URBAN HEAT ISLAND GUIDEBOOK

MITIGATION STRATEGIES FOR UBC VANCOUVER NEIGHBOURHOODS

PREPARED FOR

UBC Campus + Community Planning

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EXECUTIVE SUMMARY

The increasing frequency and intensity of climate change-induced heat waves in British Columbia, notably the 2021 heat dome event, underscore the urgent need for proactive climate adaptation measures. Urban areas, including UBC Vancouver, are especially susceptible to the Urban Heat Island (UHI) effect, where heat-absorbing materials — such as asphalt and concrete — elevate local temperatures, amplifying public health risks, energy demands, and threats to biodiversity.

As a key action in UBC's Neighbourhood Climate Action Plan (NCAP), UBC Campus and Community Planning (C+CP) are exploring a combination of nature-based and engineered solutions to address urban heat island effects in both current and future residential neighborhoods on campus. These measures include increasing tree canopy cover, expanding green infrastructure assets, and fostering resilient, restorative landscapes. These actions align with the Campus Vision 2050 goal of creating more equitable and sustainable living environments for all residents.

To further these goals, this guidebook provides comprehensive strategies for mitigating the urban heat island (UHI) effect within UBC Vancouver neighbourhoods. This includes nature-based (NbS) and other design solutions that can be implemented at neighbourhood and site scales, aimed at enhancing outdoor shading, reducing cooling demands in buildings, and promoting sustainable transportation use during periods of extreme heat. Through offering recommendations and actionable insights, this guidebook aims to be a valuable resource for UBC C+CP planners, architects, University Neighbourhoods Association (UNA) staff, and community members.

The guidebook is organized into three key chapters: 'Street Trees & Greenways', 'Green Roofs', and 'Cool Buildings'. Chapter 2 emphasizes the role of urban greening and tree canopy expansion in neighbourhood cooling and shade provision. Chapter 3 focuses on green roofs, highlighting their energy-saving potential in buildings, while Chapter 4 discusses current and emerging cool roofs and wall technologies, designed to reflect solar radiation and reduce surface and indoor temperatures.

Chapter 5 outlines potential next steps for implementing urban heat island (UHI) mitigation strategies across the UBC Vancouver neighbourhoods, with particular focus on policy tools, community involvement, equity and accessibility considerations.

DISCLAIMER

This report was produced as part of the UBC Sustainability Scholars Program, a partnership between the University of British Columbia and various local governments and organizations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability across the region. This project was conducted under the mentorship of UBC Campus + Community Planning (C+CP) staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of the University of British Columbia.

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I wish to acknowledge that the UBC Vancouver Point Grey campus is located on the traditional, ancestral, and unceded territory of the xʷməθkʷəy̓əm (Musqueam) First Nation, who have stewarded and cared for these lands since time immemorial, and whose enduring wisdom and relationship with the land continue to guide and inspire collaborative climate action and adaptation planning on the campus.

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GLOSSARY

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

Climate Change: Long-term shifts in temperatures and weather patterns. These shifts may be natural, but since the 1800s, human activities have been the main driver of climate change, primarily due to the burning of fossil fuels (like coal, oil and gas), which produces heat-trapping gases.

Climate Hazards: events or conditions that could injure people or damage assets.

Climate Resilience: The ability of people and/or ecosystems to anticipate, prepare for, and adapt to climate hazard events.

Climate Zone (CZ): In British Columbia, climate zones are classified based on average climate conditions that affect building heating and cooling requirements. According to the BC Building Code, these zones range from Zone 4 to Zone 8, with higher numbers representing colder climates.

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

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

Evaporation: The process that changes liquid water to gaseous water (water vapor).

Evapotranspiration: The sum of all processes by which water moves from the land surface to the atmosphere via evaporation and transpiration.

Green Roof (or Living Roof): A building rooftop partially or entirely covered with vegetation and additional layers of supplementary materials.

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

Heat Wave: a period with more than three consecutive days of maximum temperatures at or above 32°C [90°F].

Planning for Social Equity: Recognizing planning practices that have had a disparate impact on certain communities and actively working with affected residents to create better communities for all.

Solar Reflectance (SR): Measures a material's ability to reflect solar energy from its surface, expressed as a value between 0 and 1, with higher values indicating better reflectance.

Solar Reflectance Index (SRI): Combines both solar reflectance (SR) and thermal emissivity in a single value. SRI measures the roof's ability to reject solar heat, defined such that a standard black (reflectance 0.05, thermal emittance 0.90) is 0 and a standard white (reflectance 0.80, thermal emittance 0.90) is 100.

Street Tree: A tree planted in the sidewalk, planting strip, and/or in the public right-of-way adjacent to (or specified distance from) the portion of the street reserved for vehicular traffic. This also includes trees planted in planting strips within the roadway right-of-way, i.e., islands, medians, pedestrian refuges.

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

Thermal Transmittance (U-value): The rate of transfer of heat through matter. U-values measure how effective a material is an insulator, ranging from 0.1 (very little heat loss) to 1.0 (high heat loss).

Transpiration: The passage of watery vapor from a living body (as of a plant) through a membrane or pores.

Tree Canopy: The layer of tree leaves, branches and stems that cover the ground when viewed from above.

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

GLOSSARY CONT.

Campus Vision 2050: An ambitious, long-range plan for how UBC's Vancouver campus will change and grow to support the needs of the university, its students, residents, staff, and Musqueam.

Land Use Plan: Establishes generalized land uses and development policies for the UBC Vancouver campus. It is the guide for all of UBC's academic and residential development, providing the policy direction and regulations for building a complete, sustainable university community.

Neighborhood Climate Action Plan (NCAP): Sets a pathway to a net-zero and climate resilient community for the residential neighbourhoods on UBC's Vancouver campus.

Residential Environmental Assessment Program (REAP): A comprehensive, UBC-specific green building rating system for mandatory application to all multi-unit residential construction in the neighbourhoods.

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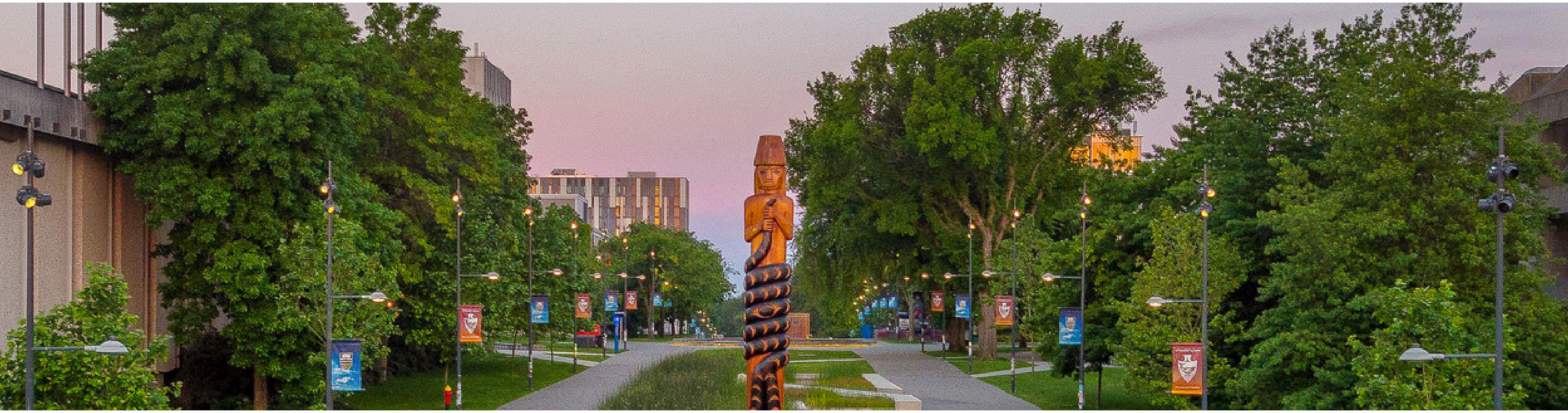


1. INTRODUCTION

1.1 Background

Cities are facing intensified challenges from climate change, including more severe and frequent heatwaves, rising temperatures, and altered precipitation patterns — all of which place increasing stress on infrastructure, public health, and natural systems[1,2,3,4]. Across Canada, cities are undergoing rapid population growth and urban densification, with nearly three in four Canadians (73.7%) living in a large urban center as of 2021[5]. In alignment with Metro Vancouver's 2050 Regional Growth Strategy, the University of British Columbia has recently amended its Land Use Plan (LUP)[6] to address the evolving needs of the campus community and neighbourhoods, as outlined in Campus Vision 2050[7]. The Vision targets a doubling of neighborhood housing units beyond 2022 levels, including 8.1 million sq. ft. (756,000 sq. m.) of additional residential development. As the campus prepares for densification over the next 30 years, ensuring that existing and future neighbourhoods are climate-resilient will be essential in supporting community well-being and sustainability.

Climate projections for the UBC Vancouver (UBCV) campus and neighbourhoods underscore the urgency of building climate-resiliency into residential areas. Projections indicate rising temperatures, shifting precipitation patterns, and an increased frequency of extreme weather events in the coming decades[8]. By the 2080s, UBCV's annual baseline temperature, which currently averages 10.4°C, is projected to rise to 13.7°C[8]. The frequency of annual heatwaves is projected to increase from 1 to 9, and number of days exceeding 30°C to increase from 1 to 11 per year[8]. Annual precipitation is predicted to increase from 1420 mm to 1515 mm, with significant changes to annual rainfall distribution. Winters will become wetter, with an increase of 38 mm of precipitation, while summers are expected to become drier, with a decrease of 34 mm and more frequent drought periods by 2080[8].

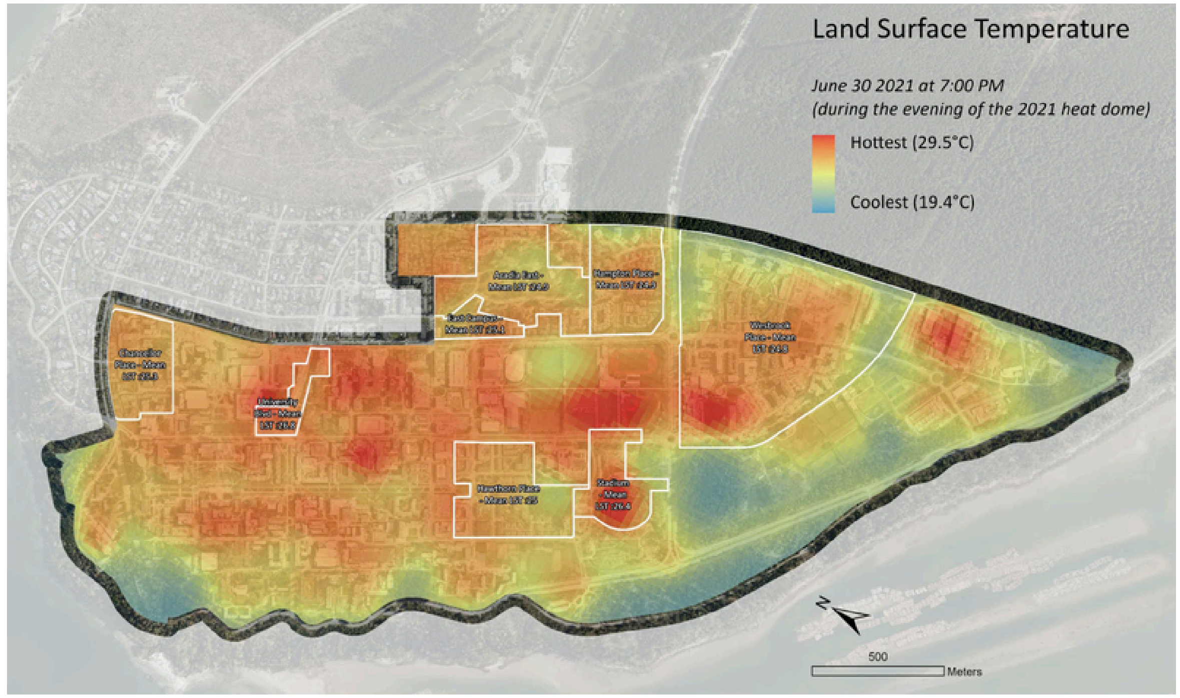


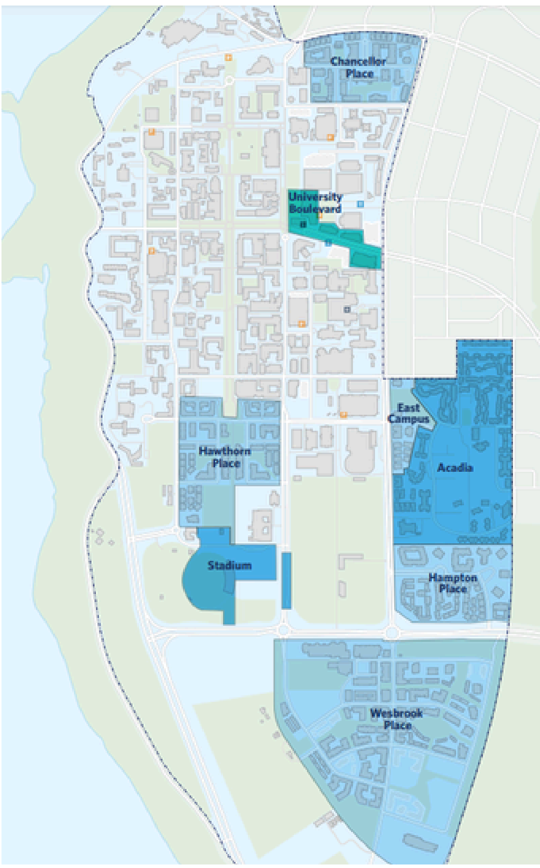
Figure 1. Land surface temperatures on campus at 7:00 PM during the 2021 heat dome (image source: Diamond Head Consulting, 2023)[9].

