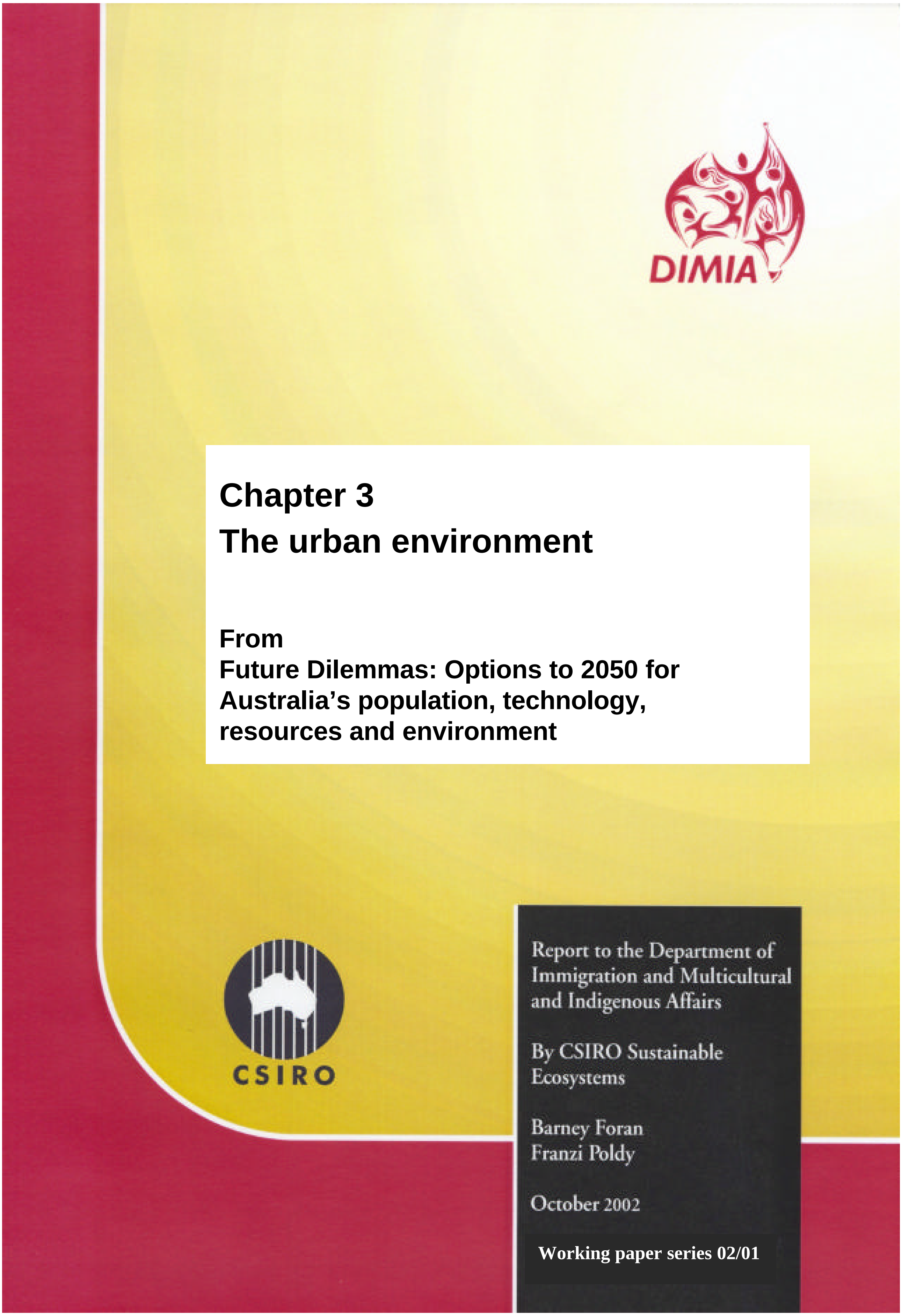

Chapter 3
The urban environment

From

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

Report to the Department of Immigration and Multicultural and Indigenous Affairs

By CSIRO Sustainable Ecosystems

Barney Foran
Franzi Poldy

October 2002

Working paper series 02/01

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

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

ISBN 0 95808453 X

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

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

Chapter 3
The urban environment

ABSTRACT

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

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

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

INTRODUCTION TO THE URBAN ANALYSIS

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

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

ISSUES FROM THE DIMA WORKSHOP SERIES

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

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

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

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

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

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

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

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

BUILDING REQUIREMENTS

Domestic housing

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

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

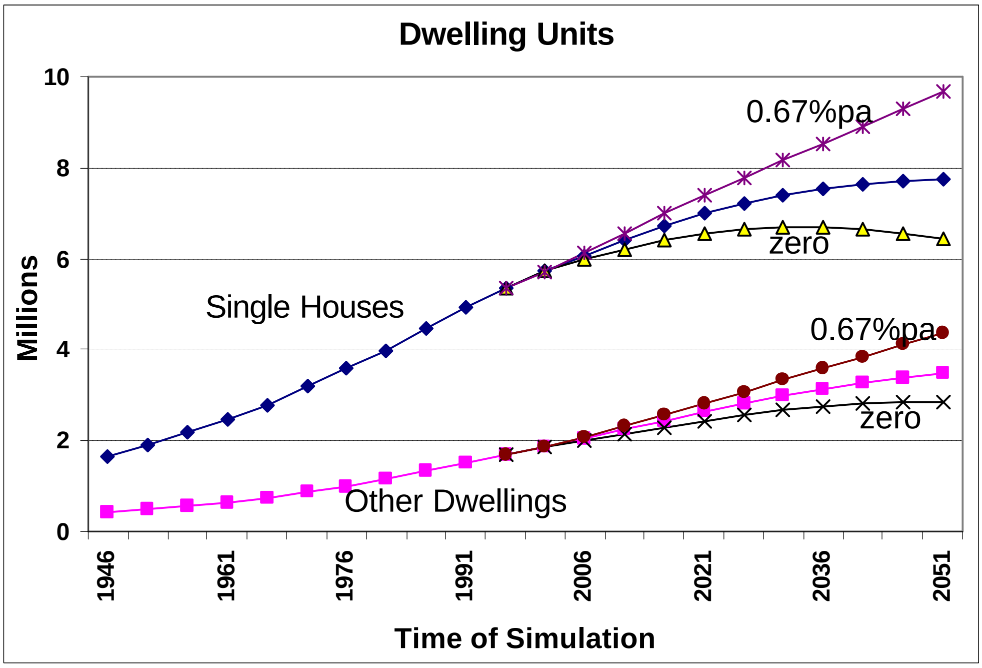

Figure 3.1. Simulated requirements for both single and other domestic housing units out to 2050 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

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

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

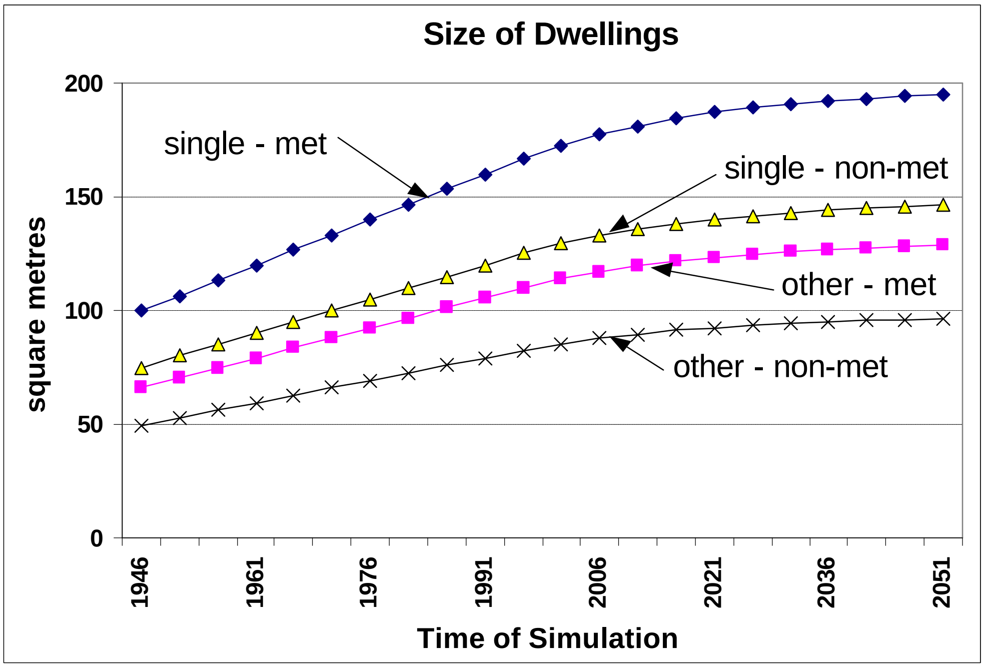

Figure 3.2. Assumptions for floor areas of domestic housing for both single and other dwelling types in metropolitan (met) and non-metropolitan (non-met) areas.

