UNIVERSITY OF NEW SOUTH WALES, SYDNEY - AUSTRALIA

IGC

Background-Western Sydney Aerotropolis

Similar to many large Australian cities, Sydney is facing a dramatic growth in its population and cities. 1.6 million new residents are expected over the next 15 years. However, the distributions of this population in relation to jobs, amenity and environment is not ideal. One of Sydney's major challenges is to balance the concentrated economic development in the east with new economic development in the west where most people live. A new model of urban development has been proposed whereby an airport and supporting grey infrastructure is used as a catalytic device to stimulate economic growth and job creation in the west. This new gateway and network of infrastructure aims to link populations with jobs both in the immediate area and the wider region and globally. This vision has been described in infrastructural terms as an 'Aerotropolis' after the populist term associated with the entrepreneurial academic John Kasarda (2011).

This concentrated new development will be constructed inland in the hottest part of Sydney where heatwaves can last for days with temperatures more than ten degrees centigrade above those in the coastal areas of the city. The site is currently dominated by degraded agricultural and ecological systems. Enhanced green infrastructure is proposed as an integral part of the new urban centre and may temper the climate impacts of the new airport and urban development. This is evident from the government concept for the west as a "parkland city". Visions for this western "parkland city" to complement the eastern "harbour city" and central "river city" are evolving and uncertain. Intense development pressure in the west is already seeing new climate insensitive developments emerge as the norm. New innovative patterns and types of urban development are needed to adapt to a hot future where heatwaves are frequent and prolonged. The future urban centre is currently being promoted as the most connected place in Australia. However, this will be a moot point unless urban micro-climate and the threat of heatwaves are addressed to create a liveable environment.

