Cooling Western Sydney

A strategic study on the role of water in mitigating urban heat in Western Sydney

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Cover photo: Parramatta River and CBD

Cooling Western Sydney

This study has challenged conventional thinking around mitigating urban heat, including the way we look at the built environment, energy demand, public health and 'greening' cities.

As part of Sydney's growth, a city the size of Adelaide and Canberra combined is being built now in Sydney's west.

Already facing higher ambient temperatures and overheating in summer, western Sydney is likely to experience extreme weather that may be exacerbated by a more urbanised environment.

With temperatures up to 6 – 10 °C higher in western Sydney during extreme events than they are in the east, there can be up to three times as many heat-related deaths in western Sydney during heat waves than in Sydney's east.

As Sydney experiences more frequent and prolonged heatwaves, it becomes increasingly important to look for new and advanced technologies to help make western Sydney a more comfortable place to live.

Cooling Western Sydney is a Sydney Water study on the role of water and other technologies in mitigating urban heat in western Sydney.

Undertaken in collaboration with the Low Carbon Living CRC and University of New South Wales, *Cooling Western Sydney* draws on leading-edge tools and world renowned expertise in microclimatic research to evaluate the impact of the urban heat mitigation technologies (greenery, water and cool materials) in western Sydney.

Specifically, the project assessed the cooling potential of these mitigation technologies and evaluated their impact on energy, peak electricity demand, health, environment and thermal comfort.

Urban zones where the technologies may present the highest cooling potential were identified and specific implementation measures were proposed.

While greenery does have a cooling effect, the study shows the most effective urban heat mitigation technologies use a combination of water-based technologies including fountains in conjunction with cool material technologies such as cool roofs and pavements.

Integrating these new and advanced technologies into urban design can greatly reduce the impact of urban heat in western Sydney.

This document is designed to communicate the results of the *Cooling Western Sydney* study, and discuss how these outcomes should inform future policy, design, planning and development of western Sydney.

The Problem

- Western Sydney presents 6- 10 °C higher temperature during extreme events in the summer period compared to the eastern suburbs

- Energy Consumption for cooling purposes in western Sydney is up to 100% higher than in the eastern zones of the city

- Heat-related mortality can be up to three times higher in Penrith than at Observatory Hill during heatwave periods

- Peak Electricity Demand increases by almost 100% when temperatures increase from 20 °C to 40 °C

The Role of Water in the Western Sydney Landscape

Western Sydney urban centres and residential areas will be oriented around a blue-green grid of parklands and waterways to provide necessary cooling and amenity. The area will depend on conscious and thoughtful water management in its urban environment to sustain its community, natural environment and economy despite a climate that also features regular cycles of prolonged heatwaves and drought.

The success and productivity of Western Sydney, as part of an international city, will depend on people choosing to live and invest here. The *Greater Sydney Commission's* vision for western Sydney is about fostering this choice, by providing a green, cool and attractive Parkland City.

The area will soon be home to a major airport and will be a key employment zone. But on average, western Sydney's climate is dryer and hotter than the coast, with less rainfall and more days with temperatures above 35 °C. This means the impacts of urban heat and climate change are more pronounced as we move west from the coast.

We need to understand more about how to use water, vegetation and building materials to mitigate the impact of heat in western Sydney. We will need to plan for new and different uses of water, and we may need more water to be made available for cooling and greening purposes.

The city's west includes sensitive flood-prone river catchments, which are already under stress from run-off from urban and agricultural areas, water extraction and sand mining. These waterways must meet the needs of over a million future residents for urban space, amenity and recreation.

Water management in western Sydney will need to:

Respond to climate change and ecosystem stress

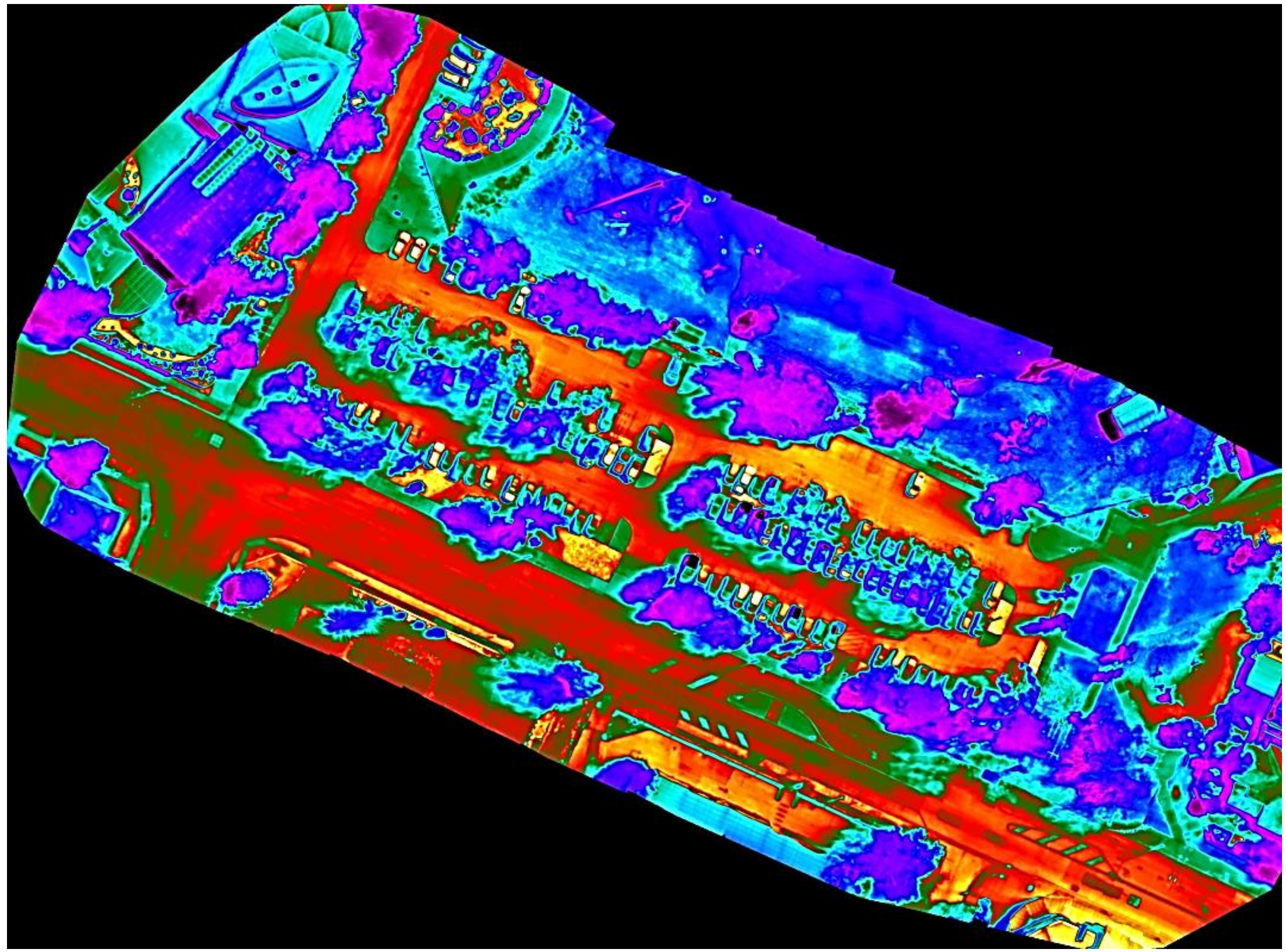
Sustain greening and cooling of our urban environment

Maintain the health and amenity provided by our waterways

We need to ensure that the interventions we choose are effective – there is no point increasing greenspace unless we have the water to sustain it. We also need to be confident that the actions we choose are sufficient to have a real impact on the comfort and wellbeing of western Sydney's communities.