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

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

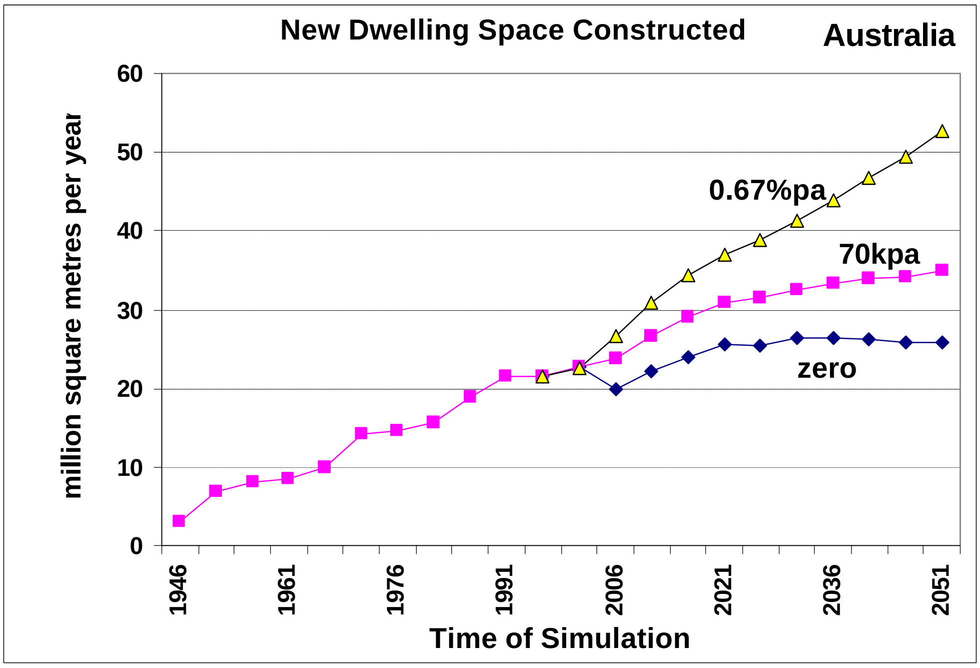

Figure 3.3. Simulated requirements to 2050 for the construction of new dwelling space on a yearly basis for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Age of the housing stock

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

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

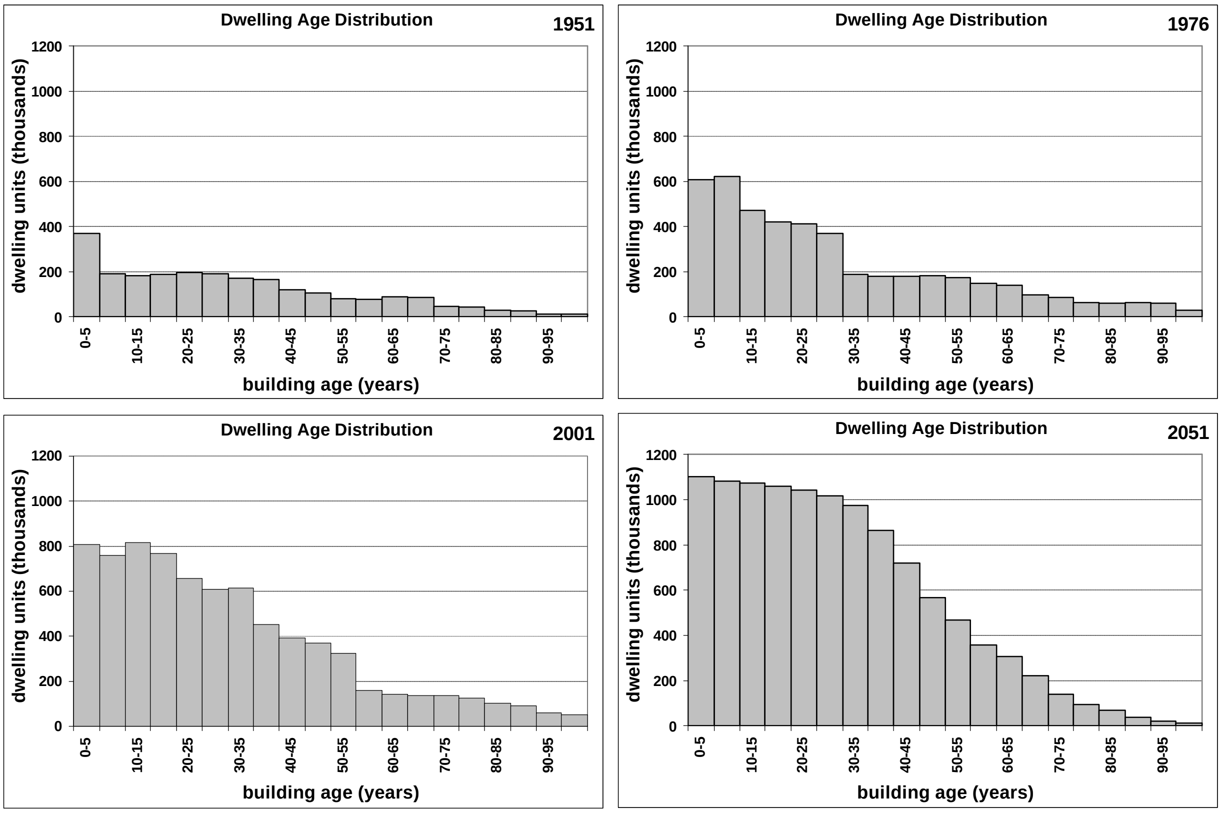

Figure 3.4. Simulated age distribution of domestic dwelling stocks of dwelling units in 1951, 1976, 2001 and 2051 for the base case scenario.

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

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

All other buildings

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

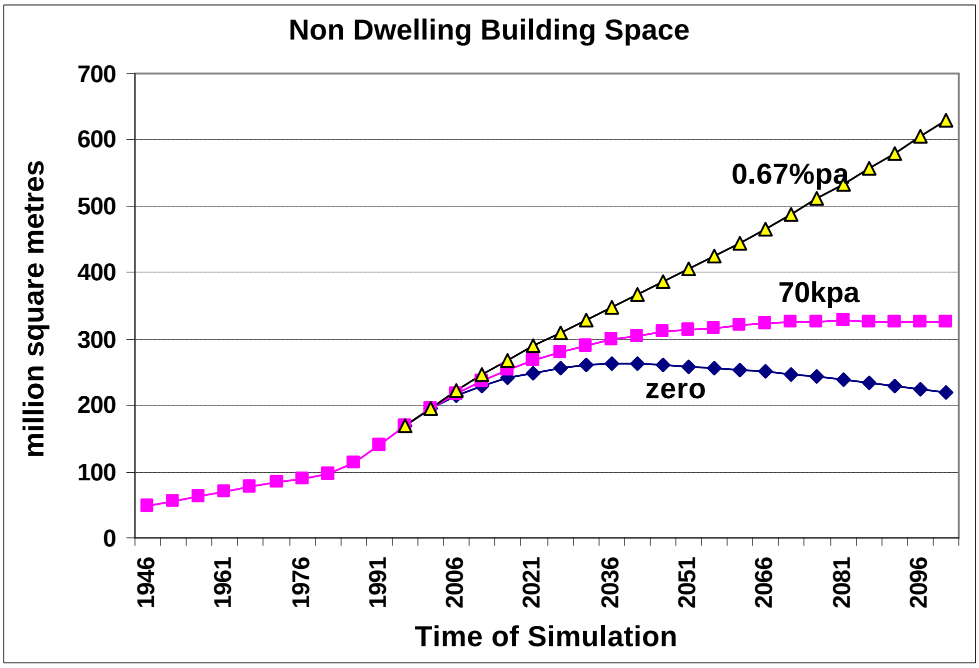

Figure 3.5. Simulated requirements to 2100 for the stock of total non-dwelling space for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

