Transport
for NSW

Central Precinct Renewal Program

Environmental Sustainability, Climate Change, and Waste Management

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NSW GOVERNMENT

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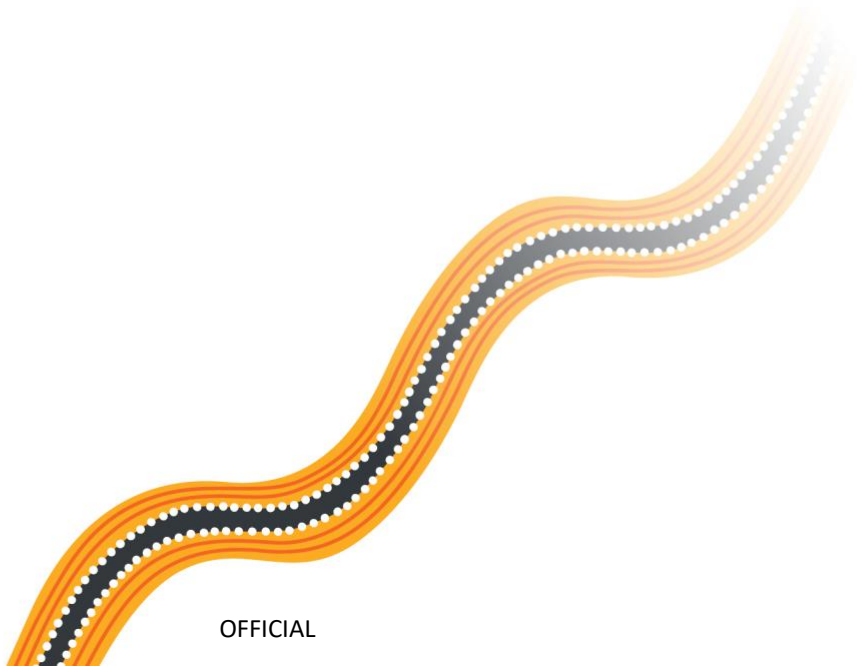
Acknowledgement of Country

We respectfully acknowledge the Traditional Custodians of the Central Precinct, the Gadigal and recognise the importance of the place to Aboriginal people and their continuing connection to Country and culture. We pay our respect to Elders past, present and emerging.



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Versions

Version	Amendment notes
0.1	Final for CPRP Public Exhibition 2022

1. Abbreviations

Abbreviation	Definition
ABS	Australian Bureau of Statistics
BASIX	Building Sustainability Index
BAU	Business as usual
BCA	Building Code of Australia
BIM	Building Information Modelling
BREEAM	Building Research Establishment's Environmental Assessment Method
CAP	Climate Adaptation Plan
CBD	Central Business District
CHP	Combined heat and power
CIV	Capital investment value
CoS	City of Sydney Council
CPRP	Central Precinct Renewal Program
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSPS	Central Sydney Planning Strategy
DA	Development application
DCP	Development control plan
DEC	Department of Environment and Conservation
DECC	Department of Environment and Climate Change
DPE	NSW Department of Planning and Environment
EPA	Environmental Protection Authority
EP&A Act	*Environmental Planning and Assessment Act 1979*
EP&A Regulation	*Environmental Planning and Assessment Regulation 2000*
EPD	Environmental Product Declaration
EPI	Environmental planning instrument
ESD	Environmentally/Ecologically Sustainable Development
F&B	Food and Beverage
FOGO	Food Organics and Garden Organics
FSR	Floor space ratio
GANSW	Government Architect NSW
GBCA	Green Building Council of Australia
GCC	Greater Cities Commission
GFA	Gross floor area

Abbreviation	Definition
GHG	Greenhouse gas
ha	Hectare
IEQ	Indoor Environmental Quality
IoT	Internet of things
IS	Infrastructure Sustainability
ISC	Infrastructure Sustainability Council
LCA	Life Cycle Assessment
LEED	Leadership in Energy and Environmental Design
LEP	Local environmental plan
LGA	The City of Sydney local government area
LSPS	Local strategic planning statement
MBR	Membrane Bioreactor
NABERS	National Australian Built Environment Rating System
NARCliM	NSW and ACT Regional Climate Model
NRAS	National Rental Affordability Scheme
NZE	Net Zero Emissions
OEH	Office of Environment and Heritage
PRP	Project Review Panel
RCP	Representative Concentration Pathway
SCA	Special character area
SDCP2012	Sydney Development Control Plan 2012
SDRP	State Design Review Panel
SEPP	State Environmental Planning Policy
SLEP2012	Sydney Local Environmental Plan 2012
Sqm	Square metre
SRI	Solar Reflectance Index
SSDA	State significant development application
SSP	State Significant Precinct
TCFD	Task Force on Climate-related Financial Disclosures
UNSDG	United Nations Sustainable Development Goals
UV	Ultraviolet
VPA	Voluntary Planning Agreement
W/m^2	Watt per square metre

2. Definitions

Term	Definition
Accessibility	The ability for everyone, regardless of age, disability or special needs or where they live, to use and benefit from the transport system
Active transport	Transport that is human powered, such as walking or cycling
Amenity	The extent to which a place, experience or service is pleasant, attractive or comfortable. Improved features, facilities or services may contribute to increase amenity.
Bradfield Flying Junctions	Series of flyover tracks between the Cleveland Street bridge at Redfern and Central Stations that allow trains to move from any one line to another without crossing a line in the opposing direction
Bus interchange	Where customers have access to a number of different bus routes at a central location
Bus stand	A place to board or alight from bus services
Camperdown-Ultimo Collaboration Area	The Health and Education Precinct which includes the Royal Prince Alfred Hospital, TAFE NSW, University of Notre Dame, University of Sydney and University of Technology Sydney, and medical and research institutions and other health services facilities and educational establishments
Catchment	Area from which a location or service attracts people
CBD and South East Light Rail	means to the light rail network extending from Randwick and Kingsford to Circular Quay
Central Precinct	Central Precinct State Significant Precinct
Central Sydney	Land identified as Central Sydney under the Sydney Local Environmental Plan 2012 and represents the Metropolitan Centre of Sydney. Central Sydney includes Sydney's Central Business District
Central Walk	The underground paid pedestrian connection, currently under construction, that is to be delivered by Sydney Metro City and South West. Once complete, it will be a link between the new station entrance on Chalmers Street, the Eastern Suburbs Railway concourse, suburban platforms 16-23 (via escalators and lifts) and the new Sydney Metro north-south concourse
Character	The combination of the attributes, characteristics and qualities of a place (GANSW, 2021, Draft Urban Design Guide)
City Plan 2036	City of Sydney local strategic planning statement
Community	Particular types of stakeholder and refers to groups of people in particular places who are both affected by our work and experience the outcomes and benefits of our activities
Control	A numerical standard that is applied in a prescriptive manner
Corridor	A broad, linear geographical area between places
Council	The City of Sydney Council
Customer interface	The point at which transport services interact with their customer
Customers	Those who use transport networks and services. They include car drivers, heavy vehicle operators, public transport and point to point passengers, pedestrians, cyclists and freight and goods providers

Term	Definition
Department	The Department of Planning and Environment
Determination	The approval made in accordance with the *Environmental Planning and Assessment (EP&A) Act 1979.* In relation to Central Precinct SSP, a determination will be made by the Minister for Planning and Public Spaces
Devonshire Street Tunnel	The official name of the pedestrian tunnel connecting Chalmers and Lee Streets
District Plan	means the Eastern City District Plan
Future Transport Strategy	Transport for NSW's approach to planning transport and engaging customers, to address future technological, economic and social changes. Future Transport Strategy comprises two focus areas – planning ('Future Transport Planning') and technology ('Future Transport Technology' and 'Technology Roadmap')
Gateway	Cities that provide state level services and facilities to support a broad population catchment while also having international connections through their cities airport and/or port.
Goods Line	The official name for the partly elevated walkway from Central Station to Darling Harbour following the route of a disused railway line
Grand Concourse	Part of Central Station
Greater Sydney's Green Grid	The link between parks, open spaces, bushland and walking and cycling paths
Interchange	A facility to transfer from one mode of transport or one transport service to another. For example, a station with an adjoining light rail stop
Local streets	Places that are part of the fabric of suburban neighbourhoods where we live our lives and facilitate local community access
Merit based assessment	An assessment of a matter that allows for reasonable flexibility to consider a range of possible solutions
Minister	The Minister for Planning
Mixed-use	A building or area containing more than one type of land use
Mobility	The ability to move or be moved easily and without constraints
Mortuary Station	The building formerly used as a railway station on the Rookwood Cemetery railway line, now disused
NABERS	A national rating system that measures the environmental performance of Australian buildings and tenancies
Objective	A statement of a desired future outcome, generally expressed in a qualitative manner that enables merit based assessment
Over rail corridor development or Over Station Development	Development of air space over railway corridors
Place	An intersection of transport infrastructure with social infrastructure and commercial activity. These are the areas within and around transit stops where people live and commute. Places can be created as an outcome of Placemaking
Placemaking	Scoping and delivering places for the community, beyond the immediate transport infrastructure. Successful placemaking either

Term	Definition
	preserves or enhances the character of our public spaces, making them more accessible, attractive, comfortable and safe
Planning instrument	Means any of the following: • strategic plan (comprising regional strategic plans and district strategic plans) and local strategic planning statements • environmental planning instrument (comprising State environmental planning policies and local environmental plans) • development control plan
Planning Secretary	The Secretary of the Department of Planning
Precinct	Geographical area with boundaries determined by land use and other unique characteristics. For example, an area where there is an agglomeration of warehouses may be termed a freight precinct
Principal development standards	Matters addressed in Part 4 of the Standard Instrument
Proponent	Transport for NSW
Proposal	Proposed amendments to the planning framework
Provisions	means a broad term covering objectives and controls
Public spaces	means areas that are publicly accessible where people can interact with each other and make social connections
Rail network	means the rail infrastructure in NSW
Railway corridor	The land within Central Precinct on which a railway is built; comprising all property between property fences, or if no fences, everywhere within 15m from the outermost rails. Under planning legislation rail corridor is defined as land: a) that is owned, leased, managed or controlled by a public authority for the purpose of a railway or rail infrastructure facilities: or b) that is zoned under an environmental planning instrument predominately or solely for development of the purpose of a railway or rail infrastructure facilities
Railway Square	The area between Lee Street and Broadway, comprising a plaza, bus stands and underground access/uses
Reference Master Plan	A non-statutory document that shows one way in which the precinct may develop in the future in accordance with the proposed amendments to the planning framework Note: Refer to the GANSW Advisory Note v2, dated 12/09/2018 for further guidance
Region Plan	The Greater Sydney Region Plan - A Metropolis of Three Cities
Rezoning	Amendments to environmental planning instruments, in particular for land use zones and principal development standards such as height of buildings and floor space ratio
Shocks and stresses	The acute short term damaging events or long term trends causing inequity impacting a city's resilience
Siding	A short stretch of rail track used to store rolling stock or enable trains on the same line to pass
Social procurement	Purchasing decisions based on good social outcomes
Standard Instrument	The Standard Instrument—Principal Local Environmental Plan
State	The state of New South Wales

Term	Definition
State-led rezonings	A focus on precincts where there is a strategic imperative for the Department of Planning to lead the process, including places that benefit from current or future city-shaping infrastructure or investment, and where we can create great public spaces in collaboration with councils and communities. These rezonings generally occur under a SEPP
State Significant Precinct	The areas with state or regional planning significance because of their social, economic or environmental characteristics
Strategic Framework	The document prepared by Transport for NSW for Central Precinct in 2021 that addresses key matters including vision, priorities, public space, strategic connections, design excellence, identify sub-precincts for future detailed planning and also outlines the next steps in the State Significant Precinct process for Central Precinct
Strategic plan	The regional strategic plan, district strategic plan or a local strategic planning statement
Sub-precinct	The definable areas within Central Precinct SSP due to its unique local character, opportunities and constraints, either current or future. The Western Gateway is a sub-precinct
Sydney Metro	A fully-automated, high frequency rail network connecting Sydney
Tech Central	The State government initiative as set out in The Sydney Innovation and Technology Precinct Panel Report 2018. Previously known as the Sydney Innovation and Technology Precinct. Tech Central is located south of the Sydney central business district, surrounded by the suburbs of Redfern, Ultimo, Haymarket, Camperdown, Chippendale, Darlington, Surry Hills and Eveleigh
Transport for NSW	The statutory authority of the New South Wales Government responsible for managing transport services in New South Wales.
Transport interchange	A facility designed for transitioning between different modes, such as a major bus stop or train station
Transport modes	The five public transport modes are metro, trains, buses, ferries and light rail. The two active transport modes are walking and cycling
Urban renewal	A planned approach to the improvement and rehabilitation of city areas with new infrastructure, new commercial/mixed uses, improved services and renovation or reconstruction of housing and public works
Vibrant streets / places	Places that have a high demand for movement as well as place with a need to balance different demands within available road space

3. Executive summary

This report has been prepared to address the environmental sustainability, climate change, and waste management requirements of the Central Precinct State Significant Precinct application. Additional outcomes from the design process are that sustainability outcomes are embedded not only in this report, but also the reference design, and other reports, particularly:

- Public Domain, Place and Urban Design;
- Social sustainability and infrastructure;
- Green infrastructure, Ecology, Urban Forest, and Greening; and
- Utilities Servicing.

It identifies the existing situation, including constraints, opportunities and key issues, determining the existing site has several attributes that support sustainability outcomes, however, in many ways it represents an under-utilised part of the city which could support more urban function and avoid further impacts outside of the CBD.

It elucidates the approach to sustainability which is framed by a level of ambition that represents world's best practice, and presents a series of sustainability themes, each of which is supported by a brief series of objectives that support its delivery, and aim to embed world's best practice in resource efficiency, ecological stewardship, adaptability, accessibility, and enabling infrastructure in both the physical fabric and ongoing operations of CPRP.

The bulk of the report addresses four key areas of consideration:

- Energy and GHG emissions;
- Integrated water cycle management;
- Integrated waste management; and
- Climate change and resilience.

In each of these sections the:

- Strategic planning context is provided;
- Sustainability objectives presented;
- Impacts of the proposal are modelled;
- Opportunities explored; and
- Benchmarks identified.

An approach to assurance is proposed based on an assessment of global peer precincts, and a comparison of Australian and global rating tools, the outcomes of which are detailed in 14.1 Performance targets.

Significant consultation in multiple forms has been undertaken with a variety of internal and external stakeholders to arrive at a series of recommendations, and ensure:

- Their sustainability concerns and objectives are captured;
- The level of ambition is consistent;

- Sustainability principles are understood;
- Sustainability initiatives are embedded in the reference design; and
- Targets and metrics are ambitious but achievable.

The recommendations which represent the outcome of this consultation process take three forms:

- Performance targets - certified ratings for development type from a series of rating tools;
- Design considerations for the master plan - considerations for inclusion in the masterplan design; and
- Development control provisions - considerations for the Sustainability chapter of the Design Guide for the CPRP Design Guide.

Key sustainability outcomes for Central Precinct are:

- Low carbon precinct and buildings;
- Net zero precinct and buildings from day one;
- All electric operations; and
- Powered by 100% renewable energy.

Delivery of the outcomes will be assured by certification with the Green Star suite of tools. The delivery method for these outcomes will be up to delivery partners or proponents to address in future stages and represents an opportunity to deliver innovative responses.

The recommendations in this report seek to focus on embedding the requirements for delivering world's best practice sustainability outcomes, ensuring there is space provision in the design, and not to limiting how they could be delivered.

4. Introduction

Located within the heart of Eastern Harbour City, Central Precinct is Australia’s busiest transport interchange. The precinct currently holds latent potential with all its inherent advantages of location and transport connections to revitalise Central Sydney. Capitalising on Central Precinct’s prime location within Tech Central, a NSW Government commitment to create the biggest technology hub of its kind in Australia, Central Precinct presents the ultimate transformative opportunity to deliver a connected destination for living, creativity and jobs. The renewal of Central Precinct will provide a world-class transport interchange experience, important space for jobs of the future, improved connections with surrounding areas, new and improved public spaces and social infrastructure to support the community.

In July 2019, Central Precinct was declared a nominated State Significant Precinct (SSP) in recognition of its potential to boost investment and deliver new jobs. The SSP planning process for Central Precinct will identify a new statutory planning framework for Central Precinct. This involves two key stages:

- **Stage 1**: Development of a draft Strategic Vision which has since evolved into the Central Precinct Strategic Framework
- **Stage 2**: Preparation of an SSP study with associated technical analysis and community and stakeholder consultation.

In March 2021, the Central Precinct Strategic Framework was adopted representing the completion of Stage 1 of the planning process to develop a new planning framework for Central Precinct. The Strategic Framework outlines the vision, planning priorities, design principles, and the proposed future character of sub-precincts within Central Precinct. This is intended to inform and guide further detailed planning and design investigations as part of this SSP Study (Stage 2 of the SSP planning process).

This SSP Study intends to amend the planning controls applicable to Central Precinct under the SSP SEPP 2005 to reflect the vision and planning priorities set for the Precinct under the Strategic Framework. Study Requirements were issued in December 2020 to guide the investigations and the proposed new planning controls.

4.1 Tech Central

4.1.1 Overview

The NSW Government is committed to working with the local community to develop the biggest innovation district of its kind in Australia. Bringing together six neighbourhoods near the Sydney CBD (Haymarket, Ultimo, Surry Hills, Camperdown, Darlington North Eveleigh and South Eveleigh), Tech Central is a thriving innovation ecosystem that includes world-class universities, a world-leading research hospital, 100 + research institutions, investors and a wide range of tech and innovation companies. The vision for Tech Central is for it to be a place where universities, startups, scaleups, high-tech giants and the community collaborate to solve problems, socialise and spark ideas that change our world. It is also for it to be place where centring First Nations voices, low carbon living, green spaces, places for all people and easy transport and digital connections support resilience, amenity, inclusivity, vitality and growth.

Tech Central is an essential component of the Greater Sydney Region Plan's Eastern Harbour City Innovation Corridor. It aims to leverage the existing rich heritage, culture, activity, innovation and technology, education and health institutions within the precinct as well as the excellent transport links provided by the Central and Redfern Station transport interchanges.

The Central Precinct is located within the Haymarket neighbourhood of Tech Central. Planned to become the CBD for Sydney's 21st century, this neighbourhood is already home to The Quantum Terminal (affordable coworking space in the iconic Central Station Sydney Terminal Building) the Scaleup Hub (affordable and flexible workspace for high-growth technology scaleups) and is soon to be the home of Atlassian's headquarters. It is also in close proximity to a number of important education and research institutions.

The planned urban renewal of the Central Precinct has been identified as a key project to achieving the vision for Tech Central.

4.1.2 Background & Context

In August 2018, the NSW Government established the Sydney Innovation and Technology Precinct Panel (the Panel) comprising representatives from various industry, health, education, government agencies and key community members. In December 2018 'The Sydney Innovation and Technology Precinct Panel Report' was produced, setting out the Panel's recommendations for a pathway to delivering a successful innovation and technology district at Tech Central. In February 2019, the NSW Government adopted the Panel's report and committed to delivering the following:

- 25,000 additional innovation jobs

- 25,000 new STEM and life sciences students
- 200,000 m² for technology companies, and
- 50,000 m² of affordable space for startups and scaleups

In February 2019, the Greater Cities Commission released a Place Strategy for the area that is now known as Tech Central (Camperdown-Ultimo Collaboration Area Place Strategy, GCC). The Place Strategy, developed collaboratively by a range of stakeholders involved in planning for Tech Central's future, was prepared to inform public and private policy and investment decisions by identifying and recognising the complex, place-specific issues inhibiting growth and change. The strategy identifies shared objectives for the place and sets out priorities and actions to realise the vision for the area under the key themes of Connectivity, Liveability, Productivity, Sustainability and Governance.

Both the Panel Report and Place Strategy recognise the importance of the Central Precinct to Tech Central's future.

4.2 Reference Master Plan

Architectus and Tyrrell Studio have prepared a Place Strategy, Urban Design Framework and a Public Domain Strategy which establishes the Reference Master Plan for Central Precinct. The Urban Design Framework and Public Domain Strategy provides a comprehensive urban design vision and strategy to guide future development of Central Precinct and has informed the proposed planning framework of the SSP Study.

The Reference Master Plan includes:

- Approximately 22,000 sqm of publicly accessible open space comprising:
    - Central Green – a 6,000 square metre publicly accessible park located in immediately south of the Sydney Terminal building
    - Central Square –7,000 square metre publicly accessible square located at the George Street and Pitt Street junction
    - Mortuary Station Gardens – a 4,470 square metre publicly accessible park (excluding Mortuary Station building) located at Mortuary Station
    - Henry Deane Plaza – a publicly accessible plaza located in the Western Gateway sub-precinct
    - Eddy Avenue Plaza – a 1,680 square metre publicly accessible plaza located in the north-eastern portion of the Sydney Terminal building
    - Western Terminal Extension Building Rooftop - a 970sqm publicly accessible space above the Western Terminal Extension Building Rooftop.
- Approximately 269,500 square metres of office gross floor area (GFA)
- Approximately 22,850 square metres of retail GFA
- Approximately 53,600 square metres of hotel GFA
- Approximately 84,900 square metres of residential accommodation GFA, providing for approximately 850 dwellings (assuming 1 dwelling per 100sqm GFA).
- The Central Precinct SSP Study will include the commitment to deliver 15 per cent of any new residential floor space as affordable housing.

- Approximately 47,250 square metres of education/tech space GFA
- Approximately 22,500 square metres of student accommodation GFA
- Approximately 14,300 square metres of community/cultural space GFA.

The key features of the Indicative Reference Master Plan, include:

- A network of new and enhanced open spaces linked by green connections. This will include:
    - A Central Green (Dune Gardens) at the north of Central Precinct that will create a new civic public realm extension of the Sydney Terminal building and a new vantage point for Central Sydney
    - A new Central Square which will deliver on the vision for a new public square at Central Station, as one of three major public spaces within Central Sydney connected by a people-friendly spine along George Street
    - Mortuary Station Park at Mortuary Station that will be a key public domain interface between Chippendale and the over-station development. that will draw on the story of Rookwood Cemetery and the Victorian Garden context with the established rail heritage of the Goods Line and the rail lines
    - Henry Deane Plaza which will prioritise the pedestrian experience, improving connectivity and pedestrian legibility within the Western Gateway sub-precinct and provide clear direct links to and from the State heritage listed Central Station and its surrounds
    - Eddy Avenue Plaza – will transform into a high-amenity environment with significant greening and an enhanced interface with the Sydney Terminal building.
- A new network of circulation that will establish a clear layer of legibility and public use of the place. This will include:
    - A 15 - 24 metre wide Central Avenue that is laid out in the spirit of other street layouts within Central Sydney and which responds to the position of the Central clocktower, providing new key landmark views to the clocktower. Central Avenue will be a place for people to dwell and to move through quickly. It brings together the threads of character from the wider city and wraps them
    - Three over-rail connections to enhance access and circulation through Central Precinct, as well as provide pedestrian and bicycle cross connections through the precinct
    - The extension of public access along the Goods Line from Mortuary Station Gardens, offering a new connection to Darling Harbour
    - New vertical transportation locations throughout the precinct allowing for seamless vertical connections.
    - An active recreation system supports health and well-being through its running and cycling loops, fitness stations, distributed play elements, informal sports provision, and additional formal recreation courts.
    - a network of fine grain laneways that are open to the sky

The proposed land allocation for Central Precinct is described in **Table 3** below.

Table 1 Breakdown of allocation of land within Central Precinct (note: below figures, except for total Central SSP area, excludes WGP)

Land allocation	Proposed
Open-air rail corridor	sqm 101,755
Developable area	sqm 119,619
Public open space	19,185 sqm / 16% of Developable area
Other publicly accessible open space (Including movement zones, streets and links)	sqm 41,773 / 35% of Developable area
Building area	58,661 sqm / 49% of Developable area
Central SSP total area (incl. WGP)	**23.8 ha**

The Indicative Reference Master Plan for Central Precinct is illustrated in Figure 1 below.

Figure 1 Indicative Reference Master Plan for Central Precinct

4.3 Central Precinct vision

Central Precinct will be a vibrant and exciting place that unites a world-class transport interchange with innovative and diverse businesses and high-quality public spaces. It will embrace design, sustainability and connectivity, celebrate its unique built form and social and cultural heritage and become a centre for the jobs of the future and economic growth.

4.4 Case for change

Over the coming years, Central Station will come under increasing pressure as technological innovations progress, investment in transport infrastructure increases and daily passenger movements increase.

Sydney Metro, Australia's biggest public transport project, will result in the delivery of a new generation of world-class, fast, safe, and reliable trains enabling faster services across Sydney's rail network. In 2024, Sydney Metro's Central Station will open with daily passenger movements forecast to increase from 270,000 persons to 450,000 persons over the next 30 years.

In its current state, Central Station is underperforming as Australia's major transport interchange – lacking connectivity, activation and quality public spaces.

The renewal of Central Precinct will expand and revitalise Central Station, and transform this underutilised part of Sydney from a place that people simply move through to one where they want to visit, work, relax, connect and socialise. Its renewal also presents the potential to deliver on the strategic intent and key policies of regional, district and local strategic plans, providing for a city-shaping opportunity that can deliver economic, social and environmental benefit. Specifically, it will:

- make a substantial direct and indirect contribution to achieving the Premier's Priorities by facilitating upgrades to Sydney's largest and most significant public transport interchange, improving the level of service for users and visitors, and supporting the creation of new jobs and housing
- implement the recommendations of the NSW State Infrastructure Strategy 2018-2038, in particular the upgrading of the major transport interchange at Central to meet future customer growth
- contribute to key 'Directions' of the Greater Sydney Region Plan, to deliver 'a city supported by infrastructure', help create 'a city of great places', support 'a well connected city', deliver new 'jobs and skills for the city' and create 'an efficient city'
- implement the outcomes envisaged within the Eastern City District Plan including reinforcing the Harbour CBD's role as the national economic powerhouse of Australia and supporting its continued growth as a Global International City
- deliver on the shared objectives and priorities for Tech Central, the future focal point of Sydney's innovation and technology community, which aims to boost innovation, economic development and knowledge intensive jobs while creating an environment that foster collaboration and the exchanging of ideas
- deliver an outcome that responds to the overarching vision and objectives of the Central Sydney Planning Strategy. In particular it will assist with implementing a number of 'key moves' outlined in the strategy, including to 'ensure development responds to its context', 'ensure infrastructure keeps pace with growth', 'move people more easily', 'protect, enhance and expand Central Sydney's heritage, public places and spaces', and to 'reaffirm commitment to design excellence.'

5. About this report

The purpose of this report is to provide a detailed Environmental Sustainability, Climate Change and Waste Management assessment of the proposed changes and consider any potential impacts that may result within and surrounding the Central Precinct. This report addresses study requirement 8. Environmental Sustainability, Climate Change and Waste Management. The relevant study requirements, considerations and consultation requirements, and location of where these have been responded to is outlined in **Table 1** below.

This report has been prepared by environmental design and sustainability consultants Atelier Ten and Integral Group, by authors whose combined experience equates to several decades and backgrounds range from architecture, urban design, engineering, and academia.

The Central Precinct Renewal Program (CPRP) has a clear vision to demonstrate best-practice environmental, social, and economic outcomes for urban renewal.

5.1 The SSP Study

The SSP Study supports two implementation mechanisms for delivering sustainability at CPRP:

1. Design Considerations within the master plan;
2. Development Controls within the precinct Design Guide.

5.2 SSP Study requirements

Table 2 Study requirements, considerations, and consultation requirements

Ref	Requirement or consideration	Summary response	Where addressed
Study requirement			
8.1_A	Identifies the existing situation, including constraints, opportunities and key issues	Constraints, opportunities, and key issues relevant to environmental sustainability, climate change, and waste management are addressed.	Section 6. Existing situation and business as usual (BAU)
8.1_B	Outlines the likely impacts of the proposal in relation to energy use, greenhouse gas emissions, water use, waste water, solid waste and climate change resilience	Likely impacts of the proposal are modelled based on BAU minimum performance for buildings and precincts and can be found in each of the key report sections, with reference data in the Appendices.	Section 8. Energy and GHG emissions contains modelling of annual energy use, cumulative energy use, operational GHG emissions, embodied GHG emissions, and total cumulative GHG emissions. Section 9. Integrated water cycle management contains modelling of annual water use, and cumulative water use. Section 10. Integrated waste management contains modelling of annual waste generation, and cumulative waste generation. Section 15.2. Climate Adaptation

Ref	Requirement or consideration	Summary response	Where addressed
			Plan contains climate projections and data use for the risk assessment.
8.1_C	Provides detail of proposed sustainability principles and how they will be incorporated into the proposal	The study identifies three key implementation opportunities to embed sustainability principles: • Performance targets; • Design considerations within the master plan; and • Development Controls within the precinct Design Guide. These are detailed in key sections (8 Energy and GHG emissions, 9 Integrated water cycle management, 10 Integrated waste management, and 11 Climate change and resilience), and summarised in Section 14 Recommendations.	Section 7.4 Implementation
8.1_D	Includes an integrated water cycle management strategy	An integrated water cycle management strategy is included.	Section 9. Integrated water cycle management
8.1_E	Includes an integrated waste management strategy that maximises resource recovery	An integrated waste management strategy that maximises resource recovery is included.	Section 10. Integrated waste management
8.1_F	Includes measures to address the impact of climate change including urban heat and extreme weather events	Measures to address the impact of climate change including urban heat and extreme weather events are included.	Section 11. Climate change and resilience, and Section 15.2. Climate Adaptation Plan
8.1_G	Informs and supports the preparation of the proposed planning framework including any recommended planning controls or DCP/Design Guideline provisions that would deliver an appropriate sustainability outcome	The recommendations which represent the outcome of this consultation process take three forms: • Performance targets - certified ratings for development type from a series of rating tools; • Design considerations for the master plan - considerations for inclusion in the masterplan design; and • Development control provisions - considerations for the Sustainability chapter of the Design Guide for the CPRP Design Guide.	Section 14. Recommendations.
8.1_H	Identify appropriate sustainability benchmarks for each development type within the precinct	Sustainability benchmarks in the form of third party ratings are identified for each development type within the precinct.	Section 14.1. Performance targets.
Study consideration			
8.1_I	The NSW Government's net zero emissions target, by creating a low-carbon precinct	The development aims to be net zero at the scale of the precinct and individual building from day one with assurance provided by the Green Star suite of tools.	Section 8. Energy and GHG emissions
8.2_J	The goal of achieving a water - positive precinct, strategies to achieve 100% renewable energy supply for the precinct including maximising on-site generation and securing a supply of off-site renewable electricity	The ambition for water resource management at Central Precinct is to preserve non-renewable water resources and to provide a net improvement to environmental water quality as an outcome of renewal. The objectives for responsible water management at Central Precinct are: • To reduce overall consumption of water resources to achieve the equivalent of 5 star NABERS Water and 6 Star Green Star	Section 9. Integrated water cycle management

Ref	Requirement or consideration	Summary response	Where addressed
		baselines through best practice water-conserving systems, equipment, fixtures, fittings and appliances; • To reduce stormwater pollution flowing to Sydney Harbour significantly beyond best practice guidelines; • Alignment of water quality, supply source, and treatment needs to enable effective water harvesting and re-use; • To identify mechanisms for waste-water treatment and re-use aligned with best practice utilities and implement solutions that can be sustainably operated over the full life of the asset. While the majority of the water demand objectives can be achieved through the design brief, there remain several large-scale opportunities for addressing the water supply and storm-water management with an integrated water cycle management plan. For planning purposes, Central Precinct should make spatial allowance for a precinct utility to provide: • On site renewable generation, emergency and stand by power supply, and electrical energy storage for the district. Buildings are to be designed to achieve net zero emissions by being highly efficient, all-electric and using a minimum of 100% renewable electricity (by maximising on-site generation and offsite renewable energy procurement).	Section 8. Energy and GHG emissions Section 14.3.3 Performance design guidance
8.1_K	How sustainability principles will be incorporated into the design, construction, and ongoing operation phases of the redevelopment to achieve sustainability best practise initiatives	Sustainability principles will be embedded in the design and construction phases of the redevelopment using the Design Guide and Green Star suite of tools. Sustainability Principles will be embedded in the ongoing operation phase of the redevelopment using the NABERS suite of tools.	Section 14.1 Performance targets.
8.1_L	High benchmark sustainability performance targets for the precinct	Sustainability performance targets are aligned with the ambition for world's best practice.	Section 14.1 Performance targets.
8.1_M	Compliance with BASIX and opportunities to deliver beyond BASIX scores	Performance targets are based on the outcome of the assessment of global peer precincts, all of which seek to attract world-class developers and tenants, and the ambition for world's best practice. All of these performance targets will result in significantly better sustainability outcomes in comparison to statutory requirements, like BASIX. Embedding the requirement for certification with third party sustainability rating tools also ensures outcomes which would otherwise be impossible for TfNSW to deliver with statutory requirements only.	Section 14.1 Performance targets.
8.1_N	The incorporation of Green Roofs, Cool Roofs and Green	Roofs at CPRP should always contribute to sustainability objectives, including reducing urban heat, and all roofs should be:	Section 9.5.1 Urban heat management

Ref	Requirement or consideration	Summary response	Where addressed
	Walls into the design of any future buildings	• Solar PV; • Amenity; • Green infrastructure; or • Materials with a low SRI value in line with Green Star requirements. Buildings should have roofs clear of mechanical plant, to enable rooftop amenity and green infrastructure. Apply the principles of biophilia in design, incorporating green walls and roofs at a minimum	Section 14.2.2 Precinct utility – thermal energy Section 14.3.3 Performance design guidance
8.1_O	Climate change, including the urban heat island effect, changing temperatures and rainfall patterns	As part of the SSP process, a detailed climate risk assessment was undertaken in line with relevant standards and guidelines and a climate adaptation plan was prepared to comply with Green Star Communities v1.1 requirements.	Section 11. Climate change and resilience, and Section 15.2. Climate Adaptation Plan.
8.1_P	Urban forest and biodiversity	The preferred solution on sustainability grounds is to maximise the urban green coverage as much as possible with greening in the public realm and built form that: • Provides shading from tree canopy coverage; • Has high evapotranspiration potential to maximise the cooling effects; • Provide foraging and roosting habitat for local mobile species; • Supports connection to Country; • Supports habitat connectivity, especially between the two parks and enables continuous green space to be accommodated down the length of the site.	Section 14.2.5 Urban Forest
8.1_Q	Taking a whole-of-life-approach to sustainability through planning design, construction and ongoing precinct management	Sustainability principles will be embedded in the design and construction phases of the redevelopment using the Design Guide and Green Star suite of tools. Sustainability Principles will be embedded in the ongoing operation phase of the redevelopment using the NABERS suite of tools.	Section 14.1 Performance targets.
8.1_R	Maximising resource efficiency to contribute to net zero emissions by 2050	World's best practice resource efficiency will be assured through the Green Star suite of tools and the ambition for the precinct and individual buildings to be net zero from day one.	Section 14.1 Performance targets.
8.1_S	The protection and enhancement of biodiversity through the greening of public and private spaces	The preferred solution on sustainability grounds is to maximise the urban green coverage as much as possible with greening in the public realm and built form that: • Provides shading from tree canopy coverage; • Has high evapotranspiration potential to maximise the cooling effects; • Provide foraging and roosting habitat for local mobile species; • Supports connection to Country; • Supports habitat connectivity, especially between the two parks and enables	Section 14.2.5 Urban Forest

Ref	Requirement or consideration	Summary response	Where addressed
		continuous green space to be accommodated down the length of the site.	
8.1_T	The replacement of any trees removed at a ratio greater than 1:1	The Green Infrastructure, Ecology, Urban Forest and Greening study also confirms that the number of trees the reference scheme proposes to remove is 45, and the number of new trees the reference scheme proposes is 510, with a replacement ratio of 1:11.3.	Section 14.2.5 Urban Forest
8.1_U	The use of local native plant species in street tree planting and landscaping (rather than exotic species and non-local natives)	Urban heat management is a substantial resilience concern for Greater Sydney. One of the most effective mechanisms to mitigate urban heat is the provision of green infrastructure and the maintenance of canopy cover. However, the maintenance of effective green infrastructure and the water intensity of the infrastructure is an important consideration: • If high evapotranspiration species are chosen, the cooling effect is greater but so too is the need for reliable and low-impact water supply; • If low evapotranspiration species are chosen, the cooling effect is lower but the drought-resilience of the landscape is greater without any additional water re-use systems. There are several important considerations: • The range of cooling benefits that different landscape options contribute; • The range of water intensity of different landscape solutions; • The design implications for landscape location and public amenity. The landscape design seeks to target a high evapotranspiration species selection, with attendant water demands on the basis that a precinct water recycling facility is available to provide reliable supply that does not further deplete potable water resources.	Section 9.5.1 Urban heat management
8.1_V	Water, waste water and stormwater plus options for potential alternative water supply including potential to achieve a water positive precinct	The ambition for water resource management at Central Precinct is to preserve non-renewable water resources and to provide a net improvement to environmental water quality as an outcome of renewal. The objectives for responsible water management at Central Precinct are: • To reduce overall consumption of water resources to achieve the equivalent of 5 star NABERS Water and 6 Star Green Star baselines through best practice water-conserving systems, equipment, fixtures, fittings and appliances; • To reduce stormwater pollution flowing to Sydney Harbour significantly beyond best practice guidelines; • Alignment of water quality, supply source, and treatment needs to enable effective water harvesting and re-use;	Section 9. Integrated water cycle management

Ref	Requirement or consideration	Summary response	Where addressed
		• To identify mechanisms for waste-water treatment and re-use aligned with best practice utilities and implement solutions that can be sustainably operated over the full life of the asset. While the majority of the water demand objectives can be achieved through the design brief, there remain several large-scale opportunities for addressing the water supply and storm-water management with an integrated water cycle management plan.	
8.1_W	Opportunities for and assessment of the feasibility of a precinct-scale recycled water scheme including the possibility of connecting to the recycled water pipeline that runs along the CBD light rail route	The provision of a reliable recycle water supply should be a priority for Central Precinct to mitigate water resource constraints. There are several mechanisms by which such a system could be realised: • Private water recycling scheme supported by the new development opportunity (such as Central Park or Barangaroo); • Public authority water recycling scheme (such as Rouse Hill); • Connection to a shared water recycling scheme via the George St recycled water main, with recycled water being supplied by an independent party (either public or private). For planning purposes, Central Precinct should make spatial allowance for water recycling within the masterplan. The investment case for which model of delivering recycled water is most appropriate should be established through a bespoke feasibility assessment and the precinct procurement process.	Section 9.4 Water Demand at Central Precinct
8.1_X	Precinct scale measures to ensure effective operational waste management	The preferred solution on sustainability grounds is to identify opportunities for the advancement of the circular economy and not preclude a low-emissions approach to the construction of the precinct and its embodied carbon impacts. Opportunities that should be enabled include: Waste management • Spatial provision made in alignment with City of Sydney's guidance across all uses and in both buildings and shared service areas; • Opportunities for managing waste at the precinct level (such as a connected network for food waste in retail F&B areas or shared dehydrators). All new buildings are to develop an operational waste management plan and demonstrate a 60% reduction in operational waste to landfill	Section 14.2 Design considerations for the master plan Section 14.3.3 Performance design guidance
8.1_Y	Options for achieving net zero buildings and net zero precinct	The development aims to be net zero at the scale of the precinct and individual building from day one with assurance provided by the Green Star suite of tools.	Section 8. Energy and GHG emissions.
Consultation			

Ref	Requirement or consideration	Summary response	Where addressed
8.1_Z	The Study is to be informed by consultation with the City of Sydney and the NSW Environment Protection Authority	Through significant consultation with TfNSW, design and consultant teams, and external stakeholders the sustainability principles and strategies have been refined to reflect project-specific opportunities. Consultation activities have included: • holistic sustainability workshops and presentations • focused briefings and discussions on individual sustainability issues • detailed consultations around defining sustainability metrics • dedicated climate resilience workshops	Section 13. Consultation
Author			
8.1_AA	The Study is to be prepared by suitably qualified sustainability professional(s) with the necessary experience and expertise to undertake the required works	This report has been prepared by environmental design and sustainability consultants Atelier Ten and Integral Group, by authors whose combined experience equates to several decades and backgrounds range from architecture, urban design, engineering and academia.	Section 5. About this report
Guidance documents			
8.1_AB	The following documents provide guidance for this Study: Eastern City District Plan (in particular, actions 69 and 72); City of Sydney Guidelines for Waste Management in New Developments; The Better Practice Guide for Waste Management in Multi-Unit Dwellings (DECC 2008); Better Practice Guidelines for Waste Management and Recycling in Commercial and Industrial Facilities (EPA, December 2012); Better Practice for Public Place Recycling (DEC 2005); NSW Climate Change Policy Framework, October 2016; Draft Central District Plan "Creating an efficient Central District" to achieve netzero carbon emissions by 2050; NSW and ACT Regional Climate Modelling: NARCLI; Urban Green Cover in NSW Technical Guidelines (OEH, 2015); Greener Places (Government Architect NSW); The Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Environment Protection and Heritage Council, the Natural Resource Management Ministerial Council and the Australian Health Ministers' conference 2006);	Guidance documents, including these, are included in the relevant section of this study.	Section 7. Sustainability principles Section 8. Energy and GHG emissions Section 9. Integrated water cycle management Section 10. Integrated waste management Section 15.2. Climate Adaptation Plan

Ref	Requirement or consideration	Summary response	Where addressed
	United Nations Sustainable Development Goals; Future Transport 2056; Government Resource Efficiency Plan; and NSW Circular Economy Policy Statement.		

