ADAPTATION-MITIGATION CONFLICTS IN MUNICIPAL PLANNING: THE CASE OF HEAT WAVE PREPAREDNESS IN VANCOUVER, CANADA

by

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Executive Summary

This study explores how government policies and practices regarding the built urban environment can act as institutional barriers to climate change adaptation, by examining the impact of City of Vancouver greenhouse gas emissions reduction policies on the City's ability to respond to heat waves under climate change. City of Vancouver policies related to emissions reductions through building stock energy savings are negatively affecting the City's future ability to protect the population from heat waves, as they discourage air-conditioning and encourage passive design solutions, leading to new construction unsuited to the extremes of future climatic conditions. The City of Vancouver can improve its adaptive capacity in relation to heat waves by addressing the need for cool interior spaces and refugia in its development strategies and by seeking emissions savings in areas other than building cooling. In general, the City of Vancouver can improve its preparedness for climate change by integrating climate change adaptation considerations into its policy development and decision-making in all areas. The study also underscores the following lessons for municipal policy in general: climate change will cause significant new health issues; urban planning and property development decisions affect residents' health in the long-term and planned adaptation will support healthy outcomes for residents; a range of existing policies, practices and standards act as institutional barriers to effective climate change adaptation at the municipal level, but not all of these policies, practices and standards are within municipal jurisdiction; climate change adaptation considerations need to be wholly integrated into municipal policy- and decision-making; and the modification of mitigation programs in light of adaptation needs will secure better medium- and long-term outcomes.

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I. Introduction

From July 27 to July 30, 2009, the Lower Mainland experienced an unprecedented heat wave.[1] The average daily temperature at the Vancouver International Airport climate station over this four-day period was 25.9°C with maximum temperatures reaching 33.7°C and 33.9°C on the afternoons of July 29 and 30 (Environment Canada 2010b).[2,3,4] A climate station in downtown Vancouver recorded temperatures up to one degree higher (Environment Canada 2010b, see Table 1). Data from other climate stations located in Vancouver, Port Moody, Pitt Meadows, Cloverdale (Surrey) and Abbotsford indicate that extreme heat was experienced across the region during this period, with temperatures reaching 38.0°C in one case (Environment Canada 2010b; see Table 1). Media reports describe the unusual nature of this weather (Hottest day ever recorded in Vancouver 2009; Anyas-Weiss 2009). A subsequent analysis of reported deaths indicates that the heat wave caused 156 excess deaths in the Fraser and Vancouver Coastal Health districts during the period July 27 to August 3, 2009 (Kosatsky 2010). The excess deaths were primarily persons over the age of 65; however, there was a notable increase in the proportion of excess deaths of people aged 45 to 64 (Kosatsky 2010). Clearly summer heat waves can be a serious public health concern for citizens and government in the Lower Mainland of British Columbia.

[1] On July 27, a heat advisory was issued predicting a heat wave lasting five or six days (BCCDC 2009). However, a review of the Environment Canada records (2010b) suggests that temperatures meeting the subsequently developed local heat wave definition lasted only four days, with maximum temperatures dropping by several degrees on July 31 and subsequent days. Despite this, Kosatsky (2010) reports that the heat wave lasted from July 27–August 3, 2009. Indeed, as discussed in the Relevant Concepts section, a comprehensive heat wave definition involves more than maximum daily temperature, so the exact duration of this heat wave is open to debate.

[2] Simple average of hourly temperature recordings from midnight on July 27, 2009, to 11pm on July 30, 2009. Data taken from Environment Canada (2010b).

[3] Official Environment Canada climate station for Vancouver, located at the International Airport in the City of Richmond.

[4] These temperature readings do not necessarily reflect actual temperatures in the City of Vancouver, given that they come from the climate station located at the Vancouver International Airport. Vancouver as a whole produces an urban heat island, and different locations within the city are undoubtedly hotter than others. See CIHI (2011) for an examination of urban heat island effects in Canada.

Table 1. Maximum daily temperatures at lower mainland climate stations for the period July 27-30, 2009.

Climate station / Date	Jul-27	Jul-28	Jul-29	Jul-30
White Rock Campbell Scientific CS	26.6	27.9	31.4	29.7
Vancouver International CS	**27.1**	**30.5**	**33.7**	**33.9**
Vancouver Harbour Station CS	29.7	31.3	34.9	34.0
Burnaby SFU CS	Not available	Not available	33.0	32.5
Port Moody Glenayre CS	30.0	32.0	35.0	35.0
Pitt Meadow CS	33.7	36.4	37.6	35.7
Haney UBC FR Admin CS	32.5	35.0	37.0	35.5
Cloverdale East CS	33.5	35.5	**38.0**	35.3
Abbotsford Airport CS	33.2	36.1	37.6	35.3

Source: Data taken from Environment Canada (2010b).

Note: The colours indicate days where the subsequently instated Vancouver Coastal and Fraser Health heat advisory minimum two-day temperature threshold was met for coastal municipalities (31°C, yellow) and for interior municipalities (33°C, green).

This particular climatic event can be best understood when viewed within the larger framework of climate change. Environment Canada (2005: 44) predicts more and hotter summer heat events as a result of climate change. Hence, the 2009 heat wave should be taken as a sign of things to come in the Lower Mainland. While the timing of future events is impossible to predict, extreme summer heat events of this magnitude and greater will reoccur, with the potential for negative impacts on human health as demonstrated by the 2009 event. Fortunately, excess deaths during a heat wave are avoidable. The success of municipal heat wave preparedness in other jurisdictions proves that coordinated institutional efforts reduce or avoid excess deaths during a heat wave (Ebi et al. 2004; Ebi and Schmier 2005; Basu and Samet 2002: 200). Thus, heat wave preparedness can be framed as an adaptation to climate change.

In Canada, governments are active in the field of climate change mitigation, while climate change adaptation planning in Canada, as in the most of the world, is only just beginning (Adger et al. 2007: 719). Thus, most mitigation decisions in Canada to date have been made without corresponding consideration of the implications for associated adaptation issues. Nonetheless, an understanding of the sequential nature of decisions (that is, how decisions taken today affect the range of choices available in the future) makes it clear that climate change mitigation and adaptation decisions should be taken in a coordinated fashion. Considering future adaptation needs now will provide for mitigation decisions that continue to serve communities in a future of

more extreme environmental conditions. Indeed, according to the IPCC, buildings and urban infrastructure are a sector ripe for synergies between adaptation and mitigation (Klein et al. 2007).