Major IGC Innovations Applied

Transport: TRA 1, TRA 4, TRA 14, TRA 18, TRA 19, TRA 21

Green Infrastructure: GRN 1, GRN 3, GRN 4, GRN 5, GRN 8, GRN 9, GRN 10, GRN 12

Mixed Use : MIX 1, MIX 2, MIX 12, MIX 15, MIX 14

Blue Infrastructure: WAT 2, WAT 8

Agriculture: AGR 10, AGR 12

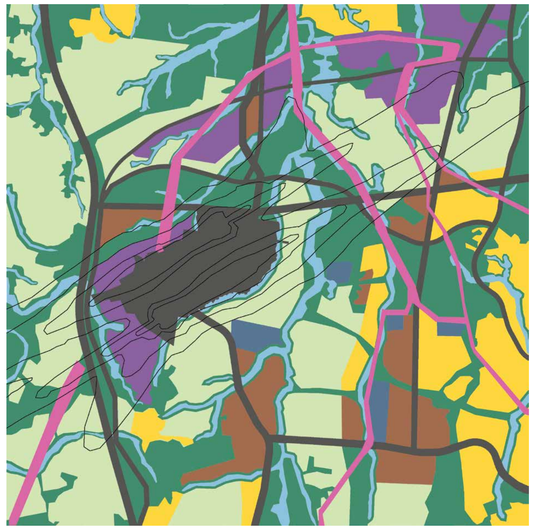
Lower Density Residential: RES 1, RES 3

Industry Commerce: IND/COM 13

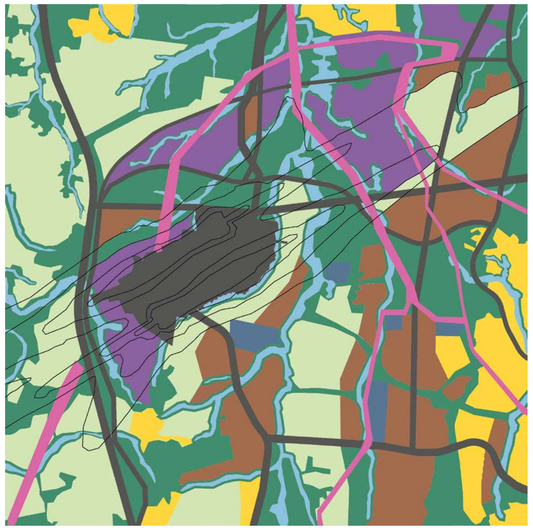
Energy: ENE 13

Institutional: INS 2, INS 6

Early adopter 2020



Early adopter 2035

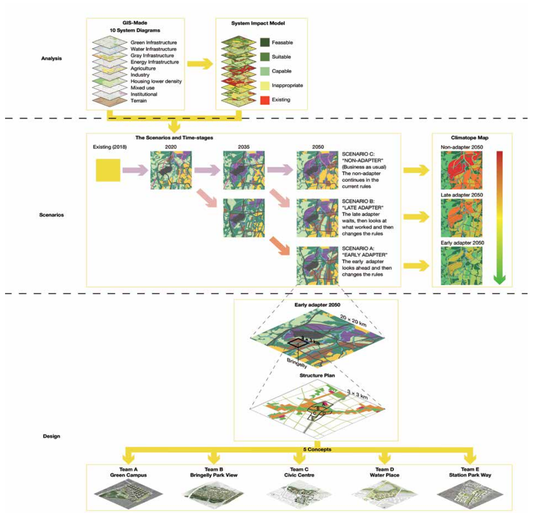


Early adopter 2050

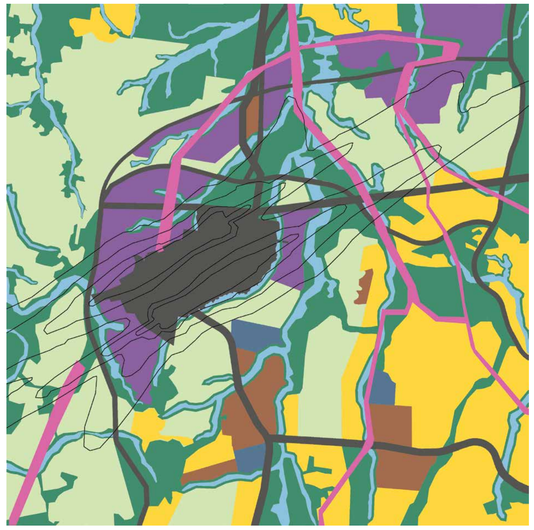
Early adopter scenario (EAS)

In 2020 the airport is being planned and early intervention ensures that cool materials are integrated into its runway, terminal buildings and associated landscapes. Around the airport low density residential and a degraded agriculture landscapes initially form the dominant land-uses. To address the increasing duration, frequency and intensity of heat waves a strategy of mixed-use development and green networks are interlaced and simultaneously developed to create the proposed urban centre. This ensures that new neighbourhoods developed for 2035 have access to cool air production zones and airflow is promoted across the district.

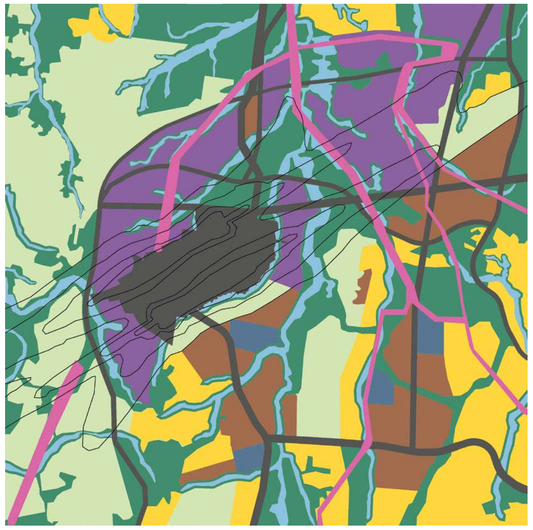
Between 2035-2050 new residential development is achieved by transforming low density to mixed use development rather than the conversion of greenfield landscapes to residential land-uses Urban transformation of greenfield landscapes is limited to new industrial estates and is organised around the airport and the cooling structure of the existing creek and hydrological system. New parks continue to be developed up to 2050 to promote both active transportation routes and cool air flow zones from the northeast along and between urban development. Selected agricultural areas are transformed into high tech urban farms.



