URBAN MICROCLIMATES: RETROFITTING AUSTRALIAN PRECINCTS FOR HEATWAVE RESILIENCE

PHD RESEARCH

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25 Augustus 2014

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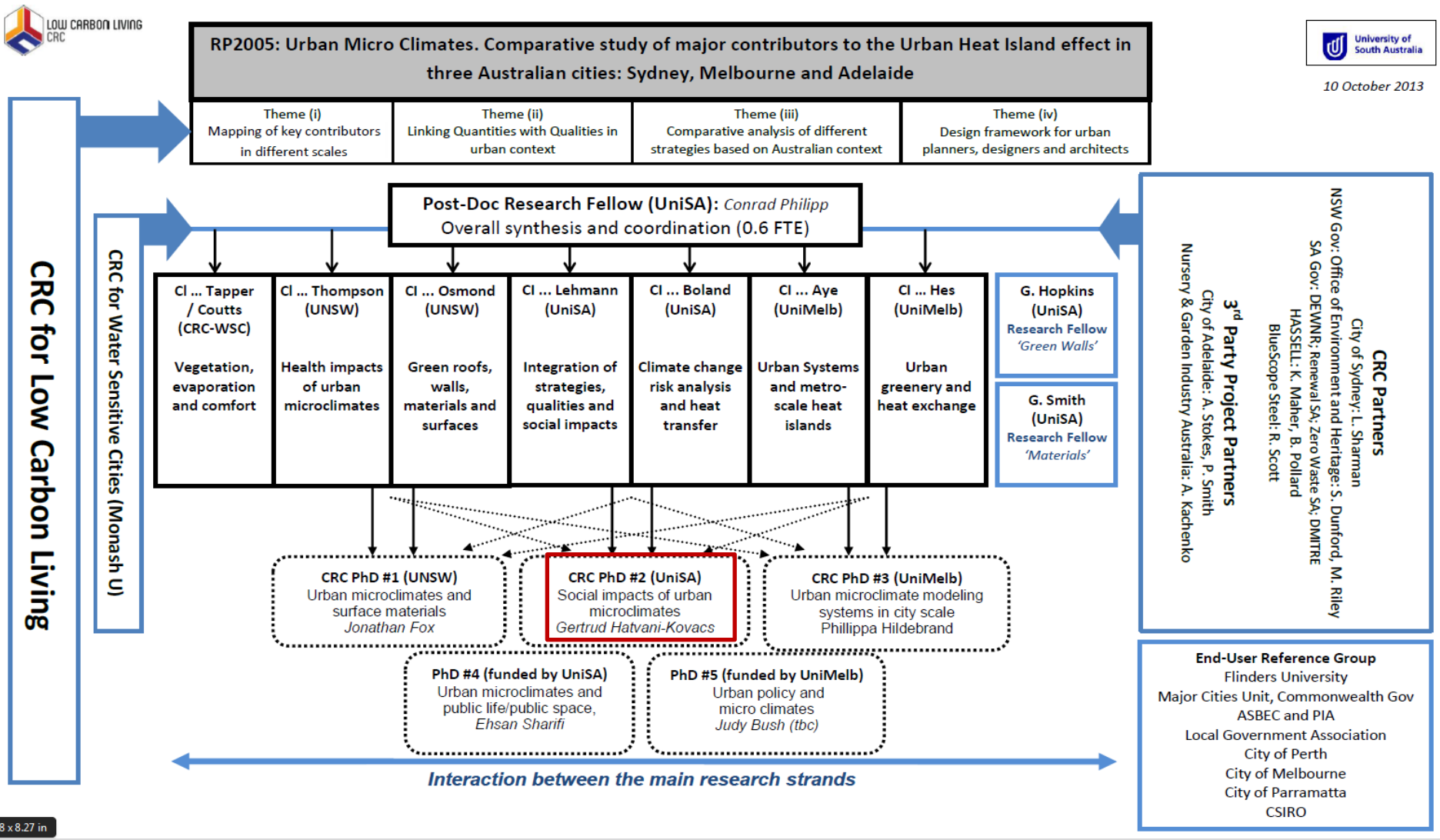
Started the PhD candidature:
02 September 2013

LOW CARBON LIVING CRC

UCR Urban Climates Research

UniSA Zero Waste SA Research Centre for Sustainable Design and Behaviour



The project CRC LCL project on Urban micro climates : Comparative study of major contributors to the UHI effect in three Australian cities: Sydney, Melbourne, Adelaide