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

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

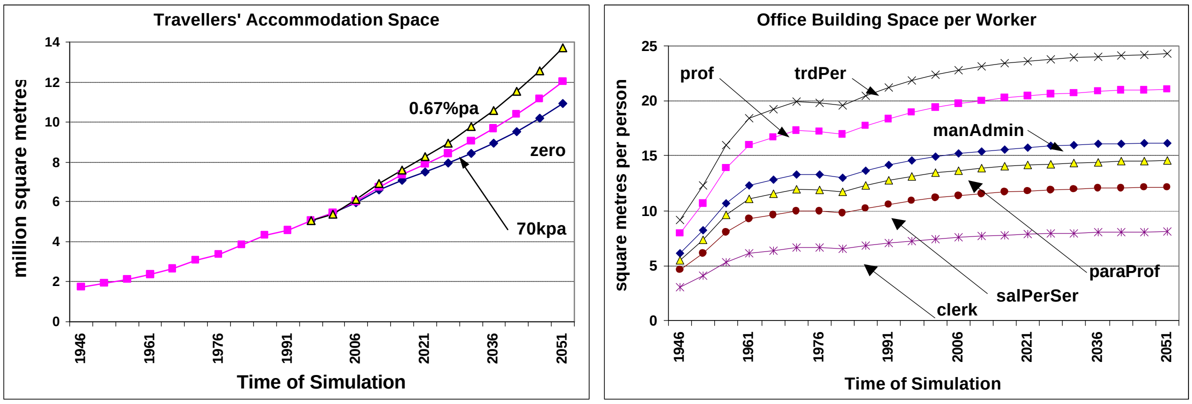

Figure 3.6. (a) Simulated requirements to 2050 for tourism accommodation space for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa); (b) Settings for all scenarios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

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

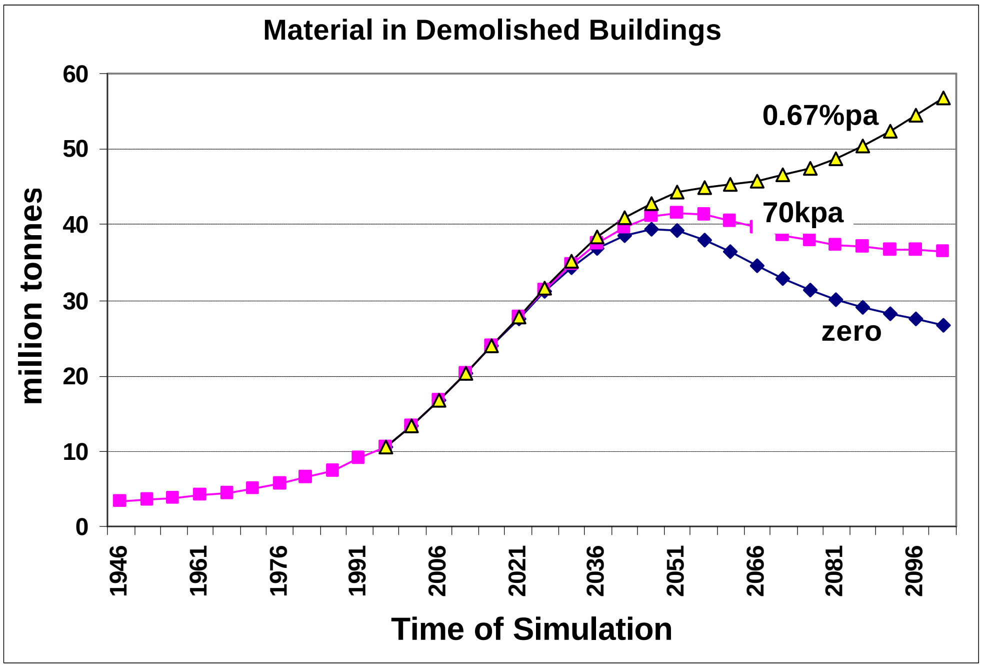

Figure 3.7. Simulated generation of materials from demolished buildings to 2100 for total dwelling and non-dwelling space for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per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

Demolition, waste and recycling

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

Energy use by buildings

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

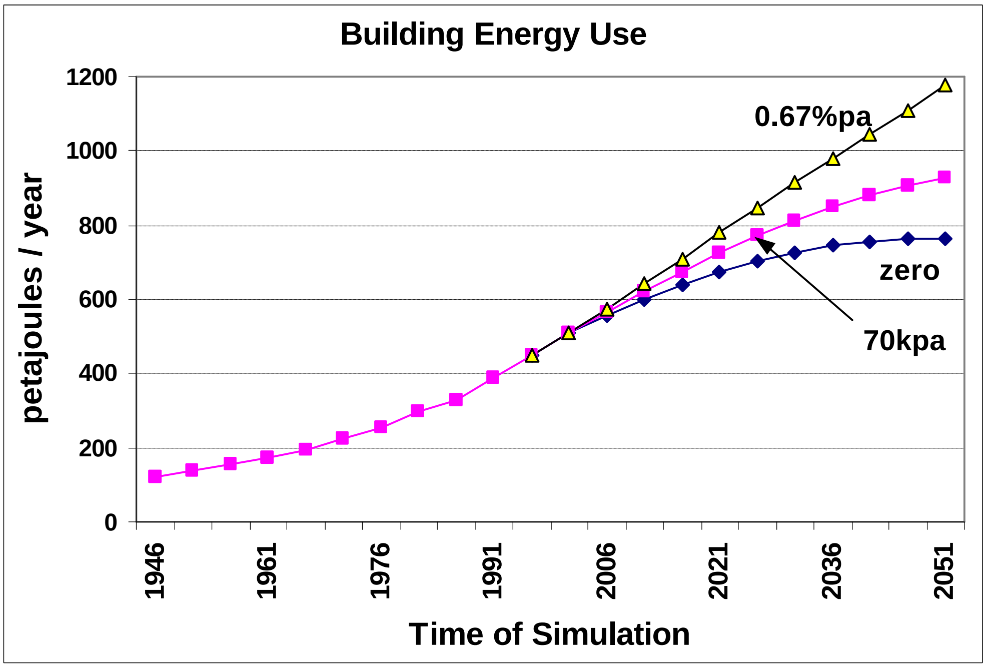

Figure 3.8. Simulated total energy use in petajoules (10^{15}J) per year to 2050 for total dwelling and non-dwelling space for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration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

.

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

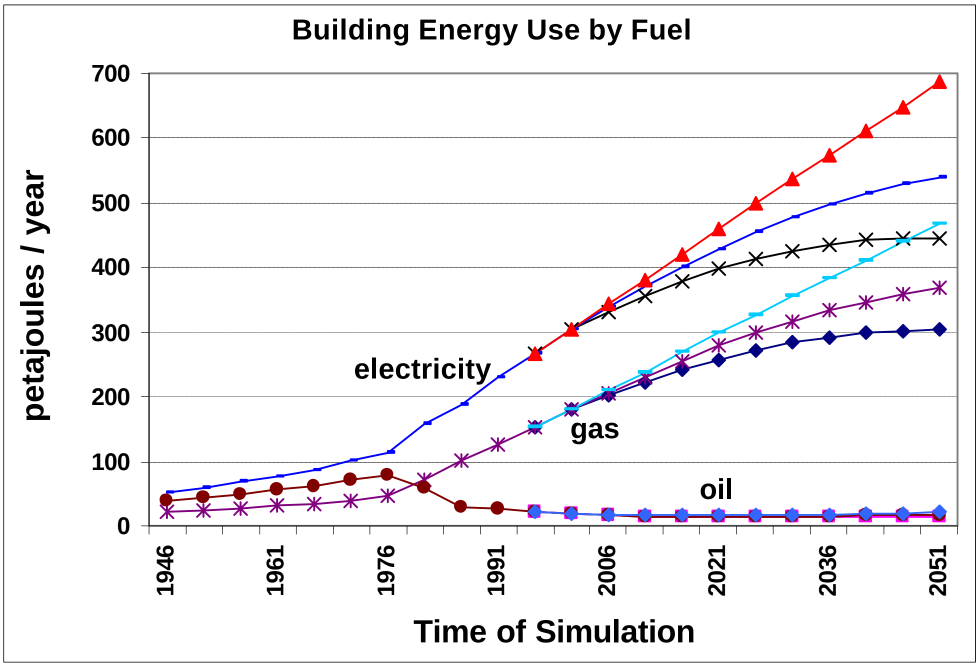

Figure 3.9. Simulated total energy mix of electricity gas and oil in petajoules (10^{15}J) per year to 2050 for total dwelling and non-dwelling space for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population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