6. Existing situation and business as usual (BAU)

6.1 Central Precinct existing conditions

Comprising land in and around Central Station transport interchange, CPRP will be a new destination for the local, metropolitan, regional, and global community. It will draw on the character and significant heritage within Central Precinct and the surrounding suburbs to foster a unique and vibrant urban place.

6.1.1 Constraints

Major urban renewal is necessarily constrained in my ways, and this is evident too in sustainability opportunities.

- Dense urban location and over station development limiting vehicular access (construction and operations) and utility supply.
- Confluence of transport networks and necessity to retain ongoing operations throughout entire development program.
- Significant modern and pre-colonial heritage sites and structures which must be retained, preserved, and integrated.
- Competition from other similarly sized precincts in the Sydney metro area (Bays West, Pyrmont-Ultimo, Camperdown, Eveleigh, Randwick), and greater Sydney (Aerotropolis, Macquarie Park, Westmead).
- There are also constraints in the proposed construction methodology, where conventional structural materials are likely necessary for the major deck and primary structural system with limited opportunities for circular approaches that may introduce uncertainty or limited capacity to structural systems.
- The proposed density of the development also constrains the opportunities for on-site renewable power to play a meaningful role in emissions reduction, with necessary reliance on renewable power procurement.
- The deck structure also constrains some of the opportunities for green habitat connectivity with deep soil constrained to a selection of zones.
- A major constraint on utilities systems is the lack of basement access due to the over-rail build, and the location of district energy systems and distribution corridors in the deck zone will introduce several design challenges for implementation.

6.1.2 Opportunities

CPRP has a clear vision to demonstrate best-practice environmental, social, and economic outcomes for urban renewal.

- Taking a whole-of-life approach to sustainability through planning, design, construction, and ongoing precinct management.
- Maximising resource efficiency to contribute to net zero emissions by 2050.
- Strengthening the precinct's resilience to urban hazards such as noise, air quality and potential shocks and stresses, including climate change.
- Enabling positive social and community outcomes including through the promotion of a healthy community, high levels of amenity and social workforce opportunities.
- Enhancing biodiversity through the greening of public and private spaces.
- Embedding sustainable procurement throughout the precinct's development, activities and uses.
- It represents an opportunity to deliver sustainability objectives with development partners in innovative ways.

There are also several specific opportunities that come from the precinct characteristics:

- The renewal of an infrastructure site offers a range of opportunities for materials recovery with demolition to advance circularity on the precinct.
- The modal diversity of the Central Precinct is peerless in connectivity in Australia and an opportunity for exemplar performance
- The proximity of Belmore Park and Prince Alfred Park provide the foundation of a connected green spine which could substantially enhance habitat connectivity in the city.
- The extensive heritage resources within the precinct provide an opportunity for exemplar re-use of existing built assets.

6.1.3 Key issues

The existing site has several attributes that support sustainability outcomes:

- Its primary use as a major public transit interchange and corridor supports modal diversity in the city.
- The scale of development could have a potentially huge impact on GHG emissions and waste in construction and operation.
- It contains valuable high-energy-intensity materials which may be a resource for future building needs.
- Ensuring sustainability outcomes are embedded in all stages of development.

However, in many ways it represents an under-utilised part of the city which could support more urban function and avoid further impacts outside of the CBD.

6.2 Business as usual

The proposed design reference case for BAU is the minimum performance for buildings and precincts defined by the regulatory requirements of the building and construction sector.

- The National Construction Code Section J provides the reference point for energy efficiency and GHG emissions.
- For the residential sector, the minimum BASIX requirements provide further performance as a regulatory minimum.
- Within the City of Sydney, the Development Control Plan also provides a baseline reference point for the Central Precinct BAU.

The resource intensity baselines have been assessed on industry best practice:

- Energy: Commercial: NABERS 4 star
- Water: Commercial: NABERS 4 star

7. Sustainability principles

7.1 Sustainability approach

The approach to sustainability for the CPRP is guided by the Transport Environment and Sustainability Policy (2020).

Transport for NSW is committed to delivering transport which contributes to economic prosperity and social inclusion in an environmentally responsible and sustainable manner, consistent with the Future Transport Strategy 2056.

The principles of the policy have been embedded within this strategy for CPRP:

- Leadership
- Environmental protection
- Energy and carbon
- Resilience
- Sustainable procurement
- Whole of life
- Social sustainability
- Awareness.

The approach to sustainability is also informed by the UN Sustainable Development Goals, notably:

- Good health and wellbeing (UNSDG 3)
- Affordable and clean energy (UNSDG 7)
- Decent work and economic growth (UNSDG 8)
- Industry, innovation and infrastructure (UNSDG 9)
- Sustainable cities and communities (UNSDG 11)

- Responsible consumption and production (UNSDG 12)
- Climate action (UNSDG 13)
- Life on land (UNSDG 15).

Figure 2 United Nations Sustainable Development Goals

7.2 Sustainability ambition

This study is framed by a level of ambition that represents world's best practice.

This is based on the key drivers for ambition:

- The emerging research on how society and the natural environment impact each other;
- The competitive environment for major urban renewal precincts; and
- The established level of ambition with local and international policy.

Figure 3 Supporting World's Best Practice

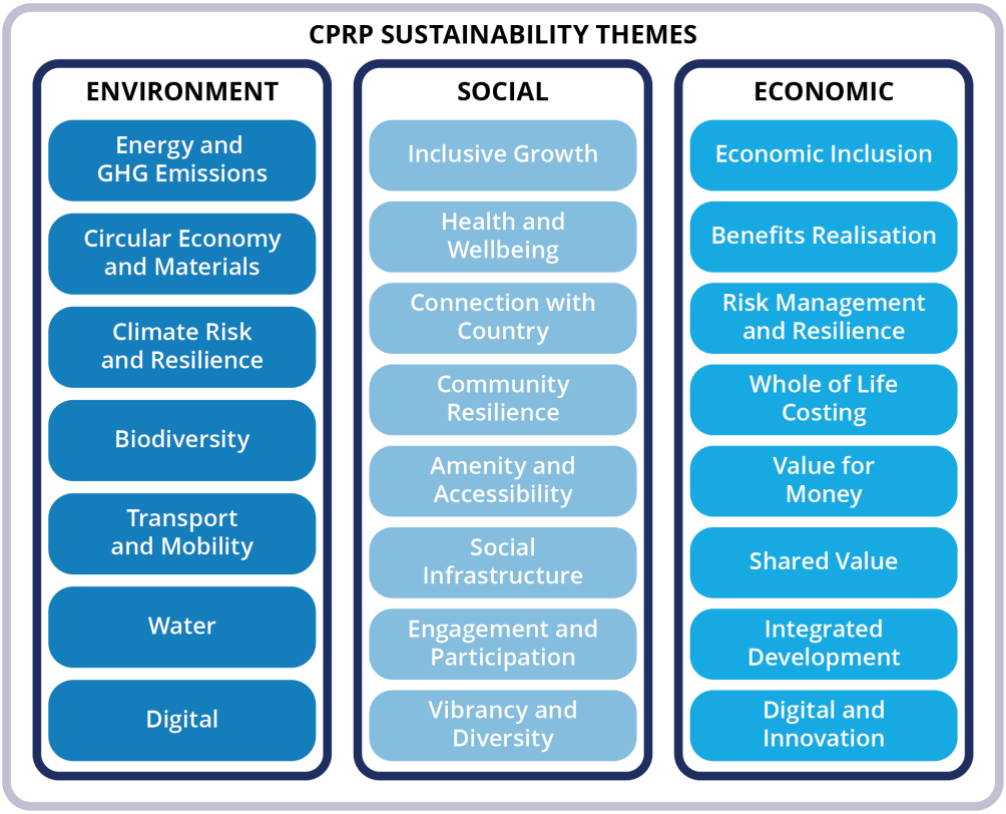
The concept of world's best practice provides a goal for the precinct that can be held and developed over time. World's best practice relies on making environmental, social, and economic sustainability (aligned with international best practice) priorities for this urban development.

7.3 Sustainability themes

The sustainability themes for CPRP represent a synthesis of the attributes which define world's best practice. This study has, for each sustainability theme, described an ambition for CPRP aligned with world's best practice and the Strategic Vision. This ambition is then supported by a brief series of objectives that support its delivery.

The sustainability themes aim to embed world's best practice in resource efficiency, ecological stewardship, adaptability, accessibility, and enabling infrastructure in both the physical fabric and ongoing operations of CPRP.

Figure 4 Sustainability Themes



7.3.1 Energy and GHG emissions

The ambition for energy and GHG emissions at the CPRP is to be net zero emissions in construction and operation by 2030.

The World Green Building Council's target of net zero emissions and a 40% reduction in embodied emissions by 2030 is already being met by Australia's leading property companies and represents world's best practice for CPRP.

The objectives to achieve net zero emissions are aligned with industry best practice:

- Electrification of all normally-operating systems - electrification is a necessary step for considering net zero emissions certification by most Net Zero Energy (NZE) frameworks that may apply;
- Energy efficiency and demand control – the building design ambitions for energy efficiency should include passive design, efficient systems and demand control strategies;
- Use of low-carbon materials and construction processes (provisional target of 40% below BAU) – opportunities for reducing embodied emissions should be explored for the major structural and components and construction operations;
- Procurement of 100% renewable energy (on-site and off-site);
- Offset all residual emissions (scope 1, 2 and nominated scope 3) from construction and operation with nature-based solutions.

7.3.2 Circular Economy

The ambition for the Circular Economy is to achieve circularity in the operational and construction stages of the project by 2030.

The objectives to achieve circularity are aligned with industry whole of life resource use best and emerging practices:

- Maximise the use of re-used material or material from a renewable source in construction;
- Divert the majority of construction waste from landfill to beneficial re-use (provisionally 95%, in line with Green Star benchmarks);
- To eliminate single-use plastics from the upstream supply chain by 2025;
- Divert operational waste from landfill;
- To establish high levels of recyclability in the upstream supply chain by 2025;
- To separate and recycle recoverable waste by types; consideration of operational waste streams that could be repurposed or reused within the precinct (i.e. food waste stream);
- Supporting stewardship in procurement, procuring services rather than products;
- Embedding end of life considerations at design stage for building disassembly or long-term re-use;
- Supporting flexibility of form to support building longevity beyond its original intended use.

7.3.3 Climate risk and resilience

The ambition for resilience at CPRP is to effectively mitigate chronic stresses and insulate against acute shocks through design.

The objectives for resilience at the CPRP are:

- To embed design for a future climate in all design processes using RCP 8.5 in 2050 climate scenarios;
- To identify mechanisms to manage heat, bushfire (and smoke), flood and storm impacts through extreme events;
- To provide community facilities that support social resilience during major shock events;
- To effectively mitigate climate risk in alignment with the Taskforce for Climate-related Financial Disclosures (TCFD);
- To enable flexible, adaptive and regenerative systems with the capacity to be changed subject to uncertain future pressures.

7.3.4 Biodiversity

The ambition for supporting biodiversity at the CPRP is to have a net positive impact on biodiversity through project activities by 2030.

The objectives in support of increasing biodiversity are:

- To provide local biodiversity initiatives that mitigate the immediate impact of the program on-site and create new urban habitat for the city's ecosystem;
- To provide habitat connectivity for mobile species between key local and regional green spaces: Prince Alfred Park and Belmore Park, as well as the Domain, Hyde Park and Moore Park;
- To establish a biophilic environment at Central Precinct that provides a material connection for tenants and visitors to natural systems;
- To achieve a Net Positive Impact on biodiversity through support for off-site land projects that generate biodiversity offset credits aligned with negative emissions instruments (afforestation, reforestation and soil carbon sequestration).

7.3.5 Transport and mobility

The ambition for transport and mobility at CPRP is to enable a more sustainable transport network in greater Sydney.

The objectives for supporting sustainable transport options at CPRP are:

- Reduce private vehicle use in this car-dominant environment by supporting non-vehicular transport modes;
- Providing an exemplar of movement and place mutually enhancing the quality of the respective experiences;
- Encouraging and enabling active mobility to the site (pedestrian and bicycle);
- Provision for the electrification of road mobility options – 100% of parking to have charging capability;
- Improving the experience of customers traversing through CPRP - amenity, comfort, ease of movement, modal change options and wayfinding;
- Providing an exemplar of universal, equitable access;
- Supporting future mobility transitions - including vehicle sharing, ride-sharing and connected and autonomous vehicle interfaces;
- Supporting emerging transitions in the freight network, including the electrification of logistics systems.

7.3.6 Water

The ambition for water resource management at CPRP is to preserve non-renewable water resources and to provide a net improvement to environmental water quality as a result of development.

The objectives for responsible water management at CPRP are:

- To reduce overall consumption of water resources to achieve the equivalent of 5 star NABERS Water baselines through best practice water conserving systems, equipment, fixtures, fittings and appliances;
- To reduce stormwater pollution flowing to Sydney Harbour significantly beyond best practice guidelines;

- Alignment of water quality, supply source, and treatment needs to enable effective water harvesting and re-use;
- To identify mechanisms for waste-water treatment and re-use aligned with best practice utilities and implement solutions that can be sustainably operated over the full life of the asset.

7.3.7 Digital

The ambition for a sustainable digital precinct at CPRP is to enhance social and environmental performance and disclosure through emerging digital technology and the internet of things (IoT).

The objectives for delivering sustainability outcomes through the IoT are:

- Identify mandatory disclosure of ongoing performance and assurance of key sustainability objectives with a public interest (GHG emissions, waste-to-landfill and operational water consumption at a minimum);
- Identify key performance data for commercial benefit or operational improvement (not for public disclosure);
- Develop a single digital platform for data management, monitoring and disclosure of environmental performance;
- Develop physical infrastructure (fibre, Wi-Fi and narrowband) and IoT sensor strategy for mandatory disclosure and for commercially beneficial data;
- Provide a way-finding platform and hub for future mobility interface;
- Enable an eco-system of application development;
- Develop protocols for privacy, access, data security, educational benefit and civic engagement;
- Support the effective implementation of the circular economy;
- Build a digital engineering framework for consideration of sustainability improvements over design and tracking of operational data.

7.4 Implementation

The implementation of an ambitious sustainability agenda requires the sustainability principles, objectives, and requirements to be embedded within the primary workflows that will guide the program development.

The study identifies three key implementation opportunities to embed sustainability principles:

- Performance targets;
- Design considerations within the master plan; and
- Development Controls within the precinct Design Guide.

These are detailed in key sections (8 Energy and GHG emissions**, 9** Integrated water cycle management**, 10** Integrated waste management**, and 11** Climate change and resilience**), and summarised in Section 14** Recommendations**.**

8. Energy and GHG emissions

The study addresses energy and greenhouse gas emissions as interrelated elements of a holistic climate positive approach to development.

The study provides direction across the entire development life cycle across two domains:

- Integrated building design (operational GHG emissions)
- Materials lifecycle approach (upfront and embodied GHG emissions)

8.1 Strategic Planning

The importance of energy and greenhouse gas emissions is enshrined at all levels of Australian government and is already critical to contemporary urban development of all scales.

8.1.1 NSW Government

The NSW Government has set a goal of net zero emissions by 2050, and a target of 50% below 2005 levels by 2030.

The NSW Government's *Net Zero Plan Stage 1: 2020–2030* sets out four priorities:

1. Drive the uptake of emissions reduction technologies that also support economic growth, or reduce cost of living or doing business
2. Empower consumers and businesses to make sustainable choices
3. Invest in the next wave of emissions reduction innovation to ensure economic prosperity from decarbonisation beyond 2030
4. Ensure the NSW Government leads by example.

8.1.2 City of Sydney

The City of Sydney has a goal of reaching net zero by 2035, and embedding optimum energy efficiency, on-site renewable energy, and off-site renewable energy to set a path to net zero in the planning and design process for larger buildings.

The City's *Planning for net zero energy buildings* report recommends a first and second target for each asset class, with the first target implemented in 2023 and the second in 2026. This includes a single on-site energy intensity (kWh/yr/m^2) target for each asset class or equivalent options to meet that target within existing planning and design tools. These targets are shown in Table 3.

Table 3 Asset classes and targets

Asset class	First target (2023)	Second target (2026)
Office building (base building)	Maximum 45 kWh/yr/m^2, or equivalent NABERS Energy or Green Star Buildings credits, or equivalent	Maximum 45 kWh/yr/m^2, or equivalent NABERS Energy or Green Star Buildings credits, or equivalent, and renewable energy procurement to net zero
Shopping centre (base building)	Maximum 55 kWh/yr/m^2, or equivalent NABERS Energy or Green Star Buildings credits, or equivalent	Maximum 45 kWh/yr/m^2, or equivalent NABERS Energy or Green Star Buildings credits, or equivalent, and renewable energy procurement to net zero
Hotel (whole of building)	Maximum 245 kWh/yr/m^2, or	Maximum 240 kWh/yr/m^2, or

Asset class	First target (2023)	Second target (2026)
	equivalent NABERS Energy or Green Star Buildings credits, or equivalent	equivalent NABERS Energy or Green Star Buildings credits, or equivalent, and renewable energy procurement to net zero
Multi-unit residential (whole of building)		
6–10 storeys	Basix Energy 40	Basix Energy 45 and renewable energy procurement to net zero
11–20 storeys	Basix Energy 35	Basix Energy 40 and renewable energy procurement to net zero
21–30 storeys	Basix Energy 30	Basix Energy 35 and renewable energy procurement to net zero

8.2 Objectives

The ambition for energy and GHG emissions at the CPRP is to be net zero emissions in construction and operation by 2030.

The World Green Building Council's target of net zero emissions and 40% reduction in embodied emissions by 2030 is already being met by Australia's leading property companies and represents world's best practice for CPRP.

The objectives to achieve net zero emissions are aligned with industry best practice:

1. Electrification of all normally-operating systems -electrification is a necessary step for considering net zero emissions certification by most NZE frameworks that may apply;
2. Energy efficiency and demand control –the building design ambitions for energy efficiency should include passive design, efficient systems and demand control strategies;
3. Use of low-carbon materials and construction processes (provisional target of 40% below BAU) –opportunities for reducing embodied emissions should be explored for the major structural and components and construction operations;
4. Procurement of 100% renewable energy (on-site and off-site);
5. Offset all residual emissions (scope 1, 2 and nominated scope 3) from construction and operation with nature-based solutions.

The assurance for net zero emissions will be provided by appropriate ratings and certification standards at design, construction, and operational stages.

8.3 Impacts

Energy demand and GHG emissions impact scenarios at Central Precinct have been assessed in terms of equivalent building ratings and industry consumption data applied across the development build-out over time. The resource demand trajectory design considerations are included in 15.1 Resource Design and Performance Baselines.

8.3.1 Energy demand

The energy demand trajectory indicates several key outcomes:

- Energy efficiency, evidenced through improved NABERS Energy performance is an important driver of energy efficiency.
- More than 50% of building energy demand is used by space cooling (air conditioning).
- Annual energy use illustrates the compounding effect a change in NABERS rating from the 'good' 4 Star to the 'market leading' 6 Stars will have during the development program.

Figure 5 Annual energy use by NABERS rating by end use

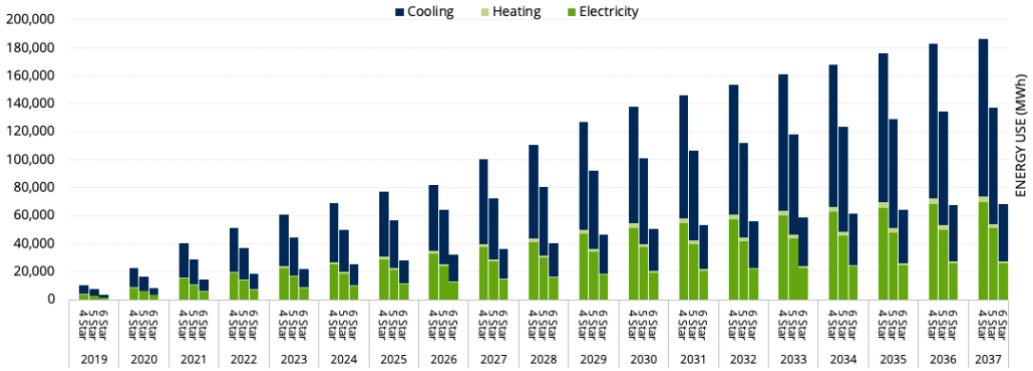
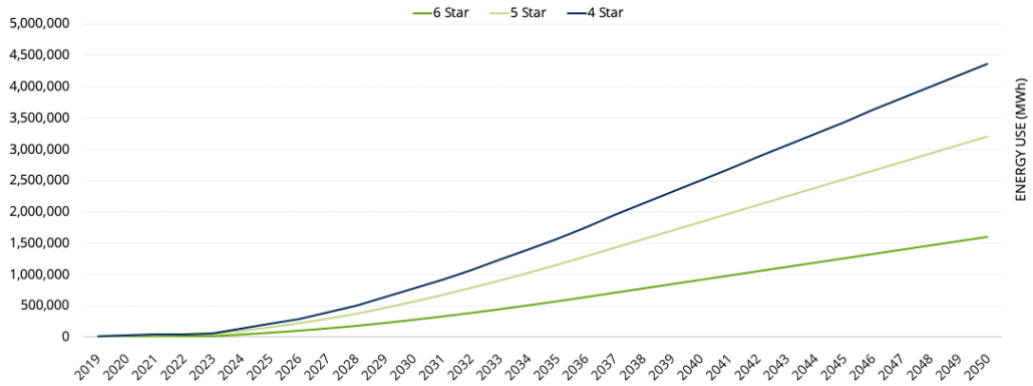


Figure 6 Cumulative energy use by NABERS rating by end use



8.3.2 Operational GHG emissions

The operational GHG emissions demand trajectory indicates several key outcomes:

- Same compounding effect between NABERS ratings.
- Electricity dwarfs water supply and wastewater treatment emissions.

Note: There is great variability in the waste volume and emissions data, with outputs ranging from waste emissions as a modest fraction of annual emissions to the overwhelming preponderance of emissions. A detailed waste study should be undertaken to establish accurate estimates for the precinct.

Figure 7 Annual operational GHG emissions by NABERS rating by end use

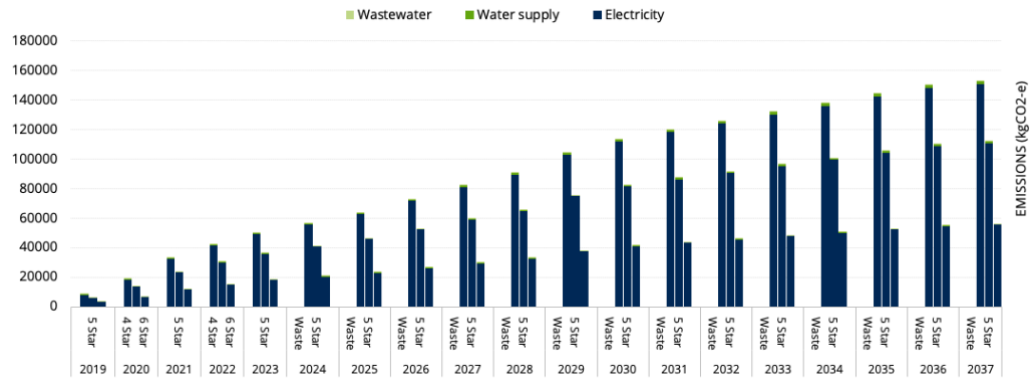
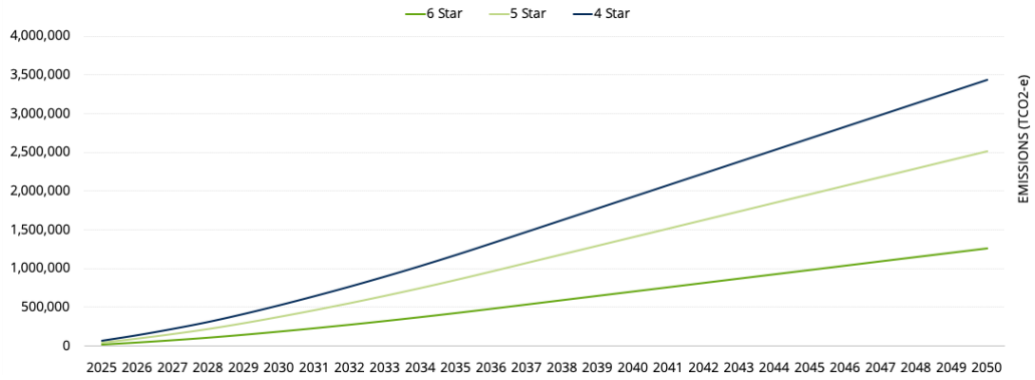


Figure 8 Cumulative operational GHG emissions by NABERS rating by end use

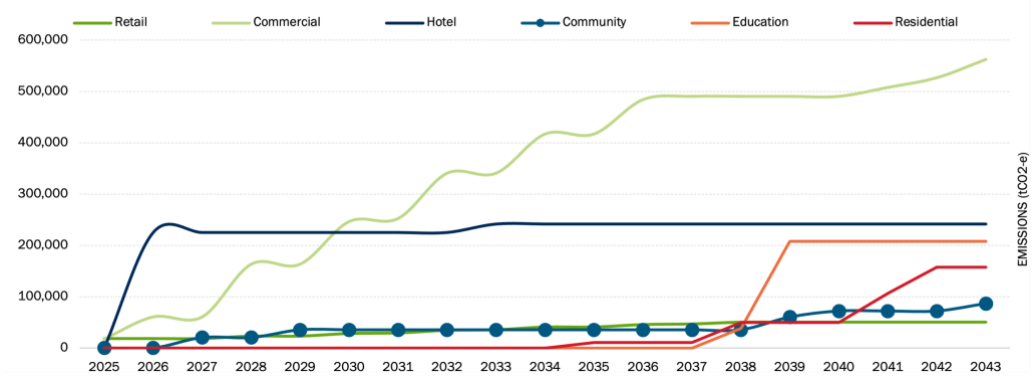


8.3.3 Embodied GHG emissions

The embodied GHG emissions demand trajectory indicates several key outcomes:

- Commercial and residential have the lowest embodied emissions because they are standard building types
- Community and education are proportionately much higher (2-3x)

Figure 9 Cumulative embodied emissions by program type

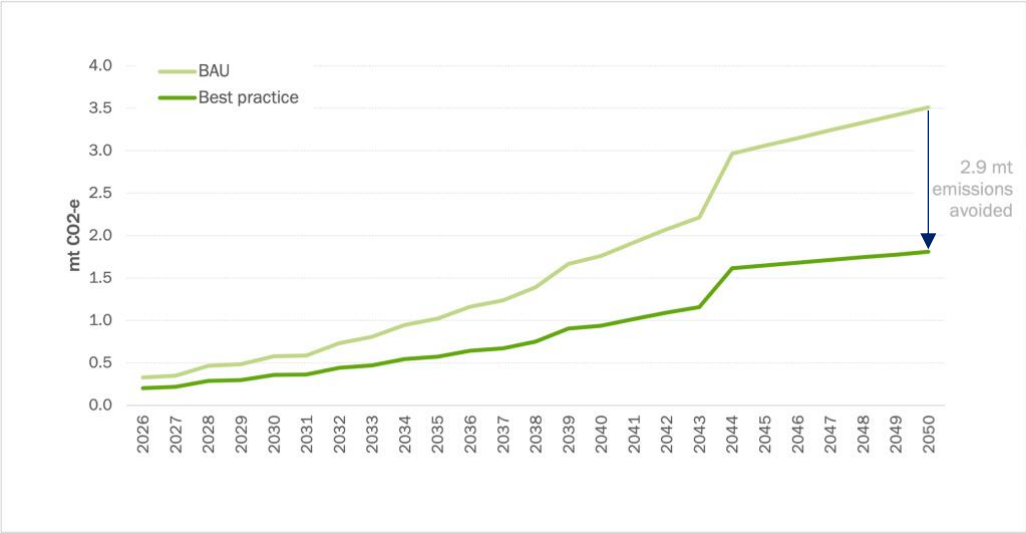


8.3.4 Total cumulative GHG emissions

Total cumulative emissions, embodied and operational, from project inception to 2050.

- BAU comprises:
  - NABERS Energy 4 Star
  - NABERS Water 4 Star
  - Embodied carbon "traditional style concrete and steel box type building with limited sustainability initiatives beyond retention of part of the existing foundation which will be tied into the new build"
- Best practice comprises:
  - NABERS Energy 6 Star
  - NABERS Water 6 Star
  - Current best practice = "early and considerable engagement with sustainability initiatives which reduces CO2"

Figure 10 Total Cumulative Emissions



8.4 Integrated building design

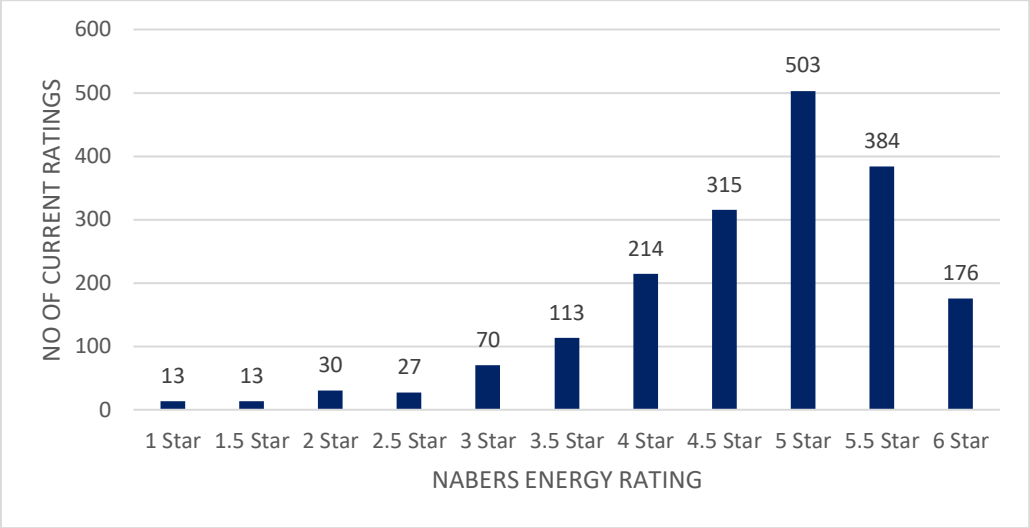
The recommended approach to energy demand management in buildings is to establish a performance benchmark using an operational target for other building types using the Green Star Performance rating tool (6 Star) with the option for a NABERS Energy rating for commercial and retail buildings (5 star).

There are several design considerations that can be implemented to meet this benchmark:

- Facades that limit cooling peak loads to less than 80 W/m2;
- Facades that eliminate typical space heating needs through sufficient insulated area;
- Building configuration that locates all regularly occupied work areas within 8m of a building perimeter for ample daylight;
- Buildings that can open up windows and doors for natural ventilation and comfort cooling when outdoor conditions allow.

This study suggests that a performance outcome of no less than 6 star NABERS Energy rating for commercial uses with a Commitment Agreement, and 4.5 star NABERS Energy rating for hotel and multi-unit residential uses with a Commitment Agreement represents an appropriate level of ambition for planning while leaving a range of design and operational options available to the delivery of future development.

Figure 11 Current NABERS Energy ratings



World's best practice points to the role the bespoke precinct utilities can play in securing long term low emissions performance. Precinct utilities can support three emissions reduction objectives:

- Efficiency (through central systems)
- Renewable energy procurement (Power Purchase Agreement, Energy Supply Agreement or Certificate purchase)
- Emissions offset programs

A precinct utility may be embedded in the development agreement or procured separately in its own right.

The precinct utility initiative may also have an important role to play in resilience; providing emergency or stand by energy and water and a coordinated approach to business continuity in the event of major shock events

Considerations could include:

- Energy storage (thermal and electrical)
- Plant capacity redundancy

For planning purposes, Central Precinct should make spatial allowance for a precinct utility to provide:

- A micro grid electrical network, which could include an embedded network retailer, HV infrastructure, smart grid demand controls, and electric vehicle infrastructure;
- On site renewable generation, emergency and stand by power supply, and electrical energy storage for the district;
- A district thermal system for building heating, cooling, and thermal energy storage.

The level of ambition for energy efficiency should be established through performance requirements for each building (NABERS and 6 Star Green Star).

The investment case for which model of delivering energy is most appropriate should be established through a bespoke feasibility assessment and the precinct procurement process.

8.5 Materials lifecycle approach

8.5.1 Low embodied carbon construction materials

World's Best Practice points to reducing embodied carbon in new buildings and infrastructure through the following design and construction measures:

- Material reduction through maximally structural efficient design
- Low carbon concrete mixes using recycled cementitious materials
- Mass timber structures
- Specifying low carbon steel, glass, aluminium

8.5.2 Organic waste composting

Greenhouse gas emissions from methane produced by decomposing organic waste in landfills can be eliminated by managing organic wastes as a resource to avoid methane release.

For a dense urban development like Central Precinct, this will happen through off site waste management solutions like:

- Composting waste for agricultural fertiliser
- Capturing methane from waste for energy generation

Embodied carbon targets for development at this scale would be a first in Australia.

8.5.3 Construction energy efficiency

Opportunities to reduce GHG emissions through construction should be explored; considering:

- Location for raw materials sourcing and truck movements
- Logistics modal choice (rail vs truck vs ship)
- Construction equipment fuel efficiency
- Construction equipment fuel selection.

Construction stage emissions should be reduced in support of the overall embodied emissions reduction target.

8.5.4 Scope 3 emissions reductions tenant emissions, water efficiency, vehicle electrification and waste management

Scope 3 emissions within the operational control of the project should be reduced and offset; including from water pumping and waste management.

To the degree possible within the influence of the project, but not direct control, scope 3 emissions should be influenced downward.

Opportunities include:

- Electric vehicle charging
- Tenant incentives

- Influencing pedestrian modal choice.

9. Integrated water cycle management

9.1 Water in Sydney

This Sustainability Study addresses water at Central Precinct in terms of resilience, biodiversity and ecological health, and water resource management.

The water study provides direction on three precinct systems: the building systems that consume water, the landscape and green infrastructure system, and the precinct utility system.

9.2 Water as a strategic planning outcome

The Eastern District Plan identifies several planning priorities relating to water resources and infrastructure:

- E14. Protecting and improving the health and enjoyment of Sydney Harbour and the District's waterways.
- E17. Increasing urban tree canopy cover and delivering Green Grid connections.
- E18. Delivering high-quality open space.
- E19. Reducing carbon emissions and managing energy, water and waste efficiently.
- E20. Adapting to the impacts of urban and natural hazards and climate change.

