Time to Tackle Toronto's Warming

Climate change adaptation options to deal with heat in Toronto

The Clean Air Partnership

Principal Investigator:
Eva Ligeti, LLM, Executive Director, Clean Air Partnership

Researchers and Authors:
Ireen Wieditz, MES, Researcher, Clean Air Partnership
Jennifer Penney, ScD, Director of Research, Clean Air Partnership

Advisory Committee:
Ian Burton, Scientist Emeritus, Environment Canada
Monica Campbell, Environmental Protection Office, Toronto Public Health
Priscilla Cranley, (formerly) Office of the City Manager, City of Toronto
Martin Herzog, Office of the City Manager, City of Toronto
Christopher Morgan, Toronto Environment Office

Heat Working Committee:
Carol Mee, Toronto Public Health
Marco Vittiglio, Toronto Public Health
Liora Zion-Burton, Toronto Planning
Deyan Skoric, Toronto Facilities and Real Estate
Amy Leung, Toronto Environment Office
Brad Bass, University of Toronto/ Environment Canada
Kate Bassil, University of Toronto/ Toronto Public Health
Keir Brownstone, Toronto Community Housing Corporation

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For more information, contact:
Clean Air Partnership
75 Elizabeth Street
Toronto, Ontario M5G 1P4
Canada
416-392-6672
www.cleanairpartnership.org

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About the Clean Air Partnership

The Clean Air Partnership (CAP) is a registered charity that works in partnership to promote and coordinate actions to improve local air quality and reduce greenhouse gases for healthy communities. Our applied research on municipal policies strives to broaden and improve access to public policy debate on air pollution and climate change issues. Our social marketing programs focus on energy conservation activities that motivate individuals, government, schools, utilities, businesses and communities to take action to clean the air.

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FOREWORD

This report is part of a four part project, *Adapting to Climate Change in Toronto* undertaken by the Clean Air Partnership (CAP) in collaboration with the City of Toronto. CAP is working with the City to incorporate adaptation to climate change into program planning and implementation to reduce the vulnerability of the city and its inhabitants from the impacts of climate change. This project includes:

Phase 1: Scan of Climate Change Impacts on the City of Toronto
This scan was completed in May 2006. It outlines the expected impacts on various sectors within Toronto, and highlights changes that are already underway. The report is available at **www.cleanairpartnership.org/climate_change.php**.

Phase 2: Cities Preparing for Climate Change
This report examines what other leading cities are doing to tackle expected climate change impacts, and identifies strategies that appear promising for Toronto and other cities.

Phase 3: Decision-Makers Workshops
Two workshops were held, one in November 2005 and the other in June 2006, with Toronto decision-makers to identify areas where the City could develop and implement adaptation strategies.

Phase 4: Adaptation Strategies
A menu of adaptation options for two areas: a) the Urban Forest, and b) Heat (and its impacts on health and energy use) have been developed in collaboration with City of Toronto staff and other interested stakeholders. This report outlines adaptation options for dealing with heat in Toronto.

EXECUTIVE SUMMARY

Toronto, like other urban regions, has been steadily getting warmer. The continuous replacement of vegetated surfaces with asphalt and concrete, coupled with waste heat emissions have created what is now commonly called the urban heat island effect. Temperatures in cities will continue to rise as the recent surge of infill development creates more hard surfaces and increases human activity in the urban core.

Climate change will exacerbate the urban heat island effect and is expected to bring about more prolonged and intense heat waves, and periods of drought. This report examines the impacts of rising temperatures on human health and electricity use, and recommends a series of actions to help cities such as Toronto cope with the effects.

Impacts of Rising Temperatures: Extreme heat poses a serious risk to public health, particularly to vulnerable individuals such as the elderly, those with pre-existing health conditions, and those without access to air conditioning. High temperatures also lead to greater demand for cooling, which places greater strain on an already stressed electrical system. This can lead to brownouts and blackouts, with potentially serious consequences for the economy and for vulnerable populations.

Adapting to Heat: Toronto and many other urban centres will need to develop and implement adaptation strategies to reduce vulnerability to rising temperatures. A number of measures to cope with heat waves are already in place, but these will need to be expanded and new measures undertaken to deal with the additional stress brought on by climate change.

Adaptation Actions to Reduce the Urban Heat Island Effect: Adaptation measures may be categorized as preventive or reactive. Preventive measures serve to reduce overall ambient air temperatures. Such measures include: expanding and maintaining healthy green spaces in the city; planting more trees and vegetation (particularly in deficient areas); accelerating the use of green and high-albedo roofs and green walls. Other important measures include using cool and/or porous paving, reducing hard surfaces, reducing waste heat emissions and altering urban design and form.

Adaptation Actions to Reduce Heat-Related Illness: Adapting to heat will also include measures to reduce heat-related illness and death when rising temperatures cannot be avoided. Toronto already has a well-developed heat response plan involving public education and outreach, heat watch monitoring, the issuing of advisories, and an emergency response plan that includes opening cooling centres for vulnerable populations. Current efforts to identify hotspots and vulnerable populations will become more important as extreme heat episodes become more common and severe under climate change. More resources will need to be allocated to heat response systems to ensure that they remain effective.

Adaptation Actions to Reduce Energy Demand for Cooling: Higher ambient air temperatures will increase thermal discomfort in buildings, leading to increased energy demand for cooling. Reducing heat gain in buildings is not only an important adaptation option, it also mitigates against climate change by reducing the need for electrical energy for air conditioning, and therefore decreasing greenhouse gas emissions. Heat gain can be minimized by planting shade trees along the south and west side of buildings, and by constructing and retrofitting buildings with "green" elements such as green roofs, living walls, cool roofs, and hybrid cooling systems that utilize natural ventilation and efficient mechanical systems. New buildings should be designed and oriented so as to limit solar heat gain in summer.

Energy Conservation for Adaptation: New approaches to building design will have a limited impact on reducing heat gain in existing building stock, which turns over slowly. In built-up urban areas, other energy conservation measures are important for alleviating the impacts of increased electricity demand for cooling. The Toronto Energy Plan contemplates a variety of peak-saving mechanisms, renewable energy systems, district heating and cooling, and other measures which will reduce the stress on energy generation and distribution systems and decrease the potential for brownouts and blackouts.

Reducing the Impact of Blackouts: Creating more distributed energy systems such as local combined heat and power plants, solar power and micro wind installations will reduce the impacts of future blackouts. The City will also require emergency response plans for at-risk individuals in shelters, old-age homes and palliative care as well as business continuity planning to ensure the least disruption possible from power failures.

Conclusions: The City will need to consider a combination of both proactive and reactive measures to adapt to the increasing incidence of extreme heat events. Proactive measures that reduce the intensity of extreme heat will lower the costs and resource requirements of more reactive measures, such as emergency response plans. Both sets of measures are needed to safeguard the wellbeing of Toronto residents, and the City will need to consider an integrated strategy that enhances their co-benefits.

1. INTRODUCTION

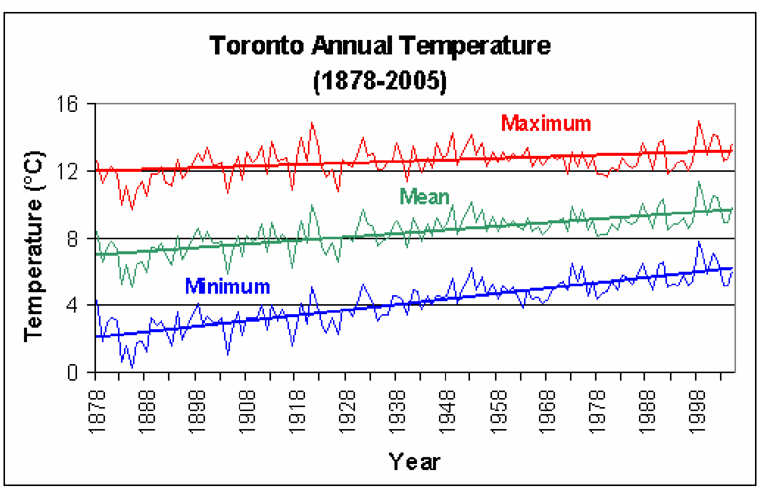
This report outlines a menu of adaptation options to cope with the impacts of heat (and its effects on health and energy use) in the City of Toronto. Toronto, like many urban areas, experiences higher average temperatures than the surrounding countryside. Climate change is expected to intensify the urban heat island effect and contribute to more frequent and intense heat waves.