Design studio flowchart



Late adopter 2035



Late adopter 2050

Late adopter scenario (LAS)

In 2020 the airport is being planned and climate change complacency limits the integration of cool materials into the large infrastructure. New mixed-use urban centres are planned but commitment to green infrastructure is limited and the planning policies are not in place to ensure that an extensive green network is implemented by 2050. Intensive industrial development occurs around the airport making the airport into a large heat island.

Despite these setbacks in 2035 policy changes towards climate and a moratorium is placed on all new development and remaining agricultural zones are preserved as cool air production zones and recreational areas.

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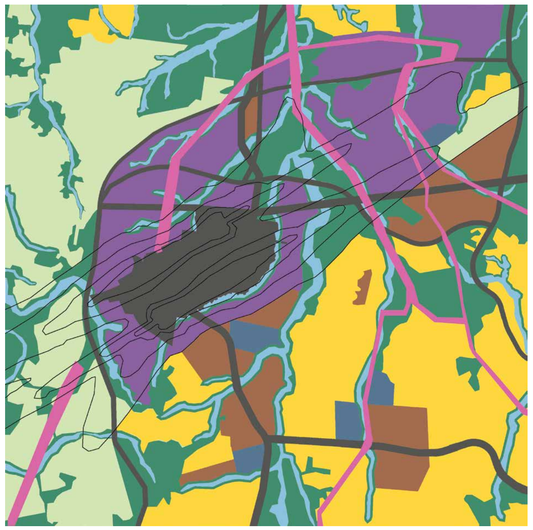
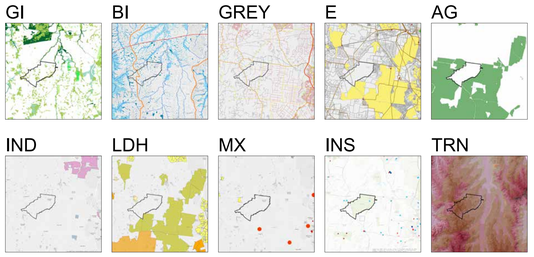


Non adopter 2050

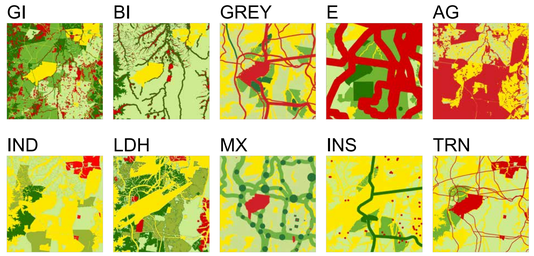
Non-adopter scenario (NAS)

Current trends in the development of the Aerotropolis see the construction of some mixed-use urban centres but also the continued roll-out of extensive low density residential and associated energy intensive suburban modes of living. Such suburbs currently use hot materials and are often hotter than equivalent high-density areas in Sydney. Weak policy for green infrastructure and blue infrastructure sees that vast swathes of industrial development and residential development are without green infrastructure and the associated cooling air currents produced and facilitated by green space.



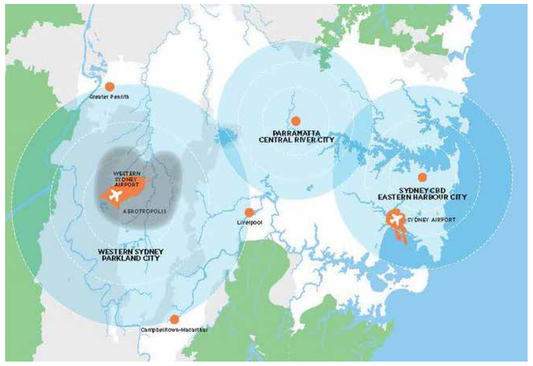
GIS-based 10 system diagrams

1 Green Infrastructure (GI)
2 Blue infrastructurec (BI)
3 Grey infrastructure (GREY)
4 Energy (E)
5 Agriculture (AG)
6 Industry (IND)
7 Low density housing (LDH)
8 Mixed use (MX)
9 Institutional (INS)
10 Terrain (TRN)