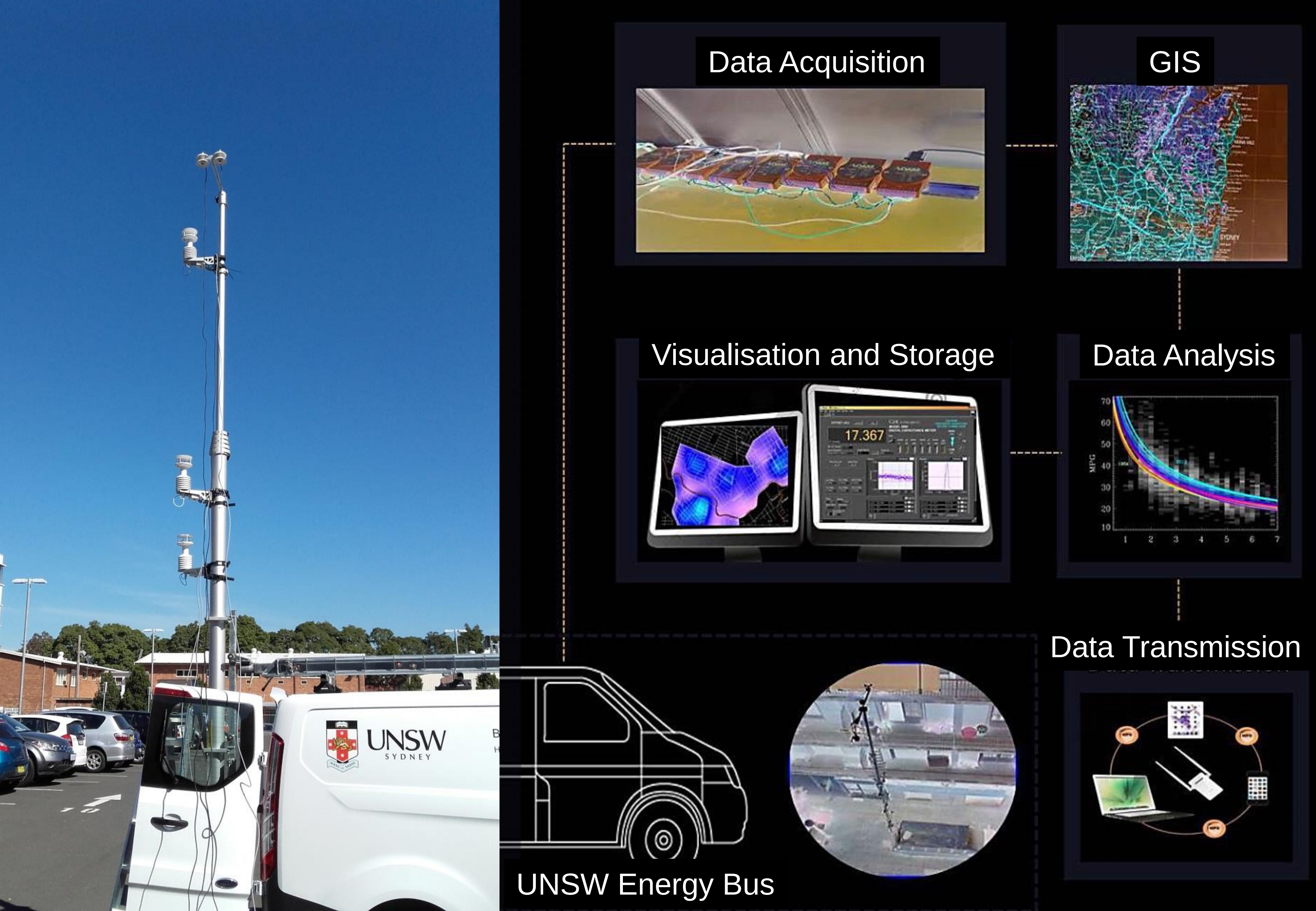
The Urban Heat Island Effect

The Urban Heat Island Effect (UHI) is a local climate change phenomenon whereby urban areas present higher air temperatures than their rural proximities. The difference is often 3-4 °C, but higher peak differences can reach 10 °C.



UHI experimental data has been collected for 101 Australian and Asian cities, and it is showing that UHI is already a major climatic occurrence nationwide with major energy, environmental and health impacts.

Several factors influence the UHI intensity. Maximum intensity always occurs during summer, except in cities with humid climates where the maximum occurs during the dry season. The peak local rise above ambient temperature varies in time; some cities near midday, others during the late afternoon. UHI impacts may also compound by partly carrying over into the next day.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SYDNEY
Data Acquisition
GIS
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Data Analysis
Data Transmission
UNSW Energy Bus

The Study

OBJECTIVES

The main objective of the project was to evaluate the impact of the main urban heat mitigation technologies (greenery, water and cool materials) in western Sydney.

Specifically, the project assessed the cooling potential of these mitigation technologies and evaluated their impact on energy, peak electricity demand, health, environment and thermal comfort.