A working committee comprised of City of Toronto staff, university researchers, and health advocates advised the authors in the preparation of this report. Committee members provided expertise on the current state of initiatives to deal with heat in Toronto, presented ongoing research, and suggested additional measures to cope with extreme heat events in the city.

Drawing on suggestions from the committee, as well as a previous report, *Scan of Climate Change Impacts on the City of Toronto* (Clean Air Partnership 2006) and adaptation planning lessons from other cities, this report presents a series of adaptation options to reduce the impacts of heat on health and energy use.

2. CLIMATE CHANGE AND HEAT

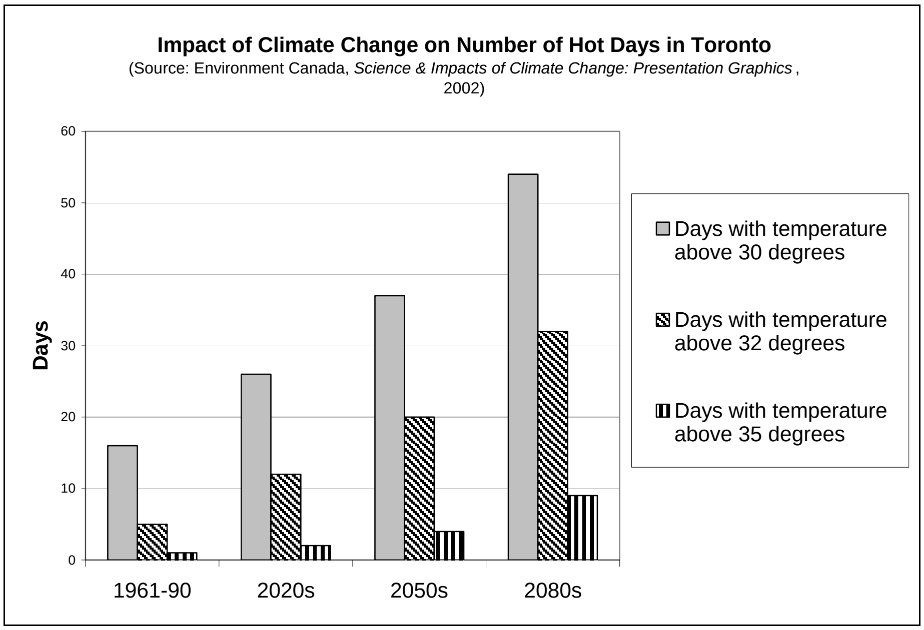
Toronto, like many urban centres, already experiences warmer average temperatures than the surrounding countryside. Since the late 1800s, Toronto's average temperature has increased 2.7°C, due in part to the urban heat island effect (Environment Canada 2006). Heat islands develop in cities as naturally vegetated surfaces are replaced with asphalt, concrete, rooftops and other manufactured materials that absorb the sun's energy, and release it as heat. The graph below illustrates how maximum, mean and minimum temperatures in Toronto increased from 1878 to 2005.



MAXIMUM, MEAN AND MINIMUM TEMPERATURES IN TORONTO HAVE RISEN SINCE THE LATE 1800s.

SOURCE: Environment Canada 2006

Climate change, in combination with the urban heat island, is expected to exacerbate Toronto's warming trend and bring about more intense and prolonged heat waves. The summer of 2005, for instance, witnessed a record 37 hot days, compared to an average of 13 hot days in the years from 1971 to 2000. A record number of 48 smog days also occurred in 2005. Under climate change, this situation is expected to become the norm. Projections for Toronto summers are shown in the graph below.



THE NUMBER OF HOT DAYS IN TORONTO WILL CONTINUE TO RISE UNDER CLIMATE CHANGE.

SOURCE: Environment Canada, Science & Impacts of Climate Change 2002

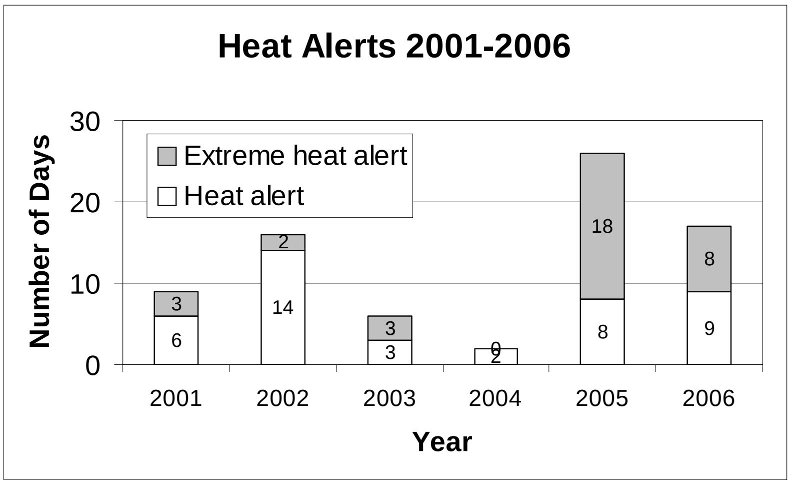
3. IMPACT OF HEAT ON HEALTH

Heat waves can pose a great risk to public health, particularly to vulnerable populations such as the elderly, individuals with pre-existing health conditions, and those living without air conditioning and/or in crowded conditions. A heat wave that hit Chicago in 1995 killed an estimated 550 to 800 people (Klinenberg 2002), and in Europe more than 35,000 people died from a heat wave that struck in 2003 (De Bono *et al*. 2004). In Toronto during the summer of 2005, six deaths occurred in rooming houses and shelters (McKeown 2006), where a lack of air conditioning and fire codes that required doors to remain shut raised the air temperature inside these buildings to intolerable levels (Smyer 2006).

Exposure to heat can also cause dehydration, heatstroke, heat cramps, heat exhaustion and fainting in healthy individuals (Carty et al. 2004), and can worsen pre-existing health conditions such as cardiovascular illness, diabetes, and respiratory disease

(Clarke 2005). Hot summer temperatures have also been linked to increased violence and homicides (Anderson 2001).

In response to the growing number of hot days and to prevent heat-related illness and death, the City of Toronto issues "heat" and "extreme heat" alerts. The graph below illustrates the total number and type of heat alerts in Toronto since 2001. Notice the high number of total and "extreme" alerts in 2005 – some of which lasted several days.



A RECORD NUMBER OF HEAT ALERTS WERE ISSUED BY THE CITYOF TORONTO IN 2005.

SOURCE: Toronto Public Health 2007

Under climate change the number of hot days, associated heat alerts, and heat-related illness and mortality are expected to rise. Toronto Public Health and Environment Canada determined that heat-related mortality in Toronto averaged 120 deaths per year over the last five decades (Pengelly *et al,* in press). From one year to the next there can be a two- to four-fold difference in heat-related mortality, reflecting the variability of hot weather. Mortality is greatest in July and August when the greatest number of multi-day heat episodes occur. The longer the heat wave, the greater the daily risk for mortality. A study released by Toronto Public Health in 2005 indicated that heat-related mortality is projected to double by 2050 and triple by 2080.

Hotter summer temperatures and prolonged heat waves can also worsen air quality. In hot weather, more people turn to air conditioning for relief, which in turn increases energy consumption. Because peak energy on hot days is supplied by coal-fired generating plants downwind of Toronto, this in turn leads to increased air pollution. Higher temperatures also speed up the series of chemical reactions among air pollutants that produce smog (Nugent 2004).

In Toronto, 1,700 people are estimated to die prematurely each year from acute and chronic exposure to polluted air and 6,000 more are hospitalized (Toronto Public Health

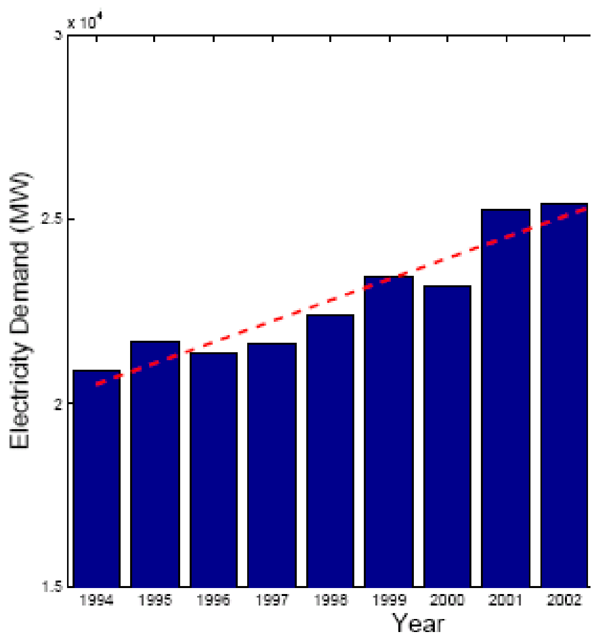
2004). Air pollution has been linked to numerous medical conditions such as asthma and bronchitis (Gauderman 2005), heart attacks and strokes (Clarke 2005), and an increased risk of death (Goodman 2005). Research has also demonstrated that socially isolated seniors, children, newborns and people with pre-existing health conditions, are particularly vulnerable (McKeown 2006).

