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Urban Resilience in Canada

Research Priorities and Best Practices for Climate Resilience in Cities

May 2016

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Key Messages

More desirable definitions of resilience tend to be holistic and transformative

- Confusing and conflicting definitions of resilience are often used. Precise definitions are essential in order to avoid confusion, to properly direct action, and to enable measurement and evaluation (Bours, McGinn & Pringle, 2014a).
- Ecological formulations of resilience can be maladaptive (i.e., having adverse effects despite being well-intentioned) if they are regressive instead of transformative.
- Resilience should be expanded to emphasize net-positive benefits.
- The Paris Agreement's definition of adaptation includes a shift towards adaptation as a process of iterative cycles, normative principles for adaptation, and a wider array of stakeholders (Bahadur at al., 2016), providing important overlaps with resilience.

Measurement methods need to be carefully considered as resilience moves from implementation to evaluation

- Certain alternate measurement approaches should be considered, these include qualitative indicators, process indicators, and outcome harvesting.
- The definition of outcomes can be expanded to include "changes in the 'behaviour writ large' (such as actions, relationships, policies, practices) of one or more social actors influenced by an intervention" (Wilson-Grau, 2015).
- Champions of qualitative research need to continue to demonstrate its value to decision-makers.

Infrastructure and the built environment are an important (though not sufficient) component of city resilience

- The PIEVC was develop to assess critical infrastructure, and needs to be applied to more utilities in large cities, as it was in Toronto.
- Buildings are an important leverage point for resilience. New codes and standards need to ensure that their contribution to resilience is maximized, as does work pertaining to building and site design, and occupant behaviour.

Social determinants and outcomes need to be considered in resilience assessment and planning

- An emerging area of work involves enhancing the capacity of the resilience process to explore "how power relations affect how people benefit (or do not benefit) from resilience-building projects" (Bahadur et al., 2016).
- Further work also needs to explore the extent to which emerging resilience standards (e.g., ISO, UN-Habitat) are capable of assessing social determinants, and leveraging social capital.

Well-designed strategic frameworks for resilience assessment and planning in large cities exist

- The City Resilience Framework is the most promising tool studied, and creates an iterative planning process that engages diverse stakeholders, while leveraging social capital.
- This framework does not seem to provide explicit guidance for measurement and evaluation, though the Resilience Measurement Community of Practice will likely produce these at the end of their grant (March 2017).

Executive Summary

The past year saw the launch of the Sustainable Development Goals, the Sendai Framework for Disaster Risk Reduction, the Paris Agreement, Mission Innovation, and countless other steps towards a better world. It was also a big year for the field of urban resilience, with many of the sources used in this report coming from the last 18 months. This report provides a synthesis of the current research and activity in the area of urban resilience, and is meant to guide future work being carried out by the many resilience practitioners across Canada and North America (and potentially internationally, though this was not our focus, see Figure 1).

Findings

Definitions

Precise definitions are essential in order to avoid confusion, to properly direct action, and to enable measurement and evaluation (Bours et al., 2014a). The present work accepts the simple yet transformative definition that resilience is the "capacity to buffer change, learn, and develop" (Folke et al., 2002). For Bahadur et al. (2015), resilience is comprised of adaptive capacity, anticipatory capacity, and absorptive capacity (i.e., the "Three A's"), which represent an important conceptual framework that will undergo testing in further work. It was also found that urban resilience finds common ground with climate change adaptation, current formulations of which tend to be more nuanced than they were a decade ago. For example, the Paris Agreement's definitions of adaptation include a shift towards adaptation as a process of iterative cycles (as opposed to isolated actions), normative principles for adaptation (e.g., diversity and inclusion), and a wider array of stakeholders (Bahadur et al., 2016).

Social Resilience

Urban resilience, like sustainability, often has social, as well as economic and environmental prerogatives. Urban resilience strategies are often informed by social justice agendas. But it is not just the outcomes of resilience initiatives that are social, the determinants of resilience are also often social in nature. Bahadur et al. (2016) highlight that an emerging area of work in this area involves enhancing the capacity of the resilience process to explore "how power relations affect how people benefit (or do not benefit) from resilience-building projects." For example, equitable access to essential resources and capitals cannot be assumed, and resilience planning needs to take this into account.

Physical Resilience

A great deal of important work within the larger field of practice of urban resilience is concerned with the ability of critical infrastructure (e.g., stormwater management, electricity distribution, transportation systems) to function during extreme events. In line with IPCC (2014) recommendations, Canada's Public Infrastructure Engineering Vulnerability Committee has created the PIEVC Engineering Protocol to assess the vulnerability of critical Canadian infrastructure. Results are presented from a high-level assessment of the climate change induced infrastructure vulnerabilities faced by Toronto Hydro, the first deployment of PIEVC for this sector at this scale (AECOM and Risk Sciences International [RSI], 2015). Further work involves exploring the relationships between engineers working in this area, and non-engineers involved in resilience planning.

The American Council for an Energy-Efficient Economy (ACEEE) makes explicit connections between energy efficiency and resiliency (Riberio et al., 2015). Things like energy-efficient buildings, district energy systems, and transit-oriented development all have clear resilience benefits in the areas of emergency response and recovery, social and economic benefits, and climate mitigation and adaptation (Ribeiro et al., 2015; Smith & Levermore, 2008; Xu, Sathaye, Akbari, Garg & Tetali, 2012). C40 and Arup (2015) point out that in "2015, cities reported taking a total of 438 adaptation actions" and it was shown that building often play an important role in creating opportunities for these actions to emerge (described in Section 4). Encouragingly, the 2016 Federal Budget allocates $40 million over five years to "to integrate climate resilience into building design guides and codes" that will apply to both buildings and the rehabilitation of public infrastructure (Government of Canada, 2016). Further work needs to critically evaluate and influence these new standards and codes so that they maximize their resilience potential. But it is not just the design of buildings which is important; better understanding the behaviour of occupants within buildings is an important part of improving a building's resilience (Brown & Gorgolewski, 2015).

Resilience Activity

It was found that climate change adaptation activity can be used as a proxy indicator of resilience activity. The 2014 scientific assessment performed by NRCan found that "adaptation implementation in Canada is still in its early stages" but that action was being facilitated by concrete tools which include strategies, frameworks, guidance documents, decision support tools (e.g., maps and visualizations, guidance for scenario interpretation and use, and adaptation guidebooks and toolkits) (Eyzaguirre & Warren, 2014). Holly-Purcell (2015) echoes this for resilience, writing that there is a "vast array of tools and diagnostics designed to assess, measure, monitor, and improve city-level resilience." Appendix B contains a list of many of these, in addition to those presented in Section 4.

Strategic Frameworks

There are numerous strategic frameworks available for cities to use in resilience assessment and planning. The City Resilience Framework was developed by Arup (with support from the Rockefeller Foundation) and is meant to "identify critical areas of weakness, and to identify actions and programs to improve the city's resilience" (da Silva & Morera, 2014a; The Rockefeller Foundation & Arup, 2015). The framework enables a process during which stakeholders work towards an action plan for resilience, instead of the checkbox (or cookbook) approach where certain prescriptive elements must be present. For Boulder, Colorado, the City Resilience Framework was used iteratively to guide a process of arriving at three major priority areas (City of Boulder, 2016). It has been used in many other cities as well, and resilience strategies are currently being release on near-monthly basis.

At the highest governmental level, urban resilience assessment and planning is facilitated by the United Nations International Strategy for Disaster Risk Reduction (UNISDR). Their "Making My City Resilient Campaign" has attracted over 3,000 cities that have pledged to take part. The report presents current activity in this somewhat convoluted program, including the development of the Local Urban Indicator Tool, and the collaboration between UNISDR and the World Council on City Data. Work is also presented from Toronto, who in 2014 conducted a review climate resilience best practices in New York City, San Francisco, Chicago, Seattle/King County, Calgary, and Vancouver, finding that "cities are developing indicators to measure whether their programs and actions are successfully moving towards their climate resilience goals" (City of Toronto, 2014a).

Resilience Measurement

Echoing Eyzaguirre and Warren (2014), Bahadur et al. (2016) highlight that the "development of new tools for measuring and assessing resilience is essential so we can better understand effective resilience interventions" (Bahadur et al., 2016). It is to this end that The Windward Fund granted $800,000 to create the Resilience Measurement Community of Practice. It is expected that the community of practice will touch on many of the measurement issues that are discussed in this report, though ensuring this is the case is an area of further research.

The indicators used in resilience assessment and evaluation are a widely debated topic. On the one hand, the use of indicators is often central to resilience assessment and planning. Hicks et al. (2016) point out that indicators are powerful because "they are scalable across geographic areas and, when designed well, reduce complex phenomena to simple measures." Issues of standardization and indexing were briefly explored, as were the merits and drawbacks of resilience indexes.

On the other hand, it was found that though quantitative approaches have led to much important progress, there are those who echo the warnings originally offered by Meadows (1998), raising compelling objections to over-quantification (e.g., Cox & Hamlen, 2015), and lamenting that "by summarising data into a single quantitative score, indices take on an objective authority that commands, but does not necessarily merit, respect" (da Silva & Morera, 2014c).

To this end the report engages in a discussion around subjective data collection, process indicators, and outcome harvesting, in order to alert our knowledge users that alternate methods of 'measuring without indicators' are possible, and often desirable and necessary. To this end, Bours, McGinn and Pringle (2014b) highlight that thinking about data availability is a very important step in the design of a resilience or CCA program. Much of this work requires the use of proxy indicators, which Bours et al. (2014a) define as "(more) easily-measure-

able 'stand-ins' for concepts or variables for which data is unavailable."

And finally, a discussion is included about how best to continue 'mainstreaming' urban resilience. Despite a great deal of activity in this area, the extent to which action will be taken, and taken in a timely manner is yet to be seen. Various practical and theoretical ways forward are presented, including future work which duly emphasizes the net-positive effects of resilience action.

The report concludes with a short section presenting research gaps in the literature involving the climate change impacts on energy production in Canada. This section presents a bulleted summary of research gaps and further work pertaining to the question "How will climate change affect Canadians' access to, equity in and availability of energy?" in the context of the resilience discussion above.

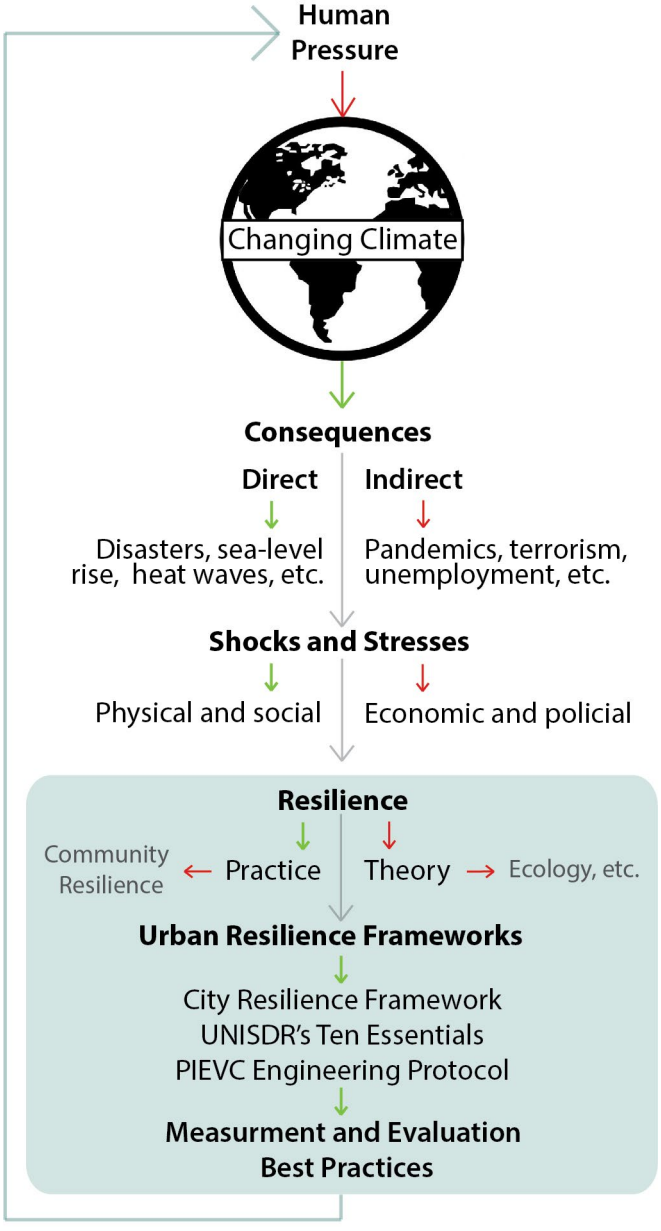


Figure 1: The focus of this project is demonstrated by the green arrows. The red arrows represent topics which were beyond our scope.

