Prairie
Climate Centre

Building a Climate-Resilient City:

Electricity and information and communication technology infrastructure

KEY MESSAGES:

- A warming and more variable climate stresses the electricity grid by increasing cooling demand requirements and by its exposure to climate shocks such as ice storms, droughts and tornados.
- Conventional infrastructure design standards need to be strengthened to account for climate change impacts; the PIEVC protocol is a proven Canadian methodology.
- Renewable energy generation and storage technologies are modular and distributed, and provide resilience to climate shocks.
- ICT is naturally decentralized and modular, and has high climate resilience. Redundant landlines, Internet service provider diversity, emergency roaming and cell phone micro-charging backup systems will increase ICT climate resilience.

In recent decades, Alberta has experienced significant changes in its climate as well as its economy, population and environment. Alberta'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.

The impacts of climate change most relevant to urban energy[2] and information and communication technology (ICT) infrastructure are the projected higher frequency of extreme events such as floods, storms, forest fires and drought episodes. This vulnerability can be addressed through resilience principles. Energy, more so than information infrastructure, will also be affected by secular climate trends, such as long-term shifts in the water resources available for hydropower generation and thermal power plant cooling as well as overall warmer temperatures that will increase air conditioning loads. While historically winter has been the season with the highest overall energy demand for cold climate cities like Calgary and Edmonton, these climate changes are likely to result in a shift in the overall energy load profile to a summer peak.

The ICT sector possesses a naturally higher degree of adaptability; it is dominated by relatively smaller infrastructure components with shorter lifetimes, higher frequency capital stock turnover and naturally redundant network architectures. A secular climate trend that will encourage resilient energy infrastructure is the continued policy commitment to low-carbon renewable energy generation technologies and distributed energy storage with similar attributes to ICT infrastructure (modular small-scale solar panels, windmills and residential batteries, for example). The Alberta government's commitment to phase coal out of the power generation mix by 2030 is one such policy example.

In response, there is a need to build the resilience of cities so that they are better able to withstand anticipated and unanticipated shocks and stresses. A resilient city is one in which its institutions, communities, businesses and individuals have the capacity to function and 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 prevent the breakdown or failure of a system and to enable it to take action in a timely manner.[3]

BOX 1. QUALITIES OF A RESILIENT CITY[4]

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.

This paper examines ways to build resilience in energy and ICT infrastructure as a contribution to building urban resilience to climate change. The purpose of this work is to demonstrate connections between energy and ICT and other city infrastructure, showcase best practices for improving resilience within these sectors and provide recommendations for action to integrate qualities of resilience into this system. 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 a Climate-Resilient Energy and ICT Infrastructure

Foundational infrastructure such as energy and ICTs are crucial for the functioning of both daily and vital services to communities; therefore, it is essential that energy and ICT infrastructure be protected against failure and maintained despite climatic disruptions. Building more robust networks, integrating redundancies and encouraging resourcefulness in these sectors can assist in reducing the myriad of impacts incurred when these systems are offline. There are many ways of building resilient cities, some of which are illustrated through interventions that enhance the qualities of robustness, redundancy and resourcefulness.

Building Robustness

Increasing the robustness of energy and ICT infrastructure generally means strengthening and hardening the design of conventional infrastructure components with respect to key climate vulnerabilities. An important Canadian example of leadership on the necessary design protocols is the Public Infrastructure Engineering Vulnerability Committee (PIEVC)[5] protocol advocated by Engineers Canada, the national umbrella organization of engineering profession regulators.

Subjecting energy infrastructure design to the PIEVC protocol may reveal, for example, that projected ice-load and wind-load conditions exceed design limits for conventional residential electricity distribution and that the distribution system should be buried underground. Hydro Québec reports that 11 per cent of their

distribution system is now underground. This figure is also increasing nationwide as the logic of a robust design to manage climate risk overcomes the deterrent of higher up-front costs to bury cables. Hydro-Québec's direction is in part a lesson learned from the catastrophic ice storm of 1998 that cut off electricity for nearly 1.4 million customers in Quebec and over 230,000 in eastern Ontario, ultimately costing CAD 5.4 billion.[7]

Another important example of robust climate design in the power sector comes from thermal power plant cooling in the context of a warmer climate. Thermal power plants normally use a surface water source for cooling, the availability and temperature of which are less certain in the context of climate change. Utilities such as Electricite de France and Eskom (South Africa) are now using dry (air) cooling technologies and combination wet-dry cooling technologies with weather forecasting systems to avoid expensive shutdowns.[8] In Calgary, the ENMAX Shepard Energy Centre uses wastewater effluent from Bonnybrook Wastewater treatment plant to generate electricity for the provincial grid.[9] Robust cooling system design is more expensive and reduces plant efficiency. However, these utilities take the enterprise risk management perspective that system reliability overrides capital cost concerns, as the economic and social consequences of forced outages can be catastrophic to the utility and the community it serves.