With the onset of hotter summers under climate change, air pollution-related deaths in Toronto are projected to increase by 20% by 2050, and 25% by 2080 (from 822 to 1070 per year in 2080).

4. IMPACT OF HEAT ON ELECTRICTY USE

Heat waves significantly impact the amount of electricity used. As ambient air temperatures climb, and thermal discomfort in buildings increases, more people turn to air conditioning for relief. Air conditioners discharge hot air outside, adding more heat to ambient air, and furthering the need for cooling. The resultant vicious cycle places the electrical system under great strain, and can lead to neighbourhood and city-wide blackouts or brownouts. This was demonstrated by the transboundary blackout in August 2003, which shut down Toronto's operations for nearly 3 days, where hot weather and high electricity demand were partially to blame (US-Canada Power System Outage Task Force 2004).

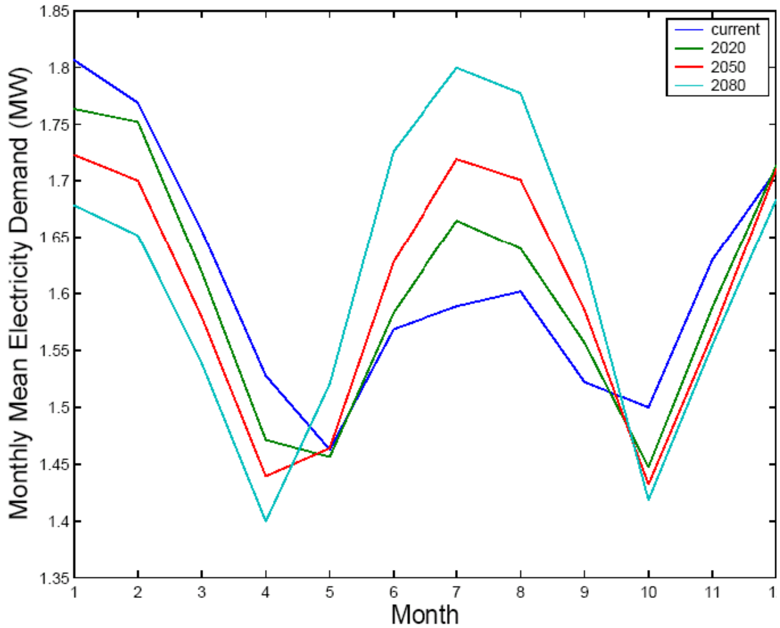
As climate change progresses, hotter summer temperatures will increase the demand for electricity accordingly. This trend is already evident, as illustrated in the graph below. Peak hourly summer demand in Ontario has risen steadily from 1994 through 2002 (Liu 2003).



MAXIMUM HOURLY PEAK DEMAND IN ONTARIO DUING THE SUMMERS 1994-2002.

SOURCE: Liu 2003

Rising annual average temperatures under climate change are expected to shift the yearly peak for electricity demand from winter to summer months (Liu 2003). Energy demand for cooling will increase, while demand for heating is expected to decline. The graph below, illustrates the projected change in electricity demand in Ontario over the next 75 years.



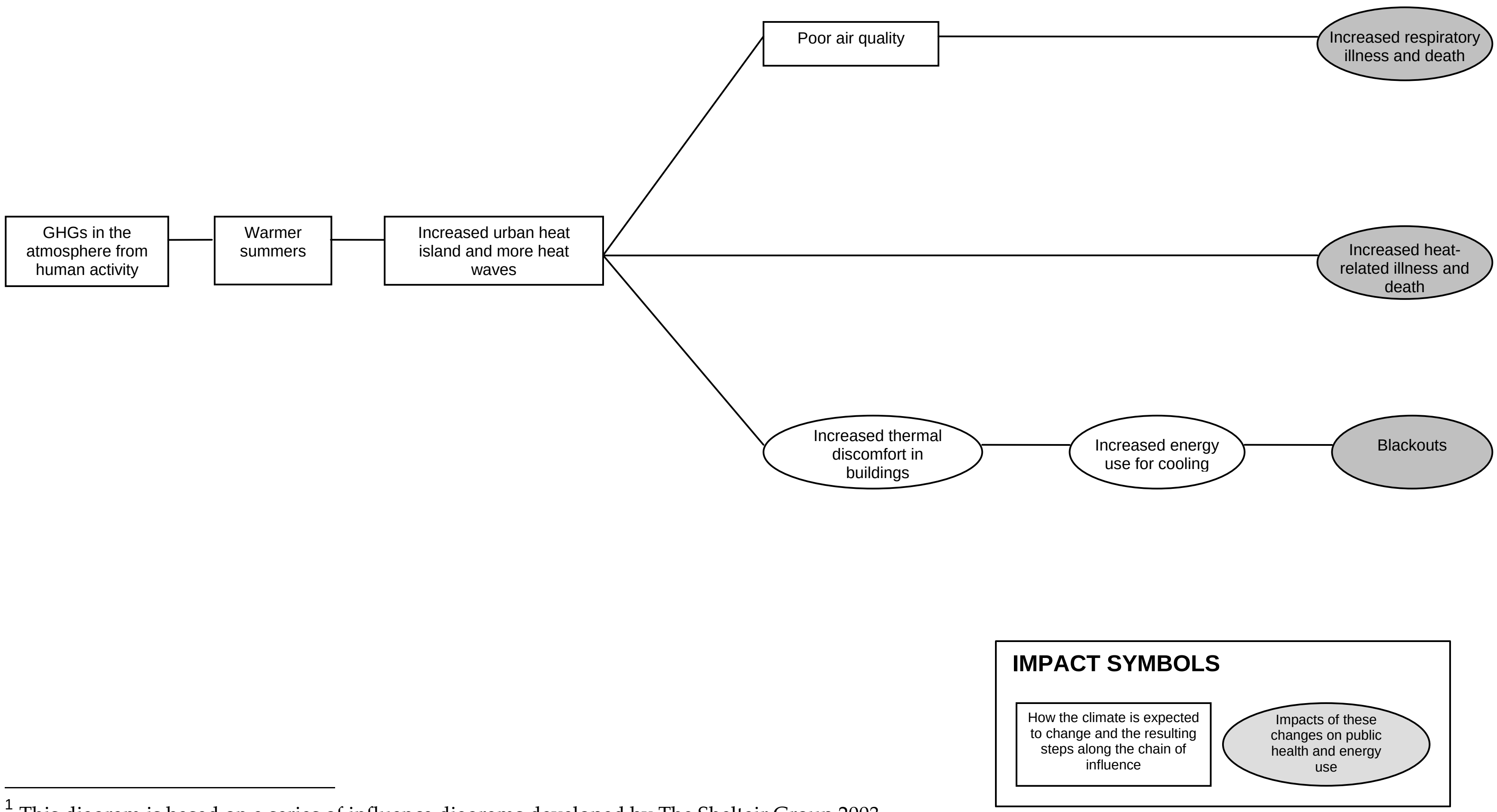
ELECTRICITY DEMAND IN ONTARIO IS PROJECTED TO INCREASE DURING SUMMER MONTHS AND DECREASE DURING WINTER MONTHS.

SOURCE: Liu 2003

Unless steps are taken to cool ambient air temperatures during summer months and/or reduce electricity demand for cooling, electrical system failure and blackouts may become increasingly common. While this inconveniences the city and its inhabitants at large, vulnerable populations such the elderly, young mothers and children in shelters, and individuals in palliative care units are the ones at greatest risk of heat-related illness or death (Smyer 2006).

The impacts of heat on public health and electricity use are summarized in Figure 1 on the next page. This diagram illustrates the various steps by which heat will impact health and electricity use, and as such is meant to be read from left to right. The rectangular boxes represent changes in the climate and in local weather as a result of greenhouse gas emissions. The ovals represent the impacts of these changes. While the diagram is a somewhat simplified overview of the process of climate change impacts (it ignores minor variables and forces) it does set the stage for identifying and prioritizing key impacts and points of intervention to reduce the adverse effects of heat on public health and energy use.

FIGURE 1. SUMMARY OF LIKELY HEAT IMPACTS UNDER CLIMATE CHANGE IN THE CITY OF TORONTO[1].