This study examines the impact of current efforts to reduce greenhouse gas emissions through policies related to the built environment in the City of Vancouver on the municipal government's ability to respond to heat waves in the future. The principal objective of the study is to explore the interconnected nature of climate change mitigation and adaptation by investigating how government policies and practices regarding the built urban environment can act as institutional barriers to climate change adaptation, using Vancouver as the example. The study will demonstrate that focusing only on climate change mitigation can reduce adaptive capacity with detrimental results for municipalities and residents. Hence, it argues that implications for climate change adaptation and mitigation should be jointly considered in long-term municipal planning. Wilson and McDaniels (2007) argue a similar point for transportation infrastructure investments in British Columbia. Certainly, successfully addressing both climate change adaptation and mitigation is important for achieving sustainable development.

This study aims to persuade the City of Vancouver to reconsider some of its climate change mitigation policies in light of certain climate change adaptation considerations, and more generally to encourage local governments in Canada to integrate climate change adaptation into their decision-making, alongside climate change mitigation, for the purpose of securing better long-term outcomes. This study is being prepared for hypothetical clients involved or interested in climate change mitigation and adaptation planning, including the City of Vancouver, Canadian municipalities at large, the Federation of Canadian Municipalities (FCM) and Health Canada. The study provides direct recommendations regarding heat wave adaptation for City of Vancouver planners and decision-makers. It provides other municipalities with a starting point from which to explore the consequences of existing climate change mitigation policies on adaptive capacity in their own jurisdictions. The FCM can benefit by integrating the study's recommendations into the climate change policy support tools it disseminates to municipalities across Canada. Health Canada can benefit from this study inasmuch as it elucidates the role of built urban form in securing human health under climate change.

Smit and Wandel (2006) categorize academic adaptation literature into four scales with four different purposes: first, large scale, statistical models that calculate to what degree the impacts of climate change can be moderated, avoided or leveraged; second, models that rank the relative merit of alternative adaptation options in order to pin-point the best course of action for any one adaptation risk; third, frameworks to measure the relative adaptive capacity of nations or communities in order to decide where to concentrate resources; and finally, locally-focused participatory studies that seek to understand the specific actors, mechanisms, opportunities and barriers to actually demonstrating or activating adaptive capacity. While not participatory, this study falls within the fourth approach.

The study is divided into seven sections. Section II introduces the reader to relevant concepts, ranging from climate change and climate change mitigation and adaptation to the sequential nature of decisions, institutional barriers and heat waves and heat wave response. Section III and IV describe the study's methodology and results. Section V elaborates on the claim that institutional barriers and uncoordinated climate change decision-making is leading to less than optimal climate change adaptation outcomes in Vancouver. Section VI provides recommendations for the City of Vancouver in relation to climate change planning and heat waves. Section VII provides a brief conclusion including general lessons that can be drawn from the study.

II. Relevant Concepts

1. Climate change

While the earth's climate has constantly been changing through geologic time, human activity since the Industrial Revolution has accelerated certain climate processes. The burning of fossil fuels has increased the concentration of greenhouse gases (GHGs) in the atmosphere, trapping more of the sun's energy inside the atmosphere. This additional energy is leading to an increase in atmospheric temperature that, while slow in terms of human time, is rapid relative to geologic time. The increase in atmospheric temperature alters the earth's climate patterns upsetting the weather patterns that humans have come to expect and causing extremes in

temperature, precipitation and wind, among other elements of weather. This is what is known today as climate change (Environment Canada 2005).

While the specific impacts of climate change on local weather patterns is impossible to predict, in general, extreme events are expected to become more common and the maximum parameters of these events for any one locale are expected to increase (Environment Canada 2005: 44; McDaniels 2010). In other words, the mean for specific variables shifts to the right and the shape of the distribution curve changes, as there is more variation around the mean. In the case of heat waves, their occurrence is expected to increase and be accompanied by higher mean temperatures.

The expected manifestations of climate change for the Vancouver region are sea level rise, increased annual average temperatures, more variable precipitation and more extreme weather events (Taylor and Langlois 2000). These same authors point out that these changes will cause coastal erosion, inundation of low-lying amenities and infrastructure, saltwater intrusion into ground water, changes to inter-tidal and riverine ecosystems, increased flood-risk, increased pressure on water reservoirs, new pests and disease vectors, reduced air quality, reduced stream flow, increased water temperatures in fish-bearing streams and increased risk of forest fire, among other impacts. Crawley's (2008) examination of the expected impacts of climate change on building performance in North America suggests that the cooling needs of Vancouver buildings will increase as climate change progresses. Doyon et al. (2008) predict that climate change will increase summer mortality in three cities in the Province of Quebec. Thus, climate change and its consequences will have an extensive impact on Vancouver's social, economic and environmental systems. Hence, these systems need to begin to adapt to the new climatic conditions and find ways to accommodate the uncertainty related to the magnitude and rate of the various changes.

2. *Mitigation, adaptation and adaptive capacity*

Climate change *adaptation* from a human perspective encompasses the anticipatory or reactive, autonomous or planned modifications of social, political and economic systems, which

allow societies to adjust to the changing environmental conditions wrought by climate change (Smit et al. 2000; Smit and Wandel 2006). As mentioned above, climate change adaptation is necessary in order for societies to accommodate the changing climate without suffering losses in social, political and economic wellbeing.

Governments are promoting another set of changes to social and economic systems in relation to climate change, known as climate change *mitigation*. Mitigation refers to efforts that reduce greenhouse gas (GHG) emissions in order to limit the extent of future climate change (Adger et al. 2007). In short, mitigation seeks to reduce the total amount of GHGs released into the atmosphere and increase carbon sequestering (Glenn 2010: 2).

Climate change mitigation and adaptation operate at different scales. As the atmosphere encompasses the globe, the issue of atmospheric GHG concentrations is a global problem. Emissions must be collectively reduced for mitigation to be effective. Thus, while local efforts are needed to carry out specific measures (and some local benefits may accrue), the overall goal will only be attained through international agreement and cooperation (Adger et al. 2007). The impacts of climate change on the other hand, differ in every location and every community and society has different adaptation needs. Thus, adaptation measures are highly context-dependent. Furthermore, the ability of each community and society to adapt differs in relation to the social, economic, cultural, political and environmental factors specific to each place. For this reason, climate change adaptation is best resolved at local to national scales (Adger et al. 2007).

