Urban Heat Island Mitigation Strategy Toolkit

EC²

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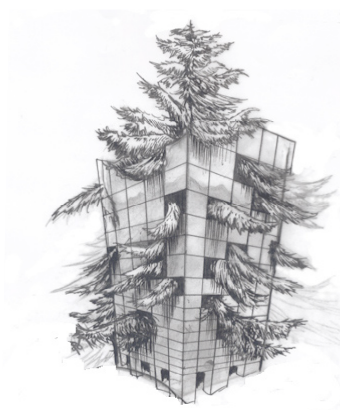
Created for the City of Toronto
by EC²



This toolkit has been created to provide a quick overview of different Urban Heat Island Mitigation Strategies. The information contained in this toolkit is intended for reference purposes only.

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Executive Summary

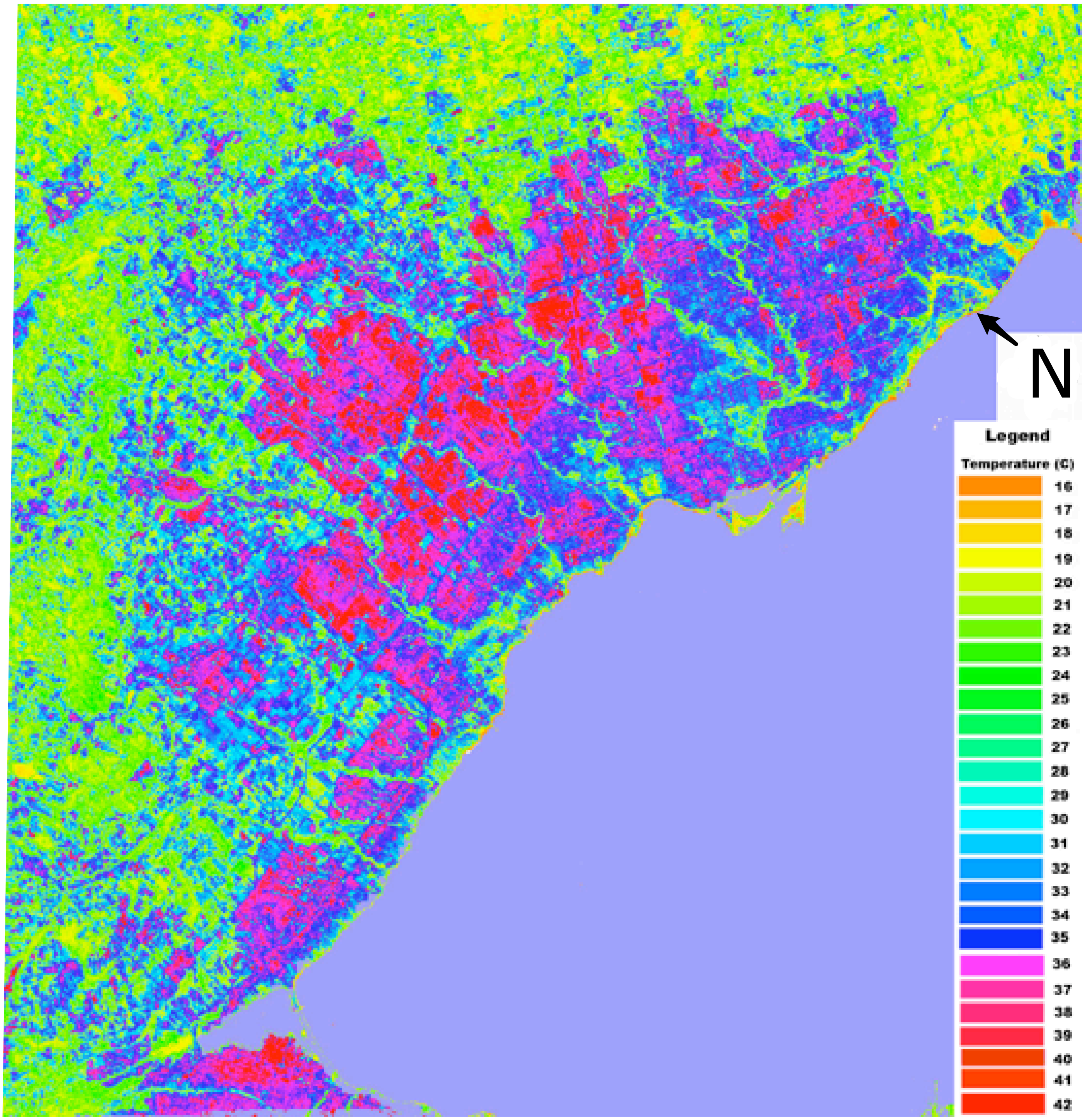
Climate change is currently a rising global issue. The Urban Heat Island (UHI) effect is directly related to climate change and the human activities that cause it. The UHI effect occurs when heat from solar radiation is absorbed by man made surfaces such as rooftops and pavement and then released into the air increasing the temperature of the area. The UHI effect is known to have detrimental impacts on public health, and is a direct cause of increased energy usage from the use of air conditioning and refrigeration systems. The UHI effect can be mitigated through the implementation of environmental strategies developed to decrease the amount of solar radiation absorbed by man made surfaces.

Numerous strategies have been created to mitigate the UHI effect in many of the world's largest cities, while new mitigation strategies are consistanly being developed. Cities now have a wide range of mitigation strategies available to them to help minimize their contribution to the global urban heat island effect.

The Urban Heat Island Mitigation Strategy Toolkit outlines a diverse set of mitigation strategies including cool pavement, cool roofs, green walls, urban forestry, shade, other technologies and public art and community engagement. In addition, the Toolkit defines key terms and concepts related to the UHI effect and available mitigation strategies. This toolkit provides policy and decision makers with a "one-stop" UHI reference guide to assist in making appropriate and informed decisions.

Toronto Heat Map

This satellite image of Toronto is a surface temperature map created from Landsat thermal data acquired on August 10th 2002. The high temperature was 26°C and the low was 16°C on that day. The pink and red colours represent the hottest areas in the city, while the greens, yellow and oranges represent the coolest temperatures.