The inherent contradiction between deliberately designing less efficient thermal (fossil-fuelled) power plants and climate preparedness motivates increased investments in decentralized renewable energy generation, which has zero-carbon emissions and provides redundancy, a point we will pick up in the next section.

Climate-robust design in the ICT sector follows similar principles; cell towers and server farms are the infrastructure components typically most exposed to extreme climate shocks and most critical in emergency situations.[10] A PIEVC-type design process can reveal the critical design criteria to increase robustness, such as hardening cell towers to tolerate higher wind and ice loads, utilizing geothermal cooling for server farms for enduring long heat waves and locating server farms on mid-floors in office towers to minimize flood risks. An often overlooked urban planning principle is that critical ICT infrastructure must be flood-protected, for example, a 911 call centre must be located on high ground in a flood-prone city.

Promoting Redundancy

The principle of redundancy in the energy sector is best understood as the capability of grid subsystems to generate, distribute and, in the future, store energy in the event that other parts of the grid are disrupted from a major climate shock. Modern residential and community-scale decentralized renewable energy technologies (RETs) can provide a level of system redundancy that was inconceivable a generation ago but is now implemented in cities around the world. The redundancy available through modern RETs and distributed storage is, in a sense, a throwback to the early days of rural electrification, when communities were first electrified as independent mini-grids.[11]

Smart grid technology—smart meters, smart appliances, renewable energy generation, automatic power production, power conditioning and distribution control—is central to energy system resilience. First generation smart grid investments proved their worth in the recovery from Hurricane Irene (2011) and Hurricane Sandy (2012), as smart meters helped utilities pinpoint outage locations and optimize recovery efforts, benefitting hundreds of thousands of customers.[12] While it would require modification to the current Alberta building codes, second generation smart grid technology such as the Tesla Power Wall-Solar Roof product fully operationalizes the concept of deep decentralization, with individual households able to remain independently powered or daisy-chained to similarly equipped households in the event of grid failure.

Similar principles apply for ICT—redundancy means access to diverse communication channels in the event main channels are disrupted. The rise of independent Internet Service Providers (ISPs) allowing diverse access points to the Internet backbone and providing diverse wifi hotspots adds redundancy. A city served by a single or few ISPs is less resilient than a city with many high-bandwidth data and voice service providers. Mesh networking cellular apps such as MeshMe and Serval can also be particularly useful for emergency use. These apps allow users to communicate via text as long as wifi or Bluetooth are activated.[13] Legacy landline services also provide additional redundancy in the event that wireless services are disrupted, as they use an independent backup power supply.[14]

BOX 2. CASE STUDY: THE PECAN STREET PROJECT, AUSTIN TEXAS[15]

The Pecan Street Project (PSP) is a public-private partnership with the "very modest goals of reinventing the energy system of the United States."[16] PSP is a non-profit organization dedicated to testing and scaling up leading-edge smart grid technological and commercial concepts.

The project is a technology test-bed. It occupies 700 acres in suburban Austin and comprises 1,000 networked residences and 75 businesses. Members of the project board include the University of Texas, the U.S., Department of Energy, the City of Austin, Austin Energy (the local utility), the Chamber of Commerce, the Environmental Defense Fund, and the Austin Technology Incubator. Project partners include the IT sector, as well as consumer electronics and appliance makers. An important feature of PSP is their integrated smart metering for both energy and water systems to address key interactions such as the energy required to heat water.

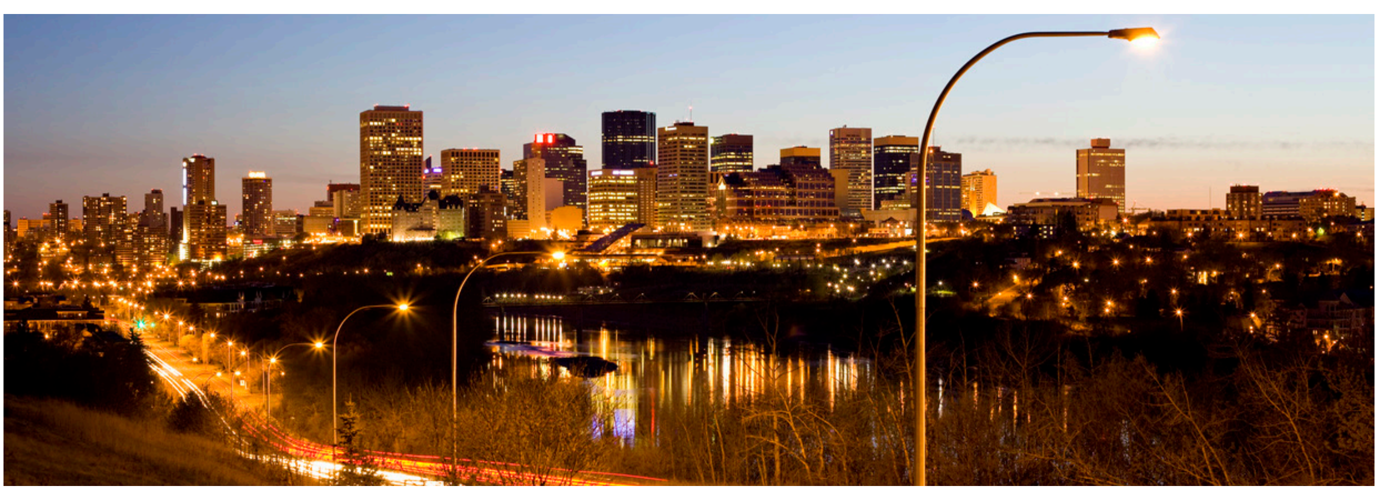
A 2015 Duke University review by Xinxing Zhang confirmed significant energy and water savings, and increased grid autonomy. Moreover PSP attracts high-tech partnerships and reinforces Austin as an innovation hotspot and a desirable investment location.

