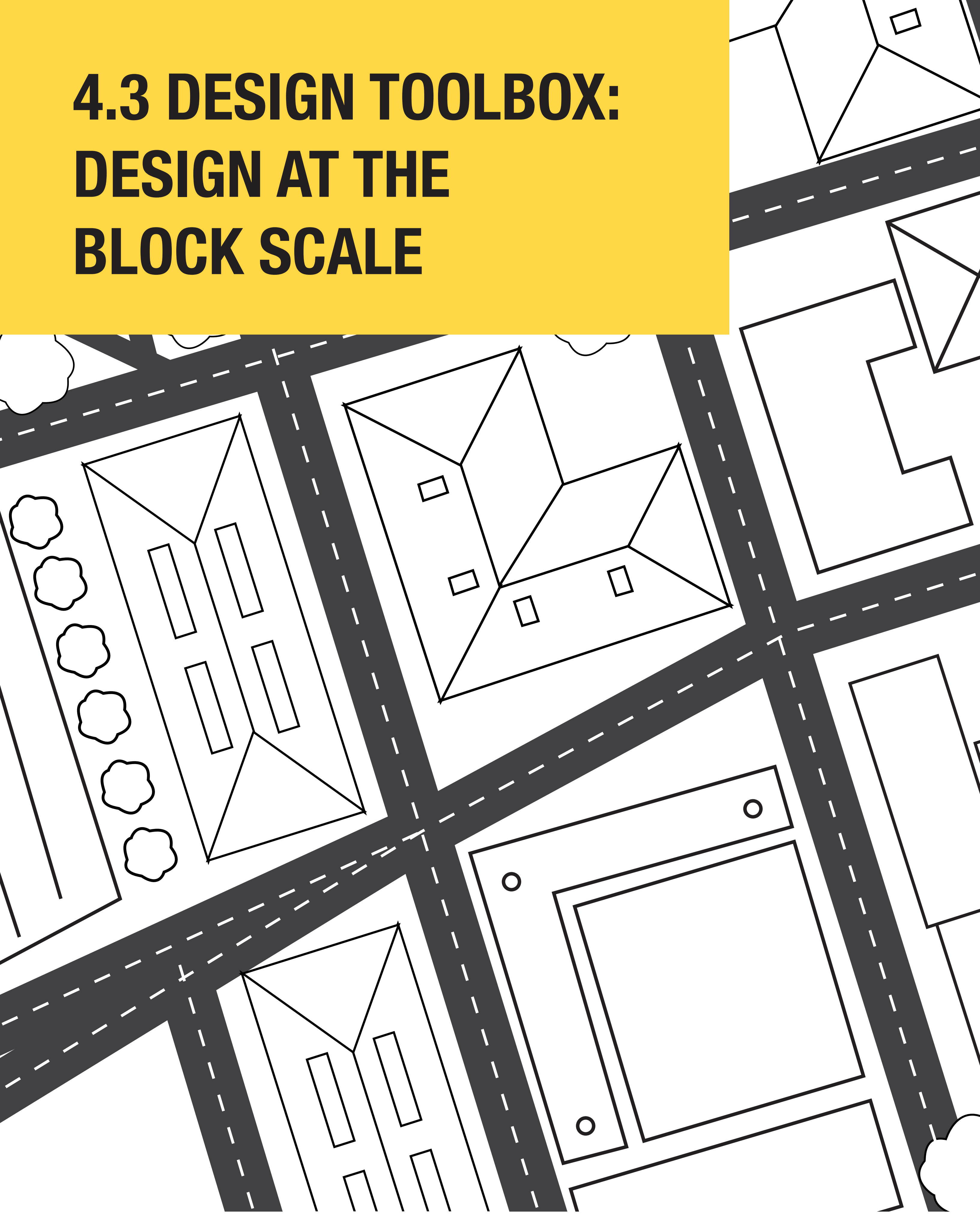
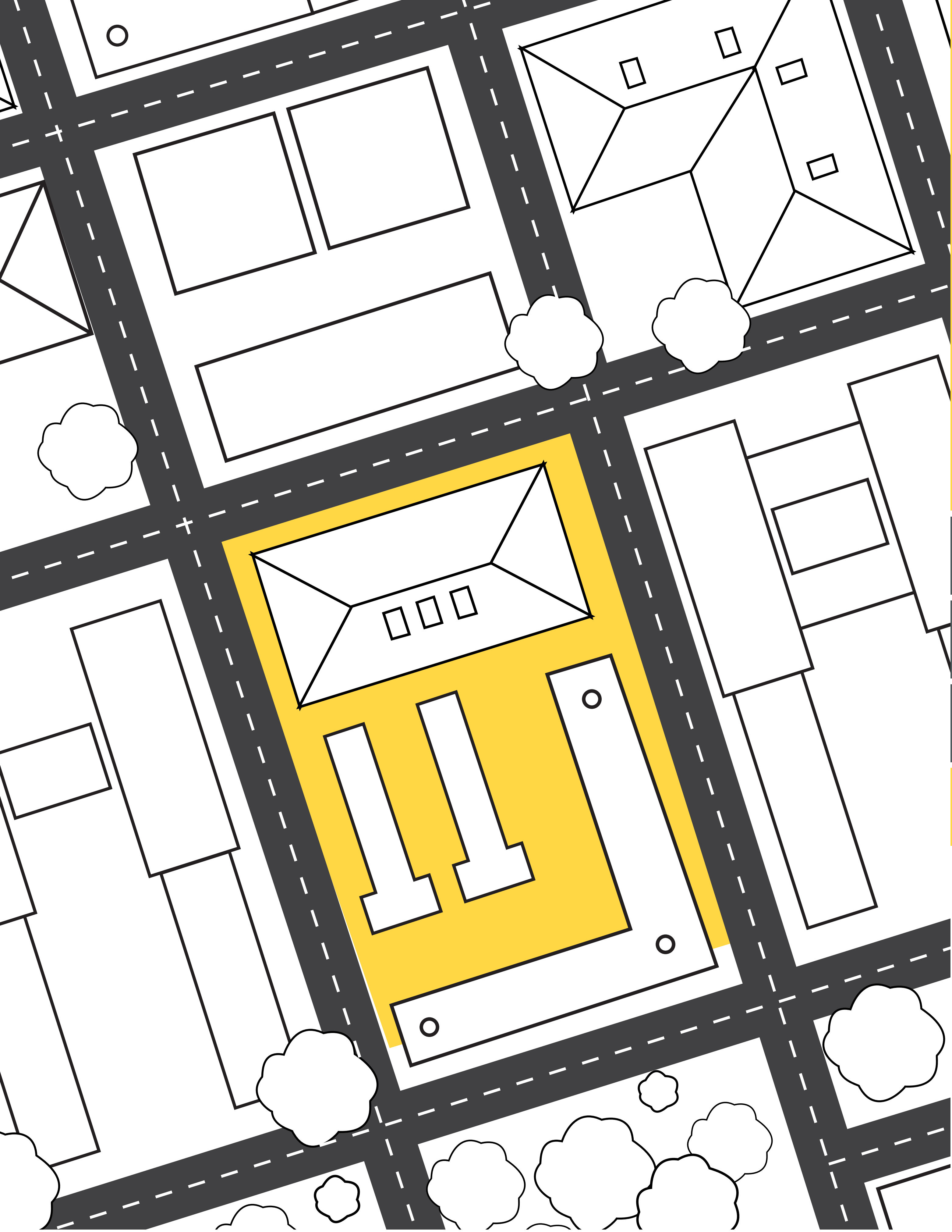
4.3 DESIGN TOOLBOX: DESIGN AT THE BLOCK SCALE





4.3 DESIGN TOOLBOX: DESIGN AT THE BLOCK SCALE

4.3.1 Placement and Orientation of Buildings (Wind)

Strategy

Place and orient the buildings to minimize the "wind canyon effect" and the acceleration of wind speeds in urban areas.

Intent

The primary intent of this strategy is to create safer, more comfortable pedestrian environments by reducing strong winds at ground level. This approach, rooted in an understanding of wind behaviour, acknowledges that the design and placement of buildings significantly influence local wind patterns, especially at the street level where pedestrians are most affected.

Guidelines

A. Refer to the Pedestrian Level Wind Study Terms of Reference Guide for Wind Responding Design Guidelines.

B. Locate and orient the buildings to minimize "wind canyon effect" (funneling, channeling) which refers to the acceleration of wind speed between closely spaced buildings. The intensity of the acceleration is influenced by the building heights, size of the facades, building separation distance and building orientation.

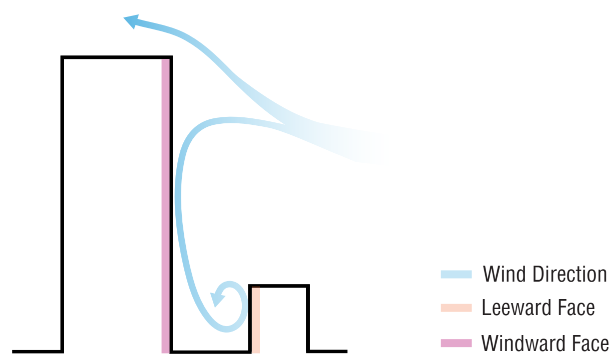
- Varying Building Heights: Avoid aligning the tops of buildings at the same height. Varying the heights of buildings disrupts the wind flow, reducing the wind tunnel effect. This needs to be reviewed case by case; but generally, a minimum height difference of 2 or more floors will have an effect on the wind patterns.

- Staggered Tall Building/Tower Placement: Instead of placing towers directly opposite each other, stagger their placement. This arrangement can help disrupt and diffuse wind flow, lessening the intensity of wind funneled between buildings.

- Orientation Considerations: Orient tall buildings diagonally to the prevailing wind directions. This alignment helps in redirecting and reducing wind speeds, improving overall thermal comfort and minimizing direct exposure to harsh winds.

- Increased Separation Distances: Increase the distance between tall buildings beyond the minimum requirements of Tall Building Design Guidelines, if possible. More space allows the wind to disperse and lose some of its speed, reducing the canyon effect. In highly dense urban areas, achieving large separation distances may be challenging. In such cases, other design strategies like building orientation, facade treatment, and the use of wind-mitigating features become crucial.

C. If possible, when positioning buildings, avoid a layout where the leeward side (the side sheltered from the wind) of a low-rise building directly faces the windward side (the side exposed to the wind) of a taller building. This setup can lead to faster winds at ground level in the space between the two buildings and near the corners of the taller building exposed to the wind. If this arrangement cannot be avoided, it's important to implement alternative wind mitigation strategies to reduce the impact on pedestrian-level wind conditions.



Prevent setups as shown above, where possible, that cause accelerated ground winds and discomfort.

Windward face vs. Leeward Face

Windward Face: This is the side of the building that faces directly into the wind. The windward face is the first part of the building that the wind "hits." This side of the building experiences the full force of the wind.

Leeward Face: This is the side of the building that is opposite to the windward face, meaning it's on the side sheltered from the wind. This side experiences less wind compared to the windward face and is often more calm and sheltered.

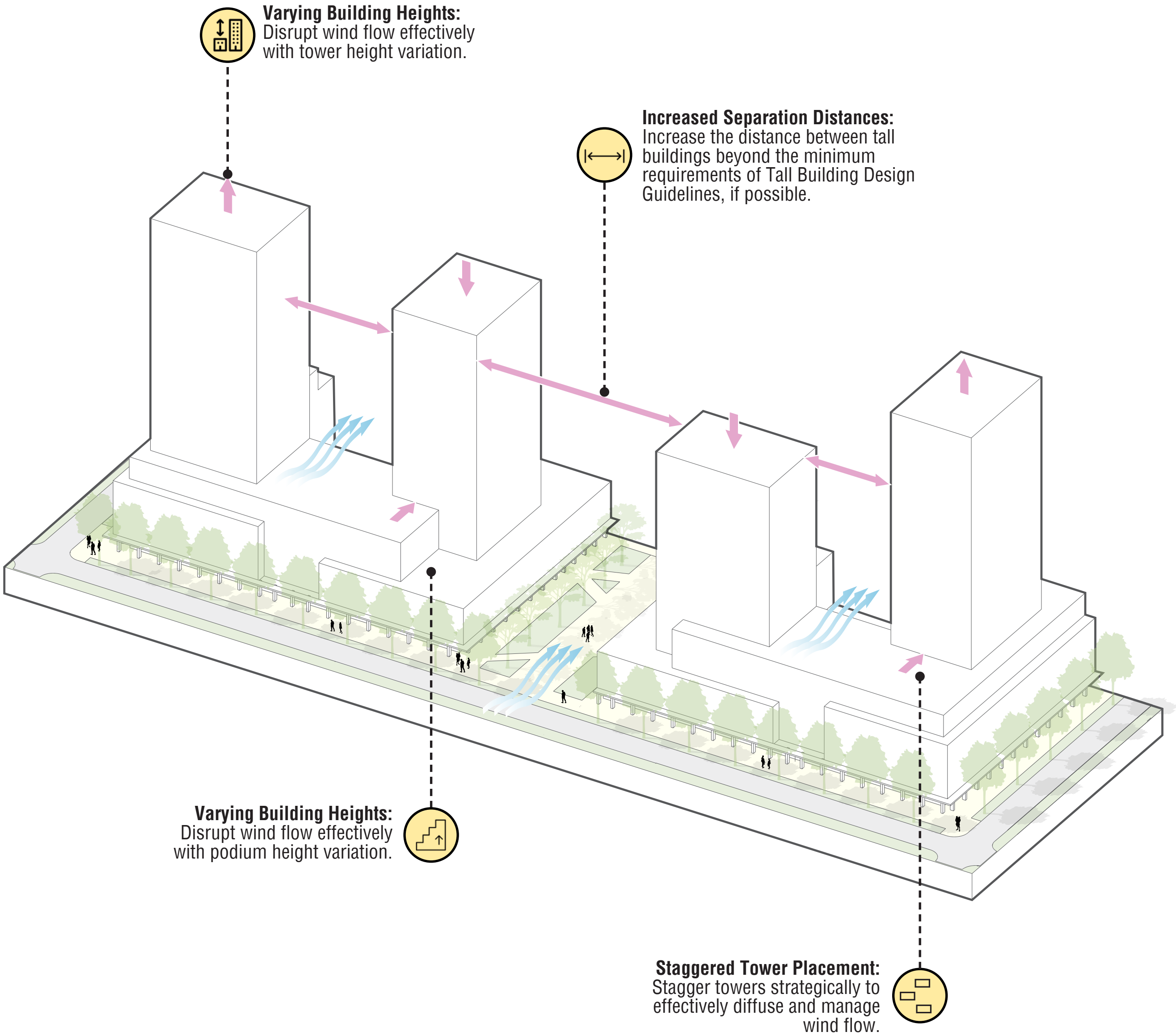


Diagram showcasing the design, strategic placement, and orientation of buildings to minimize the "wind canyon effect" and the acceleration of wind speeds in urban areas. For illustrative purposes only.

4.3.2 Placement and Orientation of Buildings (Sunlight)

Strategy

Strategically place and orient the buildings to optimize access to sunlight in publicly accessible open spaces for both human comfort and the thriving of all living beings including trees and vegetation.

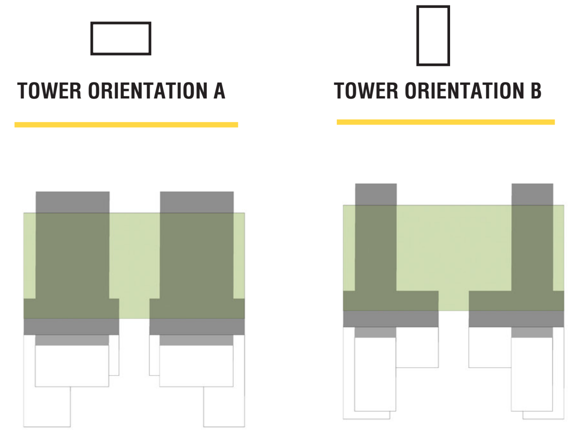


Diagram illustrating the shadow impact on a public park/open space, comparing two tower orientations at different times of the day. For illustrative purposes only.

Parkland / Open Space

Shadows Cast By Demonstration Buildings

Intent

This strategy acknowledges that proper sunlight exposure is crucial not only for human comfort but also for the health and longevity of all living beings. Particularly in high-density areas, minimizing overshadowing is essential to maintain a healthy urban environment.

Guidelines

A. Analyze the shadow patterns cast by existing and proposed buildings, especially during the fall and spring, to maximize access to sunlight and limit shadow impacts on the public realm.

B. Ensure adequate spacing between buildings to allow sunlight to penetrate public spaces.

C. In areas where sunlight is important but where there is also a risk of overheating during the summer, prioritize localized shading solutions. Focus on providing shade to key parts of the space rather than covering the entire area, allowing sunlight to reach other regions as needed.

