THERMAL COMFORT GUIDELINES | 2025

FOR LARGE AREA STUDIES, PUBLIC REALM CAPITAL PROJECTS & LARGE SITE DEVELOPMENTS

JANUARY 2025

Land Acknowledgement

We give thanks for, respect, and honour the land and the Indigenous peoples who have been its stewards for millennia. This document recognizes the need for reconciliation with Indigenous communities and acknowledges the importance of integrating Indigenous cultures and practices into city planning.

For time immemorial, the land which is now the City of Toronto has been home to Indigenous peoples. The City acknowledges it is located on the traditional territories of many nations, including the Mississaugas of the Credit, the Anishnabeg, the Chippewa, the Haudenosaunee, and the Wendat peoples and is now home to many diverse First Nations, Inuit, and Métis peoples. These territories are currently covered by Treaty 13 with the Mississaugas of the Credit and the Williams Treaties signed with multiple Mississaugas and Chippewa bands.

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1.0 Introduction

1.1 What is Thermal Comfort

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1.1 WHAT IS THERMAL COMFORT?

Thermal comfort is the state of feeling neither too warm nor too cold in a given environment. It is when the conditions are just right for you to be comfortable. Achieving thermal comfort depends on a few key factors:

Air Temperature

This simply means how warm or cool the air around you feels. Extremely high or low temperatures can make you uncomfortable.

Humidity

This refers to the amount of moisture in the air. High humidity can make a space feel sticky, while low humidity can lead to dryness and discomfort.

Wind Speed

This is how fast the air moves. A gentle breeze can be pleasant, but high winds can make it feel colder in the cold

Radiant Temperature

This considers the temperature you feel from nearby surfaces, like the warmth you get from the sun or the coolness from shade.
In the winter cold surfaces and clear night skies will increase the cold sensation, access to the sun will help reduce this effect.

These factors interact with each other and with your personal characteristics, like how active you are and what you are wearing. Thermal comfort is a fundamental aspect of human well-being, as it directly affects people's physical health, mental health, and overall quality of life.

Radiant Temperature vs. Air Temperature

Radiant temperature is different from the air temperature that we measure with a thermometer. Imagine standing in the sun on a cool day - even if the air is not too warm, you feel hot because of the sun's rays directly hitting you.

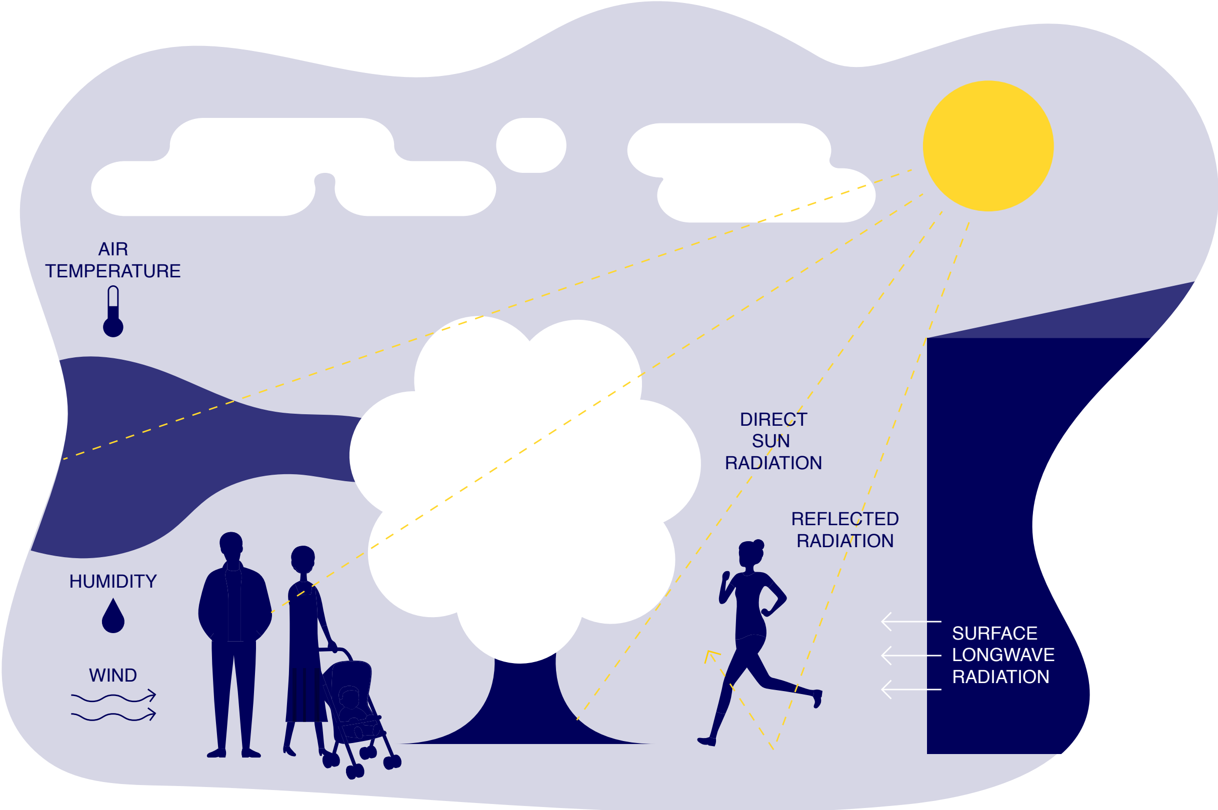
Impact of Sun (Direct Radiation)

When the sun shines on us, it sends out invisible rays that carry heat. These rays warm up our skin and clothes. So, even if the air temperature is not extremely high, the direct sun can make us feel warmer. It's like feeling the heat when you stand in sunlight versus finding shade.

Impact of Nearby Surfaces (Indirect Radiation)

Surfaces around us, like the ground, walls, or even nearby buildings, can also absorb and give off heat. If these surfaces have been soaking up sunlight, they can release that warmth back into the air, affecting how we feel. So, being close to surfaces that have absorbed sunlight can impact our comfort, especially in the shade where the direct sun is not hitting us. Radiant temperature of a surface will be affected by many factors including the albedo (percent reflectivity) of solar radiation. Dark convoluted surfaces absorb more radiation than light flat surfaces. In the extreme case of glass or even mirrored glass, sunlight can be reflected directly.

INTRODUCTION
PRINCIPLES
METRICS
TOOLBOX



Thermal comfort's key influencing factors are air temperature, humidity, wind speed and radiant temperature.

1.2 WHY IS THERMAL COMFORT IMPORTANT?

The Thermal Comfort Guidelines address thermal comfort in the public realm. The "public realm" is comprised of all public and private spaces to which the public has access. It is a network that includes, but is not limited to, streets and lanes, parks and open spaces, and the parts of private and public buildings that the public is invited into (OP Policy 3.1.1.1). The public realm is where people interact with each other and their environment daily. Ensuring thermal comfort in the public realm is essential to protect the physical and mental well-being of those who live, work, learn, play and visit the city, particularly in the wake of climate change.

The "public realm" is comprised of all public and private spaces to which the public has access.

Toronto has a semi-continental climate, with a warm, humid summer and cold winter, moderated by Lake Ontario on the southern boundary of the city. Spring and autumn (shoulder seasons) are shorter seasons than summer and winter, and they feature varied weather with alternating periods of dry, sunny weather and rain. Many days during spring and autumn are sunny with moderate rather than cold temperatures. Nights are cool, but frosts are rare. Snow can fall in early spring or late fall but usually melts quickly after contact with the ground. Winter weather brings cold temperatures with wet conditions to Toronto, while the wind can make cold temperatures feel even colder. Canada took the lead to promote an international index for wind chill that measures what the temperature feels like on exposed skin based on the speed of the wind. Needless to say, cold weather can adversely affect the health and wellbeing of many of Toronto's residents.

Toronto, like many other cities, is experiencing an increase in the frequency and intensity of extreme heat events, exacerbated by climate change. These events are anticipated to become more frequent and intense, with over 60 additional days per year experiencing temperatures above 30°C compared to the 1980s. As a result, the number of heat warnings is expected to increase and last longer. Very cold days (below -20°C) are projected to become less common; from 2000 to 2022, there were only four days with average temperatures below -20°C and 64 days where temperatures briefly dropped below this threshold. The city is also likely to get wetter, although precipitation patterns will be more variable compared to the steady increase in average temperatures.

Extreme weather conditions, in combination with power or water shortages, will strain the capacity of emergency and health providers, and ability for social services to meet citizen needs. Toronto is already experiencing more frequent and extreme weather events, which have resulted in flooding, power outages, and extensive damage to property, infrastructure and the natural environment. Overall, there is high seasonal variability of thermal conditions throughout the year, from significant freeze-thaw cycles to increased heat stress, which respectively raises challenges on how the public realm operates or is maintained within this dynamic climatic context.

Toronto's population continues to grow, with much growth occurring through vertical densification. The public realm is an important shared amenity that will be relied upon by more and more people for recreation as well as respite from the heat.

Ultimately, creating a city that prioritizes thermal comfort is about enhancing the joy of urban living, regardless of the season. It encourages residents to explore their surroundings, stay active, and engage in recreational activities. This dynamic engagement is vital for the vibrancy and resilience of the city, creating an environment where urban life thrives.

Toronto in summer

Toronto in winter

City of Toronto Official Plan - Relevent Policies

The following policies from the City of Toronto's Official Plan provide guidance related to thermal comfort.

Section 3.1.1 - Public Realm

Official Plan Amendment (OPA) 479 revised Section 3.1.1 of the Toronto Official Plan, introducing updated public realm policies. OPA 479 was approved by Toronto City Council on January 29, 2020, and came into effect on September 11, 2020, following provincial approval.

Policy 3.1.1.3 provides that the public realm will:

(d) provide a comfortable, attractive and vibrant, safe and accessible setting for civic life and daily social interaction' and

(h) contribute to the City's climate resilience.

Section 3.2.3 - Parks and Open Spaces

Section 3.2.3 of the Official Plan provides direction regarding parks and open spaces.

Policy 3.2.3.1 provides that Toronto's system of parks and open spaces will continue to be a necessary element of city-building as the City grows and changes. Maintaining, enhancing and expanding the system requires, among other things, designing high quality parks and their amenities to promote user comfort, safety, accessibility and year-round use.

Policy 3.2.3.3 provides that the effects of development from adjacent properties, including additional shadows, noise, traffic and wind on parks and open spaces will be minimized as necessary to preserve their utility

Section 3.4 - The Natural Environment

Policy 3.4.1 provides that city-building activities and changes to the built environment, including public works, will be environmentally friendly, based on d) preserving and enhancing the urban forest by:

i. providing suitable growing environments for trees;

ii. increasing tree canopy coverage and diversity, especially of long-lived native and large shade trees; and

iii. regulating the injury and destruction of trees.

Sunlight and Well-being: A Holistic Approach to Thermal Comfort

In recognizing Toronto as a city with a semi-continental climate, with cold winters typically extending three to four months from mid-December to late March, the comfort of public spaces in Toronto is greatly influenced by access to sunlight and protection from wind chill. Beyond seasonal preferences, this consideration is deeply rooted in the understanding that sunlight is indispensable for all living entities to thrive – from animals, plants, and trees to humans. (Please refer to Chapter 2 – Guiding Principles to read more about promoting a life-centric approach)

Sunlight plays a vital role in both plant growth and human health. Plants need sunlight for photosynthesis, a process that helps them produce their own food. This process is essential for the growth, development, and overall health of plants. For humans, sunlight exposure triggers the synthesis of Vitamin D, a nutrient vital for various physiological functions. Vitamin D is essential for calcium metabolism, contributing to bone health, as well as neuromuscular function, ensuring proper nerve signaling and muscle contraction. Additionally, Vitamin D is crucial for immune system function, aiding in defense against infections and diseases.

Access to sunlight has profound implications for mental health. Regular exposure to natural light is known to enhance mood, improve sleep, and reduce the risk of Seasonal Affective Disorder (SAD), a type of depression related to changes in seasons. In urban settings, where built environments can significantly limit access to sunlight, designing public spaces with adequate sun exposure becomes not only a matter of physical health but also of mental well-being.

The intricate relationship between sunlight and the physiological processes of animals, plants and humans emphasizes the scientific foundation of the approach to these Guidelines. By optimizing public spaces for sunlight exposure, we aim to contribute not only to the aesthetic and comfort aspects of urban living but also to the fundamental biological well-being of the diverse life forms inhabiting these spaces.

Pompeii, an ancient Roman city, ingeniously integrated climate-responsive design to enhance outdoor thermal comfort in public spaces. Its streets were strategically aligned to optimize shade and sunlight at optimal times, while porticoes and colonnades along main thoroughfares provided continuous shaded walkways. Public squares utilized light-colored paving stones for cooler communal areas, and scattered fountains throughout the city offered cooling effects through evaporative cooling.

These architectural and urban planning choices collectively mitigated the harsh Mediterranean climate, maintaining comfortable public realms for social and commercial activities.

Flemingdon Park in Toronto with towers in the park, circa 1970s. Photographer: Northway Survey Corporation Ltd.

1.3 HISTORY OF CONSIDERING THERMAL COMFORT IN URBAN PLANNING

The history of thermal comfort in urban planning stretches back over two millennia, illustrating the enduring influence of climatic considerations on architectural and city design. Notably, Vitruvius, an ancient Roman architect, emphasized the significance of adapting architectural layouts to varying climates and latitudes, as detailed in his seminal work, 'The Ten Books on Architecture.' He advocated for site selection that accounted for microclimates, aiming for health-promoting environments free from extreme weather.

Aristotle and other ancient thinkers also recognized the importance of wind direction and exposure in urban siting, suggesting that cities benefit from orientations that protect against harsh weather while promoting beneficial breezes. This ancient wisdom was echoed and expanded upon in modern times by architects like Victor Olgyay in the 1960s, who integrated detailed wind and sun analyses to refine the siting and design of buildings, highlighting a continued reverence for the principles first laid down by Vitruvius.