Encouraging Resourcefulness

Resourcefulness is the intelligent use of existing resources; in the energy sector, the key enabler is smart grid technology that increases citizen awareness of the timing and magnitude of their power consumption, and helps citizens reduce consumption. Time-of-use pricing schemes, where energy use is priced based on peak and off-peak hours, can also help to drive behaviour towards conservation through financial motivation. Encouraging people to change their habits and use energy at off-peak hours can result in savings for individuals and reduce the surge in energy demand during peak times of day.

Smart grids can also disconnect high-load, discretionary appliances such as hot tubs when the availability of grid power is reduced due to a major climate event. In a complete blackout, the ability to self-generate sufficient power to maintain communications (cell phones, radios) is crucial.[17] Hand-cranked cell phone chargers and radios are examples of household-level products that increase citizen resilience.

In the ICT sector, resourcefulness exists primarily at the network level. Hurricane Sandy knocked out 25 per cent of mobile phone masts across 10 states—serious but not catastrophic. Customers would have been largely unaffected had they been allowed to roam during the emergency and connect to any available resource rather than remaining tied to a single network.[18]



Recommendations

Strategic

- Creating a climate-resilient city is a form of enterprise risk management that should be embraced at senior political levels as an economic development narrative and understood by the bureaucracy as modern asset management. Develop key messaging that climate resiliency will reduce future risk and cost, and makes the city more attractive.
- With respect to energy and ICT infrastructure, the resilience narrative is highly compatible with the cleantech and smart grid narratives that the most innovative international cities embrace. With this narrative widely accepted as a consensus vision in senior political and business circles, the regulatory reform agenda becomes easier to implement. A local version of the Pecan Street Project in Austin, Texas, is an appropriate aspiration for resilient urban life.

Regulatory/Administrative

- Relatively straightforward regulatory and administrative measures that enhance energy and ICT infrastructure robustness include an engineering procurement protocol that new public or private infrastructure investments (power distribution, cell towers) require a PIEVC process to identify key climate vulnerabilities.
- Other regulatory approaches to enhance redundancy include conforming new subdivision and industrial park development with the Canadian SmartGrid Standards Roadmap[19] and compatibility with the Alberta Microgeneration Regulation.[20]
- For ICT, policy-makers could heed the lessons from Hurricanes Irene and Sandy and require that wireless providers allow full roaming in emergency situations.

Economic Instruments

- Jurisdictions around the world have experimented with feed-in tariffs to subsidize grid-connected renewable energy for its positive environmental externalities. As renewable energy drops in price, the logic for conventional feed-in tariffs may diminish; however, the logic for incentivizing smart grid, distributed renewable energy and distributed storage for climate resilience is increasing and its economics should be examined from an enterprise risk-management perspective.
- Implementing time-of-use pricing structures for residential and commercial use can have the two-fold benefit of (i) influencing energy consumption behaviours to spread out usage across peak and non-peak times and (ii) decreasing stress on the energy grid during peak use times.
- Policy-makers should also consider incentives to encourage new entrants into the ISP space, a good example being www.les.net, which is essentially a start-up telecom company offering gigabit connectivity and enabling a cluster of new technology companies in downtown Winnipeg.

Voluntary/Community Linkages

- The most critical citizen-level initiatives relate to self-interested smart consumption like engaging with the smart grid and technology-enabled emergency preparedness. Outreach campaigns to encourage preparedness should include promotion of hand-cranked cellphone chargers and radios to ensure communication in blackout situations.

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] In the context of this White Paper, energy is limited to electrical grid infrastructure and alternative electricity sources therein.

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[16] McLean et al. (2015), *supra* note 13

[17] A significant public health risk during blackouts is from carbon monoxide poisoning due to car charging in garages. See: http://www.ct.gov/dph/lib/dph/environmental_health/eoha/pdf/co_video_script.pdf

[18] Ospina et al. (2014) *supra* note 10.

[19] CNC/IEC Task Force on Smart grid Tecnology and Standards. (2012, October). *The Canadian Smart Grid Standards Roadmap: A strategic planning document*. Retrieved from http://www.scc.ca/sites/default/files/publications/Smart-Grid-Report_FINALOCT2_EN.pdf

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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.

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