Adaptation requires technical know-how, financial resources, coordination between policy and action, risk management governance structures and the integration of long-term horizons in infrastructure investment decision-making (McDaniels 2010). Planned, anticipatory adaptation is a complex decision-making process involving anticipating challenges of an uncertain environmental, social and economic future. These inherent uncertainties make climate change adaptation particularly difficult to address (Wilson and McDaniels 2007). It is not surprising therefore that research demonstrates that climate change alone rarely triggers adaptive action (Smit and Wandel 2006; Adger et al. 2007). In fact, systems are expected to respond first to extreme events before reacting to more gradual shifts in the climate mean (Yohe and Tul 2002).

While the concept of adaptation encompasses a process, action or outcome in response to a change, adaptive capacity is the *ability* to actually initiate and follow-through with a process or action in order to achieve the desired outcome (Smit and Wandel 2006). In other words, adaptive capacity is the ability to perceive, manage and adjust to a change in exterior conditions. Adaptive capacity is a function of knowledge, technology, infrastructure, financial and natural resources, human and social capital, institutions and governance framework (Klein et al. 2007; Smit and Wandel 2006). It is important to consider the influence of institutional, behavioural and distributional issues on adaptive capacity, which may significantly alter outcomes independent of resources, information and technology. As an example, Adger et al. (2007: 719) state, "there are substantial limits and barriers to adaptation" and give the example of heat-related deaths in Europe.

Finally, the following lessons can be gleaned from the past decade of climate change decision-making experience:

- Because climate change mitigation and adaptation require fundamental changes to the way governments, institutions, corporations and society operate, it is important to nest these considerations within the larger strategic planning processes of these entities (Smit and Wandel 2006);
- As alluded to in the introduction, mitigation and adaptation actions interact in multiple ways: consequences of a decision in one arena on the other, decisions that involve a trade-off between the two arenas, decisions that involve synergies, and decisions with consequences for both arenas (Klein et al. 2007).
- Responses to climate change should not lead to a deterioration in other concerns already addressed by public policy, as is the case with NOx emissions and vehicle fuel choices (Mazzi and Dowlatabadi 2007);
- Distribution of impacts and costs and public perceptions of justice are important considerations for decision-makers (Klinsky 2010); and
- Climate change mitigation measures tend strongly towards sub-additivity, whereby multiple actions result collectively is less than expected emissions reductions (Dowlatabadi per. comm.).

3. The sequential nature of decisions

Complex problems often involve multiple, linked decisions over time, and deal with uncertain future conditions. Such is the case with climate change decision-making. In these sorts of cases, it is important to consider the sequential nature of decisions.

The sequential nature of decisions refers to the fact that once a decision is taken it affects the range of possible follow-up decisions (Hammond et al. 1999). For example, an initial land use decision made with regards to a particular parcel of land affects the future possible uses of that land. Or, in the case of urban development decisions, such decisions continually modify a city's landscape with impacts on suitable uses of space and how activities are carried out. Linked decisions are generally complex and involve making an initial decision despite uncertain outcomes, which will affect follow-up decisions and where it is not always feasible to reduce the initial uncertainty (Hammond et al. 1999). To return to the urban development example, future uses must conform to the existing urban landscape but not all future needs can be known at the time of a specific property development decision. To this end, risk and uncertainty in climate change decision-making can be addressed through selecting alternatives that are the most robust over the possible range of future scenarios (McDaniels 2010).

4. Institutional barriers

Following van Bueren and Priemus (2002: 78), institutions are understood to be "rules that structure, but do not determine, the decisions of players within… [a certain] sector" and institutional barriers are interactions between institutions and actors that hinder the achievement of a desired outcome. Rules can refer to a range of conventions that guide human decision-making such as laws and regulations, social and cultural norms and individual decision-making heuristics. It is important to not underestimate the influence of this last practice on decision-making. For example, past experience influences human perception of the frequency, probability, risk and/or causes related to a particular type of event, which is known as the availability heuristic (Bazerman 1998) and can also be classified as perception bias. Humans also use pre-existing categories to understand the world around them, which is known as the representativeness heuristic (Bazerman 1998), of which status-quo bias is one aspect.

5. Heat waves and heat wave response

A heat wave can be defined as a period of high temperatures causing negative health outcomes in a population (Robinson 2001). Other variables beyond temperature provoke a sense of heat in humans, and thus a comprehensive measure of a heat wave involves not only maximum daytime temperatures, but extends to nighttime temperature values and other aspects of meteorology, a duration criteria, urban structure and demographics (Clean Air Partnership 2007; Kalkstein et al. 1996; Robison 2001). While by the strict definition a heat wave can occur at any time of the year, in this study "heat wave" refers to extreme temperatures experienced during the summer (or potentially late spring or early autumn).

Human vulnerability to heat is related to a number of factors including: age, mobility, level of contact with other people, disease profile (specifically cardiovascular, cerebrovascular, respiratory or renal diseases), socio-economic position, housing, access to air conditioning and individual decisions (McMichael et al. 2003; Hajat et al. 2010). Experience indicates that heat waves tend to affect primarily the elderly (Hémon and Jougla 2003; Klinenberg 2002; Kosatsky 2010; McMichael et al. 2003). A suite of other factors, beyond age, determines the vulnerability of an elderly individual (e.g. mobility, social networks, housing) (see for example Klinenberg 2002). Other notable sectors of society vulnerable to heat waves are the chronically ill and the socially marginalized (McMichael et al. 2003; Hajat et al. 2010: 858). The temperature threshold above which a given population is sensitive to the heat depends on the climate to which a population is acclimatized. Thus, under similar hot, summer air masses people in the northeast United States suffer worse health outcomes than people from the southern US (Kalkstein et al. 1996: 1520).

A variety of jurisdictions have successfully implemented heat wave response plans, minimizing excess deaths (Bernard and McGeehin 2004; Matthies et al. 2008). Examples of direct interventions carried out by municipalities targeting vulnerable populations include: having neighbours or mail or utility workers check in on elderly and infirm residents, homeless outreach, operating heat information hotlines targeting the elderly, opening cooling centres and transporting vulnerable individuals to them (Bernard and McGeehin 2004; Clean Air Partnership 2007; City of Philadelphia – Office of Emergency Management n.d.). Some jurisdictions have

instituted voluntary sign-up lists for at-risk individuals in order to be able to locate them (Bernard and McGeehin 2004). While the provision of heat-stress prevention advice for individuals to apply in their home is important (Hajat et al. 2010), air conditioning is required to save lives (Bernard and McGeehin 2004). In fact, the interior temperatures of cooling centres in the City of Philadelphia are regulated by law and must be at or under 27°C (City of Philadelphia – Office of Emergency Management n.d.).

From a long-term perspective, urban planning also has a role to play in heat wave preparedness, as structural interventions can create a cool city both in interior and exterior spaces (Matthies et al. 2008). Such approaches would allow cities not only to respond to the inequitable distribution of heat island effects along socio-economic lines (CIHI 2011), but also to a warming climate.

