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### Canada in a Climate Disrupted World

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## Canada in a Climate-Disrupted World

SSHRC Knowledge Synthesis Grant | Imagining Canada's Future Initiative

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**Abstract:** Climate change has already begun impacting economies and societies across the globe, and its impacts are expected to increase into the future. Adaptation to climate change is and will continue to be one of the greatest policy challenges facing the Canadian government. However, important and much-needed work on understanding the future of climate change has not yet been completed. Gaps remain in the body of academic, government, and other policy-relevant publications. Specifically, there is a relative paucity of research done on the indirect impacts of climate change on Canada. These external impacts outside of Canada's borders may have second-order effects, the implications of which have thus far remained largely unexplored. In this report, we identify key issue areas which are currently or potentially affected by these indirect impacts. We also undergo a thorough literature review, and locate areas in which further data research is required.

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# Canada in a Climate-Disrupted World – Synthesis Review

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## Key Messages

1. *Earth's climate is changing rapidly, but fundamental uncertainties remain.*

The future of our climate-disrupted world, whether by 1.5°C of average warming or more, will be characterized by unbounded risk and great uncertainties. The interaction between climate change and the wider Earth system remains largely uncharted territory (Steffen et al., 2015). The nature, pace, and severity of these changes will vary across the planet's surface, affecting countries in different ways and to different degrees.

2. *The countries of the world are more integrated than ever before in history; adaptation to climate change must also become integrated.*

Although the impacts of climate change will vary around the world, the degree of global integration that exists today means that local impacts may have non-local, globalized ramifications. No country can hope to adapt successfully on its own, without considering its relationship to the wider community of nations.

3. *Knowledge of how Canada will be affected by climate change outside our borders is limited.*

The current state of knowledge on Canada's international and indirect exposure to climate change elsewhere is minimal and fragmented. It can and should be extended, deepened, and consolidated. Clear near-term disruptions can be identified, especially with regard to the Arctic and evolving Canada-US relations. Even where such knowledge exists, however, it has not been completely incorporated into government mandates (Commissioner of the Environment and Sustainable Development, 2017).

4. *Distant climate disruptions—i.e. outside North America—should not be discounted or underestimated in their importance for Canada.*

While Canada's social, political, and economic relationships with the international community of nations are primarily with our North American neighbours to the south, this does not mean that impacts in these areas are necessarily the most concerning for Canada. Without a global assessment, we simply have insufficient information on which to make such a judgment. Changes that could occur farther out in the future, while more uncertain, also require serious attention and further study.

5. *Mitigation remains the first and most essential requirement for successful adaptation.*

Some degree of climate disruption is 'baked in' to the future of the Canadian policy landscape, but the difference between a 1.5°C warmer world and a 4°C warmer world carries an extremely large difference in its adaptation burdens. Reaching the 1.5°C target will be difficult but manageable, if Canada and the world commits to massive, concerted efforts towards climate change mitigation (Millar et al., 2017).

# Executive Summary

## Introduction

Climate change is having increasingly visible and costly impacts on Canada, and around the globe. It is imperative that Canada's government effectively manage both impacts domestically, and adapt to its evolving external environment. In spite of clear necessity, an assessment of the Office of the Auditor General found that only five government departments have completed their mandated assessment of their climate risks, while fourteen have not (Commissioner of the Environment and Sustainable Development, 2017). International risk assessments and analysis of adaptation is similarly found wanting in academic, business, government, and NGO literature. In our report, we have conducted a thorough literature review of the past decade, identifying the extent of current knowledge and gaps that require attention from the broader research community.

## Key Messages

1. Earth's climate is changing rapidly, but fundamental uncertainties remain.
2. The countries of the world are more integrated than ever before in history; adaptation to climate change must also become integrated.
3. Knowledge of how Canada will be affected by climate change outside our borders is limited.
4. Distant climate disruptions—i.e., outside North America—should not be discounted or underestimated in their importance for Canada.
5. Mitigation remains the first and most essential requirement for successful adaptation.

## Context and Implications

In a world of intense globalization and increasing economic interconnectivity, climate change will present risks to the global economy that will be unavoidable. Other countries, such as the United Kingdom, have found that indirect impacts from climate change may be an order of magnitude greater than domestic impacts (Gledhill et al. 2013). The Netherlands has also conducted a similar study which arrived at similar conclusions (Vonk et al. 2015). While Canada has its own context, and is not necessarily going to experience the same challenges as these other countries, our research agenda has identified a clear need to achieve a better understanding of the social, economic, and security impacts climate change will have on Canada in the future.

## Results

**The Arctic:** Climate change is already having dramatic impacts on the Arctic, which is warming twice as fast as the rest of the globe (AMAP, 2017). With an earlier-than-expected arrival of ice-free summers, the opening of the Northwest Passage (NWP) will likely be a commercial reality in the next few decades. Furthermore, mineral and fossil fuel resources currently locked under ice may become exploitable, and therefore subject to intense geopolitical contestation over territorial boundaries and sovereignty rights (Elliot-Meisel, 2009; Loboda, 2014; Pharand, 2007). Complicating matters is the issue of melting permafrost. While the risks are better-known than in other issue areas, without any armed icebreakers Canada is not militarily prepared to secure its sovereignty rights in this region (Wezeman, 2012).

**Economic Issues and International Trade:** Canada has been called an ‘energy superpower’ by past governments, thanks in part to high oil prices allowing for economical exploitation of the oil sands (Rubin, 2016). However, the possibility that there will be an internationally-set and legally-binding carbon price means that there is also the chance that these will become stranded assets (Leaton et al., 2015; Rubin, 2015). Presently, carbon pricing schemes are widely considered to be too low by various international organizations (Farid et al., 2016).

**Transportation and Infrastructure:** Given the predominance of gasoline-powered road vehicles in Canada and globally, significant mitigation of greenhouse gas emissions must come from the transportation sector. The auto industry may be vulnerable to shocks as the global manufacturing capacity shifts towards battery-electric vehicles (Shankleman, 2017). However, the implications of this potential disruption for Canada have not yet been adequately explored. The Great Lakes will likely be significantly affected by climate change in the future. This will have impacts on shipping traffic, coastal infrastructure, and Canada-US relations in this region (Millerd, 2011).

**Security and Migration:** While the exact relationship between climate change and violent conflict remains controversial, the possibility of a linkage cannot be ignored. Recent crises like the Syrian Civil War may have been caused by environmental factors which may have been exacerbated by climate change (Kelley, Mohtadi, Cane, Seager, & Kushnir, 2015). A recent government report has identified climate change as a potential source of conflict (Department of National Defence, 2017), but otherwise there is a dearth of concrete planning or information on this issue.

**Food and Agriculture:** Climate change may benefit Canadian agriculture by increasing the length of the growing season and expanding the types of crops that can be grown on Canadian soil (Lewis & Witham, 2012). As such, Canada stands to benefit from increasing food exports and perhaps leveraging its role as a food exporter for diplomacy and geopolitical strategy. However, the future of domestic food production, given the likelihood of increases in pests and extreme weather events, makes these benefits far from certain (I. D. Campbell, Durant, Hunter, & Hyatt, 2014). Marine ecosystems and fisheries are also being affected by climate change. The warming of the upper ocean is comparable to warming on land, with great risks and uncertainties in its impacts on marine life (Poloczanska et al., 2013). Canadian fishing subsidies may be encouraging overexploitation, which could create a repeat of the Atlantic Cod fishery collapse if poorly managed (McIlgorm et al., 2010; Sumaila, Lam, Le Manach, Swartz, & Pauly, 2016).