9.3 Water objectives at Central Precinct

The ambition for water resource management at Central Precinct is to preserve non-renewable water resources and to provide a net improvement to environmental water quality as an outcome of renewal.

The objectives for responsible water management at Central Precinct are:

- To reduce overall consumption of water resources to achieve the equivalent of 5 star NABERS Water and 6 Star Green Star baselines through best practice water-conserving systems, equipment, fixtures, fittings and appliances;
- To reduce stormwater pollution flowing to Sydney Harbour significantly beyond best practice guidelines;
- Alignment of water quality, supply source, and treatment needs to enable effective water harvesting and re-use;
- To identify mechanisms for waste-water treatment and re-use aligned with best practice utilities and implement solutions that can be sustainably operated over the full life of the asset.

While the majority of the water demand objectives can be achieved through the design brief, there remain several large-scale opportunities for addressing the water supply and storm-water management with an integrated water cycle management plan.

9.4 Water Demand at Central Precinct

Water demand scenarios at Central Precinct have been assessed in terms of equivalent building ratings and industry consumption data applied across the development build-out over time. The resource demand trajectory design considerations are included in 15.1 Resource Design and Performance Baselines.

The water demand trajectory indicates several key outcomes:

- Water efficiency, evidenced through improved NABERS Water performance is an important driver of water resource management.
- Approximately 50% of the water demand can be met with non-potable (or recycled) water supply sources.
- Precinct water challenges and opportunities for landscaping and heat rejection can substantially shift the water performance away from individual building design to precinct-scale water management.

Figure 12 Predicted annual water use for CPRP by NABERS rating by end use

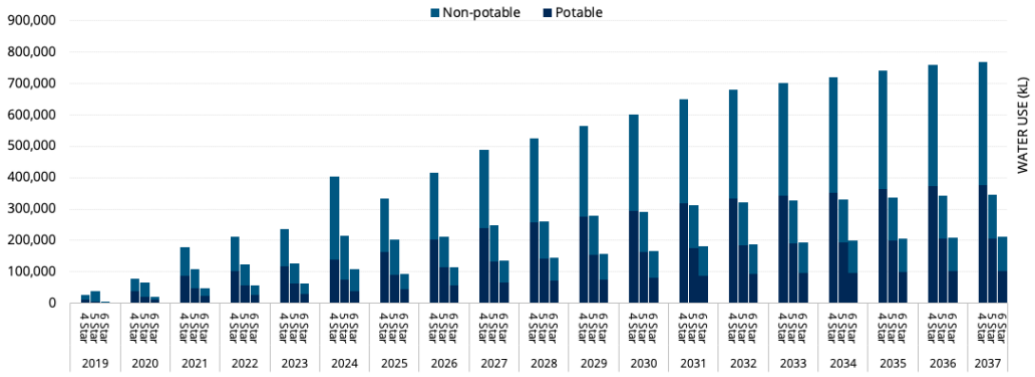
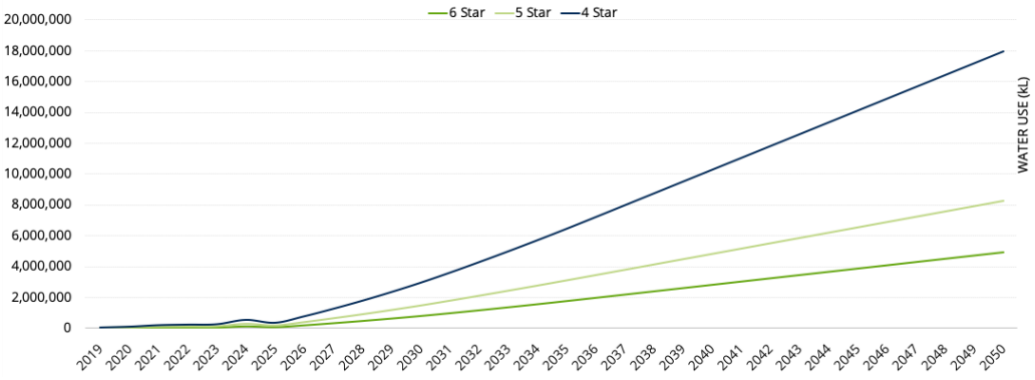


Figure 13 Predicted cumulative water use for CPRP by NABERS rating



The recommended approach to water demand management in buildings is to establish a performance benchmark using an operational target for other building types using the Green Star Performance rating tool (6 star) with the option for a NABERS Water rating for commercial and retail buildings (5 star).

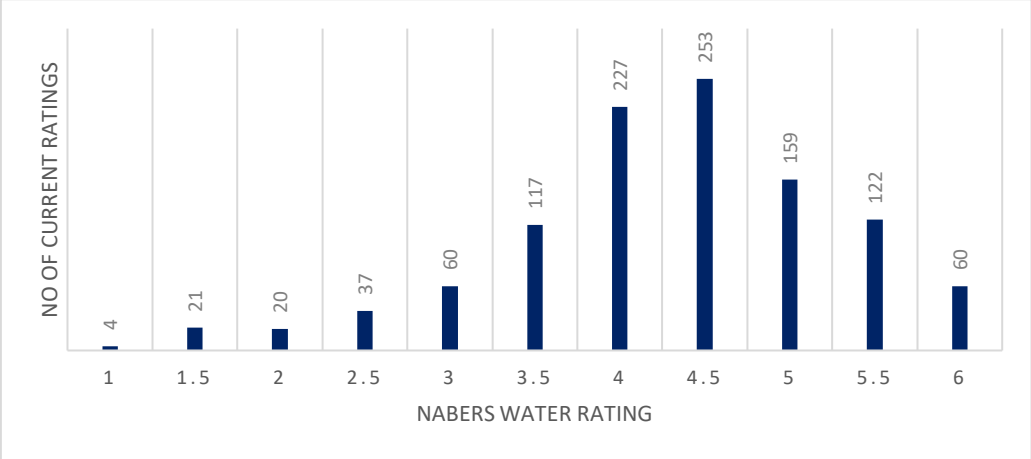
There are several design considerations that can be implemented to meet this benchmark:

- Efficient fittings, fixtures and appliances;
- Harvesting rainwater for re-use;
- Use of recycled water for toilet flushing, heat rejection and irrigation.

This strategy suggests that a performance outcome of no less than 5 star NABERS represents an appropriate level of ambition for planning while leaving a range of design and operational options available to the delivery of future development.

This is supported by the distribution of current NABERS ratings in the Australian market, where a 5 star rating is achieved by more than 30% of buildings with NABERS Water ratings, excluding any allowances for recycled water.

Figure 14 Current NABERS Water ratings (excluding recycled water)



The precinct systems for landscape and heat rejection provide an exceptional opportunity for a consolidated recycled water supply and substantial potable water reduction across the precinct.

The provision of a reliable recycle water supply should be a priority for Central Precinct to mitigate water resource constraints. There are several mechanisms by which such a system could be realised:

- Private water recycling scheme supported by the new development opportunity (such as Central Park or Barangaroo);
- Public authority water recycling scheme (such as Rouse Hill);
- Connection to a shared water recycling scheme via the George St recycled water main, with recycled water being supplied by an independent party (either public or private).

For planning purposes, Central Precinct should make spatial allowance for water recycling within the masterplan.

The level of ambition for water efficiency should be established through performance requirements for each building (5 star NABERS and 6 Star Green Star).

The investment case for which model of delivering recycled water is most appropriate should be established through a bespoke feasibility assessment and the precinct procurement process.

These ambitions along with the performance targets, design considerations for the master plan, and Development Control Provisions in Section 14 Recommendations contribute to the Eastern City District Plans Actions 69 and 72.

9.5 Resilience and future water demand

9.5.1 Urban heat management

Urban heat management is a substantial resilience concern for Greater Sydney.

One of the most effective mechanisms to mitigate urban heat is the provision of green infrastructure and the maintenance of canopy cover. However, the maintenance of effective green infrastructure and the water intensity of the infrastructure is an important consideration:

- If high evapotranspiration species are chosen, the cooling effect is greater but so too is the need for reliable and low-impact water supply;
- If low evapotranspiration species are chosen, the cooling effect is lower but the drought-resilience of the landscape is greater without any additional water re-use systems.

There are several important considerations:

- The range of cooling benefits that different landscape options contribute;
- The range of water intensity of different landscape solutions;
- The design implications for landscape location and public amenity.

The landscape design seeks to target a high evapotranspiration species selection, with attendant water demands on the basis that a precinct water recycling facility is available to provide reliable supply that does not further deplete potable water resources.

Roofs at CPRP should always contribute to sustainability objectives, including reducing urban heat, and all roofs should be:

- Solar PV;
- Amenity;
- Green infrastructure; or
- Materials with a high SRI value in line with Green Star requirements.

9.5.2 Extreme events: flood and rainfall intensity

One of the predicted impacts of climate change is increased extreme weather intensity, including storms and floods.

The preliminary climate risk review undertaken in the detailed climate risk assessment and climate adaptation plan attached to this study, identified the predicted seasonal rainfall and other climatic impacts predicted for Sydney (CSIRO) and the RCP 8.5 scenario on the 2090 time horizon as the preferred scenario for climate resilience and adaptation.

Figure 15 Predicted climate impacts for Sydney (CSIRO)

Variable	Season	2030 RCP4.5	2090 RCP4.5	2090 RCP8.5
Temperature	Annual	0.9 (0.6 to 1.1)	1.8 (1.3 to 2.5)	3.7 (2.9 to 4.6)
Rainfall (%)	Annual	-3 (-10 to +6)	-2 (-16 to +9)	-3 (-20 to +16)
	Summer	+1 (-10 to +15)	0 (-15 to +19)	+11 (-12 to +27)
	Autumn	-3 (-22 to +15)	-1 (-22 to +18)	-2 (-28 to +20)
	Winter	-5 (-18 to +14)	-8 (-24 to +7)	-17 (-31 to +1)
	Spring	-1 (-19 to +12)	-6 (-23 to +9)	-8 (-30 to +14)
Evapotranspiration (%)	Annual	3.4 (2.3 to 4.4)	7.8 (5.3 to 9.5)	14.3 (10.1 to 18.1)
Wind speed (%)	Annual	-1.1 (-2.9 to +0.5)	-1 (-4.2 to +0.2)	-1.1 (-6.9 to +4.2)
Solar radiation (%)	Annual	+0.5 (-1.6 to +0.8)	+1.5 (-0.3 to +3.7)	+1.3 (-1.2 to +3.4)
Relative humidity (%) (absolute)	Annual	-0.5 (-1.6 to +0.8)	-1 (-3.1 to +0.3)	-1.5 (-3.8 to +1.3)
Sea level rise (m)	Annual	0.13 (0.09 to 0.18)	0.47 (0.30 to 0.65)	0.66 (0.45 to 0.88)

The climate change risk assessment and adaptation plan should be considered within the stormwater design.

9.5.3 Systems resilience - infrastructure reliability

A third water-related challenge for resilience is infrastructure reliability due to long-term changes in rainfall patterns for the Greater Sydney region.

As the water demand in metro Sydney increases with development growth, alongside a likely increase in water demand for heat management purposes and the predicted trend for reduced rainfall on balance over the year due to climate change, there is some resource availability risk for major urban precincts.

The BAU case for urban projects is that the water utility authority will make the necessary investments to secure supply for customers into the future. While this remains the working scenario for Central Precinct, there are several considerations for discussion with Sydney Water, including:

- How does the NSW Government (TfNSW and DPE) assess the need for water resource resilience for urban renewal in Greater Sydney and its implications for Central?
- Does Central carry any residual risk to long term water availability and reliability?
- Does the scale of renewal and redevelopment at Central provide an opportunity to address long-term water resource resilience for the southern CBD?
- Does the NSW government (TfNSW, DPE) or its corporations (Sydney Water) have an appetite to take a position of high ambition with respect to water supply resilience in the Sydney CBD?

The long-term operational risk of water scarcity ultimately falls to asset owners, so there is a case for Central Precinct to improve its own resilience in this regard with a precinct-scale water recycling facility.

10. Integrated waste management

This study addresses waste management and resource recovery as one element of a wider circular economy and part of a precinct life cycle analysis model.

The study provides direction across the entire development life cycle across five domains:

- Design for circularity
- Construction circularity: urban metabolism

- Operational circularity: waste reduction
- Operational circularity: sharing platforms
- Operational circularity: products services

10.1 Precinct planning requirements

The importance of waste reduction, resource efficiency and recovery, and circular economy is enshrined at all levels of Australian government and is becoming increasingly critical to contemporary urban development of all scales.

10.1.1 City of Sydney

The City of Sydney's *Waste strategy and action plan 2017 – 2030* sets out six priorities for becoming a leading environmental performer:

- **Priority 1** Promote innovation to avoid waste
- **Priority 2** Improve recycling outcomes
- **Priority 3** Sustainable design
- **Priority 4** Clean and clear streets
- **Priority 5** Better data management
- **Priority 6** Future treatment solutions

Both the *City of Sydney Guidelines for Waste Management in New Developments* and the draft *Environmental Strategy 2021 – 2025* also set targets for the local area:

- 90% diversion from landfill of residential waste, with 35% as source-separated recycling by 2030;
- 90% diversion from landfill of commercial and industrial waste by 2030;
- 90% diversion from landfill of construction and demolition waste by 2030;
- 15% reduction in residential waste generation per capita by 2030, from a 2015 baseline.

10.1.2 NSW Circular Economy Policy Statement

The State of NSW and NSW Environment Protection Authority (EPA) through the *NSW Circular Economy Policy Statement: Too Good To Waste* advises the NSW Government will adopt the following circular economy principles:

- Minimise consumption of finite resources;
- Decouple economic growth from resource consumption;
- Design out waste and pollution;
- Keep products and materials in use;
- Innovate in resource efficiency, give preference to higher-order re-use and repair opportunities;
- Create new circular economy jobs.

10.1.3 Infrastructure Australia

The Australian Government's 2021 *Australian Infrastructure Plan* proposes two key *Reforms* and a series of supporting *Recommendations* related to waste:

Reform 9.1 Valuing resources to enable a circular economy

9.1 Recommendation

Avoid waste, improve resource recovery and build demand and markets for recycled products by integrating the circular economy into national waste policy and infrastructure projects.

- **9.1.1**. Increase understanding of the role of consumers in the circular economy through community education on responsible waste behaviour.
- **9.1.2.** Reduce the impact of plastic on the environment by implementing the National Plastics Plan.
- **9.1.3** Build support for the circular economy and embed circular practices by developing a circular economy roadmap for the infrastructure sector, including annual progress reports.
- **9.1.4** Support co-location of circular economy facilities by undertaking collaborative land-use planning.
- **9.1.5.** Reduce organic waste to landfill by mandating local council food organics and garden organics (FOGO) collection services.

Reform 9.2 Waste data to drive innovation

9.2 Recommendation

Encourage market development through government and industry partnerships to accelerate and extend the implementation of the National Waste Policy's data actions and bring national consistency to the household waste collection and landfill levy system.

- **9.2.1** Support coordinated policy through an integrated whole-of-life waste data strategy for priority resources.
- **9.2.2** Create a high-quality recycling system with lower processing costs by developing common benchmarks for each material stream, consolidating services and targeting infrastructure investment.
- **9.2.3.** Increase landfill diversion by developing a waste levy pricing strategy and national levy protocols.

10.2 Key outcomes

10.2.1 Design for circularity

Delivering a product that works within a circular environment can be conceived from the concept stage through:

- Designing built forms that enable alternative long-term uses;
- Designing for deconstruction and disassembly;
- Resource reduction by increased material use efficiency;

- Modular and prefabrication processes that reduce waste;
- Flexible fit-outs that address modular components which enable dismantling and relocation to allow different configurations or repurposing of buildings. This aspect can play a key role in decision making between rebuild or refurbishing.

10.2.2 Construction circularity: urban metabolism

Circularity during construction is best addressed through materials procurement & management.

- Responsible sourcing of materials, considering their recycled content;
- Management of construction and demolition focused on re-use and diversion from landfill;
- Engagement with suppliers that apply models for delivery and return logistics or incentivise end-of-life return options

Circular economy at construction stage must have at its core collaboration with the supply chain.

10.2.3 Operational circularity: waste reduction

Best practice operations focus on both upstream materials filtering and waste contracting. Strong and continuous monitoring is needed to measure outcomes against targets.

Australian best practices that would contribute to operational circularity include:

- Precinct-wide recyclable stream separation;
- Organic waste composting;
- Single-use plastic free environments;
- Procurement practices to eliminate waste streams and mandate recycled content.

Circular economy in operation requires core collaboration with the waste management industry.

10.2.4 Operational circularity: sharing platforms

Maximise product and equipment use by mutualising the assets through sharing platforms and exchange schemes. Shared logistic hubs are already part of the precinct planning; other opportunities include:

- District energy and water utilities
- Shared conferencing facilities
- Car and bike-share vehicles
- Maker spaces/dry labs/fab labs

The sharing can be managed by either precinct management or through commercial service providers where available.

10.2.5 Operational circularity: products services

Emerging global best practice is to replace asset ownership with product service systems deep into tenant business operations. Targeted products are high-churn assets, for example:

- Carpeting (tiles replaced as they wear in high traffic areas);
- Lighting (fixtures relocated with churn and updated with advancing technology);
- Desking/workstations (relocated or replaced with churn).

The product service model facilitates easy refurbishment and reuse of products that otherwise typically go to landfill after a short service life. Note that many of these are require tenant partnerships to be put into action.

10.2.1 Quantity

The waste generation scenarios at Central Precinct have been assessed in terms of equivalent building ratings and industry consumption data applied across the development build-out over time:

- City of Sydney, Guidelines for Waste Management in New Developments
- NSW EPA, Waste Levy Guidelines, 2018

Figure 16 CPRP projected annual waste generation by type

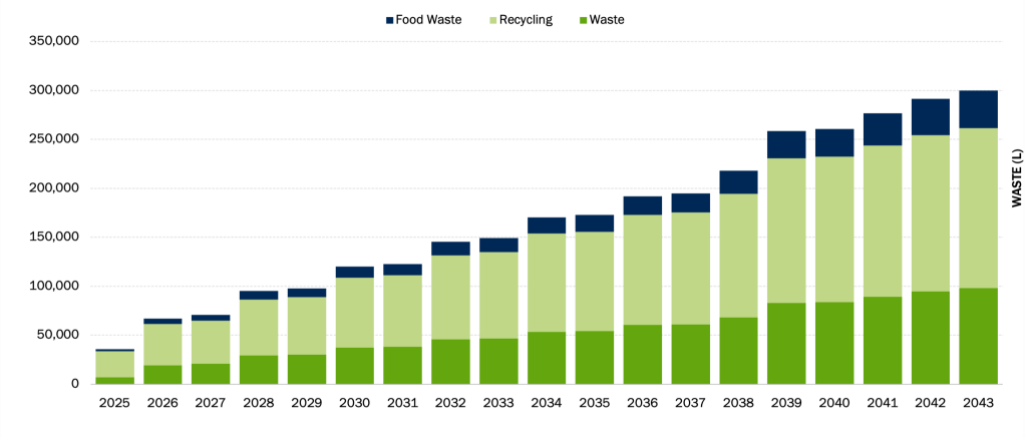
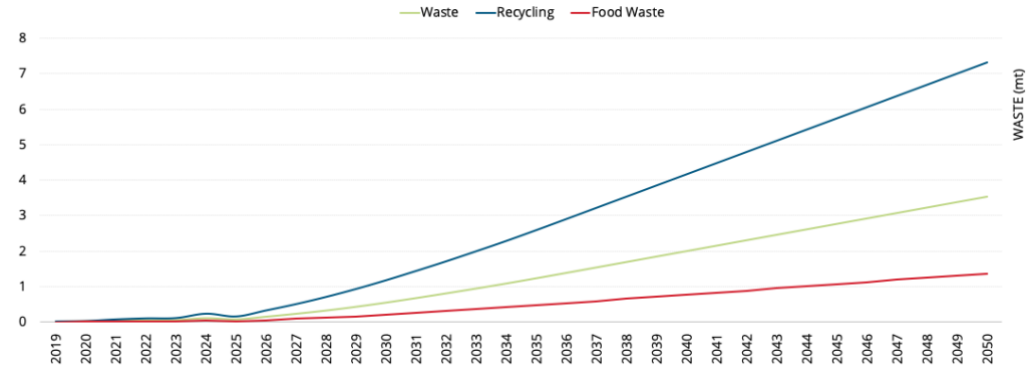


Figure 17 CPRP projected cumulative waste generation by type



10.2.2 Controls

The controls are primarily based on the targets from the Green Star tools, represent current world's best practice, and are significantly more ambitious than existing statutory requirements. The following are the applicable provisions for waste and materials:

- Divert at least 90% of construction and demolition waste from landfill;
- Demonstrate a 60% reduction in operational waste to landfill;
- The building's upfront carbon emissions are at least 10% less than those of a reference building;
- Requirement for industry/product specific environmental product declarations (EPD) or any equivalent third-party certification recognised by the Green Building Council of Australia (GBCA). This is applicable to all building materials, including structure, envelope, systems and finishes.

Beyond these Green Star Buildings v1.0 also has the following minimum expectations:

- The building is designed for the collection of separate waste and resource streams.
- The building provides a dedicated and adequately sized waste and resource storage area.
- The building ensures safe and efficient access to waste and resource storage areas for both occupants and waste and resource collection contractors.

Green Star Communities v1.1 has points available where measures are implemented to reduce the overall environmental impacts associated with operational waste. Points are awarded based on the initiatives implemented in the project from the following list:

- A. Public place recycling scheme;
- B. Residential recycling scheme;
- C. Hazardous waste collection or disposal services;
- D. Pay as you throw (PAYT) scheme; or
- E. Composting or Green Waste scheme.

11. Climate change and resilience

This study addresses climate change and resilience at Central Precinct in terms of acute shocks and chronic stresses, including urban heat and extreme weather events.

As part of the SSP process, a detailed climate risk assessment was undertaken in line with relevant standards and guidelines and a climate adaptation plan was prepared to comply with Green Star Communities v1.1 requirements.

11.1 Methodology

The climate projections for this Climate Adaptation Plan (CAP) were selected using a conservative climate modelling pathway (representative concentration pathway (RCP 8.5)), so that practical and realistic design and operational action can be taken. This pathway represents not only the worst-case emissions scenario but also the most likely case, and aligns with best practice industry expectations.

The risk assessment covers three timescales (2036, 2056 and 2096) and covers the following climate variables. The objective of this research is to better understand the climate trends, which in turn will set the foundation for risk management decision making.

Key projections for this project cover the climate variables set out in Table 4.

Table 4 Key projections for this project cover the climate variables

Element	Climate change variables
Sea	Sea level rise
Temperature	Average annual temperature
	Extreme temperature events
Precipitation	Average annual rainfall
	Extreme rainfall events
Drought	Increase in duration
Wind	Gales and extreme wind events
Extreme storms	Hail size and location
	Dust storms
	Frequency and severity of storms
	Electrical storms and lightning strikes
Relative humidity	Average annual
Bush fire	Fire danger index
Solar radiation	Increased level of UV
Waterway health	Discharge runoff

Resilience is a multi-faceted area of integrated design and management, and as such the risk assessment framework also takes into account a series of non-climate-related variables. These civil and infrastructure variables represent the key acute shocks and chronic stresses identified in Resilient Sydney (2018) and the stakeholder engagement process, and are set out in Table 5.

Table 5 Civil and infrastructure variables

Element	Civil and infrastructure variables
Civil disturbance (stresses identified by Resilient Sydney)	Diminishing community cohesion
	Disease pandemic
	Financial crisis
Civil disturbance (shocks identified by Resilient Sydney)	Civil unrest
	Cyber attack
	Terror attack
Critical infrastructure failure	Transport network failures
	Digital network outages
	Electrical network outages
	Water network outages
	Healthcare services overload
Shift in business models	Shift in mobility systems

	Shift in workplace needs
	Carbon pricing
	Changing residential models
	Ageing population
	Cultural backgrounds
	Changing demographics
Social stresses	Homelessness
	Increasing inequality
	Housing affordability
	Financial collapse
	War

11.2 Climate risk assessment

The climate risks identified for the infrastructure within the scope of this CAP following the application of adaptation measures are summarised below.

Table 6 Climate risks

Risk Rating	Extreme	High	Medium	Low	Total
Number of risks	2	16	37	15	70
Number of reassessed risks	0	2	22	46	70

All 70 potential climate change risks identified received adaptation measures which help to mitigate and reduce the likelihood of that event occurring.

Both extreme risks have been mitigated. All but two high risks have been mitigated to medium level risks and 15 medium risks have been mitigated to low-level risks through adaptation measures.

11.3 Adaptation measures

The purpose of the climate adaptation workshop with the design team was twofold:

- Record incumbent adaptation measures embedded in the reference design; and
- Propose potential additional adaptation measures for consideration at later stages of development.

A full list of the these adaptation measures can be found in the Appendix, with a selection below:

- Substation footprints take into account increased loads.
- Energy demand modelling should include future temperature projections to allow adequate planning for power infrastructure upgrades associated with the precinct's redevelopment.
- Whole-of-life materials approach to consider material degradation under RCP 8.5 climate scenarios in life cycle analysis (LCA).
- Plant selection includes a diversity of locally indigenous species adaptive to RCP 8.5 climate conditions.
- Building design prioritises passive design and world's best practice energy efficiency.
- Stormwater collection and storage on deck used to irrigate landscapes.

- Provision of mechanically cooled, freely accessible community facilities (such as play areas, libraries etc) and commercial areas provides a place of refuge during extreme heat days.
- Building design controls require passive performance through 80W/m² max solar load in perimeter zones.
- Western forecourt designed to direct overland flows and avoid flooding.
- Climate Adaptation Plan (CAP) to be updated regularly to include latest information.

11.4 Climate Adaptation Plan (CAP)

The full detailed CAP can be found in 15.2 Climate Adaptation Plan and is structured as follows:

- **Introduction** | Outlines the study context and Study Requirements addressed by this report.
- **Methodology** | Outlines the risk management process and stakeholder engagement undertaken.
- **Context** | Outlines the context of the project and the scope and boundaries of the assessment.
- **Climate change** | Provides the current and future climate context that forms the assessment.
- **Risk assessment** | Provides a summary of the risk assessment undertaken.
- **Adaptation plan** | Provides the adaptation actions that have been integrated and considered in early planning.
- **Monitoring and review** | Outlines next steps for consideration in subsequent planning and design phases.
- **Assurance** | Summarises the key requirements for compliance with Green Star Communities.

12. Sustainability benchmarks

12.1 Benchmarking principles

The approach to benchmarking for sustainability performance will give public and private stakeholders a high level of confidence that the claimed outcomes are being achieved in reality.

This requires a framework for assurance that covers the sustainability themes and provides:

- Independent review;
- Transparency of methodology;
- Accountability at each phase of the project life cycle.

In the property sector, sustainability rating tools are the primary assurance mechanism as they provide independent review, transparency, and accountability across all project life cycle phases. Rating tools also provide a benchmark for global comparison.

This strategy considers several rating tool frameworks for Central Precinct.

12.2 Peer review

In establishing the ambition for sustainability at Central Precinct an assessment of global peer precincts was conducted; all seeking to attract world-class developers and tenants. A global trend in city-shaping precincts is the amplification of social and environmental sustainability and its role in exemplary place-making as a core pitch to stakeholders and customers.

The global precincts that could reasonably be compared to Central Precinct and with which Central Precinct will compete, exhibit a series of key attributes related to environmental and social sustainability.

12.2.1 Kings X, London

The 67-acre (27 ha) redevelopment and 26 acres of open space. Principal uses include 3.4 million square feet (316,000 sq. m) of office space, 2,000 residential units, 500,000 square feet (46,400 sq. m) of retail and leisure space, a hotel, and educational facilities.

Environmental Outcomes

- District Combined Heat and Power (CHP)
- 90% of construction waste was diverted from landfill
- 40% of the 67-acre development is given over to open space
- Monitors biodiversity and water quality
- Office buildings designed to a BREEAM rating of “Very Good”

Social Outcomes

- Deep and wide-ranging community engagement
- Minimal car parking, pedestrianised public space, bike lanes and over 700 cycle parking spaces
- Community garden run by a non-profit group

Figure 18 Kings X, London Site

12.2.2 Central Park, Sydney

5.8 ha site includes high-density commercial development, housing, open space, connections to surrounding streets and neighbourhoods, and adaptive re-use of heritage buildings. Designed around a network of lanes, streets, parks and important heritage buildings.

Environmental Outcomes

- Membrane Bioreactor (MBR) recycled water facility
- Can be completely controlled remotely
- Provides constant and stable water and chilled water flows

Social Outcomes

- Strong social connectivity with surrounding neighbourhoods and communities
- Delivery of community infrastructure
- Creation of high-quality open spaces and amenities
- Provision of student housing, delivered under the National Rental Affordability Scheme (NRAS)

Figure 19 Central Park, Sydney

12.2.3 Barangaroo, Sydney

22 ha and $6 billion it provides over 11 ha of public space. Barangaroo South comprises three major commercial office towers, three tall residential towers, several mid-rise mixed-use residential and retail buildings, and a significant public realm.

Environmental Outcomes

- Climate positive outcomes
- Zero Carbon
- Innovative offset mechanism built into lease structure
- Sustainability assured by precinct delivery authority

Social Outcomes

- Barangaroo Skills Exchange, an award-winning partnership with TAFE NSW, delivered training for over 11,000 workers over 5 years
- Delivery of multiple hectares of public park and waterfront access

Figure 20 Barangaroo, Sydney

12.2.4 Mission Rock, San Francisco

$1.6 billion development spans 28 acres prioritises outdoor public space, includes 1.4 million square feet of office and commercial space, 1,500 units of rental housing, a brewery, and 8 acres of new and redeveloped park space with shops and cafés.

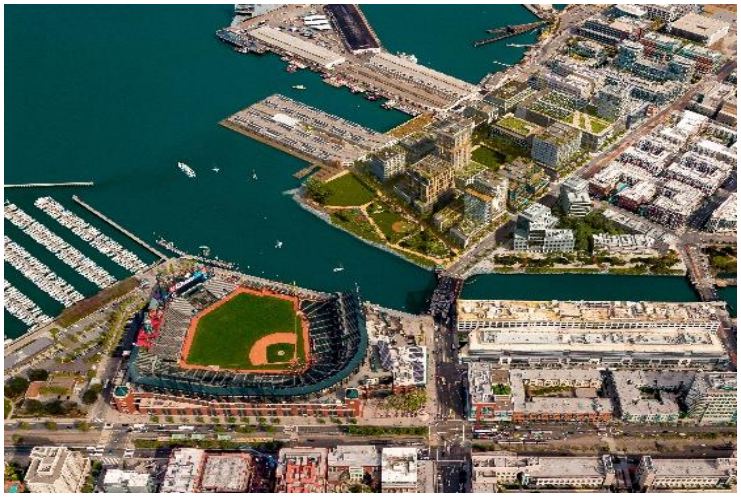
Environmental Outcomes

- Carbon emissions reductions target of 80%
- Resilient design outcomes
- 45% potable water use reduction
- 'LEED ready' site

Social Outcomes

- 40% mix of affordable housing
- 8 acres of new parks and open space
- Improvement of waterfront access and Blue Greenway trail, and the historic rehabilitation of Pier 48

Figure 21 Mission Rock, San Francisco



12.2.5 Toronto Waterfront, Toronto

800 ha (1,977 acres), will create approximately 40,000 new residences, 5 million square feet of commercial development and 30,000 residential units, including affordable housing.

Environmental Outcomes

- Resilience to extreme climate
- Sustainability assurance provided by LEED system
- Failure to address digital governance led to the withdrawal of Sidewalk Labs

Social Outcomes

- 16,200 person years of employment and contributed roughly $3.2 billion to the Canadian economy.
- Commitment to 20% affordable housing
- Constructed or restored over 12 waterfront parks and public spaces, including living infrastructure of aquatic, wetland and terrestrial habitats.

Figure 22 Toronto Waterfront, Toronto

The review of world-leading precincts shows high ambition for integrating social and environmental outcomes in urban renewal projects. While local context plays a strong role in priorities, there is an emergent commonality between leading precincts:

- The primacy in sustainability of climate change and low-carbon outcomes;
- The role district systems play in delivering exceptional service quality and performance outcomes;
- Robust support for non-vehicular transport;
- Social housing in precincts with residential development;
- Workforce and skills development.

In all cases, top-level formal certification using independent sustainability rating tools demonstrates the commitment to and reliable delivery of the environmental and social outcomes.

12.3 Rating tool assessment

A comparative assessment of Australian and global rating tools has been undertaken to assess the most applicable tools for the CPRP throughout its life.

The assessment has considered two types of rating frameworks:

- Holistic sustainability tools addressing several themes;
- Thematic tools focusing on just one theme.

The **Green Star** tools provide an optimal balance of scope coverage, project type and ease of certification for CPRP. They also allow consistent carriage of responsibility between different stages of the project life cycle, and at both the scale of the precinct and the individual buildings.

While the **IS Rating** from ISCA is another consideration, its lack of focus on amenity, health and wellbeing misses a range of outcomes that are critical to successful property and public realm development.

The **Living Building/Community Challenge** and **One Planet Living** present a high bar for mandatory compliance while also being based offshore. These frameworks may be worthy of consideration for any proponents seeking to break new ground.

The **NABERS** framework is hampered by its limited scope (Energy, Water, Waste and IEQ only) and its focus on operational stages of the life cycle. However, it does present an excellent benchmark for those things it does measure and should be considered due to the robustness of its benchmarks and ease of use. **NABERS** is also regularly referenced in the NSW planning context and the City of Sydney DCP.

The **WELL** rating is the only one of its type that comprehensively addresses health and wellbeing. While **Green Star** does provide basic coverage on these topics, many property companies and major tenants now require **WELL** ratings as a basic requirement of property development.

13. Consultation

Through significant consultation with TfNSW, design and consultant teams, and external stakeholders the sustainability principles and strategies have been refined to reflect project-specific opportunities.

Consultation activities have included:

- holistic sustainability workshops and presentations
- focused briefings and discussions on individual sustainability issues
- detailed consultations around defining sustainability metrics
- dedicated climate resilience workshops

13.1 Workshop and presentations

Holistic sustainability workshops and presentations have been held with a broad group of key internal and external stakeholders including TfNSW, the design team, subject matter experts, DPE, GANSW, GCC, City of Sydney, and the SDRP, to ensure:

- Their sustainability concerns and objectives are captured;
- The level of ambition is consistent;
- Sustainability principles are understood;
- Sustainability initiatives are embedded in the reference design; and
- Targets and metrics are ambitious but achievable.

13.2 Briefing and discussions

Focused briefings and discussions have been held with key stakeholders including TfNSW, the design team, subject matter experts, Sydney Water, Ausgrid, Jemena, NSW EPA, on individual sustainability issues including:

- Water resource management;
- Waste and materials;
- Precinct utilities opportunities; and
- Green infrastructure and biodiversity.

Outcomes of engagement with Sydney Water were a series considerations for ongoing discussion:

- How does the NSW Government (TfNSW and DPE) assess the need for water resource resilience for urban renewal in Greater Sydney and its implications for Central?
- Does Central carry any residual risk to long term water availability and reliability?
- Does the scale of renewal and redevelopment at Central provide an opportunity to address long-term water resource resilience for the southern CBD?
- Does the NSW government (TfNSW, DPE) or its corporations (Sydney Water) have an appetite to take a position of high ambition with respect to water supply resilience in the Sydney CBD?

Outcome of engagement with the NSW Environmental Protection Authority was that they needed more detailed information on the project to provide feedback. Consultation should therefore continue throughout subsequent stages of development.

13.3 Sustainability metrics

Detailed consultations have been held with key stakeholders including TfNSW, the design team, subject matter experts, GBCA, NABERS, around defining sustainability metrics, including:

- Statutory requirements and industry expectations;
- Precinct and building scale metrics;
- Planning, design, construction, and operations stage targets; and
- Holistic vs. themed third party certification systems;

13.4 Climate resilience

As part of the SSP process, a detailed climate adaptation plan was prepared to comply with Green Star Communities v1.1 requirements, and represents the outcome of two detailed workshops:

- Climate scoping workshop with TfNSW - define scope and boundaries and undertake initial risk assessment; and
- Climate adaptation workshop with TfNSW and the design team – review scope and boundaries, and implement adaptation measures.

14. Recommendations

The recommendations which represent the outcome of this consultation process take three forms:

- Performance targets - certified ratings for development type from a series of rating tools;
- Design considerations for the master plan - considerations for inclusion in the masterplan design; and
- Development control provisions - considerations for the Sustainability chapter of the Design Guide for the CPRP Design Guide.

14.1 Performance targets

Performance targets are based on the outcome of the assessment of global peer precincts, all of which seek to attract world-class developers and tenants, and the ambition for world's best practice.

All of these performance targets will result in significantly better sustainability outcomes in comparison to statutory requirements, like BASIX. Embedding the requirement for certification with third party sustainability rating tools also ensures outcomes which would otherwise be impossible for TfNSW to deliver with statutory requirements only.

Table 7 Performance targets

Development type	Rating tool	Rating type	Target rating
Public domain	Green Star	Communities	6 Star
Commercial	NABERS	Energy	6 Star
		Water	5 Star
		Waste	5.5 Star
	Green Star	Buildings	6 Star
	WELL	Core & Shell	Silver
Hotel	NABERS	Energy	4.5 Star
		Water	4 Star

	Green Star	Buildings	6 Star
Residential	Green Star	Buildings	6 Star

14.2 Design considerations for the master plan

The sustainability considerations for inclusion in the masterplan design are based on the strategic initiatives identified in the Sustainability Strategy.

14.2.1 Suggested design considerations

The optimal sustainability outcome is based on the following considerations as a basis for design:

- The precinct must be able to operate with 100% electricity as its energy source (i.e. no reliance on fossil fuels);
- The precinct must be able to continue to function effectively under the predicted climate change impacts associated with the RCP 8.5 scenario (flooding, heat, storm as per the climate risk workshop);
- The precinct must be able to include low-emissions structural solutions and not be reliant only upon concrete/steel structure;
- The precinct must enable a wide range of energy and water-systems approaches, and specifically not preclude central thermal plant, embedded energy systems and recycled water systems.