System evaluation models

1	2	3	4	5
Existing	Inappropriate	Capable	Suitable	Feasible



New urban centre for Sydney.
Source: Greater Sydney Commision

Targets and requirements of study

- Development of new airport and associated new urban centre.
- Development of airport to be completed in 2026.
- Population Growth in Study Area to be 200,000
- Development of industry to support jobs in area - 28,000 direct and indirect jobs by 2031.
- New and upgraded roads under the $3.6 billion Western Sydney Infrastructure Plan.
- Integration of 10 million passengers to pass through the terminal each year.
- In the 2050s a second runway is likely to be added.

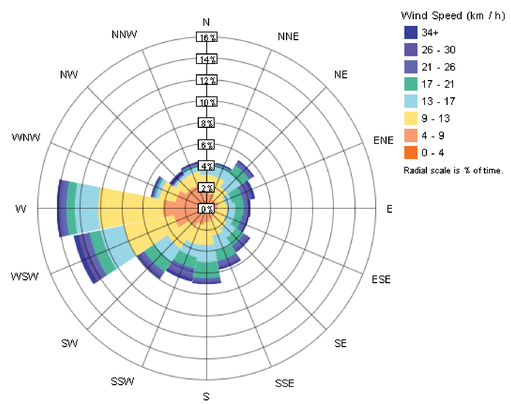
Weather and Climate in Western Sydney

Sydney has a humid subtropical climate according to the Köppen classification. It is mild and cool in the autumn-winter and warm to hot in the spring-summer and generally no extremes due to the regulating effect of the pacific ocean and deep harbours and inlets which moderate the temperature of areas near the ocean. However, with climate change Sydney is increasingly facing prolonged and more frequent heatwaves which intensify the urban heat island effect which raises the city's temperature by as much as 10 degrees more than surrounding areas. In 2019 Sydney experiences several record breaking heatwaves for the second year running. Further, the city's geographic situation and development trajectory is exposing the population to the area which are most vulnerable in the west.

Western Sydney suffers from temperatures above 40 degrees centigrade which sometimes are 10 degrees greater than those experienced in the east close to the sea breezes. In the west hot air is trapped in the basin form of the metropolis and temperatures rise as a result. It is imperative that mitigation measures such as cool air production zones (*i.e.* parks and wetlands), shaded streets and reflective materials are used to moderate the impact of the urban heat island and the increasingly common heatwaves. Such heatwaves also increase the city's vulnerability to other disasters such as drought and bushfire which are relatively common challenges for Australia's urban landscape.

In Sydney the prevailing wind comes from the north-easterly direction. This can be a cooling wind. Close to 40% of the warm months experience northwest or south-westerly winds which are dry winds from the hot desert interior of Australia.

Annual Wind Rose
(Speed and frequency distribution)



Participant team credits:

Geodesign leaders: Scott Hawken and Carlos Bartesaghi Koc.

UNSW UDES0002 Urban Development and Design Class: Team 1: Hailing Gu (Ling), Lixuan Huang (Miki), Zixiang Ma (Mark), Xuduo Xu (Leo), Pei Xu (Penelope), Team 2: Weiyu Han, Shenqin Jiang (Nick), Yaying Wang (Cassie), Nanrong Xiao (Vicky), Jiajing Xu (Jean), Team 3: Ziyi Bai (Danni), Hao Chen (Jessica), Hongqiao Liu (Grace), Yuxi Ren (Becky), Lingling Zheng (Lilian), Team 4: He Gong (Herman), Xiaohan Hu, Sidi Li (Sidi), Tian Tang (Tiya), Wentong Xu (Talia), Team 5: Xin Chen (Tiffany), Eileen Ng (Eileen), Aranaya Sabbarwal, Jagjeet Shergill, Yan Zhou (Yan).

Expert consultants: Jodi Lawton, Prof Rod Simpson, Jonathan Knapp, Glyn Richards, Prof James Weirick, Prof Robert Freestone, Hrishi Ballal.

