MITIGATING URBAN HEAT ISLANDS

The Intersection between Built Form, Policy, and the Urban Heat Island Effect in the City of Kelowna

PREPARED FOR

The City of Kelowna

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City of Kelowna

SCARP School of Community And Regional Planning

LIVABLE PLANIT

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ACKNOWLEDGEMENTS

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We respectfully acknowledge that the City of Kelowna is located on the unceded, traditional territory of the syilx/Okanagan peoples. This report is submitted on behalf of the University of British Columbia's SCARP Studio course, situated on the unceded, traditional territory of the Musqueam peoples.

PROJECT TEAM POSITIONALITY

Our team, Livable PlanIT, is a fictional consulting firm composed of four graduate students in the SCARP program with backgrounds in environmental planning. We recognize that our team members are not from nor part of the community of Kelowna and that our backgrounds, experiences, and positionalities may differ from those of the local community. We strive to be reflective in our practice and mindful of the community we are planning for in the project's processes and outcomes.

Extreme heat impacts from climate change disproportionately affect vulnerable populations, notably in neighbourhoods lacking tree cover and homes without access to functional mechanical cooling.[1,2] As Kelowna lays out in its OCP, the City strives to ensure that all community members are safe and included.

We continue to remain aware of our individual and group privileges, and in our approach, we aimed to work with an equity-based lens.

EXECUTIVE SUMMARY

This final report has been created for, and in partnership with, the City of Kelowna as part of the University of British Columbia's School of Community and Regional Planning (SCARP) Studio course.

CONTEXT

The City of Kelowna is actively working to address weather-related impacts from climate change. Climate change is impacting the community at the local level, amplifying extreme weather events and creating significant climate hazards for the City's residents. Climate projections for the Okanagan Region predict that hotter and drier summers are to become more common over the next three decades, creating urgency to act.

Extreme heat is exacerbated in the City's five Urban Centres due to the Urban Heat Island (UHI) effect. The UHI effect occurs when dark surfaces (e.g., concrete) hold and retain heat longer than vegetated surfaces. UHI processes occur at multiple scales throughout urban centres, where urban surfaces can increase daytime temperatures from 1°C to 3°C compared to surrounding vegetated areas, and even hotter from 8°C to 11°C in highly developed urban areas.[3] The UHI effect impacts people's mental and physical health and contributes to increased air pollution and exacerbated heat waves.

What is the Urban Heat Island Effect?

Urbanization has changed land use patterns worldwide, resulting in urban temperatures being 1°C to 3°C warmer than surrounding regions. This is known as the Urban Heat Island (UHI) effect.[3]

PROJECT OVERVIEW

This project, completed over a multi-phased, eight-month approach, was designed to examine the intersection between built form and the UHI effect. The five project phases were as follows:

(1) Literature and Background Research
(2) Promising Practices and Case Studies Review
(3) Cost-Benefit Analysis
(4) Policy and Design Recommendations
(5) Reporting

The background research phase produced an in-depth literature review of factors that influence the intensity of the UHI effect. It was found that land use planning, urban design, and building design influence the impact of built form on UHI. With this understanding, the team reviewed promising practices for effective UHI mitigation measures and identified case studies from around the globe that showcased those practices in action.

A cost-benefit analysis was then performed to determine which UHI mitigation measures were most cost-effective and feasible and to identify co-benefits associated with them. Using the cost-benefit analysis, policy actions and design recommendations were drafted and compiled to put forth suggestions on ways the City of Kelowna can implement UHI reduction measures.

Concluding the reporting phase, this report outlines **85 policy actions** that the City of Kelowna can undertake to reduce the UHI effect in the built environment.

POLICY & DESIGN GUIDELINE RECOMMENDATIONS

Policy actions and design recommendations were based on identified promising practices for reducing the UHI effect in the built form. These practices included urban greening (street trees, green roofs, and green walls) and urban and streetscape design (cool roofs, cool and permeable pavements, and engineered shade) as the most common methods to reduce the UHI effect. The recommendations prioritize bold action to address the climate crisis and extreme heat, focusing on how the community can build towards a greener future. A total of 85 policy actions were recommended in the following five categories:

BYLAWS (19 ACTIONS)

- **12** for Subdivision, Development, & Servicing Bylaws
- **7** for Zoning Bylaws

DEVELOPMENT PERMIT AREAS (DPA) (30 ACTIONS)

- **9** for Tree Canopy & Landscaping
- **6** for Roofs (Green & Reflective)
- **4** for Pavements (Reflective & Permeable)
- **3** for Building Materials
- **3** for Engineered Shading
- **3** for Urban Form
- **1** for Green Walls
- **1** for Development Application Checklist

STRATEGIC PLANS (14 ACTIONS)

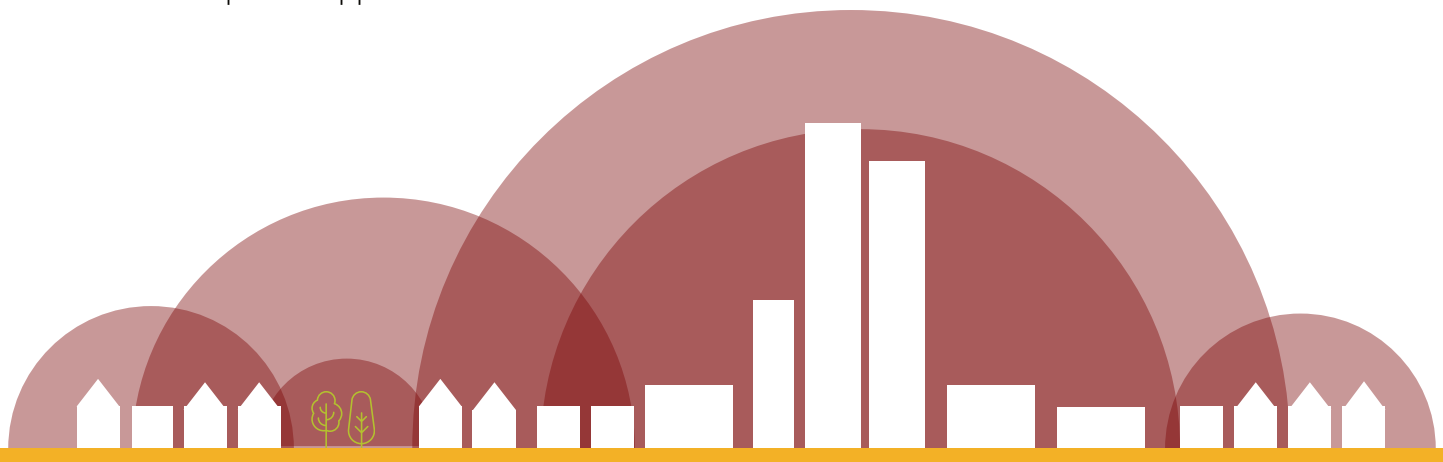
- **4** for the 2040 Transportation Master Plan
- **4** for the Urban Forestry Strategy
- **3** for the Urban Centres Framework
- **2** for the Official Community Plan
- **1** for a Wind & Ventilation Plan

PROGRAMS & OUTREACH (7 ACTIONS)

- **4** for Programs & Funding
- **1** for Development Application
- **1** for Building Certifications
- **1** for Public Outreach

ENHANCING KELOWNA'S EXISTING POLICIES (15 ACTIONS)

- **7** for the Form & Character DPA
- **6** for the Official Community Plan
- **2** for the 2040 Transportation Master Plan



GLOSSARY

Albedo: The fraction of light that a surface reflects (i.e., reflectivity of a surface).

Aspect Ratio: The ratio of the mean height of the buildings to the width of the street.

Building:
- *Low-Rise Building:* Structure with 3-4 storeys.
- *Mid-Rise Building:* Structure with 5-12 storeys.
- *High-Rise Building:* Structure with 13+ storeys.

Climate Change: Long-term shifts in temperatures and weather patterns that vary from the average weather conditions.

Co-Benefits: Beneficial outcomes from actions related to Urban Heat Island mitigation.

Cool Roof (or Reflective Roof): A roof designed to reflect more sunlight than a conventional roof.

Core Areas: Neighbourhoods in City of Kelowna that are adjacent to and connecting the five Urban Centres within the central part of the City.

Cost-Benefit Analysis (CBA): Comparing the costs and benefits of Urban Heat Island mitigation measures.

Development Permit Area (DPA): Prescribe the general criteria for new development and form the basis for the review and approval of a development permit.

Engineered Shade: Structures designed to shade the streetscape.

Extreme Heat: When daytime and nighttime temperatures get hotter for over three consecutive days and are well above seasonal norms.

Floor Area Ratio (FAR): Relationship between a building's total usable floor area and the total area of the lot on which the building stands.

Green Roof (or Living Roof): A roof containing green space on top of a building.

Greenhouse Gas (GHG) Emissions: Gases released into the atmosphere that trap heat and contribute to climate change.

Official Community Plan (OCP): Long-term vision of the community.

Permeability: Ability of a substance to allow gases or liquids to go through it.

Resilience: Community's ability to recover from and adapt to climate change hazards.

Sky View Factor: Ratio of sky hemisphere visible from the ground.

Social Equity: Recognizing inequalities and working towards fairness in every area of society.

Street Trees: Trees planted in the public right-of-way along city streets.

Subdivision, Development, & Servicing Bylaw: Outlines regulations and requirements for land subdivision, setting the standards for the design and construction of infrastructure in the creation of lots, roads, and utilities.

Thermal Admittance: A material's ability to absorb and release heat as temperature changes through a period of time.

Tree Canopy: Measurement that encompasses the layer of leaves, branches, and stems of trees that shelter the ground when viewed from above.

Urban Centre: Five designated dense hubs in Kelowna - Downtown, Rutland, Midtown, Capri Landmark, and South Pandosy.

Urban Form: The physical characteristics and the built environment of a city.

Urban Heat Island (UHI): Significantly warmer temperatures experienced in urban areas compared to surrounding rural areas.

Zoning Variances: Exception to zoning bylaws that is granted on a case-by-case basis by a local government.

Zoning Bylaw: Defines how specific areas of land can be used, specifying the nature of these uses in more detail and regulating the density and height of structures.

2040 Transportation Master Plan: Long-term, citywide plan for transportation improvements in City of Kelowna.

CONTEXT

PROJECT OVERVIEW

BACKGROUND

The City of Kelowna is actively working to address weather-related impacts from climate change on its built environment in tandem with the City's housing needs. Climate projections for the Okanagan Region (2020) show that as greenhouse gas (GHG) emissions increase, hotter and drier summers are predicted to become more common in the next three decades.[4] These drier conditions increase risks and concerns over heat waves, wildfires, water security, and drought.[4]

The City of Kelowna recognizes the urgency to act on this issue and is developing a *Climate Resilient Kelowna Strategy*.[5] This strategy includes a recently completed Climate Vulnerability and Risk Assessment, identifying extreme heat, wildfires, and flooding as Kelowna's most significant climate hazards.[5] This project focuses on extreme heat in the City of Kelowna's Urban Centres, where, as per the *Official Community Plan* (OCP), densification is expected to occur.[6]

PROJECT GOAL

The City recognizes that extreme heat is exacerbated in its Urban Centres due to the UHI effect. The UHI effect occurs when surfaces like concrete absorb and hold heat longer than vegetated landscapes, resulting in higher core temperatures within urban areas.[7] Without mitigation of UHI, there is potential for the built environment to worsen the impacts of extreme heat on the City and its citizens. Challenges have also arisen from community pushback to taller built forms in the urban core. Pressures on the City's housing demands coupled with the urgency to act on climate change establish the basis of this project.

This project carefully examines the intersection between built form and the UHI effect, and sets out how to address this through planning policy recommendations.

PROJECT OBJECTIVES

(1) Understand how the built form influences the UHI effect through literature review.

(2) Research best practices to understand what other communities are doing in urbanized areas to address the UHI.

(3) Undertake a cost-benefit analysis to understand the level of impact of policy recommendations, implementation costs, and intensity of recommendation.

(4) Prepare recommendations for the City of Kelowna on the following topics:

- Zoning and land development;
- Design and streetscape; and,
- Key Performance Indicators to track success of UHI measures.

PROJECT APPROACH

The project consisted of five phases:

(1) Literature and Background Research
(2) Promising Practices and Case Studies Review
(3) Cost-Benefit Analysis
(4) Policy and Design Recommendations
(5) Reporting

The project begun in September 2023 and concluded in April 2024. Deliverables for the project include this report, a presentation, and a poster that highlights the key policy actions and design recommendations.

KELOWNA CONTEXT

THE PLANNING CONTEXT

In British Columbia, the effects of climate change are already being felt and are expected to cause further warming and a shift in weather extremes.[8] These climatic changes will have environmental consequences and create intersectional risks to human health, physical infrastructure, and the economy.[8]

Resilience, which results in communities' ability to recover from and adapt to climate change hazards, can be built through mitigation and adaptation actions. Municipalities are well-positioned to take action on climate change and extreme weather to create resilient communities, as they have jurisdiction over land use decisions, utility provision, transportation infrastructure, and waste management.[9]

While there are no direct policies aimed at reducing the UHI effect at the provincial level, there are initiatives and guidelines that aim to minimize health impacts from the built environment during extreme heat events. At the provincial level, the Healthier Built Environment Linkages Toolkit (2018) and Extreme Heat Preparedness Guide (2022) touch on reducing UHIs with vegetation and recognizing the critical role of UHIs in extreme heat events.[10, 11] However, there is a significant gap that municipalities must fill to address extreme heat and the UHI effect.

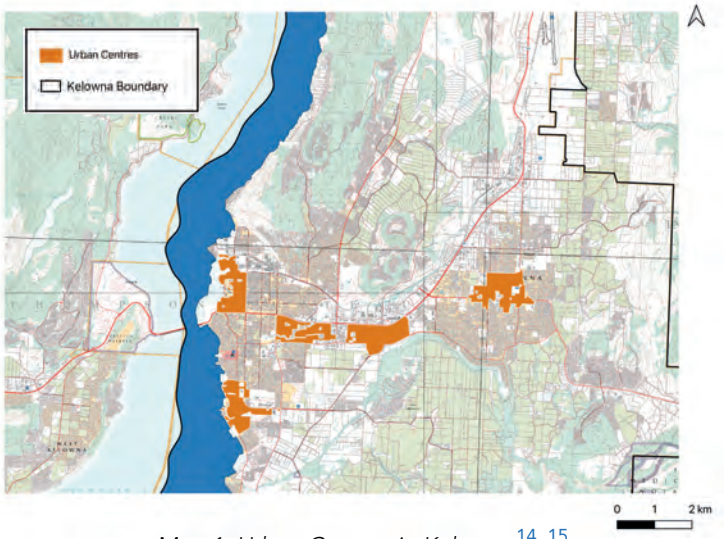
The UHI effect will have site- and regional-level impacts in Kelowna, creating hotter temperatures that reduce quality of life and raise public health and equity concerns. Further, as the City seeks to densify its Urban Centres to meet increased housing demand, it is important to consider how to undertake densification to create more resilient urban environments that minimize heat-related risks. Urban planners at the local government level are on the front lines of climate change and, through policy and practice, can take a bold place-based approach to building resilience that accounts for the geographic variability of the UHI effect.

In planning for UHI, as outlined by scholars and practitioners, it is imperative to utilize a social equity lens to understand how communities are differently affected by extreme heat and UHI.[12] By addressing UHI through planning interventions, the City of Kelowna can alleviate the disproportionate burden of extreme heat on vulnerable populations and promote justice. The mapping on the following page sets out the intersection between extreme heat and vulnerable populations in Kelowna. It can inform climate planning and the implementation of UHI mitigation measures in a way that addresses the impacts of UHI on the natural, social, and built environment.

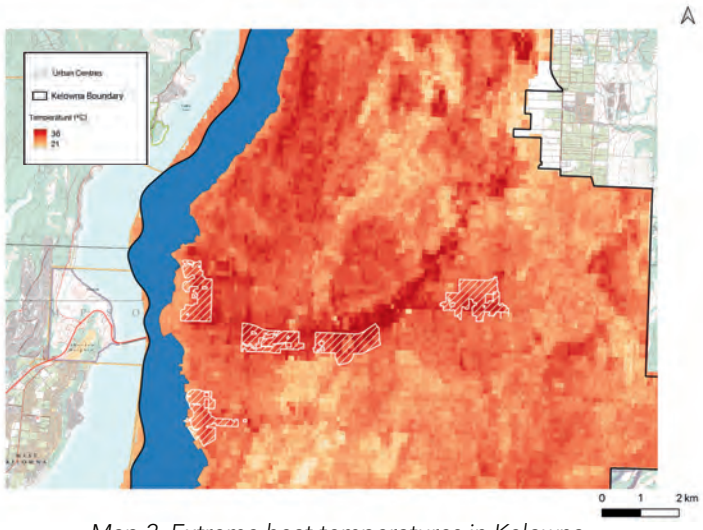
EXISTING HEAT CONDITIONS

URBAN CENTRES

This project's scope focuses on the City of Kelowna's Urban Centres, where, as per the OCP, densification is expected to occur. Kelowna has five Urban Centres: Downtown, Rutland, Midtown, Capri Landmark, and South Pandosy (see Map 1). The City's OCP states the Urban Centres are intended to be complete communities with various land uses, including medium- to high-density housing and sustainable transportation. Understanding the current conditions in Kelowna's Urban Centres is essential to addressing the UHI effect through policy action.



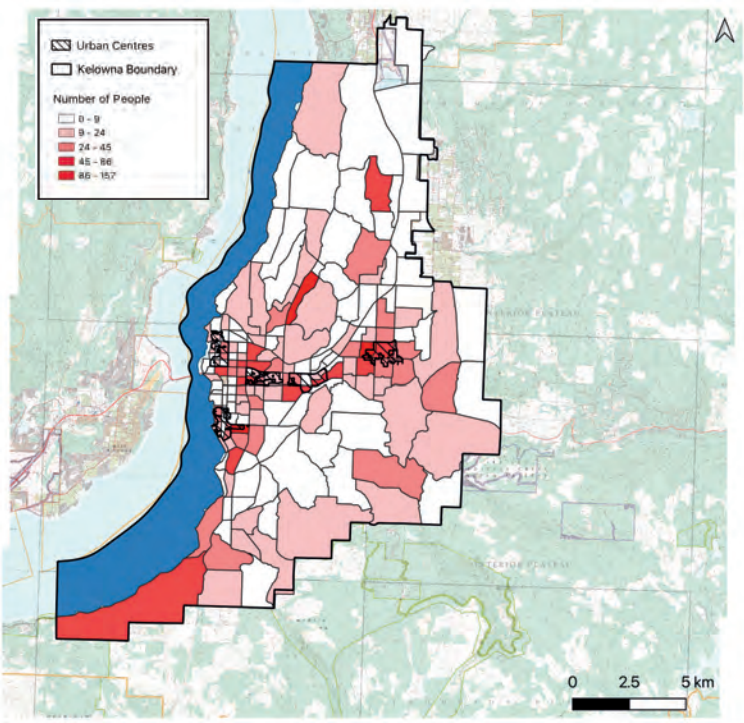
Map 1. Urban Centres in Kelowna [14, 15]



Map 2. Extreme heat temperatures in Kelowna (June 2021) [13, 14, 15]

HEAT VULNERABILITY MAPPING

Examining heat mapping from Kelowna sets the stage for our work and allows us to identify what areas are experiencing the most significant UHI effect.[13] Map 2 depicts extreme heat in Kelowna.[13] This map shows that extreme heat is more significant in Urban Centres and Core Areas than in rural areas. Thus, it is likely UHI will be exacerbated in these areas.[13] Map 3 depicts where vulnerable populations (i.e., low income and over 65 years of age) are currently facing heat risk. As can be seen, there is an overlap between vulnerable populations experiencing heat risk and the location of Urban Centres.



Map 3. Heat risk facing vulnerable population's (low income and over 65 years of age) [13, 14, 15]

COMMUNITY PROFILE

RELEVANT COMMUNITY DEMOGRAPHICS

The City of Kelowna, located on Okanagan Lake in the Southern Interior of B.C., is the seventh largest municipality in the province and is considered to be a mid-sized urban center.[16] Kelowna has a total of 144,576 residents (2021), totaling 2.9% of the province's population.[17, 18] Kelowna is a rapidly growing city, and between 2016 and 2021, Kelowna's population increased by 13.5%, compared to 7.6% in BC and 5.2% in Canada.[19]

Emerging trends over the past 20 years highlight that Kelowna's population is not only growing fast, but is getting younger.[19] The Indigenous population in Kelowna is growing even faster, along with immigration that is driving population growth and increasing the City's diversity.[19] Kelowna's population growth is primarily driven by people moving to the City rather than by births.[19]

144,576 residents (2021)

13.5% increase in population from 2016 to 2021

2.9% of BC's total population

LAND USE

The City of Kelowna spans over an area of 211.85 km^2, with a population density of 682.4 per km^2. Much of Kelowna's natural beaty remains, with approximately 48 km^2 covered by water area and 12.68 km^2 covered by parks and green space.[20]

The land use in Kelowna's Urban Centres is characterized by a mix of high density residential, commercial, institutional and public outdoor spaces like parks and waterfronts, serviced by public transit and a mix of active transportation and shared mobility options.[21]

211.85

Land Area in Square Kilometres

682.4

Population Density per Square Kilometre

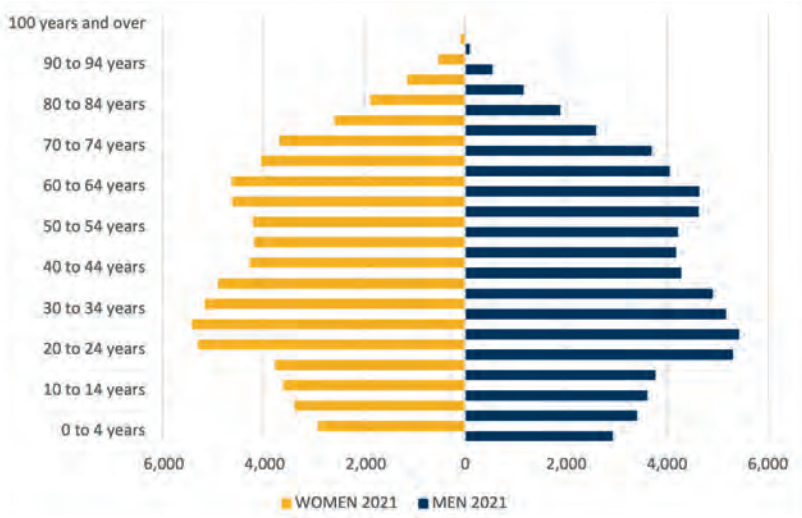
48

Square Kilometres of Water Area

SOCIO-DEMOGRAPHIC INFORMATION

AGE DISTRIBUTION

As can be seen in the population pyramid (Graph 1), the population is not only growing but is getting younger. The median age of the population is 42.4, which is below the provincial median of 42.8 (2021). While the number of Kelowna residents 65+ continues to grow, residents age 20 to 44 is outpacing all other age groups.[19]



Graph 1. Kelowna's Population Pyramid

Median Age

City of Kelowna 42.4

Province of British Columbia 42.8

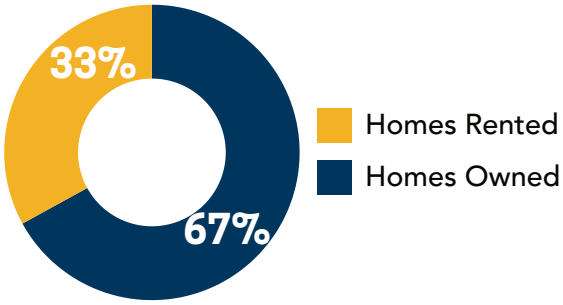
HOUSING TYPOLOGIES

Kelowna is seeing smaller households, more renters, and more multiple dwelling units. Residents 65+ are more represented and likely to live in segments of the Urban Core, whereas families with younger children live in areas outside of the Urban Core.[19]

There has been an increase in the quantity and variety of housing types, including a shift towards more dense infill and multi-family housing, notably in the City's Urban Centres. Apartments and rental housing are the most common form of housing in the Urban Centres.[19]

67,115

Private Dwellings



2.3

Average Census Family Size

LITERATURE REVIEW

UHI: BACKGROUND REVIEW

URBAN HEAT ISLANDS (UHI)

Urbanization has changed land use patterns worldwide, resulting in urban temperatures being 1°C to 3°C warmer than surrounding regions – this is referred to as the UHI effect.[7] The UHI effect is happening in cities worldwide, but the intensity will vary depending on how land use has changed the extent of green spaces, permeable soils, and the built environment.[22, 23, 24, 25] As well, the impact of UHI on people will differ based on neighbourhood demographic information and what activities are conducted in those areas.[26]

UHI is caused by the following factors:

- "The release of anthropogenic heat;
- The excess storage of solar radiation by the city structures;
- The lack of green spaces and cool sinks;
- The non-circulation of air in urban canyons; and,
- The reduced ability of the emitted infrared radiation to escape in the atmosphere" (p.1).[27]

UHI PROCESSES

The UHI effect is "the most documented [urban] phenomenon of climate change" (p.1).[27] In literature, UHI is commonly differentiated into three types of processes: (i) surface, (ii) canopy layer, and (iii) boundary layer UHI.[28, 29, 30, 31] UHI processes can be examined at various scales throughout urban centers, ranging from the larger mesoscale (whole city) to the local-scale (neighbourhood) and even further down to the micro-scale (building and street surfaces).[32, 33] It is key to consider how these scales interact with each other and influence heat distribution and risk.

Academic literature has found that six factors influence the urban climate: (i) Weather, (ii) Time, (iii) Geographic location, (iv) City size, (v) City function, and (vi) City form.[34]

Among them, only the last three factors are "controllable" variables shaped by the processes of urban planning and spatial design.[34] These three factors are essential to examine as land use, urban design, and building design in urban areas will "determine at large the magnitude of the urban overheating" (p.2).[27]

Research has found that UHI's also have unique impacts in coastal regions, along seas, lakes, and bays, as temperature gradient changes alter wind strength due to urbanization.[23, 35] Lakes may also help mitigate UHI by absorbing heat during the day and releasing it at night, creating cooler microclimates.[36, 37] The interaction between UHIs and water bodies will be meaningful in Kelowna, as two of Kelowna's Urban Centres are located along the Okanagan Lake waterfront.