As urbanization intensified in the 20th century, urban planning shifted towards rapid growth and economic gain, often at the expense of traditional climatic considerations. In Toronto, post-war development was influenced by Le Corbusier's "Tower in the Park" concept, emphasizing large open spaces and access to air and sunlight. The city's ravine system also provided a natural resource for thermal comfort. However, the rise of mechanical heating and cooling systems reduced the focus on designing outdoor spaces for optimal solar orientation and ventilation, while the increase in built up areas throughout the city exacerbated the urban heat island effect.

Today, many urban environments suffer from diminished natural ventilation, lack of comfortable public spaces, and increased heat retention, reflecting a disconnect between traditional climatic design and modern practices. Re-prioritizing climatic considerations in urban planning is essential for restoring balance, enhancing thermal comfort, and fostering more sustainable cities.

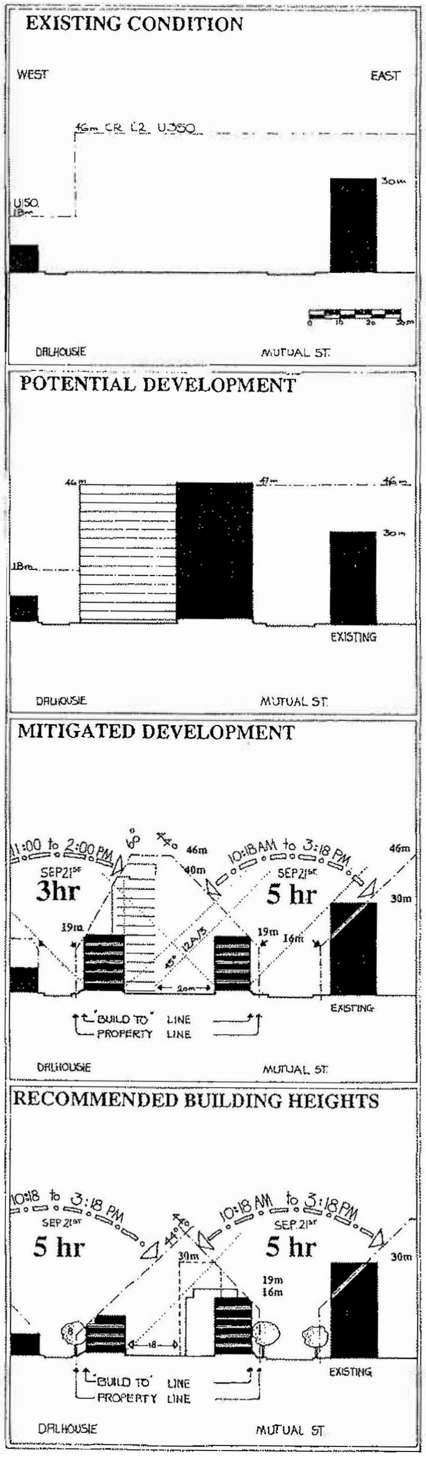


Diagram from Sun, Wind, and Pedestrian Comfort: A Study of Toronto's Central Area, showing recommended building heights for east Downtown future development

1.4 HISTORY OF THERMAL COMFORT IN TORONTO

"Sun, Wind, and Pedestrian Comfort: A Study of Toronto's Central Area." City of Toronto Planning & Development Department, December 1990. Peter Bosselmann, Edward Arens, Klaus Dunker, and Robert Wright.

In response to urbanisation of the railway lands, City Planning commissioned the "Sun, Wind and Pedestrian Comfort" study in 1990, which later became part of the City Plan '91. The Study established performance standards to measure sunlight access in the public realm and pedestrian-level wind comfort. The principles outlined in this groundbreaking Study are still relevant today.

The methodology for assessing thermal comfort as outlined in the Thermal Comfort Guidelines builds on the 1990 study, incorporating updated metrics to quantify comfort and integrating future weather projections.

Within the Bosselmann study, focus is given to wind and sun – which form the principal components influencing thermal comfort in Toronto. These two elements are used to determine quantifiable levels of performance used to assess designs against a common standard and suggest how design can be used to influence the results of such assessments to change their outcome.

Forest and Field Landscape Architecture Inc. "On Shade and Shadow: A Case Study on the Impacts of Overshadowing by Tall Buildings on Toronto's Greenspaces," November 2018.

The separation of shade and shadow as different terms to describe positive and negative categorization of shadows or shade cast by urban massing or vegetation, has been used in Toronto in conjunction with targets for time that direct sunlight is available in public realm spaces. The shade cast by vegetation, or shadows cast from a building both occlude the sun and reduce the effective radiant temperature; however, there is a difference between intentional and unintentional shading. Adherence to this categorization is further complicated due to perceptions of whether shade is beneficial or not, and seasonally these often change. In summer, shade is often beneficial from the harsh sun whereas during winter that shade is detrimental as it reduces temperature at a colder time of year.

As Canada's largest city, Toronto has had the highest number of active cranes in North America during the first part of the 21st century. With this rapid growth, it is important to to ensure that the expansion is balanced by maintaining a high-quality and comfortable public realm.

1.5 STUDY BACKGROUND

These Thermal Comfort Guidelines (the Guidelines) are one of the foundational climate action pieces from the City of Toronto's City Planning Division. The City of Toronto identified the need to update guidance related to thermal comfort in the public realm, through City guidelines, standards and policies.

DIALOG and Buro Happold (Consultant Team) were retained in early 2022 to work with City Planning to create Thermal Comfort Guidelines. The City also engaged a team of professionals from various City Divisions and Agencies including City Planning (Urban Design, Community Planning, and Strategic Initiatives, Policy & Analysis); Environment & Climate; Parks, Forestry and Recreation; Public Health; and Transportation Services to form a Technical Advisory Committee (TAC). The Consultant Team engaged the TAC and other stakeholders, researchers, and academics regularly to report on the work to date and gather input and direction for next steps.

1.6 INTENT OF THE GUIDELINES

The Thermal Comfort Guidelines aim to address thermal comfort in the public realm throughout the year. Importantly, they incorporate future climate projections and considers how the urban environment influences thermal conditions in the surrounding open spaces.

As Canada's largest city, Toronto has led North America in the number of active cranes throughout the early 21st century. The rapid urban growth places significant pressure on the city to preserve the quality and comfort of its public spaces. At the same time, climate change is intensifying these challenges, with extreme cold and heat days becoming more frequent and severe. As more people make Toronto home, the public realm—serving as the citizenry's shared living room, backyard, front yard, and communal space—will play an increasingly crucial role in fostering social connection, leisure, and refuge.

As a matter of public safety and social equity, outdoor public spaces may become places of refuge for people of all ages and abilities, especially during extreme heat events. The design of these spaces, with thermal comfort in mind, is essential to building a resilient city capable of withstanding the growing impact of climate change. While it may be impossible to ensure comfort during all extreme weather conditions, improved design strategies can extend the time during which outdoor spaces remain welcoming and comfortable for all.

1.7 HOW TO USE THE GUIDELINES

The Guidelines encourage the integration of thermal comfort considerations in developments, beginning at early design stages and through the design development. The Guidelines should be read comprehensively and together with other City documents that provide direction on built form and public realm, including the City's Official Plan, city-wide and area-specific guidelines, and other applicable regulations.

This document outlines the overarching guiding principles regarding the City of Toronto's approach to thermal comfort and specifies performance standards that should be targeted in large developments sites larger than 5 hectares, Area Studies, and public realm capital projects. It also introduces a design toolbox to use in the early design stages and for analyzing the impact of new developments on thermal comfort.

The guiding principles, performance metrics, and design toolbox collectively offer guidance intended for use by city staff, landowners, developers, and their consultants in their planning and design frameworks.

1.8 ORGANIZATION OF THE GUIDELINES

The document includes guidelines for thermal comfort under the following 4 headings:

Chapter 1 I Introduction

Introduces Thermal Comfort, underscores its importance and offers an overview of the study's background, objectives, and intended application.

Chapter 2 I Guiding Principles

Provides overarching principles that set a strong foundation to shape our approach to thermal comfort.

Chapter 3 I Performance Metrics

Provides information on weather data to be used in the thermal comfort study, including historic data and future climate projection. Defines comfort in the Toronto context using the Universal Thermal Climate Index (UTCI) and sets out thermal comfort targets in various seasons.

Chapter 4 I Design Toolbox

Offers a set of design tools that can be used both at the outset of the project to design new developments and capital projects with thermal comfort in mind and as a mitigation strategy to offset any potential negative impact a development might have on thermal comfort.

The urban heat island (UHI) effect in Toronto is uniquely influenced by the city's proximity to Lake Ontario. This gives rise to "Coastal" and "Inland" climates, the main differences between the two being the wind profile, and humidity levels changing due to proximity with the shoreline.

2.0 Guiding Principles

2.1 Apply An Equity Lens

2.2 Adopt A Life-Centric Approach

2.3 Develop Toronto-specific Approaches

2.4 Achieve Seasonal Shade and Comfort

2.5 Prioritize Shoulder Seasons

2.6 Focus On People's Experiences Using Different Modes Of Transportation

A sunny day at Nathan Philips Square.

In undertaking the Thermal Comfort Study, a strong foundation was established to shape the approach and decision-making processes. Extensive engagement took place with the City's Technical Advisory Committee (TAC), various internal and external stakeholders, Indigenous communities, the development industry, researchers, academics, and the broader public to gather valuable feedback. This collaborative effort led to the identification of key emerging themes, which shaped the fundamental principles guiding the development of the final guidelines. These principles served as a compass, steering the efforts toward creating a comprehensive and effective study.

Technical Advisory Committee (TAC)

The Technical Advisory Committee (TAC), comprised of professionals from City Planning, Environment & Climate, Parks, Forestry and Recreation, Public Health, and Transportation Services, was formed at the project's initiation. The TAC received updates on project progress and provided guidance for the subsequent steps in the process. This collaborative engagement ensured ongoing input from diverse perspectives throughout the project.

2.1 APPLY AN EQUITY LENS.

Prioritize vulnerable populations that are disproportionately affected by extreme climatic conditions, including children, seniors, low-income Torontonians, and those experiencing homelessness. Focus on the areas and populations that are disadvantaged with respect to access to high-quality public space. These areas often bear the brunt of climatic discomfort and lack features to mitigate its effects.

2.2 ADOPT A LIFE-CENTRIC APPROACH.

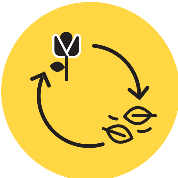
Consider all living beings – humans, animals, insects, plants, and more. Enhancing spaces for biodiversity and ecological balance ultimately fosters a comfortable and harmonious living environment for humans. This principle underscores a comprehensive perspective, recognizing the interconnectedness of all living things. Trees and vegetation, in particular, play a crucial role in moderating the climate. Therefore, by creating an environment where trees and vegetation can access sunlight and maximize their growth, we contribute to the well-being of all living things.

2.3 DEVELOP TORONTO-SPECIFIC APPROACHES.

Consider Toronto's unique physical characteristics such as topography, diversity of built form, anticipated growth, ravine networks, street patterns, and proximity to Lake Ontario and extreme wind conditions especially during winter. Focus on designing for comfort all year round, taking into consideration Toronto's climate of both extreme cold and extreme heat.

2.4 ACHIEVE SEASONAL SHADE & COMFORT.

Prioritize flexibility and adaptability in the design of outdoor spaces to ensure seasonal comfort. This involves providing options for people to choose from based on their individual needs and preferences. Strategically design outdoor areas to offer access to sunlight during colder months and ample shade during warmer months. Use elements like deciduous trees, adjustable shading structures, and movable features to optimize thermal comfort throughout the year. Additionally, incorporate features that can block wind in colder months and allow cool breezes in warmer months. This can be achieved by integrating windbreaks into design features such as walls and vegetation that both mitigate wind effects and promote airflow when needed.



2.5 PRIORITIZE SHOULDER SEASONS.

Focus on extending outdoor comfort during the spring and fall, also known as “shoulder seasons”. Toronto has brief spring and fall seasons, and by enhancing thermal comfort during these months we extend the opportunity to comfortably spend time outdoors in public space. Prioritize making outdoor spaces more comfortable during the shoulder seasons, recognizing that these transitional periods offer the greatest potential for improvement.

2.6 FOCUS ON PEOPLE'S EXPERIENCES USING DIFFERENT MODES OF TRANSPORTATION.

The study should consider the comfort and well-being of pedestrians, cyclists, public transit users, and motorists alike, recognizing that each group has unique needs and sensitivities to thermal comfort. This principle encourages a comprehensive approach to designing urban environments that prioritize the comfort and safety of all individuals during their journeys, using different modes of transportation.

Shade vs. Shadow

The report *On Shade and Shadow* presents findings aimed at clarifying apparently contradictory existing policies for the City of Toronto as they relate to access to daylight, prevention of overshadowing green spaces by buildings, and the promotion of shade. It further explains that the terminology used in policy statements should clearly differentiate between the monolithic building shadow (the overshadowing created by buildings) and human scale and seasonable shade (health promotive shade created by tree canopy and other human-scaled park design elements).

It is to be noted that overshadowing has implications for the longevity and health of the urban forest, particularly in high density areas. Trees and vegetation cannot thrive without adequate access to sunlight and urban trees are already stressed by growth pressures.

** On Shade and Shadow: A case study on the impacts of overshadowing by tall buildings on Toronto’s greenspaces. A report prepared for the Shade Policy Committee (SPC), Ultraviolet Radiation Working Group (UVRWG) of the Toronto Cancer Prevention Coalition (TCPC) by Forest and Field Landscape Architecture Inc.*

3.0 Performance Metrics

3.1 Quantifying Thermal Comfort

3.2 Related Terms of Reference and Guidance


A thermally comfortable open space is more inviting to the community.

