Introduction

The main purpose of this study is to review and synthesize the academic and policy literature relating to adaptation of neighbourhoods and built components of the urban environment to inform the development of the Sydney Climate Adaptation Strategy (SAS). This Report reviews strategies and emerging innovations employed around the globe in adapting built environments and buildings for climate change, and has been prepared to support the development of a Climate Change Adaptation Strategy for the Sydney Metropolitan Area. It presents the argument for why adapting neighbourhoods and buildings now to prepare for future climate changes is not only important but needs to be considered as a current rather than future action in the development and ongoing cycle of refurbishment of the built environment.

Based on the assessment of vulnerability to climate-related impacts for the Sydney Metropolitan Area, the report evaluates options for adaptation of neighbourhoods and buildings across the region, which are called ‘exposures’ in the report.

- Increased temperature;
- Drought and water management;
- Bushfire Risks;
- Severe storms and flash flooding;
- Sea level rise and coastal flooding;
- Urban salinity; and
- Air quality.

Table 2: Prevention actions

<table>
<thead>
<tr>
<th>Prevention measures</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree planting</td>
<td>Creating green space including tree planting to increase shade and coolness in city environments.</td>
<td>Example: Brooklyn Botanic Garden, New York City.</td>
</tr>
<tr>
<td>Water conservation</td>
<td>Implementing water conservation strategies to reduce demand and increase supply of water resources.</td>
<td>Example: Waterwise program.</td>
</tr>
<tr>
<td>Flood defences</td>
<td>Installing flood defences to protect buildings and infrastructure from flooding.</td>
<td>Example: Flood walls in Rotterdam.</td>
</tr>
<tr>
<td>Desalination</td>
<td>Implementing desalination technologies to provide alternative water sources.</td>
<td>Example: Israeli coastal cities.</td>
</tr>
</tbody>
</table>

Table 3: Mechanisms to reduce fuel loads

<table>
<thead>
<tr>
<th>Mechanisms to reduce fuel loads</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vendor Statements</td>
<td>Mandating compulsory disclosure of bushfire hazard and level of compliance</td>
<td>Example: Victoria.</td>
</tr>
<tr>
<td>Abatement Schemes</td>
<td>Supporting an insurance policy that reduces premiums for improved defensible space.</td>
<td>Example: Insurance Premium Discount Schedules.</td>
</tr>
<tr>
<td>Fuel Clearance Regulations</td>
<td>Creating fuel clearance regulations and abatement schemes to reduce fuel loads.</td>
<td>Example: Portland, Oregon.</td>
</tr>
</tbody>
</table>

Table 4: Mechanisms to retard stormwater runoff

<table>
<thead>
<tr>
<th>Mechanisms to retard stormwater runoff</th>
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<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain Gardens</td>
<td>Enhancing the hydrological system by creating rain gardens to soak up stormwater.</td>
<td>Example: Regina, Saskatchewan.</td>
</tr>
<tr>
<td>Green Roofs</td>
<td>Improving the impermeability of urban areas by using green roofs.</td>
<td>Example: Helsinki.</td>
</tr>
<tr>
<td>Permeable Pavements</td>
<td>Reducing the amount of impermeable surfaces, improving infiltration.</td>
<td>Example: Portland’s permeable pavements.</td>
</tr>
</tbody>
</table>

Table 5: Defence strategies

<table>
<thead>
<tr>
<th>Defence strategies</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptive management</td>
<td>Implementing strategies that adapt to changing conditions.</td>
<td>Example: The building’s underfloor displacement system.</td>
</tr>
<tr>
<td>Behavioural change</td>
<td>Promoting changes to human behaviour.</td>
<td>Example: Smart meters.</td>
</tr>
<tr>
<td>Physical barriers</td>
<td>Creating barriers to protect assets from climate-related hazards.</td>
<td>Example: Beach erosion.</td>
</tr>
</tbody>
</table>

Figure 2: Number of hot days in Parramatta (red) and Sydney (blue) from 1970 to 2012 (Steffen and Hughes, 2012)

