Prairie Climate Centre

Building a Climate-Resilient City:
Transportation infrastructure

KEY MESSAGES:

- Urban transportation infrastructure (roads, bridges, railways and runways) is heavily exposed to climate impacts such as rising temperatures and more frequent and intense rainfall.
- Sustainable transportation systems are physically resilient to climate impacts, provide options in case one mode is disrupted by a climate shock and reduce greenhouse gas emissions.
- Urban densification reduces the amount of transportation infrastructure exposed to climate impacts and allows re-deployment of resources to strengthen existing infrastructure.
- Complete communities where residents can easily access goods and services by foot or bicycle improve urban climate resilience.

In recent decades, Alberta has experienced significant changes in its climate as well as its economy, population and environment. The province's mean annual temperatures are increasing and projected to continue to rise in the coming decades—potentially by 2.0°C by the 2030s and 4.0°C by the 2060s (compared to the 1990s)—should the current rate of global greenhouse gas emissions remain unchanged. Total average annual precipitation is also projected to increase, but this change will vary between seasons; precipitation levels are likely to increase more in the winter and decline in the summer.[1] While these shifts in average climate conditions are significant, the more profound risk of climate change lies in the expected increase in climate variability and extreme weather events such as longer heat waves and more frequent heavy rainstorms. Should global greenhouse gas emission rates decline, the change in Alberta's climate will be less severe but still significant.

Of concern for urban transportation infrastructure are climate projections indicating a future in which there is a higher frequency of extreme events such as floods, storms and long-duration heat waves, overlain on gradual changes such as rising temperatures. Both Calgary and Edmonton are river cities that can receive large quantities of precipitation in short periods of time. Increased precipitation can cause flooding on streets and rail lines, which impedes the flow of traffic and can erode soils and weaken asphalt. Depending on the severity of the flooding, bridges can also be washed out and airports shut down. Extreme weather events such as hailstorms, gusting winds and tornadoes also can damage existing physical infrastructure and incapacitate systems controlling traffic flows across the city.

Increasing temperatures can soften asphalt, creating ruts and potholes, and place stress on railway and bridge joints. Heavy traffic flows will speed up this process, creating a greater financial burden on cities to maintain and improve infrastructure. Airports will be similarly affected as runways demand more maintenance and resurfacing to ensure safe take-offs and landings. Hotter temperatures may also alter individuals' transportation choices, encouraging them to walk or bicycle more frequently and to extend those choices into colder months.

Given the expected impacts of climate change, there is a need to build the resilience of cities so that they can better withstand anticipated and unanticipated shocks and stresses. A resilient city is one in which its institutions, communities, businesses and individuals are able to "survive, adapt and grow" in response to any kind of sudden short- or long-term disruption that they may experience. Such cities integrate the qualities of flexibility, redundancy, robustness, resourcefulness, reflectiveness, inclusiveness and integration into all aspects of city functions (see Box 1). These qualities of resilience are considered to be essential to preventing the breakdown or failure of a system and to enable it to take action in a timely manner.[2]

This paper examines ways of building resilient urban transportation infrastructure to reduce exposure to natural hazards, decrease potential risks by implementing mitigation measures and enhance adaptive capacity in a changing climate. It is one of a series of papers prepared by the Prairie Climate Centre to provide the public and government officials with an overview of the means by which to build cities that are resilient to the impacts of climate change, drawing on lived experience and best practices.

Envisioning Climate-Resilient Transportation Infrastructure

Transportation infrastructure is paramount to the prosperity of all cities and greatly affects quality of life by influencing peoples' decisions about where to live, work and spend their free time.[4] A resilient transportation system allows people to move into, out of and around their city despite climate shocks and stresses that degrade and damage infrastructure and lead to service disruptions. Greater resilience can be achieved by implementing planning and land-use policies that focus on building resilient design into existing and new infrastructure, promoting compact urban forms and encouraging the use of a variety of modes of transportation. Such policies can provide safe driving conditions and alternative routes to reach essential services in case of extreme weather events. They also can reduce overall expenditures on transportation infrastructure by limiting the total number of roads, bridges, culverts, etc. that need to be maintained and repaired due to damage caused by climate events.

There are a variety of ways in which a more resilient transportation system can be built, some of which are illustrated through interventions that enhance its qualities of robustness, redundancy and resourcefulness.

BOX 1. QUALITIES OF A RESILIENT CITY[3]

Reflective: People and institutions reflect and learn from past experiences and leverage this learning to inform future decision making.

