Global efforts to reduce urban heat and emerging technologies. Summary of Darwin initial work.

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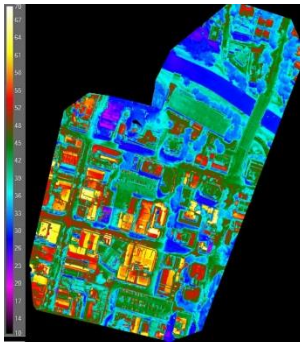
Darwin – December 2019

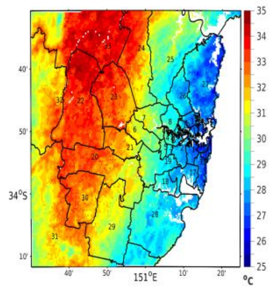
COOLING DARWIN

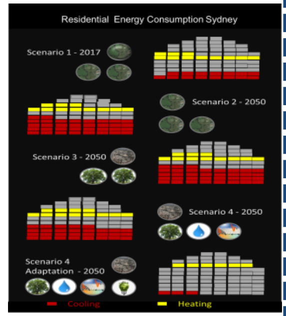
ADVANCES IN SCIENCE AND DESIGN FOR THE MITIGATION OF URBAN HEAT

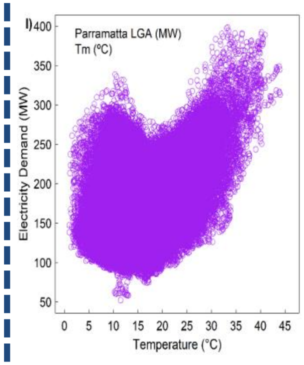
The thermal balance in the urban environment differs substantially than that of rural areas. Anthropogenic heat released by cars and combustion systems, higher amounts of solar radiation stored, and blockage of the emitted infrared radiation by urban canyons makes the global thermal balance more positive and contributes to the warming of the environment.

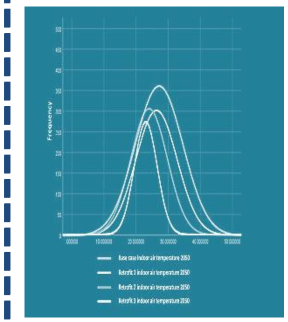
HOLISTIC MITIGATION STUDY OF DARWIN

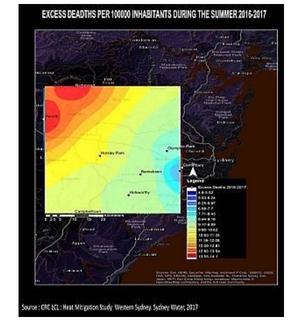


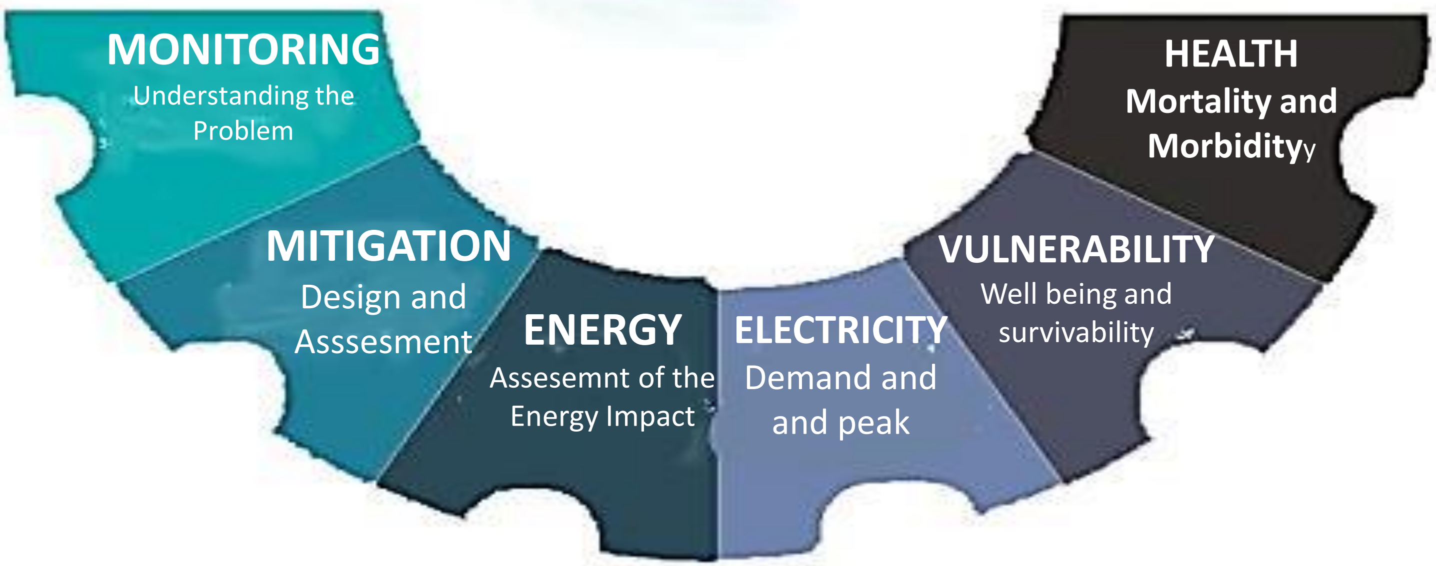




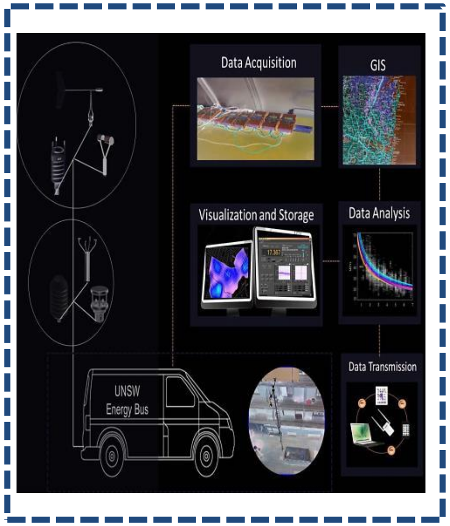


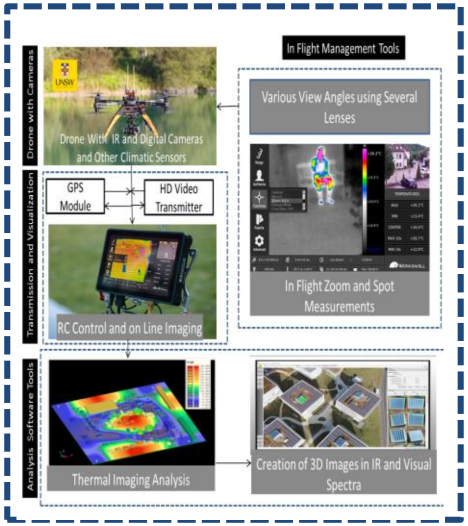


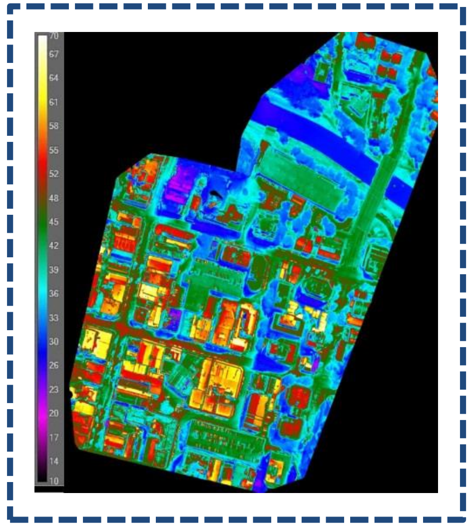


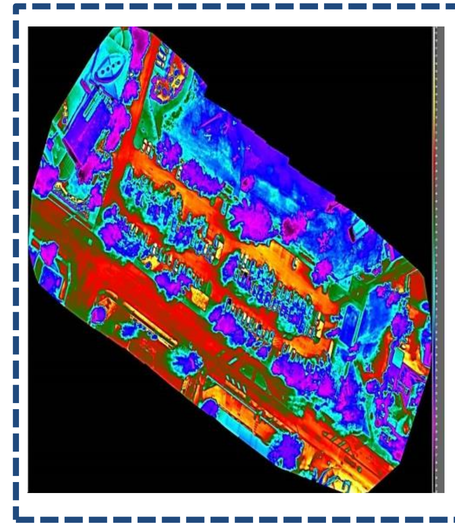


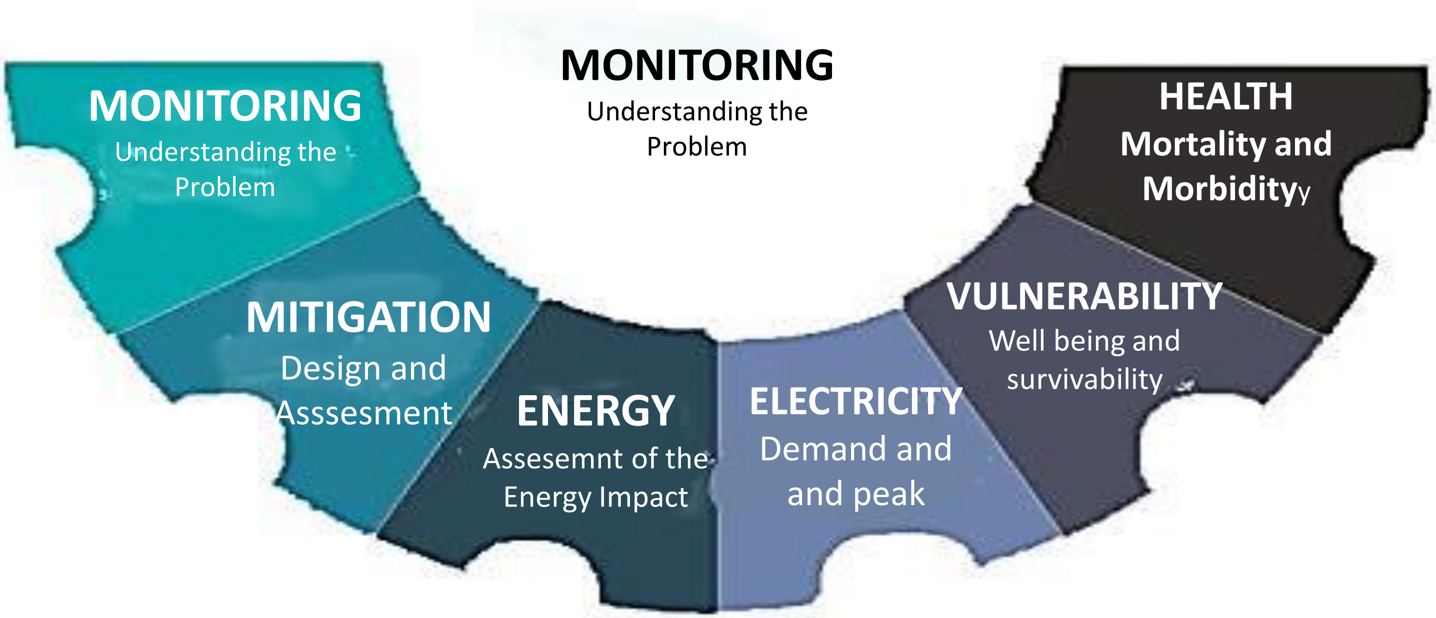
HOLISTIC MITIGATION STUDY IN DARWIN











Methodology of the Mitigation Study

2. Analysis of the Experimental Data

Methodology of the Mitigation Study

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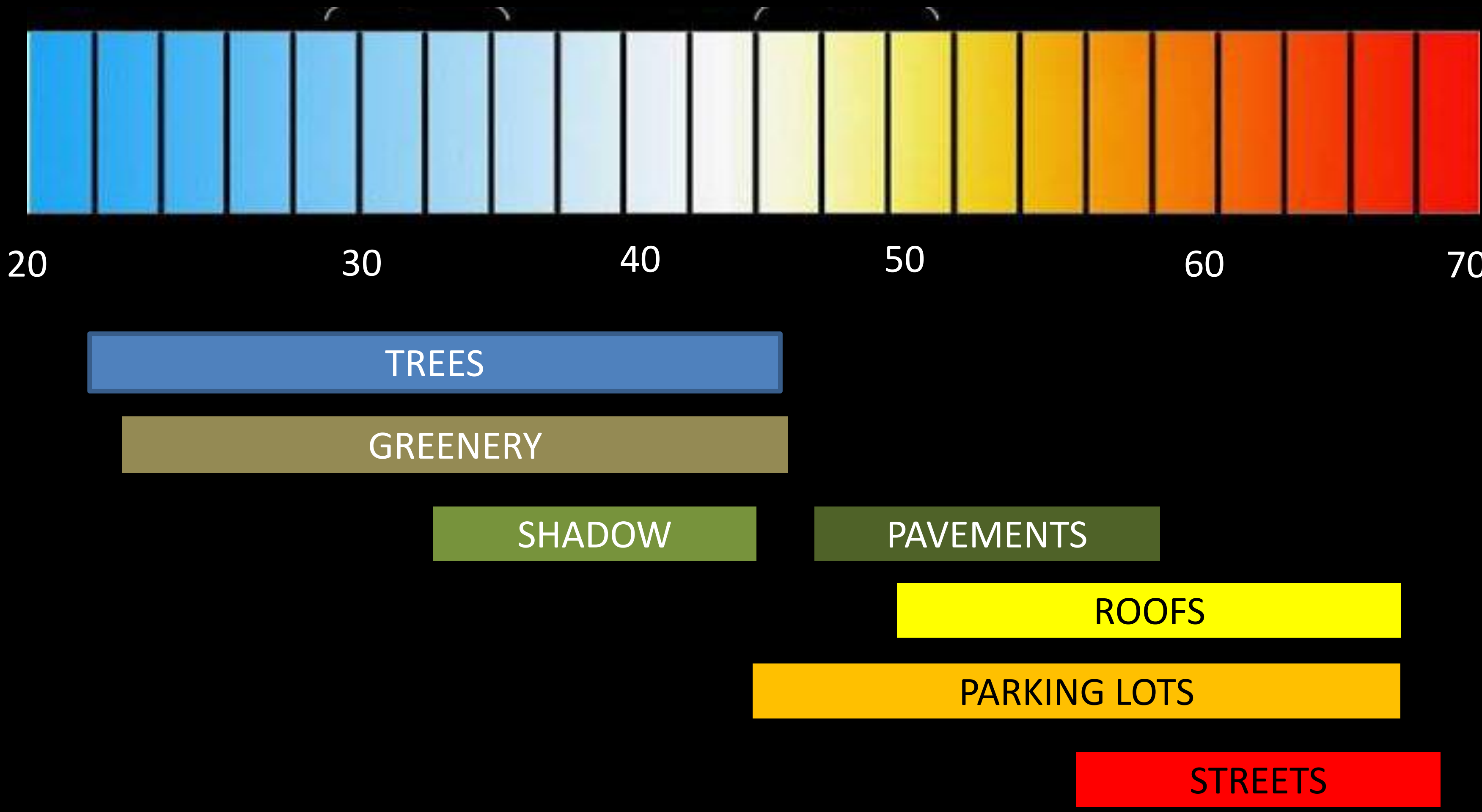
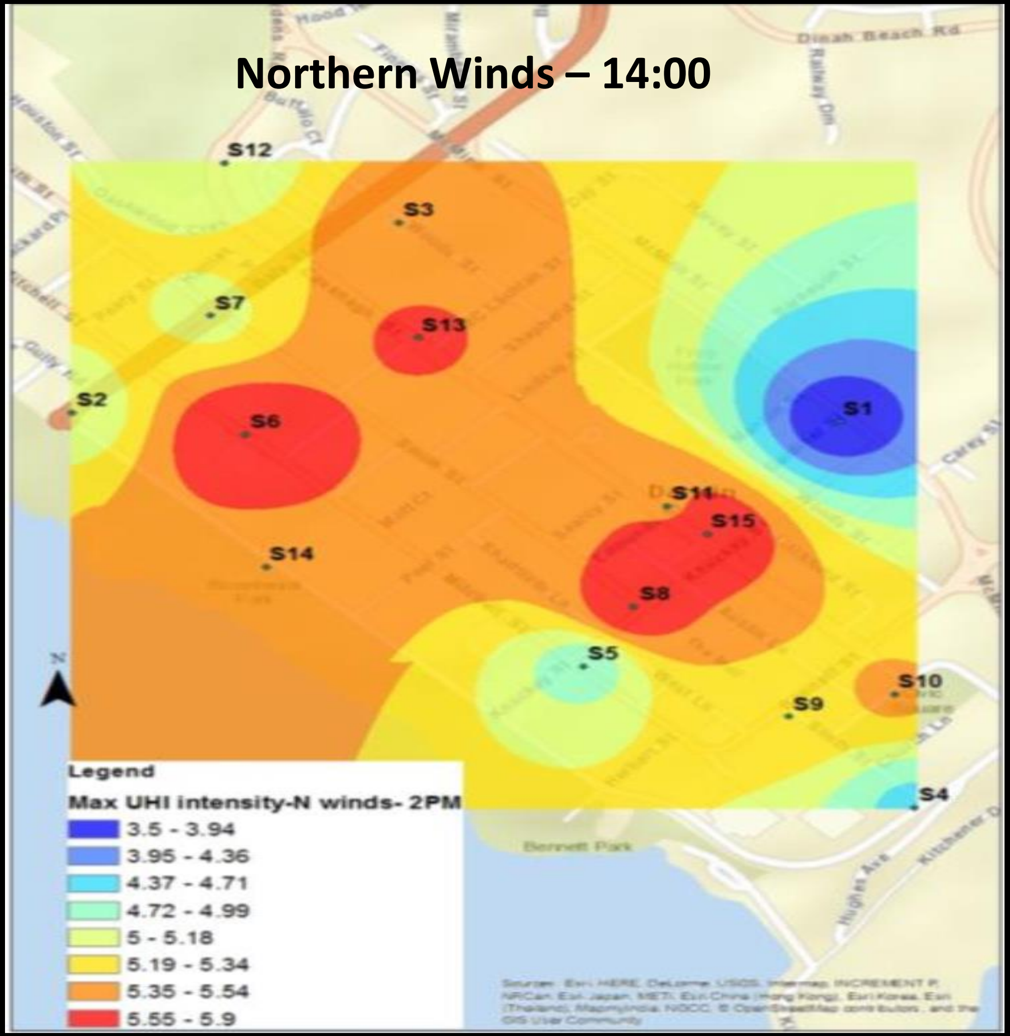
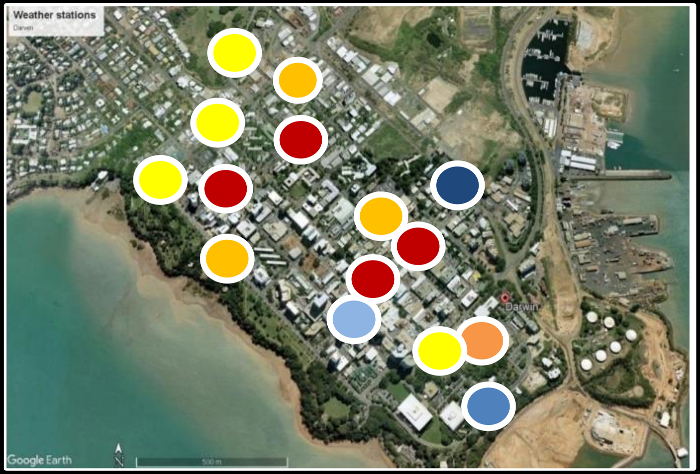


ANALYSIS OF THE EXPERIMENTAL DATA

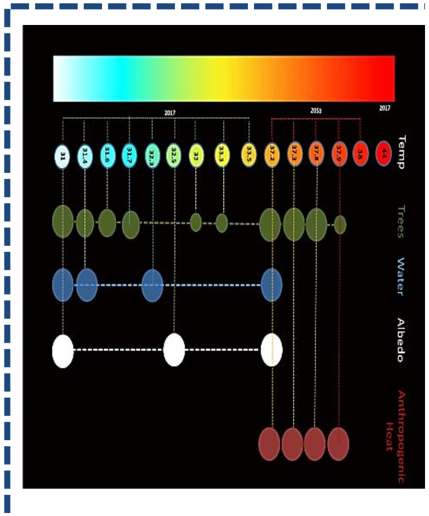


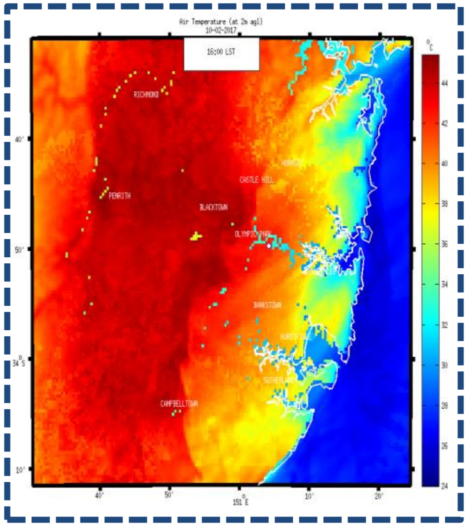


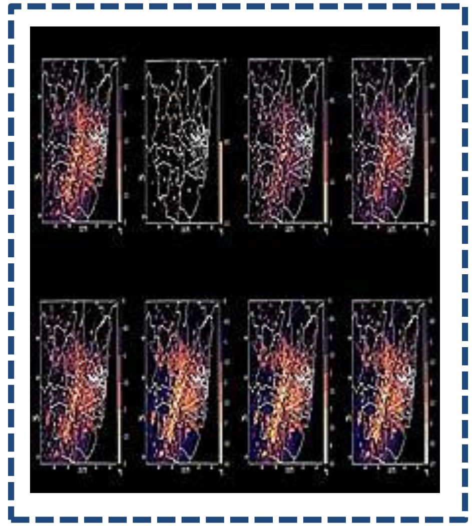
Heat Island Intensity : 3.5 C to 5.9 C
Maximum at :

