CRC for
Water Sensitive Cities

Australian Government
Department of Industry, Innovation and Science

Business
Cooperative Research Centres Programme

WP6 Economic Benefits of Urban Cooling Provided by WSUD:

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watersensitivecities.org.au

Background to WP6

- The first attempt of its kind to bring biophysical and economic modelling together to identify the economic benefits of urban greening in a green fields residential setting – a case study area in western Melbourne
- Three components
  - Scenario development and associated land use settings (E2Design)
  - Modelling a range of summer conditions using TARGET; a microclimate model developed within the CRC for use in quantifying benefits of WSUD/GI (Monash University)
  - Economic modelling of the benefits of summertime cooling for mortality/morbidity, workplace productivity, electricity use and willingness to pay (RMCG)

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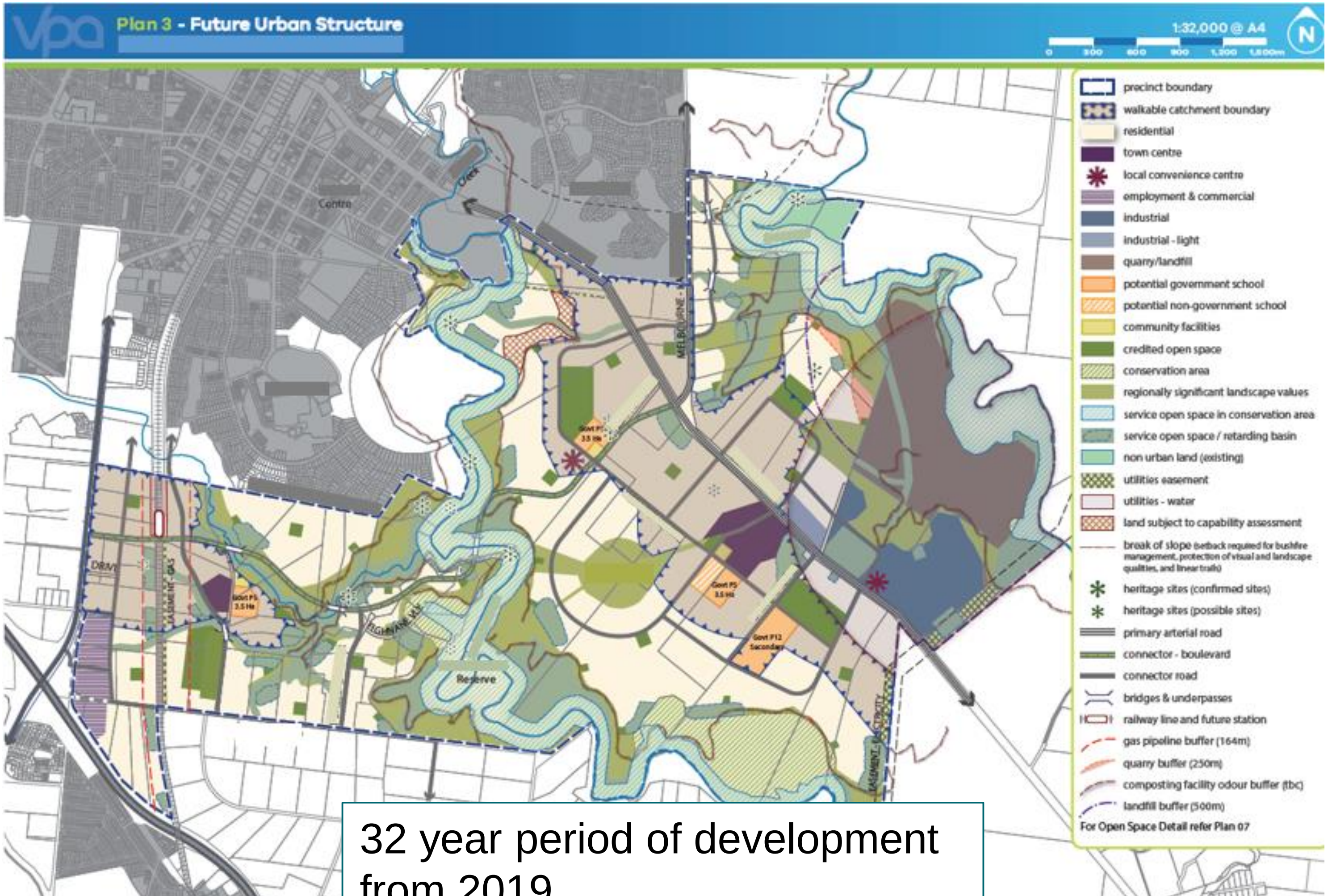
The Case Study Area