Robustness: Urban physical assets are designed, constructed and maintained in anticipation of high-impact climate events.

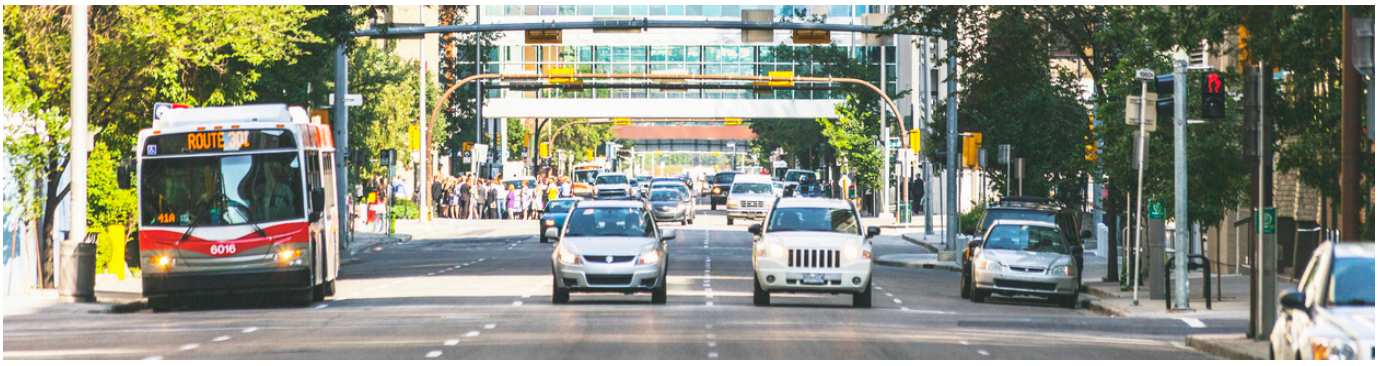
Redundancy: Spare capacity is built into the system to account for disruptions and surges in demand. It also involves multiple ways of fulfilling a need or function.

Flexible: Refers to the willingness and ability to adopt alternative strategies in response to changing circumstances or sudden crises. This can be achieved through new knowledge and technologies.

Resourcefulness: Citizens and institutions are aware of climate risks, able to adapt to shocks and stresses and can quickly respond to a changing environment.

Inclusive: Inclusive processes emphasize the need for broad consultation and many views to create a sense of shared ownership or a joint vision to build city resilience.

Integrated: Integrated processes bring together and align city systems to promote consistency in decision making and investments. Exchange of information between components of the system enables them to function collectively and respond rapidly.



BOX 2. CASE STUDY: FORECASTING PEAK WATER DISCHARGE FLOWS ON MAJOR HIGHWAYS IN IOWA[5]

In Iowa, the Department of Transportation (DOT), the Iowa State University and the University of Iowa Flood Center used historical rainfall data to forecast peak discharge flows from two local basins that had recently experienced severe flooding events that have affected primary highways and the Interstate. Using climate forecasting and streamflow modelling, researchers were able to estimate future flooding in the region. Forecasts were then compared to the DOT asset inventory, and an analysis was done of all of the transportation infrastructure. This allowed the DOT to identify at-risk roads, bridges and other infrastructure and to include design elements that help to reduce their vulnerability to flooding in the future.

Building Robustness

Assessment tools like the Public Infrastructure Engineering Vulnerability Committee (PIEVC)[6] Engineering Protocol developed by Engineers Canada provide an essential means by which to build robustness into transportation infrastructure. These tools can help identify existing vulnerabilities to extreme weather events and longer-term climatic changes so that design improvements which increase robustness and redundancies can be built into the system to account for future climate impacts. Doing so will facilitate the development of more resilient infrastructure that ensures increased safety and reduced maintenance and repair costs in the long run. The City of Edmonton has taken steps toward this objective, having applied the PIEVC protocol in 2007 to assess its Quesnell Bridge, roads and associated structures.[7]

Integrating information from climate projections into land-use planning and the design of the transportation system can also help engineers and planners to build robustness. For example, climate and hydrologic modelling can be used to identify areas at greater risk of flooding in the future. The U.S. Department of Transportation's Federal Highway Administration has used this technique in several areas across the country (see Box 2).[8] By developing potential flooding scenarios, officials are able to safeguard key transportation routes against climate impacts and focus on improving critical route infrastructure.