III. Method

The data for this project were collected through an extensive literature review relating to heat waves, climate change adaptation and mitigation and their interactions and issues relating to public policy and decision-making. In addition, the author carried out a thorough review of publicly available documents regarding climate change mitigation and adaptation, land use planning, heat wave planning and existing emergency response frameworks in British Columbia at all three levels of government (municipal, regional and provincial). Documents from Federal entities were also consulted. The author conducted one interview with a British Columbia Centre for Disease Control (BCCDC) official in relation to the 2009 heat wave and heat wave planning in the region. The author also attempted to contact both City of Vancouver officials and architects, developers and engineers involved in property development in Vancouver to better understand the City's green building policies and their influence on local property development decisions. Three interviews were completed in this regard: one architect, one engineer and a past Director of Planning for the City of Vancouver.

IV. Results

1. City of Vancouver climate change mitigation initiatives

The City of Vancouver's climate change mitigation targets and strategies are outlined in the "Greenhouse Gas Emission Reduction Official Development Plan. (Adopted by By-law No. 10041, May 18, 2010.)" (COV 2010c) as required by Section 562.01 of the *Vancouver Charter* [SBC 1953, c. 55]. The by-law summarizes the content of successive climate change mitigation plans, namely the *Community Climate Change Action Plan* (COV 2005), *Greenest City Quick Start Recommendations* (COV 2009) and *Vancouver 2020: Bright Green Future* (COV n.d. b). In addition, the City of Vancouver has a *Corporate Climate Change Action Plan* (COV 2003) outlining corporate emission reductions and is signatory to the *BC Climate Action Charter* in which it commits to achieving operational carbon neutrality by 2012 (Province of British Columbia 2009, 2010a). In summary, Vancouver's emissions reduction targets are described in Table 2.

Table 2. City of Vancouver GHG emission reduction targets.

Year	Target	Reported advances
2010	Reduce municipal operations emissions by 20% below 1990 levels	"Achieved"
2012	Achieve Carbon neutral corporate operations; Reduce community emissions by 6% below 1990 levels	"On track to achieving"
2020	Reduce community emissions by 33% below 2007 levels	
2030	Require all new construction to be carbon neutral[5]	
2050	Reduce community emissions by 80% below 1990 levels	

Sources: COV (2010c, 2003 and n.d. a).

COV (2010c), Sections 2.2.1–2.2.4 summarize the City's mitigation-relevant city policies, namely:

- Intended elimination of fossil fuel dependence by 2020 and implementation plan to meet the 2020 emissions reduction target;

[5] The City of Vancouver defines 'carbon neutral' as "a combination of greenhouse gas reductions and offset strategies, which results in achieving net zero carbon emissions" (COV 2010c).

- Emphasis on land use and transportation planning on compact, mixed-use neighbourhoods, transit and active transportation;
- Provision of mechanisms to improve existing and new building energy use including the promotion of passive design and to allow for district energy systems and residential solar systems;
- Requirements for electric vehicle charging infrastructure;
- Requirements for environmental certification (LEED Gold) on land re-zoning requests; and
- Implementation of residential food waste collection.

The emissions profile for the City of Vancouver shows that the principal sources of emissions are buildings (48%) and vehicles (46.6%) (Province of British Columbia 2010b).[6] Given the marine climate and the low incidence of air conditioning in buildings in Vancouver, building emissions are primarily from heating. Cooling consumes approximately 6% of annual energy consumption in a mixed use residential or office complex (GVRD 2006: 27).

In summary, it is clear that the City of Vancouver has an extensive climate change mitigation policy. Moreover, a significant portion of emissions reduction is sought through changes to the built environment, a logical emphasis given the contribution of buildings to overall emissions. The principal emissions reductions strategies of interest for this paper are the mandating of carbon neutral construction by 2030, the implementation of a compact, mixed-use urban development strategy, the encouragement of improvements to building stock energy use through the promotion of passive design and the requirement for LEED Gold certification in rezoning applications.

2. City of Vancouver climate change adaptation initiatives

Available documentation indicates that the City of Vancouver began considering climate change adaptation issues in 2008, with a focus on existing infrastructure and capital investments

[6] This measuring system does not consider emissions from the consumption of food and consumer goods, air travel or port-based rail and shipping activities.

(COV 2008). This document recommends expanding adaptation planning to other areas including land-use planning and building stock (COV 2008: 8). Despite this, climate change adaptation does not figure prominently in City material, including notable absence from the websites of the city departments with infrastructure and sustainability portfolios like the Engineering Department, the Sustainability Office and Parks and Recreation. However, the *Extreme Hot Weather Preparedness and Response Plan* (COV 2010b), developed in response to the 2009 heat wave, is an example of reactive climate change adaptation undertaken by the City. Moreover, in early 2011 the City of Vancouver hired an adaptation planner to lead the municipality's participation in the International Council for Local Environmental Initiatives (ICLEI) Canada's Adaptation Initiative, suggesting that climate change adaptation is beginning to enter the City's policy agenda more broadly.[7]

3. Heat waves as a policy issue in British Columbia

In general, heat waves do not figure on the policy agendas of the multiple levels of government in British Columbia. For example, at the provincial level, despite an extensive emergency response framework in British Columbia, the only mention of heat wave response in provincial emergency planning documents is in Provincial Regulation 477/94 "Emergency Program Management Regulation", enacted under the *Emergency Program Act* [RSBC 1996, c. 111], which states that were provincial government intervention required in a heat wave, the Attorney General will coordinate its response.

Heat waves do not figure in the regional policy agenda either. For example, the new Regional Growth Strategy (RGS) emphasizes flood hazard and sea-level rise as the major risks in relation to climate change (GVRD 2011: 42), suggesting that these are the adaptation issues that most

[7] As part of its relationship with the regional government (Metro Vancouver) and under the new Regional Growth Strategy (RGS), the City of Vancouver will be required to address adaptation in its updated Regional Context Statement (RCS). The RCS is the explicit statement of how a member municipality will promote the regional plan through its own comprehensive plan(s). In relation to climate change adaptation, Vancouver's RCS will need to "include policies to encourage settlement patterns that minimize risks associated with climate change…" (GVRD 2011: 42) and furthermore, the City is encouraged by the RGS to "[c]onsider incorporating climate change… into the planning and location of municipal utilities, assets and operations" (ibid.). It will be interesting to observe if and how the development of a new RCS influences the City's activity in relation to climate change adaptation.

concern municipal and regional decision-makers at present despite the importance of the public health issues related to changes in water supply, new disease vectors and extreme temperatures. In addition, information available on the regional government website suggests that heat emergencies are not under consideration by the region's emergency response coordination body, the Integrated Partnership for Regional Emergency Management (IPREM). Incidentally, the regional government has delegated responsibility for regional adaptation to IPREM (see GVRD 2011: 42) but publicly available documents indicate little work by IPREM on the issue.