32 year period of development from 2019
Eventually 11,800 extra houses and 33,000 extra people

Scenario Development

Four scenarios were chosen to represent 4 policy stances relating to WSUD and IWM investment in Victoria. These are:

- Scenario 1: No IWM regulation. i.e. no stormwater quality improvement or potable water saving targets or measures in place.

- Scenario 2: Current IWM policy setting, incorporating landscape features to meet stormwater quality for residential subdivisions that are required under Clause 56.07 of the Victorian Planning Provisions as well as requirements under the 6 Star Building Code (potable water saving targets).

- Scenario 3: Potential future IWM policy setting: representing the introduction of a 60% flow volume reduction target in addition to water quality targets for residential subdivisions.

- Scenario 4: Targeted UHI mitigation scenario: this analysis represents IWM and landscape initiatives necessary to achieve significant reduction in the UHI effect.

Modelling Approach for Development of Scenarios

- The development zones shown in the PSP were digitised into GIS layers to represent, urban residential, roads, commercial, industrial, non-irrigated open space and irrigated open space.

- These layers were imported into the Dance4Water software (https://watersensitivecities.org.au/) which was used as the interface to set-up further parameterisation of zones and create the gridded dataset required for interface to the micro-climate model.

- For each scenario, MUSIC modelling ascertained the particular design requirements necessary to meet the IWM regulation objectives.

- These were translated to urban design characteristic input parameters that were used in the micro-climate modelling.

Climate Modelling Input Parameters

Parameters	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Urban Residential				
Roof	60% of lot	60% of lot	60% of lot	60% of lot
Other Impervious	20% of lot	20% of lot	20% of lot	20% of lot
Pervious area	20% of lot	20% of lot	20% of lot	20% of lot
- **Low veg on lot**	17% of lot	17% of lot	17% of lot	15% of lot
- **Trees on lot (high veg)**	3% of lot	3% of lot	3% of lot	5% of lot
- **Irrigated grass**	30% of all lots	30% of all lots	60% of all lots	100% of all lots
- **Dry-grass**	70% of all lots	70% of all lots	40% of all lots	0 % of all lots
- **Raingarden**	none	none	2.7 m^2 per lot	2.7 m^2 per lot
- **Infiltration trench**	none	none	20 m^2 per lot	20 m^2 per lot
Trees on lot	none	none	none	1 tree on lot per lot – 22.8 m^2
Tanks	0 % of lots	30 % of lots	100% of lots	100% of lots
- **Demands on rainwater storage in tanks**	outdoor	Toilet + outdoor	Outdoor, toilet, laundry + hot water	Outdoor, toilet, laundry + hot water
Pervious soil moisture - unirrigated	9.6%	9.6%	9.6%	9.6%
Pervious soil moisture - irrigated	17.6%	17.6%	27.3%	40% (estimated – climate model iteration required)
Open Space				
Irrigated open space – typical annual values	1.5 - 3 ML/Ha	1.5 - 3 ML/Ha	3 - 5 ML/Ha	3 - 5 ML/Ha (or higher)
Water bodies	No wetlands	Wetlands	Wetlands + evapotranspiration fields	Wetlands + evapotranspiration fields
Road Reserve (FI = 70%)				
Trees on urban streets	1 tree /lot frontage* 9.6 m^2	1 tree /lot frontage* 9.6 m^2	1 Passively irrigated tree/lot (> canopy)* 22.8 m^2	2 Passively irrigated trees/lot (> canopy)* 22.8 m^2 per tree
Commercial and Industrial				
Fraction impervious	90%	90%	90%	80%