Map Source: Natural Resources Canada. Historical temperature data acquired from Weather Underground.
Map is not to scale.

How to Use the Toolkit

The Urban Heat Island Mitigation Toolkit encompasses a broad range of mitigation tools and techniques designed to be used by the City of Toronto when developing or renovating public amenities. The toolkit examines mitigation strategies associated with traditional infrastructure redevelopment such as pavement, roofing, green walls, urban forestry and shade. In addition, innovative strategies are presented as tools to mitigate the UHI effect in a non-traditional way. These innovative strategies include: new technologies and public art & community engagement. Each mitigation strategy can be either used independently or in conjunction with other strategies. The symbols below represent different land uses where these mitigation strategies could be implemented. Symbols are displayed at the beginning of each section to indicate where specific strategies would be most applicable.

Sidewalks

Roads

Parking Lots

Commercial Uses

Industrial Uses

Residential Uses

Pavement

Pavement

Introduction

The urban heat island effect in the City of Toronto is intensified in and around developed areas within the City. Toronto's urban heat island effect is partially attributed to the fact that paved surfaces within the City have been constructed using low **albedo** and impervious materials. Paved surfaces within the City of Toronto are comprised of roads, sidewalks, parking lots and residential driveways. Through "cool paving" technologies, the urban heat island effect can be mitigated as such pavements can both reflect solar energy and retain moisture, cooling the City through evapotranspiration and by reducing heat absorption in general.[1] This "toolkit" seeks to inform readers about the various high albedo and pervious pavement technologies available that can be applied within the City of Toronto to help minimize the UHI effect.

Albedo

The level of solar reflectivity in a surface. The higher the albedo, the more reflective the surface.

Implementation of Paving Goals

On average, paved surfaces must be rehabilitated every five to ten years. Consequently, the long range cool paving goals for the City of Toronto include restoring conventional low albedo and impervious pavements with the more reflective and pervious surfaces discussed in this chapter. Roads, sidewalks, parking lots and other paved surfaces within the City of Toronto should be replaced during routine paving rehabilitation.

Fact:

The City of Toronto has 5,300 kilometres of roads and 7,100 kilometres of sidewalks.

www.toronto.ca

Benefits

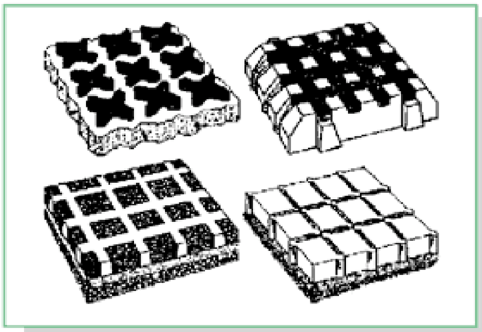
High albedo and permeable pavements have the ability to offset the problems associated with the UHI effect. Other advantages provided by pervious pavements include cooler air temperatures and increased stormwater management. Impervious and low albedo pavements not only store, but emit heat into the surrounding atmosphere. In spite of declining temperatures at nighttime, low albedo impervious pavements act as a "heat sink", allowing 'captured' solar energy to radiate and heat the air above. Pervious and high albedo pavements will help provide the City of Toronto with cooler air temperatures; as such pavements can reflect approximately 90% of direct sunlight.[2]

[1] HARC. *Cool Houston! A Plan for Cooling the Region.* The Woodlands, TX. 2004

[2] Town of Gilbert Planning Department. *Use of Cool Pavements to Reduce the Urban Heat Island Effect Cool Paving Brochure*. Gilbert Arizaon, 1996.

Cool Paving Technologies

Permeable Pavements



Examples of grid system permeable paving materials
Source: City of Chicago

There are several different types of permeable pavement technologies. These include, but are not limited to: (1) individual unit paving blocks or cobblestones; (2) plastic or fibrous grid systems filled with sand, gravel or vegetation; and (3) a combination of both concrete and asphalt.[3]

Grass Pavers

Grass pavers are made up of concrete cells or a strong plastic grid system consisting of large pores or openings. Within these large pores, either grass or herbs are planted. Aesthetically, grass pavers in use have the appearance of a large grassy field. Grass pavers are only appropriate for areas of low-traffic vehicle movement, such as fire access lanes, long term parking lots and private driveways.[4] Grass pavers help mitigate the UHI effect by absorbing direct solar radiation and by cooling the surrounding air through the process of evapotranspiration.

Gravel Pavers

Similar in appearance to grass pavers, the large openings in gravel pavers are filled with gravel, as opposed to plant materials. Gravel pavers, when in use, have the appearance of a gravel parking lot. Fortunately, the underlying grid system allows the gravel to remain intact preventing ruts and worn spots common to gravel parking lots. Gravel pavers help mitigate the UHI effect by allowing water and air to circulate throughout the 'paving' material, cooling the surface and allowing for less heat absorption than traditional concrete. Gravel pavers also have a higher reflectivity than traditional pavement.

Permeable Concrete

Permeable concrete is a combination of Portland cement, open-graded coarse aggregate and water. This combination allows for large pores to form in the hardened concrete and allows water and air flow with relative ease into the base layer below, while cooling the surface at the same time.[5]

[3] Capital Regional District Website. http://www.crd.bc.ca/watersheds/lid/permeable.htm, 2007.
[4] King County Department of Transportation. *Porous Concrete*.http://www.metrokc.gov/kcdot/roads/eng/lid/militaryS272/porousconcrete.cfmon, 2008.
[5] Capital Regional District, 2007.

High Albedo Cool Pavement

An overall reduction in the heating of hardscape is achieved through the capacity of cool pavement materials to exploit colouration, materials, porosity and other processes that worsen solar reflectivity. Cool pavements, furthermore, are able to increase cooling of hardscape by promoting air filtration and evaporation.