**Health and Wellbeing:** Climate change has been called the “biggest global health threat of the 21<sup>st</sup> century” (Costello et al., 2009, p. 1693). Some of these risks arise from the direct impacts of the changing climate and extreme storms, while others are indirect, like the spread of disease vectors (Altizer, Ostfeld, Johnson, Kutz, & Harvell, 2013; Keesing et al., 2010). As with other issue areas, there is some knowledge and planning at the domestic level, but for international considerations there is a gap in our knowledge and policy planning.

**Foreign Aid and Development:** Canada is involved in international projects to assist other countries in climate change mitigation and adaptation to climate change (da Costa Silva, 2011). Given that the impacts of climate change will intensify, these commitments will likely grow in expense and scope over the coming decades (Webster, Ginnetti, Walker, Coppard, & Kent, 2009).

**Biodiversity:** Climate change is expected to negatively impact the future of global biodiversity. The decline in biodiversity may have implications for Canadian tourism, as well as travel by Canadian citizens abroad (Amelung, Nicholls, & Viner, 2007; Scott, Jones, & Konopek, 2007). Furthermore, the integrity of regional ecosystems could be affected by interactions with other human impacts on the global environment. Preserving global biodiversity will also have implications for pharmaceutical availability, as many drugs are based on species in the tropical rainforests that are rapidly being depleted (Berrang-Ford, MacLean, Gyorkos, Ford, & Ogden, 2009). Canada is also a signatory to the Convention on Biological Diversity. Failure to meet CBD targets would have negative consequences for Canada's international perception.

**International Law:** With the move from the sanctions-based Kyoto Protocol to the voluntary process of the Paris Agreement, the risk of internationally-imposed penalties on noncompliance with climate targets has been minimized. However, Canadian oil and gas companies may be exposed to transnational lawsuits relating to their carbon-producing activities. Furthermore, while this has not yet been implemented, carbon tariffs may be employed in the future and raise the costs of Canadian exports, amongst other legal costs. (Byers, Franks, & Gage, 2017; Gage & Byers, 2014; Osofsky, 2005).

### State of Knowledge

Since the Kyoto Protocol in 1997, our understanding of climate change has grown enormously. However, the policies offered by national governments have not kept up with the challenge of mitigating climate change. If all the national targets of the Paris Agreement are met, average warming of the Earth is projected to surpass the target limit of 1.5-2°C above the preindustrial temperature (Anderson, 2015; Schurer, Mann, Hawkins, Tett, & Hegerl, 2017). Furthermore, adaptation towards future climate disruptions have not been adequately explored. Paradoxically, indirect impacts from outside of Canada's borders may be costlier than the domestic impacts of climate change. This cannot be determined with any level of certainty until Canada requires more specific knowledge on these impacts, the opportunities for adaptation, and policy aims which could help secure Canada's future in a climate-disrupted world.

### Conclusion

Canada has some of the highest per-capita greenhouse gas emissions in the world, but it also has the wealth and technical capacity to implement the necessary policy solutions. A better understanding of the interactions between various climate change impacts, both domestically and internationally, are needed to identify the avenues for policymakers to meet the challenge of future climate change. Undertaking a global assessment of all the risks and uncertainties of climate change to Canada would only be a first step, but a useful one.

## Key Findings

*The fraying thread that connects our past to our future is not limited to the flux in the natural order. The ecological shake-up wrought by climate change is also shaking up our economic and political-order. In the financial realm, as in the natural realm, the past provides fewer and fewer clues to our future. Like the migration patterns of songbirds that no longer correlate to the hatching patterns of their insect prey, or the mountain snowpacks that no longer store water for the dry summer months, the economy is facing miscues born of the feedback loop between tumult in the atmosphere and tumult on the earth. Rapid changes in the weather and temperature are outpacing our traditional ideas for assessing risk, redefining the calculus for economic success, shaking up the geopolitical status quo (Schapiro, 2016, p. xi).*

### **Context – the Issue:**

The failure of climate change mitigation and adaptation to date has recently been recognized as the greatest risk to the global economy (World Economic Forum, 2016). And while the impacts of climate change will vary in nature and severity around the world, they will not respect political boundaries. In an increasingly connected and globalized world those impacts must therefore be assessed with a transboundary, international framework – i.e. incorporating risks that reach across national borders. Such a project has begun in Canada, but it does not compare to the rapidly developing body of research on the potential direct consequences of current and future climate change within the country. That is, substantial knowledge gaps remain with respect to how impacts *outside* our borders will affect Canada’s environment, socioeconomic systems, trade relations, foreign policy, and prospects for achieving the world’s sustainable development goals (SDGs). Additionally, the assumption of ‘stationarity’ is no longer tenable; that is, past environmental conditions are no longer an accurate guide to future changes (Milly et al., 2008). This report assesses the state of knowledge on the international dimensions of climate change, and how impacts and policy changes elsewhere in the world, whether for mitigation or adaptation, may affect Canada going forward.

### **Implications**

Although differing in national circumstances, analysis for the United Kingdom has found that impacts arising due to climate change elsewhere are potentially an order of magnitude higher for the UK, through indirect pathways, than the cost of direct domestic impacts (Gledhill et al., 2013). In the near term they find that “damages to UK assets abroad, demand on foreign aid and humanitarian assistance, and increased volatility of prices for food, energy and other resources traded in the global market,” are all likely to be more severe and costlier than currently projected under a medium emissions scenario (Gledhill et al., 2013, p. 1). The Netherlands has also undertaken a similar national assessment of the global dimensions of climate change and arrives at a

similar conclusion; due to its infrastructural, economic, and foreign policy linkages with many other countries, climate change impacts in those countries will indirectly affect the Netherlands to a high degree as well (Vonk et al., 2015). Canada is certainly in different circumstances than the former two national cases. We are far more economically and politically integrated with one other country to a high degree—the U.S.—and integrated with many other countries to lesser degrees, though in ways that are no less important. Nonetheless, and as mentioned above, without a research agenda devoted to understanding all of our international connections, their exposure to climate change, as well as policy adaptations elsewhere that could affect Canada, it is impossible to assess the balance of potential opportunities and threats that the international dimension of climate change poses.

## **Approach**

Given the realities of global climate change, and the need to identify international impacts as well as the pathways by which they could affect Canada, a thorough literature review is required to assess the state of knowledge on this subject. Overall, there appears to be a relative paucity of research that draws explicit links between climate change impacts external to Canada's borders, and social, economic or environmental factors within Canada. Thus, in addition to a survey of existing literature, categorization of important issue areas must be established. Criteria for salience are assessed based on parameters developed by the Stockholm Environment Institute (SEI), and similar national adaptation studies that take a global approach (Benzie, 2014). Given the cross-disciplinary nature of the literature review, and of the very complexity of climate change as a policy challenge, some issues discussed in this report will overlap across multiple categories simultaneously.

## **Methodology**

We identified key research issue areas and selected databases available to the Waterloo-Laurier-Guelph tri-library system. We applied multiple iterations of universal search strings to these databases and created a centralized project catalog for collected sources. In addition to academic sources, including journal articles, books and monographs, we assessed governmental and grey literatures, including reports from the federal government, non-governmental organizations (NGOs), international organizations, articles from the business press, and news media. Sources were selected based on non-random purposive criteria, some of which were based on leads generated from our judgment of materials outside the systematic search results. Once all sources were collected, we assessed and synthesized them for salience to future external climate impacts on Canada.