1.2 Urban Heat Islands

Urban Heat Islands (UHIs) are areas within cities that experience significantly higher temperatures than their rural surroundings, a phenomenon primarily caused by the materials that make up urban environments. Surfaces like concrete, asphalt, and brick absorb heat from the sun and slowly release this heat into the surrounding environment, leading to consistently warmer temperatures in city centers and causing temperatures to remain elevated long after sunset[10,11]. As a result, temperatures in urban settings can be between 2°C and 12°C higher than in nearby green areas, particularly at night[12]. Without effective mitigation, the built environment can exacerbate the effects of extreme heat, making cities even hotter and more challenging to live in during heat waves and periods of drought[11].

Urban Heat Islands (UHIs) can have profound effects on human health and the safety of dwellings. Residents of neighborhoods with high ambient temperatures and limited shade face increased risks of heat stress, dehydration, and excessive UV exposure[12]. These conditions may lead to serious health issues, including heat-related illnesses and exacerbated conditions for those with preexisting health problems[12]. Similarly, UHIs impact natural systems and wildlife by elevating heat stress and altering resource availability, which can contribute to localized biodiversity loss[13,14]. The impacts of UHIs were starkly illustrated during the 2021 Northwest heat dome in Canada, where 619 human heat-related deaths were recorded across BC[15]. On the UBC Vancouver campus, the 2021 heat dome revealed striking temperature variations, with surface temperatures differing by as much as 10°C depending on tree canopy cover (Figure 1). Areas with more extensive tree coverage showed greater resilience, emphasizing the crucial role of natural assets in mitigating extreme heat.

Furthermore, UHIs contribute to higher peak electricity demands in the summer, driven by increased reliance on air conditioning in residential homes[16]. This surge in energy use creates a feedback loop, where waste heat generated by indoor cooling systems is released outdoors, further intensifying the UHI effect[17,18]. Additionally, UHIs exacerbate air pollution, as elevated temperatures promote the formation of ground-level ozone[19].



Left image: Neighbourhoods covered by NCAP include Hampton Place, Hawthorn Place, Wesbrook Place, Chancellor Place, East Campus, as well as the future Stadium and Acadia neighbourhoods.

1.3 Purpose

The Neighbourhood Climate Action Plan (NCAP) sets a pathway to a net-zero and climate resilient community for the residential neighbourhoods on the University of British Columbia's (UBC) Vancouver campus (UBCV). NCAP delivers on UBC Campus Vision 2050 and Land Use Plan commitments toward climate action by identifying both immediate and long-term actions required to reduce GHG emissions and prepare for the effects of climate change on campus. Additionally, NCAP provides a framework to guide amended and future campus Neighbourhood Plans.

As a key action in the Neighbourhood Climate Action Plan (NCAP), UBC Campus and Community Planning (C+CP) are exploring a combination of nature-based and engineered solutions to address urban heat island effects in both current and future residential neighbourhoods on campus. These strategies focus on reducing heat absorption and enhancing cooling by increasing tree canopy cover, expanding green infrastructure assets, and creating restorative, resilient landscapes. Prioritizing these solutions supports Campus Vision 2050's objective of fostering more comfortable and equitable living environments for all residents.

To further these goals, this guidebook provides comprehensive strategies for mitigating the urban heat island (UHI) effect within UBC Vancouver neighbourhoods. This includes nature-based (NbS) and other design solutions that can be implemented at neighbourhood- and site-scales, aimed at enhancing outdoor shading, reducing cooling demands in buildings, and promoting sustainable transportation during periods of extreme heat. Through offering recommendation and actionable insights, this guidebook aims to be a valuable resource for UBC C+CP planners, architects, University Neighbourhoods Association (UNA) staff, and community members working to build a more resilient and climate-adaptive campus for all residents.

2. STREET TREES & GREENWAYS

2.1 Trees, Greenways, and the UHI Effect

Urban greening is widely recognized as some of the most cost-effective strategies for mitigating urban heat islands (UHI)[20]. In addition to their aesthetic appeal, street trees are key components of urban green infrastructure and provide substantial cooling benefits to neighborhoods. For example, a study in a temperate city neighborhood in Manchester, North West England, demonstrated a 5% increase in mature deciduous trees could reduce mean hourly surface temperatures by 1°C over the course of a summer day[21]. Tree shading prevents solar radiation from directly hitting surfaces like roads, sidewalks, and buildings, which would otherwise absorb heat and contribute to the UHI effect.

Although trees have a relatively low albedo (i.e. a dark, poorly reflective surface which absorbs and retains heat; 0.15-0.18) compared to low-ground vegetation (e.g. grass, 0.25-0.35) and asphalt (0.05-0.20), their cooling benefits far outweigh this limitation[22]. Unlike concrete and asphalt, which store heat during the day and release it slowly at night, contributing to higher nighttime temperatures, trees do not retain heat in the same way. Heat absorbed by trees is predominantly used for processes such as photosynthesis and transpiration, rather than being stored and emitted into the surrounding environment[22]. The combined effects of shading, evapotranspiration (the combined loss of water via evaporation from the soil surface and transpiration from the plant), and a trees' interactions with other climatic factors such as humidity and wind speed result in the creation of cooler and more comfortable microclimates, contributing to human thermal comfort[23]. This microclimate effect extends beyond the immediate vicinity of the tree, helping to lower temperatures in nearby buildings, reducing the need for air conditioning, and subsequently decreasing overall heat generation in the area. A case study of tree shading strategies in a simulated, neighbourhood-scale area in Vancouver undergoing densification and using 2050 climate scenarios found that increasing tree volume and canopy cover could significantly reduce building solar radiation absorption (SRA) and cooling energy demand (BCED) during the summer[24]. The impact of tree shading was influenced by the intensity and location of tree planting, as well as the height of adjacent buildings. The most ambitious strategy, maximizing tree canopy (MTC), which involved 175% more trees and 150% greater canopy coverage compared to 2020 conditions, resulted in a 22% increase in neighborhood-scale building shading and a 48% reduction in BCED[24]. Tree shading was most effective for low- and medium-height (3-11 meters; one to five storeys) buildings, with the greatest reductions observed on southern facades — up to 127% for BCED — and on western facades with reductions of 70-74%[24]. Taller buildings (>11–58 meters; six or more storeys) showed more modest BCED reductions, with only 20% and 27% on southern and western facades, respectively[24]. The authors suggest that site-specific interventions, such as tree species selection and fine-tuned tree planting strategies, could produce more substantial and successful cooling energy reductions. For taller buildings, alternative UHI mitigation strategies such as cool roofs and cool exterior walls may be more effective in achieving desired BCED reduction targets.

Other forms of urban greening, such as the creation of new parks, can reduce surrounding air temperatures by 0.8°C to 6°C[25,22]. Vegetated 'green islands' (e.g. parks, gardens) within urban areas can extend their cooling effects up to 1.25 kilometers or more beyond their boundaries, depending on wind and the size of the island[26]. In Addition to cooling, urban greening provides a multitude of environmental co-benefits including carbon sequestration, air pollution reduction, stormwater management, and the enhancement of biodiversity and wildlife habitats[27].

Active Transportation and Public Transportation Use

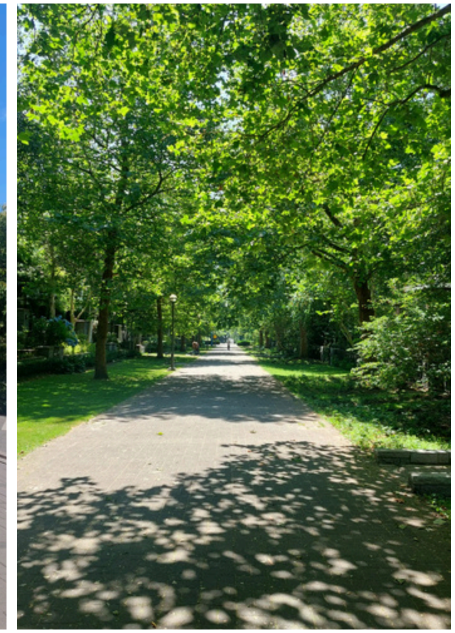
Beyond their direct cooling effects on neighborhoods, street trees play a crucial role in protecting the health and safety of street users. This aligns with the principles of Complete Streets, an emerging planning approach that prioritizes safe and convenient travel for all modes of transportation — walking, cycling, rolling, personal vehicles, and public transit[28]. Trees are an integral part of Complete Streets, contributing to safer and more attractive streetscapes by slowing traffic, offering shade, and creating a safety buffer between pedestrians and vehicles[29]. The shade provided by street trees at bus stops and along transit routes also encourages use of active and public transportation, especially during extreme heat events[30, 31, 32]. Tree canopy cover protects against heat stress and UV exposure[33], which is particularly important for vulnerable populations such as children, people with disabilities, older adults, and those without access to a personal vehicle[34]. More broadly, Complete Streets enhance public health by promoting physical activity through walking and biking, improving safety for non-vehicle users, and reducing traffic congestion[28]. Increasing tree canopy coverage in streetscapes leading to and from schools has been shown to encourage active transportation for school journeys, thanks to improved perceptions of safety, aesthetic value, and thermal comfort[35]. For bicyclists, street trees have been shown to positively contribute to bike route preference and enhance the overall livability of cities[36]. By providing shade and adding visual beauty along roadways, trees make bicycling a more comfortable and safe mode of active transportation[36].

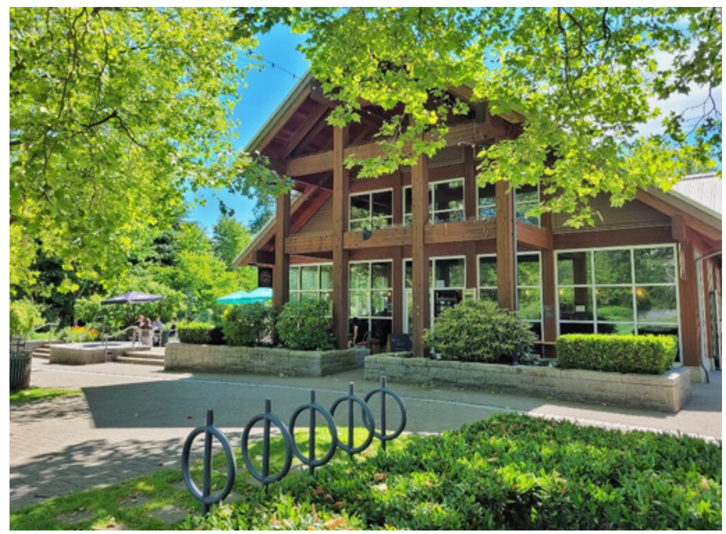
Neighbourhood Climate Action Plan (NCAP) and Campus Vision 2050

On the UBC Vancouver campus, street trees play a pivotal role in advancing the university's vision for a sustainable and resilient future, as outlined in Campus Vision 2050[7]. A central component of this vision is the expansion of the campus's greenway network, which aims to connect and enhance a series of primary and secondary green corridors (Figure 2). These green corridors are designed to serve multiple purposes: they will enhance ecological connectivity by improving habitat linkages for wildlife, and provide shaded pathways for walking, rolling, and cycling, benefiting the campus community.