Moreover, regional health authorities did not have heat wave definitions at the time of the 2009 event (Kosatsky per. comm.).[8] After the heat wave, the Vancouver Coastal and Fraser Health authorities set a forecast threshold of two consecutive days or more of 31°C at the Vancouver Airport climate station and 33°C at the Abbotsford Airport climate station for the issuing of heat advisories (Kosatsky pers. comm.). This is the default City of Vancouver definition as the municipal government defers to Vancouver Coastal Health for the issuing alerts (COV 2010b).[9]

Municipally, heat waves only became a policy issue at the City of Vancouver in 2009 with the event described in the introduction and mentioned in the previous paragraph. This event and, more specifically, the heat-induced death of a homeless man in a city park during the heat wave, prompted the City of Vancouver to develop a heat wave preparedness and response plan (COV 2010b), adopted by city council on July 6, 2010 (COV 2010d). The heat wave also prompted coordinated action between authorities and civil society in Surrey, another municipality in the region (Kosatsky per. comm.).

[8] Canadian heat-wave definitions appear to be uncommon, probably because summer heat has not in the past been a prominent public health issue. One Canadian definition (for the Province of Ontario) is "three or more consecutive days in which maximum temperature is greater than or equal to 32°C" (Meteorologic Service of Canada 2010).

[9] This threshold was set despite the fact that a recent study indicates that residents in the Vancouver region begin to demonstrate negative health effects at daily maximum temperatures above 20°C (Kosatsky pers. comm.). This is consequential with local climate norms. Average summer temperature in July and August in Vancouver are 17.5°C and 17.6°C, respectively, and average maximum temperatures for these two months are only 21.7°C and 21.9°C (Environment Canada 2010a). Undoubtedly, more research is needed on temperature thresholds for Vancouver's population and the influence of a suite of other variables on those thresholds.

In relation to individuals whose actions affect the built environment in Vancouver, neither the engineer nor the architect interviewed for the purposes of this study were aware of the death toll caused by the 2009 heat wave, nor did they feel that heat was a particularly pressing issues for the health and safety of Vancouver residents. This suggests that in general these professions and their associations are not yet aware of the dangers posed by extreme heat under climate change.

V. Discussion

Vancouver and its residents, governments, businesses and institutions are going to need to adapt to climate change, and among the many effects of climate change, the need to adapt to summer heat waves is already clear. Three questions help clarify what sort of adaptive action should be taken: who should carry the burden of adapting to heat waves? Who exactly is at risk? What are the adaptation options? A fourth question allows us to draw connections between mitigation and adaptation: how are these adaptation options constrained by current mitigation initiatives?

It is worthwhile to ask who specifically should carry the burden of adapting to heat waves.[10] Adaptation can be left to individuals or can be undertaken collectively. A collective response provides for more efficient use of resources, better equity outcomes and better mitigation outcomes. For example, leaving the responsibility for adapting to heat waves to individuals and individual businesses would lead to mass installations of air conditioners and other adjustments to private buildings and grounds. In this case, infrastructure is not maximizing gains from economies of scale (efficiency concerns), the ability to effect these changes would depend largely on access to financial resources (equity issues), and energy consumption would increase affecting GHG emissions (not to mention other negative environmental impacts of energy production) (mitigation consequence). Hence, there is a strong argument for a collective or government-led response to heat wave adaptation. Given that the concern over heat waves arises from the impact on human health, it would be logical to expect leadership on the issue from government health authorities. However, as will become clear as the discussion develops,

[10] The discussion will focus solely on heat wave adaptation; however, the arguments are largely applicable to other adaptation issues faces by Vancouver and other communities and decision-making bodies.

through its oversight of urban infrastructure, municipal governments play an important role in providing the basis for adaptive capacity in relation to heat waves. Thus, it is reasonable to ask the City of Vancouver to take steps to facilitate heat wave adaptation.

It is also important to establish who is at risk. During a summer heat wave, Vancouver residents will generally be uncomfortable. However, not everyone will be at equal risk of heat-induced illness or death, that is, part of the truly at-risk population. Past experience in Vancouver and other jurisdictions indicates that the elderly will face the highest risk. According to BC Stats et al. (2006), Vancouver had approximately 76,000 individuals aged 65 and over in 2006. Using the population growth rate for Vancouver for the 2001–2006 period (5.95%) (Statistics Canada 2007), and using projected changes in the age pyramid whereby in 2031, individuals aged 65 and over are expected to make up approximately 20% of Vancouver's population (BC Stats et al. 2006), by 2031, the population aged 65 and over will be approximately 156,000, or more than double the 2006 population. Of course, not all persons over the age of 65 will be equally vulnerable. However, this rough calculation provides some sense of the scale at which resources may need to be mobilized. Other vulnerable populations in Vancouver include the homeless (total population approximately 1,700 (Eberle Planning and Research 2010)), individuals in marginal housing (perhaps primarily tenants of single-room occupancy (SRO) hotels, population approximately 3,600 (CCAP 2009)) and chronically ill individuals (population unknown).

What, then, are the City of Vancouver's options for adapting to heat waves? In order to minimize morbidity and mortality, Vancouver needs to create cool spots for its residents in order to avoid excess deaths. In order to create cool spots, the City of Vancouver needs to apply long-term time horizons regarding the changing climate to infrastructure investment decision-making. It is important to recognize that the need for cooled spaces in Vancouver arises in a difficult context: one, the heat tolerance of Vancouver residents is low, given its marine climate, and two, air conditioning is remarkably uncommon, especially in the residential setting. Only 20.2% heated residential space is cooled in British Columbia (largely concentrated in the interior of the Province, while coastal British Columbia has minimal residential air-conditioning). Thus, the existing residential stock is not well suited to summer heat waves. Furthermore, just less than

79% of heated commercial/institutional space in British Columbia and the Territories is cooled (see Tables 4 and 5 NRCan (2010a) and Tables 24 and 32 NRCan (2010b)).

A cooler city can be created in many ways. For example:

- Create a shaded, cool exterior environment in parks and other public spaces;
- Ensure all new building stock (residential, commercial, community and institutional) performs well in summer heat; and
- Provide refugia during extreme events.