Figure 3: Adaptation process in climate change

Table 1: Most popular adaptation actions in reporting CDP cities

<table>
<thead>
<tr>
<th>Number of CDP cities</th>
<th>Most popular adaptation actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>The building’s underfloor displacement system.</td>
</tr>
<tr>
<td>21</td>
<td>Creating green space including tree planting.</td>
</tr>
<tr>
<td>15</td>
<td>Enhancing the hydrological system by creating rain gardens.</td>
</tr>
<tr>
<td>15</td>
<td>Improving the impermeability of urban areas by using green roofs.</td>
</tr>
<tr>
<td>15</td>
<td>Mandating compulsory disclosure of bushfire hazard and level of compliance.</td>
</tr>
</tbody>
</table>

Figure 4: Drivers and impacts of urban salinity (DINE, 2006)

Table 6: Energy efficient systems and low-carbon materials strategies

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<tr>
<th>Energy efficient systems and low-carbon materials strategies</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building insulation</td>
<td>Improving the insulation of buildings to reduce energy use.</td>
<td>Example: Low carbon building project.</td>
</tr>
<tr>
<td>Energy efficient windows</td>
<td>Enhancing the energy efficiency of windows.</td>
<td>Example: Low carbon buildings.</td>
</tr>
</tbody>
</table>

Findings and recommendations

The cumulative evidence suggests prudence and advance action to minimize the intense risks stemming from climate change. Therefore to encourage proactive adaptation in response to climate change, governments need not only identify opportunities and ‘risk-prudent’ approaches to deal with specific impacts, but support their adoption:

- Developing a clear framework as a guide for local planning and adaptive action;
- Promoting adaptation strategies across all levels of government and stakeholders;
- Educating communities about climate change risks, such as “understanding” is the first stage of adaptation.

Two important ‘governance’ issues need to be highlighted: Firstly, designing a new strategy, the NSW Government will need to consider the role of existing legislation and Australian buildings standards. Secondly, policy and performance standards are in place that do not directly influence adaptation for climate change. In the same way, the State Government must consider it will continue to encourage or mandate Local Governments across the metropolitan area to develop climate change adaptation strategies addressing vulnerabilities presented within their LAs.
Climate Change Adaptation: Settlements & Communities

Introduction
This report reviews local and international scientific research and professional reports on adaptation to climate change options with regard to settlements and communities. It has been prepared to support effective planning and design of a Sydney Adaptation Strategy for the Metropolitan Area.

Sydney is expected to experience warmer temperatures, more variable rainfall, increased evaporation, rising sea levels and an increased risk of flooding and bushfires in the future. This report examines Sydney’s expected impacts on the key sector of settlements and communities.

The report reviews the options for adaptation of settlements and communities across seven themes in the report:
- Urban Form, Land Use and Sustainability
- Impact of Climate Change on the City Structure
- Temperature and Urban Heat Island Effect
- Bushfires
- Riverine flooding including flash flooding
- Coastal flooding
- Social Impacts and Adaptive Capacity

Emerging Policy and Governance Initiatives

Sydney’s metropolitan planning concepts can be described, in part, as ‘multi-centralisation’, which promote many large regional centres which serve catchment areas across the metropolitan area. Up to a certain degree, urban compactness is not crucially effective, especially in the case of transport if viable public transport options are available, but may decrease green space and increase urban heat island effects and air pollution. To date, most community city planning and design strategies that have incorporated climate change have focused on mitigation and not adaptation.

Studies show that increasing the density in existing areas reduces greenhouse gas emissions due to a decrease with urban heat island effect because such urban heat island effect become more prevalent. Much more research needs to be done on urban climate change adaptation strategies vis-a-vis urban form and structure. To be able to utilize similar strategies and scenarios as using computable climate cycle methods for climate change via an extended ‘cradle to cradle’ approach.

Although there is an increasing amount of research on climate change impacts on human settlements in regard to urban planning, an integrative research framework for adaptation to climate change is needed to develop more robust public strategies, policies, plans and programs, design guidelines and implementation measures.

Temperature and urban heat island effect
Urban form has a significant impact on Extreme Heat Events (EHE). Sprawling suburbs and sprawling cities experience EHE at a higher rate compared to most compact cities, distinct from the urban heat island effect. On the other hand, the lack of vegetative cover and the amount and intensity of built areas are the most factors that contribute to the urban heat island effect (UHI). Air-conditioning units, vehicular usage and the constant use of generators exacerbate the high thermal loads within cities. Figure 3 shows the thermal imaging of Sydney CBD in February 2005, with a temperature range of 22.2 to 20.2 degrees Celsius.

