Cities Preparing for Climate Change

A Study of Six Urban Regions

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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

Adaptation to climate change is an essential part of the emerging strategy required to cope with and manage this pervasive and global threat. The need to control the emissions of greenhouse gases – mitigation – is now widely accepted and governments at all levels as well as major companies in the private sector are struggling with planning and implementation of the ways and means to achieve this goal. So far these efforts have not been crowned with much success and the prospects in the near term do not look promising.

The other important element in the response strategy – adaptation – has not yet received the same widespread recognition and public support that it so plainly merits. It is clear however, that this is now beginning to happen. A handful of cities in the developed world have started to address the issue of adaptation and to consider the ways in which they are at risk and the actions they need to begin to take to reduce their own vulnerability. The time is ripe for Toronto and other leading Canadian municipalities to join this small group of innovators. This is an area of social, economic, and environmental policy in which Canada has been slow to respond to the growing scientific consensus. It is not necessary to replace past complacency with a sense of panic or alarm. What is needed is a sober look at the issue, and a careful set of analyses designed to help develop timely and effective policies and actions.

The Clean Air Partnership (CAP) has responded to these circumstances by launching (with the help of Natural Resources Canada) the first study of climate change impacts and response in Toronto. As an initial step a scan of Toronto's exposure to climate risks has been conducted as the basis for further assessment (Wieditz and Penney 2006). This scan has shown that there are many aspects of the social and economic life of the city, as well as the environment, that are at risk from present and growing future risk from climate change. CAP has also examined climate change impacts and adaptation options on Toronto's urban forest and its urban heat island (forthcoming). The two studies confirm that climate change adaptation merits further attention by Toronto and other Canadian municipalities. As a further contribution to the development of this work CAP has made site visits to six municipalities that have been touted as "early adopters" or "early responders" on adaptation and prepared this report on the lessons for other cities from their experiences.

Many cities, including Toronto have been active in exploring their potential contribution to emissions reduction – the mitigation side of the issue. Why have cities as well as national governments privileged mitigation over adaptation? A brief explanation is in order. Climate change has been identified by the scientific community and subsequently by the policy community, primarily as an

atmospheric pollution issue. This misconception (and it is not too strong to call it that) arose in part because climate change or global warming seemed to follow in sequence from earlier problems of acid rain (precipitation) and ozone layer depletion. Both these environmental problems were seen to be the result of pollution and both were brought under control by the introduction of policies and measures to reduce the pollutants – sulphur dioxide in the case of acid rain, and chlorofluorocarbons in the case of ozone layer depletion. These policies required international agreements to be effective, and this was achieved. It was assumed that climate change could be successfully addressed in a similar manner.

Over the 15 years since the initial signing of the United Nations Framework Convention on Climate Change in Rio de Janeiro in 1992 it has become painfully clear that climate change and greenhouse gas emission are not so amenable to international agreement and action. The quantity and sources of emissions are much greater and are much more deeply embedded in the economy. There is so much dependency upon the sources of greenhouse gases (coal, oil, natural gas, forests and land use practices), that control of emissions presents a much greater challenge than in the case of sulphur dioxide and chlorofluorocarbons, which played a much smaller role in the total economy. Technological alternatives to fossil fuels that are sufficiently low cost and efficient are not yet available, and no single alternative has great promise of being able to fill the gap. In addition to these technical and economic obstacles to rapid switching away from fossil fuels there are major disagreements among the Parties to the Framework Convention about issues of equity and liability. The Kyoto Protocol to the Convention has been agreed, but at its best this represents only a small step in the right direction, and implementation is falling short even among those countries (including Canada) that have ratified the Protocol. Some other countries including the United States have declined to ratify the Protocol, and the largest and most rapidly growing sources of greenhouse gases in the developing world (China, India, Brazil) have declined to accept any curbs on their emissions.

The world's major cities have largely followed in the path of their national governments. They too have assumed that greenhouse gas emissions could be reduced and they have been willing to play their part in the process. At the same time they have quite correctly considered the most significant actions and policies to be largely in the hands of senior levels of government. Cities acting by themselves do not have the jurisdiction or capacity to reduce emissions on a large scale without leadership and direction.

Although the world is now turning its attention more urgently and with more conviction than before to the need for mitigation it is clear that sufficient results cannot be achieved in the short term, and that the earth is committed to

continuing climate change. The long time residence of greenhouse gases in the atmosphere, and the inertia already built into the climate system means that the earth's climate will continue to change for centuries even if rapid progress is made on the reduction of emissions.

In case further reinforcement of the case for urban adaptation is needed it might be helpful to consider for a moment some important differences between adaptation and mitigation. The rationale for reducing greenhouse gas emissions is the need to stabilize greenhouse gas concentrations in the atmosphere in such a way that climate change is stopped, brought under control, or at the very least, slowed down. Success in this endeavour would benefit the global environment, and in that way benefit all the world's people. This means that those bearing the costs of emissions reduction (those countries that agree to do so through the Kyoto Protocol or other means) would not benefit in proportion to their costs, and those that do not reduce their emissions would nevertheless benefit from the more altruistic actions of others. This is a classical version of the so-called free-rider problem, and it is one of the main stumbling blocks to concerted global action on emissions reduction – mitigation.

Adaptation is different. The benefits of adaptation fall largely where the costs are expended. If a city protects itself from storms, floods, droughts, heat waves, invasive pests, species, and diseases, it is the people of the city that benefit. Their environment is better, their health is more protected, and their economic activities are less liable to damage and disruption. Many political leaders and business managers in cities have enlightened attitudes to the problem of climate change and would like to make a contribution to the reduction of greenhouse gas emissions, and so they should. However, mitigation requires action at senior levels of government – provincially, federally and internationally. The primary task of municipal leaders is to care for their own citizens. That is what they are elected to do.

Why should the leaders of Toronto and other Canadian municipalities grasp the threats and opportunities of climate change adaptation vigorously with both hands? They should act because adaptation is now an imperative, and because it is primarily their responsibility to see that it happens. This research by CAP is therefore timely and appropriate.

Ian Burton, Scientist Emeritus, Environment Canada

EXECUTIVE SUMMARY

It is now unequivocal that climate change is underway and that the consequences are likely to be severe. Cities and urban residents will be directly affected by many of the impacts of climate change, which include: increased intensity and frequency of extreme weather events, heat waves, flooding from sea-level rise, water shortages and other effects.

Internationally, many cities have developed comprehensive programs to reduce greenhouse gas emissions. A few leading cities have also conducted assessments of likely climate change impacts for their regions and are beginning to take action to reduce the vulnerability of their services and their citizens to these impacts.

The study provides lessons from the experience of six of these early adapters: London, New York, Boston, Halifax, Vancouver and Seattle. The report also outlines a systematic process for municipalities to adapt to a changing climate and provides many examples of municipal adaptation policies and specific adaptation measures and actions from the cities studied.

The Elements of a Successful Adaptation Process

The most successful cities and urban regions studied for this research undertook adaptation processes that included four main elements:

- Measures to increase public awareness of likely climate change impacts and to engage stakeholders in identifying problems and solutions;
- A systematic review of climate trends and projections for the specific urban region and an analysis of where and how major impacts are likely to occur;
- Identification of a range of options for reducing vulnerability to climate change, including an assessment of existing programs that create a foundation for an adaptation strategy; and
- Developing a strategy and putting it into action.

Building Awareness and Engaging Stakeholders

Several cities developed a multi-pronged approach to building awareness and engaging stakeholders. These outreach measures included: creation and distribution of short fact sheets on climate change processes, areas of impact and adaptation strategies; visual forms of communication such as maps of current and future impact areas; dedicated web sites; workshops and conferences. These

materials and events helped put climate impacts and adaptation on the agenda and increased public support for taking action.

Engagement of stakeholders – such as municipal and regional government departments, utilities, transportation authorities, conservation authorities and financial institutions – is vital for adaptation processes. Stakeholders understand where the stress points are in urban systems for which they have responsibility, and are well situated to assess how climate change could interact with those stressors. Stakeholder involvement is also essential for measuring the extent to which current programs and activities may protect against climate impacts, and devising practical strategies to increase this protection. A structured process, and regular meetings and communications are essential for the effective participation and involvement of stakeholders.

Climate Change Impact Scans and Assessments

It is very useful for cities developing a climate change adaptation strategy to start with a systematic assessment of impacts. Useful steps in this process include;

- Review and analysis of existing data on climate change and its likely impacts for the region;
- Identification of priority impacts for further investigation and action;
- In-depth studies of specific vulnerable sectors (e.g. water, energy, health);
- Assessment of the potential costs of climate impacts (may be derived from case studies of recent extreme weather events).

Comprehensive impact assessments examine not only how climate change is likely to affect the natural environment and physical infrastructure of an urban region, but also trace likely economic impacts on municipal operations and on the city's economy, as well as social impacts on vulnerable populations.

Impact assessments often involve local climate scientists and other researchers who help identify historical climate trends as well as interpret the regional implications of future climate projections.

Identifying and Reviewing Adaptation Options

In preparing to take action on adapting to climate change, leading cities have identified a variety of strategies and options for reducing the vulnerability of their affected sectors and populations. A preliminary menu of options for coping with climate impacts such as extended heat waves, extreme weather events, water shortages or multiplying pests can be identified from the rapidly expanding adaptation literature. Many of these adaptation options have

significant co-benefits, which should be identified and evaluated as part of the assessment process. (Actions that reduce the urban heat island will also decrease stress on the electrical transmission system.)

Some options will require further technical study to assess their specific application in individual cities and urban regions. Pilots of some adaptation options may be necessary to validate the extent to which they provide the protection being sought.

Most cities already have in place programs that provide some protection against the expected impacts of climate change, even if they were not initiated specifically for this purpose. The review of adaptation options should analyze how these programs can serve as a foundation for building a more comprehensive portfolio of adaptation responses.

Taking Action

Although this research suggests the importance of a systematic approach to climate impacts assessment and adaptation planning, taking action does not have to await the conclusions of such a process. On the contrary, several cities have set priorities and gotten started in the areas of greatest concern – taking action to protect against future water shortages, flooding, heat waves and other climate related problems. There is every reason for cities to begin incorporating concerns about climate impacts into long-lived infrastructure projects for energy, water, stormwater, transportation, green corridors and waterfront or floodplain developments that are currently in the planning stages and are likely to be affected by climate change during their lifetime.

Similarly, repairs and reconstruction that follow major extreme weather events should incorporate extra protection for future climate changes that promise more of the same kind of event. Adaptation action may also be taken before all the information is in, especially in the case of adaptation options "worth doing anyway" or in pilot projects that allow the effectiveness of specific adaptation actions to be evaluated.

The experience of deliberately incorporating climate adaptation into current projects can be very helpful in developing a more systematic approach to adaptation planning for the city and can serve as a kind of project-based policy development.

Cities that have created and provided resources for clear institutional mechanisms for considering climate change impacts and adaptation strategies have made more

progress in advancing a climate adaptation agenda than cities with a more ad hoc approach. These mechanisms include:

- Stakeholder partnerships that bring together representatives from key sectors including research institutions to consider adaptation needs and recommend areas for and approaches to action;
- Internal staff steering committees that integrate adaptation into citywide policies and programs and help coordinate with regional initiatives
- Dedicated staff who conduct or coordinate impacts assessments, identify and analyze adaptation options, and implement adaptation programs.

Leading cities are tending to integrate climate change adaptation (and mitigation) into overarching policy documents such as official plans or statements of principle. Some are also developing city-wide adaptation policies, as well as sector- or department-specific adaptation guidelines.

Barriers

There are a number of barriers that cities confront to taking action on adaptation. These include:

- A poor understanding by the public of the range of impacts of climate change – though this is beginning to change;
- Uncertainty about the timing and extent of impacts;
- The practice of making important infrastructure decisions based on past conditions (storms, seasonal temperatures, water levels, snow loads etc.);
- A short-term focus on the costs of adaptation, rather than on the impacts of failing to adapt;
- Difficulties getting the attention and commitment of political leaders;
- Problems coordinating action across government departments and levels of government; and
- Inadequate financial resources of cities.

Despite these barriers, some cities and regional governments have taken action.

Lessons from Early Adapters

As with other important initiatives, effective development of adaptation actions by cities has been led by a few knowledgeable and committed political or executive champions. The active collaboration of a strong local community of interested researchers has also proved to be important to those cities that have made strides on adaptation. Leading cities have provided dedicated staff to the task of developing adaptation programs, and allocated or leveraged funds for

technical consultants, research, workshops, website development and other necessary resources and tools.

Leading municipal and regional governments have also made a concerted effort to communicate the importance of climate change impacts and adaptation internally and with the general public. Cities that maintain a process of regular stakeholder communication appear to have the greatest buy-in and strongest sectoral adaptation planning.

A long-term perspective is necessary in developing an adaptation process for a city or urban region. High-cost, preventive adaptation strategies are unlikely to be implemented unless the need for them is clear, their effectiveness established, and the costs understood. This takes time. Climate change will continue for the foreseeable future and adaptation will need to be ongoing.

It takes leadership, persistence and a broad knowledge of urban systems and how they interact with climate and with each other to get and keep adaptation on the agenda of cities and to devise and implement adaptation strategies. It is vital for cities to continue to share their experiences and to learn from each other as these processes continue.

INTRODUCTION

It is now unequivocal that climate change is underway and that the consequences are likely to be severe (IPCC 2007). These consequences will play out everywhere: in cities as well as in rural settlements, seacoasts, inland lakes and rivers, forests and other areas.

Scientists predict a wide range of climate change impacts. These include:

- Flooding of coastal areas by sea level rise and storm surges
- Increased intensity of extreme weather events including heavy rainfalls, ice storms, tornados and hurricanes – damaging buildings and energy, water, sewage and transportation infrastructure
- Continued rise in weather-related insurance losses – which multiplied more than 13 times from 1960 to 1999
- Increased heat waves and smog, resulting in ill health and deaths in vulnerable populations
- Increased incidence and extent of droughts
- Reduced availability and quality of potable water due to reduced streamflow, lower lake levels and declining snowpack
- Exposure of northern populations to disease vectors previously confined to warmer southern climates
- Expanded range of insect pests that damage agricultural production and forests
- Increased stress and damage to vulnerable ecosystems and habitats.

In cities, these impacts will negatively impact water, sewage, energy distribution and transportation systems. They will damage buildings, urban trees and green spaces. They will increase illness and deaths in vulnerable populations.

Our urban infrastructure is not designed for the new climate. We will have to make many changes to urban systems in order to reduce our vulnerability to the climate changes that are underway.

Several of the world's leading cities have begun to address the need to adapt to climate change. The process thus far is beset by difficulties and obstacles, but with perseverance these can be overcome, though the process may differ from city to city. The preparation for climate change is gathering momentum. Soon any major city without an adaptation strategy will be seen to be behind the times, or even negligent in its responsibility to protect its citizens, its economy and its quality of life.

This study examines the activities of governments and researchers in six cities and urban regions to integrate climate concerns into policy and programs, and to adapt to climate change. The cities/urban regions studied were:

- London, UK
- New York City and the Metro East Coast Region, USA
- Boston Metropolitan Region, USA
- Halifax Regional Municipality, Nova Scotia, Canada
- Greater Vancouver Regional District, British Columbia, Canada
- Seattle and King County, Washington, USA.

The report provides lessons from the experience of these early adapters, and outlines a way in which municipalities can set in motion their own process of adaptation. It also provides many examples of municipal adaptation policies and specific adaptation measures and actions.

2. THE NEED FOR URBAN ADAPTATION

Until recently, most city programs to address climate change have been focused on reducing emissions of greenhouse gases to slow the rate of climate change. These policies and programs are referred to as climate change ***mitigation*** and include activities to:

- Encourage energy conservation and energy efficiency
- Expand renewable energy
- Curb urban sprawl
- Invest in public transportation, and
- Capture methane from sewage and landfill operations, and other initiatives.

These activities are vitally important. Many reports indicate that reductions of 60 to 70% percent of emissions are needed by 2050 in order for climate stabilization to occur.[1] This will require the concerted effort of all levels of government, though cities can make an important contribution to emissions reduction.

However, it is evident that even if we were able to halt all greenhouse gas emissions immediately, climate change will continue for the foreseeable future. Greenhouse gases that have already accumulated in the atmosphere will

[1] United Nations Economic Commission for Europe, 2002. UNECE carbon sequestration workshop agrees urban action needed to reduce global atmospheric CO_2 emissions. Accessed at: http://www.unece.org/press/pr2002/02ene06e.htm.

continue to alter our climate systems. As a consequence, actions to reduce the vulnerability of populations to current and future climate impacts are also vital.

Programs that help reduce our vulnerability to climate change are referred to as ***adaptation*** to climate change. Adaptation can occur prior to expected climate events – anticipatory adaptation – or in response to an adverse climate event – reactive adaptation (Smit et al 2000).