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

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

Sub-scenario: halving energy use by 2020

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

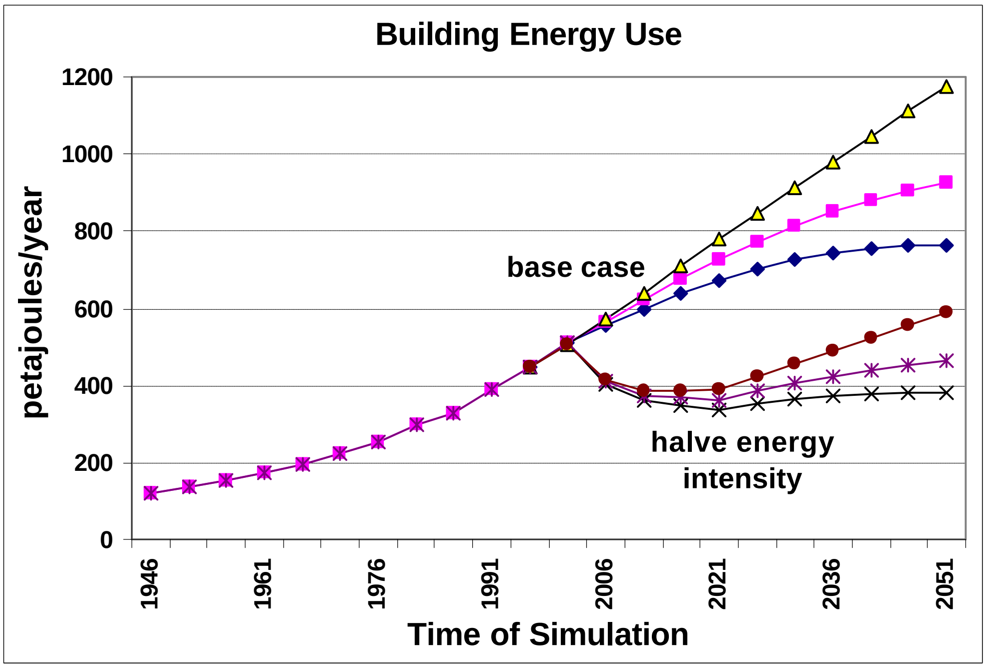

Figure 3.10. Sub-scenario of total energy use to 2050 where energy use in megajoules (10^6J) per square metre per year is reduced by 50% for total dwelling and non-dwelling space for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero)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

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

TRANSPORT REQUIREMENTS

Non-urban transport, urban public transport and urban delivery

Non-urban transport

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

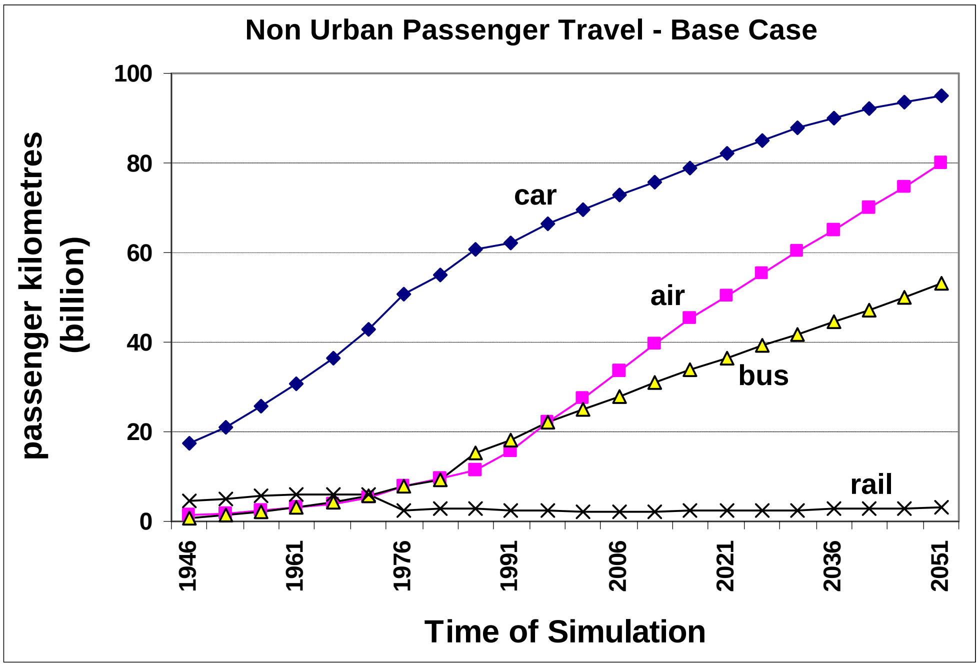

Figure 3.11. Non-urban transport task for car, air, bus and rail transport modes to 2050 for the base case scenario.

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

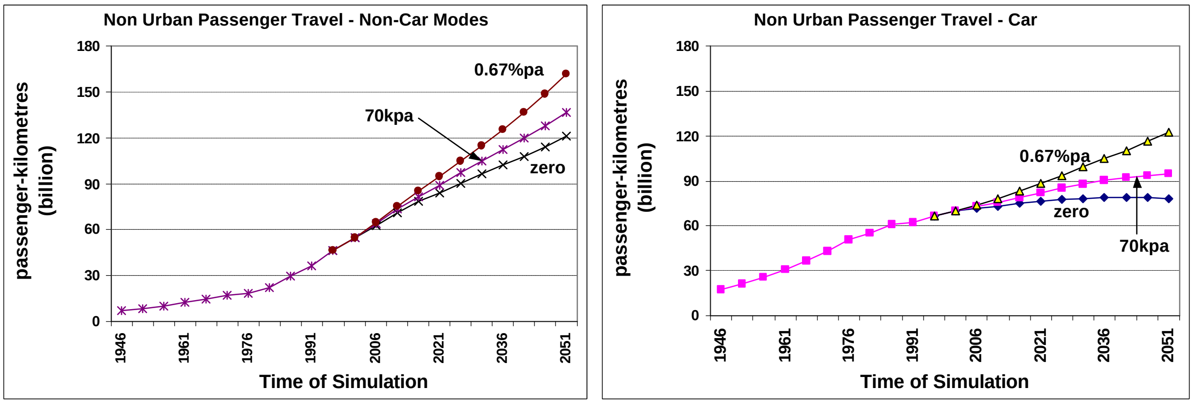

Figure 3.12. Non-urban transport requirements for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa). Non-car modes (left) and cars (right).

