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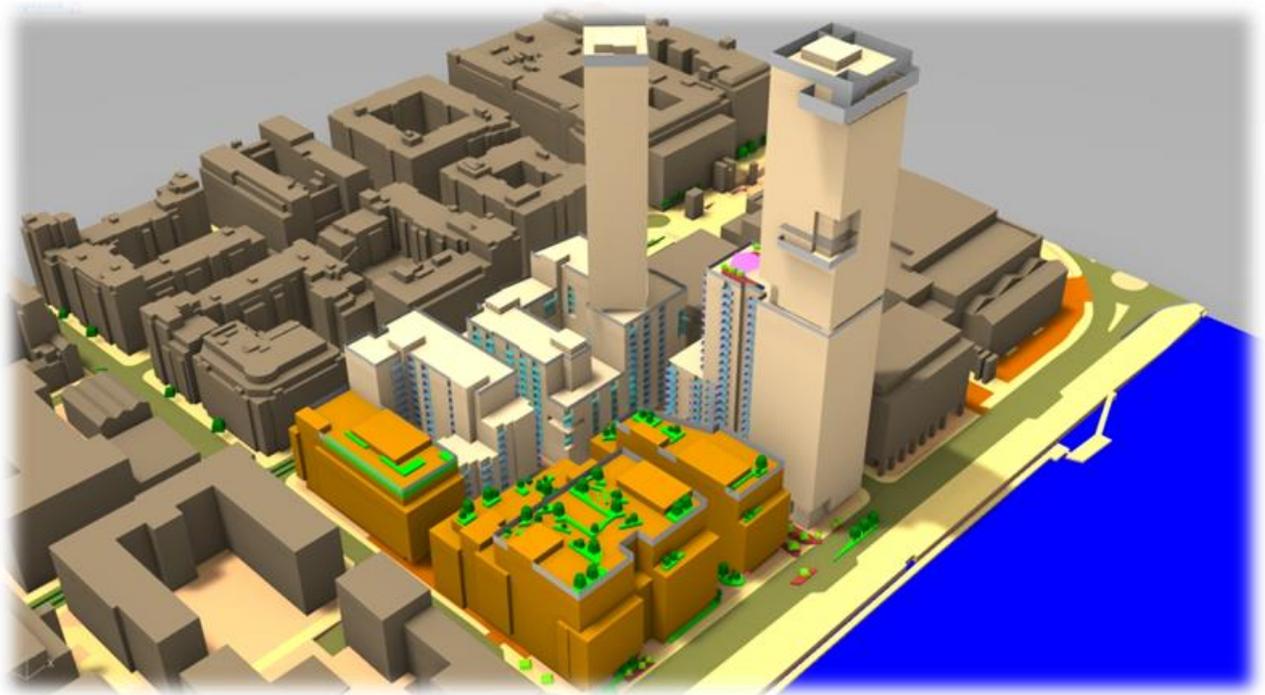
Waterfront – Wind Study

Pedestrian Comfort CFD Analysis

Report_P9

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1 Executive Summary

IES Consulting have been commissioned to investigate the potential impact of wind movement on pedestrian comfort around the proposed modifications to Waterfront plot near Dublin docklands region.

All enabling and site development works, landscaping, lighting, services and connections, waste management and all other ancillary works above and below ground including the use of secant piling permitted under Reg. Ref. DSDZ3779/17 and DSDZ3780/17 (as amended by DSDZ3042/19).

1. Construction of 1,005 No. residential units (with balconies and winter gardens) arranged in 3 No. blocks ranging in height from 8 No. storeys to 45 No. storeys over a triple-level basement, the former comprising: Block A (8-14 No. storeys (with extended core to access roof level); with an apartment mix of: 116 No. 1-bed; and 92 No. 2-bed; with landscaped terraces at Level 1 (south east elevation), Level 8 (south west elevation), Level 11 (south west elevation) and Level 14 (north east elevation)); Block B (8-41 No. storeys (with extended core to access roof terrace); with an apartment mix of: 172 No. 1-bed; and 247 No. 2-bed; with landscaped terraces at Level 5 (south west elevation), Level 8 (north west elevation and south west elevation), Level 11 (north elevation), Level 12 (west elevation), Level 13 (east elevation), Level 14 (east elevation), and at Level 41 (roof level)); and Block C (11-45 No. storeys (with extended core to access roof level); with an apartment mix of: 207 No. 1-bed; 168 No. 2-bed; and 3 No. 3-bed units; with landscaped terraces at Level 11 (north elevation), Level 24 (south elevation), Level 32 (south elevation), and Level 45 (roof level), incorporating a public viewing deck at Levels 44 and 45).
2. Provision of ancillary residential amenities and support facilities including: live/work suites (321 sq m), a gym/spa reception (52 sq m), a residents' games room (91 sq m), a residents' common room (110 sq m), a residents-only social space (193 sq m), a management office (96 sq m), a security office (50 sq m), concierge spaces (GFA of c. 381 sq m) all located at ground floor level; a residents' games room (90 sq m) located at Level 1 of Block B; a residents' common room (86 sq m) located at Level 14 of Block B; a residents' wellness club and common room (408 sq m) located at Level 24 of Block C;
3. Construction of triple height basement which will comprise double basement with mezzanine plant level (total basement area 22,499 sq m), accommodating: waste storage areas (659 sq m), plant rooms (4,228 sq m), maintenance / management offices (GFA of 92 sq m), residents' courier / parcel rooms (GFA of 210 sq m), residents' laundry rooms (GFA of 138 sq m), ancillary residential storage (GFA of 291 sq m), residents' WCs (65 sq m), a residents' gym / spa (1,529 sq m) and ancillary gym storage room (100 sq m), residents' screening rooms (240 sq m), a residents' indoor plant cultivation room (356 sq m), 176 No. car parking spaces, 10 No. motorcycle parking spaces and 1,693 No. bicycle parking spaces, with vehicular access provided by ramp from North Wall Avenue.
4. Provision of "other uses" as defined by the Planning and Development (Housing) and Residential Tenancies Act 2016, comprising: a childcare facility (450 sq m), a restaurant (110 sq m), an indoor Farmer's Market/foodhall (299 sq m), an external market area, a winter garden/seating area (130 sq m), and 3 No. café units (110 sq m, 167 sq m and 261 sq m, respectively), all located at ground floor level; a restaurant (609 sq m) located at Level 32 of Block C; office use (1,894 sq m) from Floor Level 41 to 43 inclusive at Block C; and a public bar / function room (407 sq m) located at Level 44 of Block C. The total area of "other uses" provided is 4,307 sq m.

5. Provision of a pocket park and new pedestrian lanes from North Wall Quay, North Wall Avenue and Mayor Street Upper to the center of the site.
6. All enabling and site development works, landscaping (including living walls), lighting, services and connections, waste management and all other ancillary works above and below ground including the use of existing secant piling permitted under Reg. Ref. DSDZ3779/17 and DSDZ3780/17 (as amended by DSDZ3042/19).

For the analysis, 8 steady state CFD simulations were performed for the main wind directions (N, NE, E, SE, S, SW, W and NW) and annual average wind speed for Casement Aerodrome near Dublin. The wind was assumed to have characteristics associated with wind flowing through a suburb. The results obtained from the simulations were extrapolated along the annual weather data to obtain the most probable local air speed for each hour of the year. Statistical analysis was performed on this dataset to check compliance against the Lawson's Pedestrian Comfort criterion.

The following table provides values for the Lawson's pedestrian comfort assessment criteria for various activities.

Category	Pedestrian Activity	Threshold mean hourly wind speed not to be exceeded for more than 5% of the time (m/s)
C1	Business Walking	10
C2	Leisurely Walking	8
C3	Standing	6
C4	Sitting	4

The following table provides values for Lawson's Pedestrian Safety Assessment criteria.

Category	Pedestrian Type	Threshold mean hourly wind speed not to be exceeded more than once per annum ² (m/s)
S1	Typical Pedestrian	20
S2	Sensitive Pedestrian	15

The value in each criterion will be the corresponding air speed as noted in the Lawson's comfort criterion as shown in the [section 5.1](#). The results images are reported in the form of contour plots of percentage of time the air speed exceeds a particular value in [section 7](#). From the scale under the result images following can be surmised:

Colour	Observation
Green	Comfort criterion met
Yellow	Marginal non-compliance, minor mitigation measures required
Orange	Marginal non-compliance, medium mitigation measures required
Red	Non-compliance, major mitigation measures required

1.1 Sitting and Standing Comfort

The Lawson's sitting comfort criteria states that the local air speed at designated locations should not exceed 4m /s for more than 5% of the year. The Lawson's standing comfort criteria states that the local air speed at designated locations should not exceed 6m/s for more than 5% of the year.

[Section 7.1](#) shows the results for the sitting and standing comfort results in the top left and right corner respectively of the various images for the Proposed Commercial SDZ scheme modelled alone. Similar images in [section 7.3](#) show the effect of the Proposed Residential SHD scheme on the results of the Proposed Commercial SDZ scheme.

1.1.1 Balconies

The results shows that, some of the balconies shows limited compliance to the sitting comfort as these balconies are exposed to the prevailing wind flowing from westerly and south-westerly direction, see and [Figure 42](#). However, it should be noted that all locations above are only marginally above the threshold of the Sitting Comfort Criterion. The threshold for this criterion is 4m/s. The threshold for Standing Comfort criterion is 6m/s. When we observe the standing comfort results for the same locations, we can see that the locations are quite compliant.

Further the Proposed Commercial SDZ scheme has very minimal impact on the results for the balconies. This is seen in [section 7.3](#).

1.1.2 Roof spaces

The terrace on 32nd floor of block C would have been affected by the downdrafts from the vertical façade above it. To overcome this a canopy had been proposed to be added above this terrace. This deflected the downdraft away from the terrace improving the sitting and standing comfort to required levels. The 2.3 m screen around the terrace already protects it from the horizontal winds. After implementing the canopy, the results were improved on the 32nd floor of block C.

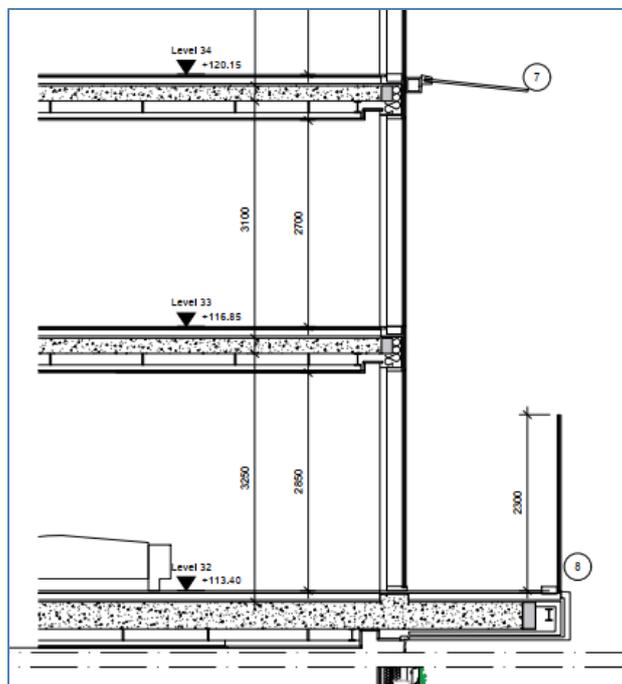


Figure 1: Proposed canopy for level 32 terrace

The [Figure 2](#) and [Figure 3](#) show the results of sitting and standing comfort on the proposed residential buildings respectively.



Figure 2: Sitting Criterion: View of the SHD residential roof areas



Figure 3: Standing Criterion: View of the SHD residential roof areas

It should be noted that some of the locations in orange and red band are above the threshold of the sitting comfort criterion of 4m/s for more than 5% of the year. However, when we observe the results of standing comfort criteria in Figure 3 and we see those locations are effectively compliant.

Overall, the results also need to be put in context of the weather data. The median wind speed for Dublin is closer to 5m/s. So for 50% of the year, the wind speed is higher than 5m/s. Further this wind speed is measured at 10m above the ground. At the roof level of these buildings, the wind speed experienced will be much higher based on the wind profile seen in [Figure 9](#). Further, it should be noted that, the top roof space of the SHD residential ‘block B’ and ‘block C’ are at 142.8m and 162.5m height above the terrain respectively. So the roof parapets have worked well to keep local air speed on roof to under 6m/s for larger part of the year.

There had also been concern for higher wind speeds on the level 14 terrace of Block B. Addition of landscape elements like plants to prevent higher air speed was proposed, which helped keep the air speeds in check. This can be observed in figures 4 and 5 below.



Figure 4: Sitting Criterion: View of the SHD residential roof areas



Figure 5: Leisure Walking Criterion: View of the SHD residential roof areas

Same as noted for the terraces before, the standing comfort results show a large proportion of the terrace meeting the requirements for this terrace. As per the layout, the terrace is being used as an outdoor exercise facility. So the level of wind acceptable can be assumed to be the leisure walking level. The location of exercise equipment shows acceptable level of wind in the figure above. The higher wind occurrence is only along the parapet, which is not a primary location of occupation.

As observed in [section 7.3](#), the proposed Commercial SDZ has minimal effect on the scheme Proposed Residential SHD scheme, as the SDZ scheme is much shorter than location of these roofs.

1.2 Walking Comfort

The Lawson's Leisure Walking and Business Walking comfort criteria states that the local air speed at designated locations should not exceed 8m/s and 10m/s respectively for more than 5% of the year.

[Section 7.1](#) shows the results for the leisure and business walking comfort results in the lower left and right corner respectively of the various images, for the Proposed Commercial SDZ scheme modelled alone. Similar images in [section 7.3](#) show the effect of the Proposed Residential SHD scheme on the results of the Proposed Commercial SDZ scheme.

The site shows good compliance with the Lawson's Leisure and Business Walking Comfort Criteria Safety Criteria

1.3 Safety Criteria

The Lawson's Normal Pedestrian safety criteria states that the local air speed at designated locations should not exceed 20m/s for more than 0.01% of the duration analysed. The Lawson's Sensitive Pedestrian safety criteria states that the local air speed at designated locations should not exceed 15m/s for more than 0.01% of the duration analysed. [Section 7.2](#) shows the results for the different safety criteria for the Proposed Residential SHD scheme modelled alone. Similar images in [section 7.4](#) show the effect of the Proposed Commercial SDZ scheme on the results of Proposed Residential SHD scheme.

As observed in [Section 7.2](#), the criterion for the normal pedestrian is achieved throughout the site for SHD residential buildings.

For sensitive pedestrians, there could be a potential for higher frequency for high winds more than 15m/s on the streets and some roof spaces of the SHD residential zone. These spaces are directly exposed to the prevailing wind flowing from westerly and southwesterly direction.

The Sensitive pedestrian safety criterion applies to the vulnerable people like OAP and children. Note the limit of the criterion is 0.01% and not 5% as with the comfort criterion

2 Introduction

IES Consulting have been commissioned to investigate the potential impact of wind movement on pedestrian comfort around the proposed development near Dublin Docklands.

The analysis is to be performed to study the effect from building layout on pedestrian comfort for the people using the public amenity spaces around the site.

The site will be studied for the new development of SHD residential only and effect of the neighbouring commercial site on the proposed residential development.

The following simulation report describes the modelling methodology used in the study, including assumptions made and calculations used to determine the boundary conditions.

3 Weather Data

The analysis is based on the 'Dublin_TMY5.epw' weather file. The variation of wind speed recorded in the weather file is shown in figure 6 below. Figure 7 shows the wind direction variation and Figure 8 shows the wind rose.

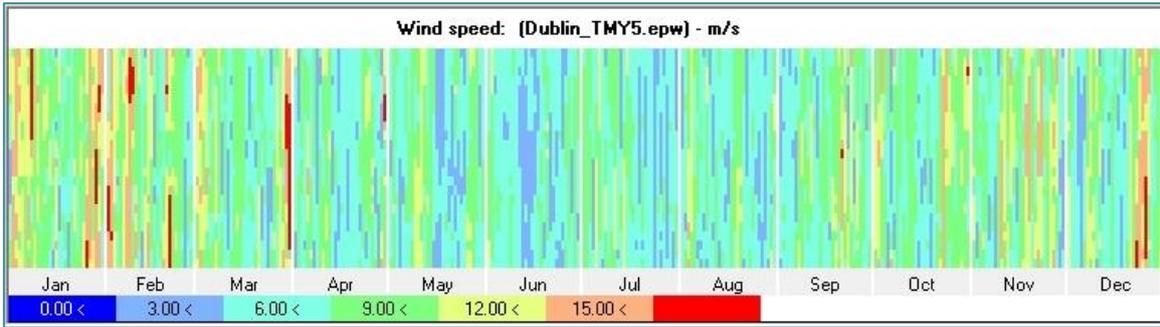


Figure 6: Wind speed variation as per Dublin_TMY5.epw

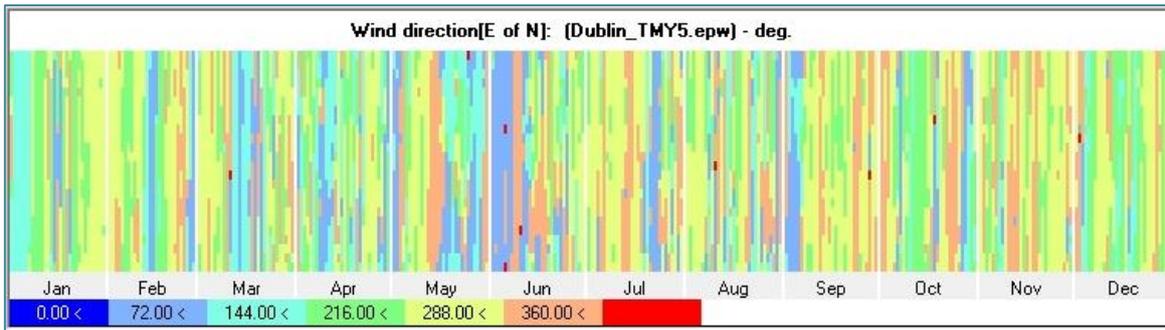


Figure 7: Wind direction variation as per Dublin_TMY5.epw

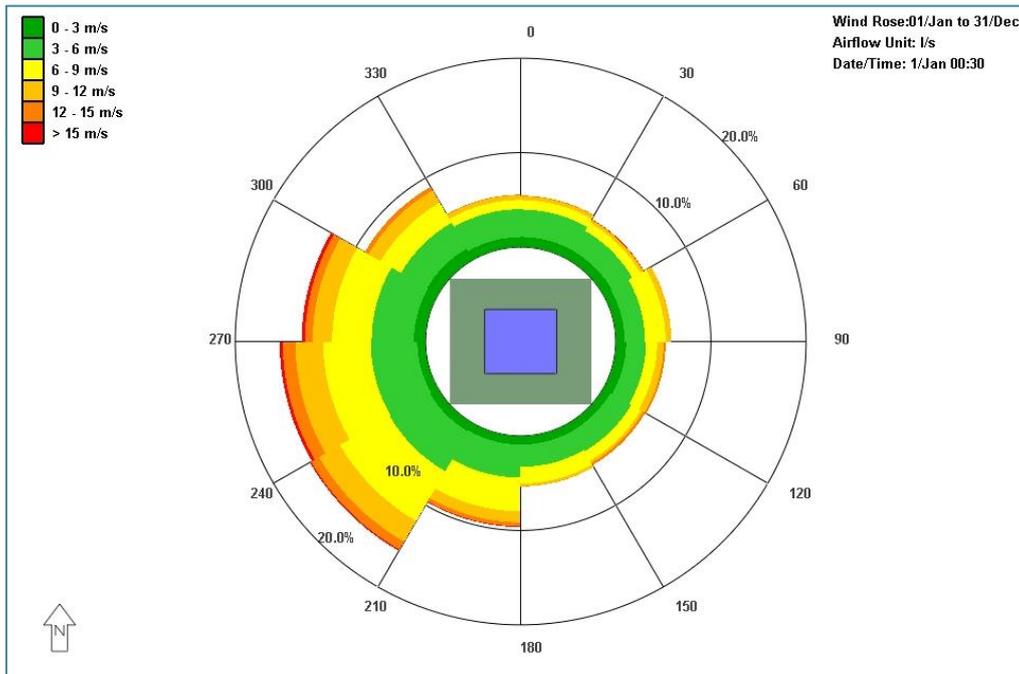


Figure 8: Wind rose as per Dublin_TMY5.epw

Based on this, the mean wind speed recorded was 6.4m/s with a westerly prevailing direction.

4 Wind Boundary Layer

In an atmospheric boundary layer, wind speed increases with height due to the influence of surface roughness (i.e. the presence of buildings, trees, roads etc. on the ground), see Figure 9.

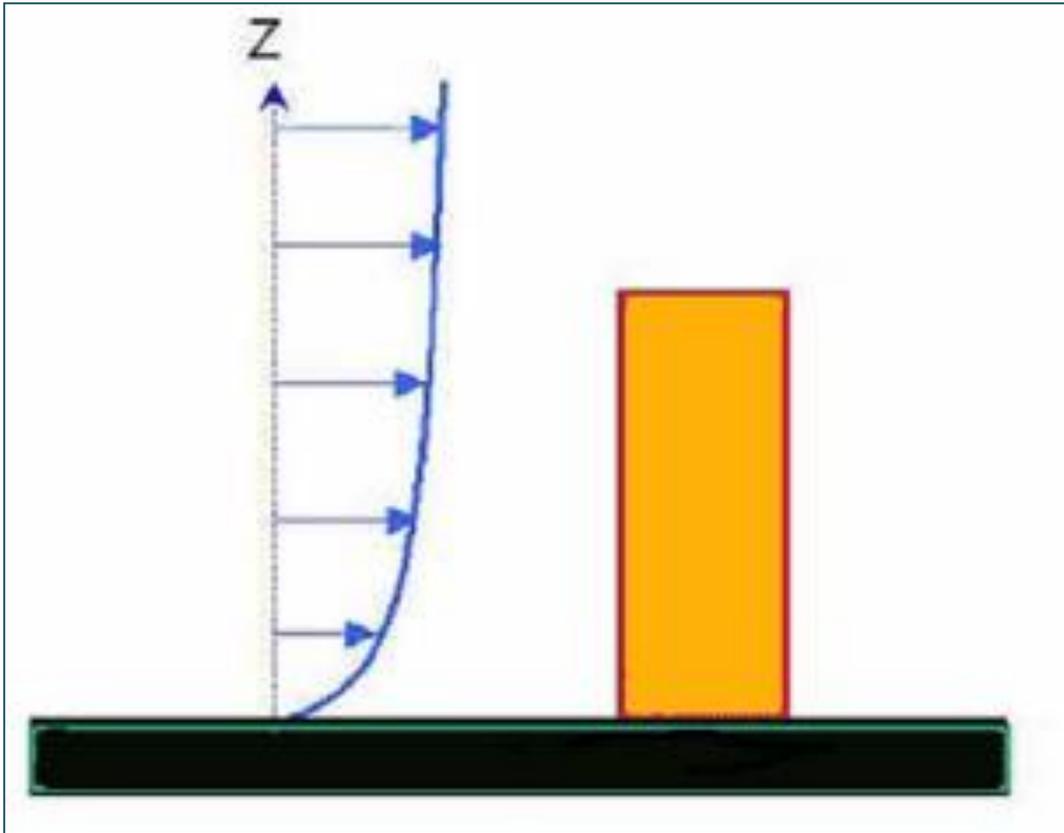


Figure 9: Typical velocity profile of an atmospheric boundary layer

In the current CFD modelling, the velocity profile was generated according to the parameterised ASHRAE methodology described below. This allows for different wind profiles across various terrain types: Open country; urban; and city centre.

The wind speed U_H at height H above the ground is given by:

$$U_H = U_{met} \left(\frac{\delta_{met}}{H_{met}} \right)^{a_{met}} \left(\frac{H}{\delta} \right)^a \dots \dots \dots (Eq. 1)$$

Where,

- a = Exponent in power law wind speed profile for local building terrain
- δ = fully developed strong wind atmospheric boundary layer thickness (m)
- a_{met} = Exponent for the meteorological station
- δ_{met} = Atmospheric boundary thickness at the meteorological station (m)
- H_{met} = Height at which meteorological wind speed was measured (m)
- U_{met} = Hourly meteorological wind speed, measured at height H_{met} (m/s)

The parameters for different types of terrain are given as in table 1.

Table 1: Atmospheric boundary layer parameters

Terrain Category	Description	a	δ
1	Large city centres 50% of buildings above 21m over a distance of at least 2000m upwind.	0.33	460
2	Urban, suburban, wooded areas.	0.22	370
3	Open, with scattered objects generally less than 10m high.	0.14	270
4	Flat, unobstructed areas exposed to wind flowing over a large water body (no more than 500m inland).	0.10	210

For the current project, we used the atmospheric boundary layer corresponding to the terrain category 1 i.e. large city centres type of site. The met data was taken on category 3 terrain at a height of 10m. Figure 10 below shows the shape of the wind boundary profile.

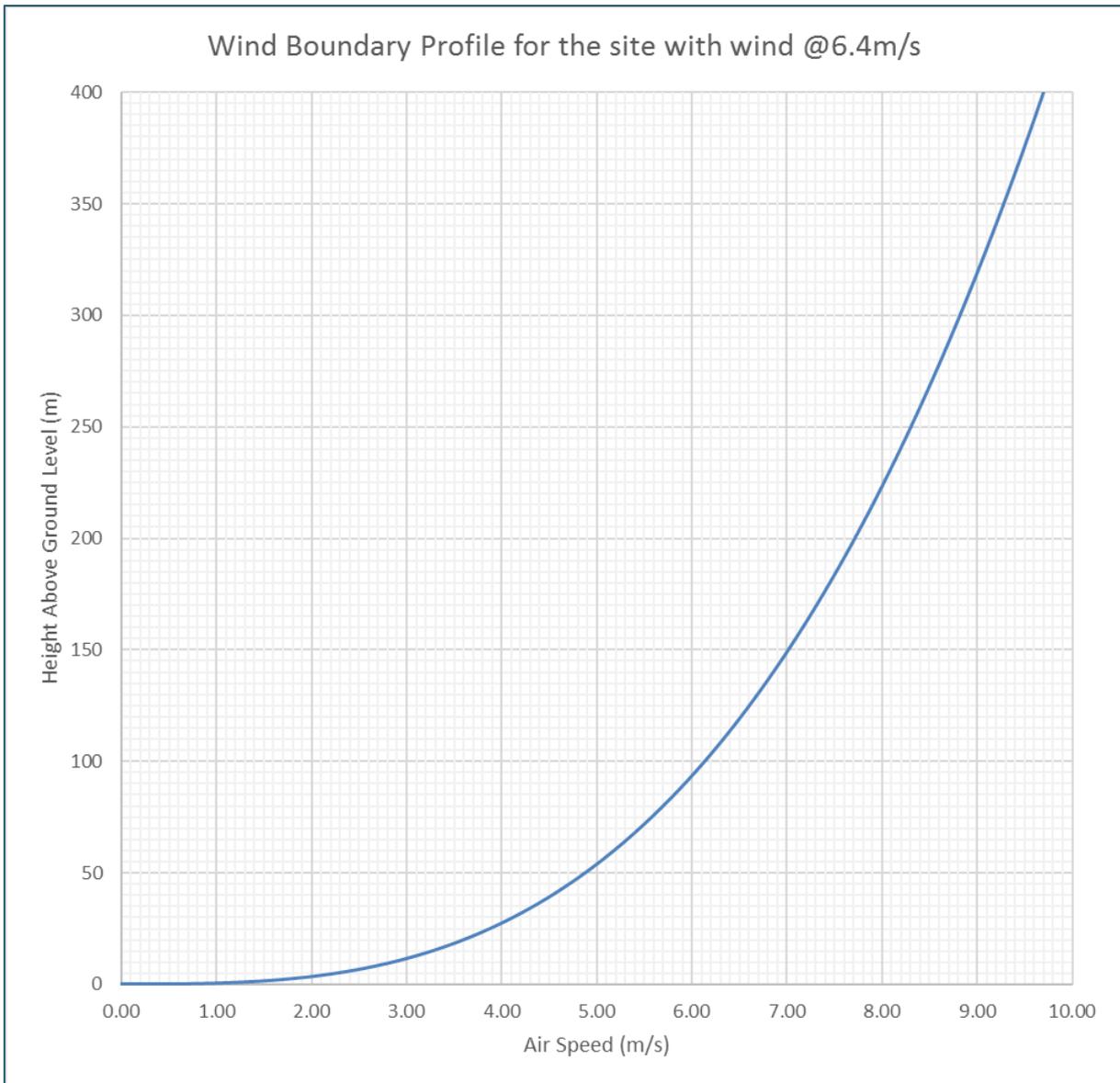


Figure 10: Wind boundary profile for the CFD simulations using annual average wind speed

5 Analysis Methodology

The methodology for the analysis was as follows:

- 1) The annual mean wind speed was determined from the weather file described earlier in [section 2](#).
- 2) 8 steady state CFD simulations were performed corresponding to the 8 directions – SW, W, NW, N, NE, E, SE and S respectively.
- 3) The local air speed at various designated locations around the site was recorded for each of the simulations.
- 4) This value was compared to the meteorological wind speed used and the magnification factor at that location for the corresponding wind direction was determined.
- 5) The magnification factor was used to determine the air speed at the designated locations for the various recorded values of the wind speed and direction in the weather file, thus generating the local air speeds at designated locations for a year.
- 6) These recorded values were compared to the Lawson Pedestrian Comfort/Safety Criteria.

5.1 Lawson Pedestrian Comfort/Safety Criteria

The Lawson Criteria¹ was used as a reference to assess the wind effects. It is the most widely used reference for assessment of pedestrian comfort. It considers the air speed at the location as well as the frequency of the occurrence of this air speed. It consists of two assessment criteria:

1. The first criteria assesses whether the air movement will be comfortable for the pedestrian for different types of activities.
2. The second criteria assess the feeling of safety or distress by the pedestrian at higher air speeds.

Following table gives the values for the Lawson's pedestrian comfort assessment criteria for various activities.