Cool pavements absorb a significantly lower proportion of the sun's heat. Lighter colour materials are extremely reflective when compared to their darker counterparts. One method that is often employed to rate the level of reflectivity in pavement is the Solar Reflectance Index (SRI). The SRI is a tool used to measure the ability of a hardscape to reflect solar heat. For example, traditional impervious surfaces tend to reflect only 5% of sunlight, resulting in an SRI value of 0. Light coloured surfaces, such as cool pavement, reflect approximately 90% of sunlight, resulting in an SRI value of 100. An SRI of 29 is the minimum requirement for Leadership in Energy and Environmental Design (LEED) certification.

Cool pavements are typically ideal in the construction of roads, driveways, parking lots, sidewalks, pedestrian ways or any other hardscape. However, they can also be used for large parking areas, terminals, airfields, urban roadways and other large paved areas. As a result of the decrease in absorption, retention and the emitting of the sun's energy, cool pavements are desirable in the reduction of the urban heat island effect. Cool pavements should work in conjunction with pervious pavements to gain the most benefit. Not only will cool pavements and pervious pavements work together to significantly reduce the urban heat island effect, they will also allow stormwater to absorb into the underlying reservoir base to act as a cooling agent.[7]

Toronto Green Development Standard

The TGDS suggests that 50% of all hardscape should be light coloured and should have a minimum reflectance of 0.3.

[6] Town of Gilbert Planning Department, 1996.

White Topping and Coatings

White Topping is a cement product used to cover existing low albedo pavement with a 10-20cm layer of light colored cement. White topping increases the albedo level of the surface reducing the amount of solar radiation absorbed by the surface. Chipseal coatings and light coloured emulsion sealcoats act in a similar fashion as white topping. They can be applied directly on top of asphalt roads and parking lots.[7]

Toronto Parking Lot Strategy

For more information on Toronto's Design Guidelines for Greening Parking Lots check out:

www.toronto.ca/planning/urbdesign/greening_parking_lots.htm

The City of Toronto's Design Guidelines for "Greening" Surface Parking Lots is a document meant to improve the quality and aesthetics of paved surfaces in Toronto. "Greening" the City's surface parking lots will mean a tremendous reduction in the Toronto's urban heat island. The Toronto Green Development Standards (GDS) has set a number of specific performance targets in relation to the contribution made by surface parking lots to the urban heat island. More specifically, such targets will include, but are not limited to, planting more trees, increasing stormwater management, providing more energy efficient fixtures and recycled materials and utilizing sustainable materials and technologies. Other targets set out by Toronto's GDS include increased pedestrian and cycling infrastructure and preserving and enhancing Toronto's urban forest.[8]

Mitigating Toronto's urban heat island will involve the replacement of current impervious pavements with more light-coloured materials, including concrete, white asphalt and light-coloured pavers.

Mitigation strategies set out in this document are consistent with those proposed in this "tool kit". Paving technologies will help to minimize local air temperatures, smog and energy demand caused by increased air conditioning.

[7] HARC. *Cool Houston! A Plan for Cooling the Region.* The Woodlands, TX. 2004
[8] City of Toronto. *Design Guidelines for Greening Parking Lots PDF,* November, 2007.

Roofing

Introduction

Building owners have available to them numerous cool roofing technologies as options in reducing personal utility fees and contribution to the urban heat island. Cool roofing is a broad term that is often used casually, without a thorough understanding of the several different types of cool roofing options available. This section will set a framework as a reference for decision makers in the employment of different cool roofing alternatives. The utilization of this toolkit will provide policy makers and decision makers with the necessary background information of the urban heat island effect and mitigation options on roofs in making appropriate decisions.

Toronto Green Development Standard

The TGDS suggests that a minimum 50% of a roofs surface should be covered by a green roof, the remainder of the roof should be covered by light coloured materials.

Implementation of Roofing Goals

The resulting urban "heat island" raises air conditioning bills and speeds up the formation of smog. Increasing the albedo (solar reflectivity) of roofs can limit or reverse an urban heat island effectively and inexpensively. When widely used in a community, cool roofing can decrease air temperature and cooling demands, which reduces the amount of smog in the air and benefits the entire community. The long-range cool roofing goal of this toolkit is the widespread implementation of diverse types of cool roofs in Toronto to reduce surrounding air temperatures and contribution to the Urban Heat Island (UHI) Effect.

Roofing in Toronto

There are approximately 5,000 hectares or 50 million squared metres of roofing in the City of Toronto that is available and appropriate to apply cool roofing technologies.[9] There are many opportunities across the land use spectrum (residential, commercial, industrial and institutional) in Toronto to implement cool roofing alternatives on new developments and existing structures.

[9] City of Toronto website, www.toronto.ca/greenroofs/pdf/fullreport103105.pdf

Cool Roofing Benefits

Cool roofs provide a number of potential immediate and long-term benefits. Cool roofs reflect heat back into the atmosphere that would otherwise be absorbed by conventional roof surfaces. A significant attribute of cool roofing is the role it plays in reducing the UHI Effect and resulting poorer air quality experienced by large cities such as Toronto.[10] The implementation of cool roofs have the potential to keep buildings cooler during summer months and ultimately reduce the need for air conditioning, which is a major contributor to CO_2 and other harmful emissions and rising temperatures resulting from the UHI.

Cool Roofing Technologies

Cool roofs consist of materials that reflect the sun's energy from roof surfaces, which reduces the energy peak demand by reflecting and releasing heat from the roof surface, and ultimately reduces the UHI effect. There are several different types of cool roofing technologies available to help mitigate Toronto's urban heat island including green roofs, metal roofs, white roofs and reflective roofs. It is critical to differentiate between the types of cool roofs and understand the benefits of employment and applicability of each in achieving a notable reduction in the UHI effect.

Green Roofs

A green roof is a roof of a building that is completely or partially covered with vegetation or soil over the existing surface. Green roofs can reduce higher temperatures produced from the UHI effect through shading and evapotranspiration. Water loss from vegetation through the process of evapotranspiration can create a cooling effect. Heat is absorbed as water evaporates from liquid into a vapor. Increased evapotranspiration resulting from green roofs can potentially reduce ambient air temperature and roof temperature as major contributors to the UHI effect.

