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ADAPTATION TO CLIMATE CHANGE TEAM

LOW CARBON RESILIENCE:

TRANSFORMATIVE CLIMATE CHANGE PLANNING FOR CANADA

AN ACT WHITE PAPER

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ACT (the Adaptation to Climate Change Team), based at Simon Fraser University's School of Public Policy, is dedicated to developing and delivering a unique combination of research, outreach and policy innovation designed to benefit Canadian decision-makers, sectors and communities as they work to respond to the challenges posed by climate change. ACT is also affiliated with SFU's Centre for Dialogue.

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TABLE OF CONTENTS

Executive Summary 1

Introduction 4

Background 6

- The Canadian Context 6
- Defining and Positioning Low Carbon Resilience 7
- Figure 1: Adaptation and Mitigation Model 9

Section 1: Low Carbon Resilience in Today's Political Climate 10

- The International Scale 10
- New Federal Approaches 12

Section 2: Incorporating Resilience into a Low Carbon Future 14

- Mitigation Through Carbon Pricing: Opportunities to Adapt 14
- Resilient Renewables 15
- Case Study 1: Alberta's Climate Leadership Implementation Act 16
- Case Study 2: Lucid Energy 17

Section 3: Low Carbon Resilience and Ecosystem Services 18

- Soil Health 18
- Extreme Heat 20
- Case Study 3: USDA Climate Smart Agriculture and Forestry Strategy 21
- Stormwater and Flooding 23
- Ecosystem Health 24

Section 4: The Business Case for Low Carbon Resilience 26

- Natural Capital and Ecosystem Services 26
- Preserving Infrastructure: The Costs of Inaction 27
- Case Study 4: Concert Properties and Waterfront Development 28

Conclusion 30

References 32

EXECUTIVE SUMMARY

Low carbon resilience (LCR) refers to climate change strategies that integrate and achieve co-benefits between greenhouse gas emissions reduction (mitigation) and planning designed to reduce vulnerability to climate change impacts (adaptation). To date, most strategies focus on one or the other of these two goals. This paper demonstrates the potential value of their integration, explores examples of low carbon resilience strategies, and considers options for their implementation in Canada.

We currently have a limited window of opportunity to plan implementation of low carbon resilience via coordinated actions, policies, pricing and planning approaches. Doing so will create win-wins and save valuable time and financial resources that may otherwise be lost due to missed opportunities or the result of building in future vulnerability.

As we plan to limit climate change and adapt to impacts we can no longer avoid, synergies between climate change adaptation and mitigation are becoming increasingly relevant at a variety of scales. The concept is gaining momentum

at the international level through the Paris Agreement, the United Nations Sustainable Development Goals, the Sendai Framework for Disaster Risk Reduction, and the Intergovernmental Panel on Climate Change (IPCC). Given the scope and influence of these international commitments, and recently established mandates and budgets pertaining to adaptation and mitigation at the federal level in Canada, now is the ideal time for broad application of low carbon resilience planning and implementation.

In Canada, action on climate change is about to be accelerated by a federally mandated transition to a low carbon economy supported by national and provincial-level climate action plans. In light of this transition, decision makers could consider ways to coordinate adaptation and mitigation planning processes, and identify opportunities to develop funding for low carbon resilience strategies using revenues from carbon pricing, since these measures are beginning to gain prominence at the provincial level, and municipalities often lack the financial capacity both to mitigate and adapt to climate change impacts.

As we transition to a low carbon future, it is essential that climate change resilience and risk planning be incorporated in the design and placement of renewable energy infrastructure. Starting now, it would save time and money if standards for implementation of both mitigation and adaptation approaches were developed in a coordinated fashion in order to enable professionals such as developers, engineers and planners attempting or required to implement adaptation and/or mitigation to easily identify co-benefits and synergies.

As we consider climate change responses, it is also essential that we place ecosystem health at the centre of our priorities. Widespread damage to ecosystems driven by systemic societal issues is a significant source of carbon emissions, and is compounding the challenges facing species struggling to adapt to changing weather and temperature patterns; meanwhile, ecological approaches to low carbon resilience have been shown to provide multiple co-benefits, from robust property values to improved human health. Investing in ecosystem health

and natural capital in ways that drive both mitigation and adaptation to climate change offers opportunities to save valuable financial and natural resources while supporting struggling species.

The current and projected economic costs of inaction on climate change and the corresponding threats to infrastructure will directly impact Canadian communities. This further highlights the need for low carbon resilience strategies, examples of which we explore throughout this paper. For instance, revenues acquired from carbon pricing strategies could also be allocated to low carbon resilience solutions that support ecosystems and the benefits they provide pertaining to soil health, extreme heat, and flooding, and new approaches to valuation of ecosystem benefits framed as critical infrastructure can save communities money while reducing emissions and nurturing ecosystem health.

Finally, this paper is intended to stimulate discussion and innovation. It does not attempt to incorporate all of the synergies and benefits of low carbon resilience, which extend into health, equity, and a wide variety of other social, financial and ecological considerations. We appreciate the contributions of many other organizations - several of whom are referenced in the paper - to the concept of low carbon resilience under a variety of names, and we look forward to next steps as experts in Canada and around the world work together to develop creative, transformational responses to the climate change challenge.

INTRODUCTION

Ongoing emissions reduction strategies are urgently required if we are to avoid runaway climate change. However, research shows that global warming and related impacts are likely to continue for centuries even if anthropogenic greenhouse gas emissions were to be reduced to zero today, due to the emissions we have already released (IPCC, 2014). As a result, we have to plan for ways to respond to the impacts via climate change adaptation.

The effects of historic and current emissions are causing increasing uncertainty in the range of expected climatic behaviours; meanwhile, the rate of loss of biodiversity and natural carbon sinks caused by human development is accelerating. These factors are combining to cause what is known as the "loss of stationarity" – new levels of extreme weather damage, and major alterations in the ecological conditions on which all life depends – even as we are planning the transition to renewable energy sources and other emissions reduction strategies.