The UBC Neighbourhood Climate Action Plan (NCAP) complements these objectives by focusing on increasing resilience and safety within transportation networks. Specifically, Transportation & Mobility sub-action TM-3.3 emphasizes the need to prioritize and protect connected greenspaces in future and amended Neighbourhood Plans, ensuring that ecological corridors are preserved and enhanced as part of transportation planning. Additionally, sub-actions TM-5.1 and TM-5.2 focus on developing resilience and safety standards for transportation networks, including retrofitting existing routes to improve shading and thermal comfort[37]. These efforts, which involve adding shaded areas and covered shelters at transit stops and along active transportation corridors, are designed to enhance thermal comfort and promote greater use of public and active transportation, particularly for residents with mobility impairments.

Ecology sub-action ES-1.3 prioritizes tree retention and increased planting in future Neighbourhood Plans[37]. A strong emphasis is placed on tree planting strategies that provide multiple climate action co-benefits — such as shade provision, carbon sequestration, and air quality improvements — along active transportation routes and connections to public transit infrastructure. Focus should be placed on selecting tree species which will thrive in current and future climates, quickly offer cooling benefits to the community, and align with the intended design and use of the area.





Top Left: University Boulevard greenway; Top Right: Main Mall Greenway; Bottom: Access to Old Barn Community Centre from Main Mall Greenway.

Figure 2. *Proposed greenway expansion from Campus Vision 2050. Primary landscape corridors will provide major opportunities for ecological connectivity, rainwater management and movement of wildlife and people. Secondary corridors will connect and revitalize smaller green and open spaces within the campus core (see 'Restorative and Resilient Landscapes' under Campus Vision 2050 for further details).*

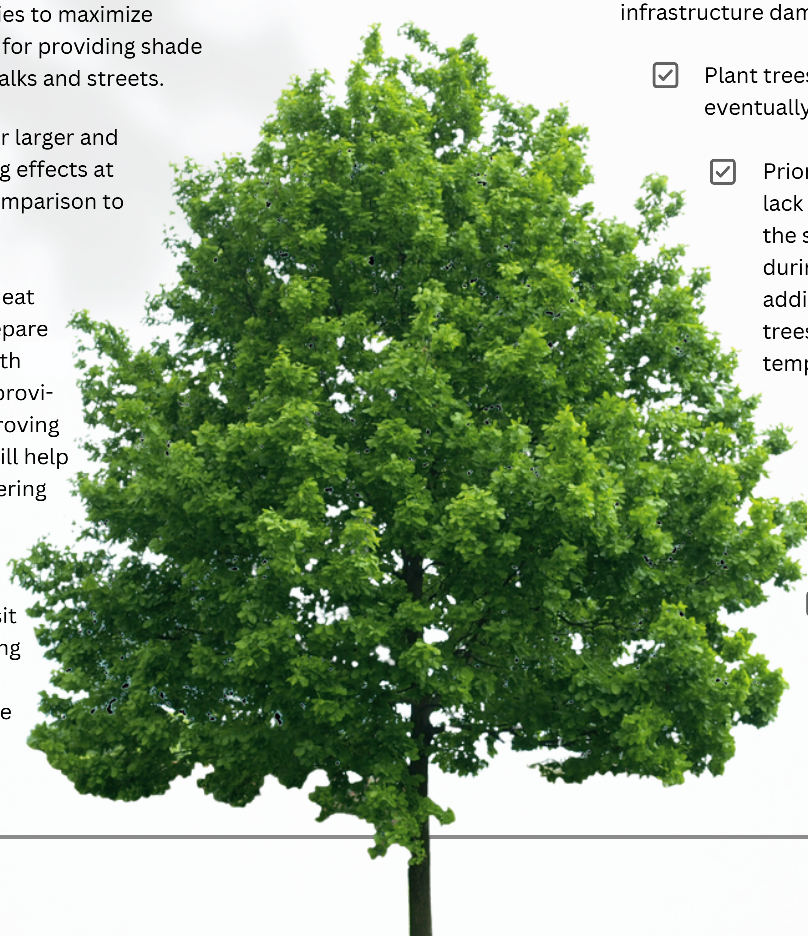
2.2 Shading and Temperature Regulation

Shade trees play a significant role in reducing urban temperatures. By blocking direct sunlight, shade trees minimize the heat absorbed by buildings and paved areas[38]. Additionally, trees cool the surrounding air and surfaces through evapotranspiration, a process in which heat energy is absorbed from the environment as water evaporates from from the leaves[39]. Through strategic planting and placement of trees, energy demands for indoor cooling can be reduced significantly[24].

Remote sensing methods such as LiDAR can be used to assess current canopy cover, identify areas in neighbourhoods with insufficient shade, and pinpoint suitable locations for new trees to be planted, based on factors like sunlight exposure, building heights, and surface temperature variations. A UBC Shade Frequency Map for the Vancouver campus was recently produced by UBC SEEDS research student Jamie Wang (2024).

Planting Strategies to Optimize UHI Mitigation

- ☑ Reduce solar heat gains from direct sunlight exposure by planting trees along the West and South sides of buildings[40].
- ☑ Select tree species with dense, broad canopies to maximize shade coverage. This is especially important for providing shade over wide impermeable areas, such as sidewalks and streets.
- ☑ Prioritize the protection of mature trees; their larger and established canopies provides greater cooling effects at both the neighbourhood- and site-scale in comparison to younger trees[41].
- ☑ Shade dark surfaces that absorb and retain heat (low albedo) such as asphalt parking lots. Prepare for the associated challenges with tree growth (space constraints, impervious surfaces) by providing adequate soil volume for roots and improving soil conditions in parking lots[42]. Tree shade will help to reduce pavement maintenance, while lowering local air and surface temperatures[43].
- ☑ Focus tree planting efforts in 1) areas of high active transportation use, and 2) public transit access points. Provide continuous shade along sidewalks, bike paths, Complete streets, and bus stops to encourage the use of sustainable modes of transportation during hot days[29].



- ☑ Ensure trees are spaced appropriately based on the species' expected height, canopy diameter, and root zone at maturity, to allow for unobstructed growth. This will minimize the likelihood of potential infrastructure damage (e.g. sidewalk heave)[44].
- ☑ Plant trees at intervals that ensure their canopies will eventually overlap, providing continuous shade along streets.
- ☑ Prioritize planting deciduous trees in hardscaped areas which lack shade provision. Deciduous trees shade windows during the summer and allow solar heat gains to enter buildings during the winter, balancing seasonal energy demands[40]. In addition, a study of UBCV campus tree stands found deciduous trees outperformed coniferous trees in reducing land surface temperatures during the 2021 Pacific Northwest Heat Wave[45].
- ☑ Select tree species that are well-adapted to both current and projected future climate conditions. This approach will enhance tree health and growth, ensuring shading benefits are sustained over a long period[46].
- ☑ Avoid planting a monoculture of street trees, which can increase the vulnerability of the urban canopy to pests and diseases[47]. The City of Surrey recommends a balanced ratio of a maximum of 30% of any one family, 20% of any one genus, and 10% of any one species or cultivar[48].

2.3 Tree Maintenance & Health

Tree canopy cover varies significantly across the UBC neighbourhoods. The highest canopy cover is found in East Campus, with 51.1%, whereas more urban areas, such as University Boulevard, have just 10.6%[9]. This disparity is partly due to the size and age of street trees. For instance, nearly 25% of trees in East Campus are over 45 meters tall, which contributes significantly to the neighbourhood's total canopy cover. In contrast, most trees along University Boulevard are young and small, with 76% standing under 10 meters tall[9]. Similarly, Wesbrook Place contains the youngest trees across all UBCV neighbourhoods.

Ensuring the survival and health of young trees is crucial, as these trees will eventually provide vital cooling and shading benefits that are key to mitigating the urban heat island (UHI) effect. Proper maintenance, such as adequate watering during establishment and the use of enhanced planting methods, is essential for supporting their growth and long-term resilience.

One way to enhance tree health in urban environments is through improving street tree planting techniques. Traditionally, new street trees in Vancouver were planted with roughly 1.8 m² of growing medium, leading to an average survival rate of only 13 years[49]. However, newer technologies such as structural soil cells (also referred to as 'soil vault systems') are revolutionizing this process. For example, in Vancouver's Southeast False Creek (SEFC), structural soil cells have been used to provide street trees with an average of 19.6 m² of growing medium — over 10 times the average amount[49]. Structural soil cells provide essential space for root growth while also supporting pavement loads, allowing trees to thrive even in compacted urban environments. This technology can extend a street tree's lifespan to as much as 50 years[49]. In addition to improving tree health, soil cells help achieve faster and more substantial tree canopy cover. However, the cost of using soil cells is significantly higher than traditional methods, ranging from $10,000 to $15,000 per tree (for Silva Cell brand soil cells), compared to a few hundred dollars per tree with conventional planting[50]. This higher expense can lead to resistance from developers. Despite the upfront costs, there is a strong business case for their application in urban areas. Trees grown in soil cells typically exhibit longer lifespans, reduced replacement costs, and deliver greater ecological benefits (such as improved carbon sequestration and stormwater management)[50].

Cities like Toronto are also adopting new technologies to extend the lifespan of street trees, using soil cells and continuous trenches to reduce soil compaction and allow root systems to expand and provide adequate space for root growth. Over 500 street trees in Toronto have been planted using these methods, with the goal of prolonging their lifespan in urban environments to 30-40 years[50].

Other factors critical to tree survival include proper pruning and mulching. The City of Surrey follows regular pruning schedules for street trees[48], requiring trees to be pruned every 3 years for the first 3 growth cycles, then pruned every 5 years thereafter. The City of North Vancouver recommends mulching to enhance soil moisture retention and insulate roots from extreme temperatures[51]. A 2–3 inch (5–7.5 cm) layer of mulch is ideal, but it should not be piled against the trunk[52]. Leaving a 1–2 inch (2.5–5 cm) mulch-free area around the base will help to prevent bark decay[52]. Additionally, mulch helps protects the trunk from lawn tools and other stressors.

Watering is another crucial factor for tree health, especially during the first few years of a tree's life. Street trees face harsh growing conditions — ensuring they receive adequate watering can significantly improve their chances of survival. The City of Vancouver recently launched an 'Adopt a Tree' program[53], encouraging residents to water young trees in their neighborhoods and offering free watering bags as part of the initiative. Watering bags slowly release water to the tree's roots, ensuring that trees have a consistent supply of water to support them over periods of drought[53]. To maximize the effectiveness of street tree watering, it is recommended to water trees directly (or fill watering bags) early in the morning or late in the evening, to minimize evaporation and maximize water absorption by the roots. Consistent and deep watering practices help trees build robust root structures, which support their growth and ability to withstand environmental stressors.

Right image: A Treegator® watering bag installed over summer 2024 to support a young ginko (Ginkgo biloba) tree on the UBCV campus.

2.4 Street Tree Species Recommendations

Selecting appropriate species for new and replacement trees will contribute to mitigating the urban heat island (UHI) effect and enhancing climate resiliency at both the neighbourhood and building scales. Priority should be placed on selecting trees which are drought-tolerant, native (with emphasis placed on selecting species of cultural significance to Musqueam) and provide substantial canopy coverage, in order to maximize cooling provision for neighbourhoods and effectively address current and future climate change challenges. Drought-tolerant species, such as Hedge Maple (*Acer campestre*) and Garry Oak (*Quercus garryana*) are well-adapted to our region's dry summers and are unlikely to require supplemental watering. Native species, such as Red Alder (*Acer rubra*), are well-suited to local climate and soil conditions, which will help support their growth and long-term survival in urban environments.