Software employed: GeoDesign Hub, ArcGIS, QGIS, Adobe InDesign, Adobe illustratror, Adobe Photoshop, Revit.

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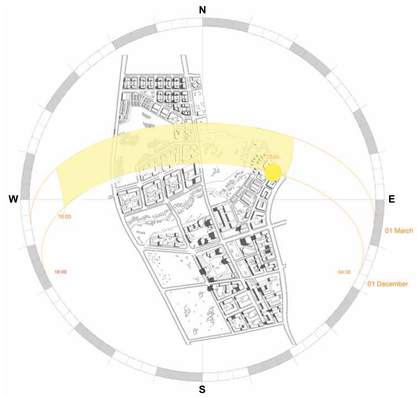
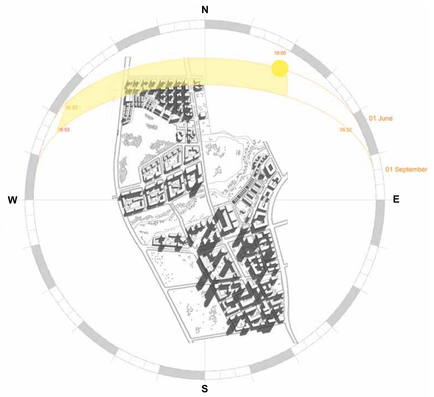
Structure plan 3x3 km

21st December, 10:00 to 17:00 (Summer)
with vegetation



Shadow analysis - Summer

21st June, 10:00 to 17:00 (Winter)
with vegetation



Shadow analysis - Winter

Early adapter 2050 climatope

Green roofs
Green walls

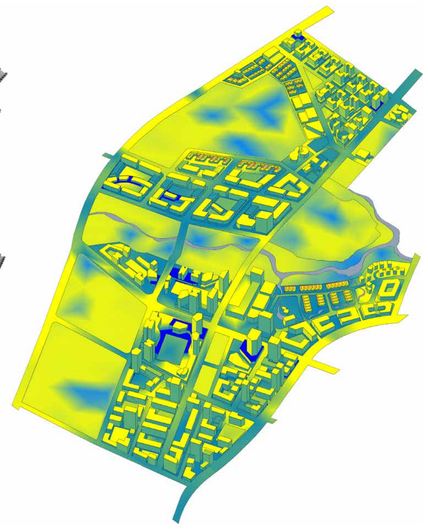
Reflective and light-coloured materials in facades and roofs

Abundant street trees and clustered trees in public open spaces

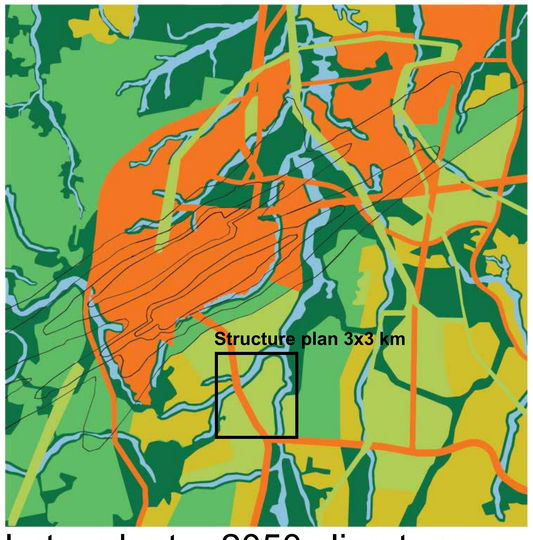
Extensive network of greenspaces, (pocket parks) water features and evaporative cooling systems