The promise of complementary solutions should therefore compel us to consider mitigation and adaptation solutions together now in order to address a variety of environmental problems and risks (IPCC, 2014). Furthermore, climate change adversely impacts a variety of interrelated and interdependent sectors, for instance, the nexus between energy, food, water and biodiversity (O'Riordan and Sandford, 2015). Using a low carbon resilience approach that considers adaptation and mitigation strategies simultaneously offers opportunities to address these challenges holistically.

If we continue to implement these two crucial pathways separately, we run the risk of either increasing emissions or missing opportunities to reduce them

via adaptation measures; we similarly risk building in vulnerability to climate change impacts in new renewable energy and energy efficiency measures. The benefits both from and to ecosystems that can be driven by this approach are one of the most important win-wins, and the dire state of the biosphere adds a moral urgency to this message. We can obtain multiple benefits if we consider the synergies between adaptation, mitigation, and ecosystem health, starting now.

The structure of this paper is as follows: First, we outline the concept and value of low carbon resilience, along with its connections to key international and national climate change commitments.

Low carbon resilience strategies are then discussed in terms of potential incorporation within mitigation strategies such as carbon pricing systems and renewable energy development, as part of the broader low carbon economy shift in Canada. For instance, carbon pricing can provide a budget to encourage innovative adaptation solutions that include the potential for both carbon capture and enhanced ecological health and resulting services.

We consider the capacity of low carbon resilience solutions to build on ecosystem services related to soil health, extreme heat, stormwater and flooding, as well as ecosystem health.

The paper concludes by touching on the business case for low carbon resilience, including the economic value of ecosystem services, and the potential costs of inaction pertaining to vulnerable infrastructure.

BACKGROUND

THE CANADIAN CONTEXT

Canada is already experiencing the effects of a changing climate; however, national and provincial adaptation policies have so far failed to keep pace with the impacts facing our communities. In the last five years alone, environmental hazards ranging from drought, flood, wildfire, wind, and ice storms have cost billions of dollars in damages, while exposing a lack of resilience within our current policies and infrastructure (Boyle, Cunningham, and Dekens, 2013; CBC News, 2014; Mills, 2013). The far-reaching impacts of these events validates a need for innovative approaches to address the multifaceted challenges of climate change, particularly since the projected accumulated costs of adaptation and mitigation measures are far beyond current government budgets.

While climate change affects all sectors, existing policies designed to respond to its threats at the federal, provincial, and municipal level are largely fragmented, both vertically between jurisdictions and horizontally amongst ministries and departments. This is partly the result of a separation between mitigation and adaptation processes, stemming from the fact that the two processes initially developed separately (Ayers and Huq, 2008). Strategies designed to reduce greenhouse gas emissions in response to the realization that their influence was causing global warming involved processes that were (and still are) largely handled in the context of air quality, energy efficiency, and various forms of carbon pricing.

Subsequently, when we realized that we were not acting fast enough to stop climate change, adaptation approaches were conceptualized based largely on engineering projects designed to reduce the impacts of stormwater and extreme

heat, and more recently, the need to restore functioning ecosystems to buffer against the effects of climate change.

We did not act fast enough to stop the accumulation of emissions, which has led to ongoing climatic instability with associated risks that are now inevitable, measurable and already causing extensive damage (IPCC, 2014). There is therefore a current and clear need to develop coordinated governance and sectoral agendas that address the uncertainties of a climate-changed future while we continue to reduce our emissions as fast as possible to avoid runaway climate change to which we cannot adapt.

The implementation of low carbon resilience approaches has the potential to address multiple problems across sectors and jurisdictional boundaries, while reducing costs and maximizing benefits to both ecosystems and human society.

DEFINING AND POSITIONING LOW CARBON RESILIENCE

Corktown Common, Toronto - absorbs stormwater, provides shade, absorbs carbon, provides amenity

The term "low carbon resilience" refers to solutions that result in both mitigation and adaptation to climate change. Mitigation can be defined as "an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases" (IPCC, 2007). Adaptation can be defined as an "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects that moderates harm or exploits beneficial opportunities" (IPCC, 2007).

In Canada, the potential to combine mitigation and adaptation solutions has already been discussed by a variety of experts in different sectors. For instance, the Adaptation + Mitigation + Sustainable Development (AMSD) and Sustainability + Adaptation + Mitigation (SAM) models recognized that climate risk vulnerability and greenhouse gas emissions could be simultaneously reduced through responsible solutions (Bizikova, Neale, and Burton, 2008). These approaches were also influential in recognizing that adapting to climatic change in a way that increases emissions can be described as "maladaptation" (Bizikova, Neale, and Burton, 2008).

The low carbon resilience approach was identified as follows in 2009 by Ontario's Expert Panel on Adaptation: "Where possible and appropriate, every policy and practice of government, the private sector and civil society should be reshaped and redesigned to achieve three objectives: The maximum reduction in GHG emissions; the greatest possible reduction in vulnerability through adaptation and climate-resilient development, and the integration and harmonization of these first two objectives with each other and with other policies such that the joint benefits or co-benefits of actions are maximized" (Expert Panel on Climate Change Adaptation, 2009).

These approaches failed to gain widespread traction in policy measures at the time, possibly due to the complexity of their components, an early lack of understanding of the mechanisms of and need for adaptation amongst policy makers, and the imperative for carbon reduction that initially dominated national thinking on climate change in Canada, plus slow progress on all these fronts. Interest in and articulation of low carbon resilience approaches is now increasing under a variety of names, for instance, Ouranos' 2016 report Synergies: Interactions Between Climate Change Adaptation and Mitigation in Canada's Energy Supply Sector.

While we are now beginning to grapple seriously with emissions reduction strategies, the measurably rising costs of wildfires, flooding and droughts are simultaneously elevating the scope and importance of adaptation strategies.