IMPACTS OF UHI

Broadly, UHI has been found to increase the intensity of heatwaves, create air pollution, and increase energy demand in cities.[28, 35, 38, 39] Further, extreme heat can significantly impact citizens' physical and mental well-being.[40, 41, 42, 43] As the Intergovernmental Panel on Climate Change (2021) notes, heat waves and extreme heat events are expected to increase and unprecedented temperatures are expected due to climate change, this puts an increased focus on addressing and mitigating UHI. Specifically, higher temperatures are a risk to:

- Elderly people
- People living in isolation
- People with chronic health issues, specifically heart and breathing problems
- People on specific medications
- Pregnant people
- Low-income populations
- Unhoused populations
- People who work outdoors and perform manual labour
- Children and infants[7, 42, 44]

IMPACTS OF UHI (CONT.)

Literature notes that racialized and low-income populations are not only more likely to experience negative impacts from heat events, but are more likely to be located in areas where the UHI effect is worse as a result of low socio-economic status, lack of green spaces, and lack of resources such as air conditioning and cooling appliances.[38, 42, 43] Homeowners have been found to value cool temperatures; thus, temperature differentials are reflected in housing prices, replicating the problem.[43] These findings emphasize the importance of using an equity lens and analyzing vulnerability in this work.

UHI also contributes to higher peak electricity demand in the summer due to the increased need for air-conditioning and other cooling devices and decreased natural cooling through convection at night.[45, 46, 47] This creates a feedback loop as the additional energy use generates additional heat, which will need to be cooled, intensifying the UHI effect.[46, 47] It is also important to note that UHI results in increased — or worsened — air pollution.

LINKING UHI & BUILT FORM

Scholarly research has examined the impact of different aspects of the built form on UHI. Land use, urban design, and building materials have an impact on the urban climate. Our literature review primarily focused on how urban core size, land development, urban form, density, building height, aspect ratio, sky-view factor, and trees and vegetation all impact UHI in cities (see Appendix A for the impact of each built form indicator on UHI).

These nine factors are discussed most often in literature and thus form the basis of our review.[22, 27, 48, 49] It is imperative to note that not only one factor but the interaction between the aforementioned nine factors significantly impacts UHI.

LAND USE PLANNING

Urban Core Size

The size of the city sets the urban surface that can interact with the atmosphere, which determines the horizontal extent of UHI and the depth of the urban boundary layer.[33]

Land Development

Industrial and transportation land uses are often relatively hot during the daytime. Areas of tightly-packed highrises are slightly cooler because of mutual shade.[33]

Urban Form

Refers to shapes of buildings and open spaces of urban areas. Effects shading at ground level.

URBAN DESIGN

Density

Scholars have found that building density increases the UHI effect by reducing green spaces and permeable surfaces in urban areas.[52, 53] Further, in multiple quantitative studies, density has also been found to lead to stronger UHI intensity as a result of the built-form trapping heat.[39]

Although densification has been found to increase UHI, research has highlighted that vertical densification increases UHI less significantly than horizontal densification.[25, 39, 54] Quantitative studies have found that increasing the area of roofs through horizontal densification produces a more significant UHI effect because roofs heat up more quickly than streets.[26] Taller buildings are also optimal because they create shade that reduces the heat absorbed by road surfaces.[26, 53]

Some studies contradict these findings, suggesting that sprawling environments are better than compact urban centers in reducing the land surface temperature for urban areas as a whole.[39, 55] Thus, as scholars have suggested, there are still questions about the optimal density level to decrease the UHI effect. However, it is clear that "distributing density on the land in a proper layout has a fundamental significance" for mitigating UHI (p.173).[56] Further, according to research by Kolokotsa et al. (2022), if density increases, there will be reduced space for UHI mitigation measures. Thus, spatial considerations for incorporating UHI mitigation must be prioritized.[27]

Height

Scholars have found that building height can affect UHI in varied and complex ways.[26, 53, 57, 58] For example, building height significantly affects wind flow and shade, influencing the urban microclimate.[57] Academic literature does not provide a consensus on the optimal building height.

Scholars commonly argue that as height increases, UHI decreases, as they find that tall buildings shade the street canyon and structures underneath, lowering the amount of direct sunlight and – therefore – the amount of solar radiation absorbed.[26, 53] The creation of shade is important because a "1% [increase] in building shade area leads to LST [land surface temperature] decreases between 0.24% and 0.79%" (p.2).[53] A common finding in the literature is that areas with diverse heights, including a mix of low- and high-rise buildings, create the lowest UHI effect.[26] The effect of height on UHI also depends on the street width, which will be discussed in the following sections.[27, 48]

Aspect Ratio

An important component of urban morphology, the aspect ratio refers to the height of buildings compared to the width of streets.[27, 48] This is also referred to as the street height-to-width ratio.[49] The aspect ratio is an essential component of determining the UHI of an area because urban street canyons can trap heat and reduce air circulation, intensifying the UHI effect.[48] Higher canyon aspect ratios have tall buildings surrounding narrow streets, compared to lower aspect ratios with shorter buildings surrounding wider streets (see Figure 1).[48]

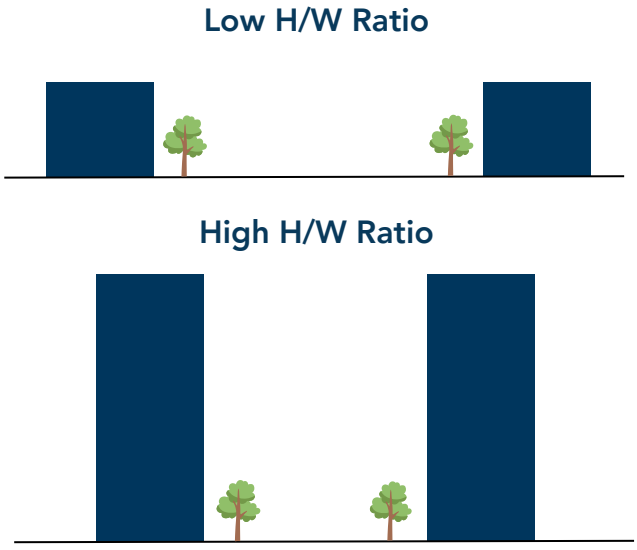


Figure 1. Aspect Ratio (Figure redrawn for clarity based on the City of Kelowna OCP) [6]

URBAN DESIGN

Aspect Ratio (Cont.)

Research finds that street canyons with a low height-to-width ratio cool down faster and have a more significant proportion of cool areas when compared to streets with a high height-to-width ratio.[27, 48] This difference is because wide street canyons have a larger increase in land surface temperature in the morning and reach a higher maximum temperature earlier, however, they also have a more considerable amount of longwave radiation able to exit the street canyon at night because air circulation is not limited.[27, 48] Thus, it is crucial to examine how changing the height-to-width ratio can improve an area's natural ventilation.[22]

Sky View Factor

The sky view factor refers to the portion of the sky that is visible from the ground.[22, 24, 25] The amount of sky visible is determined by the street geometry and building density.[50] It is essential in determining nocturnal UHI effects.[51]

Current findings suggest that having a limited sky view factor results in heat being trapped between buildings, as the heat cannot escape at night, thus increasing UHI.[22, 50] Scholars suggest that maintaining the sky view factor in new developments is crucial, specifically for street canyons with a high height-to-width ratio, in order to ensure initial daylight, maintain wind conditions at the street level, and allow for cooling at night.[25, 56] This is also important for maintaining warmth in the winter in cold-climate urban areas.

Street Trees and Vegetation

The tree canopy coverage in the city controls the availability of surface moisture.[33] Vegetated areas can stay cool because plants and soils use solar energy to evaporate water and sustain heat loss by latent heat flux.[33] The coolest surfaces in the daytime are the heavily vegetated areas and water bodies. Water bodies and well-watered vegetation are also relatively cool at night.[33]

BUILDING DESIGN

Materials

The materials used to construct the built form and streetscape also play an important role in determining, most significantly, the surface level UHI.[28, 45, 48] The permeability, albedo, and thermal admittance of materials are important factors in accounting for the impact of city form on UHI.

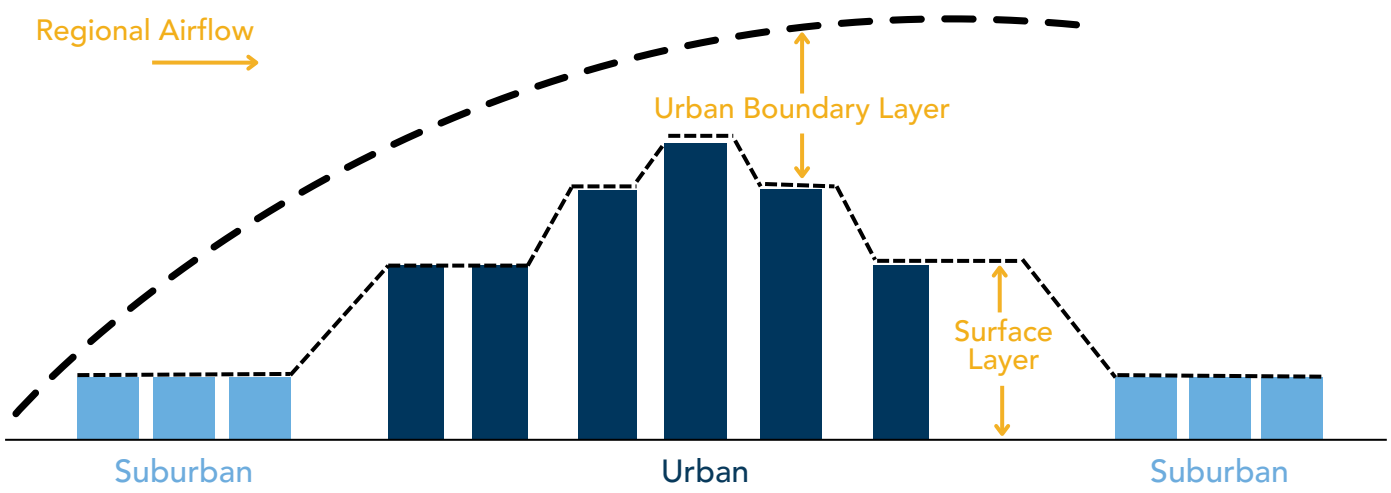
Permeability. The permeability of pavement and road surfaces is one of the most significant variables impacting UHI.[48, 59, 60] Impermeable surfaces absorb and accumulate heat and, thus, have a significant impact on the temperature of pedestrian and road surfaces.[22, 48, 60]

Albedo. The albedo of building materials, or the reflectivity of a surface, is important in determining the magnitude of UHI at the surface level.[22, 28, 48] Albedo is only an important parameter for areas that receive high sunlight during the day.[48] Higher albedo materials reflect heat, leading to lower surface and air temperatures, whereas low albedo materials absorb heat and hinder cooling at night.[22, 28, 48] Therefore, as scholars note, albedo is important in determining night and daytime temperatures.[22, 28, 48] The impact of albedo can be significant as "[by] increasing the albedo city-wide from 25 to 40%, a temperature drop of 1–4°C can be achieved" (p. 33).[22]

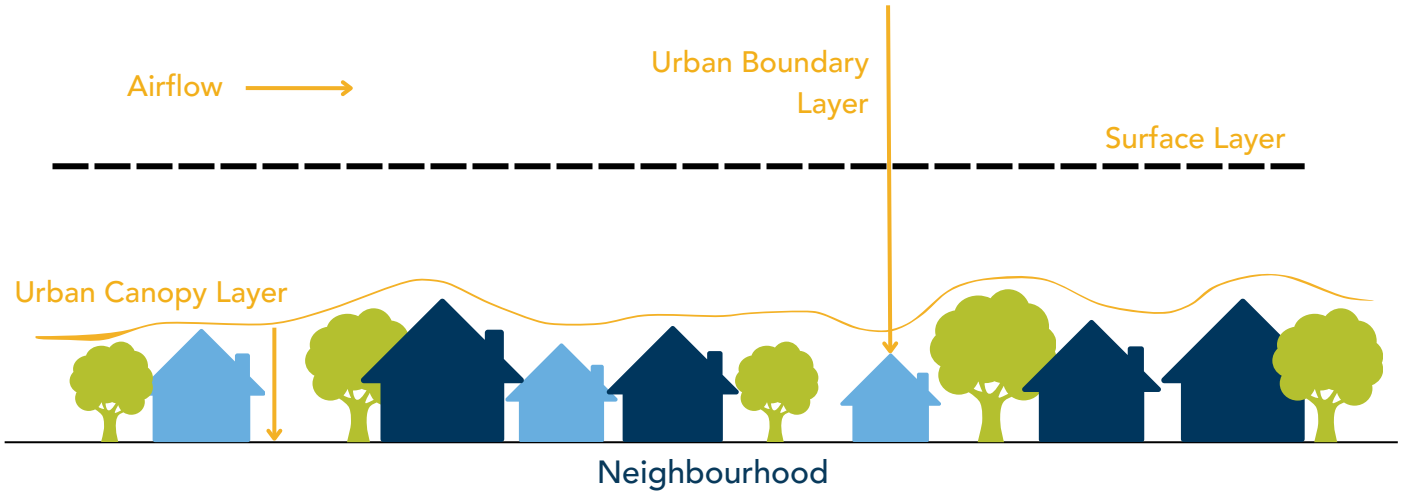
Regarding building materials, scholars find that light coloured materials reflect more light, reducing heat absorption and mitigating UHI. Contrastingly, dark colours absorb more heat and contribute to UHI. Increasing building albedo can decrease cooling demand.[61] Scholars note that high albedo building materials should only be used on the tallest roofs or if the street canyon is wide, as reflectivity from low-rise buildings may reflect and trap heat between surrounding taller buildings and exacerbate UHI.[48]

Thermal Admittance. Different materials have different thermal admittance, storing and admitting different levels of heat.[22, 28, 62] This "affects the time shift in heat release because the heat absorbed during the day will be released to the atmosphere at night" (p.12).[48] For example, brick, concrete, and asphalt store more heat and radiate it at night.[22]

WHOLE CITY



NEIGHBOURHOOD



BUILDING AND STREET SURFACES

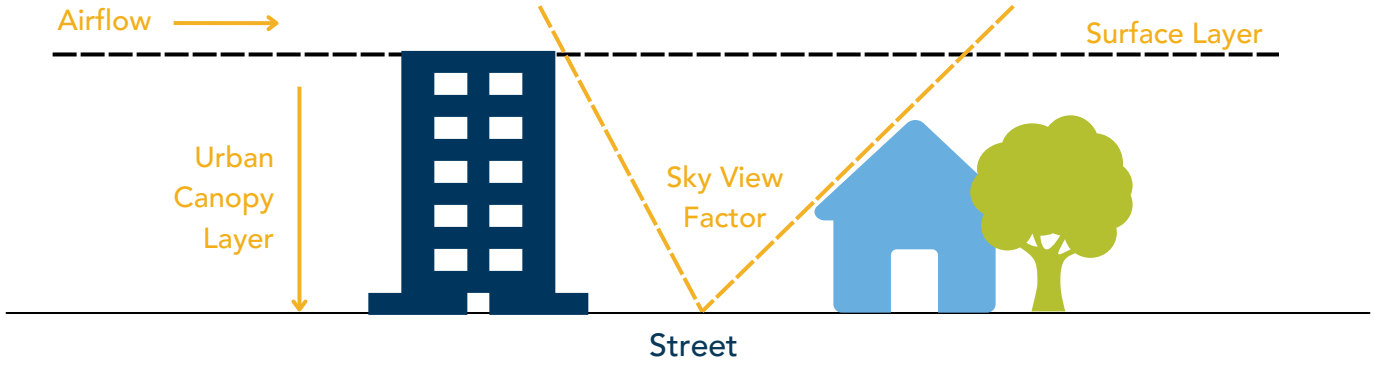


Figure 2. Three scales of the UHI effect: (i) Whole City, (ii) Neighbourhood, (iii) Building and Street Surfaces (Figure redrawn for clarity) [32]

PROMISING PRACTICES

PROMISING PRACTICES

BACKGROUND

Academic literature has identified promising practices in the built form for reducing the UHI effect. These promising practices intend to reduce the UHI effect created by land use, urban design, and building design (see Appendix B for a summary of practices). This section explores the effectiveness of each promising practice as set out by academic literature.

URBAN GREENING

STREET TREES

Literature finds that street trees can be critical in reducing the UHI intensity at the pedestrian level.[63, 64, 65] Street trees provide shade, thus reducing the direct sunlight reaching the surface.[65] Additionally, evapotranspiration releases water vapor into the atmosphere, which cools the air.[65] By absorbing and reflecting sunlight, trees prevent heat absorption by buildings and surfaces, reducing the need for air conditioning. [65]

Scholars have found that the cooling effects of tree planting can be maximized if trees are planted more densely. [63] Although the most significant cooling effects are found within 30 m of trees, scholars often indicate that urban vegetation and trees are the most effective cooling strategy available as "temperature reductions under the shade of a dense coverage of street trees obtained air temperature reductions between 1.2°C and 3.3°C". [63] Further, multiple scholars have found that if trees are planted in wind paths, significant cooling can be achieved compared to trees not planted in this way.[22, 64]

The selection of tree species can have an impact on shading.[66] For example, one study finds that deciduous trees can be planted in locations around buildings or to shade pavement as these trees reduce the heat in summer but maximize ground areas' exposure to sunlight in winter, thus ensuring that winter design is considered in planning for UHI.[66]

Drought-Tolerant Honey Locust Trees [67]

Street Trees in Kelowna [68]

LIVING ROOFS & WALLS

Globally, roofs constitute about 20-25% of the urban surface and result in increased UHI as heat is absorbed by typical roofing materials.[69] Green or vegetated roofs present an alternative to traditional roofing materials and "can reduce city-wide ambient temperatures by up to 3°C if deployed at scale" (p. 40).[70] Green roofs have been found to reduce UHI significantly through several mechanisms.

First, scholars find that the vegetation on green roofs creates shade and minimizes the direct exposure to sunlight and the absorption of solar radiation by building surfaces, lowering surface and air temperatures.[70, 71, 72] Also, green roofs enhance evaporative cooling, and the soil and vegetation on green roofs can act as insulators, helping to maintain cooler indoor temperatures.[69, 71] Scholars find that "[g]reen roofs can also reflect up to 30% of solar radiation and absorb up to 60% through photosynthesis," resulting in them being 17–22°C lower than those of conventional roofs (p. 398).[73] Green roofs produce additional co-benefits, including reducing GHG emissions, increasing biodiversity, and improving air quality.[64]

Maintaining green roofs in dry climates requires regular irrigation to support plant growth and can lead to high water usage, especially during droughts.[74, 75] In regions with limited water resources, choosing drought-tolerant plants and efficient irrigation systems can be done to minimize water usage.[75] Research suggests that to maximize plant survival in dry climates, green roofs should plant species with "low water use in substrates with high water holding capacity" (p.2).[74]

Three types of green roofs are common: extensive, semi-intensive, and intensive (see Table 1 for definitions of each type of green roof).[76] Scholars find that it is not the vegetation coverage of the roof that is most important, instead it is the shade and leaf density provided by the vegetation.[69, 76] Scholars have found that green roofs are more effective in low-rise buildings at cooling the pedestrian-level environment and suggest that street trees may be more effective in offering shade and providing evapotranspiration in areas with high-rise buildings.[77]

Type of Green Roof	Definition
Extensive	A shallow growing medium, usually ranging from 5 to 12 cm deep. Limited depth is sufficient to support low-growing vegetation such as grasses and mosses. Covers a large area.
Semi-Intensive	A growing medium ranging from 12 to 20 cm deep. Characterized by small herbaceous plants, ground covers, grasses, and small shrubs. Covers a large area.
Intensive	Deeper layer of soil (up to 1 metre) confined to smaller roof area with vegetation such as trees and bushes.

Table 1. Types of Green Roofs [76, 78]

Extensive Green Roof [79]

Semi-Intensive Green Roof [80]

Intensive Green Roof [81]

URBAN & STREETSCAPE DESIGN

COOL ROOFS

As discussed above, roofs constitute a quarter of the urban surface.[69] An alternative to green roofs, which integrate urban greening as a UHI solution, is to build a cool roof.[65, 72, 82] Cool roofs are designed to reflect more sunlight and absorb less heat than standard roofs.[65] The reflective surfaces of cool roofs are often achieved through materials with high albedo.[72, 82] This reflection minimizes the amount of solar energy absorbed by buildings, lowering surface temperatures.[72] Literature finds that cooler roofs can also indirectly contribute to energy savings by reducing the demand for air conditioning.[72]

Reflective or Cool Roof [83]

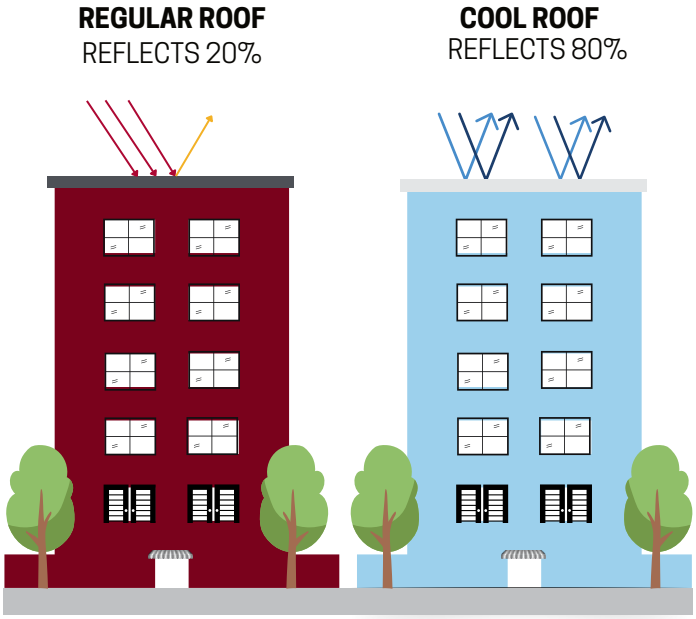


Figure 3. Cool Roofs (Graphic Redrawn) [84]

COOL & PERMEABLE PAVEMENTS

Pavements, including roads, parking lots, and sidewalks, significantly impact the intensity of the urban heat island effect.[59] Currently, pavements cover approximately 40% of city surfaces worldwide.[65]

Promising practices for reducing the effect of paved surfaces on UHI include constructing cool or permeable pavements.[72] Cool pavements reflect more sunlight and absorb less heat than standard pavements.[72] Permeable pavements allow water to infiltrate, reducing heat absorption and increasing evaporative cooling.[72] Promising practice research has found that pavements can be made "cool" in several ways, depending on whether a new paved surface is being constructed or existing dark pavements are being re-paved.[85, 86] When constructing a new paved surface, the use of materials with high reflectance in solar radiation or permeable pavements can be built. Existing pavements can also be coated in surface treatments to become cool pavements – cool surface treatments are available in several materials.

Interestingly, using permeable pavements may not be effective in climates with dry summers, where moisture is scarce because the permeable pavement system will retain less water and provide less evaporative cooling.[85]

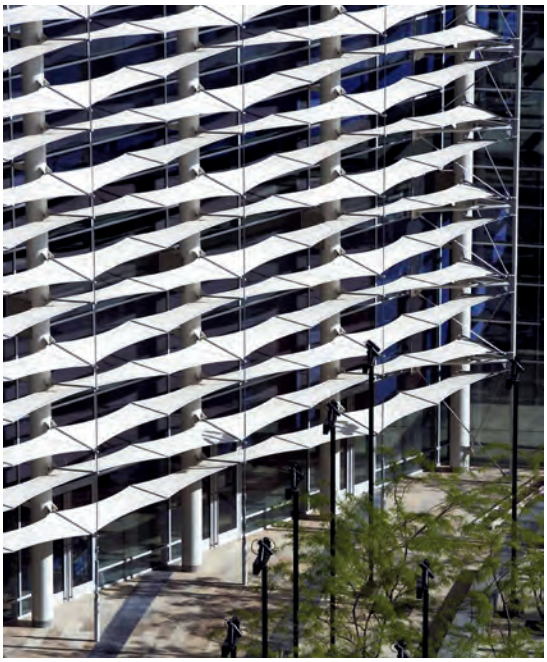
Reflective or Cool Pavement [87]

URBAN & STREETSCAPE DESIGN

ENGINEERED SHADE

Engineered shade structures can be built to reduce the amount of direct sunlight absorbed by surfaces.[82] By reducing the amount of solar energy absorbed by buildings and pavements, engineered shade helps lower surface temperatures. This shading effect is particularly impactful on outdoor spaces, creating cooler microclimates that enhance the overall comfort of urban environments.[82]

Creating shading devices, such as tents, shade canopies, and other built structures, can provide shade for the urban environment.[82] These can significantly impact the pedestrian experience in the summer months.

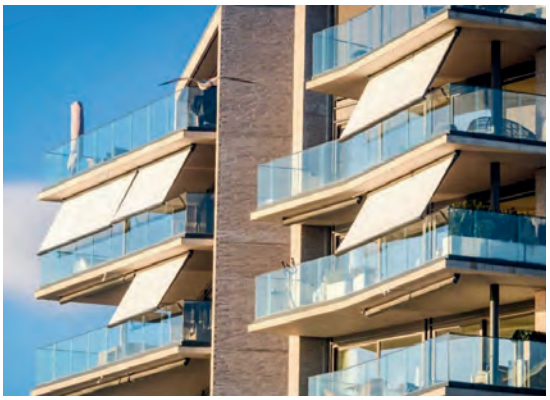


Architecture: Building Shading[90]

Public Art: Richardson Plaza (Boston, USA)[88]

Exterior Roller Shutters[91]

Public Art: Bloomcanopy (Phoenix, USA)[89]



Apartment Balconies' Retractable Awnings[92]

UHI CASE STUDIES

See Appendix C for case study methodology and detailed review of four UHI case studies.