[10] Kriner, S. *Cool Metal Roofing:An Emerging Hot Topic*. n.d. Cool Metal Roofing Coalition, p. 1-10.

The implementation of green roofs are ideal in residential areas and some business and commercial areas depending on the scale of the building. The implementation of a green roof on a large scale building may demand greater maintenance, time and money. Green roofs may be most suitable on buildings with a smaller roof surface. Green roof maintenance is likely not to be an issue on private homes and community facilities such as local schools and libraries as residents and communities are likely to maintain their roofs for personal aesthetic and health benefits

Example of an extensive green roof. Extensive green roofs require little maintenance and often feature grasses or other low maintenance plants.

Green roofs can be tailored according to the scale, type and use of the building. Green roofs can be extensive, intensive or a mixture of both. Extensive green roofs are the most common type that uses a shallow growing standard of five inches or less.

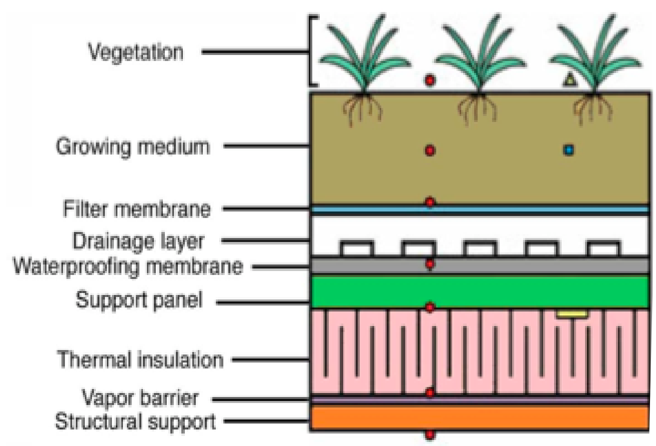
Extensive systems are intended to be low maintenance featuring relatively low-rise plants such as grasses or sedums, which are ideal on buildings and in areas that lack the time and monetary resources.[11]

Example of an intensive green roof. Intensive green roofs require more maintenance and often feature plants and shrubs requiring more attention than extensive green roofs.

Source: International Green Roof Association

Intensive green roofs use a wider variety of higher maintenance plants such as shrubs and trees that require a growing standard of six to twelve inches. Intensive green roofs have the capacity to support outdoor garden space for urban agriculture. This type of green roof requires greater maintenance, which is most applicable on buildings with a less roof surface.[12]

Figure 1: Anatomy of a Green Roof



Source: HARC. Cool Houston! 2004.

[11]Au, A. et al. *Environmental Benefits and Costs of Green Roof Technology for the City of Toronto and Ontario Centres of Excellence: Earth and Environmental Technologies*, 2005, p. 34.
[12] Au, A. et al. , p.17

Metal Roofs

Metal roofs are composed of extremely light and portable roofing products. They place fewer demands on the structure of a building, making metal roofing a great choice for retrofit projects. Metal roofing materials are durable and 100% recyclable, with most typically composed of a minimum of 25% recycled content, which inform lesser installation costs. This level of recycled content allows metal roofing to be recognized as "green" and recycled content products, which makes it a reliable contributor toward earning one LEED point.[13]

Flexibility and versatility in design is another great feature of metal roofs. Coatings with high reflective values such as steel sheeting increase energy efficiency as such materials enhance the thermal efficiency of buildings in high temperature areas. Metal roofs are also convenient and efficient as they can typically be installed over existing roofs (re-roofing).

As part of total system design, a cool metal roof can be an economical method to achieve greater energy efficiency. Metal roofing materials can achieve solar reflectance of over 70%.[14] Reflected solar energy allows the roof surface to remain cooler, which means less heat is transferred into the building, which reduces contribution to the UHI effect.

Metal roofs are likely to be optimal in industrial areas where there are scarce residential dwellings. In industrial districts where there a clusters of buildings used for industrial and manufacturing purposes, metal roofs are more ideal as living conditions and daily shopping and entertainment activities will not be disrupted in the event of precipitation. The implementation of metal roofs are ideal in industrial districts because safety is less of a concern as pedestrian and vehicular traffic in proximity to the area are limited, and during winter months, cascading snow is less of a hazard.

Metal roofs offer high reflectivity helping to mitigate the UHI effect.
Source: Cool Metal Roofing Coalition

[13] Cool Metal Roofing Coalition, 2007
[14] Cool Roof Rating Council. *For Architects, Roof Specifiers, Consultants and Contractors*. www.coolroofs.org

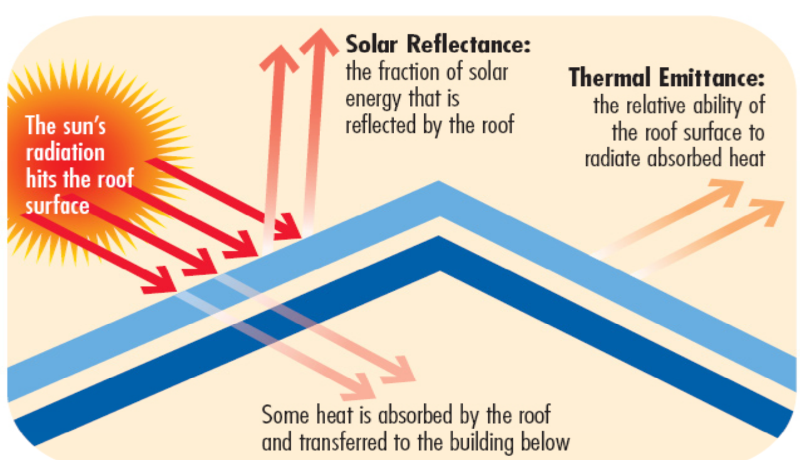
White/ Reflective Roofs

White roofs are roofing with a white reflective coating that contain transparent polymeric materials, such as acrylic, and white pigment to make them reflective. White or reflective roofs have high solar reflectance properties (SR) – the ability to reflect energy – and infrared emittance (IR) properties – the ability to release absorbed energy. White or light colored roofs have high SR and IR properties that can reflect up to 70% of the sun's energy. White roofs are effective in reducing air conditioning demand for buildings with air conditioner units and interior temperatures in buildings with no cooling units through high reflectance materials. Conventional roofing systems with conventional dark aggregate can be covered with white cement coating that can yield a higher reflectance of 70% to 80%.