Urban public transport

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

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

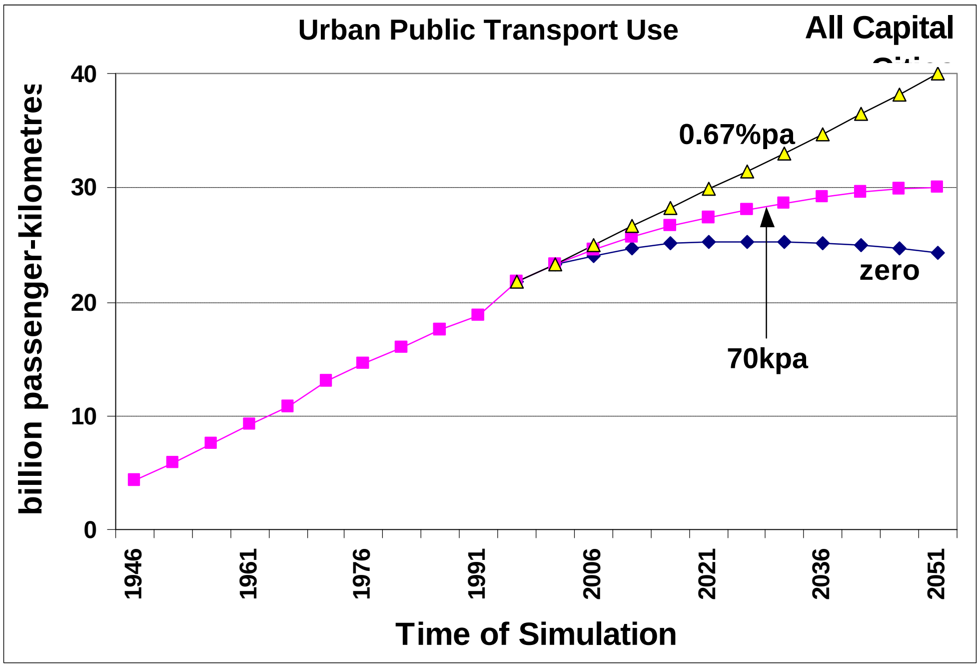

Figure 3.13. Urban transport requirements for all capital cities for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Urban delivery vehicles

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

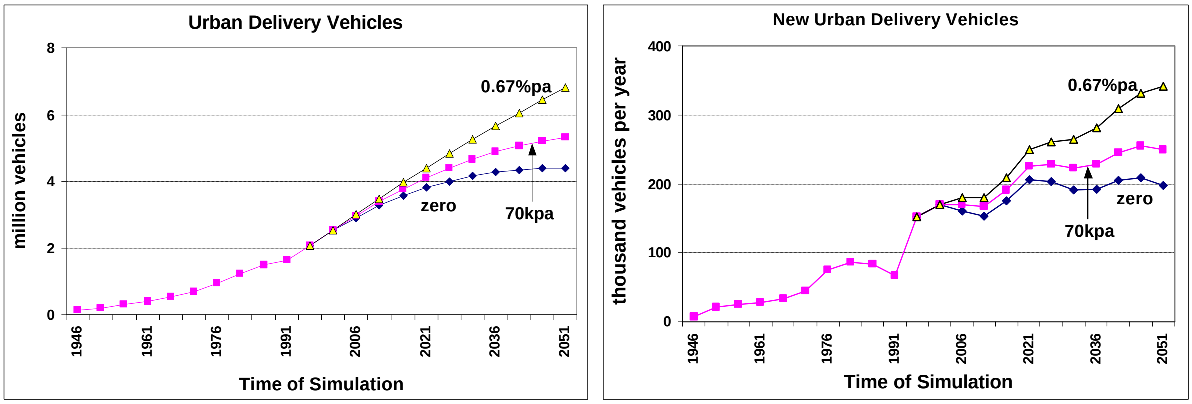

Figure 3.14. Required stock of urban delivery vehicles to 2050 (left) and yearly requirement for new urban delivery vehicles (right) for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration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

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

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

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

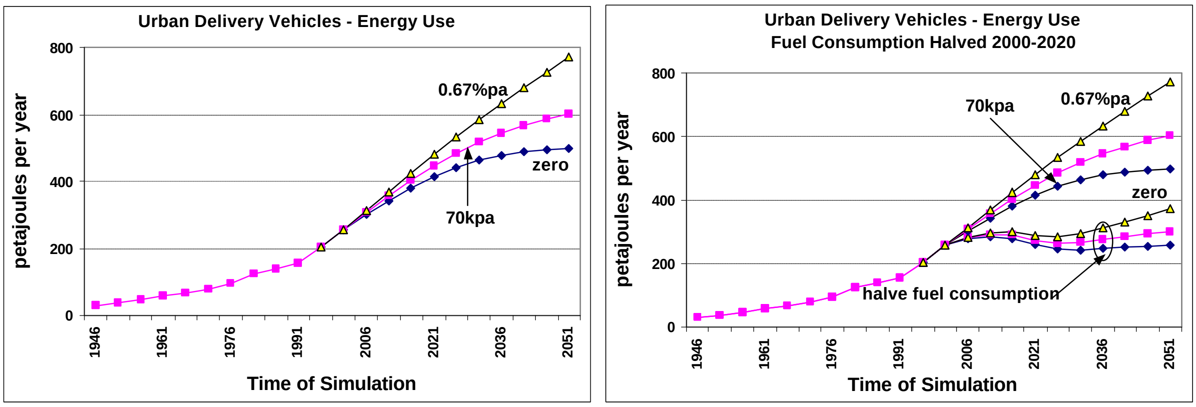

Figure 3.15. (a) Fuel energy required for stock of urban delivery vehicles to 2050 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).(b) Sub-scenario which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

Motor cars

Future vehicle requirements

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

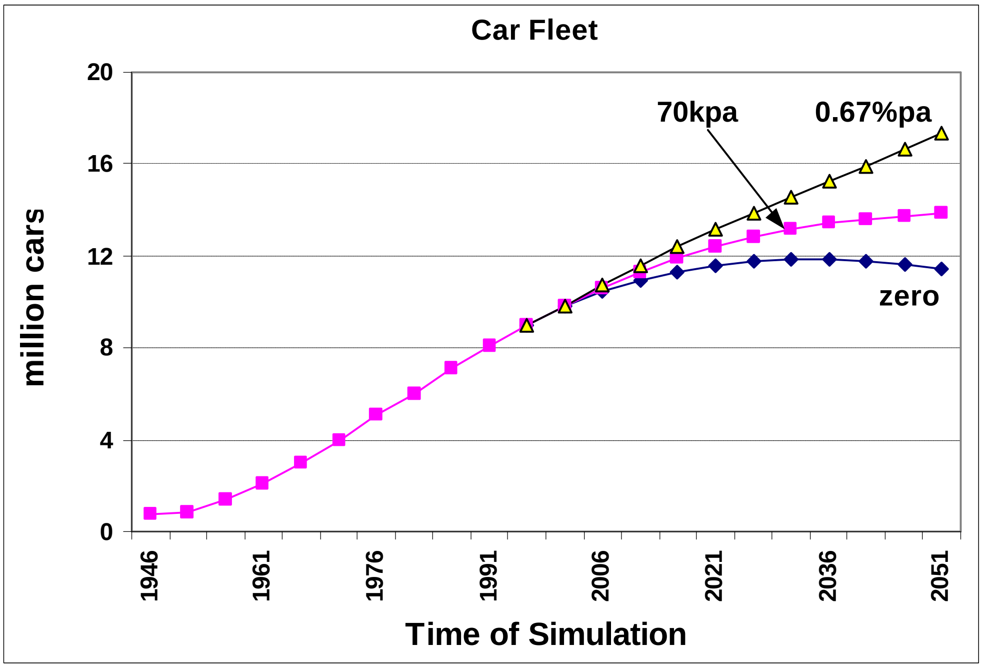

Figure 3.16. Simulated requirement for the future stock of motor cars to 2050 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

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

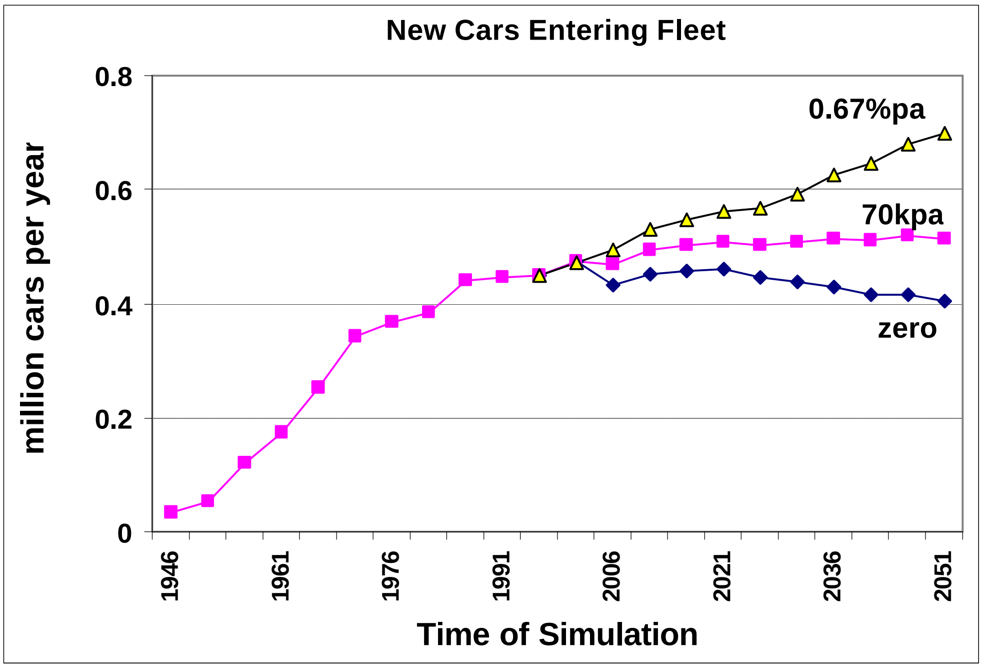

Figure 3.17. Simulated requirement for new motor cars on a yearly basis for three population scenarios to 2050: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