2.1 VULNERABILITY OF CITIES TO CLIMATE CHANGE

Cities are vulnerable because they concentrate people and buildings into a relatively small area. More than 64% of Canadians live in urban centres of 100,000 or larger. Consequently, even a relatively contained weather event can affect a large number of people. Cities are also very dependent on their "lifelines" – transportation systems to move people and goods, communications systems, water and energy distribution, sewers and waste removal systems (McBean and Henstra 2003). The concentration of people and wealth in cities, and their dependence on these infrastructure systems make urban centres particularly vulnerable to weather extremes.

Several features of modern cities interact with the changing climate to exacerbate the risks and increase vulnerability to climate change. These include:

- Asphalt, concrete and other hard surfaces in the city absorb radiation from the sun, causing the urban heat island effect, which exacerbates heat waves and puts pressure on electricity generation and distribution systems.
- Hard surfaces also prevent absorption of rainfall, creating runoff that carries pollution to lakes and streams and can overwhelm stormwater systems, leading to sewer backups and flooding during heavy precipitation events.
- Combined sewers that carry both stormwater and sewage are common in many city centres. Protracted or intense precipitation leads to overflows in these sewer systems, washing untreated pollutants into local water bodies.
- The concentration of people in urban centres puts pressure on vegetation and green spaces that could reduce heat, stormwater runoff, pollution and social pressures.
- Far-flung supply lines combined with just-in-time shipping practices can result in shortages of needed goods when transportation is disrupted by extreme weather.
- Centralized power sources, longer distribution lines, and an increasingly interconnected grid increases vulnerability to blackouts when electricity demands are high – during heat waves, for example – and when storms occur. The impact of blackouts has also grown as homes and businesses

have become more dependent on electronic control and communication systems.

- The concentration of people in large cities creates a large demand for water and can strain local water supplies, making them more susceptible to water shortages in drought conditions.
- Urban sprawl and competition for building sites has led to construction in locations such as floodplains or steep slopes that are vulnerable to extreme weather (though Canada does a better job of controlling this than many other nations).
- Low-income city dwellers in substandard and poorly insulated buildings that increase the risks from heat waves and other extreme weather. Homeless people have almost no protection from these events.

Many cities have developed policies to reduce vulnerability to these problems, but relatively few have taken into account the additional pressures that climate change will create. Costly infrastructure projects are expected to last up to a century, but are built on the assumption that climate conditions will be similar to those in the past. This results in a built environment that is not only at risk to the effects of climate change, but may exacerbate these effects.

2.2 GROWING AWARENESS OF THE NEED TO ADAPT

Two main factors are prompting cities to take action on climate change adaptation. Climate science has become more robust and more accepted, and is also reported more broadly in the media, leading to intensified public awareness and concern about climate change.

In addition, a number of recent extreme weather events have done significant damage to cities or to urban populations in different parts of the world, raising awareness about the vulnerability of cities to climate change. The 1998 ice storm that brought down power lines in Quebec and blacked out parts of eastern Ontario, the extended heat wave in the summer of 2003 killed almost 30,000 people in European cities and Hurricane Katrina, which devastated New Orleans last year, have all sounded the alarm about the impacts that extreme weather can have on cities. Events like these have led to a more systematic investigation of the urban impacts that climate change may bring, and recognition of the need to take action to reduce vulnerability and to increase resiliency.

2.3 FIRST STEPS

A growing number of cities have taken the first step in this process, by commissioning or participating in studies of the local impacts of climate change.

In Canada, impact reports have been written for the Greater Vancouver Regional District (Taylor and Langlois 2000), and for the cities of Hamilton (Ormond 2003), Halifax (Dillon Consulting et al 2006) and Toronto (Wieditz and Penney 2006). As part of a project that developed a 100-year sustainability plan for Greater Vancouver, the Sheltair Group (2003) produced a schematic overview of impacts and adaptation strategies for the region. Wittrock et al (2001) also undertook a broad study of climate change impacts on four large prairie cities (Winnipeg, Regina, Saskatoon and Edmonton) and four smaller cities (Brandon, Prince Albert, Swift Current and Grande Prairie).

These reports vary in both depth and scope. Some involved a considerable amount of original research. Others are a synthesis of existing knowledge that could be deepened if and when more resources are made available.

Outside Canada, a variety of urban impact assessments have also been undertaken. Some of the most comprehensive English-language studies were done for New York (Rosenzweig and Solecki, 2001), London (LCCP 2002a), and Boston (Kirshen et al 2005), and are described in more detail in Section 3.2 of this report.

A larger number of cities have commissioned research on specific sectors that are at risk. For example, the cities of Portland and Seattle have both investigated the impact of climate change on snowpack and water supply (Palmer and Hahn 2002, Wiley and Palmer 2005). The Office of City Auditor in Seattle also prepared a report on climate impacts on transportation in the Seattle area (Soo Hoo and Sumitami 2005).

Almost all these studies engaged municipal and regional government staff at varying levels – sometimes as key informants about how municipalities take climate into account in decision-making, and sometimes as co-researchers. However, few municipalities or regional governments have yet taken the next steps to systematically assess adaptation options and to take action.

3. THE ADAPTATION PROCESS

For this research we examined a number of recent guides and frameworks for developing an urban adaptation strategy.[2] The framework that seems to best describe the more successful processes in cities we investigated was elaborated in a recent OECD report, *Progress on Adaptation to Climate Change in Developed Countries: An analysis of broad trends* (Gagnon-Lebrun and Agrawala 2006).

[2] See Appendix A for a description of several of these guides.

This framework suggests that progress on adaptation involves these three steps or stages:

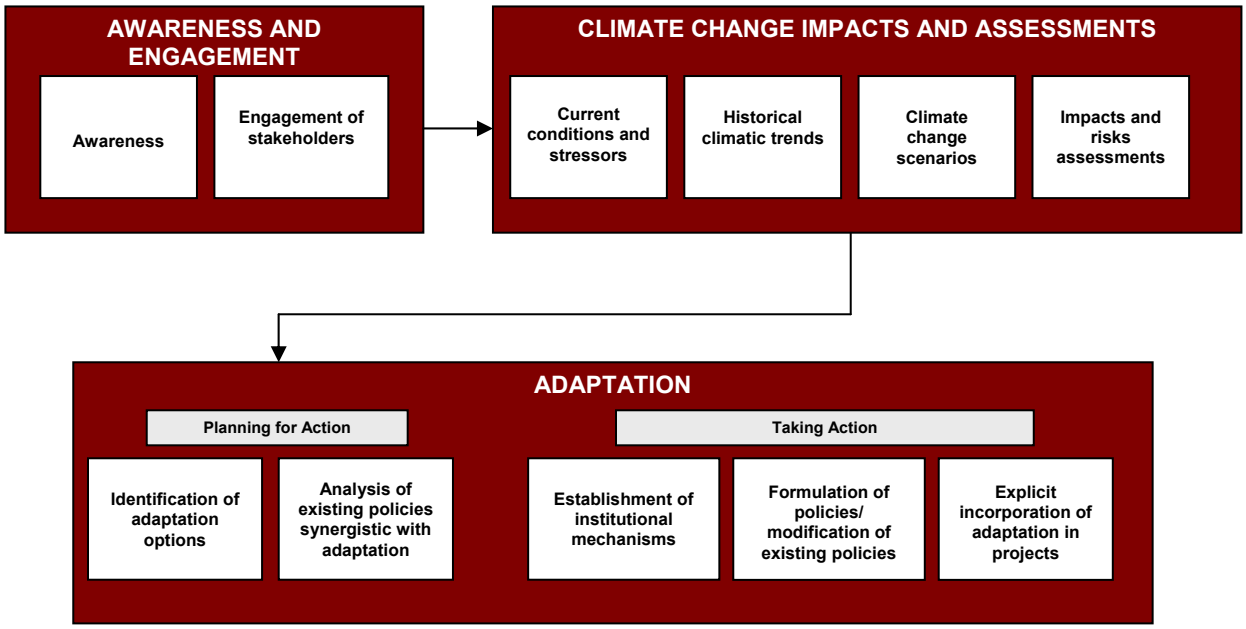
- ***Climate change impact assessments including:***
  - Historical climatic trends
  - Climate change scenarios
  - Impacts and risks assessments

- ***Articulation of the intention to act by:***
  - Identification of adaptation options
  - Review of existing policies synergistic with adaptation

- ***Adaptation action:***
  - Establishment of institutional mechanisms to guide adaptation processes
  - Formulation of policies and/or modification of existing policies
  - Explicit incorporation of adaptation in programs and projects.

The experience of the cities we studied suggests the need for another step in the adaptation process – Awareness and Engagement of Stakeholders. So we have modified the OECD framework to include this stage, as shown in the diagram below.

Figure 1: The Adaptation Process



The diagram suggests a simple linear progression in adaptation processes. However, climate change adaptation will not necessarily follow a lock-step process from awareness to action. Some forward-thinking leaders have incorporated climate change considerations into the planning and implementation of long-term projects without going through many of the previous stages suggested above. For example in Boston the Massachusetts Water Resources Authority changed the site of a sewage treatment plant built in 1998, after considering the impact of future sea level rise (Gagnon-Lebrun and Agrawala 2006).[3] And London set up the London Climate Change Partnership – which serves both to engage stakeholders, and as an institutional mechanism for enabling adaptation action – right at the beginning of their adaptation process.

While it is not necessary to follow the steps in a direct linear fashion, adaptation processes will benefit from a strategy that includes the stages mentioned above. Moreover, as the United Kingdom Climate Impacts Programme guide for decision-making suggests, the process should include ongoing monitoring of climate change – which may not develop as we expect and may require changes in strategy – and evaluation of implemented adaptation programs to assess their effectiveness (UKCIP 2003).

3.1 AWARENESS AND ENGAGEMENT OF STAKEHOLDERS AND DECISION-MAKERS

For a number of years, climate scientists and adaptation researchers have been analyzing the impacts of climate change and suggesting strategies for increasing the resilience and reducing the vulnerability of cities. They have created a strong foundation for action.

3.1.1 Heightening Awareness

For adaptation processes to get a foothold in local governments, it is vital that decision-makers and the people who influence them are made aware of the importance of climate impacts in their spheres of responsibility and understand that there are sensible and practical measures that can be taken to reduce vulnerability, often as small incremental cost.

Which decision-makers need to be aware of climate impacts and be thinking about adaptation strategies? Adaptation is needed in many different sectors.

[3] Although the Massachusetts Water Resources Authority attended to climate change concerns on this specific project, it has not incorporated climate concerns into its general project planning work (Estes-Smargiassi 2005), possibly because some of the work that might support a more generalized adaptation strategy was not done.

The priorities will vary to a large extent on specific local and regional vulnerabilities.

In cities or regions where heat waves will be a major problem under climate change, key stakeholder groups will include health departments, energy suppliers and distributors, emergency measures organizations, parks and urban forestry managers, planning departments and building officials. Where water shortages are likely to develop, stakeholders will include water and wastewater departments, major water consumers, conservation authorities, and others.

Where stormwater flooding is possible, stakeholders will include city planners, wastewater departments, utilities, transportation and transit services, and the insurance industry among others.

Local politicians are key stakeholders who need to appreciate the need to allocate resources to investigating local impacts, and identifying, testing and implementing solutions. In climate change adaptation, as elsewhere, leadership and champions are needed. Action on climate change adaptation has occurred in some regions because key political or management figures had an appreciation for the issue and the need to act on it. The awareness and long-term commitment of Mayor Ken Livingstone in London, and Executive Ron Sims in King County, Washington, for example, were critical factors in the development of dedicated adaptation programs in these urban areas (Nickson 2006; Howell 2006). Similarly, the Commissioner for the Department of Environmental Protection in New York City became concerned enough about climate impacts to initiate a departmental adaptation program (Major 2005).

Heightened awareness of decision-makers and other staff in local governments occurs as a result of many independent factors including problems such as water shortages or events such as storms or heat waves linked to climate change. However, conscious efforts to inform stakeholders and the public at large form an important part of an adaptation strategy. In the cities studied for this report, these awareness efforts included:

- Dedicated websites (London, Halifax)
- Factsheets (Columbia University's Earth Institute, Halifax)
- Short, colourful publications that summarize key research findings for the public and decision-makers (London, and produced for the Boston project by the National Environmental Trust)
- Presentations to a range of audiences (Seattle, King County, London, Halifax)
- Stakeholder and staff workshops (London, New York City Department of Environmental Protection, Halifax)
- High-profile conferences (King County)

- Maps showing the potential geographical distribution of impacts, and in one case
- An animation of sea level rise, showing how seawater might inundate low-lying areas of Boston.

In almost all the cities studied, conferences and/or workshops were convened with targeted stakeholder groups and agencies near the beginning of (and in some cases, throughout) the adaptation process. New York and London have both put substantial resources into holding multiple workshops with groups of stakeholders, and each has developed a standard format for running the events.

In New York, where an intensive process is underway to incorporate adaptation strategies into the City's water and sewage system, workshops have been held in seven water department bureaus. The two-hour workshops cover four topic areas:

- State of the science;
- Regional climate projections;
- Possible impacts on the sector; and
- Processes for developing adaptation strategies.

NASA scientists attached to Columbia University made the science presentations to these workshops. "Grounding in science is key," David Major, a scientist involved in the workshops, told us (2005). A key member of the host bureau introduced each workshop in a bid to increase buy-in of other bureau members. Workshop organizers changed the PowerPoint presentations for each workshop to provide the most relevant information for each stakeholder group. Half of each session was reserved for discussion (Demong 2005).

In London Alex Nickson, a senior policy officer currently developing a city-wide adaptation strategy, is also building awareness through an extensive series of presentations and workshops.[4] In an 18-month period in 2005-2006 he made an estimated 100 presentations and organized 15 workshops with different stakeholder groups and agencies to build awareness of how climate change might affect their services (Nickson 2006). The workshops start by asking participants to identify the measures they use to judge the success of their work (numbers of people served, effective delivery of service, costs, etc.) and then utilize an interactive process to explore how climate changes in London might affect these measures of success. The workshops also include a brainstorm with participants to begin to identify adaptation options. Following each awareness-

[4] According to a UK government official interviewed for this study, Nickson was chosen to develop London's adaptation plan was chosen for the job at least partly for his capacity to interest and engage people (Bramwell 2006).

raising workshop, a second meeting is held with a subset of participants who are asked to help contribute to the development of the adaptation strategy for their sector.

King County has taken a different approach, kicking off an adaptation initiative with the conference *The Future Ain't What It Used to Be*. The event drew more nearly 700 participants, 60% of them staff from local, regional and state governments and agencies. Breakout sessions were organized to discuss several areas of urban impact: municipal water supply; flooding, stormwater and wastewater; and hydropower among others. According to King County's climate change project manager, Doug Howell, the conference was a pivotal moment for raising awareness on climate impacts and moving forward on adaptation in the County (Howell 2006).[5]

In addition to conferences and workshops, several of the adaptation projects we studied developed websites to communicate basic climate impacts information, and adaptation options and strategies for their city or region. As the adaptation projects developed, these websites also added detailed research reports and links to other resources. The most impressive of these websites was developed by the Climate Impacts Group (CIG) at the University of Washington in Seattle. This website serves the whole Pacific Northwest region – Washington, Oregon, Idaho, and to some extent British Columbia – not just the Seattle region. But it includes a broad range of introductory information as well as climate forecast and planning tools, and many detailed research reports. The website is updated regularly and serves as an important awareness and information resource for the region.

Impacts and adaptation projects in New York, London and Halifax have created more limited websites to provide background information for policymakers and the public.

While general awareness of climate impacts is important, and this awareness can be strategically heightened by well-designed workshops, conferences and other activities, our research found that awareness alone was not enough to stimulate action on adaptation in cities. When we began our research, we investigated a number of cities that had made a strong commitment to reducing greenhouse gas emissions, assuming that these cities would also understand the importance of actions to reduce vulnerability to climate change. However, we found that many

[5] Although only a day long, the conference was a year in planning, bringing together King County, the Climate Impacts Group at the University of Washington, the State of Washington, and others. See http://dnr.metrokc.gov/dnrp/climate-change/conference-2005.htm.

cities that have made substantial efforts to reduce emissions have not begun to move on adaptation.

The Director of Environmental and Transportation Planning at the City of Cambridge – which has a strong mitigation plan for reducing greenhouse gas emissions – told us that a strong emphasis on adaptation may send a "defeatist" message that accepts the inevitability of climate change and undermines programs to reduce emissions (Rasmussen 2005).

A Cambridge environmental planner told us at the same meeting, that a more concerted adaptation process might be stimulated by a local climate disaster such as Hurricane Katrina[6] (Bolduc 2005). This was a theme that recurred in our research. Stephen King, an environmental manager for the Halifax Regional Municipality informed us that Hurricane Juan, which hit Halifax in 2003, followed a few months later by "White Juan", an immobilizing blizzard, had a powerful effect in raising awareness of the impacts of climate change and encouraged local politicians to support adaptation planning (King 2005).