Measure	Promising Practice City	Implementation Mechanism	Mandatory or Discretionary
Street Trees	City of Toronto	Greening Surface Parking Lots Design Guidelines [93]	Discretionary
	City of Melbourne	Urban Forest Precinct Plans [94]	Discretionary
Living Roofs & Walls	City of Surrey	Biodiversity Design Guidelines (see p.62)	Discretionary
	City of Austin	Downtown Density Bonus Program (see p.68)	Discretionary
	City of Melbourne	Growing Green Guide [96]	Discretionary
	City of London	Living Roofs and Walls Policy [97]	Discretionary
Reflective Roofs	City of Houston	City of Houston Construction Code [98]	Mandatory
Engineered Shade	City of Phoenix	Walkable Urban Code [99]	Mandatory
Cool & Permeable Pavements	City of Glasgow	City Centre Strategic Development Framework [100]	Discretionary
Green Corridors & Protected Areas	City of Saskatoon	Green Infrastructure Strategy [101]	Discretionary
Urban Geometry	Hong Kong SAR	Urban Climatic Map and Standards for Wind Environment [102]	Mandatory & Discretionary
Comprehensive Approach	City of Seattle	Seattle Green Factor [103]	Mandatory
	City of Vancouver	Green Buildings Policy for Rezonings [104]	Mandatory
	City of Toronto	Toronto Green Standard (see p.64) [95]	Mandatory
	City of Phoenix	Climate Action Plan (see p.66)	Mandatory & Discretionary

Table 2. List of Promising Practices Examples

COST-BENEFIT ANALYSIS (CBA)

CBA METHODOLOGY

OUR APPROACH

The CBA plays a crucial role in prioritizing recommendations based on their cost-effectiveness and co-benefits, allowing the City of Kelowna to make informed decisions on where to allocate resources.

In undertaking the CBA, a background review of economic costs and co-benefits for promising practices was gathered from literature and government publications. The financial implications of each promising practice, including implementation and operation costs, were highlighted to provide a basis for prioritizing recommendations moving forward. It is important to note that much of the research for costing of mitigation measures has occurred in the United States. Thus, dollar values and material costs may not reflect the actual cost in the Canadian Dollar (CAD).

Co-benefits of promising practices were also considered in the CBA. Given that competing priorities at the municipal level present a considerable challenge for addressing climate action, highlighting co-benefits supports the City of Kelowna in advancing multiple priorities simultaneously. Biodiversity, stormwater management, equity, and public health were included as co-benefits as they were commonly discussed and quantified in research on UHI (see Table 3 to 7).

In analyzing the CBA, trees and green roofs emerge as highly advantageous mitigation measures (see Table 4 and 6). They substantially reduce ambient temperatures and provide co-benefits ranging from improved stormwater management to enhanced habitat creation. Green walls and facades were found to have variable temperature reduction (see Table 5). Thus, it is imperative to consider the co-benefits alongside their effectiveness in mitigating urban heat. Similarly, permeable pavements effectively manage stormwater and provide comparable cooling benefits to other mitigation measures (see Table 3). Engineered shade and reflective roofs present cost-effective alternatives, demonstrating notable temperature reduction and serving as economically viable options for UHI mitigation (see Table 4 and 7). Ultimately, the success of these measures hinges on the careful consideration of local context, climate, and industry costs, ensuring an optimal and tailored implementation strategy for each urban setting.

To effectively present the costs and benefits for the City of Kelowna's future use, we created tables to summarize the installation and maintenance costs. These are the total costs of using each measures, including the design, materials, labour, and installation. Direct benefits, including carbon emissions reduction and improved air quality, were also accounted for, along with a qualitative breakdown of co-benefits. For additional information on the CBA, including further data and resources used, see Appendix D.

The following pages summarize the CBA for:

- Pavements (Permeable & Reflective) (Table 3)
- Roofing (Green & Reflective) (Table 4)
- Walls (Green & Living) (Table 5)
- Street Trees (Table 6)
- Engineered Shade (Table 7)

CBA SUMMARY TABLES

PAVEMENTS

	Permeable Pavements	Reflective Pavements
Description	Permeable pavements allow air, water, and water vapour into the voids of pavement, keeping the material and the subsurface cool by evaporation. They are made of either a porous substance that allows water to pass through or nonporous blocks spaced so that water can flow between the gaps. [30]	Reflective pavements allow more sunlight to be reflected from the pavements surface and less to be absorbed by its mass.[105]
Total Initial Costs	CAD $33.76 to $173.32 per m^2 [106]	CAD $2.79 to $62.08 per m^2 [107]
Total Operation Costs	CAD $1.16 to $6.25 per m^2 [108]	Requires little to no maintenance
Temperature Reduction	Ambient temperature: 4°C [109] Surface temperature: 10°C [107]	Ambient temperature: 2°C [110] Surface temperature: 8°C [107]
Co-benefits	• Reduced energy use and greenhouse gas emissions • Increased pavement life by slowing the rate of aging • Improved human comfort [30, 106]	
	• Improved water quality and stormwater runoff • Improved traffic safety via better water drainage [30]	• Enhanced nighttime visibility [30]
Considerations for Use	• Reduced efficiency during dry seasons and without the presence of water • Not appropriate where stormwater picks up high pollutant loads from oil, grease, sediments, pesticides, and heavy metals and would be released directly into a natural body of water • Not appropriate for roads that carry heavy-axle loads and where the slope of the road is too steep (over 5 percent grade) • Snow storage on permeable pavement should be avoided because it could lead to sediment accumulation and clogging[30, 106, 108, 111]	• Increased pedestrian exposure to heat [30]
Lifespan	20 years [30]	20 years [106]

Table 3. Costs and Benefits of Permeable and Reflective Pavements

ROOFING

	Green Roofs		Reflective (or Cool) Roofs
	Intensive	*Extensive*	
Description	Intensive and semi-intensive green roofs consist of layers of vegetation and specially engineered soil laid over a conventional roofing surface. Intensive green roofs have deeper soil, allowing more plant diversity.[112]	Extensive green roofs have a shallow soil base. Modular trays containing the soil and vegetation are placed on top of a conventional roof. They can be removed during maintenance checks.[112]	A cool roof is one that strongly reflects sunlight and also cools itself by efficiently emitting any heat that was absorbed.[113]
Total Initial Costs	CAD $527.76/$m^2$ Including the design, materials, labour, and installation[112]	CAD $211.08/$m^2$ Including the design, materials, labour, and installation[112]	CAD $25.55 to $126.67 per m^2 Depending on material and colour[30]
Total Operation Costs	CAD $18.60 to $29.79 per m^2 Including irrigation costs and labour: 6 person-hours per 1,000 square feet per year[114]	CAD $11.19 to $29.79 per m^2 Including irrigation costs and labour: 4 person-hours per 1,000 square feet per year[114]	Requires little to no maintenance
Temperature Reduction	Ambient temperature: 0.3°C to 3°C[115]		Ambient temperature: 0.1°C to 0.33°C per 0.1 increase of the roof's albedo[115]
Co-benefits	• Reduces greenhouse gas emissions • Improves human health and comfort		
	• Improves air quality and reduces noise pollution • Provides natural habitat and increases biodiversity • Enhances energy efficiency by providing additional insulation to the roof • Generally, adds usable space and increases a building's property value • Extends roof life by protecting roofing membranes from ultraviolet radiation[112, 116]		• Reduces energy use[30]
Considerations for Use	• Buildings must be able to support additional weight[106, 112]		• May cause an increase in demand for building heating in the winter[106]
Lifespan	30 to 50 years[30]		15 to 25 years[117]

Table 4. Costs and Benefits of Green and Reflective Roofing

GREEN WALLS

	Green Facades		Living Wall Systems
	Direct	*Indirect*	
Description	Direct green facades use evergreen or deciduous climbers that attach themselves directly to the building surface.[118]	Indirect green facades use a vertical support structure with trellis or steel cables that guide plant development along the support structure. In addition to the shading impact, they can provide promising thermal insulation due to the air gap between foliage and the external walls.[118]	Living wall systems are constructed from modular panels, each containing its own soil or other growing medium, which meets the plant's nutrition and water requirements.[119]
Total Initial Costs	CAD $65.52 to $98.29 per m^2[120]	CAD $87.36 to $163.82 per m^2[120]	CAD $873.64 to $2,620.93 per m^2[120]
Total Operation Costs	CAD $3.94 to $17.34 per m^2[121, 122]		CAD $36.29 per m^2[121, 122]
	Includes pruning, irrigation, plant species replacement, and irrigation-system replacement.[123]		
Temperature Reduction	Ambient temperature: 1.2°C[119]	Ambient temperature: 2.7°C[119]	Ambient temperature: 5.0°C[119]
Co-benefits	• Enhanced building energy efficiency and reduced greenhouse gas emissions • Improved air quality • Increased biodiversity • Enhanced building aesthetics, increased property values and improved rental rates[106, 123]		
Considerations for Use	• Lighting is often required for green walls positioned in low-light exposure areas, as plants require specific lighting quantities and qualities to photosynthesize, grow, flower, and develop appropriately • Additional ventilation may be needed to prevent fungal growth • Green walls require irrigation, especially in consideration of drought conditions, to ensure optimal plant health[124]		
Lifespan	25 to 30 years[123]		

Table 5. Costs and Benefits of Green Facades and Living Wall Systems

STREET TREES

	Street Trees
Description	Leaves and branches reduce the amount of solar radiation that reaches the ground surface below the tree canopy. Trees also absorb water through their roots and emit it through their leaves via evapotranspiration.[30]
Total Initial Costs	CAD $392.14 to $784.28 per tree [125]
Total Operation Costs	CAD $29.42 to $127.48 per tree [30]
Temperature Reduction	Ambient temperature: 2.3°C [126]
Co-benefits	• Reduced energy use • Reduced air pollution and greenhouse gas emissions • Improved biodiversity • Increased carbon storage and sequestration • Improved human health and enhanced quality of life • Reduced pavement maintenance costs as tree shade can reduce the deterioration of street pavement (e.g., fatigue cracking, rutting, shoving, and other distress) • Increased aesthetic and recreational value [30, 106]
Considerations for Use	• It takes 15 years for an average tree to reach maturity and provide the full range of benefits • Irrigation may be needed to supplement precipitation and support the new tree canopy long-term • Avoid introducing non-native, invasive, or other species not suited to future local climate conditions • The use of non-FireSmart trees and vegetation around buildings can increase the fire risks of communities in fire-prone areas [30, 106]
Lifespan	Average of 19 to 28 years based on survival rates of street trees [127]

Table 6. Costs and Benefits of Street Trees

ENGINEERED SHADE

	Engineered Shade
Description	Constructed shade structures can be permanent (e.g., pavilions and overhangs) or portable/temporary (e.g., umbrellas, awnings and shade sails). These devices are deployed at carefully selected locations to supplement the lack of shade from surrounding buildings.[128, 129]
Initial Costs	Permanent Structures: • 10'x10' Conventional Shade Structure: CAD $40,356.76 per piece[130] • 10'x20' Conventional Shade Structure: CAD $82,296.14 per piece[130] • Bus Shelter: CAD $30,443.08 per piece [131] Moveable Structures: • Cantilever umbrella: CAD $2,050.11 to $3,221.60 per piece[128]
Operation Costs	Requires little to no maintenance
Temperature Reduction	Ambient temperature: 3.8°C [126]
Co-benefits	• Protecting users from rain or harsh winds [132]
Considerations for Use	• Some shading devices, particularly those fixed on building walls, may restrict light, natural ventilation, and views outside the building [133]
Lifespan	Glass, Timber, and Steel roof sheeting: Long duration if well-maintained Polycarbonate and fiberglass sheeting: 10 years Knitted polyethylene or woven PVC shade cloth: 5 to 10 years [129]

Table 7. Costs and Benefits of Engineered Shading

POLICY ACTIONS

POLICY ACTIONS

RECOMMENDATIONS

Eighty-five policy actions are proposed to address and combat the UHI effect in the City of Kelowna. These recommendations are grounded in the literature review and promising practices identified, and are organized by the relevant policy mechanism.

Zoning Bylaw (Bylaw No. 12375)

The zoning bylaw defines how specific areas of land can be used, specifying the nature of these uses in more detail and regulating the density and height of structures. The zoning bylaw is a powerful tool the City of Kelowna can use to take action against climate change and the UHI effect.

Subdivision, Development, and Servicing Bylaw (Bylaw No. 7900)

The subdivision, development, and servicing bylaw outlines regulations and requirements for land subdivision, setting the standards for the design and construction of infrastructure in the creation of lots, roads, and utilities. This bylaw can be updated to promote climate-resilient design, including green infrastructure and landscaping.

Development Permit Areas (DPA)

DPAs and associated guidelines prescribe the general criteria for new development and form the basis for the review and approval of a development permit. For DPA purposes related to climate action and reducing the UHI effect, the City of Kelowna can incorporate guidelines related to:

- landscaping (e.g. requiring drought tolerant plants);
- siting of buildings and other structures (e.g. building orientation for wind ventilation);
- form and exterior design of buildings and other structures (e.g. provision of overhangs for shade);
- specific features in the development (e.g. tree canopies); and,
- machinery, equipment, and systems external to buildings and other structures (e.g. rainwater collection systems).

Strategic Plans

Strategic plans are used by the City of Kelowna to guide the growth and development of the city. These plans include the Official Community Plan (OCP), the 2040 Transportation Master Plan, and the Urban Forest Strategy (an update to the current strategy is currently under development). There is opportunity for the strategic plans to be amended to incorporate climate mitigation and adaptation measures and UHI promising practices.

Programs & Outreach

Programs and funding sources offered by the City of Kelowna can help incentivize the uptake of UHI promising practices through credits and rebates. Public outreach is also key to raising awareness of the UHI effect and extreme heat impacts.

POLICY PRIORITY

The recommended 85 policy actions are ranked based on their effectiveness in reducing the UHI effect, as well as the feasibility of the measure. Feasibility is determined by the costs outlined in the CBA. The policy priority is ranked on a scale from 1 to 6, with 1 being the most effective and high feasibility and 6 being the lowest impact and lower feasibility. Highlighting the priority of the policy action can help the City of Kelowna determine which policies are the most critical to implement to reduce the UHI effect. The scale is ranked as follows:

1. Maximum UHI reduction impact and benefit; costs are low to moderate (high feasibility)
2. Maximum UHI reduction impact and benefit; costs are moderate to high (lower feasibility)
3. Moderate UHI reduction impact and benefit; costs are low to moderate (high feasibility)
4. Moderate UHI reduction impact and benefit; costs are moderate to high (lower feasibility)
5. Lower UHI reduction impact and benefit; costs are low to moderate (high feasibility)
6. Lower UHI reduction impact and benefit; costs are moderate to high (lower feasibility)

CO-BENEFITS

The 85 policy actions also indicate the co-benefits of the recommendations, highlighting four main co-benefit themes for reducing the UHI effect: (i) biodiversity, (ii) stormwater management, (iii) equity, and (iv) public health. Having the co-benefits identified supports the City of Kelowna in advancing multiple priorities simultaneously.

Co-benefits are identified on policy actions by the following legend:

- Biodiveristy
- Stormwater Management
- Equity
- Public Health

BUILDING TYPOLOGY

Building typology is defined in the recommendations as per the City of Kelowna's standards:

- Low-Rise Building: 3 to 4 storeys
- Mid-Rise Building: 5 to 12 storeys
- High-Rise Buildings: 13+ storeys

ZONING BYLAW

ZONING

1. Use zoning to space high-rise buildings to maximize airflow and ventilation (requires an understanding of wind patterns in Urban Centres to determine adequate spacing; see Action 63).

Priority: 2

PARKING

2. Require a 1 to 5 ratio of trees to surface parking spaces.

Priority: 1 *Co-Benefits:*

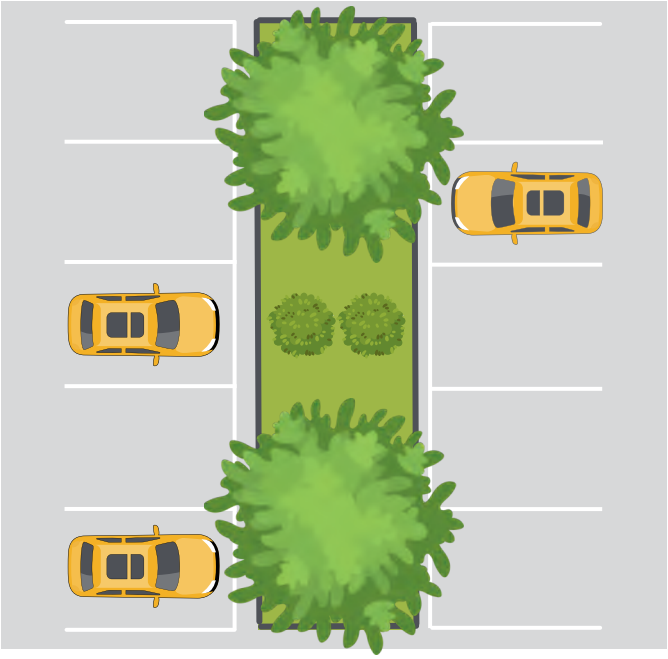


Figure 4. Action 2: Require a 1 to 5 ratio of trees to surface parking spaces.

DENSITY BONUS

3. Additional floor area* is earned as a bonus for each sq ft of planted bed on a vegetated roof**.

If 30-40% of total roof area is covered in vegetated roofing, the developer is awarded an extra 2 sq ft of bonus floor area for each sq ft of vegetated roof. If >50% of total roof area is covered in green roofs, the developer is awarded an extra 3 sq ft of bonus floor area for each sq ft of vegetated roof.

**To note: the increment has to be worth enough to the developer to be an incentive to provide the amenity, so more research and insight into land values and construction costs is required to properly calibrate the bylaw.*

***Density bonusing is best used for high-density residential or commercial buildings.*

Priority: 4

4. Additional opportunities for density bonusing could be applied to advance other UHI goals, including supplying engineered shading in pedestrian areas, installing reflective roofing, and adding green walls.

Priority: 4

FLOOR AREA RATIO (FAR) EXCLUSION

5. Energy efficient building materials and infrastructure tends to occupy more space than less efficient materials. Exclude spaces occupied by materials that reduce the UHI effect (e.g., thick walls and shading devices that provide insulation and save energy) from the FSR calculations.

Priority: 3

BUILDING HEIGHT RESTRICTIONS

6. Exclude UHI and climate-friendly building designs, such as green roofs or solar rooftop equipment, from building height measurements.

Priority: 1

VARIANCES

7. Encourage the use of green infrastructure and building features, and anticipate building height variance applications for zoning that are justified by the inclusion of urban heat island mitigation measures.

Priority: n/a

Figure 5. Action 3: Additional floor area earned for each square foot of planted bed on a vegetated roof.

SUBDIVISION, DEVELOPMENT, AND SERVICING BYLAW

SUBDIVISIONS

8. Update the subdivision and servicing bylaw to include more climate-friendly/UHI mitigation measures to promote the reduction of the UHI effect (*See Section 506 of the LGA for reference*).

This bylaw may be revised to outline how roads, sewers, and servicing can be developed to be resilient to the projected impacts of climate change. Kelowna's Bylaw 7900 currently sets out design guidelines and engineering standards for municipal services. The bylaw guidelines should be adapted to promote climate-resilient design.

One approach to doing this is implementing green infrastructure principles in infrastructure design. An example is requiring storm drainage to include green infrastructure such as natural watercourses, landscaping, and trees when planned and implemented.

Priority: 2 *Co-Benefits:*

PAVEMENTS

9. Use reflective pavement coatings or use concrete instead of asphalt on new sidewalks and roadways to reduce the Urban Heat Island effect. Reflective coatings also increase nighttime visibility, creating a safer streetscape.

Priority: 4

10. Use permeable pavements for lower traffic streets and pathways, such as parking lots, alleys, curb lanes, or trails. Avoid permeable pavements for roads that carry heavy-axle loads and where the slope of the road is over 5% grade.

Priority: 6 *Co-Benefits:*

URBAN FORM

11. Support sufficient boulevard widths not less than 48" (1.2 m) to support large-canopy street trees.

Priority: 3 *Co-Benefits:*

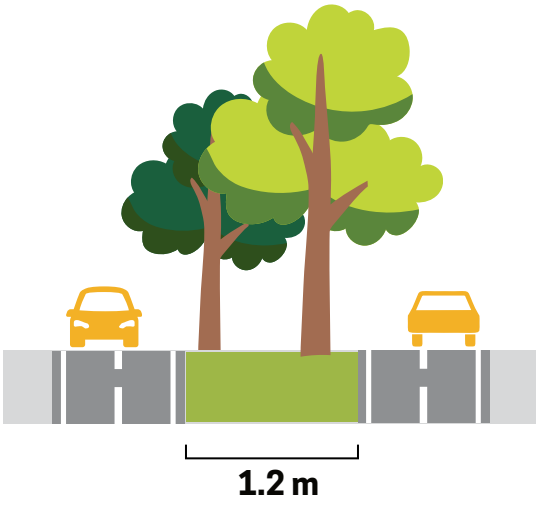


Figure 6. Action 11: Support wide boulevards for large-canopy street trees.

LANDSCAPING

12. Place trees in road medians.

Priority: 3 *Co-Benefits:*

13. Plant large canopy trees and create Urban Centre landscape landmarks in roundabouts and closed road ends.

Priority: 4 *Co-Benefits:*

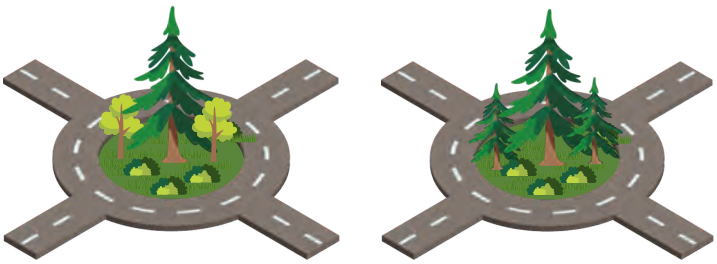


Figure 7. Action 13: Incorporate large canopy trees in roundabouts.

14. In wide medians, plant in two staggered rows to maximize canopy spread over hard surfaces.

Priority: 1 *Co-Benefits:*

Figure 8. Action 14: Two staggered rows of trees

15. Use low-maintenance, salt-tolerant species along streets, sidewalks, and other public spaces.

Priority: 5

16. Avoid materials such as rubber mulches, reused tires, and artificial turf as they can be toxic to soil and plants and contribute to the UHI effect.

Priority: 3 *Co-Benefits:*

17. For landscaping, such as green roofing and green facades, use drought-tolerant, Indigenous plant species as recommended by the na'ʔkʷulaməәn garden plant guide (*see Action 18*). Using Indigenous tree, shrub, and plant species reduces the need for supplementary irrigation.

Priority: n/a Co-Benefits:

PLANTING GUIDELINES

18. Acceptable plant species, as recommended by the na'ʔk'ʷulaмən garden plant guide,[134] include but are not limited to:

- Grasses
  - Pine grass or Timbergrass (tàkʷiɬp), Northwestern sedge (takʷiɬp), Northern Sea Oats, Sweetgrass (sxsìst'iyaʔ), and Bluebunch wheatgrass (styiʔ).

- Perennials
  - Yarrow (kʷətskʷətswixʷups), Nodding Onion / Wild Onion (x̌elíwa), Pearly Everlasting (tsəmtsəmɬk'íxʷ), Hemp dogbane (sp'its'n), Kinnikinnick (skʷalsiɬmalx), Pasture sage, Goat's-beard, Purple Aster (ntsástsestsn), Arrow-leaved Balsamroot (smúkʷaʔxn), Spring Beauty (skʷnkʷín'm), Dwarf dogwood, Prickly-pear cactus (sxʷinaʔ), and Bracken Fern (cuqcuqmáɬpu).

- Shrubs
  - Saskatoon berry, Big sagebrush (cq'ʷas'q'lstn), Rabbit brush, Oceanspray (mets'mets'íʔɬp), Tall Oregon grape (stsərsiɬmix), Blackcurrant (tq̓ʷq̓ʷyqwáʕýs), and Thimbleberry (plplqniɬmix).

Priority: n/a *Co-Benefits:*

19. Retain and/or add a healthy, absorbent topsoil layer sufficiently deep to allow for well-rooted planting and reduced irrigation requirements.

Priority: 5 *Co-Benefits:*

Using single species of plants can limit species diversity in Kelowna's Urban Centres. There is a balance to minimize the extent of homogenous planting while maintaining a strong design outcome through vegetation and trees. Promising practices to follow for planting a diversity of species include:

- Use mixed avenues of two or more species of similar form and character where appropriate.
- Identify natural breaks in streets at logical points where plant species may change.
- Use varying treatments along streets that are asymmetrical (e.g., streets where there are power lines on one side can have small vegetation on the side with the power line and large trees on the side without).
- Use informal mixes of species where acceptable (e.g., parks, gardens, planter boxes).

Figure 9. Action 18: Use Indigenous Plant Species

DEVELOPMENT PERMIT AREAS (DPA)

ROOFS

GREEN ROOFS

20. Implement green roofs on low- to mid-rise buildings, as they have a more significant impact on cooling the pedestrian environment than if implemented on high-rise buildings.

Green roofs are best suited to flat roofs or roofs that slope less than 20%.

Priority: 4 *Co-Benefits:*

21. Require intensive green roofs* for mid-rise buildings with short-spanning roofs. Require new mid-rise commercial, multi-family residential, and industrial buildings to have 50% of roof space as an intensive green roof.

Intensive green roofs should also consider:

- Plant species recommended in the Planting Guidelines (*see Action 18*). Intensive green roofs commonly use trees, shrubs, and perennials.
- Incorporating landscaped roofs, including intensive green roof systems to accommodate outdoor amenities such as sitting areas, gardening and play spaces.

**Intensive Green Roofs are defined as having planting boxes with deeper layers of soil confined to smaller roof area (e.g., trees, bushes).*

Priority: 4 *Co-Benefits:*

22. Require extensive green roofs* for low- and mid-rise buildings with long-spanning roofs. Require new low- to mid-rise commercial, multi-family residential, and industrial buildings to have 75% of roof space as an extensive green roof.

Extensive green roofs should also consider:

- Plant species recommended in the Planting Guidelines (*see Action 18*). Extensive green roofs commonly use grasses and are drought resistant.

**Extensive Green Roofs are defined as a shallow layer of soil over larger areas (e.g., grass).*

Priority: 2 *Co-Benefits:*

REFLECTIVE ROOFS

23. Require reflective roofs on high-rise buildings with flat surfaces to avoid creating dazzling reflectiveness on the pedestrian environment and other buildings.

Priority: 3

24. New high-rise buildings, new additions to high-rise buildings, and renovations in existing high-rise buildings must have a cool, reflective roof.

Priority: 3

25. Require reflective roofs to cover 100% of the surface of the roof.

Priority: 3

Figure 10. Various UHI Policy Actions Illustrated

WALLS

GREEN WALLS & FACADES

26. Utilize green facades and walls on mixed-use or commercial buildings to reduce heat absorption and create dynamic public spaces.