Sun/shadow analysis informs the placement and orientation of buildings, especially taller structures, to optimize sunlight access.

Strategically place and orient the buildings to optimize access to sunlight in publicly accessible open spaces.

4.3.3 Placement and Design of Parks and Outdoor Recreation Areas

Strategy

Implement thoughtful placement and design of parks and outdoor recreation areas such as POPS, plazas, and private amenity spaces to optimize thermal comfort, balancing sunlight exposure, wind protection, and adaptable features.

Intent

This strategy acknowledges the importance of both sunlight exposure and providing adequate shade. The strategy prioritizes human-scale localized shade and adaptable features and explores wind protection opportunities in the open space.

Guidelines

A. **Sunlight Exposure:** Orient parks and outdoor recreation areas towards the south of the building to ensure they receive the most sunlight throughout the year, especially in colder months. For warmer months, ensure these areas have adequate shade. This can be achieved through natural means like deciduous trees or adjustable structures like pergolas.

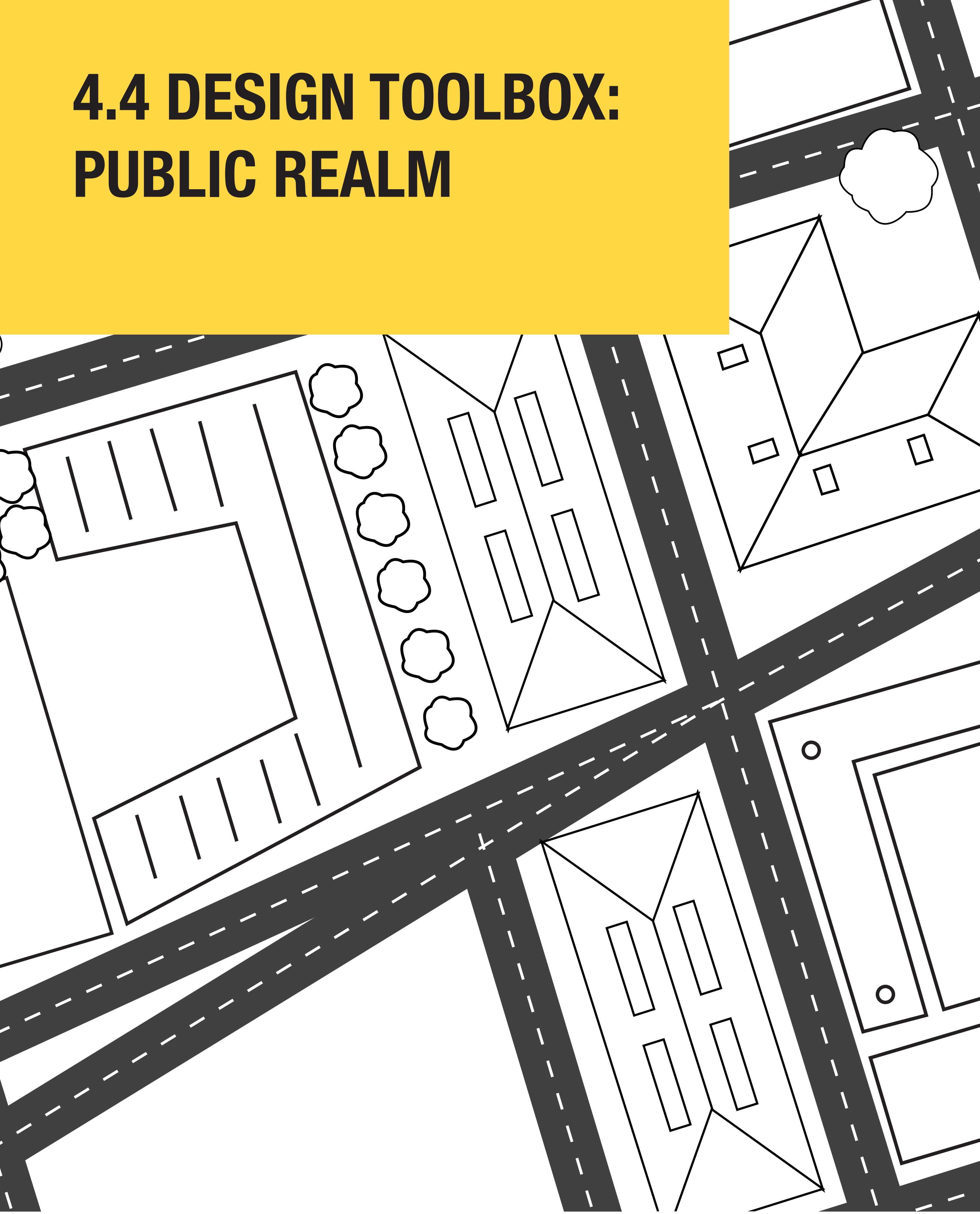
B. **Shelter from Prevailing Winds:** Identify the prevailing wind directions for different seasons and design landscapes and structures that provide shelter. Summer winds are generally beneficial and enhance thermal comfort, whereas winter winds reduce thermal comfort. This could include strategic placement of walls, fences, or dense vegetation.

C. **Strategic space programming with relation to shade:** Position seating and activity areas based on the sun/shadow analysis to ensure they are in the sun or shade, as desired, during peak usage times. Leverage Building Architecture: Use the architecture of adjacent buildings to provide wind protection. Balconies, overhangs, and walls can be effective in altering wind patterns.

St. Andrew's Playground Park is thoughtfully positioned on the south side of the block, benefits from optimal sunlight exposure and is designed to maximize winter sunlight and provide shade in summer.

St. Andrew's Playground Park design provide options for both sun and shade, with flexible seating areas and a tree-covered playground, ensuring comfort across seasons. Image Credit for the top image: DTAH

4.4 DESIGN TOOLBOX: PUBLIC REALM



4.4 DESIGN TOOLBOX: PUBLIC REALM

4.4.1 Tree Planting

Strategy

Strategically plant deciduous trees for shade during warmer months and sunlight penetration in winter, and strategically design tree planting mitigate wind impact in combination with other landscape design and features.

Intent

The purpose is to naturally regulate outdoor temperatures and wind for year-round comfort, using trees to create adaptable and sustainable environments.

Guidelines

A. Combine upper tree canopy with understory planting of shrubs and perennials for added effect.

B. Prioritize planting large-growing deciduous trees with the potential to grow large canopies in areas with full sunlight.

C. Consider species with both a high leaf-area density and a high transpiration rate to maximize the cooling effect.

D. In open spaces, favour coniferous trees on the west side of the space to mitigate Toronto's westerly prevailing winter winds.

E. Place trees in strategic locations to maintain safety and key sightlines.

F. Ensure that trees are planted in a growing environment with access to sunlight, moisture, sufficient and healthy soil, nutrients, and allowance for space to grow (both above and below ground). Trees need sunlight for energy to convert carbon dioxide into sugar and grow tall. Adequate soil volume and conditions that support tree growth are crucial for the health of urban trees. Refer to Toronto Green Standards for soil volume requirements.

G. Tree planting areas should be designed to incorporate urban features like benches, walkways, and playgrounds. This enhances the usability and comfort of these areas by providing shade and shelter.

H. Prioritize total tree canopy size over quantity of trees. With the correct spacing of trees, there is less competition for resources such as water, nutrients, and sunlight. This results in healthier and more vigorous growth for individual trees.

I. Consider species and specimens that are multibranched.

Favour multibranched species with potential to grow large canopies.

The Shade Guidelines

The Shade Guidelines (2010), developed by the Toronto Cancer Prevention Coalition, highlight the role of shade in protecting people from harmful ultraviolet radiation (UVR), a major cause of skin cancer. Children are particularly vulnerable to UVR exposure because they spend more time outdoors and have more sensitive skin. Southern Ontario, including Toronto, experiences high levels of UVR from spring to fall, making shade a critical tool in protecting public health.

Trees are a natural solution for providing shade in parks, playgrounds, and public spaces, helping to shield people and all living things from direct sunlight. By reducing solar exposure, trees not only prevent harmful UVR but also help to cool the environment, mitigating the urban heat island effect. The Shade Guidelines recommend increasing tree cover and vegetation to enhance public safety and comfort, especially in areas like playgrounds, waterplay facilities, and other outdoor venues. These efforts align with Toronto's broader goals of improving public health and promoting sustainability.

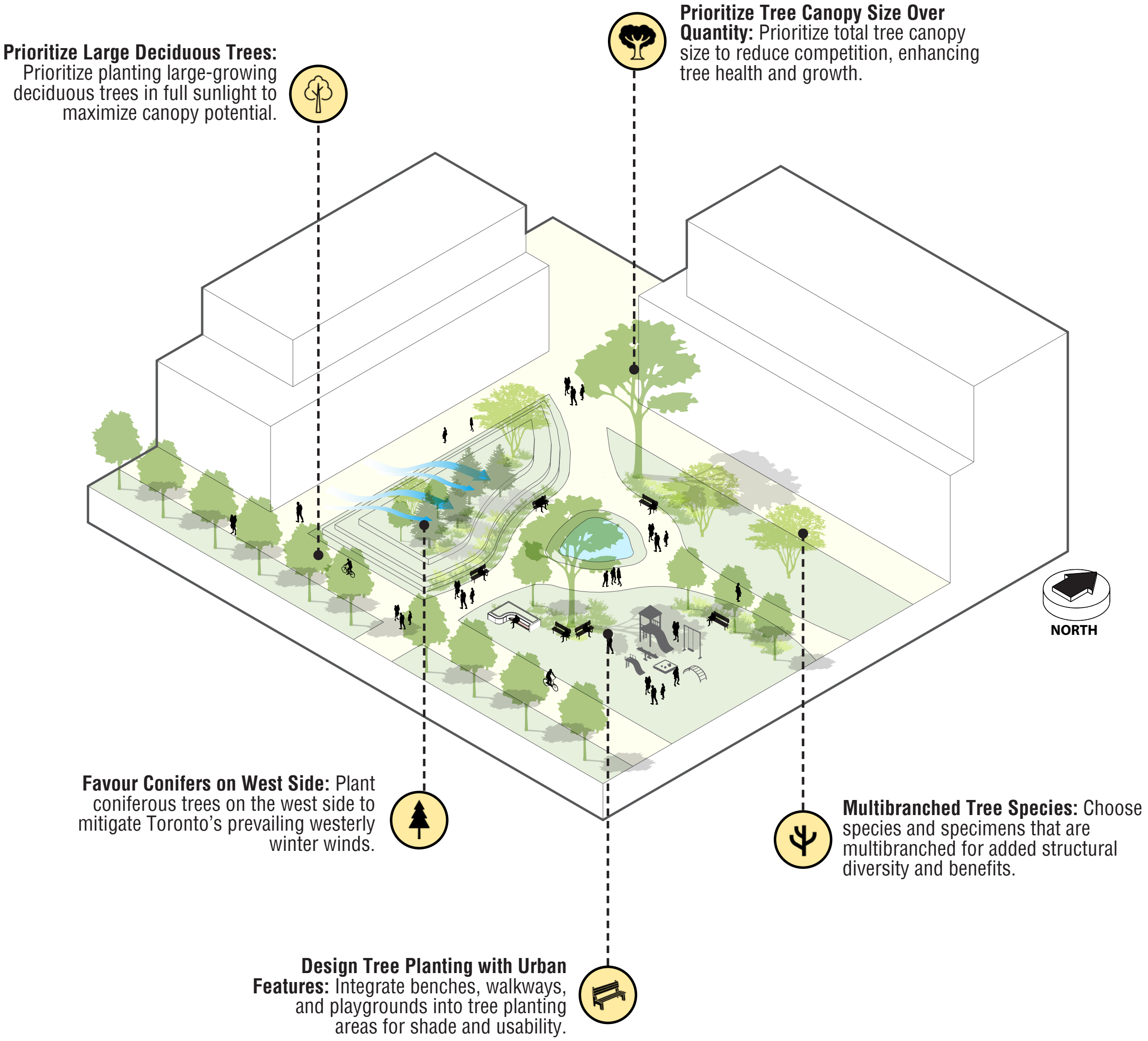
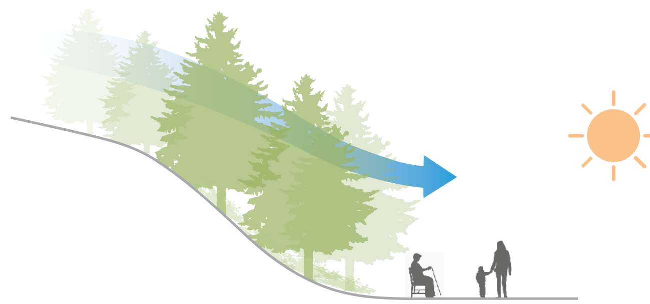


Diagram demonstrating how trees contribute to adaptable and sustainable environments. For illustrative purposes only.

4.4.2 Vegetation and Landscape Features

Strategy

Utilize vegetation to enhance thermal comfort in urban spaces by moderating wind effects and optimizing natural heat regulation.



South-facing benches and coniferous trees offer sheltered, welcoming spots for relaxation.

Intent

The objective is to create thermally comfortable outdoor environments through the strategic use of plants, contributing to a pleasant and sustainable urban experience.

Guidelines

A. Plant dense shrubbery and other vegetation along open spaces' edges and near blank walls. This helps slow down wind without completely blocking airflow, balancing protection and ventilation.

B. Employ landscape features such as grass mounds and berms as natural wind barriers and to define spaces. These can double as recreational areas, like tobogganing spots in winter.

C. Plan for growth and upkeep of vegetative windbreaks, ensuring regular pruning and care for sustained effectiveness and aesthetics.

D. Position benches and seating areas near dense shrubs or coniferous plants for wind protection, creating inviting spaces in winter. South-facing benches near wind blocks are optimal for comfort in colder months.

E. Combine soft and hard landscaping.

Position benches and seating areas near dense shrubs or coniferous plants for wind protection.

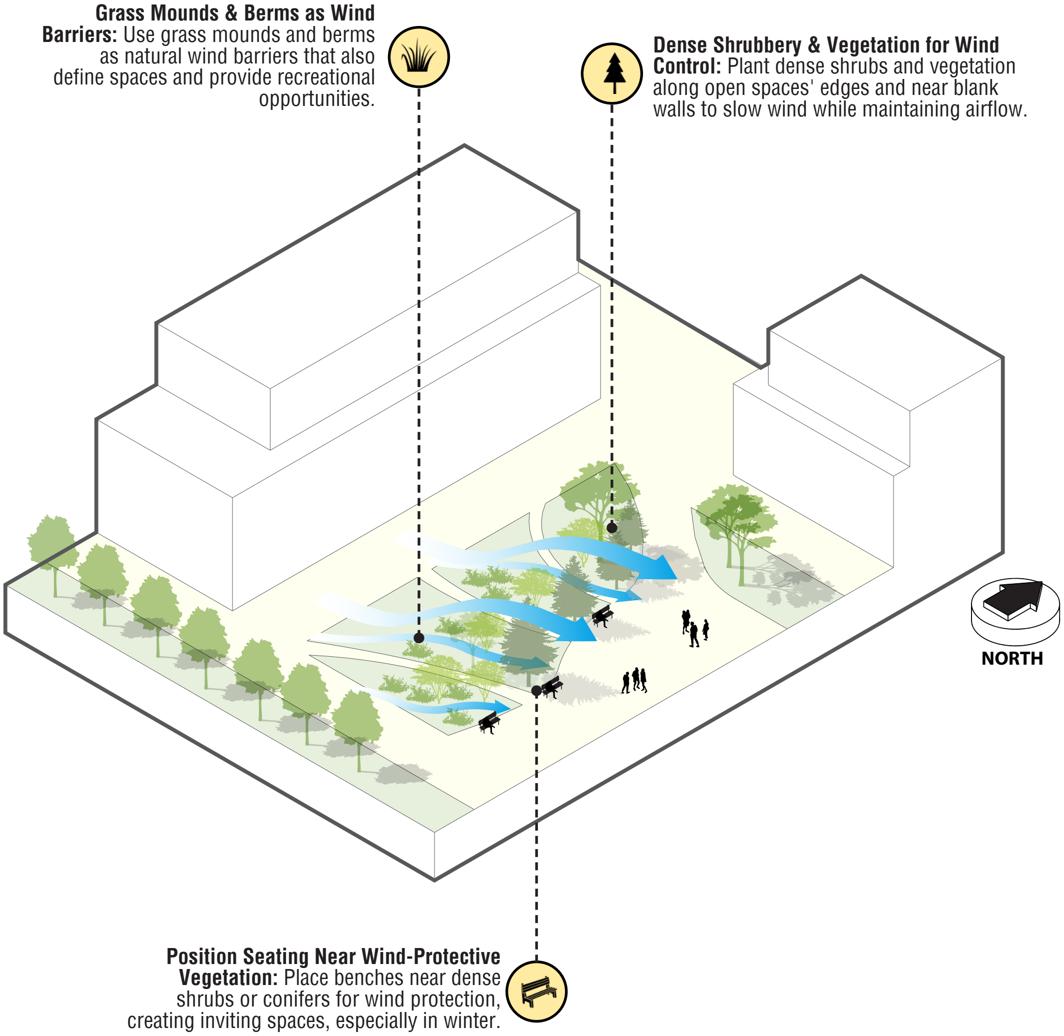


Diagram demonstrating some of the ways how vegetation can be used to enhance thermal comfort in urban spaces. For illustrative purposes only.