1. Context

The past year saw the launch of the Sustainable Development Goals, the Sendai Framework for Disaster Risk Reduction, the Paris Agreement, Mission Innovation, and countless other steps towards a better world. A quick glance through the sources used for this report will reveal that 2015 was also a big year for the field of urban resilience, with many of the sources used coming from the last 18 months.

But this flurry of activity did not come from nowhere. Like all sustainability initiatives, the seeds were sown a generation ago, long before techno-optimists and preppers were at cultural odds, and long before we knew about the planetary boundaries we were transgressing. The resilience work presented here is the result of so much good work in the fields of community development, urban planning, city management, climate change mitigation and adaptation, and more. Though Canadian researchers and practitioners have not always had the full support of the federal government --particularly during the past ten years-- cities and their partners have made tremendous progress preparing cities for the climate challenges ahead. And now, with our new government comes new activity, as evidenced by the budget, which acknowledges that "Canada's future prosperity rests on its ability to adapt to new challenges, including those that result from climate change and other threats to water and land" (Government of Canada, 2016), and even by the resurrection of the Adaptation 2016 conference held in Ottawa in April 2016.

This acceptance of the need to adapt to a changing climate is also relatively new. Where adaptation was once blasphemy, the undeniable evidence (e.g., Rignot et al., 2015; Rockstrom et al., 2009, etc.) has given adaptation, and by extension resilience, as much legitimacy and urgency as mitigation. For Bahadur et al. (2016) the inclusion of resilience in the Paris Agreement (see Article 7.1 in UNFCCC, 2016) sent "a crucial normative signal… that all states should not only seek to balance their development by limiting or reducing emissions but also adapt and build resilience to the impacts of climate change that mitigation does not prevent." Like mitigation and sustainable development, urban resilience is motivated by a desire to create a more just and sustainable world; despite the moribund nature of the word resilience, which can conjure a sense of just-getting-by.

It was at the Adaptation 2016 conference that it could continually be heard that 'we have our science, now it's time to collaborate, discuss and plan.' The same can be seen in this report. The IPCC, NRCan and others have amassed a nearly unimaginable amount of scientific information in their assessments. It is time now for collaboration and transformation. As Margaret Atwood says, "it's not climate change, its everything change." Paradoxically, write Martin-Breen and Anderies (2011), "try to keep everything the same, and the chance of future catastrophe can actually *increase*."

The various strategic resilience frameworks presented in this paper suggest that many cities around the world are engaging in transformative action. For the authors, this should help to quell the fears that arise around the pressures of urbanization, globalization, and climate change, and instead present evidence that humanity may indeed be on the precipice of a more just and sustainable world. As the recent events in Fort McMurray, Alberta have shown, cities are as rich in social capital as they are vulnerable. If Fort McMurray's experience has taught us anything, it is to heed Denis Waitley's advice to "expect the best, plan for the worst, and prepare to be surprised."

2. Implications

The users of the knowledge produced in this synthesis report are both within and beyond academia, and include city officials, provincial and federal government agencies, the private sector, foundations, NGOs, and other researchers. These users will benefit from being presented an inventory of work in the fast emerging field of urban resilience, as well as best practices for measurement and evaluation, and a review of the current, and voluminous, literature on both of these subjects.

The knowledge presented here is important for designers of resilience assessments and action plans. In uncovering well-designed and fully scaled strategic frameworks, the clear implication is that people just entering into this field should leverage the valuable progress which has been made. To this end, it is our hope that this work will be particularly useful for smaller cities who wish to undergo resilience planning, but do not

have the human or financial resources to do all of the background work which this synthesis report presents, including best practices for evaluation of resilience actions (e.g., indicator and index development). These best practices are not meant to be overly prescriptive, and are certainly not definitive, but are meant to raise important questions for those engaged in this type of work, and to encourage collaboration between practitioners. And finally, this work has implications for future researchers, including students, who will benefit from the dozens of future research areas and projects which have been explicitly suggested.

3. Approach

This report set out to synthesize knowledge relating to the question "How will global climate change alter the resilience of Canadian communities by affecting access to, equity in and availability of energy and food?" As shown in Figure 1, the elements of this question that are explored here include:

1. What is urban resilience (e.g., physical vs. social resilience)?
2. How is resilience work carried out in the built environment?
3. What strategic frameworks help guide urban resilience?
4. What best practices for measurement and evaluation exist?
5. To a limited extent, how will climate change affect energy production and distribution in Canada?

The work presented here is largely a narrative review of grey literature (see Figure 2). A scoping review was performed using academic literature, but was of limited value due to the practical nature of this synthesis report. UBC (2015) points out that grey literature is often difficult to access because it is not systematically organized, is often not indexed, and is vast in scope. Given these constraints, the process of accessing the grey literature used in this synthesis was iterative, and involved consultation with experts in the field, as advocated for by Arksey and O'Malley (2005). The research process carried on until the final few weeks of the grant, with key resources (e.g., Bahadur et al. 2016) being located only six weeks prior to completion of this report, and numerous others coming from the Adaptation 2016 conference help in mid-April, 2016. Though this report should be considered comprehensive, urban resilience is in a period of explosive growth, with new resources emerging weekly (for an example of this, see the Resilience Scans performed by The Overseas Development Institute).

Note: Both the results of the scoping study and background research done on the consequences of climate change on the Canadian food system are both available upon request, but were beyond the scope of this particular report.

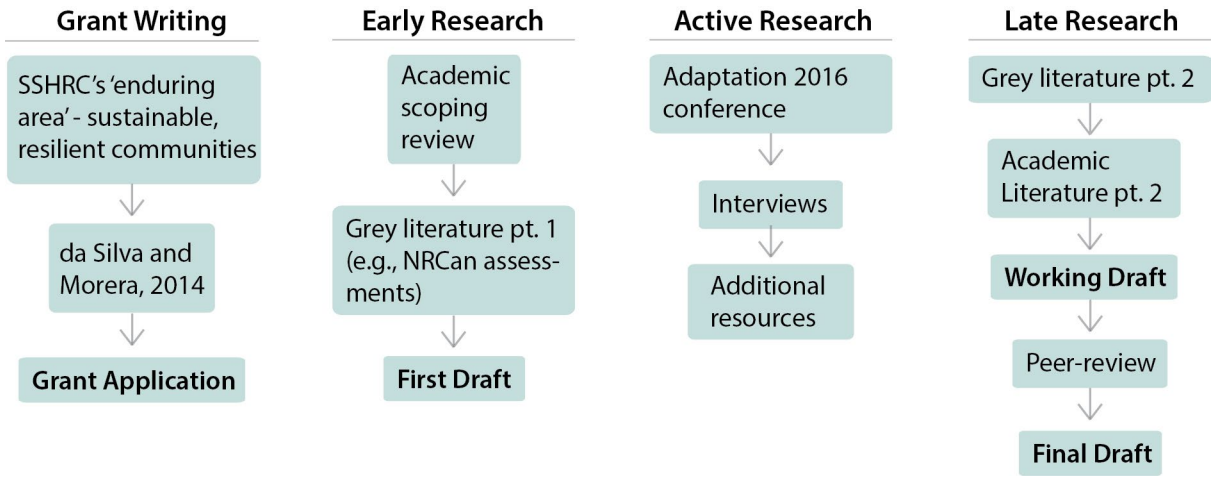


Figure 2: The research process for this project.

4. Results

4.1 Resilience 101

The term resilience has achieved buzzword status. It is widely used in the public and private sectors to describe everything from crop yields to the health of the global financial system (Holly-Purcell, 2015). For some, resilience requires a political economy approach (Friend & Moench, 2015), or community-level development path transformations (Burch et al., 2014), whereas for others it is primarily a community-building enterprise (Cox and Hamlen, 2015).

Conceptually, resilience has its roots in ecology, where definitions often describe the capability of a system to return to equilibrium after a shock (Caputo, Caserio, Cole, Jankovic & Gaterell, 2015). But resilience assessments which are dogmatically ecological (e.g., Resilience Alliance, 2010) tend not to translate into action at the city level. Moreover, as Fisichelli, Schuurman, and Hoffman (2016) point out, the ecological formulation of resilience can be *maladaptive* (i.e., having adverse effects despite being well-intentioned) because it is regressive instead of transformative. That is, it implies returning to previous stable states, whereas definitions ought to strive to produce transformative change. That being said, the authors agree with the Stockholm Resilience Centre that ecological literacy encourages planners to see "the numerous possibilities in investing in sustainable use of ecosystems and their services" (Moberg & Simonsen, 2014).

Whatever the case, precise definitions are essential in order to avoid confusion, to properly direct action, and to enable measurement and evaluation (Bours et al., 2014a). You cannot manage what you do not measure, and you cannot measure what you do not name; and as recently as 2014 urban resilience was without a "common definition" (da Silva & Morera, 2014b). Though various definitions have emerged, Bahadur et al. (2016) highlight that research in this area must remedy the fact that "academics, policy-makers and practitioners often use resilience terminology in confusing and conflicting manners." The present work accepts the simple, yet transformative, definition that resilience is the "capacity to buffer change, learn, and develop" (Folke et al., 2002).

Some resilience initiatives are created to respond to a particular threat, for example the RAND Corporation's Consortium for Resilient Gulf Communities which assesses and addresses the public health, social, and economic impacts of the 2010 Deepwater Horizon oil spill in the Gulf of Mexico (Consortium for Resilient Guelf Communities, 2016); while others can be much more broad, as in the RAND Corporation's Water and Climate Resilience Center, which is designed to address the challenge of "changing how we plan, build, and organize our societal systems to become more resilient to the unavoidable impacts of climate change" (RAND Corporation, 2015).

Urban Resilience

When applied to cities, (i.e., urban resilience) the focus is concentrated and involves "sustaining – and, in some cases, transforming - the systems and conditions within a city that affect its ability to function and deliver essential services, especially to poor and vulnerable communities" (Holly-Purcell, 2015). The challenges faced by cities are often referred to as shocks and stresses, and for ICLEI (n.d.) these can occur in the following areas: public health and safety, local economy and growth, community and lifestyle, environment and sustainability, and public administration; though they could be conceived in different ways as well. Urban resilience is often concerned with managing the effects of climate change within cities --sometimes referred to as climate resilience-- as seen in this definition offered by The White House: "a climate-resilient community has the capability to anticipate, prepare for, and recover from climate impacts on public health and safety, the local economy, and natural resources" (ICCATF, 2011).

Resilience and Sustainability

Urban resilience has important relationships with the sustainable development work occurring in cities around the world. This can be seen in Sustainable Development Goal #11 (i.e., make cities inclusive, safe, resilient and sustainable), in the relationship between UNISDR and the World Council on City Data (described below), and in the shared goals of both concepts, which can be seen when cities (e.g., Victoria, B.C.) include resilience in their sustainability planning activities (Burch et al., 2014). Exploring the potential for synergy between these two initiatives at the city-level is an important area of further work.