[1] This diagram is based on a series of influence diagrams developed by The Sheltair Group 2003.

5. ADAPTING TO HEAT

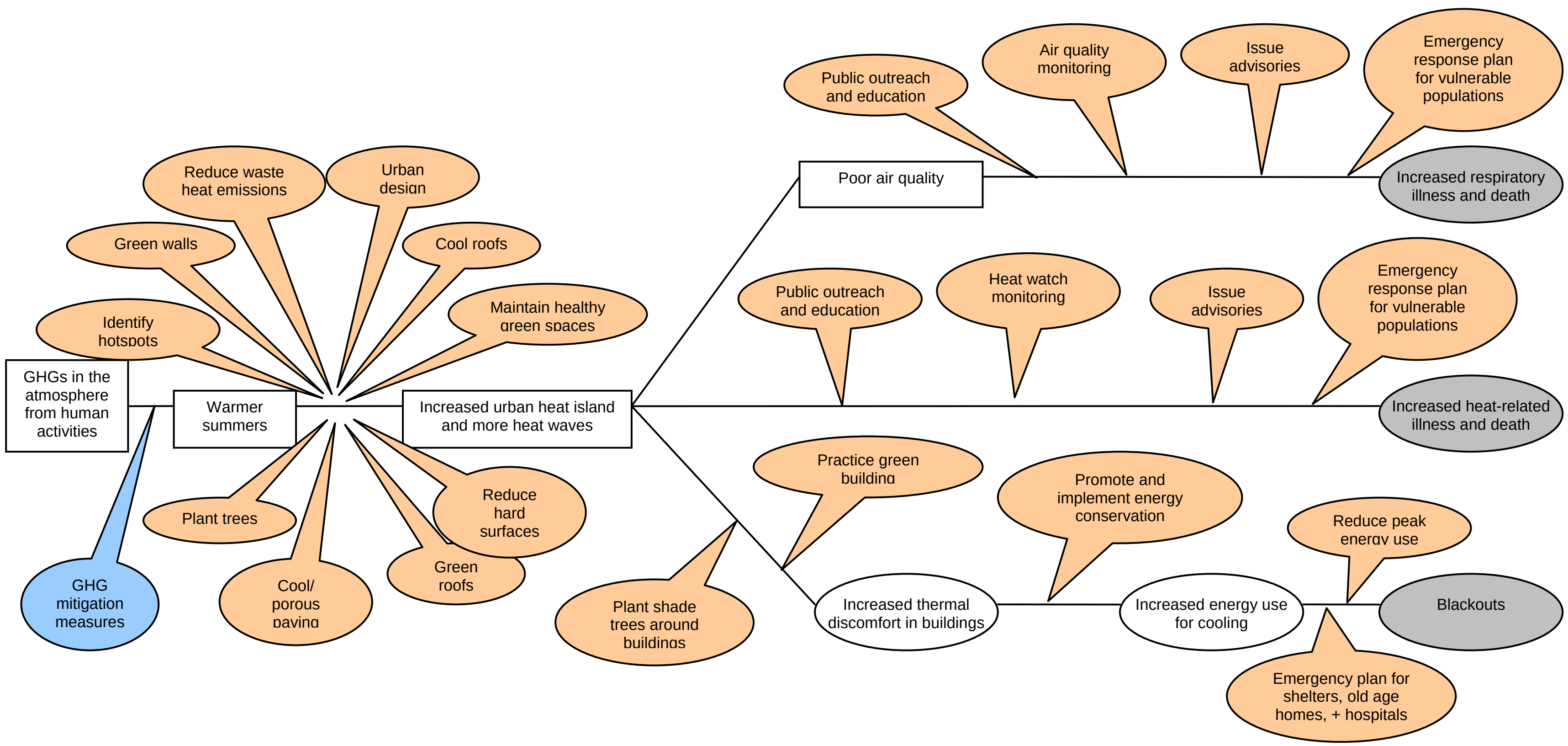
Adapting to climate change means taking measures to reduce the vulnerability of a system or sector to the expected impacts of climate change. Where the impacts of heat on public health and electricity use are concerned, such measures include planting more trees and vegetation, making use of green or high-albedo roofs (to reduce ambient air temperatures), and practicing energy conservation (to reduce electricity demand), among others.

In many cases, adaptation measures are already under consideration or underway, but need to be ramped up to deal with the additional stress from climate change. For instance, a key adaptation strategy to deal with the impacts of hotter summers on public health is to issue heat alerts and open cooling centres. While these steps are already being taken by Toronto Public Health, the scope of the effort will likely need to be extended to deal with more frequent or prolonged heat waves.

Figure 2 illustrates a series of adaptation options to both reduce and cope with heat, superimposed on the impacts diagram in Figure 1. These adaptation options reduce or eliminate the effect of the impact to the *right* of the point of intervention. This highlights the importance of focusing adaptation efforts as high up the influence chain as possible – the higher up the chain, the more preventive the strategy. Certain adaptation efforts higher up the chain also have the added benefit of mitigating climate change by reducing atmospheric levels of greenhouse gases.

Because greenhouse gases have already increased in the atmosphere by about a third since pre-industrial times, the climate will continue to change for the foreseeable future. This presents a challenge for municipal decision-makers, who will have to assess how to allocate limited resources amongst preventative (e.g. planting more greenery) and reactive measures (e.g. hot weather response plans). While reducing greenhouse gas emissions must remain high priority, programs that prepare us to adjust to climate change are becoming increasingly vital.

FIGURE 2. ADAPTATION STRATEGIES TO DEAL WITH HEAT IN THE CITY OF TORONTO.



6. CLIMATE CHANGE ADAPTATION OPTIONS

A broad overview of adaptation options to deal with heat and its impacts on public health and energy use is provided below. It is important to acknowledge that a number of these measures are already underway. The authors have highlighted these to the best of our knowledge. Where applicable, examples of what other communities are doing have been included.

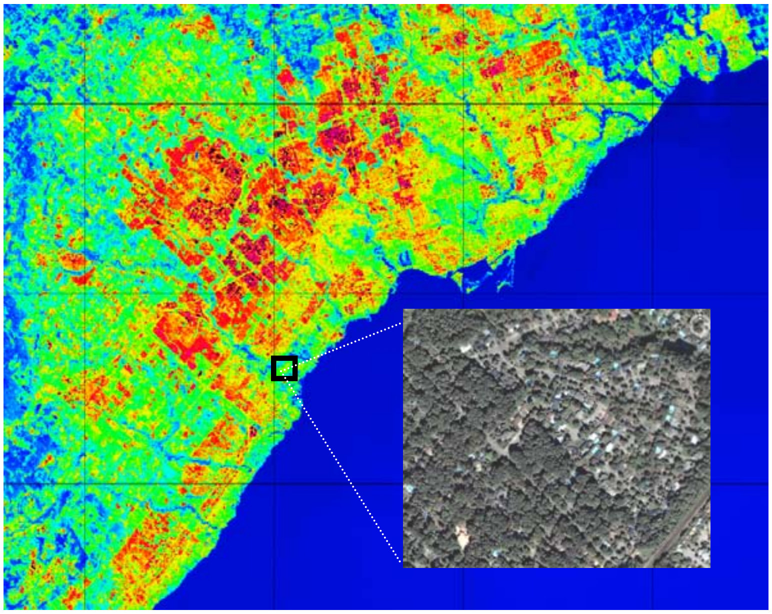
6.1 REDUCING THE IMPACT OF HEAT WAVES AND THE URBAN HEAT ISLAND EFFECT

Under climate change, the urban heat island effect will become more pronounced and heat waves more frequent and severe. The urban heat island is a city-wide phenomenon that is affected by the features of individual buildings, neighbourhoods and broader urban form. Measures to reduce heat island effects can be developed at all these levels and over different timescales (Greater London Authority 2006). Changing urban form in a city as developed as Toronto, particularly in the inner core, is slow. For this reason, the majority of the adaptation options presented below focus on the building and neighbourhood scales as these can be more realistically implemented within the existing urban fabric. New developments, however, present an opportunity to design with heat island reduction measures in mind.

6.1.1 IDENTIFY HOTSPOTS

Thermal mapping is employed to identify the hottest areas within a city and can inform the selection of priority areas for urban heat island mitigation strategies. Typically, light industrial areas are among the hottest locations, with parks and tree-lined residential areas the coolest. Thermal mapping has been conducted for various US cities, such as Houston and Sacramento as part of the US Environmental Protection Agency's Heat Island Initiative (US Environmental Protection Agency 2007).