In recognition of the synergies between mitigation and adaptation promoted by recent international agendas and agreements, political momentum towards low carbon resilience is building, and can and should now be applied in Canada.

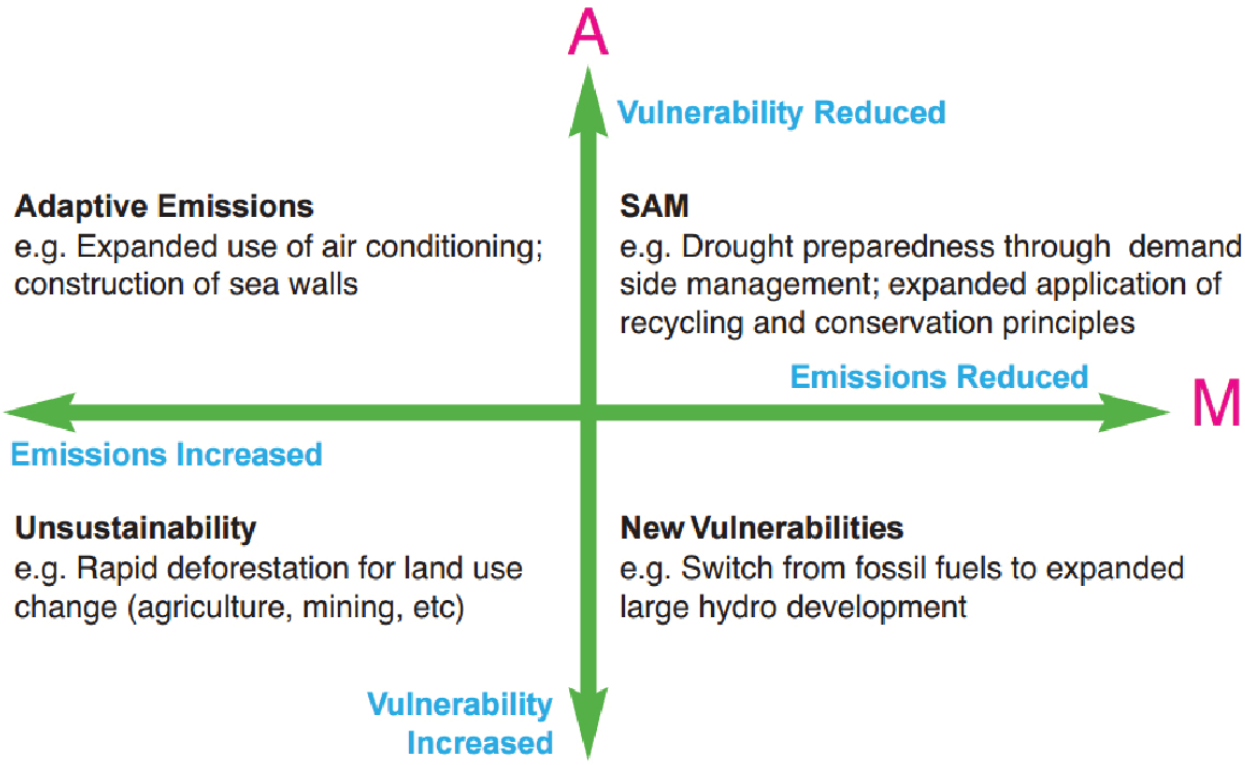


Figure 1: Adaptation and Mitigation Model (Bizikova, Neale and Burton, 2008, p. 21). This model represents the connections between adaptation and mitigation (SAM), warning of the dangers of maladaptation. The vertical axis (A) represents adaptation, and the horizontal axis (M) represents mitigation.

SECTION 1: LOW CARBON RESILIENCE IN TODAY'S POLITICAL CLIMATE

THE INTERNATIONAL SCALE

Current international climate policies urge individual nations to take action on climate change and to incorporate strategies related to low carbon resilience. One hundred and seventy-five countries, including Canada, ratified the Paris Agreement in April of 2016. Article 40 of this agreement recognizes the potential connections between mitigation and adaptation, and requests that further work be done to "enhance linkages and create synergy between, inter alia, mitigation, adaptation, finance, technology transfer and capacity-building" (United Nations Framework Convention on Climate Change (UNFCCC), 2015, p. 6).

The recently updated United Nations Sustainable Development Goals (UN SDGs), released in September 2015, advocate for international cooperation aimed at "accelerating the reduction of greenhouse gas emissions and addressing adaptation to the adverse impacts of climate change" (United Nations, 2015, Declaration 31). The SDGs also acknowledge the potential for climate resilience strategies that have benefits across sectors, which is typical of strategies associated with low carbon resilience, as we shall demonstrate in Sections 2, 3 and 4. Goal 13.3 emphasizes the need to "improve education, awareness-raising and human and institutional capacity on climate change mitigation and adaptation,

impact reduction and early warning" (United Nations, 2015, Goal 13.3). Goal 13.2 describes a need to "integrate climate change measures into national policies, strategies, and planning" (United Nations, 2015, Goal 13.1- 13.2). Goal 11.7b advocates for development in line with the Sendai Framework for Disaster Risk Reduction 2015-2030 through "holistic disaster risk management at all levels" (United Nations, 2015, Goal 11.7b).

The Sendai Framework was adopted by United Nations member states in March of 2015, and places emphasis on developing a more complete understanding of disaster risk in all its dimensions. The Framework recommends the adoption of national and local disaster plans across different scales so that the prevention of risk is an integral component of overall resilience (United Nations, 2015b). In accordance with the Sendai Framework, Canada should strive for governmental cohesion to implement disaster management legislation across provinces and territories, since current disaster management legislation remains fragmented and ambiguous, and typically fails to include standards that municipalities must meet in preparation of disaster management plans (Raikes and McBean, 2016). The importance of holistic disaster management implied by the Sendai Framework in combination with the mitigation requests of the Paris Agreement and SDGs demonstrates that implementing low carbon resilience strategies in Canada would align with new international sustainability requirements.