4.4.3 Water

Strategy

Strategically place water features, such as ponds and fountains, to utilize evaporative cooling to enhance microclimates.

Intent

The primary goal is to leverage water features not only for their cooling effects but also for their psychological benefits, enhancing the visual appeal and comfort of outdoor spaces.

Guidelines

A. Avoid static or more permanent water bodies that might intensify heat loss and cause more thermal distress during cold seasons.

B. Prioritize active water features that create/form smaller water droplets to enhance evaporative cooling in summer.

C. Water feature placement should be carefully considered to avoid stagnant areas to reduce the chance of increasing mold growth.

D. Active water features require schedules and maintenance. Ensure systems are lined and treated to avoid long-term maintenance and account for freeze thaw cycles.

Pools and Reflective Ponds

E. Design and position pools in central public spaces and densely built areas or places along the prevailing wind direction with accessible features to maximize their cooling effect and visual appeal.

F. Design certain pools to be convertible into ice rinks in winter, providing year-round recreational value and community engagement opportunities.

Fountains

G. Install fountains in key public spaces to benefit from the cooling effect of water evaporation. Active fountains that repeatedly elevate water vertically can be more effective in cooling an area.

H. Use fountain designs that maximize surface area for evaporation, thereby increasing their cooling potential.

Splash pads

I. Place splash pads in parks to provide a cooling play area during hot weather. Subject to public health considerations, splash pads could be designed to recycle water efficiently, minimizing waste while maximizing cooling effects.

J. Additional benefits: Splash pads encourage outdoor physical activities and social interactions among children, fostering community engagement.

Misting

K. Strategically place misting stations in high-traffic areas for immediate pedestrian cooling during heatwaves, particularly beneficial during heatwaves for vulnerable populations such as children, the elderly or people exposed under the sun for long duration including those experiencing homelessness.

L. Where present, misting (and any other means of adding moisture to the air to provide cooling effects) should be periodic. They should only be active when conditions allow them to be effective to reduce water use.

M. Shelter from wind is often necessary to achieve cooling effects from misting, or the effects are dispersed to widely to be effective.

N. Design for portability creates solutions for flexible spaces during events or high foot traffic areas.

Water Features and Mental Health

Water features can contribute to greater psychological comfort by enhancing the visual appeal of outdoor spaces. These can be part of the “cool spaces” network that the City of Toronto has identified to provide refuge during heat waves. The psychological benefits of being surrounded by nature can positively influence perceived thermal comfort. People are more likely to spend time outdoors and engage in physical activities when the environment is aesthetically pleasing and comfortable.

City of Toronto Parks and Recreation Facilities Master Plan (FMP)

To manage investment and facility provision over the next twenty years, the City of Toronto prepared a 20-year Parks and Recreation Facilities Master Plan (FMP), which was unanimously adopted by City Council on November 9, 2017. The FMP considers various facility types including outdoor pools, splash pads, and wading pools. The Implementation Strategy for the FMP provides strategic direction and design and operational considerations for these facilities.

Splash pads in parks and plazas provide a cooling play area during hot weather.

Portable misting stations can be placed in high-traffic areas for immediate pedestrian cooling during heatwaves.

4.4.4 Shelter Structures

Strategy

Locate shelter and overhead structures to reduce direct sunlight exposure and provide protection from wind and weather conditions.

Intent

Shelter structures, including transit shelters, are designed to offer flexible and effective weather protection across Toronto's diverse environments. Movable structures provide adaptability to seasonal changes, while permanent structures ensure consistent protection with minimal upkeep. Additionally, transit shelters can be tailored to local microclimates, enhancing comfort and contributing to the overall functionality of public spaces.

Guidelines

Movable Overhead Structure

A. Movable shading devices should be integrated into areas with variable sunlight exposure throughout the year. They should offer sun protection during warmer months and be adjustable to allow more sunlight during colder months.

B. Incorporate features such as retractable awnings into building designs to enhance flexibility.

C. Position movable overhead structures in high-traffic areas like outdoor dining spaces, seating areas, and playgrounds to maximize their benefit.

Permanent Overhead Structure

D. Install permanent overhead structures in areas where continuous shade and weather protection is desirable.

E. Canopies should be placed over bike parking areas and stations to protect bikes from excessive heat in summer and snowfalls in winter.

F. Opt for permanent structures over movable ones when minimal maintenance and long-term operation are desired. These structures can also create visually distinct areas that serve as community landmarks or meeting points, adding functional and aesthetic value beyond thermal comfort.

Transit Shelter

G. Locate shelters considering solar and prevailing wind directions to maximize natural comfort conditions.

H. Design transit stops and stations with features such as shelters, roofs, canopies, and overhangs to provide maximum weather protection.

I. Customize shelter designs to fit the specific microclimate of the site. Consider designs ranging from wrap-around structures for maximum protection, especially near tall buildings where wind downwash needs buffering, to more open structures for natural ventilation.

J. Install side panels or barriers that can shield occupants from wind. Design these panels to be adjustable, allowing them to be opened in warmer months to facilitate air circulation and closed in winter to provide warmth and wind protection.

K. Select materials with suitable albedo and reflectivity to avoid unnecessary heat gain or glare. This is crucial in managing the thermal environment inside the shelter.

L. Ensure adequate ventilation to prevent overheating and provide air circulation. Design seating that is elevated to prevent cold transfer, using materials like wood that are less conductive to heat and cold.

M. Create a diversity of microclimates within the bus stop area, allowing commuters to choose environments that suit their comfort needs or engage in adaptive behaviour.

N. Install energy-efficient, motion- or user-activated heaters at transit shelters and centres where possible, prioritizing locations with high-frequency transit service, high passenger volume, or exposure to harsh weather conditions. Ensure that the shelter design supports effective heater use, and assess potential snowmelt and drainage issues to avoid creating icy surfaces around the shelter

O. Transit shelters can be added to the cooling space network if they are well-ventilated, provide ample shade, comfortable seating, have access to drinking water, and potentially include active cooling features, while being accessible, well-maintained, and clearly marked as part of the cooling network.

Portable canopies provide flexible shade, allowing for sun protection in warmer months.

Permanent overhead structures in play areas offer continuous shade and weather protection.

Position the transit shelter opening strategically to minimize the impact of prevailing winds at the site.

4.4.5 Windbreak

Strategy

Design open spaces with integrated features that mitigate wind effects, using landscaping and public art elements to enhance thermal comfort.

Intent

The intent of this strategy is to enhance thermal comfort in outdoor spaces by effectively mitigating wind effects. By integrating windbreaks into the landscape and public art features, we aim to create sheltered zones that protect users from cold winds in the winter and reduce wind chill effects. This approach encourages the use of natural and multi-functional elements, ensuring that outdoor spaces remain comfortable and usable throughout the year without relying on standalone windbreak structures.

Guidelines

A. Avoid standalone windbreak structures that detract from the space's cohesion and visual appeal. Instead, integrate windbreaks into the design of buildings, landscaping, furniture, and public art.

B. Orient windbreak structures perpendicular to the prevailing wind direction for maximum effectiveness. Place them at strategic locations where wind acceleration in the form of funneling effects are most pronounced or where pedestrian traffic is highest. (Placement of mitigation measures may need to be supported by analysis.)

C. Consider the following when using trees and vegetation for wind breaks:

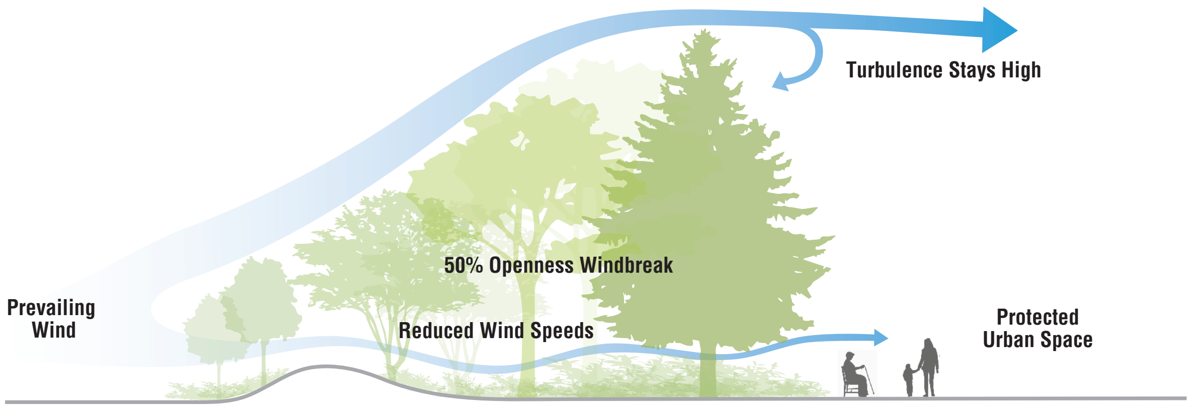
- Select plants with dense foliage to block wind but allow some airflow to prevent turbulence.
- Consider evergreens to provide year-round protection and maintain foliage in winter.
- Combine trees and dense shrubs to create a low barrier and fill gaps between trees.
- Use multiple rows of vegetation, combining tall trees, medium-height shrubs, and low ground covers.
- Avoid large gaps in the wind break to maintain its effectiveness.

D. Incorporate sculptural elements that double as windbreaks. These can add aesthetic value to the space while serving a functional purpose. Ensure their design disrupts and slows down wind flow effectively. Combine different types of windbreaks, such as walls with hedges or trees, to create layered protection. This can be more effective than a single type of windbreak.

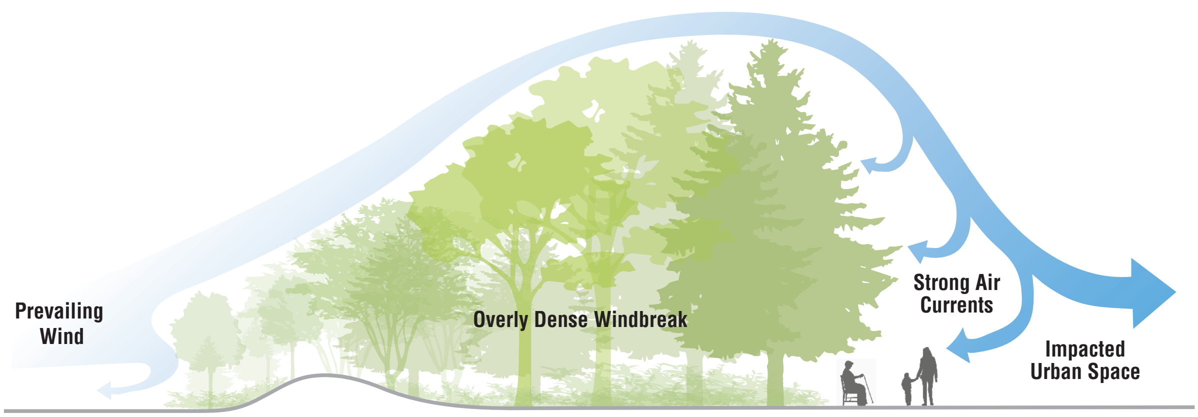
E. Integrate windbreaks with urban furniture like benches or seating areas to provide sheltered spots for relaxation and social interaction.

F. Design natural windbreaks with about 50% openness to prevent turbulence on the sheltered side. This level of porosity effectively reduces wind speed without creating swirling air currents (eddies).

Integrate windbreaks with urban furniture to enhance comfort.



Design natural windbreaks with about 50% openness to prevent turbulence on the sheltered side.



If a natural windbreak is too dense, it may lead to the creation of strong, concentrated air currents in urban spaces.

4.4.6 Material (Surface)

Strategy

Select surface materials for sidewalks, roads, plazas, surface parking, and public spaces that optimize heat absorption, reflection, and evaporation to enhance comfort and reduce the urban heat island effect.

Intent

Surface materials are crucial for managing thermal comfort in urban environments. By using light-colored, reflective, and permeable materials, public spaces can minimize heat absorption and enhance cooling through evaporation.

Guidelines

A. Use light-coloured, reflective materials in the design of pedestrian pathways and public spaces to minimize heat absorption. For non-roof hardscapes, use high-albedo paving materials with a solar reflectance of at least 0.33 or an SRI of 29 to reduce heat absorption.

B. Incorporate permeable paving materials to aid in cooling through water evaporation and reduce the urban heat island effect. Permeable surface materials also help in stormwater management and reducing flood risk. For more information, refer to the City of Toronto's Construction Specifications and Drawings for Green Infrastructure.

C. Explore alternatives to asphalt for trails and cycling paths, considering materials that have lower surface temperatures during heat events.

D. Select seating materials that are less heat conductive. Wood and coated metals are preferable to bare metal, which can become very hot in summer or cold in winter.

E. Opt for lighter-coloured materials for playgrounds as they absorb less heat compared to darker surfaces, and/or provide them with shading.

Wooden benches provide a comfortable seating option by minimizing heat and cold conduction, suitable for all seasons.

Light-coloured concrete surfaces in the park and around the wading pool reduce heat absorption and improve thermal comfort.

Incorporate permeable paving materials to aid in cooling through water evaporation and reduce the urban heat island effect.

4.4.7 Public Amenities

Strategy

Design and position public amenities to support thermal comfort.

Intent

While these amenities may not directly impact the microclimate of the area, they offer crucial refuge for people, helping them manage their thermal comfort through opportunities for rest, hydration, and protection from the elements. Thoughtfully designed amenities, such as seating and drinking water stations, enhance the overall comfort experience by offering necessary breaks from extreme weather, thus contributing to a more pleasant and usable public space.

Guidelines

Drinking water fountain

A. Install water fountains and/or water bottle filling stations in strategic locations to provide easy access to drinking water, helping to prevent heat-related illnesses. Strategic locations include:

- In parks, near playgrounds and recreational facilities
- In trails at all trailheads and trail access points as well as rest stops and viewing areas when possible.
- Urban squares and plazas

B. Where possible, locate the fountains in sheltered areas, ensuring they are usable even during hot conditions.

C. Prioritize water bottle filler stations over drinking fountains.

Seating

D. Offer a variety of fixed and flexible street furniture styles. This diversity allows users to choose seating based on their preference for sun exposure, proximity to others, or nearby street features like trees.

E. Provide seating under shade, whether from trees, canopies, or umbrellas, to offer a respite from the intense sun. This is crucial during hot days as it allows people to rest and cool down.

F. Orient seating and gathering places to maximize sunlight exposure while providing some wind protection. Consider how the sun's position changes across seasons to ensure comfort throughout the year.

G. Select seating materials that balance durability, comfort, and aesthetic appeal. Avoid materials like metal that can become extremely hot or cold. Opt for wood, coated metal, or composites that maintain a more neutral temperature.

H. Incorporate features such as fire pits or other heating elements in seating and dining areas to enhance comfort during cooler weather.