Category	Pedestrian Activity	Threshold mean hourly wind speed not to be exceeded for more than 5% of the time (m/s)
C1	Business Walking	10
C2	Leisurely Walking	8
C3	Standing	6
C4	Sitting	4

Following table gives the values for Lawson's Pedestrian Safety Assessment criteria.

Category	Pedestrian Type	Threshold mean hourly wind speed not to be exceeded more than once per annum ² (m/s)
S1	Typical Pedestrian	20
S2	Sensitive Pedestrian	15

¹T. V. Lawson (2001) *Building Aerodynamics*, Imperial College Press, London.

²Once per annum means the safety threshold is not be exceeded 0.01% of the year.

6 CFD Model

The CFD model was created based on the CAD drawings provided.

6.1 Proposed SHD Residential Zone

6.1.1 Model Geometry

In this scenario, only residential buildings will be simulated for comfort calculations. The neighbouring proposed commercial site will be empty. Figures 11 to 25 show the various views of the SHD residential buildings.

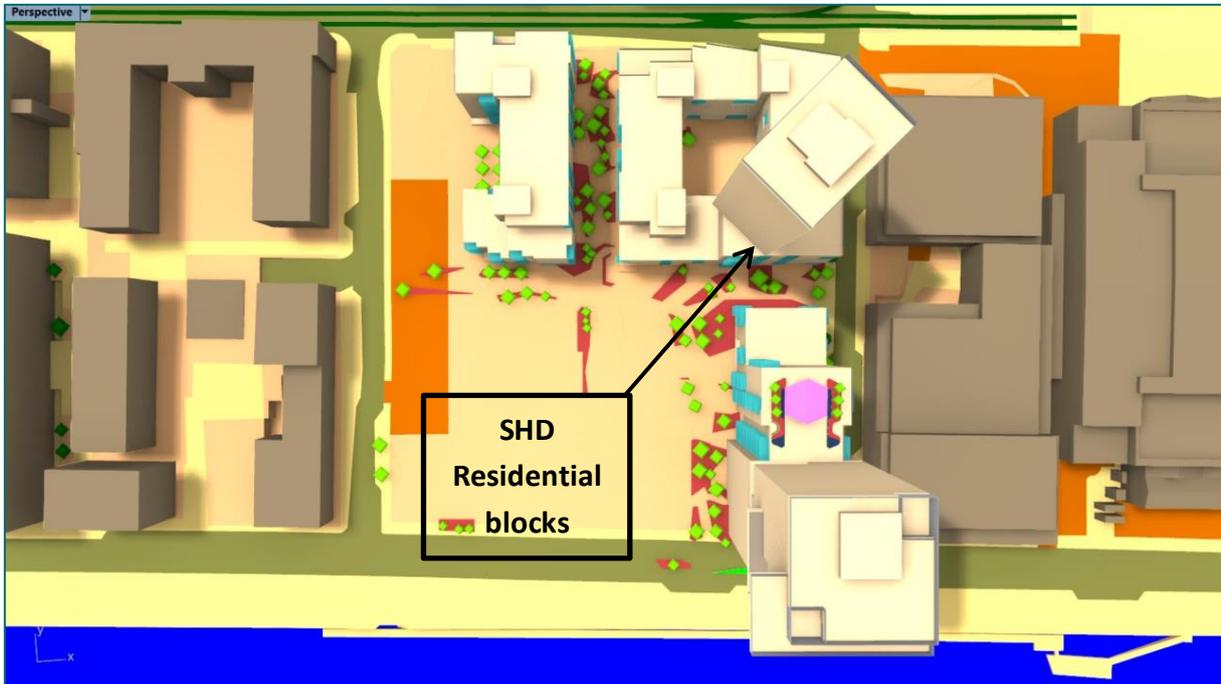


Figure 11: View of the SHD residential site from the top

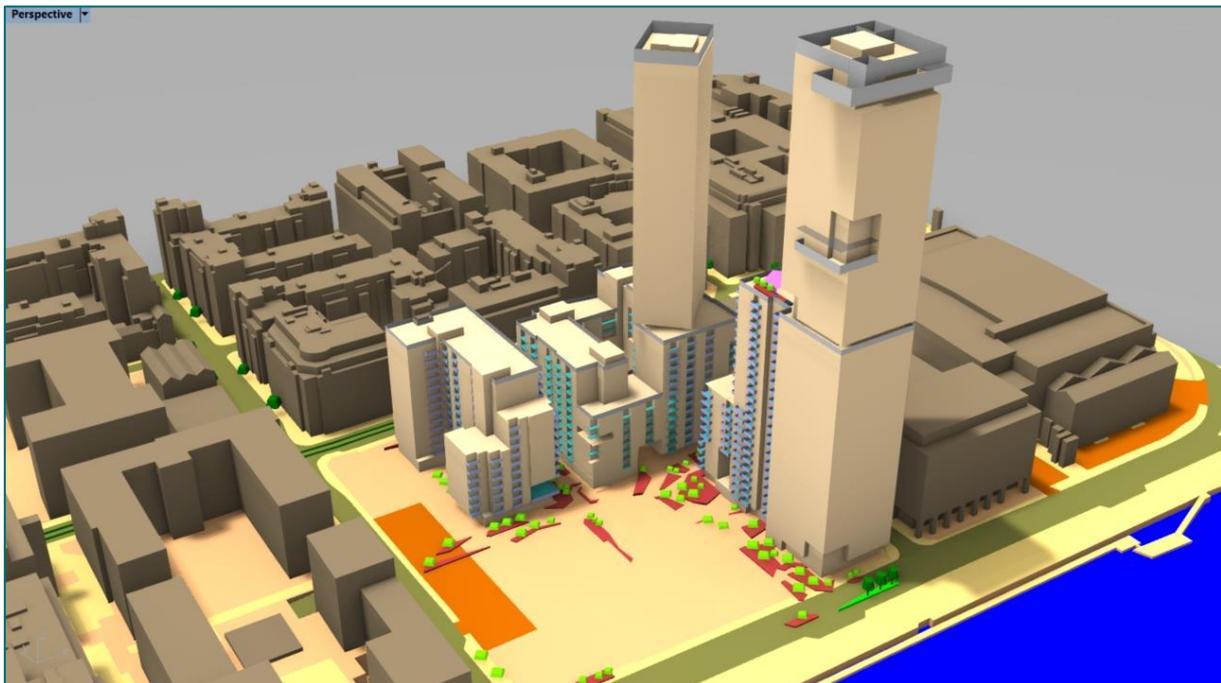


Figure 12: View of the SHD residential site from the southwest



Figure 13: View of the SHD residential site from the northwest

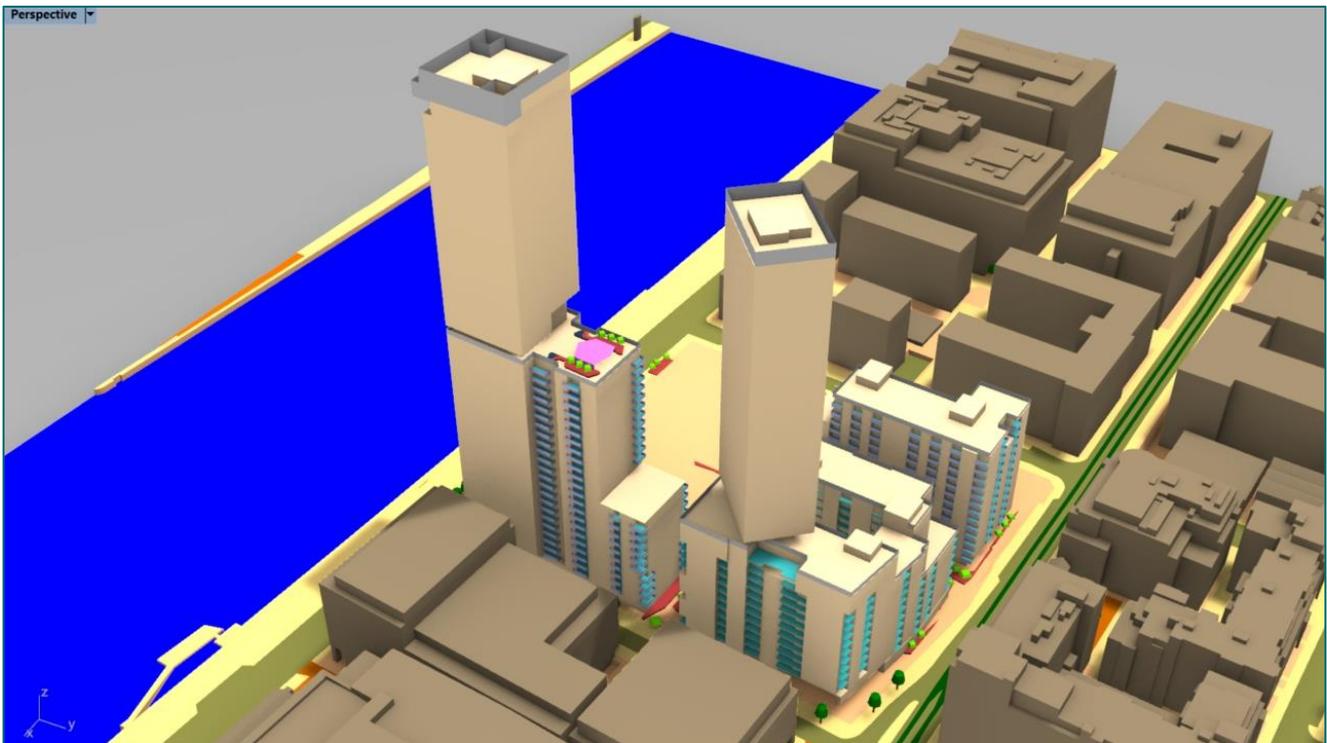
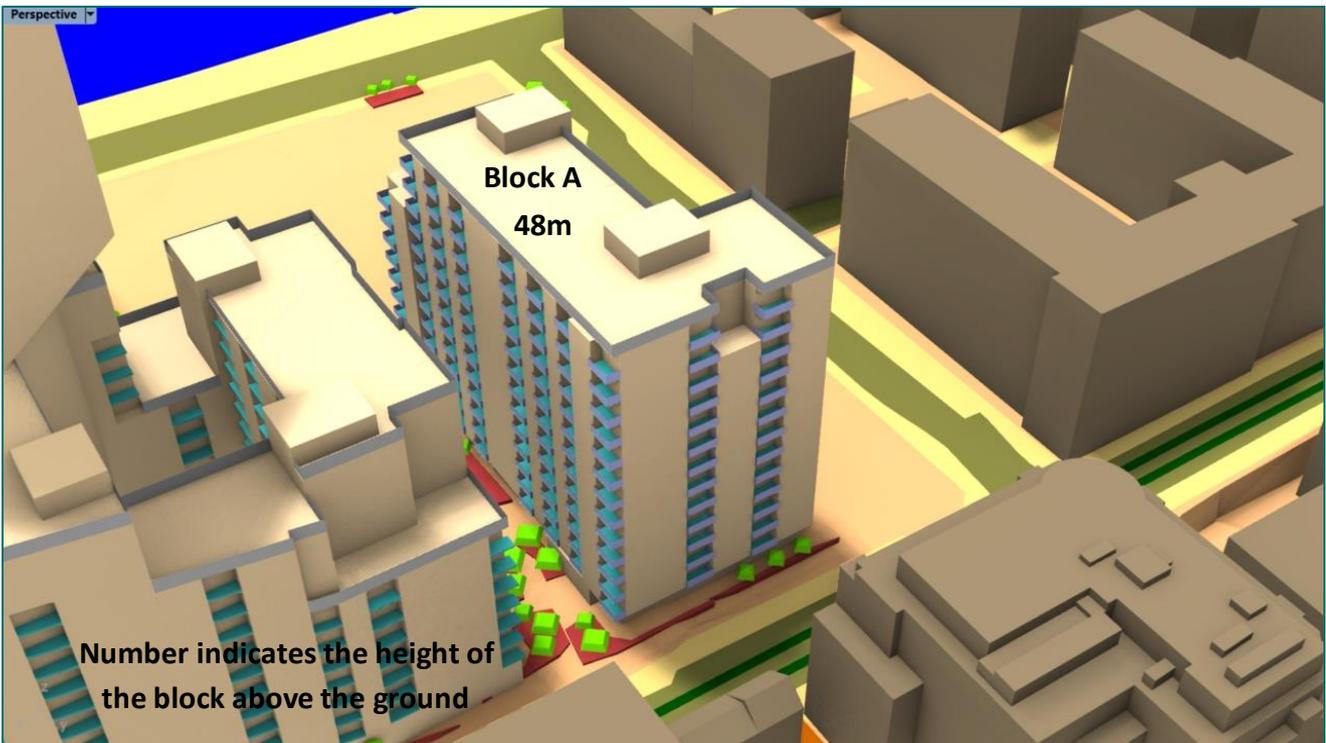


Figure 14: View of the SHD residential site from the northeast



Figure 15: View of the SHD residential site from the southeast



Number indicates the height of the block above the ground

Figure 16: View of the SHD residential block A



Figure 17: View of the SHD residential block A



Figure 18: View of the SHD residential block B



Figure 19: View of the SHD residential block B

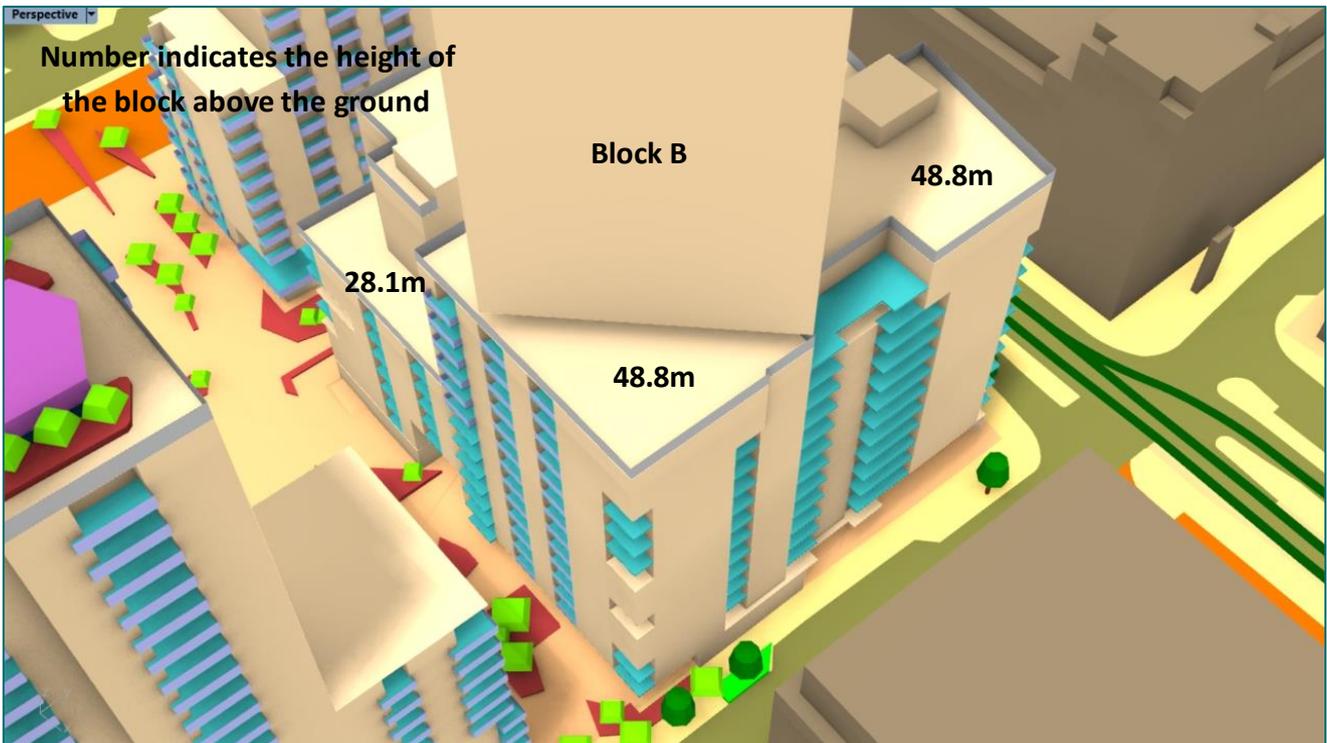


Figure 20: View of the SHD residential block B

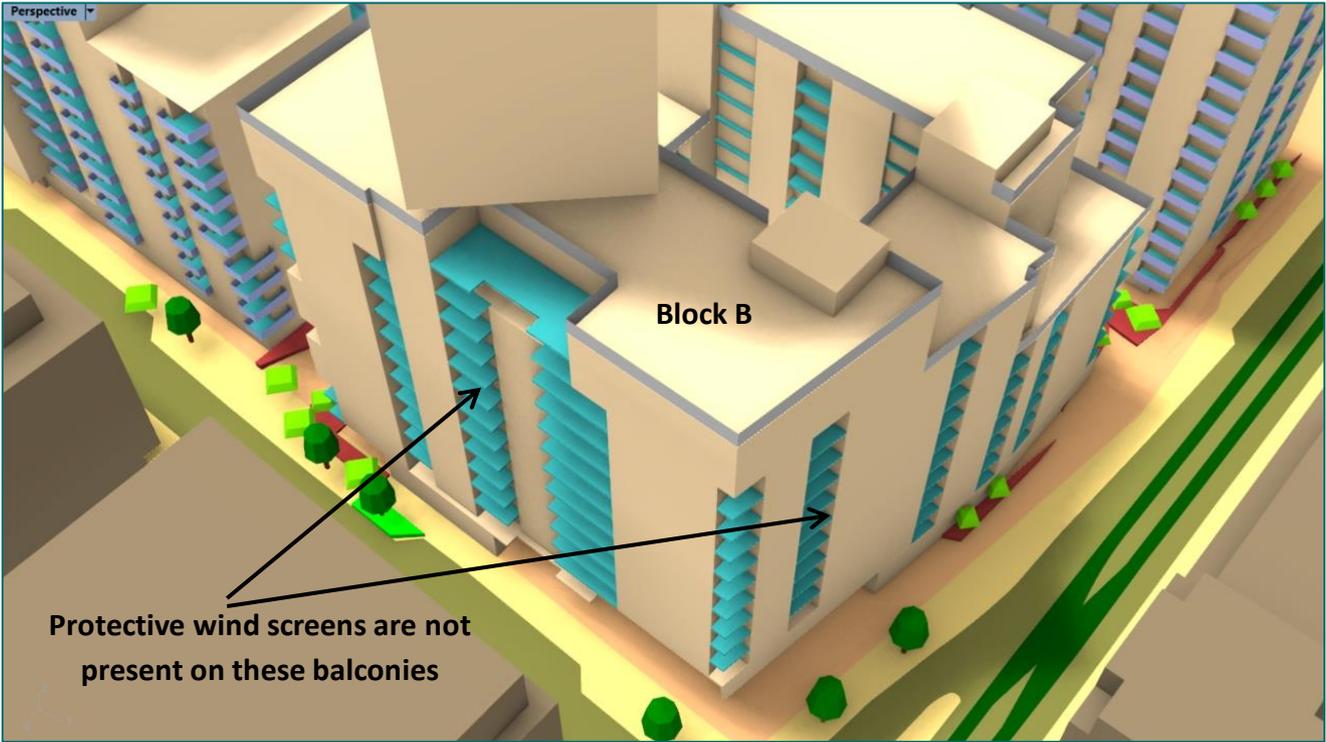


Figure 21: View of the SHD residential block B

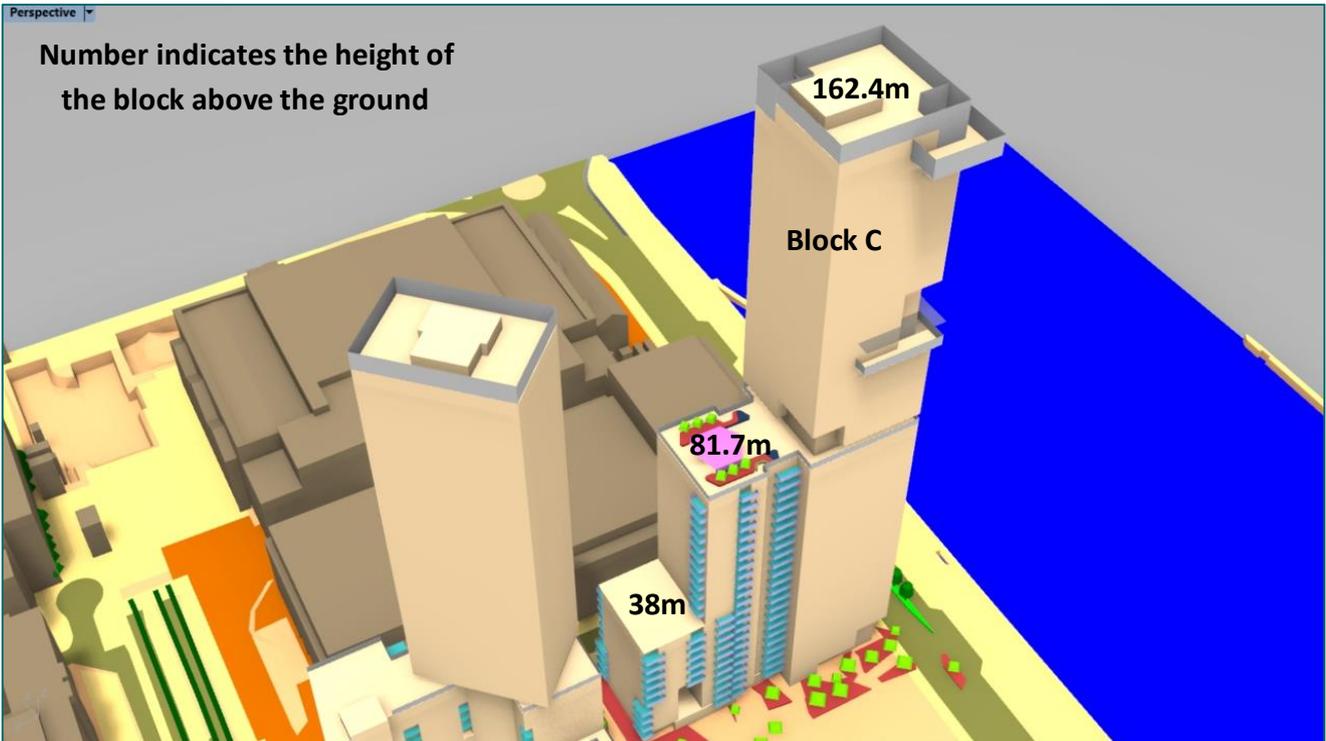


Figure 22: View of the SHD residential block C

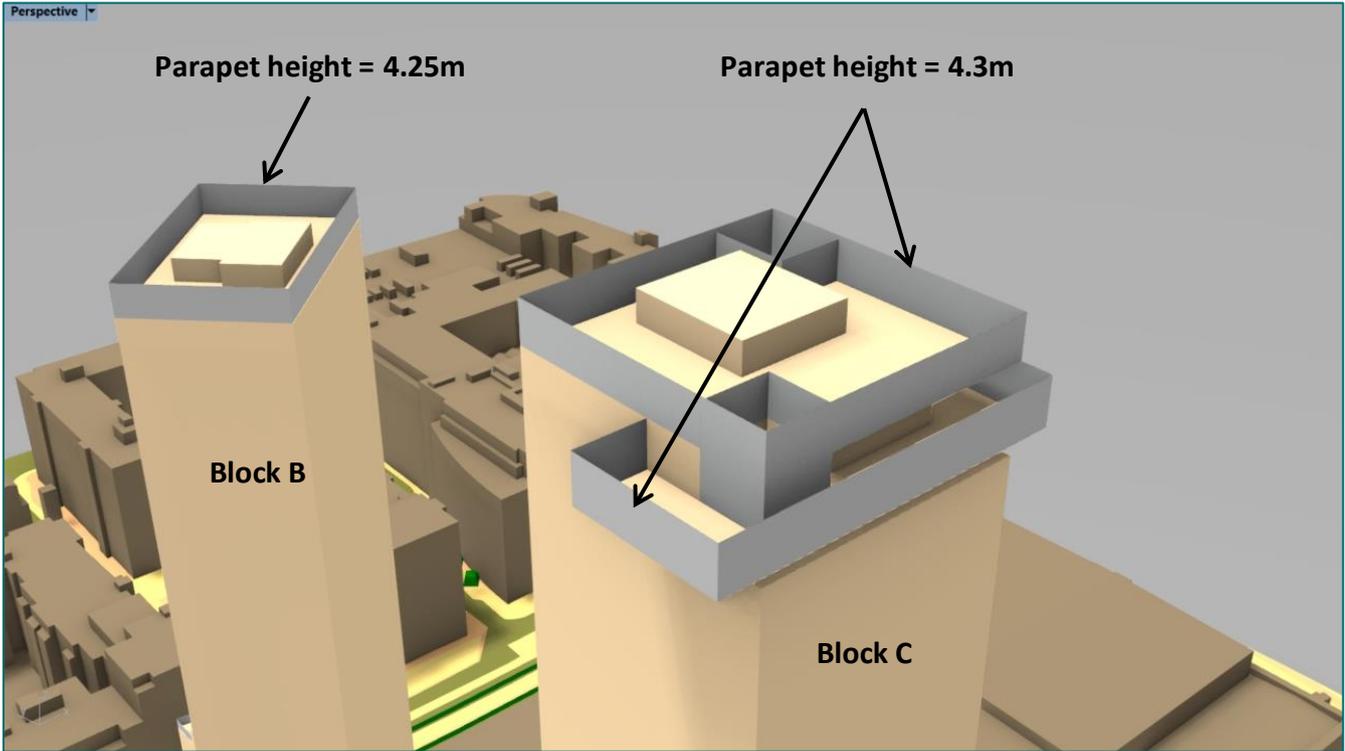


Figure 23: View of the SHD residential block C

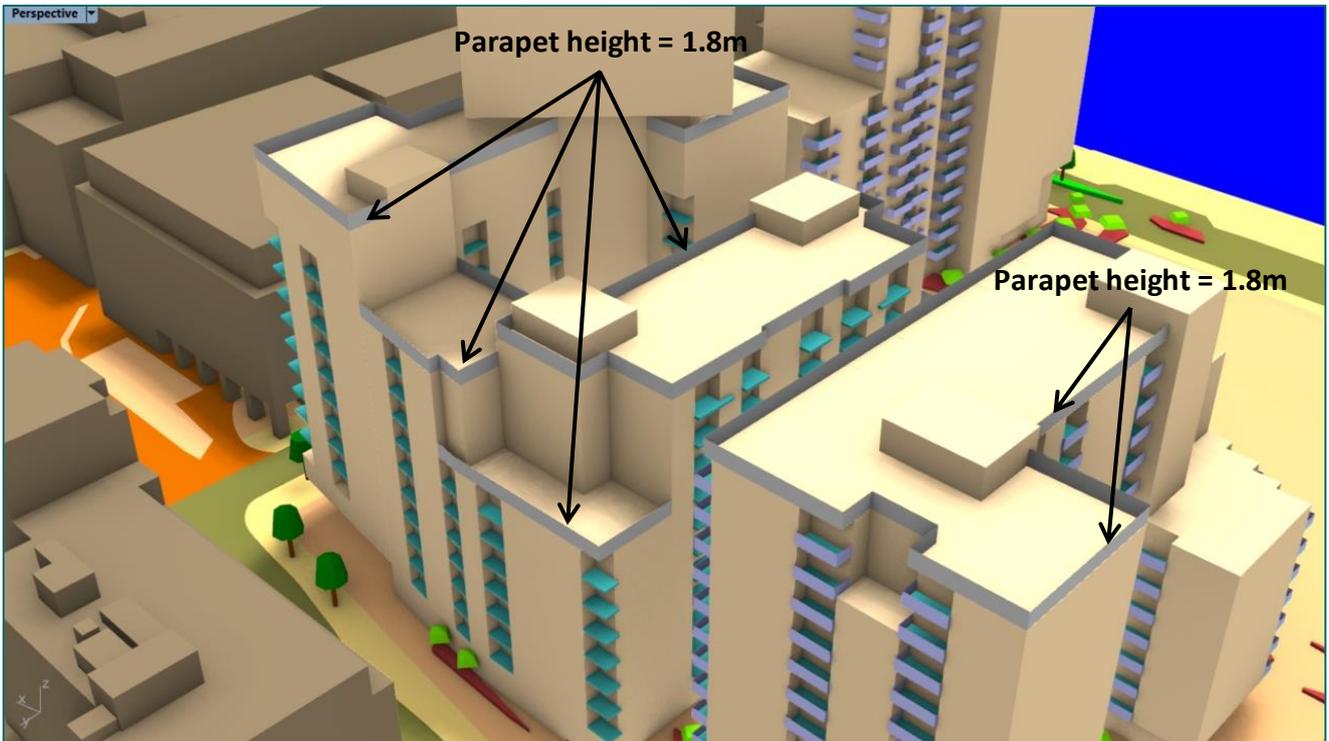


Figure 24: View of the SHD residential block C

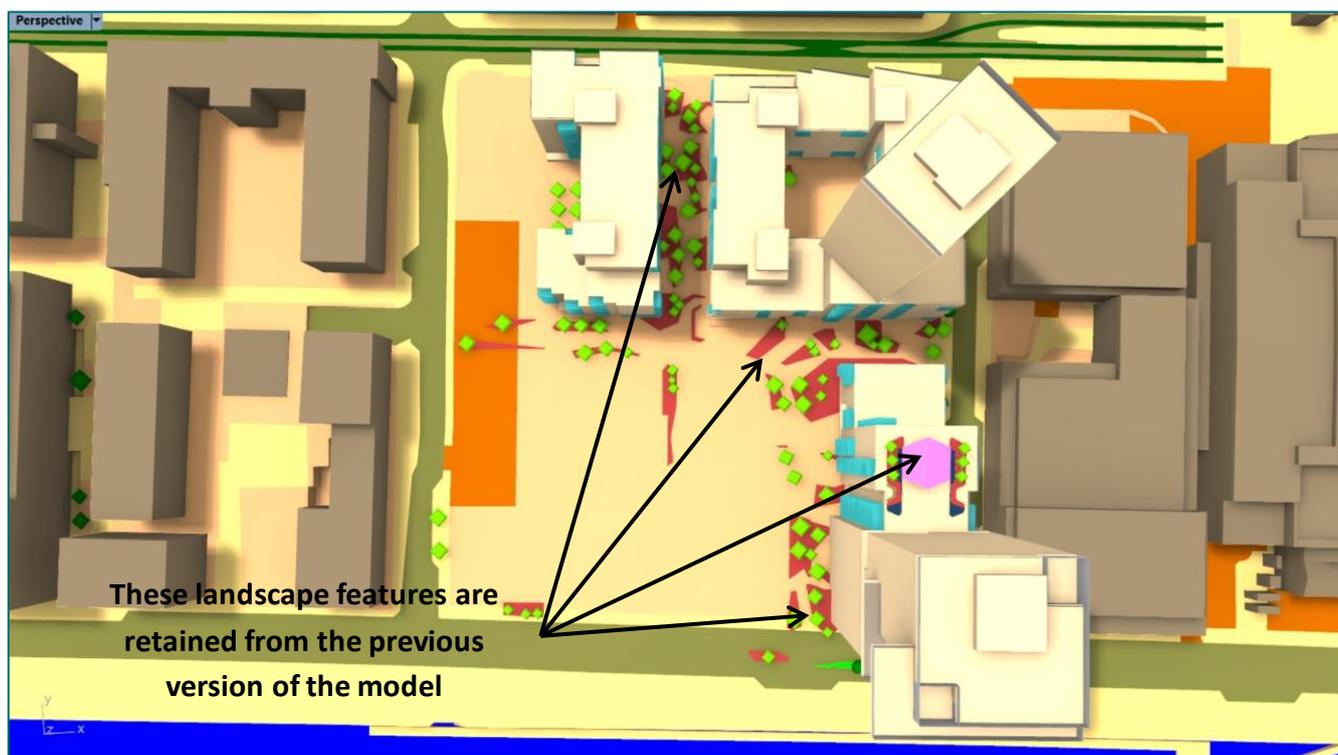


Figure 25: View of the SHD residential block C

6.1.2 Reportage Locations

Figures 26 to 35 show the designated locations, with all lying 1.5m above the immediate ground/floor level. Balcony locations lie 1.1m above the floor.