The IPCC recommends aligning climate policy with sustainable development, and acknowledges that this will require attention to both adaptation and mitigation (IPCC, 2014). Highlighting the urgency of acting in a timely manner, the IPCC also states that, "opportunities to take advantage of positive synergies between adaptation and mitigation may decrease with time, particularly if limits to adaptation are exceeded" (IPCC, 2014, p. 31).

The IPCC also recognizes that efforts to mitigate and adapt to climate change involve delving into the complexity of interactions between human health, water, energy, land use, and biodiversity (IPCC, 2014), which is consistent with the concept of low carbon resilience, as we illustrate in Section 3.

NEW FEDERAL APPROACHES

Canada's recently elected Prime Minister expressed the intent to develop a new climate change plan in his inaugural mandate letter to the newly minted Minister of Environment and Climate Change. This letter promotes the goal of emission reductions and a shift towards a low carbon economy, and describes the need to protect Canadian communities "from the challenges of climate change and supporting them in the transition toward more sustainable economic growth by making significant new investments in green infrastructure" (Government of Canada, 2015). Green infrastructure can be defined simply as infrastructure that reduces emissions; however, many planners in Canada and internationally are beginning to use this designation for ecosystem-based responses to flood control (also known as "blue-green infrastructure") and heat mitigation. These ecosystem-based responses are discussed in the context of low carbon resilience in Section 3.

The Liberal budget for the next five years allocates $518 million towards local government infrastructure needs to adapt to a changing climate; $128.8 million to develop higher energy efficiency standards for products and vehicles and to retrofit buildings; and $2 billion towards water and wastewater infrastructure treatment (McDiarmid, 2016). By far the biggest investment, however, is in infrastructure, with a $125-billion commitment that is almost double the $65-billion committed by the previous government. An additional $60 billion has been dedicated to public transit, social infrastructure, and green infrastructure (ReNew Canada, 2016). With these recent budget commitments and climate change directives in place, an opportunity exists to endorse low carbon resilience solutions throughout all tiers of government.

While some climate change responses will by their nature be obliged to feature primarily either mitigation or adaptation strategies, mutual benefits can be attained by combining these processes together when the opportunity arises. In fact, many communities throughout Canada have already achieved aspects

of low carbon resilience without explicitly referring to it as such; we offer examples and brief case studies throughout this paper.

The LCR concept now needs to be promoted and widely explored for the co-benefits it offers in the context of the international and national goals outlined above, as well as provincial, local and sectoral actions and operations.

SECTION 2: INCORPORATING RESILIENCE INTO A LOW CARBON FUTURE

MITIGATION THROUGH CARBON PRICING: OPPORTUNITIES TO ADAPT

Achieving and maintaining the international and national climate change commitments outlined in the previous section requires progressive mitigation strategies throughout multiple tiers of government. Transitioning towards a low-carbon future is essential in order to attain significant reductions of greenhouse gas emissions in Canada, and putting a price on carbon is the preliminary step in moving towards this goal (Hodgson, 2016).

Carbon pricing is an essential policy mechanism for driving minimization of greenhouse gas emissions and development of low-carbon economies. Examples of carbon pricing tools include taxes, trading mechanisms, and combination approaches (BC Climate Leadership Team, 2015). Prime Minister Trudeau's mandate letter to the Minister of Environment and Climate Change outlined the need for provinces and territories to establish pricing strategies, as well as partnerships with the federal government on emissions reductions strategies (Government of Canada, 2015). British Columbia, Alberta, Ontario, and Quebec have all established forms of carbon pricing through legislation, and regions

are beginning to work together towards this goal, as evidenced by the collaborative carbon trading system between Quebec, British Columbia, Ontario, and the State of California as part of the Western Climate Initiative. There is now an opportunity to utilize carbon pricing-related funds for low carbon resilience projects. For example, revenue from a carbon tax or cap and trade system might be re-invested into resilient infrastructure, and offset systems could be used to acquire lands for adaptation purposes.

Investing in low carbon resilience solutions such as green infrastructure requires substantial funding. Many municipalities face significant infrastructure deficits and limited financial resources, as well as the requirement to both prepare for and recover from local climate change impacts, all of which are hampering their ability to respond to a changing climate (Adaptation to Climate Change Team, 2008). One example of a carbon pricing mechanism that could create funding opportunities for low carbon resilience projects is outlined in Case Study 1.

RESILIENT RENEWABLES

Renewable energy production and energy conservation measures that replace fossil fuels are required if we are to significantly reduce our emissions, and the Paris Agreement has spurred a global sense of urgency towards implementation of these technologies. The world must collectively shift to zero carbon sources of electricity as soon as 2018 to avoid adding new fossil fuel infrastructure that would lock in future emissions (Pfeiffer, Millar, Hepburn, and Beinhocker, 2016). Member nations of the Group of 7 (G7), including Canada, have pledged to end fossil fuel subsidies by 2025 (Ministry of Foreign Affairs Japan, 2016). As noted above, the Government of Canada has also mandated a transition to a low carbon economy (Government of Canada, 2015/2016).

Meanwhile, Canadian provinces are enacting legislation to move towards a low carbon energy future, often in conjunction with carbon pricing strategies, as exemplified by Ontario's Climate Change Mitigation and Low-carbon Economy Act of 2016 (Legislative Assembly of Ontario, 2016). British Columbia's Greenhouse Gas Reduction (Renewable and Low Carbon Fuel Requirements)

Act of 2008 and Alberta's Climate Leadership Plan and current low carbon economy agreement with the United Kingdom also indicate this shift towards a renewable energy future (Alberta Government, 2016; CBC News, 2016; Legislative Assembly of British Columbia, 2008). Municipal governments are also taking the initiative to invest in a low carbon economy, such as the City of Vancouver's 2016 Renewable City Strategy, which commits to using 100% renewable energy sources to power city infrastructure by 2050 (City of Vancouver, 2016).