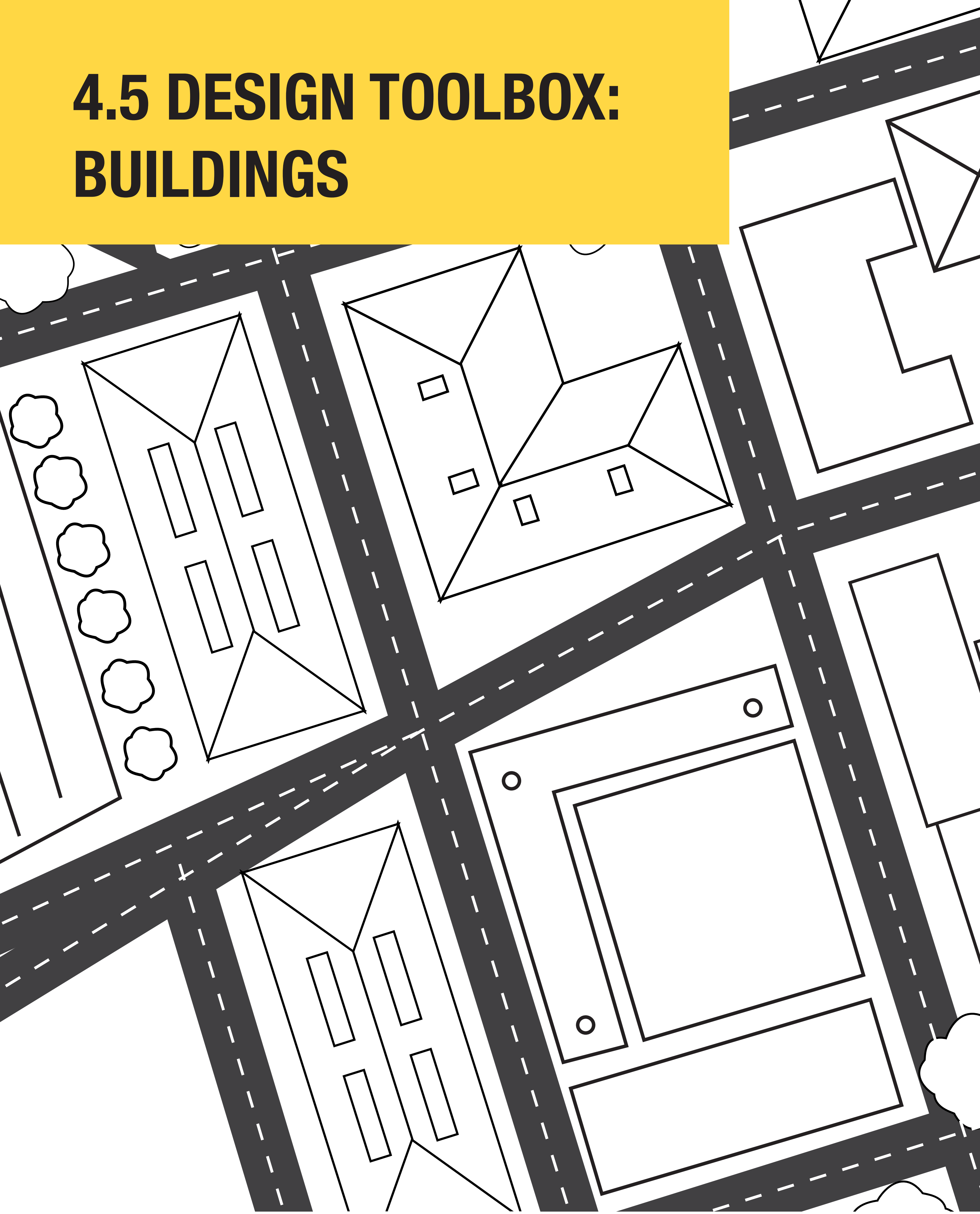
I. Design seating with ease of maintenance in mind, particularly for snow-clearing. Arrange benches in straight lines to accommodate snow plows and consider using central pedestal benches, which are easier to clear of snow than traditional four-legged benches.

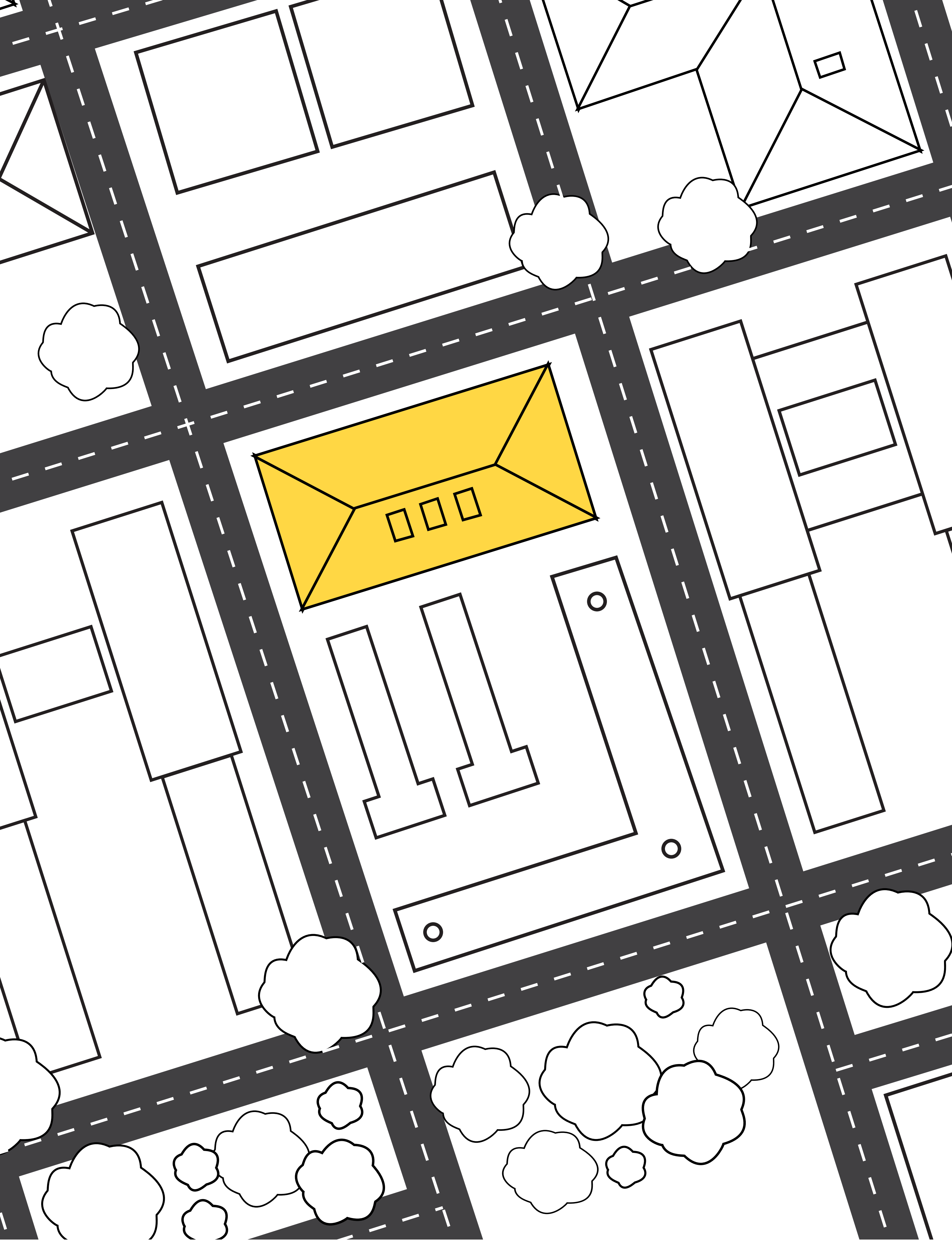
Benches in this park are strategically positioned, with some fully under the canopy for complete shade and others near the edge, offering a choice between sun and shade to suit user preferences

Flexible seating options under the natural shade of a tree allow users to choose their preferred sun exposure and enjoy a cooler, more comfortable environment.

Seating is thoughtfully positioned with backs facing the prevailing wind direction, using shrubs and greenary as natural windbreaks to enhance comfort.

4.5 DESIGN TOOLBOX: BUILDINGS





4.5 DESIGN TOOLBOX: BUILDINGS

4.5.1 Building Form and Wind

Strategy

Design tall building elements to adopt strategies to mitigate negative impacts of wind at the pedestrian level.

Intent

Wind can be beneficial or detrimental for thermal comfort. During the summer wind movement is likely to enhance thermal comfort, but wind speeds need to be kept within the activity thresholds set by the Wind Study Terms of Reference Guide. In Winter the opposite occurs, wind movement is likely to reduce comfort conditions, so a reduction in the wind movement is desired. The careful design of tall buildings can help to mitigate the negative impact of wind at the pedestrian level.

When wind hits the windward face of a tall building, the building tends to deflect the wind downwards, causing accelerated wind speeds at the pedestrian level and around the windward corners of the building. The intent is to introduce design interventions to mitigate the wind downwash and increase thermal comfort during winter months when wind is the principal factor influencing thermal comfort.

Guidelines

A. Refer to the Pedestrian Level Wind Study Terms of Reference Guide for detailed Wind Responding Design Guidelines.

B. Downwash occurs when winds are pushed down by large flat wind-facing facades. To reduce downwash driven acceleration:

- Avoid flat tall slab building facades that face the prevailing winds.
- Use step-backs on windward sides to deflect downward wind
- Design buildings with more aerodynamic shapes to allow wind to flow around them smoothly

C. Implement landscaping on the podium roofs and the stepped-back sections of towers to further reduce wind speeds at grade. Addressing wind conditions on these roofs is crucial, as intense, unmitigated winds can create discomfort and pose safety risks for pedestrians.

D. Adding parapet walls around podium edges can further increase their effectiveness in managing wind flow at the pedestrian/ground level.

E. Consider the use of porous materials to abate wind movement while also allowing solar radiation to pass through.

F. Incorporating a colonnade to the windward side (the side facing the wind) of a building can offer pedestrians two options: a sheltered, calm walking area within the colonnade, or a breezier experience just outside of it. This design feature can also provide shade, particularly when on the southern side of a building where it provides shade during summer when that shade is most needed. Colonnades need to be carefully considered, as in some configurations, their inclusion can increase local wind speeds.

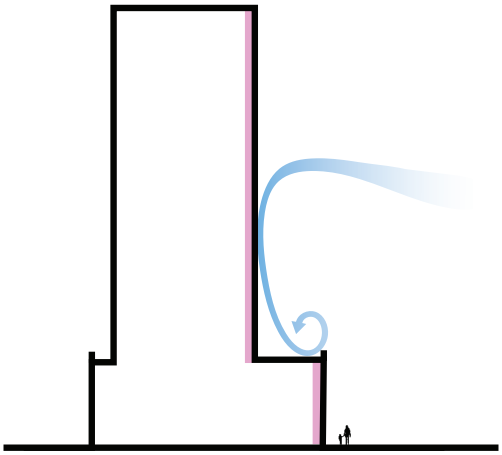
G. Design ground-level structures, such as pavilions or arcades, with a degree of porosity to allow wind to pass through without creating strong gusts.

H. Wind mitigation should be mostly addressed through appropriate massing, design and orientation of a building. Mitigation measures such as wind screens on public sidewalks and in open spaces are to be avoided.

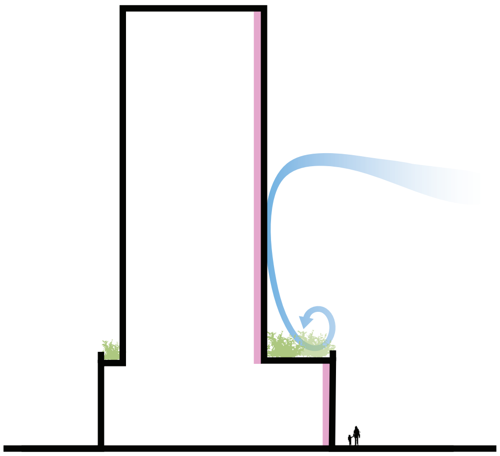
Corner Treatment

I. Incorporate architectural elements like rounded corners or chamfered edges on building masses that can effectively redirect wind flow, reducing the wind tunnel effect at street level.

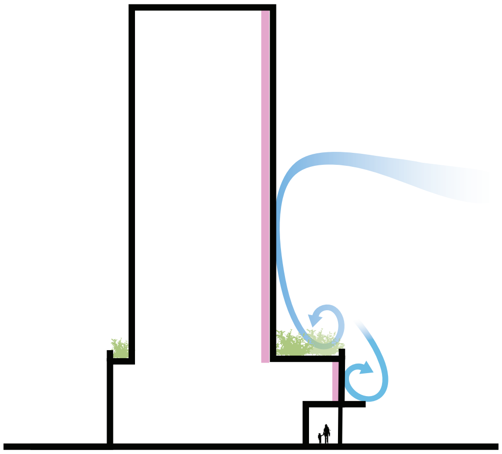
J. Place sculptural elements at corners that disrupt and slow down wind, while adding aesthetic value.



Use step-backs on windward sides to deflect downward wind.



Implement landscaping on the podium roofs and the stepped-back sections of towers to further reduce wind speeds at grade.



Adding a colonnade on the windward side of a building provides pedestrians with a sheltered walk inside or a breezier path outside.

Wind Direction
Windward Face

4.5.2 Building Form and Sunlight

Strategy

Design building forms and elements to balance sunlight access and thermal comfort in surrounding areas by minimizing negative shadowing and prioritizing adaptable shading solutions.

Intent

The design of a building—its form, height, and articulation—significantly impacts the surrounding area's access to sunlight. The taller the building, the broader the impact boundary. Careful consideration must be given to how the building's mass will affect thermal comfort in its vicinity.

In colder months, access to sunlight is highly desirable to provide warmth and enhance comfort. Conversely, in hotter months, relief from the sun is preferred to maintain cooler, more comfortable conditions. This strategy distinguishes between shade and shadow, as detailed in Chapter 2, and prioritizes localized shade provided by trees and shade structures over the permanent shadows cast by buildings.

Guidelines

A. Design the building's form and height to minimize extensive shadowing on adjacent areas.

B. Use architectural articulation to break up the building's mass, allowing more light to penetrate surrounding spaces. Incorporate design elements such as recesses, projections, and varied facade treatments to break up the building's bulk. This creates opportunities for light to filter through and reach adjacent areas.

C. Consider the high angle of the sun in summer months and the lower angle in winter when designing sun shades and shelters.

D. Integrate features such as retractable awnings or adjustable shading devices that can be adapted seasonally to optimize sunlight access. These features allow for the control of sunlight exposure, providing shade during the hot summer months and allowing sunlight to enter during the colder winter months.

E. Prioritize minimizing shadow impact on tree and vegetation zones, as well as seating and gathering areas. Ensure that these critical areas receive ample sunlight to support the health of the vegetation and provide comfortable, inviting spaces for people to sit and gather. Avoid placing large building masses that would create long-lasting shadows over these areas, especially during times of the year when sunlight is most needed.

Incorporate retractable awnings or adjustable shading devices that can be adapted seasonally to optimize sunlight access.

The quarter-circle form of one tower allows sunlight to penetrate between the two buildings.

4.5.3 Balconies

Strategy

Incorporate balconies in tall buildings to reduce wind speeds at ground level and provide comfortable, weather-adaptive outdoor spaces.

Intent

Balconies can contribute to the building's wind management strategy while also enhancing thermal comfort for users. By strategically designing balconies, they can deflect wind away from pedestrian areas and offer a pleasant, functional outdoor space that remains comfortable in different weather conditions. Additional steps can be taken to ensure balconies are thermally comfortable and pleasant for their users.

Guidelines

A. Consider larger, more protruding balconies on the windward side of the building instead of smaller, flush balconies.

B. Incorporate balconies with shading elements to create comfortable amenity spaces that provide protection from excessive heat, snow, and rain.

C. Orient balconies to balance sun exposure and shade. South-facing balconies can maximize sun exposure, while east or west-facing balconies may provide a comfortable balance of morning or afternoon sun and shade.

D. Install adjustable shading devices such as retractable awnings, pergolas, or balcony umbrellas. These allow residents to control the amount of sunlight entering the balcony, providing flexibility for different weather conditions.

E. Consider incorporating an overhang or a cantilevered design. This provides built-in shade and can protect the balcony from rain and direct overhead sun, especially during the hottest parts of the day.

F. Include windbreak features such as glass panels, lattice screens, or tall plants. These can reduce the impact of strong winds, making the balcony more comfortable to use, particularly in high-rise buildings.

G. Add plants and greenery to create a natural cooling effect through evapotranspiration, which will have a direct comfort benefit to people using the balconies. Plants can also provide additional shade and improve the aesthetic appeal of the space. Balconies and green roofs, help with the overall impact of UHI effect.

H. Choose materials for the balcony floor and railings that do not heat up excessively in the sun. Wood, tiles, or heat-resistant outdoor rugs can make the balcony more comfortable underfoot.

Adjustable shading, greenery, and heat-resistant materials enhance thermal comfort on balconies.


Protruding balconies strategically located on the windward face of the building help reduce wind speeds at street level.

4.5.4 Building Materials

Strategy

Choose building materials optimized for thermal insulation and reflection to reduce the urban heat island effect in the outdoor environment.

Intent

The built environment contributes to the urban heat island effect, as materials in buildings and the landscape absorb heat differently than natural landscapes. By using materials which reflect more solar radiation (and absorb less) as well as increasing building insulation levels (to keep cooler air in during summer and warmer air in during winter), the energy demands, and therefore the heat emitted by those buildings, can also help reduce the UHI effect.

Guidelines

Building envelope

A. Utilize cool materials, retroreflective materials, and phase change materials in building cladding to reflect solar radiation and reduce heat absorption.