Priority: 3 *Co-Benefits:*

Green Wall on Musée du Quai Branly in Paris [135]

Arid Green Facade [136]

Public Art Green Wall in City of Surrey [137]

PAVEMENTS ON PRIVATE PROPERTY

27. Grade hard, impervious surfaces towards landscaped areas.

Priority: 5 *Co-Benefits:*

REFLECTIVE PAVEMENTS

28. Use reflective pavement coatings on new sidewalks and roadways to reduce the UHI effect. Reflective coatings also increase nighttime visibility, creating a safer streetscape.

Reflective coating materials can include white asphalt, concrete made with white cement mixtures, or light-coloured pavers.

Priority: 4

PERMEABLE PAVEMENTS

29. Use permeable pavements for lower traffic surfaces and pathways, such as parking lots, alleys, curb lanes, or trails.

Priority: 6 *Co-Benefits:*

30. Limit impervious paving and/or dark-coloured absorptive materials for sidewalks, driveways, and parking lots.

Priority: 1 *Co-Benefits:*

TREE CANOPY

31. For low-rise and mid-rise buildings, add vegetation and tree canopies to shade the streetscape and site area on private property, as low-rise buildings provide less shading to pedestrian pathways compared to high-rise buildings.

Priority: 1 *Co-Benefits:*

Figure 11. Action 31. Add trees to shade streetscape.

32. Give preference to large canopy trees over smaller canopy trees totalling the same extent, as a single large canopy tree provides greater benefits in terms of cooling, rainwater interception, and other ecosystem services.

Priority: 2 *Co-Benefits:*

33. Use deciduous trees for trees on footpaths.

Priority: 3 *Co-Benefits:*

34. Plant trees for passive solar gain and cooling, such as using deciduous trees on the side of a building to maximize the warming effect of solar radiation in winter months and the cooling effect of shade in summer months.

Priority: 1 *Co-Benefits:*

35. Plant trees around buildings to direct cooling summer breezes and act as windbreaks against cold winter winds.

Priority: 1 *Co-Benefits:*

PLANTING GUIDELINES

36. For landscaping, such as green roofing and green facades, use drought-tolerant, Indigenous plant species as recommended by the na'ʔkʷulaməәn garden plant guide (*see Action 18*).

Priority: n/a *Co-Benefits:*

37. Design the development so that high-value natural vegetation and soil are retained.

Priority: 1 *Co-Benefits:*

38. Retain and/or add a healthy, absorbent topsoil layer sufficiently deep to allow for well-rooted planting and reduced irrigation requirements.

Priority: 5 *Co-Benefits:*

LANDSCAPING MATERIALS

39. Avoid materials such as rubber mulches, reused tires, and artificial turf, as they can be toxic to soil and plants and contribute to the UHI effect.

Priority: 3 *Co-Benefits:*

BUILDING MATERIALS

40. Use building materials with high albedo and low thermal admittance to reduce energy consumption and enhance the comfort of buildings and urban spaces.

Priority: 1

41. Use tinted glass or windows with special coatings to reduce the amount of heat let inside the building (e.g., low E windows).

Priority: 5

42. Use a lighter value of colour on building exterior to reflect heat or cool materials (e.g., naturally high reflective white coatings, phase-change materials (PCMs), thermochromic, and fluorescent materials). However, walls should not be fully reflective (e.g., painted white) due to the negative impact the reflectivity may have on the pedestrian experience and on other buildings.

Priority: 1

ENGINEERED SHADING

BUILDING DESIGN

43. Add structural canopies and fabric awnings to buildings in order to provide shade at the street level (e.g., provisions of overhangs for shade).

Priority: 3

44. Use deep window overhangs and/or fixed operable external shading devices to control solar and heat gain through blocking out high-angle summer sun and allowing entry of low-angle winter sun.

Priority: 3

STREETSCAPE DESIGN

45. Encourage the use of innovative public art pieces that provide shade at the street level while enhancing the character of Urban Centres.

Priority: 4

URBAN FORM

46. Maximize desirable shade from direct sunlight through the use of landscaping and building siting and design.

Priority: 2

47. Orient building facades towards prevailing breezes to maximize ventilation and passive cooling (*see Action 63 for Wind Study*).

Priority: 2

48. Design new buildings to maintain sky view factors for narrow outdoor plaza spaces to ensure initial daylight, wind conditions at the pedestrian level, and night-time cooling.

Priority: 2

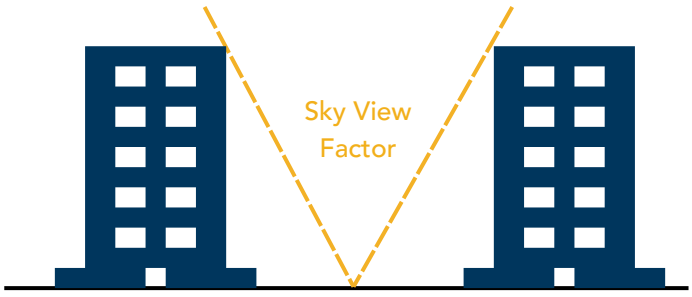


Figure 12. Action 48: Maintain sky view factor.

DEVELOPMENT APPLICATION CHECKLIST

49. Develop a *Development Application Checklist* for UHI mitigation measures.

The checklist will be provided to developers to ensure that UHI mitigation measures are considered in development applications. City of Kelowna staff will consider the input received from the applicant and the preliminary checklist will form part of the evaluation of the development application. The checklist can be based on UHI mitigation measures and OCP objectives for climate resiliency.

There is the option to use the checklist as an incentive tool, tying a completed checklist to potentially reward tax exemption, development cost charges (DCC) reduction, parking minimums relaxation, and application fast-tracking.

This checklist will include:

- Following and incorporating DPA requirements on:
  - Green roofing or reflective roofing
  - Building materials
  - Reflective pavements
  - Landscaping and tree planting
  - Engineered shading

Priority: 1 *Co-Benefits:*

See Appendix F for a proposed *Development Application Checklist* for UHI measures.

STRATEGIC PLANS

2040 TRANSPORTATION MASTER PLAN

50. Prioritize green, cooling corridors in vulnerable communities (see p.47 for Map 4).

Priority: 2 *Co-Benefits:*

51. Establish transit shelters for shading, prioritizing where vulnerable populations live (see p.47 for Map 4).

Priority: 3 *Co-Benefits:*

52. Provide shading with shelters – either engineered shading or tree canopies – for short-term bicycle parking.

Priority: 5

53. Establish seasonal misting stations at major transit hubs and transit stops in order to reduce the risk of extreme heat and heat-related illness.

Priority: 5 *Co-Benefits:*

URBAN FOREST STRATEGY

54. Preserve existing trees and open spaces to reduce non-permeable spaces in Urban Centres.

Priority: 1 *Co-Benefits:*

55. Use new LiDAR data and past understanding of Kelowna's climate to update canopy coverage targets for each growth strategy district, ensuring that they consider cooling at the city block scale.

Priority: 2 *Co-Benefits:*

56. Enhance the natural green network by increasing the quantity, density, and diversity of trees.

Priority: 2 *Co-Benefits:*

57. Use a tree equity approach to ensure equitable tree cover is provided for all residents and planting is prioritized in identified areas lacking urban forests.

Priority: 1 *Co-Benefits:*

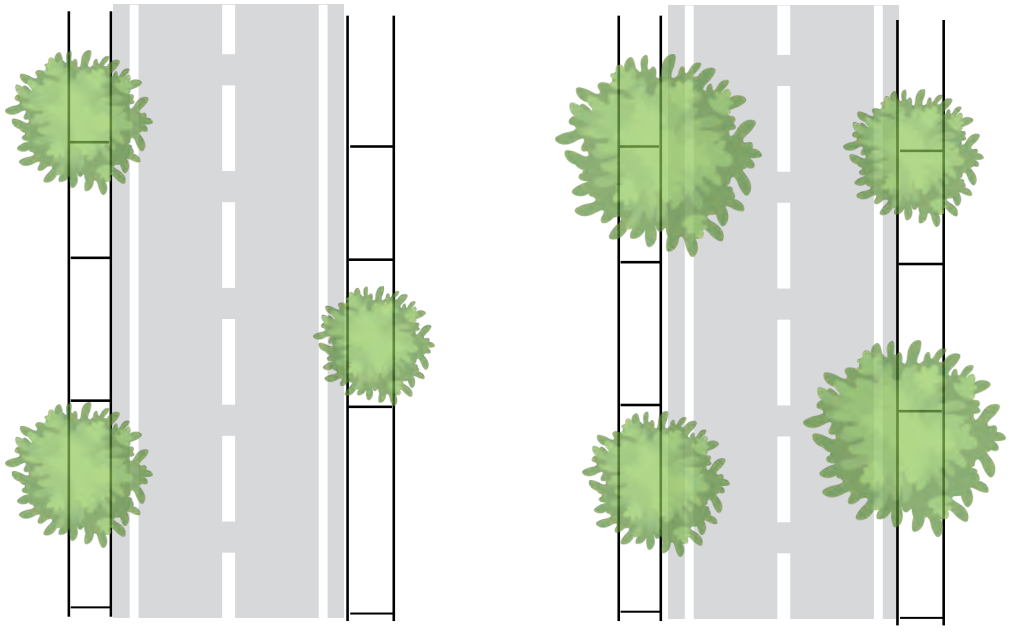


Figure 13. Action 55: Update tree canopy coverage targets.

OFFICIAL COMMUNITY PLAN

58. Ensure that urban form is built considering the impacts of height, aspect ratio, and sky view factor on the UHI effect.

Priority: 2

59. Utilize tree planting, paving type, and light-coloured, reflective roof surfaces or green roofs to reduce the UHI effect.

Priority: 2

URBAN CENTRES FRAMEWORK

60. Reference height recommendations set out in the zoning bylaw recommendations.

Priority: n/a

61. Increase shading structures and shelters where vulnerable populations reside (see Map 4).

Priority: 3 *Co-Benefits:*

62. Encourage activating underutilized spaces between buildings, such as courtyards, for summer-time use by adding splash pads that provide cooling.

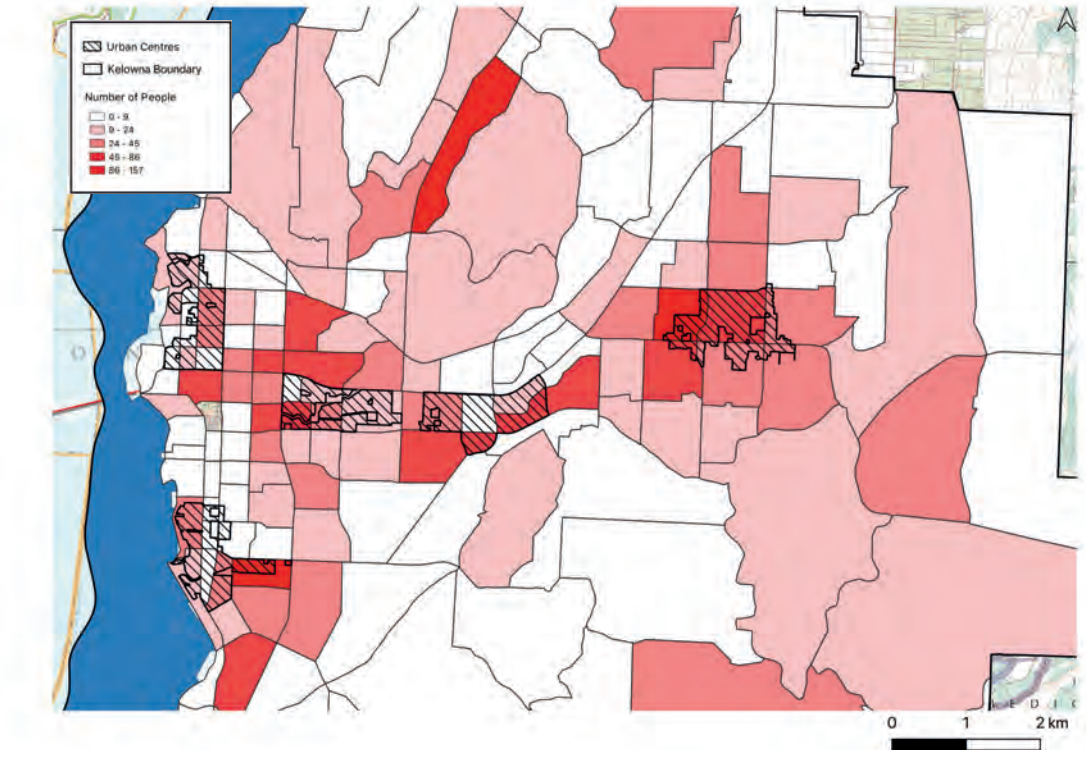
Priority: 5

NEW WIND & VENTILATION PLAN

63. The City of Kelowna should undertake a wind study to understand wind patterns and how to harness winds to increase street level and city-wide cooling. Research has found that harnessing wind patterns can reduce temperatures.[64]

A wind study can help determine where new buildings can be placed and oriented to harness wind patterns and create urban ventilation, as well as determine where to plant trees to place them directly in wind paths to increase cooling.

Priority: 2



Map 4. Action 61: Increase shading structure and shelters where vulnerable populations reside. [13, 14, 15]

PROGRAMS & OUTREACH

DEVELOPMENT APPLICATIONS

64. Investigate options for DCC rebates or other incentives to encourage the uptake of UHI initiatives as outlined in the Development Application Checklist (*see Action 49*).

Priority: n/a

PROGRAMS

65. Recommend the City of Kelowna to uptake UHI practices (e.g., green roofs, green walls, reflective pavements) on new and existing civic buildings and public spaces.

Priority: n/a

FUNDING

66. *UHI Charge System:* Investigate a financial program in which the City of Kelowna pays upfront capital costs related to UHI initiatives on building retrofits (e.g., installing green roofs), and building owners can repay the cost over a period of years through a charge on their property tax bill.

Priority: n/a

67. *Green Infrastructure Grant Program:* Investigate a program where private property owners can apply for a grant to fund the design and construction of a green roof on new and existing buildings. Roofs must be between 3,500 sq ft and 20,000 sq ft.

Priority: n/a

68. *Stormwater Runoff Credit Incentive:* If a stormwater utility is established, consider incorporating a stormwater credit for all non-residential or multi-residential property owners who reduce peak flow, reduce runoff volume, and add water quality treatment and operations. Maximum available credit is 50%, and it is recommended to use green roofs to achieve this.

Priority: n/a *Co-Benefits:* 

BUILDING CERTIFICATIONS

69. Investigate building certification programs, such as Leadership in Energy and Environmental Design (LEED) standard, to encourage holistic responses from the pre-design phase to construction of buildings to address equity, carbon emissions, public health, and UHIs.

Priority: n/a *Co-Benefits:* 

PUBLIC OUTREACH

70. Create public education and outreach programs to raise awareness about the UHI effect and encourage residents to adopt heat-reducing practices (e.g., retaining tree canopy, installing green or reflective roofs) on their own private properties.

Priority: n/a

ENHANCING EXISTING POLICIES

Of the 70 proposed policy actions for bylaws, DPAs, strategic plans, and programs and outreach listed thus far, various policies align and overlap with the current policies at the City of Kelowna. This section suggests ways these policies can be modified and enhanced to reduce the UHI effect.

2040 TRANSPORTATION MASTER PLAN

TMP Policy 2.1: Prioritize renewal and enhancement of existing infrastructure over the construction of new infrastructure, where possible.

71. When renewing transit infrastructure, including sidewalks and roadways, consider repaving using reflective paving materials (*see Action 9*).

TMP Policy 3.3: Prioritize bus shelters and amenities along Transit Supportive Corridors that are clean, attractive, safe, and accessible for people with disabilities.

72. Shelters in TOD areas and at transit stops can provide shading for pedestrians and create a safer environment during summer months (*see Action 51 and 52*). Additional amenities in TOD areas that can provide cooling to pedestrians include misting stations (*see Action 53*).

OFFICIAL COMMUNITY PLAN

Policy 12.8.2. Green Infrastructure Investment

73. Green infrastructure includes increasing the tree canopy (*see Action 55*), integrating UHI mitigation measures into buildings with green roofs (*Action 20*) and green walls (*Action 26*), and reducing UHI on the streetscape with paving (*Action 29 to 30*).

Policy 12.8.3. Green Infrastructure in Development, Policy 12.8.4. Ecosystem Connectivity, & Policy 12.8.5. Multi-Purpose Design

74. More detailed actions on how to include green infrastructure, including tree canopy, green roofs and green walls and facades in new developments can be found in the DPA recommendations (*Action 20 to 49*).

Policy 14.2.1. Urban Forest as Green Infrastructure & Policy 14.2.2. Kelowna's Tree Canopy

75. Use new LiDAR data and past understanding of Kelowna's climate to update canopy coverage targets for each growth strategy district, ensuring that they consider cooling at the city block scale (*see Action 55*).

Policy 14.2.3. Plant Selection.

76. Provide specific plant species guidelines to determine which plant species are resilient and can withstand the local climate (*see Action 17 and 18 for local species planting guidelines*).

Policy 14.2.6. Trees in Development.

77. This policy should be bolstered when densifying Urban Centres, as mature vegetation and large canopy trees provide greater cooling potential than smaller, newly planted trees (*see Actions 31 to 35*).

Policy 10.2.4. Urban Linear Parks, Policy 10.2.2. Parks on Streets & Policy 5.5.2. Urban Forest Canopy

78. Establishing and maintaining street trees in both Urban Centres and Core Areas is important. See Action 54 to 57 for overarching Urban Forestry Strategy tree planting goals and guidelines, and see Action 12 to 14 for recommendations on including tree canopies in the road medians and roundabouts.

2.1.4 Site Servicing, Access and Parking

- **e. Design parking areas to maximize rainwater infiltration through the use of permeable materials such as paving blocks, permeable concrete, or driveway planting strips.**

79. Permeable pavements have implementation limitations due to high costs and the dry climate context of Kelowna. However, permeable pavements can still be utilized to increase runoff during wet weather. See Action 10 for more detail on what streetscape components can utilize permeable pavements.

2.1.5 Streetscapes, Landscapes, and Public Realm Design

- **e. ensure site planning and design achieves favourable microclimate outcomes through strategies such as:**
  - **Locating outdoor spaces where they will receive ample sunlight throughout the year**

80. When locating outdoor spaces, it is important to provide adequate shading to protect pedestrians, specifically during the summer months and extreme heat events (*see Action 43 to 45*).

  - **Using materials and colors that minimize heat absorption**

81. More information should be provided to set out what materials are best for minimizing heat absorption. See Actions 40 to 42 for more information on building materials, Actions 20 to 25 for roofing, and Actions 28 to 30 for sidewalks and pavements.

  - **Using building mass, trees, and planting to buffer wind.**

82. Wind can be an important component of cooling the urban environment and reducing the UHI effect (*see Actions 1, 47, and 63*).

2.1.5 Streetscapes, Landscapes, and Public Realm Design

Landscape Materials

- **g. Plant native and/or drought tolerant trees and plants suitable for the local climate.**

83. Provide specific plant species guidelines to determine which plant species are resilient and can withstand the local climate (*see Action 17 and 18 for local species planting guidelines*).

2.1.2 Scale and Massing

- **Step back the upper storeys of buildings and arrange the massing and siting of buildings to:**
  - **Minimize shadowing on adjacent buildings as well as public and open spaces such as sidewalks, plazas, and courtyards**

84. When addressing the UHI effect, the shading provided by high-rise buildings can be important for cooling the pedestrian environment. If shading from buildings is not desired, see Actions 31 to 35 for shading buildings and streetscapes through tree canopy coverage, and Actions 43 to 45 for alternative mechanisms for cooling public and open spaces through engineered shade.

Site Planning & Orientation

e. Use appropriately designed exterior shading devices to block unwanted solar gains in warmer months while welcoming solar gains from lower winter sunlight. Additional considerations include:

- **Their use should be prioritized on southern elevations;**
- **Shading is not necessary on north-facing facades; and**
- **Vertical fins are a good strategy to use for blocking incoming summer sun on western elevations.**

85. External building shading is a key component when addressing the UHI effect at the neighbourhood scale, and Kelowna's current practices align with UHI mitigation techniques. See Action 43 and 44 for more engineered shading options through building design.

See Appendix E for the proposed 85 policy actions in a table format, with linkages to direct case study examples for each policy action.

KEY PERFORMANCE INDICATORS

OVERVIEW

Key Performance Indicators (KPIs) play a vital role in guiding, evaluating, and improving efforts to mitigate the UHI effect. KPIs can provide quantitative metrics to evaluate the 85 policy recommendations and identify areas for improvement and future policy action.

The following KPIs can be utilized to track progress in achieving UHI mitigation measures.

TEMPERATURE REDUCTION

Temperature reduction serves as a crucial KPI because it directly measures the effectiveness of UHI mitigation measures. By monitoring temperature reduction, the City of Kelowna can assess the impact of all 85 interventions in mitigating UHI. Temperature reduction KPIs provide tangible data for evaluating heat mitigation measures and guiding future planning decisions.

The following two KPIs can be used to measure temperature reduction:

- Average land surface temperature reduction in Urban Centres across summer months.
- Average regional-scale air temperature reduction across summer months.

TREE CANOPY COVERAGE

Using tree canopy as a KPI offers an essential metric for measuring progress because trees play a critical role in reducing urban temperatures.[58, 64] Monitoring changes in tree canopy coverage allows the City of Kelowna to assess the effectiveness of green infrastructure and urban forestry policies and strategies.

The following two KPIs can be used to measure tree canopy coverage:

- Percentage increase in tree canopy coverage.
- Number of trees planted in Urban Centres.

ENERGY USE

Employing energy use as a KPI allows the City of Kelowna to monitor changes in energy demand and gauge the effectiveness of urban heat island mitigation strategies such as cool roofs, green infrastructure, and street trees.

The following KPI can be used to measure energy demand reduction:

- Percentage decrease in energy demand for cooling purposes during summer months.

HEALTH IMPACT REDUCTION

Health impact reduction serves as a crucial KPI because it reflects the effectiveness of strategies in safeguarding public health and well-being.[2] Using health impact reduction as a KPI highlights the importance of prioritizing human health in planning decisions and underscores the broader public health benefits of heat mitigation measures. It also helps justify investments in UHI mitigation measures and informs targeted interventions to protect vulnerable communities.[2]

The following KPI can be used to measure the impact of UHI mitigation on health:

- Reduction in the number of heat-related illnesses or fatalities[2] (*Note: Need to consider summer temperature variations with this KPI*).

CLIMATE-FRIENDLY DEVELOPMENT

Monitoring the uptake of green infrastructure, cool roofs and pavements, and engineered shade through development applications is an important KPI for UHI mitigation. It reflects the integration of heat mitigation measures into urban development.

The following KPI can be used to measure uptake of climate-friendly development:

- Percentage of new development projects incorporating UHI mitigation measures.

NEXT STEPS

GAPS & LIMITATIONS

PROJECT GAPS & LIMITATIONS

This project may contain gaps because, as a result of the vast amount of literature available, generalizing findings on UHI impacts and mitigation measures' effectiveness was necessary. Additionally, as the literature acknowledges, the effects of UHI and the efficacy of solutions can vary based on the local context. Given that there is limited testing of mitigation measures in climates similar to Kelowna's desert-like conditions, not all mitigation measures may work as effectively as is set out in the CBA and recommendations.

A significant limitation was the lack of case studies addressing the role of mitigating UHI through urban form, despite frequent mentions in the literature review. Further, conducting a comprehensive CBA was challenging due to currency fluctuations and different material costs across countries. Co-benefits were also not quantified, and only those deemed most relevant to Kelowna were included.

REGULATORY LIMITATIONS

In Canada, all levels of government influence the adaptation actions taken. Challenges exist, specifically in British Columbia, as climate action has been downloaded onto local governments, putting the liability and burden of climate change impacts on municipalities. However, the B.C. provincial government is well-positioned to take action to address the UHI effect, as they can implement updates to building code, including the Energy Step Code, to include UHI promising practices.

In the case of our project, in the Spring of 2015, the B.C. Government passed the Building Act, a piece of legislation dedicated to building and construction that changed local governments' role in regulating UHI mitigation measures.[138] This change resulted in municipalities no longer being able to set technical building requirements. Though there are no building code requirements for green roofs in the new building code, local governments cannot enact requirements because they are related to roofing construction, which the provincial government regulates.[138] Therefore, local governments do not have the legal force to implement green roofs and technical building requirements for green roofs to mitigate UHI, which is why green roofs have been included in the DPA section of our recommendations.

NEXT STEPS

As the City of Kelowna densifies, a continued focus on mitigating extreme heat and UHI is imperative. Bylaws and policies are powerful tools local governments can use to help mitigate and adapt to climate change and the UHI effect.

While developing the recommended 85 policy actions are one major step towards reducing the UHI effect in the City of Kelowna, they are not the last step. To reduce heat in urban centres, the policy actions laid out in this report will need to be implemented and monitored over the short, medium, and long term.

IMPLEMENTATION

While outside this project's scope, it is recommended that the City of Kelowna develop an implementation schedule for the 85 policy actions. This implementation schedule should set the timeframe for achieving each action and the partnerships required. As well, some of the policy actions require more detailed input and technical work. In the process of creating an implementation schedule, the City of Kelowna can review the actions set out in this report and determine the staff capacity, time, and funding available to undertake this work.

SHORT TO MEDIUM TERM

Short- to medium-term implementation is often defined as planning for the present day to five years in the future. In the first five years, actions should be implemented by priority, as set out in the policy recommendations, to ensure that the most feasible and cost-effective actions are prioritized. As well, reference should be made to the heat vulnerability mapping to ensure equitable distribution of mitigation measures.

Given our understanding of current work happening in the City of Kelowna, we believe that in the short-term, there are opportunities to integrate UHI mitigation actions in the Urban Forestry Strategy and Urban Centres Frameworks.

The OCP, which is being updated before the end of 2025, should also include language and policies around UHI mitigation measures.

The City should also work closely with partners, residents, and stakeholder groups to move the actions forward. Developers are key to achieving success in reducing the UHI effect through private development requirements. It is important for the City to continue establishing partnerships with developers to provide a general understanding of the importance of their role in reducing the UHI effect.

MEDIUM TO LONG TERM

Implementation over the medium to long term, defined as 5 to 10 years, is crucial in reducing the UHI effect as climate change is projected to worsen extreme heat. During this period, the City should consider undertaking a wind study and more extensive program and funding initiatives. The City should also incorporate policy actions it intends to take into its short-, medium-, and long-term budgeting plans to ensure that the projects are accounted for in the City's capital planning process.