Adaptation strategies include preserving and incorporating more green and green infrastructure, creating light-reflective surfaces on paved surfaces and building rooftops, and creating more compact city forms. Green infrastructure also provides numerous other benefits as part of an ecosystem service.

Hazard reduction
Hazard reduction is an essential tool for managing bush fire risk but it is also high risk, resource intensive intervention with method variation, depending on the area and the management of hazardous vegetation.

Although evidence suggests that community education and public engagement improves preparation and planning for the impact of the events. California has developed the Cal-Adapt Online Tool (Figure 4) to assist in estimating climate change impacts. This online tool provides a self-assessed spatial resolution and an ability to quickly evaluate several climate impacts for any location in California. Questions have been raised concerning both mitigation strategies and the logic of land-use planning decisions that support the continued development of housing and associated infrastructure in bush prone areas, as well as prioritising hazard reduction at the expense of reducing urban density. Place-based planning that is sensitive to bushfires can play a greater role in achieving climate adaptation. Adaptation options include the modification of the urban form to allow for a greater distance between bushland and developments, continuous use of hazard reduction measures, and community education, networks and engagement to encourage householders to implement strategies to reduce the impact of the events.

Sydney Bushfire Climate Change Implications
Table 1 shows the seasonal projections of the maximum and minimum temperature, rainfall and evaporation to 2050, estimated sea level rise, flood and bushfire assessment to 2050 and 2100.

A moderate increase in evaporation is projected for spring and summer, leading to slightly dryer soil conditions. Figure 1 indicates increased run-off during summer and autumn with decreases in winter and spring by 2050.

Sydney Subregions

Temperature and bushfire risk is expected to increase. Extreme bushfire events are expected to occur more frequently and for longer periods within the future, creating increased thermal loads within the city. Figure 4 shows the spatial pattern of Wildfire Risk for California. Overall, the report suggests that adaptation strategies should be developed to address the impacts of climate change on bushfires.

Research Recommendations
Key research priorities were identified throughout the paper and are summarised as follows:

1. There is a need to be able to quantify the impact of adaptation options such as green infrastructure, greening urban spaces or reduction in vehicular usage, however there is not enough research to be done here to understand these effects for Sydney and to apply climate modelling and understanding of thermal norms to practical applications of building design and planning.

2. An understanding of which material and colour of facades that best reflect heat, the impact of building orientation and height on radiant rate compared to most compact cities, distinct from the urban heat island effect. On the other hand, the lack of vegetative cover and the amount and intensity of built areas are the most factors that contribute to the urban heat island effect (UHI). Air-conditioning units, vehicular usage and the constant use of generators exacerbate the high thermal loads within cities. Figure 3 shows the thermal imaging of Sydney CBD in February 2005, with a temperature range of 22.2 to 20.2 degrees Celsius.

3. Bushfire and other hazard planning needs to be more closely linked to community based development of local environmental plans, this includes the responsible state agencies working closely with local government.

4. Explore the economic, environmental and social costs and benefits of zoning flood prone areas in Sydney versus adapting existing buildings in flood prone areas.

5. Developing a set of criteria that are specific to Sydney in order to develop the metro area as a “disaster resistant community”, including urban planning and design guidelines, policies, and strategies.

6. Develop a life-cycle based cost and impact assessment model for climate change in the Sydney metro area.

7. Develop GIS based tools that display and help visualise the projected impacts and effects of climate change in the Sydney metro area.

8. Research that enables the modelling and assessment of degraded behaviours (at the individual human level) of individuals in the face of climate change, such as residential and business location choices, and transport demand.

Overall, we identify three key challenges to incorporate climate change adaptation into land use planning and disaster risk reduction:

1. securing ongoing, sustainable funding for adaptation
2. coordination and need for adaptation to selected officials and local departments
3. gaining commitment and generating appreciation from national government for the readiness of local adaptation challenges.

London’s climate change adaptation strategy centres on the three policy pillars of retrofitting, greening, and cleaner air. Retrofitting London’s buildings reduces London’s CO2 emissions, energy and water use, and reduces energy bills. Greening London reduces the impact of rain and air pollution and makes the city more resilient to flooding and extreme weather such as heatwaves. Greening programs are in place to increase tree cover by five per cent by 2025 (equivalent to one tree for every Londoner) and creating a better network of interconnected, multifunctional and high quality open and green spaces.

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