14.2.2 Precinct utility – thermal energy

The preferred solution on sustainability grounds is to make spatial provision for a central thermal utility that includes centralised heat rejection and an all-electric chilled water and hot water plant with thermal storage, as well as a four pipe thermal distribution network that connects the central plant to all buildings.

Buildings should have roofs clear of mechanical plant, to enable rooftop amenity and green infrastructure.

14.2.3 Precinct utility – electrical energy

The preferred solution on sustainability grounds is to allow for 100% electrification of all building services including food and beverage (F&B) tenancies and a private electricity network for Central Precinct. The electricity network should have the following capabilities:

- Embedded network retail capability for 100% renewable energy;
- Embedded generation and battery storage (sized for equivalent performance to emergency generator requirements);
- Smart grid controls (demand control, building systems integration).

14.2.4 Precinct utility – water

The preferred solution on sustainability grounds is to allow for a water recycling facility within the CPRP that can treat 100% of the wastewater from the precinct for re-use in buildings systems and irrigation, in concert with an integrated system of stormwater management and rainwater harvesting that includes green infrastructure.

Each building should have a rainwater tank, that is topped up with portable water. The landscape should assist the management of stormwater quality and quantity, to meet best practice stormwater management guidelines.

The water treatment plant could be basement-based or located within the landscape of un-utilised land within the broader precinct or on adjacent lots.

In the event of very high predicted water usage for irrigation, the potential for sewer mining should be considered. In the event of low demand during wet seasons, the potential for contributing to the City of Sydney's recycled water network should be considered.

14.2.5 Urban Forest

The preferred solution on sustainability grounds is to maximise the urban green coverage as much as possible with greening in the public realm and built form that:

- Provides shading from tree canopy coverage;
- Has high evapotranspiration potential to maximize the cooling effects;
- Provide foraging and roosting habitat for local mobile species;
- Supports connecting with Country;
- Supports habitat connectivity, especially between the two parks and enables continuous green space to be accommodated down the length of the site.

Canopy and greening cover targets have been developed as part of the Green Infrastructure, Ecology, Urban Forest and Greening study and summarised below in Table 8. The Green Infrastructure, Ecology, Urban Forest and Greening study (July 2022) also confirms that the number of trees the reference scheme proposes to remove is 45, and the number of new trees the reference scheme proposes is 510, with a replacement ratio of 1:11.3.

Table 8 Canopy and Greening Cover Targets

Location	Land use type	Planning guidelines canopy cover requirement	Planning guidelines greening cover requirement
Central Green	Iconic Park	50%	75%
Central Square	Civic Open Space	50%	60%
Eddy Avenue Plaza	Civic Open Space	50%	50%
Central Avenue	Civic Open Space	50%	60%
Devonshire Link	Civic Open Space	50%	50%
Southern Plaza	Civic Open Space	50%	55%
Mortuary Station Garden	Civic Open Space	20%	55%
Link Between Block B and C	Civic Open Space	50%	50%
Western Edge, including Western Extension Building Rooftop and adjacent Central Avenue	Civic Open Space	0%	10%
Ibero American Plaza and Chalmers St light rail station	Civic Open Space	10%	16%
Devonshire Bridge	Targets are not set for bridges in the Greening Strategy	0%	0%

Prince Alfred Park Bridge	Targets are not set for bridges in the Greening Strategy	0%	15%
George St Bridge	Targets are not set for bridges in the Greening Strategy	0%	15%
The Goodsline	Adaptive reuse of a rail cutting, not a typical land use type	10%	15%
Block A, Block B and Block C, Block D, Block E and Block F	Property	0%	20%

14.2.6 Integrated building design

- The preferred solution on sustainability grounds is to embed high passive performance into the design controls for the precinct. These controls could include:
- Peak cooling load limits on façade, nominally 80W/m². This would have the impact of reducing window to wall ratio and balancing transparent and opaque fabric (no more than 55% glazed);
- Requirement for breathable buildings and for all spaces to have the ability to be naturally ventilated;
- Requirement for biophilic design and the inclusion of vertical and horizontal greening in the built form;
- Inclusion of very high energy efficiency thresholds (6 star NABERS Energy and Green Star);
- Buildings to be configured spatially to accommodate multiple use types beyond the typical workplace to enable long-term adaptability that will extend building life.

14.2.7 Materials life-cycle approach

The preferred solution on sustainability grounds is to identify opportunities for the advancement of the circular economy and not preclude a low-emissions approach to the construction of the precinct and its embodied carbon impacts. Opportunities that should be enabled include:

Material substitution

- Embodied carbon reduction opportunities in the deck (such as the requirement for supplementary cementitious materials in the concrete procurement);
- Embodied carbon reduction opportunities in the built form (such as the requirement for a maximum upfront carbon intensity).

Waste management

- Spatial provision made in alignment with City of Sydney DCP and 'Guidelines for waste in new developments' across all uses and in both buildings and shared service areas;
- Opportunities for managing waste at the precinct level (such as a connected network for food waste in retail F&B areas or shared dehydrators).

Circular economy opportunities:

- Products as a service – the requirement to consider the stewardship approach of products as a service (such as lighting, cooling, mobility among others);

- Material loops – the requirement for construction materials and operational material flows to be made circular, such as the substantial inclusion of re-used materials as a planning requirement;
- The requirement for material databases (such as a materials passport) to assist Circular Economy approaches and guarantee high-quality waste management.

The requirement for whole of life cost analysis in design, that can support the strategies for longevity, adaptability, re-use and design for disassembly.

14.2.8 Integrated mobility

The preferred solution on sustainability grounds is to deliver a precinct with no reliance on private motor vehicles and provide the uses of the precinct a variety of mobility options to access it. Some considerations in achieving this include:

- A suite of mobility initiatives that reduces personal vehicular trip generation to zero in the traffic generation model;
- The inclusion of the health benefits of active mobility in cost-benefit analysis to support investment in pedestrian and bicycle infrastructure systems;
- Opportunities for Central Precinct to enable sustainable travel choices across the network, increasing the use of active mobility, public transit and shared mobility;
- Electrical capacity that allows for 100% electric recharging of delivery/service vehicles as well as any vehicles parked on site.

14.2.9 Off-site biodiversity

The preferred solution on sustainability grounds is to create a precinct that mitigates impacts on local ecosystems and resident species during construction and supports local biodiversity within the landscape and pocket habitat within the built form such that there is a net positive benefit on local biodiversity

Further to on-site measures, the masterplan and business case processes should consider how off-site biodiversity projects could be supported in their relationship to the carbon management opportunities for the project.

14.2.10Digital masterplan

The preferred solution on sustainability grounds is to embed a digital framework for the project that includes the following attributes:

- Includes both the hard infrastructure (fibre, Wi-Fi, sensors, converged networks etc) and soft infrastructure (databases, interoperability protocols, privacy, public interest disclosure etc);
- Enables an IoT sensor strategy for real-time reporting of sustainability metrics: whole of life carbon, mobility patterns, water consumption, heat, air quality etc?
- Enables the Circular Economy and materials reduction strategies to interface with the proposed digital engineering strategy (BIM).

14.3 Development Control Provisions

14.3.1 Sustainability Requirements

The Ecologically Sustainable Development requirements of the City of Sydney DCP (section 3.6) are to be superseded by the Sustainability chapter of the Design Guide for the CPRP Design Guide.

The Sustainability Requirements are addressed as follows:

- Energy and GHG Emissions
- Climate Change Adaptation and Resilience
- Integrated Water Management
- Waste Management and the Circular Economy
- Transport, Mobility and Access
- Biodiversity
- Digital

14.3.2 Performance objectives

a) Development should seek to achieve the Action of the Eastern City District Plan, including:

68 - Support initiatives that contribute to the aspirational objective of achieving net-zero emissions by 2050, especially through the establishment of low-carbon precincts in Planned Precincts, Collaboration Areas, State Significant Precincts and Urban Transformation projects.

69 - Support precinct-based initiatives to increase renewable energy generation, and energy and water efficiency, especially in Planned Precincts, Collaboration Areas, State Significant Precincts and Urban Transformation projects.

72 - Encourage the preparation of low-carbon, high-efficiency strategies to reduce emissions, optimise the use of water, reduce waste and optimise car parking provision where an increase in total floor area greater than 100,000sqm is proposed in any contiguous area of 19 or more hectares.

a) Ensure development incorporates best practice sustainability and environmental performance measures and initiatives for individual development sites and the whole precinct that:

- Minimise greenhouse gas emissions
- Demonstrate innovation in reducing greenhouse gas emissions through energy efficiency, renewable energy and other measures
- Reduce the urban heat island effect
- Achieve high levels of waste separation and diversion from landfill
- Minimise consumption of mains potable water
- Improve air quality.

14.3.3 Performance design guidance

a) Development proposals for new buildings are to be accompanied by an Environmental Sustainability Design (ESD) strategy that demonstrates how the following standards will be achieved or exceeded for the relevant developments:

- 6 Star Green Star for Buildings rating for all uses
- 6 Star Green Star Communities rating for the precinct
- 6 Star Green Star Performance rating for all uses
- 6 star NABERS Energy rating for commercial uses with a Commitment Agreement,
- 4.5 star NABERS Energy rating for hotel and multi-unit residential uses with a Commitment Agreement
- 5 star NABERS Water rating for commercial uses
- 4 star NABERS Water rating for hotel and multi-unit residential uses
- 5.5 star NABERS Waste rating for commercial uses
- Silver core and shell WELL rating (or equivalent industry standard) for commercial uses

b) Buildings are to be designed to achieve net zero emissions by being highly efficient, all-electric and using a minimum of 100% renewable electricity (by maximising on-site generation and offsite renewable energy procurement);

c) The precinct shall be designed to achieve at least 15% coverage with landscaping that has an urban cooling, water-cycle management and biodiversity function;

d) All new buildings are to:

- Include suitable self-shading elements and window-to-wall ratio to minimise undesirable solar gain and improve the passive sustainability performance of buildings with the goal of achieving no greater than 80W/m² solar load in perimeter zones
- Have the capacity for at least 80% of GFA to be naturally ventilated
- Deliver a reduction in embodied emissions of at least 20% compared to a reference building, assessed in accordance with the Green Star LCA criteria
- Develop a Climate Risk and Adaptation Plan and implement measures to improve the resilience of the precinct to heat, bushfire smoke, storm and pandemic events
- Develop an operational waste management plan and demonstrate a 60% reduction in operational waste to landfill
- Apply the principles of biophilia in design, incorporating green walls and roofs at a minimum
- Provide appropriate habitat within the built form for the mobile species nominated in the Biodiversity Management Plan
- Be delivered within the context of a Reconciliation Action Plan approved by Reconciliation Australia and include design elements using Indigenous Design and Planning Principles

15. Appendices

15.1 Resource Design and Performance Baselines

15.1.1 Retail

Resource			Value	Units	Notes	Sources
Energy	4 Star	Electricity	0.0474	MWh/m²	Assumptions: - Building postcode: 2000 - Total Shopping Centre Area GLAR 49,226m² - Central Services Shopping Centre Area 41,842m² - 0 car spaces - Annual trading days 365 - Weekly hours of service 72 - Multi Storey - Number of food court seats 300 - 0 cinema seats - 0 gymnasium area - 100% electricity - 2% electricity for heating - 61% electricity for cooling - 49% potable water and 51% non-potable water - 21% of total water use for toilets	NABERS Energy and Water for Shopping Centres Reverse Calculator, Version 6.0, October 2019 Department of Industry, Science, Energy and Resource, HVAC Factsheet, HVAC Energy Breakdown, https://www.environment.gov.au/system/files/energy/files/hvac-factsheet-energy-breakdown.pdf Building Codes Illustrated: A Guide to Understanding the 2006 International Building Code, Francis D. K. Ching, Steven R. Winkel, 2007 City of Sydney: Recycled Water Plan, 5 June 2012
		Heating	0.0026	MWh/m²		
		Cooling	0.0781	MWh/m²		
	5 Star	Electricity	0.0316	MWh/m²		
		Heating	0.0017	MWh/m²		
		Cooling	0.0521	MWh/m²		
	6 Star	Electricity	0.0158	MWh/m²		
		Heating	0.0009	MWh/m²		
		Cooling	0.0260	MWh/m²		
Water	4 Star	Potable water	0.4450	kL/m²		
		Non-potable water	0.4632	kL/m²		
		Blackwater	0.1907	kL/m²		
	5 Star	Potable water	0.2967	kL/m²		
		Non-potable water	0.3088	kL/m²		
		Blackwater	0.1271	kL/m²		
	6 Star	Potable water	0.1473	kL/m²		
		Non-potable water	0.1533	kL/m²		
		Blackwater	0.0631	kL/m²		
Waste		Landfill	0.68	t/m²		City of Sydney, Guidelines for Waste Management in New Developments NSW EPA, Waste Levy Guidelines, 2018
		Recycling	2.98	t/m²		
		Food waste	0.20	t/m²		
Operational emissions	4 Star	Electricity	103.75	kgCO2-e/m²		NABERS Energy and Water for Shopping Centres Reverse Calculator, Version 6.0, October 2019
	5 Star	Electricity	69.16	kgCO2-e/m²		
	6 Star	Electricity	34.58	kgCO2-e/m²		
	Water supply		4.63	kgCO2-e/kL		Sydney Water, Environment Compliance and Performance Report 2018-19 Sydney Water, Annual Report 2018-19
	Wastewater		2.29	kgCO2-e/kL		
	Landfill		364.20	kgCO2-e/kL		Greenhouse gases from the waste sector and opportunities for reduction, Randell Environmental Consulting and Sustainability Victoria, August 2019 NSW EPA, Too Good To Waste, Discussion paper on a circular economy approach for NSW, October 2018
	Recycling		627.87	kgCO2-e/kL		
	Organic waste		1,900	kgCO2-e/kL		

Resource	Value	Units	Notes	Sources
Embodied emissions	2.20	tCO2-e/kL		Edge Environment, unpublished data, 2020

15.1.2 Commercial

Resource			Value	Units	Notes	Sources
Energy	4 Star	Electricity	0.0977	MWh/m²	Assumptions: - Building postcode: 2000 - Operational hours/week: 50 - Rated floor area = 603,512 m² - 2% electricity for heating - 61% electricity for cooling - 49% potable water and 51% non-potable water - 21% of total water use for toilets	NABERS Energy for Offices Reverse Calculator, Version 12, October 2019 Department of Industry, Science, Energy and Resource, HVAC Factsheet, HVAC Energy Breakdown, 2013, https://www.environment.gov.au/system/files/energy/files/hvac-factsheet-energy-breakdown.pdf
		Heating	0.0053	MWh/m²		
		Cooling	0.1611	MWh/m²		
	5 Star	Electricity	0.0733	MWh/m²		
		Heating	0.0040	MWh/m²		
		Cooling	0.1209	MWh/m²		
	6 Star	Electricity	0.0367	MWh/m²		
		Heating	0.0020	MWh/m²		
		Cooling	0.0605	MWh/m²		
Water	4 Star	Potable water	0.3341	kL/m²		NABERS Water for Offices Reverse Calculator, Version 1.0 City of Sydney: Recycled Water Plan, 5 June 2012
		Non-potable water	0.3478	kL/m²		
		Blackwater	0.1432	kL/m²		
	5 Star	Potable water	0.1676	kL/m²		
		Non-potable water	0.1744	kL/m²		
		Blackwater	0.0718	kL/m²		
	6 Star	Potable water	0.0838	kL/m²		
		Non-potable water	0.0872	kL/m²		
		Blackwater	0.0359	kL/m²		
Waste		Landfill	0.14903	t/m²	Non-residential developments - commercial offices Typical waste generation rate = 15 L/100m²/day x 365.25 days = 5,478.75 L/100m²/year ÷ 100 m² = 54.79 L/m²/year = 0.05479 m3/m² x 2.72t = 0.14903 t/m²	City of Sydney, Guidelines for Waste Management in New Developments NSW EPA, Waste Levy Guidelines, 2018
		Recycling	0.14903	t/m²		
		Food waste	0.04967	t/m²	Non-residential developments - commercial offices Typical waste generation rate = 15 L/100m²/day x 365.25 days = 5,478.75 L/100m²/year ÷ 100 m² = 54.79 L/m²/year = 0.01826 m3/m² x 2.72t = 0.04967 t/m²	
Operational emissions	4 Star	Electricity	213.95	kgCO2-e/m²		NABERS Energy for Offices Reverse Calculator, Version 12, October 2019
	5 Star	Electricity	160.52	kgCO2-e/m²		

Resource			Value	Units	Notes	Sources
	6 Star	Electricity	80.26	kgCO2-e/m²		
	Water supply		4.63	kgCO2-e/kL		Sydney Water, Environment Compliance and Performance Report 2018-19 Sydney Water, Annual Report 2018-19
	Wastewater		2.29	kgCO2-e/kL		
	Landfill		364.20	kgCO2-e/kL		Greenhouse gases from the waste sector and opportunities for reduction, Randell Environmental Consulting and Sustainability Victoria, August 2019 NSW EPA, Too Good To Waste, Discussion paper on a circular economy approach for NSW, October 2018
	Recycling		627.87	kgCO2-e/kL		
	Organic waste		1,900	kgCO2-e/kL		
Embodied emissions			2.20	tCO2-e/kL		Edge Environment, unpublished data, 2020

15.1.3 Hotel

Resource			Value	Units	Notes	Sources
Energy	4 Star	Electricity	0.1468	MWh/m²	Assumptions: - Building postcode: 2000 - 5 star hotel rating - 1,405 rooms at 30m² - 0 function room seats - 0 pools - 100% electricity - 2% electricity for heating - 61% electricity for cooling - 49% potable water and 51% non-potable water - 21% of total water use for toilets	NABERS Energy and Water for Hotels Reverse Calculator 2020, Version 2.1, October 2019 Department of Industry, Science, Energy and Resource, HVAC Factsheet, HVAC Energy Breakdown, https://www.environment.gov.au/system/files/energy/files/hvac-factsheet-energy-breakdown.pdf
		Heating	0.0079	MWh/m²		
		Cooling	0.2421	MWh/m²		
	5 Star	Electricity	0.0906	MWh/m²		
		Heating	0.0049	MWh/m²		
		Cooling	0.1493	MWh/m²		
	6 Star	Electricity	0.0599	MWh/m²		
		Heating	0.0020	MWh/m²		
		Cooling	0.0605	MWh/m²		
Water	4 Star	Potable water	2.0212	kL/m²		NABERS Energy and Water for Hotels Reverse Calculator 2020, Version 2.1, October 2019 City of Sydney: Recycled Water Plan, 5 June 2012
		Non-potable water	2.1037	kL/m²		
		Blackwater	0.8662	kL/m²		
	5 Star	Potable water	1.1180	kL/m²		
		Non-potable water	1.1636	kL/m²		
		Blackwater	0.4791	kL/m²		
	6 Star	Potable water	0.5590	kL/m²		
		Non-potable water	0.5818	kL/m²		
		Blackwater	0.2396	kL/m²		
Waste		Landfill	0.20	t/m²		City of Sydney, Guidelines for Waste Management in New Developments NSW EPA, Waste Levy Guidelines, 2018
		Recycling	0.25	t/m²		
		Food waste	0.05	t/m²		
Operational emissions	4 Star	Electricity	321.46	kgCO2-e/m²		NABERS Energy and Water for Hotels Reverse Calculator 2020, Version 2.1, October 2019
	5 Star	Electricity	198.25	kgCO2-e/m²		
	6 Star	Electricity	99.13	kgCO2-e/m²		

Resource		Value	Units	Notes	Sources
	Water supply	4.63	kgCO2-e/kL		Sydney Water, Environment Compliance and Performance Report 2018-19 Sydney Water, Annual Report 2018-19
	Wastewater	2.29	kgCO2-e/kL		
	Landfill	364.20	kgCO2-e/kL		Greenhouse gases from the waste sector and opportunities for reduction, Randell Environmental Consulting and Sustainability Victoria, August 2019 NSW EPA, Too Good To Waste, Discussion paper on a circular economy approach for NSW, October 2018
	Recycling	627.87	kgCO2-e/kL		
	Organic waste	1,900	kgCO2-e/kL		
Embodied emissions		4.50	tCO2-e/kL		Edge Environment, unpublished data, 2020

15.1.4 Community

Resource			Value	Units	Notes	Sources
Energy	4 Star	Electricity	0.0977	MWh/m²	Assumptions: - Building postcode: 2000 - Operational hours/week: 50 - NLA = 603,512 m² - Number of computers: 100/1,000 m² (1 per person with 1 every 10 m²) = 60,351 - 100% electricity - 2% electricity for heating - 61% electricity for cooling - 49% potable water and 51% non-potable water - 21% of total water use for toilets	NABERS Energy for Offices Reverse Calculator, Version 12, October 2019 Department of Industry, Science, Energy and Resource, HVAC Factsheet, HVAC Energy Breakdown, https://www.environment.gov.au/system/files/energy/files/hvac-factsheet-energy-breakdown.pdf
		Heating	0.0053	MWh/m²		
		Cooling	0.1611	MWh/m²		
	5 Star	Electricity	0.0733	MWh/m²		
		Heating	0.0040	MWh/m²		
		Cooling	0.1209	MWh/m²		
	6 Star	Electricity	0.0367	MWh/m²		
		Heating	0.0020	MWh/m²		
		Cooling	0.0605	MWh/m²		
Water	4 Star	Potable water	0.3341	kL/m²		NABERS Water for Offices Reverse Calculator, Version 1.0 City of Sydney: Recycled Water Plan, 5 June 2012
		Non-potable water	0.3478	kL/m²		
		Blackwater	0.1432	kL/m²		
	5 Star	Potable water	0.1676	kL/m²		
		Non-potable water	0.1744	kL/m²		
		Blackwater	0.0718	kL/m²		
	6 Star	Potable water	0.0838	kL/m²		
		Non-potable water	0.0872	kL/m²		
		Blackwater	0.0359	kL/m²		
Waste		Landfill	0.35	t/m²		City of Sydney, Guidelines for Waste Management in New Developments NSW EPA, Waste Levy Guidelines, 2018
		Recycling	0.50	t/m²		
		Food waste	0.10	t/m²		
Operational emissions	4 Star	Electricity	213.95	kgCO2-e/m²		NABERS Energy for Offices Reverse Calculator, Version 12, October 2019
	5 Star	Electricity	160.52	kgCO2-e/m²		
	6 Star	Electricity	80.26	kgCO2-e/m²		
	Water supply		4.63	kgCO2-e/kL		Sydney Water, Environment Compliance and Performance Report 2018-19 Sydney Water, Annual Report 2018-19
	Wastewater		2.29	kgCO2-e/kL		
	Landfill		364.20	kgCO2-e/kL		Greenhouse gases from the waste sector and opportunities for reduction, Randell Environmental Consulting and Sustainability Victoria, August 2019 NSW EPA, Too Good To Waste, Discussion paper on a circular economy approach for NSW, October 2018
	Recycling		627.87	kgCO2-e/kL		
	Organic waste		1,900	kgCO2-e/kL		
Embodied emissions			5.00	tCO2-e/kL		Edge Environment, unpublished data, 2020

15.1.5 Education

Resource			Value	Units	Notes	Sources
Energy	4 Star	Electricity	0.0977	MWh/m²	Assumptions: - Building postcode: 2000 - Operational hours/week: 50 - NLA = 603,512 m² - Number of computers: 100/1,000 m² (1 per person with 1 every 10 m²) = 60,351 - 100% electricity - 2% electricity for heating - 61% electricity for cooling - 49% potable water and 51% non-potable water - 21% of total water use for toilets	NABERS Energy for Offices Reverse Calculator, Version 12, October 2019 Department of Industry, Science, Energy and Resource, HVAC Factsheet, HVAC Energy Breakdown, https://www.environment.gov.au/system/files/energy/files/hvac-factsheet-energy-breakdown.pdf
		Heating	0.0053	MWh/m²		
		Cooling	0.1611	MWh/m²		
	5 Star	Electricity	0.0733	MWh/m²		
		Heating	0.0040	MWh/m²		
		Cooling	0.1209	MWh/m²		
	6 Star	Electricity	0.0367	MWh/m²		
		Heating	0.0020	MWh/m²		
		Cooling	0.0605	MWh/m²		
Water	4 Star	Potable water	0.3341	kL/m²		NABERS Water for Offices Reverse Calculator, Version 1.0 City of Sydney: Recycled Water Plan, 5 June 2012
		Non-potable water	0.3478	kL/m²		
		Blackwater	0.1432	kL/m²		
	5 Star	Potable water	0.1676	kL/m²		
		Non-potable water	0.1744	kL/m²		
		Blackwater	0.0718	kL/m²		
	6 Star	Potable water	0.0838	kL/m²		
		Non-potable water	0.0872	kL/m²		
		Blackwater	0.0359	kL/m²		
Waste		Landfill	0.35	t/m²		City of Sydney, Guidelines for Waste Management in New Developments NSW EPA, Waste Levy Guidelines, 2018
		Recycling	0.50	t/m²		
		Food waste	0.10	t/m²		
Operational emissions	4 Star	Electricity	213.95	kgCO2-e/m²		NABERS Energy for Offices Reverse Calculator, Version 12, October 2019
	5 Star	Electricity	160.52	kgCO2-e/m²		
	6 Star	Electricity	80.26	kgCO2-e/m²		
	Water supply		4.63	kgCO2-e/kL		Sydney Water, Environment Compliance and Performance Report 2018-19 Sydney Water, Annual Report 2018-19
	Wastewater		2.29	kgCO2-e/kL		
	Landfill		364.20	kgCO2-e/kL		Greenhouse gases from the waste sector and opportunities for reduction, Randell Environmental Consulting and Sustainability Victoria, August 2019 NSW EPA, Too Good To Waste, Discussion paper on a circular economy approach for NSW, October 2018
	Recycling		627.87	kgCO2-e/kL		
	Organic waste		1,900	kgCO2-e/kL		
Embodied emissions			4.50	tCO2-e/kL		Edge Environment, unpublished data, 2020

15.1.6 Residential

Resource			Value	Units	Notes	Sources
Energy	4 Star	Electricity	0.0172	MWh/m²	Assumptions: - Building postcode: 2000 - Dwelling size 100m² = 617 dwellings - All condenser water serviced - All lift serviced - No pool or gym facilities - No parking spaces - 100% electricity - 2% electricity for heating - 61% electricity for cooling - 49% potable water and 51% non-potable water - 21% of total water use for toilets	NABERS Energy and Water for Apartment Buildings Reverse Calculator, Version 1.0, October 2019 Department of Industry, Science, Energy and Resource, HVAC Factsheet, HVAC Energy Breakdown, https://www.environment.gov.au/system/files/energy/files/hvac-factsheet-energy-breakdown.pdf City of Sydney: Recycled Water Plan, 5 June 2012
		Heating	0.0040	MWh/m²		
		Cooling	0.0075	MWh/m²		
	5 Star	Electricity	0.0115	MWh/m²		
		Heating	0.0027	MWh/m²		
		Cooling	0.0050	MWh/m²		
	6 Star	Electricity	0.0057	MWh/m²		
		Heating	0.0013	MWh/m²		
		Cooling	0.0025	MWh/m²		
Water	4 Star	Potable water	0.7405	kL/m²		
		Non-potable water	0.7707	kL/m²		
		Blackwater	0.3173	kL/m²		
	5 Star	Potable water	0.4936	kL/m²		
		Non-potable water	0.2518	kL/m²		
		Blackwater	0.0529	kL/m²		
	6 Star	Potable water	0.2468	kL/m²		
		Non-potable water	0.2569	kL/m²		
		Blackwater	0.1058	kL/m²		
Waste		Landfill	0.17	t/m²		City of Sydney, Guidelines for Waste Management in New Developments NSW EPA, Waste Levy Guidelines, 2018
		Recycling	0.17	t/m²		
		Food waste	0.17	t/m²		
Operational emissions	4 Star	Electricity	23.22	kgCO2-e/m²		NABERS Energy and Water for Shopping Centres Reverse Calculator, Version 6.0, October 2019
	5 Star	Electricity	15.48	kgCO2-e/m²		
	6 Star	Electricity	7.74	kgCO2-e/m²		
	Water supply		4.63	kgCO2-e/kL		Sydney Water, Environment Compliance and Performance Report 2018-19 Sydney Water, Annual Report 2018-19
	Wastewater		2.29	kgCO2-e/kL		
	Landfill		364.20	kgCO2-e/kL		Greenhouse gases from the waste sector and opportunities for reduction, Randell Environmental Consulting and Sustainability Victoria, August 2019 NSW EPA, Too Good To Waste, Discussion paper on a circular economy approach for NSW, October 2018
	Recycling		627.87	kgCO2-e/kL		
	Organic waste		1,900	kgCO2-e/kL		
Embodied emissions			2.20	tCO2-e/kL		Edge Environment, unpublished data, 2020

15.2 Climate Adaptation Plan

Central Precinct

CLIMATE ADAPTATION PLAN

SEPTEMBER, 2021

atelier ten INTEGRAL GROUP

Acknowledgment

We acknowledge the Traditional Owners of country throughout Australia and recognises their continuing connection to land, waters, skies, and community.

We are inspired by and learn from knowledge and stories of Country.

Atelier Ten and Integral Group pay our respect to Traditional Owners and their cultures, and to Elders past, present, and emerging.

PROJECT INFORMATION

JOB TITLE:	CENTRAL PRECINCT
JOB NUMBER:	1398
DOCUMENT TITLE:	CLIMATE ADAPTATION PLAN
VERSION:	00

PREPARED

PREPARED BY:	STEWART MONTI
SIGNED:	SM
DATE:	23/09/2021

CHECKED

PREPARED BY:	PAUL STOLLER
SIGNED:	PDS
DATE:	23/09/2021

APPROVED

PREPARED BY:	RICHARD PALMER
SIGNED:	RP
DATE:	23/09/2021

REVISIONS

NO	DATE	CHECKED	APPROVED
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Glossary

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AR4	The IPCC Fourth Assessment Report (2007)
AR5	The IPCC Fifth Assessment Report (2013)
ARI	Average Recurrence Interval
AS	Australian Standard
BoM	Bureau of Meteorology
CAP	Climate Adaptation Plan
CRA	Climate Risk Assessment
CSIRO	Commonwealth Scientific and Industrial Research
EIS	Environmental Impact Statement
ENSO	El Niño–Southern Oscillation
FFDI	Forest Fire Danger Index
FRM	Floodplain Risk Management
GBCA	Green Building Council of Australia
HAT	Highest Astronomical Tide
GCM	Global Climatic Models
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
IP	Infrastructure and Place Division
ISCA	Infrastructure Sustainability Council Australia
NARCliM	NSW / ACT Regional Climate Modelling project
OEH	NSW Office of Environment and Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RCPs	Representative Concentration Pathways
RCMs	Regional Climate Models
REF	Review of Environmental Factors
SDG	Sustainable Development Guidelines
SLR	Sea Level Rise
SS	Storm Surge
TERM	Transport for NSW Enterprise Risk Management

TfNSW	Transport for NSW
TSR	Transport for NSW Standard Requirements
WCRP	World Climate Research Program's
WRF	Weather Research and Forecasting model

Executive Summary

This Climate Adaptation Plan (CAP) has been prepared to support the State Significant Precinct application for Central Precinct and will form part of the Green Star Communities (v1.1) submission for the project.

Climate Trends

Climate change is having worldwide impacts on society, the economy, and the environment. In Australia, the CSIRO Climate Change in Australia 2020 publication, states that: "Observed climate information indicates that Australian average surface air temperature has increased by 0.9°C since 1910, and many heat-related records have been broken in recent years. Sea level has risen about 20cm over the past century."

Climate Projections

Across Australia the upward trend in temperature and sea level together with an increased intensity of rainfall and cyclonic activity pose an increasing humanitarian and financial risk to business over time.

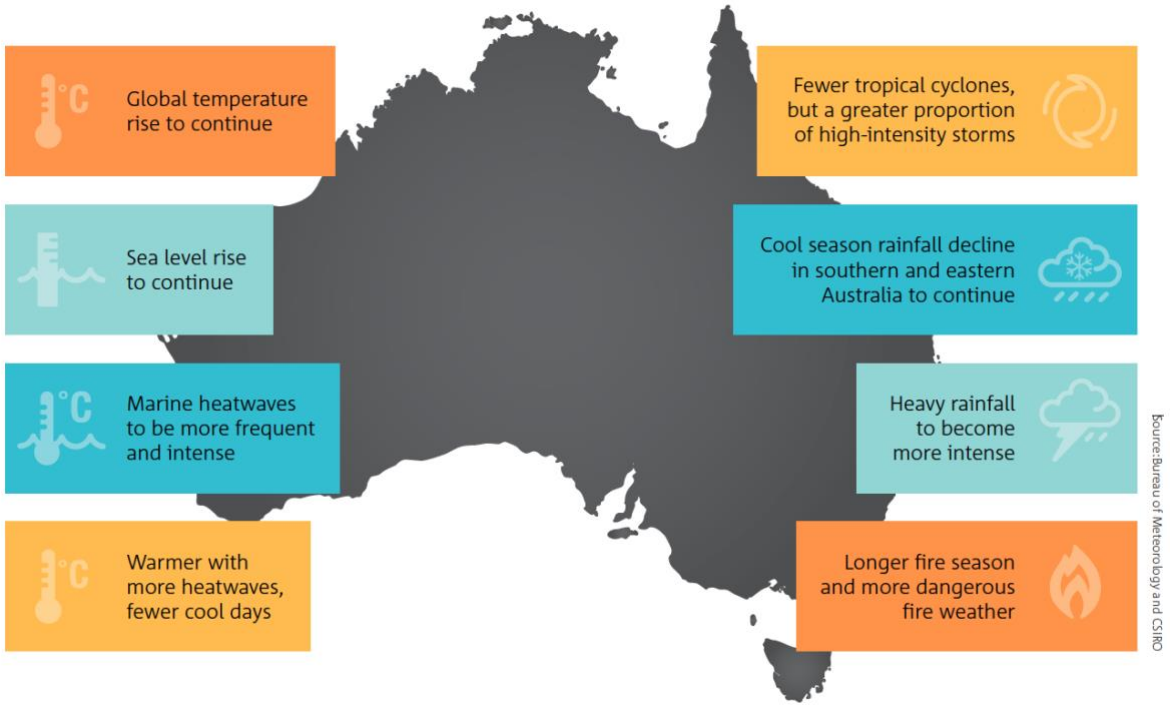


FIGURE 0.1: BOM AND CSIRO GENERAL SYNOPSIS (BOM & CSIRO 2020)

The climate projections for this Climate Adaptation Plan were selected using a conservative climate modelling pathway (representative concentration pathway (RCP) 8.5), so that practical and realistic design and operational action can be taken. This pathway represents not only the worst-case emissions scenario, but also the most likely case, and aligns with best practice industry expectations.

The risk assessment covers three timescales (2036, 2056 and 2096) and cover the following climate variables, the objective of this research is to better understand the climate trends, which in turn will set the foundation for risk management decision making.

Key projections for this project cover the climate variables set out Table 0.1

TABLE 0.1: CLIMATE VARIABLES CONSIDERED

Element	Climate change variables
Sea	Sea level rise
Temperature	Average annual temperature
	Extreme temperature events
Precipitation	Average annual rainfall
	Extreme rainfall events
Drought	Increase in duration
Wind	Gales and extreme wind events
Extreme storms	Hail size and location
	Dust storms
	Frequency and severity of storms
	Electrical storms and lightning strikes
Relative humidity	Average annual
Bush fire	Fire danger index
Solar radiation	Increased level of UV
Waterway health	Discharge runoff

Resilience is a multi-facetted area of integrated design and management, and as such the risk assessment framework also takes into account a series of non-climate-related variables. These civil and infrastructure variables represent the key acute shocks and chronic stresses identified in Resilient Sydney (2018) and the stakeholder engagement process.

TABLE 0.2: CIVIL AND INFRASTRUCTURE VARIABLES CONSIDERED

Element	Civil and infrastructure variables
Civil disturbance (stresses identified by Resilient Sydney)	Diminishing community cohesion
	Disease pandemic
	Financial crisis
Civil disturbance (shocks identified by Resilient Sydney)	Civil unrest
	Cyber attack
	Terror attack
Critical infrastructure failure	Transport network failures
	Digital network outages
	Electrical network outages
	Water network outages
	Healthcare services overload
Shift in business models	Shift in mobility systems
	Shift in workplace needs
	Carbon pricing
	Changing residential models
	Ageing population

	Cultural backgrounds
	Changing demographics
Social stresses	Homelessness
	Increasing inequality
	Housing affordability
	Financial collapse
	War

Green Star Communities Adaptation and Resilience Credit Requirements

Implementation of the Climate Adaptation Plan must meet the following criterion:

- At least two risk items identified in the risk assessment component of the Climate Adaptation Plan must be addressed by specific design responses; and
- All risk items identified as 'high' or 'extreme' must be addressed by specific design responses.

Where no risks are identified by the Climate Adaptation Plan, this criterion is deemed to be met.

Summary of reassessed climate risks

The climate risks identified for the infrastructure within the scope of this CAP following the application of adaptation measures, are summarised below.

TABLE 0.3: SUMMARY OF INITIAL AND REASSESSED RISKS FOR SHORT-TERM (2036) TIME SCALE

Risk Rating	Extreme	High	Medium	Low	Total
Number of Risks	2	16	37	15	70
Number of Reassessed Risks	0	2	22	46	70

All 70 potential climate change risks identified received adaptation measures which help to mitigate and reduce the likelihood of that event occurring.

All 2 extreme risks have been mitigated, all but 2 high risks have been mitigated to medium level risks and 15 medium risks have been mitigated to low level risks through adaptation measures.

