

Table H3 Social costs of congestion for private vehicle travel per migrant, 2006-2026 ($ in 2000 values)

City/Year	Annual social cost per migrant	
	Without mitigation	With mitigation
Sydney 2006	$1527	$1527
Sydney 2026	$2410	$1807
Melbourne 2006	$1731	$1731
Melbourne 2026	$2398	$1799
Brisbane 2006	$949	$949
Brisbane 2026	$2164	$1623
Perth 2006	$897	$897
Perth 2026	2022	1517

The fourth essay calculated the costs of a migrant owning a car in Sydney Melbourne or Perth. The summary finding is in Table H4:

Table H4 Vehicle costs per migrant

Year	Vehicle costs per migrant, without mitigation (A$ in 2000 values)	Vehicle costs per migrant, with mitigation (A$ in 2000 values)
2002	$254.60	not applicable
2006	$260.70	$251.40
2026	$282.10	$228.00
2056	$282.10	$167.70

The Table accounts for costs associated with mortality and morbidity from air pollution caused by cars: between approximately 900 and 2000 premature deaths in Australia, with more than 85 percent of these in the capital cities (BTRE 2005). Motor vehicle pollution is also estimated to have accounted for between approximately 900 and 4500 morbidity cases—cardio-vascular disease, respiratory disease, and bronchitis—and to have contributed to between 700 and 2050 asthma attacks.

Sydney and Melbourne were the worst affected cities. These levels of mortality and morbidity were estimated to have a total economic cost in 2000 in the order of $2.6 billion. Another study estimated the health cost of ambient air pollution in the Sydney Greater Metropolitan Region to be between $1.01 billion and $8.40 billion per annum in 2003. If it was assumed that there was no level below which particulate matter (PM) did not affect health, the cost increased to between $1.66 billion and $15.21 billion per annum (DEC 2005). A study of the health costs of traffic related air pollution in Perth arrived at a best estimate of $7.86 per kilogram of PM of less than 10 micrometres in size, which is the most dangerous type (Cockroft and Pryor, n.d.).

Motor vehicle emissions also contribute to global warming, an issue which is examined in another section of this report. Other impacts of air pollution include:

- Reduced environmental quality in areas of high air pollution, which discourages investment and lowers property values;
- Reduced scenic value as a consequence of haze;
- Increased use of home or car air conditioning indoor, which increases the amount of energy consumption (Sirikijpanichkul, Iyengar and Ferreira 2006); and
- Building, forest and crop damage (Tsolakis 2003)

Tsolakis et al. (2003) also provide cost estimates for several other impacts of motor vehicle use. These are:

- Noise, which is estimated by combining a willingness to pay component with a health cost component.
- Nature and landscape, described as 'effects on nature (including biodiversity) and landscape (such as loss of natural land area, reduction in

the quality of the landscape and land pollution)' (Tsolakis et al. 2003, p. 17);

- Urban separation costs, described as 'constraints on the mobility of pedestrians and community severance' (Tsolakis et al. 2003, p. 17).

Introduction

Scenarios is a word that is very carefully selected. The ABS use 'scenario' rather than 'projection' or 'forecast', because these latter two words convey meaning about what is a likely outcome based on present data. A 'scenario' on the other hand acknowledges that the forces creating the future are not foreseeable and therefore whatever assumptions are made, are going to be affected by the bias of the author. One could replace bias with imagination as the following quotation from Carrington et al 2007, p.161 suggests:

> Scenarios combine the rigour of theory and statistics with the essential flair and imagination necessary to the future of multi-faceted issues embracing economy, society and the environment.

The use of scenarios in this study is used highlight current limitations and opportunities such as they emerge, about the impacts of population growth through different levels of NOM on Australia's physical environment. The following three essays portray the impacts of increased NOM at the micro-scale, the level of the individual. Scenario one describes the series of environmental impacts of (migrant ownership of) a car in a major Australian city. Scenario two attempts to elucidate the cost, in dollars, of congestion, as a proxy for the qualitative, subjective influence that congestion adds to living and working in an Australian city. Scenario three attempts to elucidate a social cost of carbon, again using dollars as a proxy for qualitative subjective experience.

Scenario A: The car

This section evaluates some of the urban environmental impacts and costs associated with motor vehicle use by immigrants. These include air pollution, noise, loss of biodiversity, loss of natural land, reduced landscape quality, constraints on the mobility of pedestrians and fragmentation of urban space. Two other important effects of vehicle use, congestion and carbon emissions, are discussed in other sections of this report.

Air pollution

Air pollution is predominantly an urban problem, and the major contributor to most but not all types of air pollution in Australia's cities is the motor vehicle (Sirikijpanichkul, Iyengar and Ferreira 2006). Given Australian car ownership patterns, which are adopted by immigrants through choice or necessity, a growing number of immigrants will lead to an increase in the number of private vehicles, and a corresponding increase in commercial vehicles to service their needs. This increase in vehicle numbers might be expected to produce more emissions and a decline in air quality.

The topographic and atmospheric conditions of several of Australia's major cities make them particularly susceptible to air pollution, with polluted air blown inland by sea breezes but trapped by hills and returned to the coast during the night. Until it is broken by the passage of a front or by rain, this recirculation of air produces increasing levels of pollution, and visible photochemical smog. Western Sydney is particularly at risk from this condition (Bridgman, Warner and Dodson 1995), yet this will be the location of many immigrants, who will both contribute to and suffer from air pollution.

The social and economic significance of air pollution is that it contributes to increased mortality and morbidity (Department of Environment and Conservation NSW 2006; Howie *et al*. 2005; Hurley 2004). A BTRE study estimated that in 2000, motor vehicle pollution accounted for between approximately 900 and 2000 premature deaths in Australia, with more than 85 percent of these in the capital cities (BTRE 2005). Motor vehicle pollution is also estimated to have accounted for between approximately 900 and 4500 morbidity cases—cardio-vascular disease, respiratory disease, and bronchitis—and to have contributed to between 700 and 2050 asthma attacks. Sydney and Melbourne were the worst affected cities. These levels of mortality and morbidity were estimated to have a total economic cost in 2000 in the order of $2.6 billion. Another study estimated the health cost of ambient air pollution in the Sydney Greater Metropolitan Region to be between $1.01 billion and $8.40 billion per annum in 2003. If it was assumed that there was no level below which particulate matter (PM) did not affect health, the cost increased to between $1.66 billion and $15.21 billion per annum (Department of Environment and Conservation 2005). A study of the health costs of traffic related air pollution in Perth arrived at a best estimate of $7.86 per kilogram of PM of less than 10 micrometres in size, which is the most dangerous type (Cockroft and Pryor, n.d.). PM was used as the indicator of air pollution in this study because it is the cause of the greatest health costs, and is strongly correlated with other air pollutants.

Motor vehicle emissions also contribute to global warming, an issue which is examined in another section of this report. Other impacts of air pollution include:

- Reduced environmental quality in areas of high air pollution, which discourages investment and lowers property values;
- Reduced scenic value as a consequence of haze;
- Increased use of home or car air conditioning indoor, which increases the amount of energy consumption (Sirikijpanichkul, Iyengar and Ferreira 2006); and
- Building, forest and crop damage (Tsolakis 2003)

Because urban air quality has been generally improving in Australia's cities, as a result of environmental regulation and higher fuel quality standards, it might be expected that the health costs of air pollution will decline in the future. However, while levels of sulphur dioxide, nitrogen dioxide, lead and carbon monoxide in the air have been declining for some years, and are not considered be a significant problem in any city, photochemical smog, as indicated by high ozone levels, and particulate matter (PM) are both still of concern, as they have not declined and have the greatest impacts on human health. A recent study shows that ozone levels in Sydney increased from 1992 to 2001 and then stabilised in 2002 and 2003. Particulate matter decreased from 1993 to 2000, and then exhibited a slight upward trend (Azzi and Duc 2008).

Tsolakis *et al*. (2003) provide an approximate method for estimating the air pollution costs created by each additional migrant to Australia. They review a number of European studies of the cost of various transport externalities, and adjust their findings to Australian conditions of urban population density and vehicle occupancy. They include health costs and the costs of damage to buildings, crops and forests. They arrive at an average air pollution cost for cars of A$19.00 per 1000 passenger kilometres, in 2001 prices, or A$18.40 in 2000 prices (Tsolakis 2003, p. 10). In the absence of a marginal cost, this figure will be used as an approximation of the marginal cost of air pollution created by one additional migrant. Gargett and Gafney (2003, p. 4) report that the annual vehicle kilometres travelled per person by car in 2002 was 7,035 km in Sydney, 8,089 km in Melbourne and 7,474 km in Perth. The average of these distances, weighted by the number of permanent migrants settling in each city between 2004 and 2006, was 7,508.6 km. If migrants adopt similar car ownership and travel patterns as the Australian-born, then the annual marginal cost from air pollution of an additional migrant is A$138.20. Projected growth in travel will raise this cost to A$153.10 in 2020 (in 2000 prices). After 2020 BTRE expects little or no further increase in car travel per person (BTRE 2007, p. 45), so the cost per migrant in 2000 prices will remain the same.

Projections of vehicle emissions into the future point to a decrease in most but not all emissions. A BTRE consultancy report projects continuing reductions in carbon monoxide, sulphur dioxide, lead and volatile organic compounds (including particularly toxic volatile organic compounds) to 2020 in response to new vehicle emission standards and more efficient vehicles, despite increases in the vehicle fleet (Cosgrove 2003). However, PM is projected to remain stable, with emissions from diesel vehicles declining as a result of regulation, but those for petrol vehicles increasing in the absence of regulation. The report cautions that the projections for PM are the most uncertain part of the analysis, because of the lack of adequate data on these emissions from vehicles. Ozone levels are projected to decline, as they are produced by chemical reaction in sunlight between nitrous oxides, carbon monoxide and volatile organic compounds, and all three of these are projected to decrease. However, the BTRE report does not take into account the strong possibility that the higher temperatures produced by global warming will increase concentrations of ozone, which is a temperature dependent photochemical pollutant (Hansen, Bi and Nitschke 2009). Furthermore, a study of Brisbane, where air quality has been improving, suggests that continuing rapid population growth without commensurate improvements in vehicle emissions technologies will produce a high risk of exposure to ozone (Killip *et al*. 2007).

The BTRE report also models the effects of a combination of road pricing and a variety of measures to change people's travel choices on emissions. The results suggest that emissions could be reduced by a further 26 to 33 percent, depending on the type of pollutant (Cosgrove 2003, p. 290). The adoption of tighter emissions standards could reduce these emissions by a further 9 to 12 per cent, except in the case of PM for which little change is projected to 2020. Using the projected reduction for PM of 19 per cent, because this pollutant is the major contributor to health costs, the annual air pollution cost per migrant could be reduced to A$124.00 in 2020 (in 2002 prices).

The contribution of immigration after 2020 to air pollution depends on assumptions about future trends in vehicle standards and vehicle efficiency, as well as assumptions about the balance between private and public transport usage. For example, it seems possible that by 2050 petrol- and diesel-powered vehicles will have been replaced by new technologies that will eliminate emissions altogether, in response to climate change policies and a growing shortage and cost of petroleum fuels. It is also possible that the provision of efficient public transport and the construction of higher density cities could reduce vehicle usage even if it does not reduce vehicle ownership. If some progress is made in both these areas it could be possible to reduce PM emissions by 50 per cent of the unmitigated level by 2050. This would reduce the annual air pollution cost per migrant to A$76.60 in 2050 (in 2002 prices).

Other impacts

Tsolakis *et al*. (2003) also provide cost estimates for several other impacts of motor vehicle use. These are:

- Noise, which is estimated by combining a willingness to pay component with a health cost component.
- Nature and landscape, described as 'effects on nature (including biodiversity) and landscape (such as loss of natural land area, reduction in the quality of the landscape and land pollution)' (Tsolakis *et al*. 2003, p. 17);
- Urban separation costs, described as 'constraints on the mobility of pedestrians and community severance' (Tsolakis *et al*. 2003, p. 17).

Combined, these impacts add A$15.50 per 1000 passenger kilometres (in 2000 prices), or A$116.40 per migrant, to motor vehicle costs in 2002, and A$129.00 in 2020. It will be difficult to significantly reduce these costs in the future, because the projected increasing size and density of Australia's cities will counteract any improvements achieved through technology and planning. On the assumption that it may be possible to decrease these costs by 10 per cent by 2020 and 20 per cent by 2050, additional vehicle-related costs per migrant will be A$123.60 in 2020 and A$109.80 in 2050. Note that the estimates for 2050 assume no further increase in annual travel distances, which would be a significant break with past trends, and with those projected up to 2020. Extrapolation to 2006, 2026 and 2056 and conversion to 2000 prices, for comparisons with other sections of this report produces the estimates illustrated in Table H5. These costs will probably be higher for Sydney than for other cities, because of that city's expected higher population and traffic density, and the particular atmospheric conditions of the Sydney airshed.

Table H5: Vehicle costs per migrant

Year	Vehicle costs per migrant, without mitigation (A$ in 2000 values)	Vehicle costs per migrant, with mitigation (A$ in 2000 values)
2002	$254.60	not applicable
2006	$260.70	$251.40
2026	$282.10	$228.00
2056	$282.10	$167.70

References

Azzi, M. and Duc, H. 2008, 'Recent trends in ozone and particle concentrations in the Sydney (Australia) airshed', *American Journal of Environmental Sciences*, vol. 4, no. 5, pp. 454-461.

Beeton, R.J.S., Buckley K.I., Jones, G.J., Morgan, D., Reichelt, R.E. and Trewin, D. (2006 Australian State of the Environment Committee) (2006), *Australia State of the Environment 2006*, Independent report to the Australian Government Minister for the Environment and Heritage, Department of the Environment and Heritage, Canberra.

Bridgman, H., Warner, R. and Dodson, J. 1995, *Urban biophysical environments*, Oxford University Press, Melbourne.

Bureau of Transport and Regional Economics (2005), *Health impacts of transport emissions in Australia: economic costs*, Working Paper 63, Bureau of Transport and Regional Economics, Department of Transport and Regional Services, Canberra.

Bureau of Transport and Regional Economics (2007), *Estimating urban traffic and congestion cost trends for Australian cities*, Working Paper 71, Bureau of Transport and Regional Economics, Department of Transport and Regional Services, Canberra.

Cockroft, C. and Pryor, T. (nd), *The health costs of traffic related air pollution in Perth* (www.dpi.wa.gov.au/mediaFiles/alt_confcolin_health.pdf).

Cosgrove, D.C. (2003), *Urban pollutant emissions from motor vehicles: Australian trends to 2020*, Consultancy Report for Environment Australia, Final Draft, Bureau of Transport and Regional Economics, Canberra.

Department of Environment and Conservation NSW (2005), *Air pollution economics: health costs of air pollution in the Greater Sydney Metropolitan Region*, Department of Environment and Conservation, South Sydney.

Department of Environment and Conservation NSW (2006), *NSW State of the Environment 2006*, Department of Environment and Conservation NSW, Sydney.

Gargett, D. and Gafney, J. (2003), *Traffic growth in Australian cities: causes, prevention and cure*, Staff Paper, Bureau of Transport and Regional Economics, Canberra.

Hansen, A., Bi, P. and Nitschke, M. (2009), 'Air pollution and cardiorespiratory health in Australia: the impact of climate change' *Environmental Health*, vol. 9, nos 1 & 2, pp. 17-37.

Howie, J., Tong, S., Verrall, K., Gerber, R. and Wolff, R. (2005), 'Air pollution and cardiopulmonary diseases in Australia: a review of epidemiological evidence', *Environmental Health*, vol. 5, no. 1, pp. 23-36.

Hurley, F. (2004), Does reducing air pollution really lead to improvements in health? A discussion note and assessment of the evidence on ex post health studies. Appendix 1 in Watkiss, P. et al., *An evaluation of the Air Quality Strateg:y Final report to Defra*, AEA Technology, Didcot.

(http://www.defra.gov.uk/environment/quality/air/airquality/publications/stratevaluation/documents/appendix1.pdf)

James, M.L. (2009), *The (green) car of the future*, Background Note, Parliamentary Library, Parliament of Australia, Canberra.

Killip, C., Leishman, N., Heuff, D., Schloss, A. and Welchman , S. (2007), *Is the clean air of Brisbane threatened by future population growth?* Paper presented at the 14th IUAPPA World Congress in Brisbane, Queensland, Australia, 2007

NSW Department of Environment and Conservation (2006), *NSW state of the environment 2006*, Department of Environment and Conservation NSW, Sydney.

Sirikijpanichkul, A., Iyengar, M. and Ferreira, L. (2006), *Valuing air quality impacts of transportation: a review of literature*, School of Urban Development, Faculty of Built Environment and Engineering, Queensland University of Technology, Brisbane.

Tsolakis, D., Houghton, N., Lester, C. and Seethaler, R. (2003), *Valuing environmental and other externalities*, Austroads, Sydney.

Scenario B: Social Cost of Congestion

Population growth, by increasing the number of motor vehicle owners and the demand for other forms of road transport, increases traffic congestion in the cities in the absence of any measures to manage this growth. The Bureau of Transport and Regional Economics identifies the following costs associated with increased congestion:

- longer average journey times because of interruptions to traffic flow
- more uncertain travel times, leading to travellers having to allow for a greater amount of travel time than previously
- increased vehicle operating costs primarily because of higher fuel consumption, and
- poorer air quality because of increased emissions of pollutants (BTRE 2007, p. 77).

BTRE has estimated the social costs of traffic congestion resulting from these factors for each Australian city, and projected these to 2020. Their estimates are of how much total costs (for time lost and other wasted resources) could be reduced if traffic volumes were reduced to the economically optimal level, which they define as 'the level of traffic beyond which the full social costs of any further travel would outweigh the benefits of that extra travel' (BTRE 2007, p. 78). This is described as the avoidable cost of traffic congestion. The estimates are not based on a comparison with a situation of freely-flowing traffic, which BTRE describes as unrealistic.

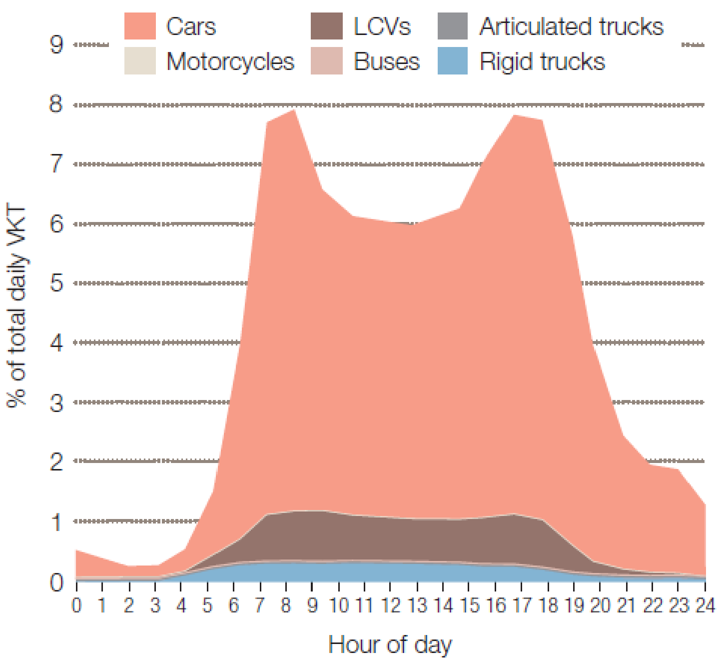
BTRE projects that the total social costs of congestion in Sydney will rise from $3.5 billion in 2005 to $7.8 billion in 2020, in Melbourne from $3.0 billion to $6.1 billion, in Brisbane from $1.2 billion to $3.0 billion and in Perth from $0.9 billion to $2.1 billion (BTRE 2007, p. 107).

