Prairie Climate Centre

Building a Climate-Resilient City:

The built environment

KEY MESSAGES:

- Buildings are now and will be increasingly exposed to higher climate stresses and more frequent co-occurrences of climate shocks such as more variable and episodic snow loads and rain-on-snow episodes. New design tools such as the PIEVC protocol and the Climate Change Hazards Information Portal help developers and asset managers assess climate risk. Climate-smart design tools will provide a long-term strategic benefit to cities.
- The built environment creates urban heat island (UHI) effects, which amplify heat waves and can be deadly to vulnerable elderly and infirm populations. UHI can be mitigated through spatial planning, including the strategic use of green space. UHI impacts can also be mitigated by designating and maintaining cooling stations.
- Architectural protocols such as LEED and district-planning paradigms such as EcoDistricts encourage patterns of resource use and community dynamics that increase resilience to the impacts of climate change.

In recent decades, Alberta has experienced significant changes in its climate as well as its economy, population and environment. Provincial mean annual temperatures are increasing and are 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.

In the context of Edmonton and Calgary, these changes have a myriad of implications and pose multiple threats to the built environment. The physical exposure of buildings to climate stress and shock should be a basic and fundamental concern to asset managers everywhere. The codes and standards used in the construction of existing buildings have, with very rare exceptions, not accounted for the effects of climate change.

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 essential to preventing the breakdown or failure of a system and enabling it to take action in a timely manner.[2]

With this in mind, the paper examines ways to build resilience in the built environment. Specifically, the paper will explore climate-robust design options, effectively raising the bar in building design, and highlight some emerging Canadian best practices. 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.

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.

Envisioning a Climate-Resilient Built Environment

The concept of the urban built environment can be extended to cover essentially all human-constructed infrastructure—residential, commercial and industrial buildings, as well as the water, energy, information and transportation networks that link them together. However, infrastructure networks are covered in other papers in this series. This paper focuses on buildings themselves and the spatial structure of the built environment—the contiguity and concentration of buildings in the urban context.

The urban built environment remains crucial in the broader battle against climate change.

Ours is an urban world and increasingly so; the global urban population is now 53 per cent and expected to be close to 70 per cent by 2050.[4] Urban buildings produce approximately 20 per cent of global greenhouse gas emissions and exert a long-lasting influence on our greenhouse gas emissions profile.[5] The built environment is exposed to the impacts of climate change for decades, given how slowly our capital stock of buildings turns over. We are now building the cityscapes of 2070, and approximately 80 per cent of the total environmental impact of the built environment is determined at the design stage.[6] It is therefore essential that the decisions we make now in policy, planning and design increase climate resilience in the urban built environment. There are a variety of ways to contribute to building a more resilient built environment, some of which are illustrated through interventions that enhance the qualities of robustness, redundancy and resourcefulness.

Building Robustness

Key climate impacts affecting buildings that we can reasonably project for Calgary and Edmonton based on the results from the Prairie Climate Atlas include: increases in freeze-thaw cycles, humidity (especially in winter), precipitation intensity (heavy rain, freezing rain and rain-on-snow events), snow loads (episodically), temperature and wind speeds (episodically).

The Public Infrastructure Engineering Vulnerability Committee (PIEVC)[7] protocol advocated by Engineers Canada, the national umbrella organization of engineering profession regulators, is an emerging norm for assessing climate impacts on buildings, the relative risks to specific building components and the appropriate design or retrofit revisions that ensue from applying the protocol. Building components that are typically evaluated include: cladding and insulation, glazing, water and wastewater systems, structural elements, HVAC systems, electrical systems, exterior elements and foundations. The magnitude of the interaction between climate impacts and building components is then

evaluated through expert engineering judgement. For example, even substantial increases in freeze-thaw cycles may impose negligible risks to structural elements, but impose a material risk to cladding and foundations. Where material climate risks are identified, further analysis and design are applied to those building components to satisfy the client's risk tolerance.

In addition to the PIEVC protocol, additional decision support systems are now commercially available to assess the climate risk exposure of buildings, including the Climate Change Hazards Information Portal (CCHIP). CCHIP is a web-based product from Risk Sciences International, an Ottawa-based company specializing in risk management consulting. CCHIP organizes access to localized historic climate information and comparisons to projected changes in climate parameters such as temperature, precipitation, snow and wind for structured climate risk analysis; more advanced CCHIP applications involve assessing risk interactions such as cumulative rain/snow events leading to roof collapse.

