ATSE

CLIMATE CHANGE AND THE URBAN ENVIRONMENT

Managing Our Urban Areas in a Changing Climate

WORKSHOP REPORT

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CLIMATE CHANGE AND THE URBAN ENVIRONMENT: Managing Our Urban Areas in a Changing Climate

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The Australian Academy of Technological Sciences and Engineering (ATSE)

Level 1/ 1 Bowen Crescent

Melbourne Victoria 3004 Australia

GPO Box 4055

Melbourne Victoria 3001 Australia

Telephone +613/03 9864 0900

Facsimile +613/03 9864 0930

Website www.atse.org.au

Editor: **Professor Michael Manton FTSE**

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Foreword

Climate change has been widely recognised in Australia as a phenomenon that is impacting on our society. The challenge in responding to climate change arises not only from the actual impacts on society but also from the need for society to dramatically reduce its carbon footprint. We must ensure that urban regions effectively adapt to and mitigate the impacts of climate change. This issue is especially important to Australia, which is one of the most urbanised countries in the world, with about 90 per cent of the population living in urban areas.

While there have been a range of studies on the impacts of climate change in Australia, the amount of work on the impact on the urban environment has been limited. We need not only to identify the impacts of climate change but also to develop strategies to manage those impacts. Australian cities are more dispersed than cities in most other countries, and the consequences of this geographical feature require special consideration. For example, the value of urban consolidation under increasing impacts of climate change is one issue that should be discussed widely. A national research strategy is required to manage the systematic evolution of our cities under a changing climate.

The workshop on 8-10 July 2009, in Melbourne, brought together national and overseas leaders in a range of disciplines that relate to the design, development and management of urban areas. The meeting aimed to maximise the opportunities for participants to contribute to the preparation of this report that identifies key issues as well as strategies to manage those issues. The meeting was organised by the Academy of Technological Sciences and Engineering (ATSE) in cooperation with the National Committee for Earth System Science of the Australian Academy Science, and it was supported by ATSE through the International Science Linkages program of the Commonwealth Department of Innovation, Industry, Science and Research.

Michael Manton FTSE
Director, ATSE
Workshop Convenor

Executive Summary

Australian and overseas experts in architecture, town planning, water management, human health and climate science met in Melbourne on 8-10 July 2009 to prepare this report on climate change and the urban environment. The report considers key issues associated with

- the climate of urban areas
- water management
- building design
- urban planning and transport
- human health and well-being

in the context of a changing climate associated with global warming. The major findings under each issue are outlined below and details on each issue may be found in the report.

NATIONAL PRIORITY

The vast majority of Australians live in cities. These cities are major sources of greenhouse gases and major consumers of resources. If Australia is to maintain and enhance the well-being of its citizens while mitigating greenhouse gas emissions and adapting to the inevitable impacts of climate change, immediate actions are required to ensure that our cities remain resilient and sustainable.

CLIMATE EXTREMES AND VULNERABILITY THRESHOLDS

The climate thresholds that trigger vulnerabilities to climate extremes are not fully understood in urban areas. City-by-city assessments of the vulnerability of systems to climate change are required, along with the identification of critical climate thresholds that threaten key urban systems across Australia.

URBAN LANDSCAPE AND CLIMATE CHANGE MITIGATION

There is a need to rigorously quantify the optimum strategies to avoid climate thresholds being triggered under extreme synoptic conditions through urban landscape management. Research into these issues needs to include quantifying the multiple benefits of urban green-space to both ameliorate local climate and to reduce urban greenhouse gas emissions.

SYSTEMATIC OBSERVATION AND MODELLING

Modelling provides our only tool for exploring how various strategies for urban landscape design might impact on extremes of weather and climate. Urban-scale processes need to be integrated into the Australian Community Climate & Earth System Simulator (ACCESS), with supporting research to link building-resolving modelling with ACCESS. A systematic measurement program including meteorological, flux and remote sensing data, complemented with air quality measurements, over sub-tropical and Mediterranean-type cities should be implemented. The Terrestrial Ecosystem Resource Network (TERN) could be expanded to include such a program. The relevant data sources over Australian cities need to be integrated in a common system, quality controlled and made accessible to stakeholders.

CARBON-WATER-ENERGY INTERACTIONS

The goal of understanding carbon-water-energy interactions is to provide a framework to better quantify the role of urban water use in managing the micro-climate, energy consumption, carbon emissions and urban land use. A national multi-discipline research program should be established to investigate the interactions of carbon, water and energy in urban systems.

WATER AND UNCERTAINTY

Water is a key human, environmental and economic need in Australia. Climate change brings a higher level of uncertainty to the management of water for Australian cities which are already under stress. The effective management of water in the light of these uncertainties needs to be flexible and utilise a diverse portfolio of structural and non-structural responses that promote adaptive resilience. The responses will be shaped by path dependencies of the existing infrastructure, the need to assure security of the overall system, and the need to provide a healthy environment. Adjustment to the way in which urban water is managed in the face of climate change highlights the issue of externalities, which lead to further constraints on the responses. Adaptation to climate change also requires a shift to active learning on the part of all concerned.

WATER-RELATED HAZARDS

As well as needing to find the right balance between human and environmental needs in the way in which we manage the urban water cycle, there will be a growing need to address the hazards caused by the greater extremes accompanying climate change. There is a need to develop approaches in partnership with planners and others that lead to urban areas that are adaptive and resilient to future uncertain hazards. Growing populations, increasing urbanisation and lifestyles will potentially further exacerbate the vulnerability of communities and individuals to flood risks. Responses to this will require different ways of living as well as a broad portfolio of structural and non-structural measures that parallel and ideally are synergistic with the measures needed to maintain supply and sanitation security without compromising environmental integrity.

WATER SECURITY AND RESOURCE MANAGEMENT

The uncertainties of climate change mean that water resource management strategies need to recognise the connectedness of the overall urban water system, to promote innovation, to harness emerging technologies, and to utilise comprehensive data and information systems. Recognising that cities can utilise water of different quality and reliability, diverse non-traditional sources of water should be developed. The challenge of climate change emphasises the need to implement new strategies to utilise waste from urban water.

WATER USE

Recent reductions in urban water use across Australia highlight the benefits of innovative demand management, and such strategies must be continued and enhanced, especially because of the increasing population and changing life-style expectations of Australians.

PROTECTING AQUATIC ECOSYSTEMS

Urban impacts on the natural aquatic environment are currently more profound than that associated with climate change. Nevertheless these two emerging challenges are not mutually exclusive. Protecting the environment from which water is diverted for urban consumption, and to which treated waste-water and storm-water is discharged, is a key objective of sustainable water resource management. Urban pollution, coupled with increased global temperatures and other climate changes, will inevitably increase the risk of environmental degradation. Urban landscapes now need to accommodate ecological functions beyond providing spatial amenities for an environment of increasing urban density. These urban landscapes capture the essences of sustainable water management, micro-climate influences, facilitation of carbon sinks and use for food production.

ZERO-CARBON BUILDINGS

A trajectory to a low-carbon Australia needs to be established. This should involve long term overall targets, together with medium and short term targets subdivided into sectoral responsibilities. Evolving policy and regulatory frameworks for building design need to reflect the trajectory.

CLIMATE-ADAPTIVE BUILDINGS

A clear vision of what constitutes a climate adaptable and resilient building needs to be established, including appropriate overall regional variations. These adaptive measures need to be embedded within assessment tools, like Green Star, and progressively introduced as experience grows into the building regulatory framework. Fundamental changes are needed to the financial support systems to ensure that there is a clear free market driver towards climate responsive buildings. Currently the *status quo* is maintained because the investment returns are measured in time-scales that are far longer than market economic return expectations. Furthermore, legislation discourages the integrated management of resources at the precinct level. Municipal, state and national regulations could be changed to allow capital-efficient distributed renewable-energy networks and non-traditional water supply systems to be prototyped. Nationally recognised contracts should be introduced for energy and water supply services so that all stakeholders are properly acknowledged and unnecessary transactional cost are avoided. Methods for assessing climate change resilience should be established by municipal regulations.

BUILT-ENVIRONMENT EDUCATION, TRAINING AND RESEARCH

The building industry is currently not trained to deliver climate-adaptable and zero-carbon buildings as either renovations or new buildings. In addition professional education does not sufficiently prioritise or effectively deliver curricula that educate graduates to shape a zero-carbon and climate adaptable urban environment. Reform and expansion of built-environment education and training with climate change mitigation and adaptation as its main intent should occur within the next 10 years. Research needs to identify best practice and its application in a holistic way, developing performance-based principles for compact urban form, energy-efficient buildings, and more flexible, adaptable building typologies. Better methodologies for measuring sustainability, resource management and material flows need to be developed.

URBAN FORM AND TRANSPORT

Australian cities are currently designed with predominantly low-density urban housing, and it is not clear that this urban form will support the low-emission targets expected under any carbon reduction scheme. Land use, planning, and design controls, together with building codes, require more consistency at all three levels of government to ensure housing location and type deliver an overall form that is compatible with future emission targets. A more compact urban form with higher densities around transport networks is therefore expected to be necessary. This transition will require an integrated framework cascading from commonwealth to local government levels, with rigorous implementation.

URBAN PLANNING POLICY

Climate change should be a material consideration in all future planning decisions in all public agencies dealing with urban planning and infrastructure development. Any future urban development (such as an infrastructure project) needs to demonstrate not only that it is appropriate under its own terms but also that it does not conflict with climate change objectives. The establishment of the required integration will involve the development of metropolitan strategic partnerships within cities that bring together the key stakeholders from the public, the private and community sectors.

RETROFITTING CITIES

A nationally-agreed integrated-assessment tool should be developed and introduced to assess the climate change impact of buildings, in order to decide the relative appropriateness of renovation as opposed to demolition of older housing. Policy and financial mechanisms will be needed to ensure equity, efficiency and effectiveness in the implementation of decisions taken on the basis of such assessments.

HEALTH

Climate change will affect key determinants of human health: air, water, food and shelter. Climate change will also influence the frequency of heat-waves, floods and storms as well as the transmission of infectious diseases. In addition, policies to mitigate climate change (for example in the energy, transport or urban planning sectors) have potential co-benefits for health, for example through their effects on local air pollution, physical activity, or road traffic injuries. Impacts on human health should be a primary considerations in urban planning and policy responses to climate change.

HEAT STRESS

In the absence of proactive mitigation or adaptation actions, heat-related mortality and morbidity may triple over the next 40 years, with the potential for catastrophic disasters in unprecedented heat waves. Actions that can be taken immediately to reduce the threat include improving warning systems, ensuring that essential services operate robustly during heat extremes, and improving public and private amenities to provide cool refuges. Longer-term changes include reducing urban heat retention through changes to urban form and increased urban greening, and retrofitting and design improvements for individual dwellings.

AIR QUALITY

The cost of urban air pollution in Australia is greater than $3 billion each year, and this is expected to increase under changing demographics and changing climate. There is considerable uncertainty about many natural and anthropogenic influences which need to be resolved before engaging in policy development. There can be both benefits and harms from greenhouse gas mitigation actions that affect urban air quality and human health. Integrated assessments are essential to evaluate the benefit of these actions.

MENTAL HEALTH

Mental health problems comprise at least 14 per cent of the global burden of disease, and climate change poses substantial additional mental health risks. An understanding of how climate change affects mental health, including special groups such as children and vulnerable adults, and an understanding of how to foster resilience in individuals and communities is essential to Australia's healthy response to climate change.