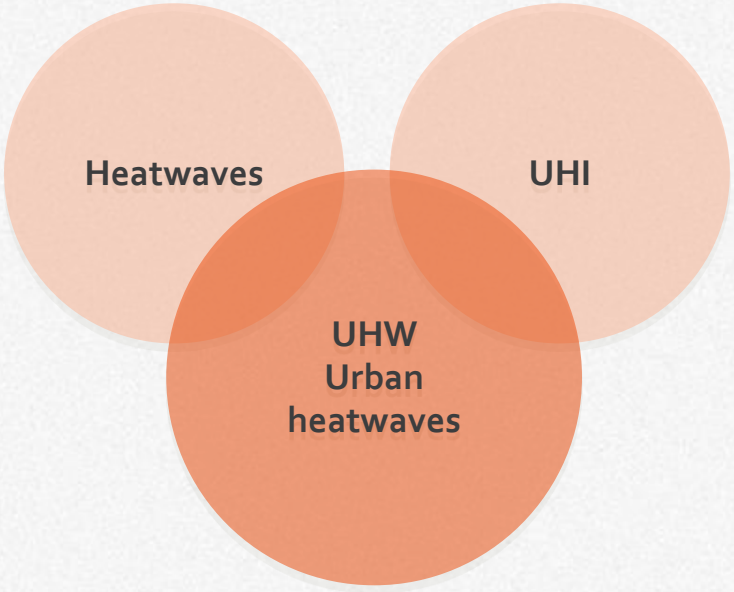
The increased GHG emissions will potentially raise the overall temperature in Australian cities by up to 1.2°C by 2030, up to 2.2°C by 2050 and up to 3.4°C or more by 2070 (CSIRO 2007a, p.124; 2007b).

The risk of climatic extremes is growing (Frich et al. 2002, 209) .

The frequency and intensity of heatwaves in Australia and globally are rising (Alexander et al. 2007, 17; Nairn and Fawcett 2013, 29).

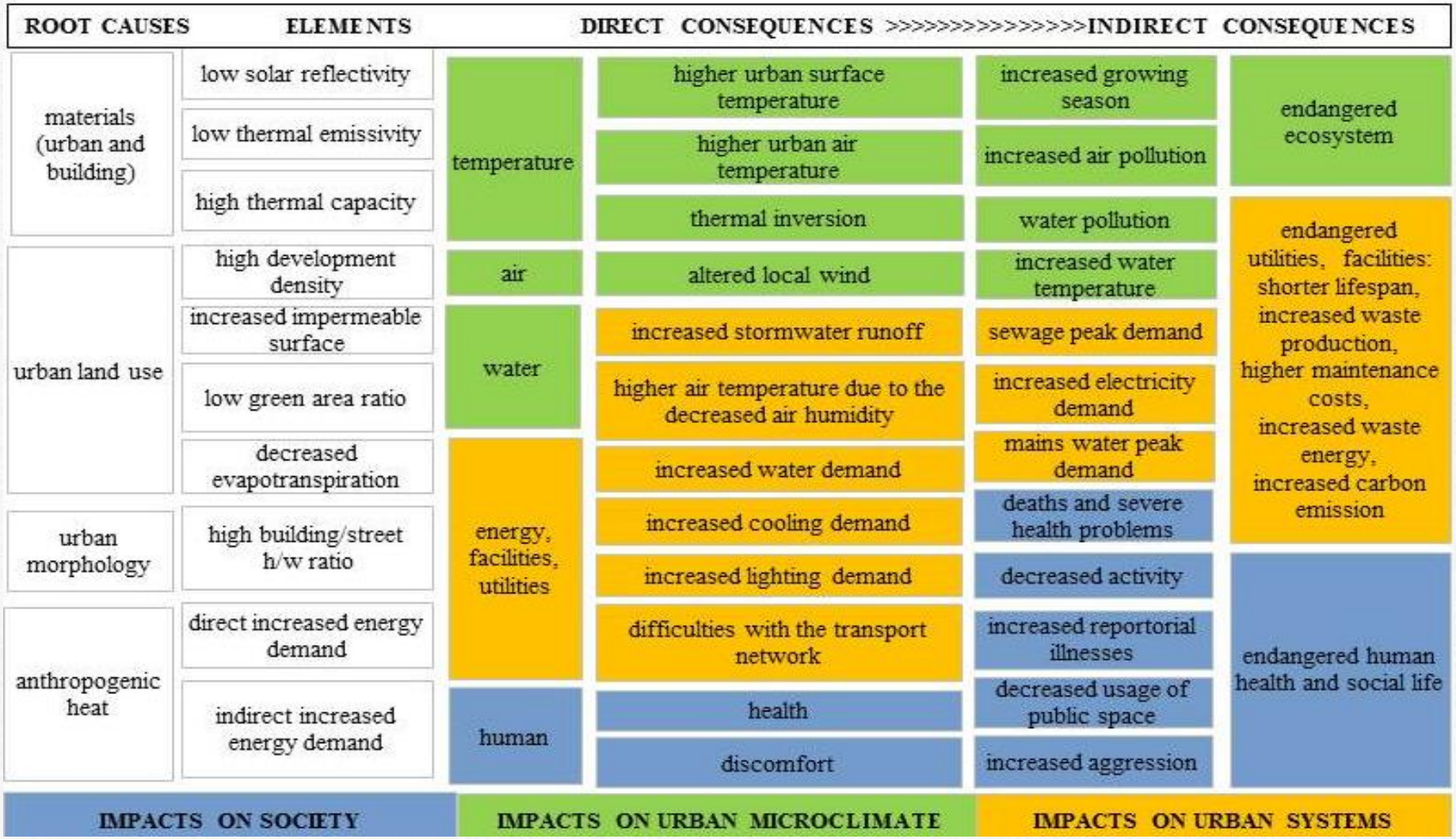
The urban heat island (UHI) is the discernible temperature difference between urban and rural areas, peaking at late evening and night caused by the excess urbanisation (Gartland 2008, 2).