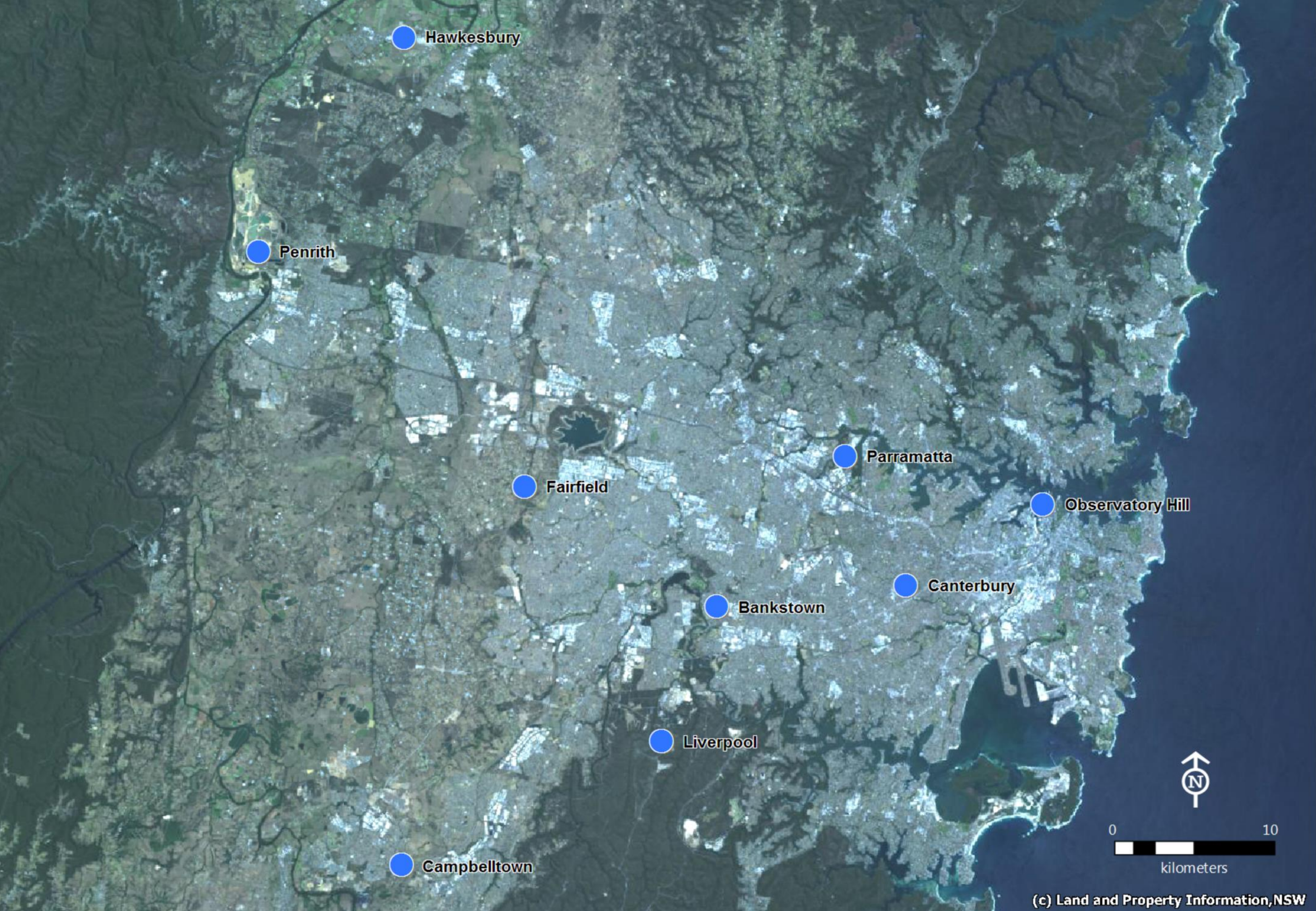
Urban zones where the technologies may present the highest cooling potential were identified and specific implementation measures were proposed.

METHODOLOGY

Weather data was collected from nine study sites in the Greater Sydney area from the Bureau of Meteorology. Mitigation scenarios were created based on past evidence indicating their effectiveness. Advanced microclimatic modelling was used to analyse the cooling potential of the different mitigation scenarios.

To analyse cooling energy loads for each mitigation scenario, three methods were used: empirical literature, cooling degree days and building energy simulation modelling. Semi-hourly electricity demand was obtained from the Australian Energy Market Operator, with which a correlation was found with ambient temperature, and the impact of local climate on peak and total electricity demand was estimated.

Data collected concerning heat-related mortality was correlated with maximum daily temperatures and heat-related excess deaths due to local climate in each study site was calculated for each mitigation scenario. Using the Universal Thermal Comfort Index, which is considered to be the most reliable metric, the impact of local climate on outdoor thermal comfort was assessed..


Hawkesbury
Penrith
Parramatta
Fairfield
Observatory Hill
Canterbury
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Liverpool
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kilometers
(c) Land and Property Information,NSW

Study Sites

Eight study sites were chosen in western Sydney representing different local government areas (LGAs). Data from the Bureau of Meteorology (BoM) weather stations were used in the analysis.

BANKSTOWN

Weather station: Bankstown Airport

Bankstown has been identified by the state government as a major centre in Sydney's south-west region. The average daytime outdoor temperature for the warmest 2017 summer day was 35.5 °C.

CAMPBELLTOWN

Weather station: Campbelltown

Campbelltown's large health and education facilities make it a key metropolis in Sydney's south-west growth corridor. The average daytime outdoor temperature for the warmest 2017 summer day was 35.9 °C.

CANTERBURY

Weather station: Canterbury Racecourse

Canterbury is eastern-most of the weather station used to collect data for analysis of mitigation scenarios. The average daytime outdoor temperature for the warmest 2017 summer day was 33.3 °C.

LIVERPOOL

Weather station: Holsworthy Aerodrome

In Sydney's south-west, Liverpool is a major transport link, commercial hub and health services centre. The average daytime outdoor temperature for the warmest 2017 summer day was 35.9 °C.

HAWKESBURY

Weather station: Richmond RAAF

The northern-most study site chosen, Hawkesbury remains a largely rural area at the fringe of Sydney's metropolitan area. The average daytime outdoor temperature for the warmest 2017 summer day was 37.7 °C.

PARRAMATTA

Weather station: Sydney Olympic Park AWS

Parramatta , the demographical centre of Sydney, is the city's second CBD. The average daytime outdoor temperature for the warmest 2017 summer day was 34.6 °C.

FAIRFIELD

Weather station: Horsley Park Equestrian Centre

Characterised by a mix of residential and commercial developments, Fairfield is a multicultural hub of Sydney. The average daytime outdoor temperature for the warmest 2017 summer day was 36.4 °C.

PENRITH

Weather station: Penrith Lakes

As the western-most study site, Penrith has the hottest summer days of the eight chosen sites. The average daytime outdoor temperature for the warmest 2017 summer day was 37.5 °C.

* *Observatory Hill has been used as a reference for heat related mortality and peak electricity demand*

UHI Mitigation Strategies

Extensive research has been carried out to identify and test a range of countermeasures to local overheating. Actual precinct applications to date have demonstrated 2.5 °C reductions of the peak ambient temperature. However, intensive research is still needed to achieve widespread, affordable implementation and even better performance if the twin challenges of dramatic increases in urbanisation and climate change are to be manageable.

WATER

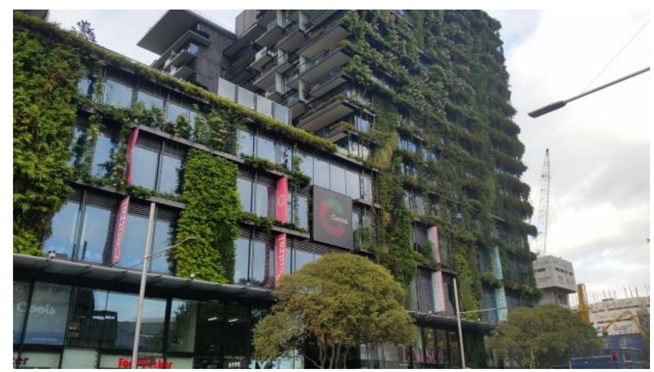
The mitigating potential of water-based techniques has been thoroughly investigated by studies analysing the temperature patterns in cities surrounded by lakes, rivers and other water reservoirs. It is a common conclusion that urban wetlands contribute to create 'Urban Cooling Islands' resulting in a significant decrease of the urban temperature.