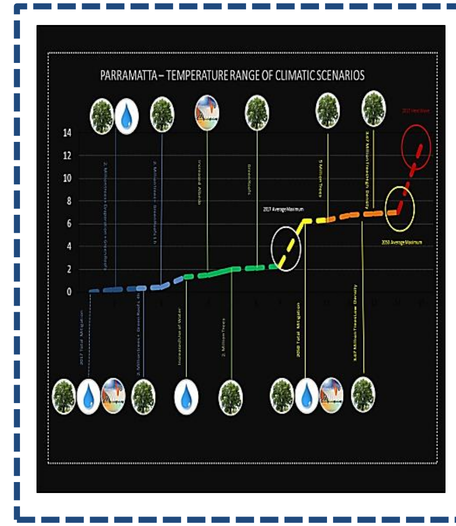
- Knuckey Street, corner of Knuckey Street & Smith Street
- Cavenagh Street, just back from the Knuckey Street
- 80 Cavenagh Street
- 86 Mitchell Street, opposite Darwin Entertainment Centre

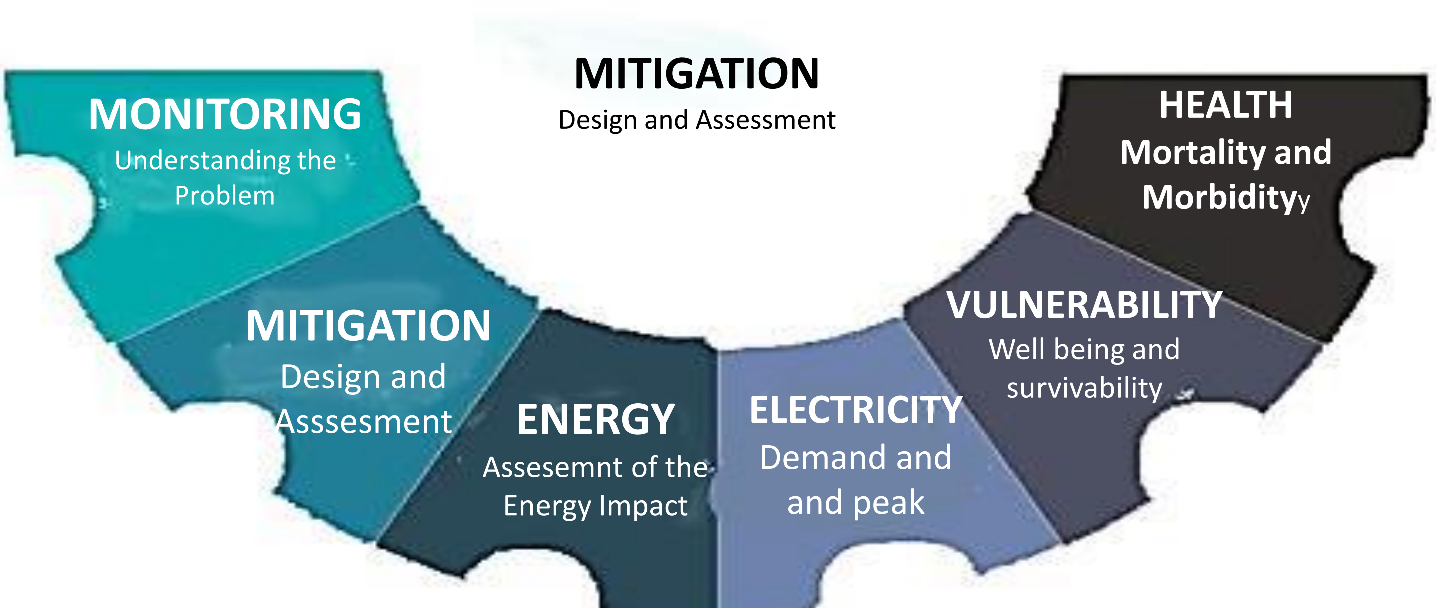
HOLISTIC MITIGATION STUDY OF DARWIN



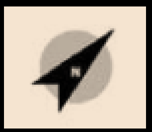


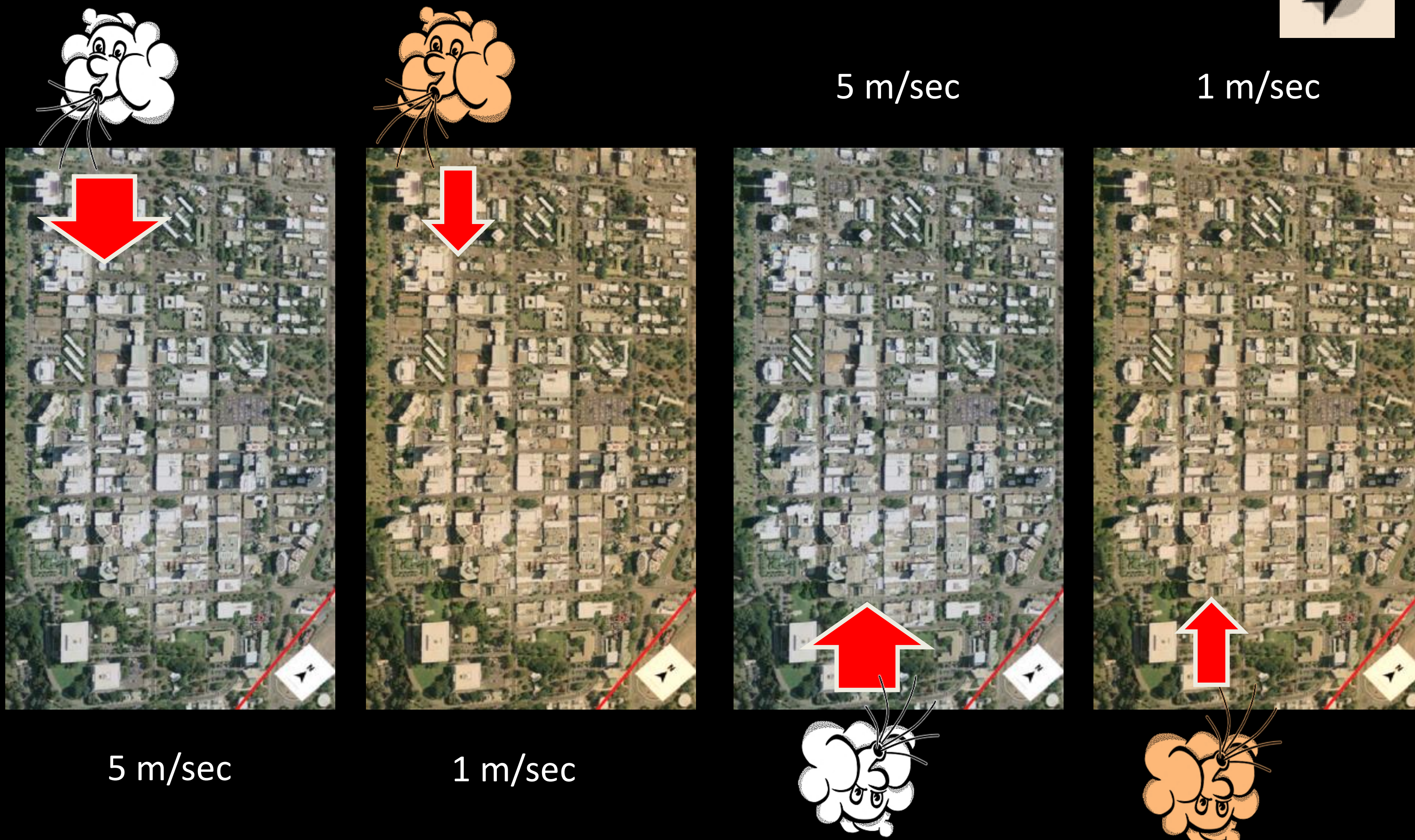




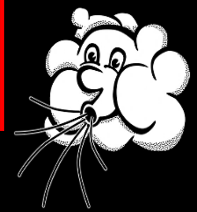


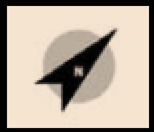
3. Simulation and Analysis of the Existing Conditions – The Reference Case