In particular, Australia is exposed to urban heatwaves due to its high-degree of urbanisation; in 2011, 89 per cent of Australians lived in cities (UN DESA 2011, Appendix File 1).



The problem

Urban heatwaves (UHWs): The combined impact of urban heat island and heatwaves.



The causes and consequences of Urban Heatwaves

Mainly **psychologists, public health scientists and climatologists** have investigated so far the population vulnerability to heatwaves, focusing on the impacts of socioeconomic factors on mortality and morbidity rates.

*Neither the findings for **socioeconomic vulnerability** nor real-world **thermal perception** have been integrated in the evaluation of mitigation techniques.*

UHI literature exists on city, building, public space or canyon-scales. **Precinct analysis** provides the opportunity to examine the relationship between indoor and outdoor spaces within UHIs.

UHI research concentrates on city centres and neglects **suburban** areas.

Existing building stock is a major burden on sustainable development. Therefore, **retrofitting** has to be explored in association with UHW mitigation.

The characteristics of the **daytime and the night-time UHIs** and their impacts on the citizens are divergent. Therefore, precinct function conscious mitigation is essential.

*Studies mostly focus on one particular city and miss the opportunity of UHI comparison in **various climates**.*

Identified research gaps and questions

RQ1. What are the most economically and socially feasible mitigation techniques for retrofitting the existing building stock in Australian context in order to increase its resilience against heatwaves?

RQ2. What are the social and economic factors of the inhabitants that influence precincts' resilience to heatwaves?

RQ3. How and to what extent could heat resilient retrofitting techniques contribute to the decrease of energy consumption and the reduction of greenhouse gas emissions in Australian cities?

Research questions

How can we measure the intensity of heatwaves?

$$EHF = EHI_{sig} \times \max(1, EHI_{accl}).$$

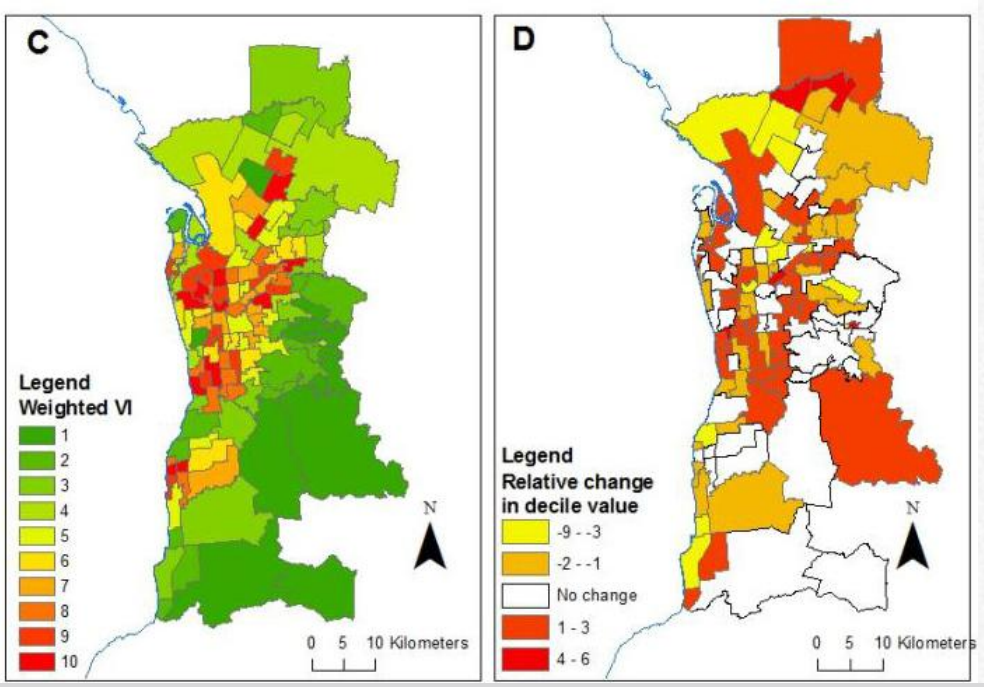
Adopted from (Nairn & Fawcett 2013)

- uses **daily mean temperature,** not just daily maximum
- Excess heat factor (EHF) compares three days daily mean temperature (DMT) with the climate specific temperature (**recent 30 days and 30 years**).
- enables the comparability of HWs **in different climates**.
- clear correlation is proved between **mortality and EHF**