## Results

### The Arctic

Of the various aspects of climate change under discussion, the Arctic stood out as a subject of especially high concern to Canada. There are various estimates of hydrocarbon and mineral resources which are currently inaccessible because of permanent Arctic sea ice. As the melting of Arctic sea ice increases with climate change, the summer may be open to exploration for primary resource extraction. In addition, the Northwest Passage (NWP) will likely be opened for shipping traffic over the next few decades. Through resource extraction and taxing shipping lanes, Canada could benefit tremendously from a melting Arctic (Koring, 2008).

However, these potential benefits may be overvalued if Canada implements substantial carbon pricing mechanisms domestically, or if such measures are imposed by an international agreement. At present, the exact costs or benefits to the opening of the Arctic remain highly uncertain. To date, expeditions to the Arctic have shown that despite unprecedented levels of sea ice extent minima, operating that environment remains enormously challenging. The *Financial Times* reported that Shell was forced to cancel offshore drilling projects off the coast of Alaska, investing over \$5bn USD without managing to drill a single well (Pfeifer & Chazan, 2013). Thereafter, other oil companies decided to pull out of costly Arctic prospecting without any possibility of recouping their costs. One historian also argued that unconventional oil reserves, including purportedly massive Arctic reserves, are not based on reliable estimates (Mitchell, 2013). Consequently, assessments of the potential benefits that the Arctic may provide for Canada are wide ranging as well as uncertain.

There are many drawbacks associated with a melting Arctic which may exceed the benefits gained. Permafrost melt is likely to increase, creating roadblocks to building durable infrastructure. Such impediments have already been observed in Siberia (Morozov, 2012). Increases in the rate and intensity of extreme weather and the calving of icebergs may make the NWP hazardous to unprotected vessels without the aid of expensive icebreakers and search-and-rescue capabilities (Bruce & Haites, 2008). Specifically, icebreakers will play a critical role in ensuring the safety of the NWP for shipping traffic (Parsons, Dinwoodie, & Roe, 2011). Permafrost melt will additionally have wide-ranging impacts on both human health and terrestrial biodiversity. The melting Arctic sea ice and changing temperature structure of the oceans will have further impacts, creating new challenges in maintaining marine biodiversity and Canada's upholding of the Convention on Biological Diversity (CBD). Arctic ecosystems are especially sensitive to Anthropogenic influences, and therefore may be strongly and negatively affected by climate change (Darnis et al., 2012).

Finally, another policy challenge that the melting Arctic poses is competition and control over resource extraction and shipping lanes. Pharand (2007) argues that according to his analysis of international law and treaties signed by Canada, that the NWP is legally Canadian waters is indisputable. However, at least one American commentator has argued that the Arctic in general should be declared international waters, and that Canada cannot functionally govern the Arctic with its minimal military force projection capability in that region (Dobrinsky, 2012). According

to Elliot-Meisel (2009), failing to quickly negotiate territorial control of the Arctic between Canada and the US could negatively impact international security, through potential increases in environmental disasters, smuggling, illegal immigration, and even the transit of transnational terrorists. Stakeholder rights have also been asserted by the European Parliament, which notes that three EU members are a part of the Arctic Council and have vital interests in the region (Gahler, 2010). Wezeman (2012) notes that the Arctic region is presently characterized by a lack of clarity, with major uncertainties in jurisdiction, sovereignty, policy, and military capabilities.

Furthermore, while Canada possesses unarmed Coast Guard icebreakers operating under the Department of Fisheries and Oceans (DFO), they are only capable of operating in the summer. The Canadian Navy possesses no ice-strengthened warships, and plans to build new icebreakers have been seriously delayed and gone overbudget (Wezeman, 2012, 2016). In terms of ground forces, Canada fields a battalion-sized force of Canadian Rangers which has been trained and equipped for Arctic operations (Wezeman, 2016). A re-assessment of Arctic nations' capabilities found that not only has uncertainty persisted, but tensions have been heightened by recent aggressive behaviour from Russia. Different authors echoed concerns of Russian aggression, and also noted China's expressed interests and challenge to Canadian sovereignty in the Arctic (Parker & Madjd-Sadjadi, 2010). Researchers in geopolitics also note that changes in important trade routes have historically been associated with redeployments of naval forces, geopolitical shifts in the balance of power, and thus turmoil amongst the great powers (Blunden, 2012). However, Wezeman (2016) also concluded that the five Arctic states under review, Canada, the US, Russia, Denmark, and Norway, are all still committed to resolving disputes through multilateral negotiations and diplomacy. Nonetheless tensions have increased between the US and Russia, and given the most recent events at the time of writing, this situation is still far from resolved.

Should Canada lose jurisdiction over the Arctic, Canada's territorial sovereignty would be challenged and access to any benefits would be likely diminished. The contentious nature of Canadian sovereignty over the Arctic, and the security conflicts that may result from competition over Arctic shipping lanes and resources, have been identified as a major concern for the future of Canadian foreign policy. For Asian exporters like China and Japan, the NWP may offer a substantial benefit by reducing travel times and costs in shipping goods to Europe (Parker & Madjd-Sadjadi, 2010). Given the strong rhetoric and proliferation of research on the issue, the rhetoric on Arctic sovereignty and Arctic governance does not seem to match with actual policy outcomes. On the other hand, the security challenges associated with the melting Arctic may not necessarily be as dire as some authors have purported. For example, the NWP is not considered a vital strategic chokepoint by the US military, and that situation may not necessarily change in the future from melting sea ice (Parker & Madjd-Sadjadi, 2010). In any case, the authors mentioned here have urged Canada explicitly (or through analysis of Arctic countries' national interests, implicitly) to expand its role and presence to preserve its territorial sovereignty and expand governance over the Arctic.

## **Economic Issues and International Trade**

Another key dimension through which climate change impacts or adaptations elsewhere may affect Canada is through its economic relationships, including in trade, finance, and overall domestic

business competitiveness in international markets. There is currently no consensus on the net balance of potential changes being positive or negative, though nor may there ever be such a consensus. There are important points of agreement, however, on several critical issues.

One of the first important and agreed-upon concerns is the status of our hydrocarbon industries, and what it will mean for all those involved in them should they soon enter their 'sunset phase' (Rubin, 2016). Decarbonization of the global economy, to the extent that it progresses, will invariably cause some degree of demand reduction for Canada's fossil fuel resources, especially the oil sands, already one of the highest-cost producers in the world. Although it has been primarily due to a glut of production in the U.S. and elsewhere, some of the potential effects of demand reduction have already been evident in Alberta over the past three years: With the price of oil hovering around \$50 per barrel over that time, "[a]n estimated US\$47 billion of oil sands projects containing 8.2 billion barrels of oil reserves have already been cancelled or indefinitely postponed" (Rubin, 2016, p. 4). With the price of oil in its current range, expansion of the oil sands has become far less certain today than when former Prime Minister Stephen Harper touted Canada as a potential 'energy super power' over a decade ago.

Moreover, the increasing recognition that previously economical reserves—when oil prices are high—may never make it to market, resulting in further and more severe write-downs and losses, is an eventuality that has been called a 'carbon bubble,' 'unburnable carbon,' or, more frequently in a general financial sense, as the risk of 'stranded assets' (Leaton et al., 2015; Rubin, 2015). Although not the first to raise it, Governor of the Bank of England (and former Governor of the Bank of Canada) Mark Carney has echoed the concern over stranded asset risk, first in 2014 at a speech for the World Bank (Shankleman, 2014). And one estimate of the global carbon bubble amounts to US\$20 trillion (Fullerton, 2011)—higher than any total estimate of the worst losses incurred by the Great Recession. Canada would not be immune from the effects of this bubble bursting or deflating, as the case may be.