As the use of fossil fuels diminishes and international treaties such as the Paris Agreement pressure nations to invest in alternatives, a revolutionary transition to competitive sources of renewable energy seems imminent. This shift includes the need to electrify all systems so they can run on the power generated by low carbon technologies. However, this transition towards a low carbon economy requires careful climate change risk assessment if we are to avoid building in future vulnerability. When planning and developing renewable energy infrastructure and its implementation, we must consider climate change impacts such as disruptions to supply and other threats caused by extreme weather (International Energy Agency, 2015; Ouranos, 2016). Incorporating climate change resilience into the design and placement of new renewable energy systems can avoid the need for costly refurbishments, relocations, or upgrades in the future (Ouranos, 2016).

Assessing the resilience of energy sources is critical, as evidenced by the thousands of Canadians often left without power after extreme weather events.

CASE STUDY 1: ALBERTA'S CLIMATE LEADERSHIP IMPLEMENTATION ACT

On May 24, 2016, Bill 20 was introduced to enable passage of Alberta's Climate Leadership Implementation Act and Energy Efficiency Alberta Act. This legislation sets a price on carbon and imposes a levy on various transportation and heating fuels. Revenues gained from these levies may only be used for mitigation solutions, adaptation solutions, and rebates (The Legislative Assembly of Alberta, 2016). This legislation exemplifies a carbon pricing system designed to mitigate climate change through emissions reductions while generating revenue for adaptation solutions.

For instance, certain types of low carbon energy sources, such as solar, geothermal, and district energy systems, are more resilient to grid and fuel supply disruptions due to their decentralized design (Bizikova, Neale, and Burton, 2008); however, hydropower projects are at risk from changing hydrological patterns, and all infrastructure planning should be subjected to risk assessments that include climate change impact projections. In order to preserve the ecological functions of landscapes such as green spaces and agricultural land, renewable energy infrastructure should be located within existing urban footprints and limit strain on climate-sensitive resources such as freshwater wherever possible. This concept is explored further in Case Study 2.

Preparing for extreme weather associated with climate change when planning renewable energy infrastructure is a fundamental element of low carbon resilience thinking. As we transition to a low carbon economy, developing creative solutions to ensure renewable energy is a viable solution in a climate-changed future is an integral step.

CASE STUDY 2: LUCID ENERGY

Droughts have reduced the viability and effectiveness of hydropower reservoirs in places such as California, USA. Implementing micro-hydro technology into existing municipal pipe infrastructure can create hydropower using gravity-based systems that transport drinking water to residents to simultaneously produce electricity. This type of small-scale hydropower system helps to mitigate climate change through renewable energy production, and is more resilient to the climatic changes that typically impact large hydropower reservoirs. Systems such as these have been successfully implemented in California and Portland, Oregon, USA (Valentine, 2015).

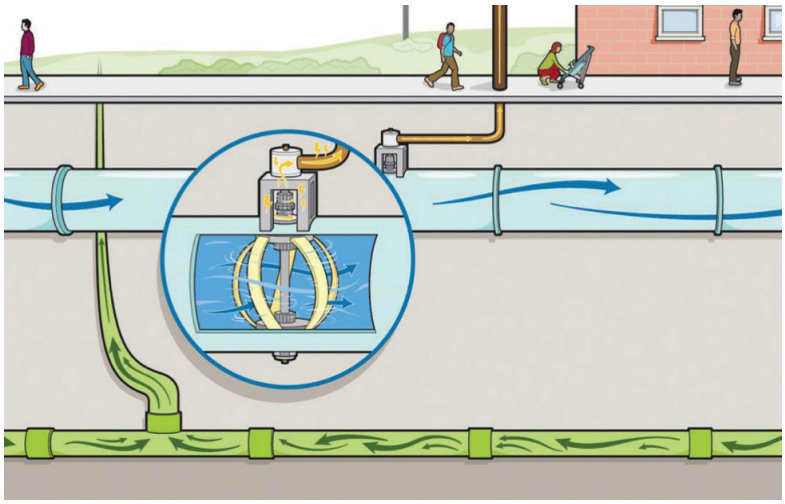


Image 1

SECTION 3: LOW CARBON RESILIENCE AND ECOSYSTEM SERVICES

As discussed in the previous sections, funds acquired from the revenues generated by mitigation strategies such as carbon pricing could be allocated towards low carbon resilience projects as part of the global and national shift to a low-carbon economy. In addition to synergistic mitigation and adaptation properties, these projects also have the potential to facilitate important ecosystem services related to soil health, extreme heat, storm water and flooding, and ecological health. The following section explores these services to examine how low carbon resilience might look on the ground in the context of a changing climate:

SOIL HEALTH

Industrial agricultural practices contribute to climate change in a variety of ways, including significant releases of carbon dioxide from unsustainable land use practices, methane from cattle, and nitrous oxide from fertilizers and waste (World Resources Institute, 2016). Moving towards an agro-ecology approach can help avoid the negative externalities associated with industrial feedlots, monoculture crops, and input-intensive farming (International Panel of Experts on Sustainable Food Systems, 2016). A regenerative approach to soil management, for instance, is consistent with the concept of low carbon resilience.

Carbon storage potential within soils is often overlooked. Research reveals that the top metre of the Earth's soil stores three times the amount of carbon currently in the atmosphere (Paustian, Lehmann, Ogle, Reay, Robertson, and Smith, 2007). However, it is estimated that almost 80 billion tonnes of carbon have been released from the planet's soils over time due to unsustainable land management and agricultural practices (O'Riordan and Sandford, 2015); almost a third of cumulative emissions since 1850 have resulted from soil disturbance and ecosystem degradation (Carbon Dioxide Information Analysis Center, 2015; Skuce, 2015). Investing in healthy soils can lead to co-benefits such as improved farm security, biodiversity, and resilience to environmental stress. For instance, practices such as zero-tillage, crop rotation, composting, and cover cropping reduce the need for nitrogen-heavy fertilizers and can increase the overall carbon storage potential within the soil, which also allows the soil to retain more moisture (Magill, 2016; Rawls, Pachepskyb, Ritchiea, Sobecki, and Bloodworth, 2003; Rodale Institute, 2014).