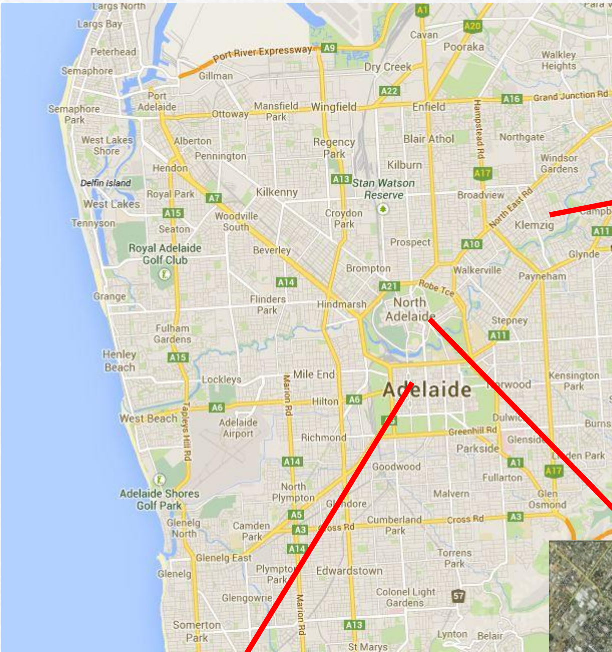
Vulnerability mapping

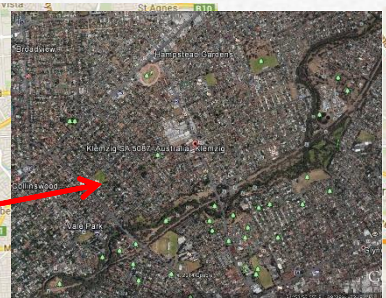
- weighted **vulnerability index** is calculated
- comprehensive research about the Australian capitals
- **EHF** could not be used
- different **mortality** data were used for each city because of the limited data availability
- only **one BOM station** is used for each city
- population is calculated based on **residential address**

Adopted from (Loughnan & Tapper 2013)

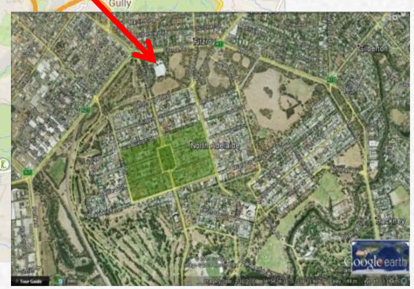


Essence of the literature review

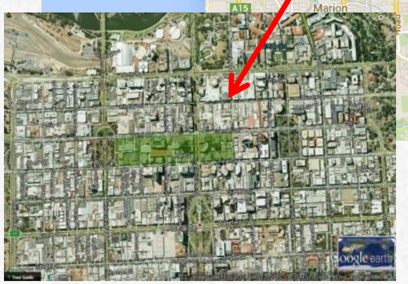




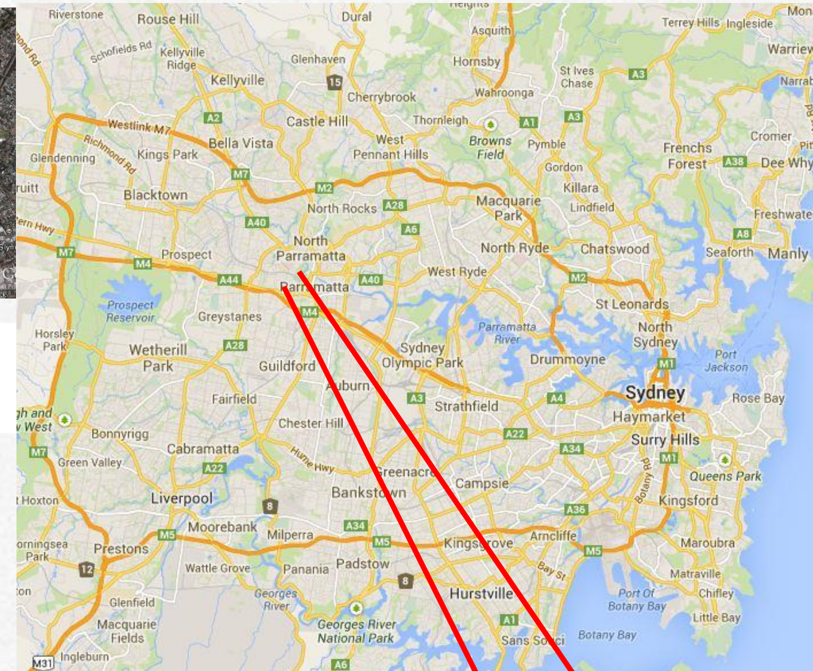
Klemzig, SA
at night-time



North Adelaide, SA at night-time



Adelaide CBD, SA
at daylight



Commercial Parramatta, NSW at daylight
Residential, Parramatta, NSW at night-time