Not all of the above options are equally suitable. For example, while shaded, cool exterior spaces would aid the comfort of Vancouver residents during a heat wave in general, it is not sufficient for dealing with the cooling needs of Vancouver's vulnerable populations during the heat event (i.e. avoiding morbidity and mortality) as the vulnerable population will need access to temperature-controlled environments maintained somewhere between 22°C and 24°C for a period of two to four hours per day for the duration of a heat wave.[11] On the other hand, the remaining two options are viable alternatives for significantly advancing adaptation to heat waves in Vancouver.[12]

First, new building stock, particularly new residential units, could be built to remain cooler in more extreme summer temperatures in order to avoid exacerbating the problem of inadequate residential shelter in summer heat into the future. If new housing stock is resistant to extreme summer heat, then the residents of those units will be comfortable in their homes and not need to

[11] Both temperature and duration are the author's preliminary best estimation of needs, based on research conducted for this project. More research would be necessary to establish an adequate threshold and access duration to ensure the best health outcomes of Vancouver's vulnerable populations.
[12] All three approaches to heat wave preparedness involve trade-offs. For example, with regard to cool exterior spaces, there are trade-offs between the benefits of exterior shading on dangerously hot days (infrequent, but deadly events) and the welcomed warming effect of direct sunlight on cooler days (general conditions majority of the time year). The trade-off with regard to dual-purpose spaces is that refugia requirements may create sub-optimal conditions for the primary purpose. Trade-offs can be lessened through a clear statement of policy objectives and creative thinking in relation to alternatives (see Hammond et al. (1999)).

seek refuge elsewhere.[13] If new commercial, community and institutional stock is resistant to extreme summer heat, then workers are kept safe, business can continue as usual and more floor space in the city will present conditions under which city residents can seek reprieve from the heat. This initiative could be pursued through changes to the "Vancouver Building By-law". For example, increasing the July design temperatures[14] by an appropriate amount and creating mechanisms to ensure buildings minimize summer solar gain[15] would help keep buildings cool in the summer.

Second, the provision of refugia through dual-purpose spaces within the building stock would allow government authorities to provide emergency heat shelters in the future. Refugia would be indoor spaces, equipped with sufficient cooling capacity and capable of receiving large numbers of people. These sites would provide life-saving conditions to vulnerable residents whose housing and neighbourhoods do not afford healthy and livable conditions during heat waves. This option entails an analysis of existing stock with the proper characteristics and the implementation of urban planning provisions to ensure existing and future needs can be met through additions to the building stock. The importance of preparing refugia capacity today lays in the common lifespan of buildings (and infrastructure in general). While other matters related to emergency response to heat waves can be organized on shorter time frames, the building stock is relatively fixed. Thus, property development decisions made today in Vancouver will affect the range of adaptation options available to authorities and residents in the future. Integrating refugia planning into current urban development decision-making is one aspect of making the urban fabric more robust over a range of future environmental scenarios.

[13] Anecdotal evidence suggests that Vancouver's condominium towers do not perform well in summer temperatures. (This type of residential development has been the primary motor for growth in residential units in the city in the last 20 or so years.) The author has heard of residents employing a range of strategies to cool down during hot summer days including: installing individual air-conditioning units, going to the movies and seeking lodging with friends. One clear reason for overheating of units would be the preference for high amounts of exterior glazing (windows) with little use of shading. More research on building and unit performance in summer temperatures and individual adaptation strategies would be interesting.

[14] July design temperatures are one aspect of data on climatic extremes included in Canadian building codes. They provide a benchmark of upper temperature limits to which cooling systems must respond in July (summer), one and 2.5 percent of the time. In British Columbia, July design temperatures are set locally for every municipality or regional district and are calculated based on historical temperature records for the month of July.

[15] Solar gain refers to the contribution of the sun's rays to interior building temperature.

The practice of constructing certain buildings to accommodate extreme scenarios is not new. In fact, examples exist in Vancouver. The well-known home renovations firm Home Depot is reported to have a policy that all its stores be built to withstand natural disaster scenarios (engineer per. comm.). Thus, the new structure housing the Home Depot on Cambie Street between 7th and 8th Avenues is built to withstand a "worst case scenario" in order to be operational post-disaster (engineer per. comm.). Nonetheless, heat wave disasters appear to not have been contemplated as a relevant disaster scenario as the building's heat pump is designed to cool the building to the one-percent Vancouver July design temperature (26°C) and the standard ASHRAE[16] occupancy intensity of 30 people per 1000 square feet (engineer per. comm.). While perhaps Home Depot's policy represents a business risk management strategy rather than a desire to be able to provide emergency shelter in a disaster situation, it provides an example of a structure built to withstand certain extreme conditions. Hence, it follows that specific sites throughout the city could be built to more extreme heat resistant specifications for the purpose of acting as heat wave refugia when needed.

Now that the City of Vancouver's heat wave adaptation options have been established, let us consider the heat wave adaptation implications of the City of Vancouver's current mitigation strategies (specifically those related to the built environment). How are the adaptation options of summer heat-resistant construction and provision of refugia constrained by current mitigation initiatives?

All new buildings will be carbon neutral by 2030

At least one aspect of this policy exhibits consequences for adaptive capacity for heat waves. The main strategies for achieving carbon neutrality are to minimize both embodied energy, minimize energy consumption throughout a building's lifetime and seek to connect buildings to renewable energy sources (COV n.d. b: 29). Evidence presented below indicates that building cooling systems are considered easy targets for building operation energy savings in Vancouver. Therefore, aiming to minimize building energy consumption will very likely directly discourage

[16] ASHRAE, or the American Society of Heating, Refrigerating and Air-Conditioning Engineers, publishes standards relating to building heating and cooling for North America that are commonly used in codified building standards.

the provision of air-conditioning in new constructions, despite the fact that cooling is not a significant aspect of present building energy use.

While minimizing building energy use is a laudable and necessary endeavour given issues like atmospheric GHG concentrations and increasing energy demands globally, such issues do not trump the protection of human health and the prevention of unnecessary deaths. Thus, the contribution of air-condition to human wellbeing during heat wave events under climate change is an important element to consider in decisions regarding mechanisms by which building stock energy use can be minimized. The latter objective addresses mitigation goals while the former addresses adaptation needs.

The other aspects of this policy may be neutral in relation to adaptive capacity for heat waves. Minimizing embodied energy may mean a tendency away from taller, cement structures in favour of six-storey, wood frame structures. Maximizing connections to renewable energy sources probably means the promotion of household solar panels and neighbourhood-based heat exchangers using waste heat from urban sources (see COV 2010c: 4-5). A change in predominant building materials and connections to renewable energy sources do not in themselves dictate building performance in summer heat. Rather, design features (orientation, shading, windows area) and design regulations (such as those contained in the Building Code regarding insulation and July design temperatures for calculating cooling needs), in addition to powerful cooling technologies, are more important in improving building performance under future heat wave scenarios.