In Canada, Natural Resources Canada's Earth Sciences Sector (NRCan-ESS) has undertaken a project titled "Identifying Urban Heat Island Vulnerabilities and Adaptation Options in the Greater Toronto Area". The aim of this study is to identify hot and cool spots in the GTA, document thermal variations over the last 25 years as a result of land use changes, determine the contribution of impervious surfaces and urban forests to thermal regimes and develop a database of thermal responses of typical urban surfaces. The data, expected to be available in 2007, will better inform Toronto decision-makers by allowing them to incorporate scientific knowledge into decision-making on climate change and heat island adaptation strategies.



PRELIMINARY RESULTS FROM THE NRCAN-ESS URBAN HEAT ISLAND STUDY. TREE LINED RESIDENTIAL AREAS ARE AMONG THE "COOLER" LOCATIONS IN TORONTO.

SOURCE: Zhang *et al.* 2007

6.1.2 MAINTAIN HEALTHY GREEN SPACES

Maintaining healthy vegetation and green spaces is essential to mitigate against the urban heat island. A recent study that compared various urban heat island mitigation strategies, determined that expanding the urban tree canopy and vegetation is the most effective way to cool a city (Rosenzweig *et al.* 2006). However, for vegetation to be able to cool its environment, it must be well-maintained and healthy, and reach a certain level of maturity. In the case of trees for instance, research has demonstrated that the cooling benefits of urban trees increases exponentially with increased leaf area of the urban forest (Kenney 2000). The greater the canopy, the more it can cool the urban environment through evapotranspiration and shade, and the more it can sequester carbon dioxide (Kenney 2005). In Toronto, the Parks & Recreation Department practices integrated plant health care to increase the health and survival rate of vegetation (Smith 2006) and Urban Forestry Services maintains over 500,000 City-owned street trees and 2.5 million trees in parks, ravines and natural areas (City of Toronto 2007a).

6.1.3 PLANT MORE TREES/ VEGETATION, PARTICULARLY IN DEFICIENT AREAS

Planting more trees and vegetation can be a very effective way to reduce ambient air temperatures, cool individual buildings, and cool entire neighbourhoods. Street trees have in fact been shown to have the largest cooling potential per unit area when compared to green roofs, cools roofs, and light-coloured surfaces (Rosenzweig *et al.* 2006). Trees provide shade and are also effective modifiers of the local climate through the process of evapotranspiration. Air temperatures have been shown to be 1.9˚C cooler around trees than over impervious surfaces (Rosenzweig *et al.* 2006). The Toronto Green

Development Standard recommends that 30% of surface parking areas and other hard surfaces be shaded by trees in order to reduce the heat build-up in these areas (City of Toronto 2006). Trees also provide many additional benefits such as stormwater management, removal of air pollutants, streetscape aesthetics, and improved quality of life. Trees that emit higher levels of biogenic volatile organic compounds (BVOCs) (such as poplars, oaks and plane trees) should be planted more sparingly as they can contribute to smog episodes (Greater London Authority 2006).

Greenery should also be enhanced in areas where the public does not have access to quality green space. Lack of vegetation can lead to local hotspots where thermal discomfort and the subsequent demand for cooling will be higher. Such areas often correspond with low-income neighbourhoods where people are less likely to afford air conditioning and will be at greater risk of heat-related illness or death. A study in New Jersey found that inner-city neighbourhoods were at the greatest risk of urban heat island impacts (Solecki *et al.* 2005). Greening these areas should be a priority.

In the UK the Greater London Authority is mapping areas deficient of green space, with the intent to enhance them in the near future (Greater London Authority 2006). In Toronto, planting trees in parking lots where there is often very little shading would greatly reduce near surface air temperatures, and help the City achieve its goal of doubling the tree canopy.

6.1.4 MAKE USE OF COOL/ HIGH-ALBEDO ROOFS

On hot sunny days, dark roofs can easily reach temperatures of 50-60˚C and consequently store significant amounts of thermal energy that is later released into the atmosphere as heat. High roof temperatures increase thermal discomfort in buildings (particularly on top floors), increase demand for cooling, and accelerate the deterioration of roof material. Cool or high-albedo roofs, on the other hand, reflect a significant amount of solar radiance back into the atmosphere, and as a result do not heat up to the same extent as dark roofs. In addition to decreasing the demand for air conditioning, cool roofs have the added benefit of extending the life span of roof materials. However, regular maintenance of cool roofs is necessary to prevent the accumulation of dirt and pollution as this lowers the effectiveness of the roof's reflectivity (Greater London Authority 2006).

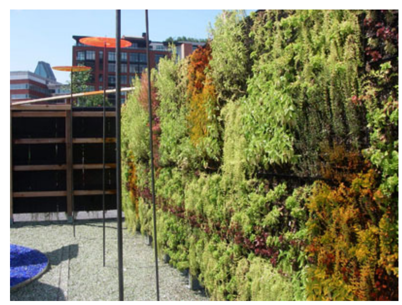
Cool roofs are used in various US cities, where they have been shown to be a cost-effective alternative to air conditioning. In California, the *Cool Savings Program* provided rebates of 15-25 cents per square foot to building owners who replaced or resurfaced their existing "hot roofs" with cool roofing material as part of a state-wide effort to reduce peak summer electricity demand (London Climate Change Partnership 2006).

6.1.5 PLANT GREEN ROOFS

Like cool roofs, green roofs can significantly decrease heat gain in buildings and cool their immediate environs. Implemented on a neighbourhood or city-wide scale, green roofs can lower ambient air temperatures over a large area. An Environment Canada study determined that greening 6% of available roof space in Toronto would reduce summer temperatures by 1˚C to 2˚C (Bass *et al.* 2003). Unlike cool roofs, green roofs have many additional benefits in urban environments, such as stormwater management, noise reduction, provision of insulation in winter months, and provision of habitat for increased biodiversity (Dunnett and Kingsbury 2004). Green roofs have been used and subsidized for many years in cities throughout Europe and are growing in popularity throughout Canada and the United States (Lawlor *et al.* 2006). To encourage green roof development, the City of Toronto is running a short-term green roof incentive pilot program where successful applicants receive $10 per square foot up to a maximum of $20,000. Sixteen (16) applicants were recently awarded funding for their green roof projects (City of Toronto 2007b).

6.1.6 PLANT GREEN WALLS

Green walls, also known as façade greening, are another effective strategy with multiple benefits to reduce the urban heat island effect. Green walls shade the sides of buildings, preventing building material from absorbing solar energy and releasing it later as heat. Façade greening also has the added benefit of reducing heat gain in buildings (this will be discussed further in section 6.5.2), providing insulation during winter months (in the case of evergreens), filtering air pollutants, and protecting the surface of the building from weather damage such as heavy rainfall, ultra-violet light, and hail (Dunnett and Kingsbury 2004).



LIVING WALLS PROVIDE ARE AN EXCELLENT WAY TO SHADE BUILDINGS.

SOURCE: www.elt.org

Clinging vines are a simpler alternative to shading buildings than more complex living walls. Virginia creeper and Boston ivy, both deciduous vines, are suitable for the south and west facing walls of buildings as they drop their leaves in the winter. English ivy, an evergreen vine, is particularly useful for north facing walls and can reduce heat loss from a building in the winter (Starbuck 2007).

6.1.7 MAKE USE OF COOL/ POROUS PAVING AND REDUCE HARD SURFACES

Many of Toronto's streets and parking lots are typified by dark, impermeable surfaces. Light-coloured or cool paving can be an effective way to reduce the amount of solar radiation stored in the urban environment. It has been shown that if all dark paving in a typical city were to be replaced with light-coloured surfaces (increasing albedo[2] from 0.1 to 0.35) air temperatures could be reduced throughout the entire urban area by 0.6˚C (Pomerantz *et al.* 2000). The Toronto Green Development Standard recommends using light-coloured materials for 50% of the hardscape around buildings to reduce the urban heat island effect (City of Toronto 2006). Light-coloured paving also has the added benefit of improving nighttime street lighting.

Porous paving, while typically employed as a stormwater management measure, can also be effective at reducing ambient air temperatures. It provides growing space for vegetation and stores water in the urban surface, which lends itself to evaporative cooling (Greater London Authority 2006). Hard surfaces should, however, be reduced or avoided to the extent possible because allowing vegetation to grow is still the best defense against heat.