Apart from the natural water bodies in the cities, various technologies or techniques based on the evaporation of water, are used to design and integrate urban evaporative cooling systems able to decrease the ambient temperature. A variety of passive systems like pools, ponds and fountains are widely used in public spaces for decorative and climatic reasons, while active or hybrid water components like evaporative wind towers, sprinklers and water curtains have been developed, installed and tested in urban public spaces around the world.

GREENERY

Urban greenery can bring about benefits to the microclimate through processes of shading, evapotranspiration, regulation of the air movement and heat exchange. These benefits also greatly contribute to a decrease in ambient temperatures in the adjacent urban zones while helping to mask urban noise, filter urban pollutants, prevent erosion, stabilise the soil and also provide relaxation to the visitors.

Urban greenery offers an important mitigation potential in cities. The exact contribution on the climate quality of a city depends on complex regional and local factors like the size and structure of the greenery, the local weather conditions, the type of plants used, the watering frequency, the thermal balance around the planted zone, and the thermal characteristics of the whole city. Most of the existing studies aiming to identify the proper size of urban greenery concluded that the larger the green area the higher its mitigation potential is.

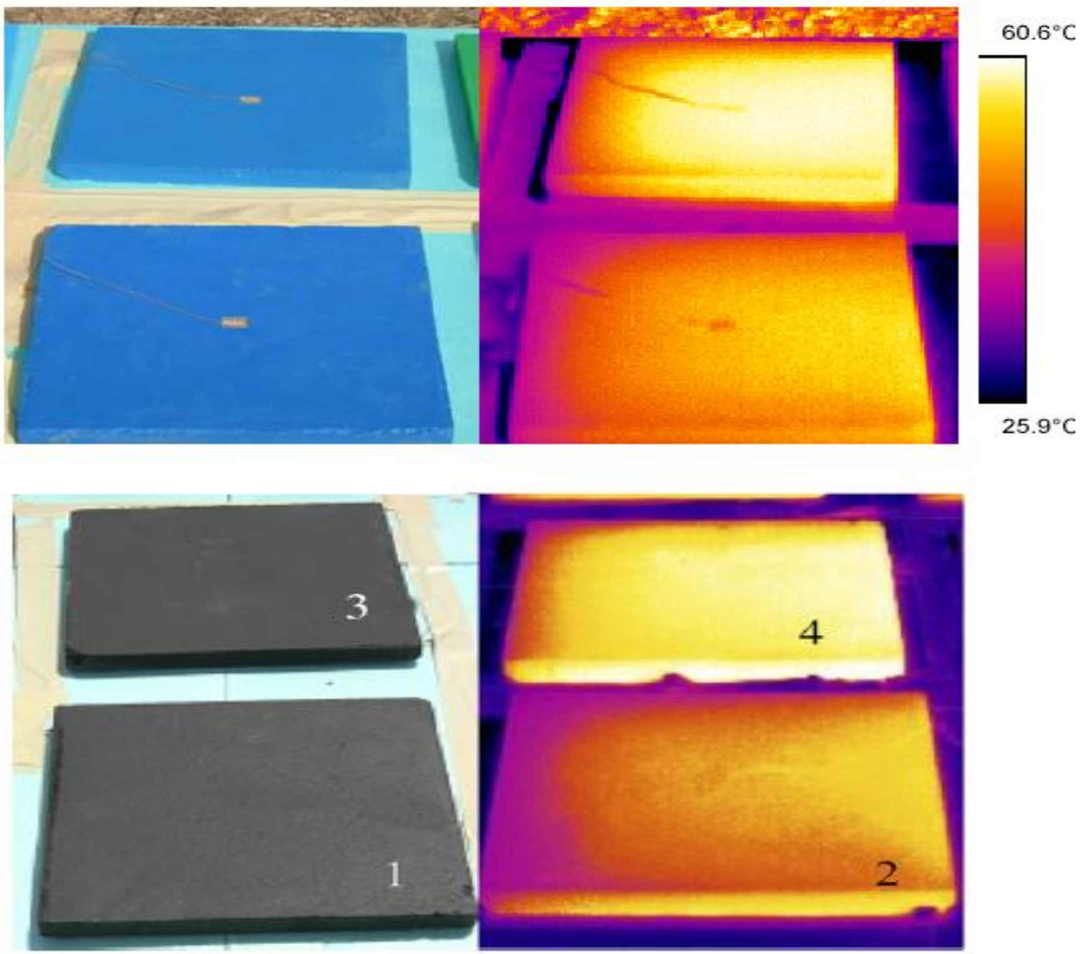


COOL MATERIALS

It is well known and documented that large-scale change of albedo has a serious impact on the local peak ambient temperature. Increase of the albedo in a city will help prevent solar radiation from being absorbed. This can be achieved using materials of high diffuse solar reflectivity and high emissivity value, known as cool materials.

The specific materials should be applied mainly in roofs, pavements and all other horizontal surfaces in the city, eg. pavement tiles, paints and membranes.

Cool materials usually present a light color, but darker colored materials can be used, provided that they present a high reflectivity in the infrared spectrum. The possible increase of the albedo of the vertical surfaces has to be moderate to avoid problems of glare and contrast.



THE STRATEGIES

Six models were considered to determine which mitigation strategies were the most successful in the eight precincts in western Sydney:

1. Reference – Albedo of walls and roofs=0.2, Asphalts Albedo=0.05, Concrete pavements Albedo=0.15, Loamy soil Albedo=0.15, Grass is used as greenery

2. Greenery – Increased urban greenery by planting a high number of mature trees in the area

3. Cool materials – Increased global albedo=0.5 by applying cool roofs and pavements in the area

4. Water – Use of evaporative cooling techniques by installing water fountains in numerous locations in the area

5. Combined scenario 1: Greenery and Water

6. Combined Scenario 2: Cool materials and Water

Combining cool materials and water-based technologies was the most effective strategy to mitigate the negative impacts of urban overheating on ambient temperatures, energy, peak electricity demand, heat-related mortality and thermal comfort