Other valued traits, such as fast growth rates, will help to ensure trees can supply shade provision to neighbourhoods as quickly as possible. The Big Leaf Maple (*Acer macrophy-llum*) is a native species known for rapid growth and extensive shade provision from its large leaves. Trees with large canopies, such as Western Catalpa (*Catalpa speciosa*), offer significant shading and contribute to microclimate regulation and reduced UHI effects.

The list below is an excerpt from the Metro Vancouver Urban Forest Climate Adaptation Initiative[54] tree species selection database. These species have been evaluated based on their suitability for the current and projected future climate of Metro Vancouver. The intended purpose of the database is to be used as a guide for informing decision-making by local practitioners, and is in no way a strict planting directive.

Large Canopy Trees (Approx. 125m^2 canopy coverage per tree)

Common Name	Botanical Name	Native to BC	Notes
Big Leaf Maple	Acer macrophyllum	Yes	Drought tolerant
Hedge Maple	Acer campestre	No	Extremely drought tolerant
Red Maple	Acer rubrum	No	Fast growing once established
Red Alder	Acer rubra	Yes	Prefer full sun
Western Catalpa	Catalpa speciosa	No	Adaptable to adverse conditions
Tulip Tree	Liriodendron tulipifera	No	One of the fastest growing shade trees
Hungarian Oak	Quercus frainetto	No	Drought tolerant, transplants easily, no significant disease/pest concerns
Garry Oak	Quercus garryana	Yes	Drought tolerant once established

Species recommended to be suitable for Oak Bay's current & future climate. For a complete list including Medium and Small Canopy Trees, refer to District of Oak Bay Bylaw No. 4742[55].

VERY SUITABLE = species anticipated to tolerate a broad range of sites under future climate

Arbutus menziesii	Cupressus arizonica *•	Koelreuteria bipinnata *•	Pinus nigra	Quercus garryana
Albizia julibrissin *	Cupressus macrocarpa *	Koelreuteria paniculata *	Pinus pinea *•	Quercus ilex •
Arbutus unedo	Cupressus sempervirens	Lagerstroemia x 'tuscarora'•	Pinus ponderosa	Quercus imbricaria •
Calocedrus decurrens *	Cupressus x leylandii	Maackia amurensis •	Pinus sylvestris *	Quercus macrocarpa
Catalpa speciosa *	Eucommia ulmoides	Maclura pomifera *•	Pinus thunbergii *	Quercus shumardii
Cedrus deodara *	Ficus carica *	Notholithocarpus densiflorus	Pistacia chinensis	Quercus suber •
Celtis occidentalis *	Fraxinus ornus	Nyssa sinensis	Prunus dulcis •	Quercus virginiana •
Celtis sinensis •	Ginkgo biloba	Olea europaea *•	Pyrus calleryana *	Rhus typhina
Cercis canadensis	Gleditsia triacanthos	Phellodendron amurense *	Pyrus pyrifolia •	Sorbus aria
Cotinus coggygria	Gymnocladus dioicus	Pinus banksiana	Quercus acutissima *	Ulmus propinqua •
Crataegus crus-galli	Juglans major •	Pinus contorta	Quercus agrifolia •	
Crataegus x lavalleei	Juniperus chinensis	Pinus flexilis	Quercus alba	
Crataegus x mordenensis	Juniperus virginiana *	Pinus mugo	Quercus coccinea	

** Invasive potential - capable of self-seeding so avoid planting in locations where seeds can disperse and germinate*
• Trial - species is present in future analog (comparable) climates and has the potential for introduction to Metro Vancouver

Big Leaf Maple (Acer macrophyllum)
Image source: Oregon State University.

2.5 Cost-Benefit Summary

	TREES AND URBAN GREENING
COSTS	• An analysis from Surrey's 2016 Shade Tree Management Plan[48] found every $1.00 spent on planting, maintaining, and managing shade trees to yield $3.18 in benefits, including energy savings, carbon sequestration, improved air quality, stormwater retention, and higher property values.
TEMPERATURE REDUCTION	• A study of the UBC Vancouver campus during the 2021 heat dome observed land surface temperatures reductions of up to 10°C, depending on the extent of urban tree canopy cover[9]. • Neighbourhoods with high canopy cover, such as Acadia East (40.9%) and Hawthorn Place (51.5%), were considerably cooler (mean temperatures of 24.9°C and 24.9°C, respectively, on June 30th 2021) than sparsely treed areas such as around the UBC Hospital and University Boulevard (26.8°C)[9]. • 'green islands' (e.g. parks composed of trees and vegetation) within urban areas can reduce surrounding air temperatures by up 0.8°C to 6°C, and extend their cooling effects up to 1.25 kilometers[22,25].
CO-BENEFITS	• Tree shade slows the rate of street pavement deterioration[48] • Trees provide significant energy-savings for residential buildings, depending on tree placement and orientation. • Supports biodiversity • Provides carbon storage and sequestration • Improves air quality • Improves human health and quality of life
KEY CONSIDERATIONS	• Proper care and maintenance are essential for street trees to reach maturity and provide their full range of benefits. • Young, newly planted street trees often require additional irrigation during their early growth stages to establish strong root systems.
EXPECTED LIFESPAN	• Approximately 18-29 years for street trees (lifespan can be extended with proper species selection, watering, and maintenance, among other local factors)[56].

2.6 Additional Resources

- PDF *Metro Vancouver Tree Regulations Toolkit: Second Edition (2024)*
- PDF *City of Surrey Shade Tree Management Plan 2016-2036 (2016)*
- PDF *'2.4.3 — Planting Guidelines' in 'Vancouver Campus Plan: Design Guidelines' (2020)*
- PDF *UBC Technical Guidelines: Tree and Shrub Preservation (2023)*
- PDF *Recommendations to improve the health of Vancouver's street trees surrounded by hardscape (2023)*

3. GREEN ROOFS

Rooftops comprise approximately 20-25% of surfaces in urban areas[57] (approx. 24% in the UBC neighbourhoods) accounting for a significant portion of the urban heat island (UHI) effect. Conventional roofing materials, such as asphalt, metal, and composite shingles are typically dark and have low reflectivity, meaning they absorb a substantial amount of solar radiation, which is converted into heat. This heat is then transferred to the air above and inside buildings, raising temperatures both locally and throughout the urban environment. Roofs typically lack the shading benefits provided by trees and other vegetation, exacerbating their heat-absorbing properties and further contributing to the UHI effect.

3.1 Green Roofs and the UHI Effect

Green roofs, also known as vegetated or living roofs, are one of two alternatives to conventional roofs covered in this Guidebook (see Chapter 4 for cool roofs). Green roofs are characterised as a partially covered rooftop with vegetation, a growing medium, and a waterproof membrane. Additional features such as a root barrier layer, drainage layer, and irrigation system may be required depending on the building's structure and local climate. These roofs are well-suited for urban buildings with low-sloped or shallow-pitched roofs, and come in a variety of forms, from low-maintenance 'extensive' roofs, to more elaborately designed 'intensive' roofs including features like gardens and small trees.

Various studies have investigated the cooling benefits of green roofs, reporting a 60-79% reduction in heat transfer (heat flux) into buildings compared to conventional roofs[58, 59, 60]. Energy savings associated with reduced indoor cooling demands are highly dependent on the thermal resistance (U-value) of the green roof[61]. Other factors, such as local climate, soil depth, and vegetation characteristics (e.g. Leaf Area Index (LAI)) will also influence the energy behaviour of a green roof system[61].

Green roofs contribute to urban heat island (UHI) mitigation by cooling buildings through three key processes:

Insulation

The vegetation, growing medium, retention fabric, and drainage layer of a green roof provides a second layer of insulation, increasing the roof system's thermal mass and blocking solar radiation from penetrating the building beneath[62]. This in turn helps regulate indoor temperatures[62]. The energy saving provisions of green roofs have been well documented[63,64], with a study published by the National Research Council of Canada demonstrating the potential of an extensive green roof to reduce heat flow by over 75% in summer months[64].

Evapotranspiration

As the sun heats a green roof, water from the soil and surface layers evaporate, drawing heat from the surrounding environment to produce a cooling effect. At the same time, plants on the green roof transpire, releasing water vapor through tiny openings in their leaves called stomata which cool the surrounding air. These two processes, collectively known as evapotranspiration, can result in extensive green roofs having maximum daytime ambient air temperatures 1.8°C cooler than those of dark roofs in summer months[65].

Albedo

Green roofs mitigate the UHI effect by increasing the albedo, or reflectivity, of rooftops. Unlike conventional roofs, green roofs reflect more solar radiation and absorb less heat, effectively lowering surface temperatures. Research has shown green roofs can reduce roof surface temperatures by 18.4 °C compared to traditional roofs[65]. This cooling effect is achieved through a combination of reflection and photosynthesis, as green roofs can reflect up to 30% of incoming solar radiation and absorb up to 60% via photosynthesis[66]. In addition to increasing roof albedo, vegetation on green roofs provide shade, further reducing the amount of heat absorbed by the building. This dual mechanism of reflection and shading helps keep buildings cooler and reduces surrounding air temperatures[67]. Moreover, green roofs with relatively abundant soil moisture and an albedo value of 0.3 can achieve surface and near-surface cooling effects comparable to cool roofs with an albedo of 0.7[68].

An extensive green roof on the UBC Vancouver campus (AMS Student Nest).

3.2 Types of Green Roofs

Green roofs are categorized into three main types: extensive, semi-intensive, and intensive. These classifications are based on the depth of the growing medium, the types of plants used, and maintenance requirements. Each type offers unique benefits and challenges, which determine their suitability for different applications.

Extensive Green Roofs

Feature a relatively shallow growing medium, typically 150 mm or less, and a saturated weight of less than 25 lbs (per sq ft)[69]. While extensive green roofs are generally not intended for heavy foot traffic, they can accommodate public access if walkways are incorporated into the design to protect the plants. This makes them a practical choice for large-scale applications where accessibility is limited[70]. Vegetation chosen for extensive green roofs is selected for its resilience and ability to thrive in harsh conditions with minimal intervention. Hardy, drought-tolerant plants such as sedums, grasses, and mosses are common choices[71]. These plants can withstand extreme temperatures, wind, and periods of drought, making them ideal for climates with fluctuating weather patterns such as in the Metro Vancouver region[70].

Extensive green roof on the Vancouver Public Library (Main Branch) (image credit: Terri Meyer Boake).

Semi-Intensive Green Roofs

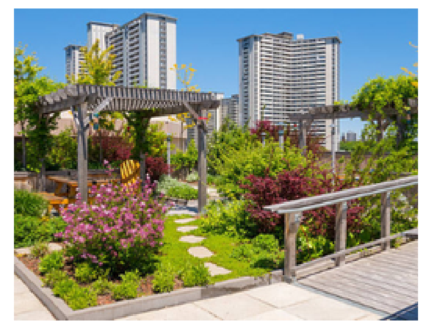
Offer a middle ground between low-maintenance extensive roofs and more elaborate intensive roofs. With a growing medium depth ranging from 150 mm to 300 mm and saturated weight under 40 lbs (per sq ft)[69], semi-intensive roofs support a wider variety of plants — including grasses, herbs, perennials, and small shrubs[72]. Native species to B.C., such as varieties of bunchgrass and Kinnikinnick (*Arctostaphylos uva-ursi*), would be suitable options for semi-intensive greenery in Metro Vancouver's climate[73]. Compared to extensive green roofs, semi-intensive green roofs host a richer biodiversity and offer greater support for local pollinators[72]. Additionally, semi-intensive green roofs enhance building insulation as a result of increased biomass and soil depth[72]. These roofs require moderate maintenance, including occasional irrigation, fertilization, and weeding[72].

Semi-Intensive green roofs (image credit: Jörg Breuning)

Intensive Green Roofs

Feature a deeper growing medium, often exceeding 300 mm, and a saturated weight greater than 45 lbs (per sq ft)[69]. Intensive green roofs support a diverse array of plants, from small trees and shrubs to perennial flowers and vegetables. These roofs are designed for accessibility and can serve as recreational spaces, community gardens, or aesthetic features in urban environments[70]. Intensive green roofs require significant maintenance, including regular watering, fertilization, and pruning. The deeper soil layer of intensive green roofs allows for greater root growth and plant diversity.

