COCKLE BAY PARK REDEVELOPMENT

Appendix W: Environmental wind assessment

State Significant Development, Development Application (SSD DA)

Prepared for DPT Operator Pty Ltd and DPPT Operator Pty Ltd

01 October 2021

Revision [3]

ARUP

DPT Operator Pty. Ltd. and DPPT Operator Pty. Ltd.

Cockle Bay Park Redevelopment

Environmental Wind Assessment

Wind

Rev.03 | 01 October 2021

Job number 238566

Arup Australia Projects Pty Ltd
ABN 57 625 911 711

Arup
Level 5, 151 Clarence Square
Sydney, NSW 2000
Australia
www.arup.com

ARUP

Document Verification

ARUP

Job title		Cockle Bay Park Redevelopment			**Job number** 238566
Document title		Environmental Wind Assessment			**File reference**
Document ref		Wind			
Revision	**Date**	**Filename**	Cockle Bay Park_Arup wind REP_20210909		
Rev.01	09 Sep 2021	**Description**	Wind assessment report		
			Prepared by	Checked by	Approved by
		Name	Lauren Boysen /Graeme Wood	Sina Hassanli	Graeme Wood
Rev.02	23 Sep 2021	**Filename**	Cockle Bay Park_Arup wind REP_20210923		
		Description	Minor changes		
			Prepared by	Checked by	Approved by
		Name	Graeme Wood		Graeme Wood
Rev.03	01 Oct 2021	**Filename**	Cockle Bay Park_Arup wind REP_20211001		
		Description	Minor changes		
			Prepared by	Checked by	Approved by
		Name	Graeme Wood		Graeme Wood
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			

Issue Document Verification with Document ✓

Executive summary

This report provides discussion on the impact of the current design of the proposed Cockle Bay Park redevelopment on the measured wind conditions for comfort and safety in and around the site. The testing for this report was conducted by Cermak Peterka Petersen (CPP) following on from two rounds of wind-tunnel testing on the reference massing scheme for the design excellence competition, and the initial post-competition testing on the winning scheme.

The inclusion of any large building in the City alters the local wind environment. The effect is greater on the fringe of the City, or on exposed corner sites, and generally decreases with larger surrounding buildings, or remote from the corners of a City block. With the site being on the western fringe of the City, the proposed building has an impact on the local wind environment near the development.

Arup analysed the wind-tunnel results with respect to the local wind climate comparing the results with the City of Sydney comfort and safety criteria and to provide greater interpretation of the comfort classifications. The results presented in this report are based on Arup’s analysis.

Quantitatively, integrating the directional wind conditions around the site with the wind climate, all locations on the ground level meet the target comfort classification for their intended use, with the majority of locations classified as suitable for pedestrian standing and sitting. Windier locations are measured remote from the isolated building, with areas classified as suitable for pedestrian walking. Close to the building, the previous measured exceedances have been ameliorated with the use of horizontal canopies to meet the comfort and safety criteria. The podium testing was conducted with a fully open western façade, therefore the proposed operability would allow further control to the podium.

Three locations on the ground plane have wind conditions that slightly exceed the safety criterion. These locations are remote from the building in the open parkland to the north, and towards Crescent Garden to the east. All locations are remote from main thoroughfares in open locations. The modelling was conducted with no landscaping or small structures, which would be expected to slightly ameliorate conditions. The magnitude of the safety exceedances are considered acceptable for the location in the open areas.

The small exceedances of the safety criterion on private terraces on the tower are common on high-rise buildings. Access to the terraces during strong wind events is unlikely, and can be further managed by the tenant. The use of external furniture on all elevated terraces should be managed.

The wind conditions in and around the site are considered suitable for the intended use of the spaces.

Table of Contents

Table of Figures

Table of Tables

1 Project Background

1.1 Introduction

This report has been prepared to accompany a detailed State Significant Development (SSD) Development Application (DA) (Stage 2) for a commercial mixed use development, Cockle Bay Park, which is submitted to the Minister for Planning and Public Spaces pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The development is being conducted in stages comprising the following planning applications:

- Stage 1 – Concept Proposal setting the overall ‘vision’ for the redevelopment of the site including the building envelope and land uses, as well as development consent for the carrying out of early works including demolition of the existing buildings and structures. This stage was determined on 13 May 2019, and is proposed to be modified to align with the Stage 2 SSD DA.
- Stage 2 – detailed design, construction, and operation of Cockle Bay Park pursuant to the Concept Proposal.

1.2 The Site

The site is located at 241-249 Wheat Road, Sydney to the immediate south of Pyrmont Bridge, within the Sydney CBD, on the eastern side of the Darling Harbour precinct. The site encompasses the Cockle Bay Wharf development, parts of the Eastern Distributor and Wheat Road, Darling Park and Pyrmont Bridge.

The Darling Harbour Precinct is undergoing significant redevelopment as part of the Sydney International Convention, Exhibition and Entertainment Precinct (SICEEP) including Darling Square and the IMAX renewal (W Hotel) projects. More broadly, the western edge of the Sydney CBD has been subject to significant change following the development of the Barangaroo precinct.

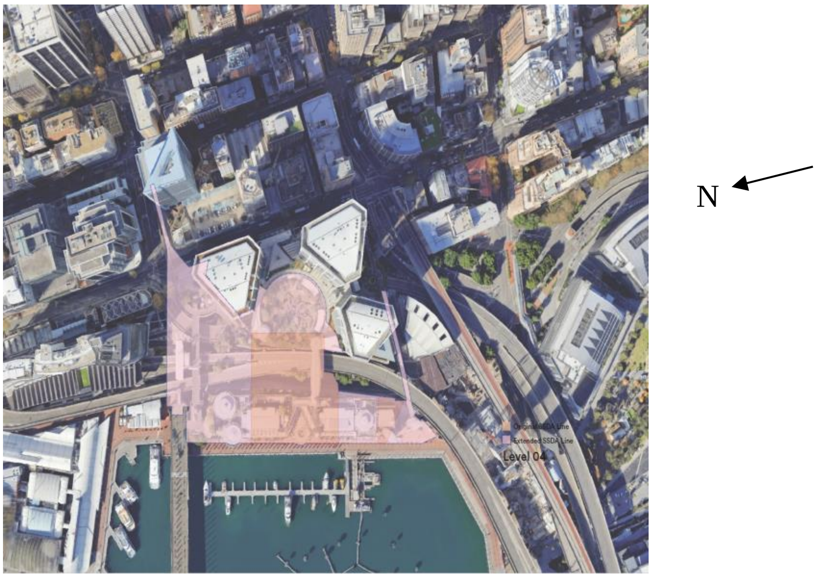


Figure 1: Location plan

This report has been prepared in response to the Secretary's Environmental Assessment Requirements (SEARS) dated 12 November 2020 for SSD-9978934. Specifically, this report has been prepared to respond to those SEARS summarised in Table 1.

Table 1: SEARs requirements

Item	Description of Requirement	Section Reference (this report)
7	The EIS must: assess potential amenity impacts associated with the proposal within the site and on surrounding area, including solar access / overshadowing, noise and vibration, view loss, visual privacy, lighting, wind, air, odour and dust during the operation and construction stages of the proposed development	3

This report has also been prepared in response to the following Stage 1 (SSD 7684) conditions of consent summarised in Table 2.

Table 2: Concept approval of Conditions of Consent

Item	Description of Requirement	Section Reference (this report)
B1 bb	Amend Built Form Design Principle 5.13, as follows: 5.13 Wind Impacts Wind conditions should be safe and appropriate for the proposed activities in all areas of the development, internal and external. **Wind impacts on Crescent Garden and the Darling Harbour promenade should be minimised so that those spaces achieve appropriate wind environments for their use.**	3 –wind conditions in these areas suit the intended use of the space and are similar to the reference scheme
C26	Future Development Application(s) shall include a Wind Impact Assessment, including wind tunnel testing, which assesses the existing and proposed wind environment, demonstrates spaces within and around the site are suitable for their intended purpose and includes mitigation measures to address adverse wind conditions, where necessary.	3

2 Introduction

This report summarises the local wind conditions in and around the site from the quantitative wind-tunnel testing conducted on the site by CPP in accordance with the requirements of Australasian Wind Engineering Society (2019).

From the previous wind tunnel testing on the site with an indicative massing design for the competition phase of the project (CPP 2017), it was evident that a large tower in this location has little impact on the wind conditions remote from the tower. As this is an isolated structure, only testing around the development was included during this testing. Later testing conducted on the competition winning scheme (Arup 2020), showed several exceedances of the safety criterion to the north-east of the precinct. Design refinement and modelling has shown a significant improvement in the wind conditions in this area.

3 Wind assessment

This report discusses the relevant results of the wind-tunnel testing study conducted on the development and interpretive discussion on the impact of the proposed buildings on the pedestrian level wind comfort and safety. From a wind perspective, the completed development will have the greatest impact on the surrounding wind conditions.

3.1 Modelling

Wind-tunnel testing was conducted in the closed boundary-layer wind tunnel by CPP in one configuration, Figure 2. The construction of the physical model was based on the 3d model provided by the Design Architect. No landscaping was included in the models as this cannot be relied on for pedestrian safety in strong winds. Generally, any landscaping would tend to improve the wind comfort conditions by up to about 10%. All approved buildings in the vicinity were included in the surround model. The greatest impact of the development on the local wind environment would be post-construction once the tower is complete and pedestrians can fully access the site, no measurements were taken during the temporary construction stages.

The wind-tunnel testing programme conducted by CPP was in accordance with the requirements of AWES (2019) and appropriate for the current initial investigation. Appropriate wind speed and turbulence profiles, and test locations were used in the testing. Testing was conducted for 16 wind directions.

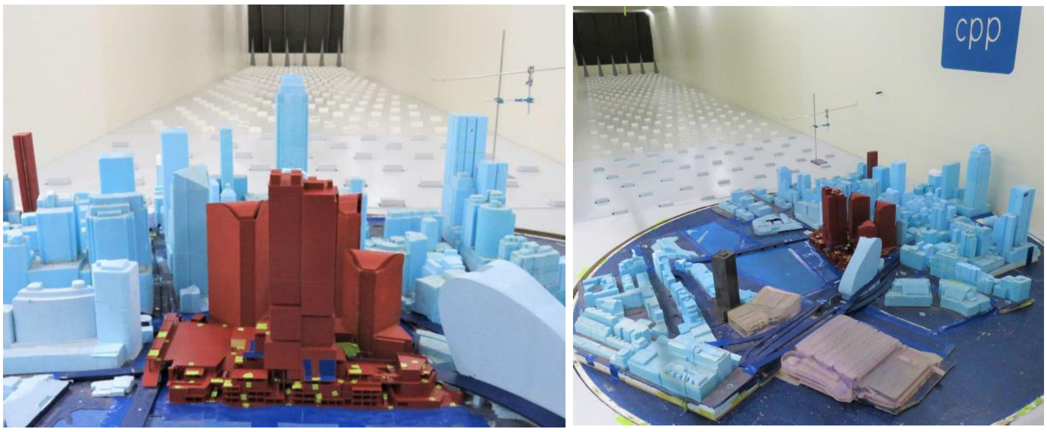


Figure 2: Photographs of tested models viewed from west (L), and south-west (R)

3.2 Local wind climate

Weather data recorded at Sydney Airport by the Bureau of Meteorology has been analysed for this project. The analysis of the wind climate taking into account the requirements of the assessment criterion described in Section 3.3 is summarised in Appendix 1.

A general description on flow patterns around buildings is given in Appendix 2.

3.3 Specific wind controls and local wind climate

The wind comfort and safety criteria used in the assessment were taken from the Draft City of Sydney Planning Strategy 2016-2036. The criteria are:

For pedestrian **safety**, the annual maximum 0.5 s gust wind speed occurring in any hour between 6 am and 10 pm should be less than 24 m/s. This represents a probability of occurrence of 0.017%.

For pedestrian **comfort**, the greater of the hourly mean or gust equivalent mean wind speed occurring for 5% of the time, i.e. no more than 292 hours per annum, between 6 am and 10 pm should be less than:

- 8 m/s for walking type activities in transient spaces,
- 6 m/s for more leisurely standing type activities such as window shopping or waiting for public transport, and
- 4 m/s for more sedentary activities such as pedestrian sitting, but not commercial outdoor dining where a more stringent criterion is required.

Transferring the 5% of the measured wind speed to ground level would result in a mean wind speed of about 6 m/s, which is classified as on the boundary of pedestrian standing and walking. This is considered representative of the relatively exposed wind conditions in this area.

3.4 Data analysis methodology

Mean wind speed and turbulence characteristics were taken with hot-film anemometers at a number of test locations around the site. Measurements were taken at pedestrian level for 16 wind directions at 22.5° intervals.

Mean, $\overline{U}$, and standard deviation, σ, values of wind speed are used to calculate the statistical peak event, $\widehat{U}$, using: $\widehat{U} = \overline{U} + g \cdot \sigma$

where g is a peak factor based on the duration of the mean and gust events. For this study a value of 3.0 and 3.6 have been used for the 3 s and 0.5 s duration gust events associated with the comfort and safety criterion respectively. For locations with a high directional mean content, the peak factor approach is less reliable and the measured peak has been used in the analysis.

The directional wind tunnel data were combined with the climate data and the specific wind controls. The directional results are presented in Appendix 4, an example presented in Figure 3.

The polar plot, to the left of Figure 3, shows the influence of wind direction relative to the local wind climate. The distance of the point from the centre of the plot is wind speed ratio, whereas the contours provide reference to the wind climate. The polar plot provides information on the incident strong wind directions, and whether a steady or gusty wind thereby allowing appropriate mitigation measures to be developed.

The probability chart, to the right of Figure 3, plots the integrated probability of exceeding a particular wind speed for the location against the mean/GEM wind speed for comfort. This graph clearly illustrates the expected probability distribution of wind speed at a specific location: for example, the mean wind speed exceeded for 5% of time would be about 4.6 m/s as illustrated in Figure 3. The 0.5 and 3 s duration gust wind speed can be estimated by multiplying this value by 2.0 and 1.85 respectively. The solid red line shows the measured results that crosses the 5% probability level to the left of the diamond symbol for the Sydney planning scheme (2016) criteria, and therefore, would be classified as suitable for pedestrian standing. On Figure 3, various internationally recognised wind comfort criteria for assessing the wind climate are presented, with the various symbols indicating the comfort category targets for specific activities.