Resilience and Adaptation

Urban resilience finds signficant common ground with climate change adaptation, current formulations of which tend to be more nuanced than they were a decade ago, when adaptation was seen as being preoccupied weather-related risks, and being uni-dimensional (i.e., non-systemic) (da Silva and Morera, 2014b; Tyler & Moench, 2012). For example, the Paris Agreement's definitions of adaptation include a shift towards adaptation as a process of iterative cycles (as opposed to isolated actions), normative principles for adaptation (e.g., diversity and inclusion), and a wider array of stakeholders (Bahadur at al., 2016; see Figure 3 for an example of iterative cycles). Bahadur et al. (2016) point out that resilience often appears alongside adaptation in UNFCCC texts, and that "resilience and adaptation are interrelated terms, although the former generally refers to a state or characteristic while the latter describes a process" (Bahadur et al., 2016; also see Article 2.1b in UNFCCC, 2016). We see this in Warren and Lemmen (2014a) when they assert that "adaptation enhances the social and economic resilience of Canadians to climate change impacts."

However, just as adaptation has developed into a more nuanced concept, so too should resilience be thought of as a process, and not merely an ideal end-state for a city (Cox & Hamlen, 2015). Exploring the emerging theoretical relationships between these concepts warrants further academic work, as we see this overlap at all levels, including the international one: Article 7.1 of the Paris Agreement has the goal of "enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change" (UNFCCC, 2016).

> Community resilience usually refers to work in smaller, often remote, communities that usually has a development component (e.g., increasing capacities like self-sufficiency, literacy, etc.).

Social Resilience

Urban resilience, like sustainability, often has social, as well as economic and environmental, prerogatives. For example, for Holly-Purcell (2015) "resilience is ultimately about securing and bettering people's lives and livelihoods." In the same way that people don't want kilowatt-hours of electricity, they want cold beer and hot showers (Amory Lovins), people don't want storm-water management for its own sake, they want it so that people can enjoy a high quality of life within cities. Though some resilience theorists would object that giving human wellbeing primacy violates an ecological imperative, most find the focus on wellbeing refreshing,

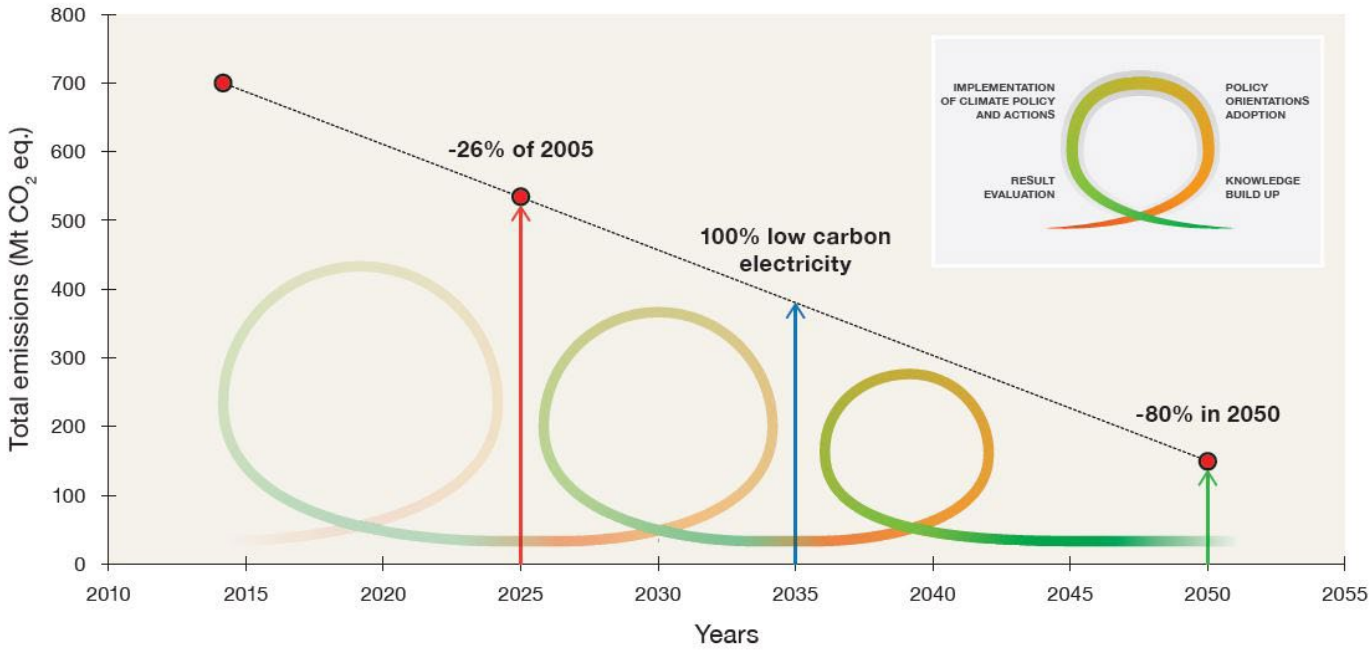


Figure 3: This figure demonstrates one way to think about interative processes that occur over decades, specifically the inset diagram in the top right. Image credit: Sustainable Dialogues Canada, 2015.

and easy to act upon.

Urban resilience strategies are often informed by social justice agendas (see Brisley, Welstead, Hindle & Paavola, 2012) and seek to ensure that climate change adaptation is not yet another activity which leaves the marginalized behind (Cox & Hamlen, 2015). To this end, Bahadur et al. (2016) highlight that an emerging area of work in this area involves enhancing the capacity of the resilience process to explore "how power relations affect how people benefit (or do not benefit) from resilience-building projects." This is a chance for social scientists to address barriers to urban resilience.

But it is not just the outcomes of resilience initiatives that are social, the determinants of resilience are often social in nature. After all, it is not only the physical infrastructure of a community that must remain resilient during times of shock, but the "equitable access and the sustainability of the community itself" (Dempsey, Bramley, Power, & Brown, 2011). Examples include Grosvenor Group Limited (2014) including community issues in its vulnerability index, or the insistence that community focus and community identity are among the five essential qualities of a resilient city (A. Hay, personal communication, May 2, 2016).

Social capital was also shown to be important in the recovery after Hurricane Sandy, where it was found that "people living in neighborhoods with more social connections and resources are more resilient" and that "social resources can help neighborhoods overcome economic barriers to resilience" (The Associated Press-NORC Centre for Public Affairs, 2012). The following were identified as overarching dimensions of social capital:

- Social cohesion: how connected people are within their neighbourhoods;
- Social control: the informal ways that people in the neighbourhood maintain public order;
- Social exchange: how neighbours help each other out;
- General trust: how much a person trusts people overall (The Associated Press-NORC Centre for Public Affairs, 2012).

But incorporating 'social resilience' into planning is difficult. Many of these non-physical aspects are often ignored and unnoticed due to the complications related to identifying and measuring them (da Silva & Morera, 2014b). Approaches to measuring these less tangible characteristics will be discussed below, as will further work that includes determining the extent to which emerging resilience tools (e.g., ISO's forthcoming resilience standard) take social factors into account.

Capacity for Resilience

For Bahadur et al. (2015), resilience is comprised of adaptive capacity, anticipatory capacity, and absorptive capacity (i.e., the "Three A's"; see Box 1). For ICLEI (n.d.) there are several key determinants of adaptive capacity, including economic resources, access to information and technology, social capital, strong institutions, and social equity. Given its relative novelty, further work needs to explore the prevalence and relevance of the "Three A's" conceptual framework, and their determinants.

Beyond these capacities, much work has been done to determine the *qualities* of a resilient city. A survey of stakeholders in the *Medellín Collaboration on Urban Resilience* (see Box 2) reported that a resilient city must be reflective, robust, redundant, and resourceful (Holly-Purcell, 2015; similar characteristics can be found in Siemens, Arup, & Regional Plan Association, 2013). The Rockefeller Foundation's *City Resilience Framework*

Box 1: For Bahadur et al. (2015), resilience is dependant on three capacities:

Adaptive capacity: "the ability of social systems to adapt to multiple, long-term and future climate change risks, and also to learn and adjust after a disaster."

Anticipatory capacity: "the ability of social systems to anticipate and reduce the impact of climate variability and extremes through preparedness and planning."

Absorptive capacity: "the ability of social systems to absorb and cope with the [immediate] impacts of climate variability and extremes."

Box 2: The Medellín Collaboration on Urban Resilience includes the UN Human Settlements Programme (UN-Habitat); the UN Office for Disaster Risk Reduction (UNISDR); The World Bank Group; the Global Facility for Disaster Reduction and Recovery (GFDRR); the Inter-American Development Bank (IDB); the Rockefeller Foundation; 100 Resilient Cities – Pioneered by the Rockefeller Foundation; the C40 Cities Climate Leadership Group; and ICLEI – Local Governments for Sustainability.

expands slightly on these, proposing reflectiveness, resourcefulness, robustness, redundancy, flexibility, inclusiveness, and integration. Still others have their own characteristics (e.g., Martin-Breen and Anderies, 2011; Cascio, 2009; da Silva and Morera, 2014b; Leichenko, 2011), and further work should involve exploring overlaps between these.

Resilience Planning

So how are people working towards encouraging these characteristics in cities? One way to approach answering this is to explore climate change adaptation work, much of which overlaps with resilience. The 2014 scientific assessment performed by NRCan found 63 examples of adaptation activities in Canada, of which 60% involved "research; monitoring climate impacts; assessing vulnerabilities, risks and opportunities; developing stand-alone adaptation strategies; and mainstreaming adaptation within existing policies and planning" and that "as such, adaptation implementation in Canada is still in its early stages" (Eyzaguirre & Warren, 2014).

In the context of Figure 4, adaptation planning is now entering Phase 3.

The prevalence of vulnerability assessments (a precursor to resilience planning) also points to the state of resilience (and CCA) work in Canada. A vulnerability assessment is "a process for assessing, measuring, and/or characterizing… exposure, sensitivity, and adaptive capacity" of certain regions or sectors (Nelitz, Boardley, & Smith, 2013). It can also be carried out at the household level, as seen in the Survey of Emergency Preparedness and Resilience, developed by Public Safety Canada and administered to Canadian families.

As seen in IPCC (2014) and NRCan (2014), as well as countless local and regional examples, there are large amounts of rigorous scientific assessments upon which to base action. Moreover, the methods used during vulnerability assessments are becoming more nuanced, and thus theoretically reflective of the many elements of resilience planning. For example, participatory

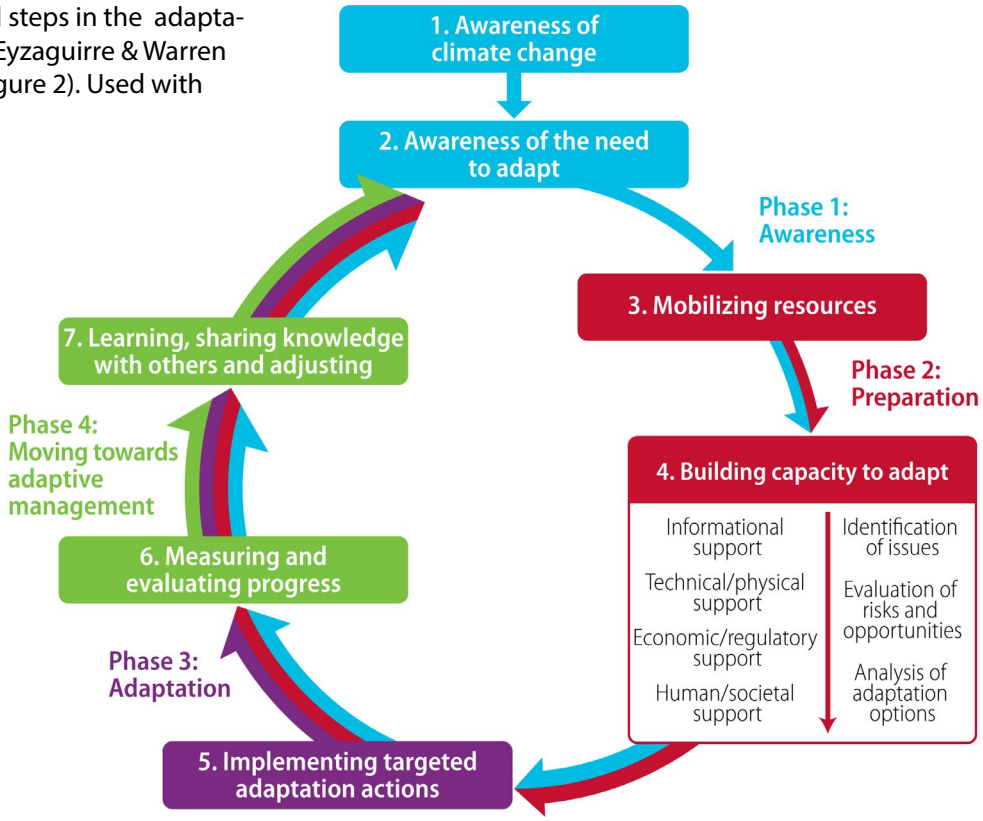


Figure 4: Stage and steps in the adaptation process (from Eyzaguirre & Warren (2014, page 260, Figure 2). Used with permission.

vulnerability assessments incorporate local knowledge and can include factors beyond climate, including "political, cultural, economic, institutional and technological forces" (Smit & Wandel, 2006). All of this points to readiness on the part of urban resilience practice to enter into implementation and evaluations phases.