Contents

1.0 Introduction

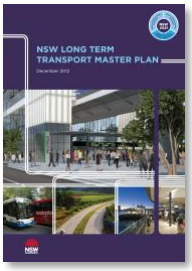
Meteorological records show that since the 1950s the duration, frequency and intensity of heatwaves have increased across many parts of Australia including NSW. Australia's warmest year on record was 2019, and the seven years from 2013 to 2019 all rank in the nine warmest years (BoM & CSIRO 2020). In parallel with rising temperatures, over the past 30 years the number of fire days has also continued to rise across NSW. Throughout the state, the fire season is starting earlier and lasting longer with fire weather often extending into spring and autumn (Climate Council 2014a). In addition to temperature related risks, impacts from flooding and sea level rise have the capacity for widespread damage and disruption. Across Sydney, flooding events became three times more frequent during the 20th century as a result of sea-level rise. By 2100 it is likely that today's 1-in-100 year flood will occur every day or so (Climate Council 2014b).

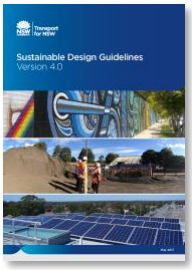
Transport for NSW (TfNSW) aims to provide a world class sustainable transport system that meets customer expectations and optimises the economic development of the state.

Recognising that the impacts from climate change pose a significant risk to its business, infrastructure assets, and the communities it serves, TfNSW is committed to building climate resilience across its network of current and future projects.

Addressing climate risk is highlighted within a number of TfNSW's guiding strategic documents including:

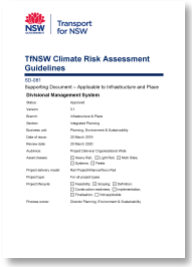
TABLE 1.1: TFNSW CLIMATE RISK-RELATED STRATEGIC DOCUMENTS

Document	Description
	**Future Transport 2056** (TfNSW 2020) The 40-year vision, directions and principles for customer mobility in NSW, guiding transport investment over the longer term identifies 'moving to an environmentally, economically and socially sustainable transport system is essential to tackle climate change…'
	**NSW Long term Transport Masterplan** (TfNSW 2012) The plan identifies responding to climate change as a state-wide action of priority, with Action 8.8.3 focused on boosting our resilience to climate change and natural disasters by assessing climate resilience.
	**TfNSW's Environment and Sustainability Policy Statement** (TfNSW 2019) A key theme within the Policy's is '*to plan and deliver transport infrastructure and operations that are resilient to the effects of climate change*.'



Sustainable Design Guidelines (TfNSW 2017)

The delivery mechanism for implementing TfNSW's sustainable project delivery requirements, the SDG require the completion of a climate risk assessment as a mandatory initiative for all projects with a capital value over $15 million.



TfNSW Climate Risk Assessment Guidelines (TfNSW 2016)

Developed to provide contractors and stakeholders with support on how to complete a Climate Risk Assessment (CRA) in line with the latest Sustainable Design Guidelines (SDG) requirements.

1.1 Purpose of this plan

This Climate Adaptation Plan (CAP) has been prepared to support the development of the Central Precinct Renewal Program (CPRP) by TfNSW and will form part of the State Significant Precinct (SSP) Application and future Green Star Communities submission for the project.

The purpose of the CAP is to:

- Define the climate change projections over the design life of the infrastructure.
- Define the risk assessment process.
- Outline the project management approach to demonstrate compliance with recognised standards and guiding instruments.
- Manage risk through:
  - identification of climate change and natural hazard related risk and assign risk rating.
  - where necessary mitigate risk though adaptation measures and re-assess risk
- Enhance resilience through design and operational action.
- Define roles and responsibilities.

1.2 Document structure

To reduce the risk to vulnerable populations from climate change and minimise the effects of climate change on the City of Sydney, this climate change adaptation report has been prepared. The report is structured as follows:

1. **Introduction** | Outlines the study context and Study Requirements addressed by this report.
2. **Methodology** | Outlines the risk management process and stakeholder engagement undertaken.
3. **Context** | Outlines the context of the project, and the scope and boundaries of the assessment.
4. **Climate change** | Provides the current and future climate context that forms the assessment.
5. **Risk assessment** | Provides a summary of the risk assessment undertaken.
6. **Adaptation plan** | Provides the adaptation actions that have been integrated and considered in early planning.
7. **Monitoring and review** | Outlines next steps for consideration in subsequent planning and design phases.
8. **Assurance** | Summarises the key requirements for compliance with Green Star Communities.

2.0 Methodology

2.1 Risk management process

This Climate Adaptation Plan (CAP) is the result of a collaborative and iterative risk management process engaging all relevant areas of the business as presented below in Figure 2.1.

FIGURE 2.1: CAP PROCESS

The purpose of the risk assessment is to help mitigate the potential for climate change induced risks through informed decision making, which in turn enables the design and operation of climate resilient infrastructure.

2.2 Guiding instruments

The climate change risk assessment provided in this report has been undertaken in line with the following relevant standards and guidelines.

TABLE 2.1: STANDARDS AND SUSTAINABILITY BENCHMARKING FRAMEWORKS

Document	Description
	**AS 5334-2013 Climate change adaptation for settlements and infrastructure – A risk based approach** (Standards Australia 2013) Provides principles and generic guidelines on the management of the risks that settlements and infrastructure face from the impacts of climate change. In particular it describes a systematic approach to planning the adaptation of settlements and infrastructure based on the risk management process given in AS/NZS ISO 31000:2009.

Climate Change Impacts & Risk Management: A Guide for Business and Government (AGO 2006)

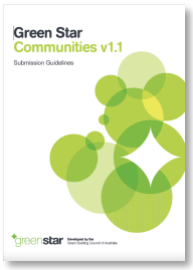
The Guide provides a framework for managing the increased risk to organisations due to climate change impacts. The prime focus of the Guide is on the initial assessment and prioritisation of these risks.

ISO 31000-2018 – Risk Management – Principles and Guidance (ISO 2018)

Adopted in Australia and New Zealand as AS/NZS ISO 31000:2009, provides a set of internationally endorsed principles and guidance on how organisations can integrate decisions about risks and responses into their existing management and decision-making processes.

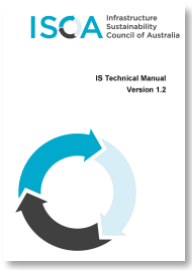
NSW Climate Change Policy Framework (OEH 2016)

Aims to maximise the economic, social, and environmental wellbeing of NSW in the context of a changing climate and current and emerging international and national policy settings and actions to address climate change.



Green Star Communities v1.1 (GBCA 2016)

Assesses the planning, design and construction of large-scale development projects at a precinct, neighbourhood and/or community scale. It provides a rigorous and holistic rating across five impact categories – including Adaptation and Resilience (Credit 04).



Infrastructure Sustainability Rating Tool Technical Manual v1.2 (ISCA 2016)

The IS rating scheme evaluates sustainability initiatives and potential environmental, social, and economic impacts of infrastructure projects and assets – including Climate Change Adaptation.

GRESB Real Estate Scoring Methodology (GRESB 2016)

The GRESB Real Estate Assessment provides the basis for the systematic reporting, objective scoring, and peer benchmarking of ESG management and performance for property companies and funds around the world.

2.3 Data sources

Recent advances in climate science, and the release of the Intergovernmental Panel on Climate Change (IPCC) Fourth and Fifth Assessment Reports (AR4 and AR5) have given rise to a wealth of climate data being made publicly available.

The following (Figure 2.2) provides a hierarchy of data sources to be referenced as part of the climate risk assessment.

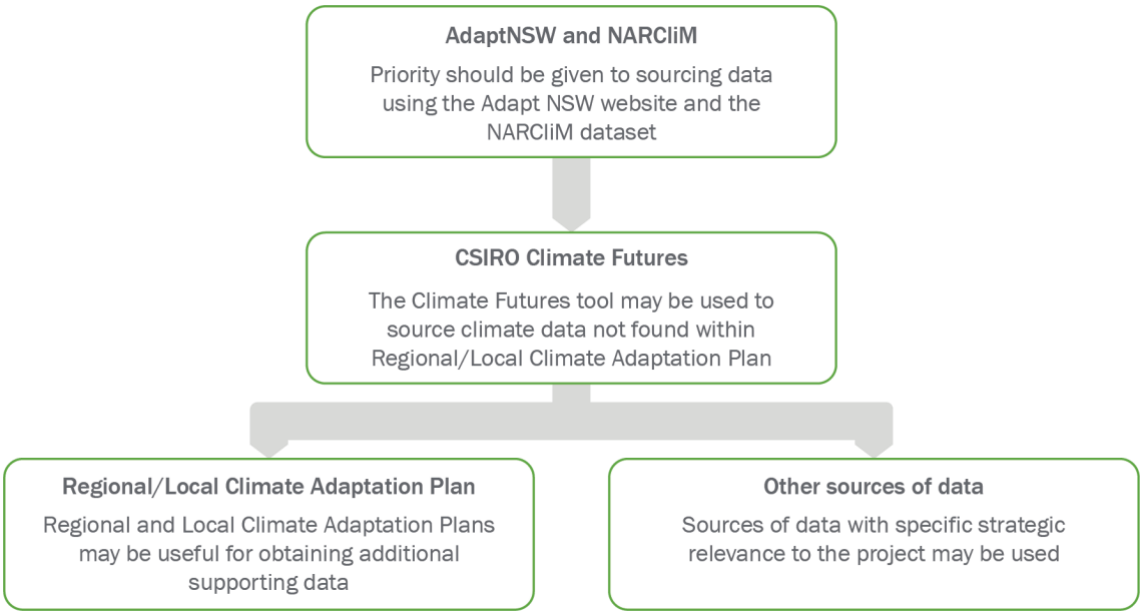


FIGURE 2.2: HIERARCHY OF CLIMATE DATA SOURCES

Adapt NSW and NARCliM: The NSW Office of Environment and Heritage (OEH 2014) has developed a range of information and tools to help government, businesses and communities build resilience in the face of future extreme events and hazards by helping them understand and minimise the impacts of climate change. NARCliM data (NSW/ACT Regional Climate Modelling project) (ARC Centre of Excellence for Climate System Science 2012) produces an ensemble of regional climate projections for south-east Australia designed to provide robust projections that span the range of likely future changes in climate.

CSIRO - Climate Futures (Clarke, Whetton & Hennessy 2011; Whetton et al. 2012): provides a selection of both AR4 and AR5 projections that enables users to explore, and obtain data for, projected monthly, 3-monthly, 6-monthly, and annual changes in up to 14 climate variables (extreme temperature, precipitation, sea level rise etc).

Regional/Local Climate Adaptation Plan: Where an overarching Climate Adaptation Plan has been developed at a regional or local authority level, climate projections from this may be used.

Other sources of climate projections may be used if they are deemed to provide specific strategic relevance.

2.4 Stakeholder engagement

A preliminary risk assessment was prepared based on the findings of a desktop review. A risk register was developed, identifying climate risks and initial likelihood and consequence ratings were allocated for each risk statement in line with criteria outlined by the Australian Greenhouse Office (AGO 2006).

The preliminary risk assessment was followed by series of stakeholder engagement activities. During the engagement activities workshops were conducted with project team members and stakeholders to inform the assessment, validate climate risks with the stakeholders, and identify appropriate adaptation responses. A summary of these activities is outlined in Table 2.2.

TABLE 2.2: STAKEHOLDER ENGAGEMENT ACTIVITIES

Workshop	Date	Description
Scoping Workshop	28/06/2021	During the initial scoping workshop participants established the context for risk assessment and reviewed the preliminary risk assessment.
Adaptation Workshop	27/07/2021	During the adaptation workshop participants reviewed the context and proposed adaptation measures with a focus on those ranked highest.

The stakeholder group engaged as a part of the CAP process and providing inputs to the risk allocation and adaptation actions are listed in Table 2.3.

TABLE 2.3: CAP RISK WORKSHOP PARTICIPANTS

Name	Organisation	Discipline	Scoping workshop	Adaptation workshop
Paul Stoller	Atelier Ten	ESD	☑	☑
Stewart Monti	Atelier Ten	ESD	☑	☑
Richard Palmer	Integral Group	ESD		☑
Hugh Thornton	Transport for NSW	Client representative	☑	☑
Bryce McCarthy	Transport for NSW	Client representative	☑	☑
Colin Sargent	Transport for NSW	Client representative	☑	
Melanie Gostelow	Arcadis	Engineering		☑
John Whatmore	Architectus	Architecture		☑
Allison Heller	Ethos Urban	Social Sustainability		☑
Mark Tyrrell	Tyrrell Studio	Urban Design + Green Infrastructure		☑
Bailey Byrnes	Arcadis	Engineering		☑
Greg Burgon	Architectus	Urban Design		☑
Jason Carr	Arcadis	Engineering		☑
Jonathan Davies	Arcadis	Engineering		☑

Emilie Kotz	Transport for NSW	Client representative	☑
David Atwood	Ethos Urban	Planning	☑
Chris Bain	Ethos Urban	Planning	☑
Tamasin Soehardi	Transport for NSW	Community Engagement	☑

3.0 Context

3.1 Project

Central Precinct will become an exciting new place for business and the community by renewing up to 24 hectares of Government-owned land in and around Australia's busiest transport interchange - Sydney's Central Station. Transport for NSW is leading the renewal of Central Precinct and this new Precinct will drive the success of Tech Central – a NSW Government commitment to create the biggest technology hub of its kind in Australia - by:

- revitalising the precinct with new and enhanced public open spaces and celebrating the heritage of this iconic location
- realising a significantly expanded Central Business District (CBD) economy through creation of the jobs of the future in an exciting and vibrant setting
- reviving Central Station as a global transport interchange, meeting the needs of local, regional, and international travellers
- planning for Country by incorporating Country-centred planning principles and actions that respect the surrounding diverse communities
- delivering a socially and environmentally sustainable precinct
- creating great new places by leveraging recent Government investment in existing and future infrastructure within the precinct, in line with global trends.

FIGURE 3.1: CENTRAL PRECINCT AERIAL CONTEXT VIEW

3.2 Scope

The process considers all matters associated with maintaining operations and meeting future requirements for any potential tenants, their workforce and visitors while onsite or commuting, and surrounding community within the City of Sydney local government area over the design life of the precinct (<120 years).

3.3 Success criteria

Success criteria are essentially a summary of the organisation's long-term objectives. By combining success criteria with a consequence scale, it is possible to describe the level of consequence to an organisation of a risk associated with climate change, should it happen.

Success criteria for Central Precinct includes:

- Maintain adaptive capacity long-term.
- Infrastructure and service continue during disruption, or bounce back immediately following, and require little to no remedial works.
- Maintain safety of occupants, visitors, and the public during disruption, and not contribute further to ongoing disturbance.
- Mitigate the threat of potential financial loss from direct and indirect climate related disruptions.
- Environmental effects eliminated.
- Economy – reduce negative impact to wider NSW economy.

3.4 Geographic boundaries

The process considers all new and existing buildings, public domain, and enabling infrastructure within the boundaries of the 10 individual sub-precincts, while also taking into account neighbouring buildings, downstream infrastructure, all transport networks (rail, metro, light rail, bus, pedestrian and active mobility routes) that converge at the site, and regional considerations related to climate change.

3.5 Stakeholders

Beyond those who participated in the risk management workshops this CAP considered additional stakeholders who will be affected by the projects ability to respond to climate related disruption and may form part of any future review.

TABLE 3.1: ADDITIONAL STAKEHOLDERS CONSIDERED

Stakeholder	Summary of objectives and concerns
Transport for NSW (as representatives for Sydney Trains, Sydney Buses, Sydney Light Rail Sydney Metro)	Continuity of operations (transport, commercial, institutional, residential); safety and accessibility of workers, residents and visitors; integrity of infrastructure
Transport for NSW (acting as developer / development partner)	Continuity of business operations, safety and accessibility of workers, residents and visitors; integrity of infrastructure; long term viability of the asset
City of Sydney	Continuity of business operations, safety and accessibility of workers, residents and visitors; integrity of infrastructure
Building owner(s)	Earnings, long term viability of the asset
Tenants	Continuity of business operations, safety of staff and visitors
Workforce	Security of employment, safety and accessibility of workplace
Visitors	Safety and accessibility
Future residents	Safety and accessibility; integrity of infrastructure

Existing community	Community cohesion and safety; integrity of infrastructure
Transit riders	Safety and accessibility; continuity of service
Government agencies (such as Police, Fire, Ambulance, Resilience NSW)	Public safety

3.6 Identified assets or asset classes

The following Identified assets or asset classes, as identified in AS 533 and referred to as Settlements and Infrastructure Sectors are covered by this Climate Adaptation Plan.

TABLE 3.2: ASSET OR ASSET CLASS – AS 5334-2013 (STANDARDS AUSTRALIA 2013)

Sector	Component (indicative)	Notes	Covered
Places	Cities		☒
	Towns		☒
	Villages		☒
	Hamlets		☒
Buildings	Residential	All housing types including mixed use centres, multiple dwellings and public and community housing such as boarding houses	☑
	Commercial	Includes all facilities that facilitate professional services, banking, administration centres, call centres, resorts, etc.	☑
	Industrial	Includes processing, manufacturing and warehousing	☑
	Recreational	Includes major event facilities	☑
	Retail	Includes shopping malls, bulky goods centres and mixed use centres	☑
	Public	Includes schools, hospitals, universities and courts	☑
	Historic	Heritage listed and state significant	☑
	Tourism	Public and private facilities	☑
OSD enabling infrastructure	Deck		☑
	Tunnels		☑
Energy	Electricity generation		☑

Sector	Component (indicative)	Notes	Covered
	Electricity transmission and distribution		☑
	Oil and gas storage, transmission and distribution		☑
	Liquid fuels storage and distribution		☑
Water	Water storage	Includes dams and header tanks	☑
	Water supply and distribution	Includes pipes and pumps	☑
	Sewerage	Includes pipes, pumps and sewerage treatment plants	☑
	Irrigation	Includes pipes and pumps	☑
	Drainage	Includes pipes and pumps, open drains such as swales, concrete formed structures, bio-filtration systems and other water sensitive urban design elements	☑
Green infrastructure	Public open space and private domain landscapes	Includes regional, district and local parks, streetscapes, trees and gardens, private open space	☑
	Natural landscape systems	Includes conserved systems such as river corridors, urban National Parks and State Forests, vegetation and habitat reserves, foreshores and cliffs	☑
	Cultural landscapes	Includes urban public lands such as botanic gardens, archaeological (indigenous and settlement) sites and monuments	☑
	Urban agriculture	Includes community gardens, urban farms for food production and/or commercial plant production	☑
Transport	Roads	Includes all gazetted roads, sealed or unsealed, formed and unformed	☑
	Tunnels	All transport tunnels	☑
	Bridges	All transport bridges	☑
	Rail	Includes railway stations, fixed structures and rolling stock	☑
	Airports		☒
	Ports	Incudes jetties, wharves, sea walls, navigational aids	☒
	Pedestrian and cycle	Includes footpaths and cycle ways	☑
Communication	Fixed line	Includes all overhead lines	☑
	Underground		☑

Sector	Component (indicative)	Notes	Covered
	Transmission facilities	Includes data, radio, TV and phone systems	☑
ICT	Critical systems and data		☑
Resource development	Mining, oil and gas extraction		☒
	Forestry		☒
	Fisheries	Includes aquaculture	☒

3.7 Design life

Design life is defined as the period within which an element of the works must continue to meet the performance and technical requirements for the project and remain within specified limits of reliability, availability and maintainability without major renewal beyond normal cyclic maintenance activities. It also benchmarks the requirements for durability.

Preliminary design life of asset elements are defined below:

TABLE 3.3: DESIGN WORKING LIFE

Asset	Design life
Structural elements	
Building structures and other common structures	60 years
Monumental building structures, bridges, and other civil engineering structures	120 years
Civil and hydraulic elements	
Drainage	100 years
Building pavement	50 years
Road pavement	15 years
Mechanical and electrical elements	
Critical infrastructure systems – security & communications	25 years
Critical system equipment (cameras, access control, etc.)	15 years
HVAC - heat pumps	15 to 25 years
HVAC – split systems	7 to 10 years
HCAV – fans	15 to 20 years
Architectural elements	
Materials and finishes	20 years
Facades	30 years

4.0 Climate change

4.1 Emissions scenarios

The Intergovernmental Panel on Climate Change (IPCC 2014) publishes four greenhouse gas concentration trajectories known as Representative Concentration Pathways (RCPs) which are used for climate modelling and research as detailed below:

TABLE 4.1: RCPS AND GLOBAL WARMING

Scenario		Global warming mean and likely range (°C)
RCP 2.6	Emissions peak 2010-2020, then decline substantially	1.0°C (0.3 to 1.7)
RCP 4.5	Emissions in RCP 4.5 peak around 2040, then decline	1.8°C (1.1 to 2.6)
RCP 6.0	Emissions peak around 2080, then decline	2.2°C (1.4 to 3.1)
RCP 8.5	Emissions continue to rise throughout the 21st century	3.7°C (2.6 to 4.8)

Recognising the degree of uncertainty that exists regarding future climate, the latest IPCC report (AR5) introduced a series of Representative Concentration Pathways (RCPs) to help provide parameters around varying greenhouse gas (GHG) emission trajectories. The RCPs represent four plausible climate futures that may eventuate over the coming years. The most conservative scenario is represented by RCP 8.5 which assumes a high emissions pathway with global GHG emissions continuing to rise throughout the 21st century. Currently, RCP 8.5 represents not only the worst-case emissions scenario, but also the most likely case. As such, until further climate data revises this prediction, TfNSW Climate Risk Assessment Guidelines (TfNSW 2016) recommended that a RCP 8.55 is used when sourcing relevant climate projections (e.g. when using the CSIRO Climate Futures portal).

4.2 Time scales

Given the scale of the proposed development and enabling infrastructure, the expected design life of the development (>120 years), the timeframe for the proposed construction works and the available climate data, three time periods have been used for the assessment. These time periods and the rationale for their selection are summarised in Table 4.2 below.

TABLE 4.2: DEVELOPMENT TIME SCALES DECRIPTIONS

Time scale	Year	Rationale
Short-term	2036	Enabling works complete; development significantly advanced and inhabited; relatively similar climate settings; alignment with existing medium-term analysis in Future Transport Strategy 2056 (TfNSW 2020)
Medium-term	2056	Development settling into operations with current systems and current design intent/use; advanced climate settings; alignment with existing long-term analysis in Future Transport Strategy 2056 (TfNSW 2020)
Long-term	2096	Development inhabited by future use scenarios, possibly adapted to future use types; significantly advanced climate change scenario; the limit of current projections.

4.3 Climate variables

The following climate variables are initially covered for potential risk consideration, however the geographical and topographical site context together with the findings of the risk workshop(s) will ultimately determine the salient risks to the project.

TABLE 4.3: CLIMATE CHANGE VARIABLES CONSIDERED

Element	Climate change variables
Sea	Sea level rise
Temperature	Average annual temperature
	Extreme temperature events
Precipitation	Average annual rainfall
	Extreme rainfall events
Drought	Increase in duration
Wind	Gales and extreme wind events
Extreme storms	Hail size and location
	Dust storms
	Frequency and severity of storms
	Electrical storms and lightning strikes
Relative humidity	Average annual
Bush fire	Fire danger index
Solar radiation	Increased level of UV
Waterway health	Discharge runoff

Resilience is a multi-facetted area of integrated design and management, and as such the risk assessment framework also takes into account a series of non-climate-related variables. These civil and infrastructure variables represent the key acute shocks and chronic stresses identified in Resilient Sydney (2018).

TABLE 4.4: CIVIL AND INFRASTRUCTURE VARIABLES CONSIDERED

Element	Civil and infrastructure variables
Civil disturbance (stresses identified by Resilient Sydney)	Diminishing community cohesion
	Disease pandemic
	Financial crisis
Civil disturbance (shocks identified by Resilient Sydney)	Civil unrest
	Cyber attack
	Terror attack
Critical infrastructure failure	Transport network failures
	Digital network outages
	Electrical network outages
	Water network outages
	Healthcare services overload
Shift in business models	Shift in mobility systems

	Shift in workplace needs
	Carbon pricing
	Changing residential models
	Ageing population
	Cultural backgrounds
	Changing demographics
Social stresses	Homelessness
	Increasing inequality
	Housing affordability
	Financial collapse
	War

4.1 Observed climate

Local climate for the region is predominantly temperate, which typically results in warm wet summers/autumn and mild, dry winter/spring. The coastal location of the development also influences local climate, with generally lower temperatures experienced when compared with inland areas (e.g. Western Sydney). Rainfall patterns are typically seasonal, with higher rainfall experienced during autumn months and lower rainfall in spring (Table 4.5). Trends indicate variability in the amount of rainfall received from year to year. Storms result in periods of heavy rainfall and strong winds and may lead to flood events.

TABLE 4.5: CLIMATE EXPOSURE (BOM 2021B)

Climate variable	Averages (1859-2020)
Average maximum daily temperature	Ranging from 26.0°C (January), to 16.4°C (July)
Average minimum daily temperature	Ranging from 18.9°C (January), to 8.1°C (July)
Extreme temperatures above 35°C	0.9 days per year over 35°C, typically in summer months
Average monthly rainfall	Ranging from 133mm (June) to 68.1mm (September)

4.1.1 Mean temperature

The local area typically experiences average maximum daily temperatures ranging from 26.0°C in January to 16.4°C in July, and average minimum daily temperatures ranging from 18.9°C in January to 8.1°C in July. Given its coastal location, the average temperatures for the local area are typically milder than those experienced by the Greater Sydney region, particularly Western Sydney which can experience significantly higher averages (e.g. Penrith Lakes Automatic Weather Station shows a January average maximum daily temperature of 32.0°C (BoM 2021a)).

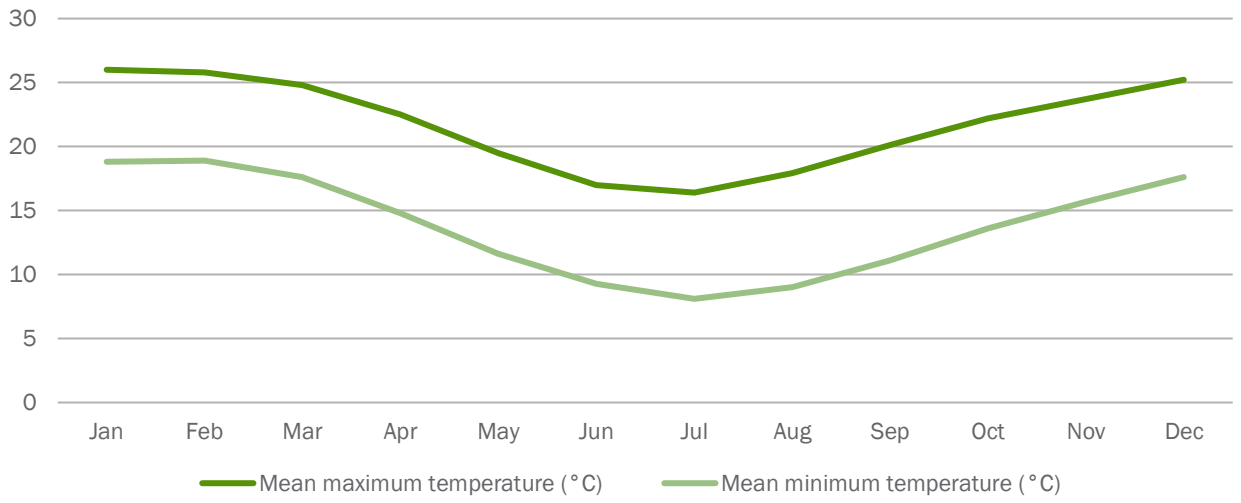


FIGURE 4.1: MEAN MAXIMUM AND MINIMUM TEMPERATURES RECORDED AT OBSERVATORY HILL (1859 -2020) (BOM 2021B)

4.1.2 Urban heat island

Urban heat islands occur in urban areas such cities or industrial sites and lead to consistently higher temperatures than surrounding areas driven by a greater retention of heat. This is caused by the sun's heat being absorbed by hard surfaces with high thermal mass such as buildings, dark roofs, car parks, paved surfaces, and roads. Human activities, such as motorised transport and using air conditioning also increase these impacts due to their generation of waste heat.

Figure 4.2 shows thermal imagery for the City of Sydney local government area (LGA). Higher temperatures are seen in parts of the city that are heavily urbanised and/or characterised by large areas of paved and roofed surfaces, such as industrial areas around Alexandria, while areas of green space (such as the Royal Botanical Gardens) generally experience lower temperatures.

Central Precinct is currently shown to have above average exposure to urban heat island effects, likely driven by the high proportion of exposed train lines, and particularly track ballast. OEH (2015b) notes that changes in land use from industrial/commercial to medium or high density is likely to result in a reduction in average temperatures. For Central Precinct, temperature decreases are likely due to the combination of shading from increased building height, increases in vegetation, and the effects of afternoon coastal sea breezes.

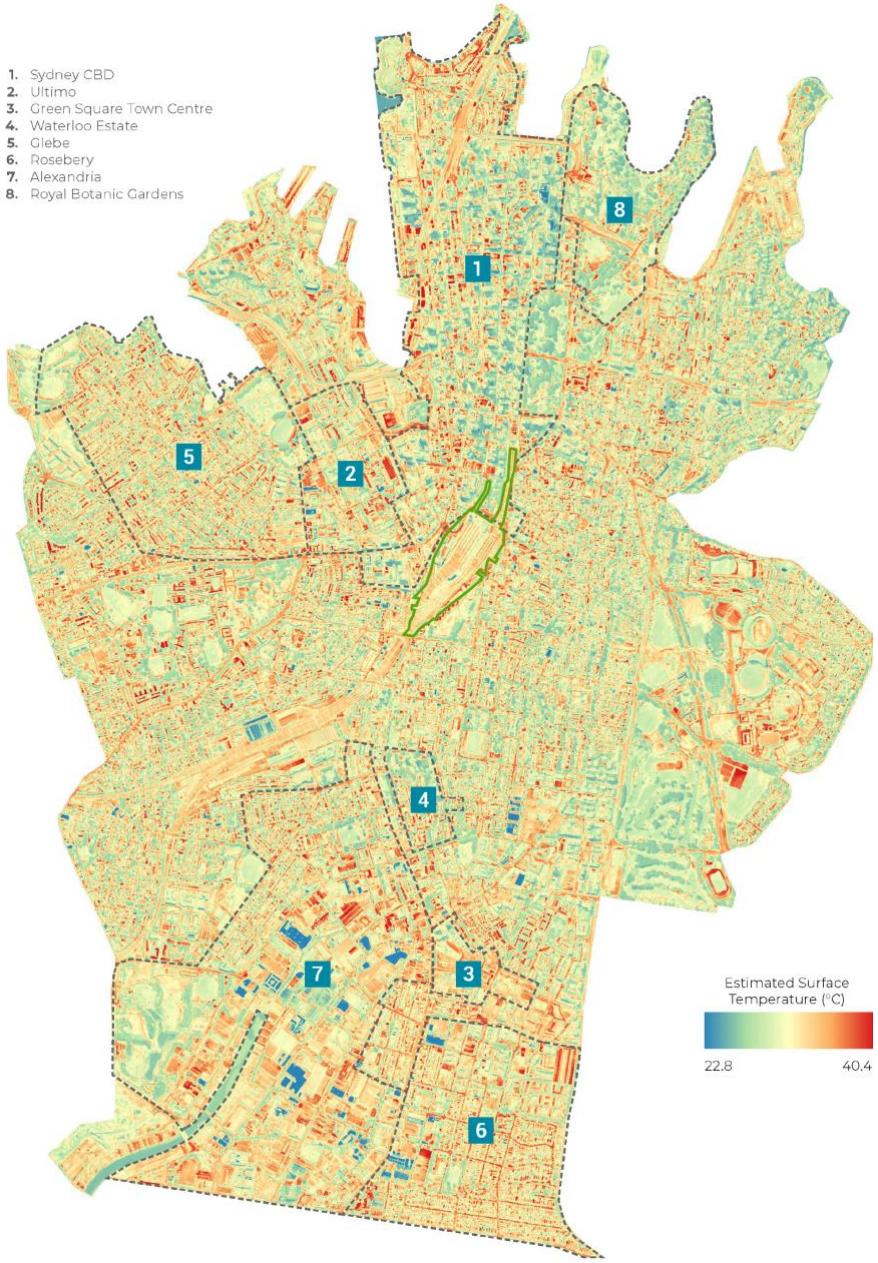


FIGURE 4.2: URBAN HEAT MAPPING (EXISTING CONDITION) (DING ET AL. 2019). CPRP HIGHLIGHTED BY GREEN BOX.

4.1.3 Extreme heat

The local area historically experiences an average of 3.2 days above 35°C per year, significantly lower than other areas of Greater Sydney (e.g. Penrith Lakes AWS historically records 22.7 days per year on average). Similar to the mean temperature averages, this is likely driven by the Precinct's coastal setting. Temperature records for Observatory Hill show highest maximum temperatures can typically exceed 40°C between November and February.

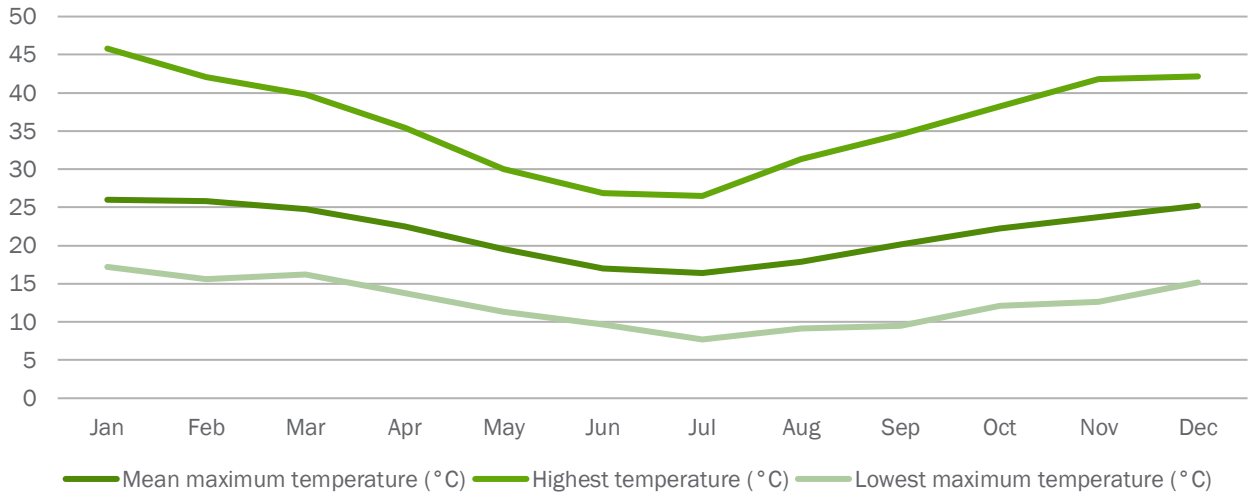


FIGURE 4.3: AVERAGE MAXIMUM AVERAGE TEMPERATURES AND HISTORICAL MAXIMUM TEMPERATURES RECORDED AT OBSERVATORY HILL (1859-2020) (BOM 2021B)

4.1.4 Mean rainfall

Annual rainfall for the local area has averaged 1,213mm over the period 1858-2020. Typically, February to June are the wettest months of the year, while August to December receive the lowest average rainfall.

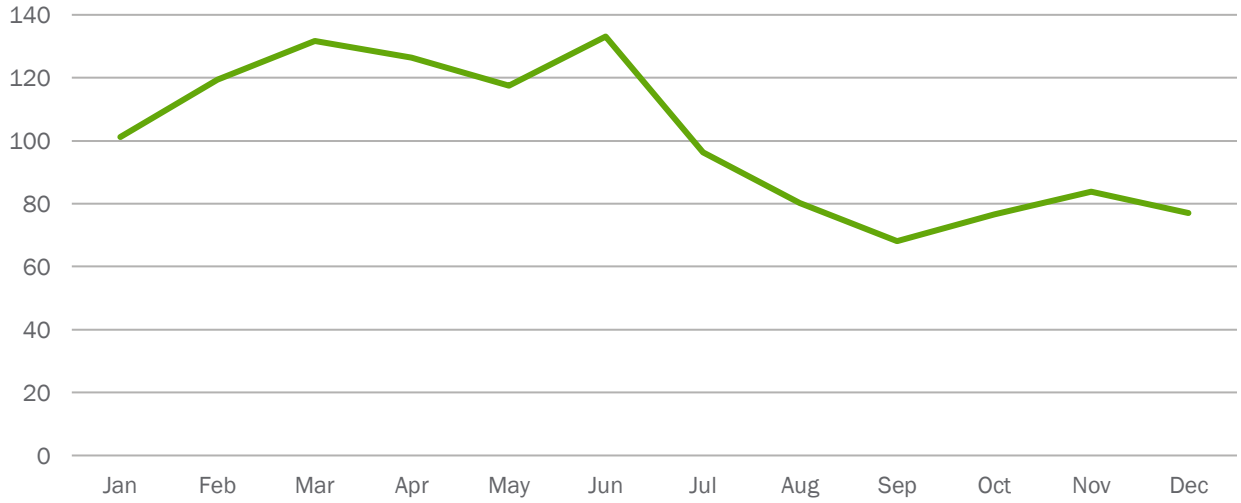


FIGURE 4.4: AVERAGE MAXIMUM AVERAGE TEMPERATURES AND HISTORICAL MAXIMUM TEMPERATURES RECORDED AT OBSERVATORY HILL (1859-2020) (BOM 2021B)

4.1.5 Extreme rainfall and flooding

Central Precinct falls within the Darling Harbour catchment which is located in Sydney's inner city suburbs of Haymarket, Surry Hills and parts of Pyrmont, Ultimo and Sydney, and has an area of 307 hectares. The Darling Harbour Catchment Flood Study (2014) was carried out to define existing flood behaviour for the Darling Harbour catchment in terms of flood levels, depth, velocities, flows, hydraulic categories and provisional hazard.

The study defined flood behaviour of the 0.5 EY, 0.2 EY, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.2% AEP and PMF design events, including peak flood levels, depths and velocities. The study also undertook sensitivity testing and considered the impact of future climate change on design events.