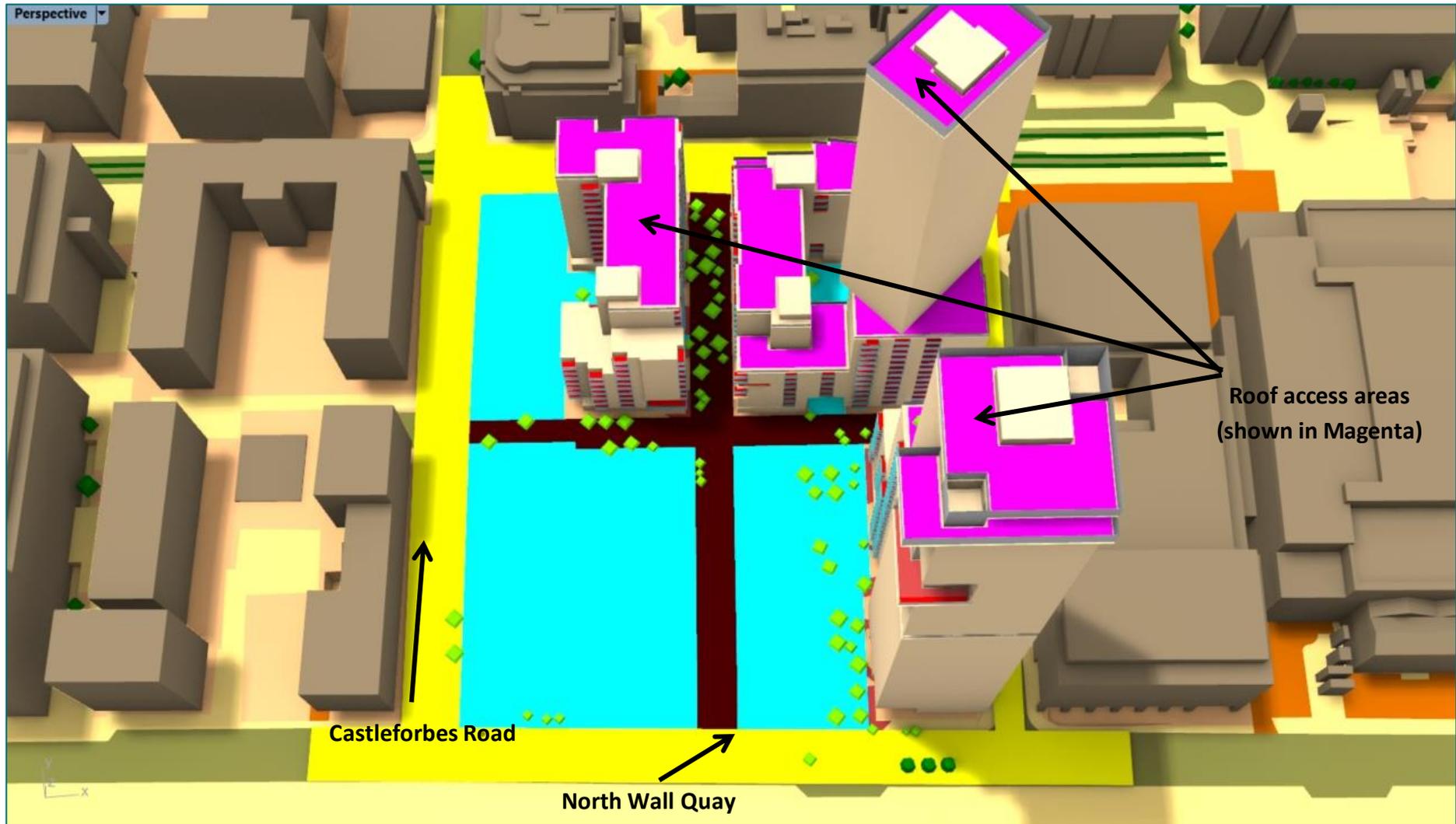


Figure 26: Reportage Locations: View 01

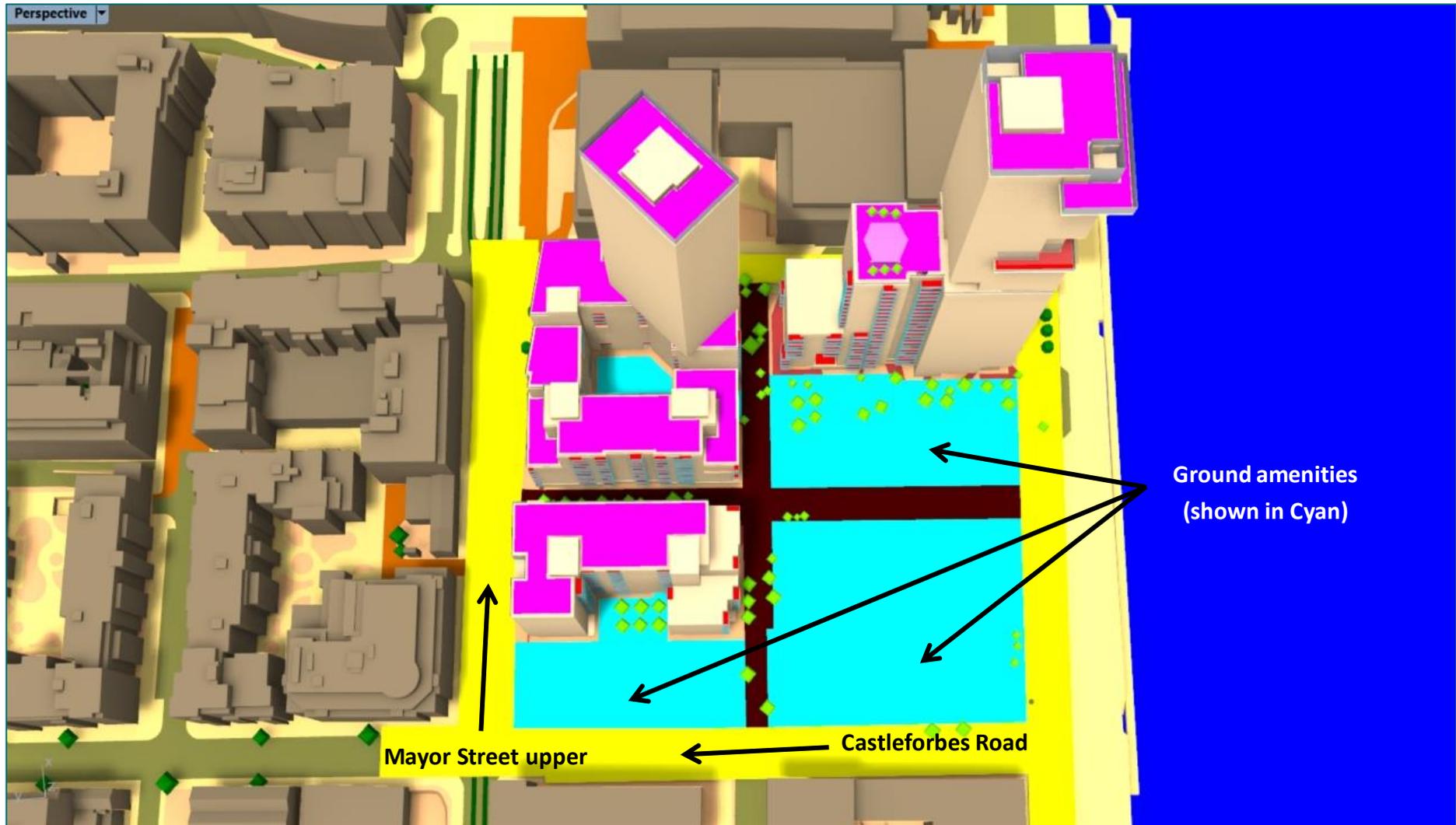


Figure 27: Reportage Locations: View 01



Figure 28: Reportage Locations: View 01

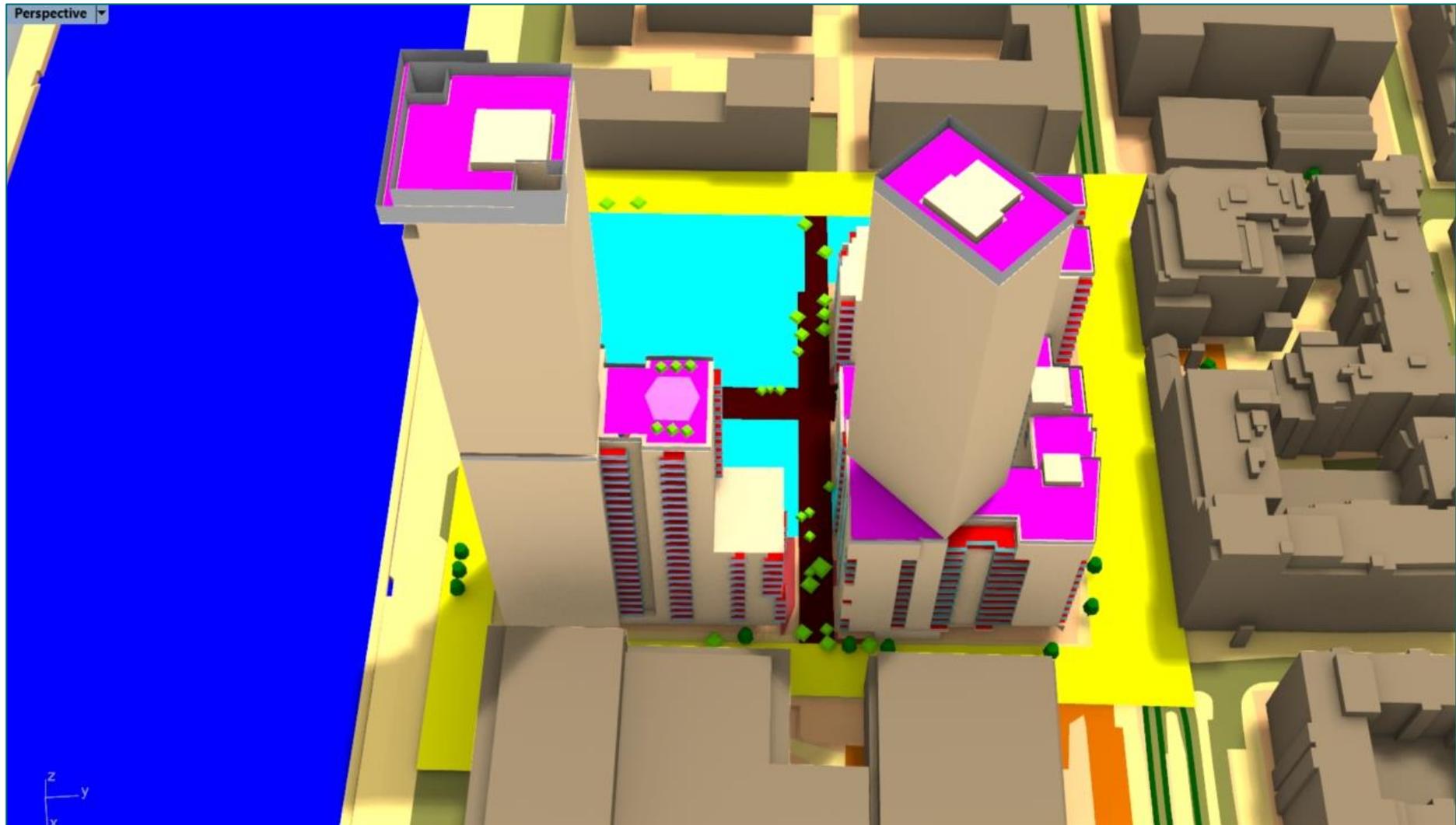


Figure 29: Reportage Locations: View 01

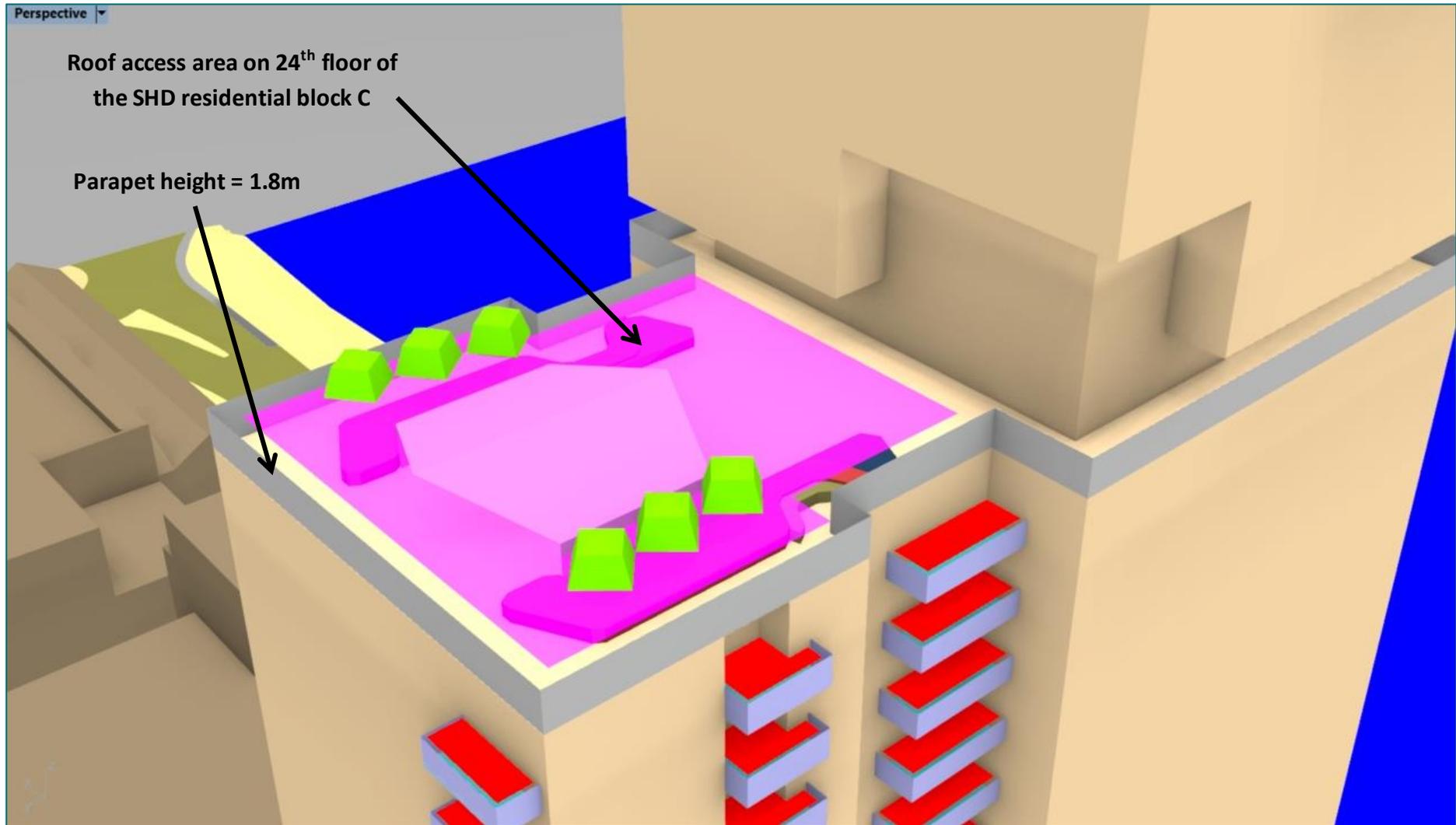


Figure 30: Reporting Locations: Roof access area

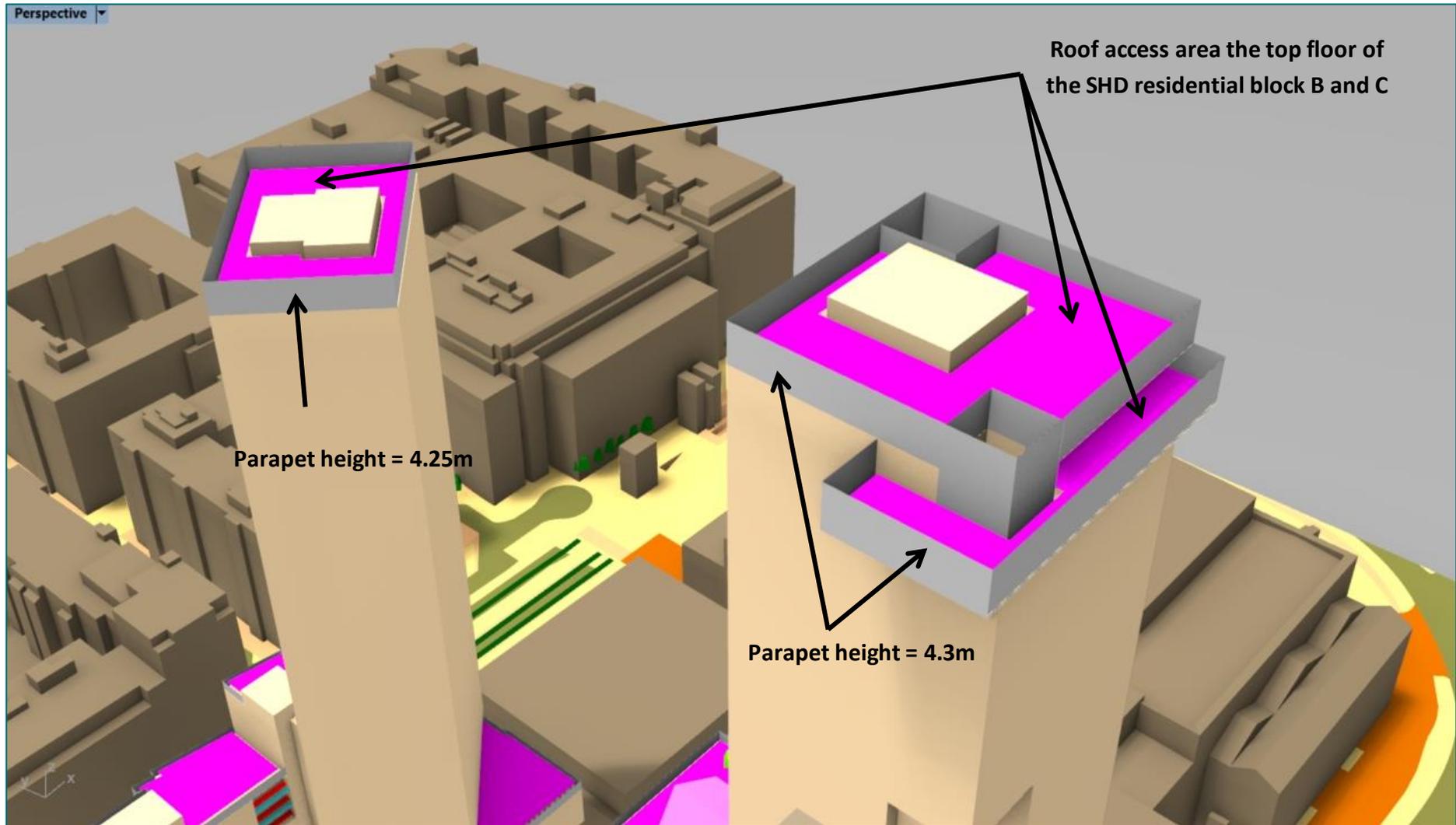


Figure 31: Reportage Locations: Roof access area

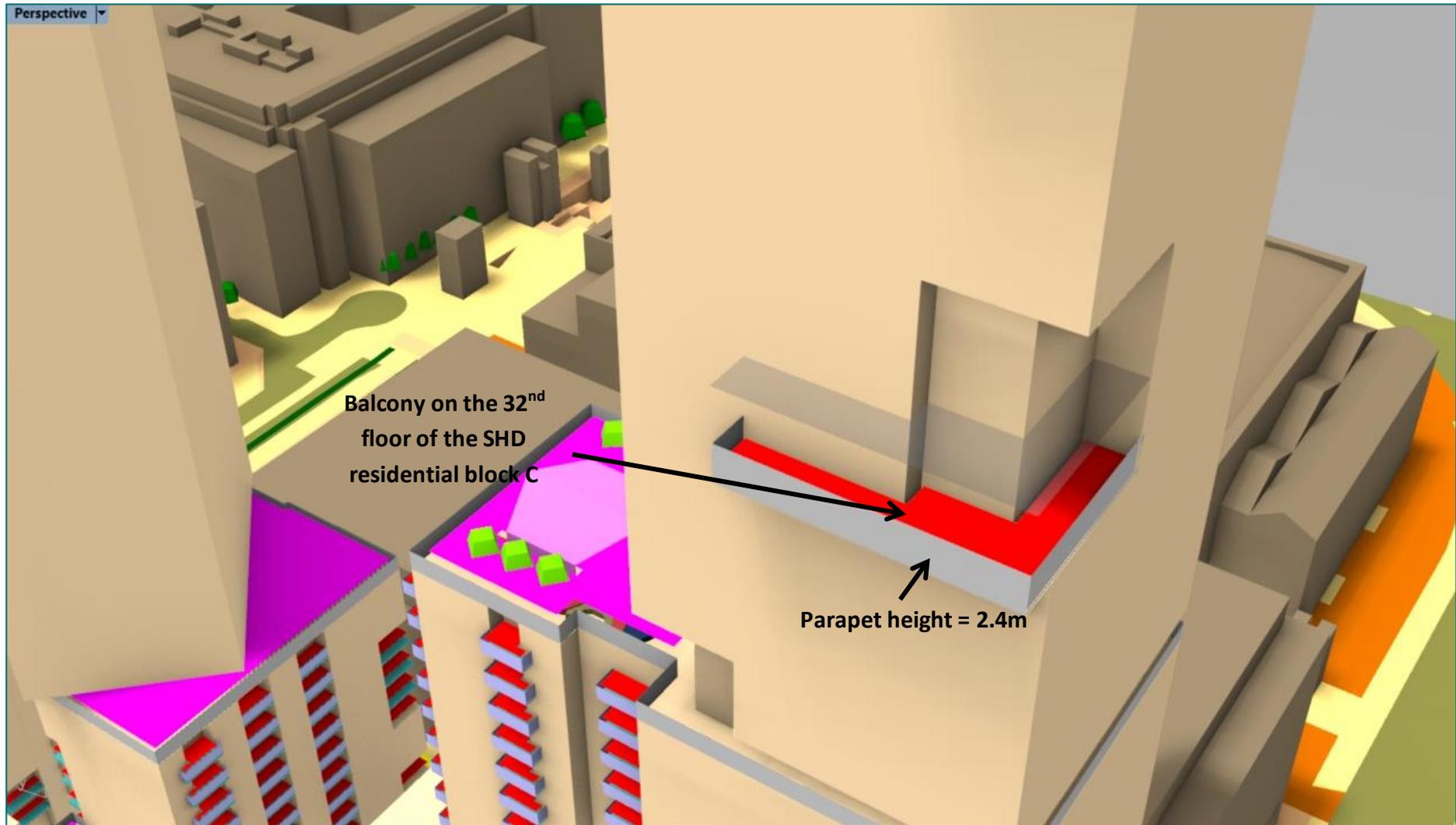


Figure 32: Reportage Locations: Balconies

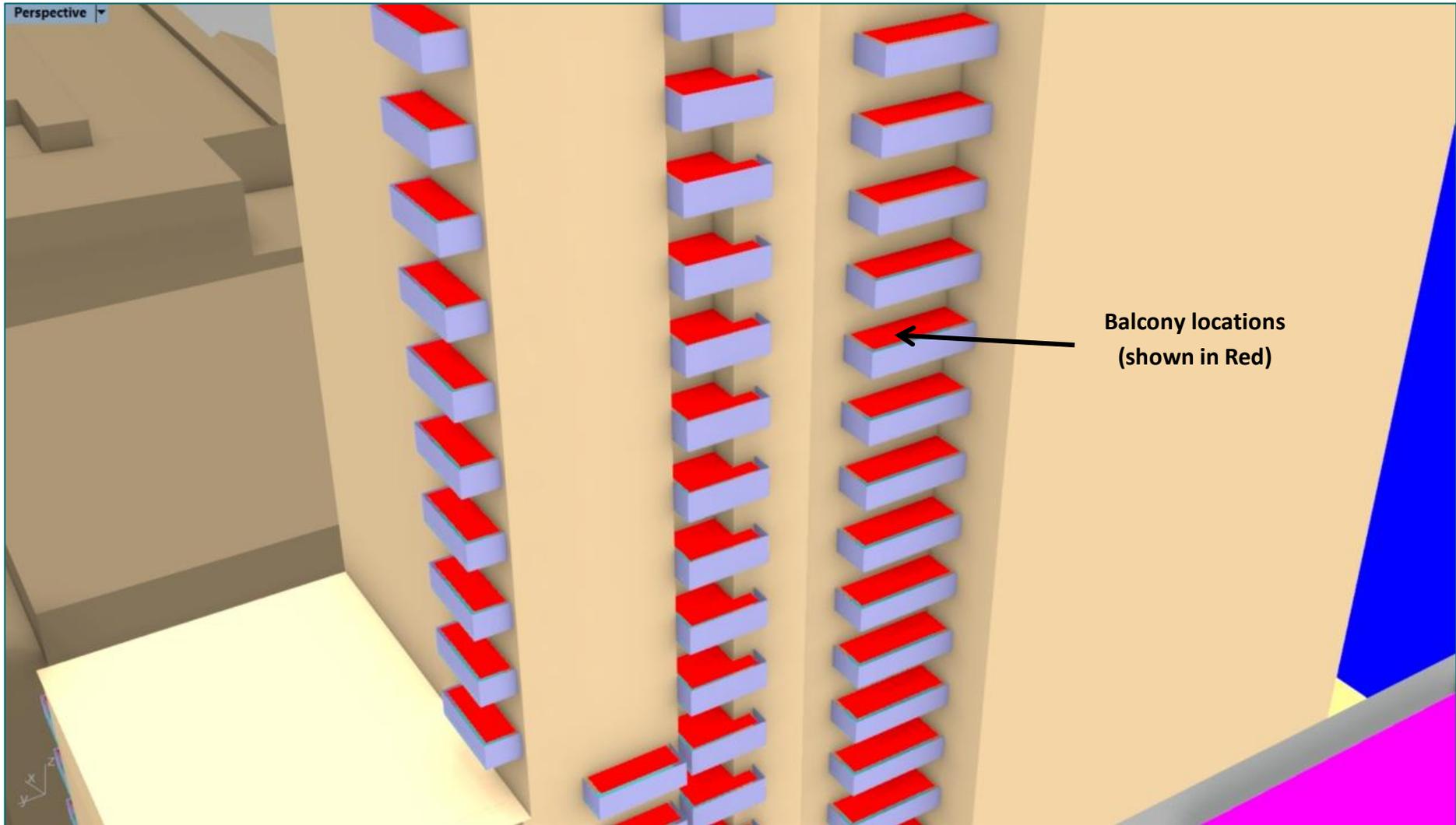


Figure 33: Reportage Locations: Balconies

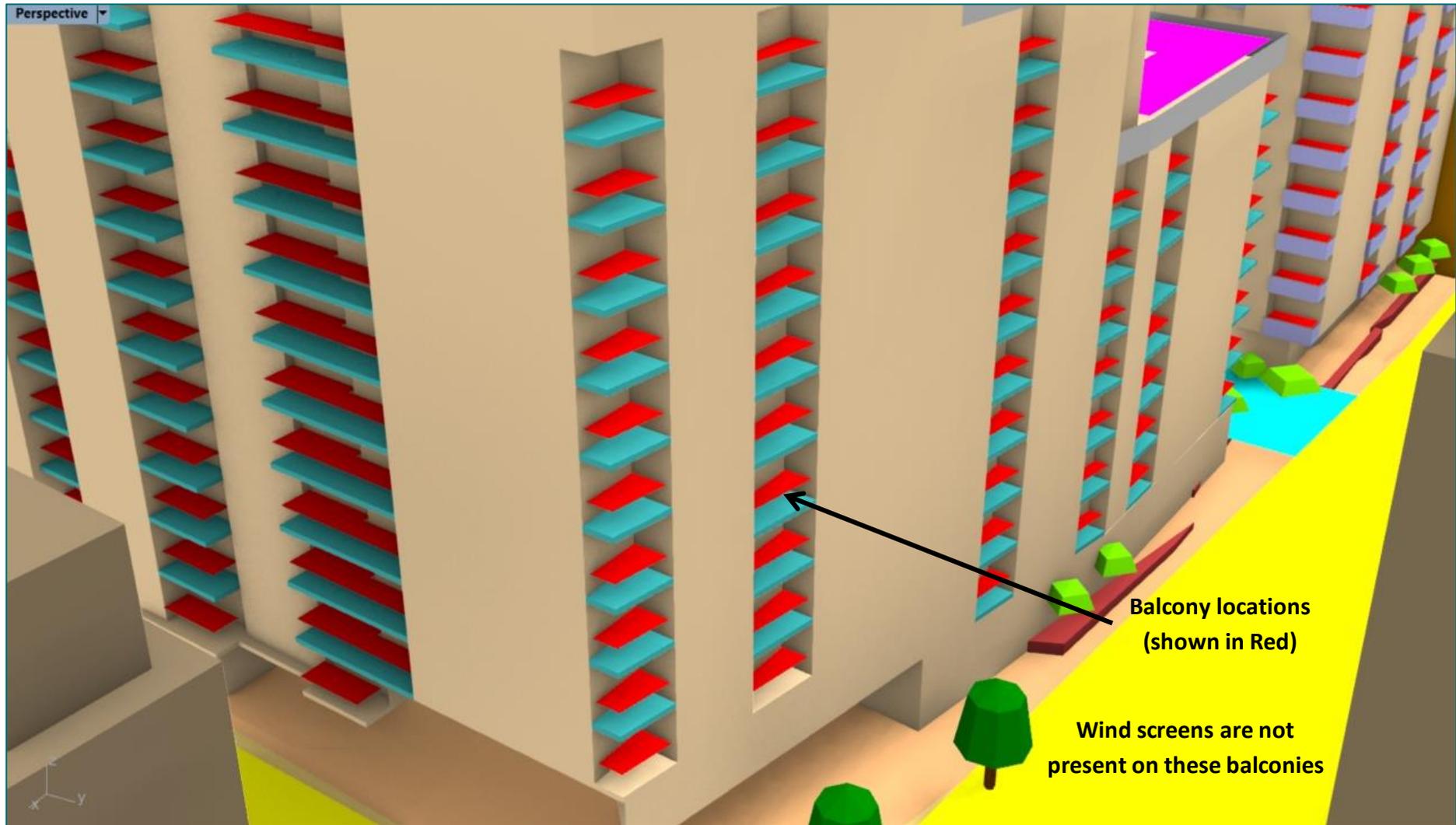


Figure 34: Reportage Locations: Balconies: Residential Block B



Figure 35: Reportage Locations: Internal streets

6.2 Full Site

6.2.1 Model Geometry

In this scenario, both SHD residential and proposed commercial blocks will be simulated for comfort calculations. Figures 37 to 41 show various views of the entire site.