There remains uncertainty in the literature regarding the nature of stranded asset risk and the trajectory of oil sands development in a carbon-constrained world (Leach, 2016). Conclusions are highly speculative and depend on assumptions not only about the future price of oil, but also on assumptions about the development of carbon capture and storage (CCS) technologies, or geoengineering projects that could allow the continued emission of GHGs (ostensibly without further warming of the atmosphere and oceans). Based on such differences, McGlade and Ekins arrive at widely differing conclusions in two separate analyses only one year apart (2014, 2015); in the first, they find the potential for bitumen production growth up to 4.1 million barrels per day (mbd) by the year 2035, whereas in the second they predict a cessation of all bitumen production by 2040, with rapidly declining production after 2020. Each pathway would have stark differences in impacts for Canada, but there is no consensus on which pathway is more likely, and therefore what the most likely impacts will be. The Province of Alberta, for its part, currently projects growth in bitumen production—from approximately 2.5mbd to over 3mbd by 2020—but this, too, is debated and uncertain (Healing, 2017; Johnson, 2017).

The same uncertainty surrounds Canada's natural gas resources. Natural gas is often presented as a 'bridge fuel'—i.e. between CO<sub>2</sub>-intensive hydrocarbons and the future mix of low-emission sources to be decided upon for a carbon-constrained world. As such, there are esti-

mates of potential short-to-medium term growth in the natural gas industry, presenting an opportunity to purportedly offset some of the losses incurred should Canadian oil production hit its peak and begin to decline (McGlade & Ekins, 2015). This no-net-loss outcome depends critically on infrastructural expansion of liquified natural gas (LNG) facilities, however, discussions about which are occurring in British Columbia and Alberta. But in the medium-to-long term, the ratcheting up of mitigation efforts can be expected to eventually cause demand reduction for natural gas as well, leading to a risk of infrastructural ‘overbuild,’ should the LNG facilities be built and no longer necessary after a certain point (Leach, 2016).

Another point of concern is the status of other emission-intensive sectors, including non-hydrocarbon resources (such as forestry, paper, steel) and in higher valued-added manufacturing that relies on carbon-intensive inputs, such as manufacturing vehicles and vehicle parts. As the price on carbon increases, nationally as well as internationally, these industries will also be affected, though to a less severe degree than fossil fuel producers. Unfortunately, the state of knowledge on these areas does not seem to have been updated beyond that of Natural Resource Canada’s own assessment in 2014, which states: “There is little published research about indirect impacts of climate change on industry, such as changes associated with consumer demand, supply chains, real estate or other assets, adaptation by other sectors, legal liability or government regulation” (Kovacs, Thistlethwaite, Scott, & Oliver, 2014, p. 137). And the focus in that work is primarily domestic, rather than international, where there appears to be even more of a knowledge gap.

Major international fora—the IMF, the World Bank, the OECD, and the Financial Stability Board (FSB) for example—are all in alignment on the need for more and higher carbon pricing: currently only 12% of global GHGs are priced, and those that are covered are often priced too low to meet environmental objectives (Farid et al., 2016). Recognizing the exposure to higher costs as the price on carbon climbs, the FSB has called for climate change-related financial disclosures; but there is a high degree of uncertainty over how they may affect Canadian financial institutions and industries (Weber & Kholodova, 2017; Bak, 2017).

As was discussed in the previous section on the Arctic, climate change and actions by other countries will have economic effects for Canada in that region as well. Warming and the consequent retreat of summer sea ice is opening up the possibility of navigation and shipping, and potential mining for resources. But as with bitumen in Alberta, Arctic natural resources are costly, perhaps the only more expensive deposits of hydrocarbons and other minerals. The state of hydrocarbon production in the region will depend on multiple factors, including the resolution of sovereignty issues, cost and price dynamics of particular resources, as well as the protection of biodiversity. Beyond the direct biophysical impacts and increasing movement through the Arctic, how the former factors will play out remains deeply speculative.

On the other hand, while there is agreement that the transition effects and costs of downscaling the fossil fuel industry in Canada are serious and potentially very high, there is other work suggesting that the opportunities are equally as high, perhaps enough to offset the costs. Blair (2016) analyzes the claim that concerns over a loss of competitiveness—what he calls the framing of a necessary ‘trade-off’ between positive environmental outcomes and economic outcomes—have been exaggerated in Canada, especially under the former Harper government. As the Chretien and Martin governments did at an earlier point in time, the Trudeau government is

again preferring to opt for what Blair calls a ‘synergy’ framing, suggesting that improvement on environmental outcomes could improve our economic performance overall, more than offsetting losses in emission-intensive sectors. It is important to keep in mind, however, that in this work Blair focuses on the nature and consequences of these *framings*, rather than the estimates themselves of the potential *real* costs and benefits of a transition away from hydrocarbons. While framing is indeed critical, the real costs and benefits of this transition must continually be sought out and appraised as well.

On the assessment of potential opportunities, recent research emphasizes the likelihood that as global mitigation increases, low-carbon goods and services (LCGS) industries will expand, and we should therefore be thinking strategically about these markets (Leach, 2016). In Canada, LCGS markets could grow to anywhere between \$36 to \$60 billion by 2050, up from \$7.9 billion in 2010 (NRTEE, 2012). At the moment, though, Canada is not poised to take full advantage of these opportunities: “Canada’s current market share as a global supplier of LCGS is far from what it could be. Canada’s LCGS sectors could well face labour shortages in a world competing for skills and innovative talent. Regional emissions profiles and related economic interests differ markedly and have precluded a comprehensive, long-term approach to climate policy to date,” according to the National Roundtable on the Environment and the Economy (NRTEE, 2012, p. 16). Other work confirms the action of other countries in moving toward specifically green innovation, a sector dominated by Europe, the U.S., Japan, South Korea, and China, along with the potential benefits of trade in ‘climate-friendly’ and ‘environment-friendly’ goods, especially with Asia (Nikzad & Sedigh, 2017; Dinda, 2014). Opportunities also exist in increased food production and export, as warming extends the growing season (Rubin, 2015; Lewis & Witham, 2012). Clean Energy Canada has noted that a traditional resource sector for Canada—metals mining—will likely benefit from global growth in the renewable energy sector, as Canada possesses 14 of the 19 most common metals required for solar photovoltaics (Clean Energy Canada, 2017).

In sum, however, barring rapid improvements in CCS or a global geoengineering project, the logical conclusion of successful global mitigation will mean leaving much of the planet’s—and Canada’s—hydrocarbons in the ground. As this scenario will play out over the coming decades, the sooner that Canada prepares for it, the better positioned we will be to take advantage of the opportunities and offset (potentially inevitable) losses.

## Transportation and Infrastructure

The electrification of transportation, both commercial and private passenger transport, will be necessary for transport sector emissions to be reduced (Weber & Kholodova, 2017). However, while there is a growing amount of research on how climate change will directly impact the transportation sector (see Palko & Lemmen, 2016) there is an absence of information on how the Canadian auto industry, and the transportation sector more broadly, will be affected by policy and industrial changes outside our borders.