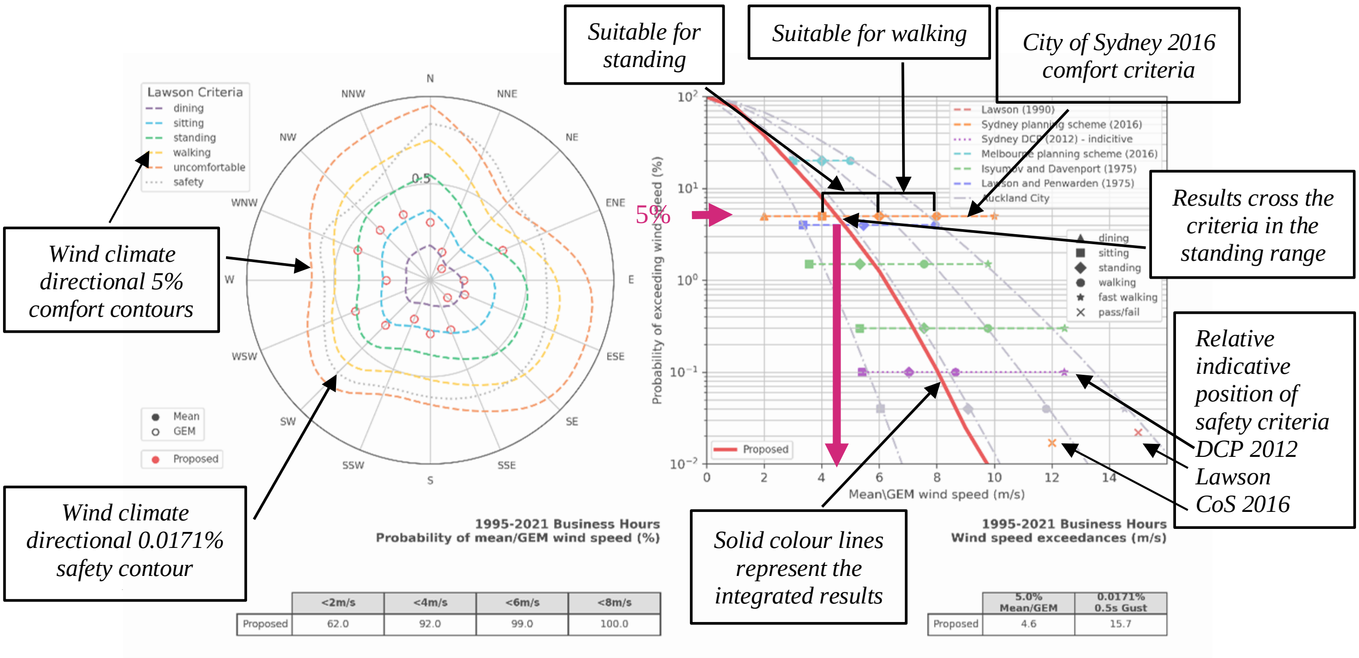


Figure 3: Example directional results and probabilistic comparison between wind criteria based on mean wind speed (for the hours between 6 am and 10 pm)

The table on the bottom left of Figure 3 gives the percentage of time that the mean/GEM wind speed would be less than the wind speed for the various classification categories. In the example, the wind speed associated with the dining and sitting criteria would be expected to occur for 62% and 92% of the time respectively. The table to the bottom right provides the integrated wind speeds associated with the 5% of the time mean/GEM (comfort criterion) and 0.0171% 0.5 s gust (safety criterion) based on a peak factor of 3.0.

Relative positions of various safety criteria are presented illustrating that the City of Sydney planning scheme (2016) criteria are more stringent than other criteria.

3.5 Discussion of results

For the ease of comparison, the primary findings of the study are summarised in Figure 4, which lists the locations selected for investigation, shown in Figure 5, along with the assumed target, and calculated safety and comfort classifications. The values presented in Figure 4 are the wind speed associated with the criterion probability of time, and the colour represents the classification associated with the criterion. A similar colour notation is used in the visual summary in Figure 5, where the central and outer colours represent the comfort and safety classification respectively.

It is evident from the results that all publicly accessible ground level locations meet the safety criterion, except for Locations 2, 5, and 11 to the east and north of the tower, which marginally exceed the criterion. The directional information is presented in Appendix 4. It is evident that for Location 2, the strong wind direction is from the north-west quadrant with the flow accelerating between the proposed and northern Darling Park tower. Locations 5 and 11 in the park to the north, are affected by winds from the south-west quadrant with downwash flow impinging in this area. These exceedances are a function of the isolated tower massing. The magnitude of the exceedances is small and the pedestrian use of these areas during extreme weather events is less likely except for the main thoroughfares from the building that pass the criterion. With the relatively stringent safety criterion, Figure 3, the usability of the spaces during strong wind events, and omission of landscaping from the model, it is considered that these exceedances would be acceptable. A canopy covering a portion of the walkways could be included to locally improve the wind conditions for pedestrians.

From a comfort perspective, it is evident from Figure 4 and Figure 5 that the majority of locations around the site are classified as suitable for pedestrian sitting or standing type activities, with some exposed locations meeting the walking criterion, and one location classified as suitable for outdoor dining. All locations meet the target classification except Location 44 on the Level 0 terrace, which slightly exceeds the 4 m/s sitting criterion with a value of 4.3 m/s. The podium was modelled in a worst case scenario with a fully open western façade, which would be closed, or partially closed when uncomfortable for patrons. The wind conditions along the semi-outdoor laneways are considered suitable for the intended use of the space as a transient and retail arcade, if it is desired to improve the local wind environment for more sedentary activities, additional amelioration such as solid vertical screens could be employed in the laneways.

Scale modelling effects impact the flow through the small volume, semi-enclosed areas and the results in these areas may underestimate the actual wind conditions.

The exceedances of the comfort and safety criteria from previous testing around the building corners have been mitigated with the use of horizontal canopy structures offering wind, rain, and solar protection.

Description / identifier			Safety		Comfort					
							% time less than mean wind speed			
			Target	Result	Target	Result	<2 m/s	<4 m/s	<6 m/s	<8 m/s
Ground Plane	Crescent Garden	1	24	17.0	>4 to 6	4.6	62	92	99	100
	North Park	2	24	**26.4**	>6 to 8	7.2	29	74	91	97
		3	24	20.4	>6 to 8	4.6	55	92	99	100
		4	24	15.4	>6 to 8	3.6	70	97	100	100
		5	24	**24.6**	>6 to 8	5.2	51	88	97	99
		6	24	23.6	>6 to 8	6.5	30	74	93	99
		7	24	23.8	>6 to 8	6.1	37	80	95	99
		8	24	21.2	>6 to 8	6.1	39	79	95	99
		9	24	23.2	>6 to 8	5.2	51	87	97	100
		10	24	21.1	>6 to 8	4.2	59	94	99	100
		11	24	**25.7**	>6 to 8	6.6	41	79	93	98
	Level 3 south	12	24	6.0	>6 to 8	1.0	100	100	100	100
		13	24	23.3	>6 to 8	5.0	41	89	97	99
		14	24	19.4	>4 to 6	4.3	73	94	98	100
		15	24	22.6	>4 to 6	4.3	74	94	98	99
	Level 3 east	16	24	18.4	>6 to 8	3.8	84	96	99	100
		17	24	20.9	>6 to 8	4.5	63	93	98	100
		18	24	19.5	>6 to 8	4.4	66	94	99	100
		19	24	19.3	>6 to 8	4.1	66	95	99	100
		20	24	23.6	>6 to 8	6.4	41	83	94	98
	Level 3 north	21	24	22.5	>6 to 8	5.3	39	87	97	100
		22	24	13.8	>4 to 6	3.0	86	98	100	100
	Level 3 west	23	24	18.9	>4 to 6	4.4	68	93	99	100
		24	24	20.8	>4 to 6	5.4	58	86	97	100
		25	24	14.7	>4 to 6	2.8	90	99	100	100
		26	24	23.5	>4 to 6	5.6	55	88	96	99
Podium	Level 2	27	24	14.0	>4 to 6	3.6	68	98	100	100
		28	24	11.9	>6 to 8	2.9	84	99	100	100
		29	24	18.9	>6 to 8	4.2	77	95	99	100
		30	24	18.4	>6 to 8	4.2	69	94	99	100
		31	24	10.9	>6 to 8	2.1	94	100	100	100
	Level 1	32	24	15.7	>6 to 8	3.5	79	97	100	100
		33	24	11.2	>6 to 8	2.9	84	99	100	100
		34	24	15.4	>6 to 8	3.8	71	96	100	100
		35	24	21.7	>4 to 6	5.3	47	87	98	100
		36	24	16.0	>6 to 8	3.5	81	97	99	100
		37	24	13.1	>2 to 4	3.1	82	99	100	100
		38	24	14.3	>2 to 4	3.0	86	98	100	100
		39	24	12.8	>2 to 4	2.9	87	99	100	100
		40	24	7.9	>6 to 8	2.1	96	100	100	100
		41	24	22.3	>6 to 8	5.1	55	89	98	100
		42	24	20.8	>6 to 8	5.9	40	79	95	99
	Level 0	43	24	10.6	>6 to 8	2.8	86	100	100	100
		44	24	17.9	>2 to 4	4.3	76	94	99	100
		45	24	13.9	>6 to 8	3.4	77	98	100	100
		46	24	10.5	>2 to 4	2.8	85	100	100	100
		47	24	9.3	>6 to 8	2.4	92	100	100	100
		48	24	14.1	>6 to 8	3.3	77	98	100	100
Tower	Level 8 terrace	49	24	**24.5**	>4 to 6	5.1	45	91	97	99
	Level 10 terrace	50	24	**24.1**	>4 to 6	5.7	54	85	96	99
	Level 15 terrace	51	24	19.5	>4 to 6	4.2	76	94	99	100

LEGEND

Safety criterion

≤24	Pass
>24	Fail

Comfort criterion

≤2	Outdoor dining
>2 to 4	Pedestrian sitting
>4 to 6	Pedestrian standing
>6 to 8	Pedestrian walking
>8 to10	Business walking
>10	Uncomfortable

Figure 4: Summary of wind tunnel results

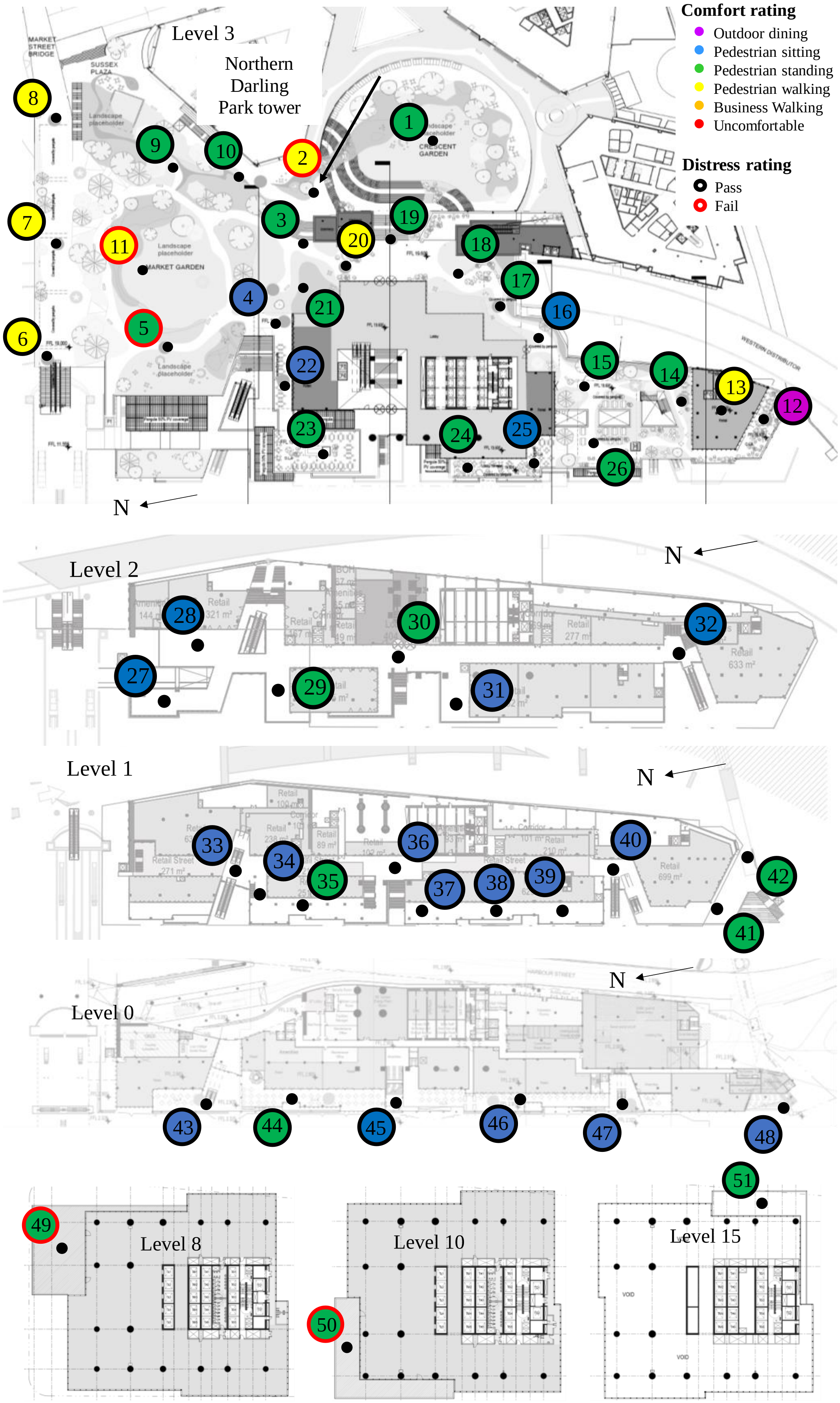


Figure 5: Measurement locations with comfort/safety classifications

4 References

Arup, (2020), Cockle Bay Wharf, Environmental wind assessment.

Australasian wind engineering society (2019), Quality assurance manual: wind engineering studies of buildings, AWES-QAM-1-2019.

City of Auckland (2016), Auckland Unitary Plan Operative.

City of Sydney (2012), Sydney Develop Control Plan.

City of Melbourne (2017), Melbourne Planning Scheme.

CPP Cermak Peterka Petersen (2017), Pedestrian Wind Environment Wind Tunnel Assessment for: Cockle Bay Park Development, CPP Report 9020.

Hunt, J.C.R., Poulton, E.C., and Mumford, J.C. (1976), The effects of wind on people; new criteria based on wind tunnel experiments, Building and Environment, Vol.11.

Isyumov, N. and Davenport, A.G. (1975), The ground level wind environment in built-up areas, Proc. 4th Int. Conf. on Wind Effects on Buildings, Cambridge University Press, U.K.