6.1.8 REDUCE WASTE HEAT EMISSIONS

Waste heat and pollutant emissions from anthropogenic activities exacerbate extreme heat events in cities. Industrial processes, air conditioners and vehicles are typical offenders (US Environmental Protection Agency 2007). A concerted effort to reduce emissions from these sources can reduce excess heat and improve air quality. During the summer Olympics of 1996, the City of Atlanta successfully encouraged people to shift from their vehicles to public transit. Traffic was reduced by 22.5%, resulting in a peak level ozone reduction of 28% (Friedman *et al.* 2007). The direct effects on the ambient temperature of this shift to public transit are not known.

In an effort to curb air pollution, and consequently waste heat emissions, the City of Toronto encourages its employees to conserve energy year round by turning off lights and other equipment at the end of each work day, reducing the idling of vehicles, and taking public transit, among other actions. On smog alert days, the City engages its *Smog Alert Response Plan,* where City divisions are encouraged to scale back non-essential activities to avoid adding more pollution to the air. Examples of such measures include suspending use of gas-powered landscaping equipment, avoiding use of oil-based paints, and suspending use of non-essential vehicles (City of Toronto 2007c). The effectiveness of these measures has not been evaluated.

[2] The albedo or solar reflectance of a surface is the percentage of incoming solar radiation that is reflected by that surface. Albedo is measured on a scale of 1 to 0, where a value of 0 indicates that a surface absorbs all solar radiation and a value of 1 represents total reflectivity (US EPA 2003).

6.1.9 ALTER URBAN DESIGN AND FORM

Urban morphology – the physical form of the city – will also affect the intensity of the urban heat island and the duration of heat waves. The rate of release of heat from the urban environment is affected by sky view, the amount of openness between buildings. A small sky view is typical of areas with narrow streets and/or tall buildings. The smaller the sky view, the less heat that will be able to escape from transportation and building surfaces. This leads to heat trapping in street canyons and the elevation of air temperatures (Greater London Authority 2006).
Street orientation will also affect how quickly heat can escape from urban environments. Streets oriented perpendicular to the direction of prevailing winds, will fail to benefit from natural ventilation, which removes trapped heat and air pollution from between the buildings (Greater London Authority 2006).

RESEARCHERS USE FISH-EYE PHOTOGRAPHS TO DETERMINE SKY-VIEW FACTORS.

SOURCE: www.gvc2.gc.se/ngeo/urban/activities/svf.htm

While changes to urban morphology cannot be easily implemented in existing built up areas, sky view and street orientation should be considered for new developments and large redevelopment projects.

6.2 REDUCING HEAT-RELATED ILLNESS AND DEATH

As discussed previously, there are a range of health impacts associated with extreme heat events and the incidence of these effects is expected to increase under climate change. Those most vulnerable are the elderly, individuals with pre-existing health conditions, and persons without access to air conditioning. Hot weather also contributes to the formation of smog, meaning that extreme heat events often coincide with poor air quality days. Hence, preparing for the increase in heat-related illness should involve mechanisms that recognize the combined impact of extreme heat and air pollution. The City of Toronto already has a well-known hot weather response plan that involves monitoring, issuing advisories, and implementing a response plan for vulnerable populations. In recognition of the effect that climate change will have on the number of extreme heat events, the City is working to expand the program to increase its effectiveness and reach. The current program and recommendations for its expansion are presented below.

6.2.1 CONDUCT PUBLIC EDUCATION AND OUTREACH

Public education and outreach is an important part of the heat response system. The City of Toronto produces a number of public education materials about how to stay cool during extreme heat events. These include guidelines for exercising during hot weather, general precautions, and fact sheets on heat and heat-related illness for landlords and residents in apartment buildings and rooming houses. The materials are distributed to community agencies that support vulnerable populations, and are made accessible through public libraries, sports associations, and school boards. In 2005, prior to the onset of hot weather, Toronto Public Health presented educational sessions to owners, operators and residents of rooming houses and boarding homes. In addition they held three news conferences, issued dozens of news releases and responded to more than a hundred media calls. During a hot weather period visits to over 500 sites were made to assess occupant risk and distribute educational material (McKeown 2006).

6.2.2 CONDUCT HEAT WATCH MONITORING

Toronto Public Health monitors the Heat-Health System from May 15 to September 30, and calls Heat Alerts or Extreme Heat Alerts based on a number of climatic indicators, including humidity. As climate change progresses, extreme heat events will appear earlier and persist later into the calendar year and consequently the monitoring of heat events will need to start earlier in the spring and extend later into the fall.

In 2008, the City will also be piloting a health-based air quality index (AQHI). This system will provide a simple measure to convey the health risks associated with the combined effects of various levels of air pollutants for the general and at-risk population. The AQHI is designed for the user to interpret and adjust their activities accordingly. It may aid in reducing heat-related illnesses and death by forecasting smog-related health risks, thereby allowing individuals to modify their activities (Campbell 2007).

6.2.3 ISSUE ADVISORIES

When a heat or extreme heat alert is called, Community Information Toronto contacts over 900 community agencies working with the elderly, isolated seniors and the homeless to communicate the onset of an extreme heat event (City of Toronto 2007d). Many of these agencies maintain registries of at-risk individuals who receive additional support during heat alerts (McKeown 2006). These agencies will likely need to secure additional resources as extreme heat events are expected to occur more frequently and persist longer under climate change.

6.2.4 ENHANCE EMERGENCY REPSONSE FOR VULNERABLE POPULATIONS

During a heat alert, the following actions take place in addition to issuing an advisory:

- The Red Cross operates an information line from 9:00 am to 9:00 pm to answer heat-related questions and check on individuals at risk
- The Red Cross delivers bottled water to agencies that work with populations at risk, and provides transportation to those that require it.
- Homeless shelters allow people to stay inside during the day
- Emergency Medical Services responds to calls of heat-related illness and transports individuals to hospitals or a cooling centre as needed.
- 99 libraries and 81 community centres, all of which are air-conditioned, are available for relief from the heat.

When an extreme heat alert is called, an additional 5 cooling centres are opened, namely Metro Hall, East York Civic Centre, Etobicoke Civic Centre, and North York Civic Centre. A number of city-owned swimming pools also remain open for extended hours (City of Toronto 2007d).

A recent report from Toronto's Medical Officer of Health to the Board of Health concluded that based on the experience of the summer of 2005, when 26 Heat Alerts were called, and in recognition that more such summers will occur under climate change, additional resources are needed for the City of Toronto to more effectively prepare for and respond to extreme heat alerts (McKeown 2006). Over 14 recommendations[3] were made to improve the robustness of the Hot Weather Response Plan, including:

- Work with Toronto Hydro and other stakeholder to determine the feasibility of establishing a subsidy program for low-income vulnerable people to own and operate air-conditioners;
- Expand the Better Buildings Partnership program to rooming houses and boarding homes which house residents vulnerable to extreme heat; and
- Increase outreach and education to landlords of rooming houses, boarding houses, group homes, hostels and property managers of Toronto Community Housing Corporation.

In addition, the City is researching the feasibility of establishing a city-wide registry of at-risk individuals, although the cost and maintenance of such a system needs to be further explored (McKeown 2006).

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[3] To view the report and the complete list of recommendations visit: www.toronto.ca/legdocs/2006/agendas/committees/hl/hl060227/it013.pdf.

6.3 REDUCING THERMAL DISCOMFORT IN BUILDINGS

As summers grow hotter, thermal discomfort in buildings will increase, which in turn will expand demand for cooling and energy use. Heat gain in buildings can be minimized by means of building orientation, design, and shading. Building orientation and design can reduce heat gain by decreasing the number and size of south facing windows. However, in a four season city such as Toronto, large south facing windows are desirable during winter months to make use of passive solar heat and natural light. Furthermore, existing buildings are limited in the extent to which their design can be modified. Shading, particularly with deciduous plants, is an effective way to prevent heat gain in many buildings. Shading has been found to be more effective than insulation as it prevents solar radiation from reaching the shell of the building in the first place (Dunnett and Kingsbury 2004).

6.3.1 PLANT SHADE TREES AROUND BUILDINGS TO REDUCE HEAT GAIN

A study investigating the impact of shade trees on the urban heat island in New Jersey concluded that shades trees are a viable and economically effective way to reduce cooling costs. (Reducing demand for cooling will be discussed further is Section 6.6.) To achieve the greatest reduction in air conditioning expenses, shade trees should planted in front of windows to the east, south and west (Solecki *et al.* 2005). It should be noted, however, that in more northern climates evergreen trees planted to block the summer sun can also block the sun in the winter when passive solar heat is desirable. As a result, the overall costs of temperature regulation can actually rise (Nowak 2007).