B. Incorporate where possible a transitional space (a semi open space) that allows users to get familiar with internal or external conditions to reduce the likelihood of thermal shock.

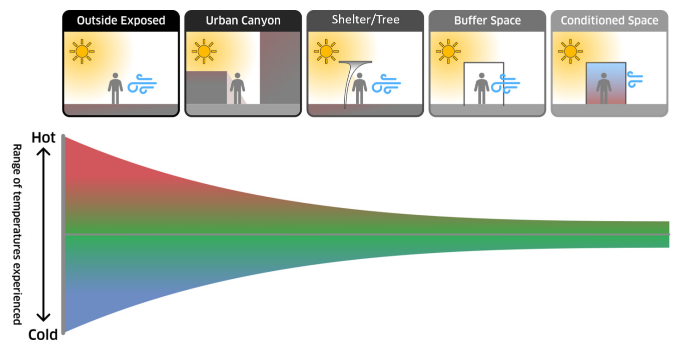
C. Implement green façades with appropriate plant species for cold winters, which can mitigate temperature extremes and contribute to the Oasis-effect in urban areas.

Roof material

D. Install green or vegetated roofs, which can reduce temperature fluctuations and provide additional insulation.

E. Use high-albedo or reflective roofing materials with a higher solar reflectance index (SRI) to minimize heat absorption. This helps reduce the urban heat island effect and keeps buildings cooler.

Green and vegetated roofs can reduce temperature fluctuations.



Analysis of comfort conditions - transition strategy

Transitional Space Strategy

A buffer zone will help the reduction of thermal shock for people moving from an internal space to the outdoor.
A transitional space will help people to acclimatize with the internal/external conditions reducing the possibility of thermal shock.

Appendices

Appendix A: Implementation

The Thermal Comfort Guidelines serve as an essential tool for city builders, encompassing planners, designers, developers, and decision-makers. These guidelines are designed to be progressively integrated into various city policies, regulations, standards, and guidelines, evolving and improving over time. This ongoing process aims to embed a thermal comfort perspective consistently and effectively in all aspects of urban development.

All development applications are required to provide a summary detailing how thermal comfort has been considered in their design as part of their planning rationale and/or urban design brief. For city-initiated studies and large scale developments, compliance with the performance metrics outlined in Chapter 3 is recommended and should be verified through a Detailed Thermal Comfort Study, where deemed appropriate.

The Thermal Comfort Study will determine the impact of a development or design intervention on the adjacent open spaces and will inform and direct the design to incorporate a thermal comfort lens ensuring that each project appropriately addresses its effect on thermal comfort.

The following sections provide more specific guidance on the criteria determining the need for a thermal comfort study, as part of the planning process in the City of Toronto.

All new developments are required to provide a summary detailing how thermal comfort has been considered in their design.

1.1 TYPES OF THERMAL COMFORT STUDY

1.1.1 Detailed Thermal Comfort Study:

A detailed study is conducted to assess the hourly thermal conditions around a new development or altered urban space in Toronto. This analysis offers a comprehensive insight into how urban changes affect pedestrian microclimate experiences. Focusing on areas within a 400-meter radius of the development, specialized thermal modeling and wind flow analysis software are utilized. These studies, using the Universal Thermal Climate Index (UTCI), clearly demonstrate the proposed design's impact on the local environment. By comparing new data with existing comfort levels, the effect of the proposed development on area thermal comfort is understood, supporting evaluation of compliance with the performance metrics outlined in Chapter 3 of the guidelines.

1.1.2 Desktop Study:

The desktop study for outdoor thermal comfort in Toronto is a preliminary study using weather files to establish a basic understanding of the climate's impact on an individual's thermal comfort. It simplifies conditions and assumes wind conditions are consistent with data from those weather files, using a representative material applied to ground and surroundings, such as concrete or soft landscaping. The study explores the impact of a simplified representation of surroundings, sheltering an individual from wind and sun to give an estimate of thermal comfort experienced in a location.

An indication of the effects of comfort enhancement strategies can be estimated in a desktop study, using modification of inputs (e.g., reducing radiant temperature based on whether the sun is shaded) to provide an estimate of thermal comfort.

As a desktop study is a basic analysis that does not account for complex spatial factors or details of the surrounding urban landscapes, it serves as an early indicator to identify potential issues that may require more detailed study.

Limitations:

Compared to the detailed thermal comfort study, the desktop study is a simplified analysis and does not achieve a complex spatial assessment of thermal comfort. It does not account for the interaction of various environmental factors in an urban context, in particular the ways that terrain and surrounding buildings impact wind speeds. However, it serves as a valuable indicator for basic thermal comfort, grounded in core principles and assumptions such as the presence versus absence of wind, and the availability of shade as opposed to direct sun exposure. This method is particularly useful at the preliminary stages of design and planning. It enables quick identification of potential thermal comfort issues, highlighting areas that may require more detailed and spatially nuanced investigation. As such, this analysis is a starting point, guiding more targeted studies and interventions to enhance outdoor thermal comfort.

1.2 WHEN RECOMMENDED

1.2.1 Detailed Thermal Comfort Study:

For a comprehensive analysis of the impact of changes to the built environment on thermal comfort, a detailed thermal comfort study is recommended for the following. The specifics of what a detailed thermal comfort study entails can be found in Appendix B - How to Conduct Thermal Comfort Study.

A. Planning Initiatives (where deemed appropriate):

- City initiated Official Plan Amendments and Large Area Zoning Bylaw Amendments
    - Master planning initiatives and area studies, particularly in areas with high pedestrian traffic or where changes could alter wind flow or solar access at street level, and in vulnerable neighbourhoods.
    - Secondary plans and Site and Area Specific Policies (SASP).
    - Large-scale Transit-Oriented Communities (TOCs) and Transit-Oriented Developments (TODs).
- Site Planning
    - Site planning and design of parks and outdoor recreation facilities, when the project involves, but is not limited to:
        - A large scale
        - A high density location
        - A significant/high profile project
        - The city ability to influence factors outside the park (e.g., adjacent municipal land)
        - A park with considerable variation in site condition across the property

B. Development Applications (where deemed appropriate):

- Large site redevelopments larger than 5 hectares in area (e.g., 200x250m) with buildings over 6 storeys are recommended to conduct a detailed thermal comfort study during the Official Plan Amendment, Rezoning, and Site Plan application stages.
- Developments that involve significant public realm and/or built form changes from Council-approved Secondary Plans and Site and Area Specific Plans (SASP) that include a City initiated thermal comfort study.

Mitigation Analysis:

If the Thermal Comfort Detailed Analysis indicates that the thermal comfort criteria, as outlined in Chapter 3 – Performance Metrics, are not met, a mitigation analysis should be prepared. Necessary changes should then be made to the proposed design to mitigate the negative impacts on thermal comfort. Following these modifications, a revised detailed thermal comfort study should be conducted to demonstrate compliance with the performance metrics. A summary of changes to the proposal should also be clearly outlined. For guidance on effective mitigation strategies, refer to Chapter 4 - Design Toolbox, which offers a range of recommendations to enhance thermal comfort.

1.2.2 Desktop Study:

To facilitate a more informed design process, it is recommended to prepare a desktop study during the early stages of design. While submitting this analysis as part of the development application process is not mandatory, it is highly recommended to conduct in order to inform the design. Additionally, presenting the desktop study during the Pre-Application Consultation Meeting is encouraged to provide insights and foster discussions. City staff may also conduct their own desktop study to guide their feedback and comments during the application review process.

1.3 REVIEW AND MONITORING

Regular Updates and Revisions:

- Establish a schedule for periodic review and update of the guidelines to ensure they remain current with the latest research, technologies, and urban development trends.

Performance Monitoring:

- Establish a system for monitoring the compliance with the guidelines and the general performance of completed projects.

Feedback Mechanism:

- Create a feedback mechanism that allows city planners, designers, developers, and the public to provide input on the effectiveness and applicability of the guidelines.

Case Studies and Best Practices:

- Document and publish case studies of successful implementations to serve as best practice examples. This can help guide future projects and demonstrate the practical application of the guidelines.

Training and Awareness:

- Conduct regular training sessions for relevant stakeholders to ensure a thorough understanding of the guidelines. Additionally, engage in public awareness campaigns to highlight the importance of thermal comfort in urban design.

Collaboration with Academic and Research Institutions:

- Collaborate with academic and research institutions to continuously improve the guidelines based on empirical data and new findings in the field of urban climate studies.

Adjustments Based on Climate Change Projections:

- Continuously adapt the guidelines in response to climate change projections and scenarios to ensure long-term relevance and effectiveness.

The Metropol Parasol in Seville, Spain, commonly known as "Setas de Sevilla" ("Mushrooms of Seville"), is an excellent example of how built forms can create canopies that provide shade and weather protection. With seating areas underneath, it ensures a thermally comfortable publically owned private space (POPS).

Appendix B: How to Conduct Thermal Comfort Study

1.1 METHODOLOGY

This section outlines the methodology for assessing thermal comfort in outdoor areas, detailing the necessary information and requirements to conduct such a study in line with the standards set by these guidelines. Two methods are provided: one for simpler cases that can be addressed through a desktop study, and another for more complex situations that require a detailed study incorporating simulated wind and radiation effects.

Rush hour in Toronto's Financial District.

1.1.1 Desktop study vs. Detailed study:

A detailed study including Computational Fluid Dynamics (CFD) simulation for an area of the city is not necessarily required in all cases. Where appropriate, a desktop study may be undertaken which assesses the impact that changes to the urban realm would have on thermal comfort using less detailed analysis.

There is a trade-off between accuracy and detail when undertaking a desktop study, as it does not consider several of the elements that influence thermal comfort in as much detail. For example, a CFD study can determine how wind will be impacted by changes in building massing, and wind speed influences thermal comfort significantly in Toronto; however, in a desktop study, that wind speed must be approximated using a designer’s experience-based judgement.

1.1.2 Desktop Thermal Comfort Study

A desktop study can be used at an early stage of a design's development process, or in situations where a full detailed analysis of local microclimate across a spatial region would be unfeasible. Examples of these include regions without sensitive surroundings, with limited publicly accessible space and minor changes to form or massing of the area. The output of this type of assessment describes conditions in a specific location subject to a series of assumptions, modifying the input to a UTCI calculation to approximate the effects of these assumptions.

A. Required information/ assumptions

Location: The source data for weather information used for a desktop assessment depends on the site's location in Toronto. See page 112 for a figure that shows Inland and Waterfront climate boundary to determine if the project location is considered Inland or Waterfront and use the appropriate dataset accordingly. While local differences would be present between these typical datasets and specific sites due to topography around each site, it is important that the same baseline data is used across all thermal comfort studies to allow for quantification of comfort against a common benchmark.

Surrounding massing: Knowing when the sun will be visible in public spaces will play a large part in how comfortable an individual would feel in that space. During winter, access to the sun will improve thermal comfort, whereas during summer it can result in heat stress, reducing overall comfort levels. Knowing when shelter from sun is beneficial or detrimental allows the designer to adjust their designs to suit the needs of the site being developed.

Local moisture sources: The addition of moisture into the air (via evaporation, from still water bodies or more active measures such as misting) modifies the temperature and humidity of the air, absorbing heat to enable liquid to change phase into a gas. This can reduce the temperature of the air, which is why during summer proximity to water bodies can have a beneficial impact on thermal comfort. The effect of this moisture source proximity can be accounted for in a desktop study by approximating the effectiveness of the moisture addition to air. For example, depending on other climatic conditions, evaporative cooling can reduce ambient air temperature by 5°C [1], and can be an effective means of managing comfort when implemented periodically – and considering air movement conditions also. However, when ambient humidity is already high, this cooling effect can be reduced, and even increase perceived thermal stress due to oppressively humid conditions.

[1] Wai K-M, Xiao L, Tan TZ. Improvement of the Outdoor Thermal Comfort by Water Spraying in a High-Density Urban Environment under the Influence of a Future (2050) Climate. Sustainability. 2021; 13(14):7811. https://doi.org/10.3390/su13147811

B. Calculation

For each hour of the year, the air temperature and humidity should be obtained, using either values directly from the provided climate data files for the selected location, or by modifying those two values based on the addition of water into the air from nearby moisture sources.

Wind: Wind speed is the most difficult to approximate for a desktop study, as wind speed and direction is highly dependent on contextual massing. For this variable, the effects of nearby massing must be estimated using guidance from the Pedestrian Level Wind Study Terms of Reference Guide for how wind behaves around large objects [4]. For example, at a time where wind prevails from the east, with a large building to the west of a location being assessed, it may be assumed that downwash will occur, and speeds would increase slightly on the ground to the east of that building.

Radiant Temperature: Radiant temperature can also be obtained using the assumption that if completely sheltered from the sun, it will equal to air temperature, or if exposed to sun, equal to the radiant uplift in temperature because of that exposure [2,3]. Radiant temperature also depends on surrounding surface temperatures, which can be included in approximation of mean radiant temperature with the method for their inclusion stated clearly.

For all the assumptions made, these should be noted and provided alongside results from this desktop assessment, with justification for why they have been made, and the adjustments that have been applied to each of the variables input into the UTCI calculation.

[2] Arens, Edward, Tyler Hoyt, Xin Zhou, Li Huang, Hui Zhang, and Stefano Schiavon. “Modeling the Comfort Effects of Short-Wave Solar Radiation Indoors.” Building and Environment 88 (June 2015): 3–9. https://doi.org/10.1016/j.buildenv.2014.09.004.

[3] ASHRAE. “ASHRAE Standard 55 - Thermal Environmental Conditions for Human Occupancy,” 2020.

[4] Section 6.7: Wind Responsive Design Guidelines

C. Results

The output of a desktop study would be an annual hourly approximation of UTCI for a specific location, representative of the thermal comfort conditions experienced by a person at that location. The results can be summarized according to the time periods outlined in Chapter 3 — Performance Metrics, and indicate whether any additional measures should be made to improve those conditions based on the targets also provided.

For Toronto, the following thermal comfort targets are specified, within discrete time periods and UTCI categories associated with those periods. These are what new developments should aim to achieve, to show their effective design incorporating outdoor thermal comfort optimization.

- >65% time comfortable in summer months (Jun-Aug, 06:00-21:00, between 9-32°C UTCI)
- >30% time comfortable in winter months (Nov-Feb, 08:00-17:00, between 0-26°C UTCI)
- >45% time comfortable in shoulder months (Mar-May and Sep-Oct, 08:00-20:00, between 9-26°C UTCI)
- <5% reduction in annual comfortable hours using the time periods and temperature ranges specified for seasonal comfort

For example, for a location being redeveloped which is partially sheltered to the south and east, during summer and between 06:00 and 22:00, the proportion of hours within the UTCI range of 9-32°C may be 80%, which exceeds the target of >65%. This suggests that this location performs well during summer; however, during winter where the acceptable UTCI range changes to 0-26°C between 08:00 and 17:00, this reduces to 30% which is lower than 45% and suggests that it may be less usable during winter months. Over the entire year assessed, the proportion of time considered comfortable increases by 3% when compared with the existing conditions in that same location, which means it also meets the <5% reduction criteria.

1.1.3 Detailed Thermal Comfort Study:

A detailed study is undertaken to determine the hourly conditions experienced across a specific area of Toronto around a new development or change to existing public realm space. This type of study can take time to complete (between 4-6 weeks), but it provides a much more comprehensive understanding of the impact changes to public realm have on how pedestrians experience the climate in a particular region of the city.

A. Required information/assumptions

Location: The location of the study is used to identify which of the two (waterfront/Inland) datasets are used as the typical year's weather on which the assessment is based.

Building massing: A detailed study comprises CFD simulation of the movement of air and solar exposure of the region being assessed. This requires access to a 3D model of that region, including details such as topography and surrounding material types to simulate these two critical factors in calculating outdoor thermal comfort.

Furniture and materiality: Features in the urban realm which are not buildings but contribute to changes in the thermal characteristics of a space can include shade (such as trees, shelter structures) and infrastructure (embankments, terraces, bridges) should be included in any 3D model used for analysis. It can also be immensely helpful to know where there are sources of moisture, vegetation, and distinct types of groundcovers, which all contribute to local microclimate conditions.

Vegetation: Including the wind porosity and radiation transmissivity of trees in any simulation is encouraged; however, it is also recognized that time-varying conditions are more complex. Urban realm planting is often designed with the vegetation as expected in several years' time and it is likely that the performance of that vegetation (providing shade and influencing wind) will not be as designed until after that vegetation has reached maturity and is established on a developed site.