Rather than wait for disaster to raise awareness of climate impacts, however, adaptation researchers in several of the cities we studied effectively used examples of dramatic impacts from international or local extreme weather events to draw attention to the dangers of climate change and the need to reduce vulnerability. Few climate scientists will claim that individual extreme weather events are caused by climate change, but they do point out that these events represent the kinds of changes and impacts that will occur more frequently in the future, and for which we need to prepare.

Visual tools can be particularly effective as a means of raising awareness about the impacts of climate change. Several of the projects studied for this report used photographs of extreme weather events, well-designed charts of weather trends and projections, and maps of areas that are vulnerable to particular climate impacts such as the expanding range of insect pests and infectious disease vectors. The National Environmental Trust in the US produced an animation showing the inundation of low-lying areas of Boston from sea level rise. The animation was used by several television stations reporting on the release of the Boston area impacts study and resulted in considerable – though short-lived – public interest in the report.

[6] He also suggested that stronger economic arguments for adaptation could also provide more impetus for adaptation planning, as could promotion of adaptation planning by ICLEI (Bolduc 2005).

Lessons on Building Awareness of Climate Impacts and Adaptation Options

- Building awareness of climate impacts and adaptation options is an essential first step in the adaptation process. It can take some time, and needs to continue throughout the adaptation process.
- Commitment to greenhouse gas emissions reduction does not translate directly into adaptation action.
- Awareness strategies should be targeted to key stakeholders, including political leaders. These strategies can include:
    - Workshops and conferences
    - Well-designed factsheets and other introductory materials
    - Maps of impact areas that highlight particular areas of concern
    - Websites and other tools
- Workshops and conferences work best when they are targeted to affected stakeholders, grounded in science, interactive and directly address concerns of participants.
- Recent extreme weather events can raise awareness of the issues of climate impacts and the necessity to plan. These can be especially motivating when the economic and human costs of these events are analyzed and presented.
- Visual tools can be an effective means of raising awareness about the potential impacts of climate change.

3.1.2 Engagement of Stakeholders and Decision-Makers

Several of the adaptation processes studied for this report included an effort to engage stakeholders on an ongoing basis. However, the role of stakeholders, their level of engagement and the persistence of their involvement varied substantially. This depended partly on who was driving the adaptation agenda and whether the primary goal was to produce an authoritative research report or to develop and implement a local adaptation agenda.

The Boston area research team provided three broad reasons for engaging stakeholders in climate change impacts assessment:

- There is "inherent democratic value" in including in a research project people who are affected by decisions based on that research.
- Stakeholders possess valuable knowledge that may be difficult to access otherwise.[7] Stakeholder involvement can also provide a means for "ground-truthing" assumptions, data and models that researchers use.
- Stakeholders may be more supportive of policy conclusions drawn from a project in which they have been involved (Kirshen et al 2005, p. 13).

For most of the cities in this study, raising awareness and engaging stakeholders was part of a continuum that started with a conference or workshops and then brought some participants into working groups. Most of these stakeholder working groups started with the relatively short-term goal of engaging stakeholders in a climate change impacts assessment. However, in at least one of the cities studied, the involvement of stakeholders in impacts assessment laid the groundwork for a more permanent stakeholder organization responsible for "mainstreaming" adaptation in the region.[8]

In New York, the researchers guiding the Metro East Coast climate impact assessment developed an explicit strategy for engaging stakeholders. The researchers identified six sectors particularly vulnerable to climate change and then paired researchers with public agencies that have responsibility for these sectors (Rosenzweig 2005). The partner for the study of impacts on water

[7] Stakeholders know much more about the systems that might be affected by climate change. Water managers know the specifics of available water resources, and projections in demand, for example. Staff in stormwater management know the vulnerable locations for flooding. Public health staff can provide data on heat-related morbidity and mortality. Electrical utilities can predict energy demand in heat waves. These stakeholders are best placed to put together data on how extreme weather has affected operations in the past and what the costs were.

[8] "Mainstreaming" is a term used to describe the process of incorporating climate change risks and adaptation into planning and programs of agencies and sectors likely to be affected by climate change.

supply, for example, was the Southeastern New York Intergovernmental Water Supply Council, for example. For health issues, the partner was the New York City Department of Public Health (Rosenzweig and Solecki 2001).

The researchers also worked at engaging mid-level officials within those agencies. "It wasn't the top level people, who would just be sending assistants to those meetings. (We wanted) a mid-level stakeholder that would come to every meeting. That was essential for the integration. They would also interact with their sector team outside of those meetings, but showing up for those monthly meetings was the key thing for building the integration" (Rosenzweig 2005). Each of the researcher-stakeholder teams met regularly over a three-year period, during which they oversaw the development of reports for their sectors.

The Boston research team also had a planned stakeholder strategy. The researchers contracted with the Metropolitan Area Planning Council (MAPC), a regional planning agency, to coordinate stakeholder involvement across the 101 towns and cities that make up the Boston Metropolitan area. MAPC prepared a brochure to invite stakeholders to get involved. The brochure highlighted several recent extreme events and warned that more were expected under climate change, underlining the message "Pay now, or pay later" (Kirshen 2005). About 30 stakeholders participated in a Stakeholder Advisory Group that met several times during the five-year project. Individual members of the group also provided input for the sectoral assessments and critiques of the sectoral analyses (Kirshen et al 2004). For the most part, these stakeholders were already concerned about climate change when they joined the project.

These stakeholders were not consistently involved, however, especially in the last two years of the project, when the final report was in preparation. Martin Pillsbury, an MAPC official involved in the project, observed that the initial outreach was good, but plans for later outreach ran out of funds. He also argued that interest fell off because the study was heavily based on technical modelling that few stakeholders understood. By the time the report was completed, "momentum and resources were gone" (Pillsbury 2005). The lead researcher for CLIMB told us: "The grant was not to get Metropolitan Boston to **do** adaptation. If it had been that, we would have involved people differently. We got enough feedback to keep the scenarios realistic, but not enough involvement to get things implemented" (Kirshen 2005).

London was better able to involve stakeholders over the long term. The London Climate Change Partnership (LCCP) was established in 2001 to involve stakeholders in a study of climate change impacts on Greater London, and to outline strategies to reduce the city's vulnerability. Though initiated by the Government Office for London, a regional office for the UK government, the

Greater London Authority took responsibility for the LCCP early on, providing a full-time staff person and other support for the partnership. A broad range of agencies participated in the early meetings of the LCCP, including local, regional and national government representatives, utilities, business organizations, environmental NGO's, climate research centre staff and others.[9] As plans for the study of climate change impacts developed, the partnership involved more stakeholders in:

- An initial workshop (70 participants from more than 50 agencies) to discuss and prioritize key impacts;
- Follow-up workshops and interviews on social, environmental and economic impacts of climate change on London;
- A stakeholder review of the draft report before its release.

When *London's Warming* was released, many stakeholder organizations continued to work with the Partnership, creating work groups to guide more detailed assessments and adaptation planning for specific vulnerable sectors. Over time, the LCCP morphed from a temporary group responsible for London's climate change impact study, to a more permanent organization with the aim of helping stakeholders integrate climate change into planning and decision-making.

This contrasts with the researcher-led processes in New York and Boston, where stakeholders scattered following publication of the initial report. Researchers in New York were able to continue climate change impacts and adaptation work with some individual agencies in the energy and public health sectors, but the impetus created by the ongoing interaction and engagement of a range of stakeholders has not been sustained.

[9] Five years later, many of these organizations are still involved. Between 15 and 20 representatives regularly attend bi-monthly meetings of the Steering Group, and another 10 participate occasionally (Tucker 2006).

Lessons on Engagement of Stakeholders

- Key stakeholders include municipal and regional government departments, transportation authorities, utilities, conservation authorities, and others.
- Engagement of key stakeholders is vital for understanding the specifics of how climate change may impact cities, for identifying practical adaptation strategies and for gaining support for implementing those strategies.
- Engagement of stakeholders often begins with an event designed to raise awareness and pique interest in climate impacts and adaptation. However, a plan for ongoing engagement of stakeholders after the event is also necessary.
- It is important to understand the general goals and concerns of stakeholders and to investigate the way in which climate change could affect these.
- While sign-off from senior management is important, ongoing engagement may be more successful with mid-level stakeholders who are more likely to be consistent in their participation in the adaptation process, and therefore likely to develop a better understanding of impacts and adaptation strategies.
- Regular communications and meetings are required for sustained stakeholder engagement.
- Stakeholder engagement can be time consuming and costs money. Allowance for the use of staff time and adequate funds are essential for successful and sustainable stakeholder involvement.
- Processes that are overly focused on technical modeling issues and reports written in technical jargon will reduce stakeholder engagement.
- Researcher-led adaptation initiatives are in danger of coming to an abrupt end when funding is over. For these initiatives to go beyond research to action, it is important that stakeholders take ownership of the process.

3.2 CLIMATE CHANGE IMPACT SCANS & ASSESSMENTS

Three of the six cities studied for this research undertook comprehensive climate change impact assessments for their regions to provide the information and analysis needed for developing an adaptation strategy.[10] In order of publication, these reports are:

- ***New York*** – *Climate Change and a Global City: An Assessment of the Metropolitan East Coast Region*, 2000 (generally referred to as the MEC Assessment)
- ***London*** – *London's Warming*, 2002
- ***Boston*** – *Infrastructure Systems, Services and Climate Change: Integrated Impacts and Response Strategies for the Boston Metropolitan Area* (also known as Climate's Long-term Impacts on Metro Boston or CLIMB), 2004

The London study cost about £50,000 (approximately $120,000 in Canadian dollars), but some researcher time was donated (Chell 2005). *London's Warming* was completed in about two years. By contrast, the Boston study of climate impacts on infrastructure cost more than $800,000 US ($950,000 in Canadian dollars), took almost five years to complete and was less effective in motivating action.

Less comprehensive scans and issues papers were produced for the other three cities included in this study. These include:

- ***Halifax*** – *Adapting to a Changing Climate in Halifax Regional Municipality: Issues Paper*, 2005
- ***Seattle/King County***[11] – *Climate Impacts on Washington's Hydropower, Water Supply, Forests, Fish, and Agriculture*, 2005
- ***Vancouver*** – *Climate Change and the Greater Vancouver Regional District*, 2000 (12 pages), and *Climate Change Impacts and Adaptation Strategies for Urban Systems in Greater Vancouver*, 2003 (a preliminary assessment by the Sheltair Group).[12]

[10] The Boston report was actually limited to impacts on infrastructure, but since this was broadly defined, the report was almost as comprehensive as the others.
[11] A variety of studies of climate impacts on specific sectors have been done for the region, but most do not have an urban focus. One exception is a 2005 report prepared by the Office of City Auditor for the City of Seattle, *Climate Change Will Impact the Seattle Department of Transportation*.
[12] This report was a preliminary assessment of impacts and adaptation strategies based on data and analysis generated for cities[PLUS], a 100-year sustainability plan for Greater Vancouver.

Two of the comprehensive reports were begun as the result of processes that had been initiated nationally. The MEC Assessment for the New York region was one of 18 regional assessments undertaken as part of the National Assessment of Climate Change Impacts on the United States, initiated in 1997 and funded by the US government. Of all the US regional assessments, however, the MEC Assessment was uniquely focused on urban issues.

London's Warming also resulted from a national process, led by the United Kingdom Climate Impacts Programme, established by the national government in 1997 to promote and coordinate research on the impacts of climate change. UKCIP encouraged the development of stakeholder groups in all regions of the country to undertake scoping studies on the likely impacts of climate change in their regions. The London Climate Change partnership was formed in 2001 to do this work for the Greater London area.

The CLIMB report for the Boston area was a research project led by academics from local universities and funded by a US EPA grant program. The project, which took five years, was designed to provide quantitative data on how infrastructure is affected by climate change.

The Halifax issues paper had a very different beginning. It was the brainchild of a private sector consortium of east coast environmental consultants with experience in international adaptation work. The consortium approached the Halifax Regional Municipality and together they were able to secure funds to develop a climate action "toolkit" that includes a climate change risk management plan and adaptation strategies for affected sectors, as well as the Issues Paper for Halifax that reviewed the vulnerabilities of the region to climate change (Dillon Consulting et al 2006).

The impact assessments had different levels of stakeholder involvement. The London and New York studies appear to have involved stakeholders most. In the case of London, stakeholder representatives had an oversight responsibility through the London Climate Change Partnership, and more were consulted during the research. In the case of New York, stakeholders were involved in regular meetings to discuss the assessment as it progressed for different sectors. As will be seen later in this paper, this engagement of stakeholders at the level of the impact assessment appears to have helped some government departments and agencies to begin incorporating climate concerns into planning and programs.

Almost all the reports reviewed:

- current conditions and stressors for the urban systems for which climate impacts were investigated,
- historical and current climatic trends in the region,
- climate change scenarios for the future, and
- key expected impacts of climate change on a variety of sectors for the city or urban region.

3.2.1 Current Conditions and Stressors

Although varying in level of detail, all of the comprehensive reports analyzed current physical, demographic, economic and social features of their regions, to set the stage for discussing how climate change may affect specific local conditions and produce significant impacts. The authors of these reports emphasized that climate change is one stressor among many that urban systems have to deal with. Population pressures, historic underfunding of infrastructure and other factors may be of larger concern to stakeholders. All the researchers indicated the need to understand how climate change might interact with current urban pressures.

London's Warming, for example, included a brief description of current conditions and stressors for most of the systems it assessed for climate change impacts. The transport section of the report pointed out that London is a national and international hub for road, rail, air and shipping. Each workday 466,000 commuters enter the city centre (LCCP 2002). Some roads are approaching gridlock and the Underground and National Rail network are overcrowded, uncomfortable and subject to equipment failures. Increased summer heat could cause a shift in transport mode and intensify pressures on the roads. Flooding and other extreme weather events could result in costly disruption of the transport system.

The New York study provided the most detailed information about current conditions and stressors on six urban systems susceptible to climate change impacts: coasts, wetlands, water, energy, infrastructure and health In addition to text that details existing concerns and vulnerabilities in each sector studied, the MEC Assessment developed maps that show land use, coastal elevations, vegetation cover, thermal patterns and other characteristics of the region. The researchers used this information to analyze areas that are particularly vulnerable to flooding, hot weather and other impacts of climate change.

In addition to describing various physical characteristics of the region, the MEC Assessment reviewed the current economic and social conditions of the region.

The authors stressed the importance of New York as an international financial centre, for example, and pointed out "any significant disruption to the communication and transportation systems can have dire economic consequences, not only locally, but also nationally and globally" (MEC Assessment Synthesis 2000, p. 9). Existing stressors include urban sprawl that has resulted in build-out into flood-prone areas and coastal locations. New York's dense development also contributes to a substantial urban heat island effect. The New York report emphasized the problem of inequity among the region's residents, and the particular vulnerabilities of the poor. These features and others foreshadow some of the susceptibilities of the urban region as it begins to feel the impacts of climate change.

The CLIMB team aimed to provide plausible cost estimates of climate impacts on Boston area infrastructure systems. As a result, the team gathered considerable data on current socioeconomic conditions, land-use patterns and infrastructure services to provide a baseline. They also used existing demographic and economic forecasts to project future demands on infrastructure (water, energy, roads and public health) and to better assess future vulnerabilities. In order to capture local variations in impacts such as flooding, the team defined and analyzed seven sub-regions within Metropolitan Boston, which differ depending on their proximity to the coast, population density, and socioeconomic characteristics.

3.2.2 Historical Climate Trends

All the comprehensive impact studies provided information on regional temperature and precipitation trends over the previous 50-100 years. Some of the study teams included climate scientists, who were able to analyze regional climate trends in some detail. The London report, for example, analyzed a broad range of variables and identified a number of important weather trends for the London region. (See Table 1.)

The kind of detailed review of current climate trends undertaken for *London's Warming* was very useful in drawing the attention of stakeholders to weather patterns that are already of concern, and set the stage for the next level of analysis – future weather scenarios under climate change.