Climate change projections can also be incorporated into decisions regarding the rebuilding of infrastructure damaged by weather-related events, such as floods and heat. These projections may suggest that similar, or more extreme, events might occur more frequently in the future. Following "building back better" principles, transportation planners may determine that it will be more cost-effective in the long term to rebuild to a standard above the pre-disaster level.

Promoting compact urban form and limiting urban sprawl can also contribute to enhancing urban resilience by reducing the need to move goods, services and people across vast areas. Creating self-sufficient, walkable neighbourhoods with mixed-use buildings reduces the extent of transportation infrastructure that may be exposed to climatic extremes and require ongoing maintenance and repair. It can also reduce the need to traverse long distances to access goods and services (e.g., grocery stores, health clinics and schools) should there be a disruption in the transportation system.

The robustness of urban transportation systems can also be enhanced through increased use of multifunctional green infrastructure. Green infrastructure-led design can provide significant opportunities for cities to influence the structure

and design of transportation networks. For instance, large trees create substantial street features while generating effective shading, reducing pavement temperatures while also creating a better microclimate for city residents on hot summer days. Similarly, constructed wetlands and permeable surfaces demonstrate how natural drainage can be integrated into urban landscapes and street design. This type of green infrastructure can effectively reduce the occurrence and risk of flooding from more intense rainfall and stormwater runoff.

Promoting Redundancy

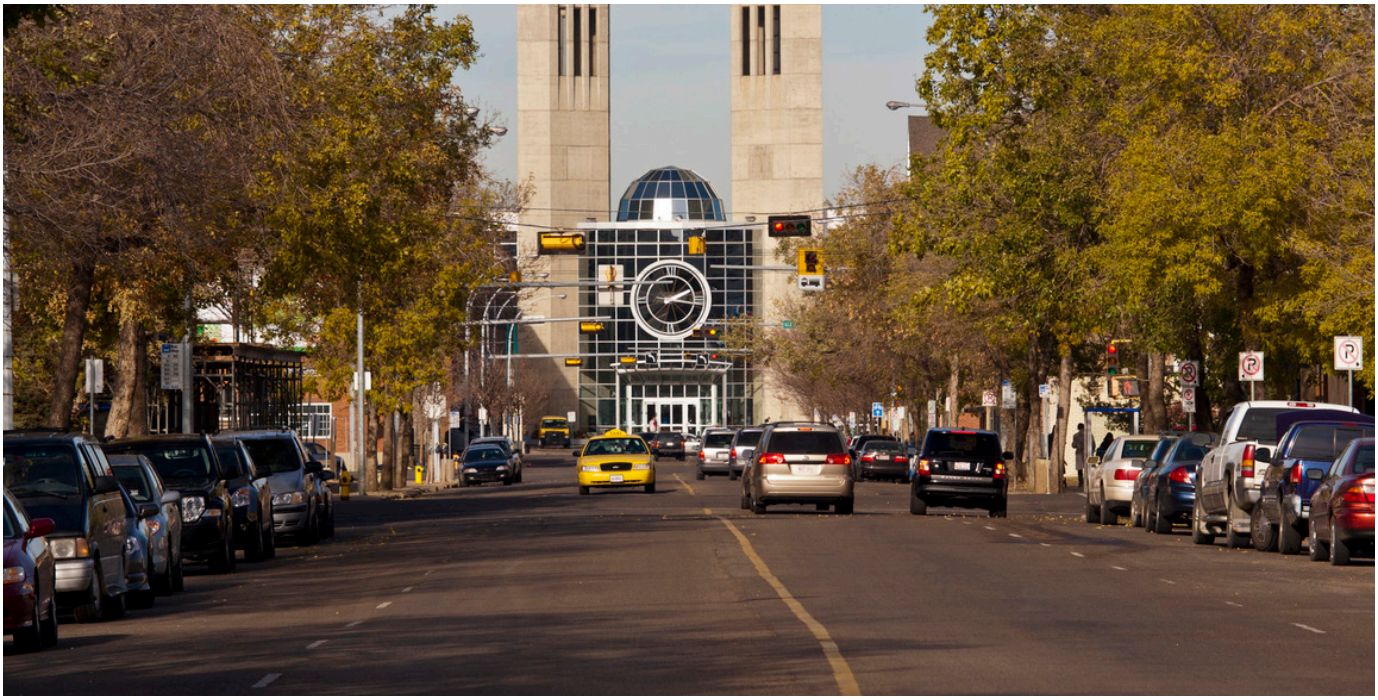
Greater redundancy in the transportation system can be achieved by diversifying transportation modes, corridors and infrastructure systems both within and between cities. Providing reliable alternatives to private vehicles reduces pressure on road infrastructure, particularly when primary routes are damaged by weather events, and aids in keeping citizens mobile if one mode is malfunctioning or damaged. By creating more seamless connections between various modes of transportation (e.g., bike routes, walking paths, bus routes), citizen have greater choice in terms of the means by which they can move around the city in support of employment and access to goods and services. Such connections can be made by: increasing the number of bicycle racks and spaces on bus and train infrastructure, especially for routes to outlying areas; connecting bicycle and walking trails close to main transit routes; and providing safe, affordable and convenient areas to secure bicycles and park automobiles that connect with frequently running bus routes. Expanding public and active transit can also provide co-benefits in terms of helping to reduce greenhouse gas emissions and infrastructure maintenance costs.