For instance, critical physical components of the automotive industry will undergo radical changes to meet mitigation targets through electrification. Some analysis suggests that electric vehicle penetration of the passenger vehicle market will occur along a baseline, business-as-usual pathway only after the year 2040. But appropriate climate, energy and transportation policies

chosen by Canadian governments could expedite this uptake by a decade or more, and contribute to GHG abatement in the transport sector (Bahn et al., 2013). What the costs and benefits of such a transition will mean for the Canadian automotive industry have not been adequately explored, however. For instance, our review found no anticipatory analysis of how rapidly advancing battery development in other countries could affect the nature of this industry in Canada. The Economics Department of ING has analyzed the risk for the European automotive industry, suggesting that the development of battery electric vehicles (EV) will be disruptive for European auto-makers and parts manufacturers if they do not begin making this shift themselves (Erich & Witteveen, 2017). Other work explores global aspects of the shift to renewables for the automotive industry, as well as the impacts that it may have on global demand for petroleum (Shankleman, 2017); but again, the risks and opportunities for Canada are unknown due to a lack of Canadian industry-specific research.

Another infrastructural issue with international connections, though primarily bilateral ones with the United States, regards new pipeline development for petroleum or natural gas exports. As was discussed earlier in the section on hydrocarbon resources, however, there is a great deal of uncertainty about the costs and benefits of such projects, which depend critically on the state of US production and consumption. Should the recent rise in US shale and tight oil peak or decline, there remains room for Canadian supply to meet American demand (Hussain, 2016); but perhaps not at an increasing rate, and not enough to offset the costs of new pipeline construction. (Domestically, the TransCanada corporation has decided to not proceed with its proposed \$15.7 billion Energy East Pipeline, taking a \$1 billion write-down in the process.)

The Great Lakes also serve as an important route of international shipping between Canada and the U.S., as well as other countries, with a large variety of products being shipped through the Great Lakes such as grains, gravel, cement, salt, iron ores, coal, and petroleum products. Climate change is expected to have several potentially likely effects on the Great Lakes' system. Changes in precipitation patterns are likely with more intense spring rains in the watershed (leading to increased erosion and effluent of pollutants into the lakes) and increased drought in the summer months (Bush, Loder, Mortsch, & Cohen, 2014; Hayhoe, VanDorn, Croley, Schlegal, & Wuebbles, 2010; Kling et al., 2003). Water temperatures have increased by as much as 3.5°C in the last century (Austin & Colman, 2007, 2008; Dobiesz & Lester, 2009; Minns, Moore, Doka, & St. John, 2011) and are projected to increase by 2.9 to 6°C in the next century (Chu, 2015; Trumpickas, Shuter, & Minns, 2008, 2009). Warming water temperatures are leading to other impacts such as the earlier onset of a thermocline (reduced oxygen in bottom water); shifted thermocline depths; reduced times of ice cover; and altered ecosystem compositions (Brown & Duguay, 2010; Bruce & Haites, 2008; Chu, 2015; Kling et al., 2003; McDermid et al., 2015; Millerd, 2011; Minns, Shuter, & Fung, 2014). Increased water temperatures combined with decreased ice cover are resulting lower water levels (McDermid et al., 2015).

As climate change has physical impacts on the great lakes (i.e., water temperature and depth), the social, economic, cultural, and human health of communities surrounding the Great Lakes as well as ecosystem services derived from lakes will also be impacted (TEEB, 2011). The Great Lakes are important for a range of industries as well as the recreation, tourism, and agricultural sectors. The Mowatt Centre has estimated that by 2030, \$9.61 billion of economic losses will result from low water levels and that by 2050 the cumulative economic losses will reach

\$18.82 billion (Shlozberg, Dorling, & Spiro, 2014). These economic losses result from impacts to various sectors including recreational boating and fishing, commercial shipping, and hydroelectric generation.

Each physical impact of climate change (e.g. increased water temperature) alone could have effects on navigation and shipping, but in combination, and especially with lowered water levels, the effects would be more profound. According to Millerd (2011), commercial ships in the Great Lakes operate with very minimal under-keel clearances (0.3 meters in some cases), so a lower water level would require restrictions on vessel drafts and reductions in vessel cargos, likely leading to rising costs. A 1 meter drop in water levels would result in a 14% reduction in cargo load increasing costs for shipping companies (Shlozberg et al., 2014). The St Lawrence would be less affected by such a consideration, but will not be immune to other direct impacts like those raised for the Great Lakes. Not all climate change impacts are negative for the Great Lakes shipping industry; climate change will lead to an increased ice-free season and therefore a longer navigation season. There is dearth of research on the international aspects of this subject matter area, however.

## Security and Migration

Several studies have now drawn links between climate change and organized violence. Civil wars, ethnic cleansings, and other forms of internecine violence may increase due to linkages to climate change or other kinds of global environmental degradation (Homer-Dixon, 2001; Zhang, Brecke, Lee, He, & Zhang, 2007). One recent study argued for a linkage between the ongoing Syrian Civil War with climate change-induced drought (Kelley et al., 2015). Apart from civil wars and 'low intensity' conflict, there is also the risk of classic interstate wars. While interstate warfare is unlikely to occur as a direct result of climate change per se, the possibility has been noted in specific circumstances. Riverine states, in which the downstream state is militarily stronger than the upstream state, may come to blows over control over freshwater resources. Egypt and Sudan are a potential future case of such a 'water war' (Homer-Dixon, 2001). In addition, it is highly probable that increased violence will trigger refugee crises in the future. The 40,000 Syrian refugees taken last year by the Canadian government will likely be dwarfed in the future, if violent conflicts proliferate due to the pressures applied by climate change (Government of Canada, 2017).

Not all refugee flows are driven by violence. One recent study estimated that the number of migrants which might be displaced by sea level rise alone could be as high as 1.4 billion by 2060, dwarfing any previous historical precedent (Geisler & Currens, 2017). If mitigation efforts fail utterly, and median projections have underestimated the magnitude of future climate change, it is possible that parts of the Earth may be rendered uninhabitable to humans due to heat stress by 2100 (Sherwood & Huber, 2010). As the Stern Review notes, climate change will impact some parts of the world worse than others. The regions which will likely be the most severely impacted also tend to be developing countries, which are less able to divert their stretched government budgets to adapting to the impacts of climate change domestically (Stern, 2006). However, it is also important to note that the notion of 'climate refugees' is legally problematic, and estimates of future climate-driven migration flows are subject to high variability and uncertainty. Indeed,

this argument was made in the Working Group II report in the most recent the IPCC update. The IPCC presented a case against quantifying projections of people rendered as legal refugees specifically from climate change, as international law has not yet clearly adopted the idea of the environmental refugee (Adger et al., 2014). Furthermore, extremely high estimates of people who move to another location because of climate change contains the problematic assumption that “climate refugees” have become refugees in the colloquial sense. People who may choose to move without being placed in a vulnerable, disempowered position that is commonly associated with refugees. However, even under this more favourable interpretation of climate change-induced displacement, significant barriers to resettlement cannot be discounted wholesale by Canadian policymakers (Geisler & Currens, 2017).

What will such climate conflicts mean for Canada? While it is something of a cliché that Canada is blessed with the longest undefended border on Earth, it is also probably one of the least vulnerable states to future climate change impacts. However, our relative safety from the worst of climate change and high standard of living also incentivizes inflows of migrations (Murray, 2010). In some estimates of future environment-driven migration flows, a part of which would be driven by climate change, the numbers of refugees could reach historically unprecedented levels (Myers, 2002). Furthermore, Canada’s future relationship with the US may not always be so friendly. One Canadian journalist and historian created a possible scenario in which a water conflict may occur between Canada and the US, as a result of climate-caused water scarcity (Dyer, 2008). His scenario was based on a report by the US Center for Strategic and International Studies (CSIS) think tank, which noted a potential conflict arising from the diversion of the Great Lakes resulting in a “fundamental clash of interests with Canada” (K. M. Campbell et al., 2007, p. 74). These suggestions may seem alarmist, as Canada has had a friendly relationship and military alliance with the US, with a history of over 70 years of strong bilateral cooperation (Elliot-Meisel, 2009). Nonetheless, a future breakdown in friendly relations is not far outside the realm of possibility.