Achieving optimal thermal comfort within an urban environment is a challenge that requires a comprehensive understanding of various influencing factors. This section delves into the intricacies of calculating thermal comfort in Toronto, recognizing that it is a dynamic and complex phenomenon shaped by numerous elements. The metrics outlined here define the amount of thermal comfort to be targeted, to provide a foundation for informed decision-making and sustainable urban planning.

From meteorological conditions to architectural and landscape design, and from vegetation cover to human activities, each factor plays a crucial role in shaping the thermal experience of urban residents. Through a thorough exploration of these components, policymakers, urban planners, and stakeholders can be equipped with the insights necessary to create environments that prioritize the well-being of the community, promoting thermal comfort as an integral aspect of Toronto's ongoing livability.

Full details on the methodology used to calculate the metrics outlined in this section are given in Appendix B - How to Conduct Thermal Comfort Study.

3.1 QUANTIFYING THERMAL COMFORT

Striking a balance between simplicity and preserving the big picture is essential when quantifying thermal comfort, as it depends on the environment, climatic conditions, and the individual's experience. Additionally, these factors will vary over time, with the preceding conditions also influencing how an environment feels because of preceding conditions that may have changed that environment (e.g., healthy green grass will provide more cooling before a heat wave than will parched brown turf). Also, psychologically, and physiologically, when people have experienced a long hot period, a sudden cold period may be less pleasant than experiencing a gradual transition from fall to a colder winter.

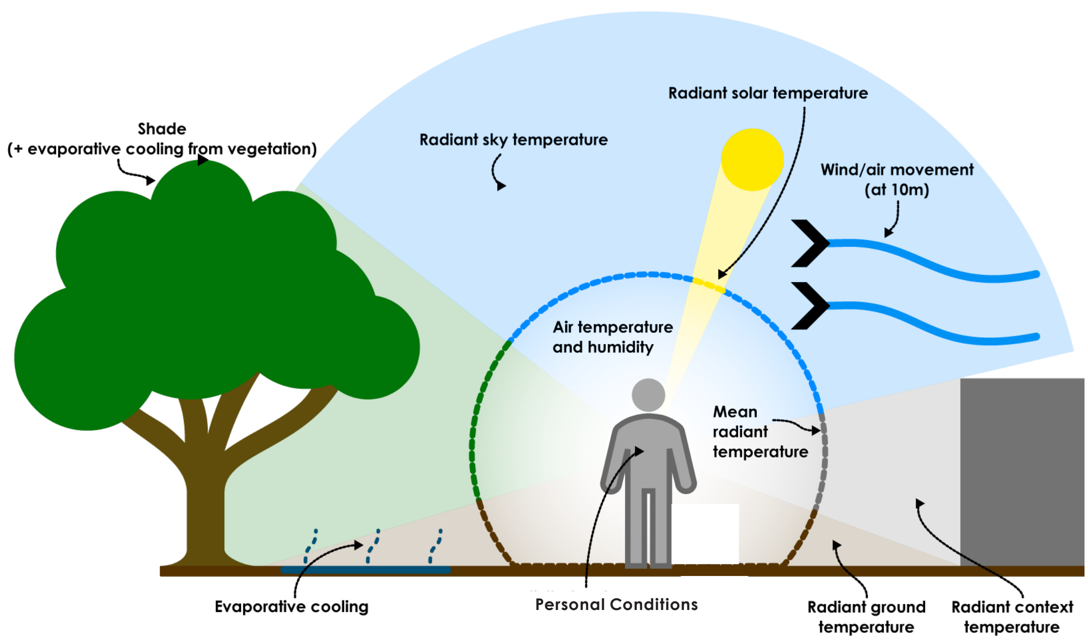
Several methods of quantifying thermal comfort are available, and for Toronto, the Universal Thermal Climate Index (UTCI) is used due to its widespread applicability, familiarity among urban designers globally and simplicity in summarizing thermal conditions from a limited number of inputs.

UTCI is represented by an equivalent temperature scale for quantifying the amount of thermal comfort a person experiences, based on four factors:

- **Air temperature** – Specifically, the temperature of air that is shielded from external radiant heat sources, also known as the dry-bulb temperature;
- **Relative humidity** – The amount of moisture in the air as a percentage of the total possible amount it could hold;
- **Wind speed** – How fast air is moving; and
- **Radiant temperature** – The overall effects of surrounding surface temperatures and sources of radiant heat (such as the sun and warm/cold ground).

These factors do not account for every influencing factor of thermal comfort but can indicate the likelihood an individual would feel too-cold, comfortable, or too-hot in an environment described by them. UTCI may also be described as a ‘feels-like‘ temperature, which corresponds with a categorical scale across ranges of heat and cold stress.

UTCI (°C) range and thermal stress category
>46° Extreme heat stress
38° to 46° Very strong heat stress
32° to 38° Strong heat stress
26° to 32° Moderate heat stress
9° to 26° No thermal stress
0° to 9° Slight cold stress
-13° to 0° Moderate cold stress
-27° to -13° Strong cold stress
-40° to -27° Very strong cold stress
<-40° Extreme cold stress



Universal Thermal Climate Index (UTCI) is a method of quantifying thermal comfort based on air temperature, radiant temperature, air speed, and relative humidity

3.1.1 Limits of applicability

Assessing comfort based on one factor alone often gives an inaccurate understanding of the overall conditions in an outdoor environment. UTCI is an equivalent temperature model, based on a more complex model of human thermoregulation, where the thermal sensation of an individual is approximated based on a series of predefined assumptions. Each individual experiences their environment in a unique way to other individuals, so the use of a universal metric is needed – even if the definition of it requires certain assumptions around their physical condition.

UTCI assumes that the individual is 75 kg and 1.75 m tall, wearing clothing which varies between light summer clothes (shorts and t-shirt) and light polar clothes (insulated jacket and layered thermals). Additionally, the person is also moving at 4 km/h with their metabolic rate reflecting this. These assumptions are broadly representative of most people's experience in an outdoor environment, though changes in these (such as undertaking exercise, which would increase our own temperature) would of course change our feeling of what comfortable is. Age, lived experiences, underlying heath conditions, ability, surroundings and even disposition can all impact how we thermally feel in a space, and consideration of these is something which should be given when designing an outdoor environment in conjunction with the quantification of comfort using well-established metrics.

The model for calculating UTCI was created in European COST[1] Action 730 and it has been tested for its suitability to conditions within the northern hemisphere. In comparison with other comfort methodologies the UTCI tends to be more conservative for colder conditions and is considered well-suited for the long winter experience in Toronto.

3.1.2 Toronto specific comfort criteria

The weather is infinitely variable. Within Toronto alone, there are areas that experience certain microclimatic phenomena more than others, and due to its location on the shoreline of Lake Ontario the effects of water on the local microclimate can be felt with proximity to the shoreline. A thermal boundary is used based on the City of Toronto Pedestrian Level Wind Study Terms of Reference Guide.

Additionally, the way individuals react to weather varies, with a 30°C air temperature perceived differently based on individuals' lived experiences, and other factors like the time of year that condition is experienced playing a part in the overall thermal comfort expected by an individual. Given that Toronto is a diverse city, with over 50% of its population born outside of Canada, and known as a city of immigrants, these perceptions can be particularly varied. A Toronto specific set of target conditions is given here which aims to supplement the UTCI comfort-criteria categories and make it more specific to the unique Toronto climate.

Dynamic Comfort Limits

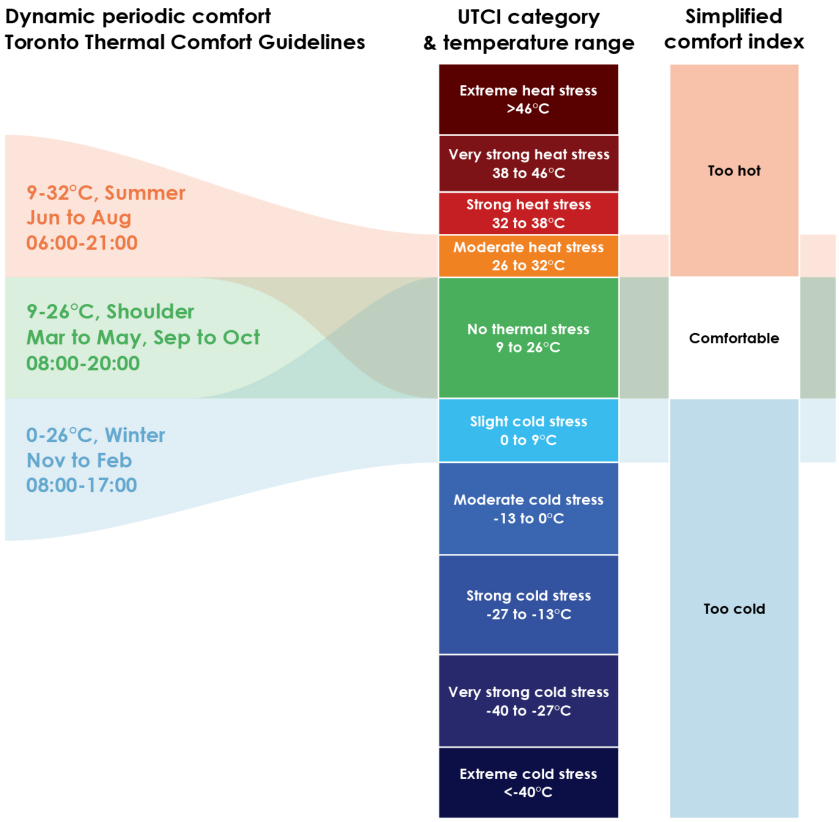
Toronto has a semi-continental climate, without a dry season and with warm/hot summers. As a result of global climate change, Toronto's historical climate record plus climate projections have become more relevant for longer-term infrastructure planning. Due to the annual variation in temperatures, Toronto residents are accustomed to cold winters and warm summers. According to the UTCI scale, conditions can vary between varying levels of heat and cold stress, though inhabitants of Toronto would typically have the means to manage their comfort when subjected to moderate levels of thermal stress as they change throughout the year. For these reasons, the thermal comfort targets given here include UTCI values within those comfort bands at different times of the year.

[1] The COST (European Cooperation in Science and Technology) is an EU-funded programme that enables researchers to set up their interdisciplinary research networks in Europe and beyond. The International Society of Biometeorology established a Commission on UTCI and through COST 730 Action 730 developed the Universal Thermal Climate Index.

During summer months, the number of daylight hours is greater, and outdoor spaces are more likely to be used into the evenings than during winter, when it is darker earlier and colder too. The following ranges of what is considered comfortable based on UTCI equivalent temperature, and the times in which that comfort should be maximized as part of the design of outdoor environments are:

Year period	Time period	Acceptable UTCI temperature range
March – May	08:00 – 20:00	9°C to 26°C (inclusive)
June – August	06:00 – 21:00	9°C to 32°C (inclusive)
Sept – Oct	08:00 – 20:00	9°C to 26°C (inclusive)
Nov – Feb	08:00 – 17:00	0°C to 26°C (inclusive)

Dynamic periodic comfort bands applied in the Toronto Thermal Comfort Guidelines



UTCI thermal stress categories related to Toronto dynamic thermal comfort targets

The intent of the ranges of thermal comfort applied at separate times throughout the year is to make the quantification of overall comfort for a typical year in Toronto achievable.

The example below shows how varying these ranges can influence better design decisions.

Example:

Within Toronto, applying a single target UTCI temperature range of 9°C to 26°C (inclusive) across an entire year, and including all hours of the day would mean that 32.9% of all hours would be considered comfortable. If only the times between sunrise and sunset are considered, then this reduces to 17.4%. This is due to hot conditions and solar exposure in the summer increasing the UTCI temperature and reducing the number of hours felt 'comfortable.'

By being specific with the times and conditions in which 'comfort' is achieved, the impact of design decisions can be made much clearer and offer designers the opportunity to enhance the thermal environment.

For Toronto, the following outlines the targets for thermal comfort achievement, within the time periods and UTCI categories associated with those periods. These are what new developments aim to achieve to show best practice design against target levels of thermal comfort within the city.

- **>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 (the combined time periods and temperature ranges for seasonal comfort)

Related Precedent Studies

The pursuit of thermal comfort is a fundamental aspect of human well-being and productivity. It is a critical factor in the design and operation of buildings, urban spaces, and cities at large. The purpose of these listed previous works varies, though through quantifying the impact of our treatment of the environment we can determine how to improve that environment in Toronto. The following precedents have been reviewed for preparation of these guidelines:

- RWDI. “Thermal Comfort Guidelines for Developments in the City of London,” December 2020.
- City of Boston. “Heat Resilience Solutions for Boston: Final Report.” City of Boston, April 2022.
- Perkins + Will. “TOcore: Building for Liveability - Recommendations Report,” April 2018.
- City of Toronto. “Christie’s Urban Design and Streetscape Guidelines.” City of Toronto, 2020.
- Los Angeles County Chief Sustainability Office. “Our County: Los Angeles Countywide Sustainability Plan.” Los Angeles County Chief Sustainability Office, August 2019.
- Health Canada. “Reducing Urban Heat Islands to Protect Health in Canada: An Introduction for Public Health Professionals.” Health Canada, March 2020.
- Ilousi Kyriaki, Kerexeta Iturritxa Oihana, Gourgoukis Dimitrios, Tryfonidou Aikaterini, Vasilakis Fotis, and Christophoridou Theodora. “Rethink Athens: Towards a New City Centre: Description Report of Overall Proposal.” Onassis Foundation, 2013.

The target values are based on studies of a series of test sites around Toronto, representative of different urban context, heights, topography and location. Using these test sites, sensitivity assessments were used to ascertain targets that are both challenging to achieve and attainable.