Trees should be included in the wind simulation, though given the variability in porosity throughout the year due to changing leaf conditions accounting for all combinations of wind speed and foliage is unfeasible. For directional CFD simulations, the average annual porosity of a tree/vegetation is acceptable to be used for all directions, which is a required simplification to make analysis of this type feasible. Due to this simplification, results presented including vegetation should note that the effects of seasonal vegetation would impact the external thermal comfort of the site being assessed and should highlight where this might increase or decrease the level of comfort expected.

Study area: The area to be assessed for a detailed thermal comfort study should have a radius similar to that of a pedestrian wind comfort and safety study (up to 400m from the site being assessed). This is to include the effects from nearby features (such as building massing, terrain, and bodies of water) on the factors influencing thermal comfort in the region being simulated. It is not strictly necessary to simulate in the same level of detail across the entire region within that distance, so long as the level of detail is enough to capture the effects of wind, humidity (if water bodies are present) and radiation.

The 400m distance from the development site does assume that the sites width and depth are similar, giving a circular domain within which the assessment is undertaken. Sites where the plot is long and linear could be assessed as a whole, though would require significant computing resources for larger sites. A more realistic approach would be to identify similar regions along its length and assess these individually as representative of the whole site.

Plot boundaries and regions simulated for (top) a simple site contained within a single region, (middle) a long linear site where the entire domain would be simulated, and (bottom) more complex linear site with specific regions simulated representative of distinct typologies (reducing simulation domain by 38%)

Areas of interest: Within a region being assessed as part of a detailed study, there are likely to be key areas where optimizing thermal comfort conditions is more beneficial. An example of this might be a region used by those with specific needs or vulnerabilities. A detailed study can give a holistic view of conditions across an entire region; but it is often in focusing on a specific location within that region that the most benefit can be made by layering different comfort enhancing strategies. Identifying these early in the assessment process can help to tailor the process to provide more relevant and accurate results (for example, simulating specific regions in more detail than others).

These specific areas of interest can also be used to increase the level of detail in simulation around that point, for example, allowing for better understanding of conditions in areas with increased dwell time such as outdoor seating. Examples of areas of interest include:

- Publicly accessible open spaces, such as parks and playgrounds
- Spaces where occupants are expected to dwell for extended periods (e.g., plazas, gathering spaces, outdoor events spaces
- Spaces where occupants may be more sensitive to thermal stress conditions (e.g., schoolyards, amenity spaces, hospital or care adjacent grounds)

B. Calculation

There are several ways of simulating temporal/spatial thermal comfort; however, each has their own benefits and limitations. The most accurate method would be to simulate every unique combination of air temperatures, humidities, wind speeds and directions and sun positions using CFD; however, this would be very time consuming and create more data than can feasibly be handled. A simplified method is proposed here which is more achievable and serves as a reasonable approximation of typical conditions over a typical year.

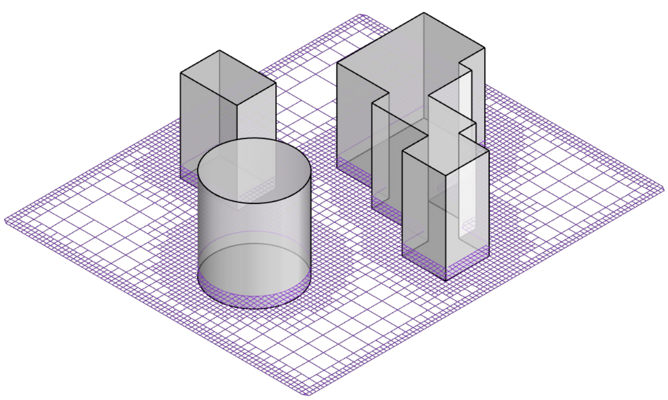
Thermal comfort conditions should be based on sensors within the simulated domain at pedestrian height (1.5m), at spatial resolution of no greater than 5m.

Wind: Wind should be simulated using CFD for a minimum of 16 directions, representing wind from all directions. The speed at which these conditions are simulated should be the 50th percentile for that direction. If no wind is expected from a specific direction, then the 50th percentile for the nearest available direction should be used. No stipulations are made for the configuration of the CFD simulation; however, it is expected that those undertaking this portion of the assessment will be capable of producing results consistent with The City of Toronto: Pedestrian Level Wind Study Terms of Reference Guide [5].

[5] https://www.toronto.ca/wp-content/uploads/2022/03/8f9c-CityPlanning-ToR-Wind-Guide.pdf

Radiant Temperature: Radiant temperature (often called Mean Radiant Temperature or MRT) may be simulated using CFD with some simplifications made for its approximation but can also be calculated independently of a CFD model using SolarCal[6] for heat exchange with the sky, surrounding surfaces and the sun.

The resolution over which this analysis is run should be for an average spatial resolution of around 5 metres. This can vary, with more sensitive areas at higher resolution (<5 metres) and less critical areas (larger open spaces, non-pedestrianized regions) greater than this.



Mesh density varying with proximity to developments

Calculation of MRT is a complex process, most often calculating surface temperatures of surrounding geometries using their material properties and then determining view-factor to each of those surfaces. A suitable approximation can be to determine incident radiation based on sun exposure and reflectivity of surrounding materials and interpolate between a shaded and unshaded surface temperature for a typical material.

Alongside the Waterfront and Inland datasets provided, a shaded and unshaded MRT is provided assuming concrete surrounding materials (concrete ground with no sky shelter for the unshaded condition, and full enclosure within an unconditioned thin concrete box). Annual-hourly irradiance and spatial sky-view simulated across the 3D model may be linearly interpolated between those shaded and unshaded MRT results to give a suitable approximation of MRT without requiring full simulation of surface temperatures.

The results from this portion of a detailed study should give MRT conditions for each analyzed point in the area being assessed, for each hour of the year.

Trees should be included in this study, with varying leaf conditions across the year based on the expected condition of those trees in 3-years from the development completion (to allow for growth and establishment of microclimates that will develop after the development happens). It is acceptable to use approximations for leaf cover based on species. This means that shade provided by a deciduous tree in summer is greater than shade provided by that same tree in winter. Where leaf coverage for specific trees is unknown, it is also acceptable to use an approximation of the average porosity to radiation for the entire year; however, this must be stated within the documents describing the assessment to make it clear that this assumption has been made, and that it would be an effect on the outputs being presented.

[6] Arens, E., T. Hoyt, X. Zhou, L. Huang, H. Zhang and S. Schiavon. 2015. Modeling the comfort effects of short-wave solar radiation in-doors. Building and Environment, 88, 3-9. http://dx.doi.org/10.1016/j.buildenv.2014.09.004, https://escholarship.org/uc/item/89m1h2dg

Universal Thermal Climate Index: Dry bulb temperature and relative humidity values should be applied uniformly across the area being analyzed. Where moisture sources are present that would impact both these variables, they may be included in the analysis, with clear description of their scheduled operation (if periodic) and evaporation/emittance rates in any CFD simulation.

UTCI should be calculated for each hour of the year, using and scaling the appropriate CFD results for the corresponding wind direction for that hour, and including MRT conditions for the corresponding time also.

C. Results

With spatial data available for every hour of the typical year, and for the area that was assessed, the proportion of that area achieving the target thermal comfort performance can be calculated.

For example, within the area assessed, the proportion of time comfortable during the period defined for winter can be calculated. This value should be calculated for the area within the site boundary, and for sensitive areas nearby. Within the site boundary (including any nearby priority sites), if more than half of that area achieves the thermal comfort targets outlined in this document it is considered a success.

Where areas fail to achieve the target levels of thermal comfort, it would be the responsibility of the designer to prove that changes to design (or through the addition of mitigation measures) can be made to increase thermal comfort and not detrimentally impact nearby areas within the requirements of the thermal comfort guidelines.

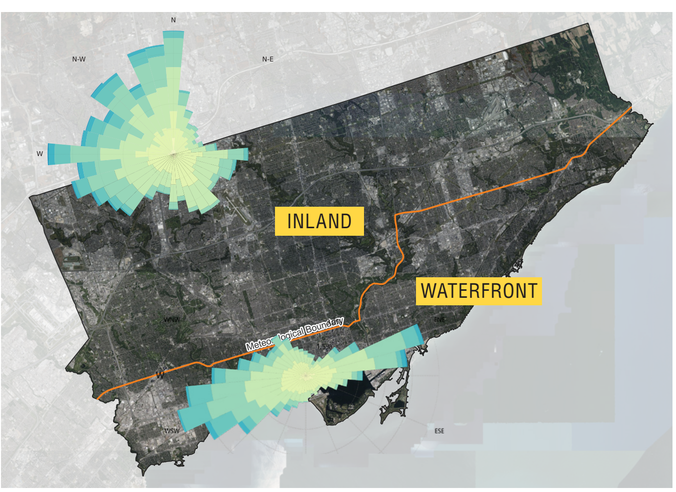
Yorkville neighbourhood in Toronto.

1.2 WEATHER DATA SOURCES

Determining the thermal conditions in any outdoor environment requires information describing the climate that environment exists within. For the purposes of quantifying thermal comfort, a baseline set of weather data describing a typical year has been created. This provides a standard set of values against which any thermal comfort assessment could be made.

The climate around Toronto varies based on local conditions. Topography, proximity to the shoreline, composition of ground and surrounding materials and many other factors contribute to subtle differences between weather across the city. To simplify assessment of thermal comfort and align assumptions regarding weather conditions with other design guidelines for Toronto, the boundary suggested by The City of Toronto: Pedestrian Level Wind Study Terms of Reference Guide is used to distinguish two areas over which these conditions vary.

The boundary is drawn based on the location of an elevation feature associated with the former Lake Iroquois shoreline, which coincides with the change in wind profiles for the demarcated areas. In waterfront areas, wind prevails from the east and west, along the edge of Lake Ontario, while inland there are more north and west prevailing winds, bringing with them different moisture and temperature conditions also.



Inland and Waterfront climate boundary

Data describing the typical years weather for the two regions (Waterfront and Inland) has been sourced for the following locations:

- Inland: Toronto Pearson International Airport (WMO #716240)
- Inland: Buttonville Municipal Airport (WMO #716390)
- Waterfront: Billy Bishop Toronto City Airport (WMO #712650)
- Waterfront: Toronto City Centre (WMO #715080)

These were then combined to create a single file per Waterfront/Inland region, representing conditions across Toronto.

The source of this data was PCIC , which provided future-shifted weather files based on an older CWEC 2016 dataset to predict future conditions based on an RCP8.5 (high emissions scenario) for 2050 – to ensure that conditions represented by this data will remain valid for several years. It is expected that the conditions represented in the two files provided alongside this document could be updated in the future with more up-to-date methods of calculating outdoor thermal comfort; however, the metrics used to assess performance of an outdoor space are compared against the baseline within these datasets. The positive or negative impact of a design choice is reflected in the results from any assessment undertaken, which would also be valid for any other data set representing Toronto's typical annual climate.

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[7] https://www.toronto.ca/wp-content/uploads/2022/03/8f9c-CityPlanning-ToR-Wind-Guide.pdf

[8] https://www.pacificclimate.org/data/weather-files

1.3 SOFTWARE

No specific software is prescribed for the detailed or desktop analysis procedure; however, it is assumed that those undertaking these types of assessments have experience in this type of work and know the most appropriate tools to use to generate results from the suggested methodologies.

At the very least, these tools should be capable of:

- Simulating wind speed and direction for a 3D domain containing building massing
- Simulating the incident solar radiation on a given point/set of points
- Calculating the sky-view (the proportion of visible sky, with 0 being completely covered and 1 being completely visible I.e., standing in an open field) for a given point/set of points
- Calculating UTCI from the results of the above data
- Visualizing spatial results in a way that can clearly show the difference between areas of greater and lesser thermal comfort
- These capabilities, along with knowledge of the subject area, are enough to undertake a spatial thermal comfort study.

While specific software is not prescribed, tools capable of undertaking these types of assessment are listed below. This list is not exhaustive but can provide a starting point from which those undertaking these assessments may approach the task. The methodology defined here may be followed using combinations of these and other tools but requires knowledge of the subject in order to produce valid results.

- Geometric modelling: Rhino, Grasshopper
- CFD simulation: Ansys CFX, OpenFOAM
- Radiation simulation: Radiance, Energyplus, Ansys CFX, ENVI-met
- Thermal comfort calculation: Ladybug Tools

An example of viable software options in-use is included in the following section.

1.4 CASE STUDIES

1.4.1 Desktop Case Study: A Park

The following case study presents an assessment of outdoor thermal comfort for a small park in north end of Toronto, surrounded by mid to high-rise buildings. As a Desktop Study, it is simpler than a detailed spatial thermal comfort analysis, using some assumptions and approximations for the impact of surrounding on factors influencing thermal comfort.

This example is illustrative of the level of detail and types of output a Desktop Study would aim to achieve. The results presented here are not to be interpreted as indicative of the actual conditions at the location being assessed.

A. Site summary and assumptions

Specific locations within the area being assessed are indicated below. These are:

- Open area on the upper right
- Seating area on the upper left
- Erskine Road edge on the lower middle

The parkette is designed for general usage and creative play and fitness activities. The hours of usage are assumed below

- Summer: 06:00-21:00
- Shoulder: 08:00-20:00
- Winter: 08:00-17:00

The desktop-level assessment undertaken here does not account for detailed wind effects from surroundings, nor from changes to topography within and around the park. As such, results cannot be used to ascertain whether wind shelter or accelerations caused by local massing would impact thermal comfort levels. A wind consultant would be required to undertake a detailed study of wind conditions for greater understanding of local wind conditions at this site.

Desktop study site and specific locations for summary, before and after development

B. Calculation

Wind

- This desktop study employs the inland weather source
- The surrounding massing and landscape approximated impact on wind conditions have been considered
- Without detailed CFD simulation – in-situ wind conditions must be approximated – or without knowledge of local phenomena, use the baseline wind conditions without modification

Sun/sky Visibility

- The surrounding massing and landscape impact on sky visibility have been considered.
- The surrounding massing and landscape impact on sun visibility have been considered

Moisture Sources

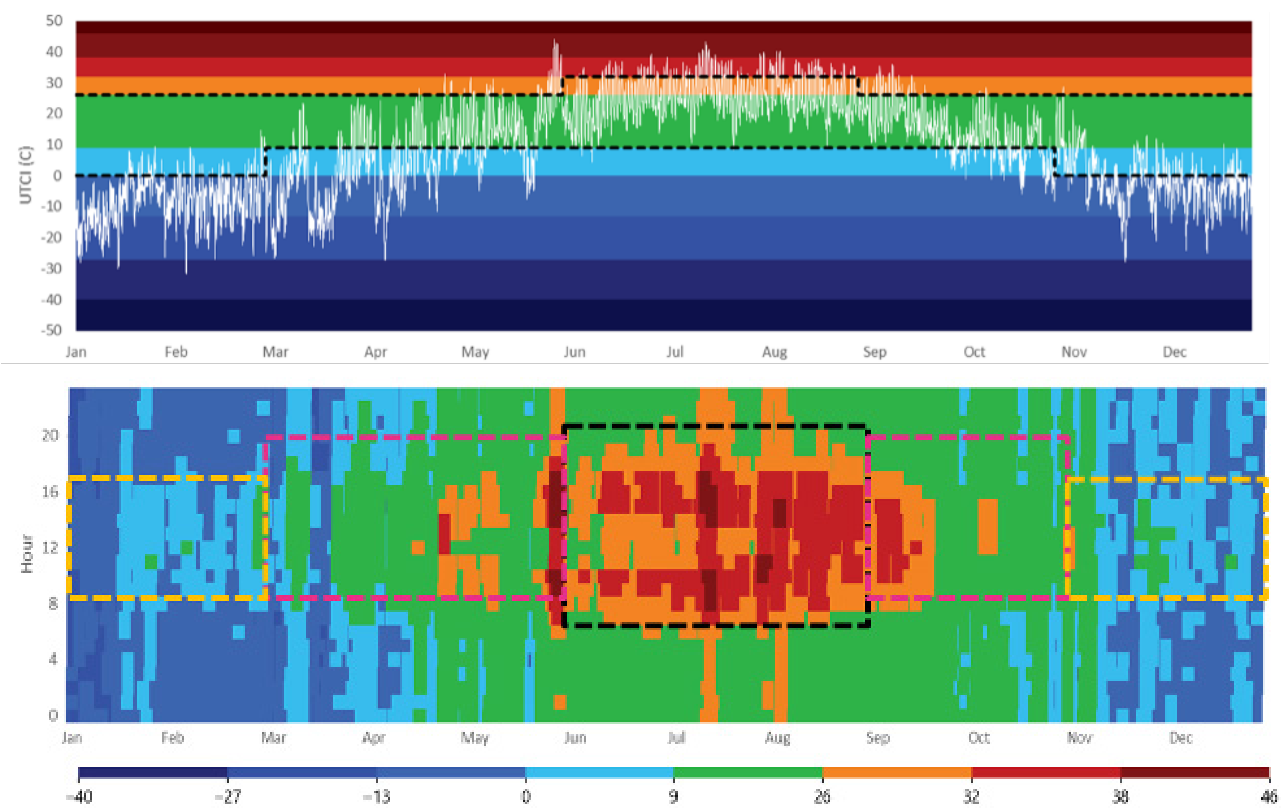
- No existing water sources found on site (pond/fountain/ mist), nor included in proposed changes (though these are included in additional measures applied within this desktop study to increase thermal comfort during summer).