MONITORING

As policy actions are implemented, the KPIs should be utilized to track progress and adjust implementation approaches. Additionally, monitoring should incorporate insights from forthcoming academic literature on UHI and future work undertaken by other municipalities. Furthermore, it's essential to prioritize equity considerations and monitor the social impacts of policies to prevent the creation or replication of inequities. This iterative monitoring process will ensure that the policy actions remain relevant and effective.

APPENDIX A

SUMMARY OF UHI FACTORS

PAGE 57

APPENDIX A

SUMMARY OF UHI FACTORS

	Factor	Relevance to UHI
Land Use Planning	Urban Core Size	The size of the city sets the urban surface that can interact with the atmosphere, which determines the horizontal extent of UHI and the depth of the urban boundary layer.
	Land Development	Land use changes the surface temperature and shading provided at ground level.
	Urban Form	Refers to shapes of buildings and open spaces of urban areas. Effects shading at ground level.
Urban Design	Density	Building density refers to the number of dwelling units per unit of land area and can be used to quantify how concentrated buildings are in a city.
	Height	Refers to the height of a building from ground to top floor. Effects shading at ground level.
	Aspect Ratio	An important component of urban morphology, the aspect ratio refers to the height of buildings compared to the width of streets.[27, 48]
	Sky-View Factor	Refers to the portion of sky that is visible from the ground.[50, 51] A higher sky view factor means that more of the sky is visible as compared to a lower sky view factor.[50, 51]
	Tree and Vegetation Cover	Refers to the amount of tree and vegetation cover. Affects shading and cooling at ground level.
Building Design	Building Material	The materials used to construct the built form also play an important role in determining the surface level UHI.[28, 45, 48] The permeability, albedo, and thermal admittance of materials are important factors in accounting for the impact of city form on UHI.

Table 8. Definition of 9 Building Typology Factors

APPENDIX B

SUMMARY OF MITIGATION MEASURES

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APPENDIX B

SUMMARY OF PROPOSED MITIGATION MEASURES

Factor	Mitigation Measure
Urban Core Size	Encourage compact urban design to reduce the extent of impervious surfaces to minimize heat buildup and look into district cooling solutions.
Land Development	Encourage mixed-use development and discourage industrial use or large parking lots.
Urban Form	Include UHI lens in Urban Core Planning Design and Guidelines, if required by having an area specific planning policy and integrate green infrastructure, such as bioswales, green alleys, and rain gardens, to manage stormwater runoff and cool the surroundings.
Density	Update Development Permit Guidelines, Zoning Bylaws, and Subdivision, Development, and Servicing Bylaws to prioritize the creation of walkable neighborhoods with well-designed public spaces.
Height	Update Bylaws as per literature review as buildings provide shade to each other.
Aspect Ratio	Promote Engineered Shade to support wide streets.
Sky View Factor	Require new developments to maintain sky view factor. Employ reflective or permeable pavement materials to reduce heat absorption and surface temperatures.
Building Materials	Encourage adoption of green or cool roofs and walls that reflect more sunlight and absorb less heat.
Tree Cover and Vegetated Cover	Increase street trees and green spaces to provide shade and reduce surface temperatures and promote the use of vegetation in public spaces to enhance cooling effects.

Table 9. Mitigation Measures for Nine UHI Factors

APPENDIX C: CASE STUDIES

CASE STUDY METHODOLOGY

OUR APPROACH

We set out to examine case study communities undertaking promising practices through planning policies and tools. Our approach to selecting case studies was based on five factors to ensure comparisons can be drawn between the case study and Kelowna. These five factors are population, density, climate, average summer temperature highs, and area size (Table 10).

Factor	City of Kelowna
Population	144,576 (2021)
Density	600 people/km^2
Climate	Humid Continental
Avg Jul/Aug Temperature High	28 C
Area	211.8 km^2

Table 10. Case Study Factors of Consideration

While we tried to keep our search within the five criteria markers, we found that cities of similar scale to Kelowna were not taking action on UHI. Therefore, we broadened our scope and included cities with larger populations that had more innovative practices and policies.

In our research, a total of 26 case studies were examined in the following places:

- 7 in British Columbia
- 7 in the United States
- 4 in Canada (outside BC)
- 4 in Australia
- 3 in Europe
- 1 in Asia

Nine of those twenty-six case studies were presented to the City of Kelowna, and, with the input of Kelowna, we selected four case studies to focus on for their innovative approaches to combating the UHI effect and their similar climate context. These cases exemplify prescriptive and discretionary policies to combat the UHI effect, including zoning bylaws, building codes, design guidelines, and action plans.

The four cities and their promising practices that were examined are: City of Surrey (British Columbia, Canada), City of Toronto (Ontario, Canada), City of Phoenix (Arizona, USA), and City of Austin (Texas, USA) (Figure 14).

Figure 14. Selected Cities for Case Studies: Surrey, Toronto, Phoenix, and Austin

CASE STUDY: SURREY (B.C.)

PROMISING PRACTICE: GREENING BUILDINGS

The City of Surrey has developed design guidelines for green roofs and walls, implementing them into many civic building designs.[137] The design guidelines set out descriptive recommendations for adding vegetation to the built environment. As academic literature highlights, living roofs and walls can significantly cool the urban environment and buildings. They can also create enjoyable public spaces and serve as recreational green spaces. Given that the City of Surrey is, similarly to Kelowna, governed by the Local Government Act, finding a case study highlighting innovative, promising practices in the B.C. context was imperative.

SURREY CONTEXT

The City of Surrey has a population of 568,322 (2021 Census), making it the second largest B.C. city.[139] During the summer months, the City experiences average temperature highs of 24 degrees Celsius.[140] Experiencing fast population growth coupled with hotter summers, the City is concerned about vulnerable residents experiencing heat risk in the Surrey City Centre.[141]

BIODIVERSITY DESIGN GUIDELINES

In 2021, the City of Surrey developed the *Biodiversity Design Guidelines*, a set of recommended actions to support the implementation of Surrey's *Biodiversity Conservation Strategy*.[137] These guidelines support land use planning and development activities on public and private land at the site level and link with associated frameworks and policies at both the local and regional scales.

The design guidelines are informed by research, guidance, and best management practices, and are organized into the following eight modules:

1. Habitat Structures
2. Light and Noise
3. Road Ecology
4. Drainage
5. Green Roofs and Walls
6. Maintained Landscapes
7. Trails
8. Signage

Modules with linkages to practices that reduce the UHI effect are Module 4 (Drainage), Module 5 (Green Roofs and Walls), and Module 6 (Maintained Landscapes).

Module 4 guides reducing hard surfaces and increasing the total green and permeable areas to help manage water at the source. It also outlines adding green infrastructure to promote habitat connectivity to reduce groundwater impacts, which are practices that can co-benefit stormwater management and reduce the UHI effect.

Module 6 also prioritizes minimizing impervious surfaces and planting low-maintenance vegetation that is resistant to droughts and adaptable to future climate conditions.

BIODIVERSITY DESIGN GUIDELINES (CONT.)

Module 5 of the design guidelines focuses on green roofs and walls, outlining information to consider for five types of green infrastructure (Figure 15):

1. Intensive green roofs (i.e., rooftop gardens)
2. Extensive green roofs (i.e., grassy roofs)
3. Vegetated mats (i.e., pollinator plants)
4. Green facades (i.e., green wall)
5. Living walls (i.e., staggered retaining wall)

Figure 15. Types of Green Walls and Roofs

The design guidelines include ideas for what type of plants are best to incorporate, how to promote variation of species and habitat, and other essential information on creating successful green roofs and walls. There is an additional breakdown of what species these roofs and walls will attract and the co-benefits from it. The document also provides estimated cost ratings, with vegetated mats and green facades as the least costly ($-$$), and living walls and intensive and extensive green roofs as the most costly ($$-$$$).

KEY PERFORMANCE INDICATORS

There are no key performance indicators provided; however, the guidelines mention that effective monitoring can be used to assess the biodiversity design guidelines' usefulness and identify further application opportunities. Recommendations are also provided for how the City of Surrey can support these practices internally and externally.

KEY TAKEAWAYS FOR THE CITY OF KELOWNA

Although the *Biodiversity Design Guidelines* is a discretionary policy and promoted as a best practice to follow, the document does outline ways the City of Surrey can implement these practices internally and externally. It advises this can be achieved internally through having City staff educated on the foundational knowledge of the guidelines as well as having staff championing for them to be used in practice. It is also key to have clear linkages to other relevant policies and understand that systemic buy-in will take time. The guidelines can be externally implemented by the development community through education and awareness, ensuring guidelines remain clear and succinct, implementing the guidelines first on City lands and City projects, and considering further ways to incentivize implementation. Places the City of Surrey has already implemented green roofs and walls in public facilities include City Hall, Semiahmoo Public Library, an RCMP Facility, and Guildford Mall. Having the City act as a demonstration facility for new mitigation measures is an important takeaway for Kelowna.

As the literature indicated, building materials play a role in street-level UHI, and green infrastructure can help increase albedo and reduce the absorption of heat.[48, 65] Although this policy tool is not enforceable, Kelowna could use these design guidelines as a starting point to help set precedence on new greening practices moving forward.

CASE STUDY: TORONTO (ONTARIO)

PROMISING PRACTICE: COMPREHENSIVE APPROACH

The City of Toronto takes a comprehensive approach to addressing UHI in the built environment through the *Toronto Green Standard*, the performance guideline for new developments.[142] This policy tool sets out prescriptive guidelines to mitigate UHI using cool and green roofs, permeable and green pavements, and tree planting. As identified in the literature, Toronto's approach to combining multiple promising practices in one policy tool will increase the cooling effect of new buildings on the urban environment. In the Canadian context, the City of Toronto has created the most innovative guidelines and standards to address UHI. It thus provides an important case study example of how we can integrate promising practices into new building and streetscape design through a prescriptive and comprehensive approach.

TORONTO CONTEXT

In 2021, the City of Toronto had a population of 3,025,647, a 2.3% increase from 2016 (2021 Census).[143] During the summer months, the City experiences an average temperature high of 28 degrees Celsius.[144] The City of Toronto has one of Canada's densest populations, with 4,334.4 people/km^2 (2021 Census).[143] Housing demand coupled with land constraints will mean that the City will need to densify further – through vertical densification – moving forward, thus raising concerns about how the City will grow sustainably.

TORONTO GREEN STANDARD

The *Toronto Green Standard* is the City of Toronto's sustainable design and performance guidelines for new private and city-owned developments.[145] The primary goal of these performance guidelines, as set out by the *Net Zero by 2040 Climate Strategy*, is to ensure that buildings constructed on or after 2030 have near-zero emissions.

The *Toronto Green Standard (TGS)* was put in place in 2006, as a voluntary standard, and made mandatory in 2010.[145] Recently, Version 4 of the *TGS* came into effect for new planning applications. The Standard aims to implement the environmental policies in *Toronto's Official Plan*. One of the key goals is to reduce the UHI effect. The Standard sets out to reduce UHI through multiple promising practices. The Standard requires – under Tier 1 – that developments increase the amount of street trees and vegetation, utilize cool and permeable pavements to reduce, and install green roofs in order to address UHI.

TORONTO GREEN STANDARD (CONT.)

In terms of implementation, the Standard consists of performance tiers, with Tier 1 guidelines mandatory through the planning approval process. Tiers 2 and 3 are higher-level voluntary standards, and developers can receive post-construction development charge refunds to incentivize the uptake of these practices.

Separate guidelines exist for low-rise residential, which applies to development under four storeys with a minimum of 5 dwelling units, mid to high-rise residential and non-residential development, and City-led residential and non-residential development projects.

KEY PERFORMANCE INDICATORS

The following key performance indicators for UHI reduction can be found in the *Toronto Green Standard*:[145]

- Requiring a 1:5 ratio of trees to surface parking spaces;
- Requiring large growing shade trees along street frontages that are spaced appropriately and have access to a minimum of 30 m^3 of soil per tree;
- Requiring green and cool paving on at least 75% of non-roof hardscape; and,
- Requiring green and cool roofs on 100% of available roof space.

KEY TAKEAWAYS FOR THE CITY OF KELOWNA

The City of Toronto takes a prescriptive approach to mitigating UHI at the building and site levels that the City of Kelowna can learn from. The enforcement of these standards is done through the use of strict guidelines that developers of City- and privately-owned buildings must undertake when building new construction. The City has set out which practices are most important by using a tiered system – the City of Kelowna could do something similar if it wanted to prioritize certain mitigation measures over others.

The *Toronto Green Standard* also has separate guidelines for low-rise buildings and mid- and high-rise buildings, which may be important when considering that different built-form and greening practices work best at different building heights, as set out in academic literature on promising practices. Kelowna may want to consider this approach when developing building performance standards.

The City of Toronto undertakes multiple promising practices within one policy tool. As the literature highlights, Toronto's comprehensive approach to implementing multiple mitigation measures will result in a more significant reduction in UHI than implementing a singular practice.[65] The City of Kelowna can look to this policy tool as an example of how one policy can – in a prescriptive way – integrate multiple best practices.

CASE STUDY: PHOENIX (ARIZONA)

PROMISING PRACTICE: STREET TREES AND SHADE

The City of Phoenix is focused – in their plans and codes – on mitigating UHI through planting and maintaining street trees and constructing engineered shade. The City's *Climate Action Plan* sets out prescriptive guidance for reducing UHI, highlighting that in a desert environment, trees may not provide enough shade to cool the urban environment.[146] Thus, engineered shade is a promising practice that can be combined with street trees and vegetation corridors to reduce the UHI effect at the street level. The City of Phoenix has also worked to ensure these mitigation measures occur in transit-rich areas and where vulnerable populations live, thus providing an exciting example of integrating promising UHI reduction practices into transit planning and equity planning.

PHOENIX CONTEXT

The City of Phoenix has a population of 1.625 million people and a density of 3,119 people/km^2 (2021).[147] Phoenix is a desert city with an average summer high temperature of 41 degrees Celsius.[148] Over the last 20 years, the average night-time temperature in Phoenix rose nine degrees due to the UHI effect, thus making extreme heat a significant risk to the City and its citizens.[146]

CLIMATE ACTION PLAN

Phoenix's *Climate Action Plan* sets out the City's approach to addressing UHI and extreme heat.[146] Phoenix takes an approach to UHI reduction focused on increasing shade from trees, vegetation, and engineered shade development. Interestingly, this work to increase shade is specifically targeted in two places: (i) where vulnerable populations live, and (ii) where transit-oriented development is built.

The City of Phoenix has five primary goals to address the UHI effect:

1) Create a network of 100 cool corridors in vulnerable communities by 2030 to facilitate the movement of people walking, biking, and using transit, particularly within and connecting to Transit Oriented Development Districts, Village Cores, and Centers.

2) Increase shade provided by trees or constructed shade in 'flatland' parks, streets, and rights-of-way to achieve a 25% tree and shade canopy in pedestrian areas by 2030, prioritizing communities most vulnerable to heat as set out in the Tree & Shade Master Plan.

3) Provide resources and services to residents to manage heat.

4) Increase the use of high albedo or reflective materials in infrastructure projects.

5) Develop HeatReady certification for cities in partnership with ASU by 2025 (p. 152).[146]

CLIMATE ACTION PLAN (CONT.)

Alongside these four main goals, the *Climate Action Plan* highlights that Phoenix has also developed an Urban Heat Island and Tree and Shade Sub-Committee focused on addressing heat in Phoenix through tree planting and shade creation. An interesting example of how the City seeks to create shade is by implementing permanent and temporary public art microclimates at transit stops. The City of Phoenix is also working to create an Urban Heat Mitigation and Adaptation Plan and corresponding Action Plan and update the Walkable Urban Code – which sets development standards in transit-oriented development districts, including 75% shade – to include additional heat mitigation standards, along with the current shade requirements.

PERFORMANCE INDICATORS

The following key performance indicators can be found in the City of Phoenix policy tool:

- Achieve a 25% tree and shade canopy in pedestrian areas by 2030.
- Create a network of 100 cool corridors in vulnerable communities by 2030.
- Increase shade at public transit stops in the city.
- Achieve "Tree Equity" where all of Phoenix's neighbourhoods will reach a minimal standard of tree canopy cover that is feasible and appropriate for the city's desert climate and conditions by 2030.
- Achieve a 75% shade cover in new transit oriented development areas.

KEY TAKEAWAYS FOR THE CITY OF KELOWNA

The City of Phoenix, as a desert city, provides an interesting example of how Kelowna can work to integrate vegetation and shade into the built environment.

Given that Kelowna is looking to densify around transit-oriented areas, the City of Phoenix also sets out how development can happen along transit corridors in a way that reduces UHI and increases comfort at the street level. This includes adding engineered shade, including bus shelters, and developing cool corridors through tree planting that encourage active transportation.

The City of Phoenix also takes an equity-based approach to UHI mitigation that is unique from other case study cities. Phoenix ensures that its UHI policy tools target areas where vulnerable population groups, including people experiencing homelessness and low-income residents, reside. The City of Kelowna can draw on the idea of "tree equity" to indicate that vegetation should be planted equitably across communities, and mitigation measures should not only occur in wealthy, predominantly white communities, which can often be the case, as the literature indicates.[38, 42, 43]

CASE STUDY: AUSTIN (TEXAS)

PROMISING PRACTICE: INCENTIVE PROGRAMMING

The City of Austin has instituted a set of robust incentives to promote the adoption of green roofs. City-led incentives play a crucial role in encouraging actions that reduce UHI from developers in the private sector and citizens. These incentives can take various forms, including grants, subsidies, and density bonuses to encourage one or more UHI mitigation measures to be adopted in building and streetscape design. The City of Austin's *Downtown Density Bonus Program* encourages green roofs as a promising practice that reduces UHI, and they also seamlessly integrate with the City of Austin's commitment to improving public well-being, as green roofs create enjoyable public spaces.[149] The City of Austin provides an exciting example of how we can use incentive-based policy tools to encourage the adoption of promising practices.

AUSTIN CONTEXT

The City of Austin has a population of 974,447 (U.S. Census Bureau, 2022) and is the fourth-largest City in Texas.[150] As the City's population grows steadily, Austin faces unique challenges tied to its climatic conditions. The City experiences warm to hot temperatures, with average highs reaching 32 degrees Celsius during the summer months. Rapid population growth and elevated temperatures raise concerns about the UHI effect, particularly in Downtown Austin.

DOWNTOWN DENSITY BONUS PROGRAM

In Austin's *Downtown Density Bonus Program*, floor area is earned as a bonus for each square foot of planted bed on a vegetated roof.[149] The program's policy sets out that if 30% to 49% of the total roof area (i.e., square feet of planted bed on a vegetated roof over total roof area) is covered in vegetated roofing, the developer is awarded an extra 2 square feet of bonus floor area per square foot of green roof. If 50% or greater of roof coverage is in vegetated plants, the developer earns a 3 square feet bonus floor area per square foot of green roof. There is also an option for earning an additional 2 square feet bonus floor area on top of the previously mentioned square footage if these green roofs are publicly accessible. Additionally, an extra 2 square feet of bonus floor area can be awarded if the roof meets the Downtown Public Plaza Standards. Therefore, if all requirements are met, developers can earn a density bonus of up to 6 to 7 square feet of floor area (per square foot of green roof) from the program.

The City also requires green roof considerations through various policies, including stormwater management requirements, commercial design standards, planned unit development requirements, the Austin Energy Green Building Rating System, and the Austin Energy Code.

PERFORMANCE INDICATORS

The following key performance indicators can be found in the City of Austin policy tools:

- A total of 30% to 49% coverage of roof area with green roofing gets 2 bonus square feet (per sq ft of vegetated roof).
- A total of 50% or greater coverage of roof area with green roofing earns 3 bonus square feet (per sq ft of vegetated roof).
- An additional 2 bonus square feet (per sq ft of vegetated roof) if the green roof is accessible to the public.
- An additional 2 bonus square feet (per sq ft of vegetated roof) if the roof meets the Downtown Public Plaza Standards.

KEY TAKEAWAYS FOR THE CITY OF KELOWNA

Austin's success in encouraging the adoption of green roofs through incentive programs and density bonus initiatives showcases a practical model for Kelowna. By offering developers tangible benefits for integrating sustainable features into their projects, such as green roofs that contribute to UHI mitigation, Kelowna can foster a culture of environmentally conscious urban development. The *Density Bonus Program*, which rewards developers for incorporating green roofs, serves as a particularly noteworthy example for Kelowna to consider, aligning financial incentives with broader goals of ecological sustainability.

Furthermore, Austin's commitment to public awareness and education stands as a crucial aspect that may be of interest to Kelowna. Disseminating information about the impacts of UHI and the benefits of green infrastructure is pivotal in garnering community support and ensuring widespread understanding. Kelowna can adopt a strategy similar to Austin's, engaging in proactive public outreach campaigns to raise awareness among residents, businesses, and policymakers. This educational approach can build a foundation for informed decision-making, encouraging widespread participation in UHI mitigation efforts and fostering a community-driven commitment to sustainable urban living.

APPENDIX D

ADDITIONAL COST-BENEFIT ANALYSIS

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APPENDIX D

ADDITIONAL COST-BENEFIT ANALYSIS

Mitigation Measure	Urban Heat Island Effect (°C)	Upfront Costs ($ per sq.m.)	Maintenance ($ per sq.m. per year)	Energy Demand Reduction ($ per sq.m. per year)	Air Quality ($ per sq.m. per year)	Carbon Emission Reduction ($ per sq.m. per year)
Trees	3°C to 4°C	$1.05/sq m	$0.88/sq m/yr	$1.26/sq m/yr	$0.35/sq m/yr	$0.1/sq m/yr
Permeable Pavements	0.5°C to 3°C	$75/sq m	$6/sq m/yr	N/A	N/A	N/A
Reflective Roofs	1.1°C to 1.5°C	$40/sq m	N/A	$2.5/sq m/yr	N/A	N/A
Green Facades	0.8°C to 4°C	$45/sq m	$5/sq m/yr	$0.75/sq m/yr	$0.01/sq m/yr	$0.01/sq m/yr
Reflective Roofs	1.1°C to 1.5°C	$40/sq m	N/A	$0.7/sq m/yr	N/A	N/A
Green Roofs	0.6°C to 1°C	$150/sq m	$10/sq m/yr	$0.5/sq m/yr	$18/sq m/yr	$0.00015/sq m/yr

Table 11. Costs and Benefits of UHI Mitigation Measures
(see p.72 for Sources)

TREES

The additional CBA analysis (Table 11) utilized iTree, a USDA Forest Service peer-reviewed software with robust scientific backing, which has been widely utilized in American Planning Association articles and peer-reviewed papers, such as the work by Millward and Sabir (2011) on Allan Gardens in Toronto.[151, 152] Averages derived from NRCan (2022), Akbari (2002), GreenBlue Urban (2020), TreePeople (2021), and Nowak et al. (2012) further inform the CBA.[153, 154, 155, 156, 157] The Urban Heat Island (UHI) factor is sourced from US EPA (2008) and Westendorff (2021), with EPA's (2008) research indicating benefits averaging from 1:1 to 3:1 of the investment cost.[158, 159, 160] Smart et al. (2020) identified Ottawa and Stockholm averaged 3.5 and 1.0 trees/100 sq.m, respectively, which was used to translate per tree costs to square metres.[161]

GREEN ROOFS

For green roofs, Table 11 draws on specific findings from Portland (2008), quantifying public benefits and private property savings of green roofs, and Bianchini & Hewage (2012), who provide installation costs and a payback time estimate of 4.2 years with a 90% confidence rate.[162, 163] UHI reduction factors, are based on Imran et al. (2018) and supported by Li et al. (2014), and US EPA (2008).[164, 165, 166]

PERMEABLE PAVEMENTS

Potential air temperature reduction of 0.6°C, as indicated by US EPA (2008), is considered alongside comparative installation and maintenance costs.[167] Construction costs, outlined by Li et al. (2022), contribute to the overall CBA (Table 11) for permeable pavements.[168]

REFLECTIVE WALLS AND ROOFS

Referencing Testa & Krarti (2017) and Taylor (2019), who aggregates data from 239 U.S. cities, Table 11 incorporates annual cooling savings ranging from 0.5 to 8.6 kWh/m^2 and annual heating savings of 0 to 6.45 kWh/m^2.[169, 170] Installation costs, triangulated from US EPA (2008), Homeguide, Architectural Energy Corporation and Nenonen & Junnonen (2016) are considered.[171, 172, 173, 174] Reflective roofs, with an albedo of 0.85, significantly mitigate near-surface UHI effects during the day, with city-scale maximum reductions reaching up to 0.60°C, 1.1°C, and 1.5°C (Imran et al., 2018) (Li et al., 2014).[164, 165]

GREEN FACADES

Table 11 incorporates data from Italy for green facades, including annual energy savings for various green façades and their impact on mean radiant temperature, sourced from Madushika et al., (2022), Djedjig et al. (2015) and Dwivedi & Mohan, (2018). Energy costs in Italy (~10 euros per kWh) are factored into the analysis, offering insights into the installation costs of vegetated facades and their potential impact on thermal comfort in street canyons.[175, 176, 177]

APPENDIX E

TABLE OF POLICY RECOMMENDATIONS

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Appendix E: Policy Action and Streetscape Design Recommendations

Action Number	Policy Intervention	Mitigation Measure	Topic Area	Building Typology (if applicable)	Recommendation	Priority	Case Study	Alignment with CoK's Existing Policies
	Type of policy intervention. *I.e., Zoning Bylaw; Development Permit Application (DPA); Design Guidelines, etc.*	*Type of UHI reduction mitigation measure.* *I.e., Tree Canopy; Building Materials, Permeable Pavement; Reflective Roof; Engineered Shade; Green Wall; etc.*	*Topic area of recommendation.* *I.e., Density Bonus, Parking, Building Materials, etc.*	*Type of building typology the policy recommendation is best suited for.* *I.e., Low-Rise (3-4 storeys) , Mid-Rise (5-12 storeys), High-Rise (13+ storeys)*	*Policy recommendation and details.*	*Prioritizing recommended policies based on which are more effective and feasible. Priority is determined based on findings from Cost-Benefit Analysis.* *1 - Maximum UHI reduction impact and benefit; costs are low to moderate (high feasibility)* *2 - Maximum UHI reduction impact and benefit; costs are moderate to high (lower feasibility)* *3 - Moderate UHI reduction impact and benefit; costs are low to moderate (high feasibility)* *4 - Moderate UHI reduction impact and benefit; costs are moderate to high (lower feasibility)* *5 - Lower UHI reduction impact and benefit; costs are low to moderate (high feasibility)* *6 - Lower UHI reduction impact and benefit; costs are moderate to high (lower feasibility)*	*Linkage to case study example(s).*	*If the recommended policy aligns with existing City of Kelowna policies and how they can work together (if applicable).*
Zoning Bylaw (Bylaw No. 12375)								
1	Zoning Bylaw	Urban Form	Building Spacing	High-rise	Use zoning to space high-rise buildings to maximize airflow and ventilation (requires an understanding of wind patterns in Urban Centres to determine adequate spacing; see Action 63).	2	n/a	n/a