These maps illustrate that the impact on the 1% AEP (100-year ARI) of:

- 30% increase in rainfall intensity typically less than 0.1m surrounding the CPRP site. This is typical of urbanised catchments.
- 2100 (+ 0.9m sea level rise) impacts limited to the downstream of site.

As part of the SSP process, it has been proposed that flood related development controls have climate change imbedded into them (e.g. floor levels set above the 1% (including climate change).

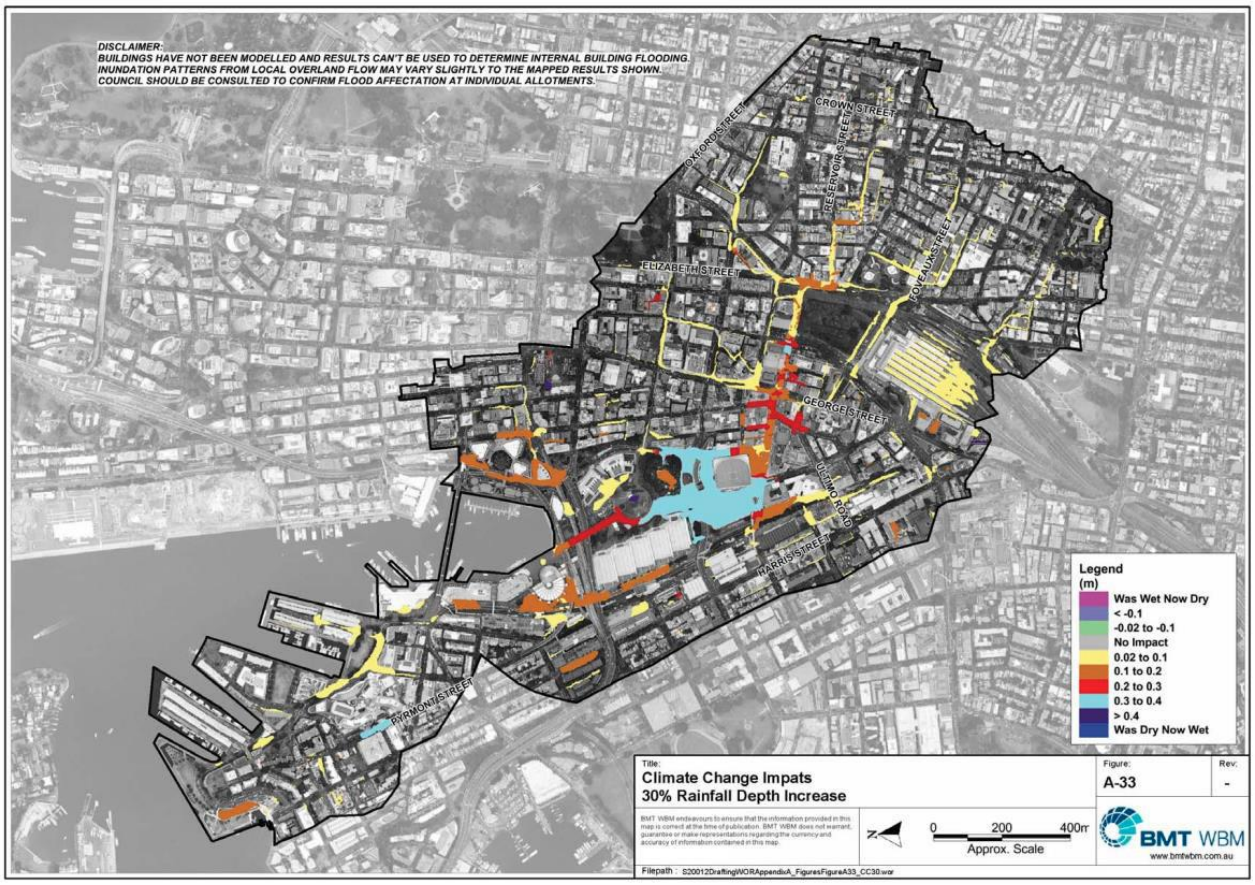


FIGURE 4.5: CLIMATE CHANGE IMPACTS FLOOD MAP – 30% RAINFALL DEPTH INCREASE (CITY OF SYDNEY 2016)

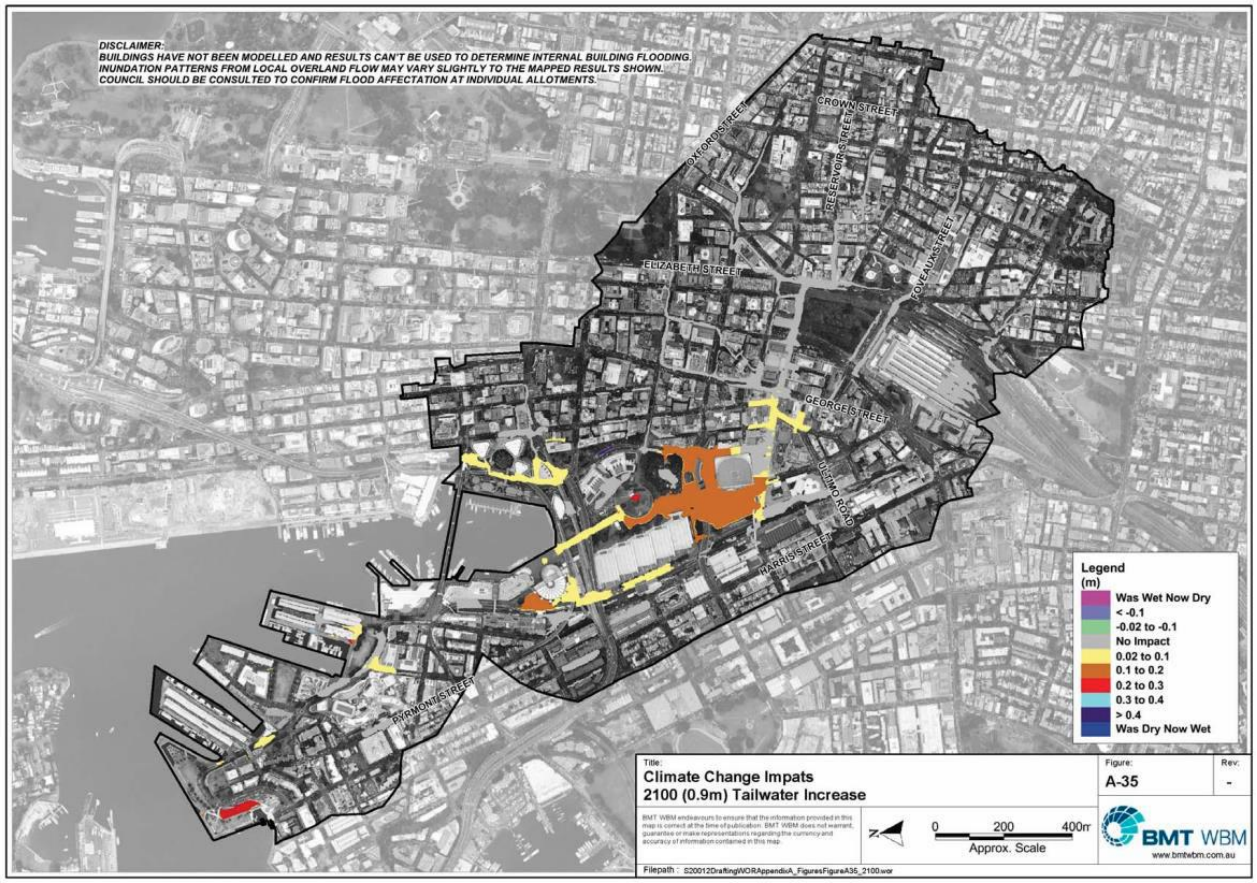


FIGURE 4.6: CLIMATE CHANGE IMPACTS FLOOD MAP – 2100 (0.9M) TAILWATER INCREASE (CITY OF SYDNEY 2016)

4.1.6 Storm events

The Sydney region is susceptible to storm events, predominantly in the form of east coast lows (ECLs) that develop as a result of ex-tropical cyclones that decay as they move south or interactions between troughs of low pressures/cold fronts with warmer sea surface temperatures. Within the Greater Sydney area, several recent storm events (BoM 2021c) have been recently observed:

- In June 2016, the East Coast Storms and Flood events resulted in flash flooding and property damage across Sydney
- In March 2017 a severe thunderstorm resulted in 33,000 homes without power across western Sydney and road closures
- In December 2018 a severe thunderstorm impacted Sydney's northwest, leading to 3788 calls for assistance to the NSW State Emergency Service, and left 55,000 homes without power throughout nearby Castle Hill, North Parramatta, Winston Hills, and Carlingford.
- In February 2019 45,000 homes in Sydney's northwest lost power due to a storm event, with up to 5,000 homes without power for multiple days.
- In February 2020 Sydney experienced two east coast lows (8th and 18th February) with rain up to 400mm falling over three days and winds exceeding 100km/h.

In addition to gale force winds and heavy widespread flooding, ECLs also generate rough seas and storm tides. Storm tides can lead to coastal flooding, particularly when they combine with astronomical high tides or king tides. This was evidenced in 2016 when an east coast low-driven storm tide combined with a king tide affected areas of Greater Sydney such as Collaroy which experienced severe inundation and erosion.

4.1.7 Bushfires

The development is not within proximity of bushfire prone land. However, recent experience has shown that the indirect impacts of bushfire – including poor air quality and infrastructure failure – pose significant risks for all communities in the Greater Sydney region.

The Forest Fire Danger Index (FFDI) is used in NSW to quantify fire weather. The FFDI combines observations of temperature, humidity, and wind speed with an estimate of the fuel state. AdaptNSW (2015a) notes that long-term FFDI estimates are available for two weather stations in the region, Sydney Airport and Richmond. The average annual FFDI for the period 1990–2009 is 5.5 at Sydney Airport and 7.1 at Richmond.

Fire weather is classified as 'severe' when the FFDI is above 50, and most of the property loss from major fires in Australia has occurred when the FFDI reached this level. FFDI values below 12 indicate low to moderate fire weather, 12-25 high, 25-49 very high, 50-74 severe, 75-99 extreme and above 100 catastrophic.

Severe fire weather conditions are estimated to occur on average one day per year at Sydney Airport and 1.8 days per year at Richmond. These days are more likely to occur in summer and spring months.

4.2 Climate projection snapshot

A summary of the key climate related effects relevant to operations at Central Precinct can be found below in Table 4.6. This data has been taken from the Transport for NSW *Climate Risk Assessment Tool 1: Climate Data* (2021). This tool provides a summary of the CRA model results. The CCRA model is built in Matlab using parametrization and optimisation algorithms applied to gridded NARCliM1.5 data combined with other sources.

Original NARCliM data containing projections from four Global Circulation Models and three downscaling techniques, thus, providing a total of 6 projection scenarios. This CCRA model combines all 6 ensembles (gridded raw data) and selects the most extreme values for each climate variable and a unique graphical location, thus, creating a new data set that is more suitable for climate change risk assessment. Please, keep in mind that this data is not representative of the exact climate future, and it is built for risk estimation only.

This tool can be used to get information about the changes in the near future (2021-2050), mid (2051-2080) and far (2071-2100) future. In addition, the tool provided data for sea level rise based on Climate Analytics data (using (Bamber et al. 2019)) as well as Urban Heat Island Effect, Heat Vulnerability Index and Disaster Resilience Index based on SEED and BNHCRC data as well as locations of the water bodies and bushfire risk zones.

In depth details of relevant climate data, projections, and commentary from AdaptNSW (OEH 2014) and NARCliM (ARC Centre of Excellence for Climate System Science 2012) can be found in **Error! Reference source not found. Error! Reference source not found.**.

TABLE 4.6: CLIMATE PROJECTION SNAPSHOT (TFNSW 2021)

Climate variable	2021-2050	2051-2080	2071-2100
Heat Vulnerability Index (current state)	4	4	4
Disaster Resilience Index (current state)	0.6	0.6	0.6
Maximum temperature (including UHI), °C	+3.5°C from 47.2°C	+4.7°C from 47.2°C	+4.8°C from 47.2°C
Minimum temperature, °C	+2.5°C from 11.9°C	+3.5°C from 11.9°C	+4.4°C from 11.9°C
Number of days over 35°C	+38 from 53 days	+70 from 53 days	+112 from 53 days
Number of days over 40°C	+14 from 10 days	+19 from 10 days	+38 from 10 days
Average humidity at 40°C	-5 from 66%	-5 from 66%	-2 from 66%
Duration of heavy-rain periods, days	+1 from 2 days	+1 from 2 days	+1 from 2 days

Number of heavy-rain periods	+2 from 1	+2 from 1	+2 from 1
Total amount of rain during a maximum rainfall period, mm	+24 from 90 mm	+56 from 90 mm	+123 from 90 mm
Precipitation rate, mm/h	+6 from 33 mm/h	+8 from 33 mm/h	+22 from 33 mm/h
Daily precipitation, mm/day	-1 from 148mm/d	+58 from 148mm/d	+1 from 148mm/d
Number of days with rainfall intensity over 25mm/h	+1 from 1 days	+1 from 1 days	+1 from 1 days
Drought duration, days	-10 from 48 days	+16 from 48 days	+13 from 48 days
Number of drought periods (no rain for over 2 weeks)	-1 from 7	+1 from 7	+0 from 7
Number of days with soil moisture below 20%	-4 from 4 days	-4 from 4 days	-4 from 4 days
Wind speed, km/h	+2 from 75km/h	-2 from 75km/h	-1 from 75km/h
Number of days with wind speed over 65km/h	-1 from 2 days	-1 from 2 days	+0 from 2 days
Highest Fire index	Not bushfire zone	Not bushfire zone	Not bushfire zone
Number of days with Fire index over 25	Not bushfire zone	Not bushfire zone	Not bushfire zone
Sea level rise (mean projection range), m	+0.15 metres	+0.7 metres	+1.15 metres
Sea level rise (maximum projection range), m	+0.25 metres	+1.42 metres	+2.44 metres

5.0 Risk assessment

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Key Criteria (AS 5334)	2036			2056			2090		
							Consequence	Likelihood	Initial Risk	Consequence	Likelihood	Initial Risk	Consequence	Likelihood	Initial Risk
01	Sea	Increase in sea level	Direct	**Inundation** Direct: Potential for inundation of infrastructure during storms resulting in flood damage and safety risk.	Place-based	Financial Infrastructure Economy	Major	Very Unlikely	Medium	Catastrophic	Very Unlikely	Medium	Catastrophic	Very Unlikely	Medium
02	Sea	Increase in sea level	Direct	**Intrusion** Direct: Saltwater intrusion, contaminating water sources, impacting groundwater resources and landscaping, and/or increasing degradation of building materials (e.g. foundations)	Place-based	Financial Infrastructure	Major	Very Unlikely	Medium	Catastrophic	Very Unlikely	Medium	Catastrophic	Very Unlikely	Medium
03	Temperature	Increase in mean maximum temperature	Direct	**Electrical assets - power supply on site** Direct: Extended high temperatures may have an adverse impact on the operation of some electrical equipment, such as components in kiosks or sub-substations or external control cabinets or switchboards or LED's used in street lighting leading to system failure or service interruptions.	Integrated	Financial Infrastructure	Major	Unlikely	Medium	Major	Moderate	High	Major	Moderate	High
04	Temperature	Increase in mean maximum temperature	Direct	**Structure** Direct: Structural materials may be affected by extreme heat, leading to structural fatigue.	Process-oriented	Financial Infrastructure	Major	Very Unlikely	Medium	Major	Unlikely	Medium	Major	Unlikely	Medium
05	Temperature	Increase in mean maximum temperature	Indirect	**Deterioration** Indirect: Increased mean maximum temperature and solar exposure may lead to greater material degradation and need for building and infrastructure maintenance	Integrated	Financial Infrastructure	Minor	Almost Certain	Medium	Minor	Almost Certain	Medium	Minor	Almost Certain	Medium
06	Temperature	Increased annual mean temperature	Direct	**Biodiversity colapse** Direct: Loss of biodiversity and ecosystem function (e.g. extreme heat mortality)	Integrated	Environmental Social	Minor	Unlikely	Low	Minor	Moderate	Low	Minor	Moderate	Low
07	Temperature	Increased annual mean temperature	Direct	**Landscapes** Direct: Combined with lower rainfall will result in the loss of many plant species and less vigorous growth of many of the survivors, issues with management of pest plants and animals, loss of landscape amenity.	Place-based	Financial Infrastructure Environmental	Moderate	Almost Certain	High	Moderate	Almost Certain	High	Moderate	Almost Certain	High
08	Temperature	Increased annual mean temperature	Indirect	**Energy costs** Indirect: Increase in average temperatures may lead to an increase in energy demand and associated utility costs.	Integrated	Financial Social	Moderate	Likely	Medium	Moderate	Likely	Medium	Moderate	Likely	Medium

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Key Criteria (AS 5334)	2036			2056			2090		
							Consequence	Likelihood	Initial Risk	Consequence	Likelihood	Initial Risk	Consequence	Likelihood	Initial Risk
09	Temperature	Increased number of hot days over 35°C	Direct	**Heat Islands** Direct: Increases in number of days above 35°C may contribute towards urban heat island effects, leading to reduced comfort and increased complaints from building occupants and pedestrians	Integrated	Financial Social	Moderate	Almost Certain	High	Moderate	Almost Certain	High	Moderate	Almost Certain	High
10	Temperature	Increased number of hot days over 35°C	Direct	**Thermal comfort** Direct: HVAC system may experience overload, affecting thermal comfort for building occupants, and increasing HVAC maintenance and operating costs.	Integrated	Financial Infrastructure Social	Minor	Likely	Medium	Moderate	Almost Certain	High	Moderate	Almost Certain	High
11	Temperature	Increased number of hot days over 35°C	Direct	**Network blackouts** Direct: Frequent interruptions to mains power supply can lead to service interruption, power losses to infrastructure and buildings.	Place-based	Financial Infrastructure	Major	Moderate	High	Major	Likely	High	Major	Likely	High
12	Precipitation	Greater frequency of higher intensity rainfall events	Direct	**Flood immunity** Direct: Greater frequency of higher intensity rainfall events may lead to changes in flood immunity levels.	Place-based	Financial Infrastructure	Major	Moderate	High	Major	Moderate	High	Major	Moderate	High
13	Precipitation	Greater frequency of higher intensity rainfall events	Direct	**Building structures - floor levels and roof drainage** Direct: Greater frequency of higher intensity rainfall events may lead to localised flooding, damage due to scour and less safe operating conditions.	Place-based	Financial Infrastructure	Moderate	Likely	Medium	Moderate	Likely	Medium	Moderate	Likely	Medium
14	Precipitation	Greater frequency of higher intensity rainfall events	Direct	**Egress** Direct: Greater frequency of higher intensity rainfall events may increase events that limit access and egress, resulting in tenants being stranded at the development.	Place-based	Financial Social	Moderate	Unlikely	Medium	Major	Moderate	High	Major	Moderate	High
15	Precipitation	Greater frequency of higher intensity rainfall events	Direct	**Erosion** Direct: Greater frequency of higher intensity rainfall events may increase the potential for erosion causing potential infrastructure instability and disruption or safety risk in the event of collapse.	Process-oriented	Financial Infrastructure Environmental	Insignificant	Very Unlikely	Low	Insignificant	Very Unlikely	Low	Insignificant	Very Unlikely	Low
16	Precipitation	Greater frequency of higher intensity rainfall events	Direct	**Civil drainage** Direct: Greater frequency of higher intensity rainfall events may lead to inundation of drainage infrastructure as a result of insufficient system capacity, with resulting damage on site or adjacent, service disruption and safety risk.	Process-oriented	Financial Infrastructure	Major	Moderate	High	Major	Likely	High	Major	Likely	High
17	Precipitation	Greater frequency of higher intensity rainfall events	Direct	**Rail inundation - downstream effects** Direct: Greater frequency of higher intensity rainfall events may overwhelm civil drainage infrastructure resulting in inundation of rail corridors.	Process-oriented	Financial Environmental Social	Major	Moderate	High	Major	Moderate	High	Major	Moderate	High

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Key Criteria (AS 5334)	2036			2056			2090		
							Consequence	Likelihood	Initial Risk	Consequence	Likelihood	Initial Risk	Consequence	Likelihood	Initial Risk
18	Precipitation	Greater frequency of higher intensity rainfall events	Indirect	**Insurance premiums** Indirect: Greater frequency of higher intensity rainfall events leading to flooding causing damage to structures which may lead to increased insurance premiums for assets	Process-oriented	Financial	Minor	Moderate	Low	Moderate	Likely	Medium	Moderate	Likely	Medium
19	Drought	Decrease in annual total rainfall	Direct	**Erosion** Direct: Decrease in annual total rainfall may increase the potential for erosion causing infrastructure instability, scour and safety risk in the event of collapse.	Process-oriented	FinancialInfrastructure	Insignificant	Very Unlikely	Low	Insignificant	Very Unlikely	Low	Insignificant	Very Unlikely	Low
20	Drought	Decrease in annual total rainfall	Indirect	**Landscapes** Indirect: Decrease in annual total rainfall leading to a reduction in regional water storages and reduce water supplies making it difficult to water landscaping.	Place-based	Financial Environmental Social	Minor	Likely	Medium	Minor	Likely	Medium	Minor	Likely	Medium
21	Drought	Decrease in annual total rainfall	Indirect	**Potable water availability** Indirect: Decrease in annual total rainfall may result in water restrictions prohibiting water use in heat rejection.	Process-oriented	Infrastructure	Moderate	Likely	Medium	Moderate	Likely	Medium	Moderate	Likely	Medium
22	Drought	Decrease in annual total rainfall	Indirect	**Potable water pricing** Indirect: Decrease in annual total rainfall may result in water restrictions and pricing impacts on tenants, running costs of water cooled systems for building owners.	Process-oriented	Financial Social	Minor	Likely	Medium	Moderate	Likely	Medium	Moderate	Likely	Medium
23	Wind	Increased wind speeds	Direct	**Debris** Direct: Increasing wind speeds may dislodge loose furniture or equipment (including vegetation) damaging exposed plant equipment and facades, or make the public domain unsafe.	Integrated	Financial Infrastructure	Major	Unlikely	Medium	Major	Likely	High	Major	Likely	High
24	Wind	Increased wind speeds	Direct	**Wind driven rain** Direct: Increasing wind speeds coupled with greater frequency of higher intensity rainfall events may lead to wind driven rain flooding upper levels and penetrating facades.	Place-based	Financial Infrastructure	Moderate	Moderate	Medium	Moderate	Moderate	Medium	Moderate	Moderate	Medium
25	Wind	Increased wind speeds	Direct	**Pedestrian comfort and safety - wind tunnels** Direct: Increasing wind speeds exacerbated by tall buildings and the elevated deck may lead to wind tunnel conditions making the public realm uncomfortable and potentially unsafe.	Place-based	Financial Social	Minor	Likely	Medium	Minor	Likely	Medium	Minor	Likely	Medium
26	Wind	Increased wind speeds	Direct	**Structure** Direct: Increase in wind speeds may impact the structural integrity of some infrastructure elements	Process-oriented	Financial Infrastructure	Moderate	Very Unlikely	Low	Moderate	Unlikely	Medium	Moderate	Unlikely	Medium

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Key Criteria (AS 5334)	2036			2056			2090		
							Consequence	Likelihood	Initial Risk	Consequence	Likelihood	Initial Risk	Consequence	Likelihood	Initial Risk
27	Wind	Increased wind speeds	Direct	**Electrical assets** Direct: Wind damage to electrical circuitry (overhead wiring) may result in disruption to services and increase maintenance costs.	Process-oriented	Financial Infrastructure	Major	Moderate	High	Major	Moderate	High	Major	Likely	High
28	Extreme storms	Increase in extreme hailstorm events	Direct	**Hail storms** Direct: Increase in extreme hailstorm events may damage to cladding, exposed plant and services, landscapes, entryways and horizontal/sloped glazing.	Integrated	Financial Infrastructure	Moderate	Almost Certain	High	Major	Almost Certain	Extreme	Major	Almost Certain	Extreme
29	Extreme storms	Increase in extreme hailstorm events	Direct	**Drainage** Direct: Increase in extreme hailstorm events may overload roof drainage for buildings and result in water damage.	Process-oriented	Financial Infrastructure	Moderate	Likely	Medium	Major	Likely	High	Major	Likely	High
30	Extreme storms	Increase in frequency and severity of storms	Direct	**Dust storms** Direct: Last major dust storm 2009, combination of drought, hot weather and westerly wind. Increased risk of systems damage and occupant respiratory illness	Integrated	Financial Social	Moderate	Moderate	Medium	Moderate	Moderate	Medium	Moderate	Moderate	Medium
31	Extreme storms	Increase in frequency and severity of storms	Indirect	**Usability** Indirect: Increase in frequency and severity of storms may lead to reduced usability and increased complaints.	Integrated	Social Economy	Insignificant	Unlikely	Low	Minor	Moderate	Low	Minor	Moderate	Low
32	Extreme storms	Increase in frequency and severity of storms	Indirect	**Displacement** Indirect: Increase in frequency and severity of storms may result in damage to properties, causing displacement and disruption of tenant / business activity during clean up and repair.	Process-oriented	Financial	Minor	Unlikely	Low	Moderate	Moderate	Medium	Major	Likely	High
33	Extreme storms	Increasing frequency of electrical storms and lightning strikes	Direct	**Lightning strike** Direct: Increasing frequency of electrical storms and lightning strikes can damage building elements, public infrastructure, and electrical systems either directly or indirectly through fire.	Process-oriented	Financial Infrastructure	Moderate	Likely	Medium	Major	Likely	High	Major	Likely	High
34	Relative humidity	Changes to relative humidity	Direct	**Maintenance** Direct: Build-up of mould and condensation leading to increased operations and maintenance requirements and costs.	Integrated	Financial Infrastructure	Minor	Likely	Medium	Minor	Likely	Medium	Minor	Almost Certain	Medium
35	Relative humidity	Changes to relative humidity	Direct	**Deterioration** Direct: Accelerated carbonation of concrete structures.	Process-oriented	Financial Infrastructure	Moderate	Moderate	Medium	Moderate	Moderate	Medium	Moderate	Moderate	Medium
36	Relative humidity	Changes to relative humidity	Direct	**Thermal comfort** Direct: Changes in relative humidity resulting in decreasing thermal comfort resulting in health impacts or decreased productivity.		Financial Infrastructure Social	Moderate	Likely	Medium	Moderate	Likely	Medium	Moderate	Almost Certain	High

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Key Criteria (AS 5334)	2036			2056			2090		
							Consequence	Likelihood	Initial Risk	Consequence	Likelihood	Initial Risk	Consequence	Likelihood	Initial Risk
37	Relative humidity	Changes to relative humidity	Indirect	**Pest distribution** Indirect: Changes in humidity may increase encroachment pest species.	Integrated	Financial Environmental Social	Minor		Low	Minor	Unlikely	Low	Minor	Unlikely	Low
38	Relative humidity	Changes to relative humidity	Indirect	**Disease transmission** Indirect: Changes in humidity may increase the spread of waterborne diseases.	Place-based	Financial Environmental Social	Moderate		Medium	Moderate	Unlikely	Medium	Major	Unlikely	Medium
39	Relative humidity	Changes to relative humidity	Indirect	**Energy costs** Indirect: Increase in relative humidity may lead to an increase in energy demand and associated utility costs.	Place-based	Financial Infrastructure	Moderate		Medium	Moderate	Likely	Medium	Moderate	Likely	Medium
40	Bushfire	Increase in risk of bushfires	Direct	**Air quality** Direct: Increase in number of severe fire weather risk days leading to exposure to smoke and particulate pollution for workers and visitors, that may cause respiratory distress, as well as reduced visibility.	Integrated	Social	Moderate		High	Moderate	Almost Certain	High	Moderate	Almost Certain	High
41	Solar radiation	Increase in level of UV	Direct	**Occupants, Workers and Visitor Health** Direct: Increased incidence of sunburn and associated skin cancer risks, sun stroke. Outdoor public domain and private balconies terraces key areas to consider	Integrated	Social Environmental	Minor		Medium	Minor	Almost Certain	Medium	Minor	Almost Certain	Medium
42	Solar radiation	Increase in level of UV	Direct	**Life cycle** Direct: Increased levels of UV could contribute to the increased rate of photo-oxidation and result in a shorter expected life of materials, especially polymer based products.	Process-oriented	Financial Infrastructure	Insignificant		Low	Insignificant	Almost Certain	Low	Insignificant	Almost Certain	Low
43	Solar radiation	Increase in level of UV	Direct	**Maintenance** Direct: Increased mean maximum temperature and solar exposure may lead to greater material degradation of assets, leading to increased need for infrastructure maintenance	Process-oriented	Financial Infrastructure	Insignificant		Low	Insignificant	Almost Certain	Low	Insignificant	Almost Certain	Low
44	Waterway Health	Declining Waterway Health	Direct	**Infrastructure** Direct: The increasing extreme weather conditions over time, rainfall intensity, drought, rising temperature and UV radiation is likely to lead to declining waterway health and could result in the need to retrofit additional hydraulic infrastructure.	Process-oriented	Financial Infrastructure Environmental	Major		Medium	Major	Unlikely	Medium	Major	Unlikely	Medium
45	Waterway Health	Declining Waterway Health	Indirect	**Discharge Licence** Indirect: The increasing extreme weather conditions over time, rainfall intensity, drought, rising temperature and UV radiation is likely to lead to declining waterway health and could result in increasing and more stringent discharge obligations with greater operational cost implications.	Process-oriented	Financial Environmental	Minor		Low	Minor	Likely	Medium	Minor	Likely	Medium

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Key Criteria (AS 5334)	2036			2056			2090		
							Consequence	Likelihood	Initial Risk	Consequence	Likelihood	Initial Risk	Consequence	Likelihood	Initial Risk
46	Waterway Health	Declining Waterway Health	Indirect	**Increased pressure** Indirect: Increased stress on old infrastructure through increasing density could lead to increased maintenance costs, increased risk of failure, and additional downstream effects.	Process-oriented	Financial Environmental	Moderate	Moderate	Medium	Moderate	Moderate	Medium	Moderate	Moderate	Medium
47	Civil Disturbance	Shocks identified by Resilient Sydney	Direct	**Terror attack - physical damage** Direct: Physical damage to buildings and infrastructure from targeted blasts or explosions.	Integrated	Financial Infrastructure Social Economy	Catastrophic	Moderate	Extreme	Catastrophic	Moderate	Extreme	Catastrophic	Moderate	Extreme
48	Civil Disturbance	Shocks identified by Resilient Sydney	Direct	**Terror attack - pathological damage** Direct: Potential public health effects from chemical or other biological attack requiring isolation, quarantine, decontamination.	Integrated	Financial Infrastructure Social Economy	Catastrophic	Moderate	Extreme	Catastrophic	Moderate	Extreme	Catastrophic	Moderate	Extreme
49	Civil Disturbance	Shocks identified by Resilient Sydney	Direct	**Civil unrest** Direct: Localised effects of lawlessness around the asset leading to the need to temporarily shelter in place for building occupants and business interruption to tenants.	Integrated	Financial Infrastructure Social Economy	Moderate	Unlikely	Medium	Moderate	Unlikely	Medium	Moderate	Unlikely	Medium
50	Civil Disturbance	Shocks identified by Resilient Sydney	Direct	**Cyber-attack** Direct: Data connections to the asset or tenant become compromised and may lead to Building Control Management System being compromised and interrupting business operations.	Process-oriented	Financial Infrastructure Economy	Major	Moderate	High	Major	Moderate	High	Major	Moderate	High
51	Civil Disturbance	Stresses identified by Resilient Sydney	Direct	**Disease pandemic** Direct: Interruptions to use of commercial offices during public health movement controls affecting business continuity leading to inefficient building operations at part loads and low occupancy.	Integrated	Financial Social Economy	Major	Likely	High	Major	Likely	High	Major	Likely	High
52	Civil Disturbance	Stresses identified by Resilient Sydney	Indirect	**Diminishing community Cohesion** Indirect: Evidence from places that have suffered extreme events shows constantly that mortality is highest where social cohesion is lowest. When people know each other, they look out and help one another through an extreme event.	Integrated	Social	Minor	Unlikely	Low	Moderate	Unlikely	Medium	Moderate	Unlikely	Medium
53	Civil Disturbance	Stresses identified by Resilient Sydney	Indirect	**Financial crisis** Indirect: Local or global economic disturbance can lead to negative effects on asset value and utility, and becoming stranded.	Integrated	Financial Social Economy	Moderate	Moderate	Medium	Moderate	Moderate	Medium	Moderate	Moderate	Medium
54	Critical Infrastructure Failure	Additional acute shocks	Direct	**Logistics failure** Direct: Closure of loading docks and underground access lane limiting supply of goods and services to public and private tenants and users.	Integrated	Financial Economy Social	Major	Moderate	High	Moderate	Moderate	Medium	Moderate	Moderate	Medium

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Key Criteria (AS 5334)	2036			2056			2090		
							Consequence	Likelihood	Initial Risk	Consequence	Likelihood	Initial Risk	Consequence	Likelihood	Initial Risk
55	Critical Infrastructure Failure	Shocks identified by Resilient Sydney	Direct	**Electrical network outages** Direct: As utility transitions to a smart grid and away from baseload coal and gas generation more grid instability is likely in the short to medium term as involuntary load shedding occurs over peak days.	Integrated	Financial Infrastructure Economy	Major	Moderate	High	Major	Moderate	High	Major	Moderate	High
56	Critical Infrastructure Failure	Shocks identified by Resilient Sydney	Direct	**Water quality** Direct: Drinking water quality can be affected by periods of low rain or bushfire smoke and runoff into dams leading to 'boil water' alerts to prevent water borne infections.	Integrated	Financial Social	Moderate	Likely	Medium	Moderate	Likely	Medium	Moderate	Likely	Medium
57	Critical Infrastructure Failure	Shocks identified by Resilient Sydney	Direct	**Transport network failures** Direct: Road, public transport, or airport services are interrupted leading to commuters being stranded.	Place-based	Financial Infrastructure Economy	Moderate	Almost Certain	High	Minor	Almost Certain	Medium	Minor	Almost Certain	Medium
58	Critical Infrastructure Failure	Shocks identified by Resilient Sydney	Indirect	**Healthcare services overloaded** Indirect: Public buildings (not private offices) can be co-opted under public health orders, like schools, halls leading to business interruption.	Process-oriented	Financial Economy Social	Minor	Unlikely	Low	Minor	Unlikely	Low	Minor	Unlikely	Low
59	Shift in Business Models	Shocks identified by Resilient Sydney	Indirect	**Shift in mobility systems** Indirect: Electrification of personal transport results in large shift demand profiles on electricity grid.	Integrated	Financial Infrastructure	Minor	Likely	Medium	Minor	Almost Certain	Medium	Minor	Almost Certain	Medium
60	Shift in Business Models	Stresses related to social changes	Indirect	**Cultural backgrounds** Indirect: Increased immigration leads to different and unpredictable expectations for and uses of public space and amenity type.	Integrated	Financial Economy Social	Minor	Likely	Medium	Minor	Likely	Medium	Minor	Likely	Medium
61	Shift in Business Models	Stresses related to social changes	Indirect	**Changing demographics** Indirect: Changes in expected or projected demographics for the precinct, city or region result in shift in job market and programmatic needs.	Integrated	Financial Infrastructure Social	Moderate	Likely	Medium	Moderate	Likely	Medium	Moderate	Likely	Medium
62	Shift in Business Models	Stresses related to social changes	Indirect	**Shift in workplace needs** Indirect: Long term changes in business models and operations leads to major changes in workplace requirements and buildings requiring substantial retrofits to be fit for purpose.	Place-based	Financial Infrastructure Social	Moderate	Likely	Medium	Moderate	Likely	Medium	Moderate	Likely	Medium
63	Shift in Business Models	Stresses related to social changes	Indirect	**Ageing population** Indirect: Ageing population leads to increasing demand for healthcare and allied wellbeing services along with potential reductions in workforce.	Place-based	Financial Economy Social	Moderate	Likely	Medium	Moderate	Likely	Medium	Moderate	Likely	Medium
64	Shift in Business Models	Stresses related to social changes	Indirect	**Carbon pricing** Indirect: The introduction of carbon pricing for business operations leads to elevated operational costs for businesses who may seek alternative accommodation with reduced carbon footprints.	Process-oriented	Financial Economy Social	Moderate	Likely	Medium	Moderate	Almost Certain	High	Moderate	Almost Certain	High

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Key Criteria (AS 5334)	2036			2056			2090		
							Consequence	Likelihood	Initial Risk	Consequence	Likelihood	Initial Risk	Consequence	Likelihood	Initial Risk
65	Shift in Business Models	Stresses related to social changes	Indirect	**Changing residential models** Indirect: Shifts in demand for housing types leads to increased vacancies and stranded assets.	Process-oriented	Financial Economy Social	Moderate	Moderate	Medium	Moderate	Moderate	Medium	Moderate	Moderate	Medium
66	Social Stresses	Stresses related to social changes	Indirect	**Increasing inequality** Indirect: Increasing economic inequality leads to reciprocal problems of increased vacancy rates and crime.	Integrated	Financial Economy Social	Minor	Moderate	Low	Minor	Moderate	Low	Minor	Moderate	Low
67	Social Stresses	Stresses related to social changes	Indirect	**Housing affordability** Indirect: Decreasing housing affordability leads to increased vacancy rates for residential buildings and population shift to other cities.	Integrated	Financial Economy Social	Moderate	Moderate	Medium	Moderate	Moderate	Medium	Moderate	Moderate	Medium
68	Social Stresses	Stresses related to social changes	Indirect	**War** Indirect: Conflict directly or indirectly involving the region or population which has a consequential effect on potential precinct use.	Integrated	Financial Economy Social	Major	Moderate	High	Major	Moderate	High	Major	Moderate	High
69	Social Stresses	Stresses related to social changes	Indirect	**Homelessness** Indirect: Increasing homelessness results in reduced demand for residential programs, and increasing pressure on public domain services.	Place-based	Financial Infrastructure Social	Minor	Moderate	Low	Minor	Moderate	Low	Minor	Moderate	Low
70	Social Stresses	Stresses related to social changes	Indirect	**Financial collapse** Indirect: Global or National financial and economic downturn leads to increased vacancy rates from reduced capital inflows.	Place-based	Financial Economy Social	Major	Moderate	High	Major	Moderate	High	Major	Moderate	High