If a site is vacant (e.g., a surface parking lot), achieving an improvement in thermal comfort over its previously undeveloped state may not be feasible. However, such sites should still aim to meet the thermal comfort targets outlined in this document. For redeveloped sites, meeting the defined targets is essential, but redevelopment should also avoid negatively impacting existing thermal comfort conditions within the site and the surrounding area. While the goal for any development should be a net positive improvement in thermal comfort, minor reductions may occur in some areas. Minimizing these reductions is crucial, with a 5% threshold indicating where such impacts happen.

Additionally, when a proposed development is large enough to require a thermal comfort assessment, it is important to identify priority sites and areas needing special attention. This includes public realm features such as seating areas and playgrounds, especially if they will be used for prolonged periods or during challenging times, like the height of summer and depth of winter.

A specific location carefully chosen within an assessed region might achieve the targets while others may fail to do so. At least half of the area in the thermal comfort study should achieve the thermal comfort performance targets. The areas achieving those targets should be prioritized for spaces that are designated as being in the public realm like parks, open spaces, streets and mid-block connections.

3.2 RELATED TERMS OF REFERENCE AND GUIDANCE

The Toronto Thermal Comfort Guidelines align with the existing guidance and terms of reference required for development application submissions within the City of Toronto. This alignment is particularly crucial for the following main documents:

3.2.1 Toronto Green Standard Version 4

Toronto Green Standard Version 4 requires that 75% of a site's non-roof hardscape be treated to mitigate the impacts of heat. Options to treat the site include cool paving materials and shade from tree canopy as well as architectural structures. The impact of such measures can be determined by a thermal comfort study to review its feasibility.

Deciduous trees are suggested as a suitable means of dynamic shading. Sufficient soil volume is required for deciduous trees to reach their full growth potential and in turn maximize the cooling effect. Evergreen trees are also beneficial as are other forms of vegetation as they also provide minor cooling effects through evapotranspiration and wind abatement when planted effectively. Vegetation's performance varies from its initial planting to its established condition. The expectations of a specific level of impact of such a tree would need to be managed so that it develops over time.

Hard landscape options can be used instead to be effective from day one; however, dynamic behaviour will come with a cost. More shade during summer is encouraged as heat stress becomes more common with a warming climate and aligns with the TGS requirements for tree planting on-site, in the public realm, and targets a 40% tree canopy cover across the landscape, including streets, parks, and open spaces.

This standard also closely relates to the 'Landscape and Planting Plan', 'Soil Volume Plan', and 'Concept Site and Landscape Plan' that are part of development application requirements which requires collating information on the hard and soft landscaping of a site, including vegetation details.

3.2.2 Pedestrian Level Wind Study

Using the "Pedestrian Level Wind Study: Terms of Reference Guide" (City of Toronto: Urban Design & City Planning and RWDI, June 2022), the methodology outlined in this guide focuses on the pedestrian safety aspects of wind and wind comfort around the city.

The terms of reference align with the Toronto Thermal Comfort Guidelines, particularly these following aspects:

- The use of two wind frequency data zones (inland and coastal, representative of different wind conditions across the city) has been implemented.
- The size of the domains under study is the same, so that effects from upwind massing is also included in any thermal comfort analysis using Computational Fluid Dynamics (CFD).
- The information provided by wind studies can be used in the calculation of UTCI, providing directional wind speed which can be used to approximate the air movement component of this thermal comfort metric.
- Mitigations enhancing wind conditions during winter as suggested in the Pedestrian Level Wind Terms of Reference are likely to help areas that require shelter and improve temperatures.
- The use of landscape/softscape to mitigate wind speeds is also likely to be beneficial during winter months, and providing shade in the summer. This likely applies to hard landscapes, such as canopies, as well.

3.2.3 Sun/Shadow Study

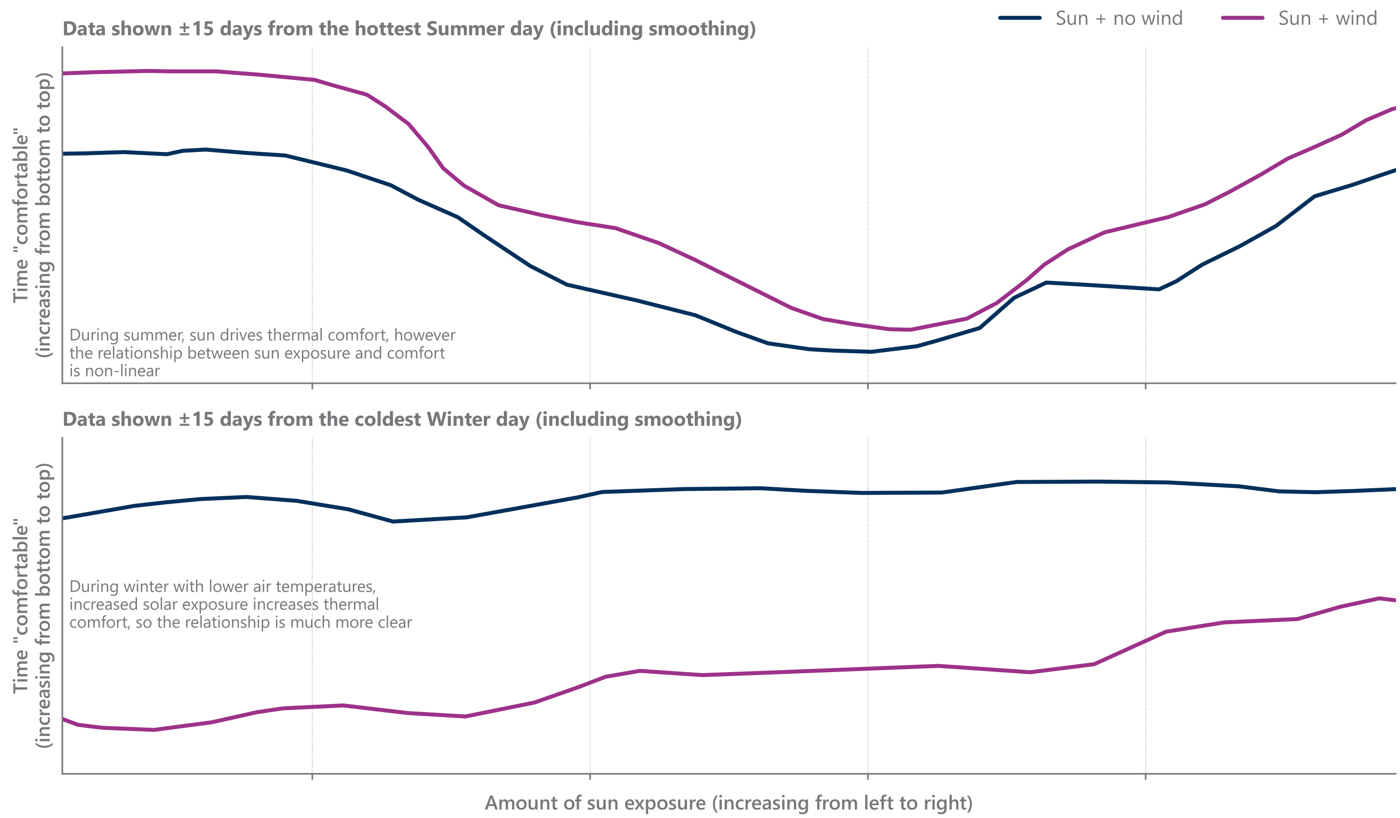
The City's solar access policies are rooted in the analysis and recommendations from the "Sun, Wind, and Pedestrian Comfort Study" (Bosselman et al, 1990), City Plan '91 and reflected within the Sun/Shadow Study Terms of Reference. This establishes the need for sunlight access, particularly in parks and on streets and open spaces, and can be used to show areas subject to higher and lower levels of direct sunlight.

The periods of the year used in the thermal comfort targets given here (March – May, June – August, September – October, November – February) align with the study months within The Sun/Shadow Study. Where a sun/shadow study has been undertaken, results can be indicative of areas which may be subject to greater heat stress during summer (without shade or shelter from the sun) or cold stress during the winter (where they are in constant shade with no solar exposure to raise UTCI temperatures). However, relating sun exposure to thermal comfort is not straightforward, as comfort involves many complex factors.

As an example, the charts on Page 24 show how by relating the number of seconds of sunlight in a day (based on sunrise and sunset times) to number of seconds achieving the target levels of thermal comfort for the period specified, using the ranges described earlier in this chapter. These demonstrate that no clear relationship exists between sunlight and comfort throughout the year; however, within specific seasons, this relationship becomes more apparent. During a summer month (July), the greater the amount of sun exposure, the less thermal comfort can be expected; whereas during a winter month (December) thermal comfort is more likely with greater amounts of time exposed to sun.

In warmer months, there is a greater risk of heat stress due to increased hours of direct sunlight.

The proportion of sky visible from the ground impacts thermal comfort by influencing exposure to direct sunlight during the day and to cooling from the night sky in the evening.



Relationship between sun-exposure and thermal comfort (within specific time periods)

While the Sun/Shadow Study aims to increase or at least maintain access to sunlight, a thermal comfort assessment might suggest that sheltering from the sun would result in a positive impact on an occupant of a space due to reductions in heat stress (particularly during summer). Over winter months, the opposite can be true, with more sun resulting in less cold stress and increasing comfort overall.

The thermal comfort guidelines and Sun/Shadow Study may sometimes exist in juxtaposition to each other. Where this occurs, the provision of shade in localized areas (e.g., from shading structures or vegetation) is more applicable as this still allows the wider public realm areas to achieve the number of hours of solar exposure specified in the Sun/ Shadow Study terms of reference, while also accounting for the needs of individuals to take shelter from the sun during periods at risk of heat stress.

For Toronto, the following relationship between sunlight access and thermal comfort may be assumed; however, detailed thermal comfort analysis is needed to understand the extent of these assumptions in a specific area:

- In warmer months, there is a greater risk of heat stress due to increased hours of direct sunlight.
- In colder months, there is a greater risk of cold stress due to reduced hours of direct sunlight.
- Areas subject to more sunlight are likely to be slightly cooler at night than more shaded areas as they will also have a higher proportion of sky visibility.
- Areas subject to shade in the morning, but not the evening would also be sheltered from winds prevailing from the east.
- Areas subject to shade in the evening, but not the morning would also be sheltered from winds prevailing from the west.

4.0 Design Toolbox

4.1 Design for Thermal Comfort: Overall Strategy

4.2 Design Toolbox: Design at the Neighbourhood Scale

4.3 Design Toolbox: Design at the Block scale

4.4 Design Toolbox: Public Realm

4.5 Design Toolbox: Buildings

4.1 DESIGN FOR THERMAL COMFORT: OVERALL STRATEGY

Designing with thermal comfort in mind should be a fundamental consideration from the outset of any development project. By implementing the design strategies outlined in this section, we, as a city, can proactively create public spaces that prioritize the physical and mental well-being of those who live, work, learn, play in, and visit the city, particularly as the climate changes. The guidelines emphasize the importance of integrating thermal comfort considerations into the core fabric of a project's planning and design strategy and strongly discourage addressing thermal comfort as a secondary consideration. The following sections outline the key steps in applying the thermal comfort lens to projects.

Within Toronto, two distinct climates emerge due to proximity to Lake Ontario: the 'Waterfront' area, which is cooler and breezier, and the 'Inland' area, which is warmer and less influenced by the lake.

4.1.1 Understand What Impacts Thermal Comfort:

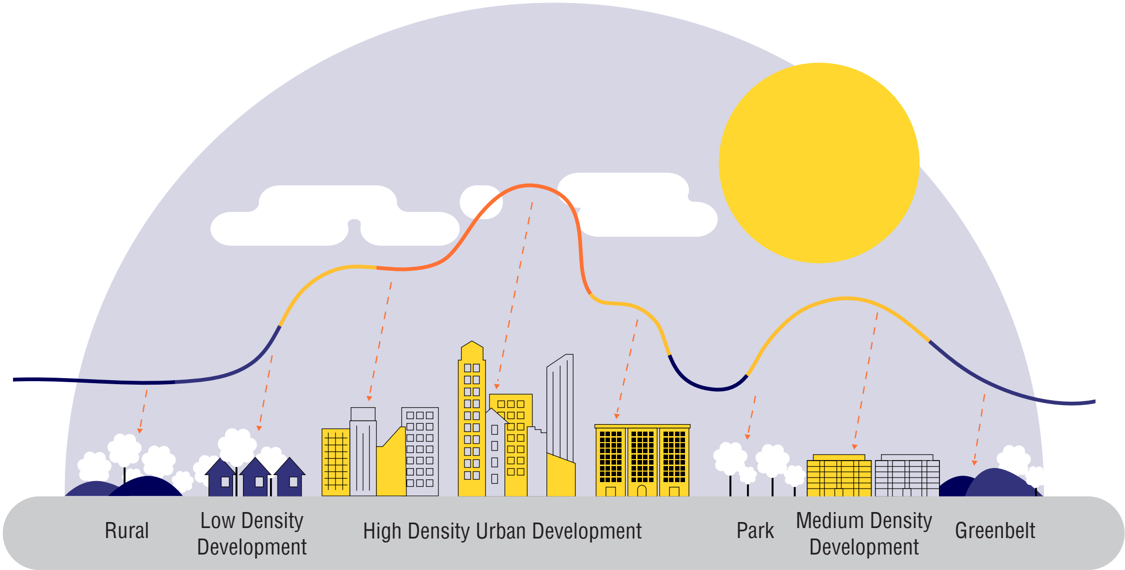
As described in Chapter 3, thermal comfort is mainly influenced by a combination of air temperature, radiant temperature, humidity, and wind speed, though other factors can influence how a person feels. The built environment, in particular, can impact wind speed and radiant temperature. With every design decision, keep in mind how the decision impacts thermal comfort's key influencing factors, and how those design features work with together or conflict to create comfortable environments.

4.1.2 Understand the Climatic Conditions:

Climatic conditions, including prevailing winds, access to sunlight and shade, play pivotal roles in shaping the microclimate of a given location.