Lawson, T.V., and Penwarden, A.D. (1975), The effects of wind on people in the vicinity of buildings, Proc. 4th Int. Conf. on Wind Effects on Buildings, Cambridge University Press, U.K.

Lawson, T.V. (1990), The Determination of the wind environment of a building complex before construction, Department of Aerospace Engineering, University of Bristol, Report Number TVL 9025.

Melbourne, W.H. (1978), Criteria for environmental wind conditions, J. Wind Engineering and Industrial Aerodynamics, Vol.3, No.2-3, pp.241-249.

Netherlands Standardization Institute, NEN (2006), Wind comfort and wind danger in the built environment, NEN 8100 (in Dutch) Dutch Standard.

Penwarden, A.D. and Wise, A.F.E. (1975), Wind environment around buildings, Building Research Establishment Report, HMSO.

San Francisco Planning Department (2015), San Francisco Planning Code Section 148.

Appendix 1: Wind climate

The wind frequency and direction information measured by the Bureau of Meteorology anemometer at a standard height of 10 m at Sydney Airport from 1995 to 2017 have been used in this analysis. anemometer is located about 10 km to the south-south-west of the site. The directional wind speeds measured here are considered representative of the wind conditions at the site. The directional wind speed distribution has corrected to the mean wind speed at the wind-tunnel reference height of 200 m for the analysis, Figure 6. The arms of the wind rose point in the direction from where the wind is coming from. The

It is evident from Figure 6 that strong prevailing winds are organised into three main groups which centre at about the north-east, south, and west quadrants.

Strong summer winds occur mainly from the south and north-east quadrants. Winds from the south are associated with large synoptic frontal systems and generally provide the strongest gusts during summer. Moderate intensity winds from the north-east tend to bring cooling relief on hot summer afternoons typically lasting from noon to dusk. These are small-scales temperature driven effects; the larger the temperature differential between land and sea, the stronger the wind.

Winter and early spring strong winds typically occur from the south-west, and west quadrants. West quadrant winds provide the strongest winds affecting the area throughout the year and tend to be associated with large scale synoptic events that can be hot or cold depending on inland conditions.

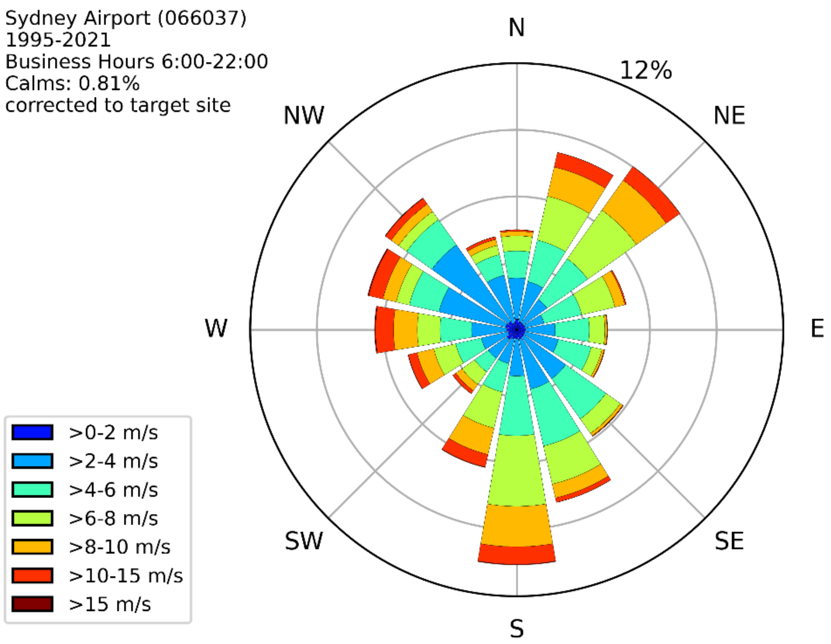


Figure 6: Wind rose showing probability of time of wind direction and speed

Appendix 2: Wind flow mechanisms

An urban environment generates a complex wind flow pattern around closely spaced structures, hence it is exceptionally difficult to generalise the flow mechanisms and impact of specific buildings as the flow is generated by the entire surrounds. However, it is best to start with an understanding of the basic flow mechanisms around an isolated structure.

Isolated building

When the wind hits an isolated building, the wind is decelerated on the windward face generating an area of high pressure, Figure 7, with the highest pressure at the stagnation point at about two thirds of the height of the building. The higher pressure bubble extends a distance from the building face of about half the building height or width, whichever is lower. The flow is then accelerated down and around the windward corners to areas of lower pressure, Figure 7. This flow mechanism is called **downwash** and causes the windiest conditions at ground level on the windward corners and along the sides of the building.

Rounding the building corners or chamfering the edges reduces downwash by encouraging the flow to go around the building at higher levels. However, concave curving of the windward face can increase the amount of downwash. Depending on the orientation and isolation of the building, uncomfortable downwash can be experienced on buildings of greater than about 6 storeys.

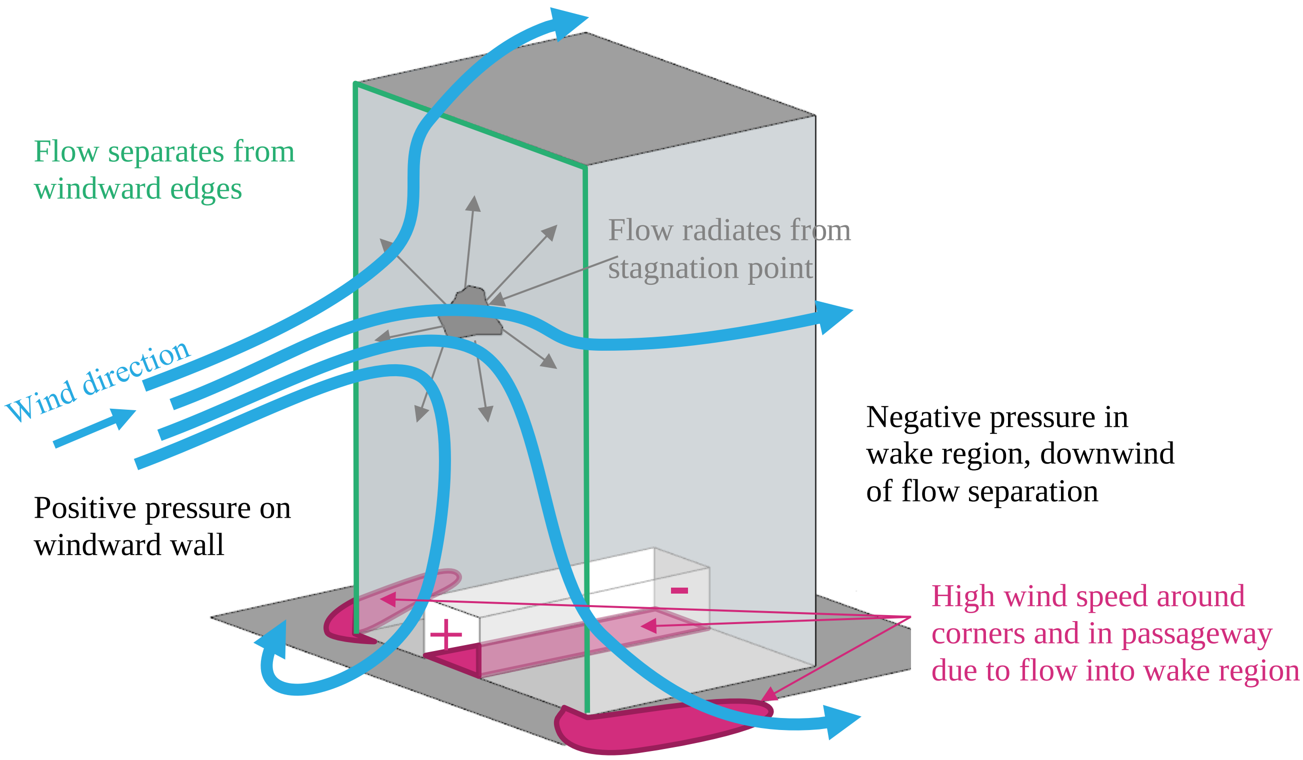


Figure 7: Schematic wind flow around tall isolated building

Techniques to mitigate the effects of downwash winds at ground level include the provision of horizontal elements, the most effective being a podium to divert the downward flow away from pavements and building entrances, but this will generate windy conditions on the podium roof, Figure 11. Generally, the lower the podium roof and deeper the setback from the podium edge to the tower improves the ground level wind conditions. The provision of an 8 m setback on an isolated building is generally sufficient to improve ground level conditions, but is highly dependent on the building isolation, orientation to prevailing wind directions, shape and width of the building, and any plan form changes at higher level.

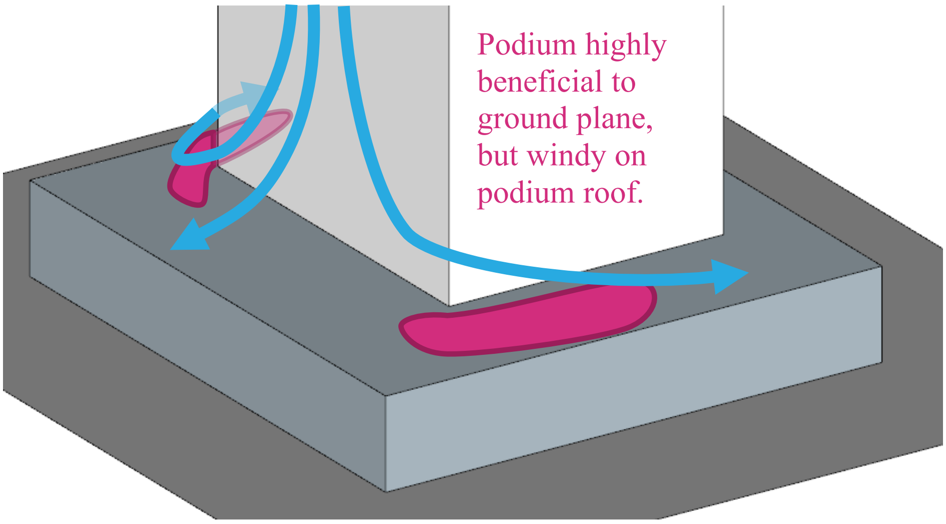


Figure 8: Schematic flow pattern around building with podium

Awnings along street frontages perform a similar function as a podium, and generally the larger the horizontal projection from the façade, the more effective it will be in diverting downwash flow, Figure 9. Awnings become less effective if they are not continuous along the entire façade, or on wide buildings as the positive pressure bubble extends beyond the awning resulting in horizontal flow under the awning.

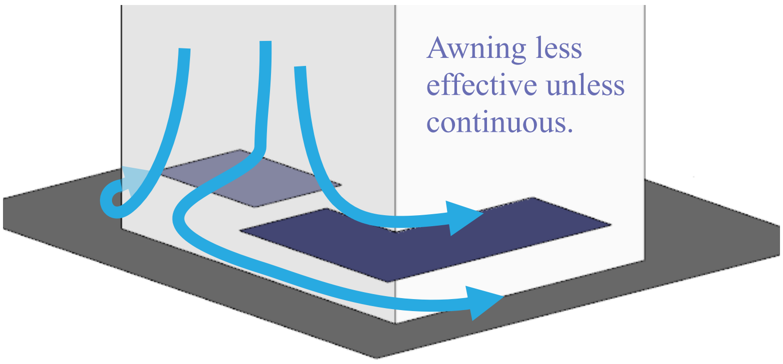


Figure 9: Schematic flow pattern around building with awning

It should be noted that colonnades at the base of a building with no podium generally create augmented windy conditions at the corners due to an increase in the pressure differential, Figure 10. Similarly, open through-site links through a building cause wind issues as the environment tries to equilibrate the pressure generated at the entrances to the link, Figure 7. If the link is blocked, wind conditions will be calm unless there is a flow path through the building, Figure 11. This area is in a region of high pressure and therefore the is the potential for internal flow issues. A ground level recessed corner has a similar effect as an undercroft, resulting in windier conditions, Figure 11.

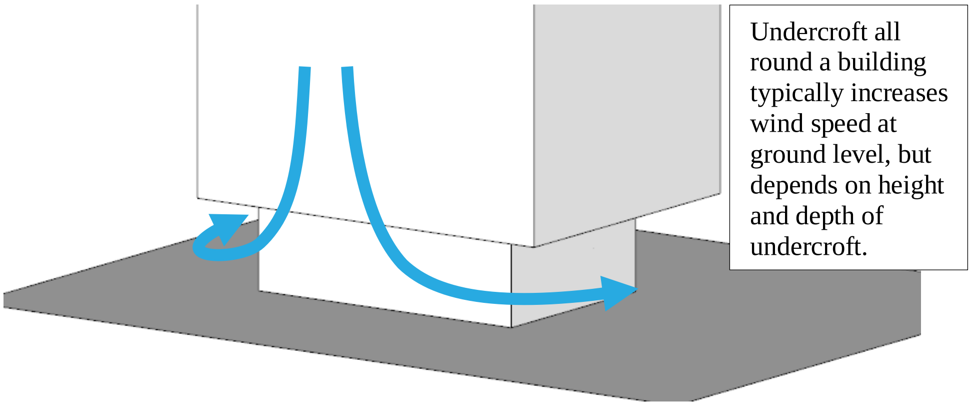


Figure 10: Schematic of flow patterns around isolated building with undercroft

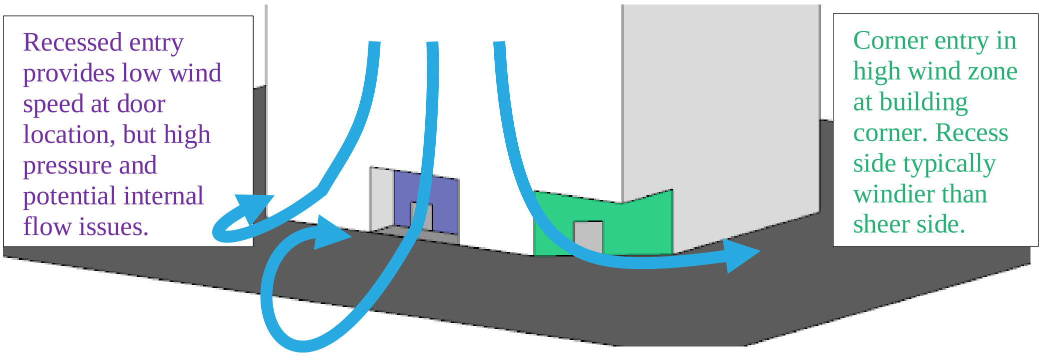


Figure 11: Schematic of flow patterns around isolated building with ground articulation

Multiple buildings

When a building is located in a city environment, depending on upwind buildings, the interference effects may be positive or negative, Figure 12. If the building is taller, more of the wind impacting on the exposed section of the building is likely to be drawn to ground level by the increase in height of the stagnation point, and the additional negative pressure induced at the base. If the upwind buildings are of similar height then the pressure around the building will be more uniform hence downwash is typically reduced with the flow passing over the buildings.