The contribution of overseas migration to these costs can be approximately estimated from the data in the BTRE report. The increase in the social costs of congestion for private vehicle travel in 2005-06 in Sydney attributable to population growth rather than income growth is estimated at $52.33 million, or $805 in 2000 values per person projected to have been added to the population of Sydney that year. If the BTRE estimate of the social costs of congestion in 2020 is projected forward to 2026 at the average rate of growth in these costs between 2016 and 2020, then the increase in the social costs of congestion for private vehicle travel in 2026 is $2292 in 2000 values per person. Note that BTRE expects that all of the increase in the social costs of congestion after 2020 will be caused by population growth rather than by a combination of population growth and higher incomes.

Table H6 below shows the corresponding values for Melbourne, Brisbane and Perth. Projecting the BTRE figures, which end in 2020, forward to 2056 to produce an estimate for that year is not considered advisable. However, it would seem unlikely that in the absence of significant mitigation measures the social cost of the congestion produced by an additional migrant will decline in the future. The estimates below do not include business vehicle use, which is projected to contribute 22 per cent more than private vehicle use to the total social costs of congestion in 2020 in the BTRE study. Population growth resulting from migration must have some effect on growth in business vehicle use, so the estimates in the Table may be considered to be conservative.

Figure H1 Typical daily VKT profile by vehicle type, Australian metropolitan traffic

Figure 50 – Typical daily VKT profile by vehicle type, Australian metropolitan traffic



Source: BITRE (2007)

> "This pattern of limited growth in peak periods, while growth in periods around the peak remains strong, is already apparent in recent yearly data for particular city links (due to many major metropolitan roads already operating close to their rated capacity at certain times of day)."(BTRE 2007)

Data on the possible effects of mitigation measures on the social costs of congestion are limited, and difficult to use to adjust the estimates in the Table. BTRE estimates that aggregate congestion costs could be reduced by approximately 27 per cent by 2020 if 12 per cent of urban travel could be switched from cars to other modes (BTRE 2007, p. 119). This estimate is based on the assumption of no increase in transport infrastructure. In earlier work, the Bureau examined the potential effects of variable congestion charges in the metropolitan areas. They estimated that the likely effects of levying such charges in the eight State and Territory capitals would be to:

- decrease total metropolitan vehicle kilometres travelled in 2020 by around 14 per cent below the level projected in the base case (where it is assumed that bus travel increases by 30 per cent);

- decrease average fuel intensity (L/100 km) across metropolitan Australia in 2020 by around 7 per cent; and thus

- decrease total metropolitan fuel use in 2020 by around 20 per cent.

These estimates do not suggest that the costs of congestion in 2026 can be reduced by more than about a quarter unless there is a massive increase in public transport infrastructure.

Table H6 Social costs of congestion for private vehicle travel per migrant, 2006-2026 ($ in 2000 values)

City/Year	Cost per migrant
Sydney 2006	$805
Sydney 2026	$2,292
Melbourne 2006	$441
Melbourne 2026	$2,064
Brisbane 2006	$410
Brisbane 2026	$1,595
Perth 2006	$356
Perth 2026	$1,194

How likely is change to occur in car use? Do our urban development scenarios – infill and fringe expansion - influence car use and if so, what parameters need to be considered in planning new housing? For example, how quickly are people likely to give up their preference for four-wheel drive vehicles in cities? Figure H2 below suggests there might be some resistance considering the oil price spike in 2006 barely dented sales. Or how likely is the scenario presented in Figure H3? What State or Local Government in Australia has the political will to implement such a solution for a CBD?

Figure H2 Sales of new personal vehicles and per capita income

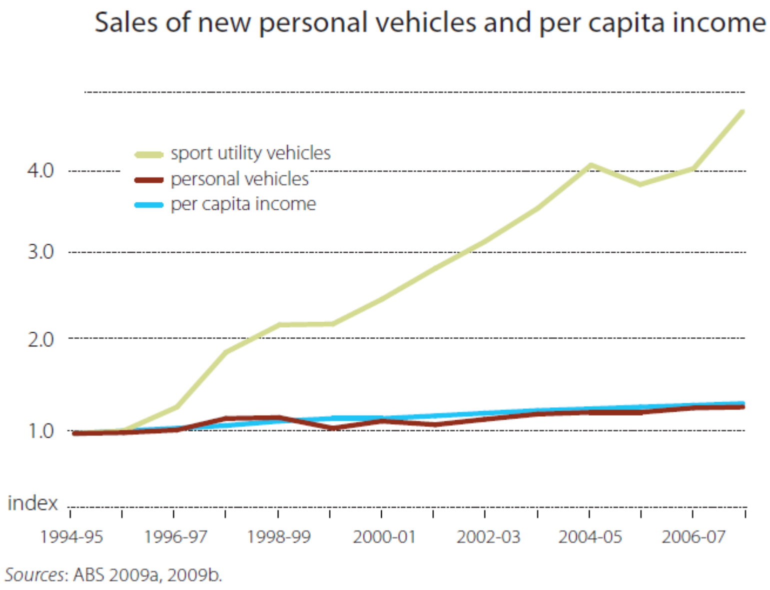


Figure H3 Seoul – before and after

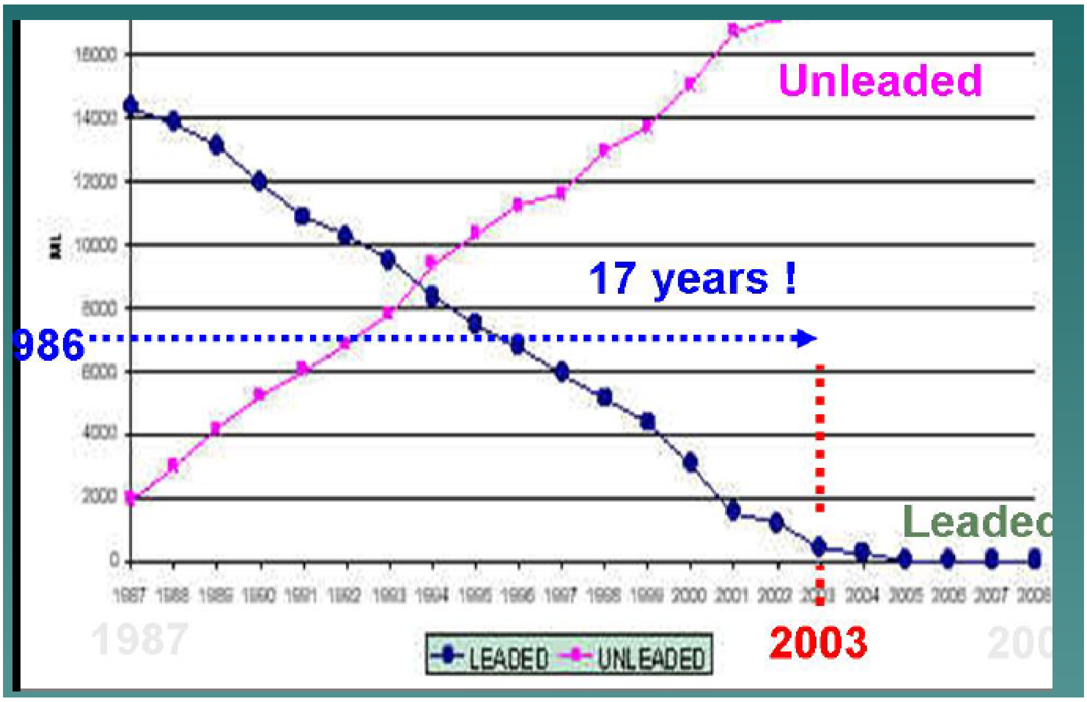
A comparison of attitudes to congestion collected by Austroads demonstrates that some states have a perceived better road system than others (Table H7), with Victoria performing the best of the more populous States:

Table H7 Attitudes to Congestion by State/Territory

Score Min = 1 Max =5	All 9 Authorities	Aust	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	NZ
'98 Mean satisfaction		3.37	3.17	3.56	3.39	3.54	3.33	3.37	na	na	3.43
'00 Mean satisfaction		3.34	3.07	3.55	3.35	3.47	3.48	3.35	3.78	3.77	3.34
'03 Mean satisfaction	3.36	3.38	3.07	3.43	3.24	3.38	3.42	3.34	3.64	3.69	3.27
'07 Mean satisfaction	3.32	3.31	2.96	3.38	3.12	3.11	3.36	3.21	3.60	3.74	3.33

Recent history offers a guide. Figure H4 shows the time lag between a regulatory demand in 1986 that all new cars run on unleaded petrol, to reduce the quantity of lead in petrol as a health initiative, and the fulfilment of that initiative in 2003, 17 years later. Glazebrook (2009) suggests it would take 30 years to change over the entire car fleet, 30 years to change land use patterns and 30 years to install a world-class public transport system in Sydney.

Figure H4 Time taken to adopt new technology



Scenario C: Social Cost of Carbon

This section discusses the effects of immigration on carbon emissions, and the contribution of these emissions to climate change and to the costs that will be produced by global warming. The aim is to identify an indicative cost that can be attributed to each new immigrant to Australia. Migrants add to Australia's carbon emissions through the energy they and their children directly or indirectly consume that is produced by the burning of fossil fuels. However, carbon emissions are a global problem. Future immigrants to Australia are already responsible for some carbon emissions in their countries of origin, so immigration is only responsible for any increase in their carbon emissions that results from their settlement in Australia. The same argument can be applied to the carbon emissions of their children, who would otherwise be living in their parents' countries of origin.

Greenhouse gas emissions, through their role in climate change and its impacts on the environment, create costs which are projected to increase over time if no effective measures are adopted to reduce emissions. Some of these costs are:

1. damage to homes and infrastructure from rising sea-levels and more severe storms;
2. increased severity of natural disasters such as bushfires and cyclones;
3. increased frequency and severity of drought and its effects on agricultural production and urban water supply;
4. increase in heat-related deaths;
5. increase in vector-borne diseases;
6. loss of habitat and animal and plant species; and,
7. damage to ecologically rich sites such as the Great Barrier Reef, the Wet Tropics of Queensland, Kakadu Wetlands and Alpine Australia (Garnaut 2008)

The Garnaut Climate Change Review has modelled the effects on the Australian economy out to 2100 of the impacts of climate change on primary production, human health, infrastructure, tropical cyclones and international trade (Garnaut 2008). The Review projects that in the absence of any mitigation of climate change, wage income will be reduced by 1 per cent in 2020 and by 3.3 per cent in 2050, and income from capital by 0.5 per cent in 2020 and by 1.6 per cent in 2050, when compared with no climate change. Real GDP is projected to be 0.7 per cent lower in 2020 and 2.1 per cent lower in 2050 as a result of climate change (Garnaut Climate Change Review 2008). The Review also identified a number of impacts which could not be quantified and used in modelling, so the costs identified above are an underestimate of the full cost of climate change.

There are several ways of attributing a cost or price to emissions of carbon by an individual such as a migrant (Minh 2009). Perhaps the most appropriate for the purpose of this report is the social cost of carbon (SCC). This is defined by the International Panel on Climate Change (Parry *et al*. 2007, p. 881) as the value of the climate change impacts from an additional 1 tonne of carbon emitted today as CO_2, aggregated over time and discounted back to the present day. As an example of the use of the SCC in government planning, in 2002 the UK Government recommended an illustrative marginal global SCC estimate of £70/ tonne of carbon (tC), rising at £1/ tC per year from the year 2000, for use in policy appraisal across Government (Watkiss and Downing 2008, p. 86).

Estimating an SCC is very difficult and the results have a considerable degree of uncertainty. As Tol (2008a) comments: "[c]limate change is the mother of all externalities, larger, more complex, and more uncertain than any other environmental problem". First, most of the future costs that are aggregated into the SSC are difficult to estimate accurately, especially those that have no market value. Second, estimates differ according to the impacts that are included (for example, whether extreme events and biodiversity losses are estimated). Third, experts differ over the discount rate to use to adjust future costs back to present values, and over whether the rate should be constant or declining. Most of the cost impacts of climate change are in the future, so the discount rate has a large impact on estimates, and high rates produce low estimates. Most studies prefer standard discount rates. However, some argue that this undervalues the interests and welfare of future generations and conflicts with the principle of inter-generational equity, and that the discount rate should be near or at zero. The Stern Report, for example, used a low discount rate and therefore produced a high SCC. Fourth, studies differ in the length of time considered. Because climate change impacts are likely to increase over time, the longer the time span, the higher the SCC. Fifth, studies use different ways of weighting the impacts in different countries, as estimates of SCC are typically global estimates on the grounds that the impacts of climate change, and the benefits of climate change mitigation, are global. Sixth, estimates vary according to the assumptions made about future temperature levels (Anthoff, Hepburn and Tol 2009; Dietz 2007; Guo *et al*. 2005; Hope and Newbery 2006; Pearce 2003; Watkiss and Downing 2008).

Some of the differences listed above are differences over technical issues; but some are the result of ethical and philosophical choices, and consequently the selection of an appropriate value for the SCC is somewhat subjective. Furthermore, many social and natural scientists argue that some environmental and health impacts cannot be given a meaningful price (Ackerman 2008; Baer and Spash 2008). However, we accept the advice of Pearce (2003, p. 363), who writes:

> It is not necessary for this estimate of social cost to be precise. Few magnitudes in economics or in policy analysis are precise. Acting on reasonable estimates is better than acting on no estimate, because the latter course of action necessarily implies a social cost. If there is uncertainty about a social-cost estimate, that uncertainty does not magically disappear by not adopting the social cost estimate.

The most recent comprehensive reviews of estimates of the social cost of carbon are by Tol (2008a; 2008b). He analyses the central tendency and variation of 211 estimates, subdivided by various characteristics of the studies. From his results we select a value of US$144/ tC for the social cost of carbon, which is the 67 percentile of studies with a pure rate of time preference of one per cent (Tol 2008a, p. 29). We do this because we believe that inter-generational equity demands a low discount rate, and because the impacts of climate change are likely to be more severe in Australia than the global average (Garnaut 2008, p. 124). This value is similar to the £70/ tC adopted by the UK Government, and translates into a value of A$42/ tCO2. Because the impacts of climate change are expected to become progressively more severe in the future, the effects of adding another tonne of carbon into the atmosphere will also become greater, and so some studies therefore increase the SCC over time. In one model, the value of the SCC increases by 2.4 per cent a year (Hope and Newbery 2006, p. 16), while the UK Government's illustrative SCC rises at £1/ tC per year, or at an initial rate of 1.4 per cent and declining over time. We accept this principle, and suggest adopting a growth rate of 2 per cent in recognition of Australia's vulnerability to climate change.

The final step in determining an indicative SCC for immigrants involves estimating the additional carbon emissions produced by their migration to Australia, which has higher per capita emissions than the countries of origin. In making this estimation the per capita CO_2 of Australia of 22.0t in 2007 was first reduced by 1.31t to remove the contribution of non-ferrous products manufacturing (Turton 2004), which is unrelated to immigration. The migration stream was then divided into three: from New Zealand, the UK and the rest. The differences between Australian per capita emissions and those of the source countries were then calculated, using data for Malaysia for the third group as an approximate figure for the mostly middle class migrants predominantly from South, North East and South East Asia. An average difference was then calculated, weighted by the size of each of these migrant streams over the period 2006-2009. This figure is 13.2t/ CO_2 per migrant.[15]

Policies to reduce carbon emissions and mitigate the costs of climate change have been thoroughly examined in the Garnaut Review. If these policies can be implemented on a global scale then the SCC will stabilise over time. Modelling by the Garnaut Review shows that if the target of stabilising the concentration of CO_2 in the atmosphere at 550 ppm can be achieved, then the projected market costs attributed to climate change increase at a declining rate after 2030, and stabilise around 2070 (Garnaut 2008, p. 267). To achieve this CO_2 target the Garnaut Review recommends per capita reductions of emissions of 30 per cent by 2020 and 90 per cent by 2050 (Garnaut 2008, p. 283).

If the value of $42/ t CO_2 for the SCC is attributed to 2000, as it is based on a range of studies from the 1990s and 2000s, we get the following estimates of the SCC per migrant. The values of the SCC with mitigation are based on an increase of 2 per cent annually to 2030, and 1 per cent after 2030, and reductions in emissions of 40 per cent in 2026 and 90 per cent in 2056.

Table H8 Social Cost of Carbon per Migrant

[15] Data on CO_2 emissions are for emissions from the consumption of energy in 2007, from the website of the US Energy Information Administration (http://tonto.eia.doe.gov/cfapps/ipdbproject/iedindex3.cfm?tid=90&pid=44&aid=8&cid=&syid=2003&eyid=2007&unit=MMTCD&products=45).

Year	SCC/t CO2 (A$ in 2000 values)	SCC per migrant, without mitigation (A$ in 2000 values)	SCC per migrant, with mitigation (A$ in 2000 values)
2000	$42.00	$554.40	$554.40
2006	$47.30	$624.30	$624.30
2026	$70.30	$927.70	$566.60
2056	$127.30	$1,680.50	$130.10

Comment: These figures do not take into account the children and grandchildren of migrants. They could be increased by adding the per capita output attributed to children expected to be born to a migrant. This is a process that has not been attempted in this report.

In the analysis above (Table H8) we do not differentiate between cities. The social cost of carbon will only vary from city to city if some become more efficient than others at reducing carbon emissions per capita, through changes in energy production and consumption. However, there is no way in which such a possibility can constructively be evaluated.

Reference

Ackerman, F. (2008), 'Climate economics in four easy pieces', *Development*, vol. 51, no. 3, pp. 325-331.

Anthoff, D., Hepburn, C. and Tol, R.S.J. (2009), 'Equity weighting and the marginal damage costs of climate change', Ecological Economics, vol. 68, pp. 836-849.

Baer, C. and Spash, C.L. (2008), Cost-benefit analysis of climate change: Stern revisited, Socio-Economics and the Environment in Discussion (SEED). CSIRO Working Paper Series no. 2008-07.

Bureau of Transport and Regional Economics (BTRE) (2007), *Estimating urban transport and congestion cost trends for Australian cities*, Bureau of Transport and Regional Economics, Working Paper no. 71, Canberra.

Dietz, S. (2007), Review of DEFRA paper: "The social cost of carbon and the shadow price of carbon: what they are, and how to use them in economic appraisal in the UK". Web

Garnaut, R. (2008), The Garnaut Climate Change Review: final report, Cambridge University press, Port Melbourne.

Garnaut Climate Change Review (2008), Modelling the costs of unmitigated climate change, Technical Paper no. 5. (http://www.garnautreview.org.au)

Guo, J., Hepburn, C., Tol, R.S.J. and Anthoff, D. (2005), Discounting and the social cost of carbon: a closer look at uncertainty. Web

Hope, C. and Newbery, D. (2006), Calculating the social cost of carbon. Web

Minh H.D. (2009), What is the price of carbon? Five definitions, S.A.P.I.EN.S, vol. 2, no. 1, [Online]. Online since 3 June 2009. URL: http://sapiens.revues.org/index793.html. Connection on 14 November 2009.

Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden P.J. and Hanson, C.E. (eds.) (2007), Contribution of Working Group II to the Fourth

Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

Pearce, D. (2003), 'The social cost of carbon and its policy implications', *Oxford Review of Economic Policy*, vol. 19, pp. 362-384.

Tol, R.S.J. (2008a), The economic impact of climate change, Working Paper no. 255, Economic and Social Research Institute, Dublin.

Tol, R.S.J. (2008b), 'The social cost of carbon: trends, outliers and catastrophes', Economics: The Open-Access, Open-Assessment E-Journal, vol. 2, 2008-25, pp. 1-22. (http://www.economics-ejournal.org/economics/journalarticles/2008-25)

Turton, H. (2004), Greenhouse gas emissions in industrialised countries: where does Australia stand?, Discussion Paper no. 66, Australia Institute, Canberra.