The 'weather whiplash' of alternating flood and drought periods over the last five years in the Canadian prairies (CBC News, 2011; The Canadian Press, 2015) exemplifies the need for healthier soil that can help mitigate climate change by acting as a carbon sink, while simultaneously adapting to unstable environmental conditions through improved water retention and slope integrity, with the co-benefit of increased food security.

Policy implementation and resource dispersal can help establish soil restoration methods for widespread use (Magill, 2016). In British Columbia, the Climate Action Initiative – a joint initiative between the provincial Ministry of Agriculture and Food and the federal Ministry of Agriculture and Agri-Food's Growing Forward program - has demonstrated a commitment to both farm and community-level planning initiatives that respond to a changing climate, including livestock evacuation planning, information dissemination on water storage and drought, and healthy soil management (BC Agriculture and Food, 2016). Agricultural landscapes occupy a significant percentage of land area in Canada, and these landscapes have tremendous ecological importance for climate resiliency and ecosystem health that simultaneously benefit biodiversity as species struggle to adapt to changing climate conditions exacerbated by loss of habitat.

Low carbon resilience thinking can therefore help develop restorative agriculture practices that foster ecosystem health as well as adaptation and mitigation synergies. Government programs and funds that encourage climate smart agricultural practices and educate farmers on their use would help to bolster this movement. This can be achieved through ecosystem governance approaches and standards within relevant sectors, such as agriculture and forestry. An example of a multi-sectoral federal policy to improve soil health in the United States is demonstrated in Case Study 3.

EXTREME HEAT

According to the National Aeronautics and Space Administration (NASA), 2015 was the warmest year recorded since modern record keeping began in 1880, and 15 of the 16 hottest years on record have now occurred since 2001 (NASA, 2016). Warming is expected to increase over the course of the 21st century, with heat waves "very likely" to occur more frequently and for longer durations (IPCC, 2014). Cities are uniquely affected by this phenomenon due to the urban heat island effect (UHI). This is a significant risk for Canada, since as of 2011, 81% of Canadians live in urban areas (Government of Canada, 2016).

The UHI occurs when outgoing longwave radiation is absorbed by surfaces within a city, augmenting the heat in urban centres and affecting climatic conditions at the city scale (Bretz, Akbari, and Rosenfeld, 1997). The resulting average temperature disparity between cities and adjacent rural areas is approximately 2.5–4.5 degrees Celsius, and this is expected to increase by one degree every decade with global warming (Corborn, 2009; Susca, Gaffin, and Dell'Osso, 2011). The UHI triggers both adaptation and mitigation concerns because warmer cities require more energy to cool, and thus more emissions are released, while humans and natural systems are forced to adapt to increased temperatures. This relationship is somewhat offset by reduced winter heating demand, but this does not dismiss the importance of planning for these shifts.

Low carbon resilience responses such as restoration or introduction of urban ecosystems can help to cool cities, reduce energy demand and associated emissions, and improve air quality. For example, in cities, buildings constitute approximately 65% of total energy consumption and 36% of total energy use (Getter and Rowe, 2006). Rooftops account for approximately 25% of the urban surface, are not frequently used by people, and offer opportunities for implementation of green infrastructure components such as green roofs and gardens. Air conditioning units use more energy when the ambient air around the intake pipe is hotter; and these intakes are often located

CASE STUDY 3: USDA CLIMATE SMART AGRICULTURE AND FORESTRY STRATEGY

The United States Department of Agriculture (USDA) has developed an integrated plan to help farmers, ranchers, and forest land owners improve the potential to store carbon in soil through both voluntary and incentive-based actions that provide economic and environmental benefits (United States Department of Agriculture, 2016). It is expected that this strategy will sequester 2% of their economy-wide net emissions, which is the equivalent of taking 25 million cars off the road. The USDA is also integrating efforts to improve energy efficiency and develop renewable and biomass energy potential in agricultural lands, further linking mitigation and adaptation potential on agricultural landscapes (United States Department of Agriculture, 2016).

on the roofs or upper walls of buildings (Susca et al., 2011). Cooling these areas through green infrastructure can help mitigate climate change through reduced energy demand, blackouts, and carbon emissions.

Greening cities using trees can provide carbon sinks (Jo and McPherson, 1995; Nowak and Crane, 2001; Nowak, Greenfield, Hoehn, and Lapointe, 2013) while driving adaptation to extreme heat by providing shade and improving air quality. In Toronto, Ontario, an estimated 120 people die every year from extreme heat (McColl, 2014). Senior citizens are particularly vulnerable to heat-related illness and mortality, which puts a significant portion of our population at risk due to Canada's aging demographic (CBC News, 2015).

Furthermore, proximity to green spaces has been shown to improve physical and mental health, as well as documented benefits to property prices (Alliance for Community Trees, 2011). Trees and other types of green infrastructure can filter harmful pollutants from the air and contribute to a decreased likelihood that smog will form in urban areas (Bretz et al., 1997; Nowak and Crane, 2001; Nowak, Crane, and Stevens, 2006). In anticipation of rising heat projections in the future, green infrastructure could assist in attaining adaptation goals such as providing cooling and refuges for humans and wildlife, while simultaneously mitigating emissions through decreased energy demand and carbon storage. It would likewise be beneficial for energy efficiency strategies to include climate

change risk projections in their planning processes, and vice versa, in order to achieve and benefit from win-wins.