Figure 36: Plan view of the site



Figure 37: View of the site from the south

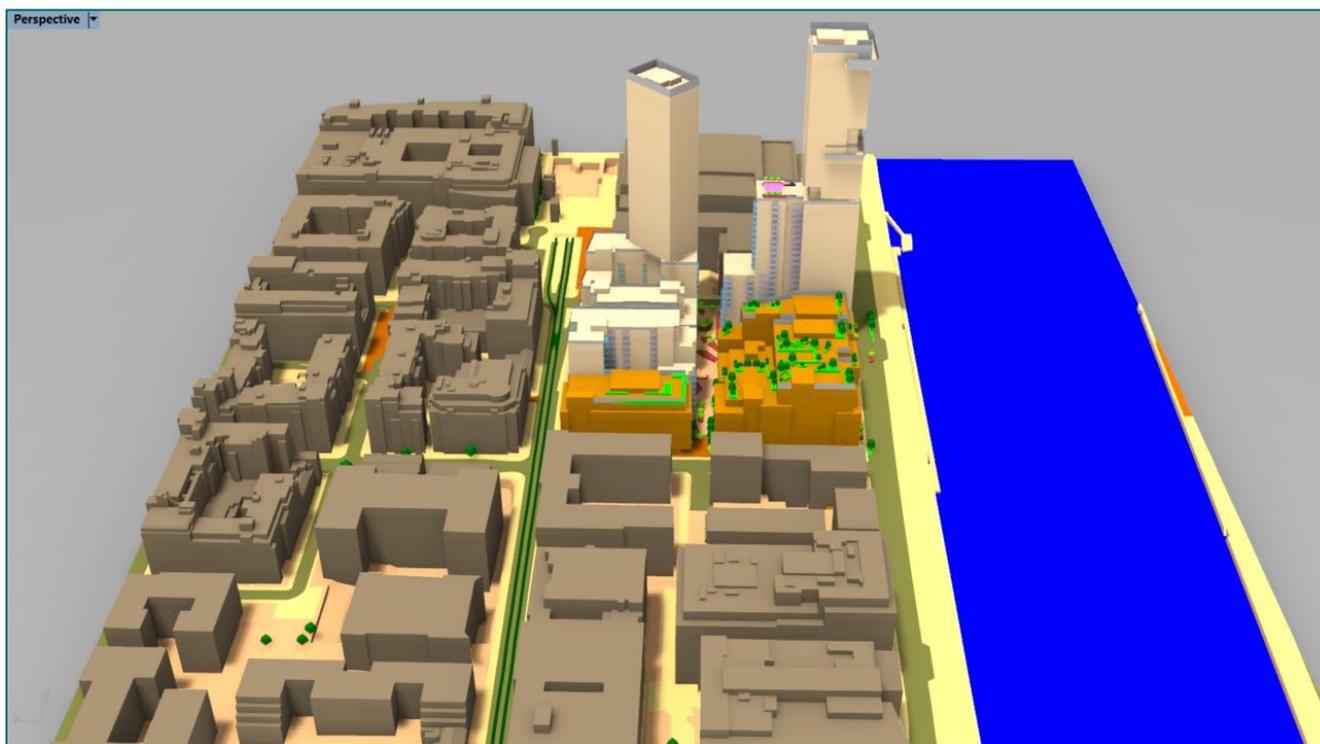


Figure 38: View of the site from the west

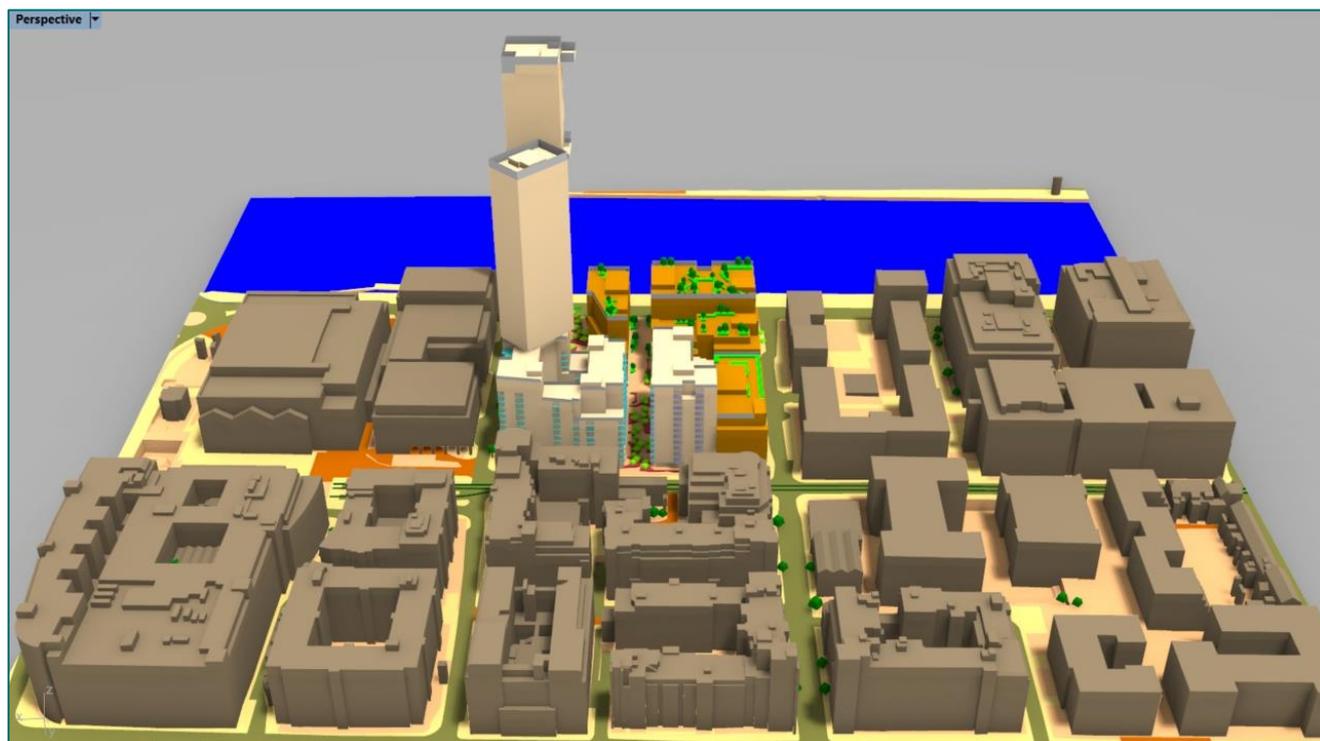


Figure 39: View of the site from the north



Figure 40: View of the site from the east



Figure 41: View of the SHD residential and proposed commercial sites

6.3 Comfort Activities

The following table lists the various activities, according to the amenity type, to be focused on in the simulation.

Amenity Area	Business Walking Activity	Leisurely Walking Activity	Standing Activity	Sitting Activity
Ground level amenities	✓	✓	✓	✓
Roof level amenities	✓	✓	✓	✓
Balconies			✓	✓
Internal Street	✓	✓		
External Street	✓	✓		

7 Results

7.1 Comfort Criteria: SHD Residential Zone

Figures 42 to 50 show the percentage of the year the hourly wind speed exceeds the threshold value for the comfort criteria such as Sitting, Standing, Leisurely Walking and Business Walking for all seasons. The threshold values are 4m/s, 6m/s, 8m/s and 10m/s respectively.