The fundamental constraint on the widespread application to these best-in-class design protocols and data resources is the political and institutional will to accept higher upfront costs to what current building codes require for both new construction and retrofits. Some jurisdictions, though, will accept these costs as prudent and risk-adverse investments.

Promoting Redundancy

Perhaps the most significant climate impact on and of the urban built environment is the urban heat island (UHI) effect. The UHI effect illustrates how redundancy attributes of climate resiliency can be designed into the built environment—specifically the spatial configuration of the built environment. UHI essentially amplifies global warming, with the most pronounced effects in winter and in summer. The summer UHI effect is much more dangerous than in winter. UHI is caused by the high thermal capacity (heat absorption) of concrete, asphalt and other dark-coloured materials in the built environment. UHI can be quite extreme even without climate-change effects; research documenting the influence of urbanization in South Florida identified an average rural-urban temperature difference of 3–4°C attributable to UHI.[8] A study of seven of the largest Canadian cities determined that the mortality rate of humans increases by 2.3 per cent for each degree above 20°C; a UHI intensity of 2–3°C therefore translates into a 4–7 per cent increase in the mortality rate.[9, 10]

The UHI effect in Calgary and Edmonton will amplify the relatively high rate of global warming projected for the Prairies, and particularly the skew towards a much greater number of hot days. UHI increases building cooling loads, exacerbates air pollution and thermal discomfort, and can induce more convective rainstorm events, making local hydrology—especially flooding—more extreme.[11] Beyond its direct environmental impacts, UHI is also a public health and social justice issue, as low-income earners and the elderly are typically least able find a cool refuge and most likely to succumb to heat stress, as was clearly shown in the 2003 European heat wave.[12]

Mitigating UHI is primarily an urban spatial design issue and secondarily a building materials issue. Both urban sprawl and contiguous high-density urban development contribute to UHI; the ideal urban system appears to be a mosaic of high-density zones with interspersed green spaces and green belts to dissipate heat.[13] Inserting green refugia at any scale should be a priority in a brownfield redevelopment context. The urban mosaic concept is strongly related to the aesthetic ideal of systems of urban public green spaces and squares as deliberate acts of beauty, culture and social interaction.[14] The green high-density urban mosaic essentially creates a system of redundant refugia—diffusing thermal stress and allowing multiple opportunities to access relief points. The Complete Streets concept of integrated forestry with transportation corridors is another important planning tool and is discussed in the paper on transportation in this series. The use of reflective (white) roofing materials and green (vegetated) roofs in high-density zones also reduces UHI.[15]

BOX 2. CASE STUDY: ECODISTRICTS[16]

A popular North American protocol for implementing the ecourban concept is EcoDistricts, a protocol for the "regeneration of cities on a neighbourhood and community scale… that achieves unsurpassed outcomes in equity, resilience and sustainability." EcoDistrict-certified projects exist in Denver, CO, Cambridge, MA, Washington, D.C., and Austin, TX. The first EcoDistrict-certified project in Canada is in central Ottawa. The 2015 Ottawa EcoDistrict action plan includes initiatives in the following clusters: health and well-being, mobility and connectivity, ecosystem stewardship, and climate protection and resource efficiency.

R-urban (France) and Transition Town (UK) are more extreme ecourban design philosophies that intend—through spatial design, governance and sustainable local livelihood creation—to address more fundamental social justice issues of inclusion, participation and equity. Urban agriculture and value-added food processing are key components of these design philosophies, motivated in large part by the belief that cycling energy and resources locally is fundamental to citizen empowerment, upskilling and, ultimately, climate resilience.