Results

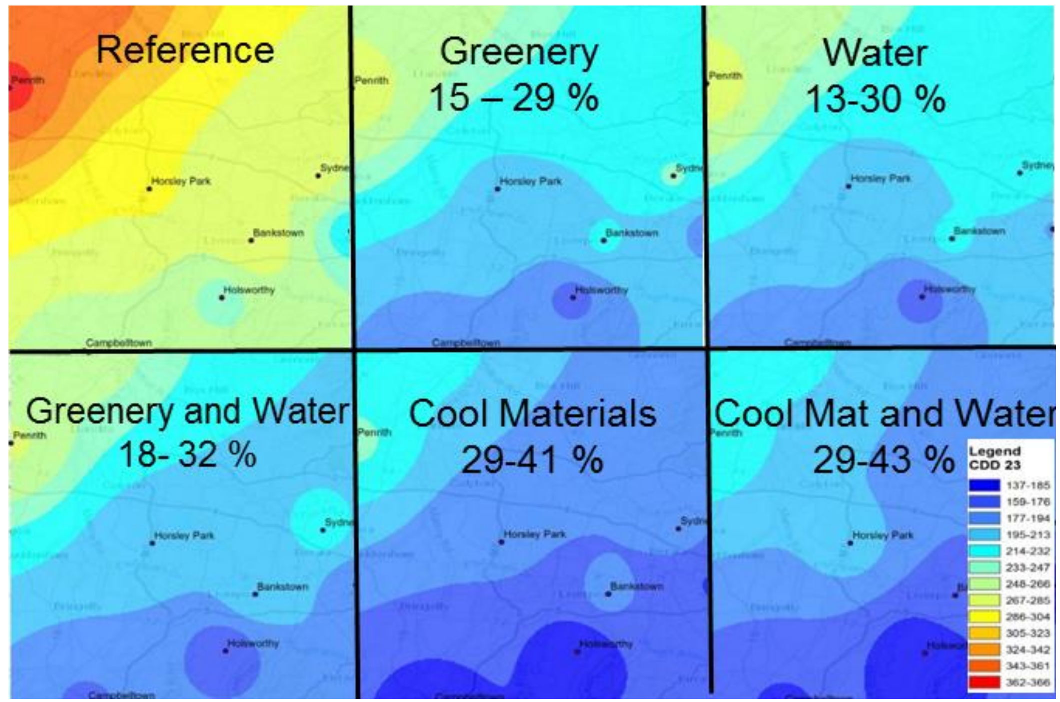
In general, the precincts located further away from the coast such as Penrith and Hawkesbury, are more exposed to higher summer temperatures, cooling energy needs, peak electricity demand, thermal discomfort and heat-related mortality rates in summer compared to the areas located closer to the coastal areas.

This is explained by the prevailing climatic patterns in Sydney characterised by hot westerly winds predominantly in summer, combined with the absence of the sea breeze penetrating inland and cooling these areas.

Appropriate UHI mitigation strategies can be very effective in lowering ambient temperatures and reducing the negative effects of urban overheating.

Higher reductions have been achieved by the scenario of water-based technologies combined with cool materials. More specifically, it was found that increasing the global albedo to 0.5 by the large scale application of cool materials and implementing water-based technologies may result in an average air temperature reduction of 1.5 °C in the area, with local reductions close to the water reaching 10 °C.

At the same time, the surface temperature decreases by an average of 10 °C, indicating lower heat release to the surrounding environment through radiation and convection.



Spatial distribution maps showing the reduction in Cooling Degree Days when comparing the reference case to the various mitigation scenarios. The combination of cool materials and water presents the greatest reduction of 29-43%.


Mitigation techniques based on the use of water,
greenery and cool materials can reduce the average
peak ambient temperature up to 2.5 ºC

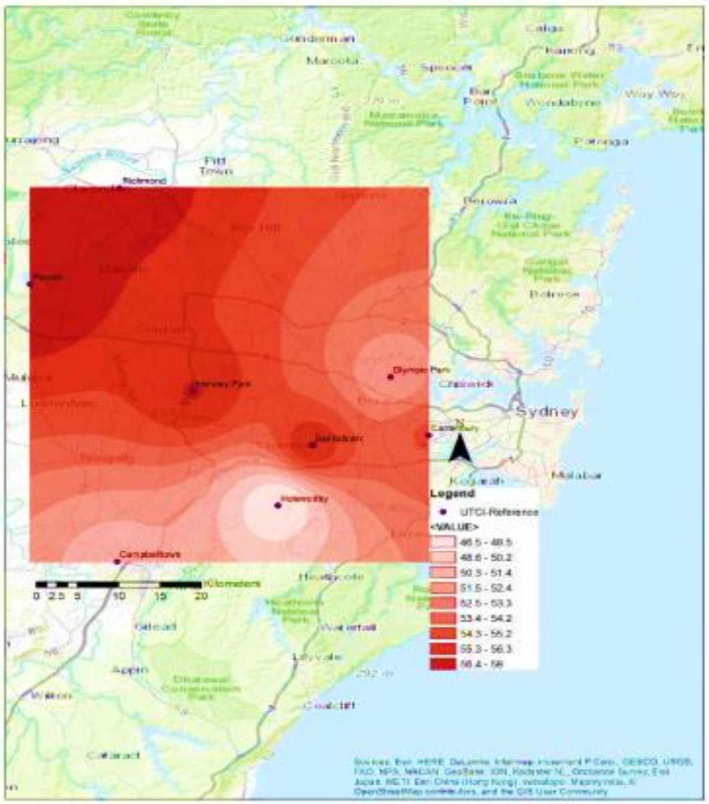
THERMAL COMFORT

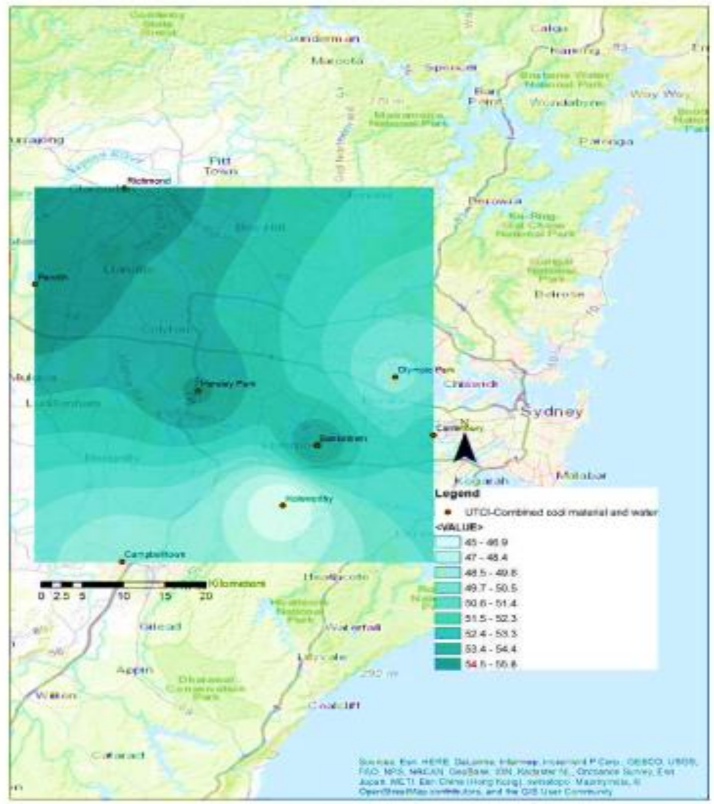
It will be critical for temperature peaks to be reduced to improve the thermal comfort for people living in western Sydney with the possibility of prolonged heatwaves in the near future.