Table 1: Historical Climate Trends Analyzed for *London's Warming*[13]

Climate Indicator	Recent Trend
Air temperature	▪ Risen by 0.6°C since 1900's ▪ Warmest years on record occurred after 1989 ▪ Fewer cold free days & longer frost free season ▪ Growing season +30 days since 1900's
Rainfall	▪ Decreasing summer rainfall since 1900's ▪ Increasing winter rainfall over 150-200 years ▪ Two of three driest summers were 1995 (1st) and 1976 (3rd) ▪ Two of three wettest winters were 1989/90 (2nd) and 1994/95 (3rd) ▪ More winter rain days & longer wet spells since 1960's ▪ Heavy storms contribute more to winter total rainfalls since 1960's ▪ Lighter, more frequent summer storms.
Snowfall	▪ Fewer snowfall events & smaller snowfalls since 1960's
Gales	▪ Record wind speeds in 1987 & 1990 ▪ No long-term trend but cluster of severe gales in the 1990's
Evaporation & relative humidity	▪ Increases in potential evaporation in all seasons, but especially spring & autumn ▪ Decline in summer relative humidity since 1920's
River flow	▪ No trends linked exclusively to climate ▪ Increases in number of high flows in last 30-50 years
Tidal levels	▪ High tide levels rising by 6 mm/year ▪ Frequency of Thames Barrier closure increased in 1990's
River water quality	▪ Water quality reflects fluctuations in rainfall intensity & river flow volume ▪ Droughts in 1989-91/1995-97 led to deterioration in water quality ▪ River water temperatures rising in the Thames ▪ Combined sewer outflows severely deplete oxygen levels following summer storms
Air quality	▪ Air quality below standards in many parts of London due to traffic emissions ▪ Weather patterns strongly affect ambient pollution levels

[13] Excerpted from *London's Warming*, pages 35-36.

Historical trend information shows climate shifts that are already occurring in the urban regions studied. All the reports showed significant warming trends – overall increases in temperature, greater numbers of hot days, and longer growing seasons. Precipitation trends were typically more difficult to decipher, though some of the studies reported seasonal changes in precipitation, and in the incidence of heavy precipitation events. Charts from the MEC Assessment, which show New York area trends for average temperature and precipitation, are shown in Figures 2 and 3, below.

Figure 2: Changes in Average Temperature, Metropolitan East Coast Area of the United States, 1900-2000[14]

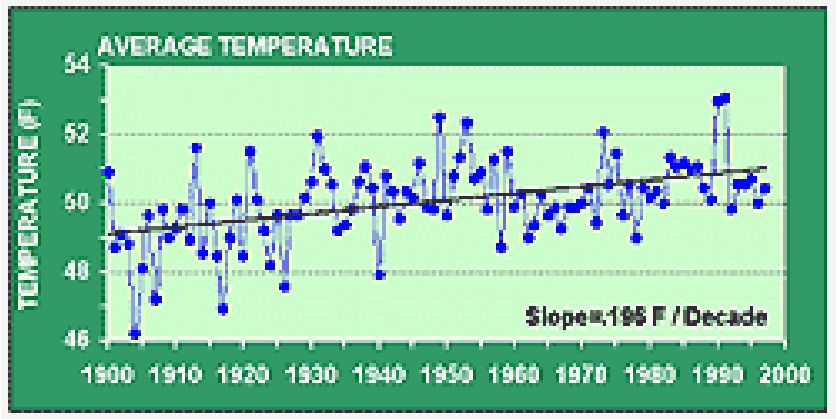
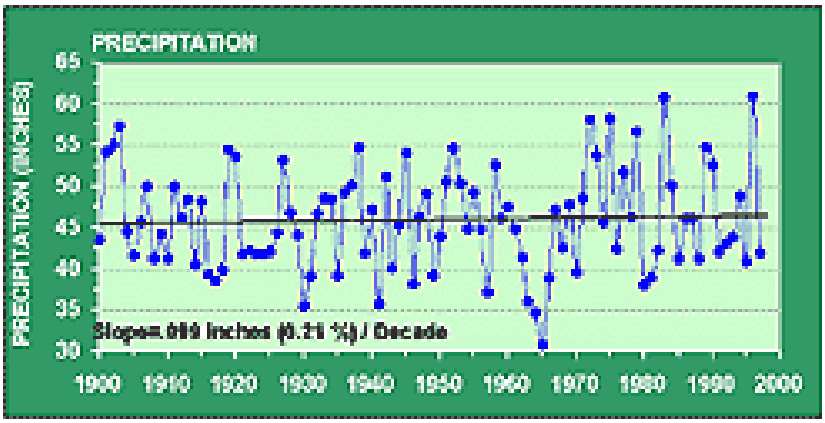


Figure 3: Changes in Precipitation, Metropolitan East Coast Area of the United States, 1900-2000[15]



[14] From Rosenzweig and Solecki, 2001 p. 11
[15] From Rosenzweig and Solecki, 2001 p. 13

3.2.3 Climate Change Scenarios

As would be expected, the impact assessment reports for the cities studied all include a key section on climate predictions for the future, drawing on climate models by the Canadian Climate Centre and Britain's Hadley Centre. All the reports point out that we are committed to climate change as a result of greenhouse gases that have already been emitted to the atmosphere. However, the extent of change will also depend on emissions to come. Continuing high levels of emissions will accelerate climate change; lower levels of emissions will reduce it.

Because we don't know what the emissions will be, there is uncertainty about the extent of the impacts to come.[16] Most of the reports deal with this by incorporating a range of emissions scenarios and providing an estimated range of changes in temperature, precipitation, sea-level rise and other effects that are expected to occur in the next century. This is important information for those doing planning now for buildings and other infrastructure investments that are expected to last 50 to 100 years.

The New York, London, Boston and King County reports all incorporated some downscaled projections, which allowed them to be more specific in their future weather predictions for their regions.[17] Climate change will vary from place to place, depending on local and regional features such as elevation, proximity to mountains or large bodies of water, and other factors. If climate change is to be taken into account in planning long-lived infrastructure and other urban services then it is important to have as clear a picture as possible of regional climate change patterns. Regional "downscaling" of global climate reports can produce finer-scale predictions for climate change that take local weather data and geography into account.

London's Warming, for example, outlines two sets of regional climate change predictions for the 2020's, 2050's and 2080's, based on a low emissions and high emissions scenario. (See Table 2, below.)

[16] Other factors also contribute to uncertainty, including ocean currents and interactions between vegetation and atmosphere that we don't completely understand (Casola et al 2005).
[17] The Halifax issues paper showed some downscaled predictions for several Nova Scotia towns, but not for Halifax.

Table 2: Climate Changes for Greater London under Low and High Emissions Scenarios[18]

Variable		2020's		2050's		2080's	
		Summer	Winter	Summer	Winter	Summer	Winter
Temperature (°C)	Low Emissions Scenario	1 to 1.5	0.5 to 1	2 to 2.5	1 to 1.5	2.5 to 3	1.5 to 2
	High Emissions Scenario	1 to 1.5	0.5 to 1	3 to 3.5	1.5 to 2	>4.5	3 to 3.5
Precipitation (%)	Low Emissions Scenario	-10 to -20	0 to 10	-30 to -20	10 to 15	-30 to -20	10 to 15
	High Emissions Scenario	-20 to -10	0 to 10	-40 to -30	15 to 20	<-50	25 to 30
Wind speed (%)	Low Emissions Scenario	0 to 1	1 to 2	0 to 1	2 to 3	0 to 3	3 to 5
	High Emissions Scenario	0 to 1	2 to 3	0 to 2	3 to 5	0 to 3	7 to 9
Net sea level Change (cm)	Low Emissions Scenario	12		19		26	
	High Emissions Scenario	22		48		86	

This kind of regional data provides stakeholders with information that can help them think about the implications of climate change for their areas of responsibility and update infrastructure design codes and standards. Water agencies can use temperature and precipitation projections to explore potential impacts on water supply and demand. Building officials may use projected increases in wind speeds to assess the adequacy of local building requirements. Planners can look at projected sea level changes and see what impact these might have on new construction in low-lying coastal areas. Of course, each of these stakeholder groups may need more specific information in order to fully incorporate climate change into major policy or capital investment decisions, but the estimates provided by the climate scenarios can help them begin this process.

3.2.4 Impact Assessments

The climate change impacts assessments for the urban regions we reviewed flowed naturally out of their analysis of current local conditions and stressors, historical climate trends and climate change scenarios.

Potential climate change impacts vary from region to region and even within regions. The impacts of sea-level rise on coastal cities, for example, will depend on geologic subsidence in the area, prevailing winds and storm patterns, coastal landform, building and infrastructure development on the coast, existing flood

[18] Excerpted from LCCP 2002, page 45.

controls and other factors. Assessing climate change impacts on coastal cities needs an examination of all these factors.

Similarly, heat impacts in an urban region will depend on latitude, proximity to water, wind patterns, distribution of tall buildings, and extent of hard surfaces, tree canopy, automobile use and air conditioning. The age, health and social conditions of local residents will also be factors in assessing the heat impacts of climate change.

Several of the cities and urban regions we studied did a preliminary review of vulnerable areas for climate impacts, chose several areas for study, and then investigated them in more depth. The sectors studied for each region are outlined in Table 3 on the next page.

Each of the studies had interesting features that may be worth replicating by other cities. The London study examined the broadest array of impacts. The researchers investigated typical areas of impact – on water resources, flood risks, energy use, health, etc. – but also included impacts that few other studies probed. These included possible climate change impacts on: lifestyles and consumption, London's historical and cultural legacy, crime and security, environmental business, and tourism and leisure. Some of the impacts were convincingly described, as the researchers were able to draw on considerable previous research and analysis that they could apply to London. Some of the descriptions of potential social and economic impacts were more speculative.[19] The LCCP has treated *London's Warming* as a preliminary assessment of impacts, and has gone on to commission additional in-depth impacts assessments for several key sectors, including transport, building development and the financial sector.

The MEC Assessment for the New York area analyzed six sectors where climate change is expected to have major impacts: water, energy, health, coastal infrastructure, health and transportation. Each sector was investigated by a team of researchers with the help of associated stakeholders from each sector. The narrower focus of this study, combined with a bigger budget and longer time-line allowed the New York researchers to investigate each sector in more depth than the initial London study. The infrastructure sector report, for instance, was able to project and map flood risks from storm surges heightened by sea-level rise, and to pinpoint at-risk bridges, tunnels, subways and highways, as well as to estimate the costs of related damages (Jacob 2001).

[19] The social impacts chapter, for example, included segments describing possible impacts on education, lifestyles and consumption and on city cleanliness, where the suggested climate impacts were quite tenuous.

Table 3: Climate Change Impacts Assessments in Six Cities/Regions

City	Sectors Investigated								
	Water Resources	Energy Demand &/or Supply[20]	Transport	Buildings/ Housing	Ecosystems (Wetlands and other)	Coastal Impacts/ Flooding	Health (Heat, Air Quality, Infectious Diseases)	Social Impacts/ Vulnerable Groups	Others
Boston	√√√	√√√	√√√ (Roads only)			√√√	√√√ (Heat-related)		
Halifax	√	√	√		√	√	√	√ (Aboriginal)	Fisheries Forestry
London	√√√	√√√	√√√	√√√	√√√ (Urban green space	√√√	√√√	√√√	Many other sectors studied
New York	√√√	√√√	√√√		√√√ (Wetlands)	√√√	√√√	√√	Institutional decision-making
Seattle/ King County[21]	√√√	√√√	√√[22]		√√√ (Salmon)				Forestry Fisheries Agriculture
Vancouver[23]	√	√	√	√	√	√[24]	√	√	Several other sectors

Legend: √√√ - in-depth research & analysis
√√ - some original research & analysis
√ - brief description of expected impacts, based on existing information

[20] Most of the studies focused on energy demand changes as a result of climate change, and to a lesser extent the potential impact on electricity distribution. Seattle paid more attention to the impacts of climate change on energy generation through reductions in snowpack.
[21] This refers mainly to a study prepared for King County (Casola et al 2005). However, there have been independent studies of climate impacts on water resources, hydropower and transportation for Seattle.
[22] This assessment was not part of the King County study, but was an investigation of climate impacts on transportation carried out by the Office of City Auditor for the City of Seattle (2005).
[23] The assessment referred to here was carried out by The Sheltair Group, 2003.
[24] Taylor and Langlois (2000) briefly describe potential coastal impacts for the Greater Vancouver Regional District.

The MEC Assessment also included an interesting analysis of decision-making by public institutions and agencies with responsibilities for sectors vulnerable to the impacts of climate change, and examined the opportunities they had to incorporate adaptation to climate change into their activities, as well as the barriers that exist to doing so (Zimmerman and Cusker 2001).

The CLIMB study took a different approach. One of the goals of the Boston research was to provide cost estimates of the expected climate impacts and damages, and for alternative strategies to prevent or reduce these impacts. The researchers worked with three scenarios.

- **"Ride it Out"** – assumes that no adaptive steps will be taken to reduce the impacts of climate change, and that facilities or systems damaged by climate change are abandoned or rebuilt in a similar configuration.[25]
- **"Build Your Way Out**" – assumes that limited structural measures are taken to reduce climate-related damages, reinforcing sea-walls, for example, or arranging for water sharing from different jurisdictions to deal with water shortages.
- The **"Green"** Scenario – assumes pro-active implementation of innovative policies and technologies to prepare for and counteract adverse climate impacts. These might include floodproofing to reduce damage from sea-level rise or intense storms; tree-planting and high-albedo roofs to reduce unsustainable energy demand on hot days and other measures (CLIMB 2005).

In the CLIMB report, this approach was fully developed only for coastal flooding impacts. The cost estimates for the three types of response to sea-level rise in the Boston metropolitan areas are shown in Table 4, on the next page.

The approach provided a challenging task for the researchers, who had to:

- Develop detailed local climate projections;
- Determine how the projected climate changes might impact on the sectors under study (water, energy demand, road transportation, etc.);
- Estimate the costs of these impacts;
- Determine what would constitute a "build your way out" or "green" response;
- Estimate the costs of these responses, including damage that these actions might not be able to prevent; and
- Compare the results.

[25] Other commentators refer to this scenario as "business as usual." The term "ride it out" arose when an official responsible for the Boston Port Authority said that MassPort (which manages the Boston's seaport and low-lying airport) would "ride it out" when sea-level rise became a problem (Pillsbury 2005).

Table 4: Costs of Sea-Level Rise for the Boston Area (in millions of dollars US)[26]

Climate Event	Scenario	Residential Costs*	Commercial/ Industrial Costs	Emergency Response Costs	Adaptation Costs	Total
Moderate sea-level rise One event (flood)	"Ride it Out"	3,563	13,525	2,905	0	19,993
	"Build Your Way Out"	1,091	3,984	863	3,462	9,400
	"Green"	756	2,697	587	1,766	5,806
One metre sea-level rise Three events	"Ride it Out"	16,140	64,250	13,666	0	94,056
	"Build Your Way Out"	1,820	6,703	1,449	3,462	13,434
	"Green"	3,272	12,760	2,726	6.798	25,556

The impacts assessments for London, New York and Boston were all published in two forms: the original, detailed research reports and also summary reports that present the key results.[27] The detailed research report provided access to the data for interested stakeholders, but the production of a separate summary also supplied the main conclusions and recommendations to senior officials and the general public in a readable and attractive format – a good strategy for building awareness of climate impacts.

While it covered some of the same ground as the London, New York and Boston studies, the Halifax Issues Paper on Adapting to Climate Change took a risk assessment approach to evaluating climate impacts. The issues paper drew on existing studies to identify potential impacts on a wide variety of sectors and to estimate the probability of their occurrence and the severity of each impact on socio-economic and environmental systems. The researchers then applied a risk assessment matrix to target those impacts of greatest concern. For each impact they identified, the researchers estimated the severity of the likely impact and the probability of the impact. Impacts with a high level of severity and a medium or high level of probability were assessed as high-risk (H), and prioritized for further investigation, as were impacts with a medium level of severity and a high level of probability. See Table 5, below.

[26] Excerpted from the CLIMB study (2005), page 67.
[27] The Boston summary was actually prepared by the National Environmental Trust, a non-profit organization dedicated to getting important environmental information into the public domain.

Table 5: Risk Assessment Matrix (Dillon Consulting et al, 2005, p 52)

	PROBABILITY			
IMPACT SEVERITY		LOW	MEDIUM	HIGH
	HIGH	M	H	H
	MEDIUM	L	M	H
	LOW	L	L	M

Priority impacts were then subject to a more detailed risk evaluation, as shown in Table 6 on the following page.

As a result of the analysis illustrated in Table 6, the Halifax researchers were able to identify 18 high-risk areas of impact. These are indicated by the red "H" in the last column of Table 6.

For each of these high-risk areas of impact, the researchers recommended an initial set of responses to better monitor and inventory vulnerable areas, and to evaluate adaptation options. They also identified the agencies that would logically have the responsibility and authority for implementing these responses.