Cool and permeable pavements

Early adapter 2050: UHI mitigation strategies



Solar radiation analysis



Late adapter 2050 climatope

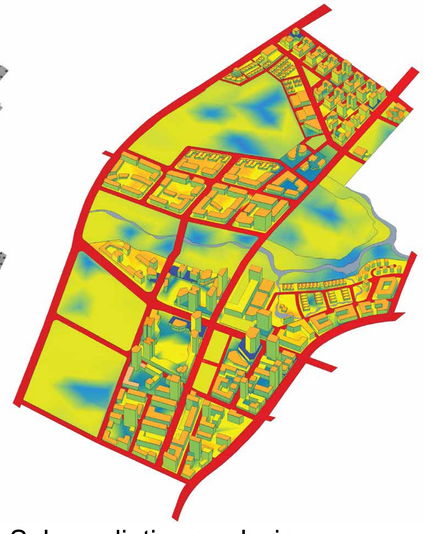
Reflective and light-coloured materials in facades and roofs

Sparsely distributed tree canopy in streets and public open spaces

Greenspaces alongside major roads and creeks. Water features in parkland areas.

Conventional pavements: asphalt, concrete, granite.

Late adapter 2050: UHI mitigation strategies



Solar radiation analysis

Techniques for climate assessement: Two Scales and Two Analytic Techniques

The studio studied and worked at two scales the urban meso scale and urban micro scale. The first is a 20 x 20km area centred on the proposed airport – this is the meso-scale. The second is a 3 x 3 km area focused on, Bringelly, a new mixed-use urban centre for the Aerotropolis district – this is the scale of urban microclimate. The two scales where developed according to the parameters of each of the three scenarios that were given as part of the International Geodesign Collaboration: Early Adapter Scenario (EAS), Late Adapter Scenario (LAS) and Non-Adapter Scenario (NAS).

The 20 x 20 km featured various urban patterns across the three scenarios. This scale was analysed using a method known as “climatope” analysis. In this analysis the ten systems are re-classified in terms of their impact on urban microclimate and coded according to the intensity of their impact. For example, Grey infrastructure (coded red) such as the airport has a much higher impact than Green infrastructure (coded green) such as the parklands. This simple but powerful technique reveals the climatic consequences of various urban patterns and highlights hot areas which require access to cool air production zones for temperature relief. This method is effective in assessing scenarios in terms of their varying spatial configuration.

In contrast to the large meso-scale approach described above the 3 x 3 km scale analysis of Bringelly featured one pattern across all three scenarios. Rather than the pattern changing the materials, such as canopy and vegetation, cool materials, standard materials, were varied across the three scenarios. The micro-climatic impacts of changing material were then modelled in Revit. This approach reveals the considerable modifications and climate mitigation possible working with existing urban form and patterns.

Further shadow analysis demonstrates which areas are sheltered by the sun during the summer. The importance of street trees to provide continuous shaded passages for active and mechanised transport are paramount. Finally wind analyses shows which areas are open to cooling north-easterly winds or exposed to heating south-westerly winds. Such analysis can help provide data for urban modifications to mitigate climate and urban radiation.

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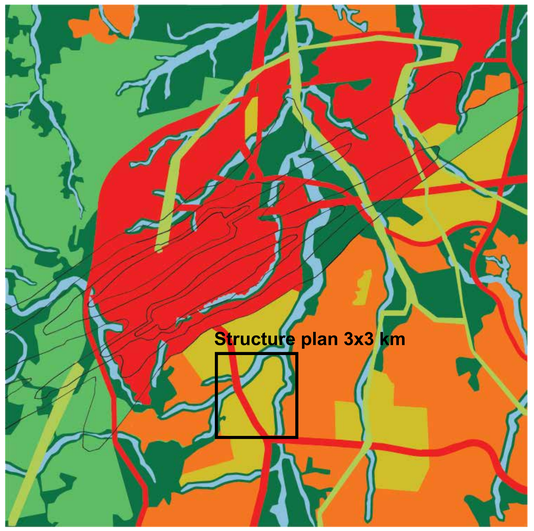