STORMWATER AND FLOODING

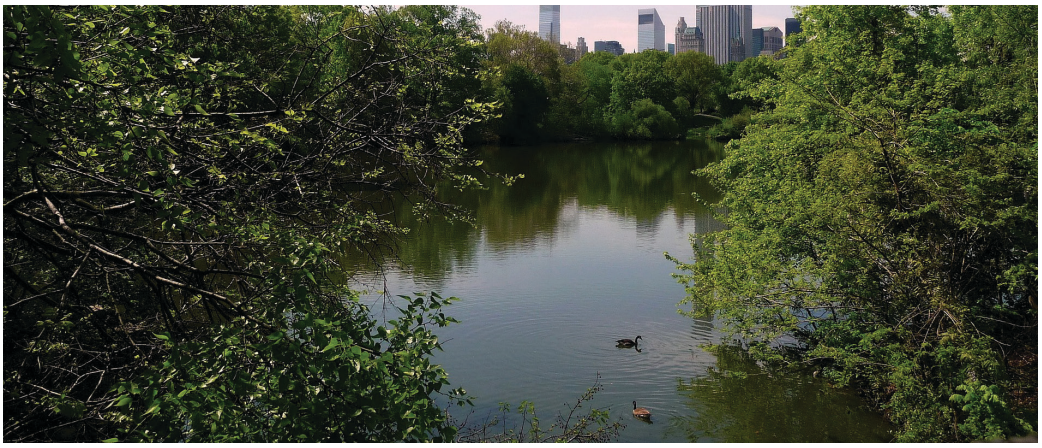
With climate change comes an increased risk of intense storms, extreme precipitation events, flooding, and sea level rise (IPCC, 2014). This risk is more pronounced in urban areas due to the preponderance of paved, impermeable surfaces and critical infrastructure such as centralized energy grids and communications systems. Ecosystem-based solutions to this problem provide more permeability, slowing and sinking excess water, which in turn reduces pressure on wastewater treatment systems and diminishes the threat of floods.

These approaches are less emissions-intensive than some traditional engineering approaches because they do not utilize as much concrete, require less maintenance, and are cheaper and easier to both install and replace (American Rivers, 2012). They also promote on-site water storage, lessening the need for energy-intensive pumping, and improve soil carbon storage. Several types of low carbon resilience systems can be effective in this regard, including green infrastructure such as green roofs, which can be used to capture rainwater, and bio-swales and rain gardens, which can be incorporated into grey infrastructure to absorb additional storm water runoff. These approaches also act as filtration systems, cleaning water before it re-enters natural water bodies (Roy, Wenger, Fletcher, Walsh, Ladson, Shuster, Thurston, and Brown, 2008).

Parks and green spaces can likewise provide effective urban flood management, capturing storm water for re-use and serving as absorbent barriers that protect urban infrastructure, while providing significant social benefits as recreational space, in addition to the other benefits listed in the Extreme Heat section above. Green infrastructure can be used as a foundational element within a city's drainage plans to reduce water stress, as demonstrated in the recent Urban Water Plan in New Orleans, USA (Waggoner and Ball Architects, 2013) and the City of Vancouver's Citywide Integrated Stormwater Management Plan (City of Vancouver, 2016b).

ECOSYSTEM HEALTH

Along with the potential to improve air quality, provide cooling, reduce storm-water runoff, benefit health and property prices, improve slope integrity, and absorb carbon, green infrastructure can nurture biodiversity and link habitat corridors. Protecting wildlife habitats that are fragmented by urbanization can help slow the unprecedented increase in the rate of species extinction that sci-entists have dubbed the "Sixth Mass Extinction" (Hance, 2015). In addition, accommodating widespread species migration occurring due to changing envi-ronmental conditions is one of the primary ways to maintain biodiversity in the face of increased climate risk (Wilson, 2016). British Columbia, for example, is home to some of the most diverse ecosystems in North America, and serves as a kind of ark for wildlife retreating from climate change and habitat loss further south (Adaptation to Climate Change Team, 2008).



The global 1-degree increase in temperature we have already seen (which has translated to 1.6 degrees in Canada) is predicted to cause ecosystem zone shifts of up to 300 metres in elevation and 150 kilometres north in latitude in British Columbia's forests (Adaptation to Climate Change Team, 2008). British Columbia's Future Forest Ecosystems Initiative is updating forest and range management services so that they are better adapted to the climate they will face in 100 years (Ministry of Forests, Lands, and Natural Resources, 2016). Protecting natural systems to preserve biodiversity and habitat health can have the added benefit of significantly increasing the carbon storage potential in forest and marine landscapes (Sierra Club, 2015).

Furthermore, in order to help reduce the threats urbanization poses to natural systems and ecosystem health, cities have a responsibility to accommodate habitat and wildlife shifts, and adjust protected areas as well as ecological management approaches to reflect changing conditions. When collaborative and regional approaches are taken to manage ecosystem threats, cities have the potential to become a habitat nexus that supports the movement and nourishment of natural systems.

It will also be necessary to more actively manage forest resources to ensure that large amounts of carbon are not lost through forest fires that are already occurring due to two climate change impacts: the spread of pests such as the mountain pine beetle that are no longer killed by freezing winter temperatures, and an increase in the size and number of wildfires due to sustained hot, dry forest conditions.

SECTION 4: THE BUSINESS CASE FOR LOW CARBON RESILIENCE

NATURAL CAPITAL AND ECOSYSTEM SERVICES

The aforementioned ecosystem services, facilitated through low carbon resilience approaches, can be categorized and valued in a variety of ways. Natural capital consists of assets related to geology, soil, air, water, and living systems – from this capital we draw from a variety of ecosystem services (World Forum on Natural Capital, 2015). Ecosystem services can be classified as provisional services for consumption (such as water, food, and raw materials), regulatory services (such as removal of greenhouse gases and pollutants, or protection from storms), habitat or supporting services, and cultural services (such as the landscapes valued for spiritual, recreational, religious, or educational purposes) (The Economics of Ecosystems and Biodiversity, 2016).