Table 6: Risk Evaluation Tabulation (Dillon Consulting et al, 2005)[28]

Impacts	Probability/ Frequency of Event	Consequence (Impact Severity)	Socio-Economic (S) & Environmental (E) Risk Levels	Integrated Risk
Communities/Infrastructure/Transportation				
a) ***From more frequent extreme weather events***				
▪ Flooding	M	H_S M_E	M_S M_E	M
▪ Insurance & property values	H	H_S M_E	H_S L_E	**H**
b) ***Impacts on settlement patterns & land-use planning***				
▪ Extreme events, sea level rise & surges	H	H_S H_E	H_S H_E	**H**
▪ Coastal ice damage	L	L_S L_E	L_S L_E	L
c) ***Impacts on transportation***				
▪ Infrastructure & patterns	M	H_S L_E	H_S L_E	M
▪ Cost of maintenance (extreme events)	M	M_S L_E	M_S L_E	M
▪ Port operations	H	H_S L_E	H_S M_E	**H**
d) ***Impacts on buildings & building code criteria***				
▪ Extreme events	H	H_S L_E	H_S L_E	**H**
Water Resources				
b) ***Impacts on water supply***				
▪ Energy/hydropower	M	M_S M_E	M_S M_E	M
▪ Domestic supplies	M	M_S M_E	M_S M_E	M
▪ Agriculture	H	M_S M_E	H_S M_E	**H**
Coastal Zones				
a) ***Impacts on coastal wetlands/ecosystems***				
▪ Sea level rise/surges	H	H_S H_E	H_S H_E	**H**
c) ***Impacts from flooding***				
▪ Sea level rise/surges	H	H_S H_E	H_S H_E	**H**
c) ***Impacts on human settlements & coastal infrastructure***				
▪ Sea level rise/surges	H	H_S H_E	H_S H_E	**H**

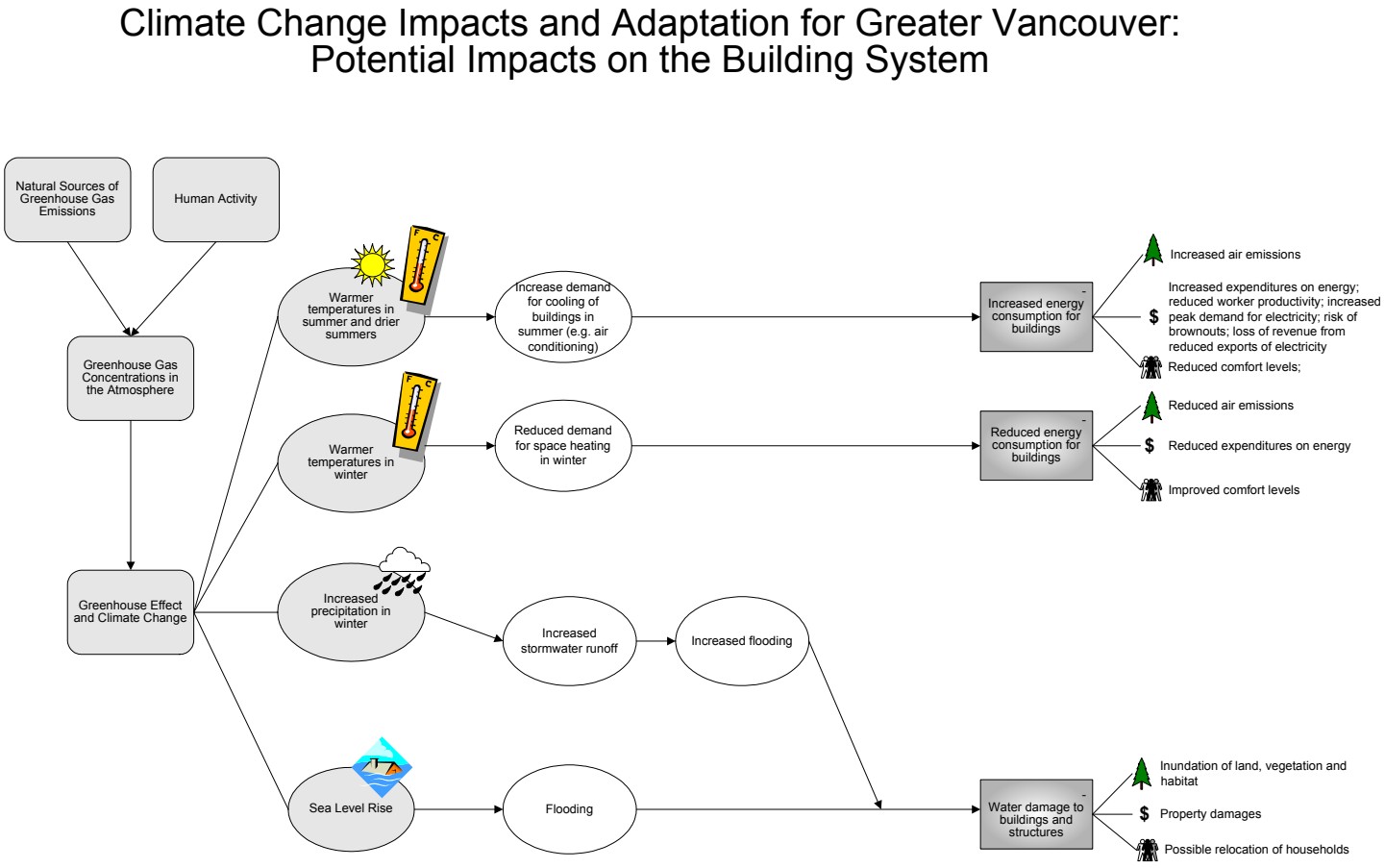
[28] Excerpted from a much longer table on pages 53-56, Dillon Consulting et al, 2005.

The Sheltair Group's review of climate change impacts and adaptation strategies for Greater Vancouver provides an overview of expected impacts on 13 urban systems (The Sheltair Group 2003). For each system – buildings, economic development, energy, health, human security, land use, etc. – Sheltair developed a summary of both positive and negative impacts identified to date. They also produced a series of "influence diagrams" for each urban system investigated. These diagrams are useful for calling attention to the sequence of events that starts with increased greenhouse gases in the atmosphere, consequent changes in temperature, precipitation and extreme weather, which lead in turn to various downstream effects.

Sheltair prepared two influence diagrams for each urban system investigated. The first diagram illustrates the ways in which climate change produces impacts on the urban system under study. The second diagram illustrates how adaptation strategies can be introduced at various points to reduce these impacts. Two of these diagrams have been reproduced as Figures 2 and 2 on the next two pages of this report.

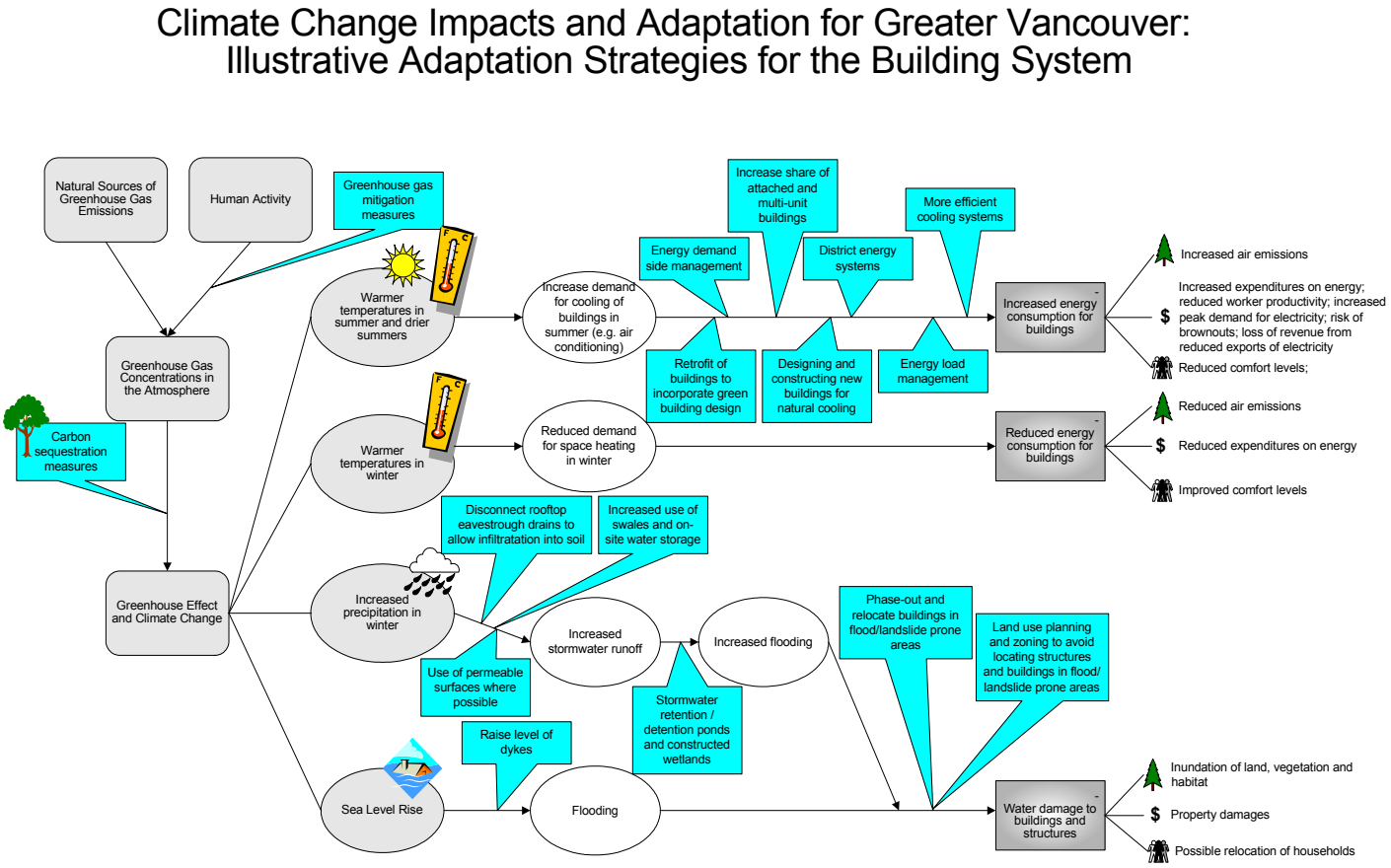
The Climate Impacts Group (CIG) at the University of Washington also prepared an assessment of climate impacts for the King County conference *The Future Ain't What It Used to Be: Planning for Climate Disruption* (Casola et al, 2005). The focus of the assessment was not specific to urban impacts, though it did look closely at effects on electricity generation, water supply, and flood and stormwater management, which are major concerns for most cities. The report showed that warming trends are already reducing snowpack, which Seattle and the surrounding region depend on for water and for hydropower in the summer months. The CIG highlighted the potential for increasing competition over water use for hydropower production, in-stream flows (to protect salmon ecosystems) and irrigation.

Figure 4: Influence Diagram of Showing Climate Change Impacts[29]



[29] Original graphic from The Sheltair Group, Climate Change Impacts and Adaptation Strategies for Urban Systems in Greater Vancouver. Volume 2. page 5. Reproduced with permission. The rounded rectangular boxes show the primary drivers of climate change at the global scale. The shaded ovals are the relevant regional manifestations of climate change. The ovals and boxes to the right of the shaded ovals represent the chains of influence that eventually have an impact on an urban system and its inhabitants.

Figure 5: Influence Diagram with Adaptation Options[30]



[30] Original graphic from The Sheltair Group, Climate Change Impacts and Adaptation Strategies for Urban Systems in Greater Vancouver. Volume 2. page 6. Reproduced with permission. The turquoise callout boxes show were interventions can occur to reduce the impact. The further to the left that the intervention occurs, the more preventive the strategy.

Lessons about Climate Change Impacts Scans and Assessments

- There are several options for analyzing and communicating information on climate change that could be helpful to urban decision-makers, including:
    - Overview scans of impacts based on existing data, taking into account local or regional variables (Halifax, Greater Vancouver, King County)
    - In-depth studies of specific vulnerable urban sectors such as water, energy, transportation, health, etc. (Boston, London, New York)
    - Costing of impacts under do-nothing, reactive and pro-active/ "green" strategies (Boston)
    - Risk evaluation to identify priority impacts for further investigation and action (Halifax)
    - Use of influence diagrams to demonstrate the sequence of changes leading to climate impacts (Sheltair for Greater Vancouver)
- A group of researchers and informants knowledgeable about climate change and about sectors expected to be vulnerable is essential for an in-depth study.
- Involving stakeholders helps ensure that research is useful to them and that data and assumptions about specific urban sectors or systems are correct.
- Impact assessments should explore how climate change will interact with current stressors.
- Historical climate trend data can demonstrate the direction that climate change may already be taking. Analyses of extreme events and variable weather in the recent past may be very useful for understanding expected future impacts.
- Future climate projections should include regionally downscaled information on expected climate changes. Projecting changes for the years ahead (typically 2020, 2050 and 2080) can be useful for decision-makers planning capital projects that are expected to last many decades.
- Descriptions of impacts should include information not only on physical and environmental systems (buildings, roads, transmission lines, sewage infrastructure, urban wetlands, etc.) but also on economic and social sectors.
- Climate change that impacts on forests, agriculture or fisheries in nearby rural areas will likely have economic and social impacts on an urban centre, even if they do not directly impact a city, and may need to be considered as part of an urban impacts assessment.
- Information that is presented visually and graphically can help decision-makers more readily comprehend the implications for their sectors.
- Credible information on the costs of inaction vs. the costs of adaptation may provide a spur to action.

3.3. IDENTIFYING AND REVIEWING ADAPTATION OPTIONS

3.3.1 Identification of Adaptation Options

Most of the reports discussed previously identified a range of adaptation options to reduce vulnerability to climate change impacts in the region. For the most part, the discussion of adaptation options was fairly generic and preliminary, with options drawn from the existing adaptation literature and from the input of stakeholders. *London's Warming*, for example, provided a brief two-page summary of adaptation options near the end of a 233-page report. The Sheltair Group referred to the options they outlined for Greater Vancouver as "illustrative" adaptation strategies. The Halifax report limited its discussion of options mainly to recommendations for further monitoring and research, in order to better pinpoint vulnerabilities and assess adaptation measures.

Though the initial identification of adaptation options was fairly generic, several of the cities studied have followed up with more in-depth studies of vulnerable sectors, and developed, or are in the process of developing more specific and targeted adaptation options for these sectors within their urban region. The London Climate Change Partnership, for example, has developed more specific recommendations and guidelines for adaptation options for London Transport (LCCP 2005b), buildings (Three Regions Climate Change Group 2005), and the financial sector (LCCP 2006b).

In most cases stakeholders have either been involved in identifying adaptation options, or in discussing the local applicability of suggested options and the costs and barriers to adopting them.

The adaptation options identified for various urban sectors in the cities studied for this report fall into several categories:[31]

[31] There are several typologies of adaptation options in the existing literature, none of which fully captured the range of options identified by the cities studied in this report.

3.3.2 Precursors for Adaptation Action

1. Education for the public and stakeholders about potential risks and building the capacity to respond, e.g.

- Education for the general public on the risks of building or acquiring homes in coastal zones vulnerable to sea-level rise and storm surges (recommended by MEC Assessment)
- Guidance for private and public sector developers on incorporating climate change into planning and development decisions (Three Regions Climate Change Group 2005)

2. Research and monitoring to better pinpoint likely impacts and prioritize adaptation efforts, e.g.

- Inventories of vulnerable infrastructure systems such as culverts, bridges, low-lying roads and airports, stormwater outfalls, surface water intakes or transmission lines (recommended by the MEC Assessment)
- Catalogue of historic storms, coastal flood heights and extents, and associated damages (recommended by MEC Assessment)
- Extensive network of sensors to provide real-time data on precipitation (undertaken by Seattle Public Utilities)
- High resolution topographical mapping to better identify areas at risk of flooding (recommended by Halifax report)
- Thermal imaging to identify urban "hotspots" for prioritizing cooling programs (recommended by *London's* Warming)

3.3.3 Adaptation Options to Reduce Vulnerability

3. Interventions to reduce existing pressures on urban systems vulnerable to climate change, e.g.

- Conservation and demand management programs to reduce demand for water in the face of declining snowpack (recommended for Seattle and Greater Vancouver)
- Energy conservation and efficiency programs to reduce summer electricity loads and limit risk of blackouts (recommended by *London's Warming* and the MEC Assessment)
- Investment in green spaces, street trees, green roofs, and high-albedo surfaces to reduce heat impacts (recommended by Rosenzweig *et al* 2006, in a follow-up to the MEC Assessment)
- Weatherization programs for low-income housing (recommended by the MEC Assessment)

4. Interventions to increase the resilience of urban systems in the face of extreme weather, e.g.

- Diversified local sources of electricity to reduce dependence on centralized generation and vulnerable transmission lines (recommended by the Sheltair report for Greater Vancouver)
- Interconnecting regional systems of water supply or hydropower to provide backup for changing regional conditions (suggested in MEC Assessment and King County)
- Home elevation program to protect houses in flood zones (in place in King County)

5. Creation of buffer zones or relocation programs to protect vulnerable urban systems, e.g.

- Consider establishing green zones/parks in low-lying areas of new developments, for flood management (London)
- Designating coastal hazard zones, establishing erosion setback requirements, and limiting development in high hazard coastal zones (recommended by MEC Assessment coastal study)
- Relocation of vulnerable transportation lines (discussed in the Halifax report)

6. Actions to fortify vulnerable structures and systems, e.g.

- Design standards for stormwater infrastructure that take into account likelihood of more intense rainstorms (recommended by the MEC Assessment water report)
- Construction or reinforcement of seawalls, dykes and other flood control systems
- More onerous requirements for bridges subject to scour (discussed in the CLIMB report)
- Construction of additional power plants, transmission lines to keep up with demand (discussed in the MEC Assessment and CLIMB report)

7. Forecasting and early warning systems, e.g.

- Forecasting and public communications systems for storms, heat, smog, high winds, water shortages, etc.
- Education about vector-borne diseases to counteract outbreaks and/or increased incidence associated with warmer winters (discussed in the Halifax report)

8. Emergency response systems, e.g.

- Improving and coordinating emergency planning and response for expected climate change impact events such as heat waves, extreme weather, flooding, etc.
- Alternative transportation routes and systems (recommended by the CLIMB report for Boston)
- Protective reconstruction programs after extreme events (such as the Flood Buyout and Home Elevation Plan in King County)

Most of the impacts and adaptation reports for the urban centres studied did not suggest a preference for specific types of adaptation options. However, the CLIMB report for Boston did make the case that proactive, "green" strategies were preferable to fortification strategies or to rebuilding once climate impacts had hit.