Although intensive roofs often require a high upfront investment, these roofs provide significant heat flow and building energy reductions due to their high biomass, greater soil depth, and superior thermal insulating properties[64]. A study conducted during a 30-day, early-autumn observation period in Vancouver recorded total heat flow through a reference roof and intensive green roof to be 2.634 kWh/m2 and 0.715 kWh/m2, respectively (resulting in a 70% improvement in building thermal performance)[74]. Due to their substantial weight, intensive green roofs are often integrated in the early stages of building design, and less commonly seen as retrofits to existing buildings.



Intensive green roof on Hugh Garner Co-op (Toronto, Ontario)

3.3 Design & Maintenance Tips

Proper design and maintenance are important to the long-term success and functionality of green roofs. The following includes recommendations for green roof planning, installation, and upkeep.

Planning

- **Roof Pitch Compatibility :** Green roofs are ideal for flat roofs, and can be installed on roofs with up to a 20º (4:12) pitch[70].

- **Structural Considerations :** Green roofs are heavier and more expensive to construct and maintain than non-vegetated roofs. The structure must bear the additional dead load imposes by the green roof, including the weight of the soil, plants, and other materials. Plant cover will require varying degrees of maintenance depending on the type of green roof selected. It is most ideal to design green roofs simultaneously with the building or during a planned retrofit to ensure the structural load of the roof. including its dead load, is properly assessed[70, 75].

- **Vegetation Selection :** Vegetation for green roofs should be chosen based on suitability for current and future climatic conditions (temperature, wind, precipitation), landscape design, solar exposure, moisture availability and irrigation, and the roof's orientation and pitch.
  - **Biodiversity :** Avoid planting monocultures on green roofs; Use a diverse array of species to increase the success of establishing a self-maintaining plant community[76].

- **Load Calculations :** Always account for the saturated weight of each material when calculating structural loads[75].

Installation

- **Waterproof Membranes :** prevent roots from penetrating the building by avoiding the use of plants with invasive root systems, installing a root barrier, and/or installing a membrane resistant to roots[75].

- **Leak Detection :** Green roofs are "inverted" roofs; their waterproofing membrane is beneath the plants and most roof components. This placement protects the membrane from UV radiation, but makes leaks more difficult to detect[77]. Electronic leak detection systems can installed to pinpoint leaks for easier repair[70].

Upkeep

- **Regular Inspections :** Conduct regular inspections to identify and address any potential issues pertaining to drainage problems, plant health, and the structural integrity of the building. Inspections should be more frequent during the first few years after installation, and during extreme weather events[70].

- **Weed Control :** Regularly remove weeds to prevent competition with desired vegetation. This is particularly important for extensive green roofs, which are vulnerable to being overrun by weeds[78].
  - **Membrane :** Identify and remove weeds (i.e. tree seedlings) by hand as soon as possible. If left to grow, tree roots can become strong enough to permanently damage the membrane[79].

- **Initial Maintenance :** Provide intensive maintenance for the first two years after planting, including irrigation during dry periods, weed removal, light fertilization with slow-release complete fertilizers, and replacing dead plants[80].

- **Irrigation Management :** Ensure proper irrigation, especially during dry periods. Extensive green roofs may require occasional watering, while semi-intensive and intensive green roofs could require an automated irrigation system to maintain plant health[80].

- **Drainage Systems :** Regularly check and clean drainage systems, to prevent water accumulation and ensure proper water flow. This is critical for all types of green roofs to avoid waterlogging and root rot.

- **Structural Load Checks :** Periodically reassess the structural load-bearing capacity of the building to ensure it can handle the green roof's weight — particularly after significant weather events, or roof modifications.

3.4 Cost-Benefit Summary

	GREEN ROOFS
COSTS	• Costs vary based on size, greenery, and type of green roof (extensive, semi-intensive, intensive). Total cost of design, materials, labour, and installation can range from CAD $211.08/m^2$ to $527.76/m^2$ [81,82]. • The Green Roof Research Facility estimates the upfront cost for installing a green roof to be about twice as much per square meter as a quality metal roof — although this can vary depending on roof design[83].
TEMPERATURE REDUCTION	• green roofs can achieve ambient air temperatures reductions of 0.3°C to 3°C when compared to traditional dark roofs, depending on scale of installation (singular site vs. widespread adoption across multiple properties) and vegetation types[84,85].
CO-BENEFITS	• Manage stormwater runoff • Energy savings (reduced demand for indoor cooling) • Provide attractive rooftop spaces for public use, which may increase property value (e.g. 'extensive' green roofs) • Enhanced quality of life for tenants • Supports biodiversity and pollinators • Improved air quality, noise reduction • Extends roof life by protecting roofing membranes from UV radiation
KEY CONSIDERATIONS	• The high initial costs of installing a green roof should be considered against the anticipated long-term benefits (energy savings, extended lifespan of roofing membranes, and any applicable tax rebates and other credits for installation)[81]. • Soil depth and measured U-value of the roof will have the greatest influence on building energy consumption. • Green roofs contribute to street-level cooling when installed on low-rise buildings[85]; however, green roofs show marginal effects on street-level cooling when installed on high-rise buildings[86].
EXPECTED LIFESPAN	• Green roofs are more expensive to install and maintain than conventional roofs; however, the roofing membrane can last up to twice as long[87]. • Investing in a quality membrane will ensure the green roof will survive up to 40 to 50 years (compared to the 10-30 year lifespan of traditional roofs)[88].

Extensive green roof (photo credit: Vancouver Public Library).

3.5 Additional Resources

PDF [BCIT Centre for Architectural Ecology]

4. COOL BUILDINGS

While nature-based solutions for mitigating the urban heat island (UHI) effect offer a wide range of co-benefits and ecosystem services that extend beyond temperature regulation, these solutions may require significant space, ongoing maintenance, and often longer times to establish their full benefits[89]. Engineered solutions, such as cool roofs and reflective or insulating building materials, can be presented as low-cost alternative options for building-scale UHI mitigation.

4.1 Cool Buildings and the UHI Effect

Albedo

Cool roofs and cool exterior walls are designed with materials that have high solar reflectance (albedo), resulting in a significant portion of the sun's rays being reflected back into the atmosphere (Figure 3). This leads to lower building surface, indoor, and outdoor ambient air temperatures, an effect that is more pronounced when implemented in clusters of buildings within a neighborhood.

Traditional dark-colored roofs absorb up to 80% of incoming solar energy, which raises the temperature of the building and it's surrounding area[87]. Common roofing materials with a low albedo, such as asphalt (albedo: 5-20%), dark roof shingles (albedo: 10-16%), and dark colored tiles (albedo: 10-13%), contribute to this heat absorption[22]. In contrast, cool roofs and walls made of light coloured, highly reflective materials -- such as reflective paints, sheet covering, tiles, or shingles — can reflect up to 90% of incoming solar radiation[90]. A summary of common single ply and liquid applied cool roofing and exterior wall materials is given in on pages 21-22.

Cool exterior walls come in a variety of colors and styles. While light-colored paints and materials are typically associated with high albedo, it's important to note that about half of the radiation in sunlight arrives as invisible near-infrared (NIR) light[91]. As such, "cool color" (spectrally selective pigment) dark walls can achieve an albedo that is approximately halfway between that of a conventional dark wall and a light-colored wall (Figures 4,5,6)[92,93].

Exterior walls receive less solar energy than roofs due to their vertical orientation, which only captures direct sunlight during specific times of the day. South-facing walls receive the most sunlight as they are exposed to the sun's path throughout the day, while north-facing walls receive the least amount of direct sunlight, mostly remaining in shadow[94]. This results in a significant difference in solar energy gain between walls and roofs, and between different wall orientations. Moreover, exterior walls are often shaded by adjacent structures, trees, shrubs, and architectural features like overhangs, which further reduce the amount of direct sunlight they receive compared to roofs[94]. However, as walls typically have less insulation than roofs (offering roughly half the resistance to heat flow), cool surface technologies — when applied strategically to walls — have the potential to yield similar energy savings to those achieved by cool roofs[95].

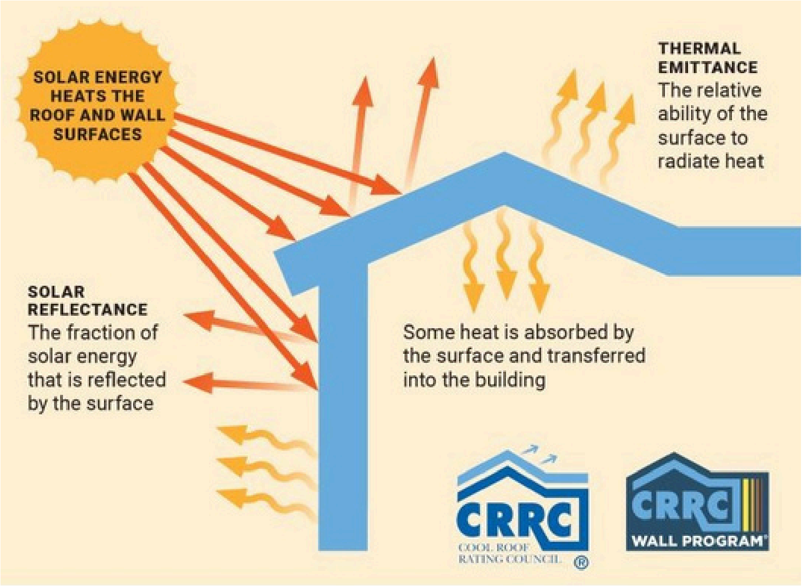


***Figure 3**. Illustration of the flow of radiant energy as heat between the sun, roof and external wall surfaces, building interior, and building surroundings. (Image credit: Cool Roof Rating Council).*

As a general principle, cool surface technologies are most effective for buildings with high sunlight exposure[94]. Scholars recommend that materials with significantly high reflectivity should be reserved for use on high-rise building rooftops[96]. For exterior walls, it is important to consider the implications of high albedo products on the nearby street canyon. Climate simulations by the Berkeley Lab Heat Island

Group have demonstrated increasing exterior wall albedo throughout Los Angeles County could lower average outdoor air temperatures in street canyons by about 0.2°C during summer months[93]. However, negative effects may arise in narrower street canyons, defined by an aspect ratio of 1.5 or higher (building height divided by street width (H/W))[97]. In these cases, heat reflected from urban surfaces may become trapped between surrounding tall buildings, impacting pedestrian comfort. These effects can be offset by incorporating street trees into canyon designs, and using lower SR (0.1-0.3) materials on sections of the building at street level (1.5m height) while reserving higher SR (>0.3) materials for sections above street level[97].

Thermal Emittance

Another important feature of cool roofs and walls is thermal emittance, which measures a material's ability to release absorbed heat back into its environment[98]. Materials with low emittance retain heat longer, which can increase the heating load of a building[90]. In addition, low-emittance materials are known to capture heat during the day and gradually release this heat back into the atmosphere at night, leading to smaller diurnal temperature ranges in urban environments[99]. This process of persistent heat retention exacerbates the UHI effect and can create a feedback loop, where consistently higher temperatures further increase heat absorption during the day[99]. Materials like polished metals typically have low emissivity (10% for aluminum), whereas matt surfaces such as brick, paint, concrete and asphalt have high emissivity ratings, ranging between 85-95%[22] [(100)]. Although white paint and red bricks have similar thermal emissivity (90%), meaning they emit thermal radiation at similar rates, the crucial factor is the amount of heat they initially absorb. White paint is frequently used in cool roof and exterior wall applications because its high reflectivity results in minimal heat absorption, reducing building cooling loads.

Solar Reflectance (SR) measures a material's ability to reflect solar energy from its surface, expressed as a value between 0 and 1, with higher values indicating better reflectance.

Solar Reflectance Index (SRI) combines both solar reflectance (SR) and thermal emissivity in a single value. SRI measures the roof's ability to reject solar heat, defined such that a standard black (reflectance 0.05, thermal emittance 0.90) is 0 and a standard white (reflectance 0.80, thermal emittance 0.90) is 100.