The utilization of white or reflective roofing materials is beneficial in the mitigation of the UHI effect. The implementation of highly reflective materials on roofs helps to increase the albedo and emissivity of the surface by reflecting and releasing heat, producing a cooling effect. Reflective roofs can reduce cooling demand and peak load during the summer, along with greenhouse gas emissions associated with energy production. Their widespread use in urban areas can reduce air pollution and smog formation produced by the UHI effect.[15]

White/reflective roofs are ideal on buildings with larger roof surfaces such as shopping centres and arenas that cannot support other cool roofing technologies such as green roofs.

Figure 2: How cool roofs reflect and absorb solar radiation.



Source: Cool Roof Rating Council

[15] Liu, K. *Green, Reflective and Photovoltaic Roofs*. National Research Council of Canada, 2006.

Roofing

Green Walls

Introduction

Green walls are a vegetation system where plants are grown on a building façade or a vertical structure adjacent to the walls of a building. Green walls are also referred to as Living Walls, Green Façades or Vertical Vegetation. Green walls can be built on both interior and exterior building walls.[16]

Green wall exhibit in Montreal.
Source: ELT Inc.

There is a significant distinction between the purpose of interior and exterior green walls. Interior green walls function mainly as a means to improve air quality, aesthetics and human health related benefits. Exterior green walls serve a wider function, reducing the amount of solar radiation absorbed by the building's exterior walls and improving microclimate through shade and insulation. Standard vertical gardens and green walls are irrigated from the top of the system using gravity to propel the water flow downwards. Both green walls and vertical gardens are to be mounted on frames and grown adjacent to building walls. The main difference between the two is that green walls use soil as a substrate medium and vertical gardens use felt layers as the substrate.

Implementation of Green Wall Goals

The long range green wall goal is to encourage the use of external green walls especially for buildings that would like to use vegetation to mitigate the UHI effect, but cannot due to structural limitations on their roofs. Green walls can be encouraged in Toronto through many methods. One method is to provide city residents with information about green walls. The city can also encourage green walls through public engagement like community workshops and installations on public buildings. Finally, the city can encourage green walls by taking the lead and implementing green walls on Civic buildings.

Green Walls in Toronto

There are a small number of green walls in the City of Toronto. However, the majority of them are indoor walls and therefore not primarily functioning to reduce the UHI effect. Exterior green walls can be used in the City by using plants that can tolerate weather fluctuations

[16] International Green Roof Association. Types of Green Roofs. http://www.igra-world.com/green-roof-types/index.html. (n.d.)

and cold winter climates. Additionally, irrigation systems can be constructed for northern temperatures or external green walls can be limited to seasonal use.

Benefits of Green Walls

Green walls have many benefits including noise reduction, waterproofing surfaces, aesthetic value, improved air quality and providing a habitat for different wildlife species. Green walls also help to cool the air through evapo-transpiration. A study found that in Montreal green walls were able to decrease the surrounding air temperatures by approximately 40C. [17] In terms of decreasing the UHI affect, green walls can increase the insulation property, R, by up to 10%. Increased insulation improves heating and cooling of buildings and can decrease the air conditioning needs of a building.

Green wall on the exterior of a restaurant in New York City.
Source ELT Inc.

Green Wall Technology

Living walls consist of plants grown on either soil substrates or other fibrous substrates such as felt. The plants needs water and nutrients to survive. Nutrients are usually delivered through an irrigated system that functions by delivering nutrients to the bottom of the wall and re-circulating excess materials through a pipe system. Other systems available include containers with plants and individual water reserves. Air circulation in green walls is also important. Active systems are designed with a fan within the wall to help circulate air. Active systems are appropriate for offices where air quality is often the primary goal of installing a green wall. Passive systems function through basic air flow.

Research is being undertaken into designing green walls. Two topics at the forefront of green wall design research include using grey water as part of their irrigation systems and how green walls can be used as a storm water management tool.[18]

[17] Alexandri & Jones, *Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates*. 2008.
[18] Capital Regional District, http://www.crd.bc.ca/watersheds/lid/walls.htm. 2007.

Urban Forestry

Introduction

Trees and other at-grade vegetation play an integral role in the mitigation of the Urban Heat Island effect. Trees and at-grade vegetation have three distinct functions: 1) to provide shade to surrounding areas, cooling the surrounding hardscape by reducing the amount of direct solar radiation being absorbed into the pavement; 2) to absorb solar energy during photosynthesis; and 3) to cool the surrounding air temperature through the process of **evapotranspiration**. Evapotranspiration has been proven to cool surrounding air temperatures by 2-9°F, which would make a significant difference in Toronto's hot summers. Trees and at-grade vegetation have been proven to be an affordable, easily implemented urban heat island mitigation tool. Trees and other vegetation also improve air quality by removing pollutants such as carbon monoxide and dust particles from the air.

Evapotranspiration

The process of water absorption by vegetation through their root systems that is then released into the air.

Implementation of Urban Forestry Goals

The tree canopy in the City of Toronto currently covers 20% of the City. The City of Toronto Urban Forestry Department's long-range goal is to have 35% average tree canopy coverage in the City by 2020. The City of Toronto is working in partnership with **LEAF** in order to achieve this goal.[19]

LEAF

Local Enhancement and Appreciation of Forests

LEAF is a non-profit organization dedicated to the protection and improvement of Toronto's urban forest. LEAF is working in conjunction with the City of Toronto's Urban Forestry Department in order to achieve the 35% tree canopy goal.

www.leaftoronto.org

Trees in Toronto

The City of Toronto is home to over three million trees located on public land, along streets, in parks and lining ravines. There are millions more trees located on private property in the city.[20] There are hundreds of different types of tree species found in Toronto. The **Toronto Green Development Standard** highlights the need to use drought resistant tree and vegetation species during landscaping in order to reduce water consumption. Trees and at-grade vegetation planted near buildings can also have an effect on internal building temperature, in turn reducing the need for air conditioning, which is a major contributor to the UHI effect.

