RESILIENT EDMONTON – WHY AND HOW?

BY CRAIG APPLEGATH AND JONATHAN YAZER

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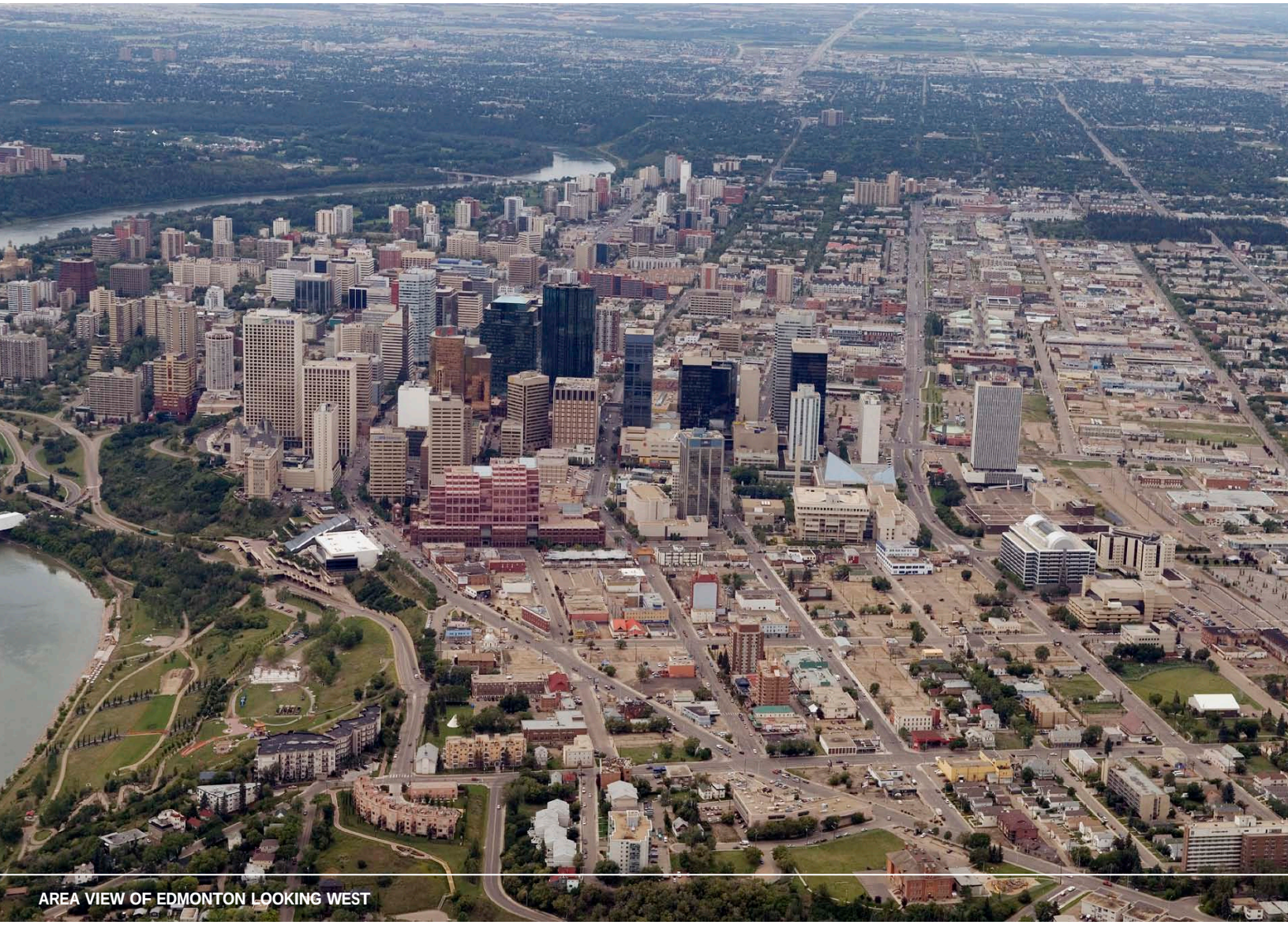
Table of Contents