Encouraging Resourcefulness

Resourcefulness in the built environment starts with our fundamental belief that citizens of resilient cities are independent, self-aware and empowered, which is built into the framework of these white papers. Resourcefulness spans a range, from citizens who live and work in resource-efficient buildings designed to mitigate global and local warming to resourcefulness as the process of empowerment: "resilience is not just an outer process: it is also an inner one, of [citizens] becoming more flexible, robust and skilled."[17]

Resourcefulness manifests first as a principle that the environmental impact and resource use within the built environment should be as low as possible. The most popular program for certifying the resource efficiency of buildings is the LEED (Leadership in Energy and Environmental Design) program developed by the non-profit U.S. Green Building Council. Buildings can be rated in order from least to highest resource efficiency as "certified," "silver," "gold," or "platinum." LEED reports that gold-certified buildings consume a quarter less energy and emit 34 per cent lower greenhouse gas emissions.[18]

A more demanding "resourcefulness in design" philosophy is the Living Building Challenge (LBC), which operationalizes the concept of the built environment as a tool for ecological and resource regeneration. Rather than merely minimizing negative impacts, LBC provides a set of building design principles for net positive environmental impact through renewable energy production, water production and integration with the local ecosystem, which—particularly through the green roof concept—also mitigates UHI effects.[19]

The LEED/Living Building Challenge philosophy can be extrapolated to larger scales through the ecourban neighbourhood concept, which is defined as "the development of multi-dimensional sustainable human communities within harmonious and balanced built environments."[20] A recent review by an

EcoUrbanism research team based at Simon Fraser University counted 420 ecourban neighbourhood projects globally, including 27 in Canada.[21] Projects differ widely in approach and range from the "econ-urban," which encourages designated innovation districts focused on green capitalism and clean technology; to "ecol-urban" design, which emphasizes energy and material efficiency with direct access to nature; to the "living-urban" philosophy of well-being, liveability and resilience to outside shocks. These ecourban design concepts overlap considerably with grid-autonomous communities discussed in the Energy and ICT paper in this series. In addition to the quality-of-life benefit for residents, the potential for ecourban neighbourhoods to significantly moderate UHI should be carefully considered.

Recommendations

Strategic

- Define a climate-resilient built form as a strategic advantage for attracting investment and a comparative advantage.
- Encode climate-resilient urban design as a distinct value proposition for your outward-facing urban brand—for example, when working with site selectors for potential in-bound investment. The most resilient buildings or neighbourhoods will be the

most competitive and will attract and retain capital and residents. The least resilient will suffer competitive disadvantages, capital outflows and expensive retrofits in future dollars.

- Conduct UHI analysis: identify “hotspots” and cross-reference with green/brown space inventory. Identify “greenable” and priority green spaces to maintain in pursuit of the optimal mosaic concept; integrate UHI mitigation as a strategic objective within neighbourhood revitalization plans. Consider deliberate planning and designation of the green spaces as (for example) cool green islands, and integrate xeriscaping and bioswale concepts for stormwater management (discussed in the water and sanitation paper in this series).
- Conduct a multi-decadal urban ecosystem services analysis such as that recently conducted for the Metro Montreal region,[22] including cooling services such as that provided by the tree canopy.

Regulatory/Administrative

- Develop and encode regulatory and procurement standards (like PIEVC and CCHP) for climate-resilient design (retrofit and new build).
- Consider dollar thresholds at which formal resilience and climate-risk management should be applied.
- Increase administrative support for climate-resilient design by requiring Municipal Development Plans to benchmark climate resilience as incorporated in the EcoDistrict and 2030 District programs.
- Require thermal (UHI) impact analysis of brown and greenfield development as a standard design consideration. Consider incentives for non-traditional building retrofits that ameliorate UHI, such as Toronto’s eco-incentives for green roofs.
- Integrate UHI mitigation with naturalized stormwater retention features.

Economic Instruments

- Incentivize climate-resilient built form through offsets, variances or planning assistance incentives to developers and consultations with insurance providers.
- Reinforce existing instruments that encourage energy efficiency within the built environment at the residential scale.

Voluntary/Community Linkages

- Develop workshops for asset managers, project developers on PIEVC protocols and other climate-risk management protocols such as CCHP.
- Promote voluntary programs such as LEED and LBC to engage city planners, citizens and the design community in the implementation of individual buildings.
- Similarly, voluntary programs such as EcoDistricts, One Planet Living and 2030 Districts engage stakeholders in broader district/neighbourhood planning initiatives. Vancouver has recently embraced both the Passive House program and the principles of the 2030 Districts with the intent to reduce greenhouse gases by 50 per cent by 2030 through incentives and offsets.[23] These new frameworks can begin to change the stakeholder dialogue beyond minimum green building code regulations to resilient, net zero and regenerative frameworks required to make the transformation to a climate-resilient built environment.