CONCLUSION

Climate change is a substantial addition to the numerous stresses ready affecting the development of Australian cities and the well-being of citizens living in them. Nationally consistent and multi-disciplinary mechanisms are needed to ensure that our cities remain resilient under climate change.

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1 Introduction

Australia is one of the most urbanised countries in the world with more than 90 per cent of the population living in cities. The activities of modern cities ensure that they affect even larger areas to provide their needs for food, water and energy. As major consumers of resources, cities in turn are major emitters of greenhouse gases. They are also sensitive to climate variations as well as climate change; for example, human health and well-being are affected not only by the physical layout of a city but also by the variations in weather and air quality across the city. As the population of Australia continues to grow, our cities are already stressed by a number of issues, such as air quality and transportation across urban areas. It is well recognised that climate change is expected to compound many of these existing stresses as well as introducing new ones.

Climate change is accepted by all Australian governments as an issue of national significance. In February 2006 the Council of Australian Governments (COAG) agreed to adopt a national Climate Change Plan of Action, and activities of the COAG Climate Change Group have included actions that relate directly to cities, such as measures for adaptation to climate change and improving the energy efficiency of households and businesses.

In considering the interactions between cities and climate change, we should assess the relationships against the four connected frameworks for societal, policy, scientific and technological issues. The societal framework needs to recognise that Australia's population (as in most developed countries) is ageing, and issues of health and well-being are very important. The time-scales and inherent uncertainties associated with climate change mean that communication of the key issues and implications across our communities is a challenge, especially as the stakeholders are spread across society and as many of our current institutional arrangements may not be optimal for managing the responses needed for climate change adaptation and mitigation. Education will be a major component of the overall communication strategy, as our cities face significant paradigm shifts in the future. As such shifts occur, there will be a need to ensure that social equity is maintained across the community through assessment of and adjustments to social vulnerabilities. In particular, it is clear that simple economic assessments and solutions are likely to be inadequate in scope.

In developing the policy framework for our cities adapting to and mitigating climate change, it will be vital to establish overarching policies in recognition of the links between all the systems that make up our cities. This approach, as accepted by COAG, should ensure that the appropriate integration can occur across our city systems. The scope of climate change issues and the complexity of city systems mean that our governance frameworks and leadership must be well informed, and especially able to manage unintended consequences that may occur as we adapt to and mitigate climate change. A part of this process will involve learning from overseas experiences and so international linkages will need to be maintained and strengthened.

In an increasingly complex environment, scientific knowledge will need to inform the policy and societal decision-making processes. This knowledge will depend upon an adequate monitoring program that ensures that we are fully aware of changes in all aspects of our cities (physical, chemical, ecological, social and economic). The program will need to include components for appropriate archive and access regimes so that the observed data can be fully utilised to provide the required information for decision makers. The city environment involves delicate balances between human health and the utilisation of carbon, water and energy. In particular, the carbon cost of actions (including inter-generational impacts) will need to be accounted in the future planning and management of our cities. Recognising the significant uncertainties associated with future projections of climate and societal conditions, decision makers expect the scientific community to provide long-term trajectories as guides for planning purposes.

While science provides the basic knowledge for understanding and predicting future scenarios, the means for implementation of the required systems inevitably depends upon technological innovation and change. The technological framework needed to ensure that our cities adapt to and mitigate climate change will have to incorporate a risk management approach so that there is a balance between robustness and optimisation of systems. This process will be informed by carefully quantified assessment of the options for action; in particular, it will be important to ensure the resilience of our cities so that there is allowance for 'economic headroom' in decision making. It is apparent that, due to past practices and policies, the retrofitting of our cities will be a major undertaking, especially when we consider the relatively short time frame in which long-lived infrastructure should be modified.

Recognising the complexity of the issues associated with climate change and Australian cities, the Academy of Technological Sciences and Engineering (ATSE), in association with the National Committee for Earth System Science of the Australian Academy of Science, convened a workshop in Melbourne on 8-10 July 2009. The workshop brought together climate scientists, engineers, architects, urban planners, and health experts in order to consider these issues across five key aspects of Australian cities:

- climate of urban areas and the impact of urban areas on climate;
- air quality and health in a changing climate;
- building design in a changing climate;
- urban planning and transport systems under climate change; and
- water and drainage systems under climate change.

The first topic recognises that there are basic differences between the climate of natural and urban areas, and it is not clear how these differences are best represented in global and regional climate models nor how they are best monitored. A key issue around the world is the potential impact of climate change on human health through both direct (for example, heat stress) and indirect (for example, air pollution) effects, and Australian scientists have already undertaken informative studies on this general topic. However, it is apparent that as temperatures increase in Australian cities it is likely to become increasingly difficult to meet air quality standards. Building design is important not only for energy efficiency but also for ensuring human health is adequately protected in a changing climate.

Key issues for urban planners are the potential impacts of climate change on urban infrastructure. In 2008, ATSE published an assessment of the potential impacts of climate change on Australia's physical infrastructure[1], with the purpose of stimulating discussion and inducing action by relevant authorities. This workshop aimed to extend the 2008 assessment to consider in detail the impacts of climate change on urban transport and water management systems. The widespread nature of Australian cities means that these issues require special consideration. The prolonged drought in south eastern Australia over the last decade has highlighted the dependence of societies on readily available water.

While the scope of the workshop was quite broad, the aim was to take an integrated view of the five key topics. The workshop provided a forum for the exchange of information and views across disciplines, and the participants considered synergies across the key topics.

The participants in the workshop are listed in Appendix 1, while the workshop program is given in Appendix 2. The participants included five experts from Hong Kong, New Zealand and the UK. The activity was supported by funding to ATSE under the International Science Linkages program of the Department of Innovation, Industry, Science and Research (DIISR).

1 Stevens, L. (2008) *Assessment of impacts of climate change on Australia's physical infrastructure.* ISBN 1 87561896 1, ATSE, July 2008, pp71.

2 Cities and Climate Change

2.1 BACKGROUND

Understanding the role of the urban environment in the context of global warming on regional scales is vital given the highly urbanised Australian population. Decades of research in Australian has focused on natural landscapes, and how these affect the exchanges of energy, water and carbon which underpin the way that cities influence climate, hydrology and air quality. While the way that natural landscapes affect weather and climate is by no means fully resolved, many well-organised research programs exist both in Australia and overseas. Such programs do not exist for urban landscapes in Australia.

As a consequence of its size and location, Australia is subject to large spatial and temporal variations in climates. Its cities are located within tropical, sub-tropical, Mediterranean, semi-arid and temperate climates, making northern hemisphere observations and understandings poorly applicable here. Although the US and China have similar climate diversity, their urban form and design fundamentally differ from that of Australia because of differences in culture, history and resource availability.

There are no systematic research programs that measure the role of Australian urban landscapes on weather and climate. There are no systematic process-based modelling studies building on observational programs and there are no programs to integrate these process-based programs into national weather and climate modelling goals. We simply do not know how Australian urban landscapes affect extremes of temperature, nor for example the probability of sequential days in excess of thresholds that increase human mortality. Critically, as large-scale warming occurs under enhanced greenhouse gas concentrations, the way that this large-scale forcing interacts with urban landscapes and the way these landscapes drive climate at regional scales is not known and no research program yet exists to develop this understanding. This leaves the Australian urban population more vulnerable to climate change than is necessary. We do not have the capability to evaluate mitigation options on global warming for offsetting urban warming. Urban systems warm the regional climate by several degrees – if this could be reduced it would provide 'headroom' for some of the regional warming that is now unavoidable given existing greenhouse gas concentrations.

2.2 ISSUES

Three critical issues of concern are identified and discussed:

- urban vulnerability and climate thresholds;
- can we use urban landscapes to mitigate climate change at the scale of cities? and
- observation-modelling fusion: global-regional-local scales.

Issue 1 – Urban vulnerability and climate thresholds

Urban systems bring together humans in a complex system of water, transport and energy infrastructure. Vulnerabilities to climate extremes in urban areas are well known in terms of health, transport and energy infrastructure failure under extreme climate events. However we do not know the climate thresholds that trigger vulnerabilities in many of these systems. In terms of human health we know that for Melbourne a 30°C average daily temperature threshold leads to elevated mortality of 15 to 20 per cent for people over 65 years of age[2]. So, utilisation of urban design that might reduce temperatures on extreme days by as little as 1°C to 2°C could reduce mortality by 10 to 20 per cent. Additionally, in relation to energy[3], it is found that an increase in energy consumption of 2 to 4 per cent for every 1°C rise above a baseline of

2 Nicholls, N., Skinner, C., Loughnan, M. & Tapper, N. (2008) A simple heat alert system for Melbourne, Australia. *Int. J. Biometeorol.*, 52, 375-384

3 Akbari, H., Pomerantz, M. & Taha, H. (2001) Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. *Solar Energy*, 70, 295-3110.

around 18°C in the United States; so even quite modest reductions in the urban heat island could provide a 5 to 10 per cent reduction in peak energy use. This has the considerable 'free' benefit of reducing the probability of a failure of the energy grid by reducing peak demand.

In summary, a city-by-city assessment of vulnerability of urban systems to climate change is required for Australia, along with identification of critical climate thresholds that threaten key urban systems.

Issue 2 – Can we use urban landscapes to mitigate climate change at the scale of cities?

The urban heat island is the observable manifestation of changes in the surface energy and water budgets across the urban landscape, which integrates from micro-scale changes to the whole city. Urban energy and water budgets have anthropogenic (for example, input of energy from heating), natural (for example, solar radiation) and biogenic components.

Mitigating climate change in this context has three elements:

i) ameliorating the local-scale climate factors that control human comfort, health and well-being;
ii) cities are a large sources of greenhouse gas emissions and so urban landscape design can play a role in mitigating emissions and thence influence the global climate, and
iii) cities, as an agent of dramatic land cover change, strongly influence regional-scale weather and climate.

The following should be noted:

- There are proposed practices for reducing the urban heat island; but which of those strategies have the most beneficial impact on those aspects of climate to which Australia's populations are vulnerable is unknown.
- Many heat island mitigation practices are water dependent: a challenge for most Australian cities, especially under global climate change when water availability is predicted to be reduced in southern Australia.
- Strategies to manage night-time warmth are less well known than strategies to minimise day-time maximum temperatures.
- Night-time minimum temperatures in particular have a direct impact on human mortality.
- Strategies to maintain warmer temperatures in winter to reduce energy use, but to dissipate summer heat to reduce cooling needs, are desirable but difficult to achieve.
- Thresholds dominate human health, as well as social and infrastructure vulnerabilities. Even if urban landscapes and urban design did not change the mean climate, if they reduce the probability of exceeding critical thresholds the benefits would be substantial.

In summary, there is a need to rigorously quantify the optimum strategies and capacity to avoid climate thresholds being triggered under extreme synoptic weather conditions via urban landscape management. As part of this, a detailed assessment of system vulnerabilities from relevant government agencies will be needed along with research by climate scientists to quantify the probability of these. Research into these issues needs to include quantifying the multiple benefits of urban green-space to both ameliorate local climate and reduce urban greenhouse gas emissions.

Issue 3 – Observation-modelling fusion: global-regional-local scales

There are two dimensions to the modelling challenge: first how urban landscapes interact with the atmospheric boundary layer and thereby to regional scales, and second how 'canyon-scale' – building interactions link through to human comfort.