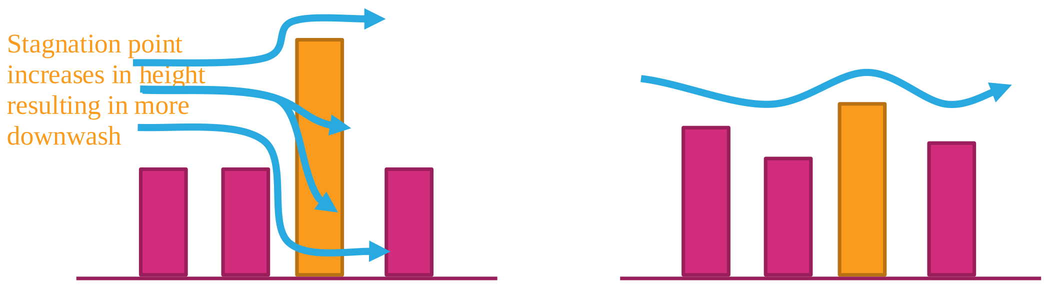


Figure 12: Schematic of flow pattern interference from surrounding buildings

The above discussion becomes more complex when three-dimensional effects are considered, both with orientation and staggering of buildings, and incident wind direction, Figure 13.

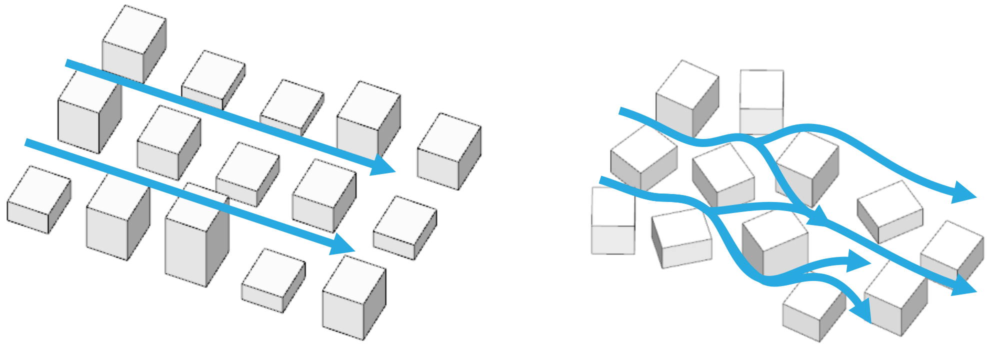


Figure 13: Schematic of flow patterns through a grid and random street layout

Channelling occurs when the wind is accelerated between two buildings, or along straight streets with buildings on either side, Figure 13(L), particularly on the edge of built-up areas where the approaching flow is diverted around the city massing and channelled along the fringe by a relatively continuous wall of building facades. This is generally the primary mechanism driving the wind conditions for this perimeter of a built-up area, particularly on corners, which are exposed to multiple wind directions. The perimeter edge zone in a built-up area is typically about two blocks deep. Downwash is more important flow mechanism for the edge zone of a built-up area with buildings of similar height.

As the city expands, the central section of the city typically becomes calmer, particularly if the grid pattern of the streets is discontinued, Figure 13(R). When buildings are located on the corner of a central city block, the geometry becomes slightly more important with respect to the local wind environment.

Appendix 3: Wind speed criteria

Primary controls that are used in the assessment of how wind affects pedestrians are the wind speed, and rate of change of wind speed. A description of the effect of a specific wind speed on pedestrians is provided in Table 3. It should be noted that the turbulence, or rate of change of wind speed, will affect human response to wind and the descriptions are more associated with response to mean wind speed.

Table 3. Summary of wind effects on pedestrians

Description	Speed (m/s)	Effects
Calm, light air	0–2	Human perception to wind speed at about 0.2 m/s. Napkins blown away and newspapers flutter at about 1 m/s.
Light breeze	2–3	Wind felt on face. Light clothing disturbed. Cappuccino froth blown off at about 2.5 m/s.
Gentle breeze	3–5	Wind extends light flag. Hair is disturbed. Clothing flaps.
Moderate breeze	5–8	Raises dust, dry soil. Hair disarranged. Sand on beach saltates at about 5 m/s. Full paper coffee cup blown over at about 5.5 m/s.
Fresh breeze	8–11	Force felt on body. Limit of agreeable wind on land. Umbrellas used with difficulty. Wind sock fully extended at about 8 m/s.
Strong breeze	11–14	Hair blown straight. Difficult to walk steadily. Wind noise on ears unpleasant. Windborne snow above head height (blizzard).
Near gale	14–17	Inconvenience felt when walking.
Gale	17–21	Generally impedes progress. Difficulty with balance in gusts.
Strong gale	21–24	People blown over by gusts.

Local wind effects can be assessed with respect to a number of environmental wind speed criteria established by various researchers. These have all generally been developed around a 3 s gust, or 1 hour mean wind speed. During strong events, a pedestrian would react to a significantly shorter duration gust than a 3 s, and historic weather data is normally presented as a 10 minute mean.

Despite the apparent differences in numerical values and assumptions made in their development, it has been found that when these are compared on a probabilistic basis, there is some agreement between the various criteria. However, a number of studies have shown that over a wider range of flow conditions, such as smooth flow across water bodies, to turbulent flow in city centres, there is less general agreement among. The downside of these criteria is that they have seldom been benchmarked, or confirmed through long-term measurements in the field, particularly for comfort conditions. The wind criteria were all developed in temperate climates and are unfortunately not the only environmental factor that affects pedestrian comfort.

For assessing the effects of wind on pedestrians, neither the random peak gust wind speed (3 s or otherwise), nor the mean wind speed in isolation are adequate. The gust wind speed gives a measure of the extreme nature of the wind, but the mean wind speed indicates the longer duration impact on pedestrians. The extreme gust wind speed is considered to be suitable for safety considerations, but not necessarily for serviceability comfort issues such as outdoor dining. This is because the instantaneous gust velocity does not always correlate well with mean wind speed, and is not necessarily representative of the parent distribution. Hence, the perceived ‘windiness’ of a location can either be dictated by strong steady flows, or gusty turbulent flow with a smaller mean wind speed.

To measure the effect of turbulent wind conditions on pedestrians, a statistical procedure is required to combine the effects of both mean and gust. This has been conducted by various researchers to develop an equivalent mean wind speed to represent the perceived effect of a gust event. This is called the ‘gust equivalent mean’ or ‘effective wind speed’ and the relationship between the mean and 3 s gust wind speed is defined within the criteria, but two typical conversions are:

$$\mathrm{U_{GEM}} = \frac{(\mathrm{U_{mean}} + 3 \cdot \sigma_{\mathrm{u}})}{1.85} \text{ and } \mathrm{U_{GEM}} = \frac{1.3 \cdot (\mathrm{U_{mean}} + 2 \cdot \sigma_{\mathrm{u}})}{1.85}$$

It is evident that a standard description of the relationship between the mean and impact of the gust would vary considerably depending on the approach turbulence, and use of the space.

A comparison between the mean and 3 s gust wind speed criteria from a probabilistic basis are presented in Figure 14 and Figure 16. The grey lines are typical results from modelling and show how the various criteria would classify a single location. City of Auckland has control mechanisms for accessing usability of spaces from a wind perspective as illustrated in Figure 14 with definitions of the intended use of the space categories defined in Figure 15.

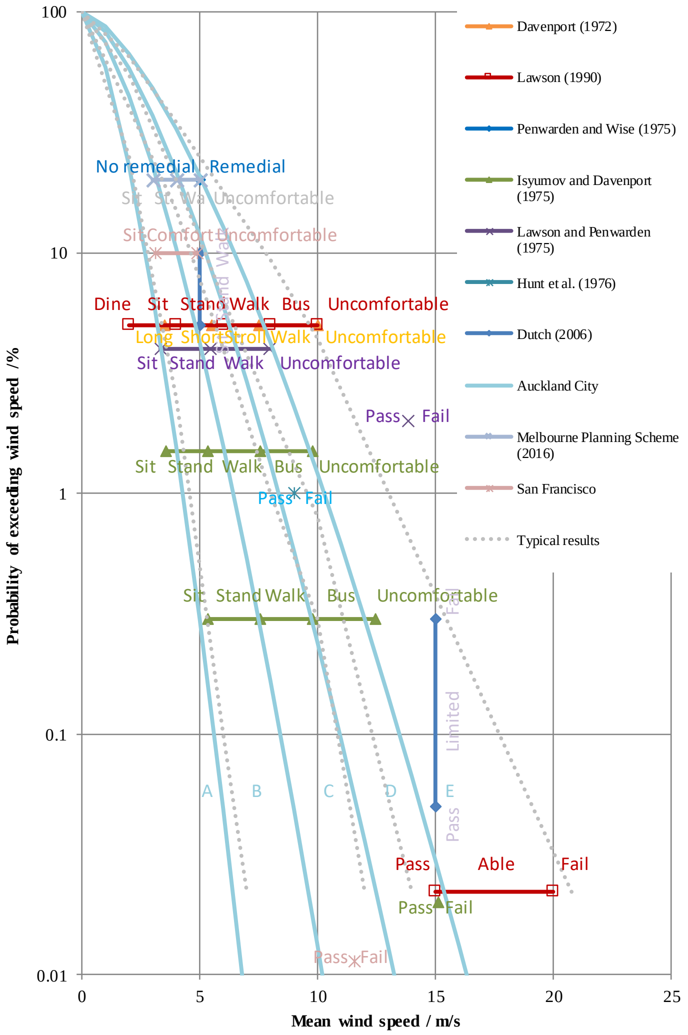


Figure 14: Probabilistic comparison between wind criteria based on mean wind speed

Category A	Areas of pedestrian use or adjacent dwellings containing significant formal elements and features intended to encourage longer term recreational or relaxation use i.e. public open space and adjacent outdoor living space
Category B	Areas of pedestrian use or adjacent dwellings containing minor elements and features intended to encourage short term recreation or relaxation, including adjacent private residential properties
Category C	Areas of formed footpath or open space pedestrian linkages, used primarily for pedestrian transit and devoid of significant or repeated recreational or relaxational features, such as footpaths not covered in categories A or B above
Category D	Areas of road, carriage way, or vehicular routes, used primarily for vehicular transit and open storage, such as roads generally where devoid of any features or form which would include the spaces in categories A - C above.
Category E	Category E represents conditions which are dangerous to the elderly and infants and of considerable cumulative discomfort to others, including residents in adjacent sites. Category E

Figure 15: Auckland Utility Plan (2016) wind categories

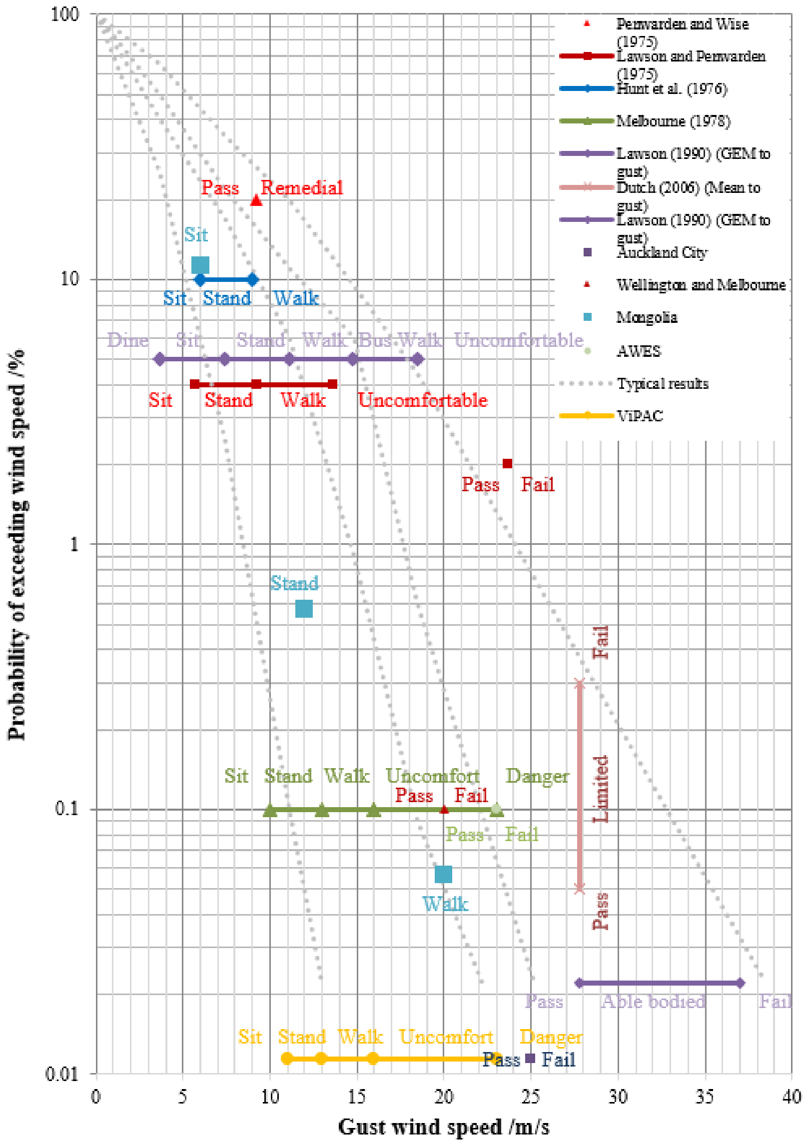
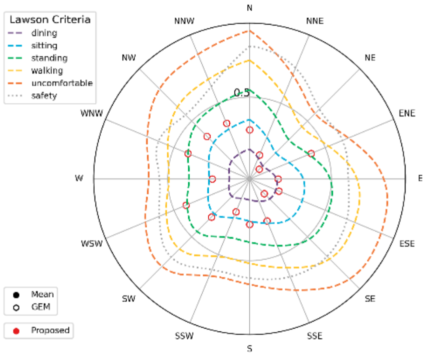


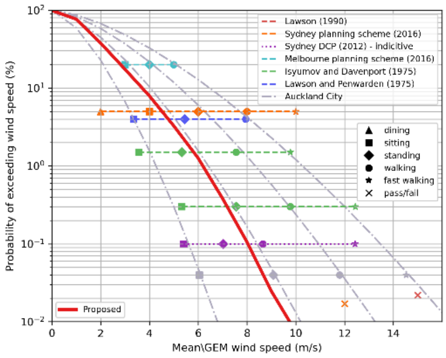
Figure 16: Probabilistic comparison between wind criteria based on 3 s gust wind speed