Resilience Tools

Eyzaguirre and Warren (2014) write that climate change adaptation is facilitated by concrete tools which include strategies, frameworks, guidance documents, decision support tools (e.g., maps and visualizations, guidance for scenario interpretation and use, and adaptation guidebooks and toolkits). Holly-Purcell (2015) echoes this for resilience, writing that there is a "vast array of tools and diagnostics designed to assess, measure, monitor, and improve city-level resilience." Similarly, Cox and Hamlen (2015) point to an "increased focus on resilience measurement that has, in turn, resulted in a growing array of resilience frameworks and indices" (see Section 4.3 for examples, as well as Appendix B). Perhaps the most basic --while still being wildly complicated-- approach that cities can take is to focus on the resilience of their critical infrastructure.

4.2 The Built Environment

Infrastructure (Physical) Resilience

The resilience of critical infrastructure is a necessary, but not sufficient condition of urban resilience (da Silva & Morera, 2014a), as can be seen in the various frameworks described in Section 4.3. That being said, a great deal of important work within the larger field of practice of urban resilience is concerned with the ability of critical infrastructure (e.g., stormwater management, electricity distribution, transportation systems) to function during extreme events (for examples of this work see University of Toronto's Centre for Resilience of Critical Infrastructure; Feltmate & Thistlethwaite, 2012; Carleton University's new Infrastructure Resilience Research Group). This works often explores the infrastructure gap, or the gap between the demand and capacity of a city's critical infrastructure, which is often divided into gray (e.g., sewers) and green (e.g., wetlands) infrastructure (see Figure 5).

The Government of Canada (2016) acknowledges the importance of infrastructure in the 2016 budget: "Canada will also need to adapt our public infrastructure to a changing climate and strengthen the resilience of our communities to the impacts of climate change." An example of a resilience assessment focused on infrastructure is Siemens' Toolkit for Resilient Cities (Siemens, Arup, & Regional Plan Association, 2013) which focuses on "physical infrastructure relating to energy, transportation, water and buildings." They explain that "these systems were chosen because they underpin many other essential city operations and services, including sanitation, emergency response, and the delivery of food, fuel and other materials" (Siemens, Arup, & Regional Plan Association, 2013).

In line with IPCC (2014) recommendations, Canada's Public Infrastructure Engineering Vulnerability Committee has created the PIEVC Engineering Protocol to assess the vulnerability of critical Canadian infrastructure. The PIEVC protocol has been used many times across Canada, including a high-level assessment of the climate change induced infrastructure vulnerabilities faced by Toronto Hydro (AECOM & RSI, 2015). This was the first deployment of PIEVC for this sector at this scale, and it was found that high ambient summer temperatures, freezing rain and ice storms, and flooding were the primary triggers of system vulnerabilities (AECOM & RSI, 2015). AECOM and RSI (2015) also identified these five areas of resilience activity for utilities: planning, infrastructure (e.g., redundancy, hardening infrastructure), operational (e.g., smart meters, advanced analytics), organizational (e.g., response time), and communications. Further work should examine the extent to which these are being undertaken, and the effect that actions have had. Encouragingly, data availability for this type of work is expected to improve, with the 2016 Federal Budget stating that "Infrastructure Canada will work with Statistics Canada to improve infrastructure-related data" (Government of Canada, 2016).

Additional work suggested by the study includes increasing capacity during heat waves, and further exploring adaptation measures for climate events causing structural damage issues (e.g., freezing rain) (AECOM & RSI, 2015). There is also a future project that involves mapping the tree canopy in relation to sub-stations and distribution infrastructure to identify vulnerabilities with more granularity than achieved in the study.

Energy Efficiency and Resilience

Energy efficiency is one of the main strategies that cities will use to reach emissions reductions targets (e.g., Socolow et al., 2004; Sustainable Dialogues Canada, 2015). In the process of becoming more energy efficient, cities will also become more resilient. The American Council for an Energy-Efficient Economy (ACEEE) makes explicit connections between energy efficiency and resiliency (Riberio et al., 2015). Things like energy-efficient buildings, cool roofs, district energy systems, and transit-oriented development all have clear resilience benefits in the areas of emergency response and recovery, social and economic benefits, and climate mitigation and adaptation (Ribeiro et al., 2015; Smith & Levermore, 2008; Xu et al., 2012). Riberio et al. (2015) offer as evidence a combined heat and power plant that enabled critical water pollution control facilities to stay online during and after Hurricane Sandy. A similar combined heat and power project was facilitated for Campbell Soup by Toronto Hydro. Doing an in-depth case study on the way that this system contributes to resilience at the building and the neighbourhood levels is a future research project. Additional further work in this area should corroborate ACEEE's claim that "most resilience efforts also do not recognize the value of energy efficiency fully, if at all" and should strive to answer ACEEE's call for "technical assistance on methods to incorporate efficiency into communities' planning processes" (Ribeiro et al., 2015).

Buildings

C40 Cities Climate Leadership Group and Arup (2015) point out that in "2015, cities reported taking a total of 438 adaptation actions", the five most common of which were:

- Storm water capture systems;
- Green roofs / walls;
- Crisis management (including warning and evacuation systems);
- Flood mapping;
- Tree planting and / or creation of green spaces.

With the exception of flood mapping, buildings can play a role in increasing each of these. It is encouraging, therefore, to see that the 2016 Federal Budget allocates $40 million over five years to "to integrate climate resilience into building design guides and codes" that will apply to both buildings and the rehabilitation of public

Figure 5: The green infrastrucutre of parks can be used as a buffer for floodwaters. See London's Harris Park Project (not pictured here) for an example.

infrastructure (Government of Canada, 2016). Though it is too soon to know what these codes will prescribe, it is likely that they will be similar to approaches already being taken. For example, BOMA Canada's BOMA BEST 3.0 program will launch in September 2016 and will reward existing commercial buildings for incorporating resilience planning (e.g., risk assessments) into their building operations. Similarly, the buildings being built on Toronto's waterfront are designed not only to be energy efficient, but also to increase the resilience of the area by managing stormwater (via site design, green roofs, etc.). Determining how to measure success in this type of endeavor is important, and will ideally be considered in the design of the new standards and codes.

Better understanding the behaviour of occupants within buildings is another important part of improving their ability to contribute to resilience (Brown & Gorgolewski, 2015). For example, energy conservation behaviours (e.g., higher summer setpoints, natural ventilation) are enable buildings to contribute to resilience (Lemmen, Johnston, Ste-Marie, & Pearce, 2014; Levine et al., 2007; Gupta & Gregg, 2012), as are occupant engagement strategies which could be useful in educating and preparing occupants for extreme events. Both of these areas warrant further study.

Other further work pertaining to physical resilience includes:

- AECOM and RSI (2015) found that higher ambient temperatures were the primary triggers of system vulnerabilities for Toronto Hydro. This can lead to power outages during which high-rise buildings that lack backup generators quickly become uninhabitable, and difficult to exit for people with mobility issues (often called thermal resilience). Assessing and mapping thermal resilience is an important area of further work.
- Research should explore the mitigation/resilience trade-offs resulting from policies which favour densification. What effect do these policies have on resilience issues like urban heat island effect, stormwater management, and thermal resilience?
- The role of energy efficient appliances (especially air-source heat pumps) will be valuable in in reducing electricity consumption and increasing resilience (Lemmen et al. 2014), but as Levinson (2015) has shown, this is not to be assumed as there is often a rebound effect with energy efficiency technologies and programs where users consume more as the cost of use decreases. Applying this critique to existing programs is a valuable piece of further work.

4.3 Strategic Frameworks

There are numerous strategic frameworks available for cities to use in resilience assessment and planning. These frameworks enable decision-makers to employ well-informed best practices, such as those offered by Rosenzweig et al. (2015), who provides five pathways (or best practices) that cities ought to pursue:

1. Disaster risk reduction and climate change adaptation are the cornerstones of resilient cities;
2. Actions that reduce greenhouse gas emissions while increasing resilience are a win-win;
3. Risk assessments and climate action plans co-generated with the full range of stakeholders and scientists are most effective;
4. Needs of the most disadvantaged and vulnerable citizens should be addressed in climate change planning and action;
5. Advancing city creditworthiness, developing robust city institutions, and participating in city networks that enable climate action.

The frameworks presented below generally embody these best practices, though further work could explore the extent to which this is the case. The frameworks also encourage collaboration between cities and sectors in order to maximize the impacts of collective efforts. Though some resilience assessment tools are "intended as rapid assessments to establish a general understanding and baseline of a city's resilience and can be self-deployed", the frameworks presented below are more action-oriented, demanding "more sophisticated technical and financial capacities to implement" (Holly-Purcell, 2015). For the purposes of this report, only a few of the leading frameworks will be discussed, with the remainder presented in Appendix B.

The City Resilience Framework

The City Resilience Framework was developed by Arup (with support from the Rockefeller Foundation) and is based on extensive background research (see da Silva & Morera, 2014a). The framework is meant to "identify critical areas of weakness, and to identify actions and

programs to improve the city's resilience" (The Rockefeller Foundation and Arup, 2015). This framework is used in the 100 Resilient Cities (100RC) program, pioneered by The Rockefeller Foundation, which provides technical and financial resources (approximately $1,000,000 per city) to 100 cities around the world, who applied to take part, and facilitates collaboration through their 100RC tool. Each city is required to hire a Chief Resilience Officer to carry out the creation and implementation of a resilience strategy. Cities include New York City, Boulder, Montreal, and many others (see link).

The City Resilience Framework has four dimensions (see Figure 6), with which 12 drivers (similar to indicators) are associated. These drivers "describe the outcome of actions to build resilience, not the actions themselves" (da Silva, 2014a). For each of these drivers, there are seven qualities that are "considered to be important in preventing breakdown or failure; or enabling appropriate and timely action to be taken" (da Silva, 2014a). These qualities are: reflectiveness, resourcefulness, robustness, redundancy, flexibility, inclusiveness, and integration (da Silva and Morera, 2014a). Referring to the use of the seven qualities, the City of New Orleans (2015) writes that "at each stage of the process, we also relied on the qualities of resilient systems as a touchstone to guide the development of our actions" (City of New Orleans, 2015).

Note: There are plans to create a City Resilience Index that will introduce the variables through which city-scale resilience can be accurately measured" (da Silva and Morera, 2014a), though nothing official has been release yet.