A. Toronto Climate Context:

Toronto has a semi-continental climate, with warm, humid summers and cold winters, moderated by Lake Ontario on the southern boundary of the city. Spring and autumn (shoulder seasons) are shorter than summer and winter, featuring varied weather with alternating periods of dry, sunny weather and rain. The majority of days in the spring and autumn are sunny and pleasant, with moderate rather than cold temperatures. Nights are cool, but frosts are rare. Winters in Toronto are cold, and snowfalls are frequent. The high annual and in-season variability of thermal conditions and significant freeze-thaw cycles pose challenges to maintaining and operating the public realm. The shift toward a warmer global climate on average has been accompanied by an increase in warm extremes and a decrease in cold extremes.



Urban Heat Island Effect

B. Urban Heat Island Effect:

The Urban Heat Island (UHI) effect refers to the phenomenon where urban areas experience higher temperatures than their rural surroundings. This effect results primarily from the absorption and retention of heat by buildings, roads, and other structures, which replace natural vegetation and soil that would typically cool the area through shading and evapotranspiration. UHI is intensified by human activities such as transportation, energy usage, and industrial processes, which release additional heat.

In Toronto, the urban heat island (UHI) effect is uniquely influenced by the city's proximity to Lake Ontario, where temperature and humidity can be moderated by the lake and land breeze mesoscale phenomena. This creates distinct "Waterfront" and "Inland" climates within the city, with the main differences being changes in wind profile and humidity levels. Proximity to the shoreline leads to windier and more humid conditions, while inland areas tend to be warmer and drier. Wind plays a significant role in the calculation of external thermal comfort – particularly in cooler climates like Toronto, where it can alleviate heat in warmer seasons but also contributes to wind chill in colder weather.

C. Projected Climatic Conditions

The weather data used to create the baseline climate for thermal comfort assessment in Toronto is based on projections representing the region's climate in 2050. These projections reflect typical future conditions rather than extremes, so they cannot predict extreme weather events like heatwaves. However, they do account for trends showing an increase in average temperature.

For both coastal and inland conditions, the forecast data indicates that the annual average air temperature will be 2.8°C higher than currently experienced in Toronto. This increase varies throughout the year, with the most significant changes occurring during winter and summer.

4.1.3 Analyze the Development Area’s Microclimate:

Every site has its unique microclimate, influenced by factors such as proximity to water bodies, topography, built environment, and vegetation. Understanding these microclimatic conditions is vital for designing spaces that are more comfortable. The existing and planned infrastructure and built form around the site can offer clues about potential thermal comfort challenges or opportunities. Consider the unique features of the development context such as:

A. Wind Direction: Wind can significantly affect thermal comfort, especially in colder months. Understanding the prevailing wind directions and velocities throughout the year helps in designing buildings and landscape elements that can serve as windbreaks or, conversely, enhance natural ventilation during warmer months by channeling the prevailing winds of that season.

B. Sunlight Analysis: Understanding the site's exposure to sunlight throughout the year is essential. This involves studying the sun's location and trajectory, considering the surrounding buildings and natural features that might cast shadows, and assessing how these factors change with the seasons. A site with limited sun exposure in colder months could be less comfortable compared to one that receives ample sunlight; it might require different strategies to improve comfort conditions.

C. Land cover: The type of land cover in a specific area can significantly impact the thermal comfort of that site. Different materials, such as asphalt, grass, water, and concrete, have distinct thermal properties that directly influence the temperature of the surroundings. Urban areas with a predominance of asphalt and concrete can contribute to the urban heat island effect, where temperatures are higher than in surrounding rural or built-up areas. This effect is due to the increased heat absorption, storage, and reduced natural cooling provided by vegetation. Conversely, lands covered with grass and vegetation absorb less heat in comparison and can provide a cooler and more comfortable environment during the summer.

Toronto’s future weather projection

According to the Pacific Climate Impacts Consortium (PCIC), Toronto's air temperatures in 2050 are projected to increase as follows:

Seasonal Temperature Changes:

- Winter: +3.1°C
- Summer: +2.8°C
- Shoulder Seasons (Spring and Fall): +2.6°C

Current vs. Forecast Average Temperatures

To put this in context, it is helpful to compare the average temperatures from a typical current year with the forecast datasets:

Inland:

- Current average: 9.3°C
- 2050s average: 11.5°C

Waterfront:

- Current average: 8.8°C
- 2050s average: 12.1°C

An update to climate projections for Toronto will be made in 2024 in collaboration between the City of Toronto and the Toronto and Region Conservation Authority (TRCA).

Thermal Comfort in Employment Areas

In Toronto’s Employment Areas, characterized by industrial buildings, dominance of asphalt and concrete, and limited greenery, several challenges to thermal comfort arise. Impermeable structures and large expanses of parking lots in industrial areas significantly contribute to heat absorption, exacerbating the urban heat island effect.

Trees, as part of Toronto's urban forest, are essential for keeping the city cool and comfortable. They provide shade and release moisture, creating a natural cooling effect.

D. Proximity to Temperature Moderating Features:

The design of urban spaces adjacent to water bodies or green features influences the creation of microclimates, impacting the thermal experience of these areas.

- Bodies of water: Water has a unique ability to moderate temperatures. Bodies of water, due to their high heat capacity, absorb and release heat more slowly than land surfaces. Areas adjacent to water bodies, such as lakes or ponds, exhibit a moderating effect on temperatures, contributing to a more stable and pleasant thermal environment.
- Trees: Trees represent one of the most effective ways to keep Toronto healthier and more thermally comfortable. Urban forests and ravines contribute to thermal comfort through shading. Trees provide shade—deciduous trees, for instance, offer dynamic shade (providing shade in the summer while allowing sunlight in the winter)—reducing the direct impact of sunlight on surfaces during the summer. Trees also release moisture through a process called evapotranspiration, which can have a cooling effect on the surrounding air.

Urban development shapes microclimates by affecting wind patterns, sunlight, and temperature.

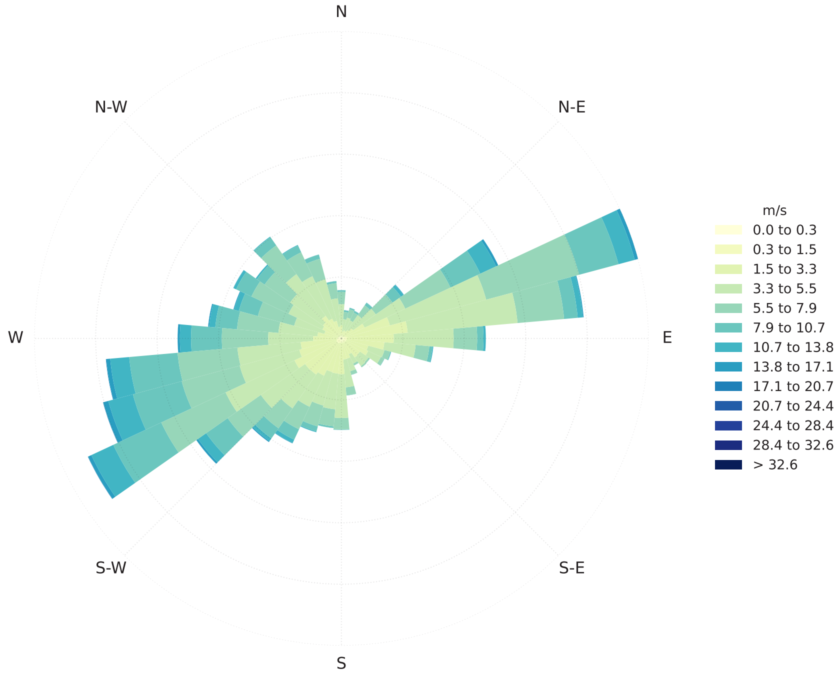
E. Urban Development

Urban development plays a crucial role in shaping an area's microclimate by influencing wind patterns, access to sunlight, and temperature regulation. High-density developments with tall buildings can create wind tunnels that accelerate wind speeds, while the strategic placement of buildings and landscape features can act as windbreaks, improving thermal comfort. The height and arrangement of buildings also affect sunlight penetration, with tall structures casting long shadows that reduce sunlight exposure. Thoughtful urban planning that ensures adequate spacing and optimizes building orientation can maximize sunlight, enhancing natural light and warmth.

However, urban development often leads to the removal of vegetation, including trees, and eliminates permeable spaces necessary for planting new trees, which are vital for natural cooling. Additionally, extensive use of concrete and asphalt can exacerbate the urban heat island effect, but incorporating green space, trees, green roofs, green walls, and permeable surfaces can help mitigate this, promoting natural cooling and ventilation. Understanding these impacts is essential for creating sustainable and comfortable urban environments.

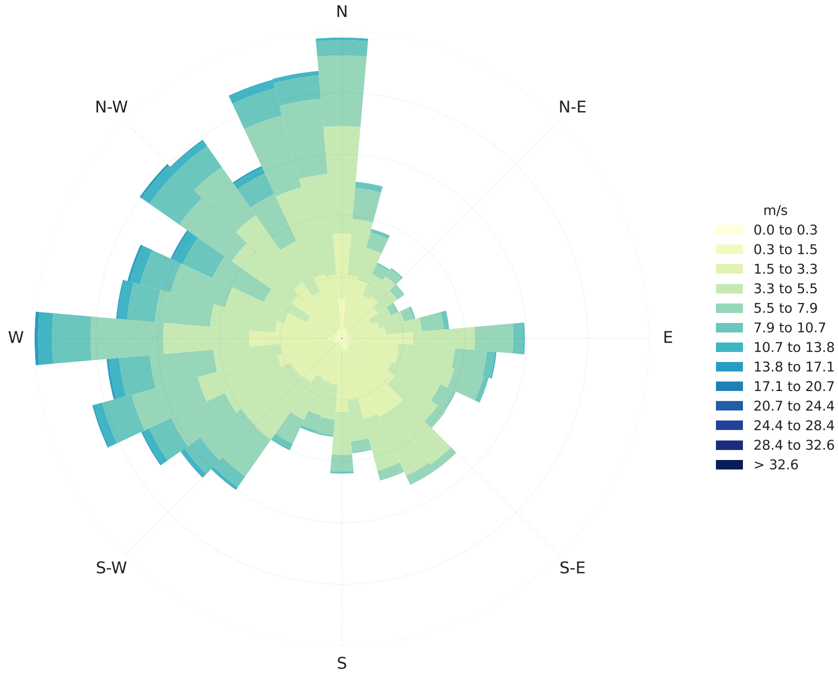
Waterfront Windrose

1998-01-01 to 2017-12-31



Inland Windrose

1998-01-01 to 2017-12-31

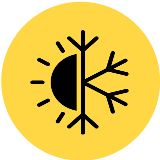


Typical wind direction in Toronto shown through windrose diagrams for Waterfront and Inland climatic conditions.

4.1.4 Understand Human Activity Patterns:

Understanding how people use or are likely to use the space can also guide design decisions and the prioritization of interventions. Areas with high pedestrian traffic might require different considerations compared to less frequented spaces.

A. Identifying Key Activity Areas: Start by identifying where the most significant human activities are likely to occur within the development and surrounding area. This could include areas with high foot traffic, such as busy sidewalks and areas for socializing, recreation, commerce, or transit. Understanding these activity hubs allows for a more targeted approach.



B. Design for Year-Round Activities: Recognize that activity patterns may change with the seasons. Spaces that are popular in summer, like outdoor plazas, might be less frequented in winter. Designing these spaces to be adaptable, such as converting a summer plaza into a winter skating rink, can keep the area lively year-round.

C. Design for Active and Passive Uses: When designing urban spaces, considering the level of activity, such as sitting, standing, walking, in relation to thermal comfort, is essential for creating environments that are both functional and comfortable throughout the year. Active areas, like sports fields and jogging tracks, require cooling strategies such as opportunities for shade and exposure to wind to counteract the increased body heat generated by physical activities. Conversely, passive areas, such as seating zones and gardens, benefit from strategies that provide a balanced access to both sunlight and shade.

Understanding where people gather helps prioritize areas for enhanced thermal comfort.

Toronto Parkland Strategy

The Parkland Strategy provides the City with a long-term vision and framework for the enhancement of Toronto's parks system through the creation of new parks, the expansion of existing parks, and the provision of improved access to them. The Parkland Strategy is a planning framework that includes the Park Catchment methodology, Parks Planning Priorities, and Acquisition Prioritization framework, and that can be implemented through Development Review and Planning Studies.

Toronto Ravine Strategy

The Toronto Ravine Strategy document outlines a comprehensive approach to managing and enhancing Toronto's extensive network of ravines with a focus on balancing protection and sustainable use. It sets out five guiding principles: Protect, Invest, Connect, Partner, and Celebrate, each with specific actions for implementation.

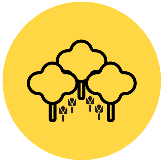
Toronto Strategic Forest Management Plan

The Strategic Forest Management Plan is a functional document that provides regional context, outlines current practices, and defines future direction for local urban forest management. This Plan provides direction for forest management over the next 10 years through the vision, strategic goals and a series of actions that address the key management challenges identified for Toronto's urban forest.

4.1.5 Apply an Equity Lens:

As emphasized in Chapter 2 – Guiding Principles, the intent of the guidelines is that focused attention should be given to vulnerable populations and areas that are disproportionately affected by extreme climatic conditions (e.g., seniors, youth, individuals experiencing homelessness, and communities in areas disadvantaged in terms of access to high-quality public open spaces). To effectively apply an equity lens in designing for thermal comfort, consider the following steps and guidance:

A. Enhancing Tree Canopy Using Toronto's Tree Equity Score Analyzer (TESA): The Tree Equity Score Analyzer (TESA) tool, developed by the nonprofit organization American Forests, assigns scores ranging from 0 to 100 to indicate the level of tree equity within a community. A lower score signifies a higher priority for addressing the tree canopy gap in that neighbourhood, while a higher score, closer to 100, indicates robust tree equity. The tool integrates tree canopy cover data with demographic and socio-economic information to pinpoint opportunities for expanding canopy cover at the neighbourhood level. Tree equity is defined by the adequacy of tree coverage in a neighbourhood, ensuring that all residents can benefit from the trees. Urban Forestry is adopting this innovative approach to address the inequitable distribution of urban forests across communities, aligning with the City's goal of achieving 40 per cent tree canopy cover. Toronto is the first Canadian municipality to use the Tree Equity Score Analyzer to strategically enhance canopy growth at the neighbourhood scale.