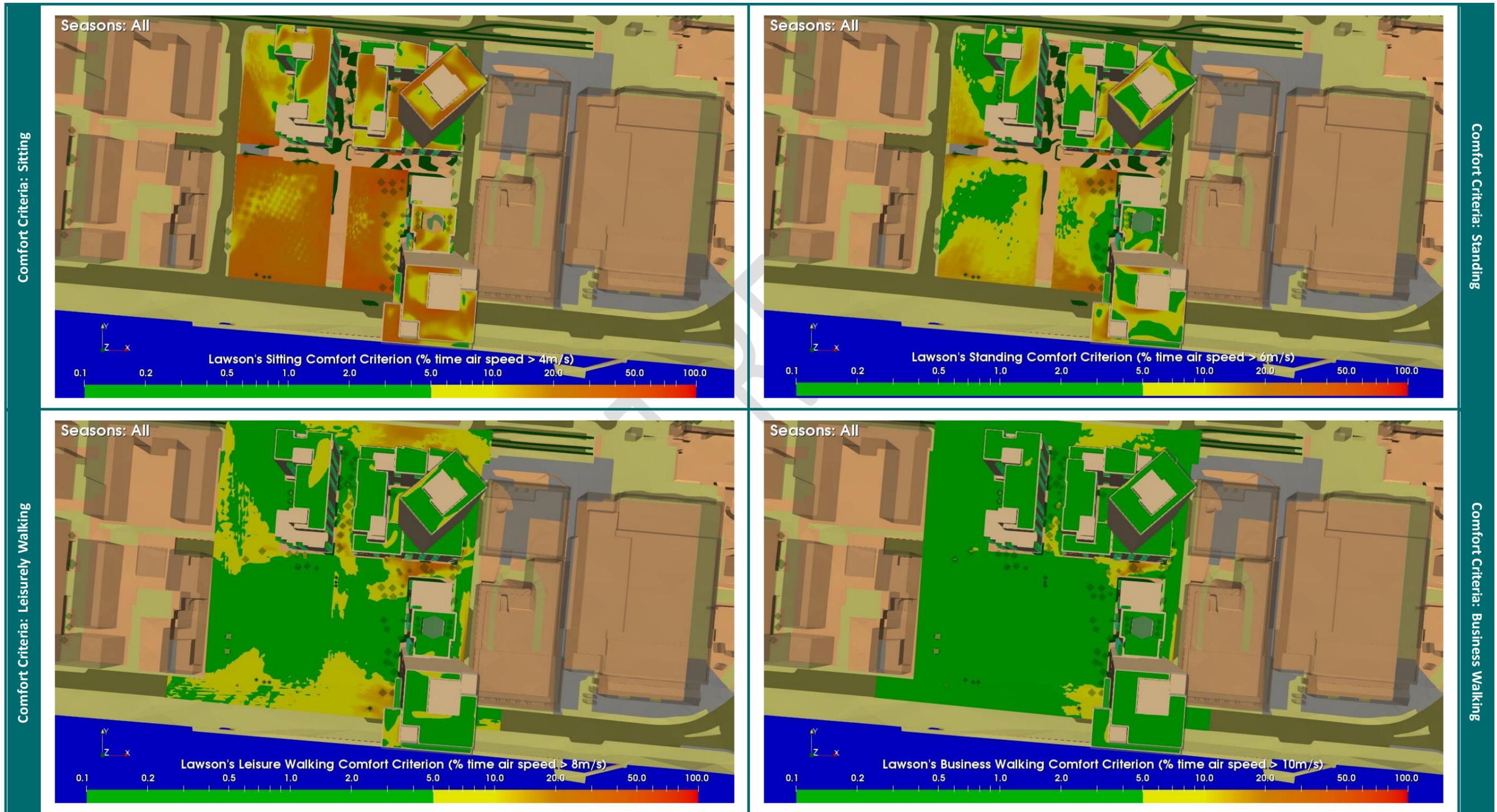


Figure 42: Comfort Criteria: All Seasons: View from above

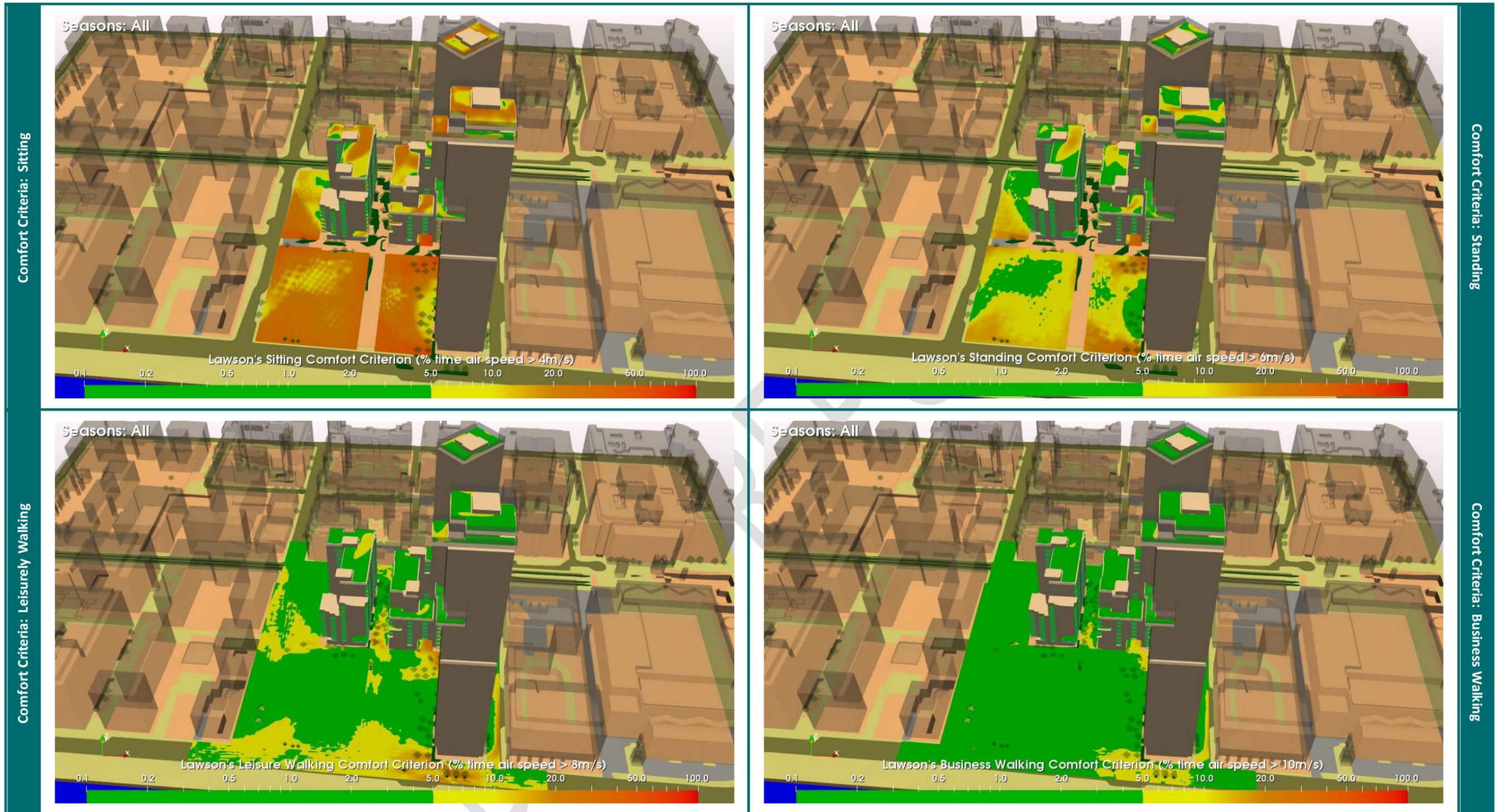


Figure 43: Comfort Criteria: All Seasons: View from the south

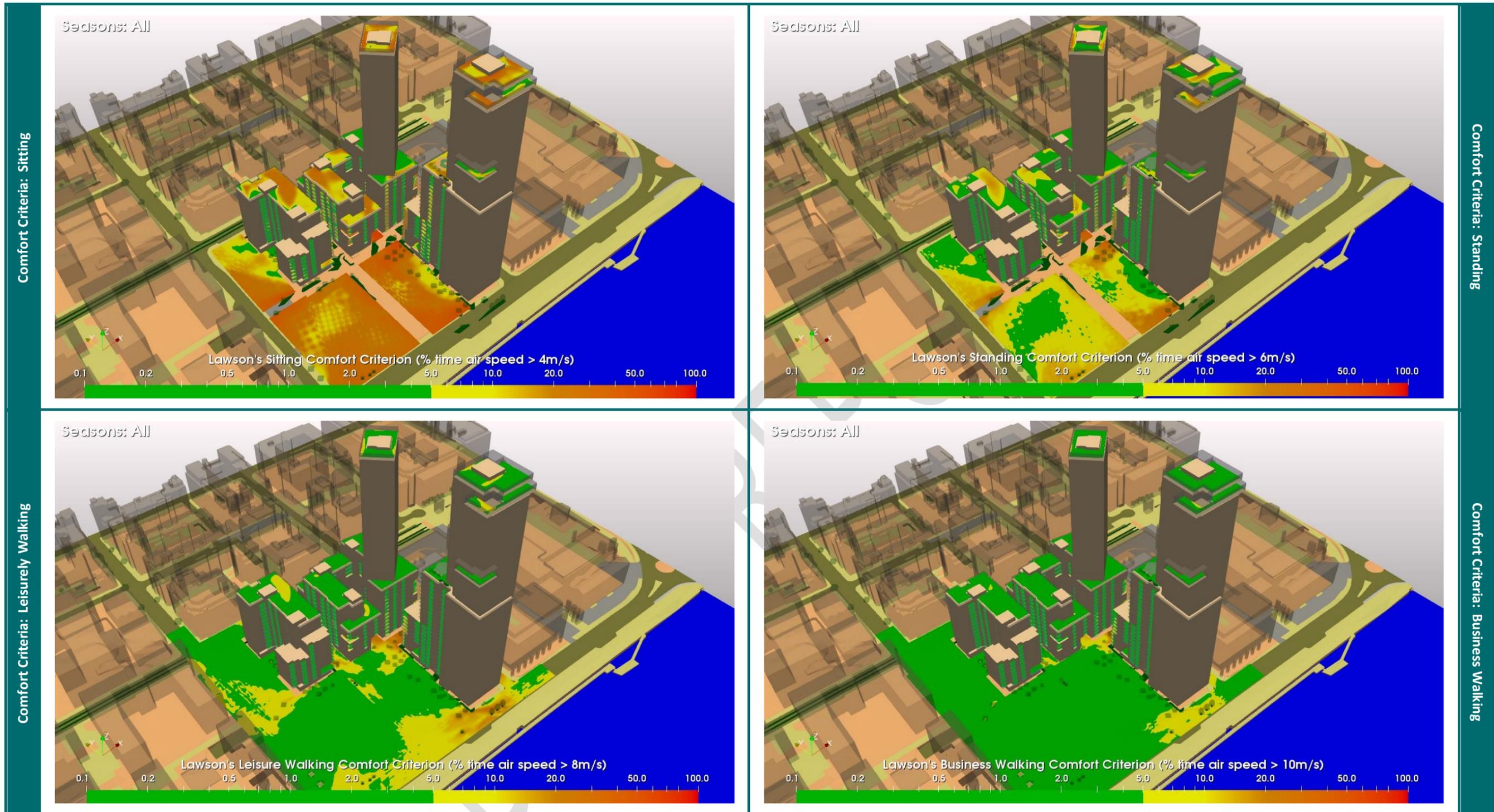


Figure 44: Comfort Criteria: All Seasons: View from the southwest

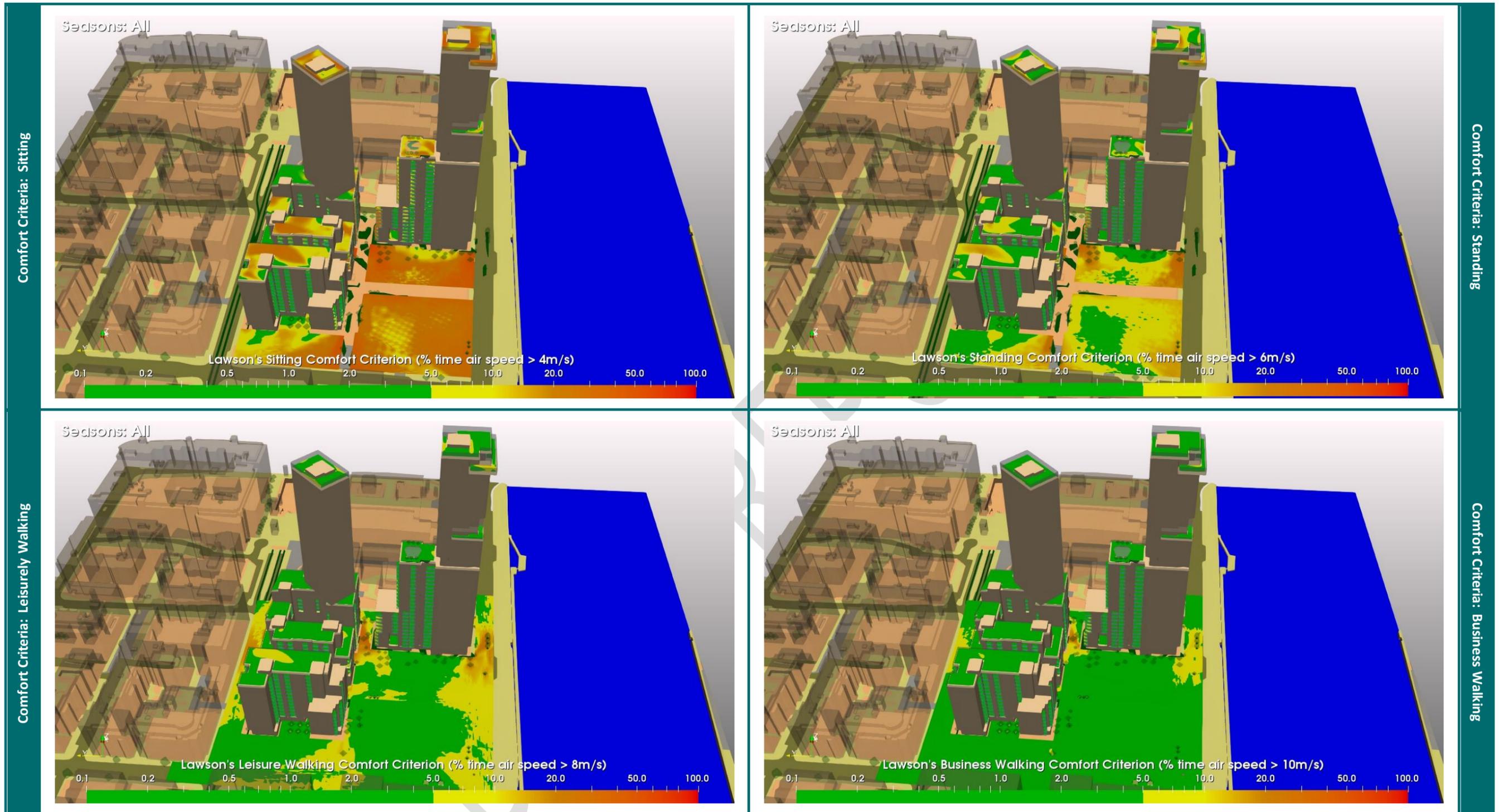


Figure 45: Comfort Criteria: All Seasons: View from the west

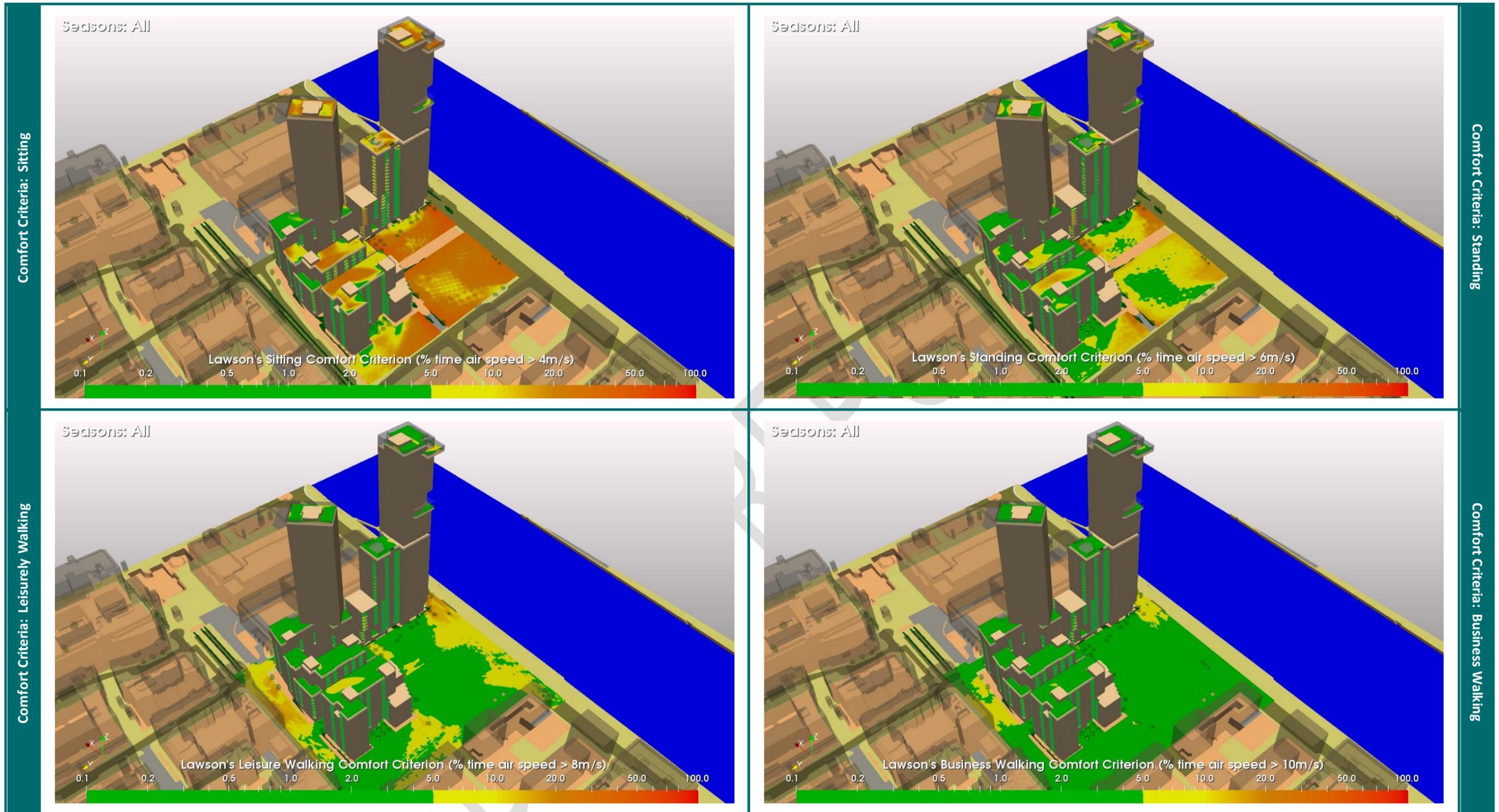


Figure 46: Comfort Criteria: All Seasons: View from the northwest

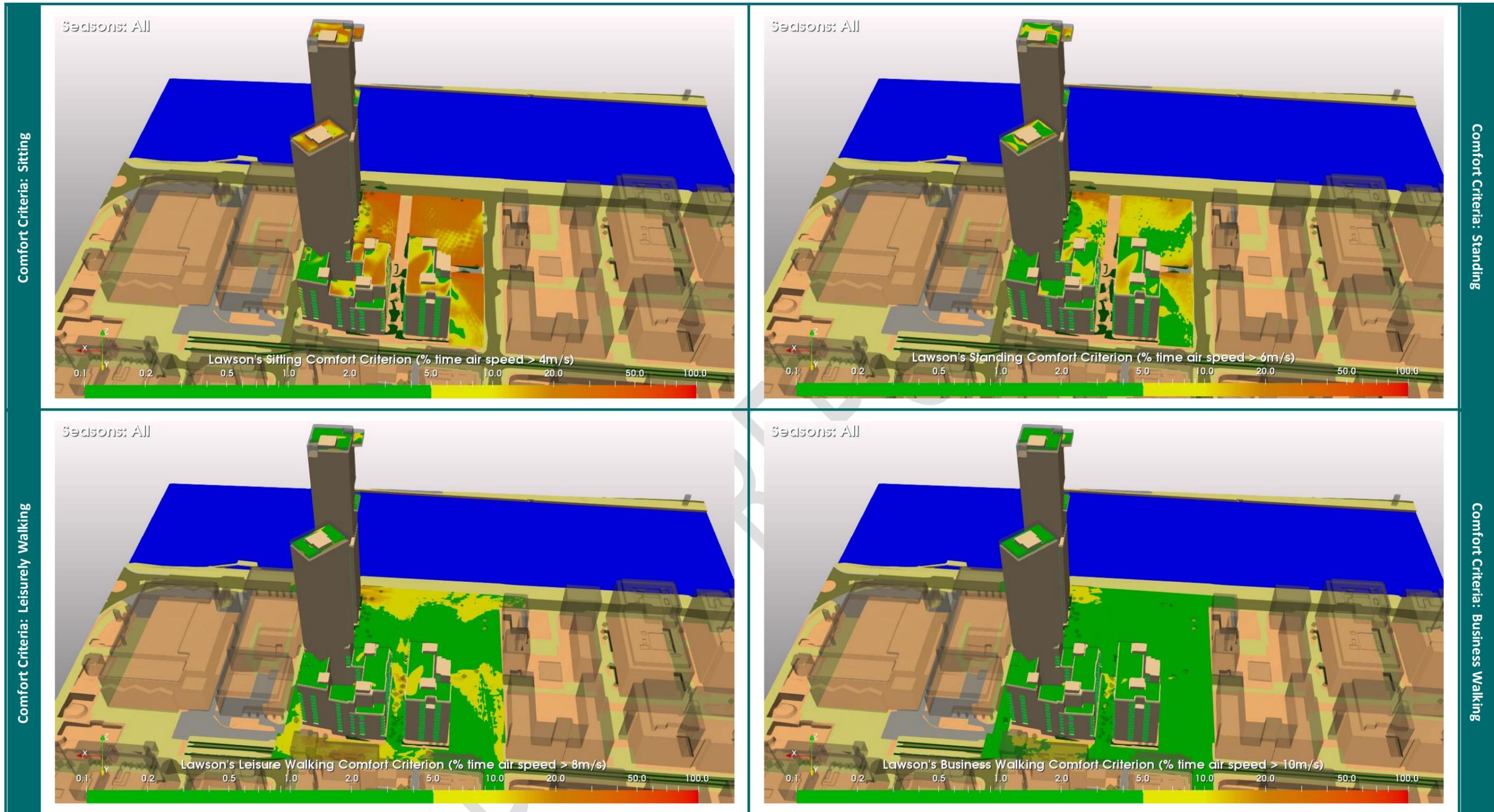


Figure 47: Comfort Criteria: All Seasons: View from the north

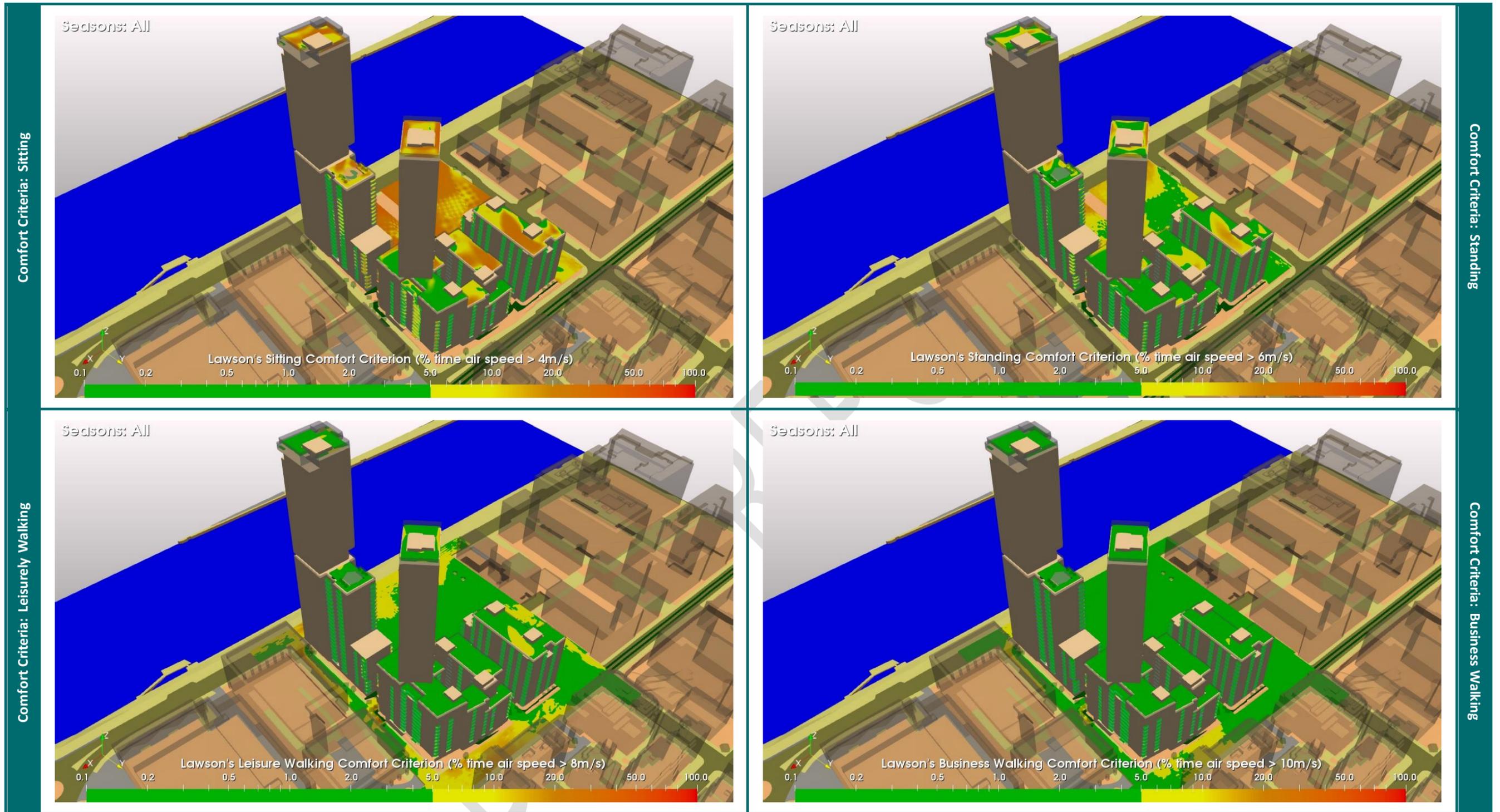


Figure 48: Comfort Criteria: All Seasons: View from the northeast

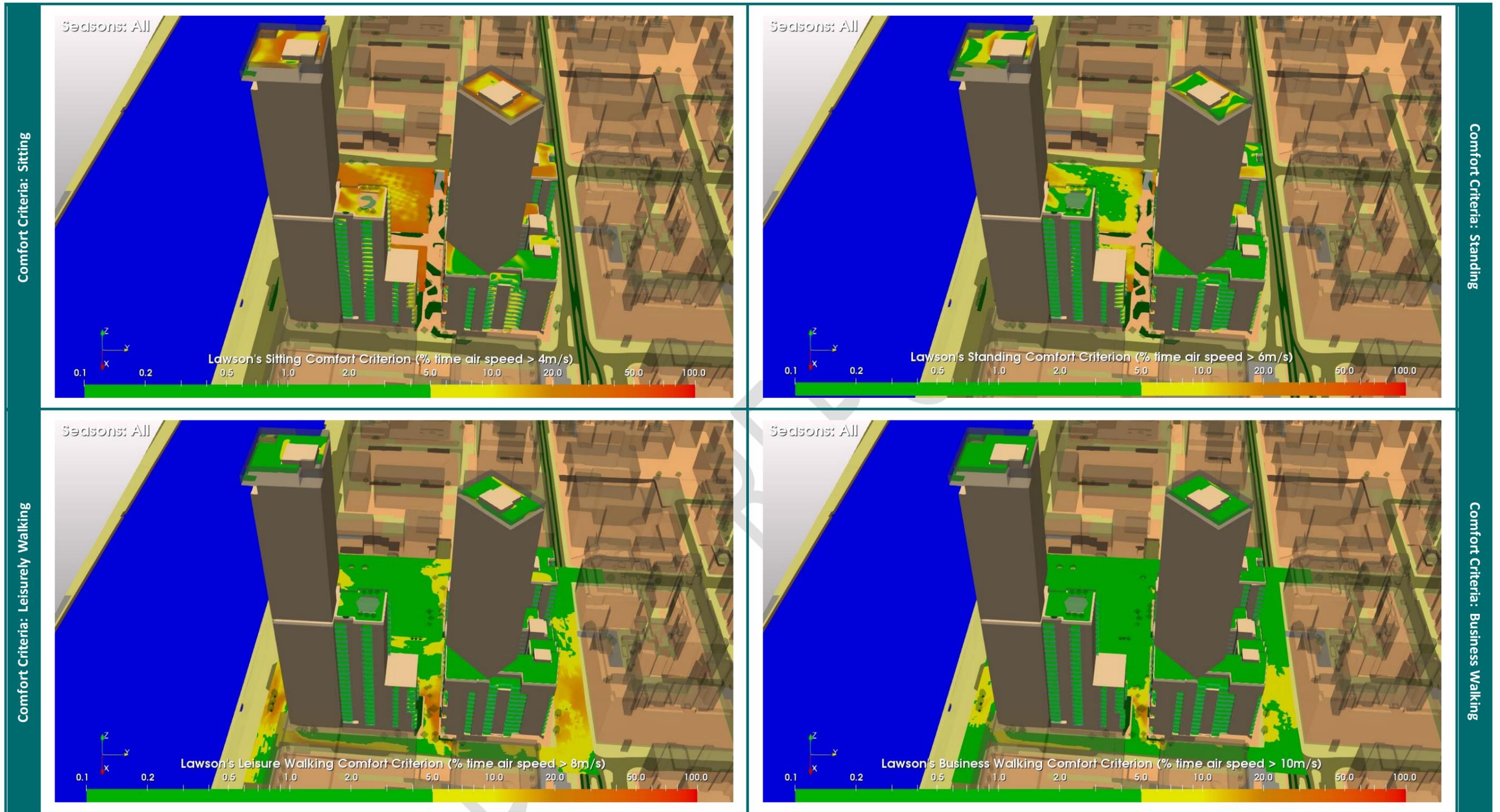


Figure 49: Comfort Criteria: All Seasons: View from the east

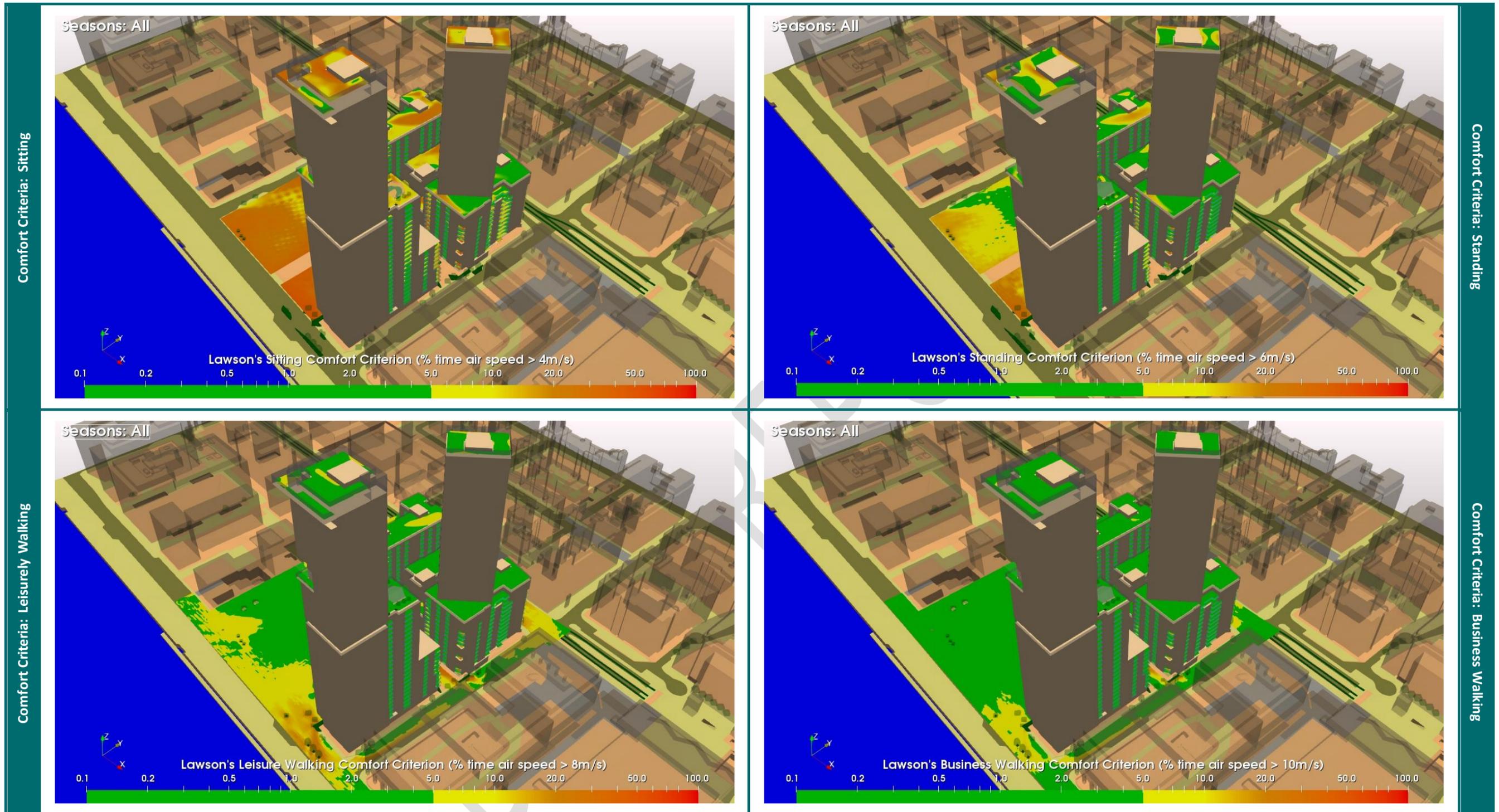


Figure 50: Comfort Criteria: All Seasons: View from the southeast

7.2 Safety Criteria: SHD Residential Zone

Figure 51 to 59 show the percentage of the year the hourly wind speed exceeds the threshold value for the safety criteria for all seasons. The threshold values are 20m/s for normal pedestrian and 15m/s for sensitive pedestrian.