C. Results

Typical Conditions (without local influences)

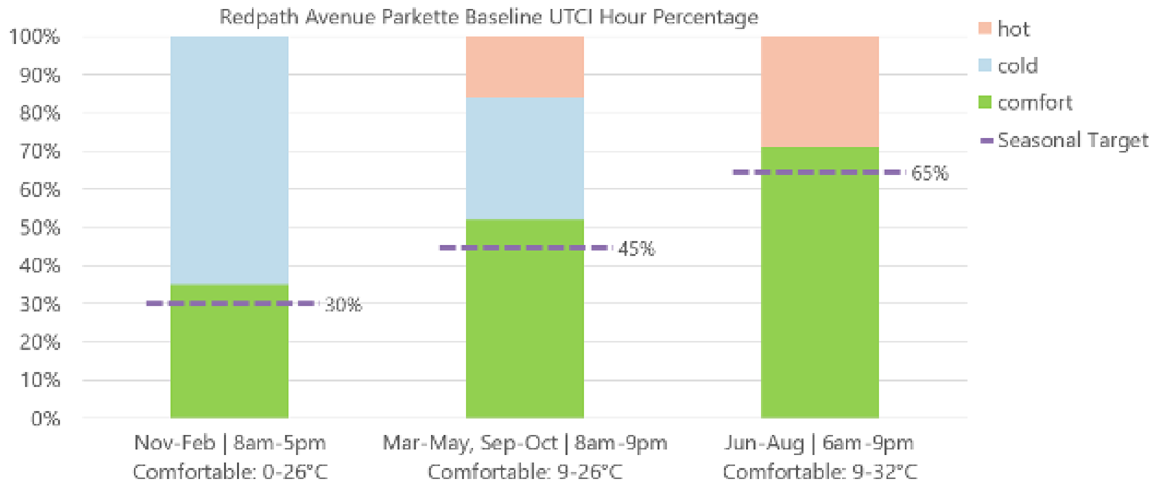
A baseline UTCI assessment has been made using information from the Toronto Inland weather dataset. This represents the average condition across all locations within the site being assessed and shows values ranging between –32C and 45C UTCI.

- During Summer months, 71% of time is considered comfortable
- During Shoulder months, 52% of time is considered comfortable
- During Winter months, 35% of time is considered comfortable



Desktop study baseline UTCI assessment, indicating comfort bands and acceptable annual ranges

Compared to the Toronto Seasonal Comfort target, the baseline condition at Redpath Avenue Parkette meets all the comfort threshold, marked in purple.



Desktop study seasonal comfort baseline against seasonal comfort targets

Location specific summary

For a specific location, approximations are made to determine the impact of changing surroundings on thermal comfort. For example, at the road edge the current conditions are compared against conditions following site development and effects from changes to surroundings – in this case the addition of a tall building to the southeast.

Existing (left) and proposed (right) conditions, focusing on road-edge location

In the existing site, the location being assessed is open to the streets on the east, southeast, and south, and shaded by nearby trees to the west and northwest.

When developed and including massing from nearby developments due to be completed at time of site redevelopment, there would be additional shade from the southeast causing late morning sun to be blocked.

Condition	Winter (Nov-Feb, 08:00-17:00)	Summer (Jun-Aug, 06:00-21:00)	Shoulder (Mar-Apr and Sep-Oct, 08:00-20:00)
Existing	35%	67%	52%
Proposed (with adjacent development)	38%	69%	53%

When including changes to wind due to surrounding massing, these values would change; however, the intention of a desktop study is to highlight where there may be significant changes to thermal comfort without undertaking a detailed analysis of the site. If such a change were identified using this simplified method of assessment, then measures to further enhance comfort and prevent detrimental effects would be necessary.

D. Conclusion

Typical conditions sit within required levels of thermal comfort against the Toronto Thermal Comfort Guidelines. No further action is required to mitigate risk of heat or cold stress in the location assessed as it meets the requirements of the guidelines.

Although within an acceptable range, the condition closest to not meeting the thermal comfort requirement occurs during the shoulder season, primarily due to wind. Results from this study indicate that protection from winds that prevail during these months may be considered if during further design this is found to be an issue, or if it is noted as an issue in occupancy.

1.4.2 Detailed Thermal Comfort Case Study: Flemingdon Park, Grenoble Drive

The following case study presents an assessment of outdoor thermal comfort for a specific area of Toronto, specifically the area adjacent to Grenoble Drive in Flemingdon Park, Toronto. The assessment procedure shown here, and outputs given as example are based on the guidelines outlined in the “City of Toronto Thermal Comfort Terms of Reference.”

It is important to note that this assessment is an illustrative example. The results from this assessment should not be interpreted to indicate actual conditions of the location being assessed, but to provide a clear example of how the methodology outlind in the this chapter can be applied in practice.

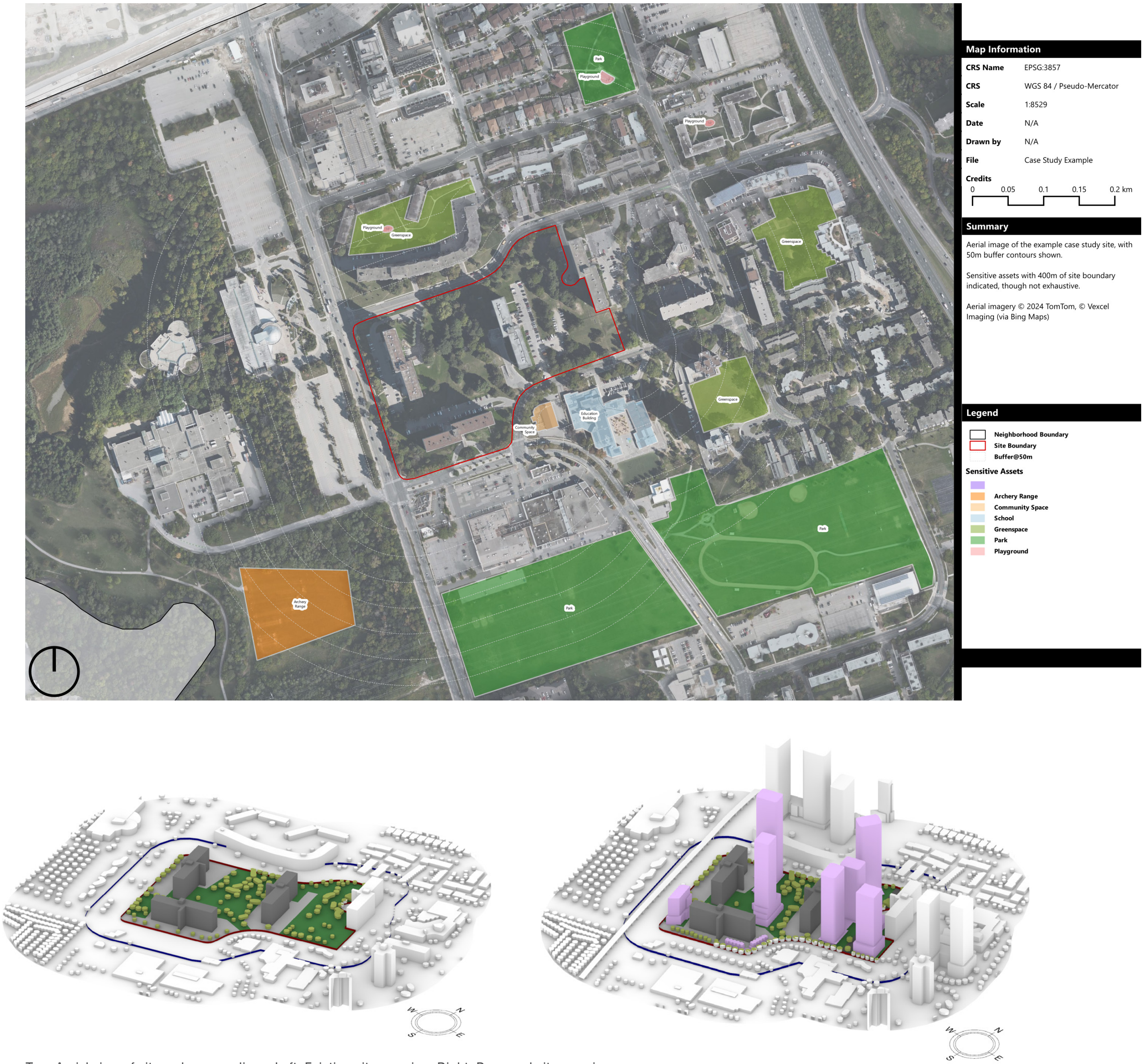
A. Site summary and assumptions

The site indicated will be developed to include a mixed-use development, comprising new landscaped greenspaces, residential and commercial buildings atop plinths and include roof terrace areas.

The proposed development is taller than current buildings on-site, which consist of 17-storey residential towers and a church and school to the south.

Results shown here will include effects from these, to reflect conditions to be expected in outdoor areas within the site, and in areas adjacent that are identified as sensitive proposed assets. The development is also being considered regarding nearby developments for which planning permission has been obtained and which will be completed prior to this site's development.

Beside, images showing the existing and proposed site layouts are presented, indicating the additional buildings and nearby amenities and assets where impact to thermal comfort and external pedestrian wellbeing are prioritized.



Top: Aerial view of site and surroundings; Left: Existing site massing; Right: Proposed site massing

The simulations undertaken here use the Inland (Inland_2050s_ ExternalThermalComfort.epw) to provide weather file air temperature, humidity, solar radiation and wind, speed & direction values. Building massing was modelled using Rhino, while radiation simulations were performed using Radiance, from Honeybee within Ladybug Tools. CFD simulations were performed using Ansys CFX meshed using Harpoon from the Rhino Model. UTCI calculations were done in Ladybug Tools using Python code, and visualizations were done with Matplotlib, also Python code. This is an example of viable software options, although others are possible as well.

B. Calculation

Two sets of results are presented: Existing (the site as it currently exists) and Proposed (the site post development, including surrounding developments that will also be completed when this proposal is complete).

Sky View

Sky visibility is a strong indicator for night-sky cooling, with greater visibility of the sky leading to cooler nights. During winter reduced sky visibility can be beneficial to increase ambient temperatures and during summer the additional shade associated with reduced sky visibility is likely to reduce radiant temperatures. However, the inverse is also true, where during winter the reduced exposure to the warming sun can reduce ambient temperatures during the day, and in summer the reduced visibility of cold sky can increase overnight ambient temperature.

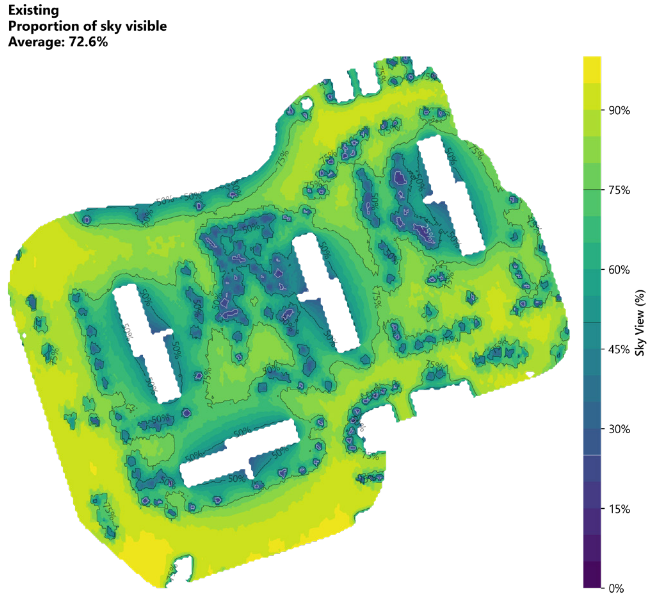
Wind Speed

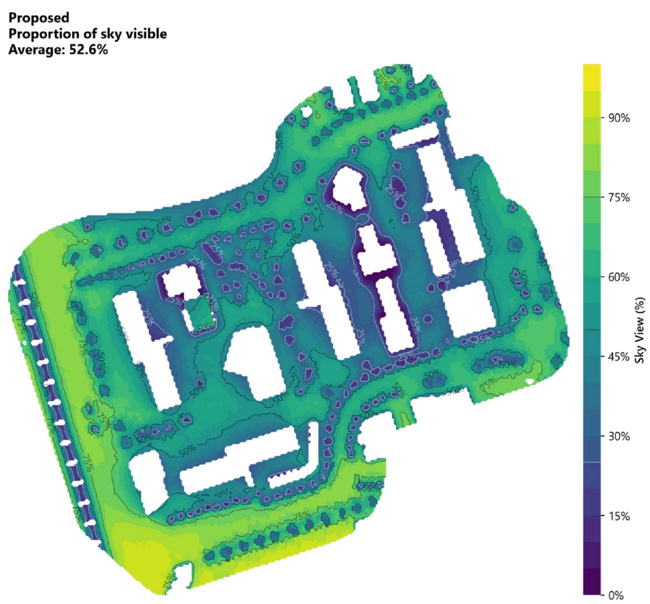
The annual-hourly wind speed results, based on simulation of 16-directions and scaled to each hours' wind speed (at 10 metres are used as input into the UTCI calculation. Below, a single point-in-time is shown representative of conditions at 13:0 on March 21st, corresponding with a prevailing wind from 319° (northwest) at 5.1m/s.

Radiant Temperature

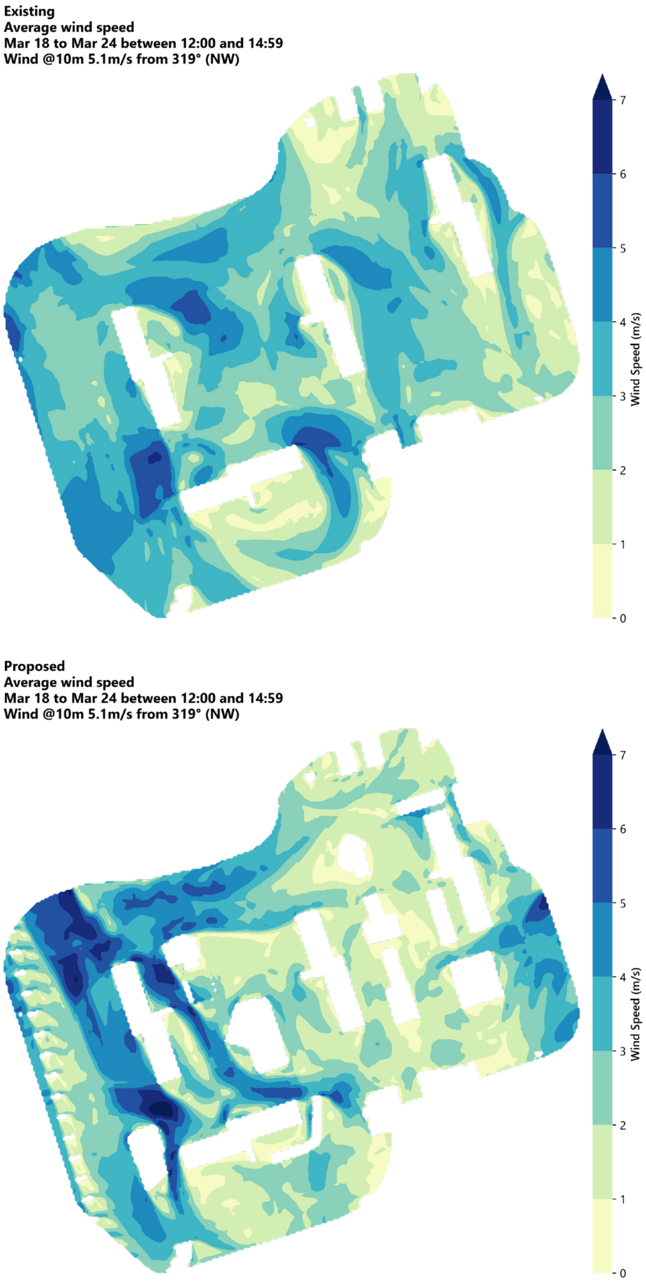
The temperature of surrounding surfaces (and the sun and sky) also contributes to the UTCI calculation and includes the effects from radiant heat sources. The images below show the mean radiant temperatures at the same time as shown in the wind results above – indicating the effects of shade from both trees/vegetation and massing. These images show the average over a time across several days around the spring equinox (March 21st), with the effects of shade cast by trees in-leaf included alongside shadows from buildings.