Overall, relatively few studies have drawn explicit links between Canada and climate-driven violent conflict, especially within peer-reviewed academic journals. These arguments are more frequently seen in think tank reports, editorial opinion articles, or in popular nonfiction books. This paucity research may be related to the academic controversy in hypothesis that climate change may be the cause of civil wars (Buhaug, 2010). Substantive policy recommendations are by-and-large offered only in the case of managing the Arctic and preserving Canadian sovereignty there (Elliot-Meisel, 2009). Elliot-Meisel argued that Canada must aim to preserve its “special relationship” with the US, seeking conciliation and harmony of interests in the Arctic, rather than the antagonistic position adopted by the government at time of writing. In general, very little has been explicitly written on Canada’s future policy responses to very large numbers of refugees and environmental migrants compelled by climate change. Nonetheless, further research into this issue is, in our judgment, both warranted and likely to continue to increase in importance as climate change accelerates further beyond the old Holocene global climate. Another report has been recently published by the Canadian military leadership, emphasizing three major points: the increased need for humanitarian response; the aggravation of socioeconomic stressors and resulting forced migrations; and the array of security challenges which are expected to emerge from the melting Arctic (Department of National Defence, 2017).

## Agriculture, Food and Marine Ecosystems

In terms of the net of all food production, Canadian productivity is expected to increase somewhat in the medium term (I. D. Campbell et al., 2014). This will provide an advantage to Canada as other regions in the world will likely see their productivity decline. Growing seasons will be longer, while the occurrence of killing frosts will decline. Crops that have thus far been climatically unsuited for Canadian farms may become a future possibility. In Eastern Canada, production of soybeans, for example, may actually increase (Antón, Kimura, Lankiski, & Cattaneo, 2012). Exports of agricultural products would likely increase, though challenges for farmers may be exacerbated from new uncertainties (I. D. Campbell et al., 2014). Overall, given the strong likelihood of a net increase in productivity, the strong future of Canadian agriculture may be considered a strategic advantage which could also provide a source of strategic and diplomatic strength.

However, these projections may be over-optimistic, as some studies have not included a full set of modelled factors. Highly uncertain and difficult-to-project factors include the proliferation of crop pests and the locations of and measurement of increases in drought and severe weather, which would negatively impact Canadian agriculture. Throughout the twentieth century, the net amount of drought as increased, likely due to the onset of anthropogenic climate change (Dai, 2011a). A state of permanent drought, in other words, permanent desertification in some regions, is projected to encompass large areas in North America which currently serve as bread-baskets (Dai, 2011b). Certain crops, such as wheat and barley, are projected to decline under increased weather variability in the Canadian prairies (Antón et al., 2012). This weather variability could include not only drought, but storms and higher precipitation in other regions which could pose enormous challenges to Canadian farmers. Such challenges to future food production, and of global food prices, may therefore be strongly impacted by the increased drought under global warming.

Another consideration for Canada is the measurement of food miles, and the carbon emissions associated with transportation and importation of foodstuffs. One study found that 30% of agricultural and food commodities consumed in Canada were imported, resulting in an additional 3.3 million tons of CO<sub>2</sub> emissions per year (Kissinger, 2012). If a carbon price were implemented domestically or internationally, this could have an impact on food prices, especially fresh fruits and vegetables which comprise the majority of imported food (Kissinger, 2012). Canada's reliance on imported foods of this type is therefore an important source of vulnerability in climate changed world. Furthermore, some kinds of crops are endangered extreme weather exacerbated by climate change, such as coffee and oranges (Bruce & Haites, 2008). Given these projections, it seems probable that the prices of specific food products will increase with advancing climate change, especially fresh fruit and vegetables. However, as we have seen in other issue areas, there are few studies which assess the future of Canadian policy in managing climate-driven changes to agriculture. From this, we now turn to a review of the literature available on the management of oceans and fisheries.

Significant attention to how climate change will affect Canadian fisheries is highly recommended by researchers (McIlgorm et al., 2010). Some authors also recommended stronger international cooperation in both research and policy implementation in protecting fisheries globally (Ricketts & Hildebrand, 2011). As ocean acidification progresses and non-climate-related stressors accumulate, it is very likely that the marine biosphere will be severely impacted (K. M.

Campbell et al., 2007). Warming of the ocean surface is comparable to recent terrestrial warming under climate change. As such, marine biodiversity has been driven to migrate, with phytoplankton being highly responsive to temperature changes. The marine food web is therefore disrupted, as a mismatch between the ranges of the lowest tropic level and all other levels grows wider (Poloczanska et al., 2013). In tropical latitudes, subtropical fish species are being threatened by increase heat stress from the warming ocean (Cheung, Watson, & Pauly, 2013). While there is still large uncertainties in assessing the overall impact climate change will have on marine ecosystems, it seems probable that many important species will be placed at risk of extinction (Keating, 2007). In terms of commercial fisheries, climate change is expected to introduce significant uncertainties and alter the ranges and migration patterns of important fish species in the waters around North America and globally. Ongoing and future changes to the marine ecosystems also have complex socioeconomic impacts on local communities which are reliant on fishing (Perry et al., 2011).

The policy challenge is about how to address the variable impacts of climate changes on diverse fisheries in some way where local fisheries are healthy and Canada's position in international markets remains strong. This requires international cooperation but also innovative ways to engage local people in governance to avoid moratoria, as witnessed in mismanagement of the Atlantic Cod fisheries (Ommer & The Coasts Under Stress Research Project Team, 2007). With respect to the impact climate change will have on the oceans, Canada has the potential to become the global leader in ocean and fisheries legislation and policy action. However, climate change is not the only challenge facing marine ecosystems and fisheries. Globally subsidies for fisheries are amount to \$35bn USD, which has incentivized overfishing in many regions. Indeed, Canada in particular has a mixed record with fishing subsidies (Sumaila et al., 2016). As we have seen from the case of the Atlantic Cod, the management of stable populations must be carefully considered by Canadian policymakers.

## Health and Wellbeing

Climate change has been called “the biggest global health threat of the 21<sup>st</sup> century” (Costello et al., 2009, p. 1693). An increasing amount of research has been dedicated to assessing the nature of the threat that it poses to health, and in this vein there is a growing body of knowledge on how direct, biophysical impacts from a changing climate may affect Canadians, in particular through extreme weather events and natural disasters (such as heat stress, flooding, and forest fires, for example; see Berrang-Ford et al., 2009; Costello et al., 2009; Ford et al., 2010; Paterson et al., 2012). But there has been a low prioritization with regard to the international dimension of this issue area, within which there is thus a clear knowledge gap.

Changing disease vectors is one instance of recognized risk – longer and warmer summer seasons on average are expected to change the prevalence and incidence of disease bearing ticks, and forest-damaging beetles, and potentially of malaria (Berrang-Ford et al., 2009). And Canadians who live or travel abroad, for work or tourism, may be exposed to worsening risk landscapes due to similar extreme weather and disease prevalence changes elsewhere. The Lancet and University College London Global Health Commission on *Managing the Health Effects of Climate Change* (2009) is still the foundational work in this issue-area. Direct and indirect links to Canada

are rarely explicitly raised in the document, but in detailing the effects elsewhere, in places where Canada has humanitarian, migration, or economic relationships, there is the potential for increased risk exposure and adverse outcomes.