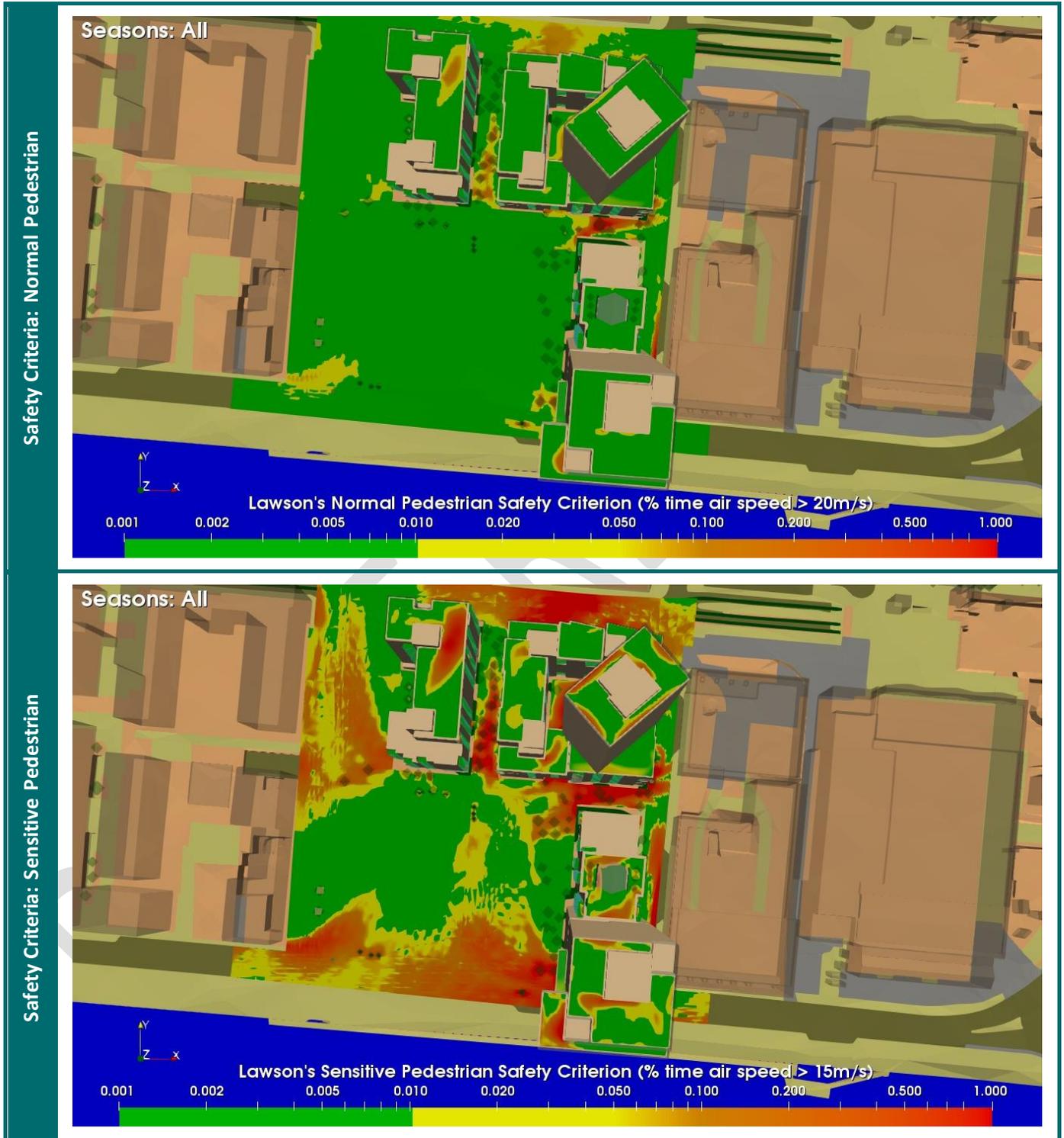


Figure 51: Safety Criteria: All Season: View from above

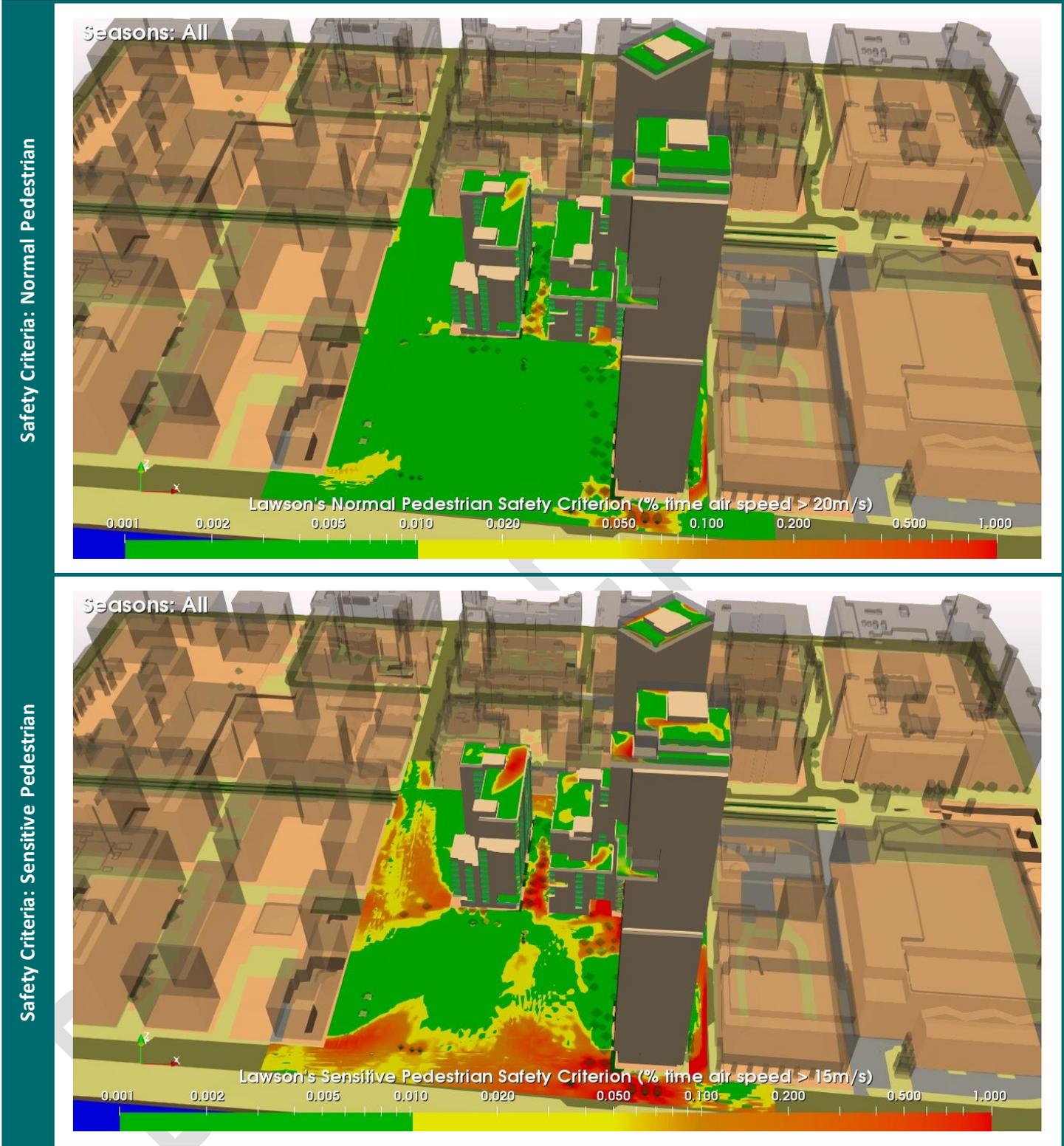


Figure 52: Safety Criteria: All Season: View from the south

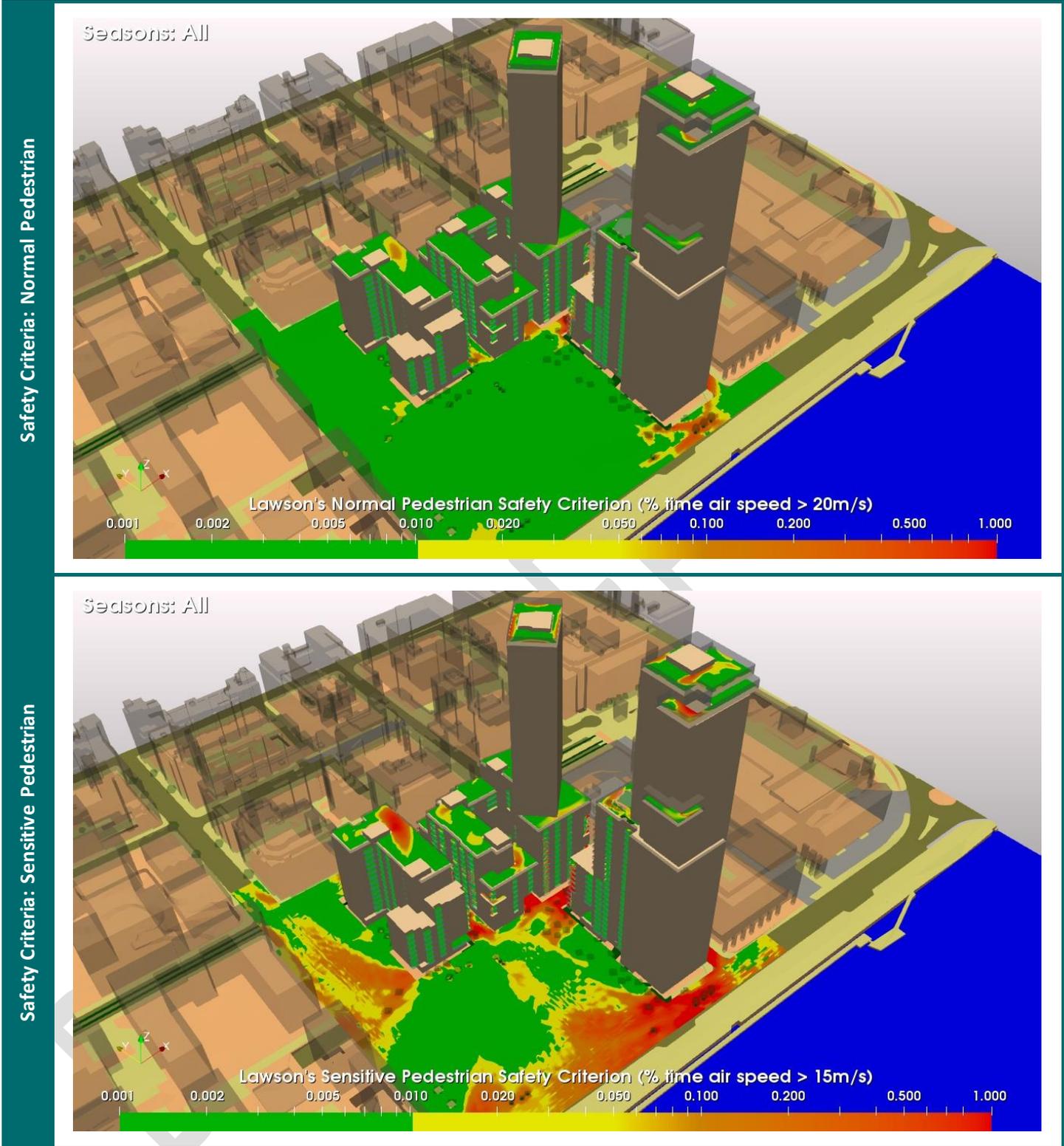


Figure 53: Safety Criteria: All Season: View from the southwest

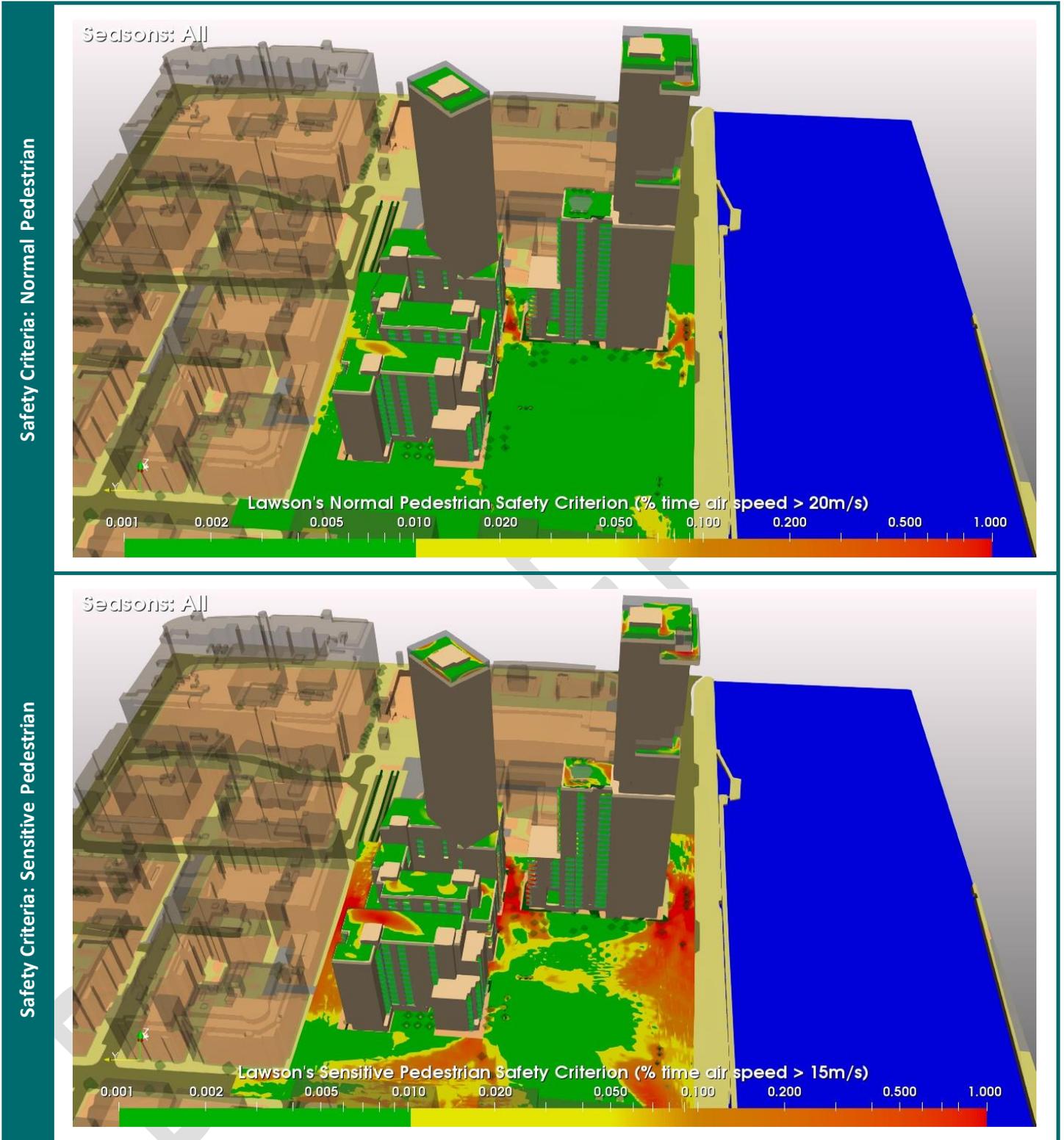


Figure 54: Safety Criteria: All Season: View from the west

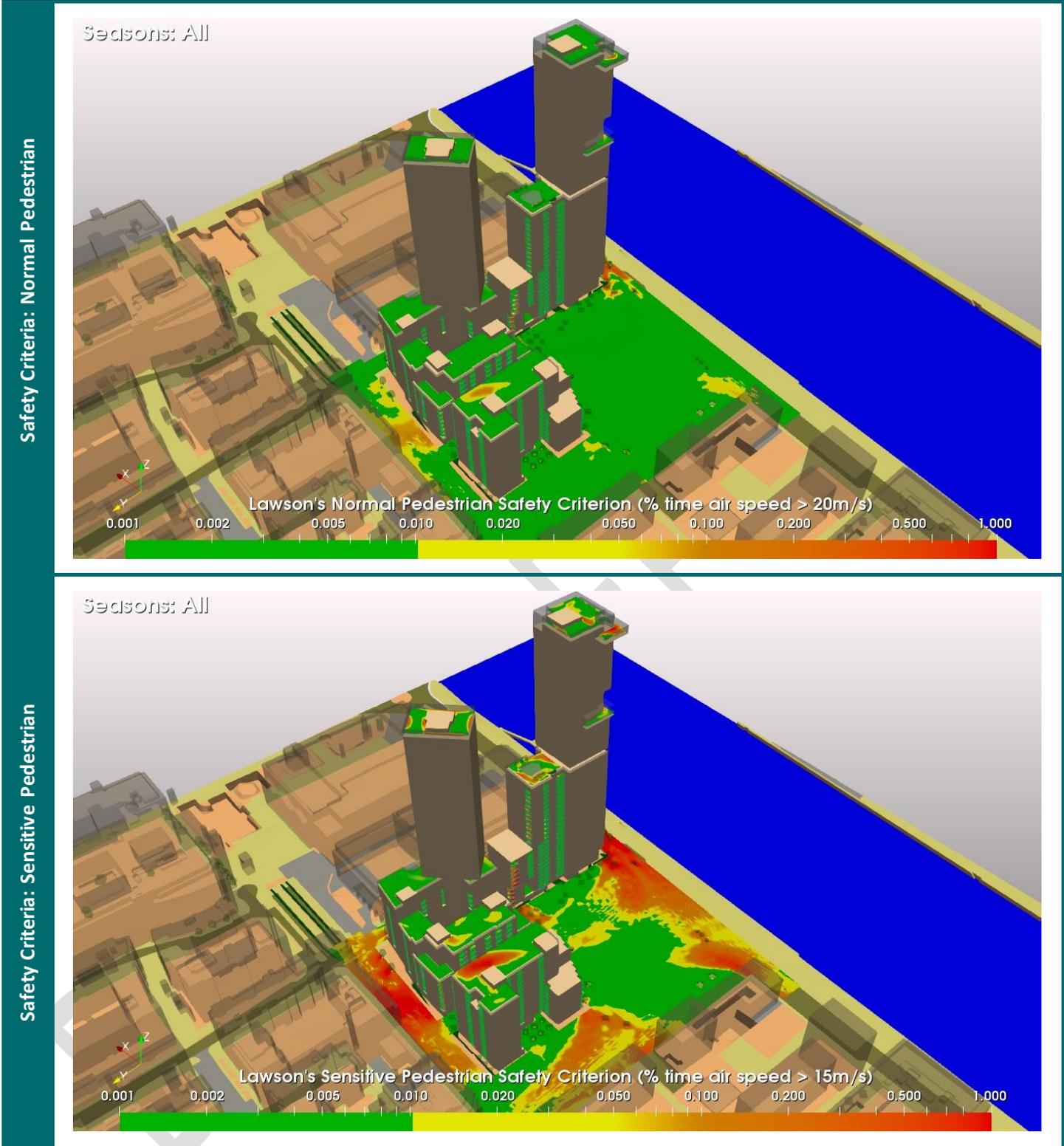


Figure 55: Safety Criteria: All Season: View from the northwest

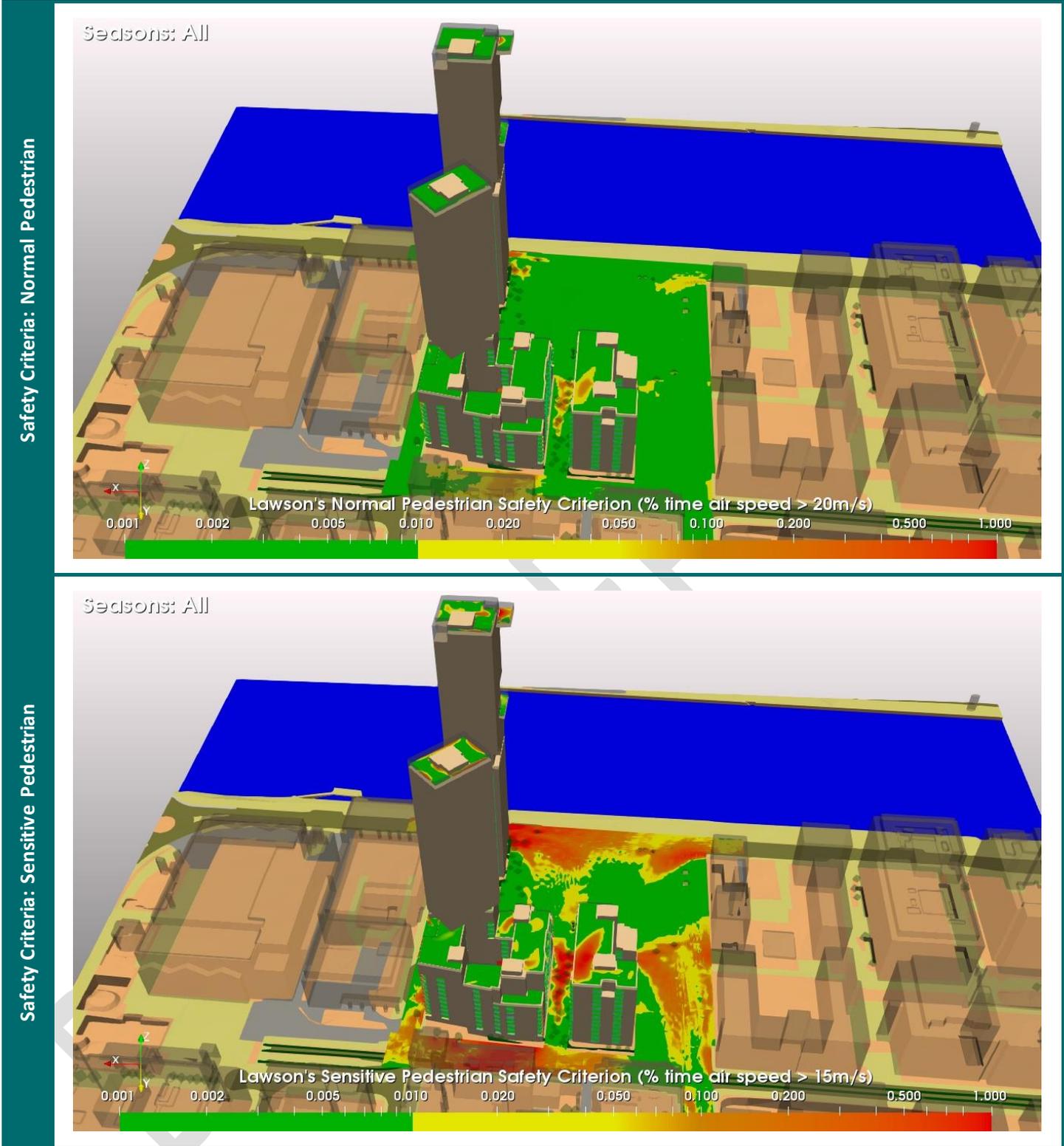


Figure 56: Safety Criteria: All Season: View from the north

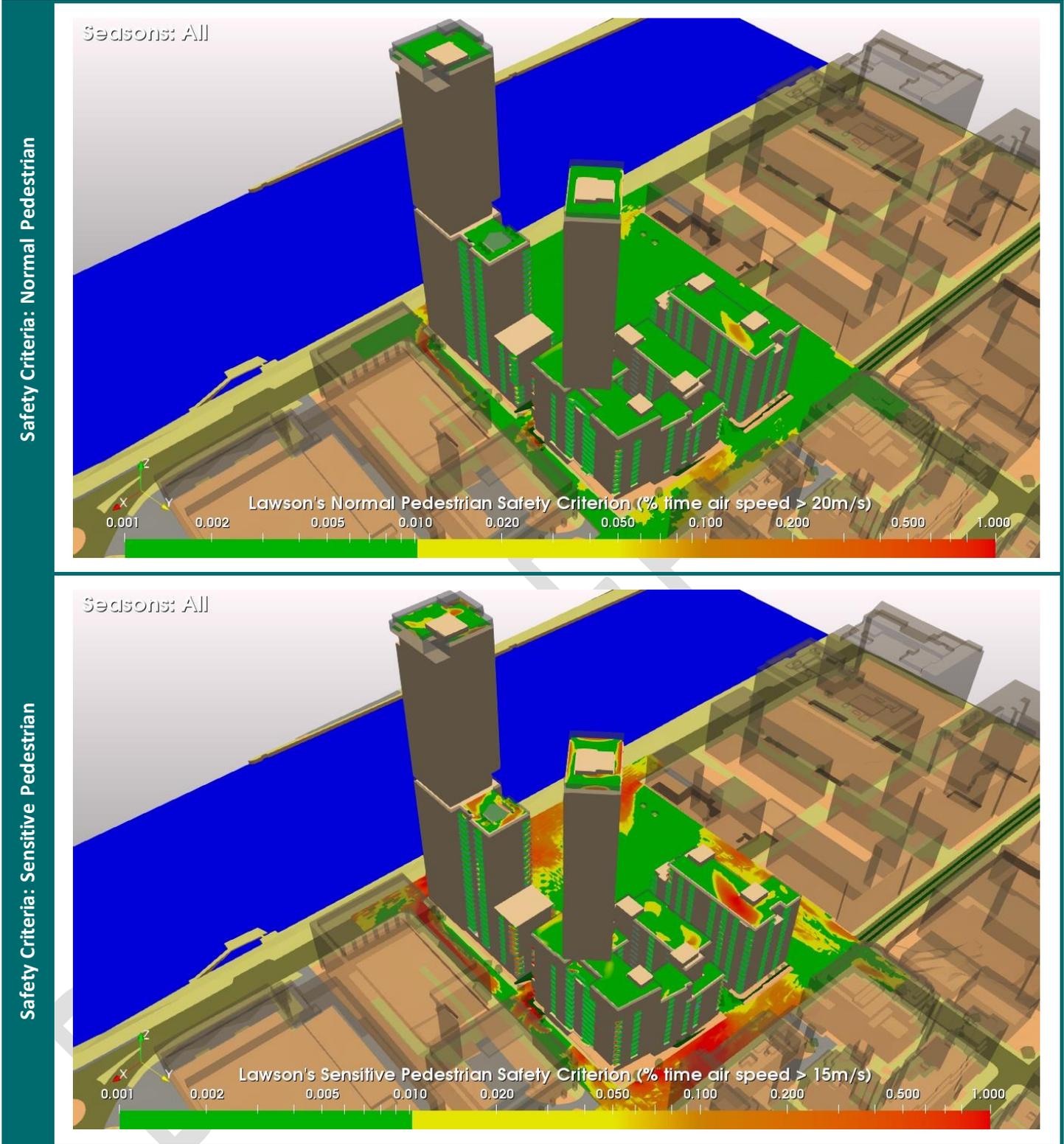


Figure 57: Safety Criteria: All Season: View from the northeast

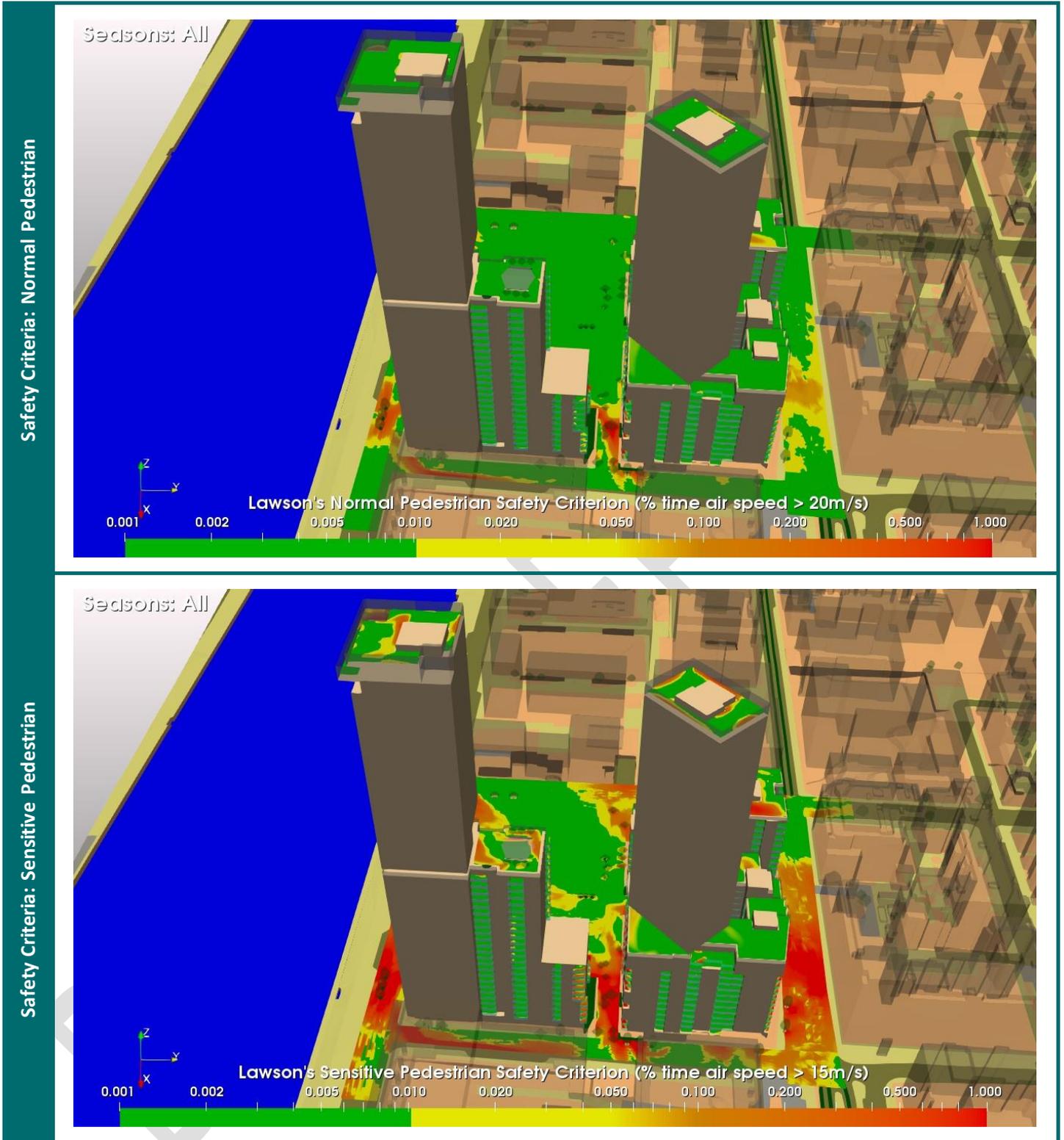


Figure 58: Safety Criteria: All Season: View from the east

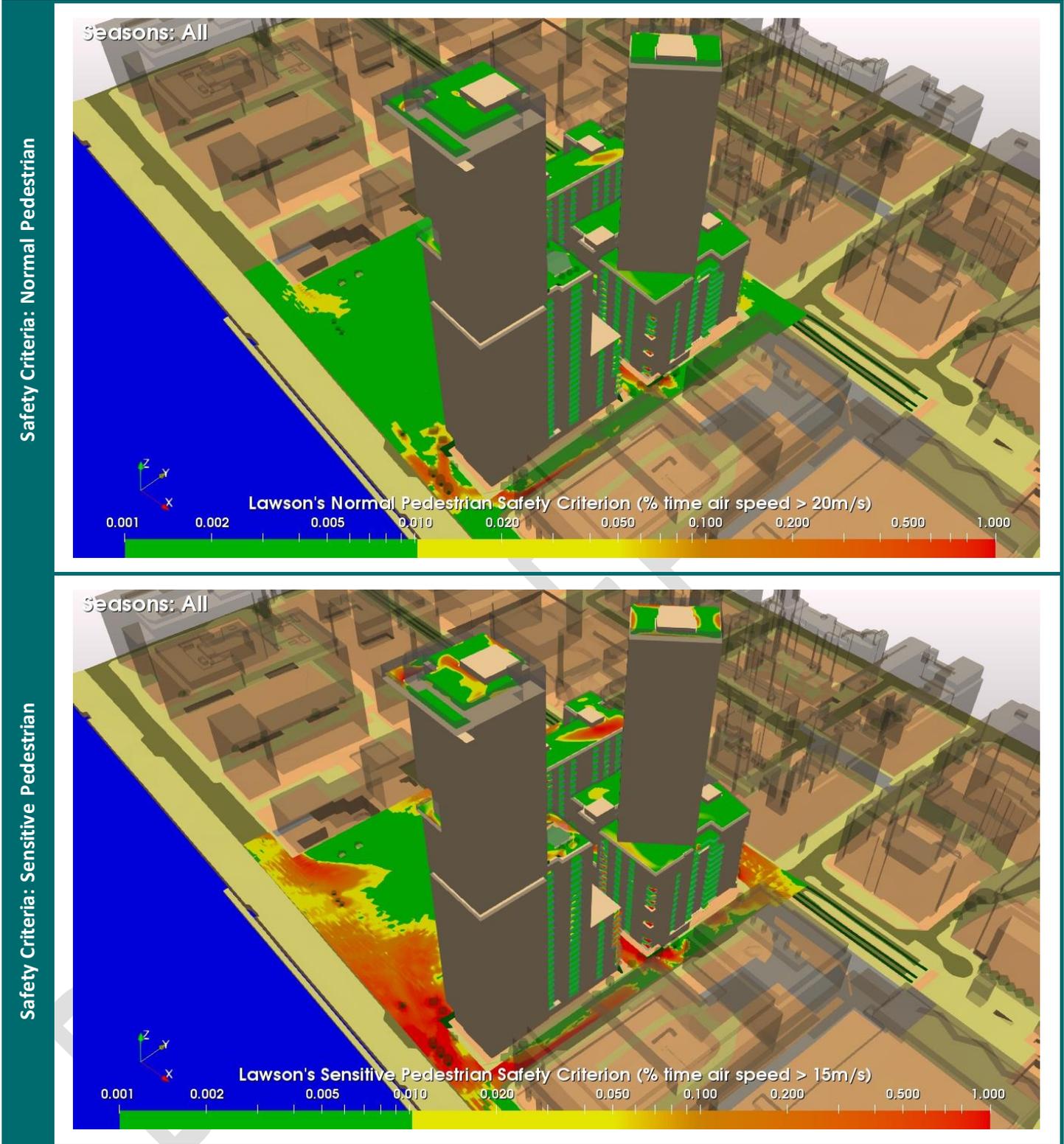


Figure 59: Safety Criteria: All Season: View from the southeast

7.3 Comfort Criteria: Full Site

Figures 60 to 68 show the percentage of the year the hourly wind speed exceeds the threshold value for the comfort criteria such as Sitting, Standing, Leisurly Walking and Business Walking for all seasons. The threshold values are 4m/s, 6m/s, 8m/s and 10m/s respectively.