The massing densification in this site reduces overall radiant temperature due to the additional shadows cast by new buildings within its boundary.

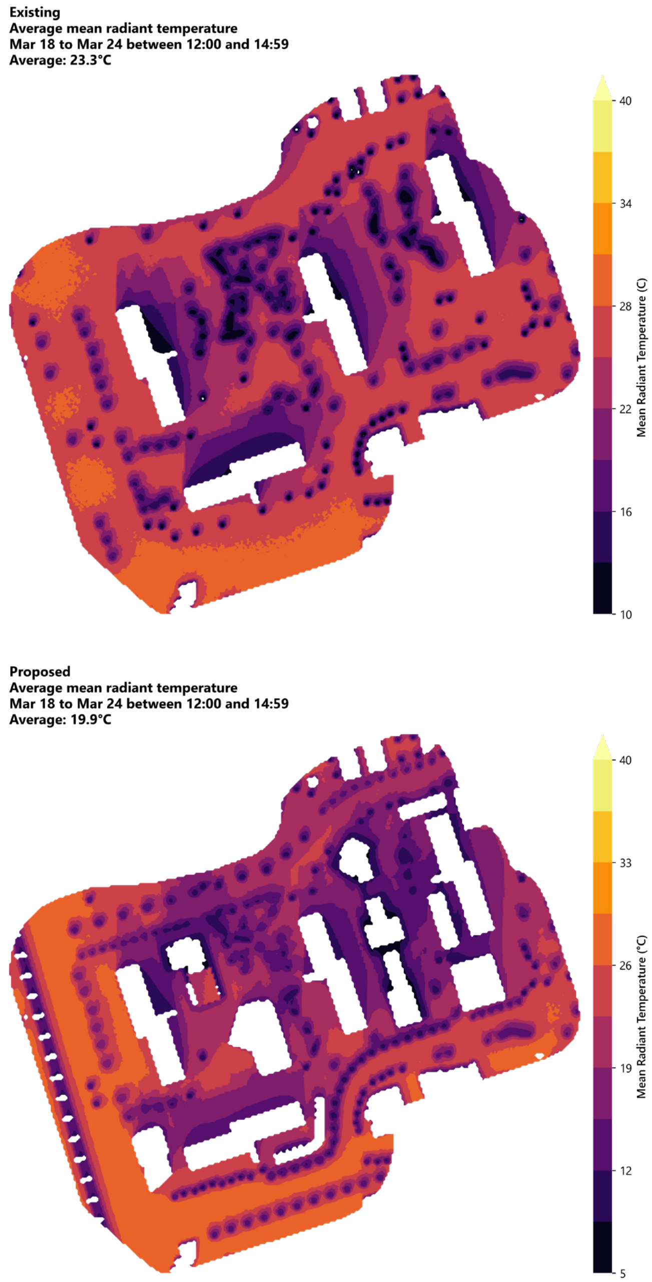




Sky View; Top: Existing site massing; Right: Proposed site massing

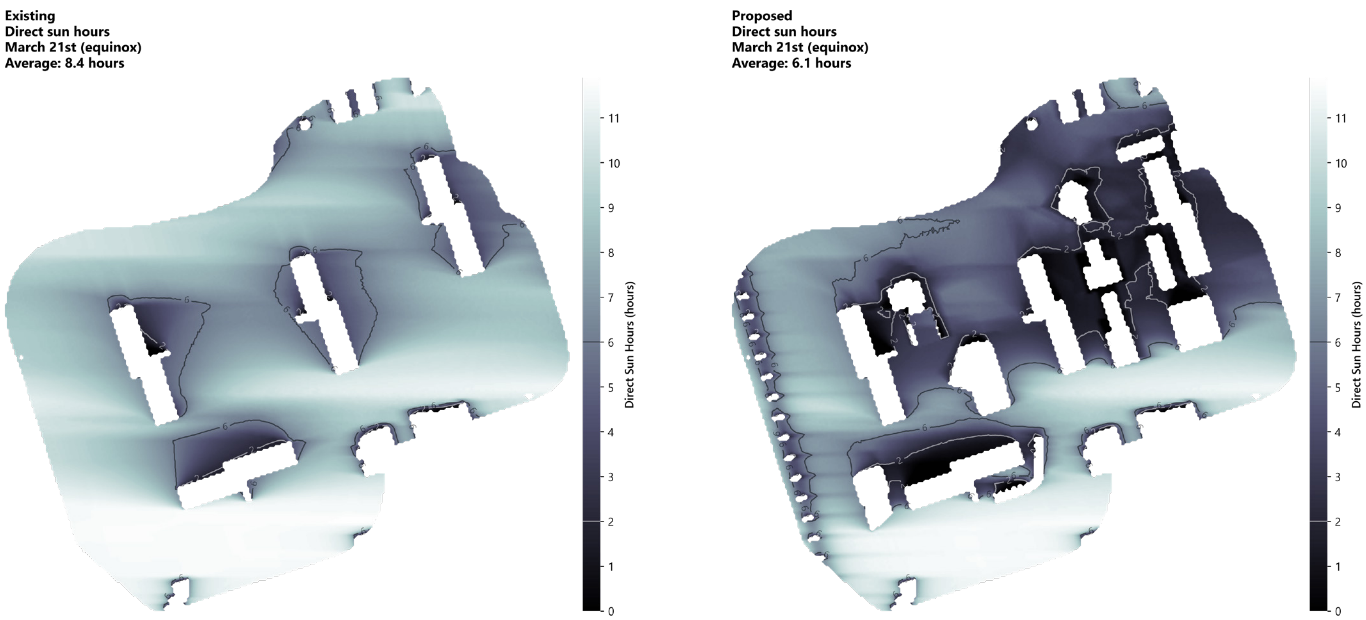


Average wind speed around March 21st at 13:00; Top: Existing site massing; Bottom: Proposed site massing



Average mean radiant temperature around March 21st at 13:00; Top: Existing site massing; Bottom: Proposed site massing

A direct-sun-hours render shows areas subject to low levels of direct sunlight. This tells the reader where may be considered darker for more hours, across the day being represented. In conjunction with radiant temperature, it can also indicate why a specific area has a higher radiant temperature as this is driven by solar exposure.



Direct sun hours on March 21st; Top: Existing site massing; Bottom: Proposed site massing

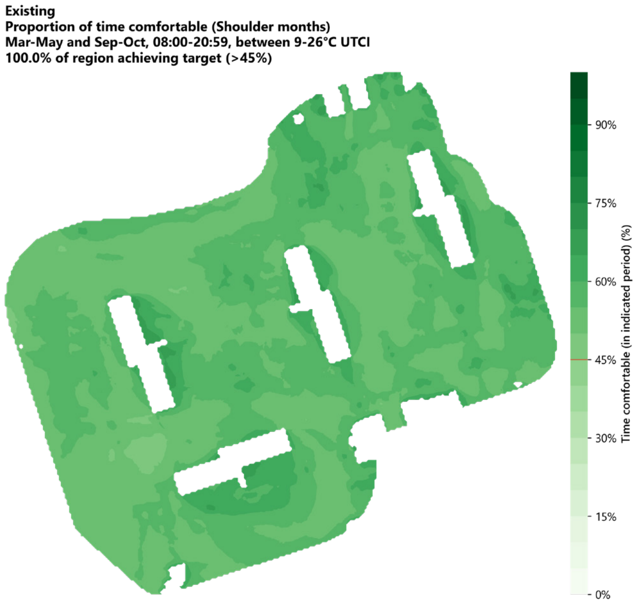
C. Results

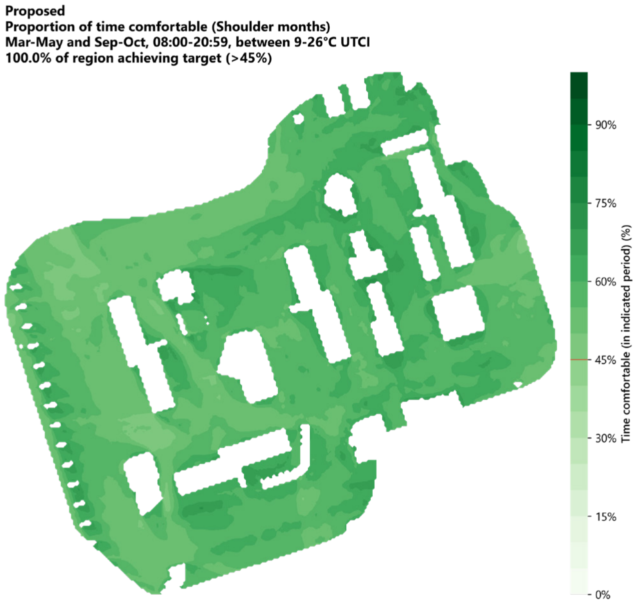
Annual hourly UTCI is calculated using the results shown previously, allowing for the summarization of spatial thermal comfort within target time periods per the City of Toronto Thermal Comfort Guidelines.

The results shown here include areas outside the site boundary, as there are some sensitive areas identified in proximity to the site being assessed.

Shoulder months

The figures below show the Existing and Proposed site layouts, with the threshold for the season shown indicated as a red line (in this instance, shoulder months should achieve >45% of the time thermally comfortable, between the hours of 08:00 and 20:59 over at least 50% of the area being assessed. As no area within the assessed area experiences hot or cold stress <45% of the time then there is no issue or cause for concern with the proposed development.



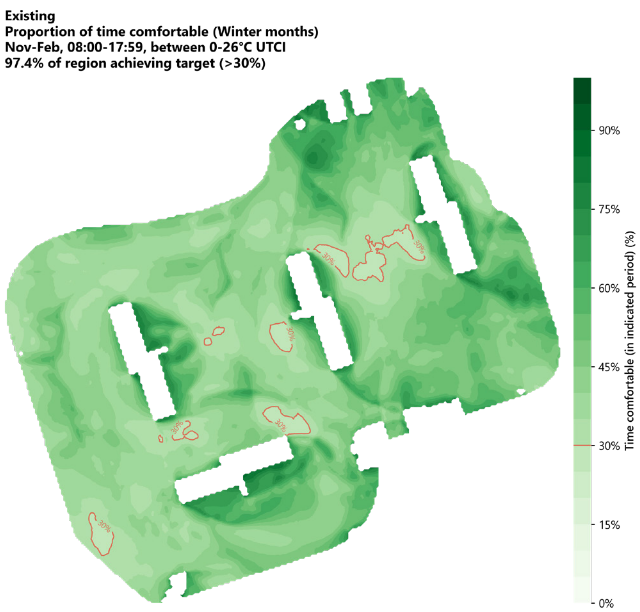


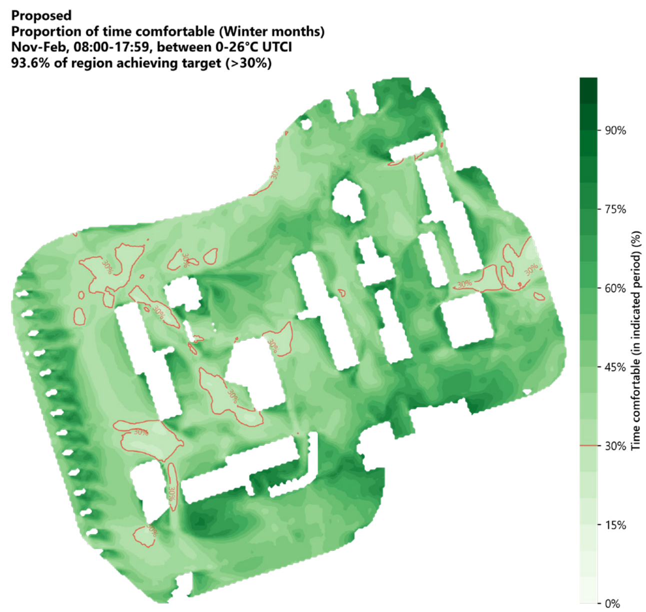
Proportion of time comfortable within shoulder months period; Left: Existing site massing; Right: Proposed site massing

Winter months

During winter months, as wind becomes a predominant factor in thermal comfort (due to wind chill effects) the changes in massing have increased wind speed between buildings and reduced the area considered “comfortable”. However, this reduction is still well within acceptable limits and only small areas are achieving thermal comfort for <30% of the time over winter months (within the bounds defined in City of Toronto Thermal Comfort Guidelines).

If one of these areas indicated by the 30% contour were to include a sensitive asset such as a playground, then it would be worth investigating how to mitigate this increase in cold-stress – through reducing local wind speed to reduce wind chill in these areas.

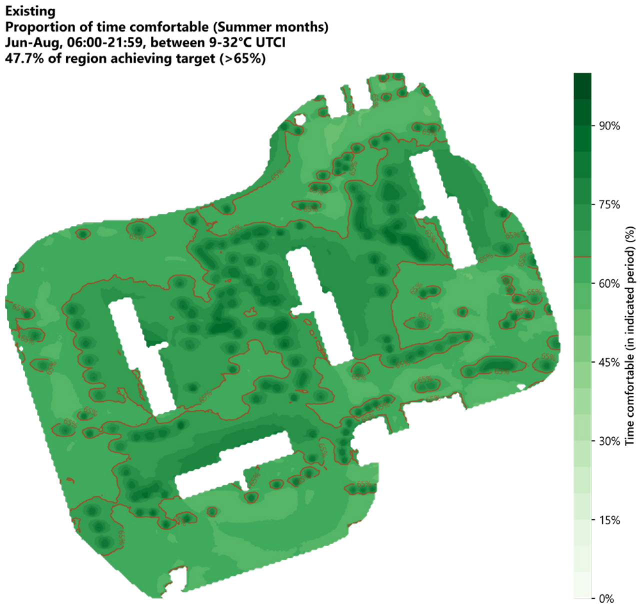


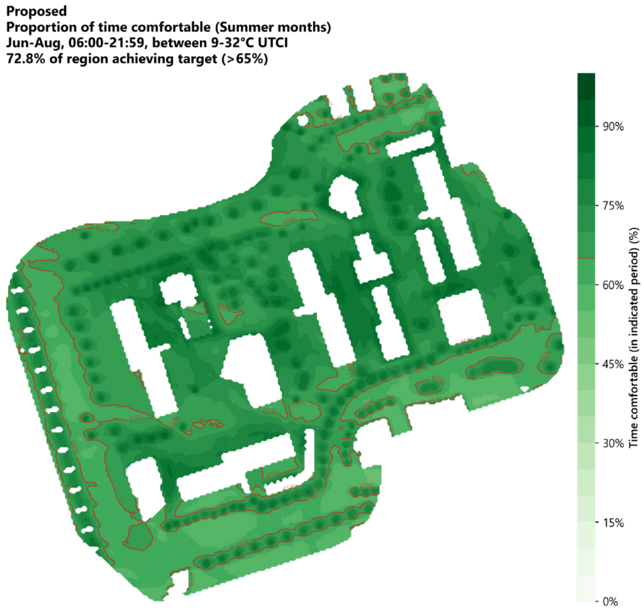


Proportion of time comfortable within winter months period; Left: Existing site massing; Right: Proposed site massing

Summer months

During summer months, solar exposure is now the predominant factor in thermal comfort, due to radiant temperature uplift from the warm sun. The Existing site comprises several mid-rise residential towers which shade regions to the north and reduce sky-view in areas immediately adjacent. With existing massing, 47.7% of the site being assessed achieves "thermal comfort" during the summer month time period. Shade is the most effective tool for increasing thermal comfort during summer months, and as the new development includes denser and taller building massing, the shadows cast by those new buildings increase this value to 72.8%. While this is beneficial for overall thermal comfort, it would also reduce sunlight availability for which the design would also need to comply with requisite shade guidelines also.





Proportion of time comfortable within summer months period; Left: Existing site massing; Right: Proposed site massing

D. Conclusions

The proposed development does not reduce thermal comfort across the site and immediate surroundings by more than the allowable threshold (5% reduction in annual comfortable hours, within the time periods and temperature ranges specified for seasonal comfort).

During Winter, a small reduction in spatial thermal comfort is experienced, driven by increases in local wind speed accelerating around building edges. While within acceptable limits, if sensitive assets are to be in areas indicated as experiencing less than the targeted thermal comfort levels, then mitigation methods to reduce wind speed in these areas should be applied.

The shade cast by buildings during summer months has a beneficial impact on thermal comfort due to protection from the sun; however, while this may be beneficial it also means reduced sunlight available during winter. A balance needs to be made where comfort is achieved in both winter and summer.

Liberty Village neighbourhood.