Watkiss, P. and Downing, T.E. (2008), 'The social cost of carbon: valuation estimates and their use in UK policy', *IAJ The Integrated Assessment Journal*, vol. 8, Iss. 1, pp. 85–105.

Key Research Question 4:

In relation to each average level of NOM, what measures may be considered by the Australian government to counterbalance the negative impacts, or to optimise the positive impacts, on Australia's Natural and Built Physical Environment?

Overall, the study finds that, for the levels of NOM nominated, there do not appear to be threshold values below which the negative impacts of NOM are benign and above which they are seriously harmful to the built or natural environment. Rather, the larger the NOM, the larger are the (unmitigated) harms. Economic growth (per capita) combines with population increases to produce environmental impacts that are proportionally larger than changes in NOM levels. These impacts grow over time with the cumulative effect of higher annual flows of net migration. The main exception is water security for Sydney, Melbourne and Perth. But even in this case, the risk is not that they 'run out' of water at some critical population level, but that water becomes rationed and/ or much more expensive as desalination and recycling are called on to supplement natural sources of supply. The study also shows that many of the negative effects are sensitive to the location of settlement. In particular, the propensity for immigrants to concentrate in Western Sydney and in Melbourne increases their negative impact on water security, traffic congestion and pollution, waste management problems, local fresh food supplies, CO_2 emissions, and local biodiversity.

ASFF: Options for Mitigating or Optimising Environmental Outcomes

The analysis presented above does include some measures intended to help relieve environmental impacts. For example, the modelling incorporates substantial improvements in efficiency in car fuel use and electricity generation, and continual crop yield gains. Other more general changes were projected from historical trends.

These background trends are insufficient to alleviate several serious resource constraints and environmental impacts that the ASFF modelling identified, particularly those relating to transport fuel security, water security, and greenhouse gas emissions. The magnitude of these issues and their rate of development imply that standard free-market responses are likely to be inadequate, as experience in recent years has shown. Markets may respond to price signals, but these signals have to be present, available in advance, and represent marginal adjustment. This is not the case in the issues that have been identified in this study—the scale and rate of change is so large that very different infrastructure and multiple strategies are necessary. This suggests the need for government interventions, either through economic instruments that stimulate market responses and/ or more direct actions. Some potential paths for tackling the environmental and resource issues are discussed below.

What do specific actions offer?

Building on the current analysis more detailed analysis is possible, and is required, to reveal the full potential of many alternative options that have been proposed to address specific issues. In terms of mitigating Australia's critical dependence on oil for example, a wide range of potential technological options exist including development of alternative fuels/ engines (e.g., electric, gas, bio-fuel, and hydrogen), mode shifts to rail, increased public transit and changes to urban form. Such mitigating options will have different implications in terms of other resource inputs required (land, water, energy, labour, capital and materials), wastes and emissions produced, the timely introduction of new infrastructure, and the capacity to supply fuels at rates commensurate with the demand.

That these implications require serious consideration is demonstrated by some related studies on "dematerialisation" of the Australian economy (Hatfield-Dodds *et al.* 2008; Schandl and Turner 2009), and capital city water supply options (Kenway *et al.* 2008). In the former, the ASFF was used to model large-scale changes to material and emission intensive sectors, including construction and housing, electricity generation, and transport and mobility. Average energy use intensity of all housing was halved (assuming retrofit and adoption of simple solar passive technology), new dwellings were of lighter construction and the trends for increasing floor area reversed; electricity generation was transformed by 2050 to a mix of wind, solar and gas as aging coal-based power plants were decommissioned; and commuting by car was reduced from 85% to 60%, with commuting distances reduced 30% to reflect improved urban design, and modal share of long distance travel switched from air to bus.

These and other changes managed to stabilise aggregate energy consumption and greenhouse gas emissions for about two decades. Subsequently though, overall economic growth offset the environmental gains and led to emissions higher than contemporary levels, albeit some 30% lower than if no transformations had been attempted.

In a separate analysis of water supply and use options for Melbourne, a dense urban form incorporating medium density townhouses and high-rise apartments to contain all urban development within a 'growth boundary' resulted in water use being about 100 GL pa lower by mid-century compared with a sprawling Melbourne (though water use grows in both cases).

By comparison, a moderately larger volume can be supplied by Melbourne's desalination plant, though this is likely to triple the electricity requirement of the water supply system. This increase, whilst a relatively minor component of total electricity use, does not help reduce the burden of anticipated growth in electricity consumption. It follows that water consumption supplied indirectly by brown coal power stations in the Latrobe Valley could more than double by mid-century.

The scale of the task for desalination (or inter-region water transfer) is illustrated by the magnitude of the growing deficit in water supply. For example, Melbourne's desalination plant is planned to produce approximately 150 GL/year. This is to be compared with some 13,000 GL/year of extra urban water use (under 180,000 NOM, in fifty years time). Some of this demand may be reduced through conservation and efficiency, but the figures imply that the number of desalination plants needed is of the scale of 100. As one desalination plant increases the total consumption of electricity by a few percent (Kenway, Turner et al. 2008), such a scheme of relying on desalination would double the current electricity generation budget. If this were supplied via the contemporary mix of power generators, clearly the GHG emissions would also be substantial. Even higher GHG emissions may result in more dramatic reductions of surface water, completing a vicious feedback.

Some offset of electricity demand can be achieved through wide-spread adoption of solar hot water systems, for example. Assuming 20% of existing dwellings and 80% of new dwellings install solar hot water yields about a 10% reduction in residential energy demand. Alternatively, this saving could be used to offset the energy of several desalination plants.

Another important feature concerns the timing or rate at which change may be required, particularly when associated with long-lived infrastructure. Analysis of the turnover of power plant under different electricity consumption growth rates indicates that plant introduced after 2011–2018 must be capable of near-zero GHG emissions in 2050 if proposed reduction targets (in the range 60–90% of 1990 levels) are to be achieved. It is necessary to have in place in the near-term plant technology that is prepared for carbon capture, even though it may not be employed initially, because a significant fraction of old plant may still be operating in 2050.

In summary, these individual studies indicate that both the magnitude and rate of change required to address or mitigate the resource and environmental challenges facing Australia are substantial. It is also evident that avoiding perverse outcomes where an initiative in one area increases the pressure in another will require policy and planning that is cognisant of the wide interactions across the economy and environment.

What does overall growth offer?

Without further detailed analysis on mitigation options, it is tempting to assert that an economy with a larger GDP is in a better position to address environmental problems. This does not appear to be supported by the modelling results. First, the modelling shows that the intensity of greenhouse gas emissions[16] per dollar of GDP is the same for all NOM levels even though GDP is higher for higher NOM.

Therefore there is no aggregate economic advantage, in terms of funding environmental programs, to having a larger economy since the size of the problem is also proportionally larger. In other words, higher NOM (and population in general) increases aggregate economic wealth, but this greater economic activity leads to commensurately larger resource and environmental challenges.

Further, the modelling shows that the aggregate carbon intensity (tonnes of CO_2 emitted per dollar of GDP) of the economy decreases continuously over time—less carbon is progressively emitted per dollar of GDP. Superficially, this seems to

[16] Greenhouse gas emissions are used here as an indicator of environmental challenges.

indicate a decoupling of the economy from the environment. However, the overall outcome is the opposite—the absolute volume of emissions continues to grow.

This finding underscores the importance for environmental policy and monitoring to be centred on absolute measures, not relative indicators such as per capita or per dollar estimates. For example, if policy is focused just on improvements in efficiencies, then the likely but unfortunate outcome is that environmental problems will grow.

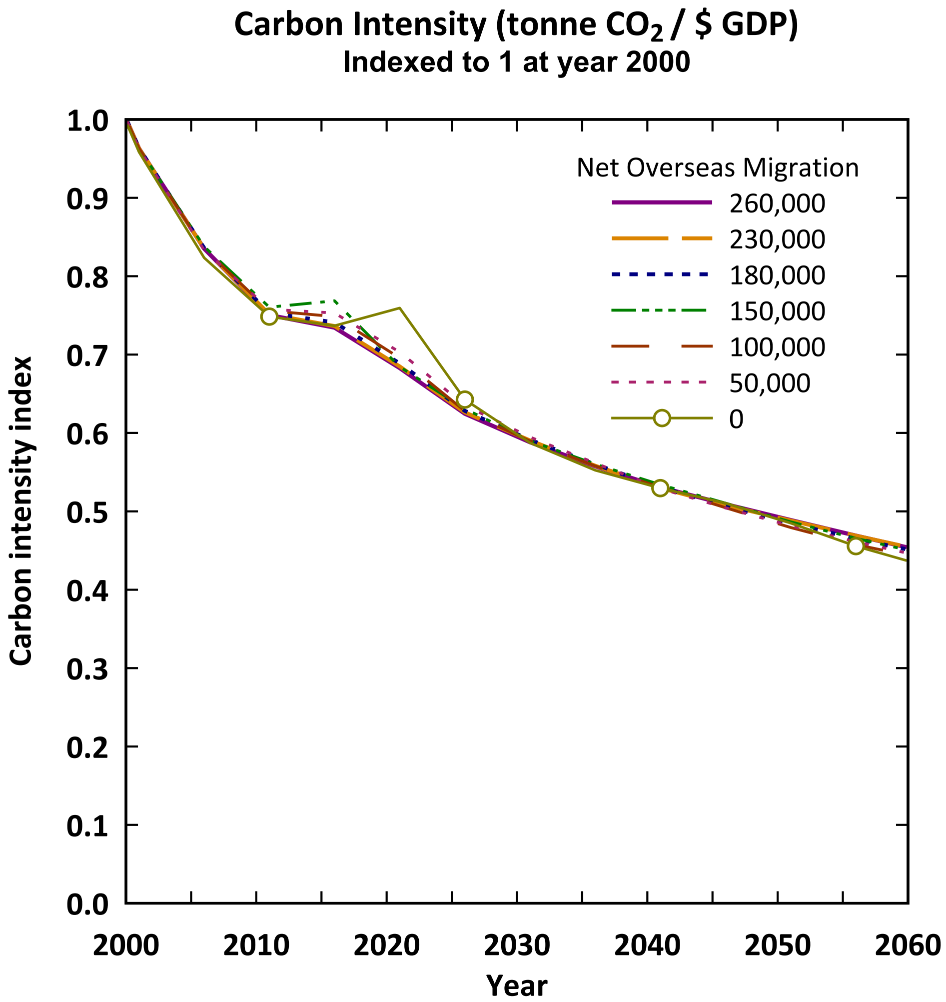


Figure I1 Aggregate efficiency of carbon emissions (from fuel combustion) increases over time.

The drivers of rebound

This perverse outcome has been shown to occur at global and national levels for well over a century. For most of the industrial revolution, carbon intensity (the inverse of efficiency) has been decreasing exponentially due to the shift to cleaner fuels, improvements in fuel use efficiency and changes in economic structure (Grubler 1998; Grubler et al. 1999), but total global carbon emissions have increased exponentially. This is effectively the rebound effect[17] writ large (to the extent that it is known as "backfire"). Many other examples and analysis of rebound exist.

Though rebound is usually described at the micro level (e.g., people drive further when petrol is cheaper), rebound also occurs at the macro level, as the ASFF modelling demonstrates. In an economy that does not grow, continual increases over decades in efficiency and productivity would lead to mass unemployment, simply because fewer workers are needed to produce the constant economic output (Turner and Baynes 2010 accepted). However, increases in consumption and the associated economic activity provide the demand to employ displaced labour. These dynamics are captured in the modelling, which achieves a stable unemployment rate of about 3.8% in each of the scenarios. But as a result, the anticipated environmental dividends from the efficiencies are not achieved because the increased economic activity offsets or outgrows the gains.

In terms of the I=PAT equation, the fallacy that efficiencies employed in throughput 'T' lead to lower impact 'I' occurs because the factors in this equation are implicitly assumed to be independent. In reality this is not the case. Under standard economic conditions, affluence 'A' is actually linked to throughput via the creation of employment opportunities. Increases in affluence effectively keep unemployment low, thereby negating the benefits of lower throughput, so that impacts do not diminish.

A possible 'mitigation' of this effect is through widely shared reduction in hours of work, over a year and over a working lifetime. Some of this has indeed occurred as a response to greater wealth, but populations choose both more goods and services, as well as more hours of leisure, as productivity rises.

What options are available to counter the rebound effect?

Changes to economic structure and specifically a move toward a larger service economy have been proposed as a way to avoid environmental impacts. In recent decades, Australia's labour force has been dominated by employment in the service sector (over 60%), and the modelling has shown that this service economy continues to grow.

[17] Rebound is also known as Jevons paradox or take-back.

However, even though services represent about 1–2% more of the labour force by 2050 for the range of NOM examined, the environmental impacts documented above are not offset. This occurs because much of the services provided, such as finance, hospitality, and tourism, are in support of other economic activities causing the impacts. More resource consumption and subsequent pollution is effectively necessary to keep people employed in such service jobs.

Alternative compositions of the service sector may yield different outcomes. It is possible for instance, that an emphasis on employment in the health and education sectors could provide employment opportunities and lifestyle improvements to the population without necessarily stimulating growth in sectors with high material and energy requirements.

Consequently, this analysis points to a more thoughtful response to environmental challenges than one based purely on population or technology. It indicates the necessity to consider lifestyle changes and work-life balance in combination with these other factors. A related approach is to consider the role of a 'Future Fund' that effectively acquires funds from efficiencies gains and banks these for use by future generations and retirees (Foran 2009).

It would be instructive to explore in the modelling if effective mitigation is more likely if efficiency and productivity premiums are invested in on-going improvements to work-life balance via reduced working hours. In other words, to reframe the driving force behind the rebound problem away from unemployment, and toward more time oriented to pursuing education, healthy leisure and social interaction (NEF 2010).

Such an approach would undoubtedly require thoughtful policy, planning and implementation (Jackson 2009) in order to distribute reductions in work hours uniformly across the labour force, and avoid pockets of unemployment in particular sectors or areas. The scale of eventual change required is large, but changes can occur incrementally, in the range of the working week (or years worked) cumulatively decreasing by an average of 1 hour or less each year.

The additional leisure time gained would be of a different character to that based on high consumption lifestyles, since both personal incomes and the physical output of the economy would be lower than otherwise. At the same time, technological progress would be required, not least to contribute to environmental improvements. It would also aim to deliver benefits in health, education and communication to further enhance livelihoods. Social benefits may also accrue, with the extra time available, for example, enabling families to support the young and elderly—therefore negating the growing dependency ratio of an aging population. This could assuage the burden that would otherwise be placed on the health system.

Overall, the analysis of options summarised here suggests that mitigating environmental impacts and providing a physically sustainable Australian economy is likely to require a careful mix of all three factors of the I=PAT equation—population, affluence, and throughput—to be considered. The analysis indicates that reductions in all areas are more likely to achieve a sustainable future than a less nuanced approach.

Levels of NOM and the Location-based Studies

Because we know where some 80% of permanent migrants will probably settle and what they will (roughly) consume, and what jobs they will do at least initially, DIAC has the opportunity to establish strong linkages with existing communities and Local and State Governments about services, facilities and the kind of lifestyle likely to be encountered. Such knowledge enables planning to be targeted for the new arrivals from historical data and the information possessed by DIAC about new immigrants. This is an institutional and governance response, DIAC could work with local communities about coping with new people, both in absolute numbers and in the specific services they require to get established in our society, against the potential impact on the physical resources of that place.

Whilst such partnerships obviously apply to the urban case studies that are the focus of this report, DIAC could also work to establish linkages with regional centres, for example, those around Melbourne – Bendigo, Ballarat, Seymour, Traralgon. They all have access via fast train to the centre of Melbourne, employment and perceptions of desirable 'liveability'. Or one could consider Albury-Wodonga on the border with NSW, most recently a centre that housed Balkan refugees, but historically the centre for immigrants who worked on the Snowy Mountains Scheme. The same background as is compiled in this report would usefully identify the physical limitations of these other centres, with the result that DIAC would possess a rationale in selecting where to invest in incentives to encourage new migrants to settle outside the traditional locales.

The following section provides suggestions about adaptation or mitigation strategies and tactics that would be likely to affect the impacts of NOM on the physical environments of Sydney, Melbourne and Perth.

Sydney

Land and Food

Sydney will be importing the vast majority of its fresh fruit and vegetables from outside the Sydney Basin by 2050, even with zero NOM for the next 20 years. Higher NOM will bring forward the time that this occurs. It will have developed the remaining horticultural land to urban and industrial uses. This introduces a weak point in the resilience of Sydney's food security and quality; in its capacity to withstand price volatility and interruptions to supply. Effectively, a significant proportion of the 12,000 jobs and $4.5 billion in economic value are at risk. So too will the opportunities for new migrants to gain an economic foothold in their adopted country through working in horticulture. The loss of jobs will have a disproportionate impact on migrants who currently occupy around 90% of jobs in the production of fresh vegetables. WSROC and NSW Government could mitigate this loss of productive horticultural land. They could confine population growth to existing urban boundaries through greater housing density, encourage development of 'high tech' glasshouses and encourage turf farmers to convert (back) to vegetable production.

Water Supply

Sydney will be subject to increasingly stringent, possibly permanent water restrictions even at zero NOM in the next forty years. Higher NOM bring forward the timing and magnitude of the water supply challenge because of the preference for NOM to settle in Western Sydney and the absolute quantity of water required even if water use efficiencies per person improve significantly. Of the future water supply, 36% is expected to be obtained from improved water use efficiencies and recycling. This relies heavily on behavioural and infrastructural changes, which are not guaranteed. There is an expectation that the 40% water savings achieved per person since 1991 will continue. Current consumption is around 100kl per person.

Sydney currently relies heavily on water from the Hawkesbury - Nepean Rivers and Shoalhaven catchment to the south. These systems are under increasing pressure from multiple competing users of a finite quantity of water, subject to an increasing probability of reduced volumes by 2050. The climate change models are predicting lower average rainfall and higher overall temperatures that will reduce the volume of water available in surface storages and reduce accession to groundwater aquifers reducing Sydney's 'pool resource' of fresh water below historic (last 100 years) averages. More desalination plants are unlikely to be able to make up the difference.

Water Quality

Western Sydney will continue to experience poor quality water in its major and minor creeks and rivers. When more than about 25% of the land surface is built on, the resulting impervious surface produces stormwater runoff that is polluted and concentrated in outflow pipes directly into local drainage lines. Excessive nitrogen, phosphorus and dissolved solids induce eutrophication and deterioration in biodiversity. Also prominent are high pollutant loads of sediment, oil and grease, metals, nutrients, organic material and detergents. The rush of stormwater torrents degrade channel stability.

In the next 20 years, the north-west and south-west Growth Areas in the South Creek catchment will accommodate people equal to the natural increase of Sydney, even with zero NOM. Mitigation requires substantial investment in stormwater management and recycling infrastructure in new housing developments and to upgrade and retro-fit into existing urban areas. It will require cooperation across LGA jurisdictions and with State agencies.

Air Quality

The localised incidence of higher levels of air pollution in Western Sydney will likely be overcome through universal changes to vehicle technology and use patterns across Sydney. Recent monitoring of air quality suggests that by 2050, behavioural and mandated changes to vehicle engines and industrial emissions, and the possible amelioration of congestion may well provide respite even as population increases. An increase in cardio-pulmonary health services in the near future would assist treatment of the effects of existing pollution, mindful of increasing NOM in the region.

Biodiversity

The Sydney Basin is one of the more biologically diverse regions of Australia. It is, however, badly fragmented. The question arises: Can planning of urban expansion because of population growth preserve areas of diversity; indeed seek to improve their quality? The Sydney Metropolitan Plan says that:

> Sydney can grow while protecting biodiversity values. This Strategy complements existing mechanisms to protect biodiversity by minimising the urban footprint and concentrating future growth in existing urban areas around centres and corridors, thereby avoiding regionally and state significant habitats.