Compact, mixed-use urban development strategy

This policy may exploit synergies between mitigation and adaptation. Other heat wave experiences have shown that compact, walkable neighbourhoods improve health outcomes for seniors in a heat wave, as they provide residents with nearby and familiar businesses in which to cool off (Klinenberg 2002). Hence, Vancouver's goal of creating compact, mixed-use neighbourhoods may increase Vancouver's adaptive capacity in relation to heat waves. However, this is only the case if local commercial spaces are equipped with sufficient cooling technology so that their interiors remain cool, which may not be the case in Vancouver, given the

characteristics of existing stock and the consequences of the following two policies. Furthermore, more compact, urban spaces may result in localized urban heat island effects, an issue that should be considered by urban designers.

LEED Gold certification requirement for rezoning applications[17,18]

This policy has consequences for adaptation. The use of LEED is discouraging the provision of adequate cooling systems necessary for protecting the population from heat waves in the future. This is evident in both the "Green Building Rezoning Policy" (COV 2010a) and in a guide regarding the use of LEED destined for municipal governments in the region (GVRD 2006).

In GVRD (2006), the regional government states: "dramatic reductions or elimination of cooling systems through effective building design is a smart energy-saving and capital cost-saving strategy" (GVRD 2006: 30). It suggests the following: "Look at orientation, shading options, and envelope performance to see if it is possible with the internal requirements of a space to use entirely natural ventilation for cooling" (ibid). In other words, municipalities are being actively discouraged from using air conditioning in municipal facilities, in favour of passive design options (see next subheading). Moreover, the City of Vancouver's "Green Building Rezoning Policy" explicitly states "[t]he application of this policy shall emphasize approaches that use passive design practices to reduce energy need…" (COV 2010a).

While, the City of Vancouver does not have control over how private property development projects choose to obtain the LEED points necessary to achieve the target level of certification, the City of Vancouver's policy on rezoning and LEED mandates that such projects achieve a minimum of six (of 10 possible) points for energy optimization under the Energy and Atmosphere category in the LEED scoring system (COV 2010a). This means that proposed

[17] For a description of LEED see Canada Green Building Council (n.d.) and GVRD (2006).
[18] Municipalities across Canada, including Vancouver, Surrey, Calgary, Edmonton, Waterloo and Halifax, are incorporating LEED certification requirements into their urban development strategies (GVRD 2006: 6; Halifax Regional Municipality 2005: 35). By 2006, there were 15 LEED-certified buildings in the GVRD and 54 LEED-registered projects of which four of the certified buildings and 19 of registered projects were located in Vancouver proper (GVRD 2006: 9). The GVRD has sought to support municipalities in adopting LEED-certified construction (see GVRD 2006). Aloisio (2007) discusses why LEED is not necessarily an appropriate tool for meeting the environmental goals of municipalities.

projects must provide models that demonstrate building energy use 40% better than the ASHRAE standard (see GVRD 2006, Appendix a). (The LEED system awards points up to a 60% improvement (ibid.).) The author was unable to obtain information from property developers or associated architects on common strategies used for Vancouver projects in achieving these six points. However, as GVRD (2006) was co-authored by a highly reputable architecture firm considered a North American leader in LEED construction (with an office in Vancouver), it appears highly likely that doing away with air conditioning is a commonly applied strategy for achieving these points. Moreover, this advice from such a source suggests that architectural practice in North America is not yet actively contemplating the impact of climate change on building heating and cooling needs.

While not all new construction in Vancouver results from rezoning, projects undertaken through rezoning are usually some of the largest and most important, affecting future directions for the neighbourhood and the city. An example is the progressive development of the False Creek perimeter since the late 1980s that transformed previously industrial lands into primarily high-density residential. Given the sheer quantity of residential units generally contained within such projects and the quantity of associated amenities, the impact of LEED requirements on the future performance and utility of these structures under climate change is an important issue to address.

The question arises as to whether or not the City of Vancouver is exchanging density for specific levels of LEED certification or equivalents. Were this the case, the City of Vancouver would be incentivizing, at a large scale, buildings that will not adequately protect residents and users from future heat waves. According to the past Director of Planning for the City of Vancouver interviewed for this study, the "Green Building Rezoning Policy" institutes LEED Gold (or equivalent certification) as a precondition for the consideration of a rezoning application, but does not value it as a feature to be directly awarded with a specific amount of additional density. However, to the extent that LEED Gold certification is a requirement, and to the extent that a successful rezoning is in effect the awarding of a density package to a developer, this policy does create a relationship between environmental certification and additional density, although the relationship is indirect and difficult to quantify. Additional policy proposals further suggest an intention to reward green construction, such as the recommendation to provide accelerated

permitting for green or low-emissions construction (COV n.d. b: 28; COV 2009: 15). The City of Vancouver's objective for its green building policies is to institute environmentally sustainable construction as the new baseline for property development in Vancouver (past Director of Planning per. comm.). Unfortunately, the current approach has the unintended consequence of reducing adaptive capacity in relation to heat waves under climate change.

Improve building stock energy use through the promotion of passive design

This fourth policy also has consequences for adaptation. Passive design refers to relying on solar energy and laws of physics for the heating and cooling of a building. This design approach seeks to use design and materials to store solar radiation and manage the factors that naturally heat a building's interior in order to create optimum comfort for building occupants yet minimize energy use required to run mechanical heating and cooling systems.[19] Any of the above policies that advocate for energy use reductions are advocating for the use of passive design. Passive design by its very nature is meant to provide a comfortable interior environment over the range of average temperatures specific to a particular place. Passive design is not meant to accommodate extreme temperatures outside the norm. The architect interviewed for this study admitted that buildings constructed by his/her firm on passive design principles would probably not provide a cool enough environment (24°C or less) during a heat wave (but would provide for occupant comfort under normal conditions). As mentioned above, while reducing energy consumption is important, so is protecting human health and passive design will not provide for the desired outcomes under heat wave scenarios.[20,21]

[19] The following environmental factors heat a building's interior: external solar gain (heat conducted through building envelope), internal solar gain (sunlight through windows), conductive gains (heat flow from hot air through materials), ventilation gains (warm air coming in through the ventilation system), artificial light gains and internal gains from occupants and equipment (like computers or other machines) (Baker and Steemers 1999). The following approaches protect a building from solar gain: envelope construction (i.e. what the building's shell is made of), insulation, orientation, airflow and shading (Baker and Steemers 1999; architect per. comm.; engineer per. comm.).