To evaluate the impact of mitigation techniques on human thermal sensation, the outdoor thermal comfort index, Universal Thermal Climate Index (UTCI), was used.

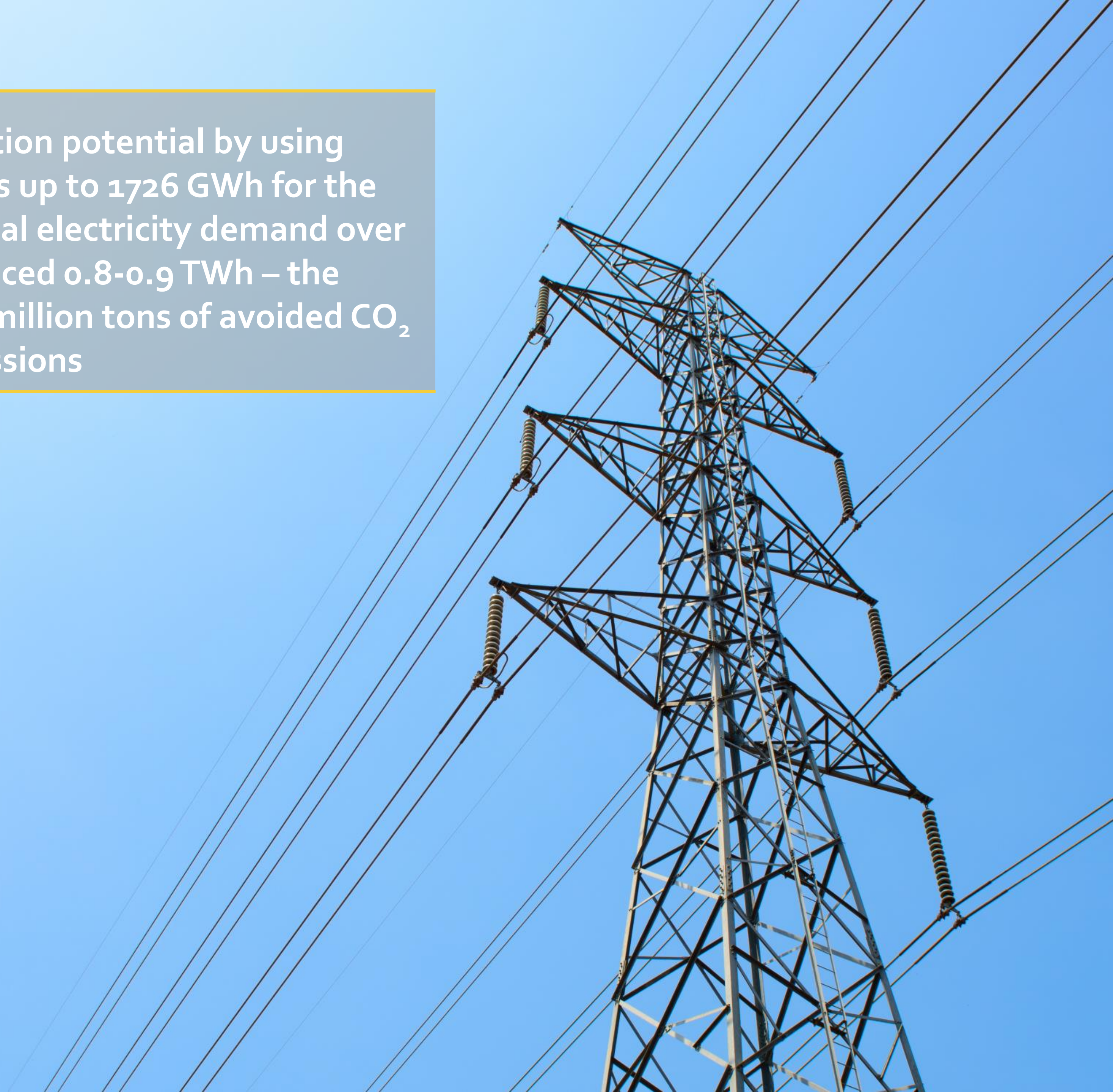
The far west Sydney precincts were exposed to higher rate of UTCI than the cases that were closer to the coastal area. For instance, Penrith was projected to have the highest unmitigated case), whilst Holsworthy and Campbelltown were predicted to have the lowest UTCI distribution (unmitigated scenario).

The combined use of reflective cool materials and water-based technologies was found to be the most effective scenario to improve the microclimate of urban areas, presenting the highest rate of UTCI reduction in the area compared with the other mitigation scenarios – on average 2 °C reduction in the far west.





The energy conservation potential by using mitigation techniques is up to 1726 GWh for the western Sydney area. Total electricity demand over summer may be reduced 0.8-0.9 TWh – the equivalent of nearly one million tons of avoided CO_2 emissions



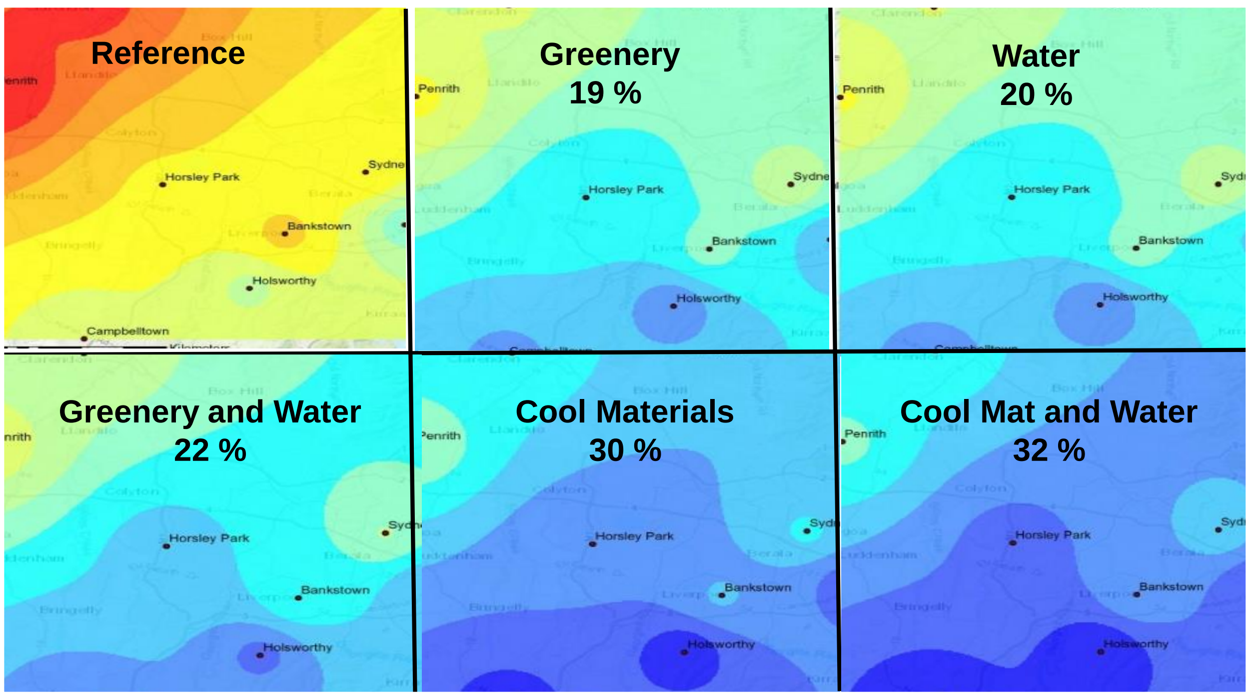
ENERGY DEMAND

Precincts located further inland in the western-northwestern part of Sydney have higher needs for cooling for the buildings compared to the rest of the studied locations due to local climate patterns and topography. Residential and commercial buildings will consume 64% and 44% more energy for cooling, respectively, if located in the far west.