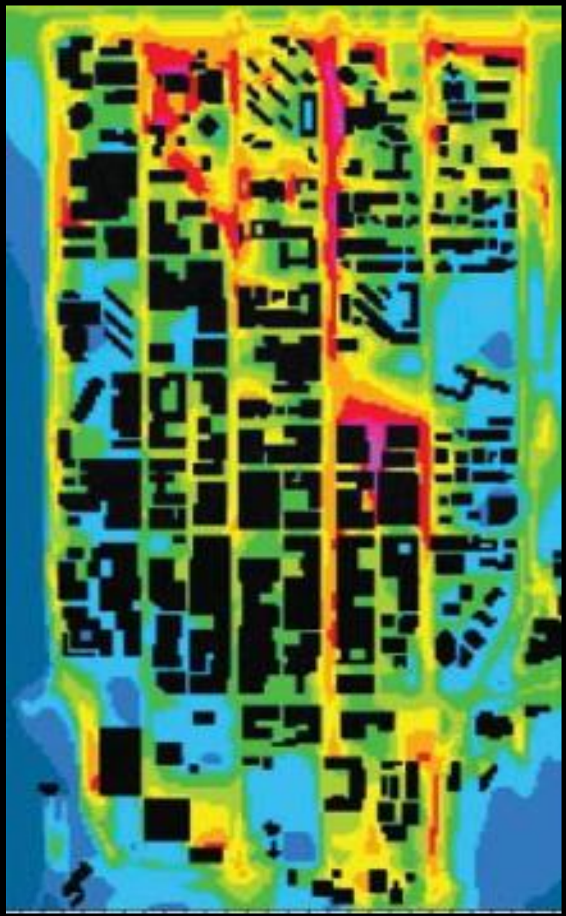
Methodology of the Mitigation Study





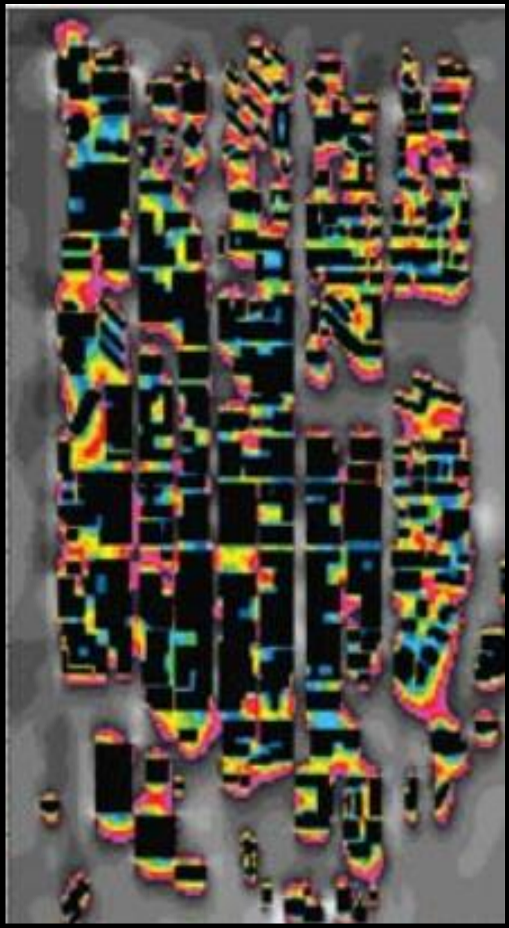
5 m/sec
14:00

Simulation and Analysis of the Existing Conditions – The Reference Case



Ambient 32-36,4 C

Surface 20-55,4 C



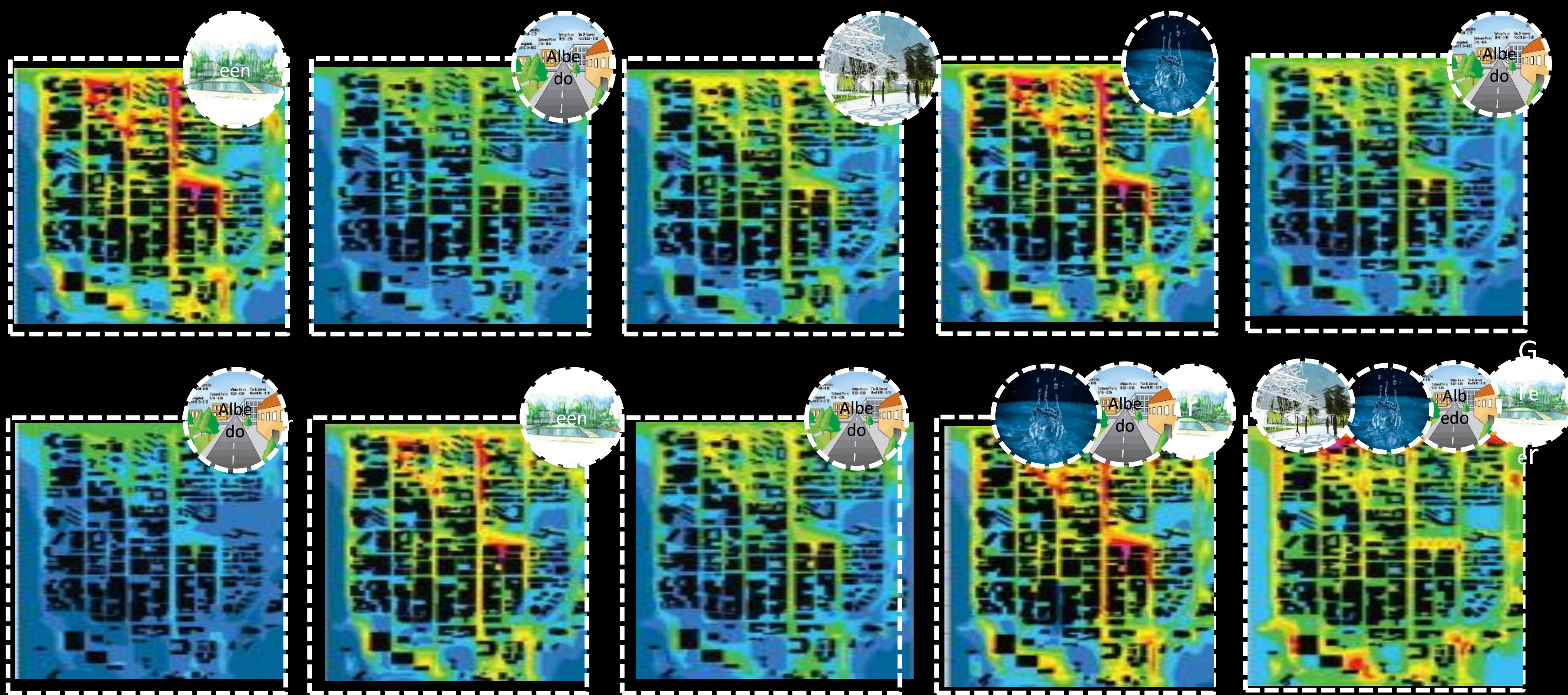
Wind Speed : 0-5 m/sec

Methodology of the Mitigation Study

4. The 4 Mitigation Techniques – The 13 Mitigation Scenarios – The 52 Case Studies

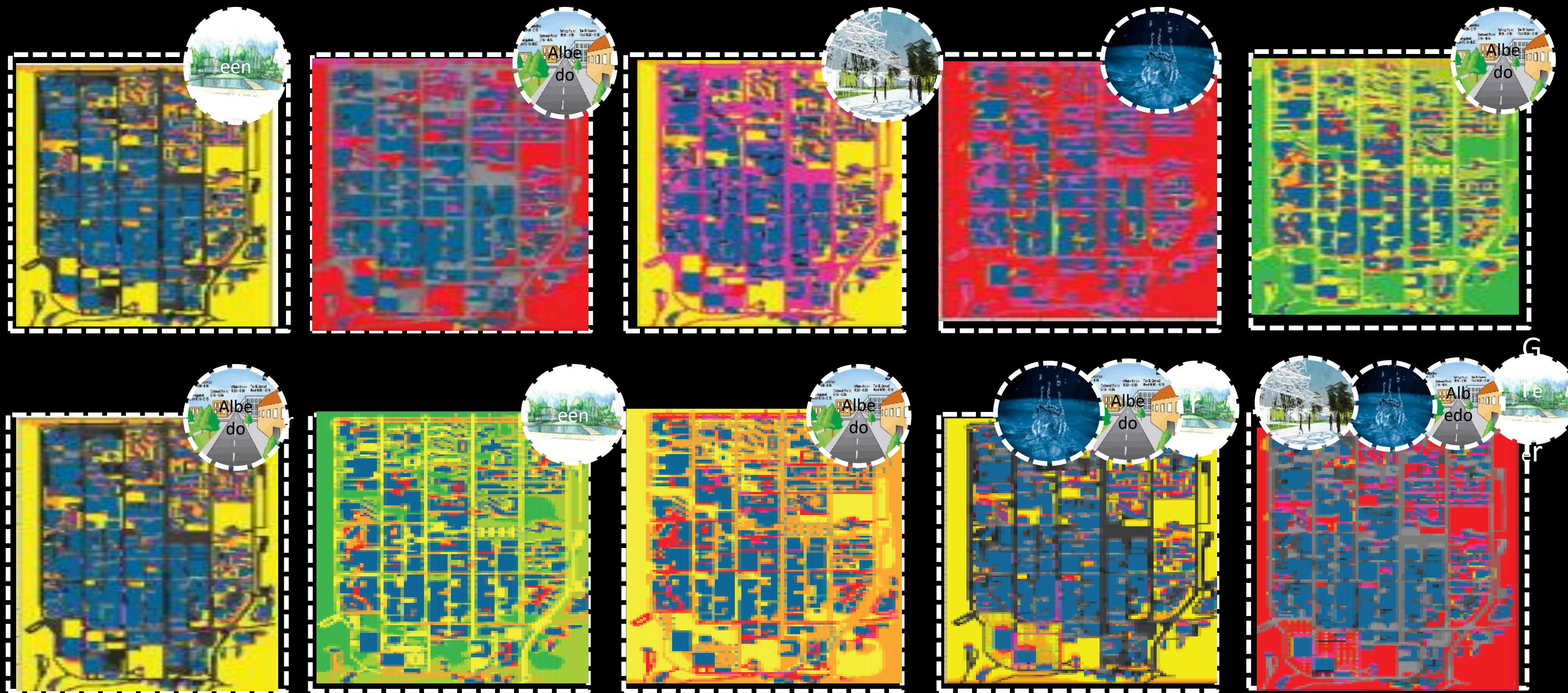
Methodology of the Mitigation Study

5. Results – Distribution of the Ambient Temperature in the CBD Area



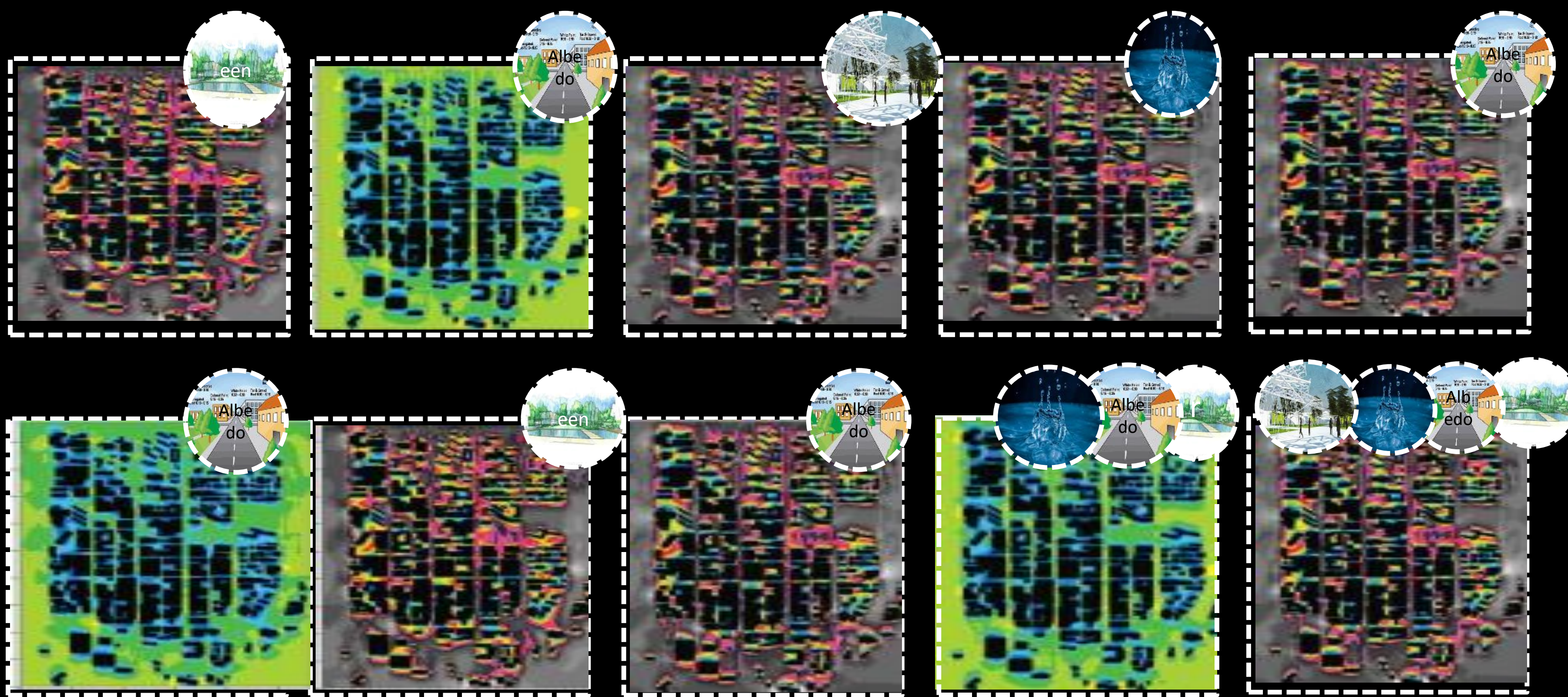
Methodology of the Mitigation Study

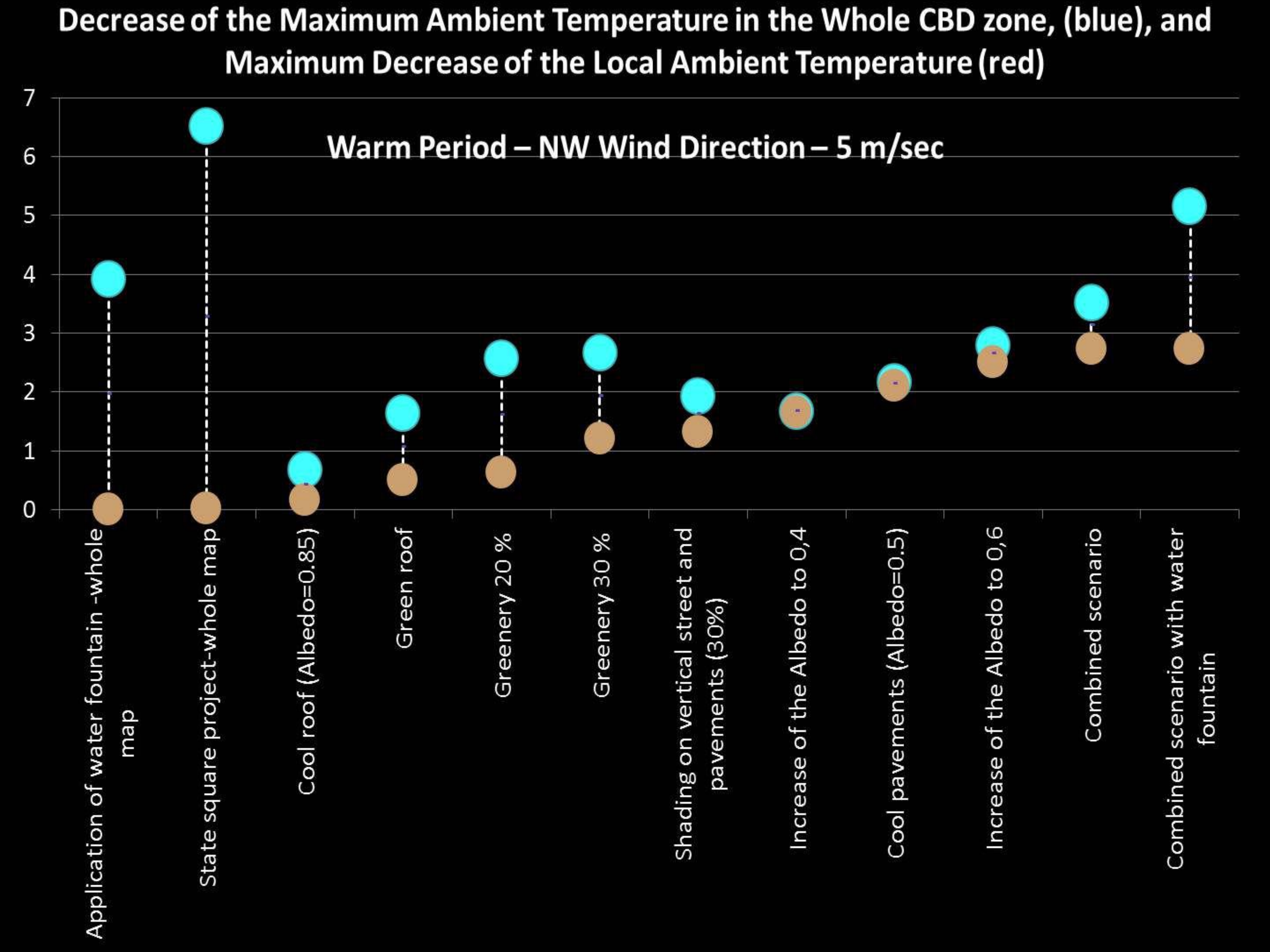
5. Results – Distribution of the Surface Temperature in the CBD area



Methodology of the Mitigation Study

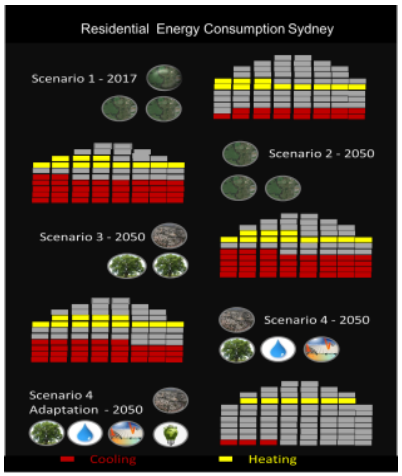
5. Results – Distribution of the Wind Speed and Direction in the CBD area

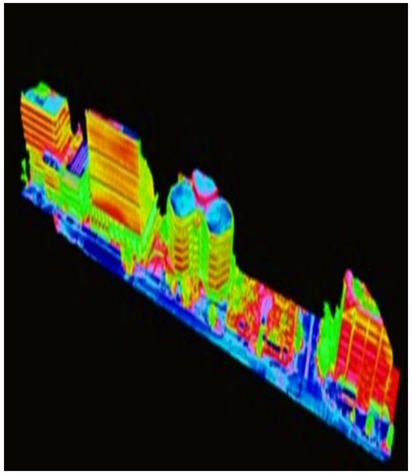


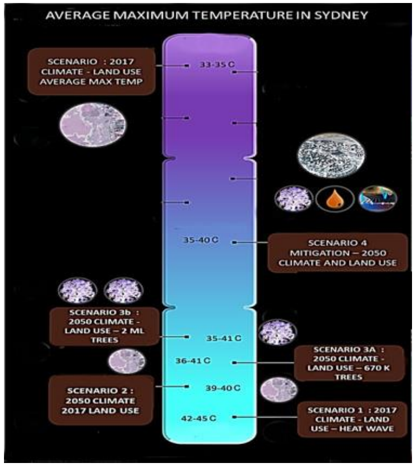


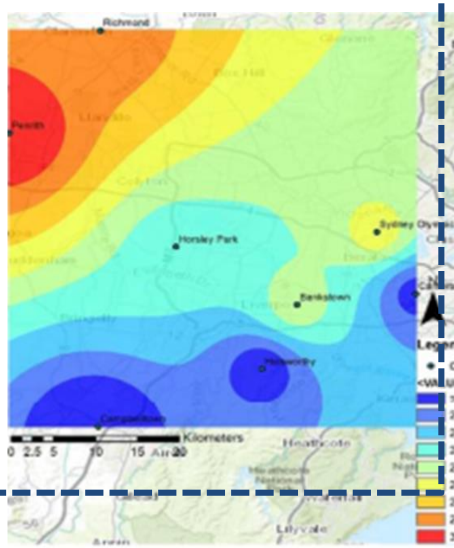
Decrease of the Maximum Ambient Temperature in the Whole CBD zone, (blue), and Maximum Decrease of the Local Ambient Temperature (red)
Warm Period – NW Wind Direction – 5 m/sec
0
1
2
3
4
5
6
7
Application of water fountain -whole map
State square project-whole map
Cool roof (Albedo=0.85)
Green roof
Greenery 20 %
Greenery 30 %
Shading on vertical street and pavements (30%)
Increase of the Albedo to 0,4
Cool pavements (Albedo=0.5)
Increase of the Albedo to 0,6
Combined scenario
Combined scenario with water fountain