Case study locations

Case study research method:

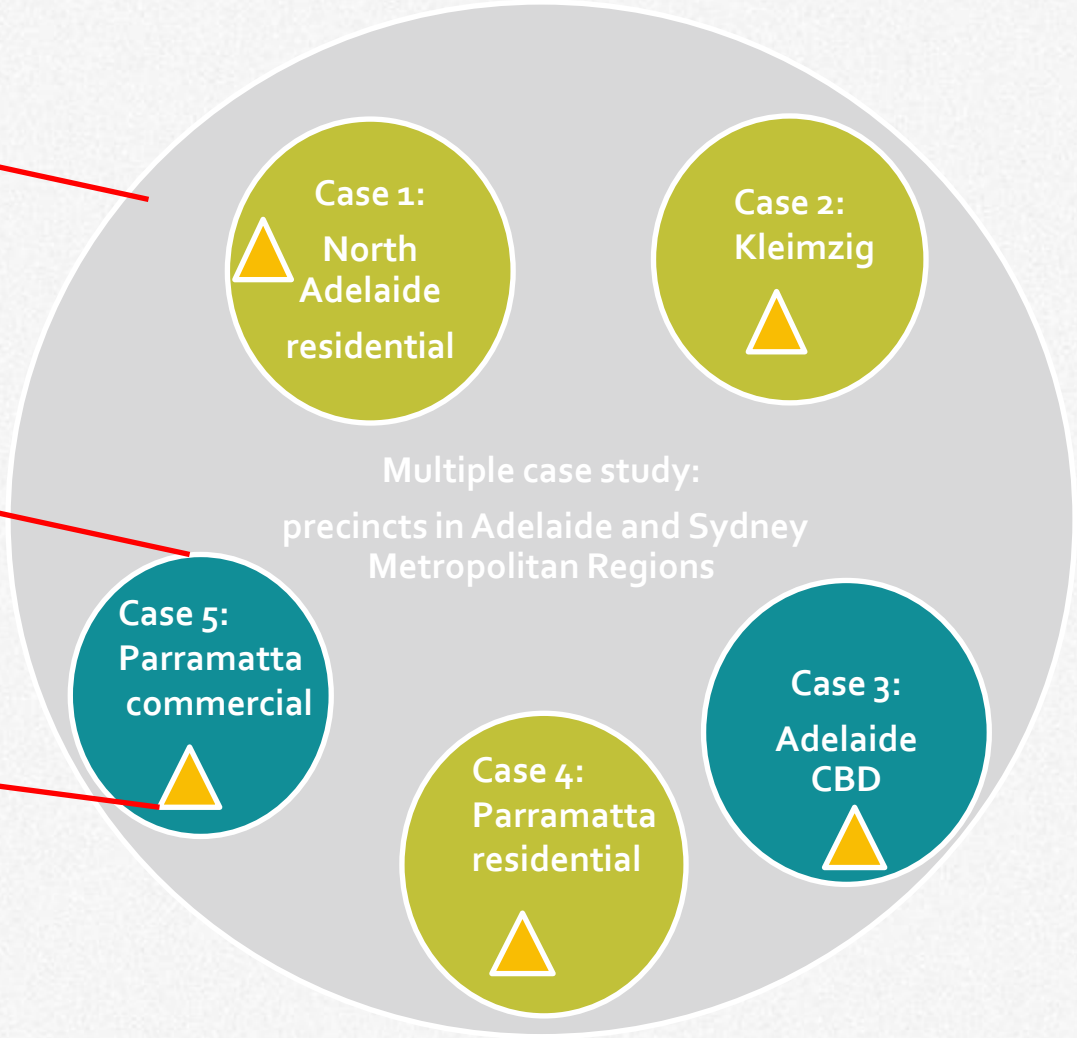
- explanatory case study
- low level of controllability
- focus on contemporary events
- complexity of real life

Each case study is a natural experiment:

- statistical control is applied
- longitudinal design is accommodated

Survey :

- To explore heatwave perception
- To explore the acceptability of different retrofitting techniques