The Sheltair Group also made the case that more preventive adaptation options (e.g. options to reduce the urban heat island effect) are more protective than reactive options (heat alert and response systems).

For the most part, the cities studied identified adaptation options by sector, rather than by type. Some of the sectoral options that these cities identified are outlined in Table 7 on the next two pages.

Table 7: Some Adaptation Options Identified by Six Cities/Urban Regions[32]

SECTOR or SYSTEM	ADAPTATION OPTIONS

Water Supply	▪ Conduct baseline monitoring and inventories for:
	  o Water resources
	  o Condition & capacity of water distribution and treatment systems
	  o Number, size & location of businesses with high water demand
	▪ Implement enhanced conservation & demand management programs to counteract increased water demand and potential decrease in supply, e.g.
	  o Leak identification & repair
	  o Metering and increased water prices
	  o Efficiency standards for appliances
	  o Xeriscaping
	  o Restrictions in periods of drought, etc.
	▪ Develop additional reservoir capacity
	▪ Capture and reuse rainwater for irrigation and other uses
	▪ Reclaim and reuse grey water or water from sewage treatment (in place in King County)
	▪ Prepare plans to balance the needs of competing users when water availability is reduced

Stormwater/ Flooding	▪ Prepare high resolution topographic mapping to identify high risk areas
	▪ Implement sustainable urban drainage systems including:
	  o Permeable pavements
	  o Green roofs to increase on-site retention of stormwater
	  o Increased use of stormwater retention ponds, constructed wetlands and swales
	▪ Create natural eco-system buffers for vulnerable water bodies, low-lying areas
	▪ Expand capacity of storm sewers to manage extreme weather events
	▪ Institute land-use planning and zoning to avoid buildings and infrastructure in flood or landslide prone areas
	▪ Flood-proof buildings in vulnerable locations

Energy	▪ Expand conservation, energy efficiency and demand side management strategies to reduce demand on hydropower systems dependent on snowpack or vulnerable to drought, and to reduce peak loads during heat waves that make transmission systems vulnerable to blackouts ▪ Increase street tree planning and maintenance, green roofs and high-albedo surfaces to reduce urban heat and unsustainable energy demand for air conditioning ▪ Amend building codes to decrease energy needs for cooling ▪ Implement weatherization programs to reduce building loads, especially for low-income people ▪ Invest in distributed energy systems such as cogeneration, and local renewable energy systems to reduce vulnerability to transmission interruptions from storms and high winds ▪ Invest in increased power generation to meet peak demands
Transportation	▪ Assess opportunities to extend the winter shipping season ▪ Evaluate the vulnerability of port facilities and associated infrastructure due to changes in water level, increased wave activity, storm surges and ice pile-up ▪ Raise levels of dykes in areas vulnerable to flooding ▪ Relocate coastal roads, rail lines and other infrastructure subject to sea-level rise

[32] Note: this table does not provide a comprehensive list of adaptation options for these sectors.

Transportation Continued	▪ Assess and retrofit vulnerable transportation infrastructure systems such as culverts, tunnels, bridges, subway entrances, etc. ▪ Ensure critical components such as switch gear or substations are above flood levels ▪ Investigate transportation modal shifts (from subways to private cars, for example) in response to high heat ▪ Ensure alternative routes are available in case of disruption and/or need for evacuation
Buildings	▪ Take account of the increased risks of flooding, heat waves, intense storms, windspeed and other climate change effects on building developments ▪ Strengthen building code requirements to reduce heat gain in summer ▪ Design drainage systems and entrance thresholds to cope with more intense rainfall ▪ In areas with flooding potential, use ground-floor spaces for flood-compatible uses such as car parking, or raise the ground floor above likely flood levels ▪ Design buildings for improved natural ventilation ▪ Utilize green roofs to insulate against heat gain and reduce stormwater runoff ▪ Ensure roof systems and cladding materials can cope with higher wind speeds ▪ Increase use of swales and on-site water storage ▪ Use permeable surfaces wherever possible
Urban Ecosystems	▪ Protect existing ecosystems (parks, tree stands, waterways, ponds, lakes, ravines, wetlands, etc.) and develop connected greenway system to allow natural species migration ▪ Consider designation of coastal hazard zones and limits on development in high hazard areas ▪ Adopt erosion setback requirements ▪ Restrict new development in existing green spaces ▪ Create and protect green spaces in low-lying areas that might serve for flood management ▪ Increase shoreline buffers to protect against increased runoff from more intense storms ▪ Plant diverse trees species and shrubs with a broad range of environmental tolerance ▪ Enhance conditions for street tree survival and growth (increase space for roots, control soil compaction, increase watering and maintenance) ▪ Monitor and control pests and invasive species that can expand with warmer winters
Health	▪ Conduct public education on climate-related health threats (vector-borne diseases, heat, air pollution, floods and storms) and prevention ▪ Interventions to reduce heat island effects including: o Increased street trees and tree canopy coverage o Increased parks and green spaces o Green roofs o High albedo (reflective) building and road surfaces o Heat alert systems o Heat response systems (cooling centres, water distribution, etc.) ▪ Interventions to reduce air pollution impacts, especially emissions reduction measures including: o Traffic restrictions o Restrictions on processes and materials releasing volatile organic compounds o Improved public transport o Pollution warning system ▪ Interventions to prevent impacts from expansion of vector-borne diseases o Early detection and warning systems o Spraying to control infestations o Control of other factors that support the expansion of disease-carrying insects (e.g. standing water) ▪ Interventions to reduce health and security impacts from extreme weather events o Early warning systems o Flood protection systems (see Stormwater/Flooding section above) o Emergency response systems

3.3.4 Identification of Existing or Proposed Policies Synergistic with Adaptation

A quick review of the adaptation options in Table 7 reveals many measures that do more than reduce the impacts of climate change. Energy conservation and efficiency programs, for example, are introduced to reduce energy demand, lower costs and make buildings more comfortable as well as to reduce the potential of blackouts from overloaded transmission systems. Expanded tree planting is encouraged to improve urban aesthetics, reduce air pollution and stormwater runoff, provide shade and reduce ambient temperatures on hot summer days.

Because they address several concerns simultaneously, stakeholders may consider implementing adaptation options that are "worth doing anyway" despite uncertainty about impacts from climate change. However, concern about climate change and knowledge about potential impacts can strengthen the motivation for taking action and provide a rationale for speeding up implementation or expanding the scale of interventions that cities have already embarked on.

Seattle Public Utilities (SPU), for example, provides retail water service to Seattle, and wholesale water service to the surrounding region. Over the last several years, SPU has instituted water conservation programs that reduced water use from 171 to 150 million gallons per day.[33] Although snowpack, which supplies Seattle's water reservoirs, has declined 40-50% in the last few decades due to higher temperatures, the Drinking Water Program Manager told us that climate change was not a driver for the conservation programs (Kersnar 2006). Rather, the drivers for these programs were stewardship, stretching current water resources as far as possible, and reducing costs. However, water conservation is regarded as an "insurance policy" to reduce the severity of water supply problems under future climate change (Kersnar 2006).

The Greater Vancouver Regional District (GVRD) has taken a similar approach in some areas of responsibility, notably stormwater management planning. The Policy and Planning Department has noticed an increased frequency in intense rainfalls and sanitary sewer overflows in the last three years. Utility Analysis staff members are trying to assess this trend, but expect that five to ten years of data might be needed before they can justify a major investment in expanded sewer capacity (Hajducovic 2006). In the meantime, the GVRD has developed

[33] Have accomplished this through water metering, seasonal rates and tiered pricing (higher for larger quantities), plumbing fixture code, rebates for efficient toilets, and distribution of low-flow showerheads, among other initiatives.

leading edge stormwater control guidelines designed to minimize flooding from land development. A senior project engineer at the GVRD told the authors: "If stormwater is managed on site – by swales, permeable pavements, green roofs and other means – climate change will not be an issue" (Hicks 2006).

A recent New York study (Rosenzweig *et al* 2006) has provided an in-depth analysis of several options for reducing the urban heat island effect in New York City. This research provided the impetus for New York City's investment in the "Greening the Bronx" urban reforestation program, which is explicitly designed to serve several purposes, including:

- Reduction of summertime temperature increases (through shading and evapotranspiration)
- Reduction of cooling loads for buildings, thereby providing energy savings
- Improvements in air quality
- Creation of wildlife habitat
- Increase in property values, and
- Improvement in the quality of life for Bronx residents (New York Energy Smart 2006).

The OECD report on adaptation to climate change in developed countries suggests that, as part of the adaptation process, governments should assess the extent to which existing (or proposed) policies and programs are "synergistic with adaptation" (Gagnon-Lebrun and Agrawala 2006, page 27). Examples of such policies include:

- The implementation of local renewable energy systems that can operate when the grid goes down. Such systems reduce greenhouse gas emissions *and* vulnerability to blackouts.
- Expanding the urban tree canopy to reduce ambient heat and therefore the health risks related to heat waves as well as greenhouse gas emissions from air conditioning.

None of the cities we studied have done a systematic review of policies synergistic with adaptation, although our interviews with city officials revealed that they are aware of many synergies. Neither have these cities assessed whether existing measures are adequate to protect against the expected impacts of climate change.

A more systematic approach to the identification and review of adaptation options remains to be done in almost all the cities studied for this report. The UKICP report *Climate Adaptation: Risk, Uncertainty and Decision-Making*, provides a guide for a systematic approach that the Greater London Authority is using in

the development of a city-wide adaptation policy, due for release later in 2007 (Nickson, 2006). UKCIP (2003) suggests a number of questions that could guide decision-makers through a review of adaptation options, including:

1. ***What type of options should be considered?***
   (Education, more research, increasing resilience, fortification, emergency response, etc.)

2. ***What generic strategies have been identified by others?***

3. ***What are the likely consequences of the "do nothing" option?***

4. ***Can "no regret" and "low regret" options be identified?***

   No regret options would provide benefits in the present, as well as under future climate scenarios.

5. ***Can flexible options that allow for uncertainty be identified?***
   Some measures can be phased in over time in response to increasing risk, for example.

6. ***Is it urgent to make a decision now or is delay an option until further information is available?***

   Consider:

   - Expected climate changes over the lifetime of the system or structure under consideration
   - The extent of the risk
   - The value to be gained from improved monitoring or research.

Lessons about Identification and Review of Adaptation Options

- A preliminary set of options for many climate change impacts on cities can be identified from the broad literature.
- Most of these will require further study, to identify options that respond to the local effects of climate change.
- Increased monitoring of local climate systems (such as that occurring in Seattle and King County) can provide important information about **when** to act.
- There are a variety of types of options that need to be considered in responding to the potential threats of climate change. These include education, research and monitoring, reducing other pressures on urban systems that are vulnerable to climate change, fortification, and warning and emergency response systems.
- A systematic approach to identification of options, such as that recommended by UKCIP, would be of great value.
- Options identification needs the input of stakeholders who are often better positioned to identify both opportunities and barriers than outsiders.
- Increased monitoring of local climate systems and pilots of specific adaptation options may be necessary to identify the most appropriate options for a specific city or urban region.
- Many adaptation options may have significant co-benefits and may be advanced as "no regrets" options or "worth doing anyway."

3.4 ADAPTATION ACTIONS

The six cities/urban regions studied for this report are all in very different stages with respect to taking action on adaptation. London is the most advanced of the cities studied in its efforts to integrate climate change adaptation into policy, planning and programs. Seattle and King County have also taken steps to integrate adaptation into planning for several key urban systems. New York City is in the process of incorporating adaptation planning into two areas of concern: water management and heat island reduction.

On the other end of the spectrum, adaptation appears to have fallen off the agenda of the cities and towns of the Boston Metropolitan Region, despite a

major study of climate impacts that involved many stakeholders. Some planners and policy staff in Greater Vancouver are keeping an eye on climate change and its potential impacts, but at the time of writing this report, had not integrated adaptation planning into their work in a systematic way. And while Halifax area consultants and environmental staff have undertaken climate impact assessments, and have produced studies on integrating climate concerns and adaptation responses into land-use planning and environmental assessments, it is not clear whether the city government is ready to take action.

3.4.1 Establishment of Institutional Mechanisms

One of the most critical stages in the development of adaptation processes in cities is to establish institutional mechanisms for taking the process forward. While it is too early to assess which institutional mechanisms are likely to work best, the experience to date suggests a need for the following:

- An ongoing process to bring stakeholders in city government and related organizations together to learn the latest information on climate impacts and to discuss adaptation options and strategies;
- Guidelines to integrate climate concerns and adaptation into decision making;
- Dedicated staff; and
- Funds for research and analysis, workshops and other activities.

London has established two complementary processes on adaptation. The London Climate Change Partnership is one of these processes. The LCCP was formed in 2001 and includes representatives from the central and local governments, utilities, transportation and public health agencies, emergency management, environmental consulting firms and the United Kingdom Climate Impacts Program, among others. The Partnership has defined for itself the following goals:

- To collect and disseminate high quality information on expected climate change impacts on London and adaptation options;
- To assist in developing London's Climate Change Adaptation Strategy (due out in 2007);
- To help stakeholders incorporate climate change into decision-making;
- To provide input into the London Plan and other plans and strategies;
- To engage the media; and
- To monitor London's preparedness for climate change (LCCP 2005).

The LCCP is chaired by a high-profile businessman, appointed to ensure that discussion of climate change issues occurs at the boardroom level (Bramwell

2006). A Steering Group of 15 to 20 members meets bimonthly and sub-groups are formed as necessary. A Transport Group oversaw research on climate impacts on London's transport system, for example. Other sub-groups have included a Planning and Development Group, an Olympics Group (to provide input into development of London's Olympic Park for the 2012 games), and a Finance Group. The LCCP has a full-time staff person, paid for by the Greater London Authority and reporting to the Mayor. The LCCP Manager is based in the Mayor's office and is part of the Environment Team (Tucker 2006).

The LCCP actively intervenes to insert climate change considerations into the discussion of long-term plans and policies at all levels of government. For example, the LCCP has publicly commented on the need to incorporate climate change impacts and adaptation considerations in: the UK Sustainable Development Strategy (2004), Regional Spatial Strategies (2004), Flood and Coastal Erosion Management (2005), UK Climate Change Program (2005), Code for Sustainable Homes (2006), the London Plan and planning for the London Olympics in 2012.

In addition to participating in and supporting the London Climate Change Partnership, the Greater London Authority in 2005 appointed a full-time officer to develop an overarching adaptation strategy for the city. The strategy is being developed in an interactive process with City staff and other agencies over a two-year period. Like the LCCP manager, the officer responsible for preparing the adaptation plan is based in the Mayor's office with other members of the Environment Team.

King County has also undertaken to develop an adaptation plan for the County. In late 2005, the King County Executive established a "strike force" to develop plans for tackling both climate change mitigation and adaptation efforts for the County. This group – now called the Global Warming Team – is led by the Deputy Chief of Staff, and meets every two weeks to coordinate research and planning for both mitigation and adaptation actions. The group includes representatives from the budget office, water planning, solid waste, air quality, parks, transportation, land-use planning and building codes, economic development, public health and executive services (which includes emergency management). They are charged with "reviewing every county business line, operation and capital plan to identify challenges and opportunities and to recommend concrete options for infrastructure and service adaptation" (Triplett, 2007). The Team reports to the King County Executive.[34]

[34] This team issued its plan too late for us to analyze it for this report. It can be accessed at: http://www.metrokc.gov/exec/news/2007/pdf/ClimatePlan.pdf.