2	Zoning Bylaw	Tree Canopy	Parking	n/a	Require a 1 to 5 ratio of trees to surface parking spaces.	1 	City of Toronto (*Green Roof Bylaw*); City of Langley (*OCP; sets 1:6 ratio*)	n/a
3	Zoning Bylaw	Roofs	Density Bonus	Mid-rise; high-rise	Additional floor area* is earned as a bonus for each sq ft of planted bed on a vegetated roof**. If 30-40% of total roof area is covered in vegetated roofing, the developer is awarded an extra 2 sq ft of bonus floor area for each sq ft of vegetated roof. If >50% of total roof area is covered in green roofs, the developer is awarded an extra 3 sq ft of bonus floor area for each sq ft of vegetated roof. **To note: the increment has to be worth enough to the developer to be an incentive to provide the amenity, so more research and insight into land values and construction costs is required to properly calibrate the bylaw.* ***Density bonusing is best used for high-density residential or commercial buildings.*	4	City of Austin, Texas (USA) (*Downtown Density Bonus Program*); Regulatory Options for Promoting Green Roofs in BC (2006)	n/a
4	Zoning Bylaw	Buildings	Density Bonus	Low-rise; mid-rise; high-rise	Additional opportunities for density bonusing could be applied to advance other UHI goals, including supplying engineered shading in pedestrian areas, installing reflective roofing, and adding green walls.	4	Regulatory Options for Promoting Green Roofs in BC (2006)	n/a
5	Zoning Bylaw	Buildings	Floor Area Ratio (FAR) Exclusion	Low-rise; mid-rise; high-rise	Energy efficient building materials and infrastructure tends to occupy more space than less efficient materials. Exclude spaces occupied by materials that reduce the UHI effect (e.g., thick walls and shading devices that provide insulation and save energy) from the FSR calculations.	3	BC Government (*BC's Climate Action Toolkit*)	n/a
6	Zoning Bylaw	Buildings	Building Height Restrictions	Low-rise; mid-rise; high-rise	Exclude UHI and climate-friendly building designs, such as green roofs or solar rooftop equipment, from building height measurements.	1	BC Government (*BC's Climate Action Toolkit*)	Zoning Bylaw
7	Zoning Bylaw	Buildings	Variances	Low-rise; mid-rise; high-rise	Encourage the use of green infrastructure and building features, and anticipate building height variance applications for zoning that are justified by the inclusion of urban heat island mitigation measures.	n/a	BC Government (*BC's Climate Action Toolkit*)	Zoning Bylaw (*1.3.1*)
Subdivision, Development, and Servicing Bylaw (Bylaw No. 7900)								
8	Subdivision, Development, and Servicing Bylaw	Green Infrastructure	Subdivisions	n/a	Update the subdivision and servicing bylaw to include more climate-friendly/UHI mitigation measures to promote the reduction of the UHI effect (See Section 506 of the LGA for reference). This bylaw may be revised to set out how roads, sewers, and servicing can be developed in a way that is resilient to the projected impacts of climate change. Currently, Kelowna's	2 	Green Bylaws Toolkit	Bylaw No. 7900 (Subdivision, Development & Servicing Bylaw)

					Bylaw 7900 sets out design guidelines and engineering standards for municipal services. The bylaw guidelines should be adapted to promote climate resilient design. One approach to doing this is implementing green infrastructure principles in infrastructure design. An example is requiring storm drainage to include green infrastructure such as natural watercourses, landscaping, and trees when planned and implemented.			
9	Subdivision, Development, and Servicing Bylaw	Pavements	Reflective Pavements	n/a	Use reflective pavement coatings or use concrete instead of asphalt on new sidewalks and roadways to reduce the Urban Heat Island effect. Reflective coatings also increase nighttime visibility, creating a safer streetscape.	4	City of Phoenix (*Climate Action Plan*)	Form & Character DPA (*2.1.5 Streetscapes, Landscapes, and Public Realm Design*)
10	Subdivision, Development, and Servicing Bylaw	Pavements	Permeable Pavements	n/a	Use permeable pavements for lower traffic streets and pathways, such as parking lots, alleys, curb lanes, or trails. Avoid permeable pavements for roads that carry heavy-axle loads and where the slope of the road is over 5% grade.	6	International Bank for Reconstruction and Development (2020)	Urban Centres Roadmap (*Going Green, Policy 2*)
11	Subdivision, Development, and Servicing Bylaw	Urban Form	Streetscape Design	n/a	Support sufficient boulevard widths not less than 48” (1.2 m) to support large-canopy street trees.	3	City of Burnaby (*Tree Management Policy for Public Lands*); City of Surrey (OCP)	OCP (*Policy 10.2.2.; 14.2.1.*)
12	Subdivision, Development, and Servicing Bylaw	Landscaping	Tree Canopy	n/a	Place trees in road medians.	3	Melbourne, Australia (*Urban Forest Precinct Plan*)	Form & Character DPA (*2.1.5 Streetscapes, Landscapes, and Public Realm Design*)
13	Subdivision, Development, and Servicing Bylaw	Landscaping	Tree Canopy	n/a	Plant large canopy trees and create Urban Centre landscape landmarks in roundabouts and closed road ends.	4	Melbourne, Australia (*Urban Forest Precinct Plan*)	n/a
14	Subdivision, Development, and Servicing Bylaw	Landscaping	Tree Canopy	n/a	In wide medians, plant in two staggered rows to maximize canopy spread over hard surfaces.	1	Melbourne, Australia (*Urban Forest Precinct Plan*)	n/a
15	Subdivision, Development, and Servicing Bylaw	Landscaping	Landscaping Materials	n/a	Use low-maintenance, salt-tolerant species along streets, sidewalks, and other public spaces.	5	BC Government (*Development Permit Areas for Climate Action, 2011*)	Form & Character DPA (*Landscape Materials*); OCP (*Policy 14.2.3*)

16	Subdivision, Development, and Servicing Bylaw	Landscaping	Landscaping Materials	n/a	Avoid materials such as rubber mulches, reused tires, and artificial turf as they can be toxic to soil and plants and contribute to the UHI effect.	3	Saskatoon, SK (*Boulevard Garden Guidelines*; *Urban Forestry Management Plan*; *Centre Median Guidelines*)	n/a
17	Subdivision, Development, and Servicing Bylaw	Landscaping	Planting Guidelines	n/a	For landscaping, such as green roofing and green facades, use drought-tolerant, Indigenous plant species as recommended by the naʼʔkʼʷulamən garden plant guide (see Action 18). Using Indigenous tree, shrub and plant species reduces the need for supplementary irrigation.	n/a	Okanagan College's Indigenous Garden Plant Guide	Form & Character DPA (*Landscape Materials*); OCP (*Policy 14.2.3*)
18	Subdivision, Development, and Servicing Bylaw	Landscaping	Planting Guidelines	n/a	Acceptable plant species, as recommended by the naʼʔkʼʷulamən garden plant guide, include but are not limited to: ● Grasses ○ Pine grass or Timbergrass (tàkʷiɬp), Northwestern sedge (takʷiɬp), Northern Sea Oats, Sweetgrass (sxsìstʻiyaʔ), and Bluebunch wheatgrass (styiʔ). ● Perennials ○ Yarrow (kʷətskʷətswixʷups), Nodding Onion / Wild Onion (x̌elíwa), Pearly Everlasting (tsəmtsəmɬkʼíxʷ), Hemp dogbane (spʼitsʼn), Kinnikinnick (skʷalsiɬmalx), Pasture sage, Goat's-beard, Purple Aster (ntsástsestsn), Arrow-leaved Balsamroot (smúkʷaʔxn), Spring Beauty (skʷnkʷínʻm), Dwarf dogwood, Prickly-pear cactus (sxʷinaʔ), and Bracken Fern (cuqcuqmáɬpu). ● Shrubs ○ Saskatoon berry, Big sagebrush (cqʻʷasʻqʻlstn), Rabbit brush, Oceanspray (mets'mets'íʔɬp), Tall Oregon grape (stsərsiɬmix), Blackcurrant (tq̓ʷq̓ʷyqwáʕý̓s), and Thimbleberry (plplqniɬmix).	n/a	Okanagan College's Indigenous Garden Plant Guide	Form & Character DPA (*Landscape Materials*); OCP (*PolicOy 14.2.3*)
19	Subdivision, Development, and Servicing Bylaw	Landscaping	Planting Guidelines	n/a	Retain and/or add a healthy, absorbent topsoil layer sufficiently deep to allow for well-rooted planting and reduced irrigation requirements.	5	BC Government (*Development Permit Areas for Climate Action, 2011*)	n/a
Development Permit Area (DPA)								

20	DPA	Roofs	Green Roofs	Low-rise; mid-rise	Implement green roofs on low- to mid-rise buildings, as they have a more significant impact on cooling the pedestrian environment than if implemented on high-rise buildings. Green roofs are best suited to flat roofs or roofs that slope less than 20%.	4 	~~n/a~~ Quebec Government (*Quebec Urban Heat Island Mitigation Strategies*)	OCP (*Policy 12.8.2.; Policy 12.8.5*)
21	DPA	Roofs	Intensive Green Roofs	Mid-rise	Require intensive green roofs* for mid-rise buildings with short-spanning roofs. Require new mid-rise commercial, multi-family residential, and industrial buildings to have 50% of roof space as an intensive green roof. Intensive green roofs should also consider: • Plant species recommended in the Planting Guidelines (see Action 18). Intensive green roofs commonly use trees, shrubs, and perennials. • Incorporating landscaped roofs, including intensive green roof systems to accommodate outdoor amenities such as sitting areas, gardening and play spaces. **Intensive Green Roofs are defined as having planting boxes with deeper layers of soil confined to smaller roof area (e.g., trees, bushes).*	4 	City of San Francisco, USA (*Central SOMA Plan Living Roof and Solar Requirements*); City of Surrey, BC (*Biodiversity Design Guidelines: Green Roofs and Walls*); City of Coquitlam (*Urban Design & Development Permit Areas*)	~~n/a~~ Form & Character DPA (*Landscape Materials*); OCP (*Policy 14.2.3.*); Urban Centres Roadmap (*Social Spaces, Policy 2*)
22	DPA	Roofs	Extensive Green Roofs	Low-rise; mid-rise	Require extensive green roofs* for low- and mid-rise buildings with long-spanning roofs. Require new low- to mid-rise commercial, multi-family residential, and industrial buildings to have 75% of roof space as an extensive green roof. Extensive green roofs should also consider: • Plant species recommended in the Planting Guidelines (see Action 18). Extensive green roofs commonly use grasses and are drought resistant. **Extensive Green Roofs are defined as a shallow layer of soil over larger areas (e.g., grass).*	2 	City of Toronto (*Green Roof Bylaw*); City of Surrey, BC (*Biodiversity Design Guidelines: Green Roofs and Walls*)	~~n/a~~ Form & Character DPA (*Landscape Materials*); OCP (*Policy 14.2.3.*)
23	DPA	Roofs	Reflective Roofs	High-rise	Require reflective roofs on high-rise buildings with flat surfaces to avoid creating dazzling reflectiveness on the pedestrian environment and other buildings.	3	n/a	n/a
24	DPA	Roofs	Reflective Roofs	High-rise	New high-rise buildings, new additions to high-rise buildings, and renovations in existing high-rise buildings must have a cool, reflective roof.	3	n/a	n/a
25	DPA	Roofs	Reflective Roofs	High-rise	Require reflective roofs to cover 100% of the surface of the roof.	3	City of Toronto (*Toronto Green Standard*)	n/a

26	DPA	Building Facades	Green Facades & Walls	Mid-rise; high-rise	Utilize green facades and walls on mixed-use or commercial buildings to reduce heat absorption and create dynamic public spaces.	3 	City of Surrey, BC (*Biodiversity Design Guidelines: Green Roofs and Walls*)	OCP (*Policy 12.8.3.; Policy 12.8.5*)
27	DPA	Pavements	General	n/a	Grade hard, impervious surfaces towards landscaped areas.	5 	City of Coquitlam (*Urban Design & Development Permit Areas*)	OCP (*Policy 13.3.5.*)
28	DPA	Pavements	Reflective Pavements	n/a	Use reflective pavement coatings on new sidewalks and roadways to reduce the UHI effect. Reflective coatings also increase nighttime visibility, creating a safer streetscape. Reflective coating materials can include white asphalt, concrete made with white cement mixtures, or light-coloured pavers.	4	City of Phoenix (*Climate Action Plan*)	Form & Character DPA (*2.1.5 Streetscapes, Landscapes, and Public Realm Design*)
29	DPA	Pavements	Permeable Pavements	n/a	Use permeable pavements for lower traffic streets and pathways, such as parking lots, alleys, curb lanes, or trails.	6 	International Bank for Reconstruction and Development (2020)	Urban Centres Roadmap (*Going Green, Policy 2*)
30	DPA	Pavements	Permeable Pavements	n/a	Limit impervious paving and/or dark-coloured absorptive materials for sidewalks, driveways, roads and parking lots.	1 	n/a	OCP (*Policy 13.3.5*); Urban Centres Roadmap (*Going Green, Policy 2*)
31	DPA	Landscaping	Tree Canopy	Low-rise; mid-rise	For low-rise and mid-rise buildings, add vegetation and tree canopies to shade the streetscape and site area on private property, as low-rise buildings provide less shading to pedestrian pathways compared to high-rise buildings.	1 	n/a	OCP (Policy 14.2.1.)
32	DPA	Landscaping	Tree Canopy	n/a	Give preference to large canopy trees over smaller canopy trees totalling the same extent, as a single large canopy tree provides greater benefits in terms of cooling, rainwater interception, and other ecosystem services.	2 	Melbourne, Australia (*Urban Forest Precinct Plan*)	OCP (Policy 14.2.1.; Policy 14.2.6.)
33	DPA	Landscaping	Tree Canopy	n/a	Use deciduous trees for trees on footpaths.	3	Melbourne, Australia (*Urban*	Form & Character DPA

							[Forest Precinct Plan](#))	(*2.1.5 Streetscapes, Landscapes, and Public Realm Design*)
34	DPA	Landscaping	Tree Canopy	n/a	Plant trees for passive solar gain and cooling, such as using deciduous trees on the side of a building to maximize the warming effect of solar radiation in winter months and the cooling effect of shade in summer months.	1	n/a	Form and Character DPA (*2.1.5 Streetscapes, Landscapes, and Public Realm Design*)
35	DPA	Landscaping	Tree Canopy	n/a	Plant trees around buildings to direct cooling summer breezes and act as windbreaks against cold winter winds.	1	BC Government ([*Development Permit Areas for Climate Action, 2011*](#))	Form & Character DPA (*2.1.5 Streetscapes, Landscapes, and Public Realm Design*)
36	DPA	Landscaping	Planting Guidelines	n/a	For landscaping, such as green roofing and green facades, use drought-tolerant, Indigenous plant species as recommended by the na'ʔk'ʷulaməɳ garden plant guide (see Action 18).	n/a	[Okanagan College's Indigenous Garden Plant Guide](#)	Form & Character DPA (*Landscape Materials*); OCP (*Policy 14.2.3*)
37	DPA	Landscaping	Planting Guidelines	n/a	Design the development so that high-value natural vegetation and soil are retained.	1	BC Government ([*Development Permit Areas for Climate Action, 2011*](#))	n/a
38	DPA	Landscaping	Planting Guidelines	n/a	Retain and/or add a healthy, absorbent topsoil layer sufficiently deep to allow for well-rooted planting and reduced irrigation requirements.	5	BC Government ([*Development Permit Areas for Climate Action, 2011*](#))	n/a
39	DPA	Landscaping	Landscaping Materials	n/a	Avoid materials such as rubber mulches, reused tires, and artificial turf, as they can be toxic to soil and plants and contribute to the urban heat island effect.	3	Saskatoon, SK ([*Boulevard Garden Guidelines*](#); [*Urban Forestry Management Plan*](#); [*Centre Median Guidelines*](#))	n/a

40	DPA	Buildings	Building Materials	Low-rise; mid-rise; high-rise	Use building materials with high albedo and low thermal admittance to reduce energy consumption and enhance the comfort of buildings and urban spaces.	1	n/a	Form & Character DPA (*2.1.5 Streetscapes, Landscapes, and Public Realm Design*)
41	DPA	Buildings	Building Materials	Low-rise; mid-rise; high-rise	Use tinted glass or windows with special coatings to reduce the amount of heat let inside the building (e.g., low E windows).	5	n/a	n/a
42	DPA	Buildings	Building Materials	Low-rise; mid-rise; high-rise	Use a lighter value of colour on building exterior to reflect heat or cool materials (e.g., naturally high reflective white coatings, phase-change materials (PCMs), thermochromic, and fluorescent materials). However, walls should not be fully reflective (e.g., painted white) due to the negative impact it may have on the pedestrian experience and reflection on other buildings.	1	n/a	Form & Character DPA (*2.1.5 Streetscapes, Landscapes, and Public Realm Design*)
43	DPA	Engineered Shade	Building Design	n/a	Add structural canopies and fabric awnings to buildings in order to provide shade at the street level (e.g., provisions of overhangs for shade).	3	Quebec Government (*Quebec Urban Heat Island Mitigation Strategies*)	Form & Character DPA (*2.2.1 High Performance Buildings – Site Planning & Orientation*)
44	DPA	Engineered Shade	Building Design	n/a	Use deep window overhangs and/or fixed operable external shading devices to control solar and heat gain through blocking out high-angle summer sun and allowing entry of low-angle winter sun.	3	Quebec Government (*Quebec Urban Heat Island Mitigation Strategies*)	Form & Character DPA (*2.2.1 High Performance Buildings – Site Planning & Orientation*)
45	DPA	Engineered Shade	Streetscape Design	n/a	Encourage the use of innovative public art pieces that provide shade at the street level while enhancing the character of Urban Centres.	4	City of Phoenix (*Climate Action Plan*)	Urban Centres Roadmap (*Placemaking Policy 5*)
46	DPA	Urban Form	Building siting and design	Low-rise; mid-rise; high-rise	Maximize desirable shade from direct sunlight through the use of landscaping and building siting and design.	2	City of Coquitlam (*Urban Design & Development Permit Areas*)	n/a
47	DPA	Urban Form	Building siting	Low-rise; mid-rise; high-rise	Orient building facades towards prevailing breezes to maximize ventilation and passive cooling (see Action 63 for Wind Study).	2	n/a	OCP (*Policy 12.4.2*); Urban Centres Roadmap (*Going Green, Policy 6*)
48	DPA	Urban Form	Building siting	Low-rise; mid-rise; high-rise	Design new buildings to maintain sky view factors for narrow outdoor plaza spaces to ensure initial daylight, wind conditions at the pedestrian level, and night-time cooling.	2	n/a	n/a
49	DPA	Buildings	Development Application Checklist	Low-rise; mid-rise; high-rise	Develop a *Development Application Checklist* for UHI mitigation measures. The checklist will be provided to developers to ensure that UHI mitigation measures are considered in development applications. City of Kelowna staff will consider the input received from the applicant and the preliminary checklist will form part of the evaluation of the development application.	1	District of Sechelt (*Sustainability Checklist*); Corporation of the Township of Esquimalt (*Green Building Checklist*)	Urban Centres Roadmap (*Going Green, Policy 4*)

					The checklist can be based on UHI mitigation measures and OCP objectives for climate resiliency. There is the option to use the checklist as an incentive tool, tying a completed checklist to potentially reward tax exemption, development cost charges (DCC) reduction, parking minimums relaxation, and application fast-tracking. This checklist will include: ● Following and incorporating DPA requirements on: ○ Green roofing or reflective roofing ○ Building materials ○ Reflective pavements ○ Landscaping and tree planting ○ Engineered shading See Appendix F for the proposed Development Application Checklist (Developer's Application Checklist).			
Strategic Plans								
50	2040 Transportation Master Plan	Tree Canopy	Transit Corridors	n/a	Prioritize green, cooling corridors in vulnerable communities.	2	City of Phoenix (*Climate Action Plan*)	OCP (*Policy 12.8.4.; 12.9.3.*)
51	2040 Transportation Master Plan	Shading	Transit Stops	n/a	Establish transit shelters for shading, prioritizing where vulnerable populations live.	3	City of Phoenix (*Climate Action Plan*)	OCP (*Policy 12.9.3.*)
52	2040 Transportation Master Plan	Shading	Bicycle Parking	n/a	Provide shading with shelters – either engineered shading or tree canopies – for short-term bicycle parking.	5	TransLink (*Transit Passenger Facility Design Guidelines*)	Pedestrian and Bicycle Master Plan
53	2040 Transportation Master Plan	Water Features	TOD Areas & Transit Stops	n/a	Establish seasonal misting stations at major transit hubs and transit stops in order to reduce the risk of extreme heat and heat-related illness.	5	City of New Westminster (*New Westminster Misting Stations*)	n/a
54	Urban Forestry Strategy	Tree Canopy & Green Spaces	Streetscape Design	n/a	Preserve existing trees and open spaces to reduce non-permeable spaces in Urban Centres.	1	n/a	Supports the drafting of the Urban Forestry Strategy.
55	Urban Forestry Strategy	Tree Canopy	Streetscape Design	n/a	Use new LiDAR data and past understanding of Kelowna's climate to update canopy coverage targets for each growth	2	City of Toronto (*TransformTO NetZero*	OCP (*Policy 14.2.2*); Supports the drafting of

					strategy district, ensuring that they consider cooling at the city block scale.		[Strategy](#))	the Urban Forestry Strategy.
56	Urban Forestry Strategy	Tree Canopy	Streetscape Design	n/a	Enhance the natural green network by increasing the quantity, density, and diversity of trees.	2 	City of Saskatoon (*Green Infrastructure Strategy*)	Supports the drafting of the Urban Forestry Strategy.
57	Urban Forestry Strategy	Tree Canopy	Streetscape Design	n/a	Use a tree equity approach to ensure equitable tree cover is provided for all residents and planting is prioritized in identified areas lacking urban forests.	1 	City of Phoenix ([Climate Action Plan](#))	Supports the drafting of the Urban Forestry Strategy. OCP (*Policy 9.1.1; Policy 12.9.3*)
58	OCP	Urban Form	Buildings	n/a	Ensure that urban form is built considering the impacts of height, aspect ratio, and sky view factor on the UHI effect.	2	n/a	n/a
59	OCP	Tree Canopy, Pavements & Roofs	Streetscape Design & Buildings	n/a	Utilize tree planting, paving type, and light-coloured, reflective roof surfaces or green roofs to reduce the UHI effect.	2	City of Coquitlam ([Urban Design & Development Permit Areas](#))	n/a
60	Urban Centre Framework	Urban Form	Building Height	n/a	Reference height recommendations set out in the zoning bylaw recommendations.	n/a	n/a	n/a
61	Urban Centre Framework	Engineered Shade	Streetscape Design	n/a	Increase shading structures and shelters where vulnerable populations reside.	3 	City of Phoenix ([Climate Action Plan](#))	OCP (*Policy 9.1.1*)
62	Urban Centre Framework	Water Features	Streetscape Design	n/a	Encourage activating underutilized spaces between buildings, such as courtyards, for summer-time use by adding splash pads that provide cooling.	5	n/a	Form & Character DPA; Urban Centres Roadmap (*Social Spaces*)
63	Proposing New Study	Wind and Ventilation	Wind Study	n/a	The City of Kelowna should undertake a wind study to understand wind patterns and how to harness winds to increase street level and city-wide cooling. Research has found that harnessing wind patterns can reduce temperatures A wind study can help determine where new buildings can be placed and oriented to harness wind patterns and create urban ventilation, as well as determine where to plant trees to place them directly in wind paths to increase cooling.	2	n/a	A wind study will help the City of Kelowna implement DPA requirements around building orientation and tree placement.
Programs & Outreach								

64	Development Applications	Buildings	Development Charge Refunds	Low-rise; mid-rise; high-rise	Investigate options for DCC rebates or other incentives to encourage the uptake of UHI initiatives as outlined in the Development Application Checklist (see Action 49).	n/a	n/a	n/a
65	Programming	Green Infrastructure	Civic Buildings	n/a	Recommend the City of Kelowna to uptake UHI practices (e.g., green roofs, green walls, reflective pavements) on new and existing civic buildings and public spaces.	n/a	n/a	OCP (*Policy 12.3.2.*)
66	Programming (Funding)	Buildings & Green Infrastructure	Retrofits & Green Roofs	Low-rise; mid-rise; high-rise	*UHI Charge System:* Investigate a financial program in which the City of Kelowna pays upfront capital costs related to UHI initiatives on building retrofits (e.g., installing green roofs), and building owners can repay the cost over a period of years through a charge on their property tax bill.	n/a	City of Vancouver (*Greenest City Action Plan*)	n/a
67	Programming (Funding)	Buildings & Green Infrastructure	Green Roofs	Low-rise; mid-rise	*Green Infrastructure Grant Program:* Investigate a program where private property owners can apply for a grant to fund the design and construction of a green roof when a building is being retrofitted. Roofs must be between 3,500 sq ft and 20,000 sq ft.	n/a	New York City, USA (*Green Infrastructure Grant Program*)	n/a
68	Programming (Funding)	Roofs	Stormwater & Green Roofs	Low-rise; mid-rise	*Stormwater Runoff Credit Incentive:* If a stormwater utility is established, consider incorporating a stormwater credit for all non-residential or multi-residential property owners who reduce peak flow, reduce runoff volume, and add water quality treatment and operations. Maximum available credit is 50%, and it is recommended to use green roofs to achieve this.	n/a	City of Guelph (*Stormwater Credit and Rebate Program*)	Stormwater Management Funding
69	Building Certifications	Buildings	Building materials and construction	Low-rise; mid-rise; high-rise	Investigate building certification programs, such as Leadership in Energy and Environmental Design (LEED) standard, to encourage holistic responses from the pre-design phase to construction of buildings to address equity, carbon emissions, public health, and UHIs.	4	LEED (*LEED Standard: LEED's social equity credits*); City of Surrey (*Building Certification & Rating*)	OCP (*Policy 9.1.1.*); Urban Centres Roadmap (*Going Green, Policy 4*)
70	Public Outreach	Buildings & Tree Canopy	Private Properties	n/a	Create public education and outreach programs to raise awareness about the UHI effect and encourage residents to adopt heat-reducing practices (e.g., retaining tree canopy, green or reflective roofs) on their own private properties.	n/a	BC Government (*BC's Climate Action Toolkit*); City of Surrey (*Urban Heat Ready Conversation Guide*)	n/a

Recommendations for Bolstering the City of Kelowna's Existing UHI Policies

Action Number	Policy Intervention	Mitigation Measure	Existing Policy	Recommendation
	Type of policy intervention. *I.e., Zoning Bylaw; Development Permit Application (DPA); Design Guidelines, etc.*	*Type of UHI reduction mitigation measure.* *I.e., Tree Canopy; Building Materials, Permeable Pavement; Reflective Roof; Engineered Shade; Green Wall; etc.*	*Overview of existing City of Kelowna's policy that reduces the UHI effect.*	*Details on the existing City of Kelowna's UHI policy, and recommendations on if the policy can be modified or bolstered to be more effective in reducing the UHI effect.*
71	2040 Transportation Master Plan	Pavement	**TMP Policy 2.1** Prioritize renewal and enhancement of existing infrastructure over the construction of new infrastructure, where possible.	When renewing transit infrastructure, including sidewalks and roadways, consider repaving using reflective paving materials (see Action 9).
72	2040 Transportation Master Plan	Engineered Shade	**TMP Policy 3.3** Prioritize bus shelters and amenities along Transit Supportive Corridors that are clean, attractive, safe, and accessible for people with disabilities.	Shelters in TOD areas and at transit stops can provide shading for pedestrians and create a safer environment during summer months (see Action 51 and 52). Additional amenities in TOD areas that can provide cooling to pedestrians include misting stations (see Action 53).
73	OCP	Green Roofs; Green Walls & Facades; Tree Canopy	**Policy 12.8.2. Green Infrastructure Investment.** Focus green infrastructure investment in Urban Centres and Core Area to reduce the amount of impermeable surfaces and help mitigate the urban heat island effect.	Green infrastructure includes increasing the tree canopy (see Action 55), integrating UHI mitigation measures into buildings with green roofs (Action 20) and green walls (Action 26), and reducing UHI on the streetscape with paving (Action 29 to 30).
74	OCP	Green Roofs; Green Walls & Facades; Tree Canopy	**Policy 12.8.3. Green Infrastructure in Development.** Encourage the inclusion of green infrastructure in new developments. **Policy 12.8.4. Ecosystem Connectivity.** Where feasible, accommodate ecosystem connectivity in green infrastructure design. **Policy 12.8.5. Multi-Purpose Design.**	More detailed actions on how to include green infrastructure, including tree canopy, green roofs and green walls and facades in new developments can be found in the DPA recommendations (Action 20 to 49).