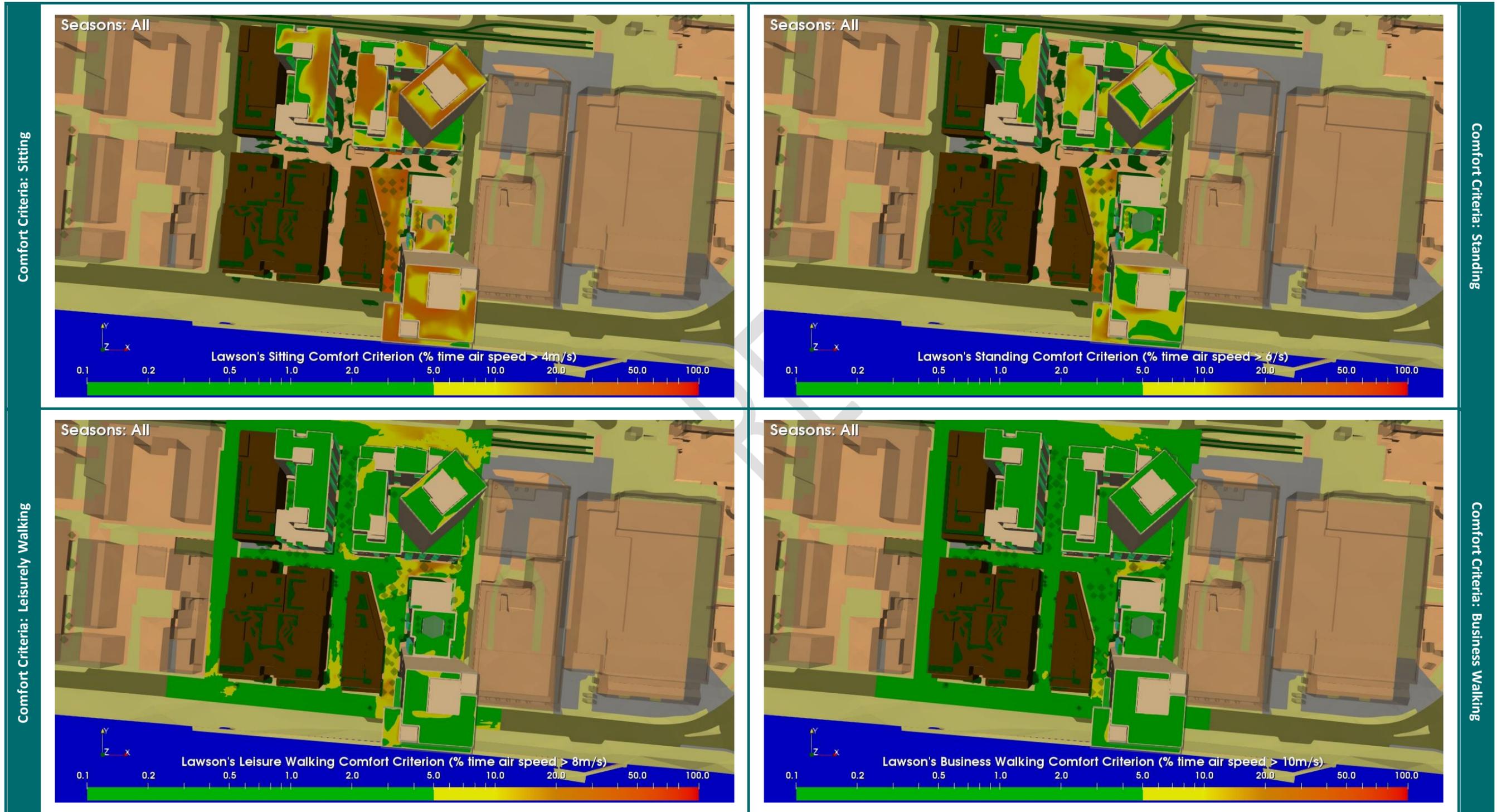


Figure 60: Comfort Criteria: All Seasons: View from above

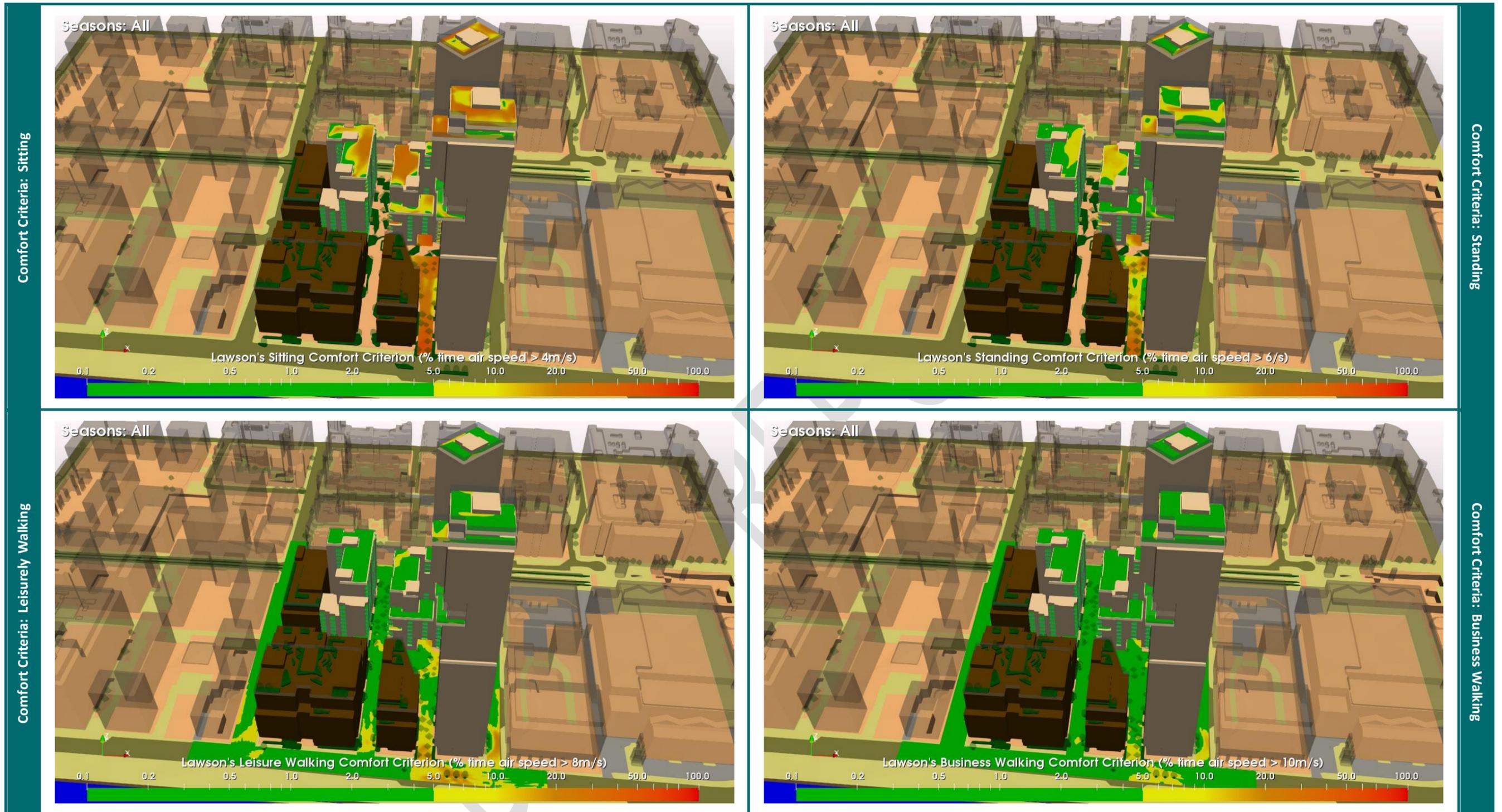


Figure 61: Comfort Criteria: All Seasons: View from the south

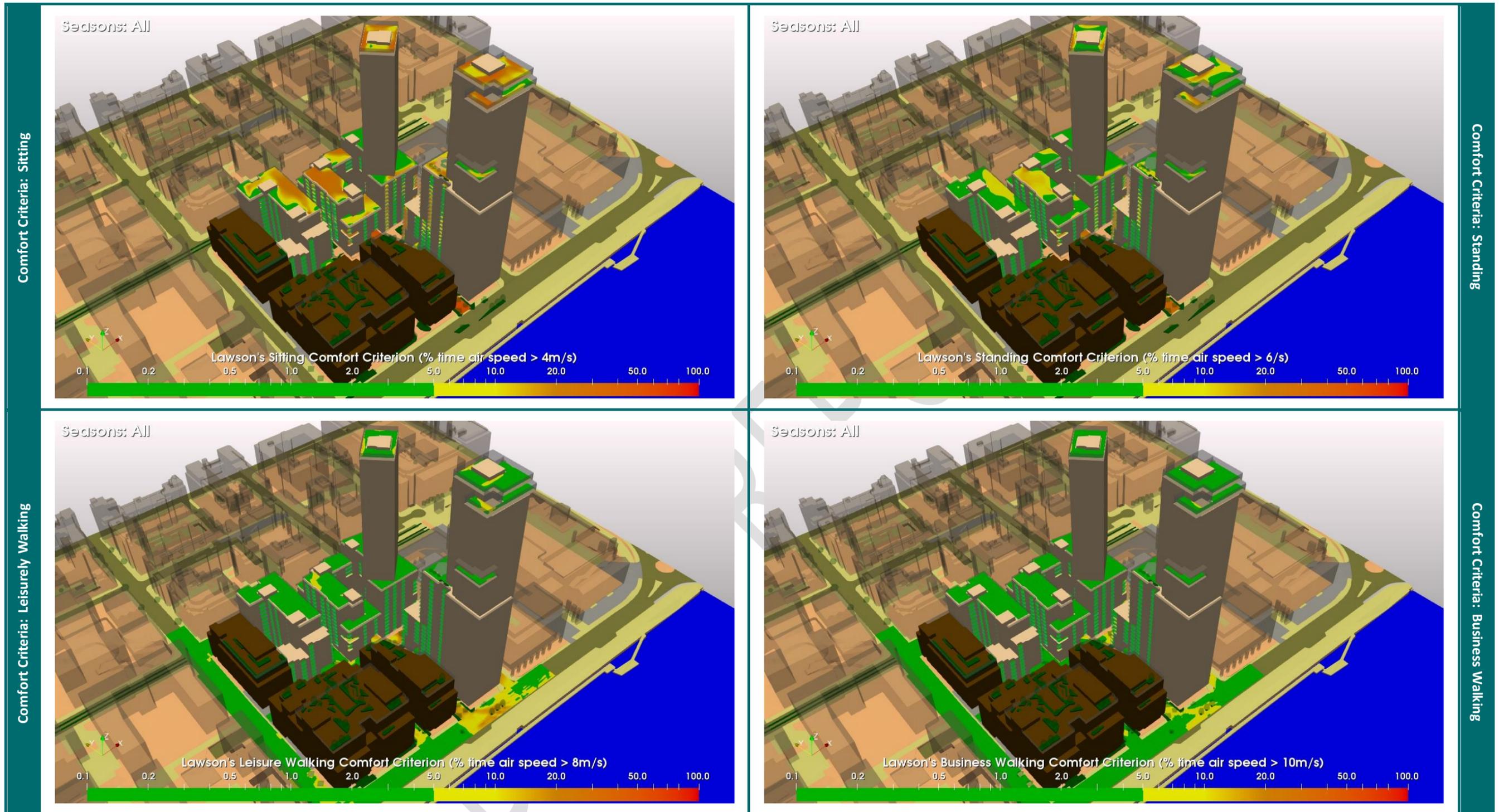


Figure 62: Comfort Criteria: All Seasons: View from the southwest

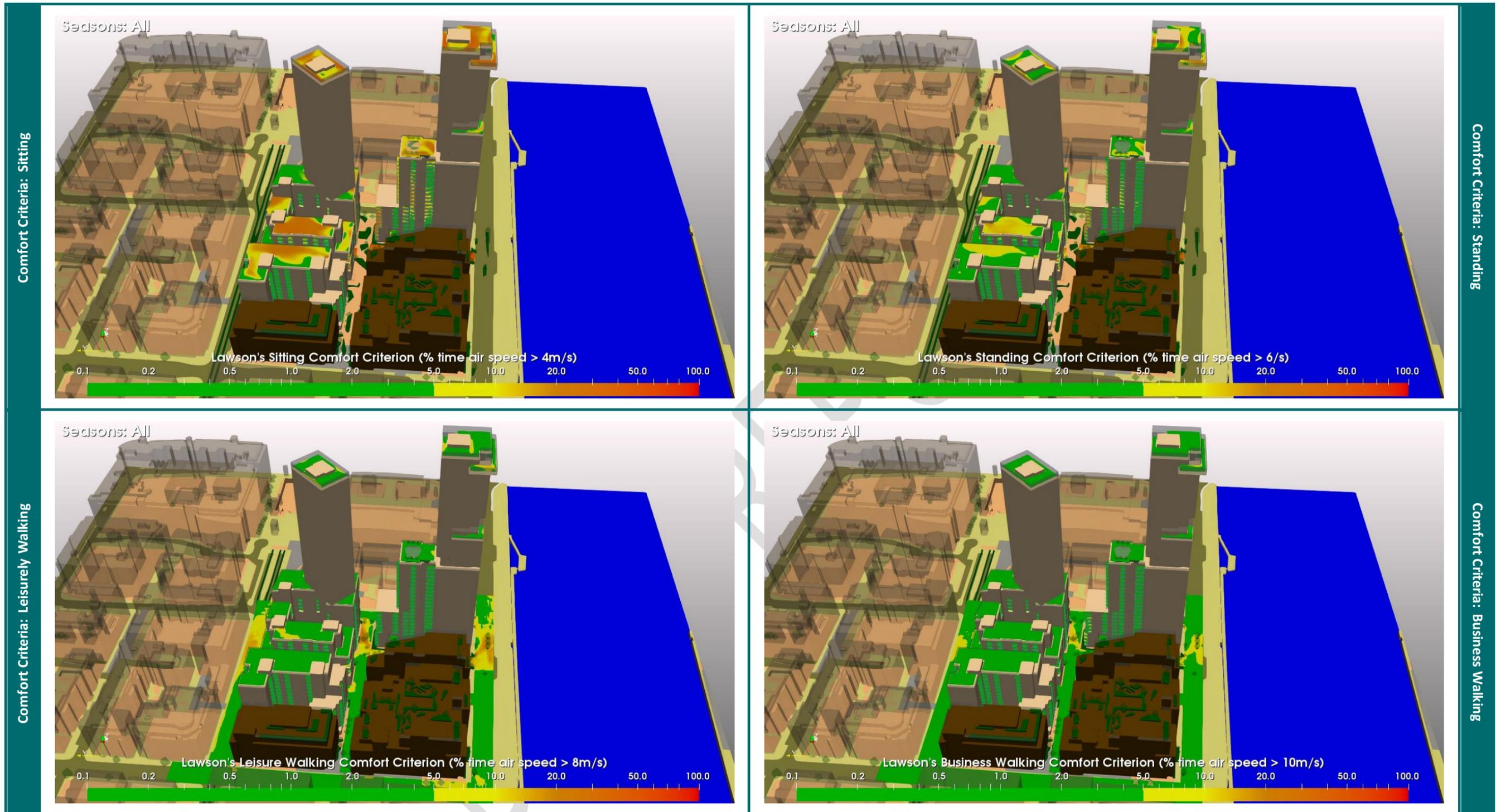


Figure 63: Comfort Criteria: All Seasons: View from the west

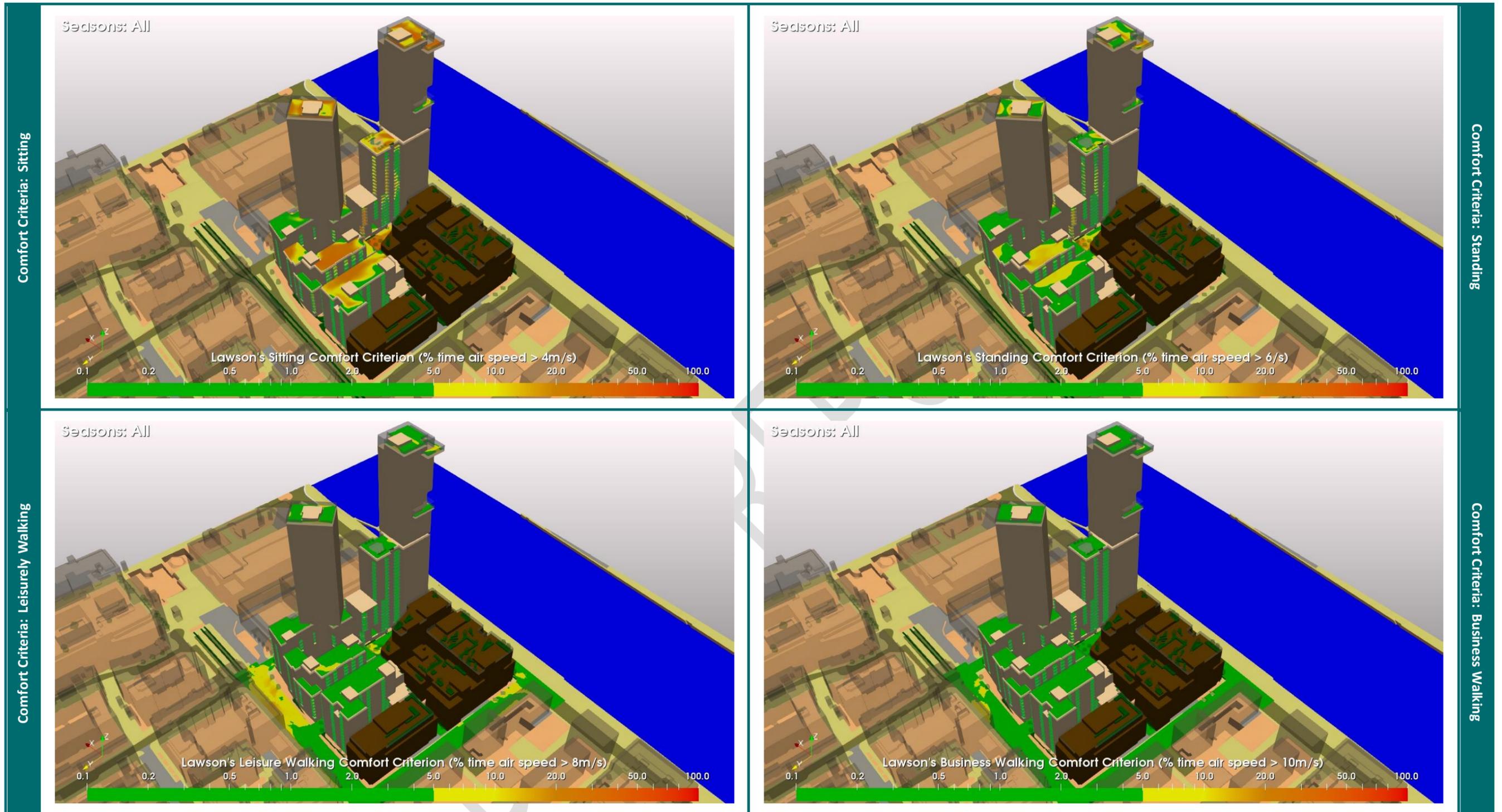


Figure 64: Comfort Criteria: All Seasons: View from the northwest

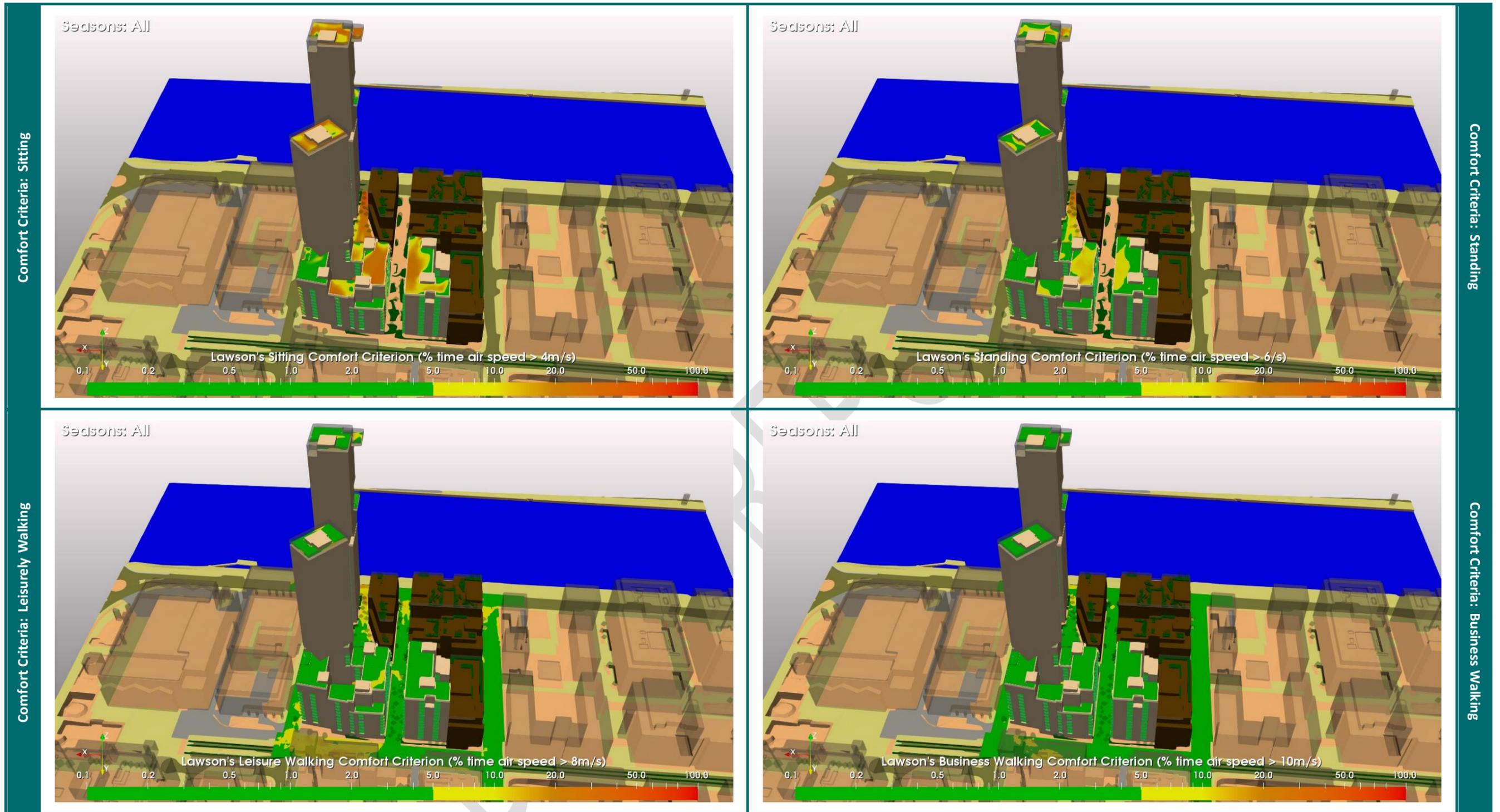


Figure 65: Comfort Criteria: All Seasons: View from the north

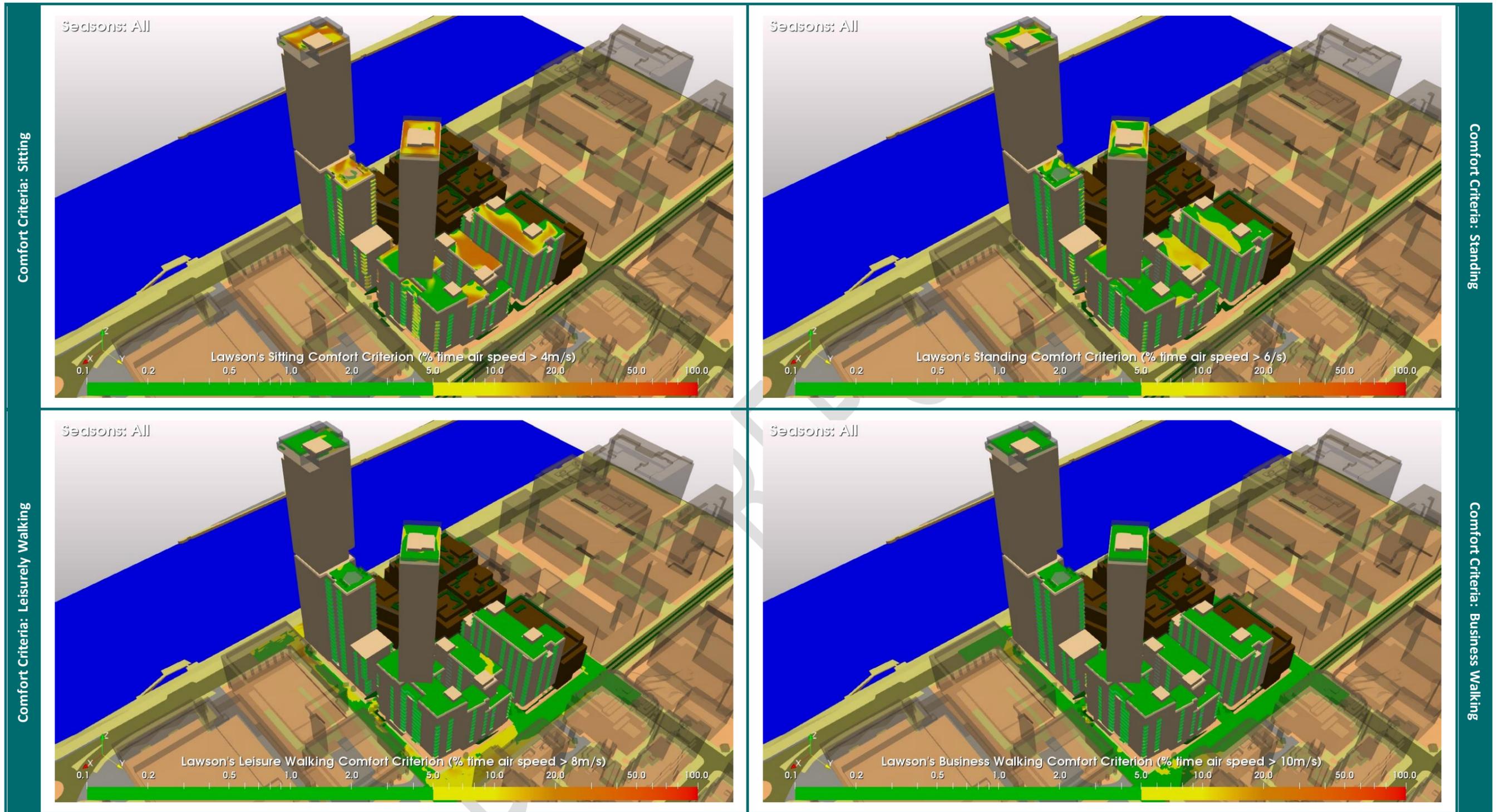


Figure 66: Comfort Criteria: All Seasons: View from the northeast

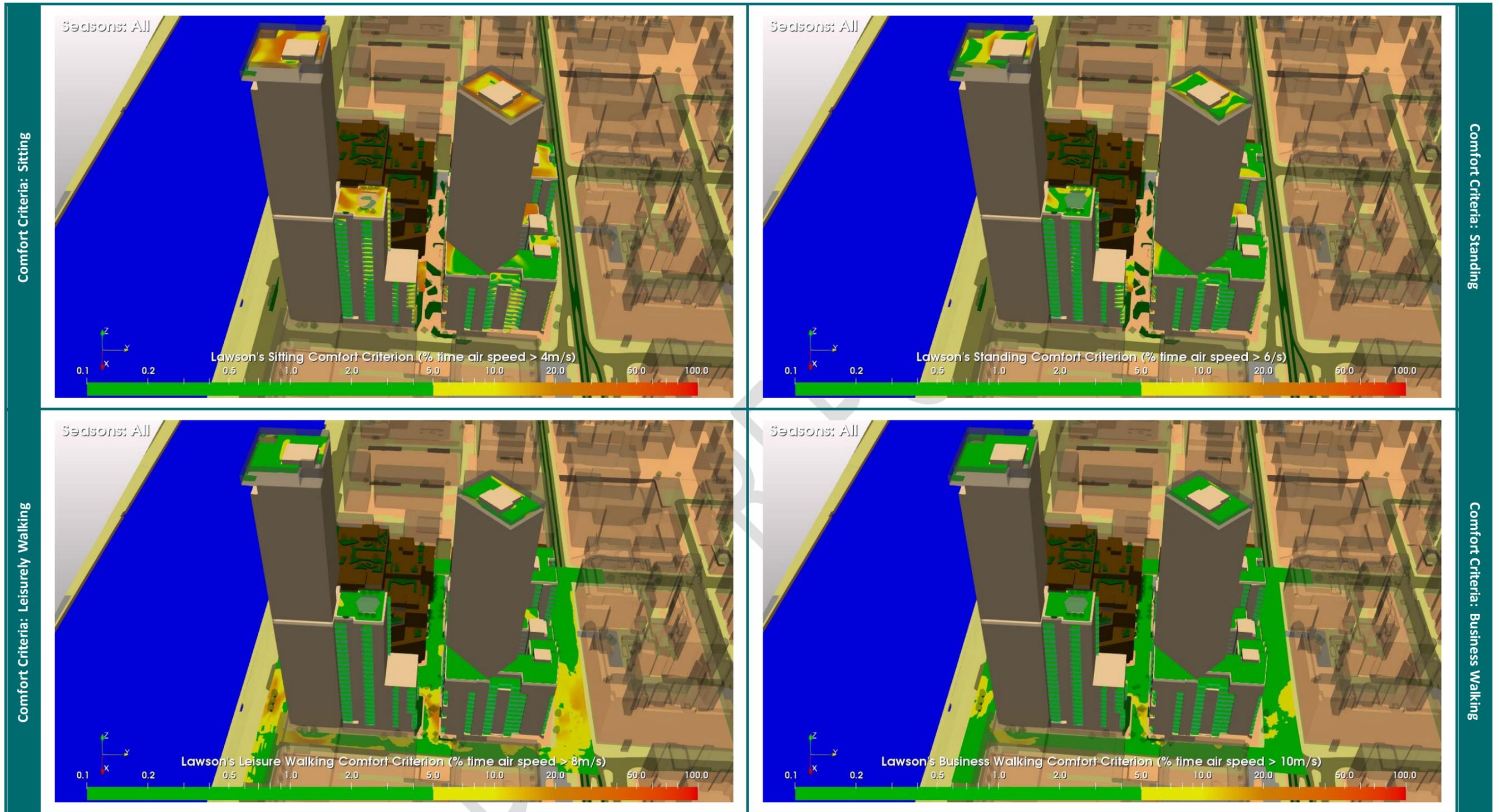


Figure 67: Comfort Criteria: All Seasons: View from the east

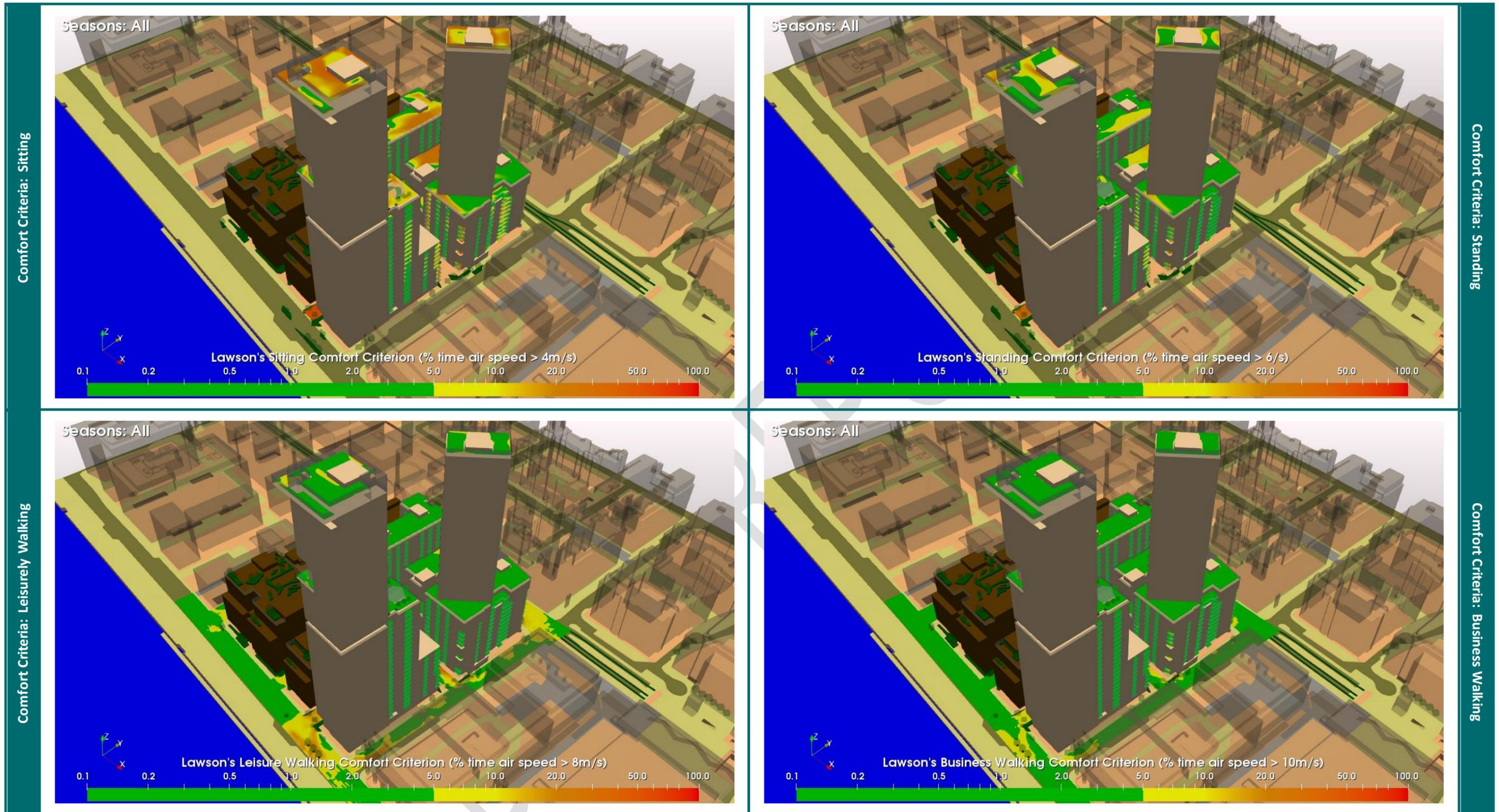


Figure 68: Comfort Criteria: All Seasons: View from the southeast

7.4 Safety Criteria: Full Site

Figure 69 to 77 show the percentage of the year the hourly wind speed exceeds the threshold value for the safety criteria for all seasons. The threshold values are 20m/s for normal pedestrian and 15m/s for sensitive pedestrian.