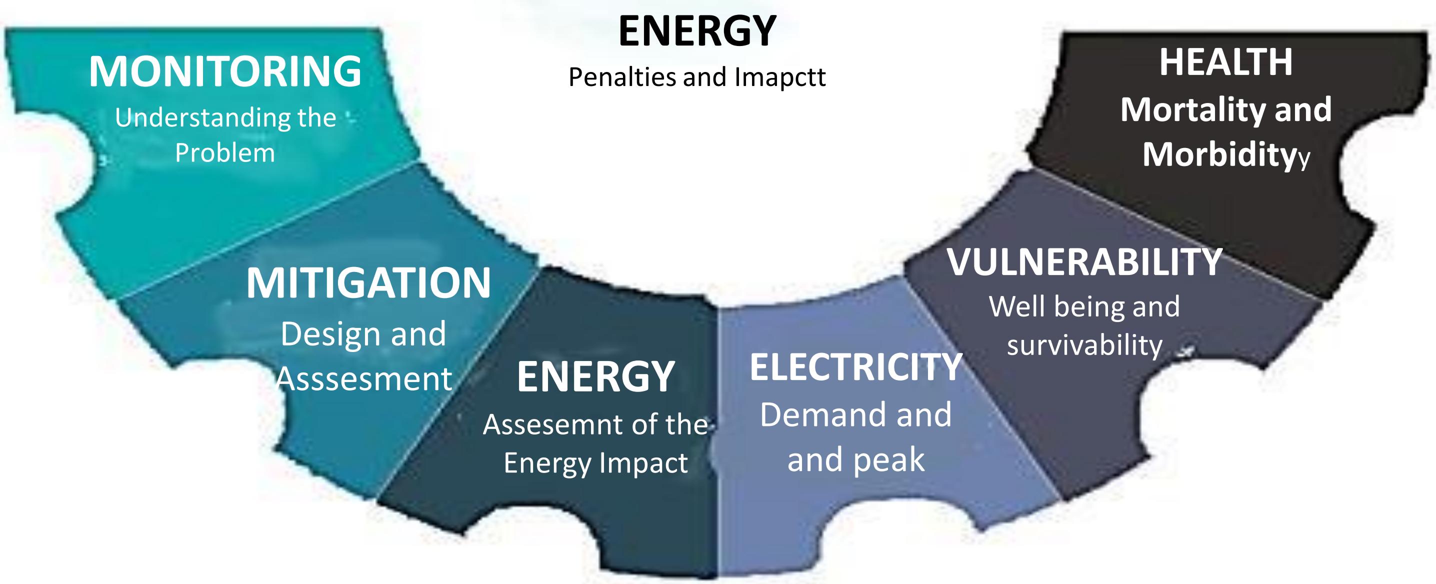
HOLISTIC MITIGATION STUDY OF DARWIN







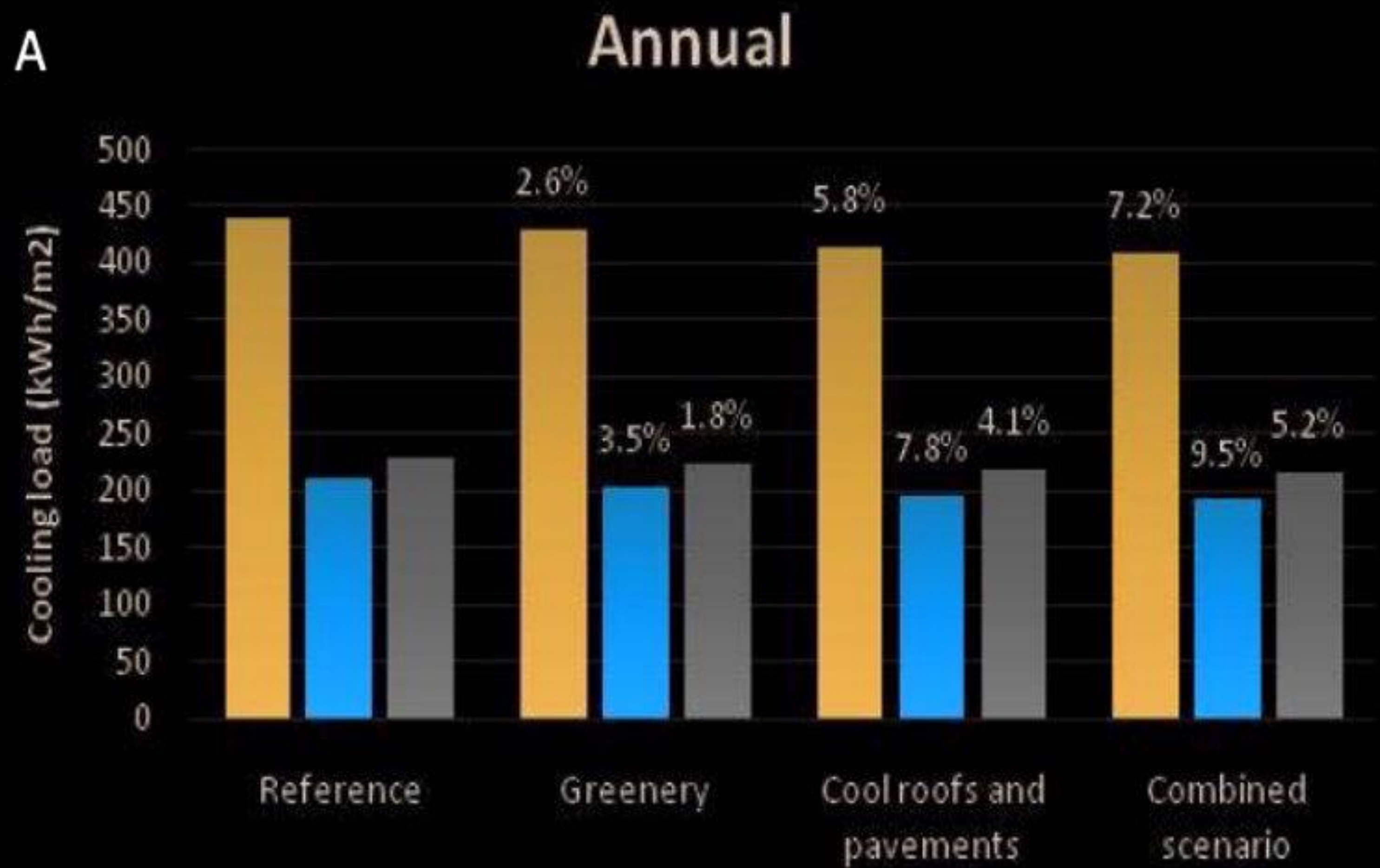




PHASE 2 OF THE MITIGATION STUDY
ENERGY CONSUMPTION STUDY

ENERGY CONSERVATION UP TO 34 KWh/m2/y

The corresponding energy savings in Sydney do not exceed 15 kWh/m2/y

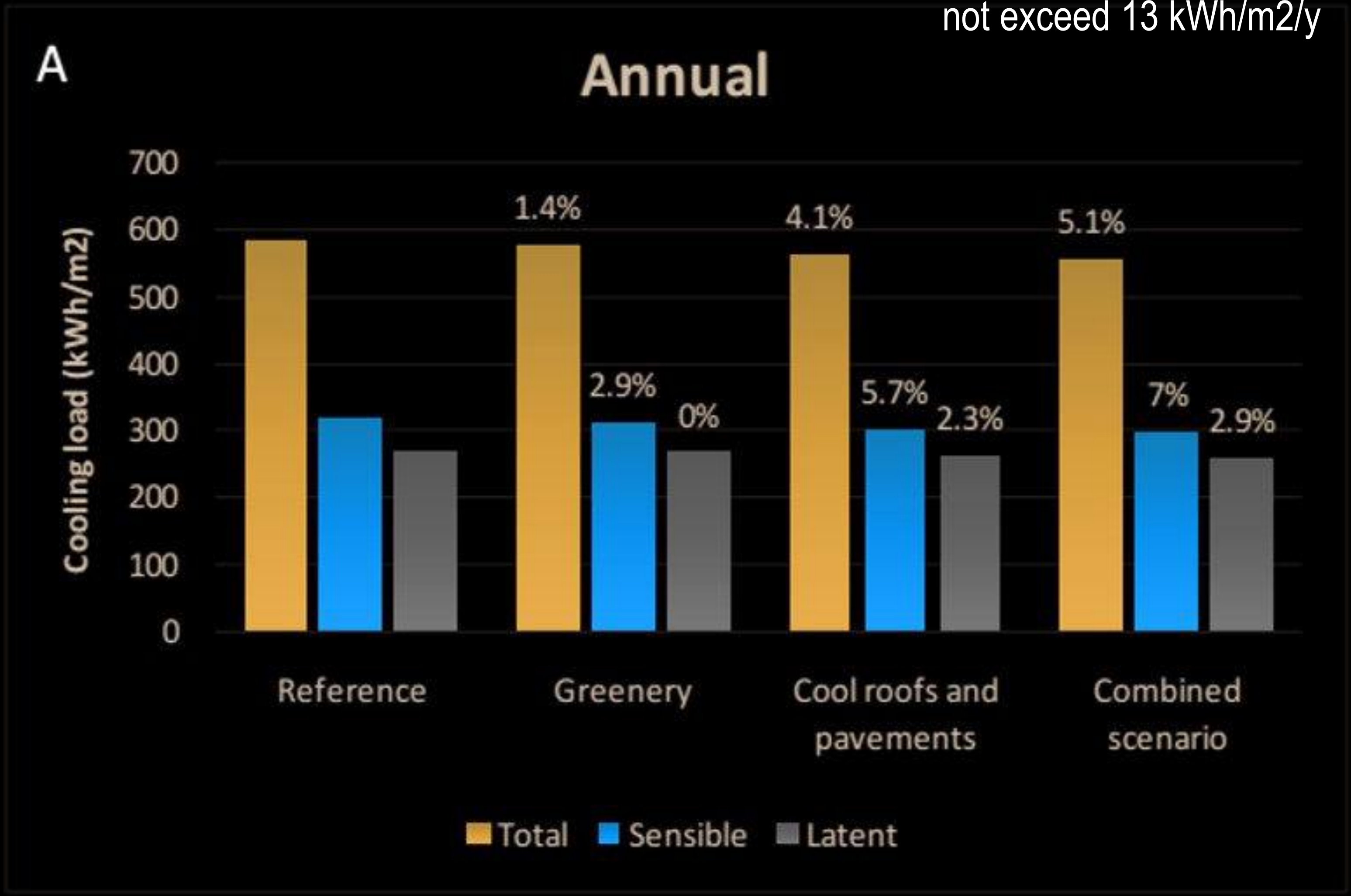


RESIDENTIAL

PHASE 2 OF THE MITIGATION STUDY
ENERGY CONSUMPTION STUDY

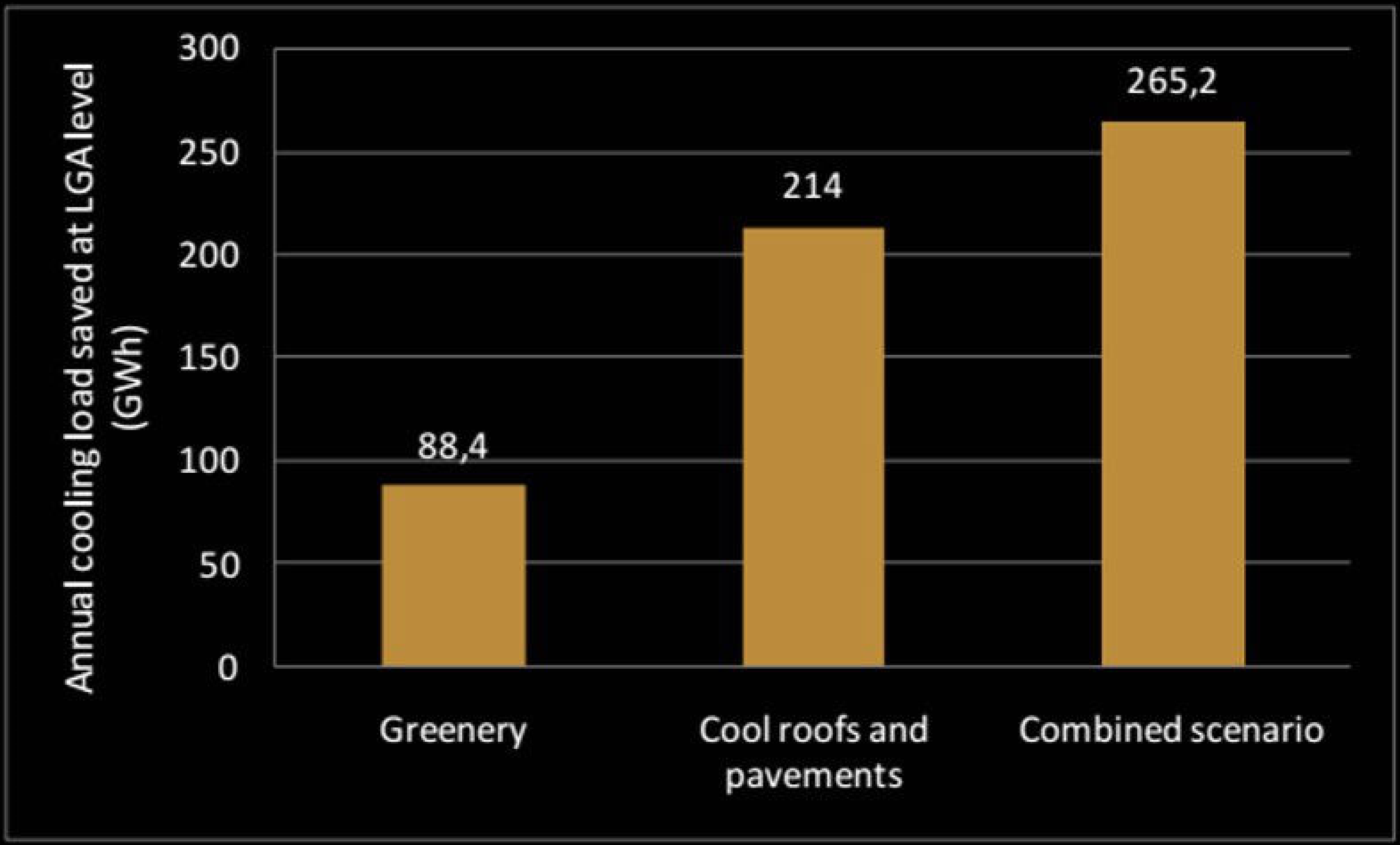
ENERGY CONSERVATION UP TO 31 KWh/m2/y

The corresponding energy savings in Sydney do not exceed 13 kWh/m2/y

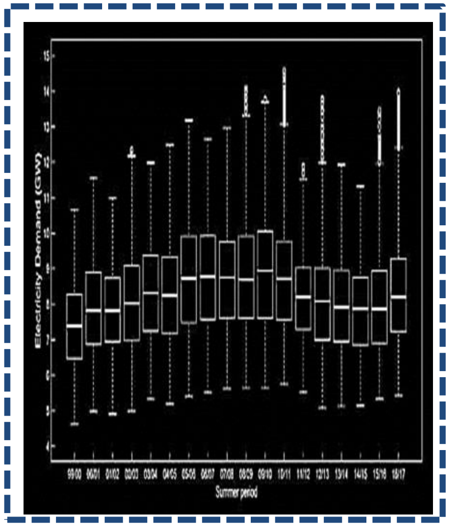


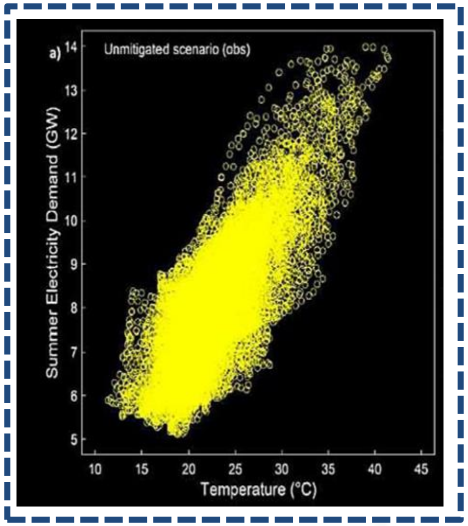
COMMERCIAL

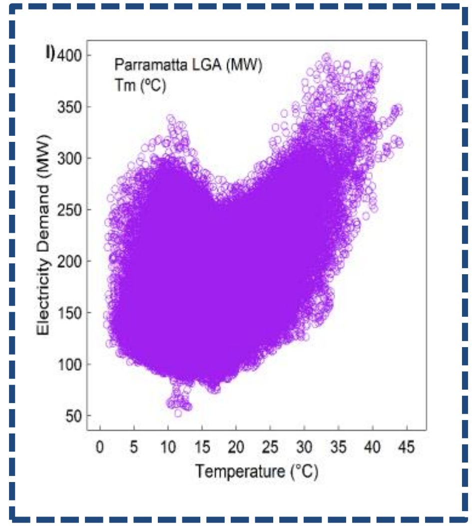
PHASE 2 OF THE MITIGATION STUDY
ENERGY CONSUMPTION STUDY

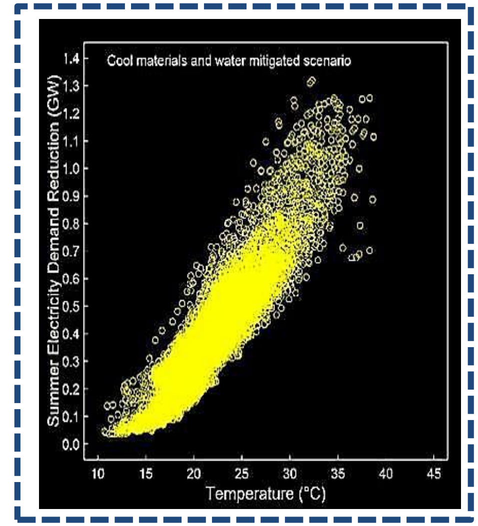


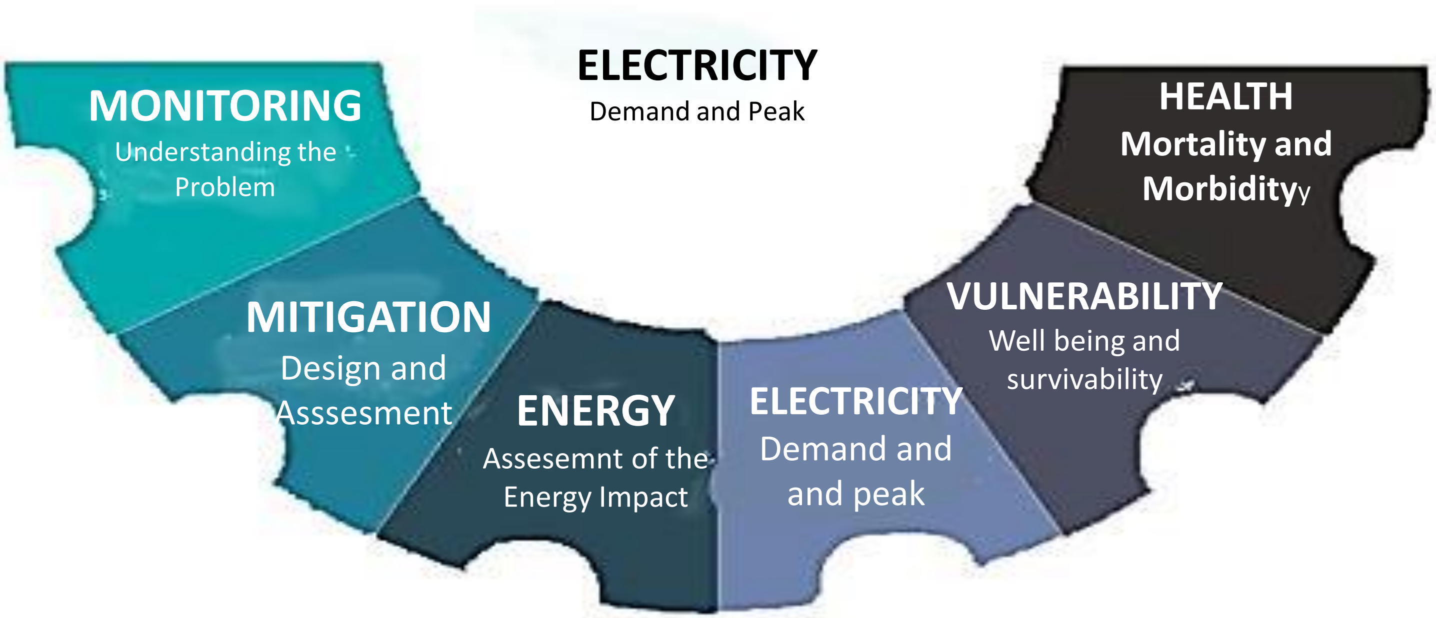
HOLISTIC MITIGATION STUDY OF DARWIN











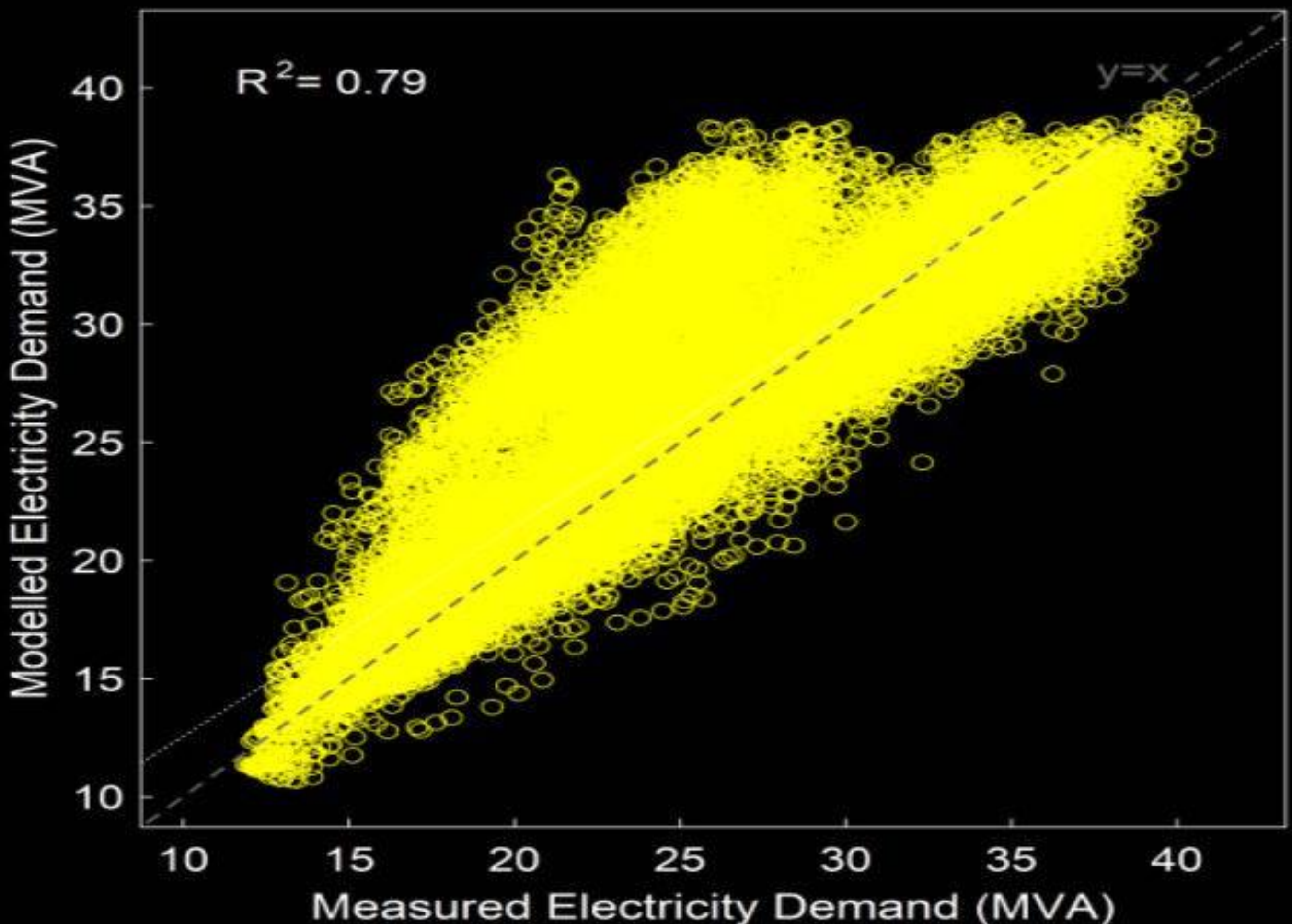
PHASE 2 OF THE MITIGATION STUDY
PEAK ELECTRICITY DEMAND

The correlation we found for the semi-hourly electricity demand (ELDem) expressed in MVA (Mega Volta Ampere) is a function of the temperature at the airport (T), the dew point temperature (Td), the global horizontal irradiance (GHI).

ELDem = 3.0243 + 0.8972*sma(T, 54) + 0.0003*Td*sma(GHI, 3) -1108/(107.0581 + 0.3116*delay(GHI, 285) + 0.0326*GHI*delay(GHI, 285) + sma(GHI, 12)

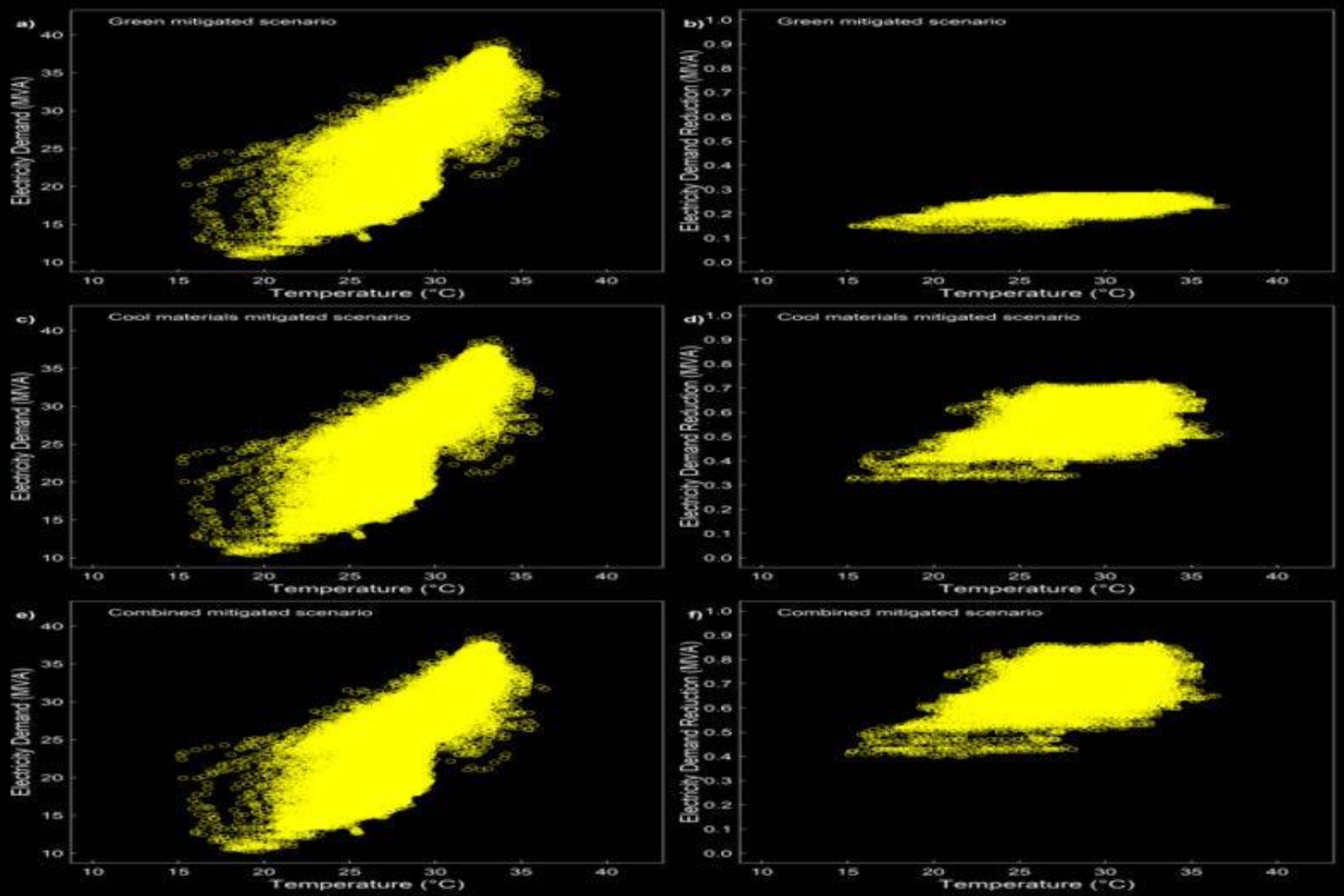
Where sma (x, n) is the simple moving average of the previous n records of the quantity x. Delay (x, n) indicates a delayed variable, namely for the time step t, it considers the value quantity n time steps before

PHASE 2 OF THE MITIGATION STUDY
PEAK ELECTRICITY DEMAND

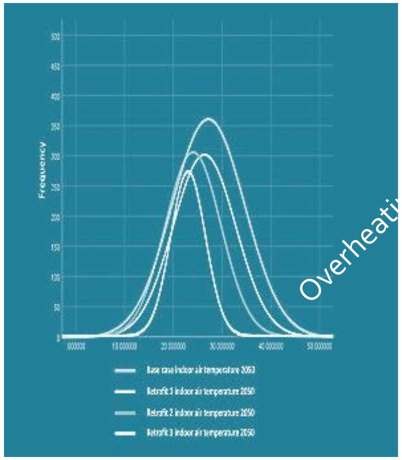


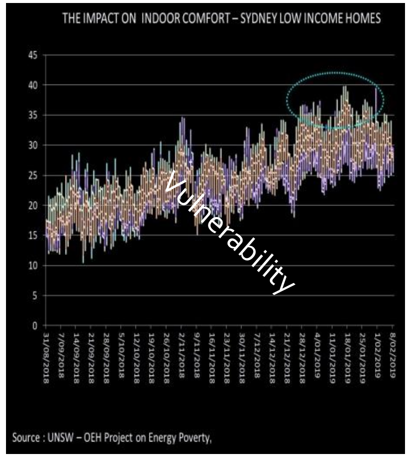
PHASE 2 OF THE MITIGATION STUDY
PEAK ELECTRICITY DEMAND

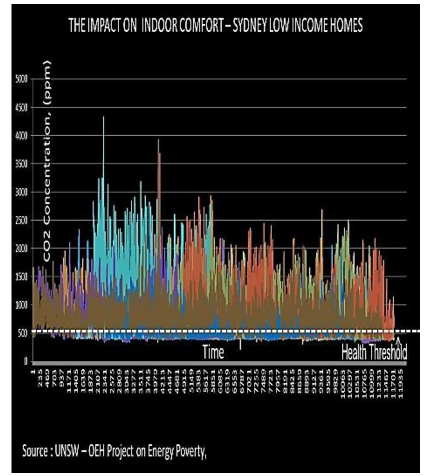
Decrease of the Peak Electricity Demand up to 0,8 MVA or 2 %