In sum, while most of the suspected health impacts of climate change will affect Canadians through direct, domestic changes, it is difficult to assert that international pathways will not also have comparable health impacts on Canadians. Other countries have recognized this risk and are beginning to systematically assess it, including the UK (Gledhill et al., 2013) and the Netherlands (Vonk et al., 2015).

## Foreign Aid and Development

Canada is currently funding or otherwise participating in transnational projects relating to climate change mitigation and adaptation. For example, Canada is financing community-based water management projects in Latin America, under the Canadian International Development Agency (CIDA) (da Costa Silva, 2011). Given the strong probability that states which will be the most severely impacted by climate change will be the least able to adapt effectively, it is therefore also likely that Canada's contributions to foreign adaptation projects will increase. Some of these projects may help Canada better meet its national and international climate goals. A future domestic legal regime or global governance effort may have strong penalties for noncompliance, or rewards for cooperation. By assisting developing countries with mitigation and adaptation projects, Canada could go beyond its originally set targets in cost-effective ways. Assisting developing countries with adaptation projects would also reduce the incentive for outmigration from severely impacted countries. However, other researchers have argued that some forms of disaster relief and development assistance may create perverse incentives. Johnston (2012) argued that post-disaster relief can effectively subsidize and incentivize development in vulnerable areas, creating a net economic loss. Overall, though, peer-reviewed analysis supporting these policies is relatively scarce.

In addition to funding foreign adaptation projects, Canada is involved with humanitarian assistance efforts and disaster response measures across the globe. Our contributions to domestic efforts are certain to increase, as extreme weather events will become more frequent and devastating (McBean, 2006). Consequently, we expect such events to be increasingly costly as the global climate continues to warm and destabilize. McBean (2006) has also made the case for greater Canadian involvement in humanitarian relief efforts, as our country is amongst those with the highest levels of per capita cumulative emissions and therefore a greater share of moral responsibility. Webster et al. (2009) also find that the financial requirements for humanitarian relief are projected to increase by up to 1600% over the next 20 years, in large part due to the effects of climate change. On a business-as-usual, unsuccessful mitigation pathway, climate change is projected to reduce the income of an average person on Earth by roughly 23% by 2100, but the distribution of impacts will be highly unequal: average incomes in the poorest 40% of countries are projected to be reduced by 75%, while the richest 20% of countries may experience slight gains (Burke et al. 2015). It is an open question for academics and policy makers alike how such changes could affect Canadian foreign policy with regard to aid and humanitarian assistance.

## Biodiversity

Climate change is having an impact on biodiversity worldwide, resulting in changes to species ranges and behaviours, and even leading to extinction and extirpation (I.-C. Chen, Hill, Ohlemuller, Roy, & Thomas, 2011; Hannah et al., 2002; Montoya & Raffaelli, 2010; Parmesan, 2006; Parmesan & Yohe, 2003; Root et al., 2003). Changes in biodiversity elsewhere—in other countries, or international waters—will likely manifest as impacts on ecosystem services, health and wellbeing through changes in disease vectors, loss of sites elsewhere for tourism, potential impacts on pharmaceuticals bioprospecting, and potentially through international ‘shaming’ effects for failing to protect certain species, should that be the case (as is likely with the polar bear); or being non-compliant or in violation of treaty obligations to protect, conserve or sustain certain other species (as may be the case with marine biodiversity).

Biodiversity is critical for the provision of ecosystem services upon which society relies, including decomposition and nutrient cycling, carbon capture and storage, pollination, food production, air purification, and water filtration as well as intrinsic cultural values (Mace, Norris, & Fitter, 2012; Oliver et al., 2015). As biodiversity declines due to climate change, so will the delivery and regulation of ecosystem services (Bellard, Bertelsmeier, Leadley, Thuiller, & Courchamp, 2012; Nelson et al., 2009). Ecosystem services have been linked to human well-being with a decline in ecosystem services resulting in decreased human well-being (Hossain, Eigenbrod, Amoako Johnson, & Dearing, 2017; Sandifer, Sutton-Grier, & Ward, 2015). For example, without animal species dispersing seeds, many plants, both wild and domestic, would fail to reproduce leading to a food shortage. It has been estimated that the agricultural value of wild pollinators is billions of dollars a year in the United States alone (Reed, 2017). A decline in ecosystem services internationally may result in an increased need for humanitarian aid due to shortages of food and clean water.

Humanitarian aid may also be required due to changes in disease vectors as a result of a decreased biodiversity (Morand, Jittapalpong, Suputtamongkol, Abdullah, & Huan, 2014). Increased rates of zoonotic and vector-borne diseases among humans, other animals, and plants have been linked to biodiversity loss (Keesing et al., 2010; Morand et al., 2014). Additionally, climate change has been found to weaken biotic regulation of disease vectors due to changes in the populations of predators and competitors (Altizer et al., 2013; Farjana, Tuno, & Higa, 2012; Hobbelen, Samuel, Foote, Tango, & LaPointe, 2013). A change in disease vectors would not only impact human well-being but would also act to further decrease biodiversity. The pharmaceutical industry is also particularly dependant on biodiversity. The more biodiversity there is on the planet, the greater the opportunity for biodiscovery and finding new pharmaceutical treatments. Approximately 25% of prescription drugs are derived directly from plants and 73% are modelled after natural substances (Reed, 2017). A loss in biodiversity, particularly in tropical regions where most planets with pharmaceutical value are found, will result in missed opportunities to discover new cures and treatments for human diseases. Losses of biodiversity elsewhere may lead to a shortage of some pharmaceuticals in Canada.

Another consideration is the impact that changes in biodiversity may have on domestic and international tourism. Losses of iconic species in Canada’s protected areas may decrease the number of visitors to protected areas. For example, if polar bears are no longer found in Polar Bear Provincial Park, the number of visitors to that park is likely to decrease. Furthermore, losses

to biodiversity in other countries may decrease the attractiveness of those destinations to Canadian travellers. Other impacts of biodiversity loss in Canada due to climate change include international shaming and implications from failing to meet international obligations. Canada is a signatory to the United Nations Convention on Biological Diversity (CBD). Through this treaty, 193 parties committed to reducing rates of biodiversity loss by 2010. In 2010, parties to the CBD agreed on a new set of biodiversity targets to be achieved by 2020 – the Aichi Biodiversity Targets. Target 12 of the Aichi Biodiversity Targets states that “by 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained” (Secretariat of the Convention on Biological Diversity, 2010). If Canada fails to meet this target, or other related targets, international shaming and negative international perceptions of Canada may occur.

## International Law

With the move toward voluntary, nationally determined contributions to mitigation, the potential legal impacts affecting Canada in the sphere of climate change appear minimal, and would likely occur in the form of economic or financial effects – i.e. through the possibility of litigation for liability or negligence issues. But the risk of this occurrence is higher domestically than internationally. In tort law, the “duty to care” principle could be employed for this purpose, which states that whenever an action or inaction could foreseeably harm others, the action or inaction that causes such harm is ethically culpable; thus, a legal obligation to ‘take care’ is imposed on actors requiring their adherence to a standard of reasonable care, such that the foreseeable harms are reduced and redress is available should they still occur. In recent years in several countries, legal actions have been initiated by citizens against their own governments for inaction on climate abatement and mitigation, including in Canada (Mittelstaedt, 2008). Legal actions that are exclusively domestically focused, however, while nonetheless important, are outside the scope of this review.