For Boulder, Colorado, the City Resilience Framework was used to guide an iterative process of arriving at three major priority areas:

CONNECT AND PREPARE Prepare all segments of the community for uncertainty and disruption by encouraging community preparedness, creating a culture of risk awareness and personalizing resilience.
PARTNER AND INNOVATE Capitalize on the collective problem-solving and creativity of our community by leveraging advances in data, research and observations to address emerging resilience challenges.
TRANSFORM AND INTEGRATE Embed resilience into city operations and systems by transforming our approach to community resilience (City of Boulder, 2016).

Each of these areas has action items associated with it. For example, within the second area, the following action item was created: "Spur creative representation of data through investments in artistic visualization and knowledge display" (City of Boulder, 2016). The framework, then, enables a process during which stakeholders work towards an action plan for resilience, instead

City Resilience Framework

Health and Wellbeing
1. Meets Basic Needs
2. Supports Livelihoods and Employment
3. Ensures Public Health Services

Economy and Society
4. Promotes Cohesive and Engaged Communities
5. Ensures Social Stability, Security and Justice
6. Fosters Economic Prosperity

Infrastructure and Environment
7. Enhances and Provides Protective Natural & Man-Made Assets
8. Ensures Continuity of Critical Services
9. Provides Reliable Communication and Mobility

Leadership and Strategy
10. Promotes Leadership and Effective Management
11. Empowers a Broad Range of Stakeholders
12. Fosters Long-Term and Integrated Planning

UNISDR Ten Essentials
1. Organise for disaster resilience
2. Identify, understand and use current and future risk scenarios
3. Strengthen financial capacity for resilience
4. Pursue resilient urban development and design
5. Safeguard natural buffers to enhance the protective functions offered by natural ecosystems
6. Strengthen institutional capacity for resilience
7. Understand and strengthen societal capacity for resilience
8. Increase infrastructure resilience
9. Ensure effective disaster response
10. Expedite recovery and build back better

Figure 6: The primary drivers/indicators used in the two most prominent urban resilience frameworks.

Figure 7: A map showing the cities participating in UNISDR's *Making My City Resilient* campaign. Image courtesy of UNISDR: http://www.unisdr.org/campaign/resilientcities/home/cities

of the checkbox (or cookbook) approach where certain prescriptive elements must be present. Fournier (2012) advocates for similar processes, writing that resilience assessments should be inclusive, flexible/adaptive, comprehensive, and iterative. This can also be seen in the "Resilient New Orleans" strategy. They point out that during the roughly eight month process, the City Resilience Framework was used "to assess the connections between our challenges, identify critical areas of weakness, and develop actions that build upon our strengths. We also used the framework to facilitate a comprehensive discussion of resilience with our stakeholders" (City of New Orleans, 2015).

Writing in 2012, which admittedly is a long time ago in this field, Fournier (2012) wrote that "there is little empirical evidence[…] that can be examined to assess the effectiveness of these new resilience assessment tools." Certainly over the next few years this will be a prominent research topic. It is also worth noting that the City Resilience Framework does not appear to offer measurement and evaluation advice, suggesting that further research should focus on helping develop these. Other further work inspired by the collaborative nature of this framework, involves empirically demonstrating that adaptive capacity increases alongside public deliberation, which has been questioned (e.g., Hobson & Niemeyer, 2011; see link for a current example of deliberation from the Government of Canada).

UNISDR - Make My City Resilient Program

At the highest governmental level, urban resilience assessment and planning is facilitated by the United Nations International Strategy for Disaster Risk Reduction (UNISDR). Their "Making My City Resilient Campaign" has "attracted over 2,200 cities who have pledged to take deliberate steps in improving resilience" (Sands, 2015; also see Figure 7), including those from the developed (e.g., North Vancouver) and developing world. This program is the embodiment of the Sendai Framework for Disaster Risk Reduction (formally Hyogo Framework) and starts with the "Ten Essentials for Making Cities Resilient" - a list of ten actions a city should take to ensure their resilience (see Section 4.3). The following briefly describes the Scorecard which guides and evaluates a city's progress through the Ten Essentials (see Figure 5). The scorecard was developed by IBM and AECOM and uses 96 disaster resilience

items/indicators, "each designed to rate on a 0 to 5 scale an aspect of a city's preparedness for, and ability to recover from, natural hazards" (UNISDR, 2015b). For example, under Essential #7 (i.e., Increase societal and cultural resilience), the presence of grassroots organizations is presented, with the indicator being "presence of at least one non-government body for pre and post event response for each neighborhood in the city" (UNISDR, 2015b). The scorecard was designed to help cities "better understand their own institutional capacity and engage in efforts to build resilience" (UNISDR, 2015a), and has been piloted in at least one US city (see IBM and AECOM, 2015 for initial results from the Stamford Connecticut pilot).

When the Hyogo Framework expired at the end of 2015, it meant that UNISDR had to update their "Ten Essentials" so that they reflected the goals/targets of the Sendai Framework. This process was guided by "a group of over 100 distinguished city and expert partners passionate in disaster risk reduction" (UNISDR, 2015a) and resulted in the creation of The Local Urban Indicator Tool which presents a total of 230 questions that can be used to better indicate and encourage resilience within each of the ten priority areas. Evaluating these various indicators presents a significant future research area, as the tool is still in its pre-piloting phase.

At the same time as the Local Urban Indicator Tool was being developed, the World Council on City Data (creators of ISO 37120) began work with ISO on a set of standardized indicators for urban resilience. Encouragingly, WCCD and UNISDR formed a collaboration in order to continue the expert review of their indicators, including a meeting in Toronto in April, 2016. Though still in the pre-pilot phase, it is expected that the new ISO standard for resilience will include measures relating to smart cities, emergency preparedness, critical infrastructure, economic and political resilience, transit and mobility, green buildings, etc. (Hernandez, 2014). Given that both of these frameworks are still emerging, there we be much further work over the next few years assessing their contribution to urban resilience around the world.

Collaborations between cities (e.g., C40 Cities Climate Leadership Group, and the Compact of Mayors) are helping drive innovation in resilience assessment and planning. The 2016 Federal Budget contains $75 million which the Federation of Canadian Municipalities will deliver in part to "support the assessment of local climate risks, and the integration of these impacts into asset management plans" (Government of Canada, 2016).

ICLEI - Changing Climate, Changing Communities

ICLEI - Local Governments for Sustainability is an international association of local governments committed to sustainable development. Among other things, they administer the annual "Resilient Cities" conference (the 2016 iteration of which will feature an abridged version of this report as a background paper). ICLEI Canada is a not-for-profit located in Toronto, Canada that has programming which though explicitly concerned with climate change adaptation, has many important links with resilience. In particular, ICLEI's *Changing Climate, Changing Communities* program provides a framework which facilitates action at the municipal level. It is a "compendium of resources that provide a milestone based framework to assist local governments in the creation of adaptation plans to address the relevant climate change impacts associated with their communities" and emphasizes that shocks can be felt across social, economic, physical, and ecological systems (ICLEI, n.d.).

The five milestone approach proceeds as follows: initiate, research, plan, implement, and monitor/review. The program is facilitated online through the Building Adaptive & Resilient Communities (BARC) tool (similar to the LGSAT tool for UNISDR's Ten Essentials), and users are encouraged to use the BARC Network to collaborate, which is an important part of a city resilience initiative.

Some unique features are worth reporting here. First, ICLEI does not produce an assessment for the city as a whole, rather it produces them across the following ten city sectors: Communications, Economic development, culture, and tourism, Engineering, Environment, General adaptation, Housing, Parks and recreation, Public health, Transportation, Water (ICLEI, n.d.). For each sector, vulnerability to specific climate impacts are assessed by first creating a composite score reflecting sensitivity and adaptive capacity, and then assigning

a risk level to each impact. Those with the highest risk rating are given priority in the action planning that ensues during implementation. This is different from the City Resilience Framework in that it includes guidance for measurement and evaluation, and different from the Ten Essentials Program in its focus on city sectors.

4.4 Resilience in Toronto

The city of Toronto will face many climate related challenges in the coming decades (AECOM & RSI, 2015; also see Figure 8). In 2014, the City of Toronto conducted a review climate resilience best practices in New York City, San Francisco, Chicago, Seattle/King County, Calgary, and Vancouver (City of Toronto, 2014a). The six cities were selected as they are mostly comparable in size to Toronto and are North American leaders in climate change adaptation and resilience to extreme weather, as evidenced in part by their high rankings in Grosvenor's Resilient Cities report (Research Group of Grosvenor Limited, 2014). This report built on some of the outcomes from the *Resilient City Roundtable* which was held in March of 2013 and was used to steer the City of Toronto's Resilient Cities Working Group, which at the moment operates behind closed doors and involves bringing together different departments and service providers to discuss synergies in resilience planning. For example, telecommunications representatives are rarely involved in city resilience planning, despite the fact that much critical infrastructure depends on their services extreme events (D. MacLeod, personal communication, April 14, 2016). This is an innovative approach which combines the sector-based approach of ICLEI with the collaborative nature of the City Resilience Framework.

The City of Toronto (2014b) has highlighted many areas of further work, much of which will be conducted internally, but which nonetheless include: integrating climate change resilience into decision making, increasing the resilience of Toronto's services and infrastructure, ensuring that priority populations are served by resilience initiatives, developing partnerships with the private sector and broader public sector, and supporting improvements in the personal resilience of residents and businesses. City of Toronto (2014a) also reported

Figure 8: A changing climate will bring with it significant challenges to electricity distribution infrastructure.

"Not everything that counts can be counted, and not everything that can be counted counts"
- William Bruce Cameron

that "cities are developing indicators to measure whether their programs and actions are successfully moving towards their climate resilience goals." Accessing and assessing these indicators using the various considerations explored in Section 4.5 is an important piece of further work as well.

In addition to areas mentioned above, further areas of work include:

- Exploring the feasibility of cities devoting "10% of their city's budget towards resilience-building goals and projects, without raising taxes", as advocated for by 100 Resilient Cities (Rodin, 2015).
- Exploring the extent to which city policies are aligned with provincial (at the least) policies in order to ensure that positive achievements in cities spill over to other jurisdictions (Burch et al., 2014). This might not be necessary given the other collaborative arrangements in which cities are engaged (e.g., C40).
- According to Bistrow (2013), Toronto has 6 days of transportation fuel, 20 days of food, and 49 days' worth of biomass for home heating. More of this type of work is needed in cities, and can be used to inform the public about the degree to which they are vulnerable.
- Compact of Mayors (2016) found that the amount of power --or "the level of control a city has over various sectors"-- was a significant determinant in its ability to lower emissions and improve resiliency in the building sector. Quantifying the varying levels of power in Canadian cities and correlating it to resilience is a long-term project implied by this work.