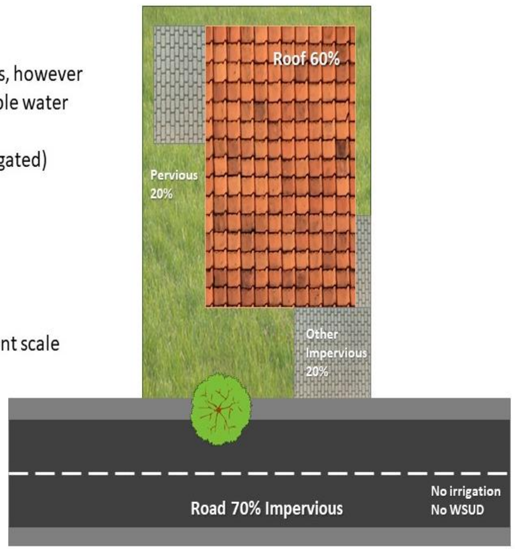
Typical Modelled Lots – Scenario 1 & 2

Scenario #1

- **0% of lots** have rainwater tanks, however
- **30% of lots** irrigate using potable water

- 1 tree per lot frontage (not irrigated) (mature tree = 9.6 m^2)

- **Catchment scale:** No catchment scale WSUD

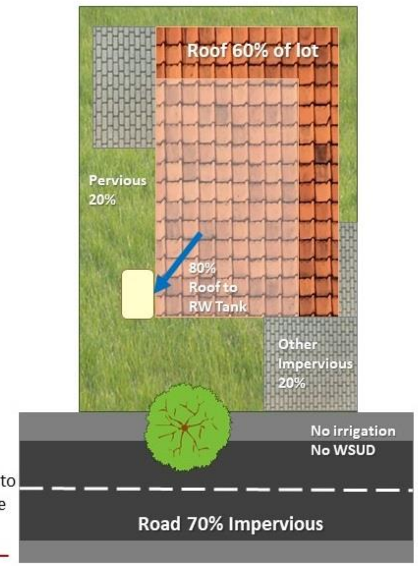


Scenario #2

- **30% of lots** have rainwater tanks for irrigation

- 80 % of roof to 5KL tank (~ 220 m^2)

- 1 tree per lot frontage (not irrigated) (mature tree canopy = 9.6 m^2)

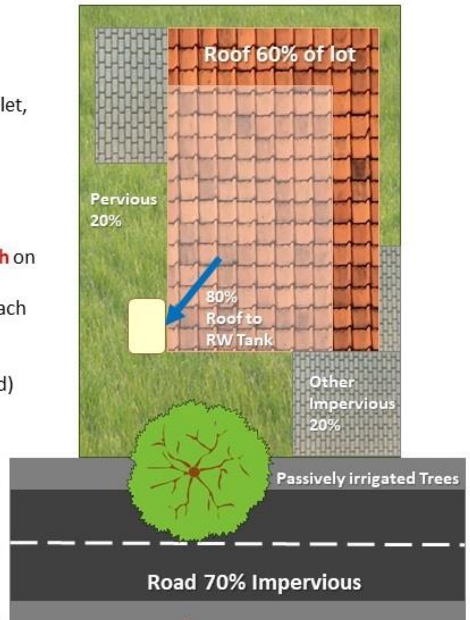


- **Catchment scale:** centralised wetlands to treat stormwater runoff to best practice standards

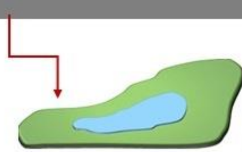
Typical Modelled Lots - Scenario 3 & 4

Scenario #3

- **100% of lots** have rainwater tanks for outdoor irrigation, + indoor demands: toilet, laundry, and hot water, assuming:
- **60% of lots** irrigate pervious areas
- 80 % of roof to 5KL tank (~ 220 m^2)
- Tank overflow to **22 m^2 infiltration trench** on each lot
- Surface runoff to **2.7 m^2 raingarden** on each lot
- 1 tree per lot frontage (passively irrigated) (mature tree canopy = 22.8 m^2)