Modelling provides our only tool for exploring how various strategies for urban landscape design might impact on extremes of weather and climate. Modelling enables strategies to be explored in various configurations, with a range of assumptions and approaches, to guide decision making. There are very few observations of urban-atmosphere interactions. Almost all our understanding is sourced from the northern hemisphere which is largely driven by a strong seasonal cycle. In Australia, where significant variability occurs on both seasonal and inter-annual time scales, urban-atmosphere interactions are very likely poorly explained by northern hemisphere observations. It is critical to inform models by observations, and to inform observation strategies via modelling. This coupling is poorly developed in Australia and is an essential prerequisite to the development of predictive skill.

These dual research and development needs can therefore be simplified to:

a) a concerted effort to represent urban landscapes and processes in the Australian Community Climate and Earth System Simulator (ACCESS, www.accessimulator.org.au) along with a strategy for achieving consistency across the various modelling systems currently used by government agencies and universities; and
b) an expansion of urban observational programs bringing together flux measurements, meteorological measurements and remote sensing both to provide process understanding and to improve model simulations.

Key observational programs must be expanded to include urban landscapes. For example, the Terrestrial Ecosystem Research Network (TERN)[4], which is aimed at building research infrastructure, does not include the urban 'ecosystem' within which 90 per cent of Australians live. Without a strategic plan for urban observations, we cannot rigorously evaluate urban ecosystem services. A synthesis of flux measurements, meteorological measurements and remote sensing must be brought together systematically and used to inform modelling. This has been achieved over natural landscapes to some degree but has only been attempted in Australia over urban landscapes once as part of a single PhD project. This is a major undertaking and requires the development of a multi-year program to develop a deep understanding of urban landscape-atmospheric interactions. There is a critical need to build these measurements across contrasting cities; perhaps starting with Brisbane and Melbourne as examples of sub-tropical and Mediterranean-temperate climate cities in Australia.

Models need to be designed for the specific purpose in mind. A model of urban landscapes designed to understand how pollutants released from a smoke stack interact with a suburb would be entirely different from an urban landscape modelled for integration with global climate modelling.

Global climate requires a representation of urban landscapes, but not for the simulation of the global climate, or the sensitivity of the climate to enhanced greenhouse gas concentrations. When global climate models are to be used for regional projections, some regions are now sufficiently spatially resolved and have been urbanised to an extent that cities do need to be represented.

Several climate models resolve the basic characteristics of urban landscapes. The Australian climate modelling developments, led through ACCESS, have not yet developed a focus on urban landscapes. However, the basic under-pinning infrastructure does now exist via collaborative efforts to develop a 'tiled' approach to the land surface. Adding an urban tile to this system is relatively trivial, but configuring this for Australian cities requires tailored observations and the integration of satellite data into the modelling. This is achievable within the Australian context quite simply, but requires leadership within the community.

Regional-scale modelling (this may be for example the whole continent at about 50 kilometres resolution, or a major city at 1 kilometre resolution and includes numerical weather prediction) requires a more

4 TERN was recently funded under the National Collaborative Research Infrastructure Strategy (NCRIS); see http://ncris.innovation.gov.au.

sophisticated approach. The detailed nature of an urban landscape (types of urban landscape, density, parkland, CBD location, etc) may affect the skill of regional models. Further, patterns of weather and climate affect interactions in the atmosphere with pollutants. These are complex, but expertise in modelling these interactions has been developed in Australia.

At these regional scales, the nature of how urban landscapes interact with the atmosphere is central. Boundary layer structure and evolution, detailed interactions between orography, synoptic-scale processes, urban landscapes etc, can strongly impact temperature and potentially rainfall. We do not understand these interactions, and we do not have the developed understanding to model how cities of different characteristics affect local climate. This requires a systematic research program that would need to be undertaken in each major city. Urban landscape models do exist and are available for regional modelling, but how well these would apply to Australian cities is very uncertain as all have been developed for northern hemisphere (mainly temperate) climates.

At the suburb or street level, different modelling techniques are required on a case-by-case basis. What is most central to this are skilled researchers; in this regard there is a critical lack of training of people with the required expertise in Australia.

Urban canyon to micro scale urban modelling is necessary to resolve building-scale climate interactions. The further development and evaluation of models of the built environment need to be coupled with the regional-scale modelling achievable using seamless systems like ACCESS. This requires a suite of scientific advances and an information technology infrastructure including data serving and high performance computing. It also requires the intellectual resources that are not currently being developed via university programs.

Finally, it is through the interaction of the carbon, water and energy cycles that cities contribute to global and regional climate change, and so an understanding of these is essential to managing urban landscapes under global warming, for example designing urban landscapes to regulate energy needs and greenhouse gas emissions and using urban vegetation to cool the city and sequester carbon dioxide. A useful focus for an observation – modelling fusion research program could be to rigorously quantify the urban carbon-water-energy budget and thence provide a framework to assess the role of urban water use in managing micro-climate, energy consumption, carbon dioxide emissions and urban land use.

In summary, the following actions are required:

- implementation of world's best practice to integrate urban modelling from global to local spatial scales into the national ACCESS program supported by research to understand how to use the building-resolving models in the parameterisation of models at larger scales;
- implementation of a measurement program including air quality, flux and remote sensing data at least over sub-tropical and Mediterranean-type cities in Australia. The TERN program could be expanded to include research infrastructure, but a focused research effort is also needed;
- over most Australian cities there are multiple sources of relevant data. In order to make best use of these data it is necessary to integrate them in a common system, quality controlled and made accessible to users. A national environmental monitoring system is required to achieve this goal; and
- the urban carbon-water-energy budget needs to be quantified to provide a framework to assess the role of urban water use in managing micro-climate, energy consumption, carbon dioxide emissions and urban land use.

2.3 CONCLUSIONS

Given the current lack of knowledge of the interactions between the urban environment and climate change in Australia, a city-by-city assessment of the vulnerability of urban systems to climate change should be prepared for Australia. This will require detailed assessment by relevant government agencies of the vulnerabilities and research by climate scientists to quantify the probability of the associated climate change impacts.

The thresholds that threaten key urban systems and their variations across Australia need to be identified. Rigorous research into the optimum strategies and the capacity to avoid thresholds being triggered under extreme synoptic conditions via landscape management is required.

Implementation of world's best practice is necessary to integrate urban modelling from global to local spatial scales into the national Australian Community Climate and Earth System Simulator (ACCESS) modelling program, supported by research to understand how to use the building-resolving modelling in the parameterisation of models at larger scales.

A detailed measurement program including air quality, atmospheric fluxes and remote sensing data over sub-tropical and Mediterranean-type (for example, at least Brisbane and Melbourne) cities should be established to monitor the interactions between the urban environment and climate. The national Terrestrial Ecosystem Research Network (TERN) program could be expanded to include these activities. Over most Australian cities, there are multiple sources of relevant data. In order to make best use of these data, it is necessary to integrate them in a common quality-controlled system and made accessible to users. A national system is required for this fuunction.

Cities involve the complex interactions between the carbon, water and energy cycles of the overall climate system. A national research program focused on the interface of carbon, water and energy in urban systems is needed to encompass the scope of these interactions between the urban environment and climate change. As a first step, a national workshop should be convened to identify the key research goals and strategies.

3 Managing urban water

3.1 BACKGROUND

TAs in other countries, the majority of Australian cities are almost entirely dependent on water resources derived from the capture of rainfall runoff from largely rural or forested catchments. Communities are now increasingly susceptible to the impacts of increasing temperatures and soil moisture deficit in water supply catchments, climate variability, drought and climate change. Transforming our cities to have more sustainable urban water provision (that is, to Water Sensitive Cities) is a goal of the Commonwealth National Water Initiative directed at Innovation and Capacity Building to Create Water Sensitive Australian Cities[5]. The development of Australian Water Sensitive Cities involves a socio-technical institutional framework to accommodate a balanced approach to the commodification of water (supply security) and the public good (hazard mitigation and environmental protection) management of water.

Water is a key human, environmental and economic need in Australia. Climate change increases the level of uncertainty to the management of water for Australian cities which are already under stress. The effective management of water in the light of these uncertainties needs to be flexible and utilise a diverse portfolio of structural and non-structural responses that promote adaptive resilience. The responses will be shaped by the path dependencies of the existing infrastructure, the need to assure security of the overall system, and the need to provide a healthy environment. Adjustment to the way in which urban water is managed in the face of climate change highlights the issue of externalities, which lead to further constraints on the responses. Adaptation to climate change also requires a shift to active learning on the part of all concerned.

The way in which water has been managed historically in Australia has progressed through a focus on human health in terms of supply and drainage, with a growing concern for environmental needs and impacts, to an awareness of the need to create the water sensitive city, utilising all water streams. The emergence of this perspective provides a means of coping with growing uncertainty and the awareness that predicting the future by simply analysing data from the past may no longer be tenable[6].

Growing uncertainty requires a reappraisal of the current approach using large-scale infrastructure engineering, leading to a more flexible, adaptable and broader portfolio of responses that include behavioural and lifestyle adjustments and the engagement of communities in partnerships with professionals and policy makers to develop the appropriate coping measures. This will require a transition away from the primary use of fixed and path-dependent centralised approaches used in our current water infrastructure systems that are environmentally damaging, energy profligate, maintenance intensive, emitters of greenhouse gases and over-users of water in transporting our wastes.

3.2 ISSUES

Within the context of managing uncertainties, four key issues are considered to be very important for urban water. These issues are:

- increasing hazards;
- resource management;
- demand management; and
- protecting aquatic ecosystems.

5 COAG (2005) 14th meeting of Council of Australian Governments, Canberra, 25 June 2005.
6 Milly, P.C.D., Betancourt, J., Falkenmark, M., Hirsch, R.M., Kundzewicz, Z.W., Lettenmaier, D.P., & Stouffer, R.J. (2008) Stationarity is dead: whither water management? *Science*, 319, 573-574.

Issue 1 – Increasing hazards

As well as needing to find the right balance between human and environmental needs in the way in which we manage the urban water cycle, there will be a greater need to address the hazards caused by the greater extremes accompanying climate change. Growing populations and increasing urbanisation will further exacerbate the vulnerability of communities to flood risks. Responses to this will require different ways of living as well as a portfolio of structural and non-structural measures that parallel and ideally are synergistic with the measures needed to maintain supply and sanitation security.

A key issue is the management of storm water in urban areas, where the landscape of natural drainage systems has generally been greatly modified. Future processes for the development of flood management strategies should involve local communities so that all stakeholders are fully informed and understand potential risks. Careful land-use planning should allow for the establishment of buffer zones for areas with high flood risk. Where needed, building design should be sensitive to flood risks.

The potential for higher intensity rainfall events creates particular challenges in urban areas. Large impervious areas (roadways, roofs areas etc) raise the potential for increased flooding in urban areas with associated risks for property, public safety and in-stream water quality. Options that seek to increase interception and attenuation (for example, open spaces, swales and rain gardens) offer combined benefits for micro-climates and flooding. They highlight the complex connections between actions that can improve landscape amenity and provide climate change adaptation benefits.

Most major cities in Australia are on the coast. Given the long lifetime of water infrastructure and the expected gradual increase in sea level due the climate change, the hazard of storm surge impacting on urban drainage systems (as well as directly on buildings and the landscape) will need to be considered in future.