6.3.2 CONSTRUCT AND RETROFIT BUILDINGS WITH GREEN FEATURES

Green buildings encompass a variety of technologies and designs that allow them to regulate indoor air temperatures and prevent excessive heat gain in buildings in a less energy-dependent manner. Because these methods reduce the demand for energy, they have the added benefit of mitigating climate change as fewer greenhouse gas emissions are generated. The potential of green roofs, cool roofs, and living walls to reduce ambient temperatures and the overall heat island effect has already been discussed. Numerous studies have also illustrated their effectiveness at preventing heat gain in buildings. Light roofs and green roofs were found to be two of the most effective measures at reducing heat gain and consequently, energy demand in buildings, with cool roofs being the more cost-effective option (Rosenzweig *et al.* 2006). A study conducted in Ottawa demonstrated that a green roof[4] was able to significantly reduce heat flow through a roofing system in spring and summer months by 75% (from 6.0-7.5 kWh/day to 1.5 kWh/day) (Liu and Baskaran 2003). The extent of this effect is presented in the graph below.

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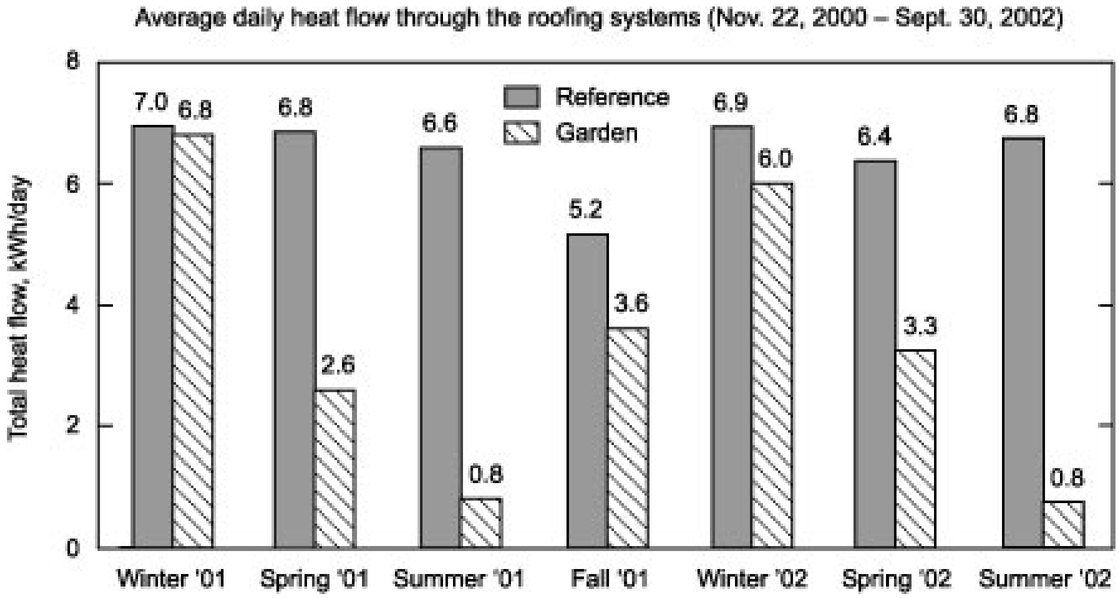
[4] The vegetated roof in this study was an extensive green roof with 160 mm (6 inches) of growing medium.



HEAT FLOW THROUGH A GREEN ROOF AND A CONVENTIONAL ROOF. THE GREEN ROOF IS PARTICULARLY EFFECTIVE AT REDUCING HEAT FLOW IN THE SPRING AND SUMMER.

SOURCE: Liu and Baskaran (2005)

Living walls can also be very effective at keeping buildings cool and reducing maximum temperatures. Daily temperature fluctuations on building walls can be reduced by as much as 50%. Living walls or climbing plants are most effective on the south or west sides of buildings, where sun exposure is the greatest. Living walls have the added benefit of trapping an insulating layer of air between plants and building walls in winter months, and reducing wind chill (Dunnett and Kingsbury 2004). This is particularly important in Toronto, where both extreme heat and extreme cold weather episodes occur.

The multiple benefits of green roofs, living walls, and cool roofs make them a powerful approach to deal with extreme urban heat events; unfortunately, they are as yet under-utilized in Toronto. The recently released Toronto Green Development Standard recommends 50% green and cool roof coverage or a combination of both to cover 75% of the roof (City of Toronto 2006). If these standards are taken up by developers, or mandated by the City, they will be a great asset to efforts geared at reducing ambient summer temperatures.

Natural ventilation and low-energy cooling can be employed to adapt to hotter summers, while reducing the amount of greenhouse gases emitted into the atmosphere.

Prior to the development of mechanical cooling systems, buildings were cooled and ventilated naturally for many years. Modern architectural practices are beginning to return to these principles once again as environmental issues become more pressing.

While natural ventilation[5] remains the preferred and least energy-dependent cooling option, it may no longer suffice to cool indoor environments as day and night time outdoor temperatures rise under climate change. A recent UK study determined that under future climate change scenarios for London, passive cooling may only be effective until 2050 or 2080 depending on the type of structure and its use. Homes may be able to rely on passive cooling until 2080, however, offices and schools will likely need to have supplemental mechanical cooling after 2050, because of high levels of waste heat from people, lighting, computers and other electrical appliances (Hacker *et al.* 2005). In light of this research, hybrid cooling systems may be the most appropriate option for Toronto given the uncertainty and volatility of the future climate, and the high amount of waste heat generated in the urban core. The Institute for Research in Construction in Ottawa is currently experimenting with "intelligent control systems" that switch between natural and mechanical cooling systems automatically (Ouazia 2006). New developments should strive to make maximum use of passive cooling, and supplement with efficient mechanical systems when necessary.

6.4 REDUCING ENERGY DEMAND FOR COOLING

As ambient temperatures rise under climate change, thermal discomfort in buildings will increase, and lead to greater demand for air conditioning. In December 2005, the Independent Electricity System Operator[6] reported that Toronto could be faced with brownouts or blackouts in the summer of 2008 if energy consumption is not curbed (City of Toronto 2007e). Ideally, building design should maximize passive cooling to lessen the demand for energy. However, in more built up areas where building design is slower to change, energy conservation measures should be rigorously promoted and implemented.

6.4.1 PROMOTE AND IMPLEMENT ENERGY CONSERVATION MEASURES

The City of Toronto's Energy Efficiency Office is already developing and coordinating an energy conservation strategy in response to the City's commitment to reduce greenhouse gas emissions by 80% by 2050 (City of Toronto 2007f). The plan will identify how City facilities, operations, and City-owned businesses can reduce their energy use by 15% and will include the following measures:

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[5] Natural ventilation is a whole-building design concept. It uses the stack effect and wind pressure to supply outdoor air to building interiors for ventilation and space cooling.

[6] The IESO is Ontario's not-for-profit corporate entity charged with balancing energy demand and supply.

- Peak-saving mechanisms
- Renewable and distributed energy
- District heating and cooling
- Demand response
- Conservation and demand management
- Various technology solutions
- Regulatory, legislative or institutional measures

The City's Better Buildings Partnership program is a successful and well-known initiative that has been in operation since 1996. Through innovative financing strategies, over 500 industrial, commercial, institutional and multi-residential buildings have been retrofitted, and as a result have reduced energy demand by more than 50 megawatts annually (City of Toronto 2007e).

In addition, the City provides tips and advice on how to reduce energy use at work (Employee Energy Efficiency at Work: E3@Work) and at home (Residential Energy Awareness Program)[7].

6.5 PREVENTING AND ADAPTING TO BLACKOUTS

The pressure on Toronto's stressed electrical transmission system will increase under climate change, meaning that brownouts and blackouts may become more common in the near future.[8] To guard against this risk, the City will need to intensify efforts to reduce peak energy use, invest in distributed energy systems and enhance provisions to protect particularly vulnerable individuals in shelters, old-age homes and hospitals.

6.5.1 PROVIDE INCENTIVES TO REDUCE ENERGY USE DURING PEAK HOURS

Efforts to reduce peak energy consumption are an extension of the energy conservation mechanisms described in section 6.6.1, with a focus on curtailing energy use during periods of peak usage, and shifting certain activities to off-peak hours[9]. An array of measures has been introduced recently to reduce peak electricity demand. The "Smart Meter" program – which allows for tracking electricity use by time of day and provides financial incentives to encourage customers to use cheaper electricity available at off-peak periods – is an important step in this process. Smart meters are currently being installed throughout Ontario, with the goal of having all homes and businesses outfitted by 2010 (Toronto Hydro 2007). Toronto Hydro has also introduced the "Keep Cool"

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[7] For more information on the work of Toronto's Energy Efficiency Office, visit www.toronto.ca/energy/index.htm.