The history of landscape and habitat nurture in the Sydney Basin is at odds with such sentiments. Increasing population growth even with zero NOM is likely to directly and deleteriously, affect the remaining pockets of diverse ecosystems in Western Sydney Basin. It is hard to see what feasible mitigation strategies could prevent higher levels of NOM from reducing biodiversity through increased areas of impervious surfaces and intensive horticulture.

Waste Assimilation

At zero NOM Sydney will have to invest substantially now in recycling and waste reception facilities in the city from where waste for landfill will be taken by rail to sites outside the Sydney Basin such as the de-commissioned Woodlawn coal mine near Goulburn. There are no new sites for landfill in the Basin and air-space in current landfills will be used up by 2020. Higher NOM out to 2050 increases the problem in absolute volumes, even were consumption levels sharply lowered (unlikely), packaging norms redesigned and recycling rates increased. Technology will continue to improve the use of waste streams for conversion to raw material inputs but there will still be a need for landfill disposal in the foreseeable future. That it has to be exported out of the Sydney Basin imposes higher costs of living in Sydney and shifts the impacts of landfill to another community to deal with.

Traffic Congestion and Transport Infrastructure

By 2050 Sydney will still be experiencing the flow-on effects of congestion from under-investment in road and rail infrastructure, and poor urban planning and or implementation, from the last 20 years. Expert opinion suggests that overhauling transportation infrastructure and congestion requires a 30 year time horizon. One presumes that this time span increases if population increases by 30% at the same time partly through higher levels of NOM. ‘Liveability’ will likely be subjectively reduced with commensurate costs to people. Zero NOM would allow some respite in such a timetable; higher NOM will increase the rate at which the capacity of the new infrastructure fills up with vehicle movements and people. Western Sydney is disproportionately affected by the lack of transport infrastructure and congestion measured in average travel times. Mitigation requires urgent action from the State Government in concert with WSROC. The role of Infrastructure Australia in funding is crucial.

Energy Supply

Sligo and Vassallo (2009) made the following observation about east cost energy supply at 2050:

> Looking at 2050 there will be limited and expensive fossil fuels available in power stations with CCS [Carbon Capture and Storage]. The remaining electricity will be supplied by many (thousands) small 2-10 MW wind/solar generators and some larger geothermal units. Nuclear will play a role but we are far behind in developing this potential. The power system will have a higher level of losses compared with now, because all the small units generate at about 600v rather than 25kV and require additional transformer stage to feed the system. The power system will also probably have a reduced level of security because of less firm load centres.

It is unlikely that Sydney or Melbourne will require different strategies to ensure the supply of energy based on levels of NOM. What is required is planning to ensure adequate transition from old plant to new and the implementation of mandated renewable supply options. Different levels of NOM are unlikely to force a change in the basic strategies and investment options.

Melbourne

Land and Food

Melbourne has a plentiful supply of land for urban expansion if and when required; the only caveat is the conflict with other land uses, which will generally be won by urban priorities. Even at zero NOM Melbourne will continue to lose agricultural production from its 'Green Wedges' regions through 2050, unless legislation preserves agricultural land uses, at least as well as biodiversity is currently protected. Melbourne does, however, have larger areas for food production land uses adjacent to the city than Sydney, losing only about 1% in Gross Value Added over the last ten years due to urban expansion. Melbourne will not be subject to the same level of vulnerability as is Sydney in terms of fresh food supply or pricing given these local sources. However the reduced volume of water storage for irrigation and reduced stream flows from lower rainfall could reduce the amount of irrigated fresh produce.

Water Supply

As is suggested by the ASFF modelling, water supply for Melbourne could become critical by 2030 at high (260 kpa) levels of NOM. Melbourne is more substantially affected by climate model outputs that suggest a fall in average rainfall of 20% to 30% resulting in a loss of run-off for dams of over 50%. By adding the Sugarloaf Pipeline to bring water from the Goulburn catchment in the north, the City has reacted decisively. The Sugarloaf supply is susceptible to the same climate change prognostications but water supply is supported by the new Wonthaggi Desalination plant which may allow the dams to fill up on reduced annual rainfall.

However, by 2050 Melbourne is likely to have permanent water restrictions on use, around 90 to 100kl per person; perhaps changed approaches to garden design and species, water-saving devices and industrial re-use and recycling technologies, have invested heavily in recycling stormwater and sewage for use in industry and irrigation applications; and aquifer storage and recharge may be applicable.

Water Quality

The same features of poor water quality that exist in Western Sydney streams are evident in Melbourne systems now and predicted to spread further unless substantial investments in managing stormwater are mandated for new residential developments and retro-fitted to existing suburbs. Greenfield developments that exceed the 25% threshold for impervious surface area are one of the most direct influences of population growth on stream health and stability. Increasing levels of NOM will contribute to the pollution stress on these streams.

The headwaters of the Yarra River are one of a handful of water catchments in the world undisturbed by human intervention in the last 100 years. The only impact likely to affect water quality of this major river is the re-occurrence of bushfires similar to the 2009 fires and unmitigated stormwater runoff.

Air Quality

Melbourne is affected by local daily wind systems that concentrate some of the ozone and particulate air pollutants of the city. As with Sydney, universal changes to vehicle technology, congestion mitigation actions and industrial emission modifications across the city will be required to further reduce the incidences of air pollution. The Government of Victoria is evaluating models of urban form to enable the distribution of employment and housing densities with the idea to reduce congestion, greenhouse gas emissions and improve the subjective assessment of liveability. One would expect Local Governments to be active partners in this process.

It is the particulate pollution from the increased probability of summer bushfires in the forested ranges adjacent to Melbourne that is responsible for the majority of air pollution events recorded in excess of healthy levels. This will occur independently of levels of NOM, to the extent that planning for urban expansion takes full account of bushfire hazard and migrants do not settle on urban fringes preferentially.

Biodiversity

Melbourne's population growth is being planned literally 'around' key biodiversity areas in the west adjacent to remnant native grasslands, and in the south east adjacent to the Mornington and Western Port Biosphere Reserve. Only 5% of the original vegetation remains within the City's Urban Growth Boundary. The Biosphere Reserve is a significant source of experimentation for managing the interaction between human population land use and important natural assets. DIAC could investigate the progress of this model of regional governance to assist it in understanding how best to proceed with the placement and management of NOM in our urban centres. Melbourne is unlikely to lose further biodiversity unless it fails to improve stream quality, which is a function of increasing population rather than NOM; the latter tends to settle in inner, older suburbs where biodiversity is already lost.

Waste Assimilation

Melbourne is well placed to handle the waste streams of NOM at the highest level (260 kpa) in 2050. Melbourne has enough putrescible landfill capacity for at least 50 years at current disposal rates in three locations in the north-west part of the metropolitan area. Melbourne is fortunate to have quarries being excavated for building and construction materials at six times the current landfill rate and so has a continuing supply of possible sites into the foreseeable future.

There is therefore a substantial opportunity for Melbourne to implement behaviour change with recycling and resource recovery with technology, and affect the extent to which packaging is minimised so that by 2050 or beyond, Melbourne can probably support a population of more than five million people and its waste streams.

Traffic Congestion and Transport Infrastructure

Melbourne has done better than Sydney in its provision of public transport infrastructure. However, the most recent rail development goes back 30 years to the City Loop underground service completed in 1985 along with track duplication and electrification. The tram networks have been extended but only modestly. In addition, buses are the only public transport option for most of the middle and outer suburbs. Approximately 84% of Melburnians live within 400 metres of a bus route, 15% live within 400 metres of a tram route and 23% live within 800 metres of a railway station (VCEC 2006). By contrast, a substantial proportion of transport money has been directed into new public-private partnerships for freeways that pay tolls.

Public transport services are showing symptoms of congestion including overcrowding and less reliable services. According to VCEC (2006) the increasing population will drive greater travel demands; *'overall travel demand in Melbourne will grow by 34 per cent between 2006 and 2031, with the strongest growth occurring in the inner city and in the west and south of the city'*

Without government intervention an exponential rate of increase in congestion is probable, given: overseas experience; that current roads have reached capacity; the population of Melbourne is increasing rapidly; economic activity is increasing; wealth is increasing; and public transport is beginning to get slower and more unreliable

Perth

Land and Food

Because of its isolation from the eastern states, Perth has had to be self-sufficient in its food supply, to the extent that it exports surplus production of fresh vegetables, fruits and flowers to south and south-east Asia. The Perth region has over 180,000 ha of land along the coastal plain available for urban expansion that will not greatly affect agricultural land uses. Perth will be able to sustain fresh food supply to an increasing population at all levels of NOM to 2050.

Water Supply

Perth will not be able to sustainably supply water to a population of more than about 2 million people in 2020. It is precariously placed in this regard because of the drying trend of lower average rainfall of 25% or more below its 100 year average. This means that both surface and shallow aquifer water supplies will be under increasing pressure as NOM levels increase due to the shortages of labour in the booming mining sector. New employees are often based in Perth on fly-in/ fly-out contracts, as well as the explosion of jobs in mining service industries also based in Perth. The plans to obtain water from catchments to the south will require careful negotiation and research of the impacts. Multiplication of the desalination plant about to come on stream in 2010 suffers the same caveats as those in Melbourne and Sydney, high energy use, limited locations and disposal of the brine waste.

Water Quality

The shallow unconstrained aquifers that link up with the Swan River provide ideal circumstances for eutrophication as nutrients and stormwater runoff percolate into the Swan. The catchment is substantially built up with impervious surfaces but the City is investing in recycling storm water to mitigate its pollution problems and increase its supply of fresh water. Higher levels of NOM will increase the volume of pollutants entering the Swan system but wetland engineering solutions are likely to prove effective at the LGA level.

Air Quality

Perth is mainly exposed to particulate air pollution from bushfires and burning off in the Darling Ranges catchment to the east of the city. Increased levels of NOM and increased car pollution are already being managed and, partly because of local wind systems, are not going to increase air pollution significantly. The implementation of new public transportation services is having a positive impact reducing commuting trips by car. All indicators suggest improvement in air quality despite Perth's recent population increase.

Biodiversity

In 2001 the Perth Metropolitan region contained 266,000 ha of native vegetation of which 191,000 ha is protected from development by State legislation and Local regulation. Similarly, private land contains 58,000 ha of native vegetation of which only 12% or 6,960 ha is zoned for urban expansion (Weller 2009). Bearing in mind that there is 180,000 ha available for urban development, further biodiversity loss will likely be avoided by appropriate planning controls especially of the remnant wetlands. A plan to link remnant habitats by 500 metre-wide strips of revegetation and fenced-off areas is currently underway by the Perth Biodiversity Project. NOM levels are unlikely to have much impact on the maintenance of Perth's biodiversity.

Waste Assimilation

Perth's increased NOM levels will provide economies of scale for local processing of waste for recycling and reduced volumes to landfill even as the population increases rapidly. There is no shortage of existing or future airspace for waste to landfill. Given

Perth's population and wealth increase due to the mining boom, the expensive export of wastes for treatment is likely to be reduced sooner rather than later.

Traffic Congestion and Transport Infrastructure

In its 2008-09 Annual Report the WA Public Transport Authority acknowledged that…

> while the population base will increase by 33 per cent over [20 years] period, demand for public transport is expected to double. We also know that WA is in the enviable position of being able to expand the passenger capacity of our rail network – which will continue to provide the major spine of our mass transit system – by 100-150 per cent without the need for major new infrastructure other than rolling stock.

Perth has invested substantial resources in its public transport system and roads infrastructure this last decade. It is well set up to cater for increases in NOM over the next 20 years. It requires a climate of ongoing investment in order to ensure it can manage its transportation needs beyond 3 million people, should water supplies become available.

Conclusion

The authors of this report spent much time seeking to clarify the 'how we know, what we know or want to find out', or the epistemology(ies) that would best suit the tasks set by the Department. We decided that the study required a mix of methods from different scientific traditions which approached the issues as different levels. Our research therefore embodies the idea of research-in-action: theoretically robust, a product of synthesis and observation, open to discussion and debate in step with real world applications.

The precursor to our study was the economic evaluation of NOM by demographers McDonald and Temple (2008). Our task was to use the same economic consequences of different levels of NOM, and to identify the impacts on the natural and built environment.

We sought to contribute to the development of a framework for the next generation of immigration and population policy for Australia. It is a call for a framework within which to cast policies, a framework that is sensitive to the complexities, conflicts, uncertainties and interdependencies of results of government action, at a range of scales, in particular locations, with a range of participative partners.

Our project provides a case study that incorporates the following theoretical constructs:

- The interdependence of theory and case studies;
- Cross-disciplinary research is essential; it requires new types of enquiry;
- We hypothesise that the new types of enquiry lead to different outcomes [perhaps new forms of policy regarding population growth?]
- Different 'stories' relate to different scientific cultures;
- These different stories are consequential; a) leading to new forms / content in … [policy development]; b) shifting knowledges and collective actions [as new forms of governance and institutions]; c) leading to different … [urban forms and lifestyles];
- [It is] possible and useful to 'reveal' the different traditions of understanding amongst social actors or stakeholders (Learn@Group 2000 p.452).

Our case studies demonstrate the value of: scientific synthesis of ideas and knowledge; the formation of a scientific collective of diverse disciplinary experience and skills; the value of rigour and the application of theory with observation (Sebilotte 2000, p. 475).

The people and environment/infrastructure relationship is complex, uncertain and contested:Relationships within physical systems are complex

To describe physical relationships we most often resort to metaphors and analogies such as ecological footprint, sustainability, or carrying capacity. This study reveals the limitations of these terms to act as frameworks for policy because of the assumptions that are built in to their conception and operation. The real world is more complicated, more uncertain and certainly more contested than these metaphors suggest.

This study explored, at a relatively gross level, the ways in which people live within their physical environment with the finding that this relationship is best understood at a regional or meso-scale as an *inter*dependent system. People interact with and react to their physical environment through time in ways that are influenced by a number of independent factors. They respond in ways that optimise their sense of well-being, a concept not generally amenable to measurement by an economic proxy value.

Figure I2 People/Physical System relationships

Independent Factors
People
Consumption
Location – bio-physical features
Scale
Institutions & governance

Subjective well-being

Our study addressed impacts of the people/ physical environment relationship at national (macro), local or regional (meso) and individual (micro) scales. Each scale must be addressed or considered in designing policy. Each level is linked and not necessarily in obvious relationships. The need for policy is to identify the pressures and challenges, risks and vulnerabilities at different scales of the different independent factors as they are affected by policy.

Three part methodology at different geographic scales.

In order to deal with the complex, interdependent relationships of people and their physical environments we embarked on a strategy to examine the nature of the impact of scale on relationships.

MACRO SCALE:

ASFF: Australian Stocks and Flows Framework

This model examined quantitative amounts of the transactions involving physical goods exchanged between people. It operates at the national scale as an abstraction of our society and produced hypothetical scenarios at five year intervals out to 2050.

Its purpose was to meet the requirements of the brief to quantify the relationship of NOM/ Physical natural environment/ infrastructure over time.

Population is regarded as a slow-moving *stock* which means that cumulative impacts are as important as the relatively short term *flows* of goods.

The ASFF explores the impact of population change/ growth on physical infrastructure and environmental assets including stocks of water, land and food, waste assimilation, housing, energy and transport infrastructure based on a series of assumptions about how the world operates. Importantly it provided information about gross *absolute* effects of stocks and not just relative or per capita values. Relative intensities might well improve as we have seen with water use efficiencies and provision of public transport, but the total amount of water used or greenhouse gas emitted still grows because of relationships with population growth and rebound dynamics.

Characteristics

1. Provides a complementary modeling framework to econometric models, in particular, that of the Productivity Commission.

2. Deals with real world facts and systems in a holistic approach rather than relying on economic proxy measures.

3. At the macro-scale some averaging of the 'lumpy' distribution of human activity occurs across different bio-physical environments ('outlier' effects).

4. The model is contested (as are all models). This model was first presented in 2002. Its so-called deficiencies then have been addressed in the latest iteration through model design, updated data and in more overtly describing its intent and expectations about what it delivers for readers. This ASFF was explicitly based on a shared set of assumptions with econometric models.

5. An important risk is that its findings will be treated as absolutes and facts rather than the hypotheses and possibilities that they are. Also, there is a risk that its findings will be interpreted as a simplistic 'cause and effect' relationship, eg. one extra migrant = one dead wombat, which is not true. There are correlations but very few relationships that are 'simple' given the range of independent variables operating in this space.

7. We strongly recommend that readers accept the ASFF model and its findings in its place, ie. at the macro-scale, of equal worth to the information presented at the meso- and micro-scales. The uncertainties above created by macro-scalar effects are considered in complementary fashion by the regional and local scale studies.

MESO SCALE

Purpose of examining the population-environment nexus at the regional level

This phase of the study was designed to meet the requirements of the brief to identify considerations, concerns and constraints the Long Term Immigration Planning Framework should take into account. It addresses some of the uncertainties and conflicts that arise/ have arisen in providing resources for a growing population, in a particular location. What the empirical study does not do in this report is to show quantifiable theoretical 'thresholds'. Rather, the focus is on 'risks and vulnerabilities' that exist now or are likely to exist by mid-century based on reasonable interpretation of future climate and technology.

Sources of Data

Our research of government documents and academic papers included both quantitative and qualitative information. Much of this data is descriptive and contained within future planning documents released within the last five years. The reports cover current pressures on resources including water quantity and quality, land and food, transport infrastructure, waste assimilation, and biodiversity.

Location

We were able to identify that migrants settle preferentially in certain Statistical Local Areas (SLAs) of Western Sydney, Melbourne and Perth. Our study focused on the regional and local impacts of people on their biophysical surroundings and on the built environment. We are able to identify people-environmental linkages and relationships at this scale which are not available to macro-scale modeling.

The meso-scale analysis describes and analyses the 'real world' of interaction and response by people and the natural environment to identified risks and vulnerabilities of population growth in Western Sydney, Melbourne, Perth.

Governance and Institutions

What emerged at this scale was the crucial importance of considering the governance and institutions that guide the allocation of resources now, and a judgment that these same local and state governments and social institutions must be involved with the Commonwealth Government to be effective in future planning and implementation. This was not part of the brief and so was not examined in any depth in this study.

Figure I3 Where NILS Report fits DIAC Research Agenda

DIAC Stage 1

Increase NOM →***variables & inputs*** →***economic growth scenario***

→Demographic Model

→**McDonald and Temple Report, 2009 ANU**

DIAC Stage 2

Increase NOM → **McDonald and Temple Report, 2009 ANU**

→***economic growth assumptions***

→***variables & inputs*** →***pressures operating on physical natural assets and built infrastructure***

→CSIRO ASFF Model

→Regional Empirical Studies

→Micro-scale Essays

→**NILS Report, 2010 Flinders University**

Figure I4 Meso-scale and Micro-scale Variables

Localised population growth|	***→ Localised pressures on built infrastructure and environmental services***
Localised governance/institutions/cultures	
Localised bio-physical terrain	
Consumption	
	→ Liveability & Well-being

MICRO SCALE

Synthesis of individual impact

The purpose of this set of essays was to synthesise current research investigating liveability and quality of life, two prominent aspects of our brief. The exercise involved an assessment of the impact of a migrant on the social cost of carbon emissions, the cost of ownership of a motor vehicle, and the social costs of congestion. The results of the syntheses demonstrated a substantial and important fact of the effect of congestion on people's lives, worth 10% of their income. Otherwise the similarity of the consumptive behaviours of migrants to Australian residents meant that estimates of the social cost of carbon and vehicle ownership reflected existing research values for developed countries. The syntheses used current literature to establish a set of assumptions about the interpretation of subjective or qualitative effects of carbon pollution and consumption on people lives into quantities and ultimately into dollars.

Main Points.