Issue 2 – Resource management

In the past water supply, sewerage and drainage systems have largely been treated as separate and independent elements. However, as a result of changing climatic conditions and greater emphasis on overall sustainability in the operation and delivery of water services, greater attention is being given by water planners and agencies to improving the integration of water systems and the delivery of different water products in terms of quality, quantity and reliability. This is resulting in the consideration of water supply, sewerage and drainage, and waterways as elements of a broader urban water cycle.

The rapid and dramatic climatic shifts experienced in many locations including Perth, Melbourne and Adelaide combined with major drought events across the eastern coast has focused attention on moving from climate-dependent water sources to a diversified portfolio of supply and demand-side initiatives. The diversification covers a range of supply and demand management options including augmenting surface water supplies, inter-basin transfers and water trading, groundwater, desalination, storm-water harvesting including rainwater tanks, recycled water and water conservation. The uncertainty of the rate of change increase the need to improve resilience of water system to climate shifts, creating greater urgency in the need to plan and implement diversified and integrated water systems.

There is also increasing attention to the energy use of infrastructure options and the relative carbon emission contributions of these options. There are many dimensions to any consideration of the appropriateness of the options to specific circumstances, including the rate and severity of expected climate variability and change, volumes supplied, the reliability and security of the supplies, timing (for example, construction and volume delivery), and energy use. There is significant interplay between these dimensions; for example, in the public discourse on desalination covering the need for security of water resources in a changing climate against the energy use. Such issues are complex, and strategies that explore the range of options and scenarios will assist broader community understanding of the challenges faced in adapting to rapid shifts in climatic conditions and on-going climate change. Furthermore, the complexity of these issues means that consideration of the range of views and technical options will result in different outcomes in different locations. As such, it is important that major water resource management decisions are supported by good technical, economic, environmental and social considerations in which the community is engaged.

There are a range of new developments where integrated delivery of water, sewerage and drainage services are being implemented (for example, Aurora Estate Melbourne). There has also been greater private uptake of non-traditional water sources (for example, rainwater tanks and grey water systems) in response to drought and water restrictions in many cities. Indeed there is a growing concept around the world of cities as water supply catchments, in which potential sources include groundwater, urban storm-water, rain water (roof run-off), recycled waste water and desalinated water. The mix of sources allows for a balance of resilience, reliability, cost, and environmental impact. However, the detailed planning and implementation of non-traditional systems can be constrained by factors such as a lack of relevant research and data on their short and long-term performance, unknown economics, and planning and institutional constraints. On the other hand, the changing climate can be expected to increase attention on the concept of 'fit for purpose water' and the associated challenges on the scale and delivery of water management infrastructure.

The increasing complexity of water management systems will require a diverse range of expertise to be available to decision makers. However, water agency downsizing during the 1980s and 1990s, combined with decreasing numbers of people with science and engineering skills, has resulted in critical skill gaps in the water industry across various levels at a time of increasing stress and increasing complexity.

New and emerging technologies provide potential benefits for assisting in climate change adaptation. Examples of technological improvements in the water sector are household water metering (i.e. smart meters), energy recovery systems for desalination, small scale treatment and disinfection systems, household grey water systems. Other improvements are occurring in water use efficiencies in household appliances achieved through a combination of regulation and market demand. There is an ongoing need to monitor the role of new and emerging technologies and how they may impact on the expected costs, energy use and volumes from a supply and demand perspective.

The increasing complexity of water systems (including greater involvement of the private sector) and the need to meet multiple and often competing objectives in a changing climate (for example, maximising system security of supply and maximising environmental benefits downstream of harvesting sites) is placing greater attention on the concepts of optimal water system operation and capital investment timing, integrated water system assessments, and transparency of system operational arrangements. In terms of climate change, system optimisation based only on historical records may reduce the robustness of systems to shifts in climatic conditions outside the expected range. While planning tools, such as real options analysis and scenario analysis, provide a basis for planning in uncertain conditions, planing under climate change conditions will need to include market, social and environmental considerations leading to 'robust' or 'no-regret' outcomes.

Computer-based analysis of the complex interactions between climate and water systems (that is, water supply, sewerage and drainage) will be used increasingly to provide water resource assessment and decision support tools. However, the increasing sophistication of these techniques, balanced by the need for transparency in decision making, places greater emphasis on effective communication of complex resource management decisions. In a changing climate, the uncertainties associated with decisions must also be recognised and communicated within the context of an 'active learning' strategy. That is, decisions will be made on the basis of contemporary information, but in the context of on-going learning and adaptation.

Sewage is increasingly being considered as a resource in terms of water content for recycling as well as the constituents. However, climate change presents significant risks for inflow volumes, the transport assets and treatment processes. The increasing attention to recycling is also leading to greater attention to source control of pollutants (for example, nutrients, salt, endocrine disruptors) to provide improved source water for recycling. Climate change will bring greater attention on the role of recycled water for uses ranging from the direct and indirect potable water reuse to substituting potable water use (for example, open space watering). A particular issue is the overall cost-benefits of centralised and decentralised treatment systems.

Issue 3 – Demand management

Australian Cities have traditionally responded to increasing demand for urban water services by adopting a 'predict and provide' approach. For a long time this appeared to be a felicitous response. The natural supply from rainfall runoff was sufficiently resilient to cope with seasonal variation and periodic drought. The increase in population and the increasing per capita use of water now has reached the point where the natural sources on which many of our cities have relied can no longer provide a secure supply. Climate change has now brought this issue into high relief.

We no longer have the luxury of being unconstrained in our use of water. We must adopt new measures of managing demand. A significant part of our response must be to reshape demand. The reductions in urban water use across Australia in recent years have demonstrated the effectiveness of innovative demand management, and such strategies will need to be continued and enhanced.

Less than 10 per cent of the water used in cities must be of potable quality (for drinking, food preparation, cooking and cleaning), and so we must explore ways of re-using water or using lower quality water for uses that do not need potable quality water. Demand for potable quality water could be reduced by on-site recycling grey water for toilet flushing or garden watering. Local area management and treatment of waste water flows could be used to water parks and gardens and in industrial processes such as cooling water for power generation. It is also important to explore new ways of managing waste flows – especially human body wastes – that do not rely on water as the transport medium.

It may prove to be uneconomic to re-engineer supplies in and to existing buildings but new standards should be applied in all new development and redevelopment of buildings so that re-use of water is facilitated. The path dependency effects created by the investment in existing water services infrastructure should not prevent their progressive upgrading to provide a more modern array of water services.

Australia can learn from experiences in other countries. However, we must recognise the risks inherent in uncritically adopting practices developed in other locations under different environmental and regulatory conditions.

Issue 4 – Protecting aquatic ecosystems

Urban impacts on the natural aquatic environment currently are more profound than those associated with climate change. Nevertheless these two emerging challenges are not mutually exclusive. Protecting the environment from water which is diverted for urban consumption and into which treated waste-water and storm-water is discharged is a key objective of sustainable water resource management. Urban pollution, coupled with increased global temperatures and greater climatic variability, will inevitably increase the risk of environmental degradation. Urban landscapes now need to accommodate ecological functions beyond providing spatial amenities for an environment of increasing urban density. These urban landscapes capture the essences of sustainable water management, micro-climate influences, facilitation of carbon sinks and use for food production.

A key strategy to reducing the adverse impacts on the aquatic environment is better management of storm-water in urban areas. Through improved land-use planning and the introduction of storm-water harvesting, the overall impact of urbanisation on the aquatic systems can be reduced. The strategies implemented to improve aquatic ecosystems have the additional benefit of reducing the likelihood of flooding in urban areas.

3.3 CONCLUSIONS

Climate change brings a higher level of uncertainty to the management of water for Australian cities, which are already under stress from shortages in supply and excesses in demand. The key strategy for managing water in the light of these uncertainties is the development of a diverse portfolio of responses that promote adaptive resilience. Assessing the options for the supply of water for urban areas involves the assimilation of information on technical, economic, environmental and social costs and benefits. Active learning by technical experts, policy makers and the general community will be important in ensuring that effective and efficient responses to climate change are implemented.

Better management of storm-water will be needed to mitigate the risk of flooding in urban areas, if severe storms become more frequent or intense. Strategies, such as the establishment of buffer zones and the local capture of storm-water for residential use, should mitigate flood risk. They can also have concomitant benefits by reducing demand from mains-supply water as well as improving conditions for natural aquatic ecosystems within and around cities.

Improvements in resource management will need to be supplemented by better management of demand. The recent reductions in urban water use across Australia demonstrate the benefits of innovative demand management, and such strategies will need to be continued.

4 Building Design

4.1 BACKGROUND

The building sector is responsible for approximately 35 per cent of Australia's greenhouse gas emissions and so has a significant long-term influence on climate change. Yet existing technologies[7] could allow this sector to provide significant immediate emission reductions at zero cost or even net savings to our economy. Indeed Australia is unlikely to meet its expected emission reduction targets unless the building sector is empowered to deliver its potential benefits.

Australian cities will be increasingly vulnerable to climate change unless innovative adaptation in the building sector is better promoted. The risk of inaction is that our cities will be exposed to serious, potentially catastrophic economic, environmental and social impacts. The time scales and uncertainties associated with climate change mean that market failure is likely without appropriate interventions. Failure to address this market failure could lead to lost social, environmental and economic opportunities.

In addressing climate change, the building sector needs to be considered as integral with the broader ecological systems in order to support rather than degrade life-supporting systems. Holistic sustainable building design cannot be an 'add-on' but must be intrinsic in all phases of design, construction and experience of the built form and its context.

4.2 ISSUES

The four key issues to be considered are:

- climate-adaptive buildings;
- zero-carbon buildings;
- urban infrastructure; and
- built-environment education, training and research.

The first two issues are aimed at ensuring that buildings are able both to adapt to climate change and to contribute to the reduction in greenhouse gas emissions. As Australian cities evolve towards a more energy-efficient form, the design of our buildings will certainly change. It is clear that the expected changes in our buildings (both old and new stock) will require concomitant changes in the expertise, expectations and understanding of architects, policy makers and the general community.

The achievement of the aims associated with these issues will require a range of strategies. The policy strategies will need to provide for:

- regulations for progressively increasing mandatory minimum performance;
- incentives to overcome market failures that present barriers to sustainable building;
- reward for innovation and leadership;
- an integrated policy framework to create market conditions for mainstream sustainable and resilient buildings; and
- policies that provide financial motivation for owners and occupiers to upgrade existing buildings.

A range of financial mechanisms could be established to promote the design and implementation of climate-responsive buildings in the free market place. Currently the *status quo* is maintained because the investment returns are measured in time-scales far longer than market economic return expectations.

7 IPCC (2007) Summary for Policy Makers by Working Group III to the Fourth Assessment Report of the IPCC, May 2007, pp24.

Possible measures to promote climate-responsive buildings include:

- 'energy mortgages' to provide capital for 'deep' refurbishment of buildings. The aim is to capture the long-term energy-bill savings as the repayment for the loans. The repayment periods to be as much as 25 years and linked to the individual property (as opposed to the relatively short-term owner). The need to minimise the cost of capital finance suggests local authorities and utilities may be the best route for sourcing the finance;
- new-build finance incentives towards improving the performance of new homes instead of simply increasing the floor area of homes; and
- promotion of energy-efficient lifestyle choices of individual occupants as such choices greatly influence the overall carbon performance of buildings; for example, taxation focused on goods and services using a banded-scale related to environmental impact, with the aim of modifying consumer choice by increasing the price of goods and services with higher embodied or in-use carbon emissions.