These services can be priced in a variety of ways, although such estimates should be considered with the caveat that such pricing does not replace the intrinsic value of ecosystems, but is designed to avoid their being valued at zero, as has often been the case (Adaptation to Climate Change Team, 2015b). For example, avoided cost pricing methods determine the savings resulting from the protection of infrastructure from flooding or sea level rise by foreshores and

forests, and replacement cost methods identify what people would be willing or required to pay to replace the service – such as air or water filtration – if a specific ecosystem was not available (Adaptation to Climate Change Team, 2015b). Natural asset management systems record and value the benefits inherent in healthy ecosystems, as exemplified at the municipal level by the town of Gibsons, BC, which has incorporated ecosystem benefits provided by its foreshore and forests into its asset management strategy.

As the risks posed by climate change intensify in tandem with public perceptions and understanding of the challenges, regions and cities that have invested in resilience and healthy ecosystems will likely become more attractive to homeowners and investors than those that have not. This phenomenon could also apply to areas that have invested in renewable energy sources and emissions reduction and the benefits, which include low air pollution, localized energy security, and lower prices for electricity.

If we act now to drive low carbon resilience planning, municipal budgets will benefit in addition to numerous other positive outcomes.

PRESERVING INFRASTRUCTURE: THE COSTS OF INACTION

The 2013 flood in Calgary, Alberta cost approximately CAD $6 billion in damages and repair costs (Environment and Climate Change Canada, 2014). The rainfall-induced flood in Toronto in 2013 was the most costly natural disaster in Ontario's history (Mills, 2013) and the recent wildfires in Fort McMurray are predicted to cost insurers $9 billion (CBC News, 2016b). These economic threats associated with extreme weather impacts (that are commensurate with predictions for conditions in a changing climate) point to the urgency of planning for coordinated adaptation and mitigation practices in Canada. As we have outlined above, doing so has the potential to benefit ecosystems and the environmental services they provide while improving our collective resilience.

In 2007, a report published by the Federation of Canadian Municipalities estimated that Canada faced a municipal infrastructure deficit of $123 billion that was growing by $2 billion per year (Mirza, 2007). Significant amounts of infrastructure will need to be replaced in the next 15 years, and replacement costs are generally high (Adaptation to Climate Change Team, 2011; Boyle, Cunningham, and Dekens, 2013). Incorporating green or blue-green infrastructure, or ecosystem-based approaches, as an alternative or complement to grey infrastructure can save money through implementation, replacement and maintenance costs; in general, ecosystem-based services tend to be more cost-efficient than hard infrastructure alternatives (American Rivers, 2012).

CASE STUDY 4: CONCERT PROPERTIES AND WATERFRONT DEVELOPMENT

Concert Properties is building a waterfront development in the City of North Vancouver that is one of the first to incorporate new provincial guidelines for flood construction levels that take into account one meter of sea level rise via a City bylaw, while simultaneously implementing energy efficiency measures (Meads, 2016). Developers are encountering increasing challenges due to the lack of alignment among policies, codes, and standards for adaptation and mitigation.

Image 2

It has been estimated that 50% of existing public infrastructure in Canada will reach the end of its lifecycle by the year 2027 (Boyle, Cunningham, and Denkens, 2013); meanwhile, new infrastructure can be expected to last for 50-100 years, during which time climate models project increasing levels of risk from extreme weather and sea level rise, and many urban populations are expected to grow. As mentioned earlier, Canadian municipalities face significant infrastructure deficits that lower their already-limited capacity to address the economic fallout of climate change impacts (Adaptation to Climate Change Team, 2015a). The combination of these factors suggests that the time is ripe for widespread low carbon resilient infrastructure investment at all levels of

government, incented through a variety of measures such as building standards and codes. These could include policies tied to standardized floodplain mapping and zoning, passive heating and cooling requirements, energy efficiency, and extreme event resilience guidelines. Such considerations could also be applied to green building certifications and lifecycle cost methodologies for building materials. However, given the challenges this cornucopia of new requirements is currently posing professionals such as developers, as outlined in Case Study 4, there is a clear need to align codes and standards and actively work to design new risk assessment and planning approaches so that they can better facilitate implementation of low carbon resilience methods, saving us time and money.

CONCLUSION

Mitigation efforts to date have failed to prevent the onset of climate change. Past and current emissions levels are now locked into the atmosphere, creating unstable climatic conditions that will worsen depending on how much the earth warms, making both mitigation and adaptation essential components of climate change planning. Low carbon resilience approaches offer ways to respond holistically to the resulting threats, with the potential to improve the health of humans and ecosystems, strengthen resilience to future shocks, save time and financial resources, and reduce the risk of runaway climate change.

This paper began with an introductory background to the concept of low carbon resilience and its relevance in relation to current climate change commitments at the international and national scale. It briefly discussed the potential incorporation of the low carbon resilience concept within carbon pricing strategies and renewable energy development as part of the current shift towards a low carbon future in Canada, as well as on-the-ground approaches and their ability to facilitate ecosystem services pertaining to soil health, extreme heat, storm water and flooding, and ecosystem health. As part of the business case for low carbon resilience, the paper concludes with the economic importance of ecosystem services, followed by an exploration of financial repercussions related to the costs of inaction and infrastructure threats and the emerging need for new codes and standards that acknowledge simultaneous pressure to both mitigate and adapt to climate change.

The climate change crisis is finally invoking a global sense of urgency that is conducive to widespread innovation. Now is the time for jurisdictional harmonization and collaboration, and to build on the opportunities that exist to develop climate leadership by promoting coordinated adaptation and mitigation

synergies that benefit ecosystems as they struggle to adapt. With many practical examples to draw from, strong political will, and strategic funding opportunities via carbon pricing policies, low carbon resilience solutions are emerging as some of the most strategic and effective tools that Canada can use to respond to the challenges posed by climate change.

St. Kjeld's Quarter, Copenhagen - artist's rendering of planning for blue-green infrastructure transformation

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