In New York, there was no city-wide uptake of adaptation planning following publication of the MEC report. However, the NYC Department of Environmental Protection, which is responsible for water, sewage and stormwater for the City, created a Climate Change Task Force in 2003 with a five-year time-line to develop responses to climate change and climate variability (Major 2005). The Task Force involves representatives from seven departments, including those responsible for water supply, water and sewer operations and wastewater treatment. Approximately 25-30 DEP members are assigned to the Task Force. About 15 of these attend regular monthly meetings (Demong 2005). The Task Force works closely with climate researchers from Columbia University's Earth Institute. The Columbia scientists have developed regional climate models to forecast local impacts on New York's water system, undertaken case studies of previous extreme weather events to pinpoint vulnerabilities, mapped inundation zones and identified likely impacts on water supply and treatment facilities (Lloyd 2005). Engineering studies have been undertaken to develop new design criteria for sewage treatment facilities that take into account sea level rise and expected increases in storm surges. Both the DEP and Columbia have assigned coordinating staff to the work. The Task Force does not have a specific budget, but has been strongly supported by two consecutive Commissioners who have ensured that the group gets adequate resources (Major 2005).

The Task Force expects to release a report on its work in the near future. The report will include an analysis of likely climate impacts on New York's water system, an outline of issues for decision-makers to consider and a planning checklist. It is unclear whether the Task Force will continue its work when this report is concluded.

Although other New York City departments have not embedded climate change adaptation planning in their planning and programs to date, a new initiative may change that. In the fall of 2006, NYC established a new Office of Long-term Planning and Sustainability. The new office is tasked with: creating a plan for the City's long-term development; integrating sustainability goals and practices into that plan; and making New York City government into a "green" organization (Office of the Mayor 2006). Although the terms of reference for this Office don't explicitly include adaptation, the Office of the Mayor has created a formal partnership with the Columbia Earth Institute to provide the City with research and advice on environmental climate change issues. The Earth Institute is the home of several prominent scientists who led the MEC Assessment, are key figures in the DEP Climate Change Task Force, and are working on other adaptation-related projects in the City, so this bodes well for integrating adaptation into sustainability planning in New York.

All these cities have strong organizational links to nearby climate research institutions, which help with the kind of in-depth analysis that some adaptation decisions require. London has been able to draw on the United Kingdom Climate Impacts Program and also on the internationally renowned Hadley Centre for Climate Change. King County and Seattle benefit from the Climate Impacts Group at the University of Washington, which for ten years has worked with governments in the Pacific Northwest region of the US on climate issues. In New York, researchers at Columbia's Earth Institute and other linked institutions have worked with City agencies since the start of the MEC Assessment in 1999.

Halifax has unique institutional mechanisms for working on adaptation. The city is home to ClimAdapt, a consortium of environmental consultancy companies with an interest in and experience working on climate change issues. This consortium felt that Halifax "was a natural for doing climate change adaptation" because of sea-level rise and related coastal issues (Young 2005). They approached the Halifax Regional Municipality (HRM) with a proposal to work together on a "toolkit" to guide greenhouse gas emissions reduction and climate change adaptation planning.[35] Following Hurricane Juan in the fall of 2003 and the blizzard "White Juan" a few months later, HRM agreed to participate in the project. HRM, ClimAdapt, Environment Canada and the Nova Scotia Department of Energy formed Climate SMART to work on both mitigation and adaptation strategies for the municipality. The first two years of the project was managed by Dillon Consulting and funded by the Federation of Canadian Municipalities and the Climate Change Impacts and Adaptation Program in Natural Resources Canada. The collaborative has produced:

- An action plan for greenhouse gas emissions reductions (Dillon Consulting 2005);
- A Climate SMART website with information for Halifax residents on climate related issues;
- An issues paper on adapting to climate change and workshop with HRM staff on climate change impacts and adaptation;
- A submission to the Regional Plan with recommendations to incorporate climate change concerns throughout the plan;
- A community action guide to climate change and emergency preparedness (Halifax Regional Municipality 2006).

Climate SMART does not appear to be embedded institutionally at HRM, especially in relation to the adaptation side of its work. While HRM has released the Climate SMART action plan for greenhouse gas emissions reduction and committed to 20% reductions by 2012, it has not publicly released the adaptation

[35] The toolkit was to serve as a prototype that could be replicated in other municipalities across Canada.

issues paper completed in July 2005 nor commented on it. The staff member who participates in and champions the work of Climate SMART within HRM has many other responsibilities. Most of the work has been done with one-time grants. The ClimAdapt network appears to have waned as an organization. So while the Halifax model for this mitigation and adaptation initiative is innovative and interesting, it is unclear that it can be sustained in its present form or serve as a model for other cities.

The institutional mechanisms for incorporating adaptation options are less clear in Vancouver, and are absent in Boston.

By all rights, Greater Vancouver should be a leader in incorporating adaptation into municipal decision-making. In 2002-3 the GVRD worked with several partners to create a 100-year sustainability plan for Vancouver, winning the Sustainable Urban Systems Design international competition over eight other finalists. The Sheltair Group, which wrote the winning cities^{PLUS} plan also prepared a preliminary assessment of climate impacts and adaptation options, and showed how these fit within a general sustainability framework for the region. In the same time period, the GVRD established the Sustainable Region Initiative (SRI) to provide a sustainability framework for the region and its plans for growth management, drinking water, waste, air quality, parks and other services. However, climate change adaptation does not explicitly figure into the Sustainable Region Initiative framework and appear to be absent from the agenda of the Task Force that oversees the SRI.

GVRD staff members *have* considered potential climate impacts in drawing up several recent plans and guidelines, but argue that more information is needed before climate considerations are likely to change policy (van Roodselaar, Woods, and Margolick 2006). In the meantime, there appears to be no clear institutional mechanism for ongoing consideration and integration of climate and adaptation into regional plans and policy.

Despite the five-year CLIMB impacts and adaptation study, which involved representatives from a number of Boston-area cities and towns and had the active support of the Metropolitan Area Planning Council, climate change adaptation has not made it onto the agenda of municipalities in the region, and no institutional mechanism has been created to take it forward. CLIMB participants who we interviewed for this report gave several reasons for this failure including:

- The technical nature of the study, which was difficult for laypeople to understand and appreciate;
- Falling away of stakeholder participation in the last two years of the study;

- The large number (101) of small towns and cities within the metropolitan region, who guard their authority jealously;
- Lack of authority of the Metropolitan Area Planning Council, which is the logical organization to house the development of regional adaptation strategies, but has no regulatory powers.

At the time of writing none of the cities and towns in the Metropolitan Boston region had integrated climate change adaptation into their planning or programs.

3.4.2 Formulation of Adaptation Policies

There are a variety of ways in which adaptation policies for cities appear to be unfolding:

- Including adaptation goals in overarching policies that govern the ways in which cities organize themselves – in the form of city official plans, strategic plans, statements of guiding principles, and other similar documents;
- Development of broad-scale adaptation plans (similar to climate change mitigation plans developed by many cities to tackle greenhouse gas emissions);
- Integrating adaptation into individual departmental and agency plans and programs.

There are examples of each of these approaches in the cities we studied for this report, although none of the cities has fully integrated climate change adaptation into its policies and programs.

The City of London has integrated both climate change mitigation and adaptation in the latest draft of the London Plan, which provides a vision and strategic planning guidance for Greater London. The first London Plan was prepared in 2004. The London Climate Change Partnership ensured that the original Plan included a commitment to incorporate substantive content on climate change issues in subsequent revisions (Bramwell 2006). In 2006, the Mayor proposed extensive revisions to the plan, incorporating strategies to reduce greenhouse gas emissions and to adapt to climate changes that are underway. Table 8, on the next two pages contains excerpts from the new draft of the London Plan. At the time of writing, the revised Plan is undergoing an extensive public consultation process.

Table 8: Excerpts from 2006 Draft of the Revised London Plan (Spatial Development Strategy for Greater London)	
Preamble	"The most substantial changes I am proposing to make to the London Plan relate to tackling climate change. If the world does not take rapid and sustained action to reduce greenhouse gas emissions then we risk leaving our children and grandchildren to cope with potentially catastrophic global warming. The majority of the world's population will soon live in cities so the cities of the world must confront climate change. To deliver my vision for London we must lead the way in showing how one of the world's greatest cities is planning for and adapting to already inevitable warming, and even more importantly achieve very substantial reductions in our emissions of carbon dioxide." *Page viii*
Introduction	Time for Change "Over the last 20 years London has changed dramatically. Some of these changes are being driven by international forces, including: … a fundamental and accelerating environmental imperative to use energy and resources more efficiently, mitigate the impacts of, and adapt to, climate change, value the environment and reduce harmful emissions and environmental stress" Page xi Growth "… (G)rowth must be accommodated in ways that respect and enhance the environment by being exemplary in mitigating and adapting to climate change, and in being energy and waste efficient." Page xiv Sustainable Development "All policies … are set within overarching policies to promote sustainable development and to tackle and adapt to climate change, which together form a powerful strand running throughout the plan." Page xv The Mayor's Objectives Objective 6: To make London an exemplary world city in mitigating and adapting to climate change and a more attractive, well-designed and green city. Page xxiii
Chapter 4A Climate Change and London's Metabolism	The Crosscutting Policies "London is already feeling the effects of climate change. It is particularly vulnerable to flooding, subsidence, overheating and to water supply shortfalls. Climate change will increase the probability and severity of these events through rising sea levels, heavier winter rainfall, higher tidal surges, hotter summers and less summer rainfall. The exceptionally high concentration of people and assets at risk means that any extreme event will have major consequences. The impacts of climate change will be detrimental to the quality and life of all and particularly to the health of vulnerable people…" "The Mayor will use all of his powers, resources and influence to work with other agencies to raise awareness and promote behavioural change in support of mitigation and adaptation. Under current Government proposals, the Mayor

Chapter 4A Continued	will have a new statutory duty to tackle climate change and to produce statutory strategies for climate change and energy and for climate change adaptation." Page 194 "The Mayor has established the London Climate Change Agency to provide practical advice and take radical measures to tackle climate change." Page 195 "The Mayor and the boroughs need to have regard to the costs and feasibility of measures to tackle climate change within developments. They also need to have regard to the potential cumulative costs of failure to respond to the need for mitigation and adaptation." Page 195
Mitigating Climate Change	"The Mayor will work towards the long-term reduction of carbon dioxide emissions by 60 percent by 2050… The targets in this plan are designed to achieve this level through progressive and cumulative change… The forthcoming decades will see a reduced dependence on fossil hydrocarbon fuels and greater reliance on renewable sources. Plant and equipment should be designed to accommodate changes in fuels and technology." Pages 198-199
Sustainable Design and Construction	"The Mayor will, and boroughs should, require all applications for major developments to include a statement on the potential implications of the development on sustainable design and construction principles… The Mayor's Supplementary Planning Guidance on Sustainable Design and Construction provides an essential context for all developments and provides a mechanism for addressing climate change impacts through all developments." Pages 200-201
Sustainable Energy	"The Mayor will, and boroughs should … require all developments to demonstrate that their heating, cooling and power systems have been selected to minimize CO_2 emissions. The need for active cooling systems should be reduced as far as possible through passive design including ventilation, appropriate use of thermal mass, external summer shading and vegetation on and adjacent to developments." Page 202
Adaptation to Climate Change	"The Mayor will and other agencies should promote the most effective adaptation to climate change, including: minimising overheating and contribution to heat island effects minimising solar gain in summer contributing to reducing flood risk including applying principles of sustainable urban drainage." Page 208
Flood Plains	"London is prone to flooding from five sources: tidal, fluvial, groundwater, surface and sewer flooding. Climate change will increase the probability of flooding from all these sources except groundwater… The Mayor will work with the Environment Agency and other key stakeholders to determine what should be the appropriate standard of future tidal flood defence and encourage its implementation." Page 210
Sustainable Drainage	"The Mayor will encourage multi agency collaboration … to identify sustainable solutions to strategic surface water and combined sewer drainage flooding/overflows… These techniques include permeable surfaces, storage on site, green roofs, infiltration techniques and even water butts. Boroughs should encourage the retention of soft landscaping in front gardens…" Page 212
Promoting World-Class Architecture and Design	"The design of developments should contribute to the adaptation to and mitigation of climate change through, for example, reducing energy use, maximizing renewable sources of energy, and using natural forms of shading and cooling." Page 242

In addition to integrating adaptation into the London Plan, staff at the City of London have been working on an overall London Climate Change Adaptation Strategy for almost two years (Nickson 2006). This Strategy is expected to roll out in two phases. Stage 1 will identify adaptation priorities for London and identify methods for each sector to put together a set of policies and proposals; and at Stage 2, develop Action Plans including key actions, lead organizations and timescales (Government Office for London 2004). The strategy is based on:

- Previous analysis by the London Climate Change Partnership
- A study of innovative policies and programs in 18 cities with similar climate issues (flood risks, heat waves and limited water resources)[36]
- Consultations with affected parties and agencies (Nickson 2006).

The London Climate Change Partnership has also developed a third type of adaptation policy – namely guidance for specific sectors on incorporating climate change impacts into planning and programs. A key example of this is the publication *Checklist for Development* (Three Regions Climate Change Group 2005), which provides guidelines for designing developments adapted to climate change that is likely to take place throughout their lifetime.

King County is the only other jurisdiction studied that appears to be in the process of specifically incorporated adaptation into overarching policy. In October 2006, the King County Council passed a motion that directs the County's Executive to develop a King County Climate Change Mitigation and Preparedness Plan by February 2007.[37] In addition to actions related to carbon inventories and greenhouse gas reduction actions, the plan is to provide direction for:

- Updating the King County Comprehensive Plan to address the impacts of climate change on water resources, erosion and landslide hazards, and fish and wildlife
- Updating the County's Shoreline Master program to incorporate consideration of climate change impacts on shoreline erosion
- Managing wastewater treatment facilities to reclaim water for industry and irrigation, helping offset climate change impacts on water supplies. (King County October 10, 2006).

New York City's Department of Environmental Protection is also working on guidelines to incorporate climate change impact considerations into water supply, stormwater management and sewage treatment planning.

[36] See *Adapting to Climate Change: Lessons for London*, acclimatise 2006.
[37] This plan has not been released at the time of writing.

The efforts of local governments to explicitly incorporate climate change adaptation into policies and planning is so new that most policies are still at the draft stage. As a consequence, it is not possible to provide an assessment of alternative approaches. Nonetheless, emerging policies – incorporating adaptation into overarching policy, development of city-wide adaptation policies, and sectoral adaptation planning – provide a comprehensive approach that local governments may want to consider.

3.4.3 Explicit Incorporation of Adaptation into Projects

Although cities have been slow to incorporate adaptation into policy, a number of the cities studied for this report have incorporated climate change concerns into the planning and implementation of specific projects. Some of this has occurred as a result of prudent leaders who understood that climate change will affect specific long-lived projects. In other cases, local governments and agencies have undertaken pilot projects to test specific adaptation strategies.

Some examples of the incorporation of adaptation into projects in the urban areas studied include:

- ***The Massachusetts Water Resource Authority Deer Island Wastewater Treatment Plant***. This plant is located on an island in Boston harbour. The plant was built at a higher level (and higher initial cost) than originally planned, to accommodate future sea-level rise and avoid the long-term cost of constructing a protective wall around the plant (Estes-Smargiassi 2005).

- ***London Transport's Tunnel Cooling Program***, designed to reduce heat in deep-level tunnels of the London Underground system. The project has installed a trial cooling system in one subway station, using naturally cool water drawn from (and returned to) the chalk aquifer below London (London Underground 2006). The project is also investigating the potential to use an absorption cooling system that uses waste heat from local electricity generation plants to chill water piped to tunnels and stations. If these systems work as hoped, they will not only reduce heat in the subway system, but decrease heat released to the general environment.

- ***New York City's Greening the Bronx Quick Start Program***. This tree-planting program is designed to help reduce summertime temperature increases in the Bronx and reduce building cooling loads. The program includes funds to maintain the trees for a two-year period.

- ***King County Flood Buyout and Home Elevation Program***. This program is designed to purchase homes in areas prone to floods or serious erosion, both

of which are expected to increase under climate change. Home elevation assists homeowners with the costs of raising the finished floor of the home above the 100-year flood level (King County n.d.).

To date, the incorporation of adaptation in cities has been piecemeal and unsystematic. As urban adaptation processes strengthen, and adaptation policies develop and take hold in cities, these processes re very likely to become more comprehensive.