Issue 1 – Climate-adaptive buildings

Buildings have lifetimes of decades, and so it is important that they have the resilience to accommodate climate change as well as decadal-scale fluctuations in regional climate. A clear vision of what constitutes a climate adaptable and resilient building needs to be established, and that vision must allow for appropriate regional variations. These adaptive measures need to be embedded within assessment tools, such as Green Star (www.gbca.org.au/green-star), and progressively introduced as experience grows into the building regulatory framework. Examples of such measures (suitably quantified) could include:

- extended-life buildings with the ability to accept changes of us – that is, buildings with long-life 'loose-fit' components. Among other aspects, this approach affects the depth and massing of buildings;
- using thermal mass (heat storing) materials in building structures;
- ability to operate buildings completely passively (without input from any energy consuming systems) for large proportions of the year;
- reducing the volume of materials needed by buildings, particularly the frequently replaced components; and
- urban heat island reduction measures to reduce the heating load on urban buildings; such measures could include changes in urban transport (for example, electric vehicles), and the introduction of extensive urban vegetation with the associated urban rainwater retention.

Issue 2 – Zero-carbon buildings

A suitable policy framework needs to be established in Australia to provide sufficient certainty to support viable commercial decisions for the building industry. As a first step, a trajectory to a low-carbon Australia needs to be established. This should involve long term overall targets, together with medium and short term targets subdivided into sectoral responsibilities. Evolving policy and regulatory frameworks need to reflect the trajectory. As noted in Section 4.1, the IPCC emphasises the important contributions that the building industry can make to achieving such a trajectory. However, the relatively long life of buildings means that the targets (both for refurbishment and new-build) need to reflect their longer term contributions to the trajectory.

The detailed policy strategies and financial mechanisms required to achieve zero-carbon buildings are similar to those outlined in Issue 1. Given the complexity of the goal of zero-carbon buildings, it will be important to have an evolving and informed policy framework, so that for instance assessment tools like Green Star could be used to test and gain experience of new techniques prior to their adoption as the regulatory minimum standards. Thus progressively higher Green Star rating should have requisite energy standards culminating in zero-carbon for the highest rating.

Innovation will be a vital element in achieving zero-carbon buildings, with new concepts being tested in design, engineering and policy. It will be important to promote not only energy and carbon efficiency but also resilience and adaptive capacity in buildings. Multi-purpose and mixed-use buildings should be encouraged, and there may be scope to use Renewable Energy Certificates or similar instruments to encourage zero-carbon approaches. Mandatory reporting of building performance and mandatory requirements for performance upgrading should also promote a regulatory environment for zero-carbon buildings.

Issue 3 – Urban infrastructure

Building design needs to be seen as an integral aspect of the overall design of urban infrastructure. For example, as cities develop a more compact form, it will be important to ensure that all three levels of government provide consistent guidelines and regulations for land use, planning, design controls and building codes. Such cooperation would ensure that housing location and type would deliver the required compact form with, for example, higher densities around transport networks.

Consistent guidelines across national, state and local governments could also promote more integrated precinct-scale resource management. For example, regulation changes at all levels could allow capital-efficient distributed renewable energy networks and non-traditional water supply systems to be established. Prototyping of such systems should be encouraged, and nationally-recognised contracts should be introduced for energy and water supply companies so that all stakeholders are properly acknowledged and unnecessary transactional costs are avoided.

Monitoring and assessment must be included in the overall process, so that progress can be readily identified. For example, rating tools, such as the Green Star rating tool, should be used to assess and influence landscape design, site resilience and resource management at precinct scales. Through such approaches, climate-sensitive building design will be incorporated in a broader framework of 'eco-infrastructure' for our cities and will contribute to the development of ecosystem services for communities.

Issue 4 – Built-environment education, training and research

In order to implement the changes implied by Issues 1, 2 and 3, there will need to be substantial changes in understanding and even culture by people at all levels in government, building professions and the general community. Thus communication, in the forms of education, training and research, will need to be a major element in the overall policy required to achieve the changes in the built environment associated with adaptation to and mitigation of climate change impacts. The changes in understanding are needed to avoid continuation of the unsustainable practices currently used in building design and construction and currently accepted by government and the community.

The building industry is currently not trained to deliver climate-adaptable and zero-carbon buildings as either renovations or new buildings. In addition, professional education generally does not sufficiently prioritise or effectively deliver curricula that will empower graduates to shape a zero-carbon and climate adaptable urban environment. Reform and expansion of built-environment education and training with climate change mitigation and adaptation as a primary focus should occur within the next 10 years to ensure that the Australian workforce develops the needed expertise in a reasonable time frame. Specific actions to achieve the changes include:

- reorientation of professional education in order to eliminate curricula that reproduce modes of practice that increase the impact of buildings on climate change;
- development and implementation of interdisciplinary curricula for professional courses;
- refocusing of accreditation criteria for professional courses on climate change mitigation and adaptation – courses that are not focused on these issues should not gain accreditation;
- retraining of industry over the next 10 years to provide the necessary leadership and capacity to engage in the mass renovation of existing buildings;

- public and formal learning must be informed by pedagogies oriented towards reflection-in-action. Formal education should be informed by detailed and continual analysis of the climate performance of buildings. There should be public feedback on the climate performance of buildings; and
- renovation of formal settings for education such as schools and universities should be prioritised to provide learning environments that exemplify climate-sensitive built environments.

The public and professional education on sustainable built environments needs to be based on sound research results; in particular, research should be focused on integrated building design and construction, supporting whole-system approaches and innovation, and aimed at unlocking knowledge from existing projects and best practices to facilitate the transition to a zero-carbon building sector. Many of our current housing and workplace models are inadequate and out-dated, and they do not deal with the immense challenge of transforming the built environment. There needs to be increased support for research activity that:

- identifies best practice and its application in a holistic way, developing performance-based principles for more compact urban form, energy-efficient buildings, and more flexible, adaptable building typologies, in order to re-conceptualise our housing and workplaces;
- renerates better methodologies for measuring sustainability and resource management; material flows need to be identified, analysed and communicated; and
- develops strategies for achieving a zero-carbon built environment, with a focus on identifying the relevant questions to future-proof the building sector and pathways to a low-carbon society.

Significant behavioural changes, based on improved understanding of the complexities and extended knowledge, are needed to create an energy-aware culture that allows decision-makers to better understand the opportunities for energy-efficient buildings and cities. These changes should be based on sound peer-reviewed research to provide clear information about the new and emerging technologies. A broad research program should be fostered within and across built-environment disciplines to promote a seamless connection between research and practice. We therefore need research that meets world standards of excellence in its field and makes an equally excellent contribution to the practice of the built-environment professions. Required activities include:

- contributing to capacity building, raising awareness;
- conducting quantitative and qualitative scientific research into design principles, developing new concepts on how to create sustainable cities, districts and buildings;
- enhancing international research cooperation to develop knowledge of international research-based best practice;
- publication and dissemination of knowledge and best practice principles, for re-engineering our buildings, districts and cities;
- knowledge-sharing – transferring knowledge to developing countries, up-skilling and training professionals, and offering wider access to information networks;
- observation of how buildings and urban environments actually perform;
- development of baselines and consistent methodologies for measuring progress and return on investment in carbon markets; and
- research and development of component prefabrication and modular construction to facilitate resource efficiency and adaptable design.

Research as 'Community Engagement' needs to involve the development of partnerships that bring real benefits to communities. Such engaged scholarship integrates student learning with research that is undertaken in collaboration with professional partners, who are involved in all stages of the discovery activities. Such research calls on many disciplines, is highly collaborative, and is strongly applied and problem-driven.

Today, we see research in the built environment transforming through new networks, which are rapidly changing all forms of design and practice into increasingly multi-disciplinary fields of innovation and experimentation. This research needs to be undertaken by strong inter-disciplinary built-environment teams in which all disciplines can make specific contributions. For instance, architecture should be understood as an exciting field of open research, rather than a field with orthodox or fixed solutions. The resources a contemporary architect can draw upon are no longer a closed body of knowledge: what must be taught and learnt are the results of a continuing research process. The constant changes in the field of built-environment technology and science, with new relationships between work and leisure, public and private space, heritage values and the demands of tourism, establishment of roots and the lure of mobility, mean there is no longer a limited set of rules that defines what research is or can be.

4.3 CONCLUSIONS

A clear vision of what constitutes a climate adaptable and resilient building needs to be established complete with appropriate overall regional variations. These adaptive measures need to be embedded within assessment tools such as Green Star, and progressively introduced as experience grows into the building regulatory framework. Fundamental changes are needed to the financial support systems to ensure that there is a clear free market driver towards climate responsive buildings. Currently the *status quo* is maintained because the investment returns are measured in time-scales far longer than market economic return expectations. Furthermore legislation discourages integrated resource management on precinct scales. Municipal, state and national regulations need to be changed to allow capital-efficient distributed renewable-energy networks and non-traditional water supply systems to be implemented. Nationally recognised contracts should be introduced for energy and water supply companies so that all stakeholders are properly acknowledged and unnecessary transactional costs are avoided. Because of the long lead times, precinct prototyping of smart grid systems is an immediate need. Methods for assessing climate change resilience must be implemented through municipal regulations. Policy tools, such as the Green Star precinct tool, should be used to assess and influence landscape design, site resilience and resource management.

Australian cities are currently designed for predominantly low-density urban housing, and it is not clear that this urban form will support the low-emission targets expected to be required under any carbon reduction scheme. Land use, planning and design regulations, together with building codes, require more consistency at all three levels of government to ensure housing location and types deliver an overall form that is compatible with future carbon emission targets. A more compact urban form with higher densities around transport networks is therefore expected to be necessary. This transition will require an integrated framework cascading from federal to local government levels, with rigorous and consistent implementation.

The building industry is currently not trained to deliver climate-adaptable and zero-carbon buildings as either renovations or new buildings. In addition, professional education generally does not sufficiently prioritise or effectively deliver curricula that will educate graduates who can shape a zero-carbon and climate-adaptable urban environment. Reform and expansion of built-environment education and training with climate change mitigation and adaptation as its main intent must occur within the next 10 years. Research needs to identify best practice and its application in a holistic way, developing performance-based principles for compact urban form, energy-effective buildings, and more flexible, adaptable building typologies. Better methodologies for measuring sustainability, resource management and material flows need to be researched and developed.

5 Urban Planning and Transport

5.1 BACKGROUND

Urban spatial planning is one of the principal means by which the public good of Australian cities has been delivered and managed since the production of the Melbourne Metropolitan Plan in the 1920s. We have come to expect city planning to deliver cities in which we can live, work and play in good health and with a sense of (social and economic) well-being. As the bedrock of an urban society, Australian cities will continue to depend upon city planning to deliver an urban fabric that is fit for purpose in the light of the climate change challenge. This challenge will be twofold in that we will expect Australian cities (including their suburban hinterlands) to facilitate the emergence of a low carbon economy and society (thus reducing or mitigating the likely magnitude of climate change) but we will also expect our cities to be adapted to the climate changes that are already inevitable.

Before setting out a series of recommendations as to what city or spatial planning might be reasonably expected to deliver in relation to the climate change challenge, it worth quickly setting out what spatial planning currently does. The Australian spatial planning system theoretically provides a framework for the management of the layout and function of our cities and other settlements. It does this through strategic land use planning, an administrative development assessment and allocation function and the planning of urban transport systems. Through these means it aims to provide an orderly guide to the development of settlements.