[19] Leaf Toronto Website. www.leaftoronto.org
[20] City of Toronto, Urban Forestry Dept. Website

Toronto Tree Canopy Grant Program

The City of Toronto, has provided funding for community tree planting organizations with a proven track record of successful tree planting on private property.

Opportunities for Trees in Toronto

The two biggest ways to achieve the 35% canopy coverage goal in Toronto are through planting and conservation. New trees need to be planted on both public and private property in the City. Working with community groups such as LEAF and the Toronto Parks and Trees Foundation, the City of Toronto can encourage private property owners to plant trees on their properties through education and community involvement. Through programs such as the **Toronto Tree Canopy Grant**, the City can continue to provide incentives to property owners who wish to plant trees on their properties. Public education about the urban forest is one of the best ways for the City to encourage urban forest conservation in the City. Working with the community to identify areas

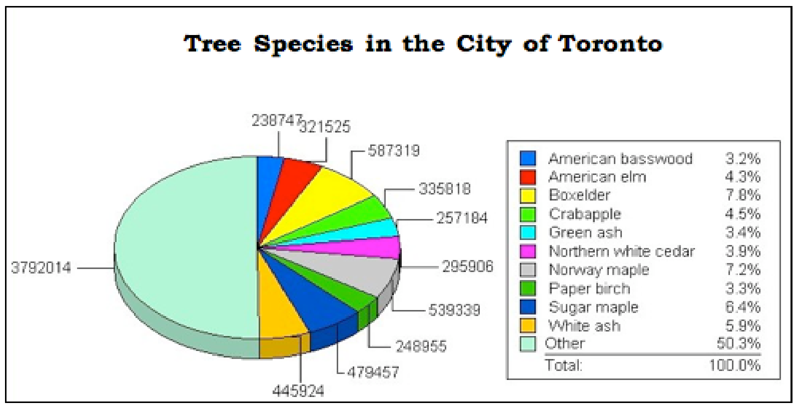


Figure 3: Chart showing the different tree species in Toronto. Source: UFore.org

Urban Forestry Challenges

Street trees in Toronto have a very short life span. Most street trees in Toronto only live to 10 years of age. Many street trees have a limited area in which to thrive, their root systems often sharing space with underground utilities. Pavement and other impervious surfaces around street trees can limit the amount of water that reaches the root system which can impede the growth of the tree.

It is also important to select the most suitable tree for each particular location. If street trees are being planted in an area with overhead wires or utility poles, the trees will need to be 'topped' frequently so they don't interfere with the power or telephone lines. It is best to select trees that do not exceed 25 ft. in height for these types of areas.[21]

[21]City of Seattle Urban Forest Coalition, 1998; http://www.ci.seattle.wa.us/td/treeplant.asp

Urban Forestry Technologies

It is important to consider the unique needs of trees in an urban setting when establishing an urban forestry UHI mitigation strategy. The following technologies are available to assist in the planting and maintenance of street trees, which can be used to mitigate the UHI effect when planted in areas with low albedo or impervious hardscape.

Soil Cell Technology

Soil cell technology refers to an urban forestry tool that is used to support hardscape and paving around the tree's root system. The soil cell acts as a 'cage' around the root system of the tree, protecting it from the weight of the pavement above and from the underground utilities below. Certain types of soil cells have the ability to conduct stormwater runoff from the paved surface down into the root system through a built-in irrigation system.

Structural Soil

Trees require loose permeable soils in order to thrive. The root systems of street trees need to be able to access rainwater or irrigation under the hardscape. Structural soil is a pavement substrate made up of a precise combination of crushed stone, clay loam, and a hydro-gel stabilizing agent. Structural soil can withstand the weight of the paved hardscape above but is still permeable enough to allow maximum root growth and water absorption. [22]

Tree Trenches

Planting trees in linear trenches allows for the interconnected soil that trees need for healthy root growth. Linear tree trenches also allow for the trees to be planted in a way as to form continuous canopies that will increase the shade quality. In order to provide the maximum benefits, street tree trenches should be at least six feet wide.[23]

Linear tree trenches provide an interconnected soil area to promote tree growth.
Source: University of Washington

[22] Basiuk, Nina. Cornell University Horticultural Deprtment. http://www.hort.cornell.edu/department/faculty/bassuk/uhi/pubs.html, 1997.
[23] University of Washington, http://online.caup.washington.edu/courses/larc433/UrbanTrees/Components.htm

Urban Forestry UHI Mitigation Strategies

The Toronto Green Development standard suggests that street trees and other urban vegetation should shade 30 percent of all paved surfaces in the City. The following mitigation strategies would help increase the size of the urban forest in the city that will help offset the UHI effect in the City of Toronto.

Tree Programs for Parking Areas

Parking lots are a leading contributor to the UHI effect. By introducing trees into parking areas, the amount of solar radiation reaching the hardscape will be reduced, helping to mitigate the UHI effect. Parking areas can incorporate trees into the overall design of the area, using them to denote and enhance pedestrian pathways or property limits.

Toronto Green Development Standard

The TGDS suggests that 30% of all hardscape should be covered by vegetation or shaded by street trees.

Alleyway Restoration

Another UHI mitigation strategy is to incorporate trees into the redesign and restoration of alleyways. By planting trees in alleyways, the tree canopy in residential areas will be increased helping to decrease the amount of solar radiation absorbed by the surrounding hardscape.

Public Education and Conservation

By educating the public about the importance of street trees, the City can help to create environmental stewardship around the urban forest. Increasing public awareness about urban forestry and its relation to the UHI effect can lead to increased ownership and conservation of trees on both public and private property. That increased awareness can be used to educate the public about the UHI effect in its entirety. The City might explore partnerships with existing Urban Forestry conservation groups such as LEAF to help create community based programs.