AREA VIEW OF EDMONTON LOOKING WEST

i Abstract

This paper introduces the concept of resilience as it applies to cities in general and the City of Edmonton in particular. The first section defines resilience and explains its value as a method of understanding and strengthening social-ecological systems. It also outlines the basic themes and principles of resilience in urban design and planning. The second section assesses Edmonton's capacity for resilience by performing a T.W.O.S. (Threats, Weaknesses, Opportunities, Strengths) analysis on its critical systems. This section presents a list of eight key opportunities for building Edmonton's capacity for resilience. It also describes how the city could realize some of these opportunities by continuing to develop its LRT network and by developing a network of Resilience Centres, which integrate opportunities for capacity-building in three critical systems – water, energy, and food – into single, integrated centres. In the final section, we suggest what tools the city might use to prioritize opportunities for capacity-building and provide a set of urban planning principles to assist the City of Edmonton in meeting the twin challenges of climate change and peak oil.

iii Acknowledgments

We would like to express our thanks to all of the people who have contributed to this paper, whether directly through the insights they have provided about resiliency for the City of Edmonton, or simply in spending time with us to discuss the concepts developed in this paper. This paper would not have been possible without their generous contributions.

Specifically, we would like to thank Jim Andrais of the City of Edmonton for inviting us to put forward our thoughts on resiliency specifically as they relate to the City of Edmonton. We are hoping that Jim finds our ideas as useful as we found the City of Edmonton a compelling case study.

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And finally, we would like to thank Karen Ng-Hem and Trista Chapple of the Toronto Studio of Cohos Evamy for their hard work in preparing the graphics for this paper.

iii Author Biographies

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Craig is a founding member of ResilientCity.org, and a pioneer in the field of urban resilience. Craig is also an Architect and Principal at Cohos Evamy Integratedesign in Toronto. Since graduating from the Graduate School of Design at Harvard University with a Master of Architecture in Urban Design he has built a considerable track record leading complex institutional design and planning projects, but is best known for his advocacy of sustainable design and resilient urban planning. A passionate advocate for developing design solutions that make sense in a world of peak oil and climate change, Craig lectures on sustainable design and urban resilience in Canada and United States. Craig was a founding Board Member of Sustainable Buildings Canada, and is a current member of the Canadian Green Building Council. Craig is also a past President of the Ontario Association of Architects, and was made a Fellow of the Royal Architectural Institute of Canada for his services to the profession.