On the international dimension, Osofsky (2005), Gage & Byers (2014), and Byers et al., (2017) are examples of important legal scholarship on the issue of climate change. Osofsky details the petition made by Sheila Watt-Cloutier, with support from the Inuit Circumpolar Conference, to the Inter-American Commission on Human Rights (IACHR) against the United States, seeking relief from the effects of climate change. Even though the IACHR would not be able to compel the U.S. to reduce its emissions or compensate the Inuit, even with a positive ruling in favour of the Inuit, the petition garnered attention and made climate change a human rights issue. Gage & Byers note that the risk of legal changes could expose Canadian oil and gas companies to financial damages through litigation: “nation-specific assessments of the potential for climate damages litigation could overlook the significant and growing risks posed to large-scale greenhouse gas producers from transnational lawsuits. These risks include the possibility that a judgment handed down by a court in one country could be enforced in the courts of another (including Canada)” (Gage & Byers, 2014, p. 6). Although not yet in use, there is also the potential risk that carbon-tariffs are eventually employed against countries that do not mitigate sufficiently.

## State of Knowledge

The state of knowledge on global climate change itself has improved dramatically since the creation of the IPCC. Climate scientists understand the long-lived nature of certain greenhouse gases and the inertia that they impart to the climate system, such that even if emissions were to drop quite fantastically to zero in short order, the average warming trend would continue – by approximately a further 0.3-0.5°C over the next few centuries, in addition to the 0.85°C above preindustrial levels already observed (Frölicher, Winton, & Sarmiento, 2013). Currently, the nationally determined contributions of the Paris Agreement put the world on track to warm by 2.6-3.7°C above the preindustrial average by the end of the 21<sup>st</sup> century, higher than the Agreement’s 2°C target (Caballero, 2016). Although the aspiration is to ratchet-up the ambition and accelerate the pace of mitigation over time, such that the 2°C target can be met, the later that this process begins, the less likely it is to be achieved. Some degree of climate adaptation being necessary is therefore already ensured.

The nature and degree of such adaptation remains to be formulated, however, in part because what is and will be required remains unknown or highly uncertain. While preparing for surprises seems counter-intuitive, if not oxymoronic, this is the orientation that national and international policy-makers must take. An immediate first step is improving the state of knowledge not merely on the likely effects of climate change, but also on a country’s exposure to transnational effects and its adaptive capacity to address them. To this end, assessments of the international environment, like those of the UK, the Netherlands, Finland, and Sweden, are important examples that other countries can follow, tailored to their own circumstances. Canada must engage in this exercise more completely than has been done up until this point. At the current moment, the state of knowledge on our exposure to climate change impacts elsewhere, and the balance of opportunities versus risks resulting therefrom, remains low.

For example, the UK is aware that in three thematic spheres—business, food supplies, and foreign policy—the magnitude of even indirect climate change impacts could amount to billions of pounds in costs and tens of millions of UK citizens affected (Gledhill et al., 2013). Although they do not make quantitative estimates, the Netherlands’ assessment largely mirrors that of the UK: they find that the risk of disruption to vital economic networks increases rapidly as climate change progresses over the course of the century. Sweden and Finland have also engaged in such an analysis; along with the UK and the Netherlands, they employ a framework of analysis that appraises every country’s exposure and sensitivity to projected climate changes with which they have a relationship. In this way they can assess the nature and extent of potential risks that could reverberate back to them from impacts that occur elsewhere, whether along a financial or economic pathway, a biophysical pathway, a migration pathway, or a foreign policy and security pathway.

Canada has not engaged in a single overarching assessment of this type. Where information is available, it is field or industry specific—as with the thematic areas discussed above. We know, for example, that the economic risk to Canada’s hydrocarbon resource sector from accelerating mitigation is high, and national and provincial policy-makers must begin planning for this industrial shift. We also know, however, that the effort to accelerate mitigation will mean not only room for growth in low-carbon goods and services industries, but in fact *depends* on

such growth in the low-carbon sector; Canada could be moving much more rapidly into this economic space. In the Arctic, Canada must firmly establish where its sovereignty lay, before other countries can claim uncertainty as a basis for any actions. We also know that the requirements for aid in humanitarian crises and natural disasters will likely increase as the average warming trend continues, and that the security situation in many countries will deteriorate. But this knowledge is disparate, high-level, and there remains much that we do not know. Especially when compared to the internationally-focused assessments of the UK, the Netherlands, Finland, and Sweden, Canada would benefit greatly from a consolidated and much more extensive primary research project on this topic.

## Additional Resources

The Intergovernmental Panel on Climate Change – Fifth Assessment Report: Represents the gold standard in expert knowledge on climate change.

<https://www.ipcc.ch/report/ar5/>

UNEP – Global Environmental Outlook-5 Report: A report on the interface between human activity and the broader global environment, including climate change.

<http://www.unep.org/geo/assessments/global-assessments/global-environment-outlook-5>

World Resources Institute: A notable think tank which studies climate change, sustainability, and other matters related to global environmental policy.

<http://www.wri.org/>

Stockholm Environment Institute: Another think tank which studies climate change and other issues of the global environment.

<https://www.sei-international.org/>

Chatham House – resourcetrade.earth: A data visualization tool that can represent various environmental indicators.

<https://resourcetrade.earth/data>

## Knowledge Mobilization

The results of this research will benefit academics from across multiple disciplines, seeking to find avenues of research to pursue on climate change which have so far been inadequately studied. It may also be a useful guidance for researchers in government, NGOs, and private businesses that are grappling with indirect impacts of climate change. Since the impacts of climate change are so all-encompassing and territorially unbounded, it will have universal applicability across multiple governance scales.

The objective of our research team is to communicate these findings through various kinds of web and print publications. Some of the expected products of this research include a synthesis report for multiple audiences, a series of policy briefs, a scholarly peer-reviewed journal article, and newspaper opinion articles. This research will also be a key input into the Network of Centres of Excellence (NCE) proposal on climate adaptation and resilience, under the supervision of prof. Daniel Scott at the University of Waterloo.

## Conclusion

Climate change is occurring, and a warmer world of some degree is a reality that Canada will increasingly have to confront. This report has detailed the strengths and gaps in our understanding of how Canadian leaders are preparing for such a world. Overall, the approach thus far has been primarily inward-looking, with a focus on how biophysical changes within our borders will affect Canadian citizens and industries. This work is certainly necessary and should continue. Considering the global nature of climate change, however, and the degree of integration between economies today, it is clear that biophysical changes and policy adaptations outside our borders could potentially affect Canada greatly. Analyses of a warming climate's international effects on Canada exist, but are minimal and disconnected from one another. Compared to the domestic half of this body of research, the international half represents an overarching knowledge gap. We are simply uncertain how much and in what ways the international effects of climate change may affect us.

It is difficult to prepare for uncertain circumstances, but it should also be appreciated that the degree of warming that obtains in the future is determined by actions taken today—not only those of Canada, of course, but of everyone. Being a resource- and emissions-intensive economy implies a different—and difficult—transition ahead. But if Canada should hope to meet its international climate commitments, and help ensure a *less* climate-disrupted world than the one we are currently heading towards, a prepared-for transition can only be better than one that is not prepared for. An essential piece of this preparation is to be aware of the ways that any degree of climate-disruption could affect us, directly *and* indirectly. Yet, without a globally-focused assessment, we do not have a full and accurate understanding of the potential risks and costs involved for Canada. Undertaking such an assessment would only be a first step, but a useful one.

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