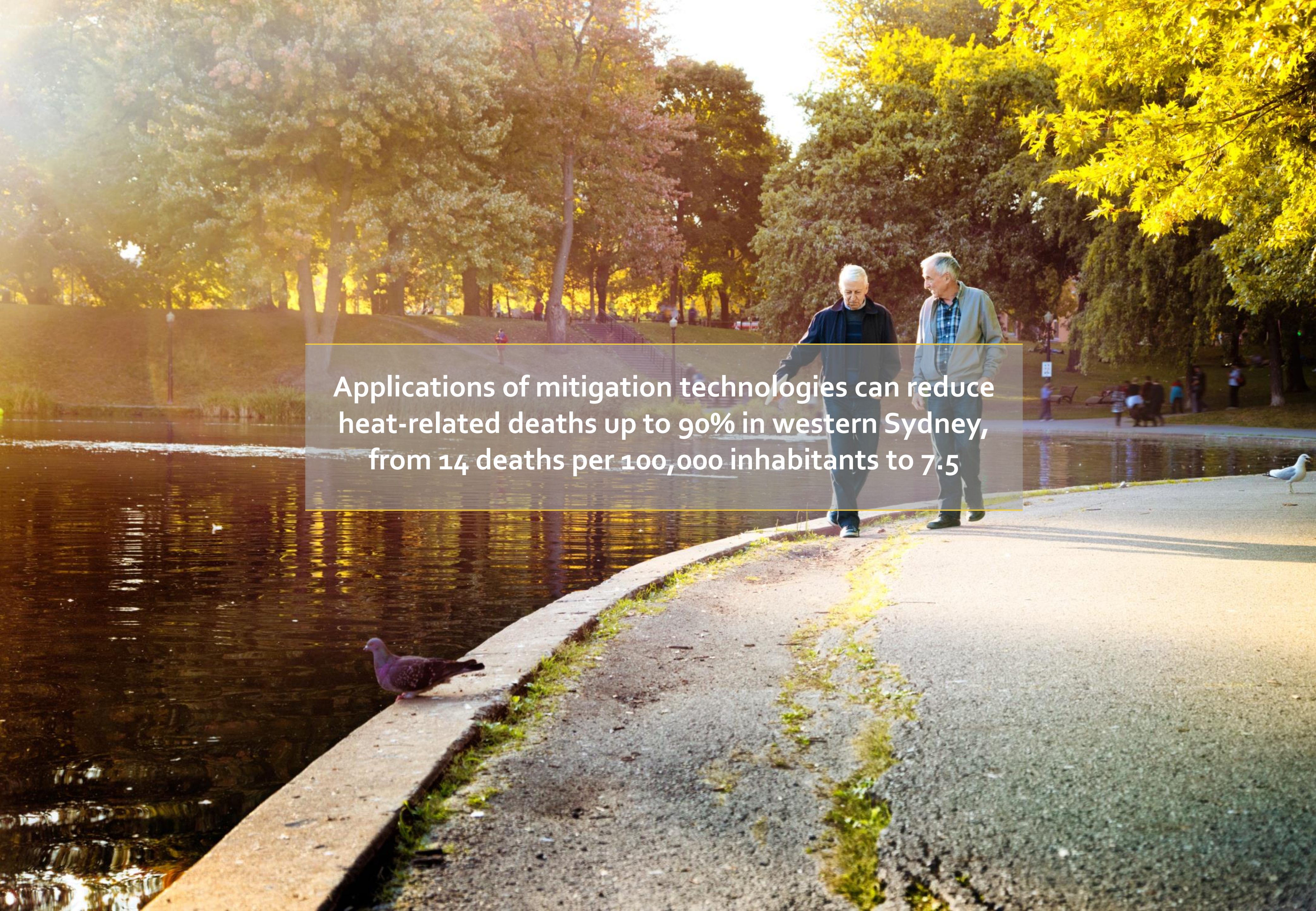
The global cooling load savings for residential and commercial buildings for the whole area of western Sydney resulting from the application of water-based technologies and cool materials combined is estimated to 1726 GWh on an annual basis. The same mitigation scenario would result in a 36% decrease of CDD (Cooling Degree Days), (indicator of severity of climate and cooling energy needs).

The considered mitigation technologies are found to be effective in reducing peak demand, the most relevant benefit of the mitigation of local climate in terms of electricity demand. The maximum reduction of the peak demand is 5%, achieved by using cool materials and water-based technologies.

With the most effective mitigation strategy, the combination of cool materials and water, it is possible to reduce the peak electricity demand by 1.2 GW, 9% of that in the unmitigated scenario. These avoided total electricity demand correspond to 0.8-0.9 million tons of avoided CO2 emissions of electricity produced by coal-fired power plants.



Distribution of the energy consumption of a typical office building in Sydney



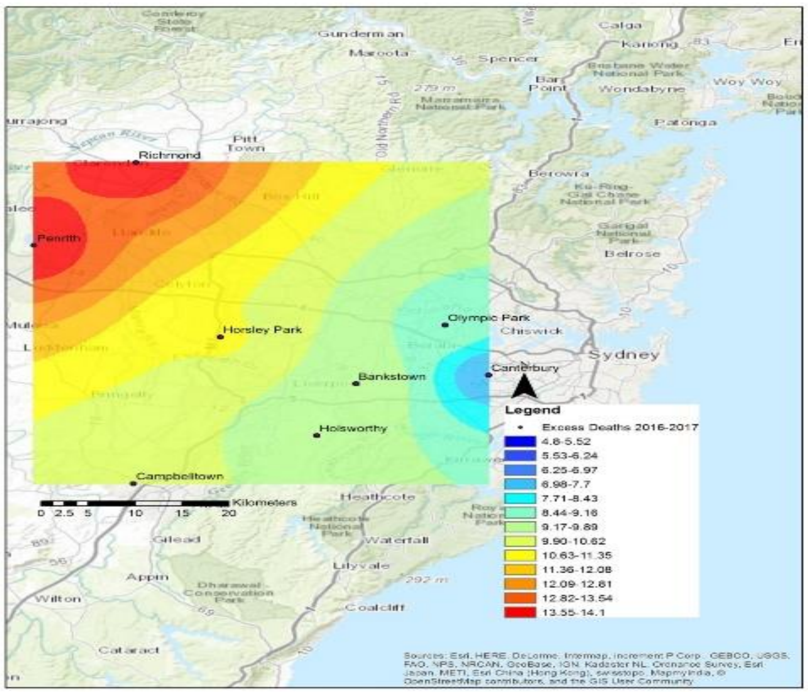
Applications of mitigation technologies can reduce heat-related deaths up to 90% in western Sydney, from 14 deaths per 100,000 inhabitants to 7.5