Our key conclusions are:

a) In general, the macro-scale modelling found that higher levels of NOM impose greater adverse impacts on the quality of our natural and built environments. Key impacts are outlined below. The modelling demonstrates an approximately linear correlation between the NOM level and the magnitude of many impacts at any given year. This does not imply cause and effect relationships due to the complexity of the physical relationships and independent social variables that are involved in our social and economic systems. In particular, other variables such as individual affluence expressed as per capita consumption, industrial activity and technological efficiency play a role in the extent of the impacts, but none were without negative consequences.

b) The meso-scale analysis established that migrants are essentially similar to Australian residents in adopting Australian consumption patterns and lifestyles except that they congregate in particular locations, especially within Sydney, Melbourne and Perth. This geographical concentration substantially increases their environmental impact.

c) Supply of urban water supply is a significant environmental constraint exacerbated by higher levels of NOM. Modelling shows the vulnerability of Sydney, Melbourne, Brisbane and Perth to deficits in water supply, on a NOM strategy of 260,000 pa., a view strongly supported by empirical review of State Government reports. The effect on water infrastructure investment of the most recent drought and entry to a drier, hotter climatic phase since the 1990s was substantial. State Governments were compelled to review future strategies and implement infrastructure spending of billions of dollars. It remains moot whether this increased capacity for our cities will cope in the next drought, given that they will have substantially larger populations nudging absolute water demand ever higher, even with improved water use efficiencies from behavioural and technological solutions.

Only NOM levels of 50,000 pa or less result in Melbourne and Sydney maintaining a small surplus of surface supply over demand on average out to 2050, assuming current climate conditions persist. Potential options to alleviate water stress at high NOM levels over the longer term may be hard to find.

d) Oil is a physical resource in a critical state of supply, which macro-scale modelling reveals to be particularly grim for transport fuel. Domestic production of oil could diminish quickly within the next 1–2 decades, independent of, i.e., at similar rates for, all NOM levels. In contrast, demand for oil increases steadily over time and at faster rates for higher NOM levels. Demand for oil reaches about double recent volumes by 2050 for a NOM of 260,000 pa. NOM levels of 50,000 pa or less result in demand remaining marginally below recent volumes. This reduction reflects increases in vehicle fuel efficiency countering most of the effects of increased affluence and consumption.

Analysis of any potential resolution of an impending gap between demand and supply of oil—or the implications of not resolving the gap—is complex, fraught with uncertainties and is beyond any predictive modelling. It is unclear, for example, what volume of foreign oil might be available for import to Australia and at what price. Substitution of conventional oil by a range of alternative transport fuels, or wider use of public transit and modal shifts present other options for maintaining transport services. Issues of timely infrastructure development, as identified in the meso-scale reviews, and of increased pressure on other environmental resources arise with such options.

e) The micro-scale analysis revealed that increased traffic congestion caused by higher levels of NOM is estimated to reduce people's subjective well-being by up to 10% of their income. Our conjecture is that this has important implications for employment location and housing (re-)development, since congestion perceived at this level alters people's preferences. Their response is to adapt to the unreasonable time and distance required to travel to work by moving to other jobs and locations. Melbourne has maintained a relatively constant average commuting time to work of 20 minutes over the last two decades.

f) Assuming that critical oil and water resource issues are addressed to support ongoing economic activity, greenhouse gas (GHG) emissions are expected to grow to several times current levels by 2050 unless substantial and rapid mitigation activities are implemented. The level of emissions is sensitive to levels of NOM, and grow in an accelerating manner with time. By mid-century, GHG emissions from fuel combustion were modelled to increase by about 60% above contemporary levels for a zero NOM level, and by 170%, and 200% for a NOM of 180,000 and 260,000 p.a. respectively.

The growth in GHG emissions is not as rapid as the modelled economic growth, calculated as GDP in the macro-scale modelling. This relative decoupling of the economy from emissions results in the aggregate carbon intensity (tonnes of CO2 emitted per dollar of GDP) decreasing by approximately 50% by 2050. This is facilitated by increases in efficiencies and structural changes in the economy, but overall economic growth results in higher absolute GHG emissions.

g) Accompanying this overall economic growth are additional pressures at the meso- or regional scale. Urban expansion occurs for all NOM levels in the modelling, with total urban area increasing about 50% in 2050 for zero NOM in a slightly saturating trend over time. For a NOM of 260,000 pa accelerating expansion results in an increase of about 150%.

Implications of such urban growth include the loss of horticultural production from peri-urban areas will reduce access to high quality fresh food especially vegetables and increase the vulnerability of food supply for consumers. Sydney is the city most at risk from losing access to fresh foods due to urban expansion into productive agricultural land**.** This may exacerbate other food security issues based on increased demand for fertilisers (for both nitrogen and phosphorus), water availability, climate change impacts, and disruption of distribution due to oil constraints.

h) We assume that additional land for urban growth will be released, and that more dense urban forms are adopted, so there is an on-going demand for building and dwelling construction. It appears that much of the decision making about resource consumption and waste disposal is made at the household scale, so it is important for policy to understand the links between the growth in population and the growth in the number of households**.** The demand for buildings increases with higher NOM levels. The growth in construction does not scale linearly with time, but demonstrates dynamics associated with population demographics and building vintage, such as reduced occupancy per dwelling or smaller households. Related to this, demolition waste was modelled to increase by at least a factor of two by mid-century. The meso-scale analysis identified additional waste streams caused by high migration inflows to be especially problematic for Sydney, which has no future landfill sites identified within the Sydney Basin, and will use up its landfill air-space within 10 years.

i) From the combined analysis, the magnitude of the impacts at all NOM levels suggests that unless substantial and timely actions are taken to address these impacts, some impacts have the potential to disrupt Australia's economy and society. Crucially, but not part of this study, will be the roles of institutions and governance in the establishment of the frameworks within which adaptation and mitigation can occur. An example is the case of transport infrastructure overhaul for Western Sydney to reduce the social and environmental impacts of congestion. This will affect the location of employment and homes and perceptions of 'liveability' in Western Sydney.

j) The case for judicious action arises due to the cumulative nature of many of the impacts for most NOM levels, that is, impacts on the natural and built environmental increase steadily or accelerate modestly with time. Small differences now in the effects of different levels of NOM on various natural and built assets in many cases accumulate to large differences 10, 20 or more years down the track.

Concepts of 'Coping': Liveability and Sustainability

The project brief states that: 'While starting from a quantitative basis, the report must also develop a qualitative assessment of particular levels of NOM on "liveability" and quality of life, for example in Australia's cities ….' This section responds to this requirement.

The concepts of "liveability" and quality of life are widely used but difficult to define. Commercial liveability surveys of cities, such as those by the Economist and Mercer, measure liveability by a wide range of external factors and amenities. These include political stability, crime, banking services, censorship, health care, waste disposal, air pollution, international schools, telecommunications, electricity, water supply, public transport, traffic congestion, international connections, restaurants, theatres, sports and leisure, housing and climate. They are measures of the 'pleasantness' of the urban physical, social and political environment. The ratings produced by these surveys are used by international corporations as a basis for the remuneration of their staff posted to these cities, and by high-ranking cities to advertise their attractions. The rankings of different surveys correspond roughly but are by no means identical, as they are based on different selections of measures and different weightings of these measures. Adelaide, for example, is 6th on the Economist's 2007 survey but 29th on Mercer's 2009 survey.

Quality of life can be measured by the same external variables as for liveability, but also by indicators of individual or household welfare (such as health, education and income), and by people's subjective perceptions of the liveability of a place or of satisfaction with life. Urban population growth, whether driven by immigration or not, could be expected to reduce the liveability and quality of life of cities by increasing noise levels, air pollution, water pollution, traffic congestion, commuting time, population densities and crime. On the other hand, larger cities can increase liveability and quality of life by providing a greater number and range of services, attractions and activities, better jobs, and a livelier ambience. Many city people are willing to trade-off the former for the advantages of the latter.

Whichever way it is measured, quality of life can be considered as an economic good which can be used to estimate the economic value or cost of some of the impacts of urban population growth. This makes it a useful way to quantify the effects of different aspects of environmental quality. As an example of this economic approach, a much-quoted study by Blomquist, Berger and Hoehn (1988) estimated the value of the quality of life in 253 counties in the US, using 1980 data in a hedonic model. The difference between two counties in the value of the index is a measure of the premium that the average household pays through the labour and housing markets to live in the more amenable county, and the study found that between the top- and bottom-ranked counties this difference was estimated to be valued at $5146 (A$5640) per household per year. The highest ranked counties tended to be located in small- and medium-sized cities in the Sun Belt and Colorado, and the lowest ranked counties were mostly in medium to large northern cities. This can be interpreted as a preference for warmer and sunnier climates and their life style, and for smaller and less industrialised cities.

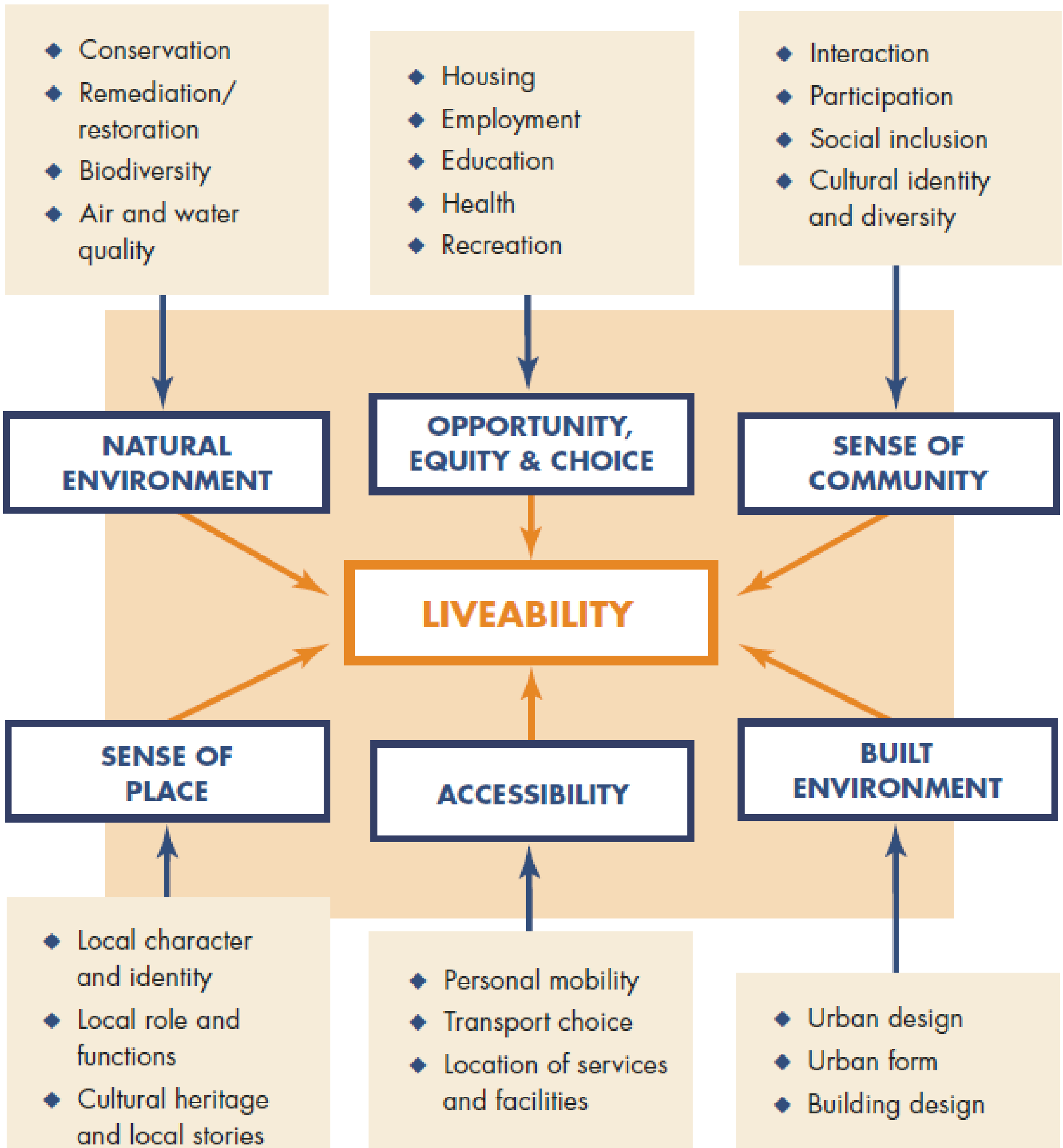
A similar study for England and Wales (Srinivasan and Stewart 2004) found an overall quality of life range between the top and bottom counties of £2696 (A$4903) per annum. The main contributors to the differences between counties were positive relationships with air quality (a range of £4,628, or A$8417) and population density (a range of £3,936, or A$7158). The authors explain the relationship between higher population density and higher quality of life by arguing that population density is a proxy measure of factors such as agglomeration economies, which produce higher wages, and the provision of a wider choice of amenities such as restaurants, theatres and galleries. Areas of higher population density, such as inner London, are therefore seen as attractive to live in by many people.

Another US study (Kahn 2001) examines the effect of rapid population growth in California between 1980 and 1990 on quality of life. The basis of the analysis was the argument that cities with a high quality of life should have lower wages and higher rents than low quality-of-life cities. To study the effects of growth, the author tested whether wages were rising and rents falling in fast-growing areas, as this would represent revealed preference evidence that growth had significantly lowered local quality of life. The results suggested that fast-growth areas had experienced reductions in quality of life relative to slow-growth areas in California. Kahn's conclusions are supported by a study of Orange County in California over the same period by Baldassare and Wilson (1995), based on a different methodology and a different data set. This study found that the urbanisation of communities on the fringes of Los Angeles and their transformation into suburbs of a major metropolitan area was associated with a decline in both overall perception of happiness and in satisfaction with a variety of aspects of the local area. However, the author warns that low income was the strongest and most consistent predictor of low quality of life ratings, and measures to control the impacts of urbanisation therefore should be designed to avoid damage to the regional economy.

A relatively new way of investigating liveability and quality of life is through the use of data on people's assessment of their life satisfaction or happiness. These data are interpreted as measures of overall quality of life, or subjective well-being, and are used in economic analysis as an empirical measure of utility (Frey and Stutzer 2002). The quality of the data on happiness or life satisfaction has been extensively assessed and generally has been found to be suitable for formal economic analysis (Welsch 2009), although Dolan, Peasgood and White (2008) identify some analytical problems and uncertainties. These studies show that subjective well-being is determined by a number of factors, of which income is only one, and that environmental variables are a minor but not insignificant contributor to people's perception of their well-being (Dolan, Peasgood and White, 2008). So far only a limited number of studies have been undertaken of the effects of urban environmental quality on happiness or life satisfaction, but they produce some interesting results:

Three studies of European countries find a significant negative association between life satisfaction and the concentration of NO_2 in the locality of the respondent, although the size of the relationship varies between the studies (reported in MacKerron and Mourato, 2009). One of these studies (Welsch 2006) estimates that a one per cent increase in NO_2 pollution is equivalent to a decrease in income of 0.27 per cent.

Figure I5: Factors contributing to high standards of liveability



A study by Welsch (2002) of the trade-off between prosperity and pollution, based on cross-section national data for 54 countries, found that 'a typical urban citizen in Germany would need to be given 1925$ [A$2120] per year to accept an increase of nitrogen dioxide pollution to the Japanese level'.(Welsch, 2002, p. 487)

A German study (Rehdanz and Maddison 2008) finds that perceived noise quality is positively related to subjective well-being. They also find that higher perceived levels of noise are not compensated for by lower house prices, possibly because of the relatively high level of renting and the regulation of the rental market in Germany.

Another German study (Stutzer and Frey 2008) finds that people who take longer to commute to and from work report significantly lower subjective well-being than those who spend less time commuting. The authors calculate that:

> *Full compensation for commuting 22 minutes (one way) compared with no commuting at all, is estimated to require an additional monthly income of approximately 470 euros [A$766] or 35.4 percent of the average monthly labor income. We do not want to insist on the specific number, but would like to emphasize that the loss in well-being due to a suboptimal commuting situation seems sizable whether put in perspective relative to other determinants of subjective well-being or translated into monetary terms (Stutzer and Frey, 2008, p. 355).*

An Irish study (Brereton, Clinch and Ferreira, 2007) finds that living in Dublin lowers life satisfaction relative to living outside Dublin, and their modelling attributes this to the higher population density and traffic congestion in Ireland's largest city.

A New Zealand study (Morrison 2007) finds that subjective well-being in the high density urban area of Auckland City and Manukau City is lower than in other New Zealand cities on all three measures used in the study. Morrison suggests that this may be a consequence of continued agglomeration.

A study of China (Smyth, Mishra, and Qian, 2008) found that subjective well-being was significantly reduced by air pollution as measured by sulphur dioxide emissions.

A preliminary cross-national study using individual data for the mid-1990s by Israel and Levinson (2003) found that happiness was inversely related to water pollution measured as emissions of organic water pollutants in grams per day per capita.

The researchers estimated that the marginal willingness to pay for a reduction of around 10 per cent in water pollution was about $US 660 (A$727). This could be interpreted to mean that an increase in water pollution of around 10 per cent reduced subjective well-being by about A$727 a year.

A study of Germany by Luechinger (2009) using high-resolution air pollution data found that SO_2 concentration negatively affected life satisfaction. The study estimated that the total marginal willingness to pay for a reduction in SO_2 concentration was between €217 (A$354) and €319 (A$520) annually. The study also estimated that the effect of a decrease in pollution by one standard deviation would be between 92 per cent and 130 per cent of the effect of a reduction in the local unemployment rate by one standard deviation.

A study of Oslo found that higher population density had a significant, although small, negative effect on quality of life as measured by subjective well-being (Cramer, Torgersen and Kringlen, 2004). On the other hand, a more comprehensive study of Auckland, a city more comparable with Australian cities, found no significant differences in overall satisfaction between high, medium and low density residential areas. The study concluded that people traded-off elements of their residential environment to maximise their satisfaction, so that people who wanted good public transport and connectedness, for example, lived in high density areas and people who wanted better school services chose medium density areas (Walton, Murray and Thomas, 2008).

Shields, Wheatley Price and Wooden (2009) have also assessed the effects of neighbourhood characteristics on life satisfaction in Australia. Their conclusion is that 'location matters, but not a great deal' (p. 439). They identify several neighbourhood characteristics that reduce life satisfaction. One of these is the percentage of immigrants from non-English-speaking countries, a finding which has clear implications for immigration policy if the aim of that policy is to maximise the welfare of Australians. The study did not include a measure of population density, but did find that an index of urban disamenity (half of which represented perceptions of noise) had no statistically significant relationship with life satisfaction.

A study of the Brisbane-South East Queensland region (McCrea, Stimson and Western, 2005) examined satisfaction with various urban attributes at three urban levels: housing, neighbourhood or the local area, and the wider metropolitan region. It found that the regional satisfaction of Generation X respondents was more likely to be concerned with sustainability issues such as pollution, population levels and transport systems than for older generations. Pollution was also a significant predictor of regional satisfaction for parents with children living at home. The study concluded that:

> As older cohorts die and more couples decide not to have children, there is likely to be increasing pressure to design environmentally friendly, sustainable and liveable urban environments with less focus on growth. (McCrea, Stimson and Western, 2005, p. 149)

A number of conclusions can be drawn from the results of the studies reviewed above.

1. Economic analysis of subjective well-being can provide quantitative assessments of liveability and quality of life.

2. The quality of urban areas, as measured by factors such as good infrastructure and services, safety, good social relationships and an unpolluted and attractive environment, contributes in a small but significant way to people's subjective well-being.