6.0 Adaptation Plan

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Incumbent adaptation measures	Potential additional adaptation measures	Design Measure Responsibility	Mitigation Stage				Consequence	Likelihood	Reassessed Risk
									Precinct Planning	Detailed Design	Procurement	Operations			
01	Sea surface temperature	Increase in sea level	Direct	**Inundation** Direct: Potential for inundation of infrastructure during storms resulting in flood damage and safety risk from backed up overland flow.	Place-based	-- no adaptation measures currently in master plan -- basements designed as drainage channels and need further consideration -- Subsequent adaptation measures TBD -- NOTE: Council flood modelling, which includes sea level rise consequences, to be reviewed through consultation with Council -- NOTE: sea level rise consequences and adaptation measures to be determined as part of SSD process	-- TBD based on modelling results.	Arcadis	☑	☑			Minor	Very Unlikely	Low
02	Sea surface temperature	Increase in sea level	Direct	**Intrusion** Direct: Saltwater intrusion, contaminating water sources, impacting groundwater resources and landscaping, and/or increasing degradation of building materials (e.g. foundations)	Place-based		-- Flood modelling to take into account RCP 8.5 future sea level.	Arcadis	☑	☑			Minor	Very Unlikely	Low
03	Temperature	Increase in mean maximum temperature	Direct	**Electrical assets - power supply on site** Direct: Extended high temperatures may have an adverse impact on the operation of some electrical equipment, such as components in kiosks or sub-substations or external control cabinets or switchboards or LED's used in street lighting leading to system failure or service interruptions.	Integrated	--HVAC loads – increasing capacity. -- Substation footprints take into account increased loads. -- Building designs minimise loads. -- Energy demand modelling should include future temperature projections to allow adequate planning for power infrastructure upgrades associated with the precinct's redevelopment. -- All equipment and materials consider RCP 8.5 conditions.		Architectus TfNSW	☑	☑	☑		Moderate	Unlikely	Medium
04	Temperature	Increase in mean maximum temperature	Direct	**Structure** Direct: Structural materials may be affected by extreme heat, leading to structural fatigue.	Process-oriented	-- Minimum design life specified for infrastructure takes into consideration solar exposure durability under RCP 8.5 climate scenarios. -- Whole-of-life materials approach to consider material degradation under RCP 8.5 climate scenarios in life cycle analysis (LCA).		Arcadis TfNSW	☑	☑			Insignificant	Very Unlikely	Low

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Incumbent adaptation measures	Potential additional adaptation measures	Design Measure Responsibility	Mitigation Stage				Consequence	Likelihood	Reassessed Risk
									Precinct Planning	Detailed Design	Procurement	Operations			
05	Temperature	Increase in mean maximum temperature	Indirect	**Deterioration** Indirect: Increased mean maximum temperature and solar exposure may lead to greater material degradation and need for building and infrastructure maintenance	Integrated	-- Careful detailing for differential expansion where composite elements are used. -- Regular maintenance and inspection cycle to identify potential issues for rectification.		Arcadis TfNSW	☑	☑		☑	Insignificant	Almost Certain	Low
06	Temperature	Increased annual mean temperature	Direct	**Biodiversity colapse** Direct: Loss of biodiversity and ecosystem function (e.g. extreme heat mortality)	Integrated	-- Plant selection includes a diversity of locally indigenous species adaptive to RCP 8.5 climate conditions. -- Develop support system for Central surrounds. -- Support community stewardship programs.	-- Landscapes designed to provide shelter to local fauna during times of heat stress in the form of beehives, nesting boxes, structured earth forms, and select vegetation.	TfNSW Ethos Urban Tyrrell Studio	☑	☑	☑		Insignificant	Unlikely	Low
07	Temperature	Increased annual mean temperature	Direct	**Landscapes** Direct: Combined with lower rainfall will result in the loss of many plant species and less vigorous growth of many of the survivors, issues with management of pest plants and animals, loss of landscape amenity.	Place-based	-- Balance of high- and low-evapotranspirative plant species takes into account RCP 8.5 climate predictions. -- Stormwater collection and storage on deck used to irrigate landscapes. -- Recycled water supply for reliable irrigation.		Arcadis Tyrrell Studio	☑	☑			Minor	Almost Certain	Medium
08	Temperature	Increased annual mean temperature	Indirect	**Energy costs** Indirect: Increase in average temperatures may lead to an increase in energy demand and associated utility costs.	Integrated	-- Building design prioritises passive design and world's best practice energy efficiency. -- Precinct and building energy storage.	-- Embedded network(s), virtual power plant(s), microgrid, precinct-scale systems	TfNSW	☑	☑			Insignificant	Likely	Low
09	Temperature	Increased number of hot days over 35°C	Direct	**Heat Islands** Direct: Increases in number of days above 35°C may contribute towards urban heat island effects, leading to reduced comfort and increased complaints from building occupants and pedestrians	Integrated	-- Urban forest strategy with vegetation and canopy coverage targets in line with City of Sydney's Greening Sydney Strategy (Draft) will reduce regional UHI effects. -- Smaller evapotranspiration gardens for urban cooling provide local areas of respite for visitors. -- Passive naturally ventilated buildings – floor plates and wintergardens; timber construction reducing thermal mass; adaptive comfort -- Provision of mechanically cooled, freely accessible community facilities (such as play areas, libraries etc) and commercial areas provides a place of refuge during extreme heat days.	-- Ground source cooling - utilising aquifers -- Other WSUD strategies? - swales, basins, wetlands, ponds, permeable pavement -- Green roofs/walls/facades -- Materials - light coloured roofing, concrete, asphalt, high-reflectivity	Architectus Tyrell Studio	☑	☑			Minor	Almost Certain	Medium

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Incumbent adaptation measures	Potential additional adaptation measures	Design Measure Responsibility	Mitigation Stage				Consequence	Likelihood	Reassessed Risk
									Precinct Planning	Detailed Design	Procurement	Operations			
10	Temperature	Increased number of hot days over 35°C	Direct	**Thermal comfort** Direct: HVAC system may experience overload, affecting thermal comfort for building occupants, and increasing HVAC maintenance and operating costs.	Integrated	-- All new buildings are to have the capacity for at least 80% of GFA to be naturally ventilated -- Building design controls require passive performance through 80W/m² max solar load in perimeter zones -- World's best practice energy efficiency assured through Green Star and NABERS		Architectus TfNSW	☑	☑	☑		Insignificant	Likely	Low
11	Temperature	Increased number of hot days over 35°C	Direct	**Network blackouts** Direct: Frequent interruptions to mains power supply can lead to service interruption, power losses to infrastructure and buildings.	Place-based	-- Passive design. -- On site energy storage as a minimum, explore on site generation on roofs, facades and integrated into public realm structures. -- Divert emergency power to vertical transportation. -- Buildings designed to operate during network blackout. -- Embed requirement to design for RCP 8.5 climate scenarios.	-- Space considerations for future battery storage either at building or precinct-scale	Architectus	☑	☑			Minor	Moderate	Low
12	Precipitation	Greater frequency of higher intensity rainfall events	Direct	**Flood immunity** Direct: Greater frequency of higher intensity rainfall events may lead to changes in flood immunity levels.	Place-based	-- Bradfield siding tracks have been designed for overland flow drainage -- Western forecourt designed to direct overland flows and avoid flooding -- Deck / OSD rainwater capture will mitigate some flooding effects, size of storage needed -- Basement entrance levels set in alignment with City of Sydney thresholds.	-- Increase basement threshold height.	Arcadis	☑	☑			Minor	Moderate	Low
13	Precipitation	Greater frequency of higher intensity rainfall events	Direct	**Building structures - floor levels and roof drainage** Direct: Greater frequency of higher intensity rainfall events may lead to localised flooding, damage due to scour and less safe operating conditions.	Place-based	-- Embed requirement to design for RCP 8.5 climate scenarios in each package. -- WSUD to reduce pressure on municipal systems		Arcadis Tyrrell Studio	☑	☑			Minor	Likely	Medium
14	Precipitation	Greater frequency of higher intensity rainfall events	Direct	**Egress** Direct: Greater frequency of higher intensity rainfall events may increase events that limit access and egress, resulting in tenants being stranded at the development.	Place-based	-- Ensure multiple egress routes from precinct in all directions at varying RLs.		Architectus	☑	☑			Minor	Unlikely	Low
15	Precipitation	Greater frequency of higher intensity rainfall events	Direct	**Erosion** Direct: Greater frequency of higher intensity rainfall events may increase the potential for erosion causing potential infrastructure	Process-oriented	-- Development is almost entirely above ground with only very minor excavation - only real threat of erosion is during construction. Main civil works contractor to have best practice OH&S procedures and EMP in place prior to work commencing.		Civil Works Contractor			☑		Insignificant	Very Unlikely	Low

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Incumbent adaptation measures	Potential additional adaptation measures	Design Measure Responsibility	Mitigation Stage				Consequence	Likelihood	Reassessed Risk
									Precinct Planning	Detailed Design	Procurement	Operations			
				instability and disruption or safety risk in the event of collapse.											
16	Precipitation	Greater frequency of higher intensity rainfall events	Direct	**Civil drainage** Direct: Greater frequency of higher intensity rainfall events may lead to inundation of drainage infrastructure as a result of insufficient system capacity, with resulting damage on site or adjacent, service disruption and safety risk.	Process-oriented	-- Embed requirement to design for RCP 8.5 climate scenarios in each package. -- WSUD to reduce pressure on municipal systems		TfNSW	☑	☑			Minor	Moderate	Low
17	Precipitation	Greater frequency of higher intensity rainfall events	Direct	**Rail inundation - downstream effects** Direct: Greater frequency of higher intensity rainfall events may overwhelm civil drainage infrastructure resulting in inundation of rail corridors.	Process-oriented	-- Sufficient drainage to prevent downstream inundation.		Arcadis	☑	☑			Minor	Moderate	Low
18	Precipitation	Greater frequency of higher intensity rainfall events	Indirect	**Insurance premiums** Indirect: Greater frequency of higher intensity rainfall events leading to flooding causing damage to structures which may lead to increased insurance premiums for assets	Process-oriented	-- Incumbent adaptaton measures combined with world's best practice assurance certifcation provide security to potential future insurance brokers. -- Climate Adaptaton Plan (CAP) to be updated regularly to include latest information.		TfNSW		☑			Minor	Moderate	Low
19	Drought	Decrease in annual total rainfall	Direct	**Erosion**Direct: Decrease in annual total rainfall may increase the potential for erosion causing infrastructure instability, scour and safety risk in the event of collapse.	Process-oriented	- Development is almost entirely above ground with only very minor excavation - only real threat of erosion is during construction. Main civil works contractor to have best practice OH&S procedures and EMP in place prior to work commencing.		TfNSW			☑		Insignificant	Very Unlikely	Low
20	Drought	Decrease in annual total rainfall	Indirect	**Landscapes** Indirect: Decrease in annual total rainfall leading to a reduction in regional water storages and reduce water supplies making it difficult to water landscaping.	Place-based	-- Recycled water supply ensures reliable irrigation. -- Onsite rainwater storage.		Arcadis Tyrell Studio	☑	☑			Minor	Likely	Medium

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Incumbent adaptation measures	Potential additional adaptation measures	Design Measure Responsibility	Mitigation Stage				Consequence	Likelihood	Reassessed Risk
									Precinct Planning	Detailed Design	Procurement	Operations			
21	Drought	Decrease in annual total rainfall	Indirect	**Potable water availability** Indirect: Decrease in annual total rainfall may result in water restrictions prohibiting water use in heat rejection.	Process-oriented	-- World's best practice water efficiency assured through Green Star and NABERS reduce pressure on municipal water systems. -- Onsite recycling ensures full water allotment from Sydney Water can be used for potable needs.		TfNSW		☑			Minor	Likely	Medium
22	Drought	Decrease in annual total rainfall	Indirect	**Potable water pricing** Indirect: Decrease in annual total rainfall may result in water restrictions and pricing impacts on tenants, running costs of water cooled systems for building owners.	Process-oriented	-- Cost risk minimised through potable water conservation.		TfNSW		☑			Minor	Likely	Medium
23	Wind	Increased wind speeds	Direct	**Debris** Direct: Increasing wind speeds may dislodge loose furniture or equipment (including vegetation) damaging exposed plant equipment and facades, or make the public domain unsafe.	Integrated	-- Design constrol require appropriate façade performance. -- Tree species selected for appropriateness to wind environments.		Architectus Tyrell Studio	☑	☑			Moderate	Unlikely	Medium
24	Wind	Increased wind speeds	Direct	**Wind driven rain** Direct: Increasing wind speeds coupled with greater frequency of higher intensity rainfall events may lead to wind driven rain flooding upper levels and penetrating facades.	Place-based	-- High performance facades eliminate thermal bridging, condensation, and water penetration.		Architectus		☑			Insignificant	Moderate	Low
25	Wind	Increased wind speeds	Direct	**Pedestrian comfort and safety - wind tunnels** Direct: Increasing wind speeds exacerbated by tall buildings and the elevated deck may lead to wind tunnel conditions making the public realm uncomfortable and potentially unsafe.	Place-based	-- Building arrangement optimised to mitigate against wind tunnels and reduce the impact of high winds resulting from extreme storms.	-- Additional localised protection from structures or vegetation.	Architectus	☑	☑			Minor	Likely	Medium
26	Wind	Increased wind speeds	Direct	**Structure** Direct: Increase in wind speeds may impact the structural integrity of some infrastructure elements	Process-oriented	-- Design Guide requires design to RCP 8.5 future climate scenarios.		Arcadis	☑	☑			Insignificant	Very Unlikely	Low
27	Wind	Increased wind speeds	Direct	**Electrical assets** Direct: Wind damage to electrical circuitry (overhead wiring) may result in disruption to services and increase maintenance costs.	Process-oriented	-- All electrical and ICT wiring is underground. -- Above ground electrical assets/structures designed to withstand RCP 8.5 wind scenarios.		Arcadis	☑	☑			Minor	Moderate	Low

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Incumbent adaptation measures	Potential additional adaptation measures	Design Measure Responsibility	Mitigation Stage				Consequence	Likelihood	Reassessed Risk
									Precinct Planning	Detailed Design	Procurement	Operations			
28	Extreme storms	Increase in extreme hailstorm events	Direct	**Hail storms** Direct: Increase in extreme hailstorm events may damage to cladding, exposed plant and services, landscapes, entryways and horizontal/sloped glazing.	Integrated	-- Design Guide requires design to RCP 8.5 including increased intensity hail storms	-- Covered access throughout public domain.		☑	☑			Minor	Almost Certain	Medium
29	Extreme storms	Increase in extreme hailstorm events	Direct	**Drainage** Direct: Increase in extreme hailstorm events may overload roof drainage for buildings and result in water damage.	Process-oriented	-- Drainage design sufficient to manage hail.			▪	☑			Minor	Likely	Medium
30	Extreme storms	Increase in frequency and severity of storms	Direct	**Dust storms** Direct: Last major dust storm 2009, combination of drought, hot weather and westerly wind. Increased risk of systems damage and occupant respiratory illness	Integrated	-- Significant public domain landscaping to capture particulate matter -- Building airtightness detailing to prevent uncontrolled dust ingress -- Improved HVAC intake filtration		Architectus Tyrell Studio	☑	☑			Minor	Almost Certain	Medium
31	Extreme storms	Increase in frequency and severity of storms	Indirect	**Usability** Indirect: Increase in frequency and severity of storms may lead to reduced usability and increased complaints.	Integrated	-- Place-based adaptation measures mitigate potential effects on tenants, residents, and businesses. -- Climate Adaptation Plan provides future residents, businesses, tenants, and visitors with transparency around potential risks from climate change and integrated adaptation measures.	-- Community Resilience Plan provides future residents, businesses, tenants, and visitors with clarity and confidence around preparation, during- and postdisaster communication, safety, and response.	Atelier Ten / Integral Group TfNSW	☑	☑	☑	☑	Insignificant	Unlikely	Low
32	Extreme storms	Increase in frequency and severity of storms	Indirect	**Displacement** Indirect: Increase in frequency and severity of storms may result in damage to properties, causing displacement and disruption of tenant / business activity during clean up and repair.	Process-oriented	-- Place-based adaptation measures mitigate potential effects on tenants, residents, and businesses. -- Regular monitoring, evaluation and review of Climate Adaptation Plan and Community Resilience Plan to ensure it remains valid.	-- Develop a Community Resilience Plan in line with Green Star Communities requirements that addresses preparation, during- and postdisaster communication, safety, and response.	Atelier Ten / Integral Group TfNSW	☑	☑	☑	☑	Minor	Unlikely	Low
33	Extreme storms	Increasing frequency of electrical storms and lightning strikes	Direct	**Lightning strike** Direct: Increasing frequency of electrical storms and lightning strikes can damage building elements, pubic infrastructure, and electrical systems either directly or indirectly through fire.	Process-oriented	-- Earthing of all structures -- Surge protection for all power supply and ICT cabling. -- Surge protection for all public domain structures (i.e. lighting, security, sensoring). -- Surge protection for all on electricity site generation and power storage.			☑	☑			Minor	Likely	Medium

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Incumbent adaptation measures	Potential additional adaptation measures	Design Measure Responsibility	Mitigation Stage				Consequence	Likelihood	Reassessed Risk
									Precinct Planning	Detailed Design	Procurement	Operations			
34	Humidity	Changes to relative humidity	Direct	**Maintenance** Direct: Build-up of mould and condensation leading to increased operations and maintenance requirements and costs.	Integrated	-- Design of public domain ensures adequate drainage of excess water, no standing water, and enhances evaporation from sun and wind. -- All new buildings provide enhanced ventilation capability for indoor spaces including natural ventilation, high rate of outdoor air supply, and highly filtered recirculated air. -- High performance facades eliminate thermal bridging, condensation, and water penetration. -- Specify mould resistant materials in areas prone to increased humidity.		Arcadis Architectus TfNSW	☑	☑	☑		Insignificant	Likely	Low
35	Humidity	Changes to relative humidity	Direct	**Deterioration** Direct: Accelerated carbonation of concrete structures.	Process-oriented	-- Design of concrete structures to consider RCP 8.5 climate scenarios.	-- Anti-carbonation coatings can be applied to the cleaned surface of the concrete to prevent the ingress of carbon dioxide and other pollutants. -- Decrease water/cement ratio, water/binder ratio, and/or slump value in concrete structures. -- Increase strength and porosity of concrete structures with admixtures, ground granulated blast furnace slag (GGBS), and/or silica fume (SF). -- Apply substantial cover to reinforcement. -- Increase curing periods.	Arcadis	☑	☑			Minor	Moderate	Low
36	Humidity	Changes to relative humidity	Direct	**Thermal comfort** Direct: Changes in relative humidity resulting in decreasing thermal comfort resulting in health impacts or decreased productivity.		-- Extensive shading in the public realm from tree canopy and buildings. -- High performance facades eliminate thermal bridging, condensation, and water penetration.	-- Design buildings and public domain to capture cool breezes during summer months when relative huidity is highest. -- Integrate fans and other methods of mechanically moving air in the public domain.		☑	☑			Minor	Likely	Medium
37	Humidity	Changes to relative humidity	Indirect	**Pest distribution** Indirect: Changes in humidity may increase encroachment pest species.	Integrated	-- Regular landscape maintenance and monitoring to ensure optimal growth and health of landscapes, and identification of any issues. -- Specify durable, pest resistant materials in the public domain and other areas prone to pest encroachment. -- Design landscapes and infrastructure for easy inspection. -- Effectively seal or screen off all openings to exclude pests and eliminate potential harbourage. -- Engineer slabs and foundations to minimise pest entry. -- Design buildings to be unattractive to pests.	-- Prioritise cultural, mechanical, biological, and biorational management of pests in the landscape so as not to encourage the development of pesticide resistance.	Arcadis Tyrrell Studio TfNSW	☑	☑	☑	☑	Minor	Unlikely	Low

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Incumbent adaptation measures	Potential additional adaptation measures	Design Measure Responsibility	Mitigation Stage				Consequence	Likelihood	Reassessed Risk
									Precinct Planning	Detailed Design	Procurement	Operations			
38	Humidity	Changes to relative humidity	Indirect	**Disease transmission** Indirect: Changes in humidity may increase the spread of waterborne diseases.	Place-based	-- Design of public domain ensures adequate drainage of excess water, and enhances evaporation from sun and wind. -- All new buildings provide enhanced ventilation capability for indoor spaces including natural ventilation, high rate of outdoor air supply, and highly filtered recirculated air.		Arcadis Architectus	☑	☑			Minor	Unlikely	Low
39	Humidity	Changes to relative humidity	Indirect	**Energy costs** Indirect: Increase in relative humidity may lead to an increase in energy demand and associated utility costs.	Place-based	-- Building design prioritises passive design and world's best practice energy efficiency. -- Precinct and buildings incorporate energy storage.	-- Onsite renewable energy generation.	Arcadis	☑	☑			Minor	Likely	Medium
40	Bushfire	Increase in risk of bushfires	Direct	**Air quality** Direct: Increase in number of severe fire weather risk days leading to exposure to smoke and particulate pollution for workers and visitors, that may cause respiratory distress, as well as reduced visibility.	Integrated	-- Design Guide requires for HVAC systems to be able to either shut-off outdoor air supply and/or provide space allowance for additional filters to be able to be dropped in when required. -- Areas of respite for visitors. -- Public help points for people requiring medical assitance.	-- Emergency medical equipment (defibrilators) in building lobbies.	Architectus TfNSW	☑	☑	☑		Minor	Almost Certain	Medium
41	Solar radiation	Increase in level of UV	Direct	**Occupants, Workers and Visitor Health** Direct: Increased incidence of sunburn and associated skin cancer risks, sun stroke. Outdoor public domain and private balconies terraces key areas to consider	Integrated	-- Extensive shading in the public realm from tree canopy and structures. -- Areas of respite for visitors. -- Public help points for people requiring medical assitance.	-- Covered access throughout public domain and along active transport routes. -- Emergency medical equipment (defibrilators) in building lobbies.	Architectus Tyrell Studio TfNSW	☑	☑	☑	☑	Insignificant	Almost Certain	Low
42	Solar radiation	Increase in level of UV	Direct	**Life cycle** Direct: Increased levels of UV could contribute to the increased rate of photo-oxidation and result in a shorter expected life of materials, especially polymer based products.	Process-oriented	-- Membranes and any photosensitive exterior products, especially wiring, are protected from solar exposure.		Arcadis Architectus TfNSW	☑	☑			Insignificant	Almost Certain	Low
43	Solar radiation	Increase in level of UV	Direct	**Maintenance** Direct: Increased mean maximum temperature and solar exposure may lead to greater material degradation of assets, leading to increased need for infrastructure maintenance	Process-oriented	-- Whole-of-life materials approach to consider material degradation under RCP 8.5 climate scenarios in life cycle analysis (LCA). -- Regular maintenance and inspection cycle to identify potential issues for rectification.		Atelier Ten / Integral Group TfNSW	▪		☑	☑	Insignificant	Almost Certain	Low

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Incumbent adaptation measures	Potential additional adaptation measures	Design Measure Responsibility	Mitigation Stage				Consequence	Likelihood	Reassessed Risk
									Precinct Planning	Detailed Design	Procurement	Operations			
44	Waterway Health	Declining Waterway Health	Direct	**Infrastructure** Direct: The increasing extreme weather conditions over time, rainfall intensity, drought, rising temperature and UV radiation is likely to lead to declining waterway health and could result in the need to retrofit additional hydraulic infrastructure.	Process-oriented	-- Design of hydraulic infrastructure takes into account RCP 8.5 climate scenarios. -- Stormwater pollution flowing to Sydney Harbour cleaned beyond best practice guidelines.		Arcadis	☑	☑			Minor	Unlikely	Low
45	Waterway Health	Declining Waterway Health	Indirect	**Discharge Licence** Indirect: The increasing extreme weather conditions over time, rainfall intensity, drought, rising temperature and UV radiation is likely to lead to declining waterway health and could result in increasing and more stringent discharge obligations with greater operational cost implications.	Process-oriented	-- Stormwater pollution flowing to Sydney Harbour cleaned beyond best practice guidelines.		Arcadis	☑	☑			Insignificant	Moderate	Low
46	Waterway Health	Declining Waterway Health	Indirect	**Increased pressure** Indirect: Increased stress on old infrastructure through increasing density could lead to increased maintenance costs, increased risk of failure, and additional downstream effects.	Process-oriented	-- Design of hydraulic systems takes into account effect of RCP 8.5 climate scenarios on downstream infrastructure. -- Regular maintenance and inspection cycle to identify potential issues for rectification.		Arcadis TfNSW	☑	☑		☑	Minor	Moderate	Low
47	Civil Disturbance	Shocks identified by Resilient Sydney	Direct	**Terror attack - physical damage** Direct: Physcial damage to buildings and infrastructure from targetted blasts or explosions.	Integrated	-- OSD deck designed to withstand blast-effects. -- Car limited public domain minimises potential for blasts from vehicles. -- Crime prevention through environmental design (CPTED) strategies. -- Perimeter control devices and strategy pop up hardening.	-- Develop a Community Resilience Plan in line with Green Star Communities requirements that addresses preparation, during- and postdisaster communication, safety, and response.	TfNSW Architectus	☑	☑			Major	Moderate	High
48	Civil Disturbance	Shocks identified by Resilient Sydney	Direct	**Terror attack - pathological damage** Direct: Potential public health effects from chemical or other biological attack requiring isolation, quarantine, decontamination.	Integrated	-- Air intakes servicing occupied areas placed as high as practically possible. -- Physically isolate unsecured areas from secured areas. -- Commission building throughout construction and prior to taking ownership. -- Provide redundant, easily accessible shutdown capabilities. -- In public access areas, use air diffusers and return air grills that are secure or under security observation.	-- Develop a Community Resilience Plan in line with Green Star Communities requirements that addresses preparation, during- and postdisaster communication, safety, and response. -- Restrict access to critical equipment. -- Isolate separate HVAC zones and return air systems. -- Use positive pressurisation of primary egress routes, safe havens, and/or other critical areas. -- Zone the building communication	TfNSW Architectus	☑	☑	☑	☑	Major	Moderate	High

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Incumbent adaptation measures	Potential additional adaptation measures	Design Measure Responsibility	Mitigation Stage				Consequence	Likelihood	Reassessed Risk
									Precinct Planning	Detailed Design	Procurement	Operations			
							system so that it is capable of delivering explicit instructions, and has back-up power.								
49	Civil Disturbance	Shocks identified by Resilient Sydney	Direct	**Civil unrest** Direct: Localised effects of lawlessness around the asset leading to the need to temporarily shelter in place for building occupants and business interruption to tenants.	Integrated	-- Crime prevention through environmental design (CPTED) strategies. -- Egress routes lead to exits that are as far as possible from high-risk areas such as the lobby, mail room, and delivery entrance. -- Create pressurized safe havens in elevator vestibules and stairwells using tightly constructed, air-tight enclosures placed in a protected core area of the building. -- Emergency power provides sufficient lighting and or phosphorescence to lead persons safely out of the building.	-- Crime Risk Assessment -- Resilient power supply (see electrical infrastructure) or backup standby electricity.		☑	☑	▪	▪	Minor	Unlikely	Low
50	Civil Disturbance	Shocks identified by Resilient Sydney	Direct	**Cyber attack** Direct: Data connections to the asset or tenant become compromised and may lead to Building Control Management System being compromised and interrupting business operations.	Process-oriented	-- ICT infrastructure incorporates a diversity of entry points to the precinct and each building to support mutliple service providers and redundancy of connection. -- Easily accessible universal communication chambers. -- Secure and dedicated space for service providers to terminate their equipment separated from that of other utilities, such as electricity, gas or water, to reduce the personnel able to access the telco equipment servicing tenants.	-- Develop a Cyber Security and Risk Mitigation Plan. -- ICT Security of BCMS and other building systems that interface with online networks. -- ICT infrastructure backbone that supports a diversity of hardwired and wireless methods of communications.	TfNSW Arcadis	☑	☑			Minor	Moderate	Low
51	Civil Disturbance	Stresses identified by Resilient Sydney	Direct	**Disease pandemic** Direct: Interruptions to use of commercial offices during public health movement controls affecting business continuity leading to inefficient building operations at part loads and low occupancy.	Integrated	-- Design control for enhanced venilation.	-- Contactless building acccess and sanitary facilities. -- Floor by floor air-handling to prevent cross-floor transmission of airborne contaminants. -- Building design to incorporate occupancy sensors and partial floor shut-downs. -- Very low turndown HVAC equipment, including screw chiller and smart controls. -- Double air lock building entries allow potential for sanitisation / public health screening.	Architectus Atelier Ten / Integral Group TfNSW	☑	☑			Minor	Likely	Medium

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Incumbent adaptation measures	Potential additional adaptation measures	Design Measure Responsibility	Mitigation Stage				Consequence	Likelihood	Reassessed Risk
									Precinct Planning	Detailed Design	Procurement	Operations			
52	Civil Disturbance	Stresses identified by Resilient Sydney	Indirect	**Diminishing community Cohesion** Indirect: Evidence from places that have suffered extreme events shows constantly that mortality is highest where social cohesion is lowest. When people know each other, they look out and help one another through an extreme event.	Integrated	-- Social infrastructure for shelter -- Water fountains in public domain -- Shading -- Local social connectedness – casual social connection -- Mitigating rising local inequality – deliver initiative to address disadvantage			☑	☑	☑	☑	Minor	Unlikely	Low
53	Civil Disturbance	Stresses identified by Resilient Sydney	Indirect	**Financial crisis** Indirect: Local or global economic disturbance can lead to negative effects on asset value and utility, and becoming stranded.	Integrated	-- Diversity of program types and associated users. -- Buildings designed for second- and third-life uses allow for easy retrofit or reconfiguration. -- Commercial floorplates adaptable for big multi-floor tenants, or multiple single floor tenants.		Architectus TfNSW	☑	☑	☑	☑	Minor	Moderate	Low
54	Critical Infrastructure Failure	Additional acute shocks	Direct	**Logistics failure** Direct: Closure of loading docks and underground acess lane limiting supply of goods and services to public and private tenants and users.	Integrated		-- Diversity in ingress and egress routes from subterranean access tunnel. -- Ability to drive on deck to access buildings for deliveries. -- Perimeter parking for delivery drivers. -- Dynamic loading dock signage to advise status and procedures.	Arcadis Architectus TfNSW	☑	☑		☑	Moderate	Moderate	Medium
55	Critical Infrastructure Failure	Shocks identified by Resilient Sydney	Direct	**Electrical network outages** Direct: As utility transitions to a smart grid and away from baseload coal and gas generation more grid instability is likely in the short to medium term as involuntary load shedding occurs over peak days.	Integrated	-- Standby backup power generation per PCA A Grade requirements for 12 hour run on partial systems. -- Passive strategies to reduce cooling demand of critical infrastructure and increase thermal autonomy. -- Battery-ready buildings and/or precinct.		Arcadis Architectus TfNSW	☑	☑			Minor	Moderate	Low
56	Critical Infrastructure Failure	Shocks identified by Resilient Sydney	Direct	**Water quality** Direct: Drinking water quality can be affected by periods of low rain or bushfire smoke and runoff into dams leading to 'boil water' alerts to prevent water borne infections.	Integrated		-- Precinct water treatment for potable use. -- Monitor chemical and biological water quality. -- Ability for tenants to install boilers.	Architectus TfNSW	☑	☑		☑	Minor	Likely	Medium

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Incumbent adaptation measures	Potential additional adaptation measures	Design Measure Responsibility	Mitigation Stage				Consequence	Likelihood	Reassessed Risk
									Precinct Planning	Detailed Design	Procurement	Operations			
57	Critical Infrastructure Failure	Shocks identified by Resilient Sydney	Direct	**Transport network failures** Direct: Road, public transport, or airport services are interrupted leading to commuters being stranded.	Place-based	-- Access to a diversity of public transport types (train, bus, metro, light rail). -- End of trip facilities to encourage and facilitate active personal mobility. -- All buildings accessible by pedestrian and cycle routes. -- Significant comfortable public domain to provide respite to stranded commuters.	-- Provision of mechanically cooled, freely accessible community facilities (such as play areas, libraries etc) and commercial areas to provide protected areas of respite for stranded commuters.	Architectus Tyrell Studio TfNSW	☑	☑		☑	Minor	Almost Certain	Medium
58	Critical Infrastructure Failure	Shocks identified by Resilient Sydney	Indirect	**Healthcare services overloaded** Indirect: Public buildings (not private offices) can be co-opted under public health orders, like schools, halls leading to business interruption.	Process-oriented	-- ICT infrastructure supports remote working. -- Multiple building entrances to support separated dual building use.		TfNSW	☑	☑			Minor	Unlikely	Low
59	Shift in Business Models	Shocks identified by Resilient Sydney	Indirect	**Shift in mobility systems** Indirect: Electrification of personal transport results in large shift demand profiles on electricity grid.	Integrated	-- Energy demand modelling includes increase EV charging loads.	-- 100% of parking to EV charging. -- Loading dock to have infrastructure for future charging of logistics vehicles. -- EOT facilities to support charging of personal micromobility.	Arcadis Architectus TfNSW	☑	☑			Insignificant	Likely	Low
60	Shift in Business Models	Stresses related to social changes	Indirect	**Cultural backgrounds** Indirect: Increased immigration leads to different and unpredictable expectations for and uses of public space and amenity type.	Integrated	-- Flexible and diverse public domain.	-- Other adaptation measures TBD based on population and demographic study.	TfNSW Ethos Urban Tyrrell Studio	☑				Insignificant	Likely	Low
61	Shift in Business Models	Stresses related to social changes	Indirect	**Changing demographics** Indirect: Changes in expected or projected demographics for the precinct, city or region result in shift in job market and programmatic needs.	Integrated	-- Diversity of program types and associated users. -- Buildings designed for second- and third-life uses allow for easy retrofit or reconfiguration. -- Commercial floorplates adaptable for big multi-floor tenants, or multiple single floor tenants.	-- Other adaptation measures TBD based on population and demographic study.	Architectus TfNSW	☑	☑			Insignificant	Likely	Low
62	Shift in Business Models	Stresses related to social changes	Indirect	**Shift in workplace needs** Indirect: Long term changes in business models and operations leads to major changes in workplace requirements and buildings requiring substantial retrofits to be fit for purpose.	Place-based	-- Buildings designed for second- and third-life uses allow for easy retrofit or reconfiguration. -- Commercial floorplates adaptable for big multi-floor tenants, or multiple single floor tenants.		Architectus	☑	☑			Insignificant	Likely	Low
63	Shift in Business Models	Stresses related to social changes	Indirect	**Ageing population** Indirect: Ageing population leads to increasing demand for healthcare and allied wellbeing services along with potential	Place-based	-- Social infrastructure including healthcare services and allied community support services. -- Public domain supports formal and informal community use.	-- Housing supports ageing in place and multigenerational families. -- Diversity of commercial space types supports variety of health and wellbeing tenants.	TfNSW Ethos Urban Tyrrell Studio	☑	☑	☑	☑	Insignificant	Likely	Low

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Incumbent adaptation measures	Potential additional adaptation measures	Design Measure Responsibility	Mitigation Stage				Consequence	Likelihood	Reassessed Risk
									Precinct Planning	Detailed Design	Procurement	Operations			
				reductions in workforce.											
64	Shift in Business Models	Stresses related to social changes	Indirect	**Carbon pricing** Indirect: The introduction of carbon pricing for business operations leads to elevated operational costs for businesses who may seek alternative accommodation with reduced carbon footprints.	Process-oriented	-- Net zero carbon requirement mitigates risk. -- All-electric building operations eliminates gas price risk. -- Space for future energy storage to replace diesel generators.	-- Carbon offset mechanism built into leasing structure.	TfNSW	☑	☑		☑	Insignificant	Likely	Low
65	Shift in Business Models	Stresses related to social changes	Indirect	**Changing residential models** Indirect: Shifts in demand for housing types leads to increased vacancies and stranded assets.	Process-oriented		-- Diversity of housing types supporting all stages of life, ageing in place, mutligenerational families, social, affordable, and community housing, build-to-rent, rent-to-buy.	TfNSW	☑	☑			Insignificant	Moderate	Low
66	Social Stresses	Stresses related to social changes	Indirect	**Increasing inequality** Indirect: Increasing economic inequality leads to reciprocal problems of increased vacancy rates and crime.	Integrated	-- Diversity of program types and associated users. -- Integrate diverse physical social infrastructure facilities (e.g. health, education, arts and culture). -- Buildings designed for second- and third-life uses allow for easy retrofit or reconfiguration.	-- Stakeholder engagement. -- Community development.	Architectus Tyrrell Studio Ethos Urban TfNSW	☑	☑	☑	☑	Minor	Moderate	Low
67	Social Stresses	Stresses related to social changes	Indirect	**Housing affordability** Indirect: Decreasing housing affordability leads to increased vacancy rates for residential buildings and population shift to other cities.	Integrated	-- Integrate diverse physical social infrastructure facilities (e.g. health, education, arts and culture).	-- Diversity of housing types supporting all stages of life, ageing in place, mutligenerational families, social, affordable, and community housing, build-to-rent, rent-to-buy.	Architectus Ethos Urban TfNSW	☑	☑	☑	☑	Minor	Moderate	Low
68	Social Stresses	Stresses related to social changes	Indirect	**War** Indirect: Conflict directly or indirectly involving the region or population which has a consequential effect on potential precinct use.	Integrated	-- Diversity of program types and associated users. -- Buildings designed for second- and third-life uses allow for easy retrofit or reconfiguration.			☑	☑			Moderate	Moderate	Medium
69	Social Stresses	Stresses related to social changes	Indirect	**Homelessness** Indirect: Increasing homelessness results in reduced demand for residential programs, and increasing pressure on public domain services.	Place-based	-- Inclusive public domain that intentionally does not integrate hostile architecture. -- Integrate diverse physical social infrastructure facilities (e.g. health, education, arts and culture).	-- Diversity of housing types supporting all stages of life, ageing in place, mutligenerational families, social, affordable, and community housing, build-to-rent, rent-to-buy. -- Compassionate infrastructure support increased use by homeless people. -- Durable materials and maintenance startegies to support increased use.	Architectus Tyrrell Studio Ethos Urban TfNSW	☑	☑	☑	☑	Minor	Moderate	Low

Risk ID	Element	Variable	Exposure	Potential Impact	Response required	Incumbent adaptation measures	Potential additional adaptation measures	Design Measure Responsibility	Mitigation Stage				Consequence	Likelihood	Reassessed Risk
									Precinct Planning	Detailed Design	Procurement	Operations			
70	Social Stresses	Stresses related to social changes	Indirect	**Financial collapse** Indirect: Global or National financial and economic downturn leads to increased vacancy rates from reduced capital inflows.	Place-based	-- Diversity of program types and associated users. -- Buildings designed for second- and third-life uses allow for easy retrofit or reconfiguration.		Architectus TfNSW	☑	☑			Moderate	Moderate	Medium

7.0 Monitoring and review

This CAP is a living document and will continue to be revised as climate change risks and associated opportunities change over time. As this is the first adaptation plan for the development, many of the proposed actions focus on improving our understanding of climate risks and integrating climate change into existing activities.