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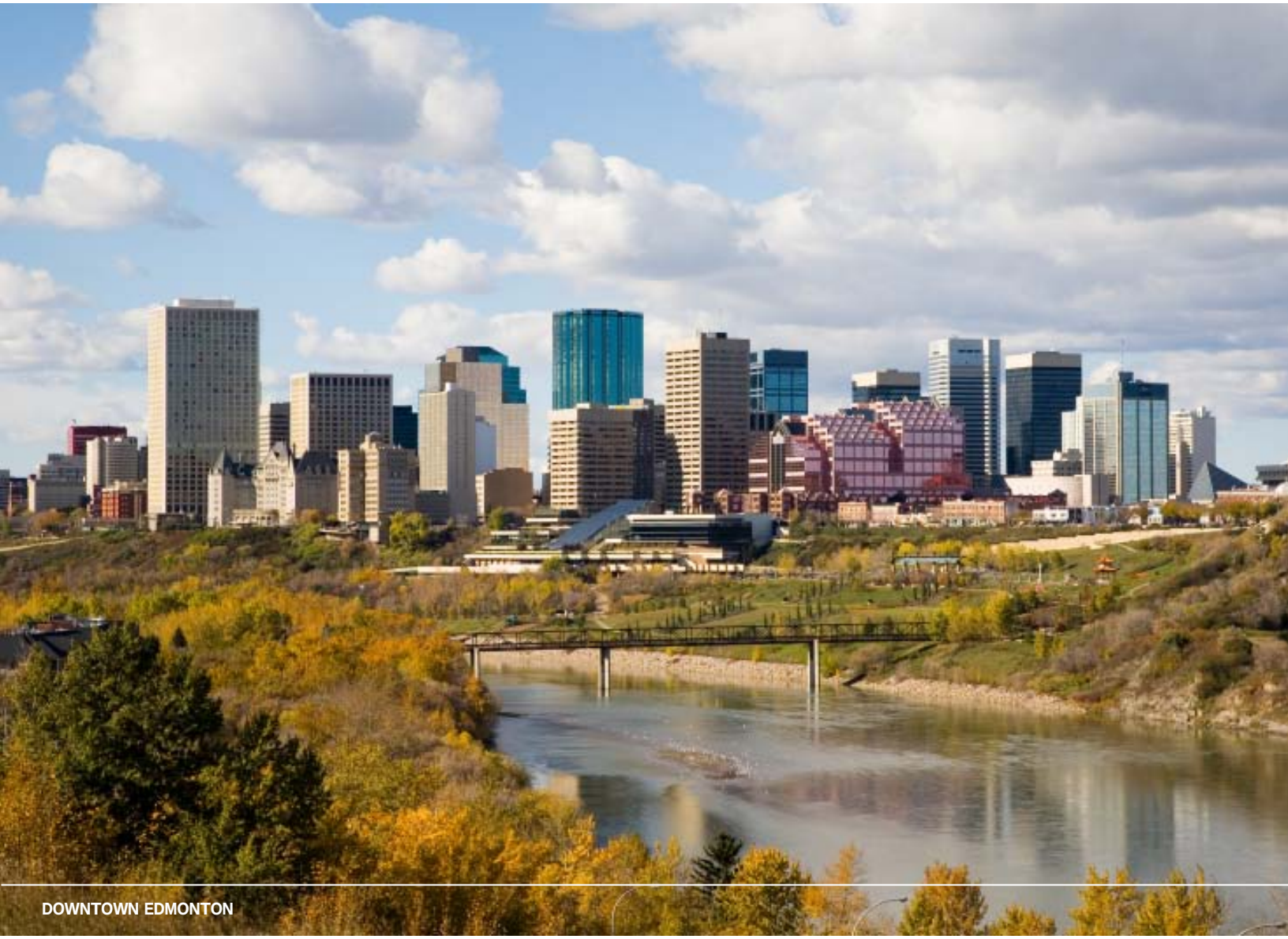
iv Goals of Paper

It is not our intention in writing this paper to provide Edmonton with a policy document. Instead, we attempt to convey why resilience is important and explain how policy makers in Edmonton can think about ways to incorporate the concept into their larger strategic thinking and planning framework.

Keeping that in mind, the main goals of this paper are threefold:

1. To outline the conceptual framework of resilience theory in the urban context, including key themes and principles;
2. To undertake a T.W.O.S. analysis of Edmonton's critical systems in order to determine key Threats, explore underlying Weaknesses, outline Opportunities for creating greater capacity for resilience, and discuss Strengths that can be brought to bare on realizing opportunities;
3. To suggest ways the city might prioritize opportunities for building resilience capacity.



DOWNTOWN EDMONTON

Section 1 Resilience: The Conceptual Framework

1.1 Defining Resilience

> *Resilience is the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks.*

Source: B. Walker et al, 'Resilience, Adaptability and Transformability in Social-ecological Systems', Ecology and Society 9 (2) p. 5

Resilience, as Walker notes above, describes a system's capacity to deal with disturbances and bounce back intact. Although from the same area of discourse as sustainability, resilience is not the same thing as sustainability. The goal of sustainability is to balance inputs and outputs in a social-ecological system, such as a neighbourhood, city, or region, so as not to impair the long-term ability of natural ecosystems to replenish the energy and environmental services essential to maintaining the integrity of the system. Resilience augments sustainability by taking into account the potential for major future disturbances and structural changes in the natural environment. Where sustainability aims to preserve a status quo, or steady state, the goal of resilience is to develop a social-ecological system's capacity to adequately absorb future disturbances and still remain intact and functional. For cities in general, and Edmonton in particular, developing resilience is about developing the capacity to absorb future shocks and stresses caused by climate change-related weather events and ecological phenomena such as droughts, as well as the socio-economic stresses and potential shocks that will be associated with peak oil.