3. If the growth of Australia's cities to the sizes projected in this report leads to higher levels of air and water pollution, noisier cities, increasing congestion and longer commuting times, subjective well-being will be reduced. [The risk of environmental degradation in the cities will be assessed elsewhere in this report] The degree of this reduction cannot be calculated, but based on the studies above it could be the equivalent of perhaps ten per cent of individual income.

4. Higher population densities, which are an inevitable outcome of urban population growth and an essential way of coping with this growth, need not produce a decline in subjective well-being. This will only be achieved, though, if higher density areas

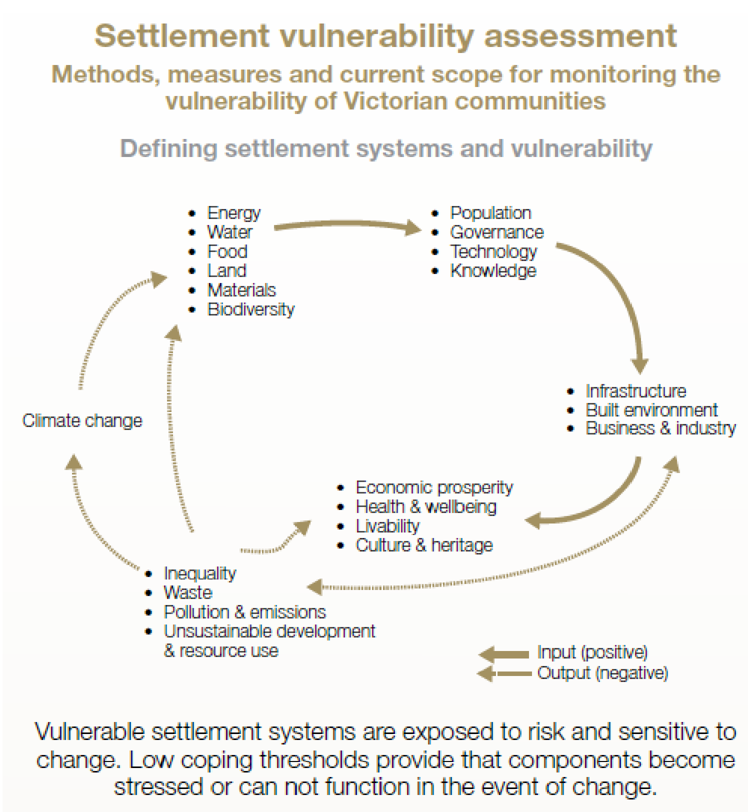
have the attributes of good public transport, a range and variety of leisure, entertainment and cultural facilities, and a stimulating life style that compensate for some of the negative aspects of higher density areas. In addition, residents' life satisfaction will be increased if the negatives of higher density areas, such as noise and air pollution, can be reduced.

5. Careful planning is also needed on the expanding fringes of Australia's major cities, to ensure that urban growth does not produce a decline in subjective well-being.

6. Policy should seek to avoid concentrations of migrants from non-English-speaking countries, if the finding of the study by Shields, Wheatley Price and Wooden (2009) is correct and the objective is to maximise the welfare of the resident population.

7. Generational shifts in the Australian population are likely to increase the influence of environmental conditions on people's subjective well-being, and produce stronger demands for governments to improve the environmental sustainability of the cities.

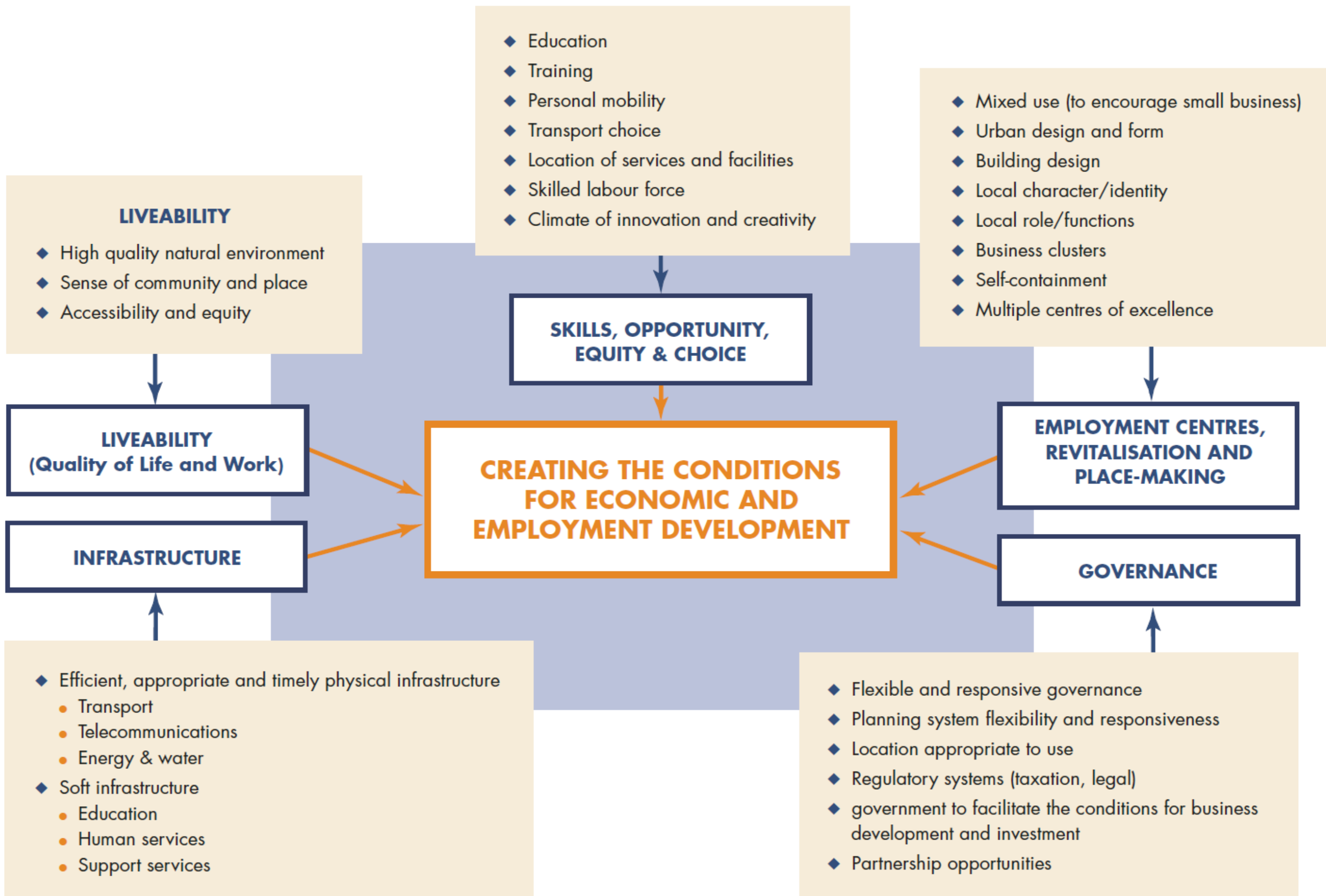
Figure I6 An outline of elements of the question of increasing population and the capacity of Australia's built and natural assets to cope



Source DPDC 2009 Research Matters #50

Figure I7 The interdependence of physical and social assets in the creation of conditions ripe for employment (WAPC 2004)

Source: WAPC 2004



References

Baldassare, M. and G.Wilson (1995), 'More trouble in paradise – urbanization and the decline in suburban quality-of-life ratings', *Urban Affairs Review*, vol. 30, pp. 690–708.

Blomquist, G.C., Berger, M.C. and Hoehn, J.P. (1988), 'New estimates of quality of life in urban areas', *American Economic Review*, vol. 41, pp. 89–107.

Brereton, F., Clinch, J.P. and Ferreira, S. (2007), 'Happiness, geography and the environment', *Ecological Economics*, vol. 65, pp. 386–396.

Cramer, V., Torgersen, S. and Kringlen, E. (2004), 'Quality of life in a city: the effect of population density', *Social Indicators Research*, vol. 69, pp. 103–116.

Dolan, P., Peasgood, T. and White, M. (2008), 'Do we really know what makes us happy? A review of the economic literature on the factors associated with subjective well-being', *Journal of Economic Psychology*, vol. 29, pp. 94–122.

DPDC (Department of Planning and Community Development) 2009, *Research Matters #50* May. Government of Victoria.

EC (European Commission) 2006 *Constructing Regional Advantage – Full Report*: principles – perspectives – policies, 104 pp Belgium: EC.

Frey, B. and Stutzer, A., 2002. What can economists learn from happiness research?', *Journal of Economic Literature*, vol. 40, pp. 402–435.

Israel, D. and Levinson, A. (2003), *Examining the relationship between household satisfaction and pollution*, Paper to be presented at the Eastern Economics Association Meetings, February 23, 2003.

Kahn, M.E. (2001), 'City quality-of-life dynamics: measuring the costs of growth', *Journal of Real Estate Finance and Economics*, vol. 22, pp. 339–352.

Luechinger, S. (2009), 'Valuing air quality using the life satisfaction approach', *Economic Journal*, vol. 119, pp. 482–515.

MacKerron, G. and Mourato, S. (2009), 'Life satisfaction and air quality in London', *Ecological Economics*, vol. 68, pp. 1441–1453.

McCrea, R., Stimson, R. and Western, J. (2005), 'Testing a moderated model of satisfaction with urban living using data for Brisbane-South East Queensland, Australia', *Social Indicators Research*, vol. 72, pp. 121–152.

Morrison, P.S. (2007), 'Subjective wellbeing and the city', *Social Policy Journal of New Zealand*, no. 31, pp. 74–103.

O'Neill, P. 2008 *Western Sydney Employment Trends,* Presentation at *"Sydney –the other city"* regional conference April, Urban Research Centre, University of Western Sydney

Power, M., Bullinger, M., Harper, A., and The WHOQOL Group (1999), 'The World Health Organization WHOQOL-100: Tests of the universality of quality of life in 15 different cultural groups worldwide', *Health Psychology*, vol. 18, pp. 495–505.

Rehdanz, K. and Maddison, D. (2008), 'Local environmental quality and life-satisfaction in Germany', *Ecological Economics*, vol. 64, pp. 787-797.

Shields, M.A, Wheatley Price, S. and Wooden, M. (2009), 'Life satisfaction and the economic and social characteristics of neighbourhoods', *Journal of Population Economics*, vol. 22, pp. 421–443.

Smyth, R., Mishra, V. and Qian, X. (2008), 'The environment and well-being in urban China', *Ecological Economics*, vol. 68, pp. 547–555.

Srinivasan, S. and Stewart, G. (2004), 'The quality of life in England and Wales', *Oxford Bulletin of Economics and Statistics*, vol. 66, pp. 1–22.

Stutzer, A. and Frey, B.S. (2008), 'Stress that doesn't pay: the commuting paradox', *Scandinavian Journal of Economics*, vol. 110, pp. 339–366.

Walton, D., Murray, S.J. and Thomas, J.A. (2008), 'Relationship between population density and the perceived quality of neighbourhood', *Social Indicators Research*, vol. 89, pp. 405–420.

WAPC (WA Planning Commission) 2004, *Network city: community planning strategy for Perth and Peel*, Government of Western Australia

Welsch, H. (2002), 'Preferences over prosperity and pollution: environmental valuation based on happiness surveys', *Kyklos*, vol. 55, pp. 473–494.

Welsch, H. (2006), 'Environment and happiness: valuation of air pollution using life satisfaction data', *Ecological Economics*, vol. 58, pp. 801–813.

Welsch, H. (2009), 'Implications of happiness research for environmental economics', *Ecological Economics*, vol. 68, pp. 2735–2742.

What is sustainability?

The Natural Step; WSROC; and Strategic Sustainable Development

At a recent workshop sponsored by the Cornell Centre for Sustainable Futures entitled 'Managing Transitions to Sustainable Cities and Regions' the 'Natural Step' program was introduced and contained a definition of sustainability that enables the term to be used with clarity. The definition boils down to four precepts:

- matter and energy are neither created nor destroyed;
- matter and energy tend to dissipate;
- the value of matter is in its concentration and structure; and
- photosynthesis is the key process by which the Sun's energy is converted into matter and energy on Earth.

The first two precepts are a re-statement of the First and Second Laws of Thermodynamics in a closed system which acknowledges our finite existence. The third and fourth precepts can be developed as 'system conditions' that frame sustainable practices such that nature is not subject to systematic increases in:

- Concentrations of substances extracted from the Earth's surface;
- Concentrations of substances produced by society;
- Degradation by physical means; (Robert et al 2002) and in that society…
- People are not subject to conditions that systematically undermine their capacity to meet their needs (The Natural Step, 2010).

From these principles can be deduced a set of sustainable development principles that include 'back-casting' from an imagined future scenario; flexible platforms that allow technically or socially feasible stepping-stones into the future; exercise of the precautionary principle In planning; and governance driven by dialogue, transparency and an understanding of the influence of norms and values on behaviours.

A way to approach future scenario building is take a leaf out of the WSROC book. The next section of the report refers to WSROC literature that speaks of recent initiatives to create "platforms' of social or societal readiness to receive more people into an area such that the livelihoods created are sustainable and liveable. This approach focuses on providing an opportunity for the 'territory' to develop its identity and in particular to evolve assets, rather than betting on one particular economic or social sector to be the main entity around which the community revolves. 'The Local Platform' requires an interdisciplinary, geographical approach which I characterise by the diagram below

In explanation, planners need to be cognisant of the social and physical structures that exist or can likely be created from the territory's existing elements. Social elements include the cultural and broader societal norms that govern people's behaviours. Physical elements include the built urban and natural environments. Once these structural elements are measured they provide the scaffold for the cognitive elements, i.e. people's preferences, to be expressed in the myriad transactions in the exchange of goods and services that comprise society's daily activity.

The cognitive elements include the generation of social capital and the importance of a learning culture to enable change to occur in a way that produces positive outcomes for people. Change will occur if there are leadership roles available to react to external stimuli and define interdependent relations with economics, governance, and natural assets. Change can also be driven from within existing social structures and preferences if a learning culture exists.

Therefore, by considering a territory rather than a sector as a community, O'Neill (2008) makes the point that the way in which the present is perceived or organised influences the flexibility of a place to deal with future circumstances. A territorial platform is more flexible because one is less committed to a particular path of micro-management decisions that have a higher probability of risk. That is, in terms of negotiating the future and allocating scarce resources, more options are likely to be available for selection as events unfold with the territorial view. This is the 'platform' from which a local council and its state agency partners can plan for the future in collaboration with their present constituents.

In terms of sustainability this process provides a more resilient approach for the management of the constructed and social environment of a region of a capital city. This approach could be applied to the assessment of other localities; parts of large urban conurbations and regional cities as locations for increasing population growth. As we have seen in this report, the likelihood is that Melbourne will become the largest urban centre in Australia by 2050 because Sydney does not have the 'platform' – the physical infrastructure, natural assets and leadership and policy environment capable of supporting more than the planned population of about 5 million people by 2036, given current lifestyles.

O'Neill asks this rhetorical question of Western Sydney which holds significance for NOM policy:

> How do we construct an employment-creating western Sydney economy that brings quality jobs nearer to western Sydney workers so that the city [can] be a better place to live with a major reduction in greenhouse gas emissions.

His answer was to adopt the EU argument for:

1. [T]he adoption of platform policies over sectoral policies. Platform policies build territorial competence. They acknowledge the impossibility of picking winning firms or winning sectors. Instead, platform policies build regional territories into platforms where successful firms and sectors can emerge and become successful over long time periods. A territorial platform, then, has these characteristics:

2. Foundational, competitive infrastructure (like transport systems that move goods and people around productively and efficiently)

3. Human capital with skills, productive ethics and access to quality training

4. Knowledge base with access to institutions (especially universities) for creating, applying and sharing new knowledge and innovation

5. Quality business climate and a quality people climate, because the two go hand in hand

6. SME and entrepreneurship policies to lower entry barriers to new firms and start-ups including access to venture capital, incubators, business training, supply chain networks

7. Quality spatial business formations be they commercial zones, business districts, office parks, industry clusters; formations that acknowledge the territorial advantages of co-location, economies of scale and shred competencies.*(EC 2006)*

This approach draws on the need for a leadership role to pull together those social and physical elements that generate organisations with resources. It is an organisational resource, the Platform, upon which the daily transactions of businesses and individuals are built. The results of these myriad transactions are outcomes that change the nature of the local social landscape. The relationships so formed and the learning that takes place re energises the original social and physical assets that produced the Platform in the first place. At the same time people and organised entities express their preferences and expectations about the outcomes. These cognitive elements feed back into the Platform as constant adaptive change which invigorates continuing development activity without having been micro-managed or cherry-picked by government. These latter options are unlikely to be nearly successful as those endeavours that arise more organically from the assets already present, that is physical infrastructure assets, the education, skills and knowledge of the locals and the opportunities for networks outside the immediate spatial or personal environment

Several other ways of conceptualising and defining environmental sustainability follow:

Generational sustainability

Some definitions are about the environmental resources and quality left to the next generation. Sustainability means that the environment should be protected in such a condition and to such a degree that environmental capacities (the ability of the environment to perform its various functions) are maintained over time: at least at levels sufficient to avoid future catastrophe, and at most at levels which give future generations the opportunity to enjoy an equal measure of environmental consumption. (Jacobs 1991, pp. 79-80). This concept is difficult to make operational, and implies that the problems are those of the future, not the present.

Maintenance of essential environmental functions

An ecological economics view of sustainability starts with the observation that the environment performs three functions in supporting human life and economic activity. The first is the production of raw materials from the natural resources of soil, water, forests, minerals and marine life (the earth's 'source' function). The second is the safe absorption (through breakdown, recycling or storage) of the wastes and pollution produced by production and human life (the earth's 'sink' function). The third function is the provision of the environmental services that support life without requiring human action, such as climatic stability, biodiversity, ecosystem integrity, protection from ultraviolet radiation, and the recreational, psychological, aesthetic and spiritual values of environments, including areas of natural beauty or wilderness (the earth's 'service' function). (Ekins 2000, pp. 53-54; Jacobs 1991, pp. 86-96). Sustainability is then defined as the maintenance of essential environmental functions.

The economist Paul Ekins has turned this definition into a set of operational principles, reproduced in shortened form below:

1. Destabilisation of global environmental features such as climate patterns or the ozone layer must be prevented.

2. Important ecosystems and ecological features must be absolutely protected to maintain biological diversity. Importance in this context comes from a recognition not only of the perhaps as yet unappreciated use value of individual species, but also of the fact that biodiversity underpins the productivity and resilience of ecosystems.

3. The renewal of renewable resources must be fostered through the maintenance of soil fertility, hydro-biological cycles and necessary vegetative cover and the rigorous enforcement of sustainable harvesting.

4. Depletion of non-renewable resources should seek to balance the maintenance of a minimum life-expectancy of the resource with the development of substitutes for it. … To help finance research for alternatives and the eventual transition to renewable substitutes, all depletion of non-renewable resources should entail a contribution to a capital fund.

5. Emissions into air, soil and water must not exceed their critical load, that is the capability of the receiving media to disperse, absorb, neutralise and recycle them, nor may they lead to concentrations of toxins that cause unacceptable damage to human health.

6. Landscapes of special human or ecological significance, because of their rarity, aesthetic quality or cultural or spiritual associations, should be preserved.

7. Risks of life-damaging events from human activity must be kept at very low levels. Technologies which threaten long-lasting ecosystem damage should be forgone.

Of these seven sustainability principles, 3, 4 and, to some extent, 2 seek to sustain resource functions. Five seeks to sustain waste-absorption functions; 1 and 2 seek to sustain life-supporting environmental services; 6 is concerned with other environmental services of special human value; and 7 acknowledges the great uncertainties associated with environmental change and the threshold effects and irreversibilities mentioned above. (Ekins 2000, pp. 95-97)

A number of these principles can be turned into operational measures, which makes them particularly useful, but some are either hard to measure or involve value judgements. These principles could be used to evaluate the results of the modelling of scenarios.