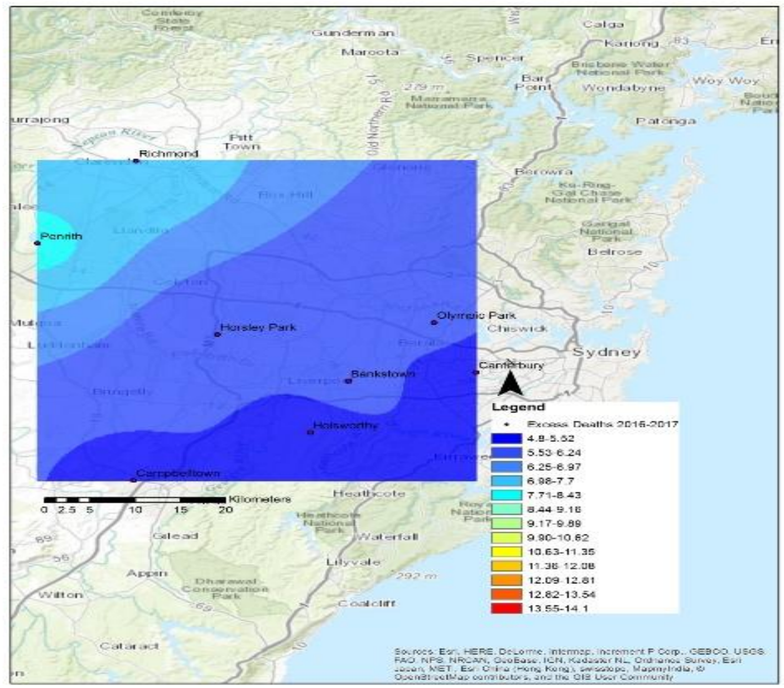
HEAT-RELATED MORTALITY

In the hottest precincts, even with the mitigation strategies, the mortality exceeds that in the unmitigated condition in precincts closer to the coast. The reductions, however, are significant.

By creating a cooler, more liveable western Sydney, the effects of extreme heat may be dramatically reduced. This, in turn, takes the pressure off essential medical services.

Considering the summer of 2016-17, which presented severe hot spells, the most effective mitigation strategy was the combined use of cool materials and water. This strategy can lower the cumulative heat-related deaths in the far west from 14 to approximately 7.5 deaths per 100,000 inhabitants. Closer to the coast, heat-related deaths are lowered to approximately 5 deaths per 100,000 inhabitants.





Calculated heat-related mortality before and after the application of the mitigation technologies

Opportunities for Integrated Water Planning

This study shows that incorporating a multi-faceted approach to reducing urban overheating will provide more comfortable thermal conditions for residents in western Sydney.

This is a new way forward that focusses on making western Sydney a more liveable and climate resilient part of our city.

Sydney Water plays a key role in the future development and shaping of a cooler western Sydney. We lead innovative research that looks at adapting essential water and wastewater infrastructure and services to meet future climate challenges to contribute to a climate-resilient future Sydney.

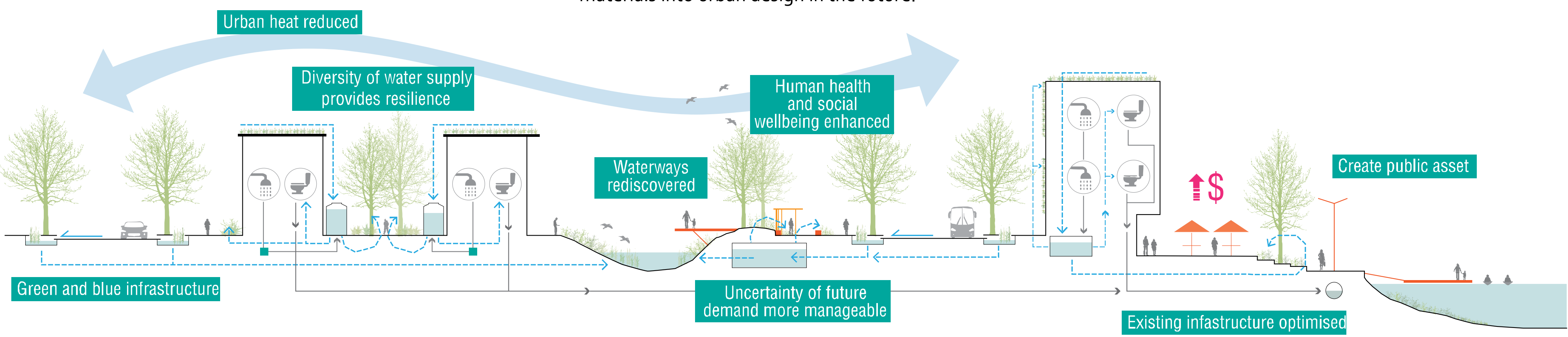
GREENING IS NOT THE ONLY ANSWER

While greenery does have a cooling effect, the study shows the most effective urban heat mitigation technologies are those incorporating a combination of water-based technologies with cool materials. Integrating these new and advanced technologies into urban design can greatly reduce the impact of urban heat in western Sydney.

There is a strong desire amongst government organisations and the community to move towards improved inter-agency collaboration of industry leaders in urban planning. This would allow stronger links between State and local government planning processes and effective planning policies to be put in place to ensure developments integrate the use of cool materials into urban design in the future.

KEY OPPORTUNITIES

1. Embed water-based technologies into district plans and planning instruments
2. Improve interagency cooperation and alignment for water infrastructure planning and delivery
3. Lead the reform of finance and governance arrangements for delivery of green and blue infrastructure
4. Strengthen the implementation of District and Local Plans to facilitate improved water sensitive outcomes and contribute to urban heat mitigation



Think Local, but Act Global

Large geographical and meteorological forces dictate weather patterns and thermal comfort in western Sydney. On one side western deserts generate hot desert winds, while on the other, the Pacific Ocean generates cool ocean breezes.

Trapped in the middle and bounded by the Blue Mountains and Sydney's CBD, western Sydney can receive little respite from ocean breezes and southerly winds.

Strong UHI factors in the CBD of Sydney can delay and even block the inflow of the sea breeze into western parts of Sydney.

Cooling Western Sydney is therefore a whole-of-Sydney issue. We must **think locally, but act globally** – Cooling western Sydney may also mean cooling eastern Sydney and its CBD.

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