Lessons about Adaptation Actions

- Cities that have created and funded clear institutional mechanisms for considering climate change impacts and adaptation have made much more progress in developing and implementing climate adaptation programs than cities with a more ad hoc approach.
- The New York and Halifax experience indicates that enterprising university researchers and private-sector consultants can go some distance to driving an adaptation agenda for urban centres. However, these outside researchers and consultants can only achieve so much. Ultimately local governments need to establish an ongoing mechanism for integrating adaptation if systematic action is to occur.
- Institutional mechanisms should include a forum that regularly brings together stakeholders in government and other relevant agencies and organizations to stay updated on climate impacts and to discuss adaptation options and strategies.
- Dedicated staff to coordinate the forum and related research and policy development are also important. Ideally this staff will report to the executive level.
- Core funds also need to be allocated to pay for staff time. These resources may be used to leverage other funds for research and events, as occurred in London and New York.
- Three levels of policy development can be used to introduce climate concerns and adaptation into local government decisions:
    - Integration of climate change adaptation into overarching policy documents such as City official plans, or statements of principle;
    - City-wide adaptation policy;
    - Sector-specific adaptation policies and guidelines.

4. LESSONS FROM EARLY ADAPTERS

The development and implementation of adaptation strategies for cities is at a very early stage. Although several of the cities studied for this report appear to be ahead of the curve, they have only engaged in analysis of climate impacts and adaptation options for a few years. Nevertheless, a number of lessons are emerging from the experience of early adapters. In previous sections of this report, we outlined a number of specific lessons for different parts of the adaptation process. In the section below, we provide more general comments about supports for and barriers to the process as a whole.

4.1 Supports for Development and Implementation of Adaptation in Cities

A number of factors appear to support the development and implementation of climate change adaptation in cities. These include:

- ***Knowledgeable and committed political or executive champions:***

  A political or executive champion can put adaptation on the agenda and keep it there. Executive Ron Sims played this role in King County Washington.[38] Mayor Ken Livingstone has made climate change his "number one priority" and has ensured that the Greater London Authority is incorporating both mitigation and adaptation planning into all major areas of responsibility. In New York City, two consecutive Commissioners for the Department of Environmental Protection have supported a major adaptation project for the City's water system, ensuring that resources and funding are available.

  While the other urban centres studied for this report have dedicated staff interested in climate impacts and possible adaptation strategies, they do not appear to have gained the focused attention of political or executive leaders and so the adaptation process is currently languishing in those cities. The uptake of adaptation processes in these and other cities may require the conscious cultivation of senior level champions in order to kickstart effective adaptation processes. As the Seattle City Auditor told us: "Get an elected official or officials on board as sponsor of an adaptation project. Even if they are not active, they will help" (Cohen 2006).

[38] Executive Sims is also playing a role on the national stage in the US, convening a group of American counties to commit to Kyoto.

- ***Creation of a specific interagency or interdepartmental organization to lead the adaptation process to ensure the collaboration of relevant stakeholders:***

  The London Climate Change Partnership and King County's Global Warming Team are two examples of organizations created to advance the adaptation agenda in urban areas. The LCCP has been operating for more than 5 years, and involves a broad range of representatives from inside and outside government in London. The much more recent King County team consists solely of staff from the several County offices (including the executive office, budget, parks, transportation, environmental services, economic development, and public health). The LCCP has a broader focus on promoting public *and* private action to adapt to climate change. The King County team is more specifically focused on developing an adaptation plan for the County government. However, both have broad representation, a clear mandate and a regular meeting schedule, all of which are necessary for moving the adaptation agenda forward.

- ***The collaboration of a local community of strong researchers prepared to work with local governments on climate impacts and adaptation;***

  All of the strong urban adaptation processes that we studied involved – and in some cases were led by – a community of researchers and scientists committed to working with local governments on the issues of climate impacts and adaptation. These researchers were based in:

  - Senior government agencies (e.g. NASA, Environment Canada)
  - Universities (e.g. Columbia University, King's College, Tufts University, Boston University, etc.)
  - Research institutes (e.g. UK Climate Impacts Program, University of Washington's Climate Impacts Group), and
  - Private sector consulting firms or networks (e.g. acclimatise in London, ClimAdapt).

  They explained the science of climate change, undertook regional climate modelling to more accurately assess local climate changes, worked with local government staff and stakeholders to identify likely impacts, and helped identify and assess adaptation options and strategies.

  It is clear from the cities we studied that local governments can augment their own staff resources for the investigation of climate impacts and planning of adaptation strategies by drawing on the skills and knowledge of scientists and researchers in other institutions. It was also clear that initial scans of climate impacts are a useful early step in developing an adaptation process,

but there is a need for detailed and technical research on specific areas of vulnerability to climate change in order to develop solutions that are cost-effective and provide co-benefits. This may require tracking the effects of recent extreme weather events, documenting what the response was, how much it cost and then assessing whether proposed adaptation solutions would have prevented the effects (Snover 2006).

- ***The allocation of financial and human resources:***

  Not surprisingly, those cities or city agencies that have hired or allocated staff to lead impacts and adaptation projects have a more advanced adaptation process than those who have simply added these tasks to other responsibilities of environmental or other staff, or who have depended on voluntary efforts of people inside or outside local government. London has provided salaries for the staff involved in coordinating adaptation processes and leveraged other funds to pay for research, workshops, publications, etc. (Chell 2005). The Department of Environmental Protection in New York City is financing a 5-year project to develop adaptation guidelines entirely from its operating budget (Major 2005).

- ***Strong communications and outreach***

  Several of the adaptation processes we studied included a strong communications and outreach strategy as part of the effort to build awareness of climate impacts and support for adaptation within government and among the public. Outreach approaches included dedicated websites, brochures and factsheets, maps of vulnerable areas, newsletters, public presentations, workshops, conferences and other communication tools. The London Climate Change Partnership posts the minutes of its Steering Group meetings on its website as well as its policy submissions, reports, and other materials. This helps to make the adaptation process more transparent.

  The Environmental Management Services department in Halifax has included articles on climate change impacts and on its Climate SMART initiative in *Naturally* Green, the quarterly newsletter it delivers to all households in the region.

  Several of the cities studied also make effective use of the media to get their reports into the public eye. The Mayor of London is involved in the release of most reports by the London Climate Partnership (Connell 2006). The City of Seattle and King County have also been successful in drawing media attention to climate change impacts. Several informants talked about feeding information to the media in "useable sound-bites" and using analogies or

stories of past events to more effectively get the message across (Kirshen 2005, Pillsbury 2005).

These activities are designed to help the public and stakeholders to understand expected climate impacts and built support for cities to undertake adaptation policies and actions.

- ***Stakeholder engagement strategy***

  Most of the adaptation processes studied for this report included efforts to engage stakeholders in discussions about climate impacts and adaptation, and in some cases in the research. This was important for a number of reasons. Ultimately, the goal of adaptation processes is to integrate consideration of climate change impacts into decision-making in all relevant sectors in the City. This will only happen if stakeholders understand how impacts will affect their sector, and are engaged in thinking about how the organization of their services can change or adjust to reduce vulnerability to these impacts.

  Stakeholder engagement and buy-in was strongest in those cities that set up and maintained a process of regular communication with stakeholders, and involved stakeholder representatives in research and adaptation options development. This took time and did not always pay off – in Boston for example. However, the most successful engagement processes – in London and New York – evolved into institutional mechanisms for developing and implementing an adaptation agenda.

- ***Set priorities and get started***

  Long research studies that result in no discernable action can set back the adaptation agenda if participants become jaded and sceptical. This appeared to be the case in Boston. Action can be taken before all the information is in, especially in the case of adaptation options "worth doing anyway" or in the form of pilot projects that allow the effectiveness of specific adaptation actions to be evaluated. This is the case in the Greening the Bronx project, where extensive tree-planting is underway to counteract the urban heat island effect and to provide before-and-after data.

  The logical approach would be to identify areas of highest likely impact – measured by potential disruption, cost, or suffering – and do the dogged legwork to get adaptation on the agenda. Jon Dickinson of the New York City Office of Environmental Coordination suggested that adaptation action should "start with City departments where impacts will be greatest and with

those that build long-lasting infrastructure" (Dickinson 2005). There is merit to this approach.

However, several other participants in the adaptation processes we studied argued the importance of taking advantage of openings for getting adaptation taken into account and projects started on the ground. This study shows that opportunities can be created by:

- Preparation for new construction or a major retrofit of long-lived infrastructure that may be affected by climate changes over its lifetime (e.g. adaptation plans for NYC water supply)
- Development of major urban plans to guide decisions and policies around land-use, water or stormwater management, energy generation and conservation, climate change mitigation, etc. (e.g. incorporation of adaptation in the London Plan)
- Political or executive leaders who are willing to pilot initiatives that will reduce impacts of current weather extremes (e.g. London Transport's pilot to reduce heat in the Underground)
- An extreme weather event that raises the issue of community vulnerability to climate change
- Excitement or concern generated by a newsworthy report (such as the recent release of the latest report by the Intergovernmental Panel on Climate Change) or a presentation by a national or international figure.[39]

- ***Need for long-term perspective***

It is clear from the experience of the cities studied that developing adaptation strategies and integrating them into policy and programs is not a process that can be accomplished quickly. London, which has had proactive leadership, research support, a successful stakeholder process, dedicated staff and other supportive features, has been working on impacts assessment and adaptation for almost 6 years and has not yet published an adaptation plan nor implemented many explicit adaptation actions. Most of the other cities studied have had fewer supports, or started more recently and have accomplished less.

This is not to suggest that adaptation options that provide a number of co-benefits cannot be developed and implemented in the short-term. But high-cost, preventive adaptation strategies are unlikely to be implemented unless the need for them is clear, their effectiveness established, and the costs

[39] Al Gore has created this kind of stir in many communities, including Seattle (Cohen 2006).

understood. This takes time. It also reinforces the need for dedicated institutional mechanisms to guide the process through many bumps and barriers.

4.2 Barriers

There are many barriers that the cities we studied encountered in development of their adaptation processes. These included:

- ***Weak understanding of impacts***

  While there appears to be a general understanding that climate change involves warming temperatures and heat waves, relatively few people comprehend that climate change will involve less predictable, more intense storms, significant sea-level rise and other problems. There is also a lack of understanding about how each of these changes can impact life in the city: that heat waves will stress electrical generation and disrupt distribution systems; that intense rainstorms will produce floods; that more frequent droughts may threaten the water supply, and so on.

  This underscores the importance of public and stakeholder education and communications to improve awareness of likely future impacts.

- ***Uncertainty about the timing and extent of some impacts***

  Even when decision-makers understand the likely shape of climate change, they may not have enough certainty about impacts to guide decisions (Anderson 2005, Hicks 2006). Uncertainties about precipitation are particularly problematic. One GVRD engineer told us: "We don't know if we are over-designing or under-designing our stormwater systems. We only have 30 years of records for some rain gauges. The Pacific Decadal Oscillation is a 60-year cycle, with a 30-year warm-dry phase and 30-year cold-wet phase. Does one of those phases get more quasi-permanent as a result of climate change? It's hard to tell" (Hicks 2006).

  Moreover, climate scientists are predicting more periods of drought as well as more intense rainstorms. Planners need to think about safeguarding the water supply for more severe dry spells as well as deal with stormwater overflow and floods. On the stormwater side there are other uncertainties. How much stormwater can green roofs, permeable pavements, swales and storage ponds take care of in an intense precipitation event? Should the diameter of storm sewer pipes be increased and if so, to what extent?

Some of this uncertainty will only be resolved with time – or, when "something bad happens, that brings out the news crews and politicians. That will catalyze change" (Tucker 2006). In the meantime, adaptation processes may need to be focused on identifying trends and triggers for taking action and creating contingency plans for what to do if that trend surfaces (Kirshen 2005).

- ***Looking to past conditions to guide decisions***

  A related issue is the practise of many decision-makers – in engineering especially – to make decisions based on past conditions (Ryan 2005). Some systems are planned to withstand a "design storm" that based on previous experience has a one percent chance of occurring in any single year, for instance. (This kind of design storm is frequently referred to as a "100-year storm.") The design storm will include worst-case expectations for duration of a storm, rainfall intensity, wind speed, etc.

  Almost all jurisdictions we visited provided anecdotal information that 100-year storms were on the increase, suggesting that the design storms need to be re-evaluated (Kirshen 2005), especially for the planning of long-lived capital projects such as bridges, tunnels, stormwater systems, dykes and levees, buildings and so on. This underlines the importance of good information on recent climate events. However, it is challenging to get decision-makers to use existing rainfall data in design guidelines, much less accommodate future shifts in climate (Watt et al 2003).

- ***Focus on short-term costs of adaptation rather than the long-term costs of business-as-usual***

  Many adaptation options will require major upfront expenditures or expensive retrofits. In an era when cities have very tight budgets, and have had a hard time maintaining existing infrastructure, the call to spend money to avoid future problems is easy to resist. The Director of New York City's Office of Environmental Coordination told us: "It is hard to weigh real costs now against possible future costs. We need real data, some of which we can get from pilot projects" (Kulikowski 2005).

  The CLIMB study was designed to estimate the costs of *not* adapting and of adaptation by fortifying existing infrastructure compared to "green" adaptation, but not many other studies have attempted this.

- ***Difficulty getting the attention and commitment of political leaders***

  Several researchers and government staff interviewed for this study identified the short attention span of local and regional politicians as a major barrier to the development of an adaptation process (King 2005, Cohen 2006). Local politicians have relatively short mandates and more frequent elections. They are called upon to respond to the problems that constituents face now, as opposed to ones that may occur in the future. "Decision-makers juggle hundreds of things that need to be done yesterday, or things with immediate implications. Many still see climate change as something to be done tomorrow" (Snover 2006).

  A related barrier is the turnover of elected officials and staff. One climate researcher in Washington told us that her institute is frequently involved in trying to bring new politicians or government staff up to speed on climate questions (Snover 2006).

- ***Difficulties getting some stakeholders to the table***

  Several of the people interviewed for this study indicated that it was difficult to get some stakeholder organizations – local government departments, semi-autonomous agencies and key businesses – to the table. MassPort in Boston, which is responsible for the seaport and the airport, both at risk from sea-level rise, wasn't interested in participating in the CLIMB study, for instance (Kirshen 2005). Similarly, the LCCP Manager told us: "A number of organizations that should be involved are not – businesses that will be impacted and organizations that could have impact – developers, landowners, individual boroughs, planning councils" (Tucker 2006).

- ***Problems coordinating across local government departments or levels of government***

  Getting agreement and action on some adaptation options will require agreement and coordination among different departments or levels of government, which is not often easy. The Boston Metropolitan area is made up of 101 towns and cities that, as several participants in CLIMB told us, jealously guard their autonomy (Kirshen 2005, Pillsbury 2006). Similarly, the Greater London Authority includes 32 boroughs and the City of London. The division of powers between the GLA and the boroughs means that some problems can only be resolved when all are on board (Tucker 2006). New York City government includes 59 departments that are difficult to coordinate (Kulikowski 2005). Some adaptation actions necessary to protect cities from climate change – to cope with sea-level rise or strengthen

requirements for buildings, for example – require action by or coordination with senior levels of government.

Strong political leadership can overcome some of these problems, but implementing major adaptation strategies in urban regions may require formal coordinating bodies. King County may provide a model for this, but it is too early to tell.

- ***Inadequate and one-off resources***

  Almost all the participants in urban adaptation processes that were interviewed for this report agreed that resources for developing and implementing adaptation strategies were inadequate. One participant in the Halifax adaptation work commented on available federal funding: "Resourcing the research and organizational work is essential. We've spent pointed $4-5 billion on greenhouse gas emissions reduction and maybe – at a stretch – $500 million on adaptation. The gap is known. We have to have more resources to convince other jurisdictions that we are serious. Adaptation needs to have resources on a similar scale to mitigation" (Lines 2005).

  Most of the adaptation processes described in this study have been funded with one-time grants for impact studies and an initial assessment of adaptation options. Once the initial grant is finished, it has proved difficult to keep the process going. But even adaptation processes that receive ongoing funding for salaries of coordinators (and sometimes for research) have very limited budgets in the face of a complex and potentially very serious set of problems.

5. CONCLUSIONS

Adaptation processes in cities are on the move. While these processes are still at a very early stage it is clear that cities and urban regions that are engaging in them are learning as they go along. Local governments that appear to be in the lead – London, King County, and to some extent New York and Halifax – have moved through some but not all of the different stages of the adaptation process. The participants in these adaptation processes continue to confront many barriers to the development and adoption of adaptation strategies, and some have been stalled or sidelined. Nevertheless, the experiences of several urban centres are beginning to show ways to move forward.

It will take leadership, persistence and broad knowledge of urban systems and how they interact with climate and with each other to get and keep adaptation on the agenda of cities and to devise and implement adaptation strategies. It will clearly be important for cities to continue to share their experiences and to learn from each other as these processes continue.

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