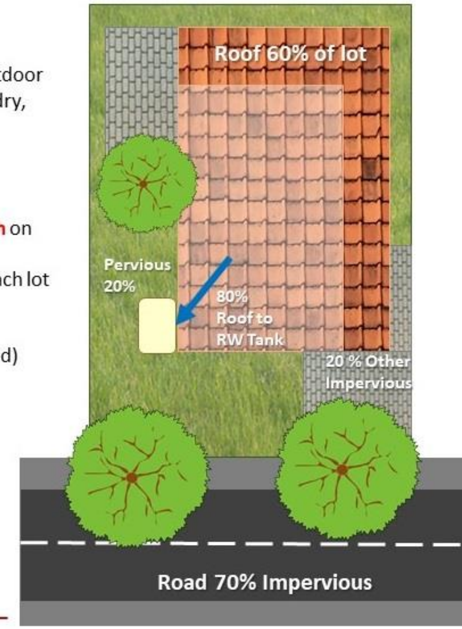


- **Catchment scale:** centralised wetlands to treat stormwater runoff to best practice standards
- Evaporation sponges to achieve 60% flow reduction target



Scenario #4-A

- **100% of lots** have rainwater tanks for outdoor irrigation, + indoor demands: toilet, laundry, and hot water. **100% irrigate**.
- 80 % of roof to 5KL tank (~ 220 m^2)
- Tank overflow to **22 m^2 infiltration trench** on each lot
- Surface runoff to **2.7 m^2 raingarden** on each lot
- 1 tree / lot (on-lot) (mature tree = 5 m^2)
- 2 trees per lot frontage (passively irrigated) (mature tree canopy = 22.8 m^2)



- **Catchment scale:** centralised wetlands to treat stormwater runoff to best practice standards

- **Commercial/Industrial:** minimum 20% pervious irrigated area/lot
- Passively irrigated trees in streetscape (1 tree /10m)

Microclimate Modelling

The Air-temperature Response to Green/blue-infrastructure Evaluation Tool (TARGET)[1.]

- Is a microclimate model developed specifically within my group for use in the CRC-WSC to evaluate the thermal benefits of WSUD.

- It is a simplified but accurate and scientifically defensible model, ultimately designed to be used by our industry partners. The accessibility allows modelling scenarios to be created from simple land cover class fractions and a few basic parameters.

- TARGET's efficiency means that modelling domains of tens of thousands of grid points can calculate weeks of simulation in seconds to minutes.

- TARGET was our model-of-choice for use in WP6

[1.] Broadbent, A., Coutts, A., Nice, K., Demuzere, M., Krayenhoff, E., Tapper, N., Wouters, H., 2018. The Air-temperature Response to Green/blue-infrastructure Evaluation Tool (TARGET v1.0): an efficient and user-friendly model of city cooling. Geoscientific Model Development Discussions, (In Review).