Appendix 4: Directional comfort data

Location 1



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

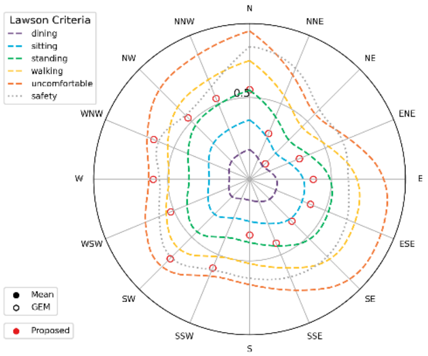


1995-2021 Business Hours
Wind speed exceedances (m/s)

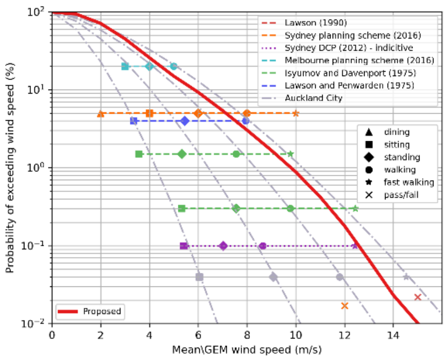
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	62.0	92.0	99.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	4.6	15.7

Location 2



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

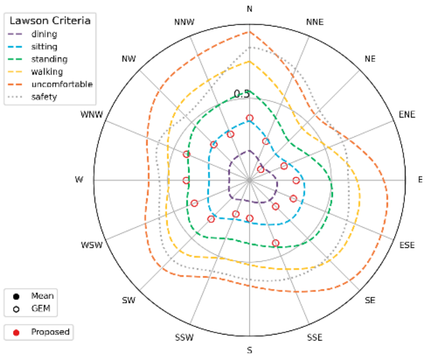


1995-2021 Business Hours
Wind speed exceedances (m/s)

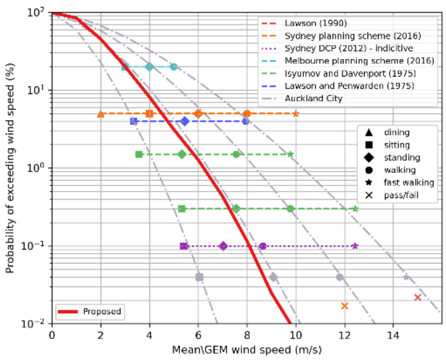
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	29.0	74.0	91.0	97.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	7.2	24.5

Location 3



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

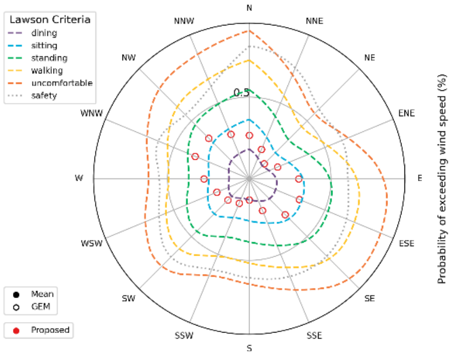


1995-2021 Business Hours
Wind speed exceedances (m/s)

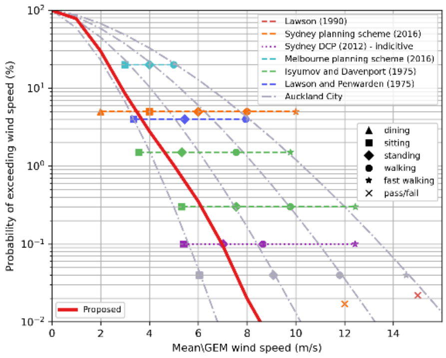
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	55.0	92.0	99.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	4.6	16.3

Location 4



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

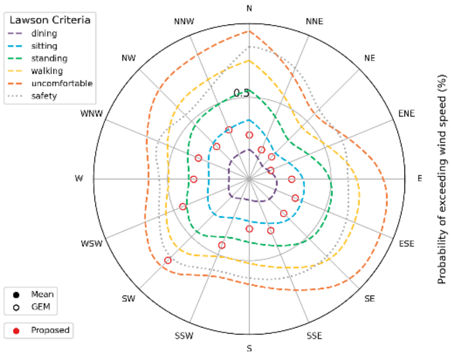


1995-2021 Business Hours
Wind speed exceedances (m/s)

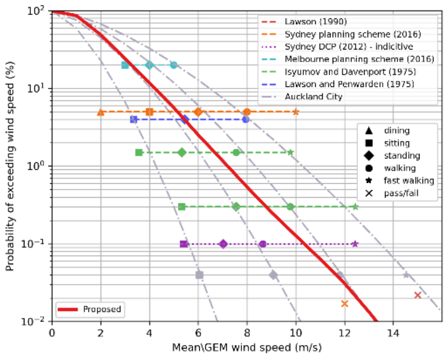
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	70.0	97.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	3.6	13.9

Location 5



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

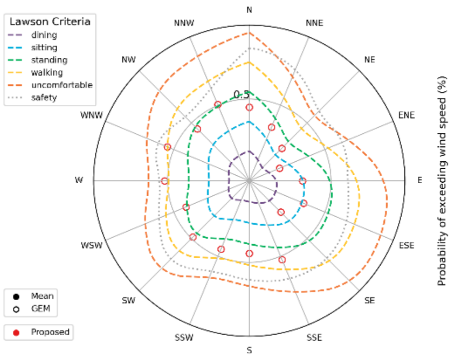


1995-2021 Business Hours
Wind speed exceedances (m/s)

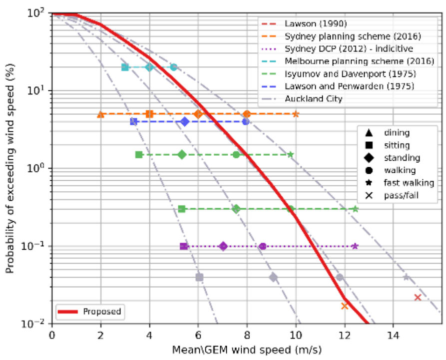
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	51.0	88.0	97.0	99.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	5.2	22.1

Location 6



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

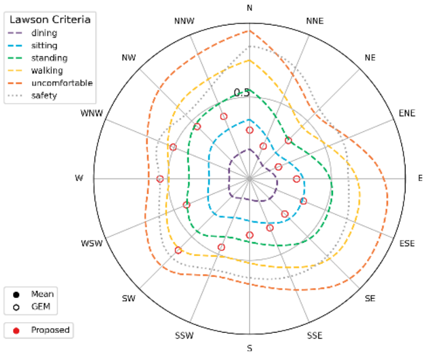


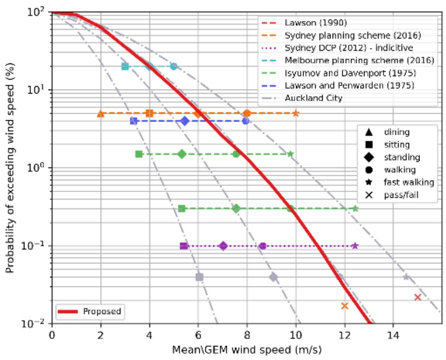
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	30.0	74.0	93.0	99.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	6.5	21.2

Location 7





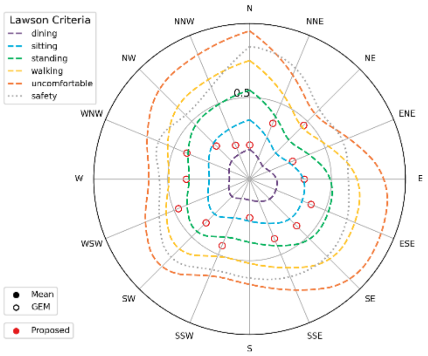
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

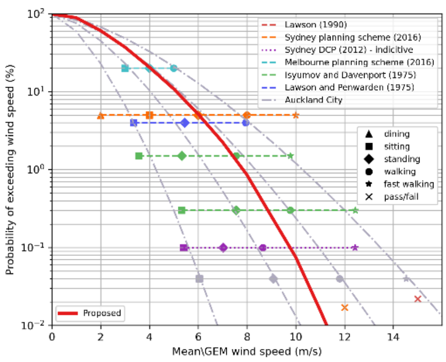
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	37.0	80.0	95.0	99.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	6.1	21.5

Location 8





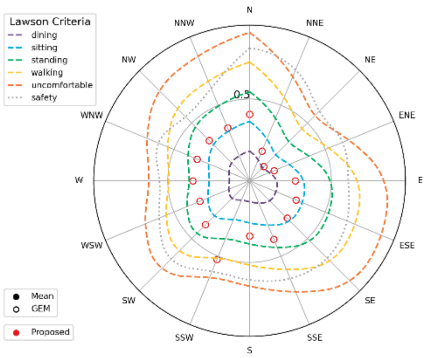
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

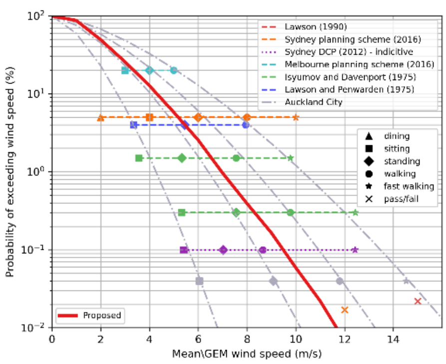
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	39.0	79.0	95.0	99.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	6.1	19.1

Location 9





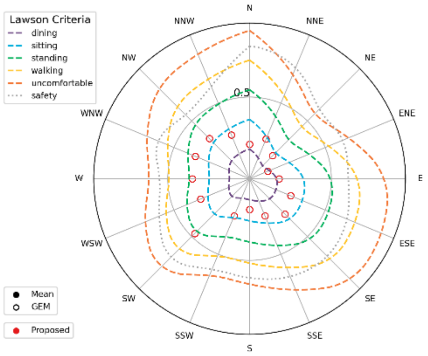
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

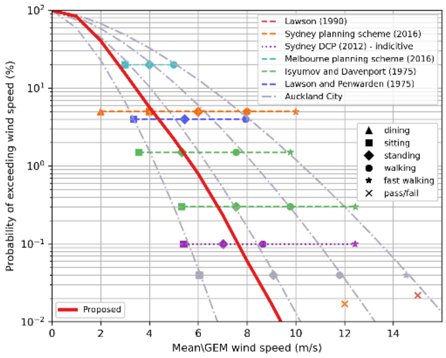
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	51.0	87.0	97.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	5.2	20.6

Location 10





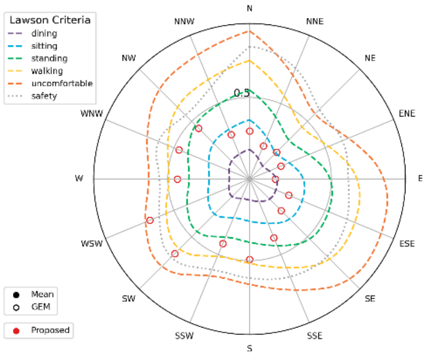
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

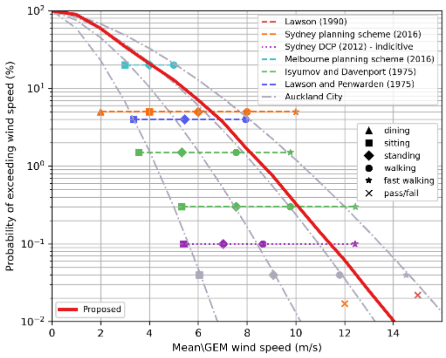
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	59.0	94.0	99.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	4.2	16.3

Location 11





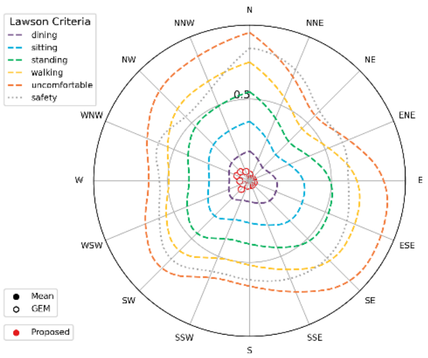
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

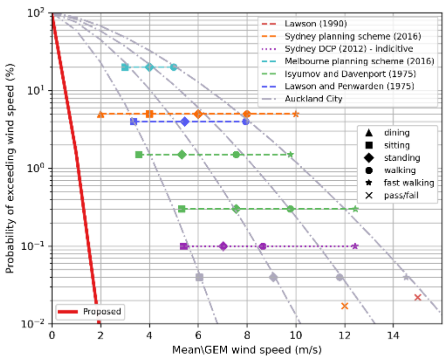
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	41.0	79.0	93.0	98.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	6.6	23.3

Location 12





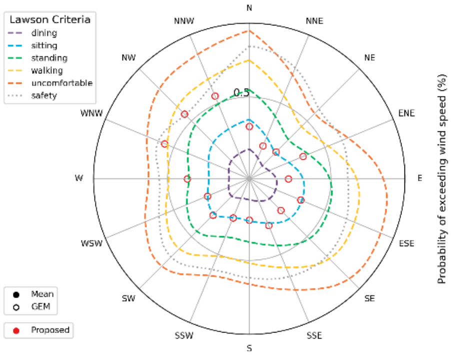
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

1995-2021 Business Hours
Wind speed exceedances (m/s)

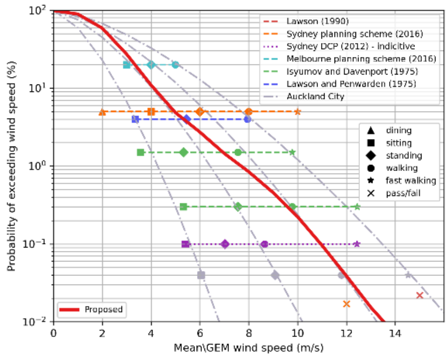
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	100.0	100.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	1.0	3.8

Location 13



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

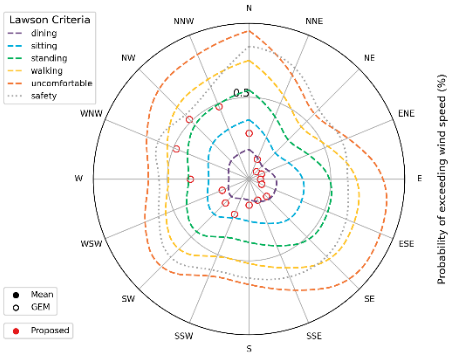


1995-2021 Business Hours
Wind speed exceedances (m/s)