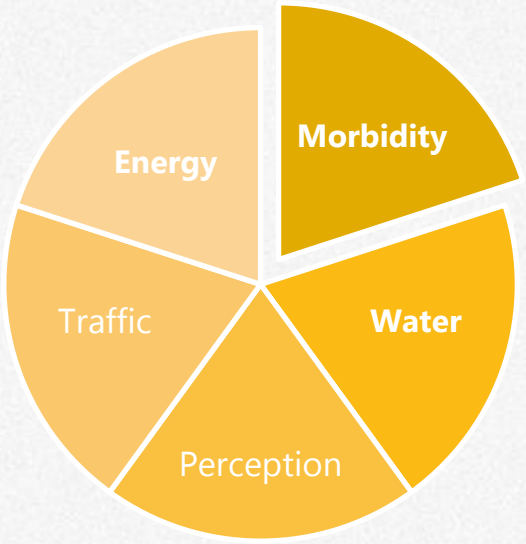


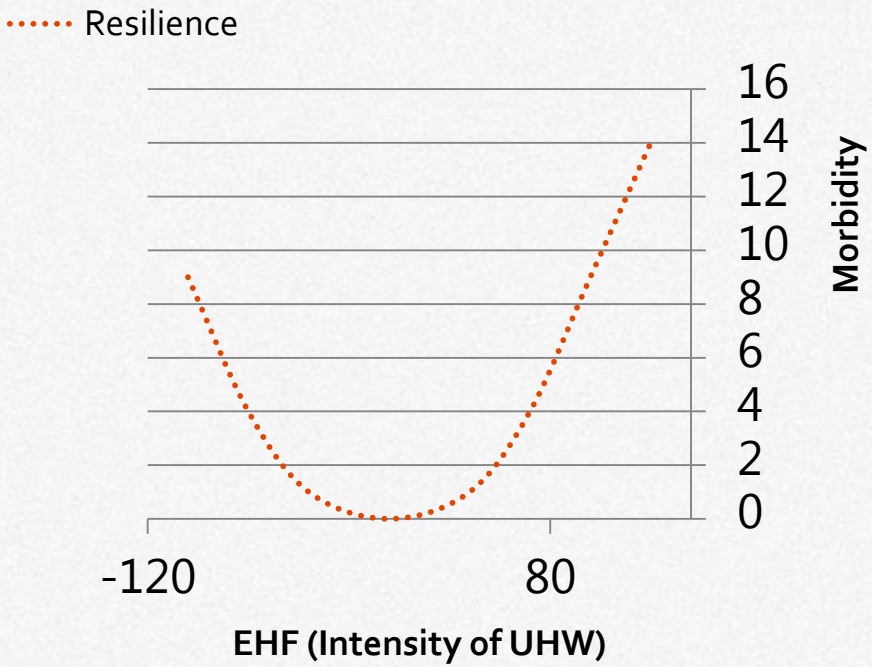
Case study research

- **Data availability**
  - Suburb is the smallest scale where morbidity data is available
  - ABS data availability (suburb or statistical area 1 or 2)

- Uniform **building functions**
- Geographic location**, closeness of water body**
- Suburbs with different **social classes**
- Vulnerable areas based on **literature review**
- Proximity of **weather stations**
- Water data availability (**smart meter** trials)
- Energy data availability (smart meter trials and geographically isolated areas with identifiable transformers)

Case study selection criteria





Impact indicators of UHWs

- Discover the correlation between EHF and the impact indicators
- Calculate precinct specific resilience

Rpr Precinct resilience

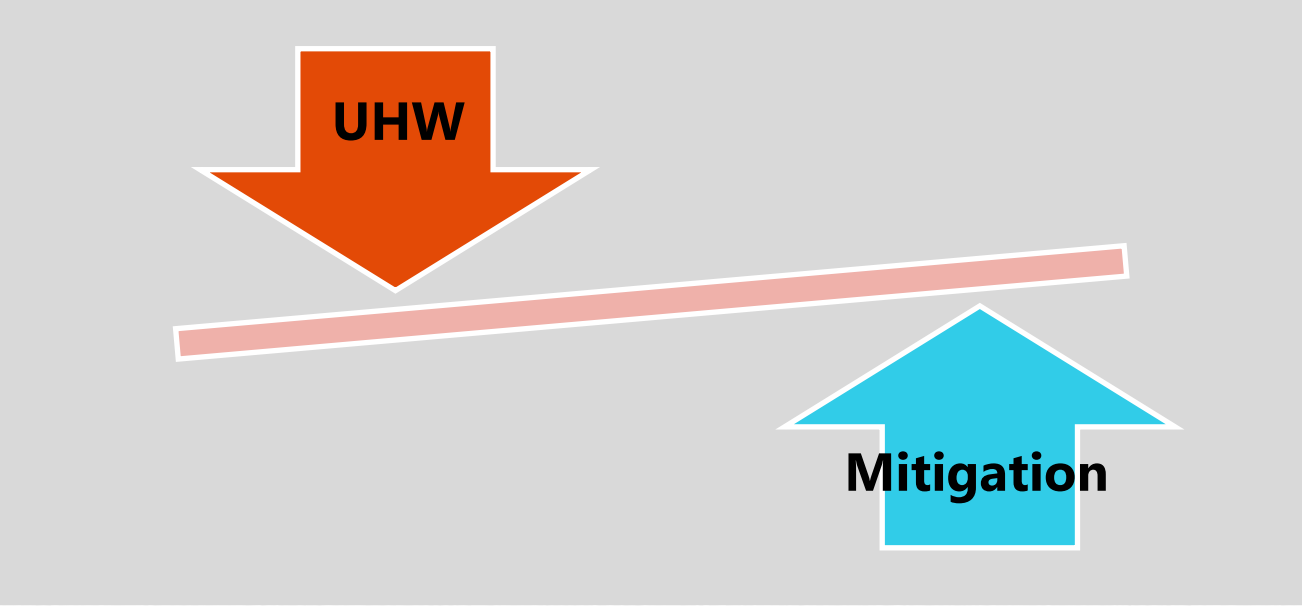
$$\int \left[|\Delta M : \Delta EHF| : \frac{M}{Mo} \right] * dEHF$$