B. The Parkland Strategy: Prioritize areas with low parkland provision, as identified by the Parkland Strategy. Parks need to be located in a way that reduces disparities in access, ensuring all Torontonians can enjoy high-quality parks and natural spaces throughout the city. The Parkland Strategy provides the City with a long-term vision and framework for the enhancement of Toronto's park system and has been developed to address the planning, acquisition and development of parks to ensure that Toronto's parks system will grow to support the needs of people and maintain a livable city.

C. Focus on High-Density Residential Areas: Prioritize areas with a high-density residential development for the development of comfortable public outdoor spaces. In these neighbourhoods, many of the residents rely on public amenities for access to outdoor space. These shared spaces support large populations and are under increasing pressure as the city grows. The City of Toronto has a 20-year plan set in 2019 that already prioritized parkland acquisition, where the development of comfortable public outdoor spaces can be achieved.

D. Use Neighbourhood Profiles for Data-Driven Planning: The City's 'Neighbourhood Profiles' provide socioeconomic and age data for each neighbourhood. This resource can help identify areas where public outdoor amenities might be lacking and where residents, especially certain age groups, might be more vulnerable to the effects of extreme weather conditions. Understanding the age demographics is crucial for tailoring outdoor spaces to meet the specific needs of different age groups, from playgrounds for young children to accessible walking paths for seniors.

E. Designing Around Child Care Centres, Schools, Playgrounds, and Senior Spaces: Prioritize thermal comfort in and around childcare centres, schools, playgrounds, and areas frequently used by seniors. Both children and seniors are more vulnerable to temperature extremes, making it essential to ensure these spaces provide adequate thermal comfort for their well-being.

F. Improving Walkability for All Abilities: Design sidewalks and public spaces with children, seniors, and differently abled bodies in mind. Ensure that routes are thermally comfortable by maximizing the planting and maintenance of street trees and providing rest areas with comfortable seating. Ensure that all public spaces are accessible and inclusive, especially for those with mobility challenges.

Toronto's diverse range of weather conditions call for flexible design solutions such as movable furniture and structures.

4.1.6: Designing for Seasonal Variability:

Toronto's approach to thermal comfort in public spaces is a unique challenge due to its semi-continental climate. The city experiences a diverse range of weather conditions throughout the year. The impact of climate change is expected to make Toronto's weather warmer and wetter – increasing the frequency of extreme weather incidents throughout the seasons.

Warmer temperatures mean the risk of heat stress increases throughout the year, and while not expected during winter months the effects of these temperatures also impact other conditions like rainfall events becoming more intense as warmer air can hold more moisture. This necessitates a versatile and adaptive design strategy for public spaces to ensure thermal comfort year-round. In Toronto, where the climate varies from hot, humid summers to cold winters, the design of public spaces involves a thoughtful integration of natural elements and built form strategies to ensure comfort throughout the year.

During hot summers, mitigating high temperatures and humidity is essential. Tree canopies help lower temperatures by shading surfaces and through evapotranspiration, which releases moisture into the air, cooling it. Beyond tree canopies, other forms of green infrastructure such as green roofs, planted meadows, and various types of green spaces also contribute to reducing the urban heat island (UHI) effect. Complementing this, water features like fountains provide immediate cooling relief through the same evaporative processes. Additionally, incorporating shade structures like pergolas or awnings enhance shade while using light-reflecting materials and vegetation minimize heat absorption. These combined approaches effectively combat the urban heat island effect, creating comfortable public spaces during summer.

In colder months, different strategies are necessary. Building designs can minimize wind channeling and downwashing, while landscape designs can include natural barriers that protect public outdoor spaces from strong winds. Maximizing sun exposure is crucial for mitigating the cold, ensuring that areas remain well-lit and warm during the shorter days.

During the transitional spring and fall seasons, the presence of deciduous trees is particularly beneficial. These trees provide shade in the summer and, as they lose their leaves in autumn, allow sunlight to filter through, warming spaces in the colder months. This natural adaptability makes them an ideal choice for providing seasonal thermal comfort.

Several Toronto parks offer a form of community and civic amenities as well as ecological elements. Each park receives different levels of solar access due to its surroundings, and local environmental conditions also vary, making each park unique. The design and size of parks should support a variety of year-round programming, maximize sunlight exposure, offer ample shade for visitors, and ensure safety and accessibility for people of all ages and abilities.

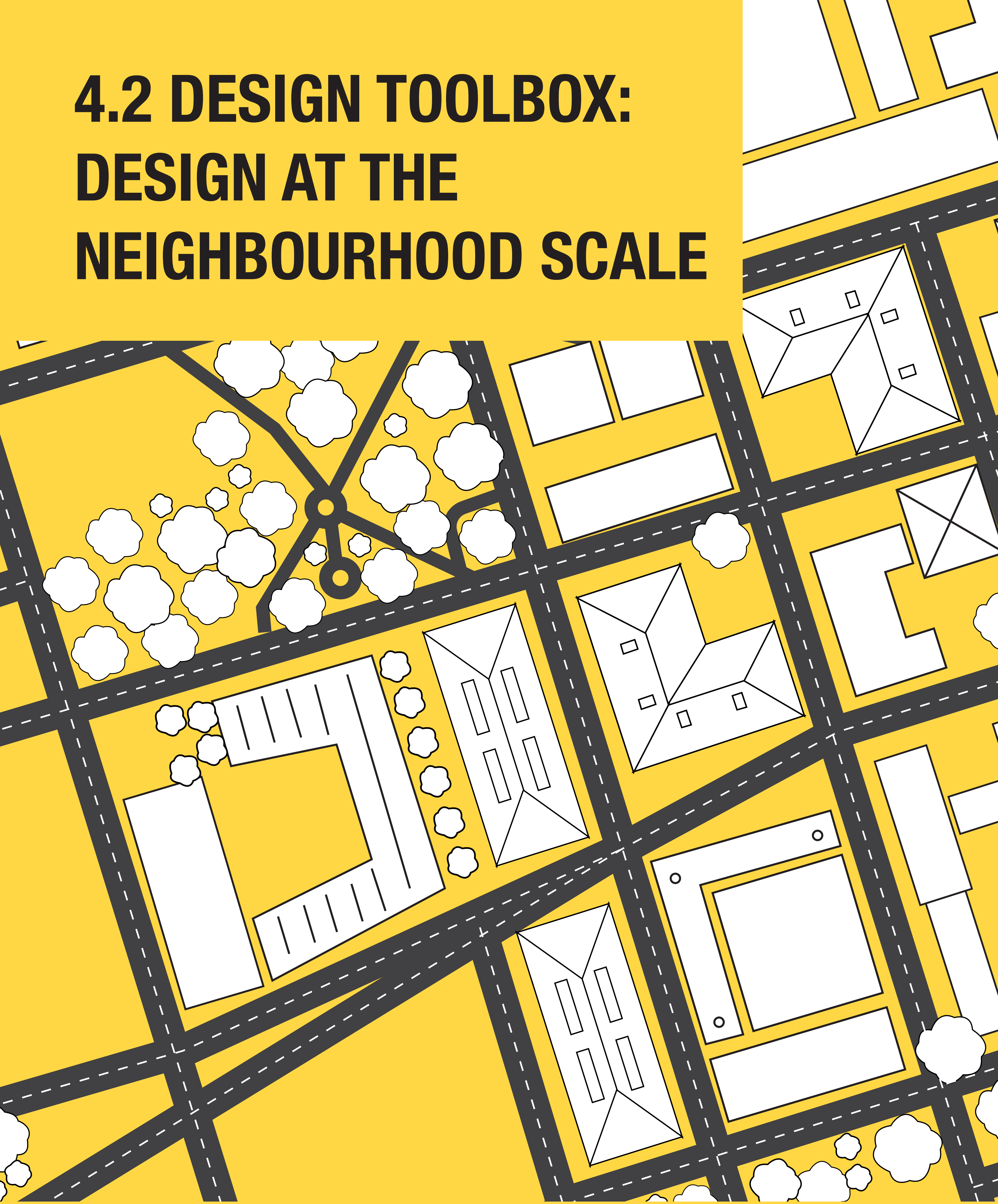
Moreover, these seasons call for flexible design, with modular elements in furniture and features that can be adjusted or moved as the weather changes. Mixed-use spaces are advantageous, serving varied purposes across seasons, such as transforming open spaces into ice rinks in winter or event spaces in summer.

The table below provides an outline of how different environmental elements like vegetation, shade, shelter, wind, and moisture can have varying impacts on thermal comfort depending on the season.

	Positive Impact in Cold Season	Negative Impact in Cold Season	Positive Impact in Warm Season	Negative Impact in Warm Season	Summary
Vegetation	Acts as natural windbreaks, reducing wind exposure.	Conifers can lead to reduced solar gain due to shading, lowering temperatures.	Provides shade and natural cooling, effectively lowering ambient temperatures.	Partially obstruct airflow, potentially increasing perceived temperatures in summer.	Urban greening is often the most effective way to increase thermal comfort and reduce urban heat island effect.
Shade/shelter From Sun	Offers protection from cold winds, minimizing wind chill effects.	Moisture retention can lead to a damp, colder microclimate.	Reduces direct solar exposure, contributing to cooler ambient conditions.	May result in reduced natural lighting.	Urban spaces benefit from well-placed shelters that balance protection and openness. Shelter from the sun is crucial during warmer months but must also be balanced with access to sun during cooler months.
Shelter From Night Sky	Creates a sense of enclosure, offering psychological comfort in outdoor areas, and protection from the colder sky.	Blocks solar gains, which are crucial for warming spaces in colder months.	Shields from direct solar radiation during daytime, reducing heat stress and discomfort.	Increases radiant temperature overnight, leading to warmer conditions in morning.	A balance between shelter when needed and openness when not is required, and considerate design of shelters can aid in making shelter from the sky effective during both cold and warm months.
Wind	Calmer conditions reduce wind chill, making outdoor spaces more bearable.	Wind chill is a significant factor in winter discomfort, amplifying cold.	Increases evaporative cooling rate, providing relief from heat.	Can create a chill effect, making warm days feel unexpectedly cooler.	Wind provides natural ventilation and cooling, but excessive or uncontrolled wind can impact comfort. Designing spaces that harness wind's benefits while minimizing drawbacks is essential for a pleasant urban experience.
Moisture	Moderate humidity can offset the perceived dryness of winter air, enhancing comfort.	Higher humidity can increase heat loss from the body, intensifying cold.	Evaporative cooling from moisture aids in reducing heat stress.	Excessive moisture can lead to issues like mold growth, especially in shade and without airflow.	Blue spaces (including lakes, rivers, and fountains) can enhance the thermal environment during warmer periods but can also cause some drawbacks during cooler periods. man-made blue spaces require appropriate maintenance and safety measures.

Urban spaces benefit from well-placed shelters that balance protection and openness.

4.2 DESIGN TOOLBOX: DESIGN AT THE NEIGHBOURHOOD SCALE



4.2 DESIGN TOOLBOX: DESIGN AT THE NEIGHBOURHOOD SCALE

4.2.1 Pattern of Streets

Strategy

Orient the streets and blocks to optimize solar access and impede prevailing winds where possible. Strategically place outdoor open space and amenities based on the impact of the street pattern on thermal comfort.

Intent

The orientation of building blocks and streets mainly influences the wind speed and direction, and the period of solar access. The objectives are to orient the blocks and streets to minimize exposure to prevailing winds and to design with an understanding of sun path and how access to sunlight varies in different street orientations.

Guidelines

A. Design the street pattern considering the sun path on the public realm. The current street grid in Toronto results in the following:

- Summer:
    - East-West Streets: Receive sunlight throughout the day.
    - North-South Streets: Receive sunlight around midday.
- Spring and Fall Equinox:
    - East-West Streets: Generally allow for morning and afternoon sunlight.
    - North-South Streets: Receive sunlight around midday.
- Winter:
    - East-West Streets: Receive limited access to sunlight throughout the day.
    - North-South Streets: Receive sunlight around midday.

B. Design the street network and pedestrian routes to support small blocks and/or mid-block pathways and crossings, offering multiple route choices which can provide shade and shelter from wind when required.

C. Design the street network to reduce exposure to prevailing winds, when possible. East-west streets are more exposed to prevailing winds while north-south orientation may provide some natural wind protection, especially if buildings are designed to act as windbreaks for the more vulnerable east and west sides.

D. Increase mid-block crossings on long blocks that are oriented east-west to reduce long distances pedestrians must travel to reach their destinations and provide them with an option to minimize exposure to prevailing winds. North-south gaps between buildings can also increase sunlight access to east-west streets.

E. Adapt to the existing street grid by being intentional about the types of uses and programs proposed for each street orientation to improve thermal comfort. While we cannot always design a new street grid, we can strategically utilize the current layout to optimize thermal comfort and functional use based on the unique characteristics of each street's orientation.