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

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

Travel task and energy requirements of motor cars

The average yearly distance driven by cars in Australia is about 15,000 kilometres compared to 20,000 kilometres in USA and 16,000 kilometres in the UK. Future decades could see an increase in the yearly distance driven per car with increasing consumer affluence and longer commuting distances as the nature of work and workplace dynamics changes. The total transport task in 2050 for motor cars is simulated as 160 billion pkm for the zero scenario, 200 billion for the base case and 250 billion for the 0.67%pa scenario (Figure 3.18). The breakdown by mode of car usage shows that personal use is the largest component with about 60% of total for each scenario. The commuting component (30%) and fleet component (taxis and hire cars, 10%) are important but the overall task is dominated by personal usage. Interactions could occur between the modes. If the commuting mode were substantially replaced by urban transport, or if most workers worked from home, a rebound effect could occur with increased frequency of long weekend trips, for example. Astute design of policies is required to avoid such rebound or perverse effects of innovations in policy and technology.

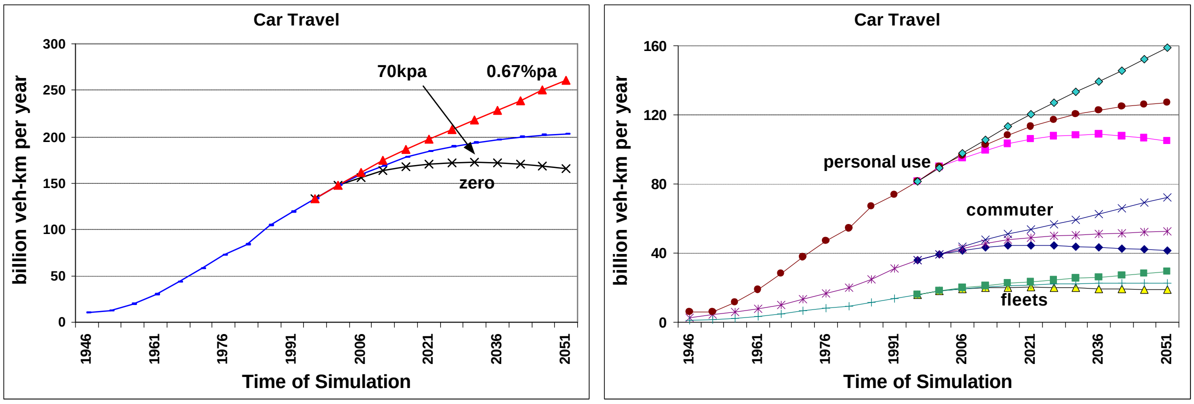

Figure 3.18. Urban transport task required by motor cars displayed by total (left) and by mode (right) for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).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

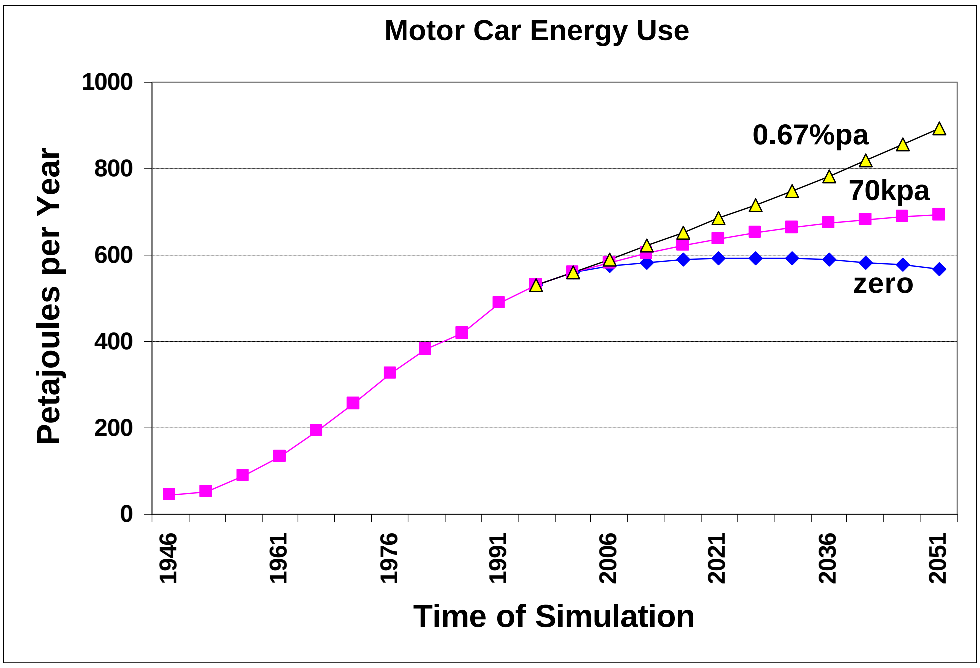

Figure 3.19. Total energy consumption by stock of motor cars for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

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

Sub-scenario: increasing fuel efficiency by 30% and 60%

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

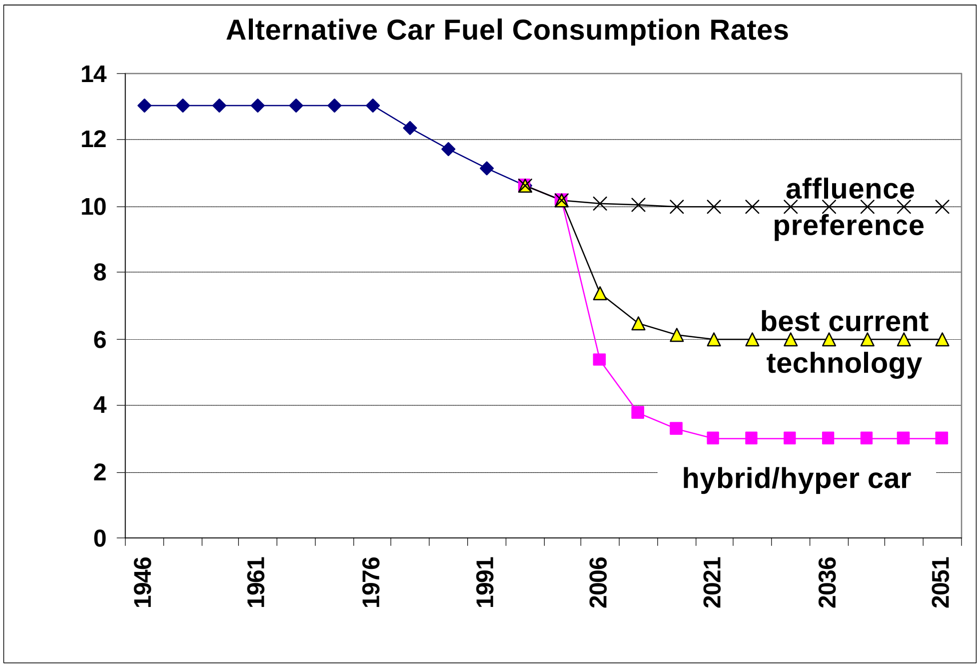

Figure 3.20. Fuel consumption (number of litres required per 100 kilometres travelled) for Australia's motor car fleet used in the car technology sub-scenario. Fuel consumption assumption is applied to flows of all new cars entering the total motor car stock.

.