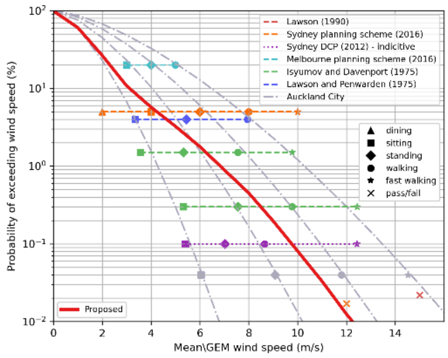
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	41.0	89.0	97.0	99.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	5.0	22.6

Location 14



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

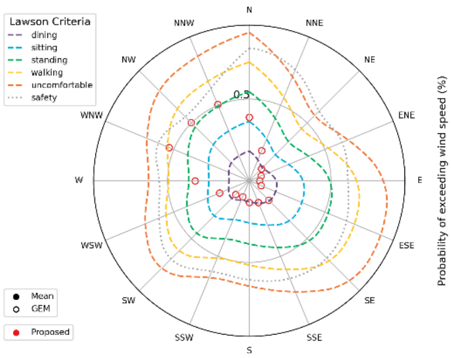


1995-2021 Business Hours
Wind speed exceedances (m/s)

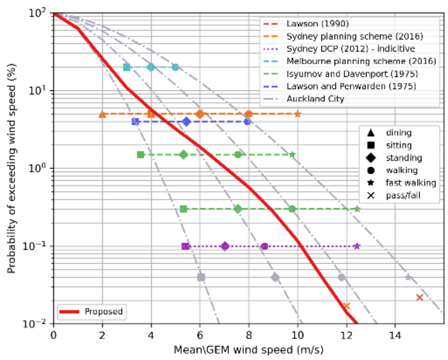
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	73.0	94.0	98.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	4.3	19.9

Location 15



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

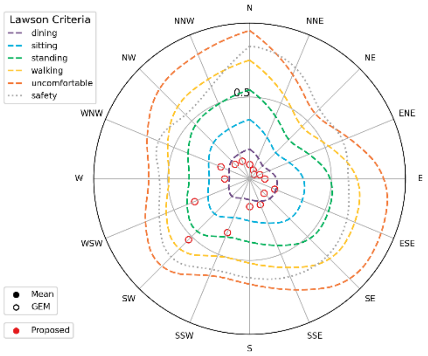


1995-2021 Business Hours
Wind speed exceedances (m/s)

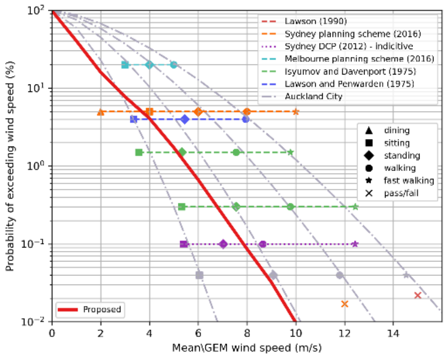
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	74.0	94.0	98.0	99.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	4.3	20.4

Location 16



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

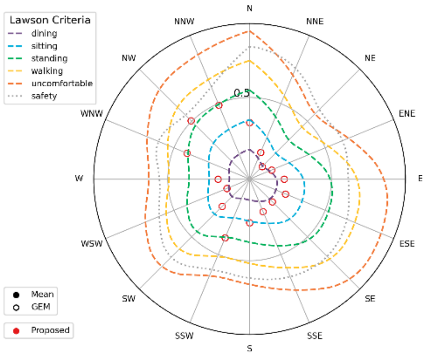


1995-2021 Business Hours
Wind speed exceedances (m/s)

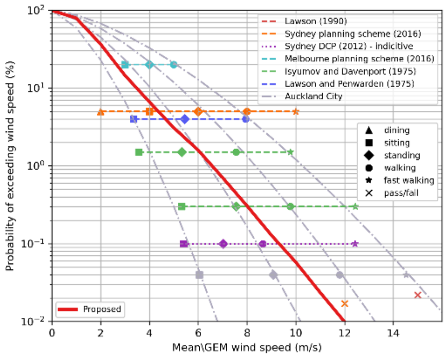
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	84.0	96.0	99.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	3.8	16.5

Location 17



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

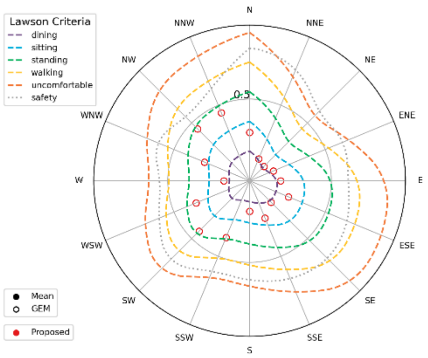


1995-2021 Business Hours
Wind speed exceedances (m/s)

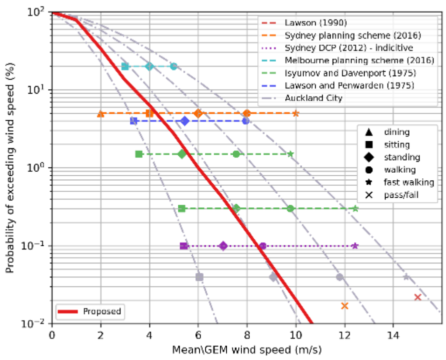
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	63.0	93.0	98.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	4.5	19.2

Location 18



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

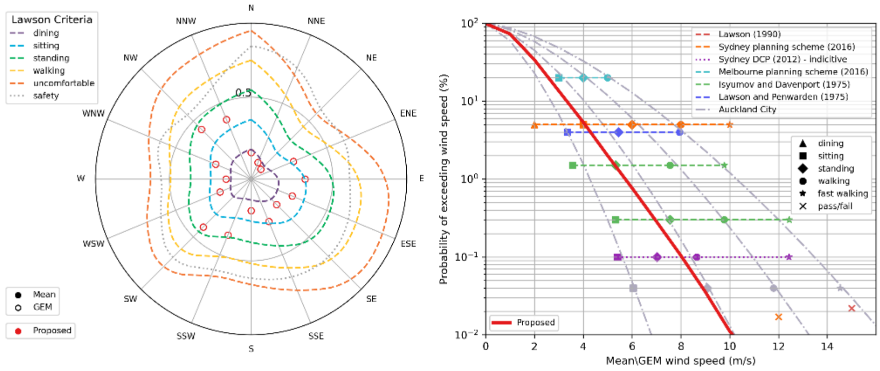


1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	66.0	94.0	99.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	4.4	17.6

Location 19



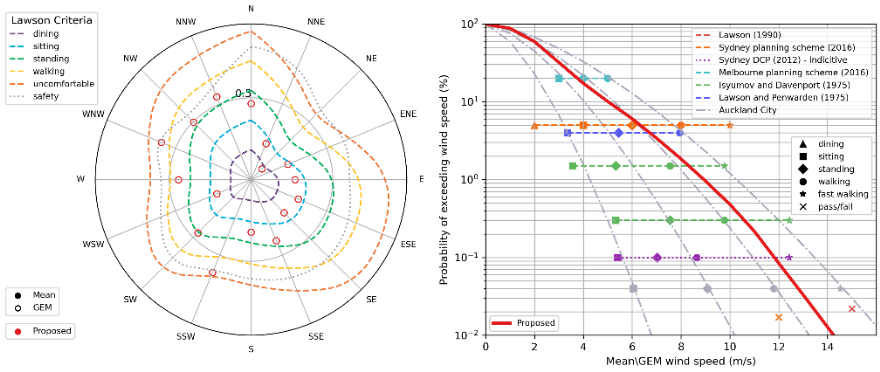
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	66.0	95.0	99.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	4.1	17.3

Location 20



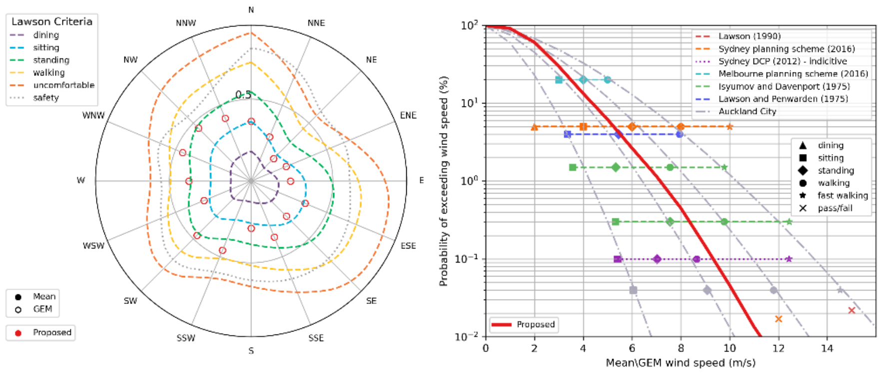
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	41.0	83.0	94.0	98.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	6.4	24.1

Location 21



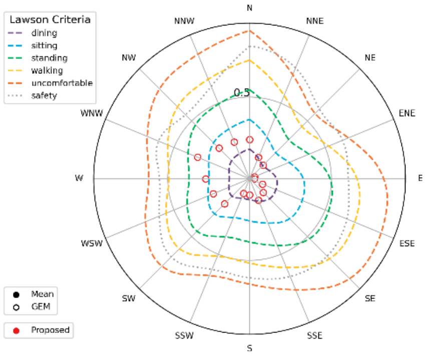
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

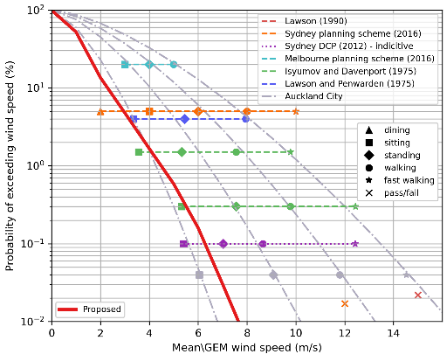
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	39.0	87.0	97.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	5.3	18.9

Location 22





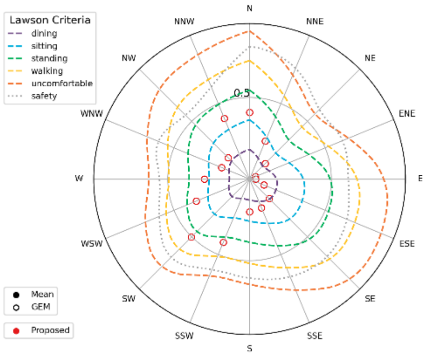
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

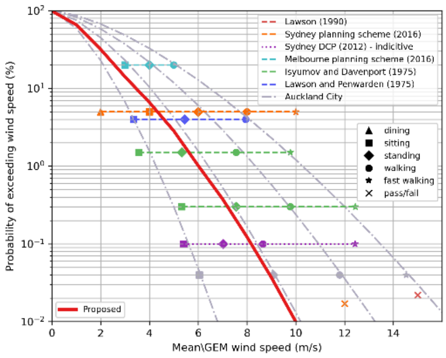
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	86.0	98.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	3.0	12.5

Location 23





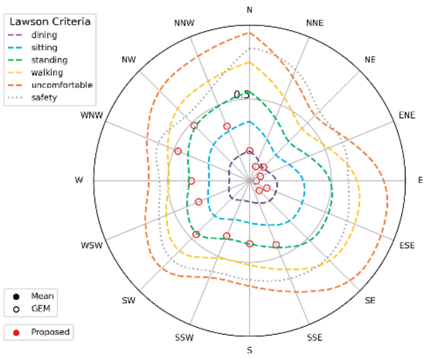
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

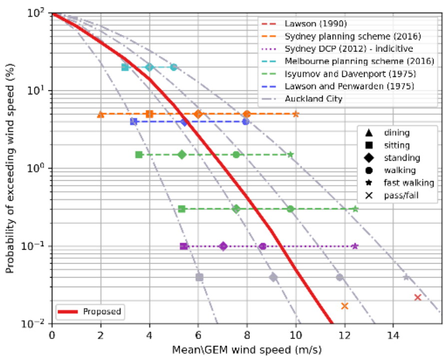
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	68.0	93.0	99.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	4.4	16.9

Location 24





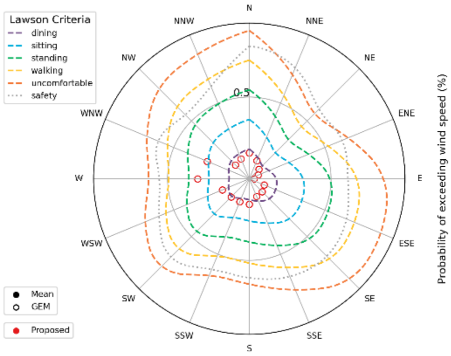
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

1995-2021 Business Hours
Wind speed exceedances (m/s)

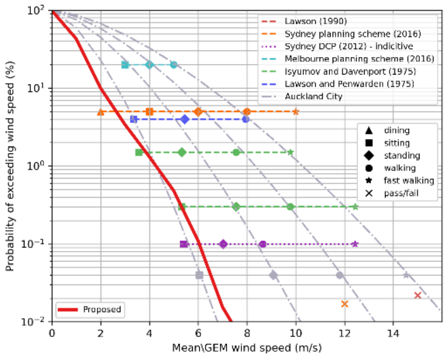
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	58.0	86.0	97.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	5.4	18.8

Location 25



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

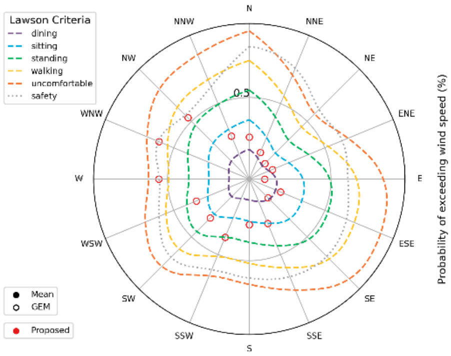


1995-2021 Business Hours
Wind speed exceedances (m/s)

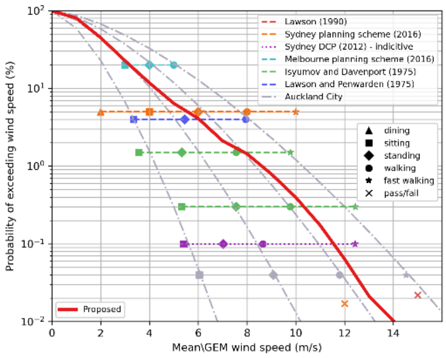
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	90.0	99.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	2.8	12.9