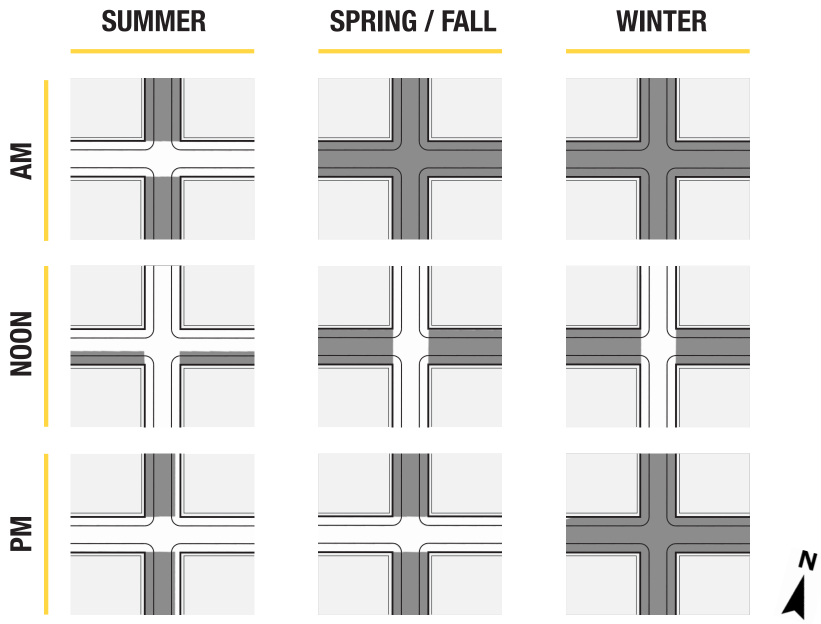
F. Determine through thermal analysis the most influential factor in the thermal comfort of that specific area. This assessment will guide the street orientation and design decisions. Ultimately, the goal is to create an urban environment that is comfortable year-round, taking into account both the sun path and wind patterns. Consequently, there might be no single 'best' orientation but rather a context-sensitive approach that considers the unique characteristics of each site and its surroundings, focusing on the predominant environmental factors impacting thermal comfort.

Toronto's Concession Street Grid

Toronto's downtown street grid consists of north-south and east-west concession lines meeting perfectly perpendicularly and corresponds to a rotation of -16 degrees from geographic North, which means that the downtown street grid aligns with sunrise and sunset in February and October.

When Toronto was founded in the 1793, the city was first surveyed to follow the shore of Lake Ontario, which results in a corresponding grid on a rotation of 16 degrees east of geographic north.

As the city expanded in the 1800s, surveyors modified the concession road alignment, particularly Yonge street which was made to better align with Lake Simcoe further north. Hence Yonge street rotates east from its established grid, north of St. Clair Avenue at Heath Street, which results in the city's major north-south streets adjusting to this shift north of Eglinton.The street grid outside downtown also often reflects constraints due to large ravine corridors which are not strictly oriented north-south.



Shadows cast during the Summer Solstice, Spring/Fall Equinox, and Winter Solstice in Toronto, demonstrated with 20-meter tall buildings spaced 20 meters apart. The illustration is based on Toronto's downtown street grid, with streets rotated -16 degrees from geographic North.

	Sunlight Access	Wind Exposure
East-West Oriented Blocks	Offer the least access to sunlight at street level but the buildings receive optimal solar gain as south-facing sides receive maximum sunlight. To address the street level sunlight access, the City Planning department has a series of sunlight related recommendations in the mid-rise and tall building design guidelines.	More exposed to westerly winds at pedestrian level, potentially increasing wind speeds in streets and open spaces, especially on west-facing sides. Soft and hard landscape (tree canopy, etc.) can help mitigate this effect.
North-South Oriented Blocks	Less optimal for winter solar gain for the buildings due to limited direct sunlight on the longer sides of the buildings but it receives sunshine around mid-day at street level when not shaded from the south.	Offers natural wind protection from westerly winds, potentially creating more sheltered east sides, with potential to increase wind on the west side from downwash from vertical facades to street-level, and wind corner acceleration.

Block orientation in relation to sunlight access and wind exposure in Toronto

Note
The guidelines provide some general guidance however, analysis may be required in some cases to determine the best combination for a given site. This becomes more important in the vicinity of tall buildings.

4.2.2 Streetscape Design

Strategy

Design the streetscape to allow for sunlight access and protection from prevailing winds, wherever possible.

Intent

The design of the streetscape should consider the impact of sunlight and wind on the thermal comfort of users as one of the key considerations. During warmer months, the objectives are to provide both areas that are sunlit and shaded spaces for repose. Also, a light breeze can be a welcome reprieve from extreme heat. Conversely, during colder months, the priority is to provide ample access to sunlight and to mitigate the effects of wind.

Guidelines

A. Street cross-sections may be asymmetrical when providing a preferential response to thermal comfort, such as a wider sidewalk on the north side of a commercial street offering sidewalk patios and/or enhanced tree planting.

B. Street cross-sections are to incorporate deciduous trees. The trees provide shade and wind dissipation in the summer and allow sunlight penetration throughout the winter, optimizing thermal comfort year-round. It is essential to ensure that the sidewalk width meets current standards and trees have access to sufficient soil volume. This is necessary for the trees to grow to a size where their canopy can effectively provide these benefits.

C. Multi-use trails are to be located on the north side of the street, if feasible, to maximize access to sunlight. This orientation increases natural snow melt during winter months, promoting safer and more comfortable walking and cycling conditions.

D. Street benches are to be strategically located to balance exposure to sunlight and protection from prevailing winds. Consider the following specific strategies:

- Placement: Locate benches in areas that receive adequate sunlight during colder months and strategically position them be positioned to benefit from shade provided by tree canopies or shade structures

- Wind Protection: Incorporate landscape features, such as hedges or low walls, near benches to act as windbreaks, reducing the cooling effects of wind during colder months. For windier sites, consider the placement of benches in the lee of buildings or solid street furniture that can block prevailing winds.

- Adaptive Design: Use movable benches where possible, allowing users to adjust their position seasonally or as daily weather conditions change. This flexibility helps users find the most comfortable spot in terms of both sunlight and wind exposure.

Street benches can be located strategically to benefit from seasonal shade cast by trees.

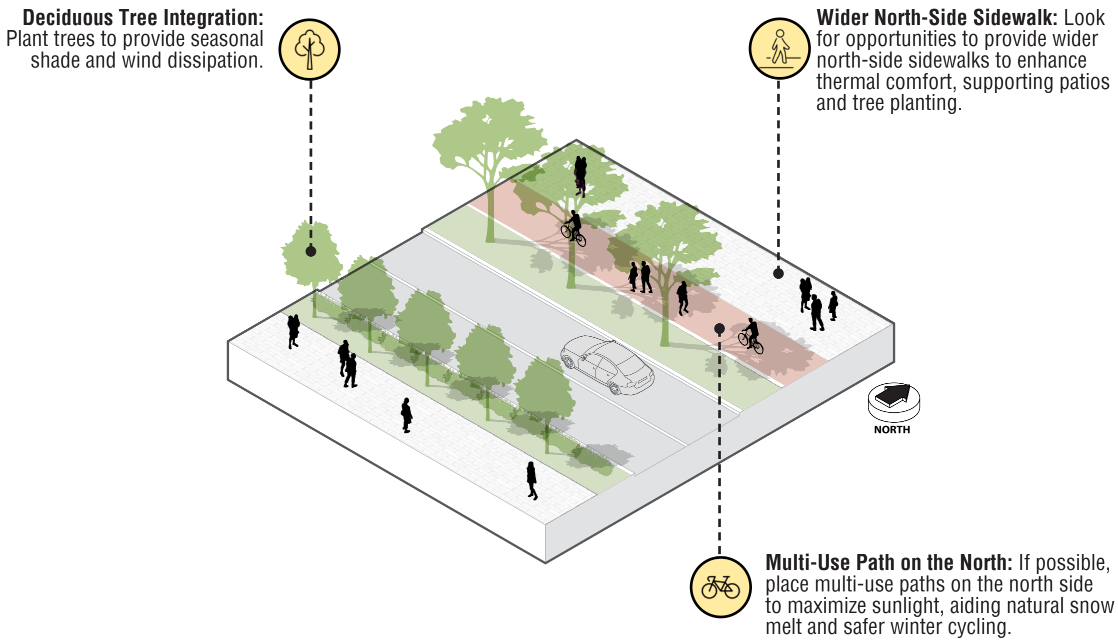


Diagram illustrating an asymmetrical street cross-section designed for optimal sunlight access and wind protection. For illustrative purposes only.

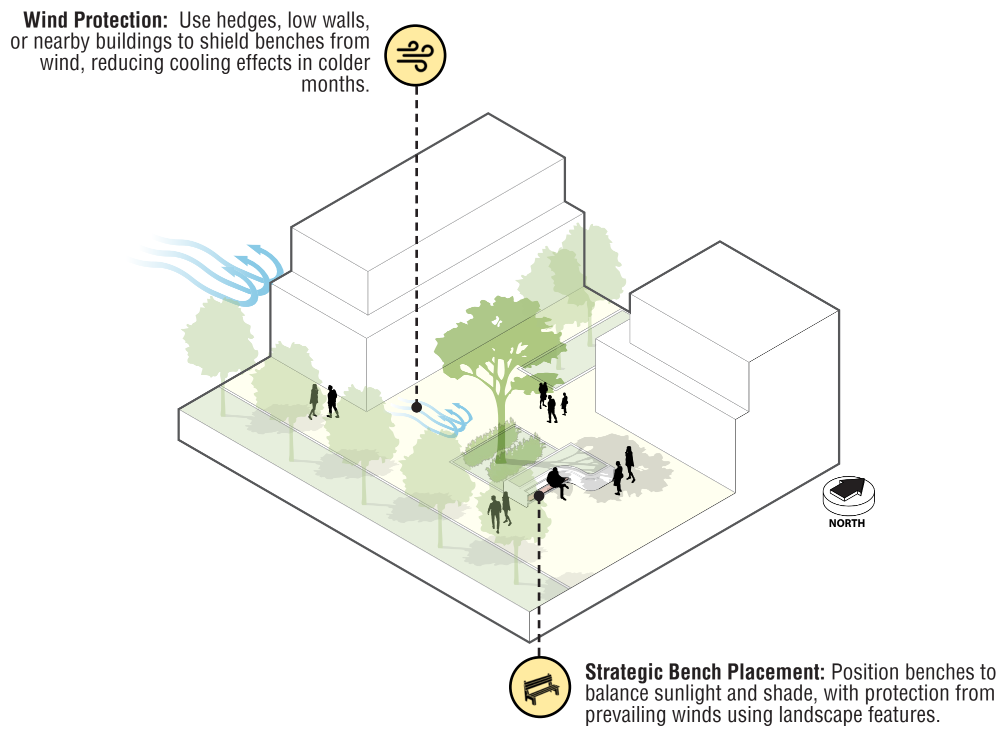


Diagram illustrating strategically placed benches to balance sunlight, shade, and wind protection. For illustrative purposes only.

4.2.3 Placement and Orientation of Publicly Accessible Open Space

Strategy

Locate, orient, and design publicly accessible open spaces including parks, plazas, and Privately Owned Publicly Accessible Spaces (POPS) to allow for sunlight access and protection from prevailing winds, wherever possible.

Intent

The location and orientation of publicly accessible open spaces should consider the impact of sunlight and wind on the thermal comfort of users as one of the key considerations when determining the placement and orientation of those spaces. Policy 3.1.3.2 of the Official Plan speaks to "prioritizing" the provision of accessible open space on blocks that have access to direct sunlight and daylight.

Guidelines

A. Locate and orient Publicly accessible open spaces to maximize sunlight penetration, if possible, such as along the south side of a block where buildings occupy the north side.

B. Provide access to sun-shelters during summer months in areas where people congregate to increase usability during periods of high air temperature.

C. Identify opportunities to expand and connect parks and green spaces. Larger parks have a more significant impact on cooling.

D. Place publicly accessible open spaces where they are shielded from prevailing winds by buildings or structures. This is of particular importance in locations where taller buildings may result in exacerbated wind conditions.

The Impact of the Size and Shape of Parks on Cooling Effect at the Neighbourhood Level

The size and shape of parks and natural features can have a significant impact on local microclimatic conditions. The cooling effects of small parks have been demonstrated to be between 1.2-2.4°C, with larger parks having a greater effect and distance around these parks where that effect can be felt up to 400 metres. These effects are further increased with vegetative landcover and water. Additionally, the shape of natural features also plays a role in affecting air temperature, with green spaces concentrated in a single region, without a complex boundary, being more effective at providing urban cooling than more complex and linear parks.[1]

[1]Feng, Xiaojing, et al. ‘Quantifying and Comparing the Cooling Effects of Three Different Morphologies of Urban Parks in Chengdu’. Land, vol. 12, no. 2, Feb. 2023, p. 451. DOI.org (Crossref), https://doi.org/10.3390/land12020451.