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

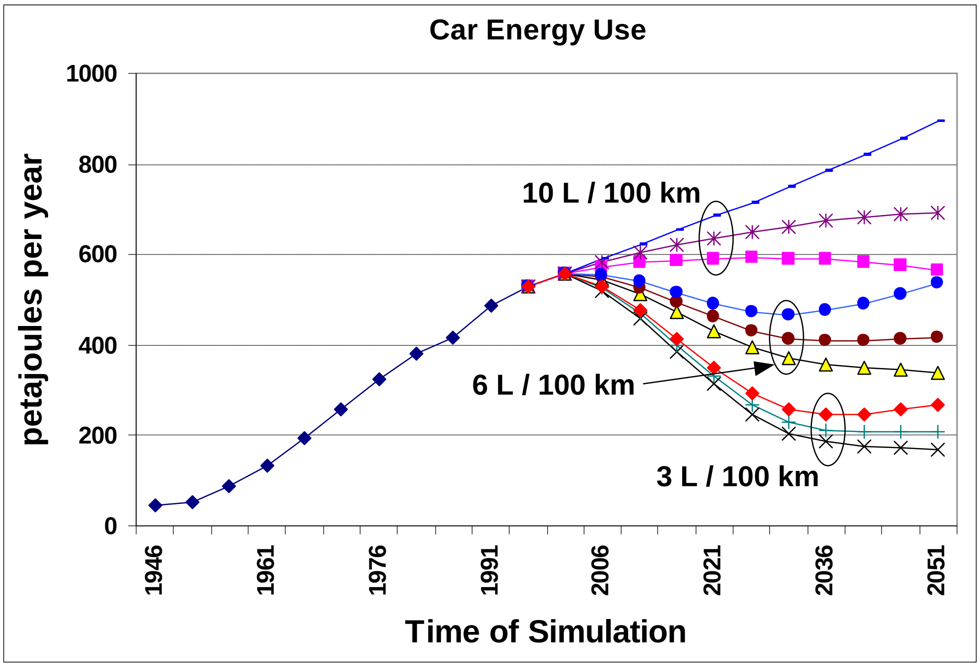

Figure 3.21. Sub-scenario of total energy consumption by stock of motor cars under three engine technologies for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).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

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

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

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

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

ROADS, LAND AND WATER

Requirements for roads

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

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

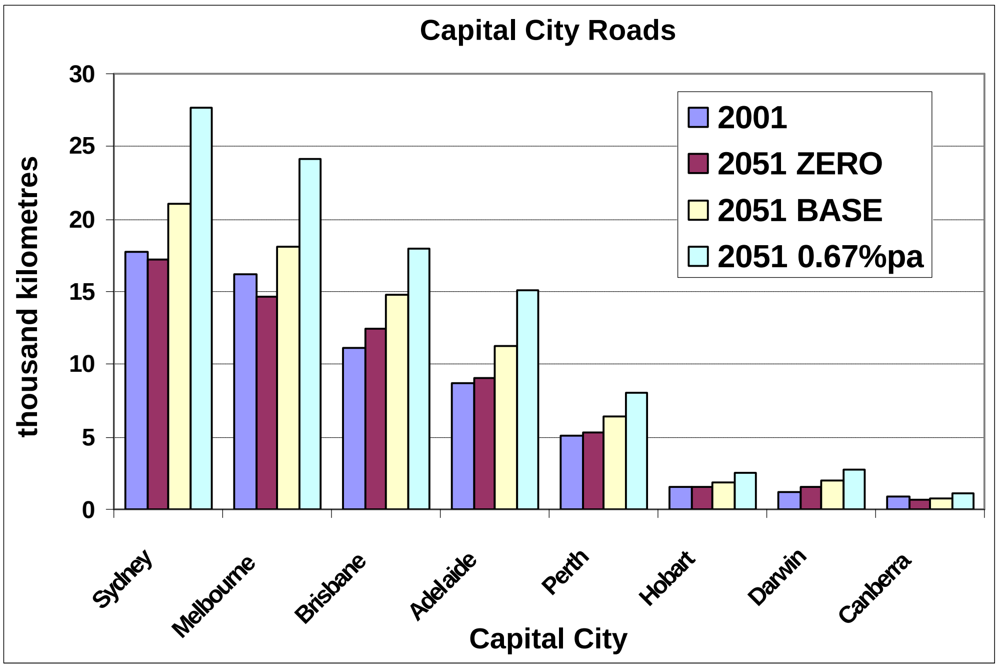

Figure 3.22. A comparison of the requirement for capital city roads now in 2000, and in 2050 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

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

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

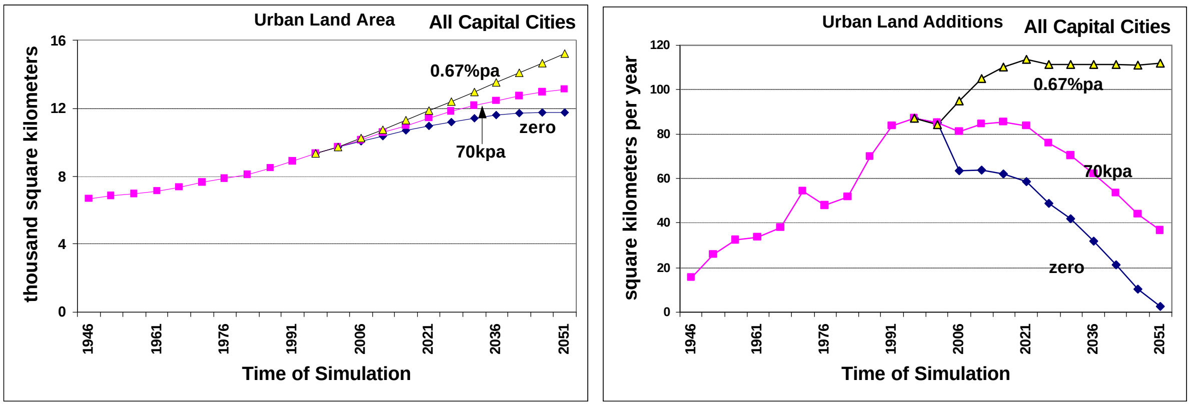

Figure 3.23. A comparison of the stock of urban land (left) and the yearly flow of urban land required (right) to 2050 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per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

Water for Buildings

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

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

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

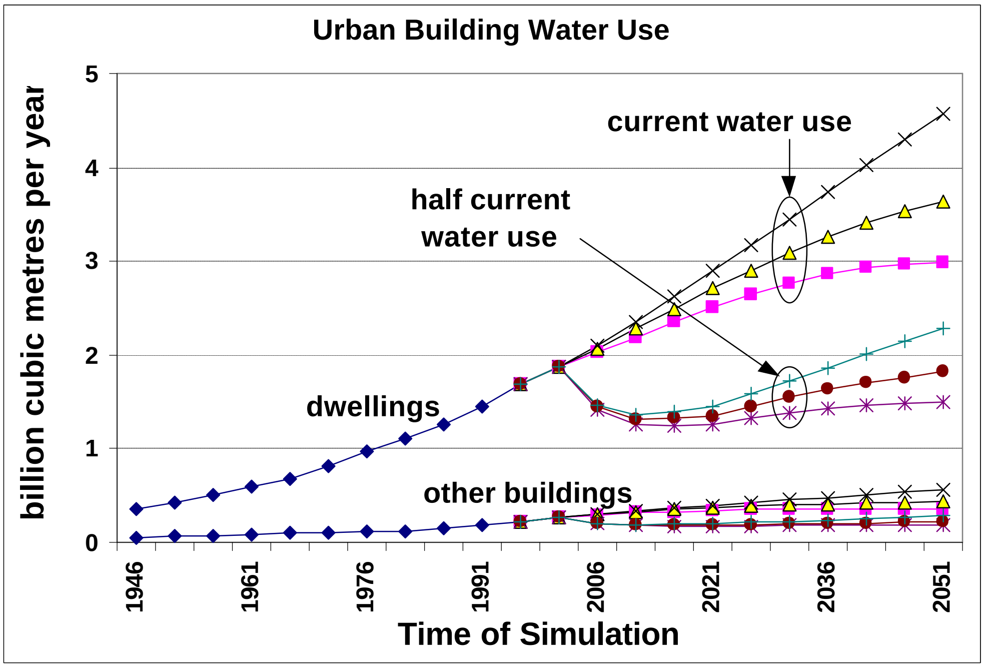

Figure 3.24. The yearly requirement (the flow) for water for buildings to 2050 for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa). Both dwellings and other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

.