Location 26



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

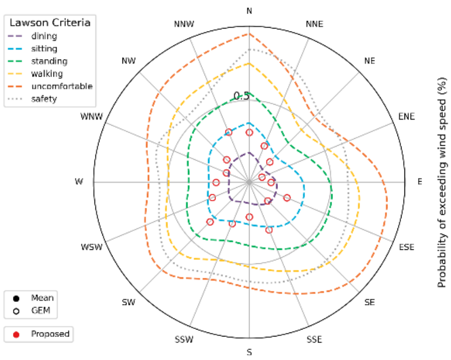


1995-2021 Business Hours
Wind speed exceedances (m/s)

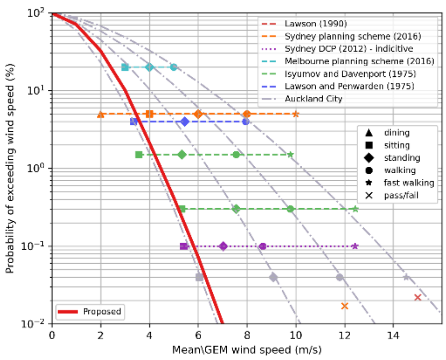
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	55.0	88.0	96.0	99.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	5.6	23.5

Location 27



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

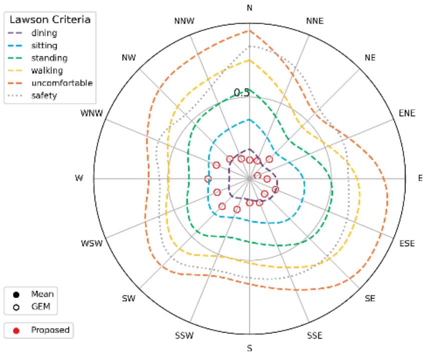


1995-2021 Business Hours
Wind speed exceedances (m/s)

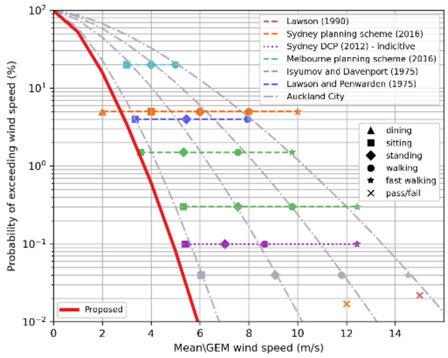
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	68.0	98.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	3.6	12.4

Location 28



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

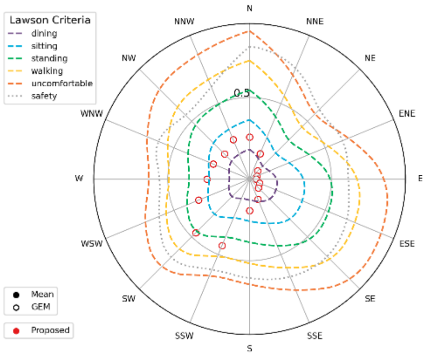


1995-2021 Business Hours
Wind speed exceedances (m/s)

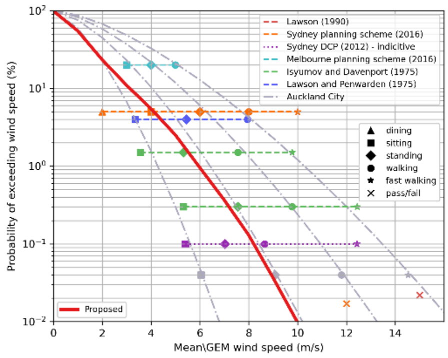
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	84.0	99.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	2.9	10.6

Location 29



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

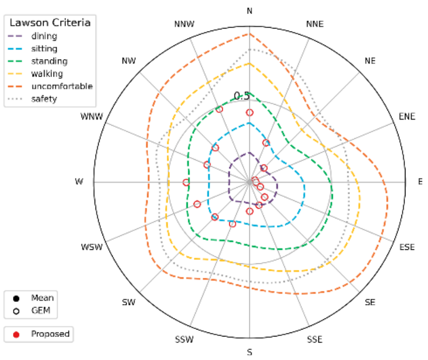


1995-2021 Business Hours
Wind speed exceedances (m/s)

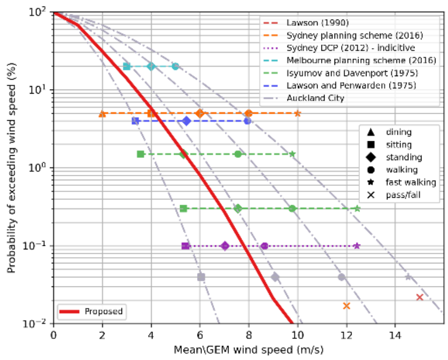
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	77.0	95.0	99.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	4.2	17.0

Location 30



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

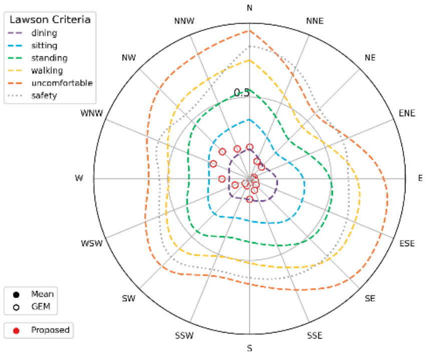


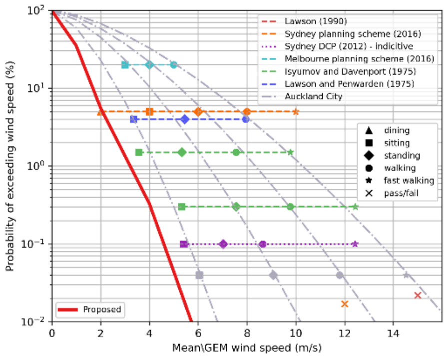
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	69.0	94.0	99.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	4.2	16.5

Location 31





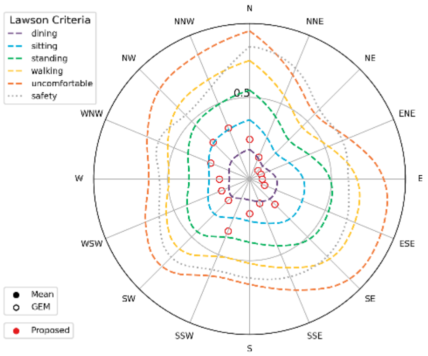
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

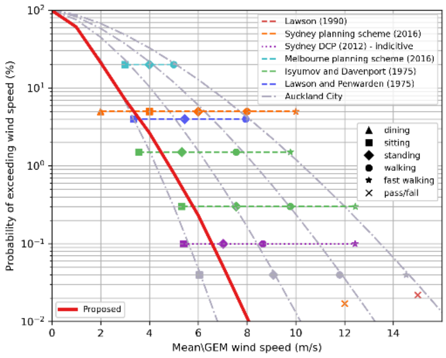
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	94.0	100.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	2.1	9.8

Location 32





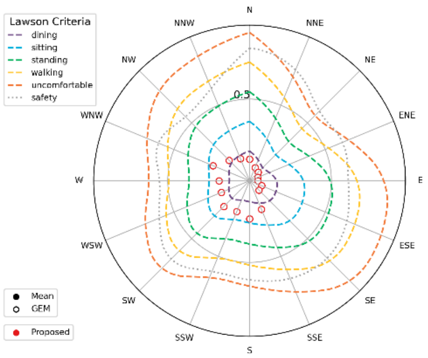
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

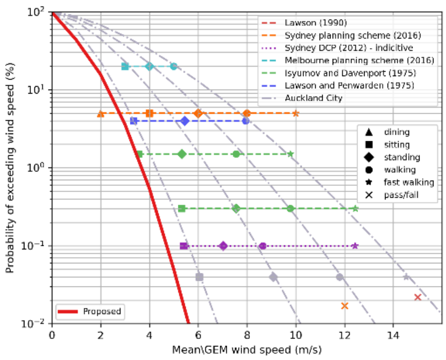
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	79.0	97.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	3.5	13.9

Location 33





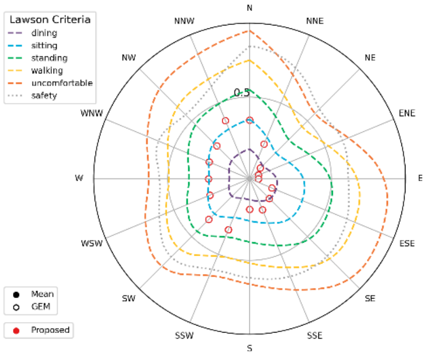
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

1995-2021 Business Hours
Wind speed exceedances (m/s)

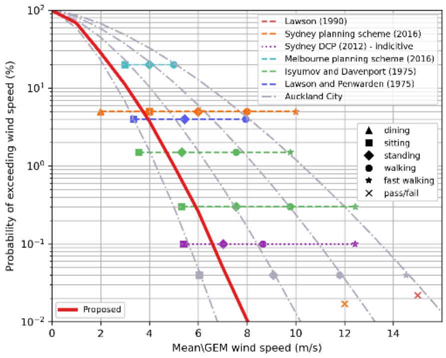
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	84.0	99.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	2.9	9.9

Location 34



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

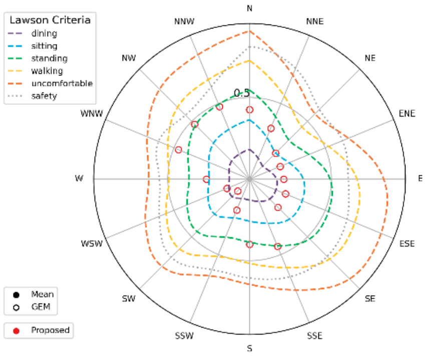


1995-2021 Business Hours
Wind speed exceedances (m/s)

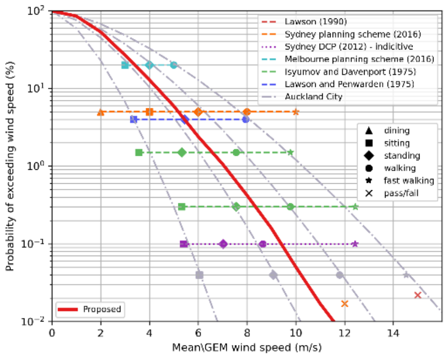
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	71.0	96.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	3.8	13.8

Location 35



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

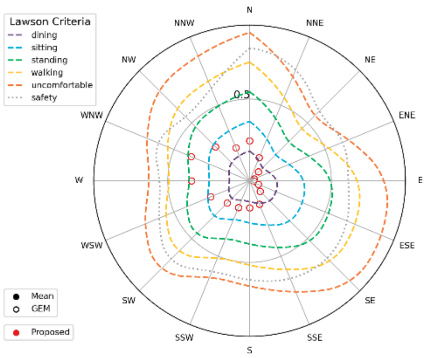


1995-2021 Business Hours
Wind speed exceedances (m/s)

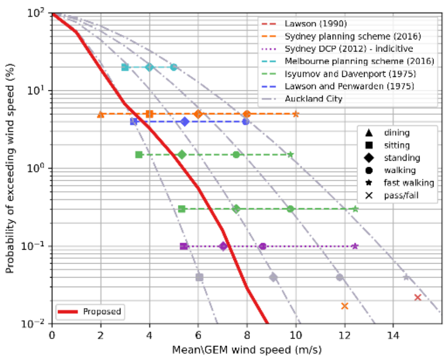
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	47.0	87.0	98.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	5.3	19.5

Location 36



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

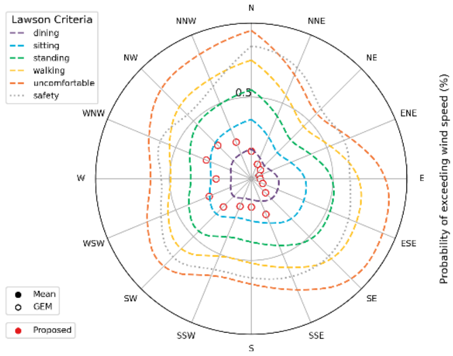


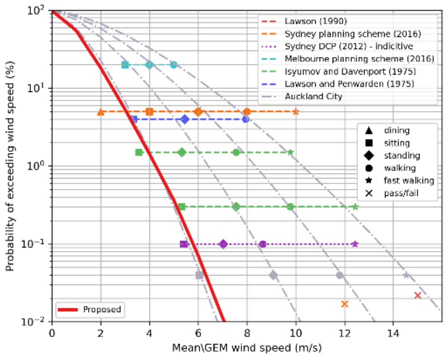
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	81.0	97.0	99.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	3.5	14.6

Location 37





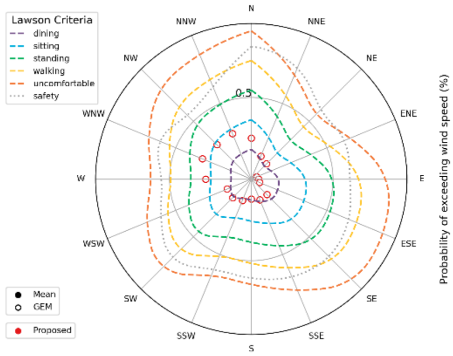
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

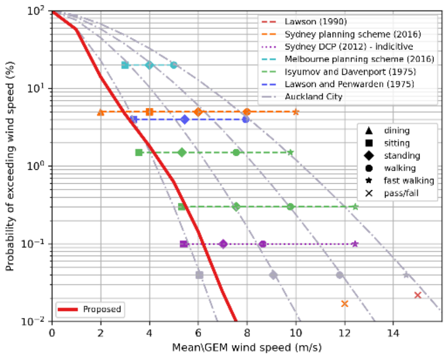
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	82.0	99.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	3.1	11.9

Location 38





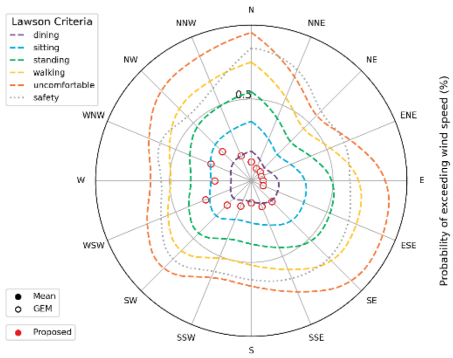
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

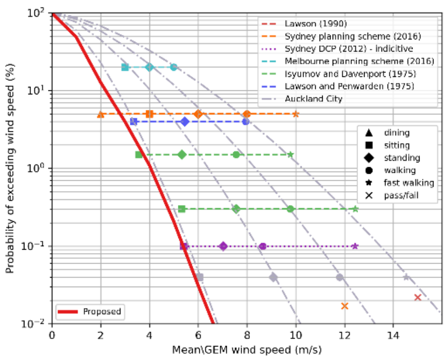
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	86.0	98.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	3.0	12.8