Shade

Introduction

One of the main contributions to the UHI effect arises from the sun's radiation. Man-made surfaces such as paved roads and rooftops can absorb a large amount of solar radiation. These surfaces then re-radiate it as heat which can contribute to the UHI effect. This section describes a mitigation strategy to reduce the UHI effect.

Implementation of Shade Goals

The goal is to encourage the wide spread use of constructed shade in private and public areas that are most vulnerable to direct sun. Constructed shade should be used as an interim solution in concert with planting shade trees; constructed shade can be primary solution where vegetation would not be a viable shade option.

For more information on constructed shade in Toronto, check out the Toronto Shade Policy Committee at:

www.toronto.ca/health/resources/tcpc

Benefits

Constructed shade is beneficial for many reasons. For one, it reduces the amount of solar radiation absorbed by surfaces such as pavement. Another benefit is that constructed shade provides immediate reduction in the UHI effect whereas a tree can take two to three years to mature enough to provide adequate shading. Finally, constructed shade is versatile and can be installed quickly and can also be designed to double as public art.

Shade in Toronto

There are several strategic opportunities to use constructed shade available; the City itself has identified many of these. A good opportunity to introduce constructed shade to a site is during the planning and developing of new City facilities such as parks or public spaces. Another opportunity is during refurbishing of existing City-owned and operated facilities and sites. In particular, implementation should focus on parking lots, pathways and schools which often have large asphalt surfaces. Not only does constructed shade have the potential to reduce the UHI affect in these areas, the high visibility of many types of constructed shade would create interest in this type of approach.

Constructed Shade Technologies

Constructed shade consists of a wide range of different products. Within the category of fabricated shade, are many subcategories. These categories are based on the lifespan of the fabric, portability or permanency of the device and the ability of the shading device to adapt to change with the angle of the sun. These types of constructed shade consist of permanent shade systems, demountable systems and shade sails.

Permanent Shade

Permanent shade is built to be durable and to last in one location for 10 or more years. Permanent shade is generally made of more durable materials such as glass, metal or wood, as less durable materials such as canvas and other types of fabric are not strong enough to withstand harsh winter weather. Permanent shade is most suitable for use in parking lots and between buildings.

Demountable Shade

This type of shade system is a less permanent option than permanent shade. Types of demountable shade include tents, canvasses and marquees. The major benefit of this type of shade is its flexibility. It can be used during the entire summer or just on hot days or during special events. Demountable shade is best suited to cover playgrounds, basketball courts, patios, and to provide sidewalk cover on public streets.

Shade sails are ideal for covering play areas.
Source: Evergreen Toronto

Shade Sails

Shade sails are very versatile in terms of price and size. They are traditionally made of fabrics such as silk or cotton or canvas and can be stretched between buildings, utility poles or trees. They can be mounted on a temporary basis in a wide variety of locations. Shade sails are best suited for providing shade in areas such as large courtyards, play grounds, street festivals and park spaces. Shade sails can also be incorporated in to UHI mitigating public art.[24]

[24]Sunsmart Australia. www.sunsmart.com.au/downloads/local_government/shade_for_everyone.pdf

New Technologies

Introduction

While the basis of this toolkit is to examine the urban heat island effect in the Toronto context, it is important to note that mitigating the UHI effect goes hand in hand with being energy efficient. Heat loss in the process of energy production and consumption is a major contribution to the UHI effect. As a result, it is worthwhile to take a closer look at new technological advancement that will assist in turning waste heat into usable energy. The following section examines current research on energy efficient technologies, and the potential effectiveness in mitigating the UHI effect by incorporating each technology to improve HVAC systems. The primary goal is to encourage the City to take a leading role in the development of new energy technology. There are three types of heat capture technology that will be explored in this section.

Thermoelectric Technology

Thermoelectric technology is the process where temperature differences are converted to electric voltage and vice versa. It is a similar concept to cogeneration technology where waste heat is harnessed for alternative uses. Rather than using the heat as thermal energy for heating purposes, thermoelectric technology turns the heat into usable electricity.[25] Once this technology is improved, it has the potential to mitigate the UHI effect by utilizing waste heat that was formerly released into the atmosphere.

Natural Resources Canada is currently undertaking a project to assess the integration of micro CHP systems for residential use.

More Information can be obtained from:

www.nrcan.gc.ca/es/etb/cetc/cetc01/TandI/resid_e.htm

Combined Heat and Power Systems

Combined heat and power systems, also known as Cogeneration, use a single fuel type to produce both electricity and useful heat. Due to technological advancement, CHP systems are made in compact sizes that each produce 1 to 4 KwH for residential use.[26] Micro-CHP systems consist of two major components, an internal combustion engine and a furnace. The CHP equipment utilizes a range of fuels to drive a generator to produce electricity. During the process, heat is created, and pumped to the furnace. Rather than having the heat pumped out as waste heat, it is captured and utilized as a useful heat source reducing CO_2 emissions which contribute to the UHI effect.

[25] Robert F Service. *Temperature Rises for Devices That Turn Heat Into Electricity*. Science, 306(5697), 806-7. 2004.
[26] Prachi Patel Predd. *A Power Plant for the Home*. IEEE Spectrum, 44(4), 14-15, 2007.

Waste Heat Transfer

An alternative technological solution for decreasing the UHI effect is to harness waste heat and convert it to usable energy. A project to turn waste heat into usable energy is currently being undertaken in the Stockholm Central Train Station in Sweden.[27] The project is expected to capture the waste body heat generated from the 250,000 people that pass through the station each day and use it to heat adjacent buildings using hot water heating. The captured heat would be used to warm up water, and the heated water would then be pumped through pipes to adjacent buildings for heating purposes. The project manager expects this innovation to reduce 20% of the buildings heating costs. [28]

HVAC
Heating Ventalating and Air Conditioning.

Implementation of New Technologies

Residential **HVAC** units have an average lifespan of 10 to 15 years. It is important to provide homeowners with a range of energy efficient products to invest in that will assist the City in reducing peak power demand. Energy efficient HVAC units can help mitigate the UHI effect by reducing the amount of waste heat generated during the cooling process.