TARGET Structure 1

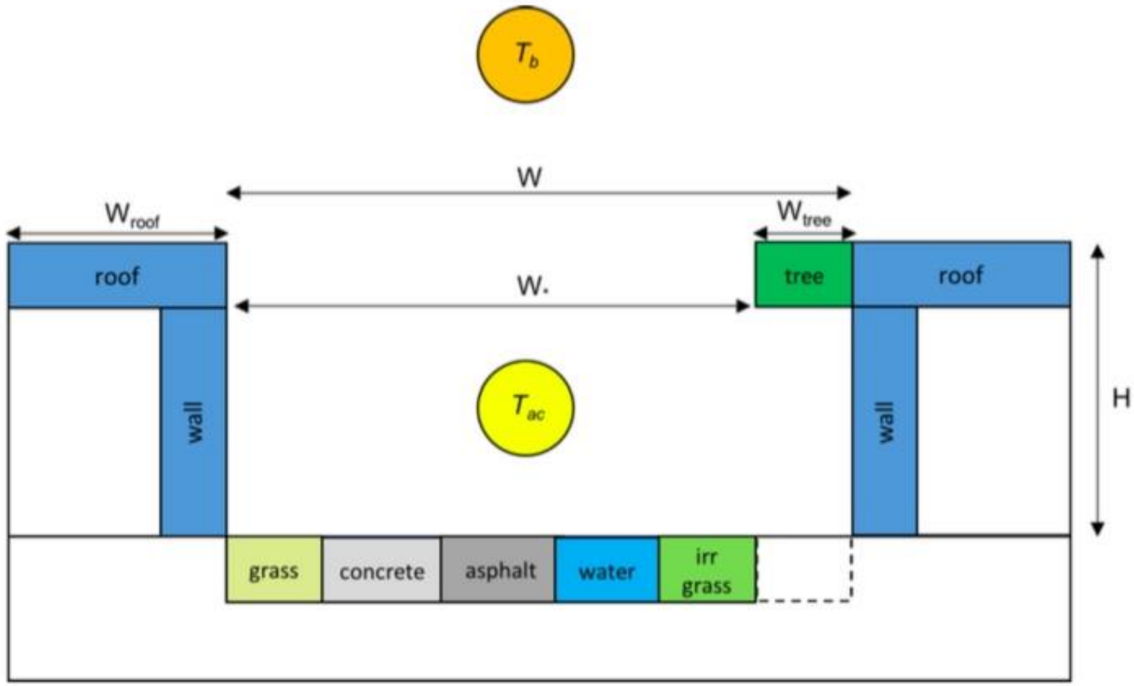


Figure 1. Schematic of TARGET urban canyon setup. T_{ac} = canopy layer air temperature and T_b = above canopy air temperature, which is a uniform value across the whole domain. W_{roof} is the roof width, W_{tree} is the tree width, W is canyon width, and $W* = W - W_{tree}$. The surface beneath trees is assumed to be representative of canyon ground-level surfaces.