Non adapter 2050 climatope

Category	Climatope	Description	Evaluation	NAS 2050	LAS 2050	EAS 2050
1.	Fresh & cool air production zones	Open areas with significant climatic activity, cool and fresh air production; Climatically active open sites in direct relation to housing area; Very high nocturnal heat degradation	Very important, preserve & protect	Green Infrastructure	Green Infrastructure	Green Infrastructure
2.	Cool air production zone	Open areas with less significant climatic activity; Cool & fresh air with effects to neighbourhoods; Areas without any emissions; High nocturnal heat degradation	Important, preserve & protect	Agriculture	Agriculture	Agriculture and Institution
3.	Mixed & transitional climate zone	Strong daily variation through income radiation, but good cooling effect; Areas with high percentage of vegetation; Low & discontinuous emissions; Buffer zones between different climatopes; Moderate / good nocturnal heat degradation	Important balancing zone due to local circulation, note circulation direction in building & planning projects, no further increase of heat storage	Energy	Energy, Institution and Mixed Use	Energy, Mixed Use, Low Density Residential and Grey Infrastructure
4.	Overheating potential zone	Some heat storage, but mainly buffered through greeneries and wind; Dominated construction areas with lots of vegetation in the open spaces; Low nocturnal heat degradation	Thermally vulnerable area, promote porous building design	Institution and Mixed Use	Low Density Residential	Industries
5.	Remarkable urban heat island	Heat storage remarkable, but still some wind effects and cooling potentials; Density development with little vegetation in open spaces; Very low nocturnal heat degradation	Thermally and air hygiene with deficits, heat stress increasing, promote vegetation shadow and green facades	Low Density Residential	Grey Infrastructure and Industries	
6.	Maximum urban heat	Heat storage high; Low cooling potentials and low ventilation; Heavily compressed and sealed inner city areas; No / very low nocturnal heat degradation	Thermally and air hygiene with high deficits, high heat stress increasing, promote shadowing i n the outer space as well as facade- & roof insulation and de-sealing of surfaces	Grey Infrastructure and Industries		
7.	Water bodies	Water courses with dual thermal behaviour (cool in the morning and warm in the evening)				

Climatope mapping assessment using UHI mitigation scenarios

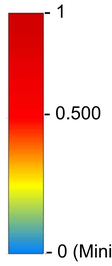
Conventional materials: concrete, red tiles, red sandstone, dark-coloured roofs and facades.

Sparsely distributed tree canopy in streets and public open spaces

Greenspaces alongside major roads and creeks. Water features in parkland areas.

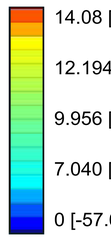
Conventional impermeable pavements: asphalt, concrete, granite, stone.

Non adapter 2050: No UHI mitigation strategies



Solar radiation study hourly
(kWh/m²)

Project location: Sydney, NSW
Study start date time: 21-12-2018 10:00:00
Study end date time : 21-12-2018 16:00:00
Type of analysis: cumulative insolation

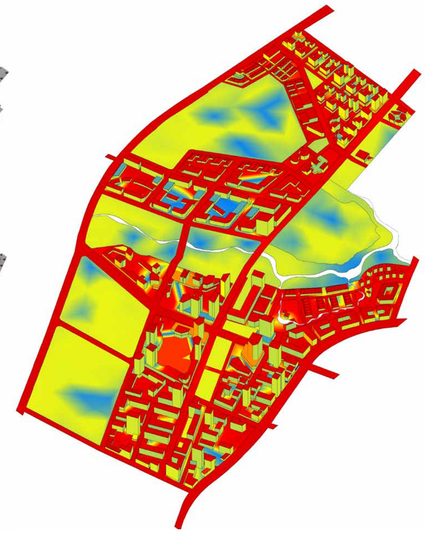


Air velocity (m/s) [Pressure (Pa)]