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] United Nations. (2014). *World urbanization prospects*. Retrieved from https://esa.un.org/unpd/wup/publications/files/wup2014-highlights.Pdf

[5] Lucon, O., D. Ürge-Vorsatz, D., Zain Ahmed, A., Akbari, H. ... Vilariño, M. V. (2014). Chapter 9: Buildings. In Edenhofer et al. (Eds.), *Climate change 2014: Mitigation of climate change* (pp. 671–738). Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, U.K.: University Press. Retrieved from https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter9.pdf

[6] Thackara, J. (2006). *In the bubble: Designing for a complex world*. Cambridge, U.K.: The MIT Press.

[7] Engineers Canada. (2016). Public Infrastructure Engineering Vulnerability Committee. Retrieved from https://pievc.ca/protocol

[8] Kandel, H., Melesse, A. & Whitman, D. (2016). An analysis on the urban heat island effect using radiosonde profiles and Landsat imagery with ground meteorological data in South Florida. *International Journal of Remote Sensing, 37*(10), 2141–2165.

[9] Wang, Y., Berardi, U., & Akbari, H. (2016). Comparing the effects of urban heat island mitigation strategies for Toronto, Canada. *Energy Build, 114*, 2–19.

[10] Smoyer-Tomic, K.E., Kuhn, R. & Hudson, A. (2003). Heat wave hazards: An overview of heat wave impacts in Canada. *Natural Hazards, 28*, 465. doi:10.1023/A:1022946528157

[11] Shepherd, J. M., & Burian, S. J. (2003). Detection of urban-induced rainfall anomalies in a major coastal city. *Earth Interactions, 7*(4), 1–17.

[12] Poumadère, M., Mays, C., Le Mer, S. & Blong, R. (2005), The 2003 heat wave in France: Dangerous climate change here and now. *Risk Analysis, 25*, 1483–1494.

[13] Venn, S.J., and Niemelä. (2004). Ecology in a multidisciplinary study of urban green space: the URGE project. *Boreal Environment Research 9*, 79-489. Retrieved from http://www.borenv.net/BER/pdfs/ber9/ber9-479.pdf

[14] Javadi, H. (2016). Sustainable urban public squares. *European Journal of Sustainable Development, 5*(3), 361–370.

[15] Debbage, N., Shepherd, J.M., 2015. The urban heat island effect and city contiguity. Computers, *Environment and Urban Systems, 54*, 181–194.

[16] Ecodistricts. (n.d.). About. Retrieved from http://ecodistricts.org/about/; R-Urban. (n.d.). About. Retrieved from http://r-urban.net/en/sample-page/; Transition Network. (2016). Home. Retrieved from https://transitionnetwork.org/; Ottawa Centre Ecodistrict. (2015, September 24). Appendix A: Action Plan. Retrieved from http://ottawaecodistrict.org/wp-content/uploads/2015/09/SNAP_Appendix_A-Action-Plan_Final.pdf

[17] Hopkins, R. (2009). Resilience thinking. *Resurgence, 257*, 12–15.

[18] U.S. Green Building Council. (2017). This is LEED. Retrieved from http://leed.usgbc.org/leed.html

[19] International Living Future Institute. (2016). Living Building Challenge 3.1 Standard. Retrieved from https://living-future.org/product/lbc-3-1-standard/

[20] Ruano, M. (1999). *Ecourbanism: Sustainable human settlements*. 60 case studies. Barcelona, Spain: Gustavo Gili.

[21] Holden, M., Li, C., & Molina, A. (2015). The emergence and spread of ecourban neighbourhoods around the world. *Sustainability, 7*(9), 11418–11437.

[22] Dupras, J. & Alam, M. (2015). Urban sprawling and ecosystem services: A half-century perspective in the Montreal Region (Quebec, Canada). *Journal of Environmental Policy and Planning, 17* (2), 180–200.

[23] City of Vancouver. (2009, July). *Passive design toolkit*. Retrieved from http://vancouver.ca/files/cov/passive-home-design.pdf

In parternership with:

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