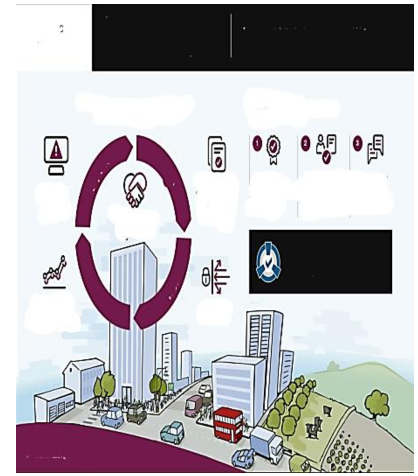


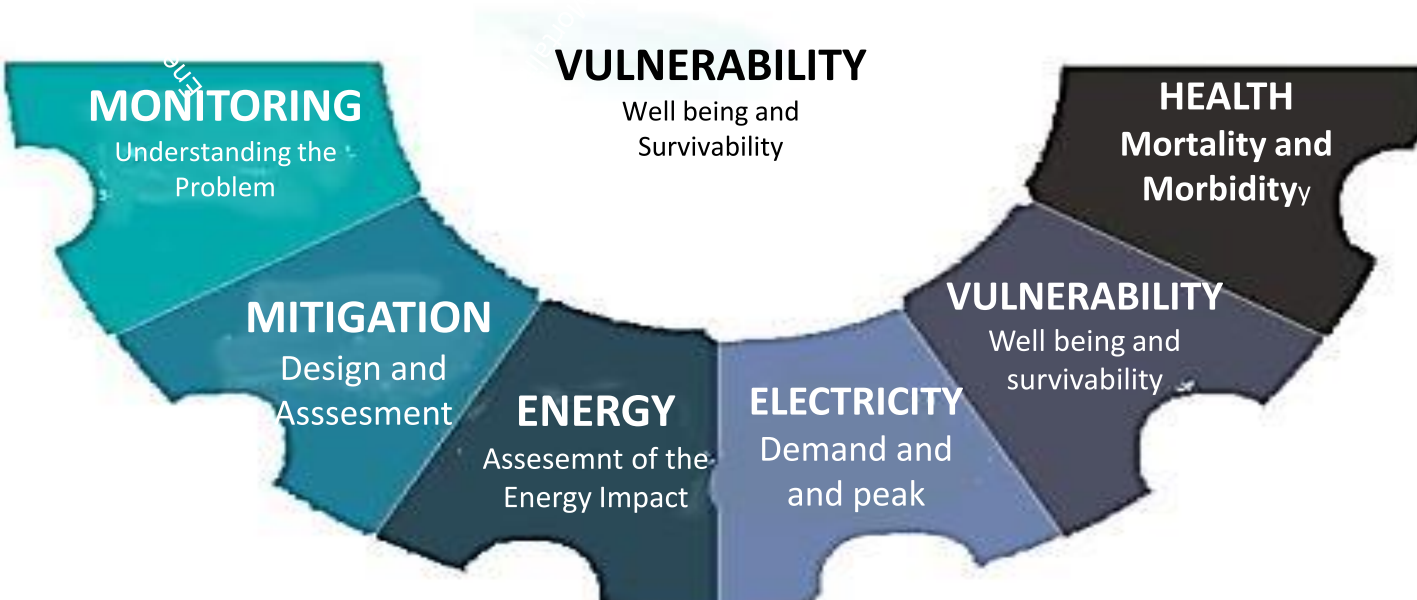
HOLISTIC MITIGATION STUDY IN DARWIN

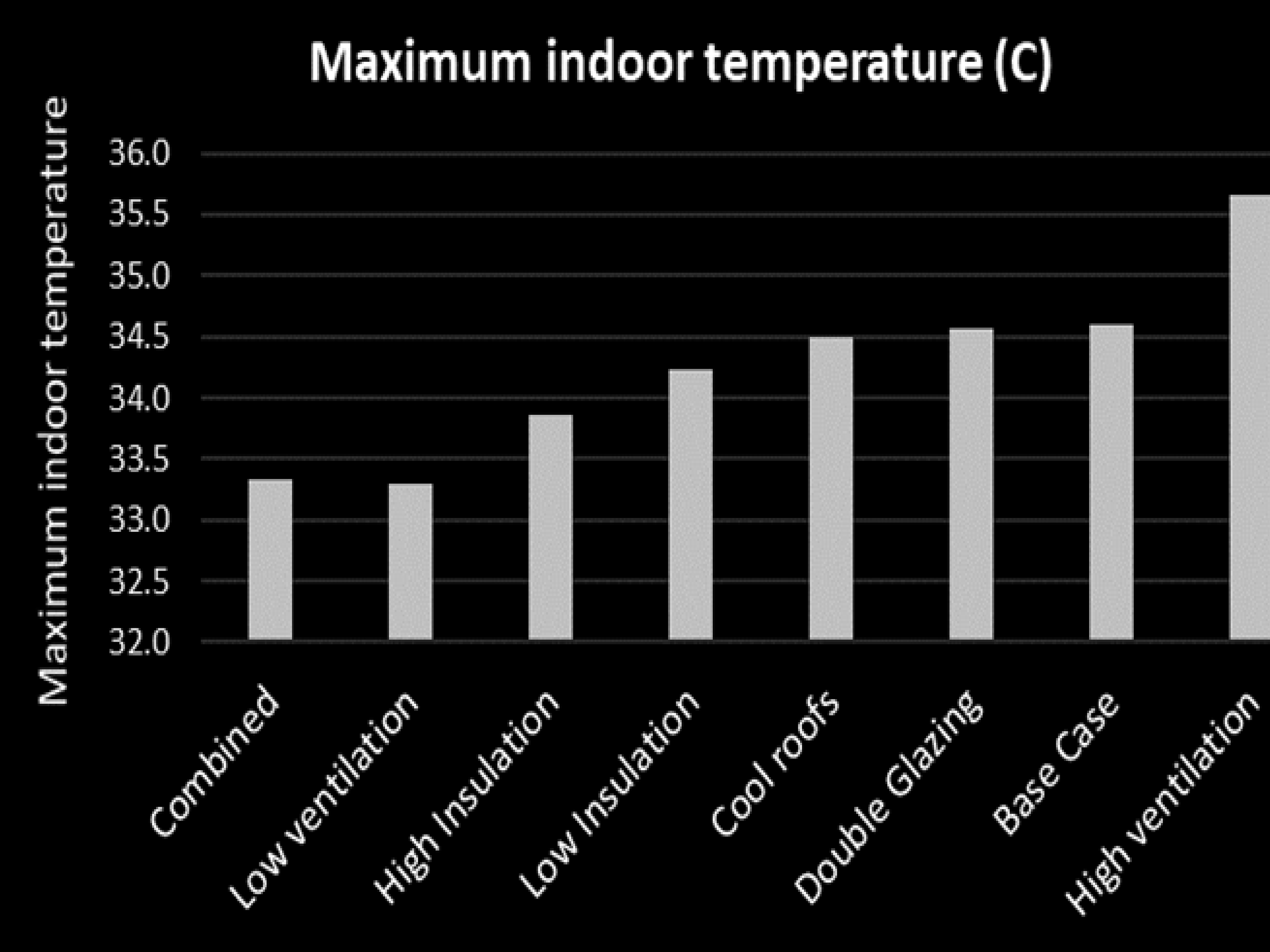




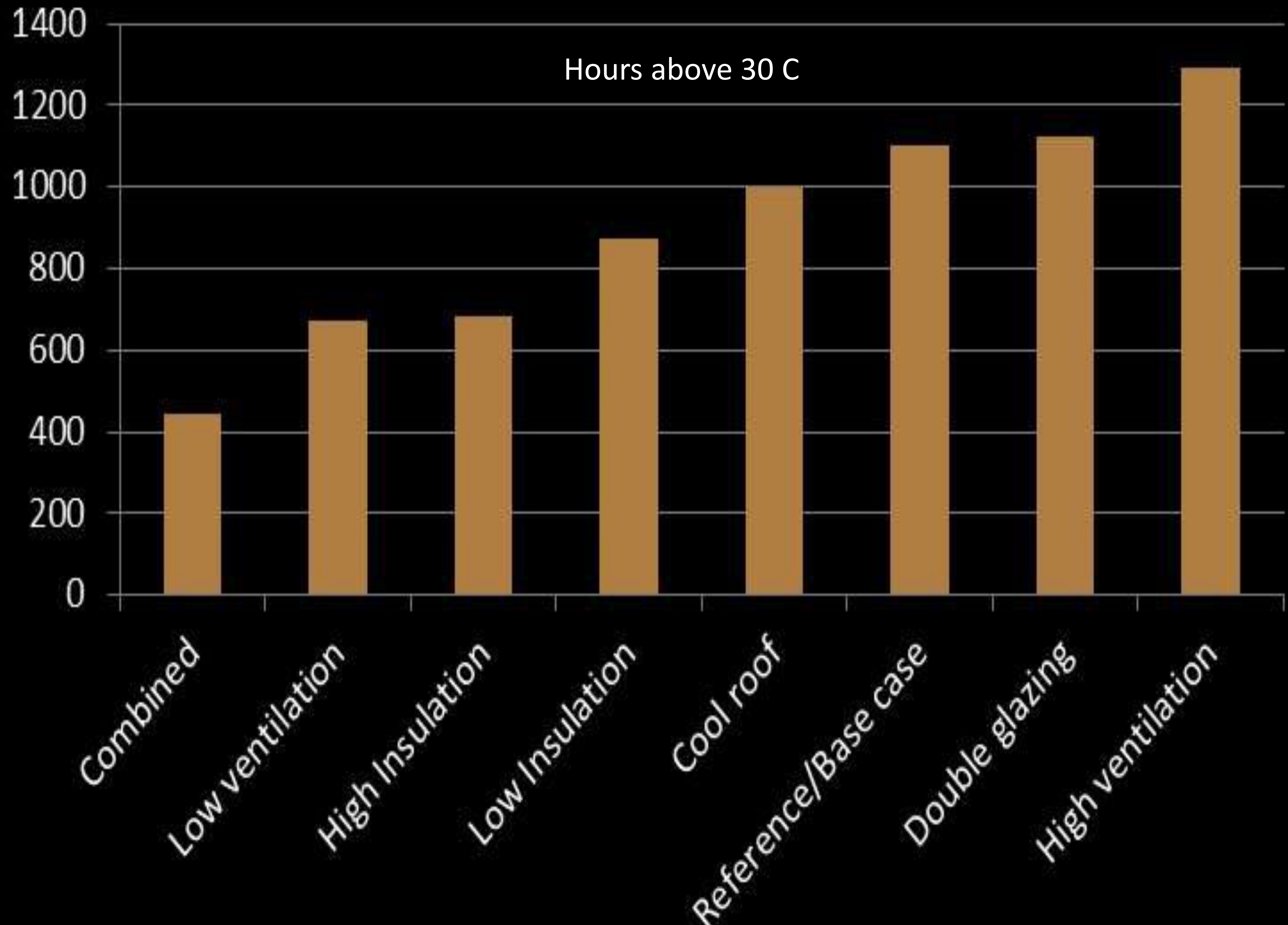






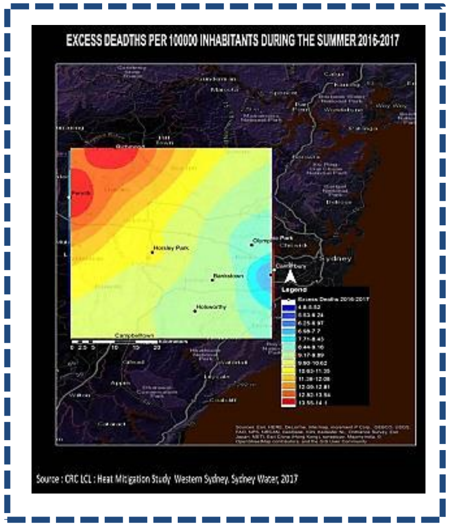


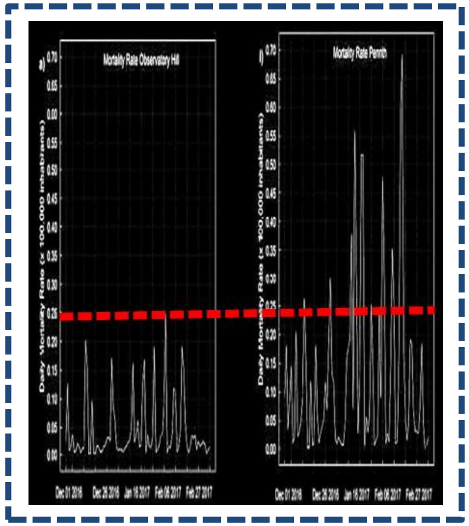
Maximum indoor temperature (C)
Maximum indoor temperature
36.0
35.5
35.0
34.5
34.0
33.5
33.0
32.5
32.0
Combined
Low ventilation
High Insulation
Low Insulation
Cool roofs
Double Glazing
Base Case
High ventilation

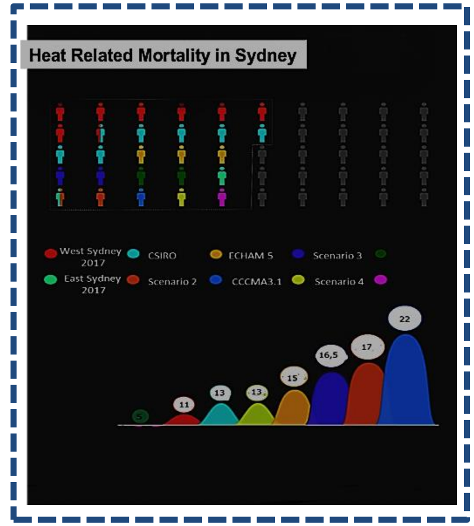


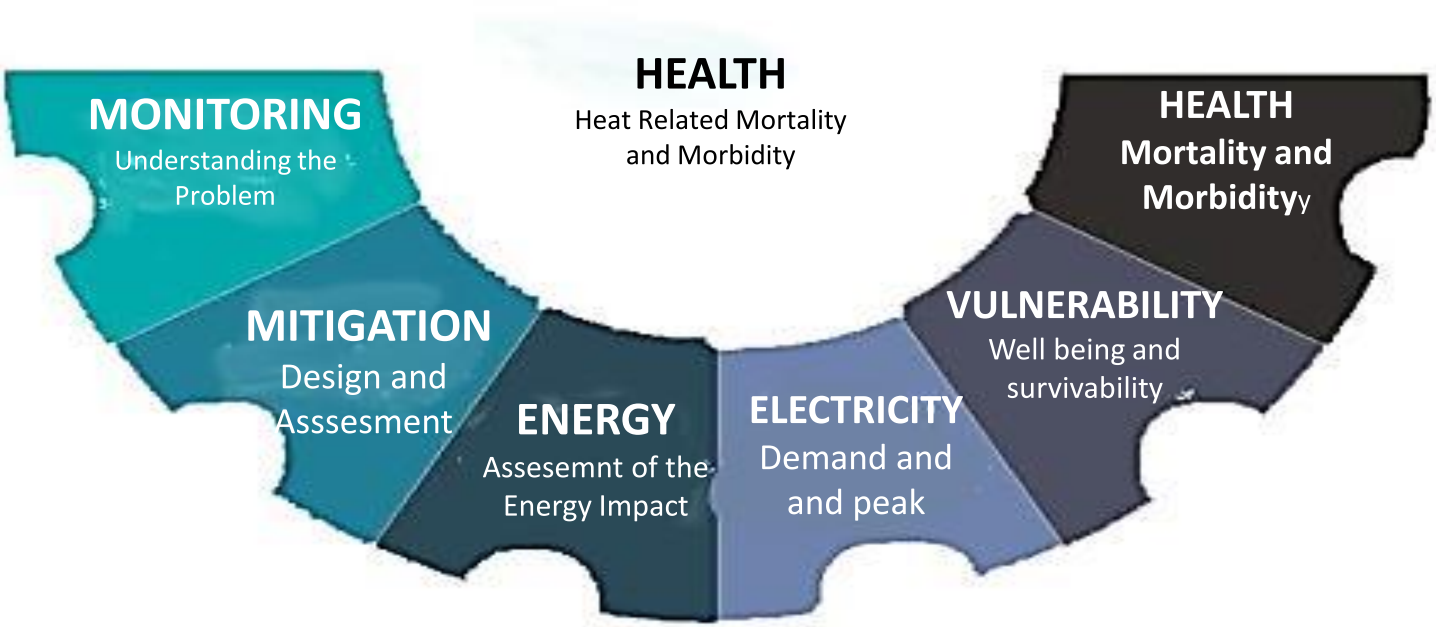
Hours above 30 C
1400
1200
1000
800
600
400
200
0
Combined
Low ventilation
High Insulation
Low Insulation
Cool roof
Reference/Base case
Double glazing
High ventilation

HOLISTIC MITIGATION STUDIES IN AUSTRALIA

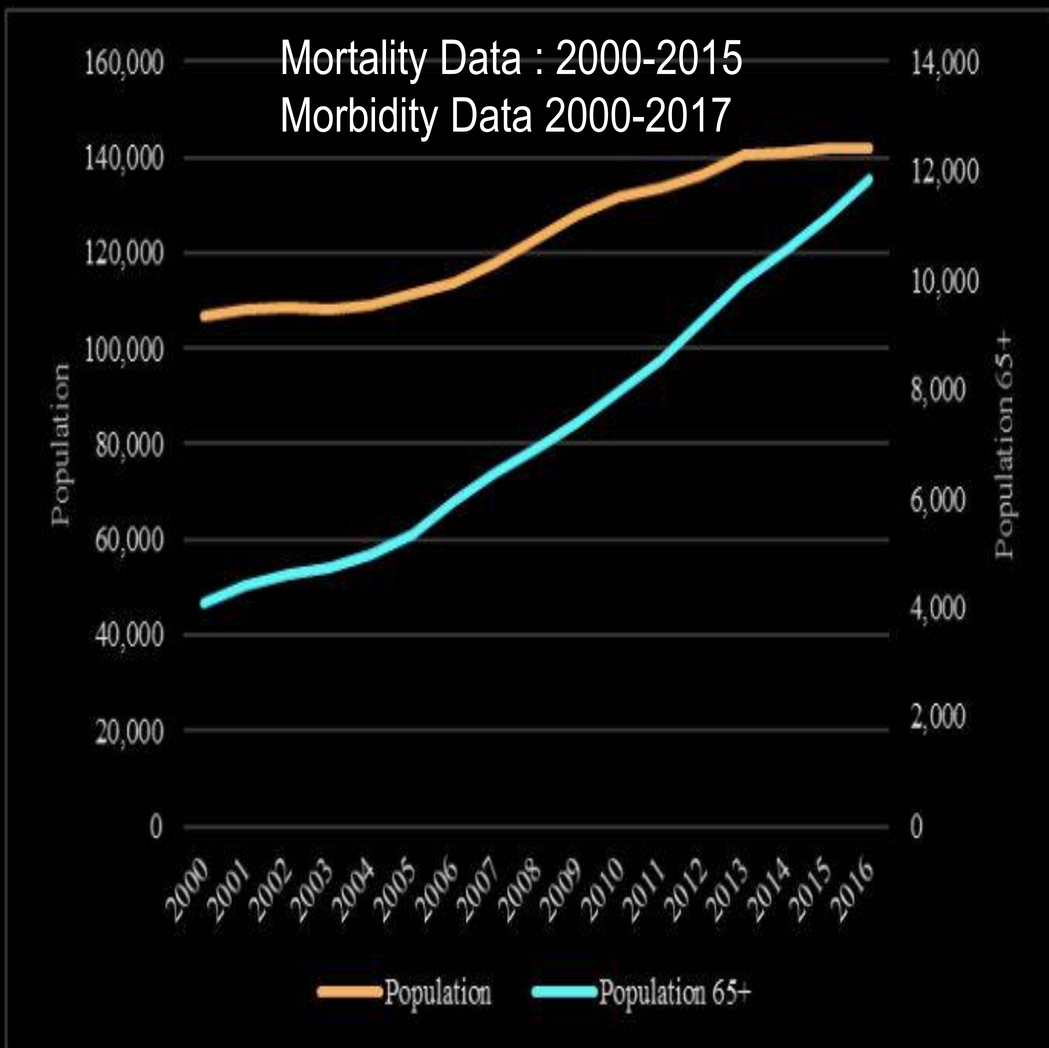








MITIGATION STUDY
HEAT RELATED HEALTH STUDY



The heat-relevant cases account for about the 55% of the all annual deaths, while this proportion is only around 17% in hospital admissions, indicating that only a portion of the morbidity cases with heat-relevant diagnoses results in deaths.