Precinct resilience

EHF	SOURCE
Temperature data	Stations of EPA, BOM, Flinders University
UHW IMPACT INDICATORS	**SOURCE**
Emergency call-outs (morbidity)	SA and NSW Health
Hospital emergency admission (morbidity)	SA and NSW Health
Energy consumption	AusGrid and SA Power network transformers and electricity trials
Water consumption	Smart meter trials in NSW and SA
Heatwave perception	Researcher's survey, representative sample population from Adelaide and Sydney
SURVEY RESULTS	
Heatwave perception ranking	• Online survey, sample population from Adelaide and Sydney metropolitan regions. • Place of residency and work, suburbs and postal code will be collected. • Pilot survey will be conducted with a cluster sampling of more affluent people with higher qualification.
Heatwave related health experience	
Applied adaptation and mitigation techniques	
Willingness to retrofit	

Data sources

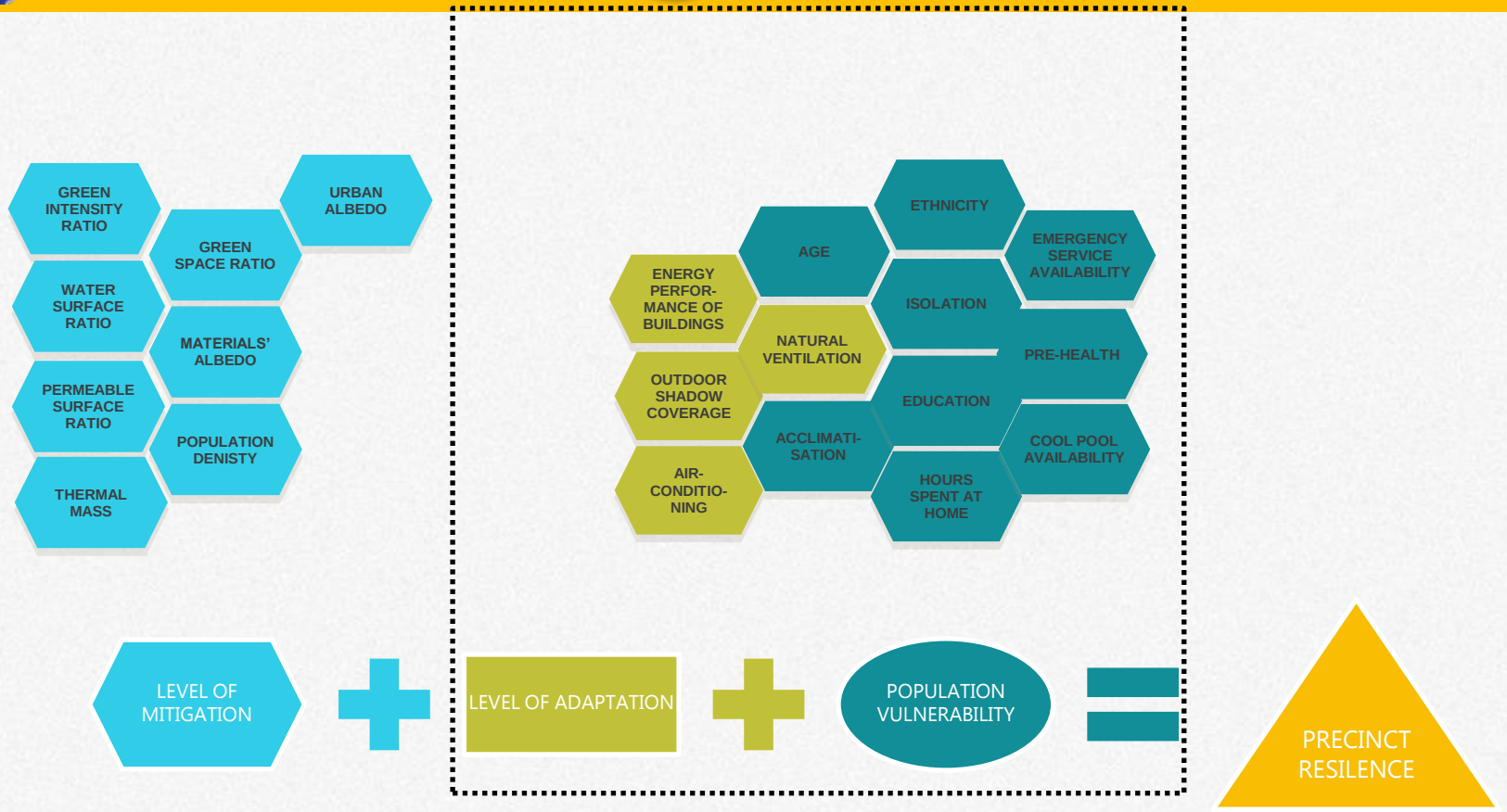
Excess heat factor (EHF): To measure the intensity of UHWs