1.2 Building Capacity

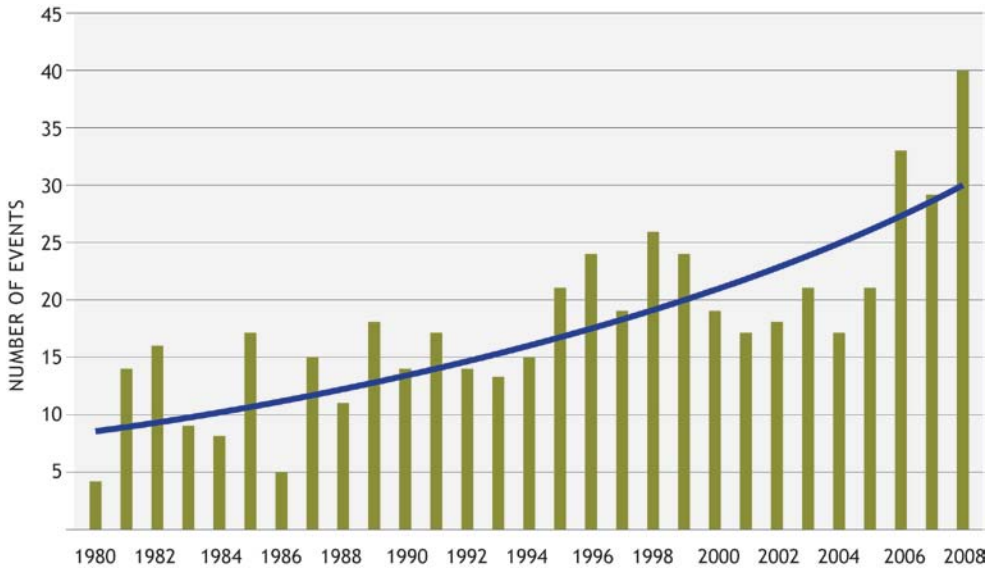
Resilience describes the capacity in a system to cope with disturbances – a capacity, however, that is unfortunately only observable after the disturbance has occurred. The resilience of a system cannot be measured in the same way as annual rainfall or GDP. Since we can only confirm whether a system has developed sufficient resilience to absorb a disturbance *after* a disturbance has occurred, it is difficult if not impossible to gauge the exact amount of capacity for resilience that is required to be added to a system prior to a disturbance to be effective.

Therefore, the goal of building the capacity for resilience into city systems is one that requires adequately predicting the probability of both the type and magnitude of potential future disturbances, as well as understanding and balancing both the costs and benefits of creating the capacity for resilience.

1.3 Understanding Disturbances

Disturbances typically fall into two categories: shocks, which are discrete events like the 2003 blackout of the North Eastern North American power grid, and stresses, which are sustained trends, like the current global water crisis. It is important to note that disturbances in each category are not necessarily independent of one another: a stress can trigger a shock or shocks, and a shock can dissipate into an on-going stress. A good example of an ongoing stress developing into a series of shocks is the gradual rise in the average global temperature caused by increasing levels of greenhouse gases in the atmosphere. This process is increasing the absolute amount of water vapour that can be stored in the atmosphere – a gradual stress – which has in turn led to the increasing frequency of more energetic weather events such as tornados, hurricanes, and flash floods – sudden shocks.[1]

Figure 1 – Number of Devastating Natural Disasters (Category 5), 1980-2008



Source: World Watch Institute

A good example of a sudden shock dissipating into an ongoing stress is the recent devastating oil spill in the Gulf of Mexico off the coast of Louisiana caused by the collapse of a British Petroleum deep-water oil rig. As this paper is being written, the oil spilling from the broken drilling pipe on the sea floor has not yet been stemmed, and is spilling at the rate of five thousand gallons of crude oil per day. The long-term negative effects of the oil on the surrounding coast and associated wetlands will place a significant level of ecological and economic stress on both the natural systems and the human settlement of the surrounding costal communities.