[8] Heat is only one of the ways in which climate change may contribute to increased power outages. Increased numbers and intensity of storms are also likely to cause blackouts.

[9] Peak energy use occurs between 11:00 am to 5:00 pm in summer months, and between 7:00 am to 11:00 am and 5:00 pm to 8:00 pm during winter months.

program to retire old inefficient window air conditioners and the "Peaksaver" program, which allows the utility to turn down central air conditioners of participating customers when the system is reaching critical demand levels. As climate change advances, these measures will need to be intensified.

The City has conducted internal education with employees to encourage energy conservation behaviour such as setting thermostats a few degrees higher in summer, and turning off computers, faxes, printers, and lights not in use. It may be important to evaluate the effectiveness of these educational efforts and to make changes that result in more compelling campaigns. On a wider corporate level energy audits and smart meters can provide an effective means of identifying, monitoring and adjusting activity to minimize use during peak hours. Through the development and implementation of its energy conservation plan and with the aid of smart meters, the City of Toronto should be able to reduce demand and the threat of related blackouts.

6.5.2 INVEST IN DISTRIBUTED ENERGY SYSTEMS

Distributed energy systems are a means of localizing the generation of electricity – by means of combined heat and power plants; micro-turbines; solar and small wind systems; fuel cells and bio-energy plants – which reduce electrical transmission losses and associated air pollution and greenhouse gas emissions. A shift from centralized electricity generation and high voltage transmission lines to local generation systems can also reduce vulnerability to blackouts from peak demands during heat waves. This was demonstrated during the August 2003 blackout, when several islands of light continued uninterrupted amidst the sea of darkness (Parks 2004). These islands were maintained by local micro-power generators that were designed to isolate from the grid and keep providing for local loads. Two unintended Ontario islands were particularly important for returning the system to normal operating condition (Fulton and Abbey 2004).

Increasing investment in distributed photovoltaic systems could have a particularly beneficial effect because system output corresponds closely with periods when air conditioning demands are highest – on hot sunny days (Rickerson 2006). Substantial solar capacity could help displace power from fossil fuel plants which currently supply much of southern Ontario's peak demand on hot summer days, and which contribute substantially to smog in the area.

Toronto has begun to invest on a small scale in distributed energy systems but so far these provide a tiny amount of load capacity. Not all of these systems can be isolated from the grid so that they continue to provide local electricity during transmission failures.

Though not strictly speaking distributed energy systems, deep lake water cooling and geothermal systems used for cooling also reduce peak electrical loads and the risk of transmission failures. The City has invested heavily in deep lake water cooling, but so far, Toronto's uptake of geothermal systems for heating and cooling has been minimal.

6.5.3 DEVELOP EMERGENCY PLAN FOR AT RISK INDIVIDUALS IN SHELTERS, OLD-AGE HOMES, AND PALLIATIVE CARE

While a loss of electrical power is inconvenient for everyone, it can be life threatening for individuals in shelters, old-age homes and palliative care. When blackouts are associated with electrical system overload in summer months, as is expected under climate change, power loss will likely coincide with heat waves when cooling is needed most.

The City already has a response protocol in place to deal with all types of emergencies, including blackouts. More early warnings about heat waves and potential blackouts would aid those assisting vulnerable populations to better execute their emergency responses (Smyer 2006).

7. CONCLUSIONS AND RECOMMENDATIONS

With climate change upon us, the need for the City of Toronto to implement strategies to deal with extreme heat events becomes increasingly urgent. The summer of 2005 provided a taste of what future summers will feel like. The following recommendations suggest a mix of preventive and emergency response measures to help the city prepare for and cope with extreme heat events.

7.1 PRACTICE GOOD URBAN FORM/ CITY DESIGN

Good urban form and design can significantly reduce the extent of the urban heat island in metropolitan areas. Compact neighbourhoods and cities will encourage individuals to leave their cars at home, reducing waste heat and air pollution emissions. Orienting buildings to make use of passive solar energy and natural air flow minimizes the energy needed for cooling and lighting. Providing adequate space for vegetation to grow and maximizing sky view can prevent urban areas from getting too hot and allow excess heat to escape. New developments and major redevelopments should strive to meet these conditions to minimize the extent of the urban heat island effect. These options may be less feasible in more densely built up areas, where change occurs on a building-by-building, rather than on a neighbourhood basis.

7.2 INCREASE URBAN VEGETATION

A recent New York study analyzed a variety of urban heat island mitigation strategies, determining that vegetation is one of the most effective cooling strategies (Rosenzweig *et al.* 2006). Of all the strategies examined, street trees were found to have the greatest cooling potential, which makes them a critical component of a strategy to deal with extreme heat. Streets trees are, however, difficult to maintain and adequate resources must be devoted to their maintenance to ensure their survival (Wieditz and Penney 2007). Other greening strategies that should be employed include green roofs, green walls and open space planting.

In New York City, combining all greening strategies was found to have a greater cooling effect than any individual strategy alone (Rosenzweig *et al.* 2006). Toronto can benefit from this analysis by identifying and analyzing neighbourhoods deficient in green space for the potential to plant trees and other vegetation along streets, in parking lots, and on buildings. Increasing the amount of vegetation in Toronto will have the added benefit of improving air quality, managing stormwater, improving aesthetics and providing animal habitat. In addition to being a key adaptation strategy, vegetation also mitigates against climate change by absorbing greenhouse gases.

7.3 INCREASE GREEN BUILDING CONSTRUCTION

Green building construction is another strategy that minimizes the effects of extreme heat, while also mitigating climate change by reducing energy consumption. Green building practices that reduce heat include the use of green roofs, cool roofs and natural ventilation systems. The City of Toronto recently developed a made-in-Toronto *Green Development Standard* (GDS) to provide guidance to those in the development community that wish to build green. The standard is mandatory for all City-owned facilities as well as its agencies, boards and commissions. It is voluntary for the private sector at this time. To encourage development to the GDS, the City requests that all applicants for site plan approvals, official plan and zoning by-law amendments complete a GDS checklist, submitted with their applications, indicating which GDS targets they intend to meet. Final development reports note the applicant’s stated intentions with regard to applying the GDS, as per the submitted checklist. The goal is to engage developers early in the application process so that green development is considered from the beginning, when it is easiest to implement.

7.4 REDUCE ENERGY USE AND ACCELERATE THE SHIFT TO DISTRIBUTED ENERGY

Reducing energy use is critical not only for mitigating climate change but for adapting to extreme heat events. Peak demand is highest on hot summer days, when air conditioning systems strain to keep indoor spaces cool – and pump hot air outside, increasing the temperature of ambient air. This leaves us vulnerable to power failure with consequences for the health of vulnerable populations and high costs to the economy. The City of Toronto and Toronto Hydro have a number of programs in place that reduce energy use and control peak demand, as well as avoid the requirement for costly new generation and transmission capacity. As climate change progresses, it will be important to expand and accelerate these programs.

A more systematic approach will need to be taken to ensure the expansion of distributed energy systems in Toronto, to safeguard against power outages. As investment in distributed energy systems increases, the City should ensure that local power generation systems can be isolated or "islanded" from the grid during transmission system failures to reduce the impact of power outages.

7.5 EXPAND HOT WEATHER RESPONSE PLAN

Toronto's Medical Officer of Health has recommended a variety of additional resources to strengthen the Hot Weather Response Plan. Certain sectors of the population, such as socially isolated seniors, are hard to reach, and with extreme heat events expected to become more frequent and severe, heat-related illness and death could become a bigger issue. Serious consideration needs to be given to implementing these recommendations. (See page 19.)

7.6 UNDERTAKE INTEGRATED HEAT REDUCTION AND RESPONSE PLANNING

Toronto needs to consider a combination of proactive measures that can limit the intensification of the urban heat island under climate change, as well as systems that help protect its citizens from heat waves that cannot be prevented. The recommendations in Sections 7.1 to 7.3 can help lower maximum daily temperatures by a few degrees, and avoid those temperatures where serious health impacts can occur. Section 7.4 outlines measures that can prevent power outages that can impact the economic health of the City as well as the physical health of its citizens. Allocating resources to proactive measures will ultimately reduce the cost and resource requirements of more reactive measures, such as the Hot Weather Response Plan, though this kind of emergency response will continue to be important to safeguard the lives and health of vulnerable people. The City should consider an integrated strategy of proactive and emergency initiatives, considering the co-benefits that can be derived from each of the measures under consideration and how to allocate resources among the approaches.

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