			Design green infrastructure to serve multiple purposes, where feasible (for example stormwater management, urban heat island reduction, and providing shaded, walkable corridors).	
75	OCP	Tree Canopy	**Policy 14.2.1. Urban Forest as Green Infrastructure.** Manage the urban forest as green infrastructure to enhance ecosystem services such as ecosystem connectivity, mitigate greenhouse gas emissions, reduce the urban heat island effect, provide rainwater interception and infiltration, improve air quality, maintain biodiversity and support public health and quality of life. **Policy 14.2.2. Kelowna's Tree Canopy.** Strengthen and expand a healthy and diverse urban forest, as per the City's Urban Forest Strategy, with tree canopy targets of ● 12% within the Urban Centres; ● 20% within the Core Area; and ● 25% for the rest of the City (Gateway, Suburban Neighbourhoods and Rural Lands combined).	Use new LiDAR data and past understanding of Kelowna's climate to update canopy coverage targets for each growth strategy district, ensuring that they consider cooling at the city block scale (see Action 55).
76	OCP	Tree Canopy	**Policy 14.2.3. Plant Selection.** Encourage the use of species of plants well-adapted to Kelowna on public and private property to increase overall tree canopy coverage. With a preference for plants native to the area, select plants that are drought-tolerant, pest-resistant, FireSmart®, are compatible with urban development and are adapted to the specific site conditions today and for a changing climate.	Provide specific plant species guidelines to determine which plant species are resilient and can withstand the local climate (see Action 17 and 18 for local species planting guidelines).
77	OCP	Tree Canopy	**Policy 14.2.6. Trees in Development.** Maximize the retention of existing vegetation and prioritize the planting of new vegetation through development approval and major construction and infrastructure projects.	This policy should be bolstered when densifying Urban Centres, as mature vegetation and large canopy trees provide greater cooling potential than smaller, newly planted trees (see Actions 31 to 35).
78	OCP	Tree Canopy; Green Spaces & Parks	**Policy 10.2.4. Urban Linear Parks.** Reclaim underutilized land within street Right-of-Way to create urban linear parks, to achieve a greater balance between the pedestrian and vehicular realm for local streets with low vehicular demand, as outlined on Map 10.1. Animate urban linear parks with elements similar to traditional parks such as trees, ornamental plantings, community gardens, seating areas, small-scale play equipment and other amenities. Installations may be temporary or permanent. **Policy 10.2.2. Parks on Streets.** To supplement park space in Urban Centres, and the Core Area, consider repurposing underused or redundant streets to provide additional public amenity space, through a permanent transition from vehicular to park use, for portions of public road right-of-way. Approaches could include, but are not limited to: ● Conversion of unused rights-of-way and laneways; ● Increased boulevards as park space; ● Increased tree canopy; and ● Programs to facilitate neighbourhood activities and events.	Establishing and maintaining street trees in both Urban Centres and Core Areas is important. See Action 54 to 57 for overarching Urban Forestry Strategy tree planting goals and guidelines, and see Action 12 to 14 for recommendations on including tree canopies in the road medians and roundabouts.

			Streets with potential to be investigated include, but are not limited to, Kingsway Street, Martin Avenue, Grenfell Avenue and Morrison Avenue. **Policy 5.5.2. Urban Forest Canopy.** Encourage the installation of street trees in Core Area streetscape improvement projects, recognizing the critical role they play in pedestrian comfort, cooling of the urban heat island, habitat for local animal species and beautification of the public realm. Protect existing mature trees where possible.	
79	Form & Character DPA	Pavement	**2.1.4 Site Servicing, Access and Parking** ● e. Design parking areas to maximize rainwater infiltration through the use of permeable materials such as paving blocks, permeable concrete, or driveway planting strips.	Permeable pavements have implementation limitations due to high costs and the dry climate context of Kelowna. However, permeable pavements can still be utilized to increase runoff during wet weather. See Action 10 for more detail on what streetscape components can utilize permeable pavements.
80	Form & Character DPA	Streetscape Design	**2.1.5 Streetscapes, Landscapes, and Public Realm Design** ● e. ensure site planning and design achieves favourable microclimate outcomes through strategies such as: ○ Locating outdoor spaces where they will receive ample sunlight throughout the year	When locating outdoor spaces, it is important to provide adequate shading to protect pedestrians, specifically during the summer months and extreme heat events (see Action 43 to 45).
81	Form & Character DPA	Urban form	**2.1.5 Streetscapes, Landscapes, and Public Realm Design** ● e. ensure site planning and design achieves favourable microclimate outcomes through strategies such as: ○ Using materials and colors that minimize heat absorption	More information should be provided to set out what materials are best for minimizing heat absorption. See Actions 40 to 42 for more information on building materials, Actions 20 to 25 for roofing, and Actions 28 to 30 for sidewalks and pavements.
82	Form & Character DPA	Urban Form	**2.1.5 Streetscapes, Landscapes, and Public Realm Design** ● e. ensure site planning and design achieves favourable microclimate outcomes through strategies such as: ○ Using building mass, trees, and planting to buffer wind.	Wind can be an important component of cooling the urban environment and reducing the UHI effect (see Actions 1, 47, and 63).
83	Form & Character DPA	Landscaping	**2.1.5 Streetscapes, Landscapes, and Public Realm Design** **Landscape Materials** ● g. Plant native and/or drought tolerant trees and plants suitable for the local climate.	Provide specific plant species guidelines to determine which plant species are resilient and can withstand the local climate (see Action 17 and 18 for local species planting guidelines).
84	Form & Character DPA	Urban Form	**2.1.2 Scale and Massing** ● Step back the upper storeys of buildings and arrange the massing and siting of buildings to: ○ Minimize shadowing on adjacent buildings as well as public and open spaces such as sidewalks, plazas, and courtyards	When addressing the UHI effect, the shading provided by high-rise buildings can be important for cooling the pedestrian environment. If shading from buildings is not desired, see Actions 31 to 35 for shading buildings and streetscapes through tree canopy coverage, and Actions 43 to 45 for alternative mechanisms for cooling public and open spaces through engineered shade.

85	Form & Character DPA	Urban Form	**Site Planning & Orientation** e. Use appropriately designed exterior shading devices to block unwanted solar gains in warmer months while welcoming solar gains from lower winter sunlight. Additional considerations include: ● Their use should be prioritized on southern elevations; ● Shading is not necessary on north-facing facades; and ● Vertical fins are a good strategy to use for blocking incoming summer sun on western elevations.	External building shading is a key component when addressing the UHI effect at the neighbourhood scale, and Kelowna's current practices align with UHI mitigation techniques. See Action 43 and 44 for more engineered shading options through building design.

APPENDIX F

DEVELOPMENT APPLICATION CHECKLIST

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APPENDIX F

POLICY ACTION 49. DEVELOPMENT APPLICATION CHECKLIST

This Development Application Checklist was created using the policy recommendations from the DPA section of this report (see pages 40 to 45). As new buildings and developments enhance the UHI effect, these checklist items are helpful in greening buildings to reduce their role in contributing to the UHI effect.

This checklist was modelled after other BC Local Governments' development checklists that place emphasis on greening buildings. These checklists incorporate UHI mitigation measures through various categories, such as building materials, landscaping, stormwater drainage, and streetscape design.[178, 179]

The checklist items, along with Policy Actions 20 to 49, should be incorporated into the City of Kelowna's Form & Character DPA to ensure UHI mitigation measures are captured in the development permit process.

A version of the fillable form can be found online.

Climate Action Developer's Checklist

For Reducing the Urban Heat Island Effect

Applicant's Name: _____

Site Address: _____

1.0 Building Certification		Please Select
1.1	BC Energy Step Code (Please indicate level)	N/A
2.0 Building Orientation		
2.1	Orient primary building facades towards prevailing breezes to maximize passive ventilation and passive cooling*. **Requires a wind study to be completed for Kelowna.*	N/A
3.0 Building Materials		
3.1	The project uses building materials of lighter colours to reflect heat or cool materials (e.g., naturally high reflective white coatings, phase-change materials (PCMs), thermochromic, and fluorescent materials).	N/A
3.2	Passive cooling is supported through external shading (e.g., overhangs or fixed operable external shading devices)	N/A
3.3	Passive cooling is support through tinted glass or windows (e.g., low E windows)	N/A
4.0 Landscaping and Tree Canopy		
4.1	The project is designed to protect and retain tree canopy as possible.	N/A
4.2	Project is designed so that high-value natural vegetation and soil are retained.	N/A
4.3	There is a net gain of trees.	N/A
4.4	Preference is given to large canopy trees over smaller canopy trees and at least 25% of replacement trees are large canopy trees.	N/A

4.5	Trees will be planted in soil volumes calculated to support the full grown size of the tree.	N/A
4.6	Topsoil will be protected from compaction, or stockpile and reused to allow for well-rooted planting.	N/A
4.7	(For low- and mid-rise buildings) Vegetation and tree canopies are added to shade the streetscape area.	N/A
4.8	Trees are planted for passive solar gain and cooling (e.g., planting deciduous trees on the side of a building)	N/A
4.9	Low-maintenance, salt-tolerant species along streets, sidewalks, and other public spaces are used.	N/A
4.10	Materials such as rubber mulches, reused tires, and artificial turf are not used in the project's landscaping.	N/A
5.0 Biodiversity (Plants)		
5.1	The local planting guide is followed for new landscaping by incorporating Indigenous plants.	N/A
5.2	Invasive species will be removed from landscaped areas.	N/A
5.3	At least three varying plant species have been incorporated into the new or existing landscape to enhance biodiversity.	N/A
6.0 Roofing (Green or Reflective)		
6.1	A green roof is included in the project. *Low- or Mid-rise (long-span roof): Extensive green roof* *Mid-rise (short-span roof): Intensive green roof* *High-rise: Not recommended*	N/A
6.1.1	IF installing an extensive green roof, at least 75% of the roof space is covered by the extensive green roof.	N/A
6.1.2	IF installing an intensive green roof, at least 50% of the roof space is covered by the intensive green roofs.	N/A
6.1.3	IF installing an intensive green roof, the addition of outdoor amenities are included (e.g., gardening, sitting areas, play spaces).	N/A
6.1.4	IF installing a green roof, the local planting guide is followed by incorporating Indigenous plants in the green roof.	N/A

6.2	A reflective roof is included in the project. *Low- or Mid-rise: Not recommended* *High-rise: Reflective roof*	N/A
6.2.1	IF installing a reflective roof, 100% of the surface of the roof should be covered by the reflective roof.	N/A
7.0 Walls & Facades		
7.1	The project includes a green wall or facade.	N/A
7.1.2	IF including a green wall, the local planting guide is followed by incorporating Indigenous plants in the green wall or facade.	N/A
8.0 Pavements (Reflective or Permeable)		
8.1	Sidewalks and roadways use reflective pavement coatings (e.g., white asphalt, concrete made with white cement mixtures, or light-coloured pavers).	N/A
8.2	Permeable pavements are used for lower traffic streets and pathways, such as parking lots, alleys, curb lanes, or trails (except if the road is over 5% grade).	N/A
9.0 Streetscape Design		
9.1	The project includes public art pieces that are used to provide shade at the street level while enhancing the character of Urban Centres.	N/A
9.2	(If applicable) The project activates underutilized spaces between buildings, such as courtyards, for summer-time use by adding splash pads that provide cooling.	N/A
9.3	The project provides seasonal misting stations to reduce the risk of extreme heat and heat-related illness in the summer.	N/A
10.0 Stormwater		
10.1	The total amount of impervious surface is not greater than 20%.	N/A
10.2	Impervious surface is graded towards landscaped areas, where possible.	N/A
10.3	The project features a green roof for stormwater management.	N/A

10.4	The project integrates water features, such as fountains, ponds, and water walls, into the design of the building to capture and store rainwater runoff.	N/A
11.0 Transportation		
11.1	Building will have a bus pass program for residents.	N/A
11.2	Enhanced facilities for bicyclists, such as showers, lockers, and long-term parking storage.	N/A
11.3	Providing shading for short-term, outdoor bicycle parking.	N/A

GRAPHIC SUMMARY

PROJECT POSTER

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MITIGATING URBAN HEAT ISLANDS

The Intersection between Built Form, Policy & the Urban Heat Island Effect in the City of Kelowna

THE ISSUE

What is the Urban Heat Island Effect?

Urbanization has changed land use patterns worldwide, resulting in urban temperatures being 1°C to 3°C warmer than surrounding regions. This is known as the Urban Heat Island (UHI) effect.

ABOUT THE PROJECT

The City of Kelowna's Climate Vulnerability and Risk Assessment identified **extreme heat** as one of the most significant climate hazards to the area, recognizing the **built environment can exacerbate heat** in Urban Centres due to the Urban Heat Island (UHI) effect. This project carefully examined the **intersection between built form, policy, and UHIs**, and set out how to reduce the UHI effect through planning policy and streetscape design recommendations.

PROJECT OBJECTIVES

- Understand Built Forms Effect on UHI
- Cost-Benefit Analysis of UHI Policies
- Review Practices for Reducing UHIs
- UHI Policy & Streetscape Recommendations

POLICY ACTIONS

LIVABLE PLAN

UBC SCARP

City of Kelowna

REFERENCES

LIST OF SOURCES

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REFERENCES

1 Anderson, V.; Gough, W.A.; Zgela, M.; Milosevic, D.; Dunjic, J. Lowering the Temperature to Increase Heat Equity: A Multi-Scale Evaluation of Nature-Based Solutions in Toronto, Ontario, Canada. *Atmosphere 2022*, 13, 1027.https://doi.org/10.3390/atmos130710277

2 Health Canada. (2020). Reducing Urban Heat Islands to Protect Health in Canada. *Government of Canada*. https://www.canada.ca/content/dam/hc-sc/documents/services/health/publications/healthy-living/reducing-urban-heat-islands-protect-health-canada/Reducing-Urban-Heat-EN.pdf.

3 Druckenmiller, H. (2023). Urban Heat Islands 101. *Resources for the Future*. https://www.rff.org/publications/explainers/urban-heat-islands-101/.

4 RDOS. (2020). Climate Projections for the Okanagan Region. *Regional District of Okanagan-Simlkameen*. https://www.rdos.bc.ca/assets/PLANNING/AreaX/2020/ClimateProjections/FinalReport.pdf.

5 City of Kelowna. (2023). *Climate Resilient Kelowna Strategy*. https://getinvolved.kelowna.ca/climatestrategy#:~:text=Climate%20%26%20Environment%20is%20one%20of,the%20changes%20we%20are%20expecting.

6 City of Kelowna. (2022). *Kelowna's 2040 Official Community Plan*. https://www.kelowna.ca/our-community/planning-projects/2040-official-community-plan.

7 Health Canada. (2020). Reducing Urban Heat Islands to Protect Health in Canada. *Government of Canada*. https://www.canada.ca/content/dam/hc-sc/documents/services/health/publications/healthy-living/reducing-urban-heat-islands-protect-health-canada/Reducing-Urban-Heat-EN.pdf.

8 Gifford, R., Brown, C., Baron, C., Clement, D., Melnychuk, N., Nelson, H., ... & Spittlehouse, D. (2022). British Columbia Chapter in Canada in a Changing Climate: Regional Perspectives Report. Ottawa: Government of Canada, Ottawa. https://changingclimate.ca/site/assets/uploads/sites/4/2020/11/British-Columbia-Regional-Perspective-Report-.pdf

9 Burch, S. (2010). Transforming barriers into enablers of action on climate change: Insights from three municipal case studies in British Columbia, Canada. *Global Environmental Change*, *20*(2), 287-297. https://doi.org/10.1016/j.gloenvcha.2009.11.009

10 PHSA. (2018). Healthier Built Environment Linkages Toolkit. *Government of BC*. http://www.bccdc.ca/pop-public-health/Documents/HBE_linkages_toolkit_2018.pdf.

11 PreparedBC. (2023). Extreme Heat Preparedness Guide. *Government of British Columbia*. https://www2.gov.bc.ca/assets/gov/public-safety-and-emergency-services/emergency-preparedness-response-recovery/embc/preparedbc/preparedbc-guides/preparedbc_extreme_heat_guide.pdf.

12 Hsu, A., Sheriff, G., Chakraborty, T., & Manya, D. (2021). Disproportionate exposure to urban heat island intensity across major US cities. *Nature communications*, *12*(1), 2721. https://doi.org/10.1038/s41467-021-22799-5

13 City of Kelowna. (Unpublished document). City of Kelowna Climate Adaptation Report – DRAFT.

14 City of Kelowna (n.d.). *Open Kelowna (Geographic Information Systems Data)*. https://opendata.kelowna.ca/.

15 DataBC. (n.d.). Maps & Orthos. *Government of BC*. https://a100.gov.bc.ca/ext/mtec/public/products/mapsheet.

16 City of Kelowna. (n.d). City Profile. https://www.kelowna.ca/our-community/about-kelowna/city-profile

17 Statistics Canada. 2023. (table). Kelowna Census Profile. 2021 Census of Population. Statistics Canada Catalogue no. 98-316-X2021001. Ottawa. Released November 15, 2023. https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/index.cfm?Lang=E (accessed December 3, 2023).

18 Statistics Canada. 2017. Kelowna [Census metropolitan area], British Columbia and British Columbia [Province] (table). Census Profile. 2016 Census. Statistics Canada Catalogue no. 98-316-X2016001. Ottawa. Released November 29, 2017.

19 City of Kelowna. (2022). *Community Trends 2022 - A Changing Kelowna: Findings from the 2021 Census*. https://kelownapublishing.escribemeetings.com/filestream.ashx?DocumentId=43078

20 Park People. (2023). *City Profile: Kelowna*. https://ccpr.parkpeople.ca/2023/cities/kelowna-2022

21 City of Kelowna. (2023). *Future Land Use*. https://www.kelowna.ca/our-community/planning-projects/2040-official-community-plan/ch-3-future-land-use.

22 Kleerekoper, L., Van Esch, M., & Salcedo, T. B. (2012). How to make a city climate-proof, addressing the urban heat island effect. *Resources, Conservation and Recycling*, *64*, 30-38.

23 O'Malley, C., Piroozfarb, P. A., Farr, E. R., & Gates, J. (2014). An investigation into minimizing urban heat island (UHI) effects: A UK perspective. *Energy Procedia*, *62*, 72-80.

24 Radhi H, et al. Impacts of urbanisation on the thermal behaviour of new built up environments: A scoping study of the urban heat island in Bahrain. *Landscape Urban Plan 2013,* 113:47-61.

25 Schroth, J., & Schiano-Phan, R. (2017). Environmental Densification Approaches for Berlin. Mitigating the Urban Heat Island Effect.

26 Salameh, M., Elkhazindar, A., & Touqan, B. (2023). The effect of building height on thermal properties and comfort of a housing project in the hot arid climate of the UAE. *Frontiers in Built Environment*, *9*, 1174147.

27 Kolokotsa, D., Lilli, K., Gobakis, K., Mavrigiannaki, A., Haddad, S., Garshasbi, S., ... & Santamouris, M. (2022). Analyzing the impact of urban planning and building typologies in urban heat island mitigation. *Buildings*, *12*(5), 537.

28 Gonzalez-Trevizo, M. E., Martinez-Torres, K. E., Armendariz-Lopez, J. F., Santamouris, M., Bojorquez-Morales, G., & Luna-Leon, A. (2021). Research trends on environmental, energy and vulnerability impacts of Urban Heat Islands: An overview. *Energy and Buildings*, *246*, 111051

29 Jabbar, H. K., Hamoodi, M. N., & Al-Hameedawi, A. N. (2023). Urban heat islands: a review of contributing factors, effects and data. *In IOP Conference Series: Earth and Environmental Science* (Vol. 1129, No. 1, p. 012038). IOP Publishing.

30 U.S. Environmental Protection Agency. (2008). Reducing urban heat islands: Compendium of strategies. Draft. https://www.epa.gov/heat-islands/heat-island-compendium.

31 Yang, J., Shi, B., Xia, G., Xue, Q., & Cao, S. J. (2020). Impacts of urban form on thermal environment near the surface region at pedestrian height: a case study based on high-density built-up areas of Nanjing City in China. *Sustainability*, *12*(5), 1737.

32 Oke, T. R. (1997). Urban environments. In W. G. Bailey, T. R. Oke & W. R. Rouse (Eds.), The surface climates of Canada (pp. 303-327). McGill-Queen's Press-MQUP.

33 Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). *Urban climates*. Cambridge University Press.

34 Unger, J., Savić, S., Gál, T., & Milošević, D. (2014). Urban climate and monitoring network system in Central European cities. Novi Sad: University of Novi Sad, University of Szeged.

35 Loughner, C. P., Allen, D. J., Zhang, D. L., Pickering, K. E., Dickerson, R. R., & Landry, L. (2012). Roles of urban tree canopy and buildings in urban heat island effects: Parameterization and preliminary results. *Journal of Applied Meteorology and Climatology*, *51*(10), 1775-1793.

36 Cai, Z., Han, G., & Chen, M. (2018). Do water bodies play an important role in the relationship between urban form and land surface temperature?. *Sustainable cities and society*, *39*, 487-498.

37 Sun, R., & Chen, L. (2012). How can urban water bodies be designed for climate adaptation?. *Landscape and Urban Planning*, *105*(1-2), 27-33.

38 Hsu, A., Sheriff, G., Chakraborty, T., & Manya, D. (2021). Disproportionate exposure to urban heat island intensity across major US cities. *Nature communications*, *12*(1), 2721.

39 Li, Y., Schubert, S., Kropp, J. P., & Rybski, D. (2020). On the influence of density and morphology on the Urban Heat Island intensity. *Nature communications*, *11*(1), 2647.

40 Anderson, V., Gough, W. A., Zgela, M., Milosevic, D., & Dunjic, J. (2022). Lowering the temperature to increase heat equity: A multi-scale evaluation of nature-based solutions in Toronto, Ontario, Canada. *Atmosphere*, *13*(7), 1027.

41 Heaviside, C., Macintyre, H., & Vardoulakis, S. (2017). The urban heat island: implications for health in a changing environment. *Current environmental health reports*, *4*, 296-305.

42 Interior Health. (n.d.). *Community Climate Resiliency Planning*. https://www.interiorhealth.ca/about-ih/climate-change-approach/community-climate-resiliency-planning

43 Palinkas, L. A., Hurlburt, M. S., Fernandez, C., De Leon, J., Yu, K., Salinas, E., ... & McConnell, R. S. (2022). Vulnerable, resilient, or both? A qualitative study of adaptation resources and behaviors to heat waves and health outcomes of low-income residents of urban heat islands. *International Journal of Environmental Research and Public Health*, *19*(17), 11090.

44 Seneviratne, S.I., X. Zhang, M. Adnan, W. Badi, C. Dereczynski, A. Di Luca, S. Ghosh, I. Iskandar, J. Kossin, S. Lewis, F. Otto, I. Pinto, M. Satoh, S.M. Vicente-Serrano, M. Wehner, and B. Zhou, 2021: Weather and Climate Extreme Events in a Changing Climate. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1513–1766, doi:10.1017/9781009157896.013.

45 Alchapar, N. L., Correa, E. N., & Cantón, M. A. (2014). Classification of building materials used in the urban envelopes according to their capacity for mitigation of the urban heat island in semiarid zones. *Energy and Buildings*, *69*, 22-32.

46 Salamanca, F., Georgescu, M., Mahalov, A., Moustaoui, M., & Wang, M. (2014). Anthropogenic heating of the urban environment due to air conditioning. *Journal of Geophysical Research: Atmospheres*, *119*(10), 5949-5965.

47 Takane, Y., Kikegawa, Y., Hara, M., & Grimmond, C. S. B. (2019). Urban warming and future air-conditioning use in an Asian megacity: importance of positive feedback. *npj Climate and Atmospheric Science*, *2*(1), 39.

48 Antoszewski, P., Krzyżaniak, M., & Świerk, D. (2022). The future of climate-resilient and climate-neutral city in the temperate climate zone. *International Journal of Environmental Research and Public Health*, *19*(7), 4365.