The expansion of transportation modes can be supported by establishing protocols that increase the walkability of all new developments, which helps to improve urban resilience over time without incurring large upfront costs. The Walk Score criteria used to evaluate neighbourhood

accessibility is one way of assessing the walkability of a community.[9] Walk Scores are calculated based on the quality of physical infrastructure used for moving from place to place as well as the distance individuals live from essential goods and services.

Cities can also improve ease of use of all modes of transportation throughout a transportation network by encouraging the “complete street” concept. Tools such as Edmonton’s and Calgary’s Complete Street guidelines and policies[10,11] can help to guide these processes.

Improving rail systems provides an alternative method for moving people and goods within and between cities. High-speed rail service between cities is one option. In 2008, Alberta Transportation undertook an Economic Benefits and Market Assessment of the feasibility of such a service between Calgary and Edmonton, which resulted in favourable projections. Expansion of Calgary’s and Edmonton’s existing intercity train systems to underserviced neighbourhoods can help to increase public transit options and ease of movement around the city.



Diversifying fuel sources can increase redundancy, and therefore the resilience of a city. The current gasoline-based system is vulnerable to surges in demand and complications related to the need to maintain a constant supply, especially in anticipation of and during extreme weather events. Increasing gasoline storage is one means of addressing this issue, but can be expensive. Building spare capacity into the fuel system therefore might also require diversifying energy sources as part of a wider effort to transition to hybrid and electric vehicles. One of the primary barriers to initiating the electric vehicle revolution is the lack of charging infrastructure. Installing adequate and reliable infrastructure for charging electric vehicles would reduce reliance on a single fuel source to power vehicles.

Encouraging Resourcefulness

Resourcefulness within the transportation system focuses on encouraging individuals to explore alternative means by which to move around the city. Engaging citizens in efforts to improve public and active transportation modes is one means by which to ensure that these systems reflect people's concerns and desires—thereby increasing the likelihood that they will be used as part of people's daily routine or as an alternative if their usual transportation mode is disrupted.

Mobile apps can be used to engage citizens in decisions regarding, for example, how transit routes are determined. By tracking their lived experience with public and active transportation infrastructure, mobile apps and Global Positioning System (GPS) technology can be used to provide accurate and realistic data to traffic planners that can be used to inform cycling and walking routes. Better decisions can be made regarding where bike routes should be located, where safety and theft is of most concern, and if there are unofficial paths that could be integrated into the system and maintained. GPS systems can be combined with commuters' ability to send in notifications to identify potholes and suggest areas where infrastructure can be improved to accommodate active transit users.

Car and bicycle share and cooperative programs can also bring an element of resourcefulness and redundancy to the transportation system. There are several models that can be implemented. Some car cooperative models, such as Winnipeg's

"Peer-to-Peer" Peg City Car Co-op,[12] have a fleet of cars with specific parking spots around the city. In models such as car2go[13] in Calgary and Vancouver and Pogo in Edmonton, there are no designated parking spots. Instead, a mobile app is used to locate and reserve cars nearby. Bicycle share programs such as Bixi bikes in Montreal[14] and Toronto[15] are convenient and provide an incentive to use bicycles for daily commuting. When these programs run in tandem with the existing public transit system, people have the added flexibility and ease to get around without the need to purchase a vehicle. Rideshare systems can be supported by cities in a variety of ways: through incentives such as reduced fare parking spaces and universal parking permits, carpool lanes and, most importantly, infrastructure to facilitate using alternative transportation modes.[16]

Recommendations

The cities of Calgary and Edmonton could consider the following options when identifying ways to increase the climate resilience of their transportation infrastructure:

Strategic

- Undertake a full vulnerability and risk assessment of the city's transportation infrastructure to identify infrastructure components that are highly vulnerable to climate change impacts and extreme weather events. This full understanding of the scope of associated costs can be used to prioritize investments for the development of cost-effective engineering and maintenance solutions to expand the lifespan of the infrastructure asset if necessary. It also highlights the full implications of short-term maintenance costs versus the need to hasten reinvestment given the new climate reality.
- Commit to further development of integrated multi-modal transportation networks that provide alternative means by which to travel throughout the city.
- Consider public-private partnerships to establish electric-vehicle charging stations across the city.
- Strengthen communications with the public regarding the potential negative impacts of climate change on existing urban transportation systems and the resilience and long-term cost benefits of promoting compact cities and greater use of public and active transit options.

Regulatory/Administrative

- Consider using the PIEVC protocol (or similar assessment tools) and incorporating "build back better" requirements in the procurement of all infrastructure retrofits and new nodes (bridges and intersections) to enhance resilience against climate shocks and stresses.

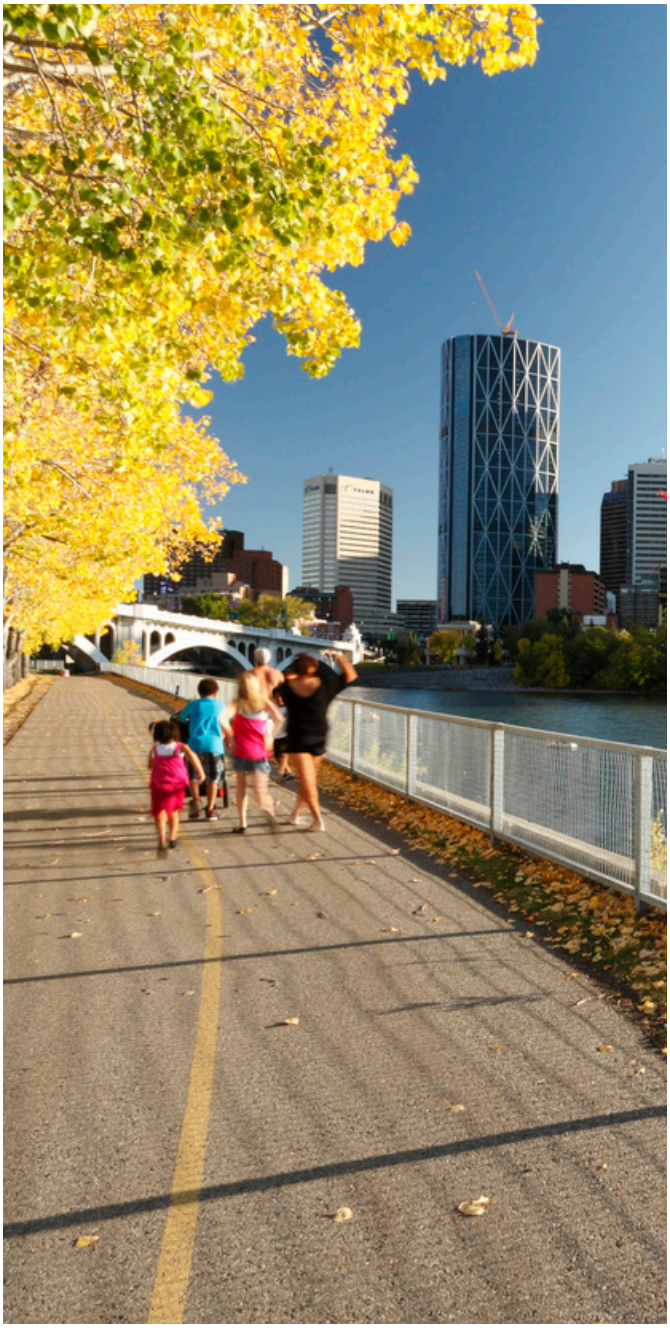
- Continue to promote sustainable urban planning processes, such as complete street design and the use of green infrastructure components, to reduce the impact of increased heat and precipitation due to climate change.
- Optimize inter-modal bike-bus-walking routes by requiring new developments to consult with the municipal Department of Transportation so that: existing public and active transportation infrastructure can be properly linked to new areas; safety precautions are taken into consideration; and existing municipal policies and guidelines are being implemented during the design process.