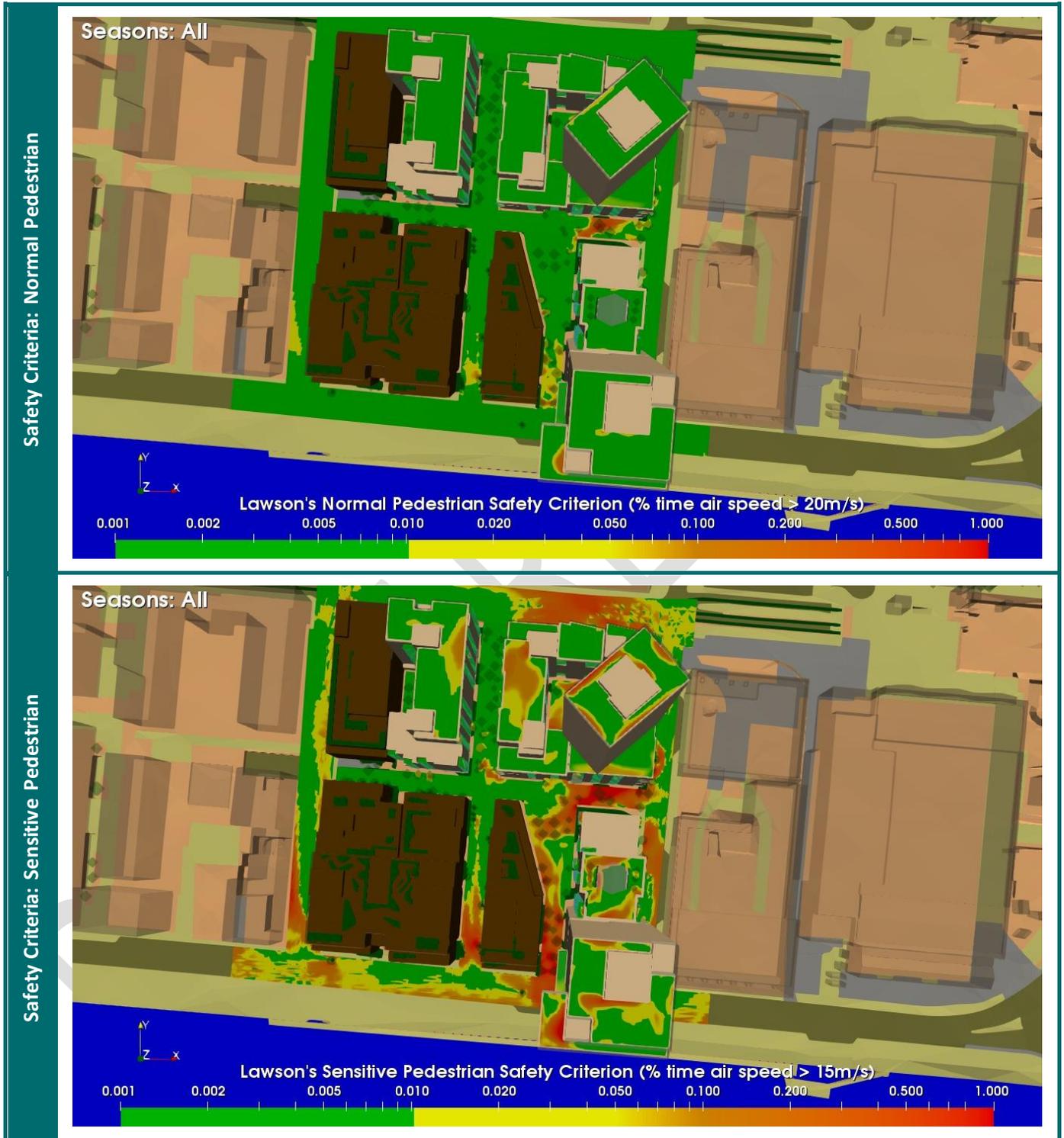


Figure 69: Safety Criteria: All Season: View from above

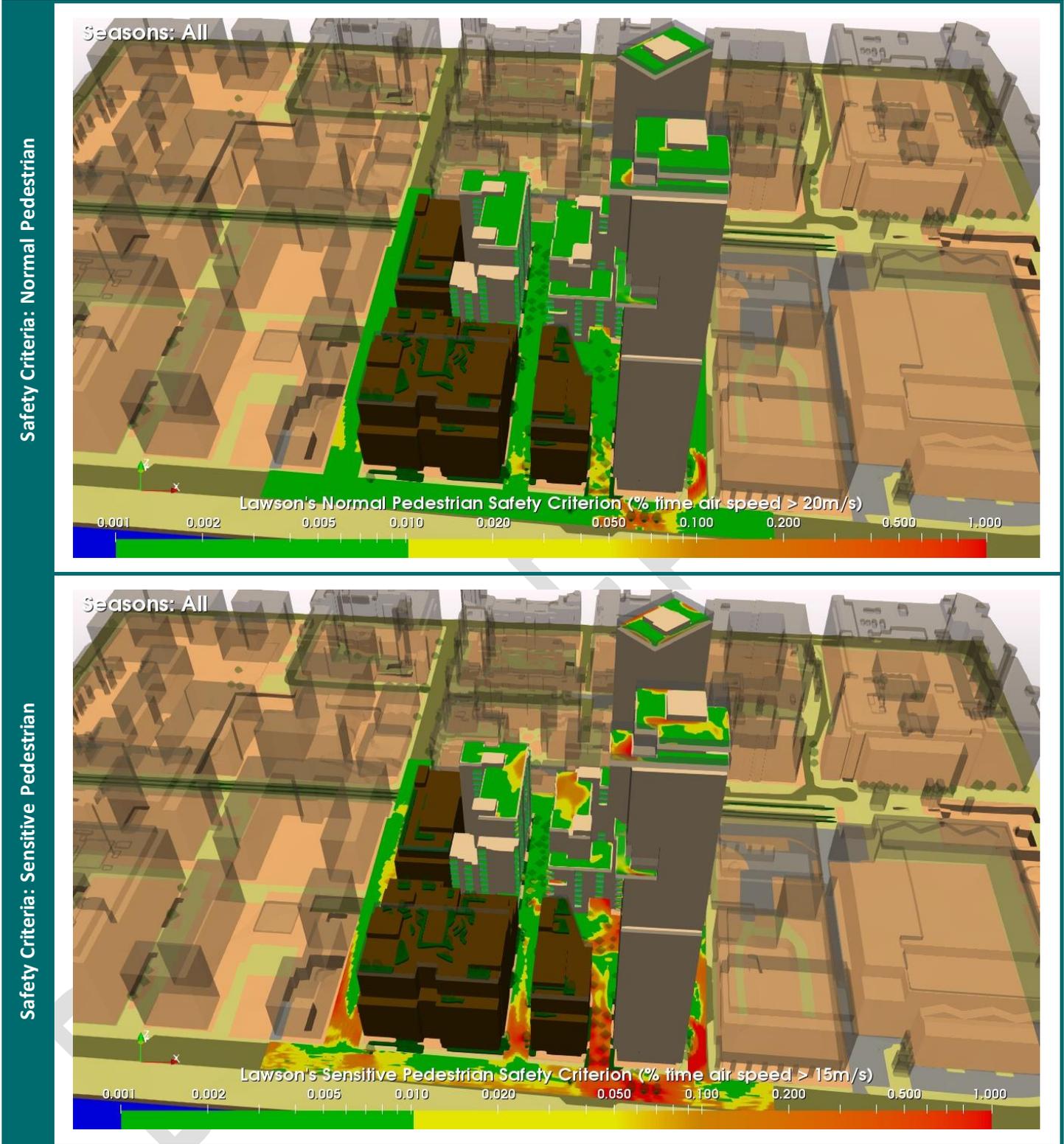


Figure 70: Safety Criteria: All Season: View from the south

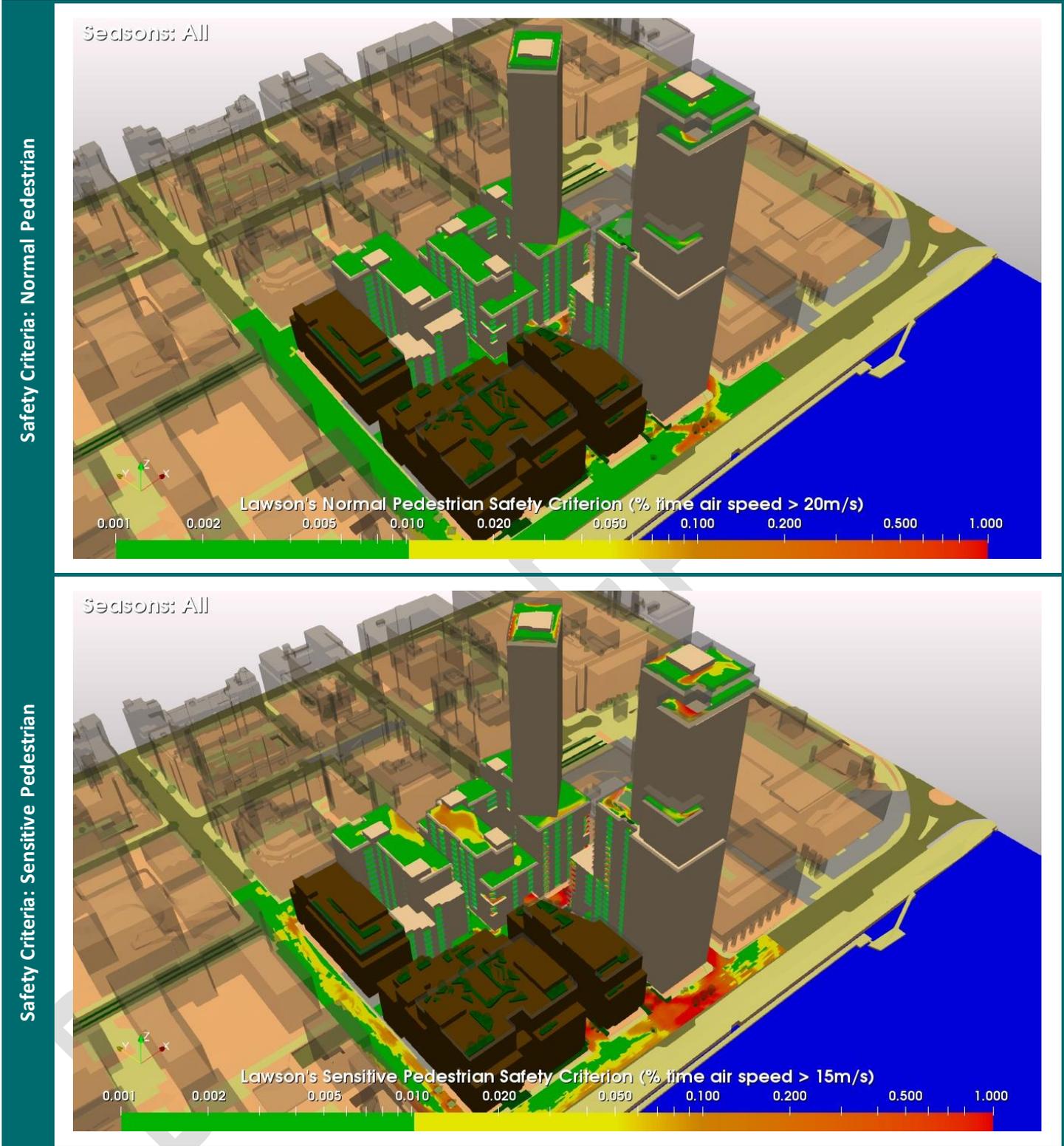


Figure 71: Safety Criteria: All Season: View from the southwest

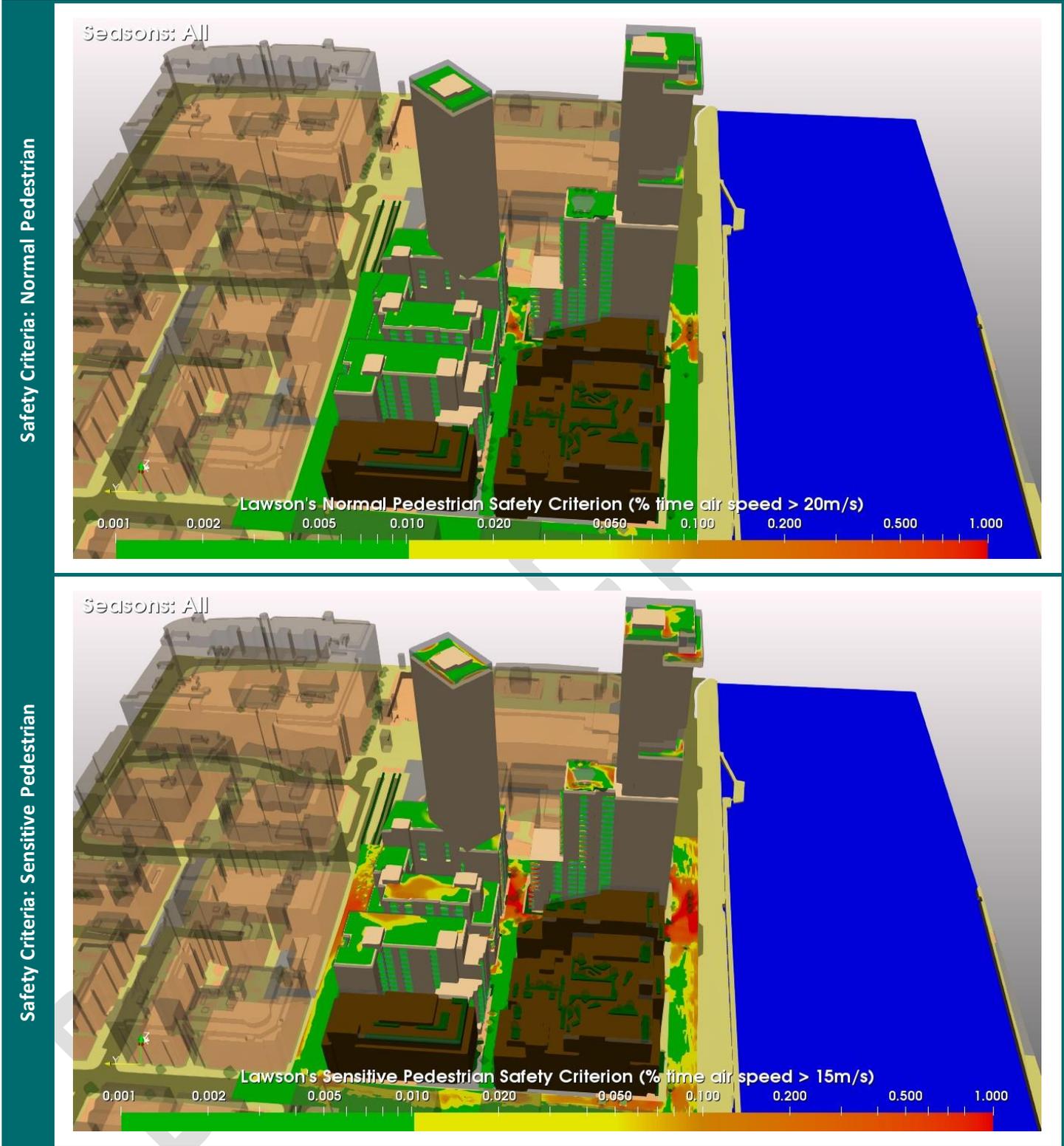


Figure 72: Safety Criteria: All Season: View from the west

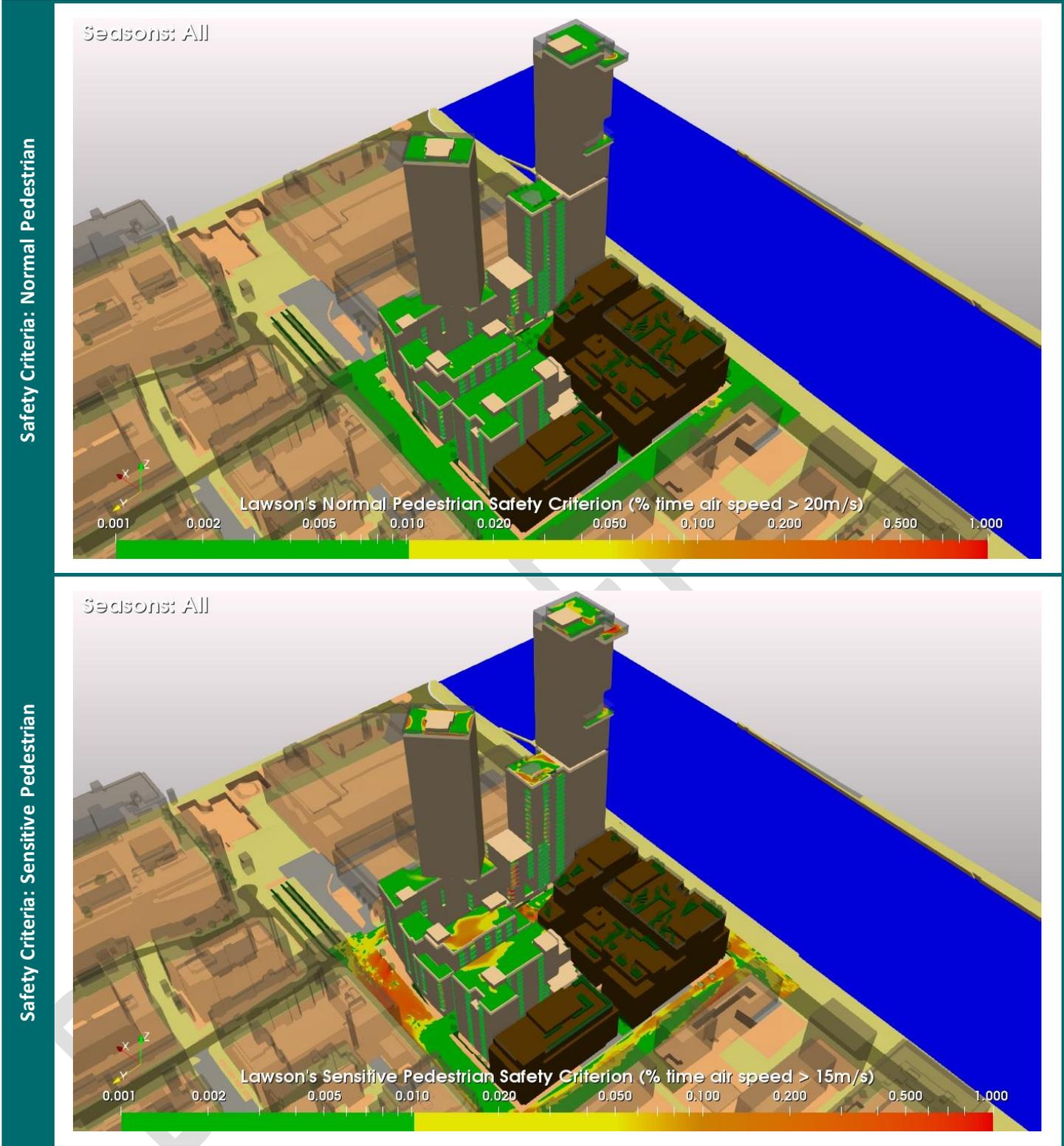


Figure 73: Safety Criteria: All Season: View from the northwest

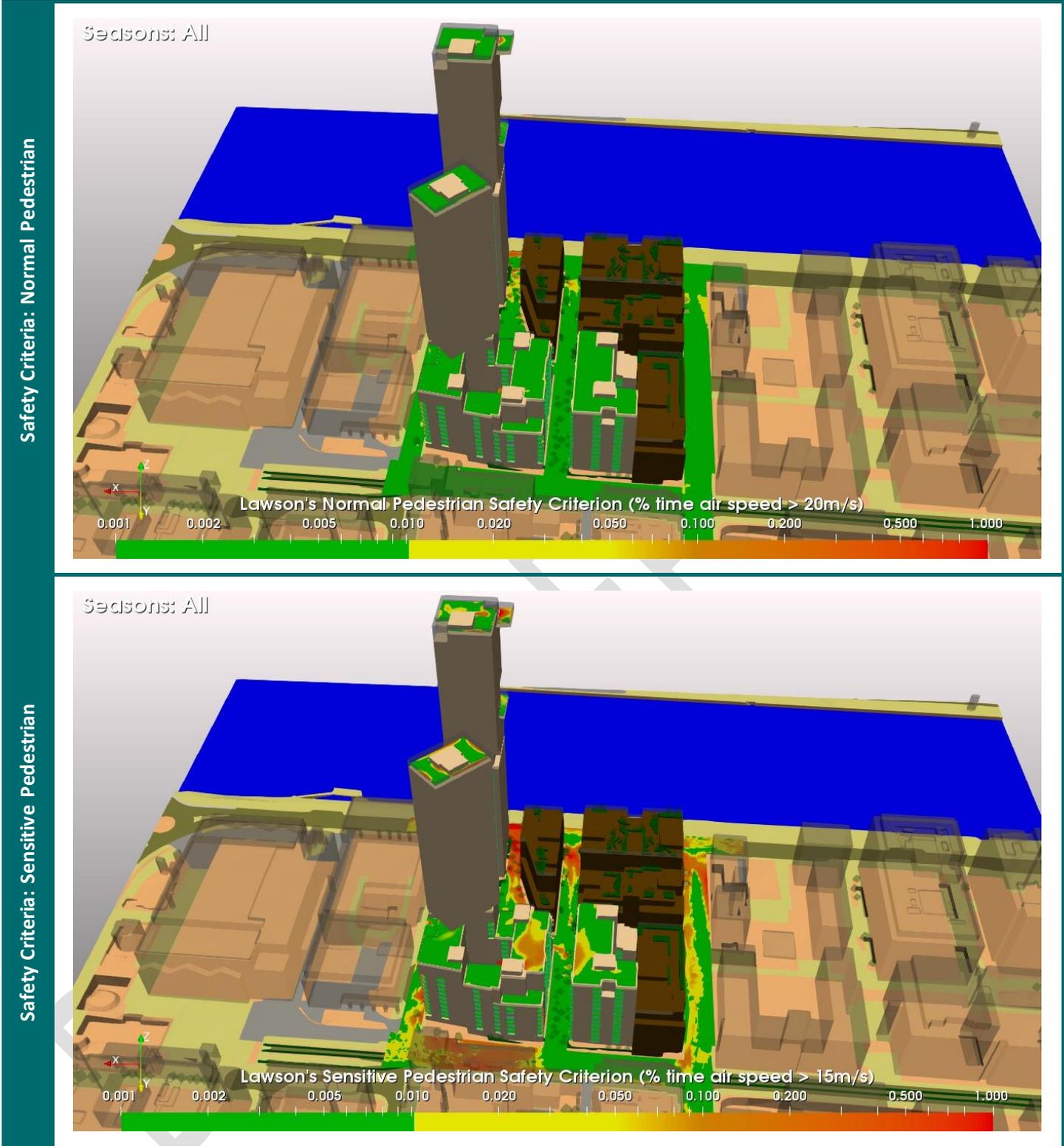


Figure 74: Safety Criteria: All Season: View from the north

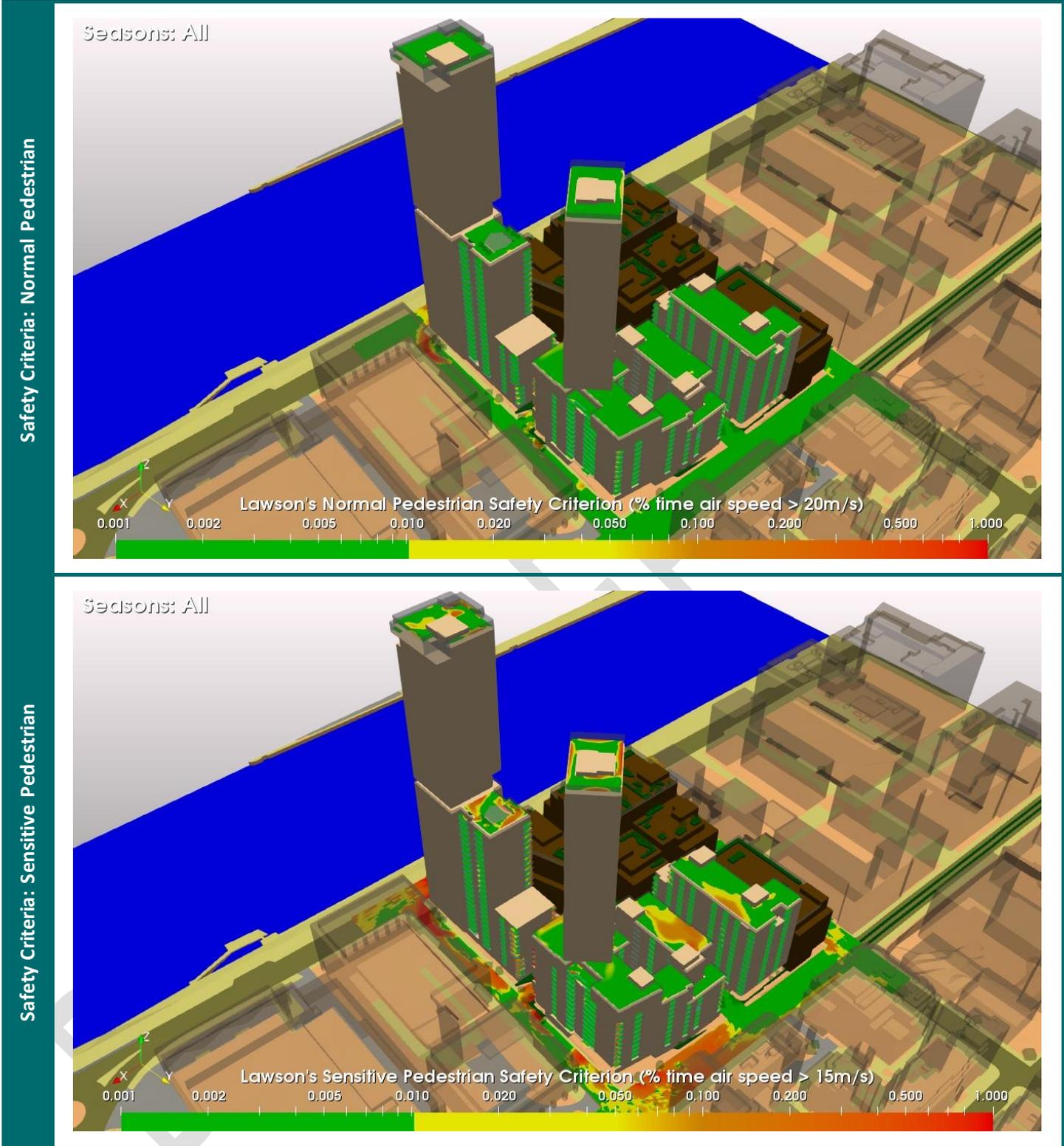


Figure 75: Safety Criteria: All Season: View from the northeast

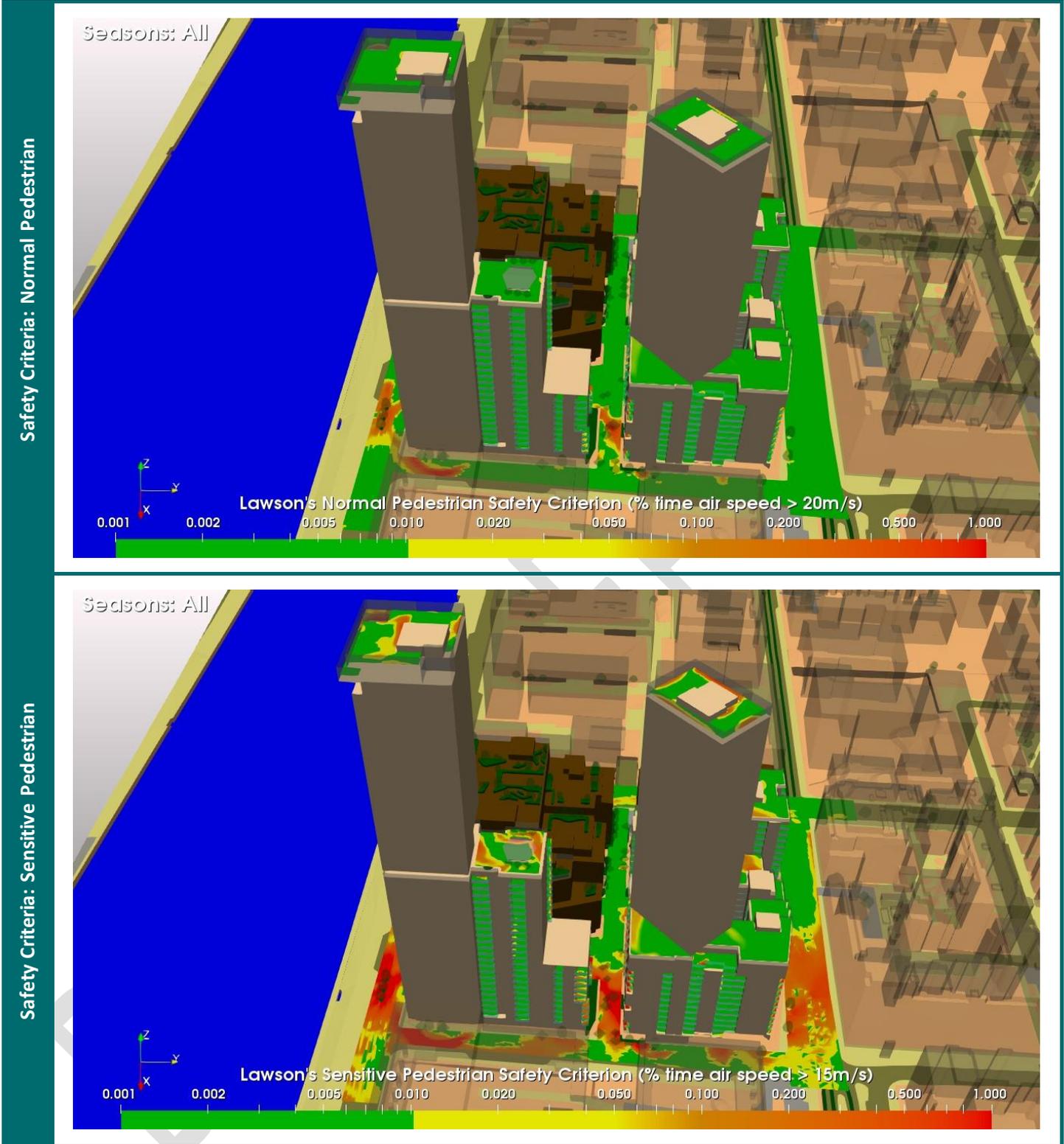


Figure 76: Safety Criteria: All Season: View from the east

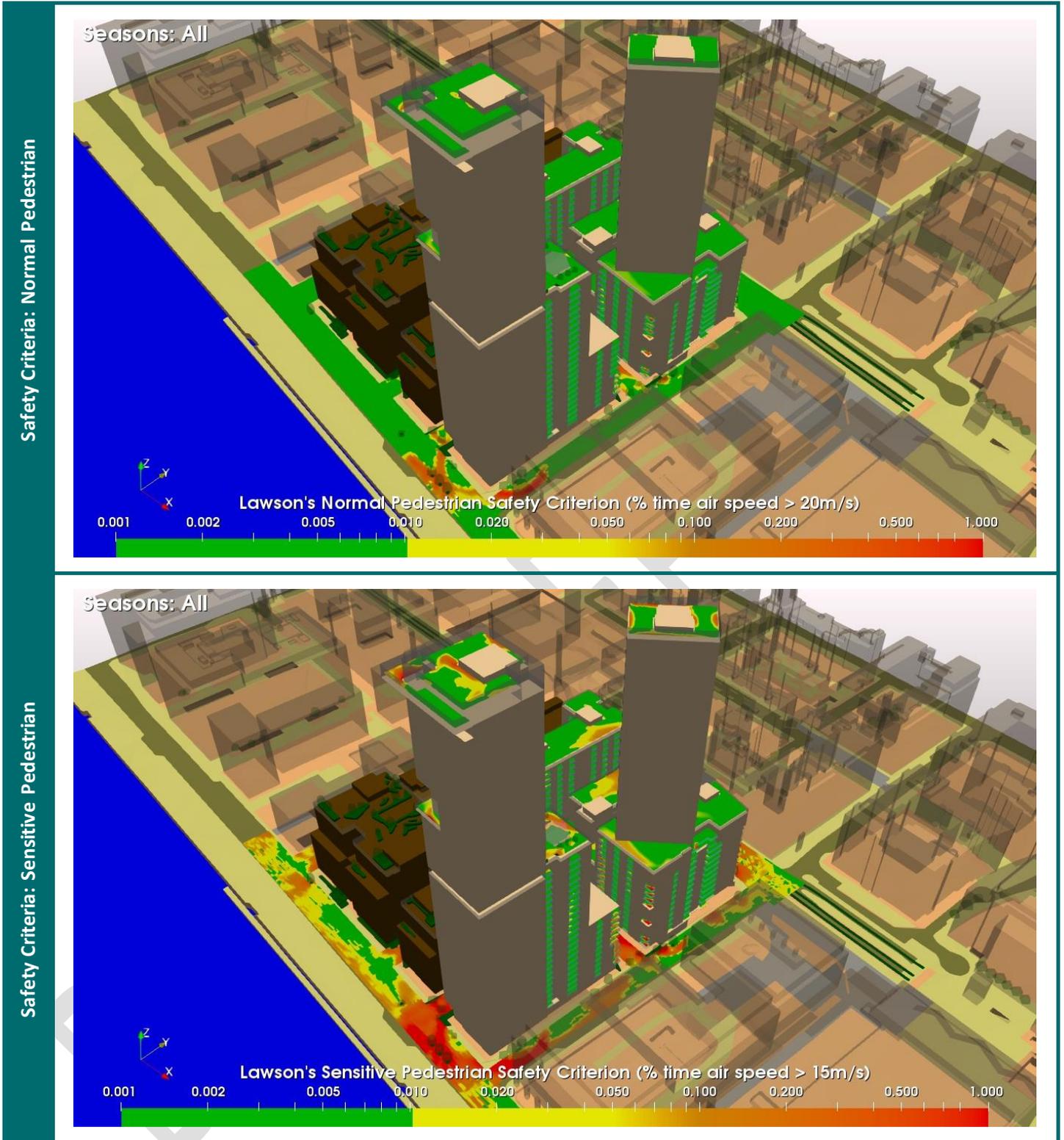


Figure 77: Safety Criteria: All Season: View from the southeast



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