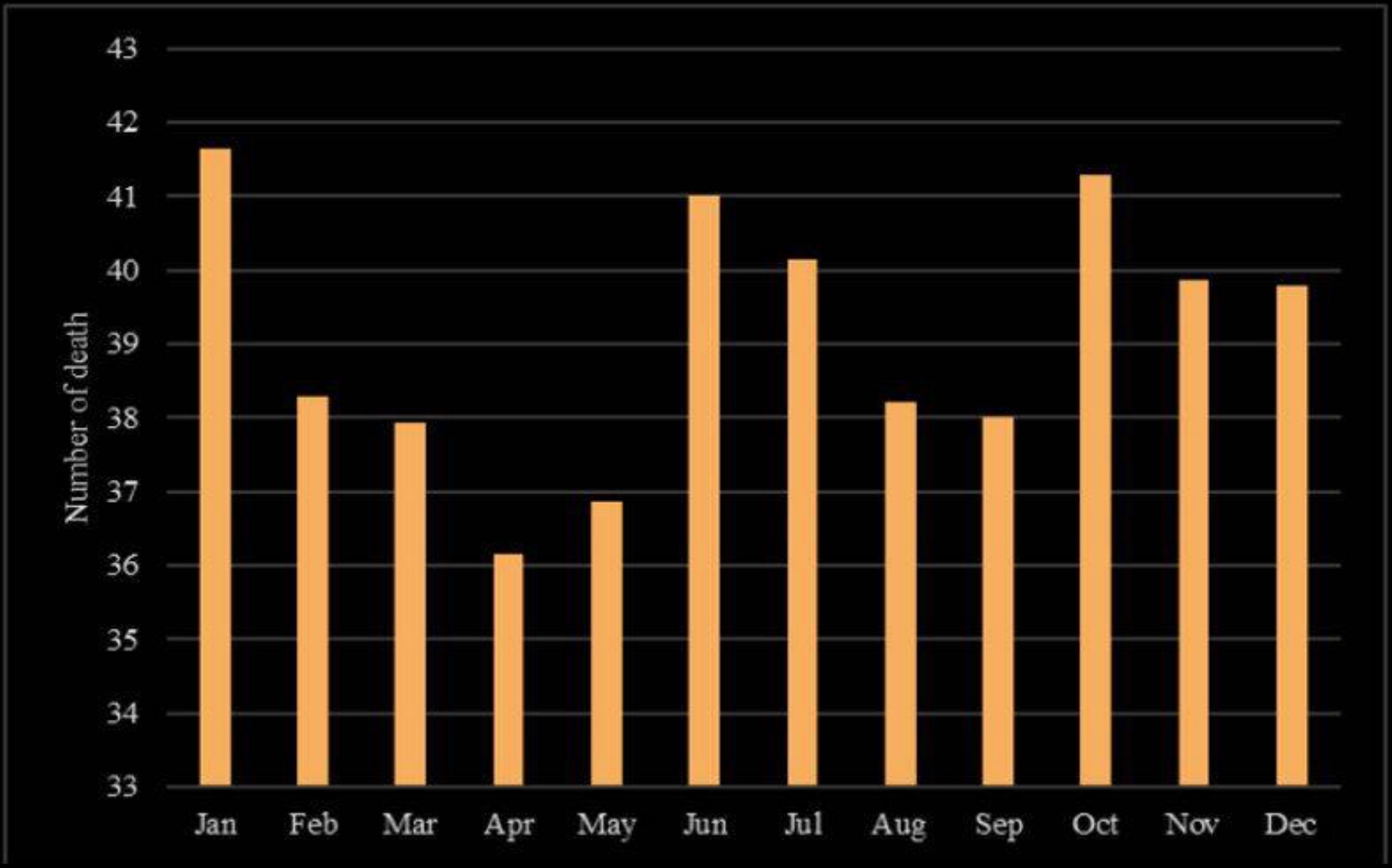
However, while people above 65 take only 43% of the hospital admissions, they account for 65% of the deaths with heat-relevant diagnoses.

These proportions reflect earlier studies claiming that older people are not just more likely to get hospitalised but even more likely to die due to excess heat.

Consequently, the ageing population poses an increased risk of heat related mortality in Darwin.

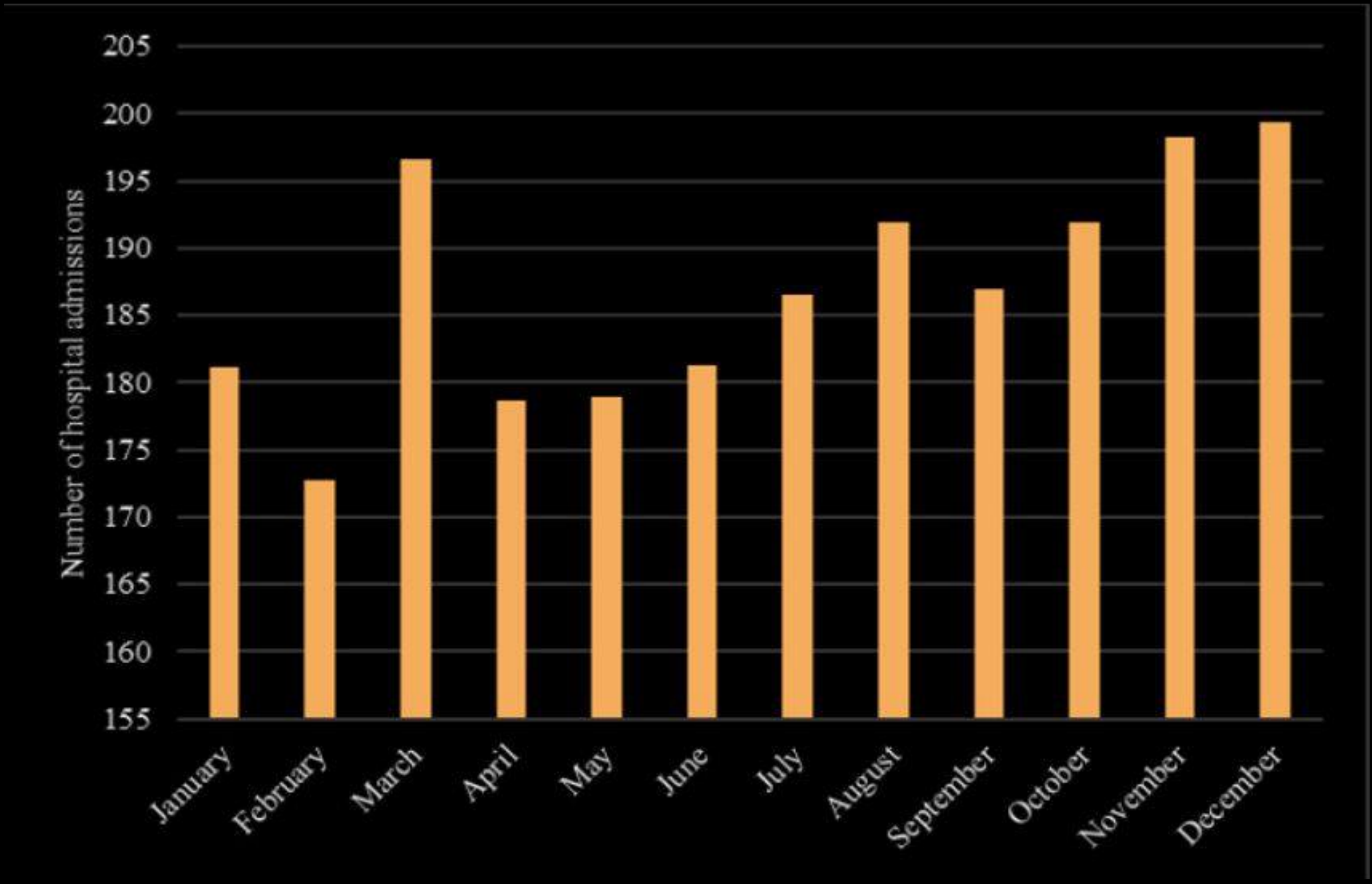
MITIGATION STUDY
HEAT REALTED HEALTH STUDY

HEAT RELATED MORTALITY



MITIGATION STUDY
HEAT RELATED HEALTH STUDY

HEAT RELATED MORBIDITY



HEAT RELATED MORBIDITY

The equations for the connections between daily maximum and mean temperatures and the daily hospital admissions are :

$$\text{Daily Hospital Admissions} = -2.45 + 0.079 * \text{DMT} + \varepsilon n$$

$$\text{Daily Hospital Admissions} = -1.74 + 0.066 * \text{MDT} + \varepsilon n$$

While 1°C increase in daily maximum causes 7.9% increase in hospital admissions, 1°C increase in daily mean temperature only raises the hospital admissions by 6.6%. This difference signals a higher dependency of morbidity on daily maximum than mean temperatures

When the dataset was filtered for days with higher temperatures and relative humidity, the strongest significant connections were found on days with both daily mean temperatures and relative humidity above the 80th percentiles calculated for the whole period

$$\text{Daily Hospital Admissions} = -76.92 + 2.63 * \text{DMT} + \varepsilon n$$

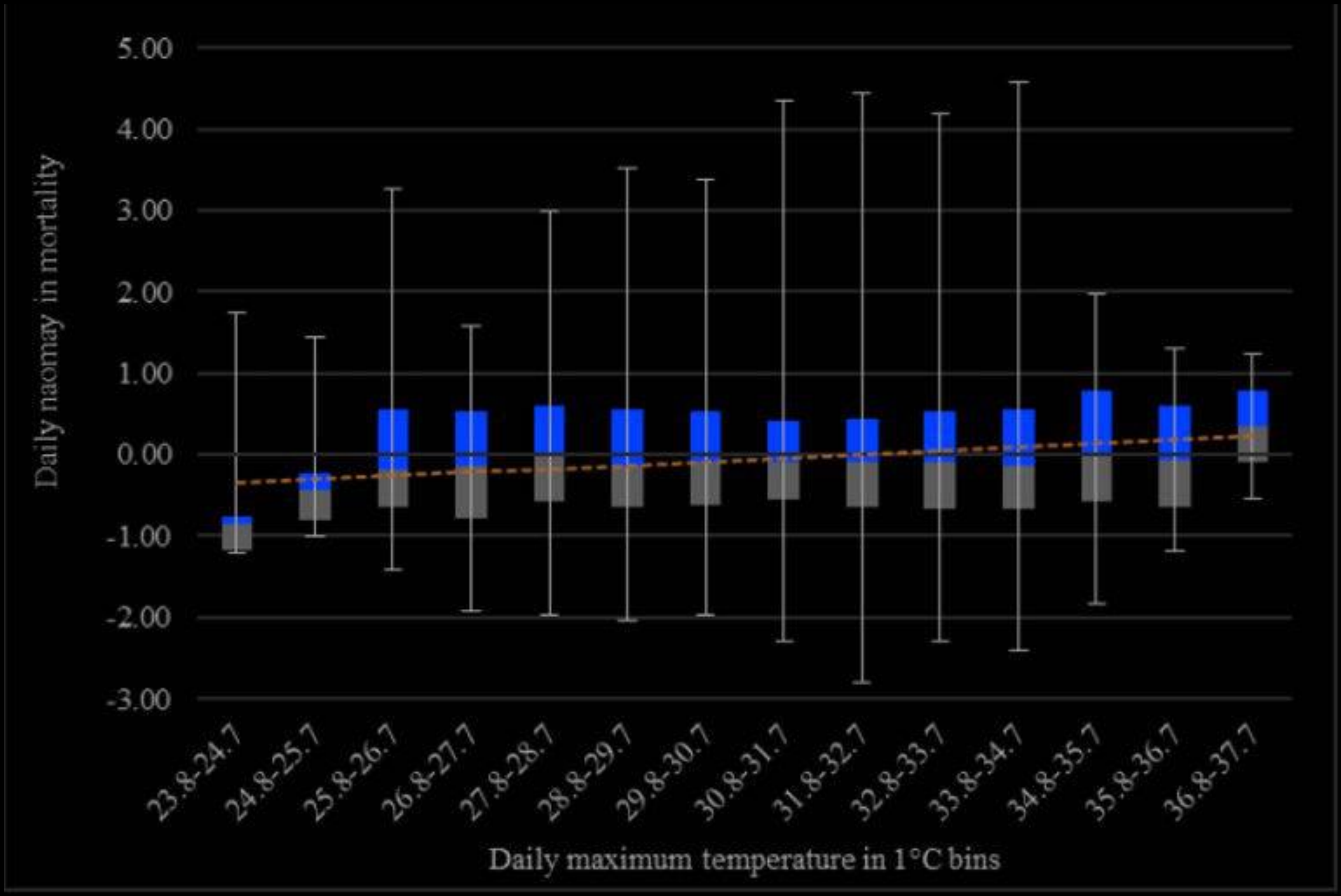
On these hot days with high humidity, 1°C increase in daily maximum temperature raised the number of hospital admissions by 263%.

Nevertheless, the strength of this connection has not increased when days with even higher temperature and humidity thresholds were considered.

This result indicates a high level of risk awareness in the local population.

MITIGATION STUDY
HEAT RELATED HEALTH STUDY

HEAT RELATED MORTALITY



HEAT RELATED MORTALITY

The equations of the connections between the daily maximum temperatures and the medians and averages of the daily mortality are l

$$\text{MEDIAN DAILY MORTALITY} = -1.70 + 0.049 * \text{DMT} + \varepsilon n$$

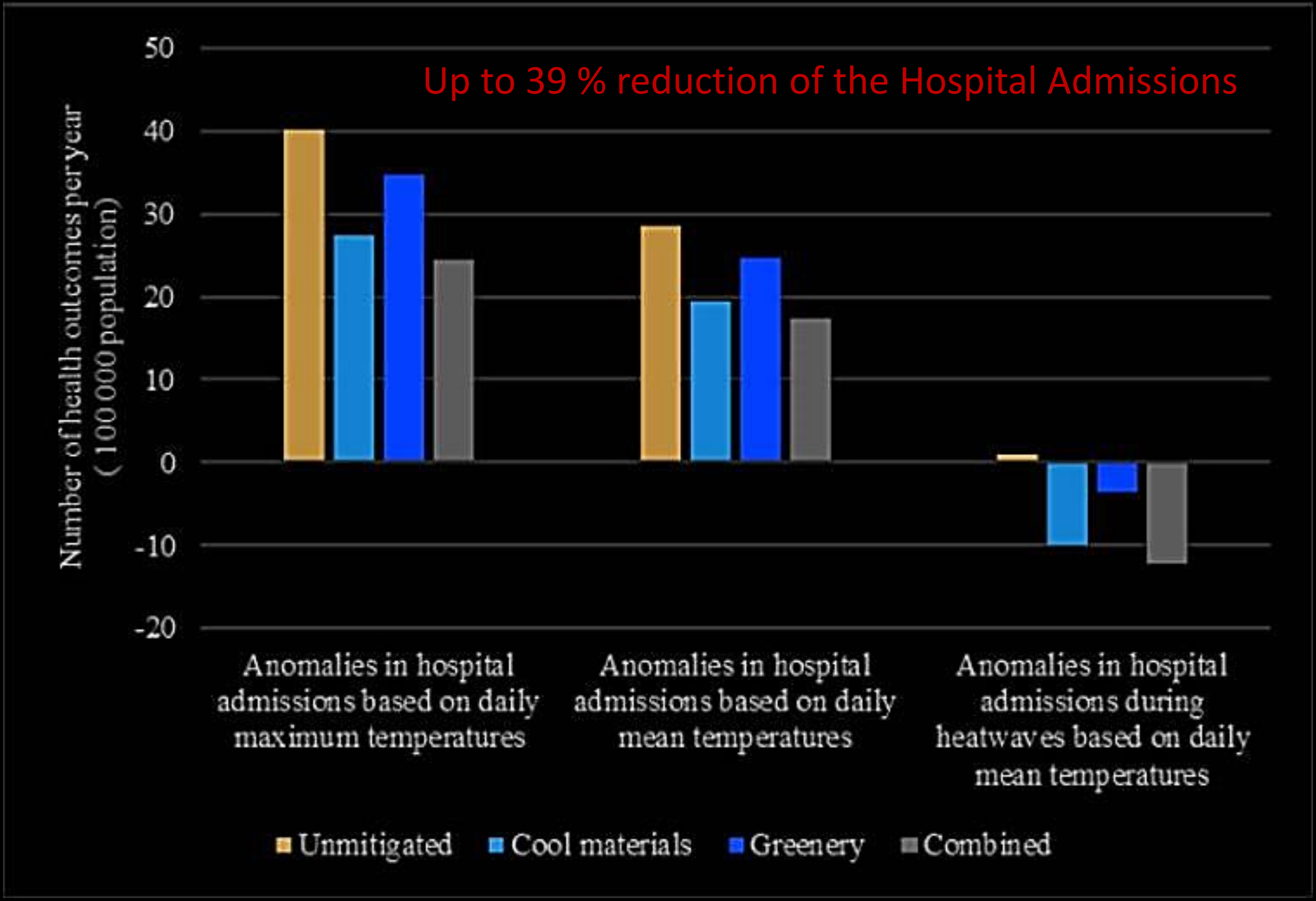
$$\text{AVERAGE DAILY MORTALITY} = -1.43 + 0.044 * \text{DMT} + \varepsilon n$$

Equations show that 1°C increase in daily maximum temperatures raises the median and averages of the mortality anomalies by 4.9 and 4.4%, respectively.

The analysis was repeated for the mortality data series aggregated for the Darwin Urban and Rural Health Districts with similar results

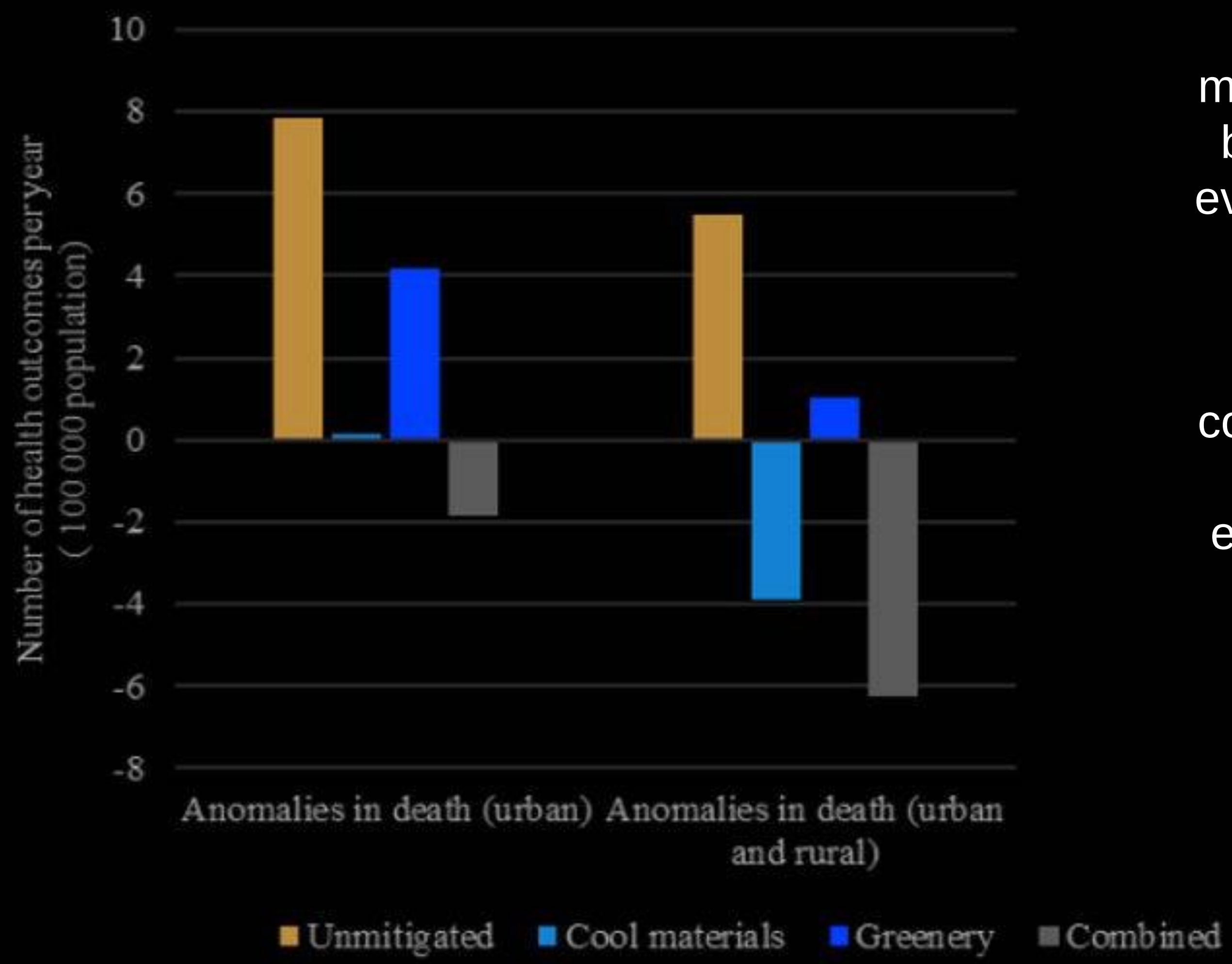
MITIGATION STUDY
HEAT RELATED HEALTH STUDY