49 Chen, Y., Shan, B., & Yu, X. (2022). Study on the spatial heterogeneity of urban heat islands and influencing factors. *Building and Environment*, *208*, 108604.

50 Dirksen, M., Ronda, R. J., Theeuwes, N. E., & Pagani, G. A. (2019). Sky view factor calculations and its application in urban heat island studies. *Urban Climate*, *30*, 100498.

51 Svensson, M. K. (2004). Sky view factor analysis–implications for urban air temperature differences. *Meteorological applications*, *11*(3), 201-211.

52 Conticelli, E., Proli, S., & Tondelli, S. (2017). Integrating energy efficiency and urban densification policies: Two Italian case studies. *Energy and Buildings*, *155*, 308-323.

53 Park, Y., Guldmann, J. M., & Liu, D. (2021). Impacts of tree and building shades on the urban heat island: Combining remote sensing, 3D digital city and spatial regression approaches. *Computers, Environment and Urban Systems*, *88*, 101655.

54 Vuckovic, M., Loibl, W., Tötzer, T., & Stollnberger, R. (2019). Potential of urban densification to mitigate the effects of heat island in Vienna, Austria. *Environments*, *6*(7), 82.

55 Zhou, B., Rybski, D., & Kropp, J. P. (2017). The role of city size and urban form in the surface urban heat island. *Scientific reports*, *7*(1), 4791.

56 Hu, Y., White, M., & Ding, W. (2016). An urban form experiment on urban heat island effect in high density area. *Procedia Engineering*, *169*, 166-174.

57 Li, J., & Donn, M. (2017). The influence of building height variability on natural ventilation and neighbor buildings in dense urban areas. Proceedings of the Building Simulation; Barnaby, CS, Wetter, M., Eds, 2805-2813.

58 Wang, M., & Xu, H. (2021). The impact of building height on urban thermal environment in summer: A case study of Chinese megacities. *Plos one*, *16*(4), e0247786.

59 Ferrari, A., Kubilay, A., Derome, D., & Carmeliet, J. (2020). The use of permeable and reflective pavements as a potential strategy for urban heat island mitigation. *Urban Climate*, *31*, 100534.

60 Santamouris, M. (2013). Using cool pavements as a mitigation strategy to fight urban heat island—A review of the actual developments. *Renewable and Sustainable Energy Reviews*, *26*, 224-240.

61 Taha, H., Akbari, H., Rosenfeld, A., & Huang, J. (1988). Residential cooling loads and the urban heat island—the effects of albedo. *Building and environment*, *23*(4), 271-283.

62 Infield, E. M. H., Abunnasr, Y., & Ryan, R. L. (Eds.). (2018). Planning for climate change: a reader in green infrastructure and sustainable design for resilient cities. Routledge.

63 Hayes, A., Jandaghian, Z., Lacasse, M. A., & Moore, T. V. (2023). Mitigating UHI Effects in Canadian Communities Using Nature Based Solutions. *Government of Canada*. https://publications.gc.ca/collections/collection_2023/cnrc-nrc/NR24-121-2023-eng.pdf

64 Tan, J. K., Belcher, R. N., Tan, H. T., Menz, S., & Schroepfer, T. (2021). The urban heat island mitigation potential of vegetation depends on local surface type and shade. *Urban Forestry & Urban Greening*, *62*, 127128.

65 Wang, Y., Berardi, U., & Akbari, H. (2016). Comparing the effects of urban heat island mitigation strategies for Toronto, Canada. *Energy and buildings*, *114*, 2-19.

66 Welegedara, N. P., Agrawal, S. K., & Lotfi, G. (2023). Exploring spatiotemporal changes of the urban heat Island effect in high-latitude cities at a neighbourhood level: A case of Edmonton, Canada. *Sustainable Cities and Society*, *90*, 104403.

67 Steele, G. (2018). Steele: Caring for your shade trees in the heat. *Kelowna Capital News*. https://www.kelownacapnews.com/opinion/caring-for-your-shade-trees-in-the-heat-3166981.

68 Potenteau, D. (2021). City of Kelowna asking residents to help water street trees during drought. *Global News*. https://globalnews.ca/news/7944815/kelowna-street-trees-water-request/.

69 Susca, T., Gaffin, S. R., & Dell'Osso, G. R. (2011). Positive effects of vegetation: Urban heat island and green roofs. *Environmental pollution*, *159*(8-9), 2119-2126.

70 Energy Sector Management Assistance Program. (2020). Primer for Cool Cities: Reducing Excessive Urban Heat–With a Focus on Passive Measures. *World Bank*.

71 Bhargava, A., Lakmini, S., & Bhargava, S. (2017). Urban Heat Island Effect: It's relevance in urban planning. *J. Biodivers. Endanger. Species*, *5*(187), 2020.

72 Li, D., Bou-Zeid, E., & Oppenheimer, M. (2014). The effectiveness of cool and green roofs as urban heat island mitigation strategies. *Environmental Research Letters*, *9*(5), 055002.

73 Anderson, V., & Gough, W. A. (2021). Nature-based cooling potential: A multi-type green infrastructure evaluation in Toronto, Ontario, Canada. *International Journal of Biometeorology*, 1-14.

74 Farrell, C., Mitchell, R. E., Szota, C., Rayner, J. P., & Williams, N. S. G. (2012). Green roofs for hot and dry climates: Interacting effects of plant water use, succulence and substrate. Ecological Engineering, 49, 270-276.

75 Fusco, M. (n.d.). Green Roofs: Dry in the Sky. *Pacific Horticulture*. https://pacifichorticulture.org/articles/green-roofs-dry-in-the-sky/

76 Morakinyo, T. E., Dahanayake, K. K. C., Ng, E., & Chow, C. L. (2017). Temperature and cooling demand reduction by green-roof types in different climates and urban densities: A co-simulation parametric study. Energy and Buildings, 145, 226-237.

77 Kim, H., Gu, D., & Kim, H. Y. (2018). Effects of Urban Heat Island mitigation in various climate zones in the United States. Sustainable cities and society, 41, 841-852.

78 Archtoolbox. (2021). *Green Roof Systems: Intensive, Semi-Intensive, and Extensive*. https://www.eng.uwo.ca/research/greenroof/.

79 Western University (n.d.). Green Roofs Research at Western. *University of Western Ontario*. https://www.eng.uwo.ca/research/greenroof/.

80 ZinCo. (n.d.). Semi-Intensive Green Roofs. *Life on Roofs - Zinco*. https://zinco-greenroof.co.uk/systems/semi-intensive.

81 Lynch, V. (n.d.). Toronto's Green Roofs. *Vivian Lynch Photography*. https://www.vivianlynch.com/green-roofs.

82 Akbari, H., Cartalis, C., Kolokotsa, D., Muscio, A., Pisello, A. L., Rossi, F., ... & Zinzi, M. (2016). Local climate change and urban heat island mitigation techniques–the state of the art. *Journal of Civil Engineering and Management*, *22*(1), 1-16.

83 American Weatherstar. (n.d.). *What are the benefits of a cool roof?*. https://www.americanweatherstar.com/what-are-the-benefits-of-a-cool-roof/

84 Santa Monica Mirror. (2024). *Board of Supervisors Takes First Step Toward Energy-Saving "Cool Roofs" Being Built*. https://smmirror.com/2017/08/board-supervisors-takes-first-step-toward-energy-saving-cool-roofs-built/.

85 CoolCalifornia.org. (n.d.). *How Cool Pavements Work*. https://coolcalifornia.arb.ca.gov/cool-pave-how

86 U.S. Environmental Protection Agency. (2023). *Using Cool Pavements to Reduce Heat Islands*. https://www.epa.gov/heatislands/using-cool-pavements-reduce-heat-islands

87 Gentry, D. (2022). Cool pavement gets cold shoulder from Clark County. *Nevada Current*. https://nevadacurrent.com/2022/08/08/cool-pavement-gets-cold-shoulder-from-clark-county/.

88 Callahan, M. (2019). New public art installation by Quintessenz brings color to Richardson Plaza. *Northeastern Global News*. https://news.northeastern.edu/2019/09/17/new-public-art-installation-by-quintessenz-brings-color-to-richardson-plaza/.

89 Kadlubowski, D. (2017). Bloomcanopy debuts in downtown Phoenix. *AZCentral*. https://www.azcentral.com/picture-gallery/news/local/phoenix/2017/07/01/bloomcanopy-debuts-in-downtown-phoenix/103349580/.

90 Wright, B. (2018). Building facades and vertical shade. *Specialty Fabrics Review*. https://specialtyfabricsreview.com/2018/02/01/peeling-back-the-facade/

91 Neuffer. (n.d.). *Front mounted roller shutters*. https://www.neuffer.de/en/roller-shutters-front-mounted.php.

92 Thompson, J. (2020). Retractable Awning for that Balcony Space. *SkyBass*. https://skybassinc.com/2020/01/09/retractable-awning-for-that-balcony-space/

93 City of Toronto. (2007). *Design Guidelines for 'Greening' Surface Parking Lots*. https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/design-guidelines/greening-surface-parking-lots/

94 City of Melbourne. (n.d.). *Urban Forest Precinct Plans*. https://www.melbourne.vic.gov.au/community/greening-the-city/urban-forest/Pages/urban-forest-precinct-plans.aspx

95 City of Toronto. (2017). *TORONTO MUNICIPAL CODE CHAPTER 492, GREEN ROOFS*. https://www.toronto.ca/legdocs/municode/1184_492.pdf

96 City of Melbourne. (2014). *Growing Green Guide*. https://www.melbourne.vic.gov.au/SiteCollectionDocuments/growing-green-guide.pdf

97 City of London. (2008). *Living Roofs and Walls Technical Report: Supporting London Plan Policy*. https://www.london.gov.uk/sites/default/files/living-roofs.pdf

98 City of Houston. (2022). *Houston Construction Code*. https://www.houstonpermittingcenter.org/media/6596/download?inline

99 City of Phoenix. (2023). *Walkable Urban Code*. https://phoenix.municipal.codes/ZO/13

100 City of Glasgow. (2021). *City Centre Strategic Development Framework*. https://www.glasgow.gov.uk/CHttpHandler.ashx?id=53335&p=0

101 City of Saskatoon. (2020). *Saskatoon's Green Infrastructure Strategy: Towards an Interconnected Green Network*. https://www.saskatoon.ca/sites/default/files/documents/transportation-utilities/strategy_-_saskatoons_green_infrastructure_strategy_towards_an_interconnected_green_network.pdf

102 Ng, E., Yau, R., Wong, K., Ren, C., & Katszchner, L. (2012). Final Report of Hong Kong Urban Climatic Map and Standards for Wind Environment- Feasibility Study.

103 City of Seattle. (2018). *Seattle Building Code*. https://www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/building-code

104 City of Vancouver. (2023). *Green Buildings Policy for Rezonings*. https://guidelines.vancouver.ca/policy-green-buildings-for-rezonings.pdf

105 The Constructor. (n.d.). *Reflective Pavements: A Unique Pavement Strategy to Fight Climate Change*. https://theconstructor.org/transportation/reflective-pavements-unique-pavement-strategy/325179/

106 Energy Sector Management Assistance Program. (2020). Primer for Cool Cities: Reducing Excessive Urban Heat-With a Focus on Passive Measures. World Bank.

107 Bloomberg Associates. (2019). *Mitigating Urban Heat Island Effects Cool Pavement Interventions*. https://www.bbhub.io/dotorg/sites/32/2019/08/20190516_Cool-Pavement-Research-FINAL.pdf

108 Minnesota Stormwater Steering Committee. (2022). *Minnesota Stormwater Manual*. https://stormwater.pca.state.mn.us/index.phptitle=Operation_and_maintenance_(O%26M)_of_permeable_pavement

109 Chen, C. F., Lin, Y. T., & Lin, J. Y. (2024). Field temperature performances of in-use permeable sidewalks and asphalt vehicle roads and the potential impacts on apparent temperature and land surface temperature. *Environmental monitoring and assessment*, *196*(2), 1-18.

110 Santamouris, M., Gaitani, N., Spanou, A., Saliari, M., Giannopoulou, K., Vasilakopoulou, K., & Kardomateas, T. (2012). Using cool paving materials to improve microclimate of urban areas–Design realization and results of the flisvos project. *Building and Environment*, *53*, 128-136.

111 Buyung, N. R., & Ghani, A. N. A. (2017, October). Permeable pavements and its contribution to cooling effect of surrounding temperature. In AIP Conference Proceedings (Vol. 1892, No. 1). AIP Publishing.

112 RAND Engineering & Architecture, DPC. (n.d.). *Green Roof Fact Sheet*. https://randpc.com/articles/energy-efficiency/green-roof-fact-sheet

113 Cool Roof Rating Council. (n.d.). *What is a Cool Roof?*. https://coolroofs.org/resources/what-is-a-cool-roof

114 General Services Administration. (2011). *The Benefits and Challenges of Green Roofs on Public and Commercial Buildings*. https://www.gsa.gov/system/files/The_Benefits_and_Challenges_of_Green_Roofs_on_Public_and_Commercial_Buildings.pdf

115 Santamouris, M. (2014). Cooling the cities–a review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. *Solar energy*, *103*, 682-703.

116 Neumann, K. B. (2023). What Are Green Roofs?. *Forbes Home*. https://www.forbes.com/home-improvement/roofing/what-are-green-roofs/

117 Leonard, J. (December, 2009). Cool roof coatings: green and growing. *Professional Roofing Magazine*. https://www.professionalroofing.net/Articles/Cool-roof-coatings-green-and-growing--12-01-2009/1602

118 Cuce, E. (2017). Thermal regulation impact of green walls: An experimental and numerical investigation. *Applied Energy*, *194*, 247-254.

119 Perini, K., Ottelé, M., Fraaij, A. L. A., Haas, E. M., & Raiteri, R. (2011). Vertical greening systems and the effect on air flow and temperature on the building envelope. *Building and environment*, *46*(11), 2287-2294

120 Perini, K., Ottelé, M., Haas, E. M., & Raiteri, R. (2011). Greening the building envelope, façade greening and living wall systems. *Open Journal of Ecology*, *1*(01), 1.

121 Susca, T., Zanghirella, F., Colasuonno, L., & Del Fatto, V. (2022). Effect of green wall installation on urban heat island and building energy use: A climate-informed systematic literature review. *Renewable and Sustainable Energy Reviews*, *159*, 112100.

122 Manso, M., Teotónio, I., Silva, C. M., & Cruz, C. O. (2021). Green roof and green wall benefits and costs: A review of the quantitative evidence. *Renewable and Sustainable Energy Reviews*, *135*, 110111.

123 Perini, K., & Rosasco, P. (2013). Cost–benefit analysis for green façades and living wall systems. *Building and Environment*, *70*, 110-121.

124 City of Melbourne. (2014). Growing Green Guide: A Guide to Green Roofs, Walls, and Façades in Melbourne and Victoria Australia. *Department of Environment and Primary Industries, State of Victoria*.

125 Houston Advanced Research Center. (2009). Dallas Sustainable Skylines Initiative: Dallas Urban Heat Island Study.

126 Qureshi, A. M., Rachid, A., & Bartlett, D. (2023). Quantifying the cooling effect of urban heat stress interventions. *International Journal of Global Warming*, *30*(1), 60-80.

127 Roman, L. A., & Scatena, F. N. (2011). Street tree survival rates: Meta-analysis of previous studies and application to a field survey in Philadelphia, PA, USA. *Urban Forestry & Urban Greening*, *10*(4), 269-274.

128 Zhao, Y., Sen, S., Susca, T., Iaria, J., Kubilay, A., Gunawarden, K., ... & Carmeliet, J. (2023). Beating the Heat: Solution Sets for Developed Cities.

129 Toronto Cancer Prevention Coalition. (2019). *Shade Guidelines*. https://www.toronto.ca/wp-content/uploads/2019/08/8ecf-AODA_Shade_Guidelines_2010_Final_Report-002.pdf

130 City of Gilbert, Arizona. (2023). *Shade and Streetscape Master Plan*. https://www.gilbertaz.gov/home/showpublisheddocument/42932/638218354161100000

131 Ernst, S. W. & Watkins, K. (2023). How METRO officials could plant a tree at every bus stop in Houston. *Houston Public Media*. https://www.houstonpublicmedia.org/articles/series/hot-stops/2023/09/21/462996/metro-could-plant-a-tree-at-every-bus-stop-in-houston-but-it-may-be-a-bit-complicated/

132 Blanchard, S. (2013). Improving thermal comfort in Windsor, ON; Assessing urban parks and playgrounds. *City of Windsor, Ontario*. https://www.citywindsor.ca/residents/environment/Environmental-Master-Plan/Documents/Improving%20Thermal%20Comfort%20in%20Parks_no%20appendices.pdf

133 Eyquem, J. L., & Feltmate, B. (2022). Irreversible Extreme Heat: Protecting Canadians and Communities from a Lethal Future. *Intact Centre on Climate Adaptation, University of Waterloo*. https://www.intactcentreclimateadaptation.ca/irreversible-extreme-heat-protecting-canadians-and-communities-from-a-lethal-future/

134 Okanagan College. (2021). Indigenous Garden Plant Guide. *Okanagan College*. https://www.okanagan.bc.ca/sites/default/files/2021-03/indigenous_garden_plant_guide_full_pdf.pdf.

135 Architizer Editors. (n.d.). *An Architect's Guide to: Green Walls*. https://architizer.com/blog/product-guides/product-guide/eantka-green-walls/.

136 ArchiExpo. (n.d.). New products and trends in architecture and design. *Pinterest*. https://architizer.com/blog/product-guides/product-guide/eantka-green-walls/.

137 City of Surrey. (2021). *Biodiversity Design Guidelines*. https://www.surrey.ca/renovating-building-development/land-planning-development/environmental-protection/biodiversity/design-guidelines

138 Government of BC. (2020). *Changes for Local Governments Under Section 5 of the Building Act.* https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/construction-industry/building-codes-and-standards/guides/section_b_appendix_dec_2020_update.pdf.

139 Statistics Canada. 2023. (table). Surrey Census Profile. 2021 Census of Population. Statistics Canada Catalogue no. 98-316-X2021001. Ottawa. Released November 15, 2023. https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/index.cfm?Lang=E (accessed December 3, 2023).

140 Weather Spark. (n.d.). *Climate and Average Weather Year Round in Surrey Canada.* https://weatherspark.com/y/1005/Average-Weather-in-Surrey-Canada-Year-Round

141 City of Surrey. (2021). *Surrey Urban Heat Ready Conversation Guide.* https://www.surrey.ca/sites/default/files/media/documents/Surrey%20Urban%20Heat%20Ready%20Conversation%20Guide.pdf

142 City of Toronto. (n.d). *Toronto Green Standard Version 4.* https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/toronto-green-standard/toronto-green-standard-version-4/

143 Statistics Canada. 2023. (table). Toronto Census Profile. 2021 Census of Population. Statistics Canada Catalogue no. 98-316-X2021001. Ottawa. Released November 15, 2023. https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/index.cfm?Lang=E (accessed December 3, 2023).

144 Weather Spark. (n.d.).*Climate and Average Weather Year Round in Toronto Canada.* https://weatherspark.com/y/19863/Average-Weather-in-Toronto-Canada-Year-Round

145 City of Toronto. (n.d). *Toronto Green Standard: Overview.* https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/toronto-green-standard/toronto-green-standard-overview/

146 City of Phoenix. (2021). *Climate Action Plan.* https://www.phoenix.gov/oepsite/Documents/2021ClimateActionPlanEnglish.pdf

147 U.S. Census Bureau. (2022). *QuickFacts Phoenix city, Arizona.* https://www.census.gov/quickfacts/fact/table/phoenixcityarizona/PST045222

148 Weather Spark. (n.d.). *Climate and Average Weather Year Round in Phoenix Arizona, United States.* https://weatherspark.com/y/2460/Average-Weather-in-Phoenix-Arizona-United-States-Year-Round

149 City of Austin. (2016). *City of Austin Density Bonus Policy.* https://www.austintexas.gov/sites/default/files/files/NHCD/Reports_Publications/Report_FINAL__Density_Bonus_Resolution_20151015_038.pdf

150 U.S. Census Bureau. (2022). *QuickFacts Austin city, Texas.* https://www.census.gov/quickfacts/fact/table/austincitytexas/LND110210

151 i-Tree. (n.d.). *About. i-Tree.* https://www.itreetools.org/about.

152 Millward & Sabir. (2010). Benefits of a forested urban park: What is the value of Allan Gardens to the city of Toronto, Canada? *Ryerson University (Toronto).* https://doi.org/10.1016/j.landurbplan.2010.11.013

153 NRCan. (2023). The State of Canada's Forests Annual Report. *Government of Canada*. https://natural-resources.canada.ca/our-natural-resources/forests/state-canadas-forests-report/16496.

154 Akbari, H. (2002). Shade trees reduce building energy use and CO2 emissions from power plants. *Lawrence Berkeley National Laboratory*. https://doi.org/10.1016/S0269-7491(01)00264-0

155 GreenBlue Urban. (2020). *Street Tree Cost Benefit Analysis*. https://greenblue.com/ce/resource-centre/street-tree-cost-benefit-analysis/.

156 TreePeople. (2021). *Tree Planting Cost-Benefit Anlaysis: A Case Study for Urban Forest Equity in Los Angeles*. https://www.treepeople.org/resource/tree-planting-cost-benefit-analysis-a-case-study-for-urban-forest-equity-in-los-angeles/.

157 Nowak, D., Greenfield, E., Hoehn, R., & Lapoint, E. (2013). Carbon storage and sequestration by trees in urban and community areas of the United States. *US Department of Agriculture*. https://www.fs.usda.gov/research/treesearch/46254.

158 US EPA. (2008). "Trees and Vegetation". In: Reducing Urban Heat Islands: Compendium of Strategies. Draft. https://www.epa.gov/sites/default/files/2017-05/documents/reducing_urban_heat_islands_ch_2.pdf.

159 Westendorff, V. (2021). Urban Trees: Strategies for Reducing Urban Heat Islands in Cities. The Field - ASLA Professional Practice Networks' Blog. Retrieved from https://thefield.asla.org/2021/07/22/urban-trees-strategies-for-reducing-urban-heat-island-in-cities/.

160 US EPA. (2008). *Using Trees and Vegetation to Reduce Heat Islands*. https://www.epa.gov/heatislands/using-trees-and-vegetation-reduce-heat-islands.

161 Smart N, Eisenman TS and Karvonen A. (2020). Street Tree Density and Distribution: An International Analysis of Five Capital Cities. *Front. Ecol. Evol. 8:562646*. doi: 10.3389/fevo.2020.562646

162 City of Portland (2008). *Cost benefit evaluation of ecoroofs*. https://www.portlandoregon.gov/bes/article/261053.

163 Bianchini, F. & Hewage, K. (2012). Probabilistic social cost-benefit analysis for green roofs: A lifecycle approach. *University of British Columbia*. https://doi.org/10.1016/j.buildenv.2012.07.005

164 Imran, H.M., Kala, J., Ng, A.W.M., Muthukumaran, S. (2018). Effectiveness of green and cool roofs in mitigating urban heat island effects during a heatwave event in the city of Melbourne in southeast Australia. *Victoria University*. https://doi.org/10.1016/j.jclepro.2018.06.179

165 Li, D., Bou-Zeid, E., & Oppenheimer, M. (2014). The effectiveness of cool and green roofs as urban heat island mitigation strategies. *Environmental Research Letters*, *9*(5), 055002.

166 US EPA. (2008). "Green Roofs." In: Reducing Urban Heat Islands: Compendium of Strategies. Draft. https://www.epa.gov/sites/default/files/2017-05/documents/reducing_urban_heat_islands_ch_3.pdf

167 US EPA (2008). "Cool Pavements." In: Reducing Urban Heat Islands: Compendium of Strategies. Draft. https://www.epa.gov/sites/default/files/2017-05/documents/reducing_urban_heat_islands_ch_5.pdf

168 Li, X. J., Deng, J. X., Xie, W. J., Jim, C. Y., Wei, T. B., Lai, J. Y., & Liu, C. C. (2022). Comprehensive Benefit Evaluation of Pervious Pavement Based on China's Sponge City Concept. *Water*, *14*(9), 1500.

169 Testa, J. & Krarti, M. (2017). Evaluation of energy savings potential of variable reflective roofing systems for US buildings. *University of Colorado*. https://doi.org/10.1016/j.scs.2017.01.016

170 Taylor, T. (2019). Reflective roofing use on commercial buildings in the United States: An energy type and cost analysis. *Building & roofing Science*, *9*(10), 212. https://doi.org/10.3390/buildings9100212

171 US EPA (2008). "Cool Roofs" In: Reducing Urban Heat Islands: Compendium of Strategies. Draft. https://www.epa.gov/sites/default/files/2017-05/documents/reducing_urban_heat_islands_ch_4.pdf.

172 HomeGuide. (2023). *How much does it cost to coat or seal a roof?*. https://homeguide.com/costs/roof-coating-or-sealing-cost.

173 Architectural Energy Corporation. (2012). *Non-residential cool roof cost summary*. https://www.coolrooftoolkit.org/wp-content/uploads/2012/07/CEC-Non-Res-Cool-Roof-Cost-summary.pdf.

174 Nenonen, S. & Junnonen, J.M. (2016). Understanding impacts and functioning of different solutions. *CIB World Building Congress*. https://usa.sika.com/dms/getdocument.get/940d9e19-a06f-4405-b253-4a852d387c91/building-a-prosperous-urban-future-with-reflective-roofing.pdf.

175 Madushika, U.G.D., Ramachandra, T., Geekiyanage, D. (2022). Economic performance of green walls: a systematic review. https://doi.org/10.31705/WCS.2022.31.

176 Djedjig, R., Bozonnet, E., & Belarbi, R. (2015). Experimental study of the urban microclimate mitigation potential of green roofs and green walls in street canyons. *International Journal of Low-Carbon Technologies*, *10*(1), 34-44.

177 Dwivedi, A., & Mohan, B. K. (2018). Impact of green roof on micro climate to reduce Urban Heat Island. *Remote Sensing Applications: Society and Environment*, *10*, 56-69.

178 Township of Esquimalt. (n.d.). *Green Building Checklist*. https://www.esquimalt.ca/sites/default/files/docs/Green_Building_Checklist_2019.pdf.

179 District of Sechelt. (n.d.). *Application Checklist for Development Applications*. https://www.sechelt.ca/en/business-and-development/resources/Documents/Complete-Application-Checklist.pdf.