I would add one further sustainability principle to Ekin's list. This is the principle of trans-frontier responsibility, which means that sustainability in one region or country cannot be achieved at the expense of environmental conditions elsewhere. A region or country cannot export its environmental impact, such as saline water from irrigation, polluted urban storm water, land degradation from logging, or atmospheric and water pollution from industrial production, and claim to be environmentally sustainable.

Natural capital

An explicitly economic view of sustainability, and one that is quite influential, involves the concept of natural capital. Natural capital is naturally occurring assets that are either used in production or provide non-market services. Refers to the earth's natural resources and the ecological systems that provide vital life-support services to society and all living things. (Grafton and others 2004, p. 482)

There are different forms of natural capital. Economists view the Earth's resources in terms of capital, which can be conveyed as bequests between generations, and they make an important distinction between constant (or substitutable) natural capital, and critical natural capital. The former refers to cultural (e.g. built), and readily renewable natural, resources. The latter includes basic life-support systems (global commons, biodiversity) which, once irreversibly damaged, cannot be re-created. Collectively, the two represent the Earth's natural capital stock. (Selman 1996, p. 12).

Weak and strong sustainability

Economists and other social scientists use arguments over the extent to which natural capital can be replaced by human-made capital to distinguish between weak and strong versions of sustainability.

The question of whether our planet can sustain humanity is, perhaps, the fundamental question of environmental economics. Given the uncertainty that surrounds what the future might bring and whether we can improve both our living standards and our environment, much of the literature on the conditions for sustainability is theoretical. Two widely used concepts are that of weak sustainability and strong sustainability.

Weak sustainability is commonly interpreted as maintaining the total stock of capital (reproducible and natural) at such a level that the welfare of today's and all future generations is non-declining. An implication of weak sustainability is that the possibility exists for the current generation to draw down the natural capital stock provided there is a corresponding net investment in reproducible capital to ensure non-declining average welfare across generations. Thus, weak sustainability implies there is some degree of substitutability between human-produced capital and natural capital in production. Given that reproducible and natural capital produce different "goods and services," weak sustainability may also be viewed as implying a degree of substitution between the flow of benefits from natural capital and mass consumption.

Strong sustainability is commonly interpreted as maintaining the natural capital stock (or some critical subset thereof) undiminished in terms of its resilience (see chapter 1) and ability to assimilate wastes and regenerate renewable resources. Even under this strict interpretation, it may still be possible to deplete aspects of natural capital, such as draw-down reserves of oil and natural gas, provided that this does not impinge on the ability of natural capital to provide its critical environmental services (Grafton and others 2004, pp. 322-23).

References

Castle, D. 2010 *The Natural Step: a Strategic Framework for a Sustainable Society,* A presentation to the Managing Transitions to Sustainable Communities Workshop, Cornell University, July.

Ekins, P. 2000, *Economic growth and environmental sustainability: the prospects for green growth*, Routledge, London and New York.

Grafton, R.Q. and others 2004, *Economics of the environment and natural resources*, Blackwell, Oxford.

Jacobs, M. 1991, *The green economy: environment, sustainable development and the politics of the future*, Pluto Press, London, chapters 6, 7, and 8.

Robert, K.-H., Schmidt-Bleek, B. de Larderel, J.A., Basile, J., Jansen, J.L., Kuehr, R., Price Thomas, P., Suzuki, M., Hawken, P. and Wackernagel, M. 2002, Strategic Sustainable Development – selection, design and synergies of applied tools, *Journal of Cleaner Production* **10** pp. 197-214.

Selman, P. 1996, *Local sustainability: managing and planning ecologically sound places*, St. Martin's Press, New York.

Appendix A: Melbourne Planning Scenario 2031: Polycentric City, Middle Centres

Figure X1 Polycentric City: Middle Centres Scenario vs. Base Case: % Change in New Employment Distribution

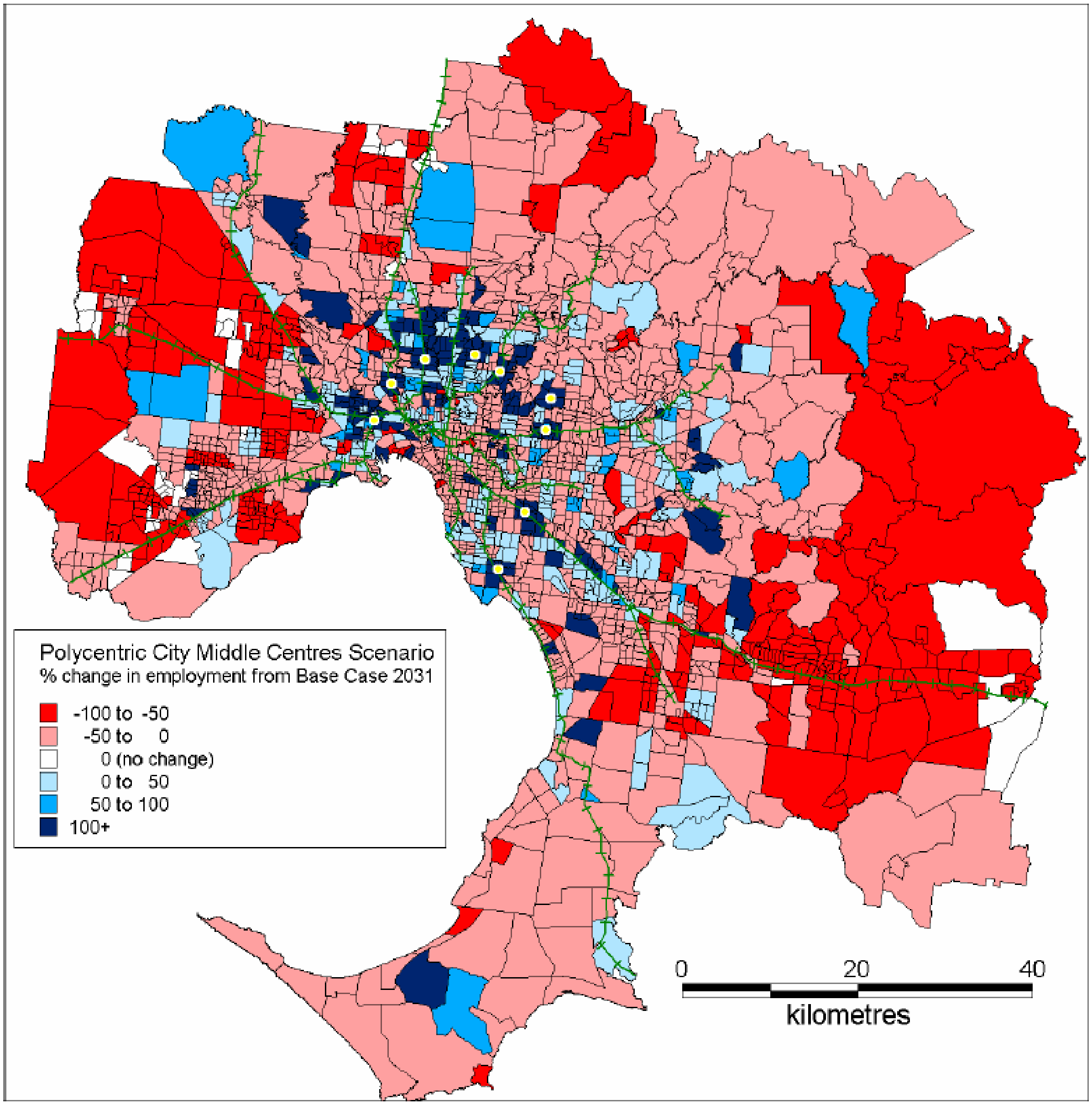


Figure X2 Polycentric City Middle Centres Scenario – Population Density (Persons per Hectare)

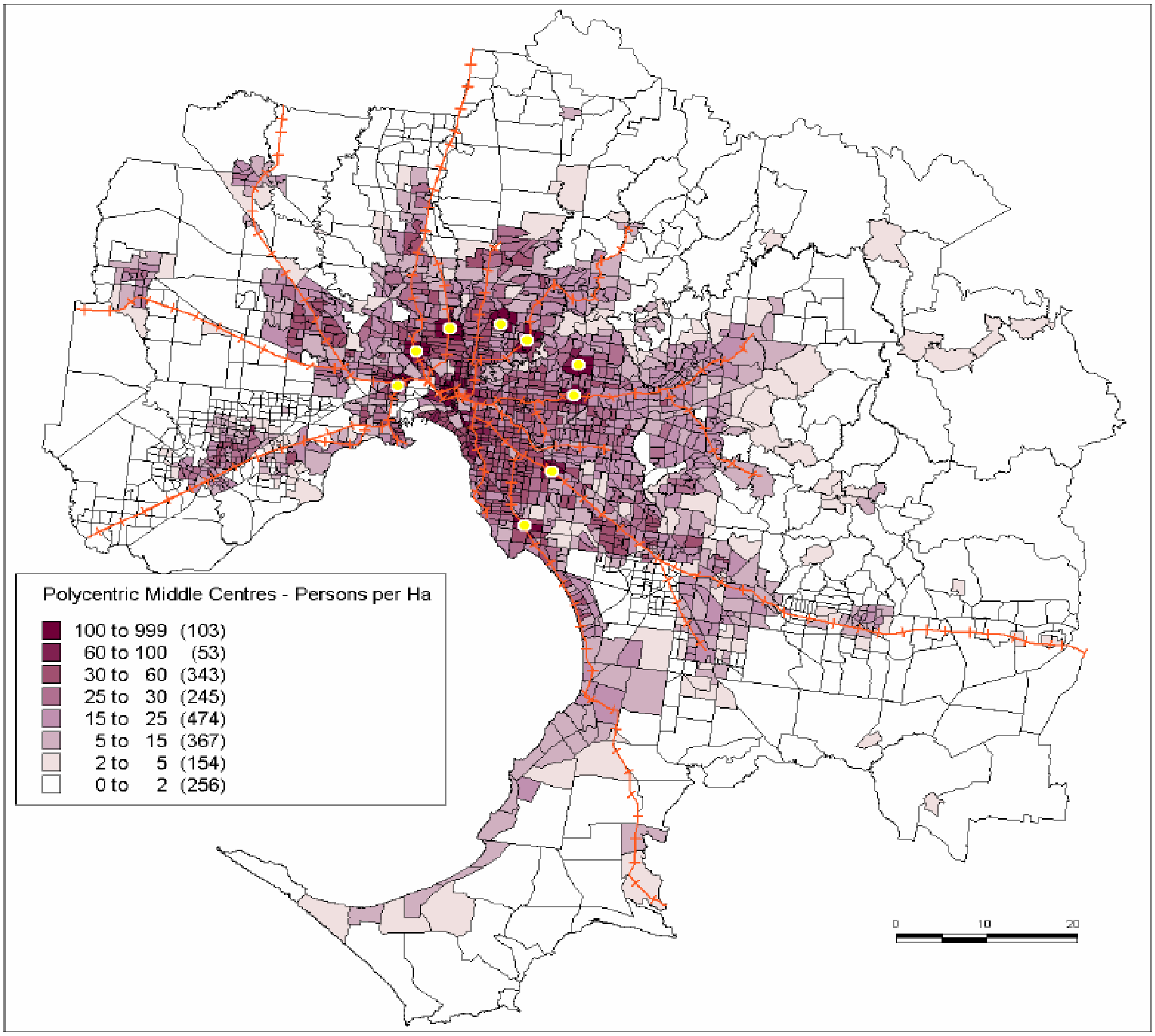


Figure X3 Polycentric City Middle Centres Scenario – Population (Persons per Hectare) – Inner Melbourne

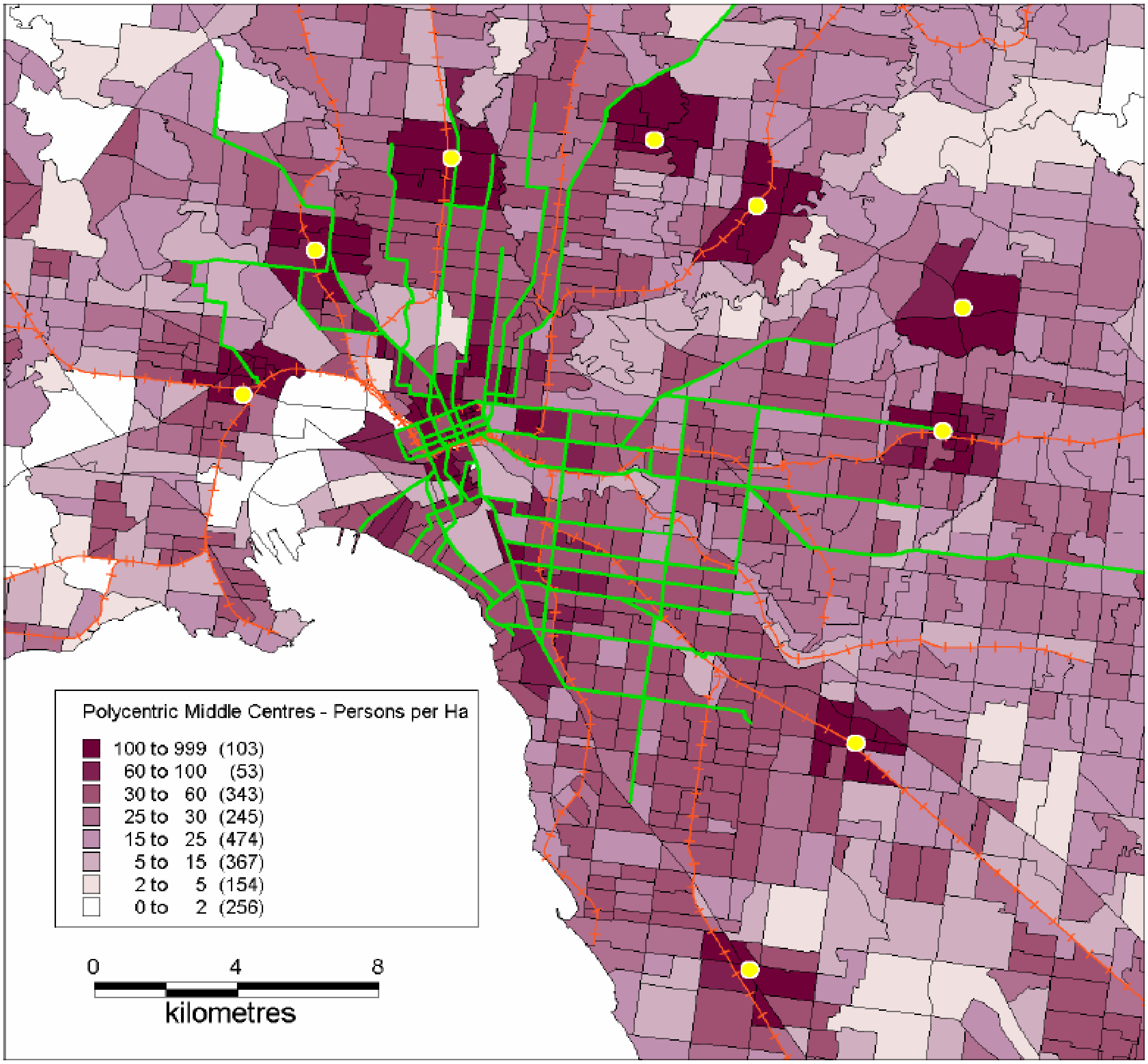
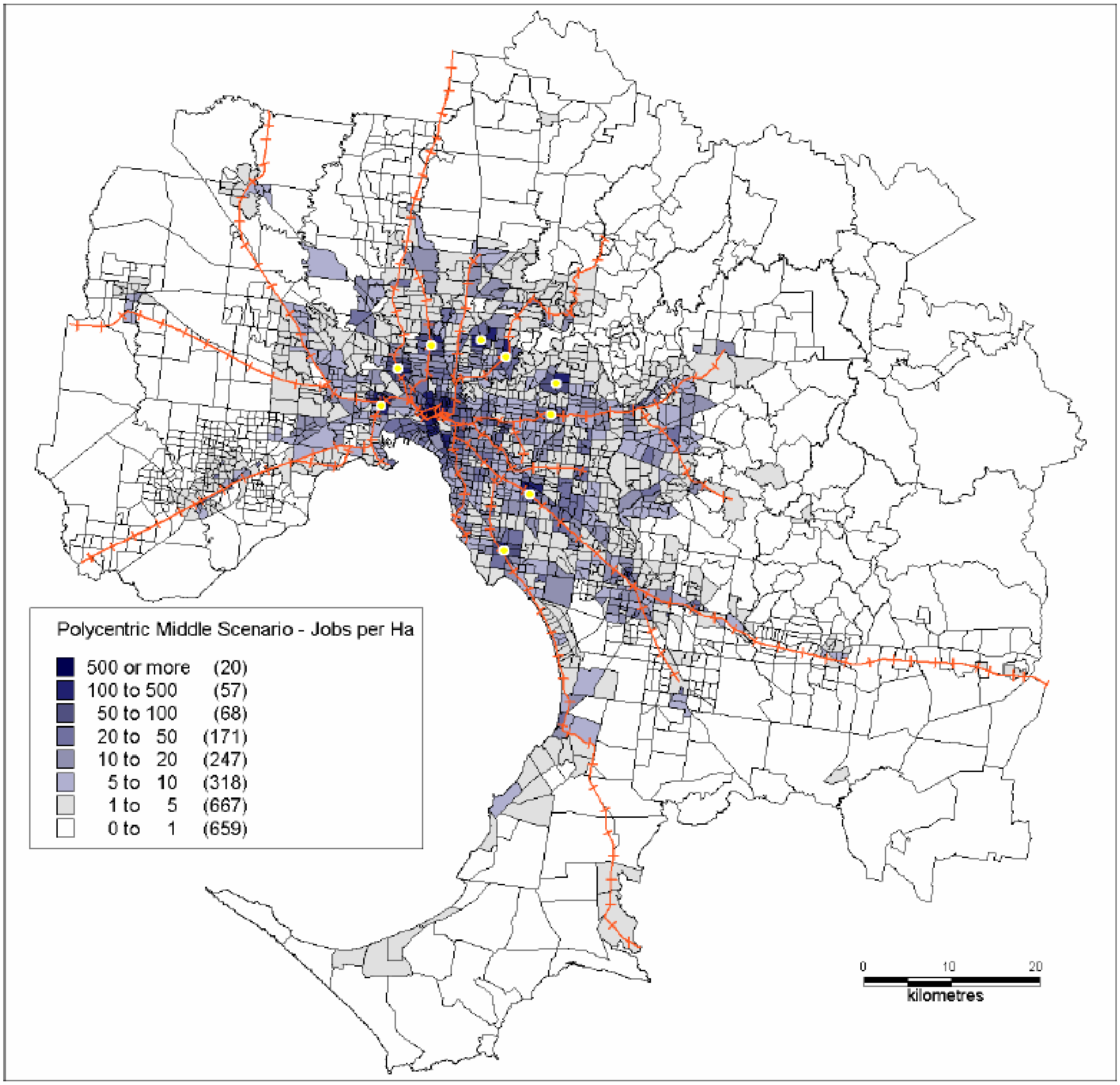


Figure X4 Polycentric City Middle Centres Scenario – Employment Density (Jobs per Hectare)



Appendix B – Comparison between the MoDEM and ASFF results on economic growth

GDP related measures provide a comparison with the McDonald and Temple (2008) work (using the Productivity Commission's MoDEM model). There is a reasonably good comparison between the two modelling outputs, which is reassuring given that they use very different ways of calculating GDP. In the absence of data from the MoDEM model, which would support correlation analysis, the comparison between the two modelling outputs is presented in graphical comparisons below.