HEAT RELATED MORBIDITY



MITIGATION STUDY
HEAT RELATED HEALTH STUDY

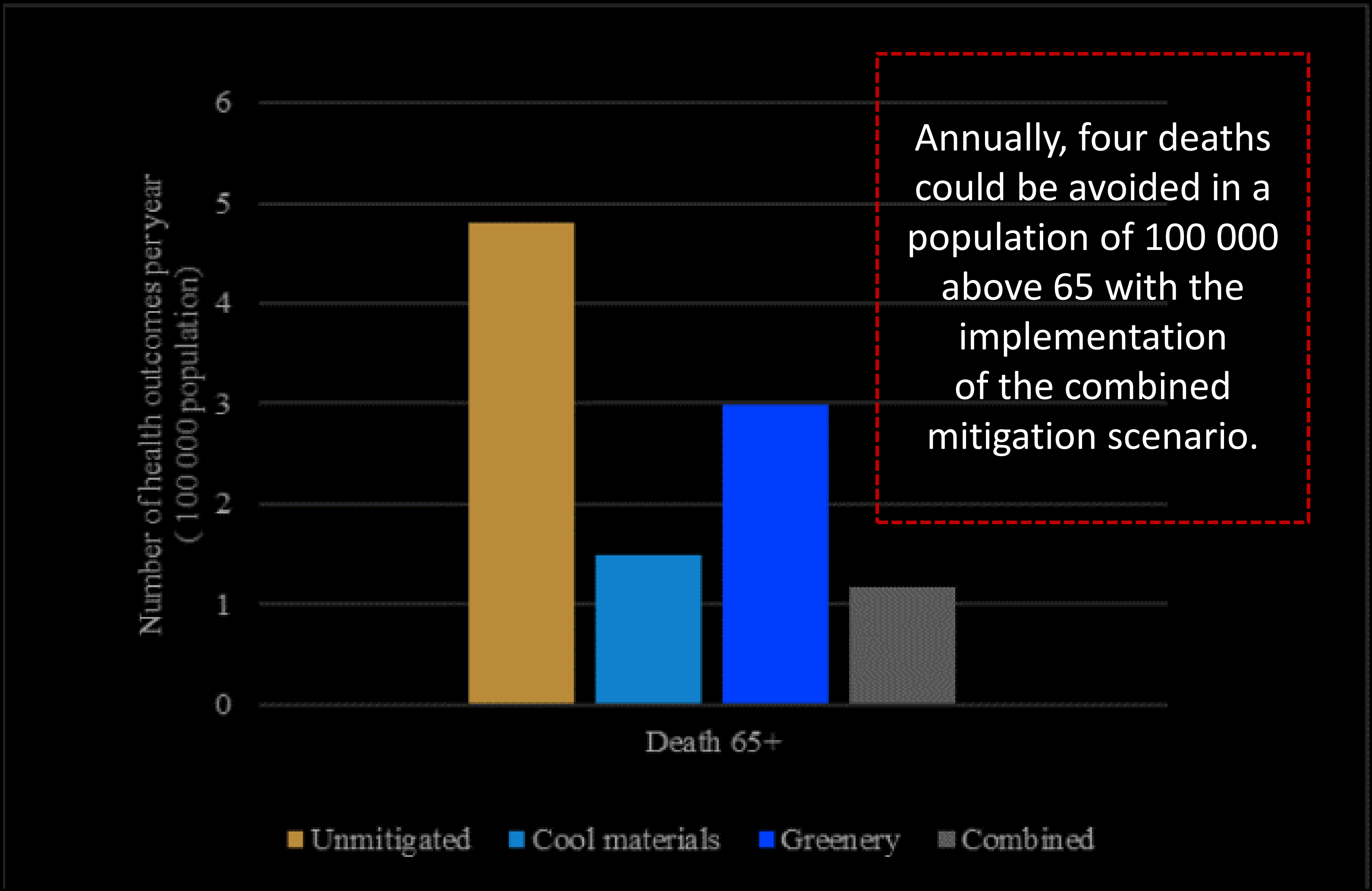
HEAT RELATED MORTALITY



Anomalies in mortality increased by 5% and 4% for every 1°C increase in daily maximum temperatures resulting that the combined scenario can save 9.66 excess deaths per year per 100 000 within the Darwin Urban Health District

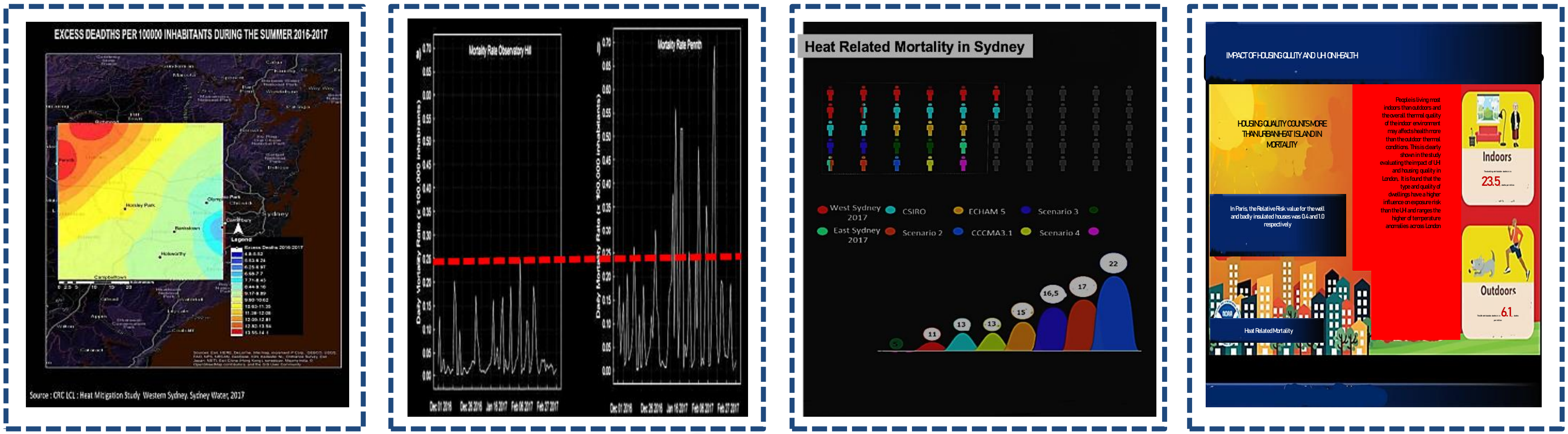
MITIGATION STUDY
HEAT RELATED HEALTH STUDY

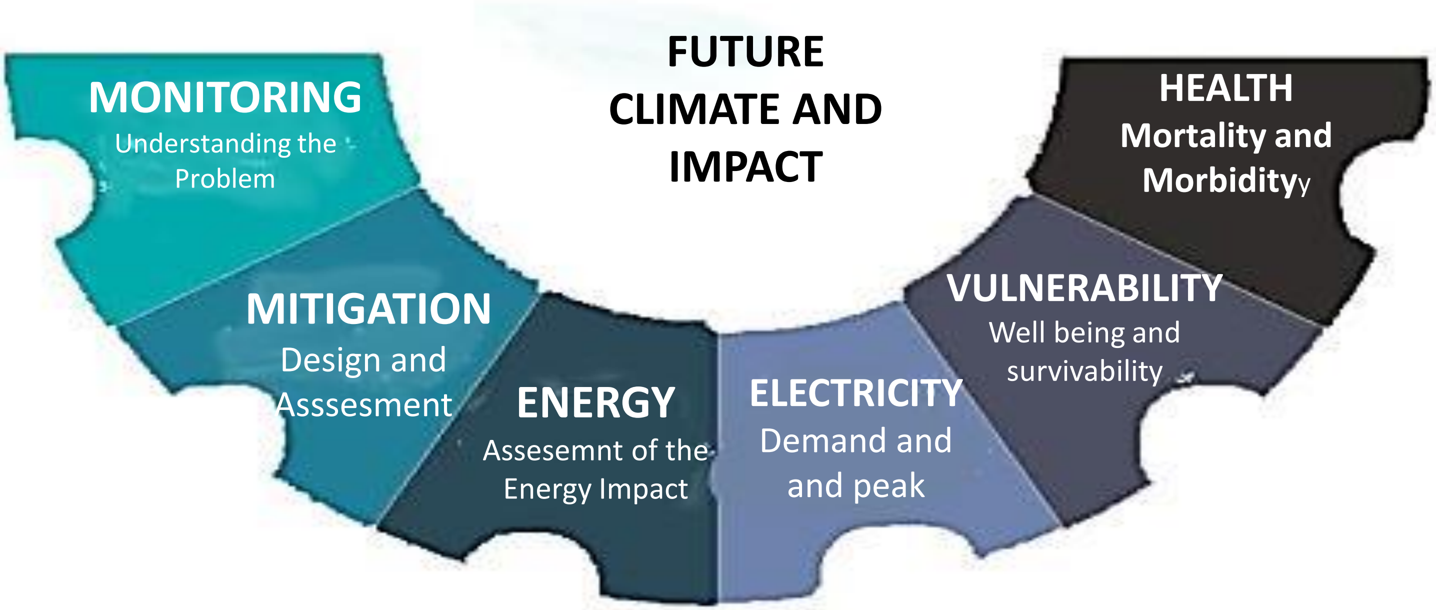
HEAT RELATED MORTALITY

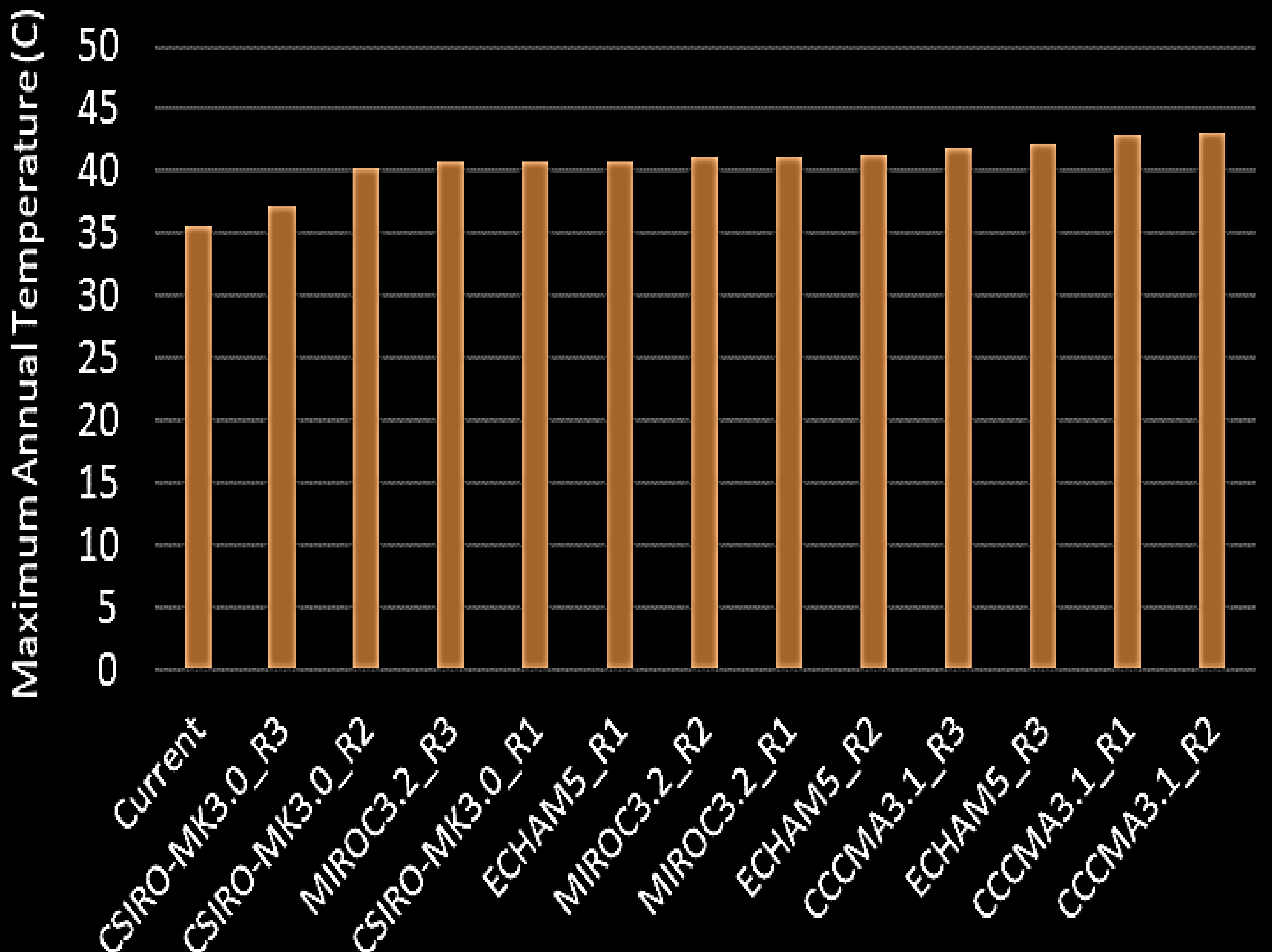


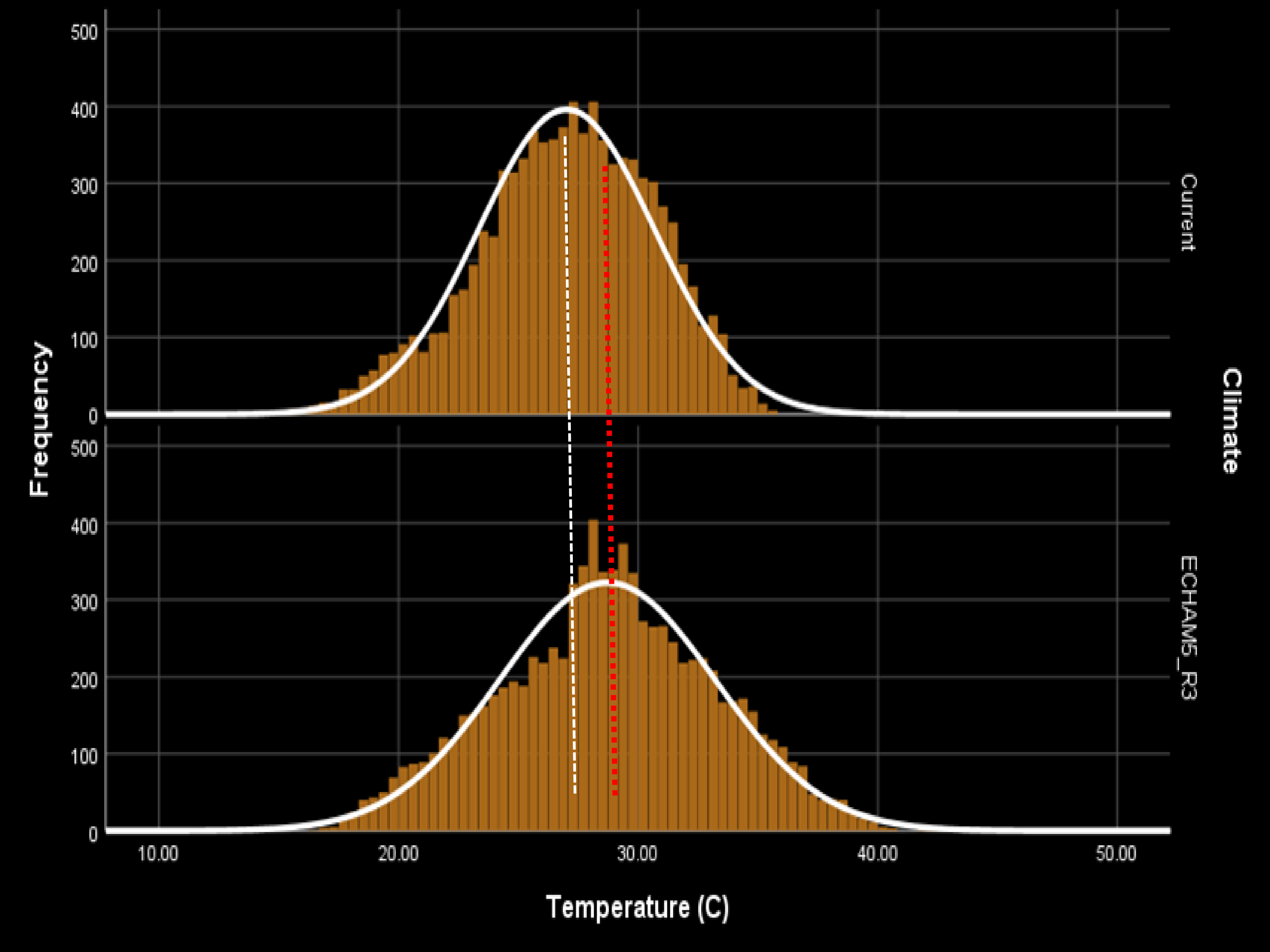
Annually, four deaths could be avoided in a population of 100 000 above 65 with the implementation of the combined mitigation scenario.