The impact of climate change will be uneven across each city and across urban society. Traditionally an important objective of spatial planning has been to deliver equitable spatial outcomes (or at least to alleviate the excesses of market led urban processes) through a mediating role in helping to balance the competing demands on urban land uses from a wide variety of stakeholders.

Whereas the management of planning applications can have a time horizon numbered in years (from planning approval to occupancy), the plan-making component of spatial planning has a time horizon typically measured in terms of decades (current strategic metropolitan plans have a typical strategic horizon of 20 to 30 years). Thus in thinking through what spatial planning can deliver, we must be mindful of these time-frames. Spatial planning in its traditional guise of land use regulation may be better suited to adaptation than to mitigation within our urban environment. However, in a highly urbanised nation such as Australia, spatial planning potentially has and will have a critical role to play in coordinating and managing the general response to climate change. This potential will not be realised until a number of key issues are addressed.

Spatial planning is a highly complex and contested area of public policy making and delivery – it is not a simple design process. In Australia the planning system is primarily a matter for State Government rather than for the Commonwealth. It involves a multitude of actors and agencies, including the millions of decisions made daily by transport users and householders in making choices about where they should live and work, the motivations of thousands of developers and builders as to what they will build, the commercial needs of many thousands of businesses and a multitude of movements across the urban system of people and freight. In addition, planning involves a consideration of both private and public realms as well as public-private actions and decisions. Despite their number and diversity, all these stakeholder groups need to be drawn into the process of deciding what needs to be done.

Three key issues need to be considered:

- In relation to policy response, it is not that Australian city governments are doing nothing in the light of the threat of climate change, it is that these activities are largely uncoordinated across the levels of government, with little analysis of how the different interventions interact (especially between mitigation and adaptation policy). *It is important to consider the role of spatial planning in integrating and coordinating policy initiatives and the delivery of the built environment within Australian cities.* It is one of the means by which Australian cities can better coordinate a response to the recommendations contained within this report (relating to public health, better buildings, water resource management, etc.). Planning practitioners in Australia are well placed to contribute to this broad role of coordination and mediation in our response to climate change (see, for instance, www.planning.org.au/index.php?option=com_content&task=view&id=291&Itemid=279).
- It is extremely unlikely that Australian cities will be able to build their way to adaptation especially with regards to housing stock. There are about 8.4 million private dwellings in Australia's capital cities (2001 Census), with an average of 89,900 new private dwellings completed per year (based on average between 1991 and 2004). At current rates of building and replacement it will take about 100 years just to replace this existing housing stock, let alone add new homes to meet growing population needs. The commercial and industrial building stock turns over more rapidly, but even so, it will take many years to replace. Thus it is imperative to think about how the existing building stock and the existing suburbs can be made better suited (or retrofitted) to the climate challenges that Australian cities are likely to face. Planning policies to make our cities more fit for purpose will also need to tackle the issue of neighbourhood design as well as the issue of the buildings. *Spatial planning in Australian cities needs to deliver retrofitted buildings and neighbourhoods that take into account issues of social and environmental justice (no one should be disadvantaged by the climate change response).*
- Whereas the links between how our cities are laid out and how people chose to move around cities are contested and complicated, it is important to think through how Australian cities can better provide opportunities for lower carbon mobility (that is, less dependent on private vehicles with a single occupant). *Organising land use to create opportunities for better collective transport and for alternatives to the private car (cycling or walking) is something to which spatial planning can contribute.* But it will also be important to think through how non-land-use policies such as road pricing and car-park charges can be coordinated with land use and transport policies that both generate low carbon outcomes (for mitigation) and that are flexible to confront climate change (that is, are either adapted or adaptable).

These three issues are inter-related. Retrofitting suburban neighbourhoods will impact on the potential mobility and connectedness of the people who live there. The delivery of retrofitted neighbourhoods and low carbon mobility is only possible through an integrated public policy framework that should include the Australian spatial planning profession. Equally the effective delivery of better public health, better water management and better buildings also requires the coordination of the multiple stakeholders in the production of urban environments and needs a process to mediate the tensions and opportunities between these interventions. It makes sense for spatial planners to contribute to the process that cuts across the landscape of local government.

Yet it will be important to maintain a sense of realism about what spatial planning can produce. The physical urban fabric of our cities changes slowly and plan-making can also be a slow business given the number of stakeholders who need to be involved. Being smart about land use gets us only so far. The climate change agenda for Australian cities requires a recognition of the role of urban planning in the strategic coordination across the broad range of policy areas (not only land use).

5.2 ISSUES

Issue 1 – Integrating the urban policy framework with climate change

By its very nature and complexity, the response to climate change demands an integrated policy response. The challenge of reducing greenhouse emissions and making urban communities more resilient will require the mobilisation of policy settings beyond the current capacity of the planning system. Spatial planning has the capacity to play a key advisory role in the response to climate change across the urban system. It can do this by offering a spatial vision of how a low carbon urban system should be designed, developed and delivered in an integrated way across our city regions.

A key example of the way the fragmentation of planning decision making is the activity of some road agencies. The direction of urban development has often been driven by the unilateral decisions of road agencies which may have little regard to sustainability outcomes required by an integrated policy response to climate change. In the context of climate change this approach may seem to undermine or deflect the objective of reducing car dependency and reducing the polluting and greenhouse gas emissions from road usage. Another instance is the influence of agencies providing urban utilities such as water, electricity and waste which often may involve the development of infrastructure with little regard for formal spatial planning or climate change considerations.

It is clear that the onset of climate change means that we cannot continue with a 'business as usual' approach with regards to the spatial planning of our cites and its infrastructure. Without clear objectives driving the current renewal of infrastructure in our cities, there is an acute danger that current decisions will lock us into longer term outcomes that will preclude more appropriate responses to climate change in our cities.

In summary, an integrated policy environment can be established by:

- development of an Australian National Adaptation Plan with specific recognition of Australian urban issues;
- development of the national Environmental Impact Assessment (EIA) process to include a mandatory assessment of climate change impacts for all major urban development projects;
- at the urban level, climate change adaptation and mitigation should be the responsibility of a Metropolitan Strategic Partnership within each city. Urban infrastructure funding should be tied to the establishment of such a partnership and the use of climate change-related EIAs; and
- climate change should be a material consideration in all future planning decisions across the full urban policy set applicable to all public agencies dealing with spatial planning and infrastructure development.

Issue 2 – Retrofitting cities

Given that the building stock of our cities increases only incrementally, perhaps at around two per cent per annum, the major challenge in dealing with climate change lies in what we do with our existing built environment, including both buildings and infrastructure. While new buildings can provide a focus for innovation in climate proofing, not least driven by enhanced building code requirements, adapting existing buildings, infrastructure and neighbourhoods represents a very different set of problems. These relate to cost constraints, design issues and construction industry resource limitations, as well as, critically, consumer attitudes, perceptions and behaviour. In addition, urban renewal is now the major focus of all Australian city planning policies, offering a major larger scale opportunity for adaptive resilience to be refitted into renewal city centre and suburban neighbourhoods.

Technologies for adaptation and mitigation in new buildings already largely exist, and it is recognised that many of the outcomes of our cities over the next generation will be drawn from what we already know, or incremental advances on technologies and practices already understood. However, while the market can be relied upon to deliver some of the changes needed, for example as a result of carbon reduction schemes and changing consumer preferences, it is likely that additional incentives, such as fiscal reforms and subsidies and new forms of regulation and direct interventions, will be needed. While the commercial and industrial sectors offer opportunities for refitting in relatively short time scales, the residential sector presents a more challenging problem in terms of the multitude of owners who will need to be engaged, the small scale and often poor quality of improvements to the stock over time, and the planning levers available to promote transition, as well as social inclusion, affordability and heritage.

Within a broader spatial planning concept, there are at least three levels of retrofitting that have relevance to a broader planning approach to refitting our cities to higher standards of adaptive resilience.

RETROFITTING AT THE TOWN CENTRE OR NEIGHBOURHOOD SCALE THROUGH CLIMATE PROOFED URBAN RENEWAL SCHEMES – DELIVERING REPLACEMENT BUILDINGS WITH HIGHER ENVIRONMENTAL STANDARDS.

This offers a substantial opportunity for the next 20 years. With all our major city planning strategies now espousing more compact cities, there is an opportunity for more rapid transformation towards greater adaptive resilience through brown field renewal, through a market which is also pursuing higher density in infill and renewal sites, and through more stringent planning interventions backed by active renewal strategies at the local level.

RETROFITTING EXISTING BUILDINGS THROUGH CLIMATE PROOFING MEASURES – SUCH AS BETTER INSULATION, RECYCLED WATER AND STORM WATER CAPTURE, AND GREENING GARDENS

While this level of change is currently mainly stimulated through building codes and other regulatory devices, as well as financial incentives and subsidy arrangements, it is also possible to promote these kinds of changes through an active planning framework, especially through Development Control Planning requirements for renovation and improvement work. Consumer demand for more adaptive homes will also play a role, although until such actions offer a positive financial return over a shorter time scale, widespread uptake of such adaptive behaviour will probably remain at a relatively low scale. A major shift will occur only when consumer sentiment for adaptation is reinforced by fiscal policy or other regulatory interventions. For example, legislative measures to introduce energy and water conservation certifications for homes on resale, such as that being introduced in England, would assist in creating a market incentive for such improvements as well as raising consumer awareness and stimulating behavioural change. A similar approach could be taken for commercial and industrial buildings, although here refitting on change of owner or tenant is more likely to generate environmental upgrading than in the residential sector.

RETROFITTING LIFESTYLES BY ENCOURAGING CHANGE IN CONSUMER PREFERENCES AND COOPERATION AT THE NEIGHBOURHOOD LEVEL TO DEVELOP LOCAL SOLUTIONS TO CLIMATE CHANGE ADAPTATION

For example, local energy co-generation schemes may offer an opportunity for neighbourhood level action by residents and businesses in delivering new forms of distributed energy generation that might not only provide for local energy needs, but also generate income through energy exporting to the grid. Similarly, schemes that provide consumers with access to bulk purchase of adaptive technologies thereby reducing costs and reducing pay-back periods could become a widespread stimulus for changing behaviours.

Retrofitting also raises substantive social sustainability considerations. Adaptation inevitably takes place in districts, neighbourhoods and infrastructure networks that present a rather more complex picture when compared to new development outside the current urban footprint. As we retool the form, function and performance of the fabric of our existing cities, a triple bottom line approach will be crucial. Environmental performance measures will have to be considered alongside urban design, social cohesion, affordability and quality of life measures. Challenges may focus on the balance between, for example, demolition or renovation of existing carbon-greedy homes and replacement with carbon neutral or indeed net energy generating forms. Determining appropriate trade-offs and acknowledging the value placed in our existing built environments will require substantial debate. The benefits of improved performance over the long term where new building takes place will need to be balanced by a consideration of the embedded energy represented in that existing built form.

In summary, a strategic approach to retrofitting our cities will require:

- development of a national integrated climate change assessment tool to measure the relative appropriateness of renovation versus demolition for each major urban area;
- establishment of demonstration projects and 'learning hubs' that will illustrate good practice and lessons on 'what might work' for practitioners engaged in the production of the built environment; and
- preparation of vulnerability assessments of likely changes within our cities and development of assistance programs to ensure environmental justice in the outcome of public policy.