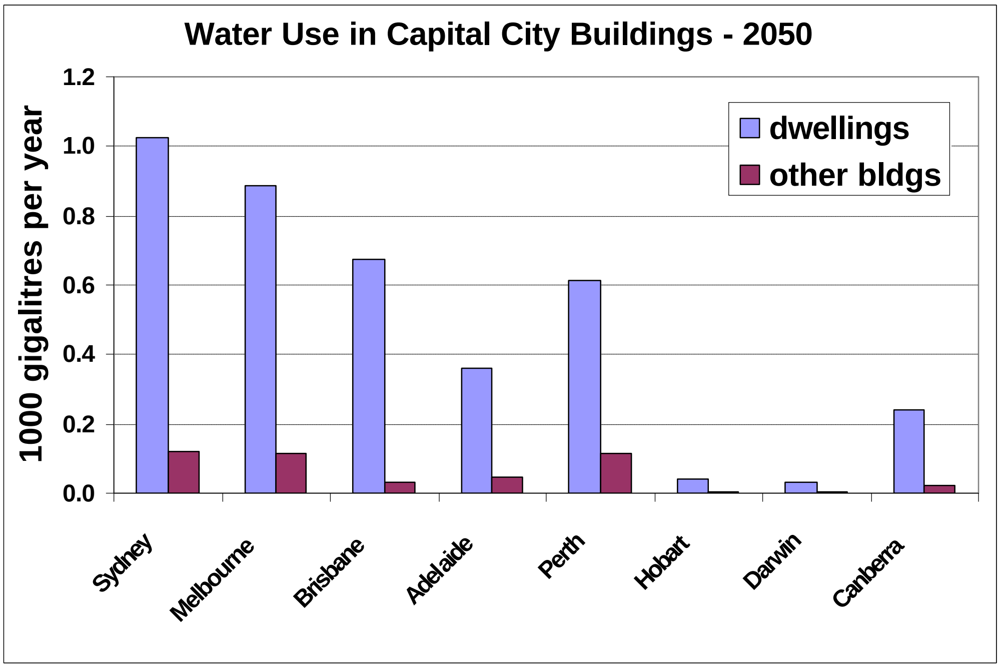

Figure 3.25. The yearly requirement (the flow) for water at 2050 for the base case scenario showing the breakdown between dwelling and other building types for the capital cities.

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

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

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

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

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

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

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

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

EMISSIONS FROM TRANSPORT ENERGY USE

Introduction

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

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

The Sydney airshed

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

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

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

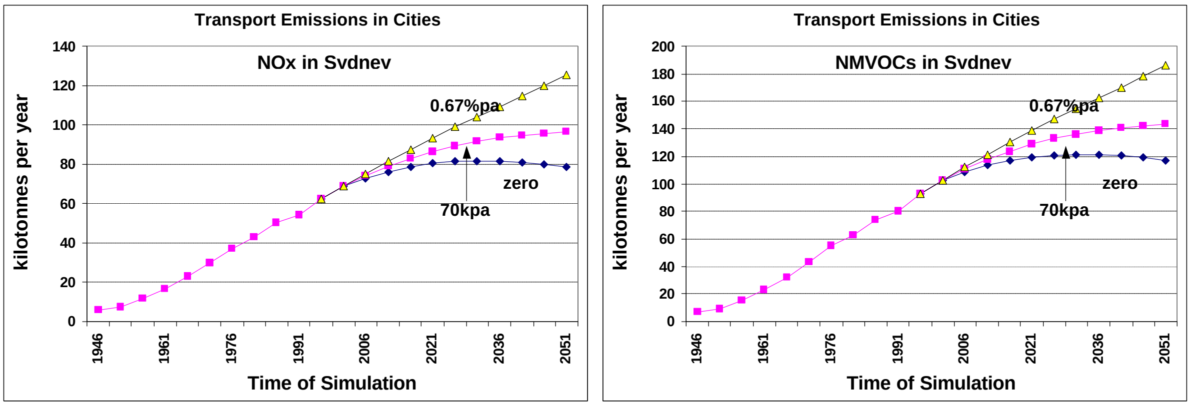

Figure 3.26. The generation of NOx emissions (left) and volatile organic compounds (right) to 2050 for the Sydney airshed for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per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

The Brisbane airshed

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

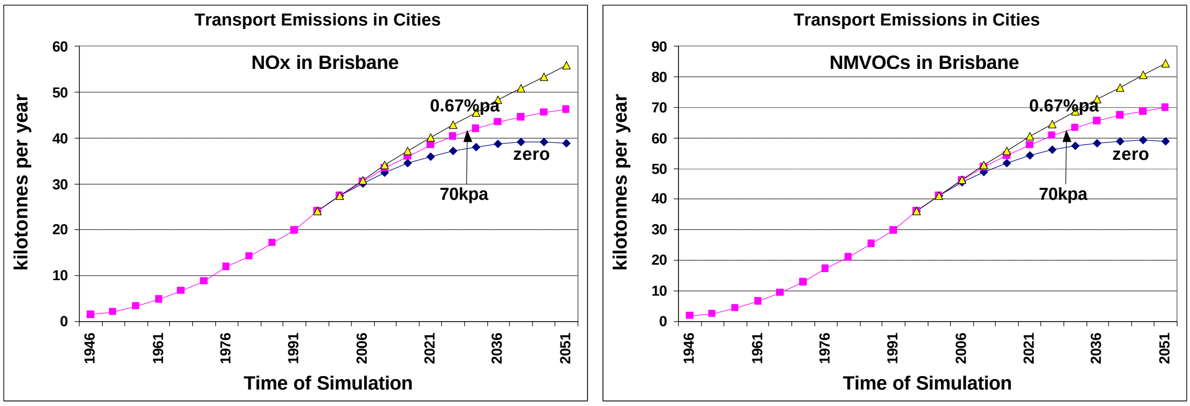

Figure 3.27. The generation of NOx emissions (left) and volatile organic compounds (right) to 2050 for the Brisbane airshed for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration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

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

The Perth airshed

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

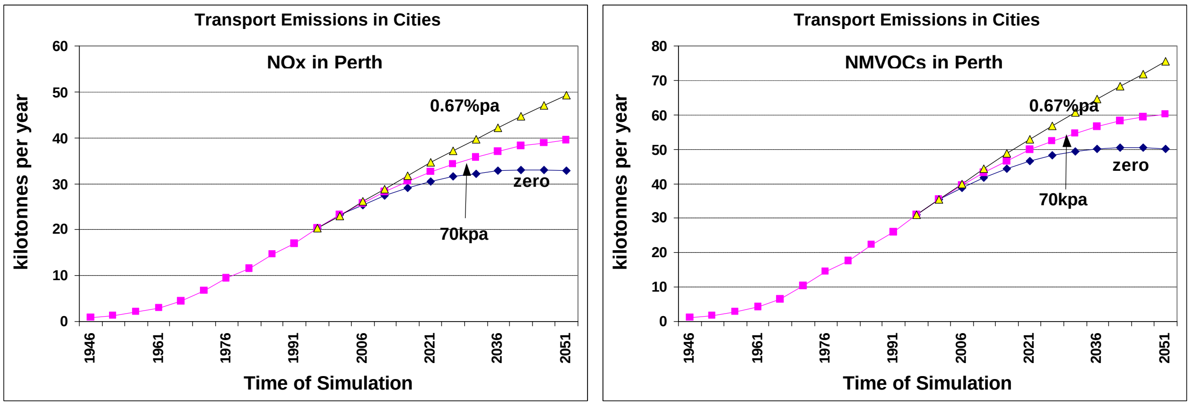

Figure 3.28. The generation of NOx emissions (left) and volatile organic compounds (right) to 2050 for the Perth airshed for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per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

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

Sub-scenario: emissions from new vehicle technology

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

SYNTHESIS OF POPULATION AND TECHNOLOGY EFFECTS

Primary driver effect of population on urban infrastructure

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

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

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

.

.

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

Issue	Zero	Base case	0.67%pa	Comment

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

.

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

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

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

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

Effect of potential technology implementation

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

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

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

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

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

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

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

URBAN INFRASTRUCTURE CONCLUSIONS

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

REFERENCES

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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