Location 39





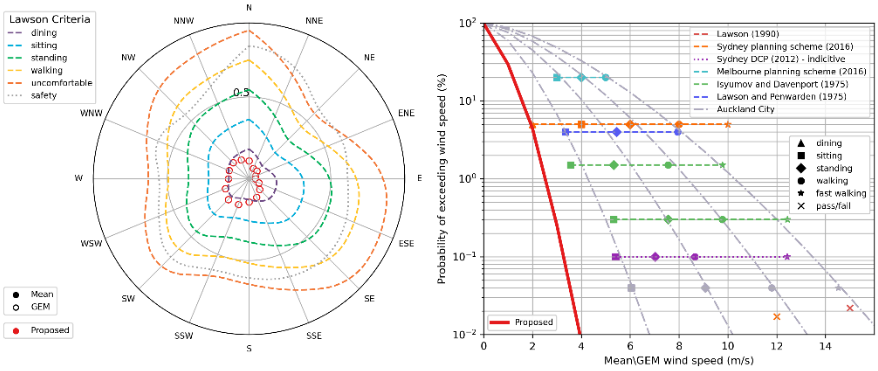
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	87.0	99.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	2.9	11.5

Location 40



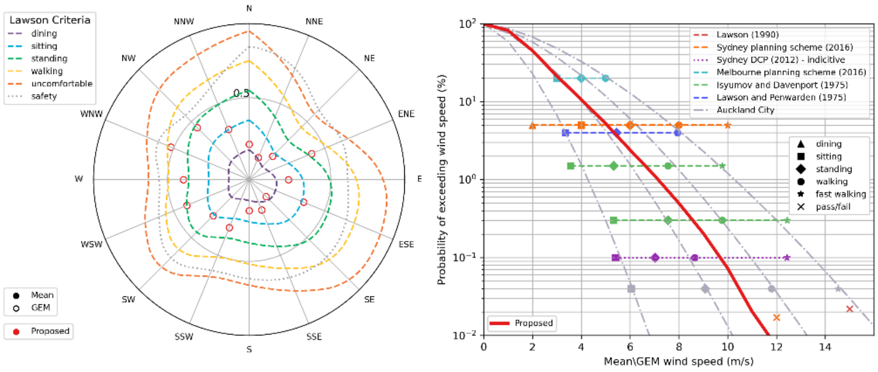
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	96.0	100.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	2.0	7.0

Location 41



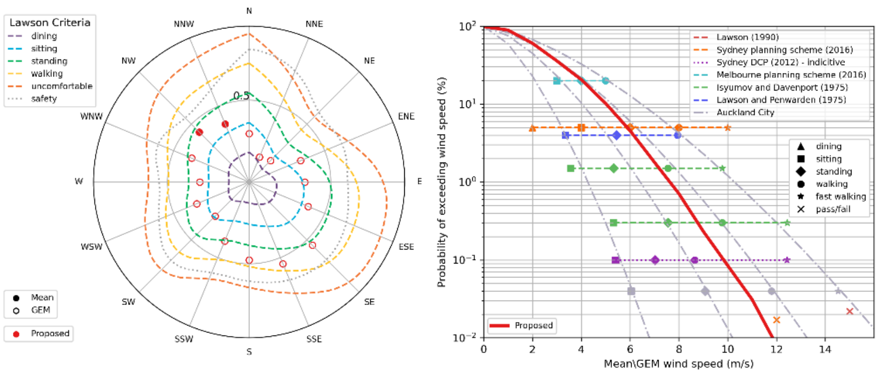
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	55.0	89.0	98.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	5.1	19.8

Location 42



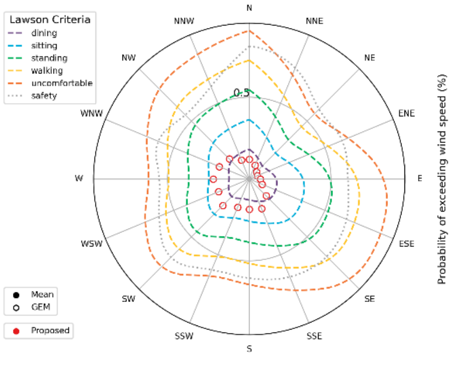
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

1995-2021 Business Hours
Wind speed exceedances (m/s)

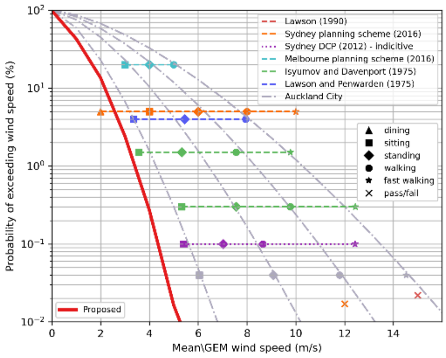
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	40.0	79.0	95.0	99.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	5.9	19.0

Location 43



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

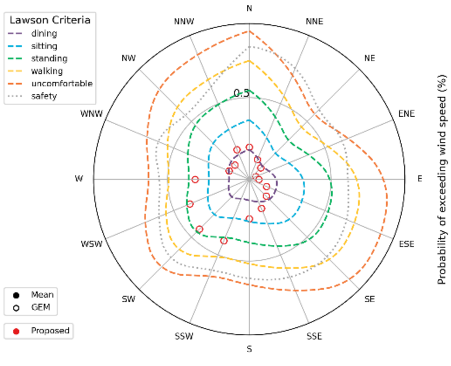


1995-2021 Business Hours
Wind speed exceedances (m/s)

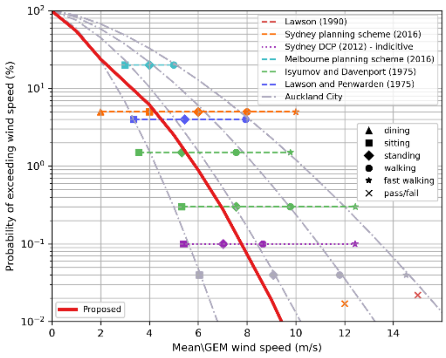
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	86.0	100.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	2.8	9.3

Location 44



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

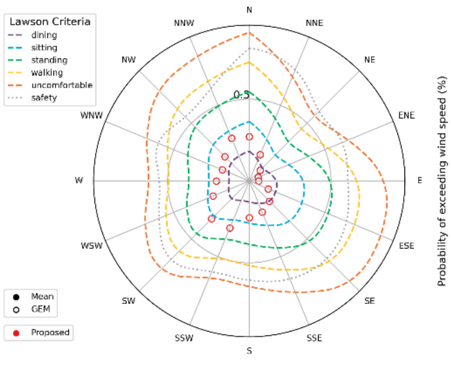


1995-2021 Business Hours
Wind speed exceedances (m/s)

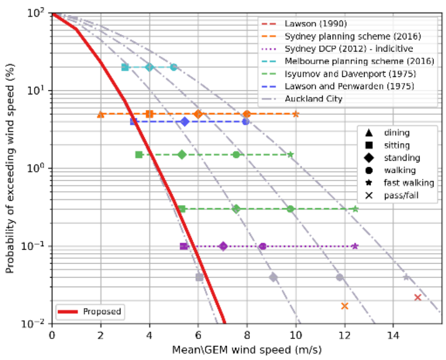
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	76.0	94.0	99.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	4.3	16.0

Location 45



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

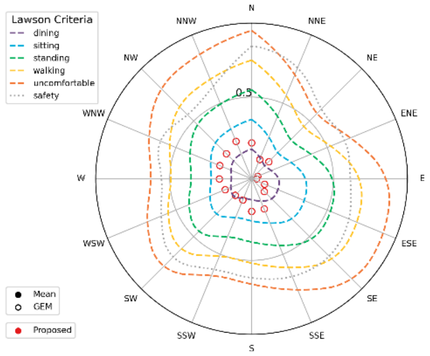


1995-2021 Business Hours
Wind speed exceedances (m/s)

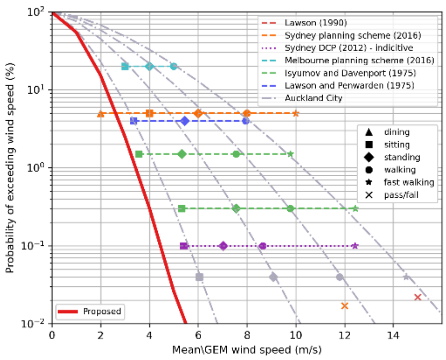
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	77.0	98.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	3.4	12.4

Location 46



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

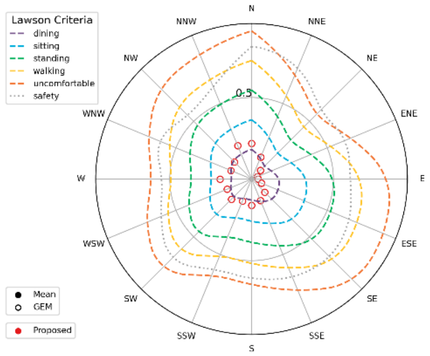


1995-2021 Business Hours
Wind speed exceedances (m/s)

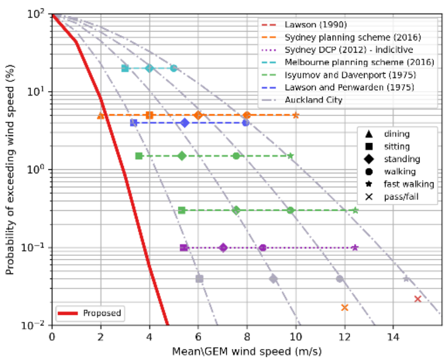
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	85.0	100.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	2.8	9.4

Location 47



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

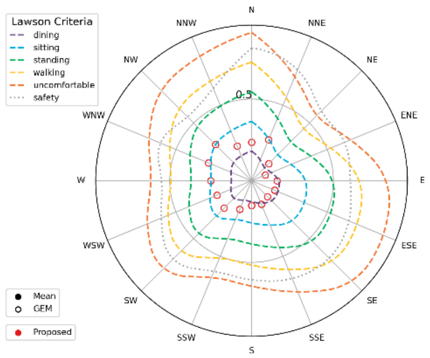


1995-2021 Business Hours
Wind speed exceedances (m/s)

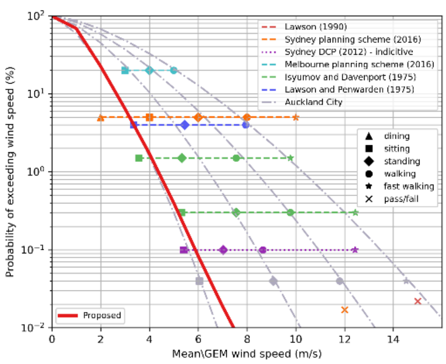
	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	92.0	100.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	2.4	8.1

Location 48



1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

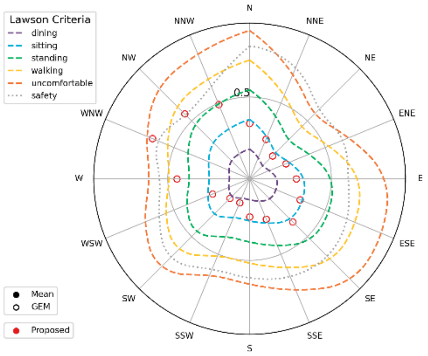


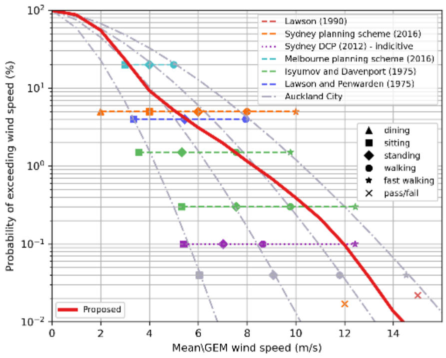
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	77.0	98.0	100.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	3.3	12.6

Location 49





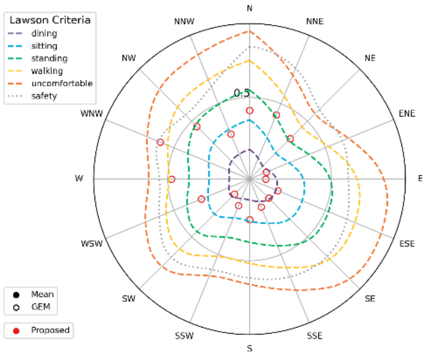
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

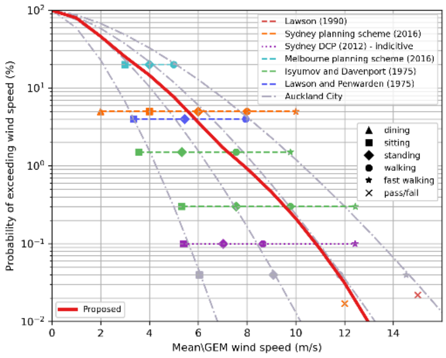
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	45.0	91.0	97.0	99.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	5.1	22.7

Location 50





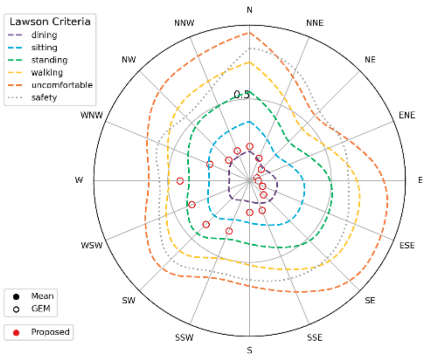
1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

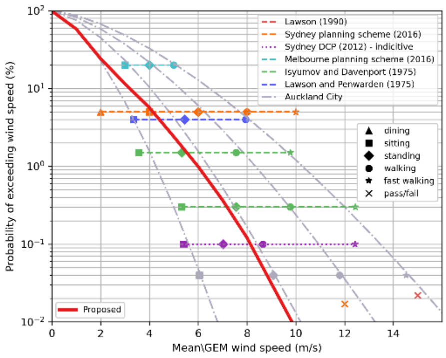
1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	54.0	85.0	96.0	99.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	5.7	21.8

Location 51





1995-2021 Business Hours
Probability of mean/GEM wind speed (%)

1995-2021 Business Hours
Wind speed exceedances (m/s)

	<2m/s	<4m/s	<6m/s	<8m/s
Proposed	76.0	94.0	99.0	100.0

	5.0% Mean/GEM	0.0171% 0.5s Gust
Proposed	4.2	17.1