Issue 3 – Transport

Urban transport systems in Australia are highly dependent upon private vehicles for urban passenger movements and trucks for urban freight. In order to be more carbon-efficient, cities need to examine a variety of responses, which provide alternative approaches to the traditional 'predict and provide' method of transport planning which has attempted to match the supply of road infrastructure to ever increasing demands for private travel. These responses should cover the following areas:

CHANGES IN URBAN LAND USE AND URBAN STRUCTURE

This could include new higher density, mixed use centres built to appropriate urban scales and orientated to improved public transport. Such centres could have a greatly enhanced public realm to encourage much higher levels of walking and cycling. These centres could connect well with existing suburban fabric allowing shorter car trips, more public transport trips and more walking and cycling as part of retrofitting suburban areas. By this means Australian cities could evolve into more poly-centric, public transport-oriented forms.

DIFFERENT URBAN TRANSPORT INFRASTRUCTURE INVESTMENT PRIORITIES

Transport infrastructure funding priorities have traditionally favoured roads. Changes can include emphasis on higher quality and more extensive urban public transport systems, and could include new suburban and light rail transit systems, both radial and orbital, public transport vehicle fleet renewal programmes, better conditions for pedestrians and cyclists, for example, through traffic calming, direct cycleway systems, and pedestrianisation. Transport infrastructure investment can address new developments as well as suburban retrofitting for climate proofing suburban areas.

NEW CARBON-EFFICIENT TRANSPORT TECHNOLOGIES THAT REPLACE FOSSIL FUELS WITH RENEWABLE ENERGY

This could entail exploration of the wide range of new vehicle technologies for cars, public transport, bicycles and freight movement systems. Technologies need to be assessed for their likely ability to meet different levels of future travel demand, since current very high levels of travel demand are the product of decades of cheap fossil fuels and a highly developed infrastructure system to support these high levels of private transport mobility. New carbon-efficient transport technologies are likely to function best in the context of reduced demand for private mobility and more use of alternative modes. Demonstration projects in different urban contexts in Australia may be an important way forward to trial such schemes.

ECONOMIC PRICING SYSTEMS FOR CAR TRAVEL WHICH SUPPORT MORE CARBON-EFFICIENT MODAL CHOICES

Various road pricing and congestion charging systems could be explored in Australian cities in order to help reduce private travel demand and to draw attention to the limited capacity of cities to meet unfettered growth in private transport demand. Funds raised from such systems can be targeted to fund improved alternative modes of travel. A number of cities around the world provide models for the different approaches, for example, London and Singapore.

TRAVEL BEHAVIOUR CHANGES WHICH ENCOURAGE MODAL SHIFTS THROUGH BETTER INFORMATION

Greater use of travel behaviour modification programmes such as the direct marketing of alternatives to the car, as used in Travel Smart programmes, can be more widely used to support other transport change initiatives that involve transport infrastructure and different urban forms.

URBAN FREIGHT CHANGES THROUGH MORE CARBON-EFFICIENT LAND USES AND TECHNOLOGICAL INNOVATION

This should include exploration of alternative, more efficient land use arrangements and technical approaches not so far explored in Australian cities (for example, freight trams, solid pipeline technologies) as well as the use of roads that are dedicated primarily to freight transport functions.

In summary, the framework for transport planning to account for climate change should include:

- changing the priorities for urban transport infrastructure investment (including freight) to promote more energy-efficient approaches;
- exploring the application of new carbon-efficient transport technologies that replace fossil fuels with renewable energy; and
- developing pricing systems for car travel that support more carbon-efficient modal choices, supported by travel behaviour modification programs.

5.3 CONCLUSIONS

An National Adaptation Plan with specific recognition of Australian urban issues should be developed to provide an overarching framework for the incorporation of climate change into environmental policy. This framework should be supported by a national Environmental Impact Assessment (EIA) process that includes a mandatory assessment of climate change impacts for all major urban development projects.

At the urban level, climate change adaptation and mitigation should be the responsibility of a Metropolitan Strategic Partnership within each city. Urban infrastructure funding should be tied to the establishment of such a partnership and the use of climate change-related EIAs. A consequence of this approach should be that climate change is a material consideration in all future planning decisions across the full urban policy set applicable to all public agencies dealing with spatial planning and infrastructure development.

To provide an objective basis for the retrofitting of urban areas and the built environment, a national integrated climate change assessment tool should be developed to measure the relative appropriateness of renovation versus demolition for each major urban area. From the results of that assessment, demonstration projects and 'learning hubs' should be developed in order to illustrate good practice and lessons for practitioners engaged in the production of the built environment. In order to ensure social and environmental justice from the outcome of public policy, vulnerability assessments and associated assistance programs should be prepared on the likely changes within our cities.

Urban transport systems in Australia are currently highly dependent upon private vehicles for passenger movements and upon trucks for freight. If Australian cities are to use more energy-efficient modes of urban transport, then a number of policy changes need to be introduced. The priorities for urban transport infrastructure investment (including freight) need to be changed to promote more energy-efficient approaches. The application of new carbon-efficient transport technologies should be explored to replace fossil fuels with renewable energy, and pricing systems for car travel that support more carbon-efficient modal choices should be introduced, supported by travel behaviour modification programs.

6 Air Quality and Health

6.1 BACKGROUND

Weather and climate (and consequently climate change) affect the key determinants of human health: air, water, food and shelter. They also influence the frequency of heat-waves, floods and storms as well as the transmission of infectious diseases and, indirectly, chronic diseases. In addition, policies to mitigate climate change (for example in the energy, transport or urban planning sectors) have potential co-benefits for health, for example through their effects on local air pollution, physical activity, or road traffic injuries. Impacts on human health should be a primary consideration in urban planning and policy responses to climate change. For Australian cities, three issues that will become of increasing importance as climate change impacts continue are heat stress, air quality, and mental health. While each issue is considered separately, it is apparent that they are connected in various ways.

Mortality in heat waves in Australia is currently comparable to the road toll and major natural disasters such as bush-fires. Due to climate change, heat wave mortality is estimated to triple by 2040. Heat stress directly affects the ability of workers to carry out physical work, and the ability of people to exercise for leisure and health. The most vulnerable groups are the aged, the very young and those with a pre-existing disease such as chronic obstructive pulmonary disease (COPD), as well as the disadvantaged. Heat stress is a cumulative process with high night-time minimum temperatures playing an important role. The physiological processes leading to mortality are high body core temperatures and lack of hydration.

There is ample evidence of the adverse health impacts of human exposure to elevated concentrations of air pollutants, particularly ozone, particles with aerodynamic diameters less than 10 µm (PM_{10}) and less than 2.5 µm ($PM_{2.5}$), sulfur dioxide, nitrogen dioxide, carbon monoxide and lead. Worldwide in the year 2000, 0.8 million deaths and 7.9 million disability-adjusted life-years lost from respiratory problems, lung disease, and cancer were attributed to urban air pollution. The Australian Bureau of Transport and Regional Economics estimated that in the country's capital cities health costs from traffic pollution alone are about $3.3 billion per year, and premature deaths attributed to motor vehicles are approximately 1200 each year[8].

Mental health problems comprise at least 14 per cent of the global burden of disease[9] and they are predicted to constitute the second greatest burden of non-fatal disease worldwide by 2030[10]. In Australia, mental health problems are the leading cause of non-fatal disease burden, accounting for nearly one-third of years lost to disability[11]. One in five Australian adults meets the diagnostic criteria for a mental disorder each year. Through direct effects of increased physical trauma and indirect effects on physical health and social and economic well-being, climate change poses mental health risks. These risks are compounded for vulnerable people and in vulnerable places, especially among Aboriginal Australians.

8 BTRE (2005) Health impacts of transport emissions in Australia: economic costs. Working Paper No. 63, Bureau of Transport and Regional Economics, Department of Transport and Regional Services, Canberra.

9 Prince, M., Patel, V., Saxina, S., Maj, M., Maselko, J., Phillips, M. & Rahman, A. (2007) No health without mental health. *The Lancet*, 370, 859-877.

10 Mathers, C.D. & Loncar, D. (2006) Projections of global mortality and burden of disease from 2002 to 2030. *PLoS Med.*, 3(11): e442. Doi:10.1371/journal.pmed.0030442.

11 Mathers, E., Vos, T., & Stevenson, C. (1999) *The burden of disease and injury in Australia*. Canberra, AIHW, Catalogue No. PHE-17.

6.2 ISSUES

Issue 1 – Heat stress

The drivers of heat stress in an urban area occur at multiple scales. At the city scale, the heat load is influenced by water availability and the three-dimensional character of the city that determines the ventilation rate. At the neighbourhood scale, the orientation of street canyons, the presence of impervious surfaces, the use of green space and the availability of open water will lead to heterogeneity in the heat load and ventilation, and hence to the occurrence of local hotspots. At the scale of individual buildings, heat load and ventilation will be affected by the orientation of individual buildings, building characteristics (for example, percentage of glass, type of roofing materials, insulation, thermal mass) and the availability of air conditioning.

The factors determining exposure to heat are well understood. Less well understood are the associated risk factors and the relationship between urban form and heat load, particularly at the building scale. In the short term, adverse health effects may be optimally minimised through policy and behavioural change. Changes in city form may represent a longer term option.

Early warning systems are needed for forecasting heat extremes. These must include well designed and effective intervention strategies. Good risk communication strategies are required to ensure that the vulnerable sections of the population are targeted. Intervention strategies should include the development of support networks for the vulnerable members of society. Cooling centres (such as shopping malls and other enclosed public spaces) form essential places of respite. Telephone support through dedicated 'heat-lines' can provide critical advice. Demand management strategies during heat waves for critical services such as power, water and health may need to be upgraded and made more robust. The improvement of public amenities is essential for heat exposure management. This includes access to public water fountains, toilets and resting places in shaded and well ventilated environments, for example park benches under trees.

For the longer term, there are two general ways in which the intensity of a heat wave can be reduced within an urban area: through urban greening and through urban form. Urban greening results in increased levels of shading and evapotranspiration and leads to reductions in heat load and temperatures. Urban form can be modified to yield optimal ventilation patterns and a resultant reduction in the intensity of the urban heat island.

The exposure of individuals can also be reduced by improving the thermal performance of the buildings that they occupy. This involves both the retrofitting of existing properties and the application of appropriate design principles for new buildings. Reliance on an increased use of air conditioning would likely exacerbate the problem through increasing greenhouse gas emissions and by increasing the likelihood of catastrophic collapse of power supplies.

Issue 2 – Air quality

It will be important to accurately project how pollutant levels and aero-allergens will change over the next 40 years due to urbanisation, land use change and climate change. Further, it needs to be established how changes in extra-urban sources (bushfires, wind-blown dust and background ozone) will impact on the air quality of our cities. Mode shifts in both transport and energy generation can potentially have major impacts on urban air quality and health, and should be carefully evaluated. Particle production and removal mechanisms in the urban atmosphere are likely to change under climate change. The net effect of these changes on total particle concentrations and the consequent health effects are currently unknown, as are the indoor air quality consequences of changes to building performance in response to climate change.

There are complex interactions between urban air pollution and global greenhouse gases and aerosols. The largest uncertainties in global anthropogenic radiative forcing comes from tropospheric ozone and aerosols (particles). Reductions in emissions of urban pollutants such as particles, for example, which have both a negative and positive impact on the radiation balance[12], can affect the radiation balance rapidly, in contrast to any reduction in carbon dioxide. That is, urban air pollutants tend to have short life-times compared with carbon dioxide and most other greenhouse gases.