TARGET Structure 2

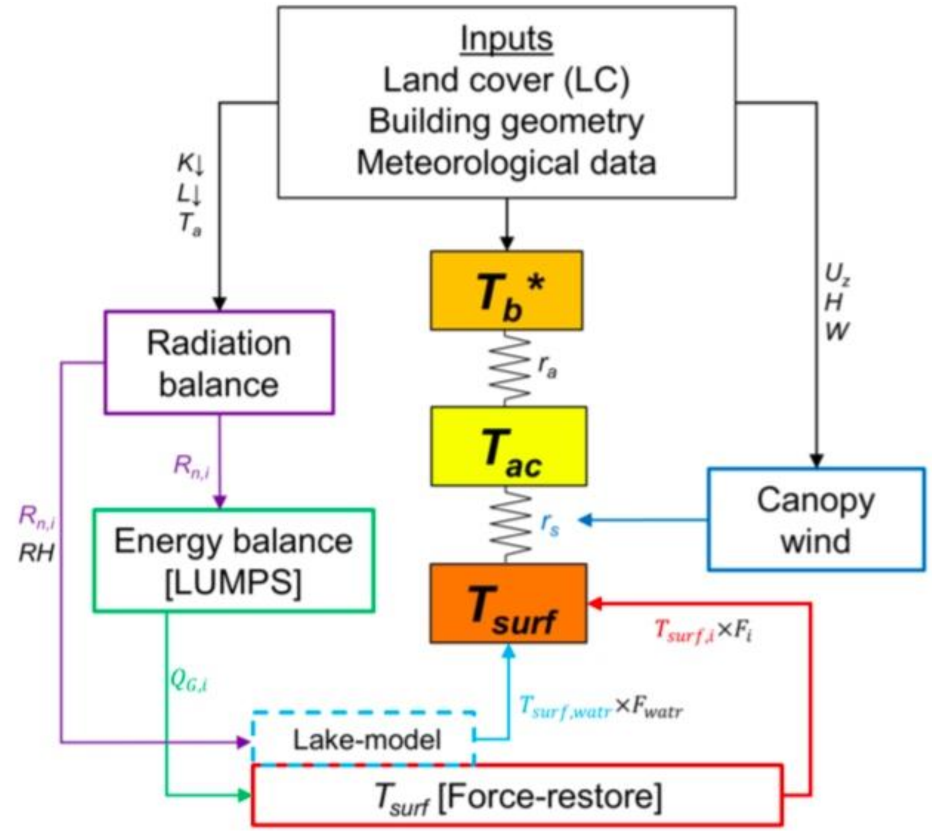


Figure 2. Overview of approach used in TARGET microclimate module. T_{ac} is street level (urban canopy layer) air temperature (°C), T_b is the air temperature above the urban canopy layer (°C), $T_{surf,i}$ is the surface temperature for surface type i, $K\downarrow$ is incoming shortwave radiation (W m^{-2}), $L\downarrow$ is incoming longwave radiation (W m^{-2}), T_a is reference air temperature (°C), R_n is net radiation (W m^{-2}), RH is relative humidity (%), F_i is fraction of land cover type i (%), $Q_{H,i}$ is sensible heat flux for surface i from LUMPS (W m^{-2}), $Q_{G,i}$ is storage heat flux for surface type i from LUMPS (W m^{-2}), U_z is reference wind speed (m s^{-1}), H is average building height (m), W is average street width (m), r_s is resistance from surface to canopy (s m^{-1}), and r_a is resistance from urban canopy to the atmosphere (s m^{-1}). *T_b is a homogeneous value for the whole domain, which is diagnosed by the processes laid out in Sect. 2.7.

Model Data Input
Land Surface Fraction and Representative Days

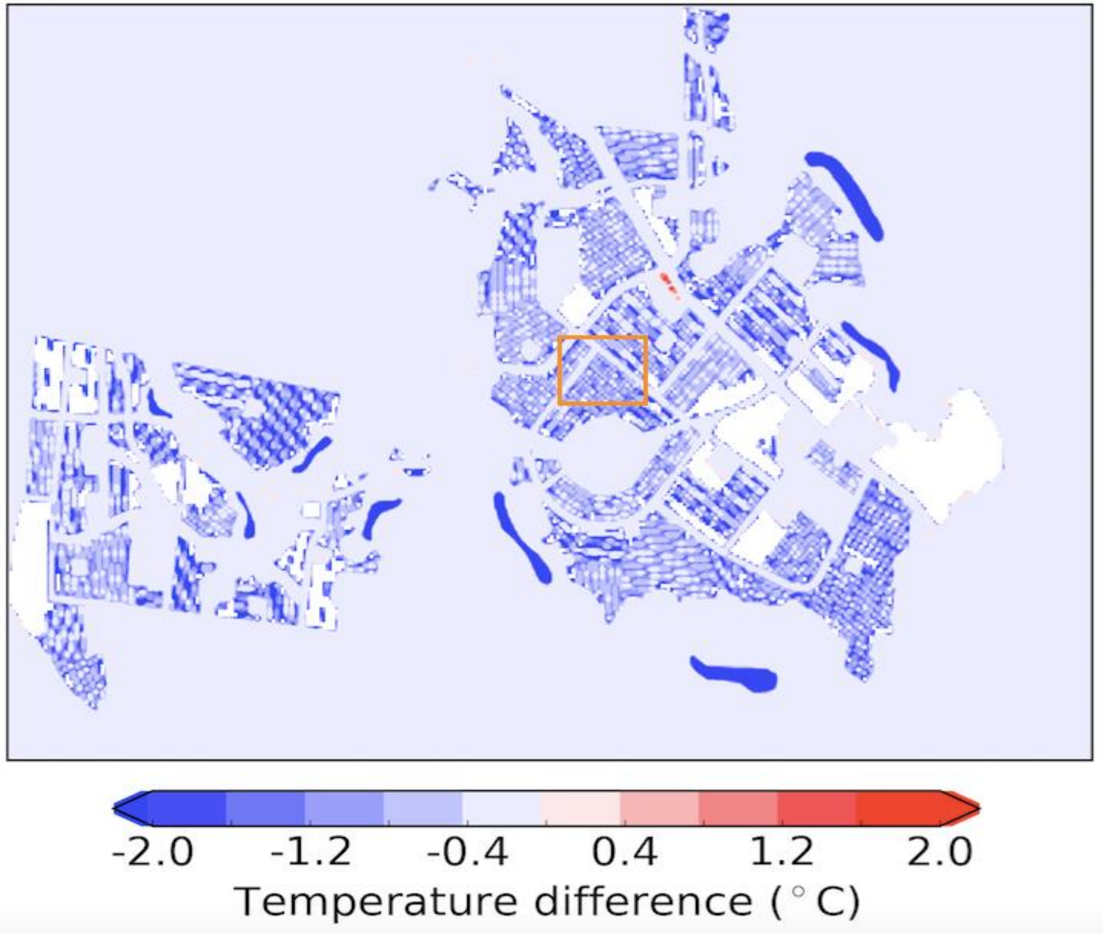
Land surface category	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Roof fraction	0.12	0.12	0.12	0.11
Road fraction	0.08	0.08	0.08	0.08
Concrete fraction	0.03	0.03	0.03	0.03
Water fraction	0	0.08	0.08	0.08
Vegetation/tree fraction	0.02	0.02	0.06	0.09
Dry grass fraction	0.73	0.73	0.71	0.70
Irrigated grass fraction	0.03	0.03	0.04	0.05