Energy Savings

Cool roofs are capable of decreasing peak summer indoor temperatures by up to 2°C in moderately insulated buildings, resulting in cooling load reductions of 10% to 40% and savings of up to 15% on total cooling costs[85]. However, one major challenge associated with cool roofs and cool exterior walls is the 'heating penalty'. This is defined as an undesired cooling effects during winter months which increases heating demands and energy consumption[101]. For a moderate climate (such as the Metro Vancouver Region) the heating penalty of cool roofs may range between 5%-10%, and will vary based on microclimate and building characteristics[85].

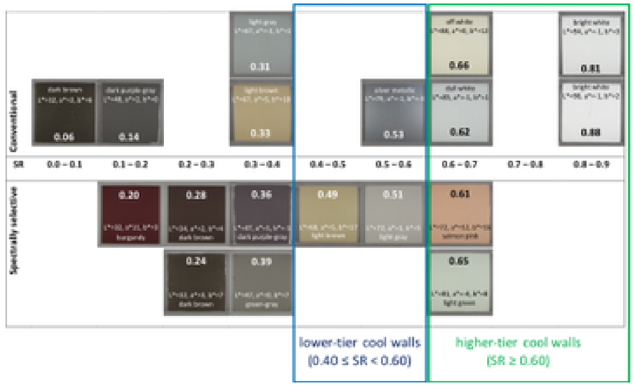


***Figure 4**. A subset of colour and tone options for exterior wall products, showing both conventional and "cool colour" (spectrally selective) materials. (Image source: Berkeley Lab Heat Island Group).*

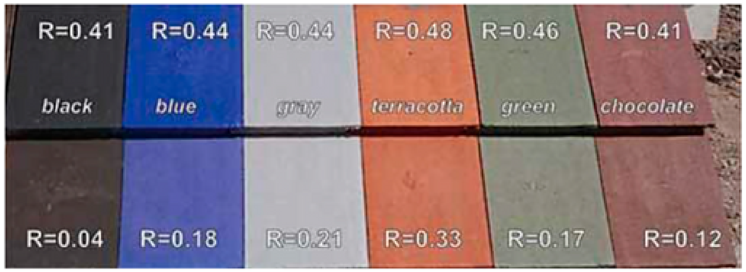


***Figure 5**. Comparison of solar reflectance (R (or SR)) for "cool colour" pigmented tiles (top) and ordinary coloured tiles (bottom) (Source: American Roof Tile Coatings and Lawrence Berkeley National Laboratory).*

In B.C., climate zones are used to classify different regions based on their typical weather patterns, temperatures, and precipitation[102]. Studies have shown cool roofs and cool walls to be effective energy saving features in new and existing homes in Climate Zones 1A to 3A and 3B. In the context of Metro Vancouver's climate zone (4)[103], the energy-saving benefits of cool roofs and walls will be greatest for older buildings lacking adequate insulation, and single-family and low-rise buildings with air handling units (AHU) and ductwork located in vented attics[94]. Although advancements in insulation standards in recent years may result in less pronounced energy savings for newer buildings, it is important to recognize that cool roofs and walls provide valuable extreme heat resistance in all climates[94]. As the Lower Mainland is predicted to experience more frequent and prolonged heatwave and heat dome events in coming years, the integration of cool roofs and walls within urban areas and neighbourhoods will likely become important to building resiliency and energy efficiency under future climate conditions.

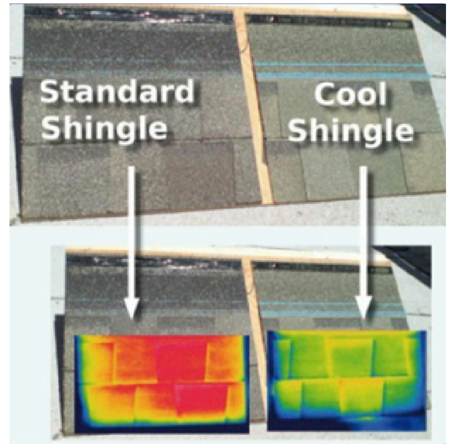


***Figure 6**. Cool shingles covered with a ceramic coating that reflects near-infrared radiation results in cooler roof surface temperatures, as captured by a thermal camera (red yellow indicating hotter temperatures, and green and blue indicating cooler temperatures). (Image credit: Building America Solution Centre; U.S. Environmental Protection Agency).*

Future Directions

Ongoing research into cool roof and cool wall technologies has focused on developing adaptive building materials. Thermochromic pigments are an emerging technology designed to alter their colour and reflective properties in response to daily and seasonal temperature variations[104]. In cool roof applications, these pigments can adjust the roof's albedo based on the ambient temperature —becoming more reflective in hot weather to reduce heat absorption, and less reflective in cooler weather to retain warmth in buildings. Thermochromic pigments have demonstrated potential in optimizing energy efficiency and indoor comfort throughout the year, although further refinement of this technology is needed to increase their longevity (Figure 7)[105].

Maintenance

While cool building materials can effectively mitigate the urban heat island (UHI) effect, their SR is prone to deterioration with age due to weathering, dirt buildup, and physical abrasion. A study conducted by the Berkeley Lab Heat Island Group found exterior wall and roof materials to deteriorate at different rates. The albedo of exterior wall materials declined slightly (0.00-0.05) over 12-24 months, whereas roof coatings on near-horizontal surfaces experienced significant albedo declines (up to 0.25) within 12 months from initial application[93]. As a result, regular maintenance and re-application of reflective coatings is necessary to sustaining their performance over time.

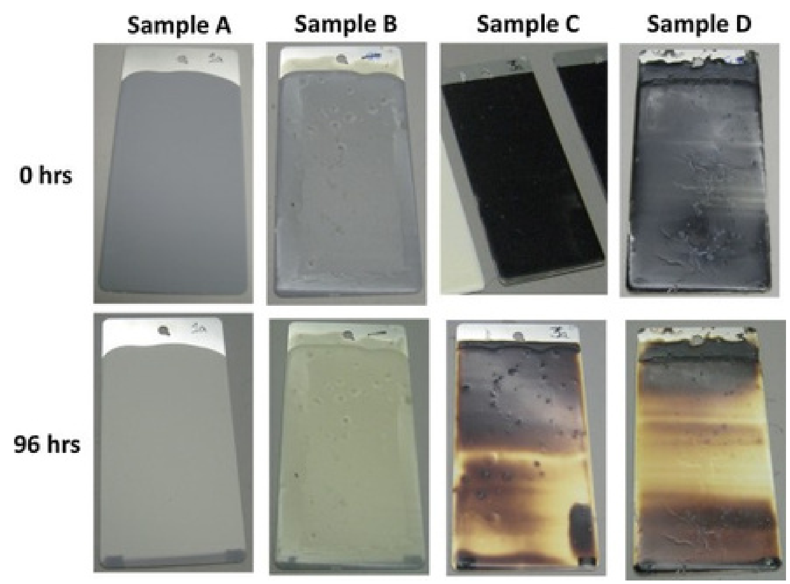


***Figure 7**. Results from a weathering study of thermochromic coatings demonstrates that paint undergoes irreversible photodegradation in as little as 96 h of accelerated aging[106]. Attempts to protect thermochromic dyes with organic (Lowilite® 20S) UV absorbers (samples B and D) were partially successful, but require significant improvements for use as roofing materials (which would require a minimum lifespan of 10 years).*

4.2 Cool Roof and Wall Materials

Name	Product Type	Use	Overview
EPDM	Single ply membrane	Roofing	• EPDM (ethylene propylene diene terpolymer) is a highly durable synthetic rubber roofing membrane commonly used in low-slope buildings. • Resists punctures, tears, and leaks; Highly durable and produced in varying thicknesses. • Resistance against tears and punctures further increases with TTR (Tri-Thermal Roofing) system instillation. TTR is stronger roofing that combines EPDM and spray-applied polyurethane foam. With the added spray polyurethane foam roofing, all possibility of leaks will be eliminated[107]. • White EPDM resists UV radiation (at similar rate to TPO) • Economical option (compared to TPO) • Can be combined with green roofs • Environmental concerns: Made from ethylene and propylene (a derivative of oil and natural gas) • Lasts up to 50 years, with minimal maintenance[107]
Elastomeric coating*	Liquid application	Roofing & Exterior walls	• Used to protect and seal roofs, or as weather-resistant barrier for stucco, concrete, and other masonry surfaces. • Adheres to a multiple surfaces (metal, concrete, asphalt shingles, etc.) • High UV resistance
Acrylic coating*	Liquid application	Roofing & Exterior walls	• Water-based • Good UV resistance, reapply periodically to maintain protection • Reflects >73% of solar radiation after 3 years[108] • High UV resistance • First application lasts approx. 10 years[108] • Budget-friendly alternative to silicone coating[109]
Silicone coating*	Liquid application	Roofing & Exterior walls	• Superior UV resistance and waterproofing[109] • Typically $$$
Polyurethane coating*	Liquid application	Roofing	• Liquid plastic-based • Can be installed with matte or high shine finish • difficulty bonding with concrete surfaces • High UV resistance • High durability
Vinyl siding	Panels	Exterior walls	• Can be manufactured with cool pigments that increase reflectivity • Durable • Low-maintenance • Available in multiple colors and styles

**Suggested materials for SBS roofing (typical of UBC institutional and residential buildings). Always check product specifications to ensure compatibility with SBS membranes.*

Name	Product Type	Use	Overview
SPF (Spray polyurethane foam)	Spray application	Roofing	• SPF is extremely versatile. Will adhere to multiple surface types (wood, steel, concrete, etc.)[110] • High reflectivity (albedo) • Insulating, with high R-value (measure of ability to resist heat flow) • Standard spray foam can reduce building energy costs up to 50%[110] • To protect SPF from UV radiation, combine with a protective coating (elastomeric, acrylic, or polyurethane) • Can be installed on low slope and flat roofs • Minimal repairs required after installation • High wind and water resistance • Lasts up to 50 years, with routine cleaning and recoating every 10-15 years[110]
TPO (Thermoplastic Olefin)	Single-ply membrane	Roofing	• A blend of a polypropylene and ethylene-propylene rubber, suitable for low-slope buildings. • High UV resistance • Lasts approx. 15-20 years[111] • Can be combined with the following insulation options[111]: - Polyisocyanurate (Polyiso): Most commonly used; High cost; high R-value rating. - Expanded Polystyrene (EPS): Used for roof, wall, and floors; highest R-value per dollar. - Extruded Polystyrene (XPS): Falls between Polyiso and EPS in price and performance range.
PVC (Polyvinyl Chloride)	Single-ply membrane	Roofing	• Environmental concerns: Made from chlorine and ethylene (derivative of natural gas)[112]; Difficult to recycle. • High UV resistance • Typically more expensive to install (compared to TPO and EPDM)
Cool Metal Shingles	Shingles	Roofing	• Metal shingles coated with reflective paints / finishes to enhance albedo • Higher upfront cost compared to asphalt shingles (materials, specialized labor required for instillation) • Typically require less long-term maintenance • High thermal conductivity and low thermal mass (compared to asphalt) results in rapid heat dissipation, helping metal roofs to stay cooler at night[113] • Last over 30 years with minimal maintenance[113]
Cool Asphalt Shingles	Shingles	Roofing	• Asphalt shingles coated with special granules engineered to possess a higher albedo and thermal emittance conpared standard shingles • Variety of colour options • Last approx. 22-30 years[114]
Thermochromic pigment	Liquid application	Roofing	• product not yet available for market purchase

Note: For solar reflectance (SR) and thermal emittance values, see Cool Roof Rating Council: Rated Roof Products Directory and Cool Roof Rating Council: Rated Wall Products Directory.