To ensure that the development's adaptation responses and approaches remain valid and relevant to local priorities and climatic conditions, a recommendation would be to review and update the CAP every five years and/or review the risks identified in this plan annually, as per standard risk management practices.

These reviews may re-assess the development's risk profile in consideration of changes to climate change information, policy, assets, and activities. Consideration should also be given to the potential opportunities and benefits that may arise as a result of the changing climate and policy environment (e.g. new funding sources, opportunities for the development of renewable energy or green business precincts). Reviews may also cover monitoring on the progress of adaptation actions. Regular and ongoing reporting of the region's climate change adaptation performance is critical to inform decision making and motivate changes in behaviour. Consideration in annual budgets, internal reporting and communication is recommended to ensure that decision-makers, staff, and the community are aware of progress in implementing the adaptation actions outlined in this CAP.

8.0 Assurance

8.1 Green Star Communities

The following table indicates documentation requirements for Green Star Communities v1.1 Credit 04 – Adaption and Resilience:

Requirements		Included	Reference
4.1.1	The CAP must be developed in accordance with a recognised standard by a suitably qualified professional.		
	Provide the name and contact details of the Suitably Qualified Professional with a formal tertiary environmental science or planning qualification	☑	10.2 CV, p. 64
	The Climate Adaptation Plan has been developed using one of the following recognised standards: – ISO 31000:2009 and the Australian Greenhouse Office (AGO) Climate Change Risks and Impacts: A Guide for Government and Business 2006. – Australian Standard AS 5334:2013 Climate change adaptation for settlements and infrastructure - A risk based approach.	☑	2.2 Guiding instruments, p. 13
4.1.2	The CAP must and contain at least the following information:		
	a. Summary of the project site's characteristics.	☑	3.1 Project, p. 18
	b. A list of identified assets or asset classes.	☑	Table 3.2: Asset or Asset Class – AS 5334-2013 (Standards Australia 2013), p. 20
	c. Assessment of climate change impacts on the project site using at least two time scales.	☑	5.0 Risk assessment, p. 33
	d. Identification of the potential risks (likelihood and consequence) for each identified asset or asset class and the potential risks to people.	☑	5.0 Risk assessment, p. 33
	e. A list of actions and responsibilities for all high and extreme risks identified.	☑	6.0 Adaptation Plan, p. 41
	f. Details of stakeholder consultation undertaken during plan preparation and how these issues have been incorporated.	☑	Table 2.2: Stakeholder engagement activities, p. 16
4.1.3	The risk identification has considered the resilience of key project assets and key infrastructure.	☑	
4.1.4	The CAP includes a timetable for regular review and requires updates where necessary. As a minimum the plan will be reviewed whenever the base information required to develop the relevant climate change scenarios is updated.	☑	7.0 Monitoring and review, p. 55
4.1.5	The climate change scenarios used were sourced from the Intergovernmental Panel on Climate Change (IPCC) endorsed Global Circulation Models (GCMs) and may include Commonwealth Scientific and Industrial Research Organisation (CSIRO), State or	☑	2.3 Data sources, p. 15

Requirements		Included	Reference
	Federal climate projections or more detailed climate modelling software.		
	Provide details of, and justify the use of ,the climate change scenarios used by the project for the Climate Adaptation Plan.	☑	Table 4.2: Development time scales decriptions, p. 23
4.1.6	The assessment of climate change impacts addresses a minimum of two appropriate time scales (e.g. 2030, 2040, 2050 and 2070) for the primary and secondary effects.	☑	5.0 Risk assessment, p. 33
The following **primary effects** are addressed in the Climate Adaptation Plan for the two selected timescales:			
	Air temperature	☑	Risk IDs 03-11
	Solar radiation	☑	Risk IDs 41-43
	Precipitation	☑	Risk IDs 12-18
	Sea surface temperature	☑	Risk IDs 01-02
	Humidity	☑	Risk IDs 34-39
	Wind	☑	Risk IDs 23-27
The following **secondary effects** are addressed in the Climate Adaptation Plan for the two selected timescales:			
	Relative humidity	☑	Risk IDs 34-39
	Bushfire weather	☑	Risk ID 40
	Sea level rise	☑	Risk IDs 01-02
	Coastal inundation	☒	N/A
	Cyclones	☑	Risk IDs 28-33
	Flood	☑	Risk IDs 12-13
	Heatwave	☑	Risk IDs 09-11
	Drought	☑	Risk IDs 19-22
4.1.7	Implementation of the Climate Adaptation Plan.		
	A minimum of two risk items identified in the risk assessment component of the Climate Adaptation Plan have been addressed by specific design responses.	☑	6.0 Adaptation Plan, p. 41
	All risk items identified as 'high' or 'extreme' have been addressed by specific design responses.	☑	6.0 Adaptation Plan, p. 41
Copy of CV of suitably qualified professional who developed the plan		☑	10.2 CV, p. 64
Evidence demonstrating the design responses to the Climate Adaptation Plan		☒	Not included

9.0 Conclusion

This Central Precinct Climate Adaptation Plan features a risk assessment in accordance with the Australian Standard AS 5334-2013 'Climate change adaptation for settlements and infrastructure' and with further guidance from ISO 31000-2009 – Risk Management – Principles and Guidance; and AGO, Climate Change Risks and Impacts: A Guide for Government and Business.

The assessment of climate change impacts has addressed three time scales relevant to infrastructure design for the primary effects of temperature, precipitation and sea-level rise. The risk assessment has also considered the secondary effects of relative humidity, drought/flood, wind, cyclones and bushfire. In addition to the climate related impacts a series of social, cultural, economic and political disturbances have been addressed, based on those identified in Resilient Sydney (2018).

All 70 potential risks identified in the risk assessment component of the Climate Adaptation Plan have been addressed by specific design and operational adaptation measures to reduce the likelihood of that event occurring, as detailed in 6.0 Adaptation Plan. All 2 extreme risks have been mitigated, all but 2 high risks have been mitigated to medium level risks and 15 medium risks have been mitigated to low level risks through adaptation measures.

10.0 Appendices

10.1 Climate Data

10.1.1 Temperature

Average annual temperature

Maximum temperatures are projected to rise by an average of 1.94ºC by 2070. The greatest increases are occurring around Blackheath and the far southwest, while the remainder of Sydney will see an increase of maximum temperatures at least 1.57ºC. All models show there are no declines in maximum temperatures across Metropolitan Sydney.

TABLE 10.1: NARCLIM MEAN MAX. AND MIN. TEMPERATURES

Observatory Hill Lat:-33.859 Lon:151.205		Baseline 1990-2016		2020-2039		2060-2079	
		NARCliM	BOM (local)	Average Change	Range	Average Change	Range
Mean Max Temperature (°C	Period	22.60°C	21.8°C	+0.69°C	+0.35 to +0.98°C	+1.94°C	+1.57 to +2.48°C
	Highest Outright	*45.8°C (18th Jan 2013)*					
Mean Min Temperature (°C)	*Period*	*14.47°C*	13.8°C	+0.64°C	+0.41 to +0.76°C	+2.02°C	+1.44 to +2.47°C
	Min. Outright	*8.1°C (12 July 1890)*					

In 2070 the mean maximum temperature will be approximately 23.74 ºC based on the local baseline.

Minimum temperatures are also projected to rise by 2.02 ºC by 2070. The greatest increases projected are from Campbelltown to north of Wiseman's Ferry, while large increases are also being seen around Mount Victoria and Blackheath. Sydney will see an increase in minimum temperature of at least 1.44 ºC. All models show there are no declines in minimum temperatures across the Metropolitan Sydney.

In 2070 the mean minimum temperature will be approximately 15.8 ºC based on the local baseline.

Extreme temperature events

Days in which the maximum temperature is over 35°C are projected to increase across Sydney by an average of 10 days per year by 2070. The greatest increases are seen in the central part of greater Sydney from Picton to north of Wiseman's Ferry and out to Katoomba. These regions are projected to have an additional 15 hot days per year. While the remained of Sydney will see at least 4 additional hot days per year.

In 2070 the number of hot days will be approximately 13 based on the local baseline.

Nights in which the minimal temperature is under 2°C are projected to decrease across the Sydney by an average of 11 nights per year by 2070. The greatest decreases are seen in the Blue Mountains during winter. These regions are projected to experience more than 40 fewer cold nights per year.

Since cold nights are rarely seen along the coast of NSW there will be little to no impact for the project area.

TABLE 10.2: NARCLIM NUMBER OF HOT DAYS AND COLD NIGHTS

Observatory Hill Lat: -33.859 Lon: 151.205		Baseline	2020-2039		2060-2079	
		BOM (local)	Average Change	Range	Average Change	Range
Number of Hot Days (Days max temp >35°C)	Period yearly average	3 days	+3.90 days	+0.24 to +5.63 days	+10.40 days	+3.91 to +14.91 days
Number of Cold Nights (Nights min temp <2°C)	Period yearly average	0 days	-4.50 days	-5.85 to -3.42 days	-10.90 days	-12.36 to +8.97 days

10.1.2 Precipitation

Average annual rainfall

As shown in Table 10.3 below, annual rainfall is projected to increase by an average of 8.90% by 2070. Large increases of around 18% are projected across the whole of Sydney throughout summer and autumn. Winter and spring rainfall is more variable and may see decreases of around 8%.

In 2070 the mean monthly rainfall will be approximately 110.08 mm based on the local baseline.

TABLE 10.3: NARCLIM MEAN MONTHLY RAINFALL

Observatory Hill Lat:-33.859 Lon:151.205		Baseline		2020-2039		2060-2079	
		NARCliM	BOM (local)	Average Change	Range	Average Change	Range
Mean Monthly Rainfall (mm)	Period yearly average	70.76 mm	101.08 mm	+1.70%	-12.99 to +18.03 %	8.90%	-8.67 to +24.18%
	Highest Rainfall	*642.7 (June 1950)*					

Extreme rainfall events

The Floodplain Risk Management Guidelines Practical Consideration of Climate Change (DECC 2007) recommends hydraulic modelling sensitivity analyses for the following rainfall intensities: +10%, +20% and +30% in peak rainfall and storm volume. Climate change related sensitivity analyses should be in addition to the usual sensitivity analyses involved in food and FRM studies undertaken in accordance with the Manual.

These parameters for modelling purposes are further supported by Book 1 of the ARR (Ball et al. 2019) where following the relationship between temperature and humidity a 5% increase in rainfall intensity per degree of projected surface temperature increase is recommended. Therefore, an average increase of approximately 2°C relates to 10% increase in rainfall intensity (the range projected for the Sydney Metro region is 1.57 to 2.48°C by 2070 NARClim).

Drought

Drought occurrence is measured using the rainfall-based metric known as the Standardised Precipitation Index (SPI) and duration of time spent in drought and changes to the duration and frequency of drought were calculated for different levels of severity (mild, moderate, severe, and extreme) for projections collated out by the CSIRO (Dowdy et al. 2015).

Projected changes to drought share much of the uncertainty of mean rainfall change, and there is no clear indication on changes to drought conditions for the East Coast region, particularly for RCP4.5 projections (Dowdy et al. 2015).

Meteorological drought will continue to be a regular feature of regional climate for the East Coast region, and while it may change its characteristics as the climate warms, there is low confidence in projecting how the frequency and duration of extreme drought may change (Dowdy et al. 2015).

10.1.3 Extreme storms

Gales and extreme wind events

As shown in Table 10.4 below projections show a decreasing trend and that there is a very small likelihood of any increases in wind speed. The reductions in East Coast South are likely related to a projected southward movement of storm tracks and the sub-tropical ridge. This would lead to a weakening of westerly winds in the East Coast South sub-cluster. In 2090 the mean 9am and 3pm wind speed will be approximately 10.6 km/h and 16.6 km/h respectively based on the local baseline.

TABLE 10.4: CHANGE IN WIND SPEED

Observatory Hill Lat:-33.859 Lon:151.205		Baseline			2030, RCP 4.5		2090, RCP 4.5	
		BOM (local)						
		max wind gust speed	mean 9am wind speed	mean 3pm wind speed	Average Change	Range	Average Change	Range
Wind Speed (%) Change	Annual	150 km/h	10.6 km/h	16.6 km/h	-0.5 %	-2 to +1.2%	0%	-2.1 to +1.6%

Storms (cyclones)

Tropical cyclones in the Australian region are influenced by a number of factors, and in particular variations in the El Niño – Southern Oscillation (ENSO). In general, more tropical cyclones cross the coast during La Niña years, and fewer during El Niño years (BoM 2016). Cyclones have a complex link to ocean surface temperatures, characteristics of a region and global climate patterns such as the El-Niño Southern Oscillation, meaning that predicting frequency of cyclone and other extreme weather events can be difficult. This results in discrepancies in cyclone frequencies between different climate models (DERM 2009).

The Australian Bureau of Meteorology states (2007):

> *While tropical cyclones do not impact NSW very often, they have caused flooding, destructive winds, storm surges and loss of life. When a tropical cyclone is affecting NSW the Brisbane Tropical Cyclone Warning Centre (TCWC) will issue a TC Advice for NSW and a Tropical Cyclone Forecast Track Map. Both these products will appear under Current Warnings for NSW on the Bureau's Website. Information is also available via the Bureau's Telephone Weather Services: Tropical Cyclone Warnings 1300 659 212.*
>
> *It is likely that Severe Weather Warnings and Flood Warnings will also be current before, during and after tropical cyclone warnings.*

Hail size and location

Hail severity may increase in most regions of the world while Australia and Europe are expected to experience more hailstorms as a result of climate change (Raupach et al. 2021). A global summary of hail trends from past observations and projected future trends from simulations and models led to the general expectation that hailstorm frequency will decrease in East Asia and North America, while increasing in Australia and Europe, and that hailstorm severity will increase in most regions.

On balance, the hail threat is likely to increase in Australia, especially in Australia's south-east including the Sydney area (Raupach et al. 2021).

However, current and future climate change effects on hailstorms remain highly uncertain, in part due to a lack of long-term observations and limited modelling studies.

Dust storms

Dust storms occur in a very sporadic nature across Australia depending on the amount of rainfall that the arid and semi-arid parts of the country have received (BoM 2006). In prolonged dry periods, dust storms are a frequent occurrence, whilst in the wetter periods dust storms are very uncommon due to the increase in vegetation and soil moisture binding dust particles to the surface.

The most recent dust storms to hit the eastern states occurred on (BoM 2019):

- **3 February 2005**. A strong cold front brought very cold air up from the south breaking many minimum temperature records. As well as the extreme temperatures, dust storms were recorded in many places west of the divide due to the intense winds. At Bourke, visibility was reduced to 500m, and Moree, visibility reduced to 600m.
- **23 October 2002**. This storm was one of the most severe on record. It was also caused by the passage of a strong cold front. This, combined with high temperatures and the prolonged drought in the region, resulted in a massive dust storm which swept across the eastern states. In Sydney, visibility was reduced to a few kilometres and pilots reported that the dust extended up 3km into the atmosphere. West of the divide experienced the most severe conditions, with many areas experiencing visibilities of just 300m. In the suburb of Roma, in southwestern Queensland, visibility was reduced to just 100m.
- **23 September 2009**. Sydney residents awoke to a thick red haze blanketing the city—it was a huge dust storm that was quickly dubbed 'Red Dawn'. The dust was so thick that visibility was reduced to below 1 km for four hours, and at the peak of the storm you could only see 400 m. The massive dust storm was 3000 km long and 2500 m high. It affected as far north as Cairns and dust from it settled as far away as New Zealand! The storm is estimated to have carried approximately 15 million tonnes of dust at its peak.

10.1.4 Bushfire

Fire danger index

Fire weather is classified as 'severe' when the FFDI is above 50, and most of the property loss from major fires in Australia has occurred when the FFDI reached this level (Blanchi et al. 2010). FFDI values below 12 indicate low to moderate fire weather, 12-25 high, 25-49 very high, 50-74 severe, 75-99 extreme and above 100 catastrophic.

Long-term FFDI estimates are available for two weather stations in the region, Sydney Airport and Richmond. The average annual FFDI for the period 1990–2009 is 5.5 at Sydney Airport and 7.1 at Richmond.

TABLE 10.5: NARCLIM SEVERE FIRE WEATHER RISK

	1990–2009	2020-2039		2060-2079	
	Baseline Average annual	**Average Change**	**Range**	**Average Change**	**Range**
Severe Fire Weather Risk (FFDI >50)	5.5 days Sydney Airport 7.1 days Richmond	0	-0.78 to +1.15	0.6	-0.72 to +2.03
	Summer	0.1	-0.28 to +0.92	0.1	-0.25 to +0.45
	Autumn	0	-0.03 to 0.00	0	-0.02 to +0.01
	Winter	0	-0.01 to +0.01	0	-0.01 to 0.00
	Spring	0	-0.50 to 0.24	0.5	-0.48 to 1.83

10.1.5 Radiation

Shown in the table below, solar Radiation projections show little change for 2030 and a slight increase of 1% for 2090. However, an Australian evaluation suggested that some models are not able to adequately reproduce the climatology of solar radiation. CMIP2 and CMIP5 models appear to underestimate trends in certain regions of southeast coast.

TABLE 10.6: NARCLIM SEVERE FIRE WEATHER RISK

Observatory Hill Lat:-33.859 Lon:151.205		Baseline	2030, RCP 4.5		2090, RCP 4.5	
		BOM (local) Mean daily solar exposure	Average Change	Range	Average Change	Range
Solar Radiation (%) Change	Annual	16.4 (MJ/m2	0.6%	-0.6 to +1.6%	1%	-0.2 to +2.9%

10.1.6 Waterway health

Discharge runoff

Climate change may alter the current patterns of diffuse source water pollution due to projected changes in the seasonality, frequency, intensity and duration of rainfall (IPCC 2014). For example, more intense storms can lead to enlargement of streams through bed and bank erosion, thus releasing significant volumes of sediment downstream. The total annual load of sediment and contaminants that attach to sediment particles is frequently dominated by one or two large storms (Drewry, Newham & Croke 2005). Therefore, climate change could further exacerbate an already significant diffuse source water pollution problem, particularly in areas that become subject to more frequent and intense storms (DECC 2009).

The cumulative impact of frequent, low volume runoff is also significant and can contribute to long periods in which waterways are unfit for use (Harhcegani & Cornish 2003).

Paul Stoller

Director

PROJECTS

Central Station Precinct Renewal Program | Sydney, NSW
TRANSPORT FOR NSW | ZERO CARBON NET TARGET

Central Precinct Renewal Program (CPRP) includes the revitalisation of the heritage terminal and over rail development incorporating new office, residential, retail, educational and cultural space, with major public realm creating Sydney's new Third Square and reconnecting surrounding neighbourhoods.
Key project achievements:

- Design to RCP 8.5 climate scenarios.
- Mechanisms to manage heat, bushfire (and smoke), flood and storm impacts through extreme events
- Community facilities that support social resilience during major shock events
- Climate risk mitigated in alignment with the Taskforce for Climate-related Financial Disclosures (TCFD).

Bays West Strategic Place Framework | Sydney, NSW
NSW DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT | TERROIR | ZERO CARBON NET TARGET

Bays West will be redeveloped into a mixed-use high density urban neighbourhood as part of the Harbour CBD Innovation Corridor. Characterised by extensive waterfront and iconic industrial heritage buildings, the Precinct creates extensive parkland and public realm while preserving active port and maritime industries.
Key project achievements:

- Design to RCP 8.5 climate scenarios.
- Manage sea level rise and incorporate it productively into a slowly changing landscape.
- Flexible, adaptive and regenerative systems with the capacity to be changed subject to uncertain future pressures.

Agribusiness Precinct Master Plan, Western Sydney Aerotropolis | Sydney NSW
WESTERN PARKLAND CITY AUTHORITY | ZERO CARBON TARGET

The Western Sydney Aerotropolis Agribusiness Precinct aims to capitalise on the development of the new Nancy (Bird) Walton International Ariport and be a world-leading place for the growing, processing, selling, and transport of food and food products, as well as centre for research into food related topics in Australia and the Asia-Pacific region.
Key project achievements:

- Design to RCP 8.5 climate scenarios.
- Repair and recreate indigenous landscapes for nutrient cycling, perennial productivity, and increasing ecosystem services.
- Floodplains manage floods naturally.

Ocean Street Village Masterplan | Sunshine Coast, QLD
HAYBALL + ARCADIA| ZERO CARBON NET TARGET

Ocean Street Village is a mixed-use lifestyle-driven masterplanned community comprising residential, commercial, retail, and tourism around significant lush green and blue public domain on a key waterfront site at the confluence of creek, river and beach.
Key project achievements:

- Residents can safely shelter in place during extreme events.
- Building systems and infrastructure continue operating during utility failure.
- On-site building PV capable of separating from grid and operating as power island.

Kambri Precinct, Australian National University | Canberra, ACT
LENDLEASE | BVN | ONE PLANET LIVING

A new heart for Australia's leading research university, Kambri brings together learning, social, community, cultural, and residential facilities in one vibrant and sustainable precinct.
Key project achievements:

- Climate-responsive building facades that minimise the need for heating and cooling.
- Precinct-wide energy and operational carbon modelling.

Managing director of Atelier Ten's Australia office and a global leader of the company, Paul is recognised for environmental planning and design consulting work on ambitious, large-scale campus, community and urban projects. Paul lectures frequently at conferences and professional forums, and he serves as a member of the NSW State Design Review Panel.

EDUCATION

M. ARCH.
YALE UNIVERSITY SCHOOL OF ARCHITECTURE, 1998

MA ARCHITECTURAL HISTORY
UNIVERSITY OF WISCONSIN-MADISON, 1995

BS ARCHITECTURAL HISTORY
UNIVERSITY OF WISCONSIN-MADISON, 1993

EXPERIENCE

ATELIER TEN AUSTRALIA
DIRECTOR, 2013-PRESENT

ATELIER TEN USA
DIRECTOR, 2001-2013

ATELIER TEN UK
ENVIRONMENTAL DESIGNER, 1998-2001

EXTERNAL APPOINTMENTS

NSW STATE DESIGN REVIEW PANEL
MEMBER

GREEN STAR EXPERT REFERENCE PANEL
PLACE-MAKING PANEL MEMBER

AIRAH
MEMBER + CHAIR, RESILIENCE TASK GROUP

USGB
LEED FELLOW

AUSTRALIAN NATIONAL CLIMATE CHANGE ADAPTATION RESEARCH FACILITY
END USER REFERENCE GROUP, 2015-2017

- Indoor environmental quality briefs articulating specific thermal and visual comfort requirements for each program types.

Warriewood Community Centre | Sydney, NSW
NORTHERN BEACHES COUNCIL | TERROIR

The Warriewood Community Centre is designed to become a new 'community living room' with the capacity to switch to an Emergency and Recovery Centre during a period of community crisis.
Key project achievements:

- Centre can work as a community refuge during climatic or social crises.
- Ventilation with filtration systems caters for bush fire, pollen and COVID events.
- Passive design features provide a thermally stable environment that can be maintained during heatwaves

Westmead Innovation Precinct | Sydney, NSW
WESTMEAD ALLIANCE | WSP AND COX ARCHITECTS

Visionary planning for a place of world-class healthcare and research. A productive, workable, liveable and accessible global health precinct.
Key project achievements:

- Urban design integration of the public domain with the surrounding Parramatta Park landscape and river ecology.
- Adaptation and resilience strategy that takes into account potential acute shocks and chronic stresses related to challenges surrounding climate, community and infrastructure.

Riversdale Arts Campus Gallery & Accommodation | Shoalhaven, NSW
KERSTIN THOMPSON ARCHITECTS

Sensitively embracing the existing landscape and its ecology, the design responds to current and future climatic conditions with inspiration drawn from rural Australia's trestle flood bridges.
Key project achievements:

- Gallery spaces are located safely uphill to avoid the risk of flooding, and submerged underground reduce the risk of bushfire.
- Resilient geothermal system provides conditioning to this cool carefully controlled thermally stable environment.
- In response to an unreliable power grid it generates its own renewable energy on site using rooftop PV for low-carbon power and a reliable, resilient energy source.
- Water is carefully captured and reused on site, and landscape-based grey water treatment minimises blackwater system requirements.

Australian Opal Centre | Lightning Ridge, NSW
WENDY LEWIN, GLENN MURCUTT & DUNN & HILLAM

The new AOC will be a national museum of opals and opalised fossils as well as a research facility and regional cultural and arts hub. Located at the 3 Mile mining site in Lightning Ridge, NSW, the two-story building will nestle within a reclaimed excavation pit. A Gondwana-inspired garden within the Centre surrounds the galleries and will house rare ancient plants.
Key project achievements:

- Earth-sheltered cooling, and middle eastern-inspired malqaf downdraft ventilation towers, which use spray misting to evaporatively cool the gardens and front of house area.
- Closed-loop ground-source cooling system provides additional passive space heating and cooling.
- On-site water recycling plant cleans all captured rainwater and wastewater for reuse.
- Large battery system powers the building through the night

Penway Place | Penrith, NSW
TOGA

Paul Stoller

Director

Penway Place is a mixed-use development comprising two residential towers, commercial space, retail precinct and 1,000 sqm Civic Square along High Street in Sydney's third CBD.

Key project achievements:

- Thermal Comfort Design Guideline.
- Typical specifications and technical design requirements related to facades and HVAC.
- Retrofitted design options to alleviate existing thermal comfort concerns.

Barangaroo South | Sydney, NSW
BARANGAROO DELIVERY AUTHORITY | LENDLEASE | GREEN STAR COMMUNITIES 6 STAR, ZERO CARBON PRECINCT

Atelier Ten was engaged by Lendlease to provide strategic Green Star Communities guidance, which led to the achievement of the highest possible (six star) sustainability rating for the precinct.
Key project achievements:

- Mapped the ambitious social and ecological sustainability programs into a format that earned the development a 6 Star rating through this new benchmarking system.

Gardens By The Bay | Singapore
WILKINSON EYRE AND GRANT ASSOCIATES | GREENMARK PLATINUM

This distinctive waterfront gardens in the heart of Marina Bay defines Singapore as the world's premier tropical garden city. The gardens are a national and international exemplar of sustainable practice.
Key project achievements:

- Innovative strategies for controlling the conditions within two biomes in the naturally humid environment of Singapore while minimising energy demand to exemplar levels.
- External supertree structures coupled with liquid desiccant systems provide cool air to the biomes.
- Solar energy entering the domes utilised as part of a 'virtuous' energy cycle.

Federation Square | Melbourne, VIC
MAJOR PROJECTS VICTORIA | LAB + BATES SMART

Atelier Ten won an International Design competition with architects LAB Architecture Studio and Bates Smart to environmentally engineer and design the building complex.
Key project achievements:

- Largest thermal labyrinth in the world.
- Central cogeneration plant with absorption chillers for efficient power generation.

WA Museum Boola Bardip | Perth, WA
HASSELL + OMA | GREEN STAR 5 STAR

The WA Museum Boola Bardip, located on Whadjuk Nyongaar land and meaining 'many stories' in Nyoongr language, features nearly 6,000 square metres of galleries across a mix of new and rejuvenated heritage museum buildings.
Key project achievements:

- Energy savings through creation of a new and highly efficient central energy plant to serve the Museum and other adjacent cultural institutions.
- Holistic engineering and facade design strategy to optimise the passive thermal and daylight performance of all buildings within the complex.

Salesforce Transit Center | San Francisco, CA
PELLI CLARKE PELLI ARCHITECTS + ADAMSON ASSOCIATES | LEED GOLD TARGET

This ambitious project transforms downtown San Francisco and its regional transportation system. It creates an iconic central station that forms the new center of a sustainable transit-friendly region and integrates an innovative urban park on its roof.
Key project achievements:

- Optimised water reuse cycle to reduce its size, cost of storage, and improve

system reliability.
- Greywater filtration wetland, habitat for local species, and native/adapted plant species on the roof park.
- Commercial greywater reuse, stormwater reuse, and on-site vegetative filtration are all firsts for San Francisco.

Kohler Environmental Center, Choate Rosemary Hall | Wallingford, CT
ROBERT A.M. STERN ARCHITECTS | LEED PLATINUM AND NET ZERO ENERGY

The Kohler Environmental Center is the first teaching, research and residential environmental center in U.S. secondary education. By achieving net zero energy use it reinforces the school's mission to promote environmental understanding, land stewardship, and social responsibility.
Key project achievements:
- Daylight-first approach allowed Atelier Ten to supplement only the areas that needed electric light during the day.
- Ground source heat pump (GSHP) system, earth duct to pre-temper outdoor air, solar hot water system, and waste oil boiler using cooking oil or biofuel to heat the greenhouse.
- 53% reduction in energy cost compared to an ASHRAE 90.1-2004 baseline.
- Photovoltaic (PV) system located adjacent to the building will provide for 100% of energy demands.

STRATEGIC

Heat Smart Resilience Framework | Sydney, NSW
WESTERN SYDNEY REGIONAL ORGANISATION OF COUNCILS' (WSROC)

Sets out a pathway for improving management of extreme heat in Western Sydney, with a focus on building systems that support community resilience.
Key achievements:
- Integrated approach to heatwave management.
- Identified 15 opporutnities for improving heatwave resilience.
- Identified 24 priority areas for action under five categories: governance, prevention, preparedness, response and recovery/evaluation.

Resilience Special Technical Group
AIRAH

Founding Chair of STG which provide members with a platform for involvement in issues that affect their industry in relation to Resilience, including: policy advice; regulation development; plus the development of, and access to, industry-leading advice.
Key achievements:
- AIRAH Resilience Forum 2018 in Sydney.
- Resilient HVAC presented at The National Climate Change Adaptation Research Facility Conference 2016.
- Participation in resilience work with the Green Building Council of Australia.
- Supporting City of Sydney and City of Melbourne resilience projects.

Resilience Policy Research
UNIVERSITY OF TECHNOLOGY SYDNEY

Working with University of Technology Sydney (UTS) engineering and architecture students to help develop Resilient Design research papers for themselves.
Key achievements:
- Multiple student publications in Ecolibrium, journal of AIRAH
- Multiple student conference presentations.
- Contribution to Resilience for HVAC Design Guidelines for AIRAH.

Building Resilience Task Force
U.S. GREEN BUILDING COUNCIL NEW YORK

Convened in 2013 at the request of the City of New York following Superstorm Sandy, 200-plus task force members led by Urban Green were charged with making

recommendations to improve building resiliency and maximize preparedness for future weather emergencies.
Key achievements:

- 33 actionable proposals for making New York buildings and residents better prepared for the next extreme weather event.

Flood Resilience Zoning Text
NYC DEPARTMENT OF PLANNING
One part of a wide range of efforts by NYC to recover from Hurricane Sandy, promote rebuilding, and increase the city's resilience to climate-related events, including coastal flooding and storm surge.

- Removes regulatory barriers that hinder or prevent the reconstruction of storm-damaged properties.
- Enables new and existing buildings to comply with new, higher flood elevations issued by the Federal Emergency Management Agency (FEMA).

PUBLICATIONS

Voices; The Environmental Education of the Citizen Architect, The Rural Studio at Twenty | PRINCETON ARCHITECTURAL PRESS, 2014
Environmental Engineering; Integrating Computer Simulation into the Design Process, Blurring the Lines | WILEY-ACADEMY, 2006

TEACHING

Senior Lecturer | UTS SCHOOL OF ARCHITECTURE, 2013-2021
Lecturer and Critic | AUBURN UNIVERSITY RURAL STUDIO, 2002-PRESENT
Instructor and Critic | YALE UNIVERSITY SCHOOL OF ARCHITECTURE, 2001-2013

PRESENTATIONS

The Future of Carbon Neutral Design
CARBON POSITIVE RESEST, 2020

FAANGing It: Toward a Circularity Economy
FIFTH ESTATE 'BUILDING CIRCULARITY' SYMPOSIUM, 2020

Zero carbon buildings: The future is now! So what do I do?
AIRAH OUTLOOK 2020

Sustainability in the Fourth Industrial Revolution
AUSTRALASIAN STRUCTURAL ENGINEERING CONFERENCE, 2020

Zero Carbon Right Now!
CLIMATE POSITIVE RESET, AUSTRALIA-PACIFIC REGION, 2020

Our All-Electric Future
THE FUTURE OF HVAC, BRISBANE 2019

Sustainable Infrastructure and the Fourth Industrial Revolution
H.R.L. MORRISON SYMPOSIUM, QUEENSTOWN, 2018

Managing Past Zero: Design Thinking to Climate Positive
AIPM, SYDNEY, 2017

Daylight Metrics and Performance Facade Design
IQPC FACADES CONFERENCE, SYDNEY, 2015

Resilient Design: Lessons From Hurricane Sandy
ARBS CONFERENCE, MELBOURNE, 2014

Integrating Environmental Analysis into a BIM Workflow
GREENBUILD, SAN FRANCISCO, 2012

10.3 AS 5334 Guidance

10.3.1 Consequences

Consequence	Adaptive Capacity	Infrastructure, Service	Social/Cultural	Governance	Financial	Environmental	Economy
Insignificant	No change	No infrastructure damage, no change to service	No adverse human health effects	No changes to management required	Little financial loss or increase in operating expenses	No adverse effects on natural environment	No effects on the broader economy
Minor	Minor decrease to the adaptive capacity of the asset. Capacity easily restored.	Localised infrastructure service disruption. No permanent damage. Some minor restoration work required. Early renewal of infrastructure by 10-20%. Need for new/modified ancillary equipment.	Short-term disruption to employees, customers or neighbours. Slight adverse human health effects or general amenity issues.	General concern raised by regulators, requiring response action	Additional operational costs Financial loss small, <10%	Minimal effects on the natural environment	Minor effect on the broader economy due to disruption of service provided by the asset
Moderate	Some change in adaptive capacity. Renewal or repair may need new design to improve adaptive capacity.	Limited infrastructure damage and loss of service Damage recoverable by maintenance and minor repair. Early renewal of infrastructure by 20-50%.	Frequent disruptions to employees, customers or neighbours. Adverse human health effects	Investigation by regulators Changes to management actions required	Moderate financial loss 10-50%	Some damage to the environment, including local ecosystems. Some remedial action may be required	High impact on the local economy, with some effect on the wider economy
Major	Major loss in adaptive capacity. Renewal or repair would need new design to improve adaptive capacity.	Extensive infrastructure damage requiring major repair. Major loss of infrastructure service. Early renewal of infrastructure by 50-90%.	Permanent physical injuries and fatalities may occur. Severe disruptions to employees, customers, or neighbours.	Notices issued by regulators for corrective actions. Changes required in management. Senior management responsibility questionable.	Major financial loss 50-90%	Significant effect on the environment and local ecosystems. Remedial action likely to be required.	Serious effect on the local economy spreading to the wider economy

Consequence	Adaptive Capacity	Infrastructure, Service	Social/Cultural	Governance	Financial	Environmental	Economy
Catastrophic	Capacity destroyed, redesign required when repairing or renewing asset.	Significant permanent damage and/or complete loss of the infrastructure and the infrastructure service. Loss of infrastructure support and translocation of service to other sites. Early renewal of infrastructure by 90%.	Severe adverse human health effects, leading to multiple events of total disability or fatalities. Total disruption to employees, customers, or neighbours. Emergency response at a major level.	Major policy shifts. Change to legislative requirements	Extreme financial loss > 90%	Very significant loss to the environment. May include localised loss of species, habitats, or ecosystems. Extensive remedial action essential to prevent further degradation. Restoration likely to be required.	Major effect on the local, regional, and state economies.

10.3.2 Likelihood

Likelihood	Description	Recurrent Or Event Risks	Long Term Risks
Almost Certain	Could occur several times per year	Has happened several times in the past year and in each of the previous 5 years or Could occur several times per year	Has a greater than 90% chance of occurring in the identified time period if the risk is not mitigated
Likely	May arise about once per year	Has happened at least once in the past year and in each of the previous 5 years or May arise about once per year	Has a 60–90% chance of occurring in the identified time period if the risk is not mitigated
Moderate	Maybe a couple of times in a generation	Has happened during the past 5 years but not in every year or May arise once in 25 years	Has a 40–60% chance of occurring in the identified time period if the risk is not mitigated
Unlikely	Maybe once in a generation	May have occurred once in the last 5 years or May arise once in 25 to 50 years	Has a 10–30% chance of occurring in the future if the risk is not mitigated
Very Unlikely (Rare)	Maybe once in a lifetime	Has not occurred in the past 5 years or Unlikely during the next 50 years	May occur in exceptional circumstances, i.e. less than 10% chance of occurring in the identified time period if the risk is not mitigated

10.3.3 Risk Rating Matrix

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Low	Medium	High	Extreme	Extreme
Likely	Low	Medium	Medium	High	Extreme
Moderate	Low	Low	Medium	High	Extreme
Unlikely	Low	Low	Medium	Medium	High
Very Unlikely	Low	Low	Low	Medium	Medium

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