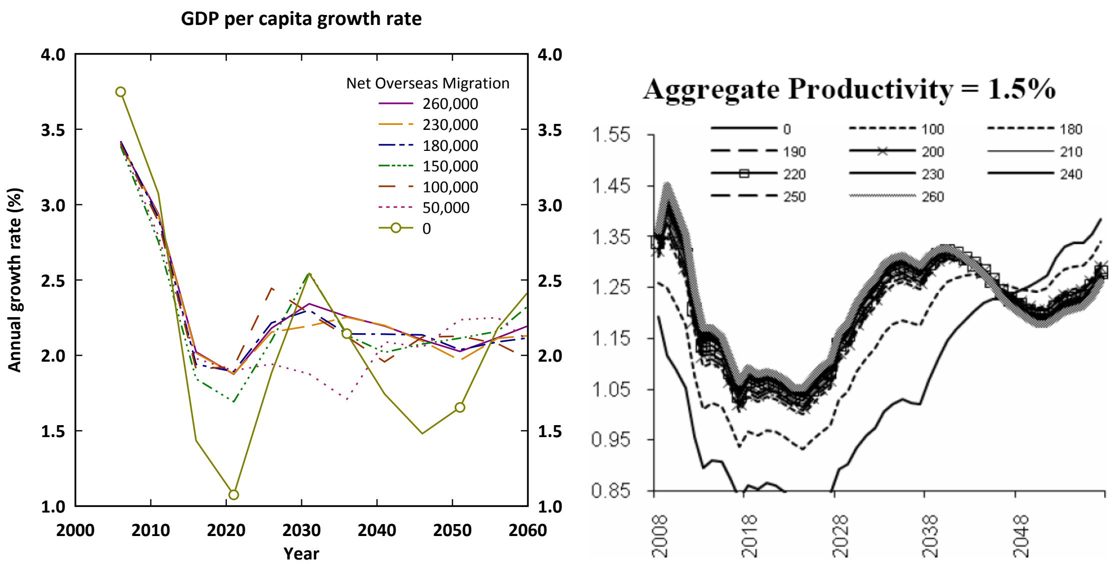


Figure X5. Annualised growth rates of GDP per capita, from the ASFF modelling (top) and MoDEM modelling (bottom) of McDonald and Temple (2008).

The graphical comparison between growth rates of GDP per capita (Figure X5) shows similar temporal trends. The growth rates decline over the next decade toward a minimum, then rise over about two decades, before falling marginally again. These cycles arise from the demographic aging characteristics of the population, which influence the size of the available labour force. There is also some similarity regarding the relative effects of NOM levels. Generally the growth rates are slightly higher and less cyclic for higher NOM, though the changes appear to be insignificant beyond a NOM of about 100,000 pa. The ASFF modelling however indicates for a given NOM a higher growth rate than McDonald and Temple's work. This is likely to be due to differences in how labour productivity and other efficiencies are represented in the models. The offset in growth rate is of largely irrelevant in this study of environmental impacts of NOM levels, since the modelling highlights the relative impacts of different NOM rates.

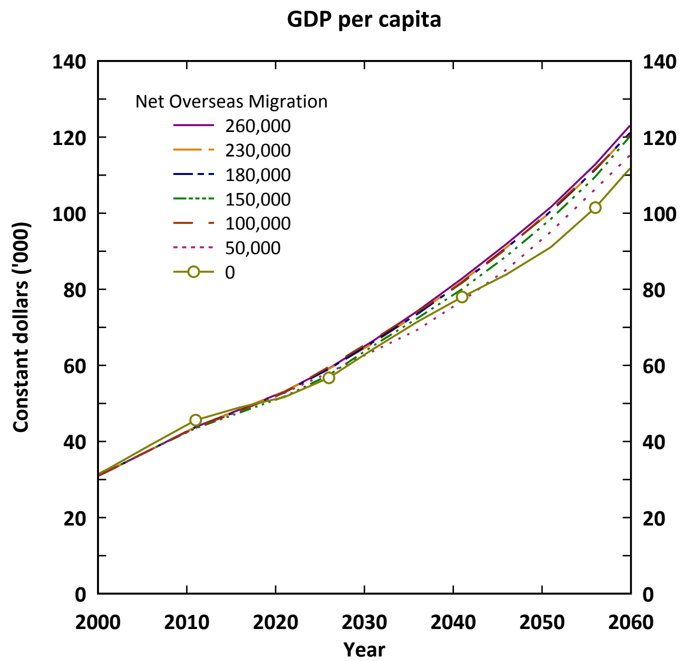


Figure 3: Relative GDP Per Capita (2007 indexed at 0) accumulated growth under differing assumptions of ANM (standard TFR assumptions, with current LFPR assumptions).

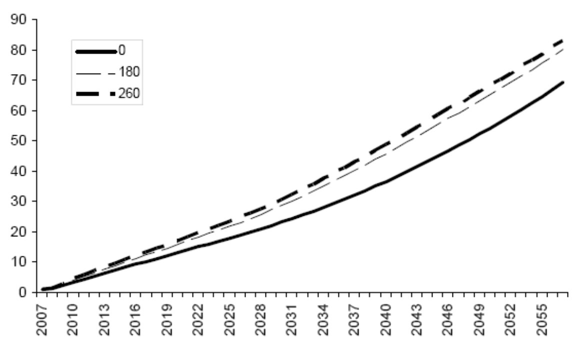


Figure X6. GDP per capita, from the ASFF modelling (top) and MoDEM modelling (bottom) by McDonald and Temple (2008).

Resultant GDP per capita compares favourably between the two modelling approaches, as shown in Figure X6.

Appendix C – Overview of the ASFF

Scope of the ASFF

The ASFF is a highly disaggregate simulation of all physically significant stocks and flows in the Australian socio-economic system (Figure X7). Stocks are the quantities of physical items at a point in time, such as land, livestock, people, buildings, etc., and are expressed in numbers or SI units. Flows represent the rates of change resulting from physical processes over a time period, such as the (net) additions of agricultural land, immigration and birth rates, etc. In the first version of the ASFF there over 800 multi-dimensional variables (about 300 that are exogenous).

The ASFF is a process-based simulation that covers the physically significant elements of each sector of the Australian economy as we currently understand them, including some service aspects. Natural resources (land, water, air, biomass and mineral resources) are also represented explicitly. Part of the framework incorporates a physical input-output model for the transformation of basic materials and energy types (Lennox, Turner et al. 2005). Elsewhere, there are physical accounting relationships that represent the key processes, such as converting the requirement for transport of goods into the size of the freight transport fleet and the fuel requirement. A detailed explanation of the relationships throughout the ASFF is available in Poldy et al. (Poldy, Foran et al. 2000). All variables representing physical stocks and flows obey the thermodynamic constraints of conservation of mass and energy.

Geographically, the ASFF covers continental Australia, including the marine area within Australia's economic exclusion zone (for fishing and fuels). Within specific sectors of the framework different geographic resolutions are used, e.g., agriculture is resolved at the 58 statistical divisions across Australia. The temporal extent of the ASFF is long-term: scenarios over the future are calculated to 2100, and the model is also run over an historical period from 1941. In some sectors such as agriculture it is necessary to provide data substantially prior to 1940 due to the lengthy life-time of important agricultural land stocks, e.g., of different quality (Dunlop, Turner et al. 2002). The time step used is 5 years, coinciding with Australian Bureau of Statistics census years.

Flows of people, energy and materials may enter and exit the economy, principally as imports and exports on the left and right respectively. Within the domestic economy, natural resources are extracted or harvested from the environment (shown at the centre bottom of the diagram). Materials are transformed progressively (going upward in the diagram), with the use of suitable energy, to eventually provide goods and services for the population. The population provides a labour force (at the top) for all the economic sectors. Wastes and emissions are generated by the economic activity, and may be recycled, exported or returned to the environment. Other flows occur between economic sectors.

Requirements from one component of another are shown as dashed red lines. Flows produced by one component for another are shown as solid blue lines. Two major components, demography and primary industries, are entirely exogenous. Components to the right and bottom of the diagram only receive information flows, and present any tensions (mis-matches) between requirements and provisions associated with international trade, natural resources, wastes/ emissions, and labour.

Figure X7 Schematic summary of physical flow connections of a modern economy like Australia's.

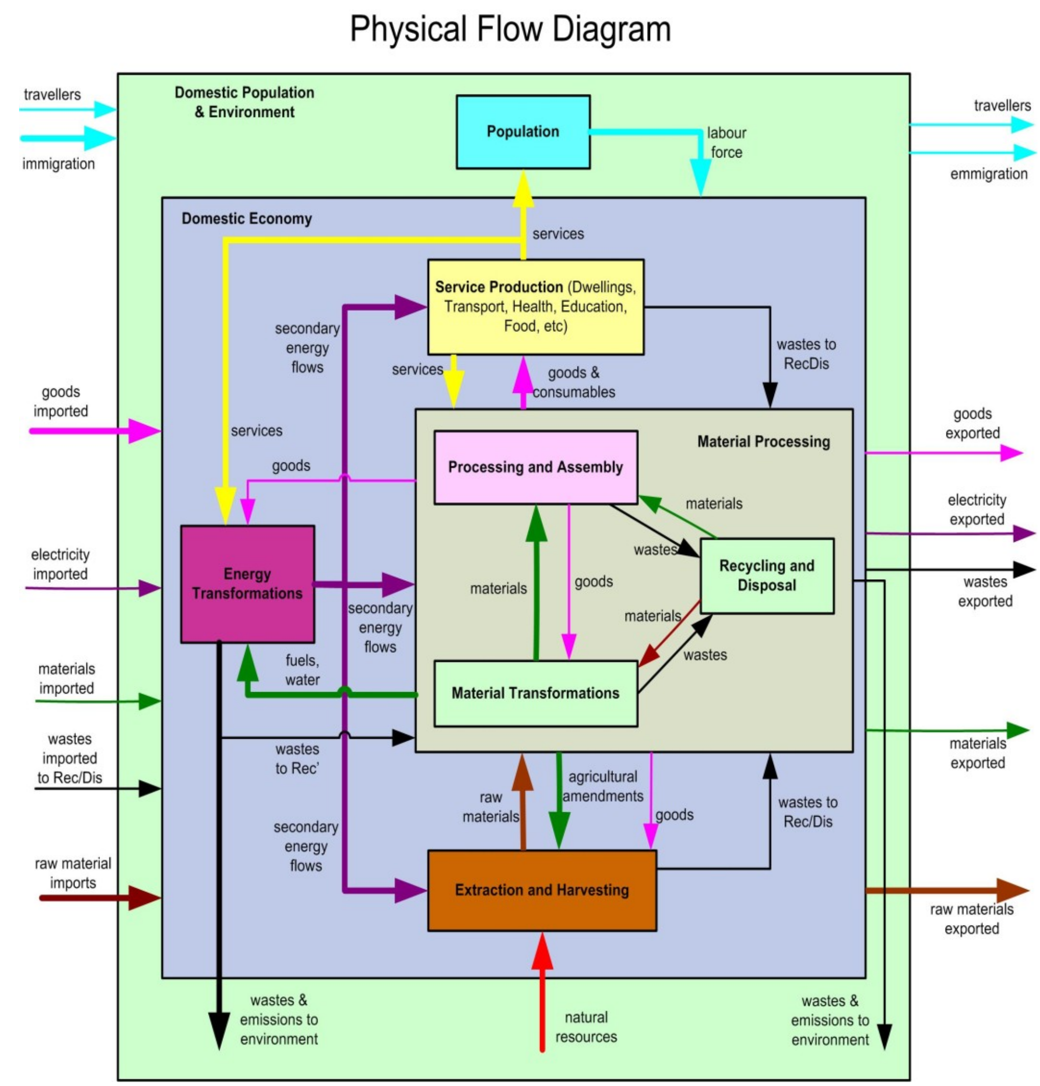
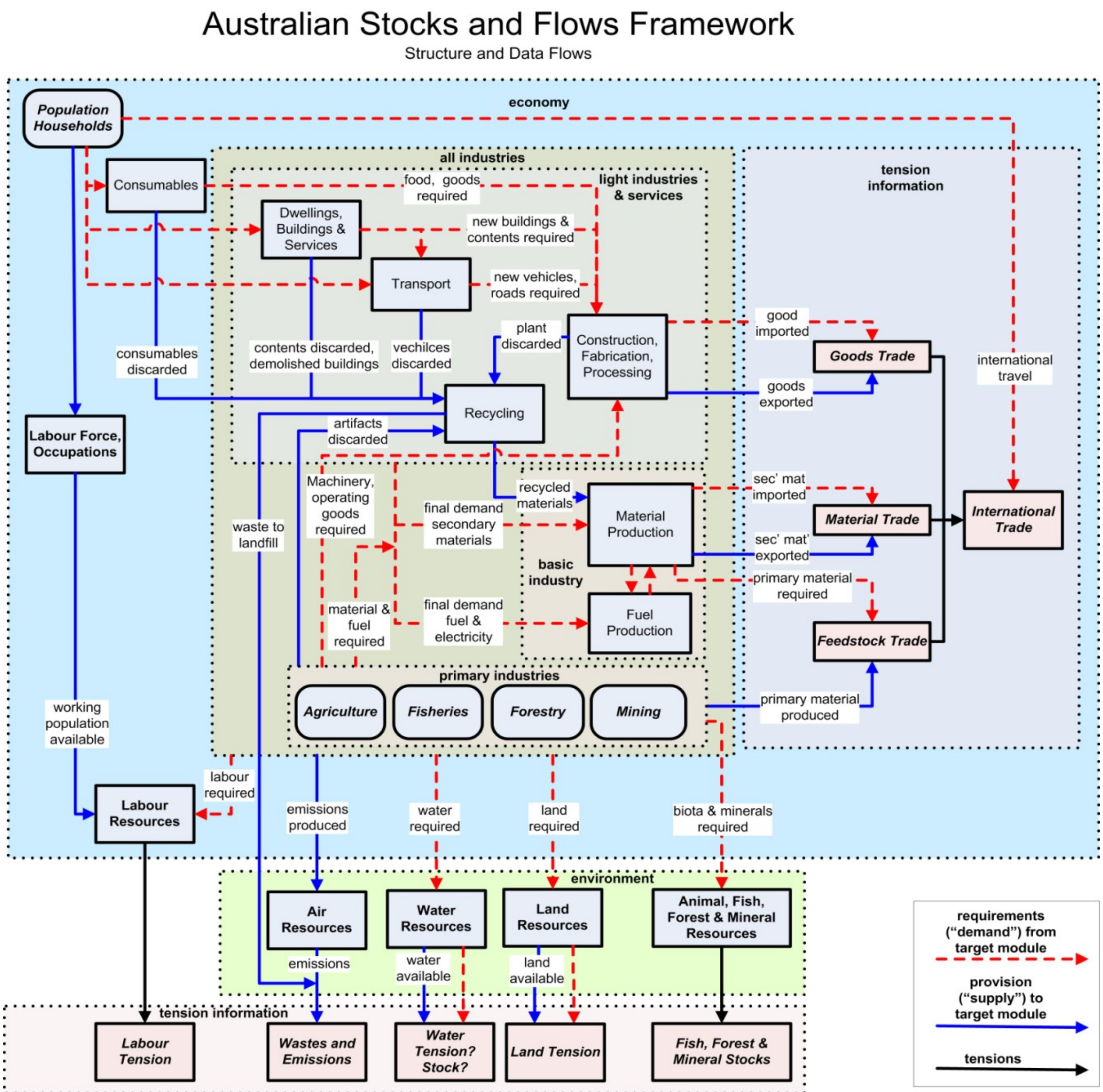


Figure X8 Major components (boxes) and information flows (arrows) between components of the ASFF.



Overview of the modular structure

The high level structure of the ASFF is illustrated in Figure X8, depicting information flows among the major components of the ASFF (shown as boxes), which may contain other modules (such as household formation, within demography). Arrows indicate data flows from one component to another within the ASFF; solid lines represent information on physical things produced or provided from one component to another; dashed lines represent physical things required by one component from another. These requirements can be conceptualized as the reverse of a flow of physical items provided, much like an electrical current is the reverse of the flow of electrons. As a central feature of the Design Approach, these information flows eventually lead to the creation of tensions between requirements and provisions (collected in the components at the bottom and right of Figure X8).

Two of the major components in Figure X8 (the boxes with round corners), representing demography and the primary industries, are driven exogenously and have only data flows exiting them. For example, the Australian population provides a labour force (blue solid line), which is subsequently compared with the requirement for labour created by activity in all industries (red dashed line exiting the box around all industries). A population consumes food and other non-durables, and needs dwellings and other buildings (for offices, education, health services, etc.), and personal and public transport. Consequently, the requirements of the Demography component drive the Consumables, Buildings and Transport components. The latter is also driven by requirements for transport services that are related to the building stock, such as urban freight.

The requirement for manufactured goods and infrastructure drives the modules in the Secondary Light Industry component. Additionally, discards of goods, durables and decommissioned infrastructure are potentially recycled in Secondary Light Industry. Manufactured goods can be sourced from overseas, so the Secondary Light Industry generates a requirement for imported goods (dealt with in the International Trade component). Likewise, manufactured goods may also be exported from Australia (also informing International Trade calculations).

The functioning of Buildings, Transport and Secondary Light Industry collectively create (with the Primary Industries) a requirement for materials, fuel and electricity from Secondary Heavy Industry ('Basic Materials and Energy'). Allowance is also made for secondary materials/ energy that are imported (to satisfy domestic demand of the other industry sectors), or exported from Australia after domestic production. This module employs a physical Input-Output process (that also incorporates evolution of productive capacity) to calculate the primary materials required.

Separately, the exogenous Primary Industry component produces primary materials from agriculture, forestry, fisheries and mining. This information is compared in International Trade with the requirement from Secondary Heavy Industry for primary materials. If there is insufficient domestic production of primary materials, then they are imported; and if there is excess, they are exported. Along with the imports and exports of secondary materials and goods, and international travel (driven from the Demography component) and invisibles, the International Trade component forms the trade balance (in financial units, using prices in combination with the physical flows). The trade balance is one of a collection of "tensions"; an excessively large positive or negative trade balance flags an unlikely international trade situation.

Other tensions occur, located in the Natural Resources and Labour components, where requirements are compared with provisions (the comparison is represented by opposing left and right arrow heads). The requirement for land, water and labour is gathered from the individual requirements in each of the economic activities represented in the prior components. Unemployment is an obvious tension between higher labour availability and lower requirements, while the opposite i.e., more workers required in the economy than is available in the labour force is also a tension, though one that is not physically feasible. Similarly, it is possible to produce a preliminary scenario where water required is greater than available resources, or more land required than land mass.

In addition to tensions, other indicators report the emissions of greenhouse and other gases to the atmosphere, and waste to landfill, resulting from all economic activity. These indicators could also be interpreted as tensions if they are compared with target emissions and wastes. Other information in the ASFF can be used to form further indicators and tensions, such as the level of education and health of the population.

Estimating GDP using the ASFF

An indicative measure of GDP has been calculated in the ASFF based on the physical stocks of capital and labour. This indicative GDP is an approximation for an income-based GDP (ABS 2000). (The alternative is expenditure-based GDP.) To calculate the income-based GDP, we combined the labour numbers in the ASFF with salary and wages data to calculate the "compensation of employees" component of GDP; and to estimate the "gross operating surplus" component, the new stocks of productive capital in the ASFF were combined with calibrated data on the cost of capital and a rate of return upon investment for all sectors. The new stocks are those items of physical capital that contribute to economic output. They incorporate machinery, commercial vehicles and commercial buildings in the primary, secondary, transport and service sectors covered in the ASFF. For the scenarios, no assumptions were made about movement in future labour salaries and price of capital or rates of return (assumed to be 10%); such changes would require economic modelling or expert advice. Instead, this analysis maintained salaries and prices at a constant level, therefore indicating the effect of physical changes in the economy on the GDP, all else being equal.