Weather	Dates - The meteorological variables used were 2m air temperature (˚C), relative humidity (%), wind speed (km/hr), surface pressure (hPa), total shortwave radiation (W/m²) and total longwave radiation (W/m²)
Cool – low 20s	3 days from February 2009
Average – high 20s	3 days from January 2011
Extreme – High 30s	3 days from January 2009

3 climate conditions x 4 Scenarios = 12 permutations

Modelling Results 1

Domain-wide and representative urban areas modelled – results for the latter are the focus of this presentation

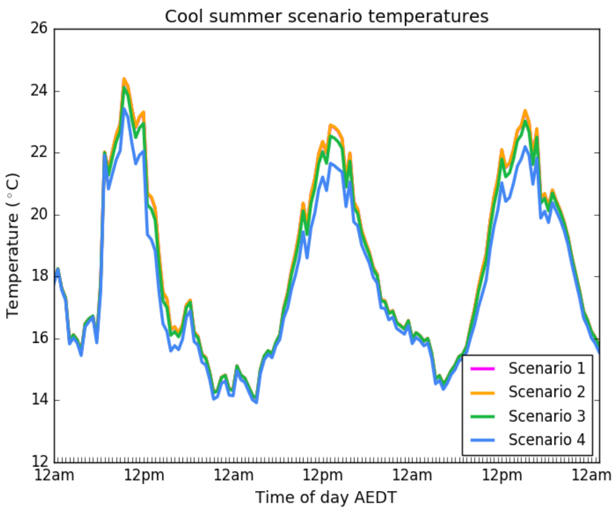


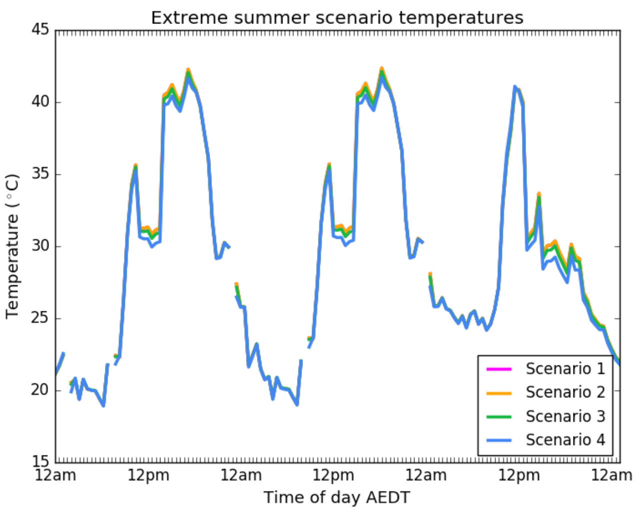
Scenario 4 minus scenario 2 for the cool summer condition
– shows the average daily temperature difference