4.5 Measurement and Evaluation

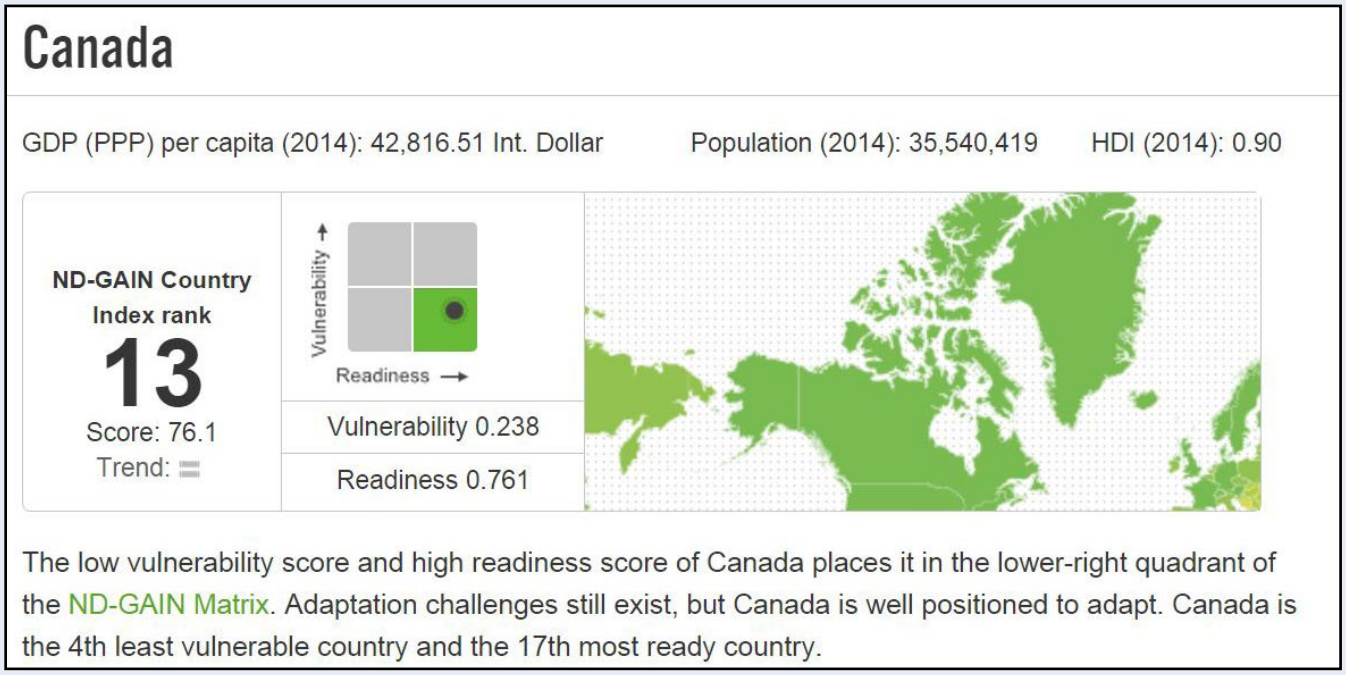
Echoing Eyzaguirre and Warren (2014), Bahadur et al. (2016) highlight that the "development of new tools for measuring and assessing resilience is essential so we can better understand effective resilience interventions" (Bahadur et al., 2016). It is to this end that The Windward Fund granted $800,000 to create the Resilience Measurement Community of Practice. The project runs from October 1, 2015 to March 31, 2017 and brings together leading resilience measurement experts and practitioners. It is expected that the community of practice will touch on many of the measurement issues that are discussed in this section, though ensuring this is the case is an area of further research.

The use of indicators is often central to resilience assessment and planning. Hicks et al. (2016) point out that indicators are powerful because "they are scalable across geographic areas and, when designed well, reduce complex phenomena to simple measures" (Hicks et al., 2016). This is the approach taken by WCCD and ISO in the creation of ISO 37120, a set of standardized indicators which "enable cities to assess their performance and measure progress over time" in key areas of service delivery and quality of life (McCarney, 2009). This standardization often leads to very desirable outcomes, including not needing to transform indicator values in z-scores (e.g., Research Group of Grosvenor Limited, 2014) and increasing the insurability and credit worthiness of cities by making rigorous comparisons and benchmarks possible.

An extension of this approach is the use of indexes, which are usually a combination (i.e., aggregation) of indicators into a single value, often involving numerical transformation of indicators values (e.g., weighting of indicators, standardizing their values) (da Silva & Morera, 2014c). An example of this can be seen in the Grosvenor Report (2014) wherein cities are ranked according to the sum of their indexed vulnerability and adaptive capacity scores. To do this, data for over 100 indicators (they call them datasets) is collected, and then transformed into standardized units (presumably z-scores) so that various indicators can be combined, enabling cities to be ranked (see also ND-GAIN in Figure 9 for a similar example). Exploring the merits and shortcomings of this type of approach represents an area of further work, as does determining precisely how tools

"Many initiatives being undertaken to build Canadians' capacity to adapt have yet to be evaluated or their lessons synthesized in scientific literature. Agreed upon methods to track and measure actions taken to reduce climate change risk and vulnerability do not yet exist"
- Eyzaguirre and Warren, 2014

Figure 9: The Notre Dame Global Adaptation Index (ND-GAIN) consists of 45 vulnerability and readiness indicators which focus on measuring exposure, sensitivity, and cities' adaptive capacity. By providing cities with this information, it increases awareness of the disproportional spread of risk across the world. Similar work is being carried out at James Ford's McGill lab (http://www.jamesford.ca/). Image courtesy of http://gain.org/



developed by the private sector, interact, or are expected to interact with other resilience initiatives (e.g., forthcoming resilience standards from ISO and UN-Habitat).

Though quantitative approaches have led to some important progress, there are those who build on the warnings originally offered by Meadows (1998), raising potent objections to quantification (e.g., Cox & Hamlen, 2015), and lamenting that "by summarising data into a single quantitative score, indices take on an objective authority that commands, but does not necessarily merit, respect" (da Silva & Morera, 2014c). Just because vulnerability, for example, can be conceptualized as being a composite of exposure, sensitivity and adaptive capacity, it does not mean that these elements "should be measured in order to numerically compare the relative vulnerability of communities, regions or countries" (Smit & Wandel, 2006). To standardize would be to ignore the fact that vulnerability is "place- and system-specific" (Smit & Wandel, 2006). For Coffee (2014), "indicator indexes should be a weather report not a thermometer. It should indicate something to you that makes you want to investigate further."

Similarly, as Hicks et al. (2016) highlight, indicators can be insidious; at best distracting "policy attention on fixing the indicator rather than the conditions represented by the indicator" (Malone, 2009), and at worst obscuring the fact that humanity is transgressing the complex planetary boundaries reported by Rockstrom et al. (2009). And so, ensuring that resilience assessments do not bias the quantifiable, and that they include key determinants of equity and action, is essential (Hicks et al., 2016; Cox & Hamlen, 2015).

To this end, Bours et al. (2014b) report that most resources urge programmers to ask the right questions, and that "there should be an appropriate medley of qualitative, quantitative, and binary indicators." Hicks et al. (2016) echo this, suggesting that "complementary, qualitative, and reflexive assessments will remain critical for development, implementation, and interpretation of robust measurement systems." Schipper and Langston (2015) elaborate: "although individual indicators may not appear relevant to resilience, if accompanied by qualitative information on context, they may be able to provide a sense of direction (built or reduced resilience)." Assessing the validity of these claims is further work which is beyond the scope of this report, as is applying these principles to evaluations of the "Three

"Bias toward easily quantifiable concepts, coupled with the tendency for indicators to direct change, can hinder progress, particularly where biases ignore key determinants of human equity and action." - Hicks et al., 2016

A's." Further work should also include further assessing the merits of resilience indexes generally, and should explore how and why the various indexes vary in their assessments of the same city or country.

Indicators

There are many ways to approach assessing the resilience of cities, identifying actions to improve resilience, and evaluating the effectiveness of those actions. Ultimately, whatever indicators are used (be they qualitative or quantitative), the end goal is to answer the questions: what aspects of the city need to be improved in order to ensure resilience, and have specific initiatives been (or will they be) successful in increasing the city's resilience?

There are many competing versions of the indicators, indexes, and frameworks that should be used to answer these questions. For Smit and Wandel (2006), for example, the adaptive capacity of a community "can be influenced by such factors as managerial ability, access to financial, technological and information resources, infrastructure, the institutional environment within which adaptations occur, political influence, kinship networks, etc." For Rosenzweig et al. (2015) variations in vulnerability are caused by "physical exposure, urban development processes, social characteristics, and access to power" while Cox and Hamlen (2015) separate resilience into different 'capitals': human capital, social capital, built capital, economic capital, natural capital, governance, and community preparedness.

Notwithstanding the merits of each of these conceptualizations, in order to be useful, these qualities of resilience need to be turned into something which can be measured. Consider the following examples:

- Percentage of critical facilities served by distributed energy or microgrids (Ribiero et al., 2015).
- Existence of recent, expert-reviewed estimates of probability of known hazards or perils and their extents, ranked out of 5 (UNISDR, 2015b).
- Percent of respondents who strongly agree or agree people in their neighborhood can be trusted (The Associated Press-NORC Centre for Public Affairs, 2012).

Qualitative/Subjective indicators

Not all indicators are based on objective and/or quantified data. Instead, some indicators of resilience are based on subjective data (i.e., relying on *subjects* [people] instead of *objects* [instruments]), often gathered using qualitative instruments (e.g., interviews, questionnaires, Delphi method, Q methodology). FSIN Resilience Measurement Technical Working Group (2014) points out that "the role played by subjective states in resilience, such as perceptions of shocks, perceived utility of actions taken or not taken, and general expectations of future states, should be included as key components of resilience measurement."

Reporting on work carried out by Oxfam, Fuller and Lain (2015) give the example of using 'anchoring vignettes' to get respondents to rate a hypothetical resilience scenario, which is then compared to respondents' rating of their own resilience. In doing so, researchers hope to calibrate the respondent, and give the assessor a sense of that calibration, thereby triangulating the subjective assessment, so to speak. Testing this approach represents an area of further work, some of which is being carried out by Oxfam.

Maxwell, Constas, Frankenberg, Klaus and Mock (2015) point out that qualitative data can provide information about social relations and power dynamics and that "this kind of information may be difficult to quantify, but it is crucial to understand." Similarly, Bours et al., (2014b) write that "complex socio-economic dynamics underlie adaptation effectiveness and are often either hard to quantify or the data is not available." Sovacool et al. (2015) warn against a "preponderance of quantitative perspectives, mapping a general tendency to propose technical solutions to social problems." That is, an aversion to qualitative and/or subjective indicators (on the part of funders, stakeholders, whomever), can obscure "key determinants of human equity and action" (Hicks et al., 2016). But Schipper and Langston (2015) add some perspective to this discussion, finding "that resilience cannot be measured only through indicators of improved livelihoods and well-being, but that it also

cannot be measured without such information."

Process Indicators

It is important to remember that in the same way that sustainability should be viewed as an emergent, context-specific process (Robinson & Cole, 2015), "resilience is a process, not simply an outcome (Cox & Hamlen, 2015). This has two important implications. First, resilience projects often operate over a very long time horizon, and second, processes should be measured alongside, or sometimes in lieu of, outcomes.

Burch et al. (2014) write that "monitoring of key indicators… requires an investment in the collection and analysis of data beyond that which might be present in a single electoral cycle of three or four years." But it is not only the lack of institutional resources that make this challenging, it is the fact that success cannot be determined until well in an ever-changing future. Bours et al. (2014a) write about "a dynamic process that cuts across scales and sectors of intervention, and extends long past any normal project cycle" and succinctly ask: "How then should we define, measure, and assess the achievements of an adaptation programme?"

One approach to this problem is to use process indicators instead of outcome indicators. Bours et al. (2014b) write that process indicators "measure progression towards the achievement of an outcome [e.g. resilience to drought], but do not guarantee or measure the final outcome itself" and are a "good fit for monitoring and evaluation of complex and large-scale endeavours." The use of process indicators has specific application the field of resilience evaluation, where it is difficult to measure resilience in an *a priori* manner, that is, before extreme events have occurred (Wilson, Gregorowski, & Standley, 2016; Bahadur et al., 2015). To this end, and in reference to Fuller and Lain (2015), Bahadur et al. (2016) write that "the measurement of drivers and characteristics allows us to measure resilience without relying on the occurrence of shocks and stresses." In other words, evaluations based on processes (i.e., drivers, characteristics) help subvert the 'a priori problem.'

Schipper and Langston (2015) offer the following example: "if we value learning as a driver of resilience, for example, we may want to measure processes of training, information sharing and awareness raising (what do people know, etc.)." Another example comes from Berkeley, California where one of six goals that came out of their participation in the 100 Resilient Cities initiative is to "advance racial equity" which will be achieved "when race can no longer be used to predict life outcomes" (City of Berkeley, 2016). Berkeley has identified processes (e.g., the creation of a "multi-departmental team of staff to oversee and implement the Berkeley Racial Equity Action Plan") that can be measured in advance of the outcome of racial equity.