1 For more information about the relationship between global warming and extreme weather events, see: The U.S. Environmental Protection Agency, "Extreme Events | Climate Change – Health and Environmental Effects," last updated 8 September 2009, available at http://www.epa.gov/climatechange/effects/extreme.html#abrupt

The majority of present-day system disturbances such as extreme weather, desertification, drought, etc., have a single source: anthropogenic carbon dependency (the basis of most of the issues captured within the current discourses relating to peak oil and climate change). So it would be misleading to think of disturbances as simply being "external" pressures lying beyond the scope of human responsibility and action. Indeed, carbon is integral to the underlying structure of our social-ecological systems, buried deep in the structure and function of our society. Because the probability and magnitude of future disturbances resulting from our carbon dependency are increasing rather that decreasing, creating the capacity for increased resilience now implies social and infrastructure transformations and investments on an unprecedented scale.

1.4 Understanding Social-ecological Systems

Resilience is a concept originally used in the study of ecological systems. Over the last two decades it has gained recognition as a conceptual framework for understanding human social systems. This paper is interested in the concept of resilience as it applies to the social, economic and environmental systems of cites, and specifically the city of Edmonton. Cities are complex and integrated social-ecological systems (SES) in which humans and their surrounding environment are integrally bound up with one another.[2] In SES, the capacity of humans in general, and social governance systems in particular, to anticipate and plan for the future forms the basis for all other resilience capacity creation.

Figure 2 – Four interconnected research themes for prioritising urban resilience research

Source: Urban Resilience Research Prospectus, A Resilience Alliance Initiative for Transitioning Urban Systems towards Sustainable Futures, February 2007, CSIRO, Australia — Arizona State University, USA — Stockholm University, Sweden, p.10

2 Berkes & Folke (1998) started to use the term to stress that the delineation between social and ecological systems is artificial and arbitrary. Berkes F. and C. Folke, eds. 1998. Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience. Cambridge, UK: Cambridge Univ. Press

Cities have their own unique attributes and needs that are distinct from other social-ecological systems. The Urban Resilience Research Project outlines four key themes of urban resilience, which are visualized in the above diagram. The diagram shows the roles:

"…of **metabolic flows** in sustaining urban functions, human well-being and quality of life; of **governance networks** and the ability of society to learn, adapt and reorganize to meet urban challenges; and of the **social dynamics** of people as citizens, members of communities, users of services, consumers of products, and their relationship with the **built environment** which defines the physical patterns of urban form and their spatial relations and interconnections."[3]

In this paper we choose to focus primarily on the roles of metabolic flows and the built environment in sustaining urban resilience, although we also engage with key demographic issues as well as some of the changing social dynamics that will result from stresses and shocks to critical systems, such as the effect of peak oil on people's choices with respect to transportation. We anticipate that the City of Edmonton will want to further explore the role of governance networks in addressing the challenges and opportunities described below.

1.5 Resilience, Planning and Design Principles

If resilience is a concept originally used in the study of ecological systems, how should we consider applying it to the city as a physical constructed reality? In applying the lessons learned from the world of social-ecology to city planning and design we think there are seven key planning and design principles that apply to creating the capacity for greater resilience in cities:

1. ***Carbon neutrality:*** Clearly, we must aim not to increase the net amount of carbon dioxide or other greenhouse gases in the atmosphere. Design and planning must be predicated on low fossil fuel usage in both the construction and operation of buildings and the cities they comprise.