Economic Instruments

- Provide economic incentives to encourage shared and collective transportation models, such as parking rebates for car cooperatives and registered car share programs, and the use of public and active transportation through mechanisms such as equipment rebates.
- Consider financing mechanisms such as taxes, levies, tolls, fees and green bonds to finance climate-resilient transportation infrastructure. For example, the City of Toronto financed its Eglinton Crosstown Light Rail Transit through Ontario's first-ever green bond issue.[17]

Voluntary/Community Linkages

- Overcome barriers to effective implementation of new transportation modes as well as changes to existing infrastructure through interactive and participatory processes, so that intentions to achieve sustainable, climate-resilient transportation systems coincide with the outcomes of policy interventions.
- Collaborate with local public health services to help educate the public about the benefits of active transportation, provide training and awareness about safe and accessible routes, and encourage people to walk and bike to work and school.



References

[1] Projections based on data generated by the Pacific Climate Impacts Consortium. The average of 12 models over a 30-year time period were used for the time frames of 2021 to 2050 (the 2030s) and 2051 to 2080 (the 2060s) against a baseline of 1981 to 2010 (the 1990s) using a business-as-usual greenhouse gas emissions scenario (Representative Concentration Pathway 8.5). Further information is available through climate profiles created by the Prairie Climate Centre for Calgary and Edmonton.

[2] Rockefeller Foundation. (2015). *City Resilience Framework*. Arup International Development. Retrieved from https://assets.rockefellerfoundation.org/app/uploads/20140410162455/City-Resilience-Framework-2015.pdf

[3] Ibid.

[4] Canadian Urban Transit Association. (n.d.). *Transit Vision 2040*. Retrieved from http://cutaactu.ca/sites/default/files/cutabook_complete_lowres.pdf

[5] Department of Transportation. (2016). *FHWA Climate Resilience Pilot Program: Iowa Department of Transportation*. Retrieved from https://www.fhwa.dot.gov/environment/sustainability/resilience/pilots/2013-2015_pilots/iowa/index.cfm

[6] Engineers Canada. (2016). *PIEVC Engineering Protocol*. Retrieved from https://www.pievc.ca/protocol

[7] Engineers Canada. (2008). *City of Edmonton assessment for the Quesnell Bridge*. Retrieved from https://www.pievc.ca/node/78

[8] U.S. Department of Transportation. (2016). Building climate resilient transportation. Retrieved from http://www.fhwa.dot.gov/environment/climate_change/adaptation/publications/bcrt_brochure.cfm

[9] Walk Score. (2016). Walk Score methodology. Retrieved from https://www.walkscore.com/methodology.shtml

[10] City of Edmonton. (2016). Complete Streets guidelines for Edmonton. Retrieved from https://www.edmonton.ca/city_government/city_vision_and_strategic_plan/complete-streets.aspx

[11] City of Calgary. (2014). *Complete Streets policy and guide*. Retrieved from http://www.calgary.ca/Transportation/TP/Pages/Planning/Calgary-Transportation-Plan/Complete-Streets.aspx

[12] Peg City Car Co-op. (2016). Home. Retrieved from https://pegcitycarcoop.ca/

[13] Car2Go. (2016). Hello, Vancouver. Retrieved from https://www.car2go.com/CA/en/vancouver/

[14] Bixi Bikes Montreal. (2016). How it works. Retrieved from http://montreal.bixi.com/en/how-it-works

[15] Bixi Bikes Toronto. (2016). Bike Share Toronto. Retrieved from: https://www.bikesharetoronto.com/

[16] Gorenflo, N. & Eskandari-Qajar, Y. (2013). *Shareable cities policy primer*. Retrieved from https://drive.google.com/file/d/0B7QZ6oJxCT4kRDRIZ1pTaG1fOXc/view

[17] Pett, D. (2015, January 30). Toronto transit project puts Canadian green bonds on track. *Financial Post*. Retrieved from http://business.financialpost.com/news/toronto-transit-project-puts-canadian-green-bonds-on-track

In parternership with:

Prairie Climate Centre
From Risk to Resilience

The Prairie Climate Centre is a collaboration of the University of Winnipeg and the International Institute for Sustainable Development established to advance practical climate change solutions for the Canadian Prairies. The centre's mandate is to translate climate science into knowledge products, frameworks and decision-making tools that will help local governments, the private sector, civil society organizations and other practitioners implement adaptation measures.

For more information visit: http://prairieclimatecentre.ca/

Authors: Jennifer Temmer and Hank Venema, International Institute for Sustainable Development