HOLISTIC MITIGATION STUDIES IN AUSTRALIA

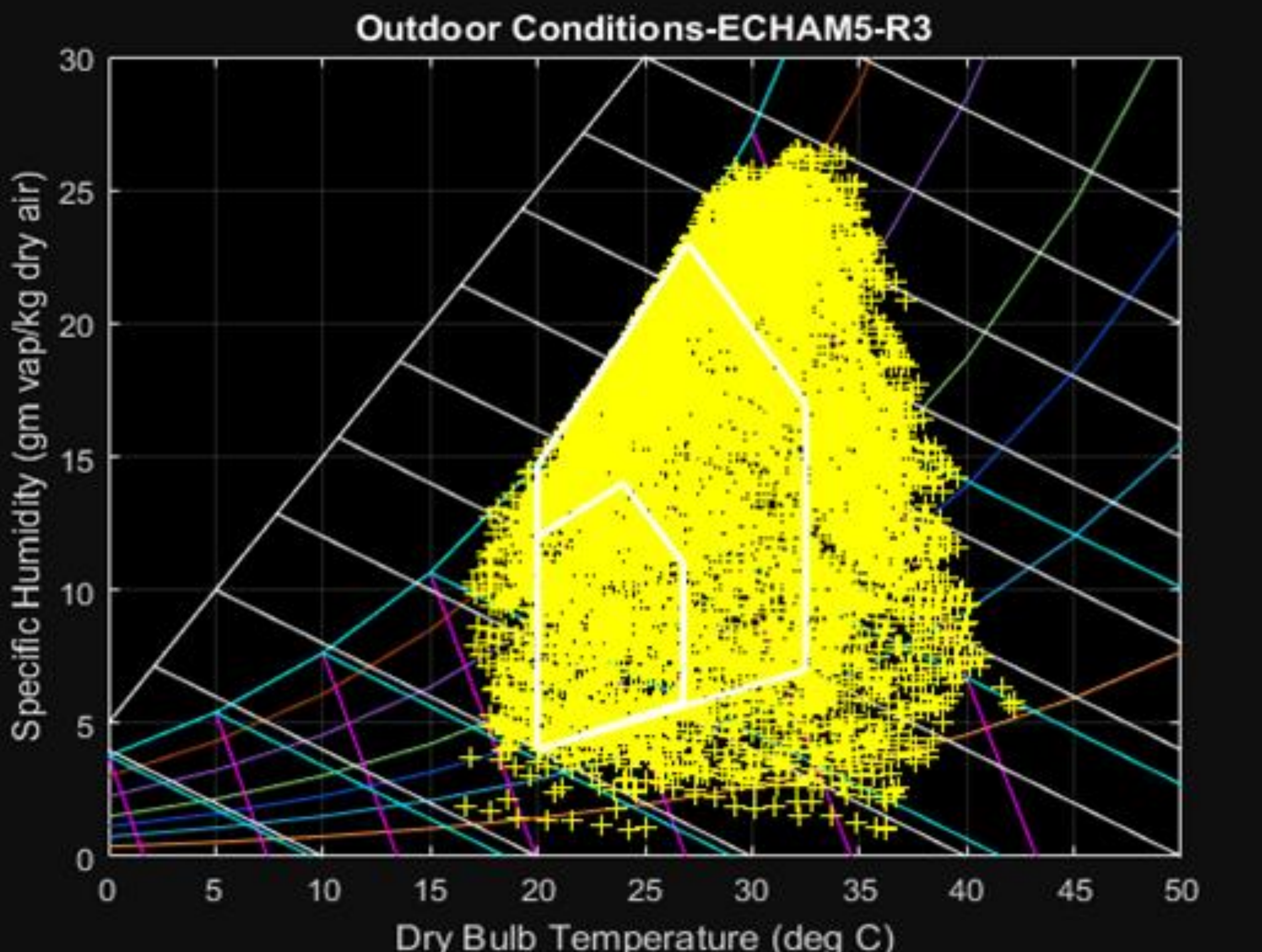


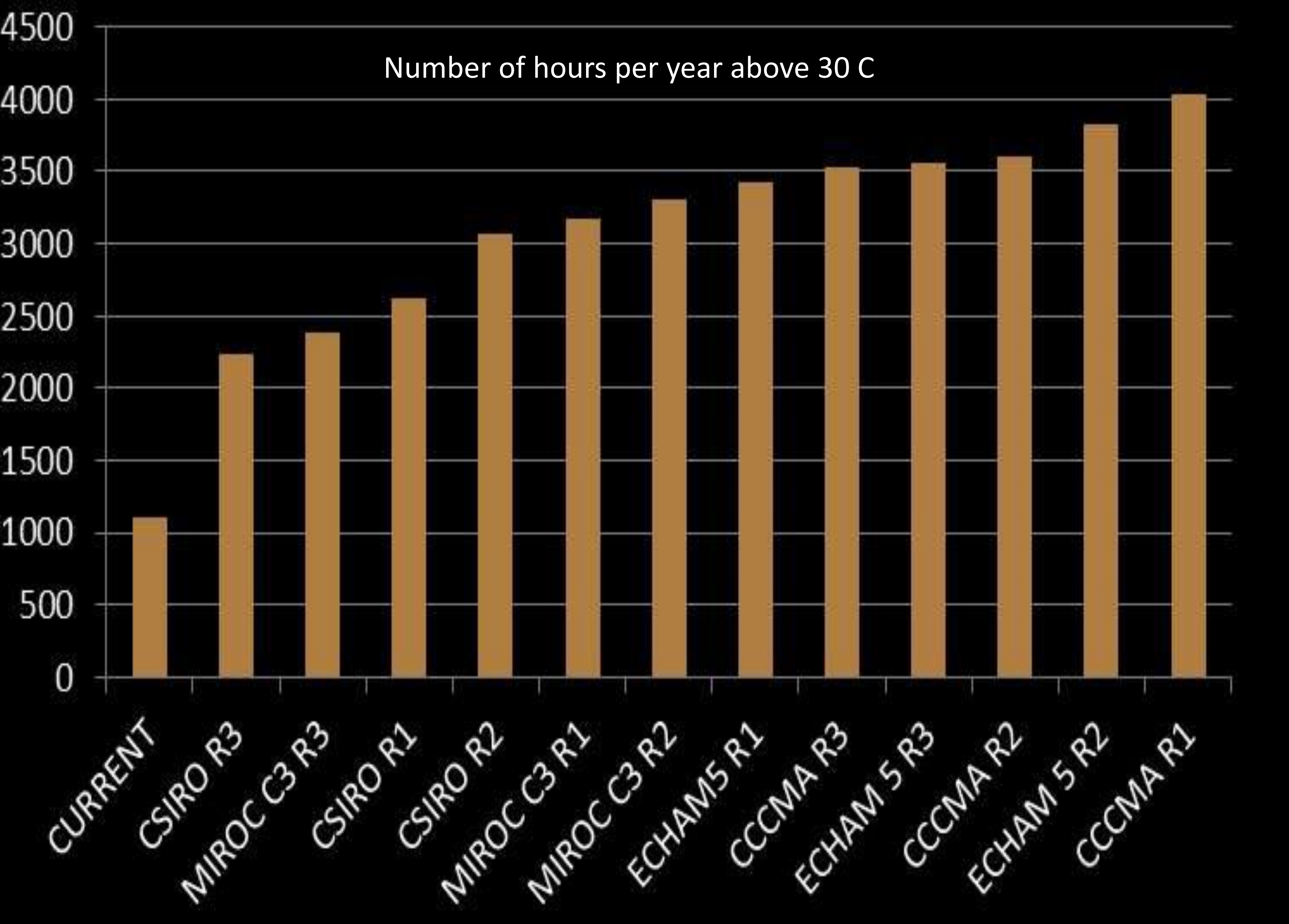


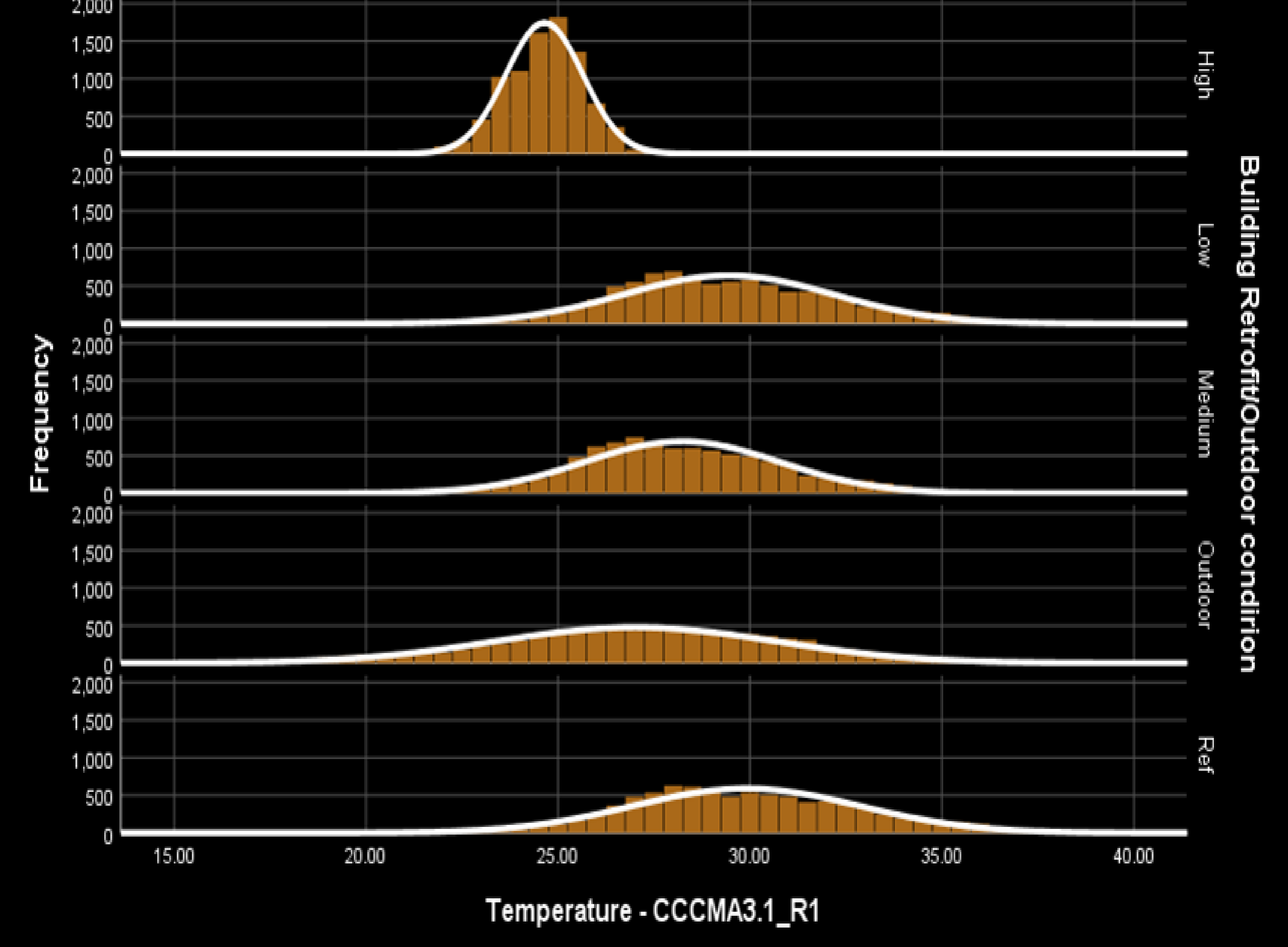

Maximum Annual Temperature (C)
50
45
40
35
30
25
20
15
10
5
0
Current
CSIRO-MK3.0_R3
CSIRO-MK3.0_R2
MIROC3.2_R3
CSIRO-MK3.0_R1
ECHAM5_R1
MIROC3.2_R2
MIROC3.2_R1
ECHAM5_R2
CCCMA3.1_R3
ECHAM5_R3
CCCMA3.1_R1
CCCMA3.1_R2

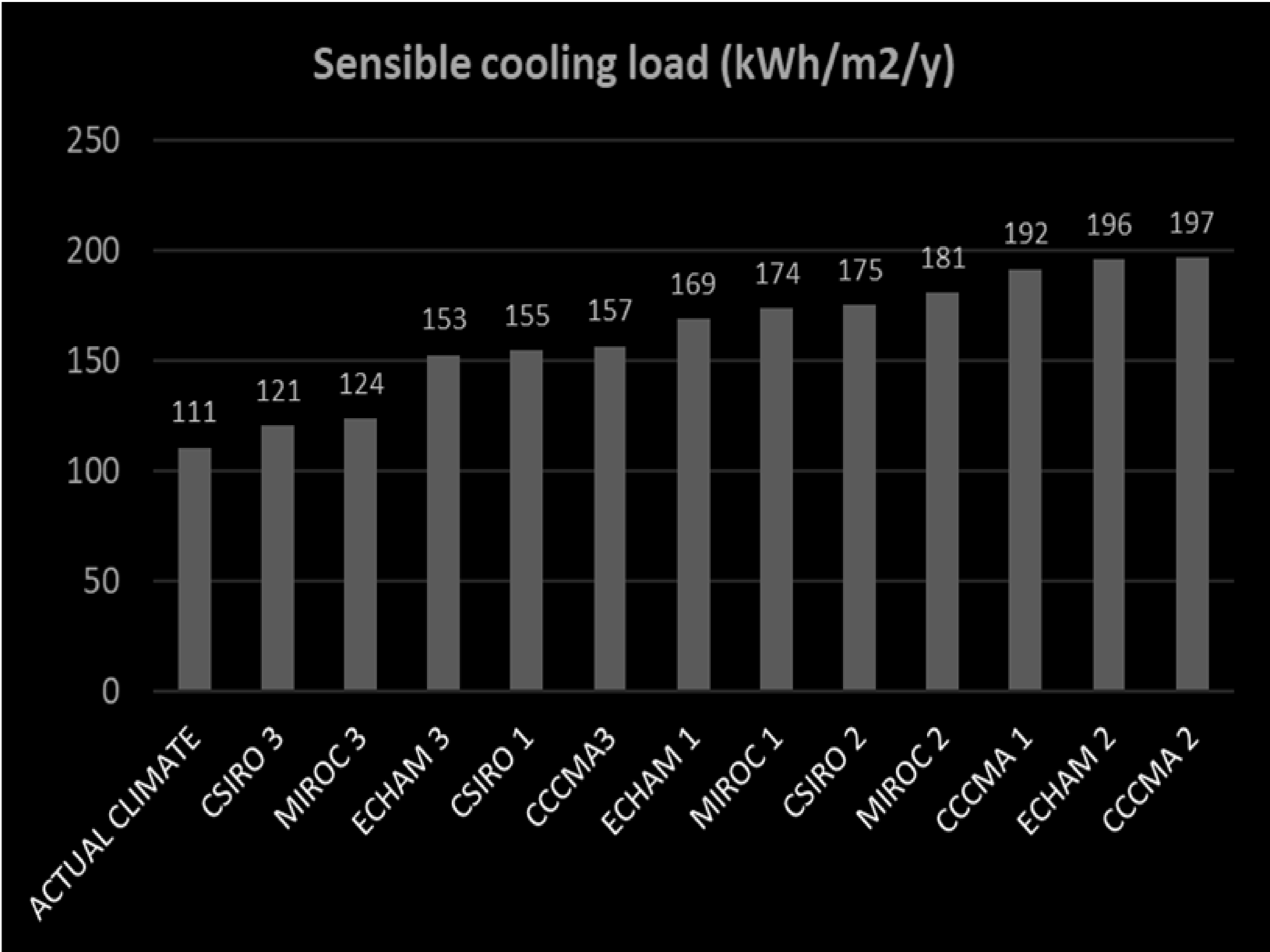


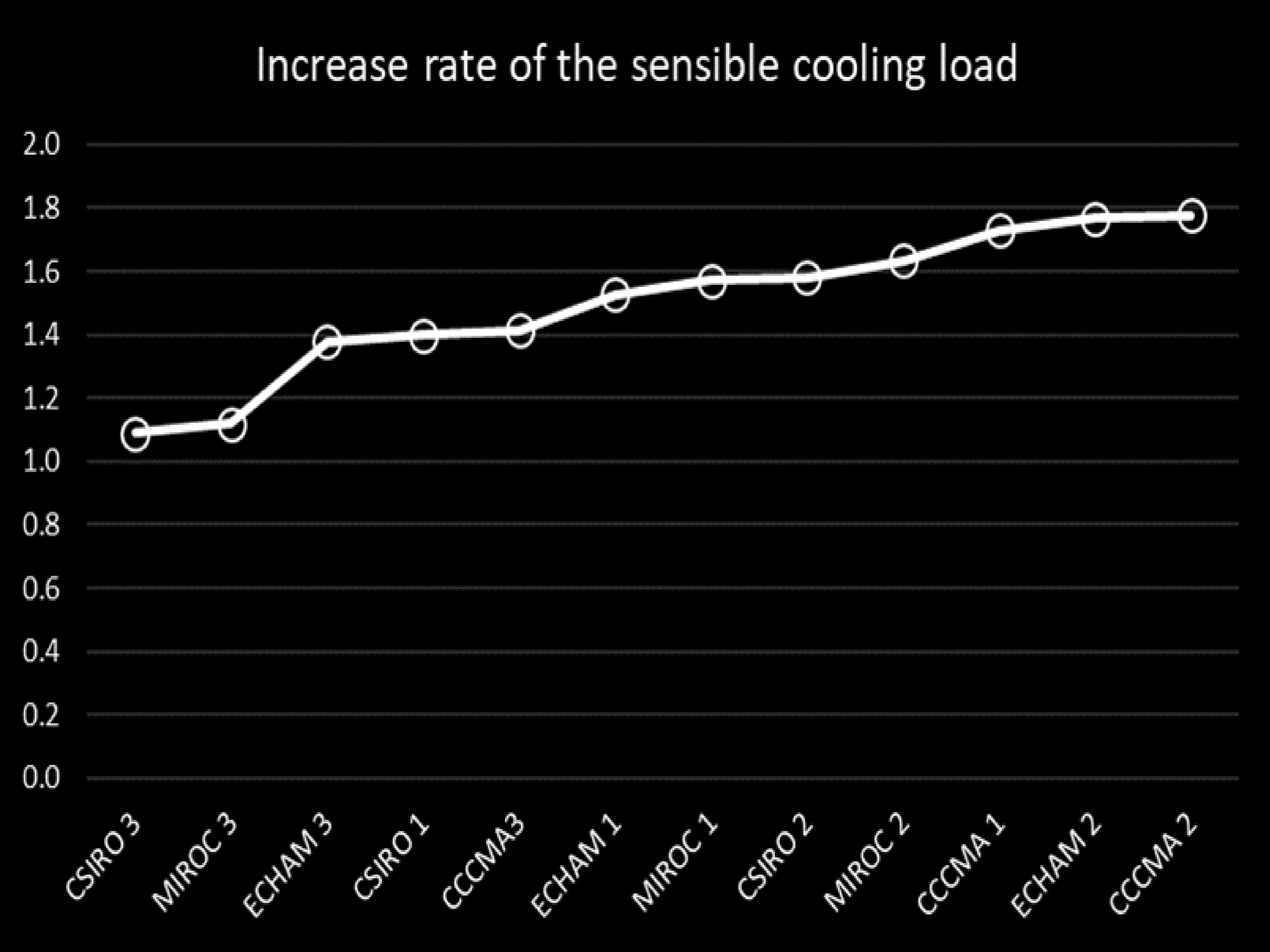
Frequency
Temperature (C)
Climate
Current
ECHAM5_R3
0
100
200
300
400
500
10.00
20.00
30.00
40.00
50.00

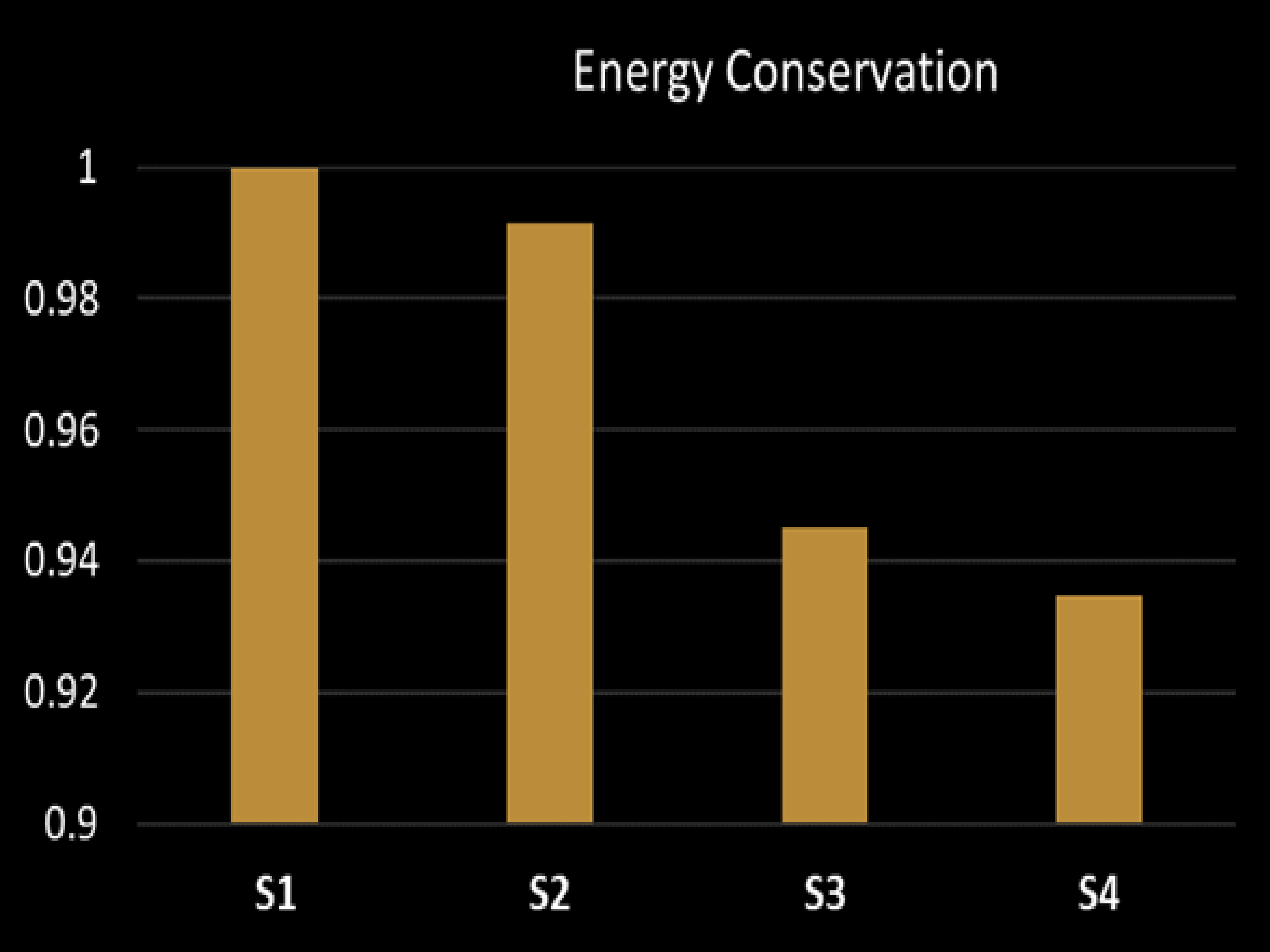

Outdoor Conditions-ECHAM5-R3
Specific Humidity (gm vap/kg dry air)
Dry Bulb Temperature (deg C)
0
5
10
15
20
25
30
35
40
45
50


Number of hours per year above 30 C
4500
4000
3500
3000
2500
2000
1500
1000
500
0
CURRENT
CSIRO R3
MIROC C3 R3
CSIRO R1
CSIRO R2
MIROC C3 R1
MIROC C3 R2
ECHAM5 R1
CCCMA R3
ECHAM 5 R3
CCCMA R2
ECHAM 5 R2
CCCMA R1


Frequency
Building Retrofit/Outdoor condirion
High
Low
Medium
Outdoor
Ref
0
500
1,000
1,500
2,000
15.00
20.00
25.00
30.00
35.00
40.00
Temperature - CCCMA3.1_R1


Sensible cooling load (kWh/m2/y)
250
200
150
100
50
0
111
121
124
153
155
157
169
174
175
181
192
196
197
ACTUAL CLIMATE
CSIRO 3
MIROC 3
ECHAM 3
CSIRO 1
CCCMA3
ECHAM 1
MIROC 1
CSIRO 2
MIROC 2
CCCMA 1
ECHAM 2
CCCMA 2


Increase rate of the sensible cooling load
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
CSIRO 3
MIROC 3
ECHAM 3
CSIRO 1
CCCMA3
ECHAM 1
MIROC 1
CSIRO 2
MIROC 2
CCCMA 1
ECHAM 2
CCCMA 2


Energy Conservation
1
0.98
0.96
0.94
0.92
0.9
S1
S2
S3
S4

Under the current climatic conditions, the estimated CO_2 reductions because of the retrofitting of the existing residential buildings is close to 49000 tonnes per year.

Under the current climatic conditions, the estimated reduction of the carbon dioxide emissions from the commercial buildings, is close to 18700 tonnes per year

For the future climate, 2050, the estimated reduction of the CO_2 emissions for the residential sector, under the CCCMA3 scenario is close to 380000 tonnes per year.

For the future climate, 2050, the estimated reduction of the CO_2 emissions for the residential sector, under the MIROC 1 scenario is close to 210000 tonnes of CO_2 per year.

About 8400 new jobs associated to the light retrofitting of the existing residential building stock

About 43000 new jobs associated to the light retrofitting of the existing commercial building stock

About 2260000 new jobs between 2020 and 2050 associated to the retrofitting of the existing residential building stock, (deep retrofitting)

About 2600000 new jobs between 2020 and 2050 associated to the construction of very energy efficient new residential buildings.

01

Mitigation techniques based on the use of water, greenery, and cool materials can reduce the average peak ambient temperature up to 2,5 C

02

Mitigation techniques can reduce the cooling needs of a residential and office building up to 33 kWh/m2/y .

The energy conservation potential is up to 1726 GWh for the Darwin area

03

Application of mitigation technologies can reduce the heat related morbidity up to 40 % and reduce the heat related mortality by 9,7 additional deaths' per 100000 inhabitants t

04

Application of Mitigation Techniques can reduce the peak electricity demand up to 2 %

The total electricity demand over the summer period may be reduced by 0.8 MVA