M=C+L+U

(Unger et al, 2001)

M is the metropolitan microclimate
C is the climatic conditions
L is the difference induced by geography
U is the urban condition



Urban design:
UHI countermeasures at precinct scale

Level of exposure depends on the built environment:
Adaptation opportunities available in the built environment

Population vulnerability:
Social characteristics that influence inhabitants capability to cope with heatwaves

Precinct resilience:
The level of precinct ignores the UHWs

Precinct resilience

UHI COUNTERMEASURES=MITIGATION	
Green space ratio	Google Earth/ Cities' maps where available
Green intensity ratio (trees or grass)	
Water surface ratio	
Permeable surface rate	
Population density	Census 2011, ABS
Materials' thermal storage capacity (type of building structure)	Google Earth/Researcher measurement
PRECINCT EXPOSURE=ADAPTATION	
Energy performance of the buildings envelope	Researcher's measurement
Outdoor shadow coverage	Google Earth/ Cities' maps where available
Cool pool availability (library, swimming pool, shopping centre)	Google Earth
Proportion of air-conditioned buildings	Researcher's measurement
POPULATION EXPOSURE=ADAPTATION	
Income	Census 2011, ABS
Crime rate	SA, NSW Crime Statistics
POPULATION VULNERABILITY	
Age	Census 2011, ABS
The level of isolation (single household)	
Pre-existing health conditions (disables)	
Education	
Hours spent at home: unemployment rate and people who work at home	
Ethnicity-born here or offshore	

Mitigation

Mitigation techniques mitigate UHWs.

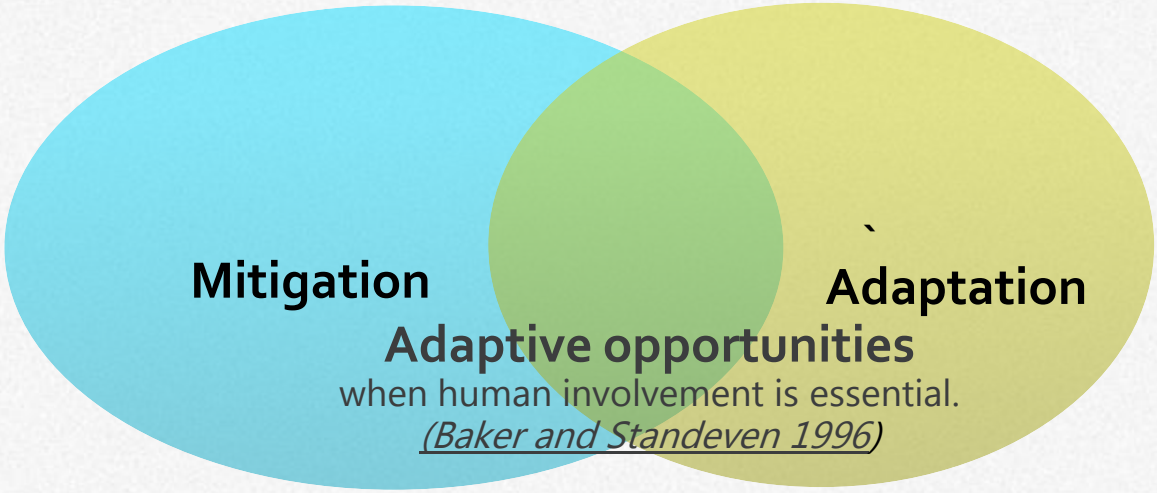
- 'Independent' mitigation, e.g.: more green space
- 'Human dependent' mitigation, e.g.: more shading on façade

Adaptation

Adaptation techniques help to build human resilient.

- Psychological adaptation, e.g.: acclimatisation
- Physiological adaptation; e.g.: clothes
- Physical adaptation e.g.: open the window

(Brager and de Dear 1998)



MEASURES	EXPLANATION
Scope of responsibility	Who can implement it?
Scope of benefit	Who can benefit from it?
Effect on the time distribution	• night-time or daytime • weekend or weekday or both
Effect on precincts' resilience	Relative achievement, depends on original precinct resilience.
Cost	The initial construction and planning costs.
Maintenance	All maintenance cost (25 years).
Lifetime	A tree's lifetime is expected to be much longer than external shading.
Willingness to adapt	Investigate the common acceptance of the mitigation techniques via survey.
'Adaptive increment' (where applicable)	The additional temperature which can be bearable by the users after mitigation.
Savings in energy and carbon emission	The findings of the calculation via EnergyPlus will be included.
Level of independency from fossil fuels	Reduce the precincts' dependency on fossil fuels.

Thank you!