Outcome Harvesting

Eyzaguirre (2015) sought to evaluate the influence of NRCan's Regional Adaptation Collaboratives (RAC) in terms of their immediate effect "in encouraging collaboration and adaptation decision-making" and in terms of their influence "beyond program timelines and scope." In order to do this, two sources of data were consulted: final reports from RAC participants, and interviews with key personnel that asked about the most exciting or successful thing that had happened in their jurisdiction as a result of the RAC program (Eyzaguirre, 2016). As such, the program employed a research method called outcome harvesting, which is "suited to examining program impact on issues defying traceability" (Eyzaguirre, 2015) and where "outcomes are defined as changes in the 'behaviour writ large' (such as actions, relationships, policies, practices) of one or more social actors influenced by an intervention" (Wilson-Grau, 2015). This method was used to demonstrate that processes (e.g., recruitment of local champions) had emerged which could reasonably be thought to engender successful adaptation efforts in the future (Eyzaguirre, 2015). Though quantified outcomes are prized (and even required) by decision-makers, it is often case that the existence of these processes are the only data that exist at certain points in the project (Eyzaguirre, 2016). As such, not only is 'measuring without indicators' essential, but so too is educating decision-makers on the merits of these types of approaches to program evaluation.

It is also important that measurement and evaluation be incorporated throughout the project, instead of just at the beginning and at the end, even borrowing practices from developmental evaluation where the evaluator is embedded within the process, instead of a third party to it (Eyzaguirre, 2016). Doing so could have

positive benefits for the program, the evaluation, and for the community. More participatory forms of program development and evaluation empower actors in remote communities, for example, by increasing "their capacity to engage with other state actors in conversations and decisions about disaster and resilience planning" (Cox & Hamlen, 2015). Incorporating these principles would hypothetically make the evaluation process more iterative, nimble, just, and effective, though future work is required to determine this precisely.

Other Measurement Challenges

CAP and ICLEI (2015) highlight a few other challenges that resilience evaluators face:

1. Uncertainty as to what to measure;
2. Measurement may involve a range of stakeholders;
3. M&E is not incorporated into project design;
4. Obtaining data may be expensive, complex, and difficult.

Evaluators should also strive for parsimony; in an effort to avoid the 'analysis paralysis trap' whereby mountains of data consume resources and prevent actionable outcomes. In reference to Spearman and McGray (2011), Schipper and Langston (2015) write that "it is more helpful to have approximate answers to a few important questions than to have exact answers to many unimportant questions."

Another problem is the issue of 'snapshots' versus measurements that are taken periodically. This is a problem that has long plagued scientists: what is the value in a one-time observation of a phenomenon, and if it is insufficient, how often should data be collected? Instead of simply revaluating indicators annually (a rule of thumb which could potentially waste resources) FSIN Resilience Measurement Technical Working Group (2014) advocates that measurement interval frequency should be "informed by knowledge of expected rates of change/growth associated with a particular unit or scale of measurement for resilience capacity."

An even bigger problem faced by those trying to demonstrate beneficial outcomes of resilience programs is the problem of attribution, which Bours et al. (2014a) sum up succinctly: "it can be almost impossible to untangle the range of interconnected factors that shape a long-term impact or outcome." Consider that within the city there are complex geographical scales operating (the neighbourhood, the watershed, the region), multiple initiatives operating, and multiple sectors at which success could be determined over multiple time-scales and parameters. Bours et al. (2014a) suggest that instead of trying to directly attribute a program to an end-state (e.g., resilience), it is usually better to situate progress made by the program within broader urban resilience and climate adaptation goals. This avoids the problem of attribution, and focuses attention on whether progress was actually made.

Some additional best practices that can help in addressing these issue include:

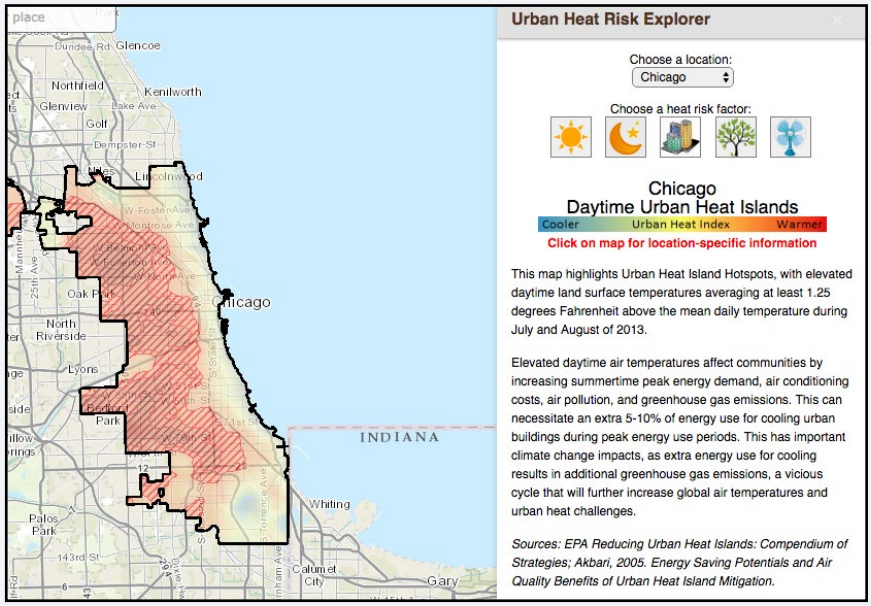
- ADAPT indicators (i.e., Adaptive, Dynamic, Active, Participatory, and Thorough) are more desirable for this kind of 'messy' work than SMART ones (i.e., Specific, Measureable, Achievable, Realistic, and Time-bound) (Bours et al., 2014b).
- Many systems use a 1-5 scoring systems for each indicator (e.g., ICLEI n.d.; IBM and AECOM, 2015). This is not the only way; Sovacool (2012) points out that indicators could "rely on a simple scoring technique of 'positive,' 'negative,' or 'neutral,' as in a given metric can worsen, improve, or stay the same over time" or that one could convert indicator values to "z-scores, the number of standard deviations from the mean to indicate if a given metric improves or worsens" as well as other scoring methods.
- Remember that "resilience is not uniformly distributed throughout a community; measures should be flexible, place-based, and context-specific; indicators may be more relevant than an aggregated index" (Cox & Hamlen, 2015).

4.6 Data sources

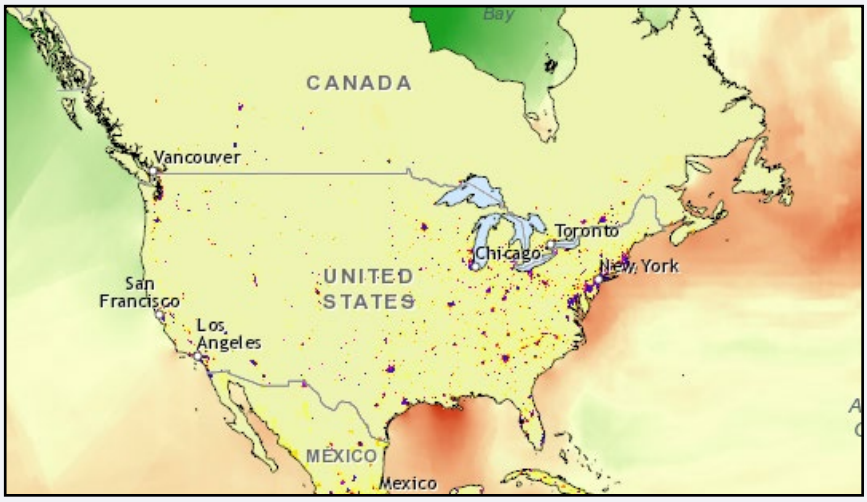
Da Silva and Morera (2014b) point out that "as resilience is a relatively new concept in its application to cities, this data may not commonly be found in all cities around the world." Bours et al. (2014b) highlight that thinking about data availability is a very important step in the design of a resilience or CCA program (see below for some sources of data). Much of this work requires the use of proxy indicators, which Bours et al. (2014a) define as "(more) easily-measureable 'stand-ins' for concepts or variables for which data is unavailable."

Figure 9: Examples of GIS tools that could be used in resilience assessments. UNISDR is beta testing a resilience mapping tool that should be available soon, see link.

The Trust for Public Land's Urban Heat Risk Explorer tool allows users to overlay various resilience paramaters for the built environment.
http://tplgis.org/UrbanHeatRiskApp/



CLIMsystems Sea Level Rise for Cities app provide seal level rise predictions by hovering a mouse over a set of coordinates.
http://slr-cities.climsystems.com/



Because resilience is such a hard concept to measure, and because data differs across cities, an element of creativity must be applied. For example, Shaker (2015) used the Human Wellbeing Index (HWI) and Ecosystem Wellbeing Index (EWI) to conduct a macroscale empirical study to further understand sustainable urban development across 33 European countries. Similarly, Shaker and Sirodoev (2016) created a "local sustainable development index using household and property composition indicators from a 2005 demographic and health survey for the Republic of Moldova" and used this index to track sustainability across 339 geographic regions (also see Malakara & Mishraa, 2016). Presumably the same could be done for resilience in many different settings. Not only does this work represent creative use of proxy indicators, it also demonstrates the utility of spatially representing data.

Beyond charts and tables (examples of which can be found in da Silva and Morera, 2014a, page 27), the use of GIS techniques can offer researchers innovative ways to collect, organize, and present their data. For example, Mastors (2015) points out that vibrant public spaces are an important element in creating resilient cities. Further work would involve using GIS to explore the frequency of these spaces across Canada and to build a picture of where planning attention is needed. See Figure 9 for examples of these tools.

Sources of data with which to populate resilience indicators and GIS tools include:

- Wellbeing Toronto
- WCCD Open Data Portal
- OECD.stat databases

- AdaptationCommunity.net Repository of Adaptation Indicators
- The Array of Things project
- Measure of America
- Canadian Extreme Water Level Adaptation Tool
- ICLEI (2015) Indicator Case Study
- Siemen's US and Canada Green City Index (private sector, no access)
- See Hicks et al. (2016) for a list of databases pertaining to social indicators

4.7 Mainstreaming Resilience

Despite a great deal of activity in the area of urban resilience assessment and planning, the extent to which action will be taken, and taken in a timely manner is yet to be seen. Burch and Robinson (2007) point out that achieving progress requires altering "potentially path-dependent systems of rules, institutional structures, and habitual practices, which may be the precursors of significant barriers to action" and that normative and motivational aspects of action need to be accounted for. As Eyzaguirre and Warren (2014) point out, "the will or desire to adapt is also necessary" and more importantly, that this "has received little attention so far in the literature on climate change and adaptation."

The concept of resilience could present a way forward. Bahadur et al. (2016) point out that "the resilience concept itself provides an important way of enabling synergy, with success seen at least in linking the SFDRR and the SDGs." Similar to regenerative sustainability (Robinson & Cole, 2015), resilience can be thought of as a set of procedures that can create their end-state in their very undertaking. That is, resilience is not a state that a city arrives at and occupies in perpetuity, but instead it is the act of discussing how best to achieve desirable future outcomes; the planning, the collaboration, the action, these continually create the conditions in which resilience emerges. Resilience shares another similarity with regenerative sustainability, in that resilience initiatives can encourage net-positive outcomes, for example, leaving communities healthier and happier than before resilience plans were put in place.