- Areas with poor thermal performance

- Areas with moderate thermal performance

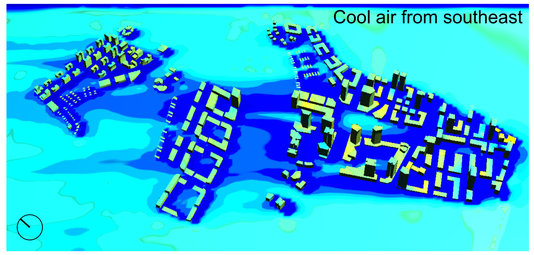
- Areas of good thermal performance

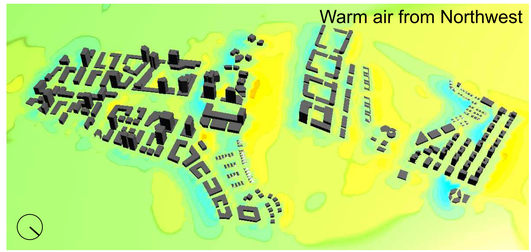


Solar radiation analysis

Solar radiation analysis shows the cumulative insolation of vertical and horizontal surfaces. Results show that conventional dark-coloured materials such as concrete, asphalt and tiles should be obviated in future.

In contrast, cool and permeable pavements, reflective materials, water features and evaporative cooling systems, green roofs, green walls/facades, green open spaces, and street trees are the best climate-responsive solutions to provide thermally pleasant and healthy environments in Wester Sydney by 2050.





Wind analysis urban precinct

Wind analysis facilitated the visualization of the effect of the cool southeasterly and warm northwesterly winds on the proposed urban precinct defined by the particualr arrangement of buildings and vegetation. Results show that during heatwave conditions (winds from hot desert) areas of relatively good thermal performance are located in well-defined street canyons that channel winds and facilitate a rapid heat dissipation. Conversely, open spaces with dense tree canopy tend to trap more heat and reduce advection.

Shadow analysis urban precinct

Shadow analysis allowed students to test different urban form scenarios and site modifications to define an adequate street width, and building density and height to provide sufficient solar access in winter and solar protection in summer. Shadow analysis also enabled to define the best location of shadow devices (*i.e.* awnings) and shading structures in public spaces.

Selected IGC Innovations

This list is an expanded list of the acronyms one the first exhibition sheet.

TRA - Transport Infrastructure
- TRA 1 THE AUTONOMOUS REVOLUTION
- TRA 4 PASSENGER RAIL
- TRA 14 BIKESHARES AND E-BIKES
- TRA 18 HEAT REFLECTIVE COATING
- TRA 19 LIGHT COLOR PAINT
- TRA 21 PERMEABLE PAVEMENT FOR UHI

GRN - Green Infrastructure
- GRN 1 RESILIENT LANDSCAPE INFRASTUCTURE
- GRN 3 VEGETATION LINKED WITH STORMWATER
- GRN 4 LINEAR VEGETATED CORRIDORS
- GRN 5 INTEGRATION OF VEGETATION INTO BUILDINGS
- GRN 8 ECOSYSTEM SERVICES OF GRN INFRA
- GRN 9 CONNECTIVITY AND ELEMENTS
- GRN 10 GREEN URBAN STREETS
- GRN 12 GREEN ROOFS

MIX – Mixed Use
- MIX 1 MIXED USE DEVELOPMENT
- MIX 2 CUSTOM-BUILD CONCEPTS
- MIX 12 INNOVATION DISTRICTS
- MIX 15 SMART CONNECTED MOBILITY
- MIX 14 SUSTAINABLE NEIGHBORHOOD PATTERN

BLU – Blue Infrastructure
- WAT 2 WATER RETENTION
- WAT 8 BIO-RETENTION

AGR - Agriculture
- AGR 10 URBAN FARMING – URBAN AGRICULTURE
- AGR 12 ROOFTOP GARDENING

RES – Lower Density Residential
- RES 1 INTEGRATED SOLAR PV PLUS STORAGE
- RES 3 DIRECT CURRENT (DC) MICROGRID

IND/COM – Industry Commerce
- IND/COM 13 INTERNET-BASED COMMERCE
- IND/COM 15 THE FUTURE OFFICE WORKSPACE

ENE Energy
- ENE 13 DEVELOPMENTS IN BATTERY STORAGE

INS
- INS 2035/2050 2 FUTURE OF HEALTHCARE
- INS 2035/2050 6 EDUCATION FOR THE FUTURE

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