[20] In arguing that passive design is insufficient for protecting human health in heat waves, the author is not dismissing the contribution of passive design to sustainable built form. Instead, the author wishes to provide an example of a sub-optimal outcome in order to engender discussion on refinements or alternatives that improve the sustainability outcomes for specific contexts and under specific circumstances.

[21] Not discussed here is the fact that to the extent that it relies on large elements of thermal mass, passive design makes it more difficult to achieve building lifecycle carbon neutrality.

The above discussion makes it clear that the City of Vancouver's current mitigation policies concerning the built environment have important consequences for heat wave adaptation. The goal of creating compact, mixed-use urban communities is the only current policy presenting synergies between heat wave adaptation and climate change mitigation. The other three policies, while perhaps providing for desired mitigation outcomes, are detrimental for heat wave adaptation.[22] Passive design and the exclusion of air-conditioning are the key strategies being employed to meet energy efficiency targets, without due consideration of a) building performance under extreme summer temperatures; b) projections regarding increasing building cooling needs under climate change (Crawley 2008) and c) the human health imperative to provide suitable alternatives. This is a clear example of an institutional barrier to adaptation.

Fortunately, the goals of reducing building energy consumption and providing for artificially cooled building interiors during heat waves are not necessarily irreconcilable objectives. In other words, technologies exist that do not demand trade-offs between the two objectives. Ground source heat pumps and large-scale inter-building heat distribution systems would provide for both emissions reductions and sufficient cooling capacity (Hanova et al. 2007). The cost-effectiveness of an alternative such as this one is increased by the fact that it exploits synergies between adaptation and mitigation (Klein et al. 2007).

This study thus demonstrates how municipal policies and practices regarding the built urban environment can act as institutional barriers to climate change adaptation. Policy refinements or policy alternatives are needed in order to reconcile adaptation and mitigation goals in Vancouver. Wilson and McDaniels (2007) suggest a framework for co-consideration of complex public policy issues involving uncertainty like climate change adaptation and mitigation.

It is important to note, however, that the City of Vancouver's mitigation policies are not the only institutional barriers that are constraining adaptation in the building sector. Bias among

[22] The City of Vancouver policy assumes that LEED-certified buildings demonstrate emissions reductions once in use. However, evidence suggests strongly that LEED certified buildings do not necessarily perform better than existing building stock. See Turner and Frankel (2008) and Scheuer and Koeleian (2002).

professionals and government proscribed standards and regulations also have the potential to act as institutional barriers to change.[23]

For example, the professionals interviewed for this paper demonstrated perception bias in that they did not perceive either the risk of heat wave occurrence or the risk posed to human health by heat waves in Vancouver. Professionals also demonstrate status quo bias, whereby air conditioning is not considered a necessary element in building design because it has not been common in the past. Indeed, it appears that architects and other professions are not yet planning ahead for changing climatic conditions in designing buildings and their systems.

In relation to standards and regulations, two examples come to mind: building codes and energy performance standards for window glass. For example, building code climatic data in general and July design temperatures in particular are based on past climatic averages and do not incorporate climate change projections. Thus, building code climatic data is not a reliable benchmark for conditions under which buildings will have to perform in the future under climate change. Another example is that of standards that encourage solar gain in Canada in order to reduce winter heating loads, like the new Energy Star requirements for window glass (NRCan 2011), which have the potential to create unintended impacts on the livability of interior spaces under heat wave conditions, consequences which perhaps have not been given due consideration.

The above examples demonstrate the difficulty of changing mindsets and of moving beyond past experience and of the unintended consequences of existing or new standards. They also confirm that municipal mitigation policies are not the only institutional barriers regarding the built environment and heat wave adaptation.

VI. Recommendations

The City of Vancouver can take the following steps to improve its adaptive capacity in general, and in relation to heat waves in particular:

[23] For a discussion of bias in individual decision-making see Bazerman (1998) and March (1994).

- Begin comprehensive climate change adaptation planning and reconsider mitigation strategies in light of the adaptation needs and risks.

- Incorporate the need for refugia into municipal planning to ensure the city has sufficient interior spaces with the required cooling capacity for use during severe heat waves.

- Seek emissions savings from new construction in areas other than cooling systems and preserve air-conditioning as an acceptable option for building cooling.

- Consider mechanisms to encourage the use of ground source heat pumps to distribute effective, low-emissions cooling (and heating) to buildings.

- Modify the "Vancouver Building By-law" to require summer solar gain control and improved building performance under summer heat conditions.

- Pursue urban design strategies that provide exterior shade during heat waves without over-shading during regular conditions.

VII. Conclusion

The principal objective of this project was to explore the interconnected nature of climate mitigation and adaptation by investigating how government policies and practices regarding the built urban environment can act as institutional barriers to climate change adaptation. The case study explored the need for heat wave adaptation planning in the City of Vancouver and the impact of mitigation policies on heat wave adaptive capacity.

The City of Vancouver's current mitigation efforts are, on the whole, negatively affecting the municipal government's future ability to protect the population from heat waves. While the compact, mixed-used development strategy potentially exploits synergies between adaptation and mitigation in relation to heat waves, policies related to emissions reductions through energy savings are leading to new construction unsuited to the extremes of future climatic conditions,

given the preference for passive design solutions among the relevant decision-makers. Thus, the study demonstrates that the lag between climate change adaptation and mitigation planning is detrimental to local adaptive capacity.

The City of Vancouver can improve its adaptive capacity in relation to heat waves by addressing the need for cool interior spaces and refugia in its development strategies. This requires anticipating the shift to the right in climate mean as it relates to building design parameters and equipping buildings with powerful cooling technologies. In general, the City of Vancouver can improve its preparedness for climate change by integrating climate change adaptation considerations into its policy development and decision-making in all areas.

The following lessons are important for the project's other imagined clients, namely Canadian municipalities in general, the Federation of Canadian Municipalities and Health Canada:

- Climate change will cause significant new health issues;

- Urban planning and property development decisions negatively affect residents' health in the long-term and planned adaptation will support healthy outcomes for residents;

- A range of existing policies, practices and standards act as institutional barriers to effective climate change adaptation at the municipal level, but not all of these policies, practices and standards are within municipal jurisdiction;

- Climate change adaptation considerations need to be wholly integrated into municipal policy- and decision-making; and

- The modification of mitigation programs in light of adaptation needs will secure better medium- and long-term outcomes.

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