It is worth pointing out that just as catastrophic messaging inspires apathy (Gifford & Comeau, 2011), the term resilience leaves much to be desired, implying as it does a state of just-getting-by. The work that has coalesced around the concept of resilience is far better described by the term thriving, which many think would have been a better banner for this movement. Semantics aside, emphasizing the net-positive benefits of resilience programming could be an important lever in further entrenching resilience in mainstream practices. One possible way to do this is to situate the goals of resilience within the hierarchy of needs that a city fulfills. These needs proceed from 'Basic needs for survival -> Security -> Health -> Good social relations and esteem -> Freedom of choice and action' (da Silva, Kernaghan, & Luque, 2012; based on Maslow, 1971). After all, a resilient city is bound to a more just, happy, and secure city. Similarly, those involved in this work need to subvert apocalyptic versions of our future with evidence (which abounds, from Fort McMurray to New York City) of people coming together during disasters and challenges. Addressing these conceptual concerns could help to invigorate the *soul* of resilience in a proactive way, instead of reacting to "extreme weather events, as well as observing impacts of gradual changes (e.g. sea level rise)" (Warren & Lemmen, 2014b).

But not all mainstreaming efforts need to be this ethereal. Though the business case for resilience (often referred to as the 'resilience dividend') has been established (Rodin, 2015; Holly-Purcell, 2015), there are lingering questions about whether cities can engage in reliance planning without benefitting from either philanthropy (e.g., 100 Resilient Cities) or disaster relief funds. Similarly, further work is needed to understand the extent to which city bonds purchased by insurance companies to minimize their risk can be useful in producing the infrastructure improvements required to achieve resilience in cities; as is work that deals with cities' and citizens' over-reliance on insurance. Still other opportunities involve using non-traditional levers to trigger change, for example the resilience work done by Faith & The Common Good.

There seem to be competing messages about the future of our cities' resilience. On the one hand, Bahadur et al. (2016) write that there is broad consensus that the co-emergence of the SDGs, Sendai Framework, and Paris Agreement "present an unparalleled opportunity for integrated planning for a climate-resilient future." While on the other hand, Burch et al. (2014) write that "while climate change action plans are becoming more common, it is still unclear whether communities have

the capacity, tools, and targets in place to trigger the transformative levels of change required to build fundamentally low-carbon, resilient, healthy communities." Perhaps all that matters is to be reminded that "only real and lasting resilience—achieved by way of innovative, systems-deep approaches—will allow us to solve for multiple problems at once, both now and on into the future." (Rodin, 2015b).

Conclusion

At the outset of this project, the aim was to explore the various ways that climate change would impact Canada's prosperity. Though there will be many challenges ahead (as well as opportunities), the strength of the strategic resilience frameworks, specifically their theoretical underpinnings and overall design, presented here will help to ensure that Canadian cities will be in a position to prosper, despite changes to the global climate. Applying these frameworks to smaller cities and communities is somewhat of a concern. However, the good work being done by other researchers in this area (e.g., Fournier, Cox, Hamlen, others) assures that this too is receiving the attention it deserves.

Even without federal support, cities are poised to lead the way in ensuring their continued prosperity. Montreal, North Vancouver, Toronto, Guelph, Victoria, the list is long of cities who are actively pursuing climate mitigation and resilience. The list is also long of researchers working to ensure that no one is left behind in this process. This puts Canada in the fortunate position of being able to help those in other countries whose journey through the next century is far more challenging than our own. Thus pointing to another truly net-positive outcome of urban resilience.

5. Research Gaps

The following presented a bulleted list of research gaps, framed as research questions/projects, that were uncovered during the synthesis project.

- What strategies are thought to be, or have been proven to be effective in Canada and elsewhere at improving community resilience? On what spatial (e.g., neighbourhood, city, regional) and temporal (e.g., short term initiatives) scales do these initiatives operate?
- What overlaps and potential for synergies exist between city sustainability plans and resilience strategies, and between climate change adaptation and resilience?
- How do power relations affect how people benefit (or do not benefit) from resilience-building projects? (Bahadur et al., 2016)
- To what extent are the tenets and determinants of social capital included in emerging resilience standards (e.g., ISO, UN-Habitat)?
- Given its relative novelty, further work needs to explore the prevalence and relevance of the "Three A's" conceptual framework in facilitating urban resilience.
- Further work pertaining to electricity distribution includes increasing capacity during heat waves, and further exploring adaptation measures for climate events causing structural damage issues (e.g., freezing rain) (AECOM and RSI, 2015). There is also a future project that involves mapping the tree canopy in relation to sub-stations and distribution infrastructure to identify vulnerabilities with more granularity.
- AECOM and RSI (2015) identified five areas of activity for utilities to take to ensure their resilience; these are: planning, infrastructure (e.g., redundancy, hardening infrastructure), operational (e.g., smart meters, advanced analytics), organizational (e.g., response time), and communications. Further work should examine the extent to which these are being undertaken, and the effect that actions have had.
- What affect has the Cambell Soup's combined heat and power system had on resilience at the building and the neighbourhood levels?
- Work which explores ACEEE's claim that "most resilience efforts also do not recognize the value of energy efficiency fully, if at all" and that strives to answer ACEEE's call for "technical assistance on methods to incorporate efficiency into communities' planning processes" (Ribeiro et al., 2015).
- Assessing and mapping thermal resilience across Toronto to identify buildings which are particularly vulnerable. And, what effect do densification policies have on resilience issues like urban heat island effect, stormwater management, and thermal resilience?
- According to Bistrow (2013), Toronto has 6 days of transportation fuel, 20 days of food, and 49 days' worth of biomass for home heating. More of this type of work is needed in cities to inform the public about the degree to which they are vulnerable.
- What were the outcomes of the Resilience Measurement Community of Practice, and how do they correspond to what was discussed in this synthesis report?

6. Additional Resources

The following are resources which warrant specific mention, and should be considered valuable investments of time for our knowledge users.

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Appendix

Appendix A: List of acronyms

ACEEE	American Council for an Energy-Efficient Economy
BARC	Building Adaptive & Resilient Communities
BOMA	Building Owners and Managers Association
C40	Cities Climate Leadership Group
CCA	Climate Change Adaptation
CRCI	Centre for Resilience of Critical Infrastructure
CRI	City Resilience Index
CRPP	City Resilience Profiling Programme
EPI	Environmental Performance Index
EWI	Ecosystem Wellbeing Index
FSIN	Food Security Information Network
GHG	Greenhouse Gas
HWI	Human Wellbeing Index
IBC	Insurance Bureau of Canada
ICCATF	Interagency Climate Change Adaptation Task Force
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
ISO 37120	Sustainable development of communities. Indicators for city services and quality of life
LGSAT	Local Government Self-Assessment Tool
ND-GAIN	University of Notre Dame Global Adaptation Index
NGO	Non-governmental organization
NORC	University of Chicago
NRCan	National Resources Canada
PIEVC	Public Infrastructure Engineering Vulnerability Committee
RSI	Risk Sciences International
SDGs	Sustainable Development Goals
SFDRR	Sendai Framework for Disaster Risk Reduction
UBC	University of British Columbia
UN-Habitat	United Nations Human Settlement Program
UNISDR	United Nations International Strategy for Disaster Reduction
U of T	University of Toronto
WCCD	World Council on City Data

Appendix B: Links to additional resilience frameworks

UN-Habitat's City Resilience Profiling Programme (CRPP)

Community Resilience System

Municipal Risk Assessment Tool

Resilience Capacity Index

Resilience Supply chain index

The Rural Disaster Resilience Index

IEST. (n.d.). Climate resilience framework

Rockefeller Foundation's Asian Cities Climate Change Resilience (ACCCRN)

Assessments of Impacts and Adaptations of Climate Change (AIACC) Sustainable livelihood approach

Action Research for Community Based Adaptation (ARCAB)

UK Department for International Development Building Resilience and Adaptation to Climate Extremes and Disasters framework (BRACED)

UNDP Community-Based Resilience Analysis (CoBRA) Framework

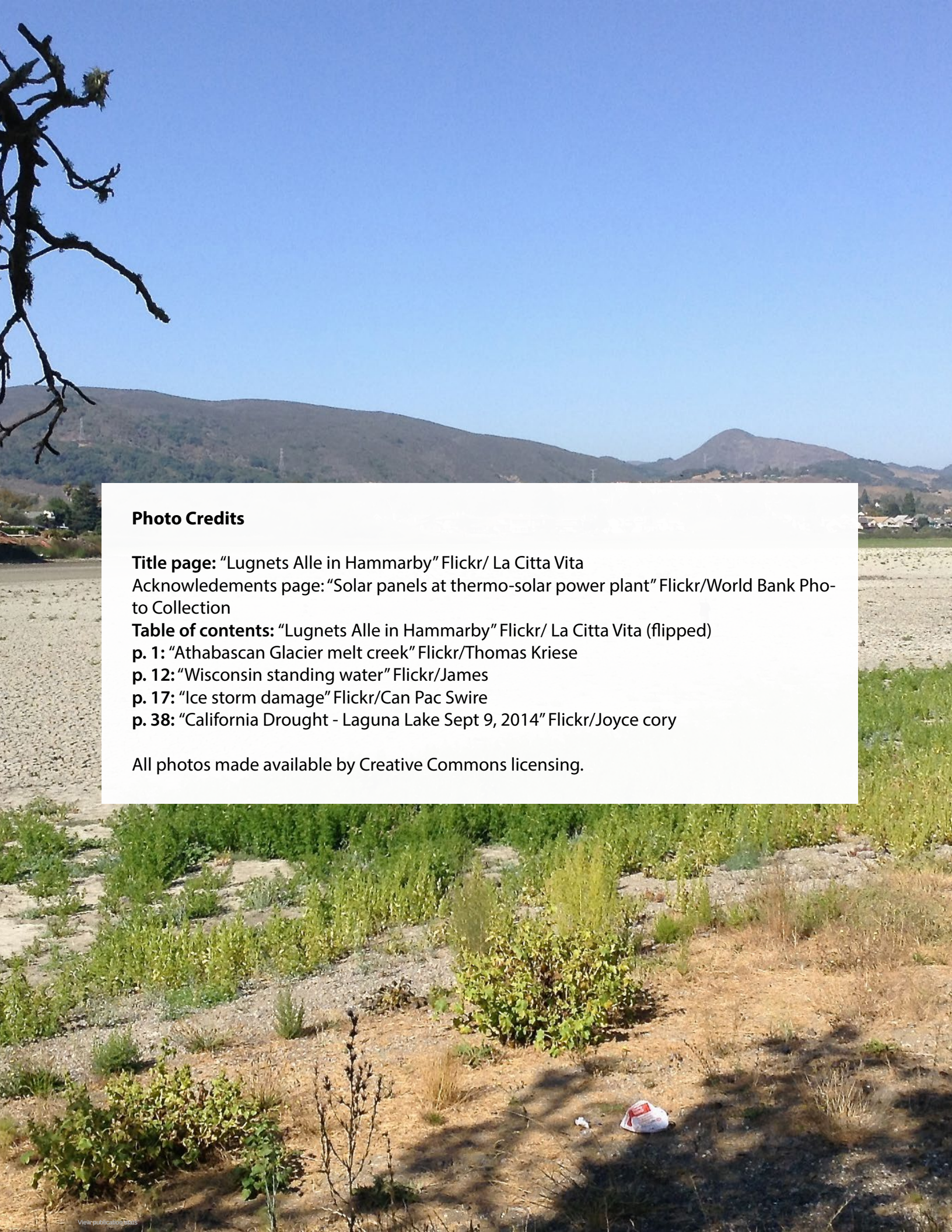
Constas and Barrett's Principles of Resilience Measurement for Food Insecurity

Feinstein International Center's Livelihood and Resilience Framework (Feinstein)

International Institute for Sustainable Development's Climate Resilience and Food Security (IISD)

UN Food and Agriculture Organisation's (FAO) Self-evaluation and Holistic Assessment of Climate Resilience of farmers and pastoralists framework (SHARP)

International Institute for Environment and Development's Tracking Adaptation and Monitoring Development (TAMD)



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