Micro CHP system for residential use.
Source: CNET.com

[27]National Post. *Swedish Firm Taps Body Heat for Eco-Friendly Office Building*. January 11, 2008.
[26] Toronto Star. *Hot Swedish Bodies May Help Heat Office Building.* January 3, 2008.

Public Art & Community Engagement

Introduction

Incorporating UHI mitigation strategies into public art and community engagement projects has enormous educational and environmental potential for the City of Toronto. Implementing UHI mitigation strategies in the form of public art and community engagement projects allows the City to showcase their environmental initiatives in a creative and educational way, and in turn bringing them to the public. Public art allows for the beautification of public spaces and can help enhance the sense of place in neighborhods across the city. Working with different community groups such as schools, youth groups, community centres and seniors groups, provides the City with an excellent opportunity to create awareness about the UHI effect and to foster environmental stewardship in urban areas.

Implementation of Public Art & Community Engagement Goals

The long range public art goal would be to implement an environmental assessment process when commissioning and developing new public art in the City. Incorporating environmental themes, messages and strategies in the pieces would allow the City of Toronto to use art as a medium for implementing environmental change. Community engagement should be encouraged as a way for the City of Toronto to connect with diverse groups across the City in order to spread an environmental message. By encouraging community engagement in the UHI process, the City can both educate residents about the UHI effect, and can promote community sustainability by involving residents in the action.

Benefits

Both public art and community engagement are relatively inexpensive ways to mitigate the UHI effect. The City already has an extensive public art collection and would only have to incorporate an environmental aspect into its existing policy protocol. Creating partnerships with existing community and local environmental stewardship groups would be an excellent way for the City to promote community engagement.

Public Art in Toronto

Art and landscape installation along the Queens Quay on Toronto's harbourfront in August 2006 provides an excellent example of how public art could have been used to mitigate the UHI effect. The installation was the winning submission to an international waterfront design competition. The installation included closing two traffic lanes on Queens Quay and replacing them with two square kilometres of lawn and 12,000 red geraniums. A bicycle lane was added along the edge of the installation, allowing the Martin Goodman trail to run uninterrupted along the waterfront. [27]

This public art installation acted as a UHI mitigation strategy in the following ways:

• First, the transformation of low-albedo pavement surface areas into vegetative surface areas help mitigate the UHI effect by decreasing the amount of impervious/low reflective surface in the area and replacing it with a cooler, energy absorbing surface that will cool the air through evapotranspiration.

• Second, the elimination of 2 lanes of automobile traffic aids in the mitigation of the UHI effect by reducing automobile exhaust emissions and waste heat from automobiles, both of which are contributing factors to the UHI effect.

• Third, the addition of an uninterrupted, dedicated bicycle lane increases the amount of non-motorized traffic (bikes, rollerblades, skateboards etc.) in the area, and encourages residents and visitors to travel to and through the area using non-polluting methods.

A public art installation such as this provides an excellent opportunity for the City of Toronto to educate the public about the UHI effect and some of the different strategies that the City is implementing in order to mitigate it. By involving the public, and tying the education element into an event such as this, it makes the information accessible and interesting to a wide variety of people.

Cyclists riding on the bike path created along Queens Quay during the art and landscape installation in August 2006.
Source: West8 Urban Design and Landscape Architecture.

[27] DuToit Allsopp Hillier Website. http://www.dtah.com
[28] West8 Landscape Architecture Website. http://www.west8.nl/

Opportunities for Community Engagement in Toronto

Mobile organic garden plots on an abandoned lot in West Oakland, CA
Source: Steinman Studios

Susan Leibovitz Steinman, an environmental and public artist from California, has created mobile organic garden plots, consisting of portable sculptural raised garden beds designed to grow organic herbs and vegetables in an urban setting. These beds are built from clean, recycled, local materials and are installed in inner city communities by neighborhood volunteers and local youth groups. The volunteers are then able to participate in eco-friendly gardening programs that result in the harvesting of fresh organic food for the community. This project is traditionally run in economically and socially disadvantaged areas that generally do not have access to fresh locally grown organic produce.[29] The City of Toronto could initiate a similar type of project in the City to help mitigate the UHI effect.

This community engagement project acted as a UHI mitigation strategy in the following ways:

- First, the portable garden beds were placed on low albedo paved surfaces (such as parking lots and paved courtyards of housing developments) or on vacant or underused properties (such as brownfield sites or city owned lots awaiting development). These beds would act as a temporary vegetative cover, therefore reducing the UHI effect in the inner city through evapotranspiration and reducing the amount of low albedo hardscape.

- Second, this project would allow the City to incorporate UHI education into the gardening lesson plan by explaining the benefits of 'green cover' in an area as well as explaining to the participants how local food production/consumption helps reduce the UHI effect by maximizing green space in the inner city and by minimizing the environmental costs of food transportation vehicle emissions.

By creating community engagement opportunities in Toronto, the City could promote environmental education and advocacy across the entire UHI mitigation spectrum. Groups could be engaged in programs involving street tree protection, constructed shading of parks and playgrounds, urban agriculture and public art creation.

[29] Steinman Studio Website. http://www.steinmanstudio.com

Conclusion

Toronto is a national leader in environmental innovation and climate change awareness. By adding these UHI mitigation strategies to the climate change agenda, the City of Toronto would help increase awareness about the UHI effect and its impact on the environment. Once implemented, these strategies could be shared with other municipalities allowing Toronto to be an environmental leader in UHI awareness.

Funding

The mitigation strategies identified in this toolkit should be implemented as the existing infrastructure is replaced. Money allocated to capital infrastructure renewal budget would be used to fund these strategies. Public/private partnerships should also be explored as a way to finance these projects.

Next Steps

The creation of an inter-departmental UHI working group would help to facilitate dialogue and aid in sharing ideas surrounding the implementation of different UHI mitigation strategies. Members could be included from the departments of City Planning, Urban Forestry, Transportation Services, Facilities and Real Estate, Shade Policy, Public Health and the Toronto Environmental Office.

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