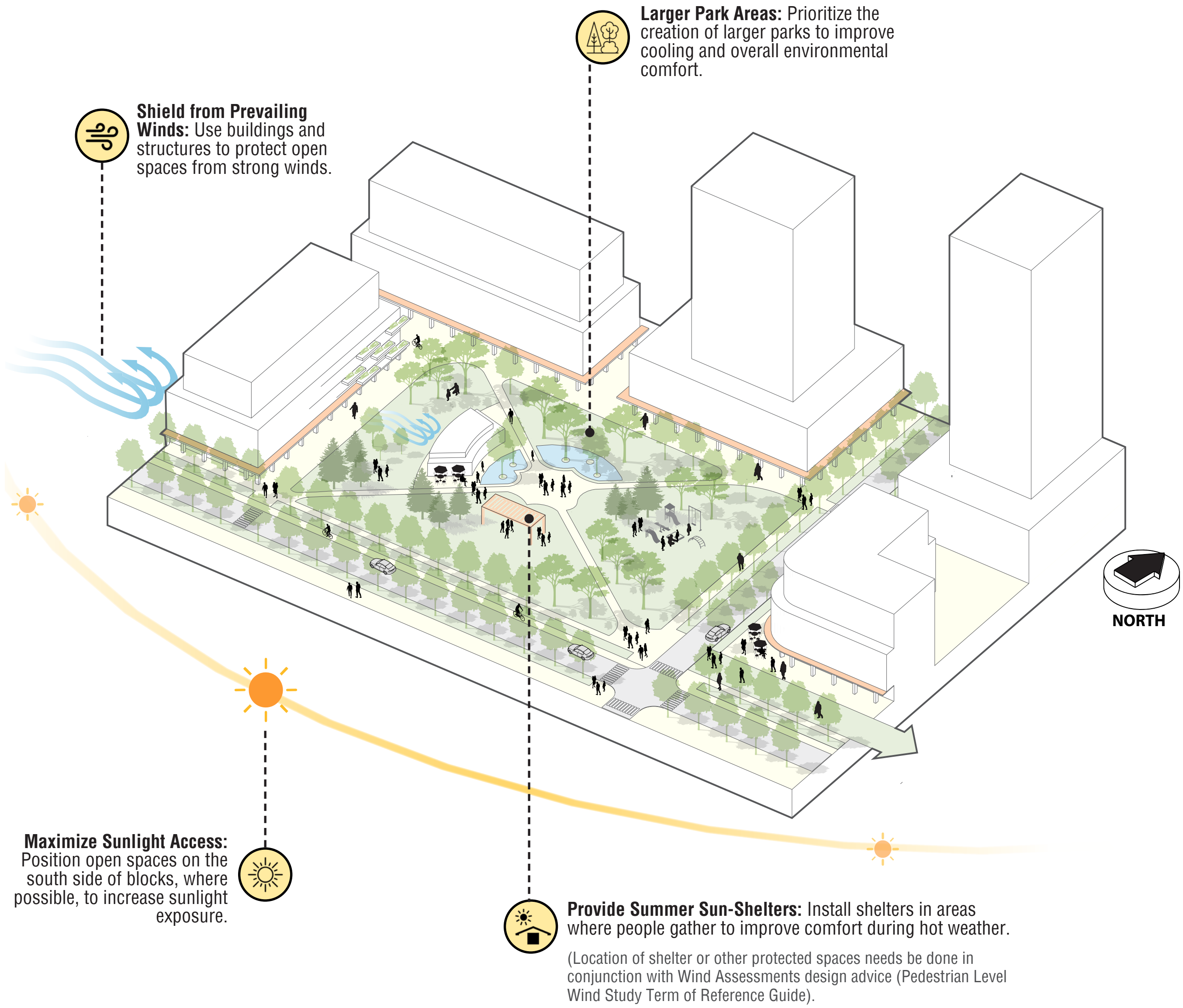


Diagram showcasing the design, strategic placement, and orientation of open spaces to maximize sunlight access and wind protection. For illustrative purposes only.

4.2.4 Proximity to Natural Features

Strategy

Leverage nearby natural features as natural cooling elements.

Intent

Cooling sources such as ravines and urban forests have significant impacts on local climates. Toronto's ravine systems contribute significantly to the city's urban forest, as they represent 38 per cent of the city's tree cover. The objective is to enhance access to the cooling effects of the natural feature, for areas adjacent to those features, to mitigate the Urban Heat Island effect on the urban built-up areas.

Guidelines

A. Preserve and expand ecological sources including forests, wetlands, ravines, natural parks, and natural reservoirs.

B. Design buildings to gradually increase in height as they move away from natural cooling sources, if possible. This stepped approach helps in extending the cooling effects further into the urban area. There are several factors affecting the benefits of cooling sources, and these need to be reviewed on an individual basis to help reap the benefits.

C. Incorporate pedestrian connections that connect neighbourhoods with these features to facilitate easier access to areas with cooler microclimates, enhancing overall urban thermal comfort.

D. Educate residents and create awareness about the City's ravine network and promote access to it through effective signage, wayfinding, and education campaigns. This will foster appreciation and use of these natural spaces.

Toronto's ravine systems contribute significantly to the city's urban forest

Facilitate access to natural features such as ravines to improve access to areas with colder microclimate.

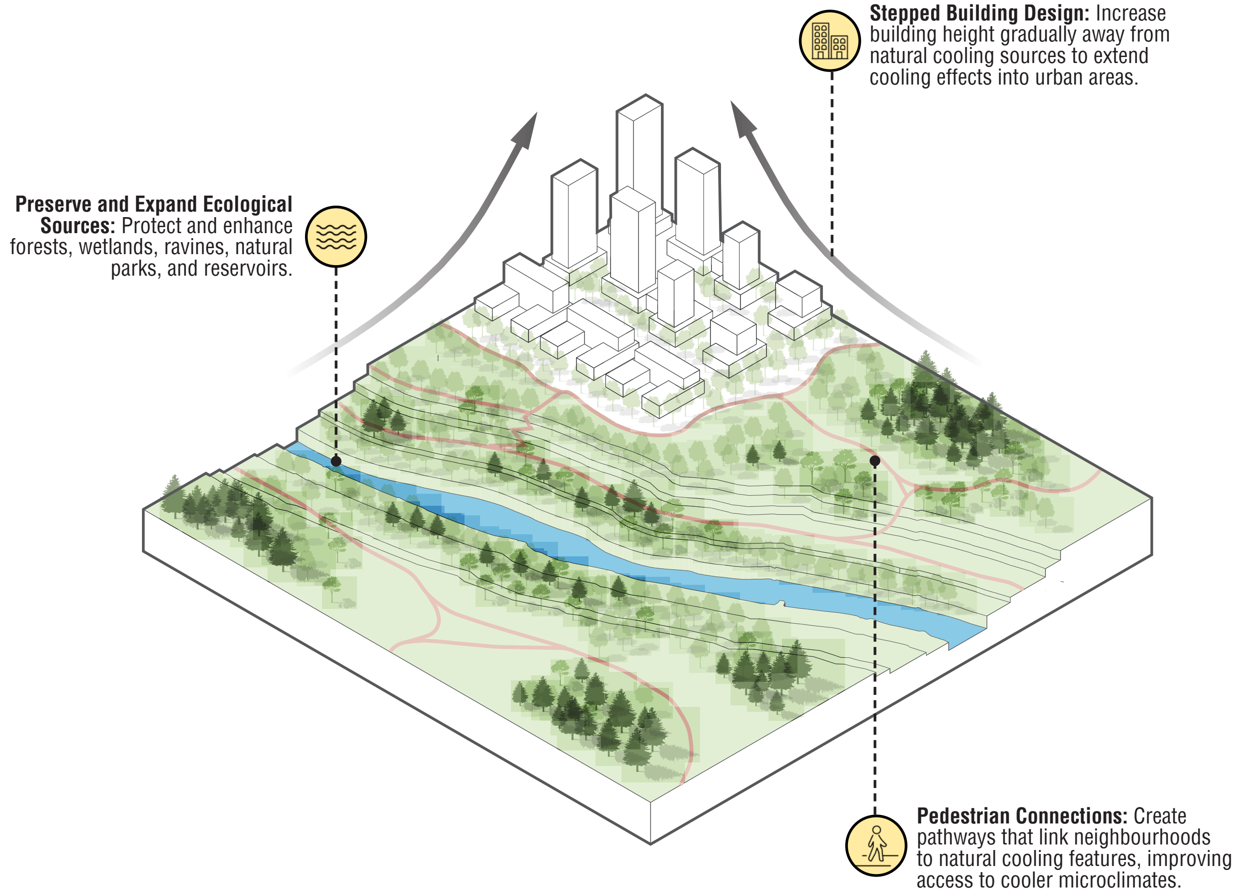


Diagram showcasing how to leverage nearby natural features as cooling elements in urban design. For illustrative purposes only.

4.2.5 Increase Cooling Features at Neighbourhood Scale

Strategy

Mitigate the Urban Heat Island (UHI) effects at the neighbourhood scale

Intent

In urban neighbourhoods that lack natural cooling features such as water bodies, forests, or parks, surface temperatures are often higher, leading to a pronounced urban heat island (UHI) effect. This is especially true in densely built areas where materials like concrete and asphalt absorb and re-radiate heat. To mitigate these effects, a neighbourhood-scale strategy is essential, focusing on increasing greenery, reducing heat absorption, and integrating water features. The aim is to create artificial microclimates that replicate the cooling effects of natural environments.

Guidelines

A. Increase green spaces through the following considerations:

- Parks and Gardens: Increase the number of parks and strategically locate them within neighbourhoods at a walkable distance, as outlined in the City-wide Parkland Strategy.
- Green Corridors: Create green corridors linking different parts of the neighbourhood, facilitating airflow and providing shaded walkways. Green corridors refer to linear stretches of vegetation that connect larger areas of natural habitat, like parks or natural reserves, but within an urban context. In cities, green corridors can include features like Green Streets, green hydro corridors, and rail trails (green pathways created along railway lines).
- Vertical Greenery: Encourage the use of living walls and green facades on buildings, which can reduce the reflectivity of those facades and improve air quality.
- Green Roofs: Promote the installation of green roofs on buildings, where not otherwise required. Green roofs contribute to overall neighbourhood cooling by replacing heat-absorbing surfaces with vegetation.
- Re-Greened Spaces: Reclaim green space by reducing excess and/or redundant paved or hardscaped areas in existing parks and public spaces through conversion to green space and softscape.

B. Incorporate water features such as public fountains, splash pads, and ponds in public spaces to provide evaporative cooling and aesthetic value.

C. Plant trees in a strategic and equitable manner through the following considerations:

- Plant deciduous trees for summer shade and winter sunlight penetration. Use coniferous trees to provide additional wind protection during colder months taking into account potential visibility issues and where space permits.
- Plant multibranch trees strategically to allow for added protection during winter months as multibranch trees reduce ground-level wind speed and reduce wind chill.
- Increase tree canopy at strategic locations. Utilize the Tree Equity Score Analyzer tool to identify areas of low tree equity and explore opportunities to increase tree canopy in the neighbourhoods that need it the most.
- Choose tree and plant species that are resilient to urban conditions and effective in providing shade and cooling.
- Refer to Section 4.4.1 for more guidelines on tree planting.

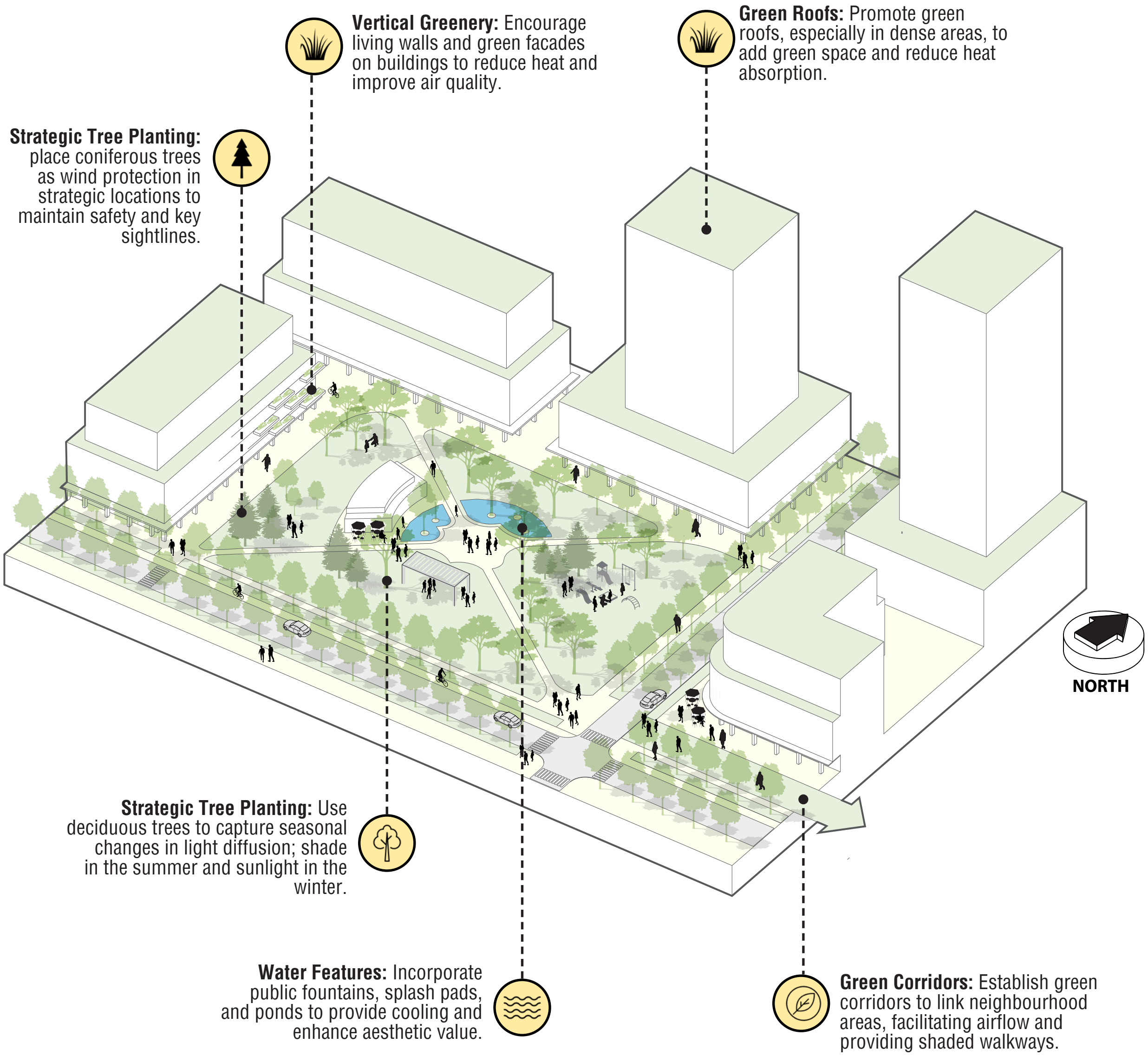


Diagram showcasing the design, strategic placement, and orientation of open spaces to maximize sunlight access and wind protection. For illustrative purposes only.