Many control technologies for air quality improvements can result in small increases in carbon dioxide emissions and other greenhouse gases (for example, catalysts and particle traps for engine exhausts, cleaner fuels which require higher refinery emissions). In assessing mitigation measures at a national policy level, fuel and life-cycle analyses must be applied to power generation and vehicular technologies. However, lack of information makes such assessments difficult. Both air quality and climate change generally benefit from demand management strategies and improvements in efficiency. Overall, behavioural change lies at the heart of measures: a challenge to society.

In the short term, existing emission reduction strategies need to be pursued vigorously. For the longer term, the air quality impacts (and other health co-benefits) resulting from urban development needs to be carefully considered by the planning community during the planning of urban form and transport. More detailed understanding of the interaction between urban air quality, greenhouse gas emissions and the urban ecosystem is required.

A full analysis of both the air quality and climate change impacts needs to be included when analysing specific developments or national policies. For this to occur, standard procedures need to be developed. This would allow the proper analyses of measures designed to improve local air quality or abate climate change, by considering their impacts on the atmosphere and other elements of the local environment.

To further assist, it would be beneficial for the development of better means to quantify the effect of air pollutants on climate (especially aerosols), and to compare of benefits of abatement strategies for both air quality and climate change.

Future climate change policy considerations should include tropospheric ozone and aerosols in the basket of greenhouse species. This approach will ensure that steps taken to improve local and regional air quality will not exacerbate climate change and vice versa. The radiative forcing of aerosols is a particularly important policy consideration.

Issue 3 – Mental health

Epidemiological data allow assessment of the mental health impacts of acute environmental events, such as weather disasters. Less is known about the impacts of chronic or long-term environmental changes, such as declining water supplies, agricultural productivity and incomes. This hampers formal risk assessment since much of the anticipated impact on mental health will be through intervening factors whose relationship with climate change has not yet been quantified. Different categories of mental health risk should be identified, and likely impact profiles should be developed for these categories.

Children are at above-average risk from physico-chemical environmental health hazards arising from climate change because they have potentially greater exposures (for physical, behavioural and biological reasons), and sensitivity (immature physiology and organ systems)[13]. Children's emotional and mental

12 Black soot absorbs solar radiation while other particles, such as sulphates, nitrates and secondary organic particles, are reflective and scatter radiation back into space.

13 Ebi, K.L. & Paulson, J.A. (2007) Climate change and children. *Pediatr. Clin. North Am.*, 54, 213-226.

health may also be affected, reflecting their developing emotional-cognitive functioning and their evolving capacity to understand, act on, and make sense of adversities related to climate change.

Children's dependency on others (especially parents and family) means that there is an additional pathway through which climate change will affect their mental health; that is, through its the impacts on their parents. Parents' mental health profoundly influences that of their children, and these influences may linger for generations. There has been, as yet, virtually no research or modelling of how climate change may affect children and the intergenerational transmission of health and social disadvantage.

As well as making some locations climatically unliveable, climate change could damage livelihoods by increasing the prevalence of poverty in some areas (for example, in rural farming areas). This is already leading to forced internal migration of rural and remotely-located Australians to urban areas, as well as to family separations. For urban children, higher food and fuel prices will compound financial stress on poorer families.

Family dislocations are also more likely for families affected by climate change-related natural disasters. Many children suffer post-traumatic stress disorders after experiencing a natural disaster. Younger children do not have the cognitive ability to comprehend and make sense of disasters that occur to themselves or others; this is especially important if the disaster affects other family members on whom children depend. There is evidence that early exposure to trauma can disrupt neural function and emotional regulation, causing more severe, long-term mental health impact.

These issues associated with children and climate change are not easily quantified. Further studies to provide key data and to improve understanding are required. As children have particular vulnerabilities and will be exposed to climate change risks for their entire lives, it will be essential to include in research planning baby or young child cohorts.

In summary, it is important to integrate mental health within the overall policy development on disaster risk reduction. A critical step is the systematic collection of relevant data in order to understand the epidemiology of climate change and mental health. Other important actions for the community include:

- understanding how climate change affects mental health, particularly in special groups such as children and vulnerable adults;
- understanding resilience (at individual and community levels) and vulnerability, and the role of social capital in both;
- learning how to develop the mental health workforce, especially for primary health care; and
- including communities and stakeholders in research, to learn how they understand climate change risk, their perceived needs, and which groups are at particular risk.

6.3 CONCLUSIONS

In the absence of proactive mitigation or adaptation actions, heat-related mortality and morbidity may triple over the next 40 years, with the potential for catastrophic disasters as experienced in unprecedented heat waves in Melbourne and South Eastern Australia in early 2009. Actions that can be taken immediately to reduce the threat include improving existing warning systems, ensuring that essential services operate robustly during heat extremes, and improving public and private amenities to provide cool refuges. Longer-term changes include reducing urban heat retention through changes to urban form and increased urban greening, and retrofitting and design improvements for individual dwellings.

The cost of urban air pollution in Australia is estimated to be more than three billion dollars per annum, and this is expected to increase under changing demographics and changing climate. There is considerable uncertainty about many natural and anthropogenic influences which need to be resolved to better inform policy development. There can be both benefits and harms from greenhouse gas mitigation actions that impact urban air quality and human health. Integrated assessments are essential to evaluate the benefit of these actions.

Mental health problems comprise at least 14 per cent of the global burden of disease, and climate change poses substantial and additional mental health risks. An understanding of how climate change affects mental health, including special groups such as children and vulnerable adults, and an understanding of how to foster resilience in individuals and communities is essential to Australia's healthy response to climate change.

7 Conclusions

The high degree of urbanisation in Australia, together with the observation that cities are major consumers of energy, water and food and emitters of greenhouse gases, means that managing our cities is an essential national issue as climate change adaptation and mitigation become increasingly important. This report of a workshop held in Melbourne on 8-10 July 2009 identifies a range of actions that need to be taken to ensure that our cities have the resilience required for adaptation to climate change, as well as for the mitigation of greenhouse gas emissions. The report considers activities related to the key functions of:

- climate of urban areas and the impact of urban areas on climate;
- air quality and health in a changing climate;
- building design in a changing climate;
- urban planning and transport systems under climate change; and
- water and drainage systems under climate change.

A number of overarching conclusions are reached through consideration of these functions both individually and collectively. It is clear that an integrated framework needs to be developed for the design and management of our cities covering health, societal, policy, scientific and technological issues in order to account for the strong linkages across city functions. Such integration requires expertise at all levels that recognises and accommodates these linkages. This multi-disciplinary understanding will need to be promoted through education, training and research, and it needs to be appreciated by the general community.

A major implication of climate change is that the inherent uncertainties associated with the planning and management of cities are being compounded, and so cities must be developed under a strategy of adaptive resilience. In order to monitor and assess city developments, it will be important to establish comprehensive observing systems that include, not only the physical, chemical and ecological features of urban areas, but also the wide range of socio-economic data that represent the structure and form of cities and the health of urban populations.

If Australia continues to grow its population and to aim to adapt to and mitigate the impacts of climate change, then it seems inevitable that our urban form will need to become more compact. Such changes will affect building design, transport systems and water management systems, as well as air quality and the health and well-being of citizens. Significant communication strategies would need to be developed to ensure that professional experts, policy makers and the general community understood and supported such change.

Appendix 1
List of Participants

Cities and climate change group

Dr Helen Cleugh, CSIRO, Australia
Professor Andrew Pitman, UNSW, Australia
Professor Nigel Tapper, Monash University, Australia
Dr Raymond Yau, Arup, Hong Kong

Managing urban water group

Professor Richard Ashley, University of Sheffield, UK
Professor Michael Manton, Monash University, Australia
Mr Bruce Rhodes, Melbourne Water, Australia
Professor Patrick Troy, Australian National University
Professor Tony Wong, EDAW AECOM, Australia

Building design group

Dr Peter Graham, UNSW, Australia
Professor Steffen Lehmann, University of Newcastle, Australia
Mr Ken Maher, Hassell, Australia
Mr Haico Schepers, Arup, Australia

Urban planning and transport group

Professor Brendan Gleeson, Griffith University, Australia
Dr Jeff Kenworthy, Curtin University of Technology, Australia
Professor Bill Randolph, UNSW, Australia
Dr Ian Smith, University of West of England, UK
Mr Chris Twinn, Arup, UK

Air quality and health group

Professor Anthony Capon, Australian National University, Australia
Dr Martin Cope, CSIRO, Australia
Mr Chris Eiser, NSW Department of Environment, Climate Change and Water, Australia's
Dr Ian Galbally, CSIRO, Australia
Professor Glenn McGregor, University of Auckland, New Zealand
Professor Neville Nicholls, Monash University, Australia
Dr Marcus Thatcher, CSIRO, Australia

Steering committee

Ian Galbally
Peter Graham
Michael Manton, Convenor
Andrew Pitman
Bill Randolph
Nigel Tapper

Appendix 2 Workshop Program

Day One – Wednesday 8 July 2009

0900-0915	Opening of workshop Professor Robin Batterham AO FTSE FREng
0915-1015	Discussion of climate of urban areas and the impact of urban areas on climate Discussion leaders: Raymond Yau (Arup) and Helen Cleugh (CSIRO)
1015-1045	Morning Tea
1045-1145	Discussion of water and drainage systems under climate change and a carbon-constrained economy Discussion leaders: Richard Ashley (Sheffield University) and Patrick Troy (ANU)
1145-1245	Discussion of building design in a changing climate Discussion leaders: Chris Twinn (Arup) and Steffen Lehmann (University of Newcastle)
1245-1345	Lunch
1345-1445	Discussion of town planning and transport systems under climate change and a carbon-constrained economy Discussion leaders: Ian Smith (UWE) and Brendan Gleeson (Griffith University)
1445-1545	Discussion of air quality and health in a changing climate Discussion leaders: Glenn McGregor (University of Auckland) and Martin Cope (CSIRO)
1545-1615	Coffee
1615-1715	Clarification of issues in preparation for report drafting

Day Two – Thursday 9 July 2009

0900-0930	Clarification of process to prepare report
0930-1030	Writing groups
1030-1100	Coffee
1100-1230	Writing groups
1230-1300	Plenary session to review progress in each group
1300-1400	Lunch
1400-1530	Writing groups
1530-1600	Coffee
1600-1700	Plenary session to review key recommendations from each group

Day Three – Friday 10 July 2009

0900-1030	Identification of gaps and inconsistencies in draft report
1030-1100	Coffee
1100-1200	Resolution of gaps and inconsistencies
1200-1230	Finalisation of key recommendations
1230-1300	Process to finalise report and close of workshop
1300-1400	Lunch

ATSE – in brief

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CLIMATE CHANGE AND THE URBAN ENVIRONMENT: Managing Our Urban Areas in a Changing Climate

The Australian Academy of Technological Sciences and Engineering (ATSE)

ATSE Office
Level 1, 1 Bowen Crescent,
Melbourne VICTORIA 3004,
AUSTRALIA

Mail address
GPO Box 4055,
Melbourne VICTORIA 3001,
AUSTRALIA

Phone
+61 3 9864 0900
Fax
+61 3 9864 0930

Email
elizabeth.meier@atse.org.au

Websites
www.atse.org.au
www.cluniesross.org.au
www.extremescience.com.au
www.stelr.org.au
www.crawfordfund.org