4.3 Cost-Benefit Summary

	COOL (REFLECTIVE) ROOFS AND WALLS
COSTS	• Depending on the product type (e.g., liquid paint, asphalt shingle, concrete tile, etc.), costs can range from approximately $0.68 to $8.20 CAD per square foot ($0.50 to $6.00 USD). Initial instillation costs can vary significantly based on the roof or walls' size, ease of roof access, and local market factors[99]. • Cool roofs and walls typically incur minimal additional costs over time in comparison to traditional building materials[99].
TEMPERATURE REDUCTION	• Roof: Urban ambient temperature reductions of 0.1°C to 0.33°C per 0.1 increase in roof's albedo[85]. • Wall: Average Internal air temperature (IAT) and mean radiant temperature (MRT) reductions inside multi-family residences with cool walls (albedo of 0.60) versus a conventional wall (albedo of 0.25) were 0.2 to 0.5°C[115].
CO-BENEFITS	• Energy savings (reduced demand of indoor cooling)[99] • Cool roof and wall materials have an extended lifespan compared to traditional building materials. This can contribute to lower material and labor costs over time[99]
KEY CONSIDERATIONS	• Cost-effective alternative to green roofs[85] • Low risk of heating penalty in winter months (Cities such as Vancouver and Montreal generally capture minimal (if any) warming potential from winter solar gains, due to reduced hours of sunlight and angle of sun's rays)[116,117]. • Cool roofs are bright with high glare, creating a harsh environment (not recommended to use as public space). For walls, glare can be mitigated by using "cool colour" pigments. • Weathering over time can be an issue, as roof reflectance may decrease over time due to dust, ultraviolet radiation, microbial growth, or biomass accumulation. • Consider the 3-year aged SRIs of selected materials[94].
EXPECTED LIFESPAN	• Roof: Approximately 10-20 years, depending on product used[111] • Wall: Comparable lifespan (Approx. 10-20 years)

4.4 Additional Resources

PDF *Cool Roof Rating Council: Rated Roof Products Directory*

PDF *Cool Roof Rating Council: Rated Wall Products Directory*

5. RECOMMENDATIONS

5.1 Policy Tools

UBC establishes policies for neighborhood development through its Neighbourhood Plans[118] and the Residential Environmental Assessment Program (REAP)[119]. Neighbourhood Plans are comprehensive frameworks that govern the planning and design of entire neighborhoods, addressing aspects such as land use, transportation, infrastructure, public spaces, and community amenities. In contrast, the Residential Environmental Assessment Program (REAP) focuses specifically on setting standards for individual buildings and their immediate site conditions. This distinction ensures that while broader community objectives are met at the neighborhood level, site-level development adheres to specific environmental and design standards. The recommendations that follow are categorized based on their relevance to neighborhood-level or site-level planning.

Residential Environmental Assessment Program (REAP) SITE-LEVEL

UBC's Residential Environmental Assessment Program (REAP) is a comprehensive, UBC-specific green building rating system that is mandated across all residential developments located in the Neighbourhood Housing Areas of the UBC Vancouver campus. REAP Version 3.3 (2023)[119] is similar in structure to other green building rating systems, such as LEED® developed by the U.S. Green Building Council (USGBC). A key feature of both LEED Version 5 (2024) and LEED Version 4.1 (2019) that has potential to be incorporated in future versions of REAP is the 'heat island reduction' and 'heat island mitigation with cool walls' credits.

LEED offers several rating systems, with Building Design and Construction (BD+C) and Operations and Maintenance (O+M) being particularly relevant to site-scale sustainability. Both systems feature a 'Sustainable Sites' (SS) credit category, which acknowledges that buildings directly influence — and are influenced by — their surrounding environment, thus playing a crucial role in sustainability[120]. Within the Sustainable Sites category, the 'Heat Island Reduction' credit[121] provides specific guidelines for using reflective roofing materials, green roofs, and vegetative cover to mitigate the urban heat island (UHI) effect on microclimates. The BD+C rating system focuses on new construction and major renovations, while O+M is designed for existing buildings looking to improve their operations and maintenance practices.

Heat Island Reduction Credit

For BD+C, the 'Heat Island Reduction' credit offers up to 2 points and can be earned through two options:

Option 1, which can award up to 2 points, allows for a combination of 'Non-Roof Measures' and 'Roof Measures.' 'Non-Roof Measures' include using reflective materials for surfaces such as sidewalks, parking lots, and other paved areas, with an initial solar reflectance (SR) of 0.28 to 0.33 or higher. 'Roof Measures' involve employing cool roofing materials with high initial solar reflectance index (SRI) values (greater than 0.82 for steep-sloped roofs) or installing vegetative (green) roofs. To qualify under Option 1, the combined adjusted area of these non-roof and roof measures must be equal to or greater than the total area of paved surfaces and roofs on the site. Projects can use a mix of both strategies to meet this requirement.

Option 2, which awards 1 point, involves placing a minimum of 75% of parking spaces under cover. The cover must meet specific criteria: (1) it should have a three-year aged Solar Reflectance Index (SRI) of at least 32 (if three-year aged values are unavailable, materials with an initial SRI of at least 39 at installation can be used), (2) it can be a vegetated roof, or (3) it can be covered by energy generation systems such as solar thermal collectors or photovoltaics.

For the O+M rating system, the 'Heat Island Reduction' credit awards 1 point. The requirements for existing buildings are similar to those outlined in BD+C, except Option 2 (Parking under Cover) is not included in the points calculation.

Heat Island Mitigation with Cool Walls Credit

The USGBC published the 'Heat Island Mitigation with Cool Walls' pilot credit in April 2021 under LEED Version 4.1 Building Design and Construction (BD+C) to test the integration of cool walls in the LEED certification program[122]. This credit awards one innovation point for the installation of a cool exterior wall product that meet the following requirements: at least 60% of a building's gross exterior wall area (including vertical fenestration) must be surfaced with a wall material that has a solar reflectance of at least 0.60 and thermal emittance of at least 0.75[122].

Integrating LEED's framework for UHI mitigation into UBC's green building rating system (REAP) offers significant potential for enhancing site-scale climate resiliency across campus neighbourhoods. This could be accomplished through including requirements for initial and aged solar reflectance (SR) and Solar Reflectance Index (SRI) values for roofing and external wall materials under REAP sections 'Materials and Resources' or 'Climate Adaptation', along with a similar calculation for assessing the combined contribution of all roof and non-roof strategies.

Further details on the requirements to fulfill LEED V4.1 'Heat Island Reduction' and 'Heat Island Mitigation with Cool Walls' credits for new and existing buildings can be found in Appendix A (pages 45-47).

Considerations for Green Roofs and Cool Roofs in Multifamily, High-Rise Neighbourhoods NEIGHBOURHOOD-LEVEL

In existing and future multifamily, high-rise neighborhoods on the UBC campus, the proportion of rooftop coverage relative to total surface area is likely to be lower than the 20-25% seen in typical single-family home neighborhoods[57], due to the vertical nature of high-rise buildings. High-rise developments reduce the amount of ground area used for housing purposes, allowing more space for green infrastructure, public amenities, or other forms of land use. This altered distribution of surfaces impacts the urban heat island (UHI) effect, as more area is occupied by streets, sidewalks, and parks, which interact differently with solar radiation and heat retention. Consequently, UHI mitigation strategies such as tree planting and the use of cool (high albedo) wall materials on high-rise buildings may offer greater cooling benefits to high-rise neighbourhoods, as these vertical structures could reflect heat more effectively and provide greater opportunities for shading.

While the direct benefits of cool (reflective) and green roofs on individual high-rises may be modest, their cumulative effect across an entire community of multifamily high-rise buildings can be substantial. Reducing rooftop temperatures contributes to cooler microclimates, decreasing heat buildup in surrounding public spaces and streets[124]. For example, a simulation of widespread cool roof adoption (high albedo, 0.8 SR) in Vancouver showed an average cooling effect of -1.6°C across the city[125].

These roof surface temperature reductions can have measurable cooling effects not only in buildings but also on the surrounding urban environment, decreasing overall heat absorption and producing cooler microclimates.

In Toronto, high-rise developers who achieve high performance in sustainability and emissions reduction can receive financial incentives offered through the Development Charge Refund Program[126]. These incentives encourage the inclusion of features such as reflective building materials, green roofs, and other sustainable design elements which adhere to the Toronto Green Standard Tier 2 requirements[127]. An example of this is 425 Wellington Street West, a 13 storey residential condominium which incorporates green roofs and a high-albedo terrace into its design to reduce the UHI effect and manage stormwater onsite[128].

425 Wellington Street West, Toronto, Ontario.

Additional consideration for mid and high-rise residential buildings is the benefit of green roofs and cool roofs for upper-floor units, which are more exposed to solar radiation and can experience significantly higher temperatures during heatwaves, even in well-insulated buildings[129]. Reflective roofs can reduce heat loads on upper floors, contribute to increased thermal comfort for residents, and lower indoor cooling energy demands[129,130]. Although the cooling benefit of green and cool roofs may be less pronounced overall within well-insulated buildings, these strategies will likely become increasing relevant as cooling needs rise with climate change, even in traditionally temperate climates such as the Metro Vancouver region.

Neighbourhood Plan NEIGHBOURHOOD-LEVEL

To strengthen policy for urban greening and forest management within the campus neighbourhoods, existing and future Neighbourhood Plans could incorporate the following:

Proportion of Native Species/Ecosystems: Neighbourhood Plans should establish clear guidelines for the proportion of native species in landscaped areas, aiming to enhance biodiversity and climate resilience. While UBC's Residential Environmental Assessment Program (REAP) includes biodiversity requirements for climate resilient plantings, these only apply at the building/ site-scale and do not extend into the surrounding neighbourhood. Policy could 1) set a minimum percentage of native and/or climate resilient species (e.g., 60-70%) to be planted within a neighbourhood to support local biodiversity and ecological health, 2) require species selection to be done in consultation with Musqueam to ensure Indigenous knowledge and values are reflected in the campus landscape[131].

Tree Regulations that Support Canopy Growth: Policies within UBC Neighbourhood Plans should prioritize the protection of large and medium-sized shade trees, particularly those at risk from development. This could involve updating tree replacement requirements, establishing minimum tree densities, and setting neighbourhood canopy cover targets informed by specific community needs. For trees that cannot be retained, replacement efforts should focus on maintaining the ecological benefits and canopy cover throughout the campus. Collectively, these measures would help to ensure UBC maintains and expands its urban forest as part of its climate action goals and commitment to a campus-wide net gain in tree canopy cover (>36%) by 2050 (UBC Land Use Plan 4.5.1.3)[6].

5.2 Policy Support

Planting Guidelines for Existing Neighbourhoods NEIGHBOURHOOD-LEVEL

A planting guidelines and best practices resource could be developed to improve coordination between the UNA, C+CP, and neighbourhood landscaping teams, ensuring that trees are planted, maintained, and protected effectively. This resource would support climate resiliency and UHI mitigation in neighbourhoods by guiding the selection of tree species for planting or replacement; emphasizing traits such as drought tolerance, shade provision, fast growth rates, and cultural significance to the Musqueam. This resource would support the long-term viability of trees and overall canopy growth in neighbourhood greenways, parks, and open spaces, and could draw inspiration from UBC's Technical Guidelines for the academic campus[41].

5.3 Programming & Community Involvement

Campus Urban Forestry Committee NEIGHBOURHOOD-LEVEL

As recommended by UBC students Lompart & Ikeda (2017) in their Social Ecological Economic Development Studies (SEEDS) report, UBC should establish a Campus Urban Forestry Committee to address two key challenges: underrepresentation of campus stakeholders in urban forest governance, and a lack of awareness about the benefits provided by the urban forest[131]. This committee could be led by the University Neighbourhood Association (UNA) with the intention of bringing together diverse stakeholders — such as Building Operations and Arborists, local First Nations groups, UBC Urban Forestry faculty, and residents of UBCV neighbourhoods — to encourage regular dialogue on tree health and management in the neighbourhoods, facilitate information exchange, and align UBC's urban greening strategies with community needs. The committee could work to promote shared responsibility of the campus landscapes, through:

- Workshops, tree walks, and informational campaigns to increase campus-wide knowledge of urban forestry and the wide range of benefits (i.e. ecosystem services) trees and urban greenspaces provide to our communities.
- Coordinate volunteer programs that engage students and community members in activities such as tree planting, watering, and monitoring (i.e. for signs of pests, disease and/or damage), with the goal of fostering community stewardship of neighbourhood trees and greenspaces.