Modelling Results 2

Average daily temperature difference for the representative urban area for the different scenarios and weather conditions

Scenario difference	Cool (˚C)	Average (˚C)	Extreme (˚C)
Scenario 1 minus Scenario 2	0.0	0.0	0.0
Scenario 3 minus Scenario 2	–0.12	–0.10	–0.10
Scenario 4 minus Scenario 2	–0.51	–0.40	–0.31





Modelling Results 3

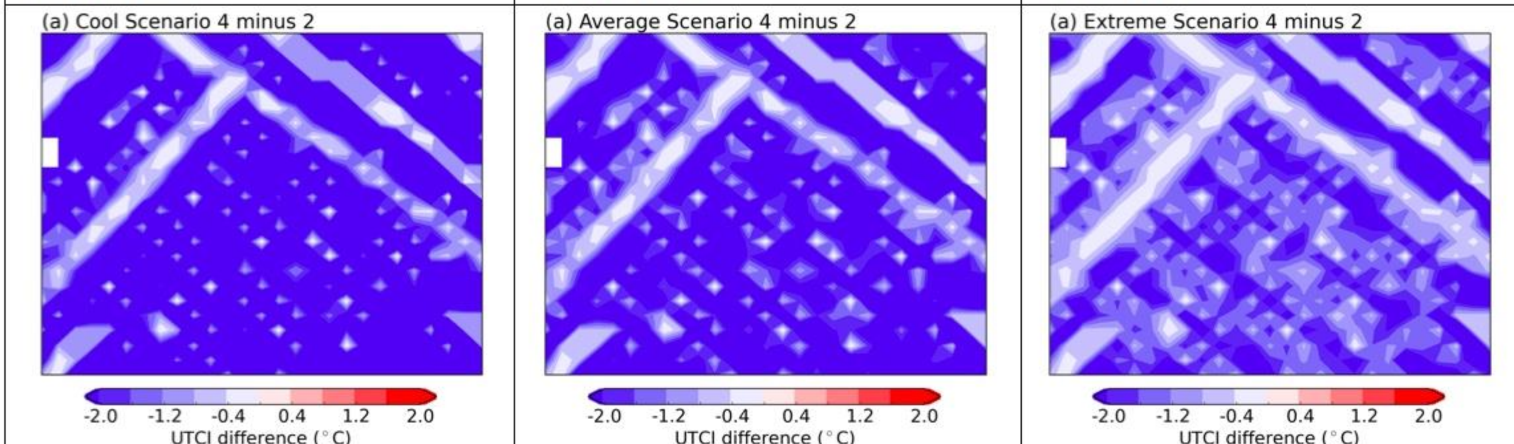
Average daily UTCI (thermal comfort) difference for the representative urban area for the different scenarios and weather conditions

Scenario difference	Cool (˚C)	Average (˚C)	Extreme (˚C)
Scenario 1 minus Scenario 2	–0.02	–0.01	–0.02
Scenario 3 minus Scenario 2	–0.22	–0.19	–0.14
Scenario 4 minus Scenario 2	–0.81	–0.68	–0.38

Midday only

~2C UTCI

Cool Scenario 4 minus Scenario 2	Average Scenario 4 minus Scenario 2	Extreme Scenario 4 minus Scenario 2



Modelling Results 4

- Economic evaluations were performed based on the climate data for a cool, average and extreme summer, where the data were reconstructed according to the modelling results from the four WSUD Scenarios and three climate Scenarios. This avoided literally having to run the TARGET model for hundreds of days

How?

- From the 1910-2017 summers (Dec-Jan), three (1986-87, 1971-72 and 2008-09) were selected statistically to represent cool, average and extreme summers, and the temperature data were transformed using a linear algorithm to represent the thermal changes related to the WSUD Scenarios 1, 3 & 4, where Scenario 2 (current settings) was equated with observations.

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Thank you.