Watering Street Trees NEIGHBOURHOOD-LEVEL

A street tree watering volunteer program, led by the University Neighbourhood Association (UNA), could be implemented within the UBCV neighbourhoods to help sustain trees during periods of drought and extreme heat. A template program structure is provided below:

1) **Volunteer Recruitment and Coordination:** The UNA would recruit volunteers from the campus neighbourhoods. Interested residents would sign up to participate in the program during the summer months when trees are most vulnerable to heat stress and drought.

2) **Training and Resources:** Volunteers would receive basic training on the proper techniques for watering trees, including the best times to water and the correct amounts. The UNA could provide educational resources to ensure volunteers understand the importance of tree watering and the specific needs of different tree species on campus.

3) **Distribution of Watering Bags:** Residents could apply to receive watering bags for the trees near their homes. These slow-release bags help ensure that water is delivered efficiently to the trees' root systems, reducing water waste and ensuring the trees are properly hydrated. The UNA would distribute these bags to participating residents and coordinate with them to track the trees being watered.

4) **Drought and Heat Alerts:** The program could include a notification system that alerts volunteers when a period of extreme heat or drought is forecasted. This would prompt volunteers to focus their efforts during critical times, maximizing the program's effectiveness.

5) **Watering Assignments:** The campus could be divided into zones, with volunteers assigned to specific areas, ensuring that all street trees receive adequate attention. This could include rotating schedules so that no individual volunteer is overburdened, and each tree gets sufficient watering throughout the drought or heatwave period.

Note: this program may be less suitable for UBC's MURB (Multi-Unit Residential Buildings) neighborhoods, if residents lack direct access to trees and water supplies. A joint effort involving strata or property management may be most effective for tree care in these areas.

Example programs within Metro Vancouver:

- Vancouver Park Board: Adopt a Tree program
- City of Surrey: Tree watering campaign
- City of North Vancouver: Tree Care & Health (tips for residents)

5.4 Equity & Accessibility

Improving Shade Distribution NEIGHBOURHOOD-LEVEL

Equity and accessibility must be central to UHI mitigation efforts at UBC, with a strong focus on prioritizing tree planting and canopy expansion in the hottest areas (Figure 1) and neighbourhoods with low tree density (i.e. trees per hectare, Figure 8). NCAP Ecology sub-action ES-1.4[37] emphasises that future targets for neighbourhood shade coverage should aim to improve equity and provide similar service levels throughout neighbourhood areas. This will be an important consideration for future residential developments on the campus, such as the planned Stadium Neighbourhood. As the area undergoes future densification, urban greening projects such as the planned ecological park for Stadium Neighbourhood[132] will serve as valuable community resources for counteracting localized UHI effects. Additionally, NCAP Transportation & Mobility sub-actions TM-5.1 and TM-5.2[37] recommend developing resilience and safety standards for transportation networks and exploring retrofits to improve them. This could involve adding shading and covered shelters along greenways and near public transit stops to improve comfort and accessibility, particularly for individuals with mobility challenges, to encourage the use of sustainable transportation modes on the campus.

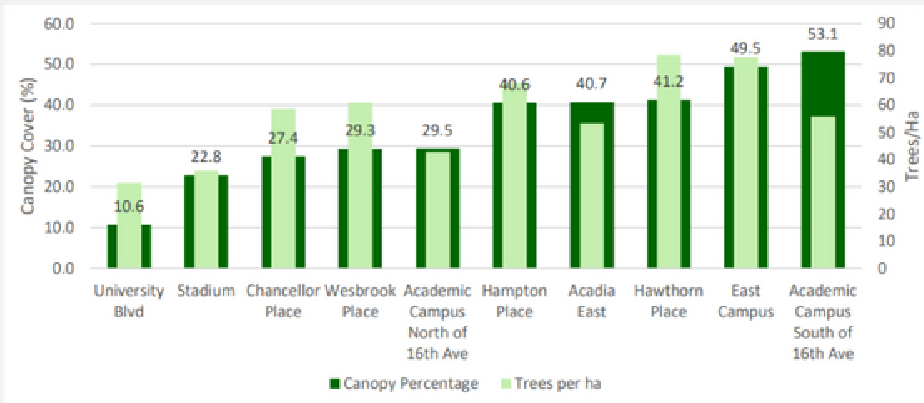


Figure 8. *Canopy cover (%) and trees per hectare for UBC neighbourhoods. (image source: Diamond Head Consulting, 2023)[7]*

At-risk groups during extreme heat events

While extreme heat affects everyone, certain groups present higher risks of developing heat-related illnesses[133] :

- Elderly people
- Infants and young children
- People with chronic illnesses (e.g. heart and breathing problems)
- People with disabilities (e.g. physical, sensory, mental, and/or cognitive)
- People on specific medications
- People living in isolation
- People unable to keep their living space cool
- Pregnant people
- Low-income populations
- Unhoused populations
- People who work in heat (indoors and outdoors)

5.5 Additional Resources

PDF *Natural Solutions Initiative Summary: Putting Nature Back into Nature-based Solutions (SFU Action on Climate Team, 2023)*

PDF *Metro Vancouver Tree Regulations Toolkit - Second Edition (2024)*

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A. APPENDIX: UHI MITIGATION CREDITS (LEED®)

Heat Island Reduction (LEED V4.1 O+M: Existing Buildings)

Credit
1 point

Requirements
Have in place strategies to minimize the project's overall contribution to heat island effects and that meet the following criterion:

$$\frac{\text{Area of Nonroof Measures}}{0.50} + \frac{\text{Area of High-Reflectance Roof}}{0.75} + \frac{\text{Area of Vegetated Roof}}{0.50} \geq \text{Total Site Paving Area} + \text{Total Roof Area}$$

Alternatively, an SRI and SR weighted average approach may be used to calculate compliance.

Use any combination of the following strategies.

Nonroof Measures

- Plants that provide shade over paving areas (including playgrounds) on the site. For newly installed plants, base shade area on 10-year canopy width at noon.
- Vegetated planters.
- Shade with structures covered by energy generation systems, such as solar thermal collectors, photovoltaics, and wind turbines.
- Shade with architectural devices or structures that have a three-year aged solar reflectance (SR) value of at least 0.28. If three-year aged value information is not available meet an initial SR of at least 0.33.
- Shade with vegetated structures.
- Paving materials with a three-year aged solar reflectance (SR) value of at least 0.28. If three-year aged value information is not available, meet an initial SR of at least 0.33.
- Open-grid pavement system (at least 50% unbound).

High-Reflectance Roof

Roofing materials with an SRI equal to or greater than the values in Table 1. Meet the three-year aged SRI value if available, otherwise, meet the initial SRI value.

Table 1. Minimum solar reflectance index value, by roof slope

	Slope	Initial SRI	Aged SRI
Low-sloped roof	≤ 2:12	0.82	0.64
Steep-sloped roof	> 2:12	0.39	0.32

Roof area that consists of functional, usable spaces (such as helipads, recreation courts, and similar amenity areas) may meet the requirements of nonroof measures. Applicable roof area excludes roof area covered by mechanical equipment, solar energy panels, skylights, and any other appurtenances.

Vegetated Roof

Vegetated roof. If newly installed, sufficient growing medium and plant material must be in place to provide full vegetative cover within 3-years.

Have in place a maintenance program that ensures all high-reflectance surfaces are cleaned at least annually to maintain good reflectance, all vegetation is maintained for plant health, and any vegetated structures or vegetated roofs are maintained for good structural condition.

PDF Online resource

Heat Island Reduction (LEED V4.1 BD+C New Construction)

Credit
1-2 points

Requirements
Choose one of the following options:

Option 1. Nonroof and Roof (2 points)

Meet the following criterion:

$$\frac{\text{Area of Nonroof Measures}}{0.50} + \frac{\text{Area of High-Reflectance Roof}}{0.75} + \frac{\text{Area of Vegetated Roof}}{0.50} \geq \text{Total Site Paving Area} + \text{Total Roof Area}$$

Alternatively, an SRI and SR weighted average approach may be used to calculate compliance.

Use any combination of the following strategies.

Nonroof Measures

- Use the existing plant material or install plants that provide shade over paving areas (including playgrounds) on the site within 10 years of planting. Install vegetated planters. Plants must be in place at the time of occupancy permit and cannot include artificial turf.
- Provide shade with structures covered by energy generation systems, such as solar thermal collectors, photovoltaics, and wind turbines.
- Provide shade with architectural devices or structures. If the device or structure is a roof, it shall have an aged *solar reflectance (SR)* value of at least 0.28 as measured in accordance with ANSI/CRRC S100. If the device or structure is not a roof, or if aged solar reflectance information is not available, it shall have at installation an initial SR of at least 0.33 as measured in accordance with ANSI/CRRC S100.
- Provide shade with vegetated structures.
- Use paving materials with an initial *solar reflectance (SR)* value of at least 0.33.
- Use an *open-grid pavement system* (at least 50% unbound).

High-Reflectance Roof
Use roofing materials that have an aged SRI equal to or greater than the values in Table 1. If aged SRI is not available, the roofing material shall have an initial SRI equal to or greater than the values in Table 1.

Table 1. Minimum solar reflectance index value, by roof slope

	Slope	Initial SRI	Aged SRI
Low-sloped roof	≤ 2:12	0.82	0.64
Steep-sloped roof	> 2:12	0.39	0.32

Roof area that consists of functional, usable spaces (such as helipads, recreation courts, and similar amenity areas) may meet the requirements of nonroof measures. Applicable roof area excludes roof area covered by mechanical equipment, solar energy panels, skylights, and any other appurtenances.

Vegetated Roof
Install a vegetated roof using native or adapted plant species.

OR

Option 2. Parking under Cover (1 point)
Place a minimum of 75% of *parking spaces under cover*. Any roof used to shade or cover parking must (1) have a three-year aged SRI of at least 32 (if three-year aged value information is not available, use materials with an initial SRI of at least 39 at installation), (2) be a vegetated roof, or (3) be covered by energy generation systems, such as solar thermal collectors, photovoltaics, and wind turbines.

The credit calculations must include all existing and new off-street parking spaces that are leased or owned by the project, including parking that is outside the project boundary but is used by the project. On-street parking in public rights-of-way is excluded from these calculations.

PDF Online resource

Heat Island Mitigation with Cool Walls (LEED V4.1 BD+C: New Construction)

Pilot Credit
1 point

Requirements

Surface at least 60% of the building's gross exterior wall area (including vertical fenestration) with a "cool-wall material". For the purposes of this pilot credit, a "cool-wall material" must be opaque to sunlight, exhibit an initial solar reflectance of at least 0.60, and exhibit an initial thermal emittance of at least 0.75. Vegetated walls may qualify as "cool walls" for the purposes of pilot credit compliance.

To avoid disproportionate placement of cool-wall materials on the building face that receives the least sun, no more than 25% of the building's total cool-wall area may be sited on the wall facing away from the equator; that is, on the north wall in the northern hemisphere, or on the south wall in the southern hemisphere.

Report for each cool-wall material its manufacturer, model, description, initial solar reflectance, initial thermal emittance, and wall area covered as shown in Table 1.

Table 1. Sample documentation of cool wall materials

Material #	Manufacturer	Model	Description	Initial solar reflectance[1] (must be ≥ 0.60)	Initial thermal emittance[2] (must be ≥ 0.75)	Wall area covered (m^2)
1	Acme	Vanilla White	White acrylic paint field applied to fiber-cement walls at a dry film thickness of ~100 µm	0.61	0.90	800
2	-	-	-	-	-	-

In addition, report gross wall and cool wall areas, as shown in Table 2.

(A)	Whole-building gross exterior wall area (m^2)	1,000
(B)	Whole-building cool-wall area (m^2)	800
(C)	Whole-building cool-wall area on equator-opposing wall (m^2)	200
(D)	Fraction of gross exterior wall area surfaced with cool-wall materials (D=B/A; must be ≥ 60%)	80%
(E)	Fraction of cool-wall area sited on equator-opposing wall (E=C/B; must be ≤ 25%)	25%

PDF [Online resource]

Note: The duration of the pilot credit is determined by the USGBC. After a trial period, the Council will decide whether to add the pilot credit to its permanent library. Typically, the trial period for pilot credits can last several months to a few years, depending on feedback and data collected during the evaluation phase.