2. ***Redundancy of Systems and Functions:*** The downward slope of the peak oil curve, in combination with increasingly more energetic weather, means cities and their communities will need to withstand more frequent and powerful environmental stressors. This forces a need for redundancy of infrastructure systems—including electrical power, fresh water supply, fuel supply, waste-water processing and, most importantly, food supply.

3. ***Systems Diversity:*** This is important because with greater diversity comes greater ability to thrive, survive and bounce back from external stressors.4 In the case of cities, we will need different business types, institutions, sources of food, and industries.

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3 Resilience Alliance, "Urban resilience," last accessed 11 May 2010, available at: http://www.resalliance.org/1610.php

4 From: Rob Hopkins, "The Transition Handbook," available at: http://transitionculture.org/about/

4. ***Systems Durability:*** In many parts of the world, global warming will increase the frequency of storms, the velocity of peak winds, and the volume and duration of precipitation. As a result, we will require more durable systems and structures that can withstand these increased stresses.

5. ***Loop Tightness:*** This is a system's ability to detect and respond to changes in its parts. The more quickly a system detects and responds to changes the greater its potential for resilience.5 Hence, we will need social, economic, and technical systems with tight feedback loops.

6. ***Local Self-Sufficiency:*** Cities and their communities will need a sustainable supply of goods and services including food, fuel and power, water—and basic manufacturing of clothing, building materials, and tools. In larger cities, self-sufficiency should be aggregated at the neighbourhood level.

7. ***Responsive to Natural Systems:*** This will reduce the cost of creating and maintaining technical infrastructure. It should, for example, incorporate passive solar energy into urban planning – the layout of streets and neigbourhoods – and building design.

5 From: Rob Hopkins, "The Transition Handbook," available at: http://transitionculture.org/about/

NORTH SASKETCHEWAN RIVER

Section 2 Turning Threats into Opportunities: how Edmonton can emerge as a Global Leader in Resilience

Because building the capacity for greater resilience implies shifting resources and priorities to cope with anticipated future disturbances, it also implies a degree of purposeful change, and the necessary planning and resource allocation for that change. Strategies that enhance the capacity for resilience of a city's systems may require significant transformations of those systems, and, if not planned for and effectively implemented could cause major upheavals to these systems, particularly if they are already experiencing an acute level of stress. Therefore, one of the first steps towards creating a more resilient city must be to identify its critical systems. These are the systems that sustain life and growth in a city. Once these are identified, it becomes possible to formulate a plan for increasing the capacity of a city for resilience under conditions of either precipitous shocks or ongoing stresses such as those that will be encountered with peak oil and climate change.

We have identified four critical systems in Edmonton: water, energy, food, and transportation. These systems are the *sine qua non* for the survival and success of any city; without them, a city cannot support other important functions, such as commerce, manufacturing, education, and law and order. In this section, we perform a T.W.O.S. (Threats, Weaknesses, Opportunities, Strengths) analysis on each critical system.

The results of our analysis are summarized in the table in Figure 3.

Figure 3 – Edmonton's Critical Systems: Threats, Weaknesses, Opportunities, Strengths

CRITICAL SYSTEMS	THREATS	WEAKNESSES	OPPORTUNITIES	STRENGTHS
WATER	- Stresses: decreasing rainfall and snowpack; increased drought risk; changes in seasons; increases in demand - Shocks: spills and wastewater contamination; rising peak demand; service interruptions	- NS River is the single source - Depleting source - Aging supply infrastructure - No water reserves - Edmonton in naturally-occurring drought zone	- Water reservoirs - ENERGY EXCHANGE CENTRES - Investing in infrastructure: natural replacement and new investment	- Excellent conservation strategies - Awareness of key problems in "Water for Life"
FOOD	- Stresses: fragility of global system and prices; diminished soil moisture; increase in demand - Shocks: spikes in global food prices; frosts killing vegetation; transportation	- Dependence on imports - No reserves - Short growing season - Paved-over black soil	- ENERGY EXCHANGE CENTRES - Economic spinoffs of local foods industry	- Availability of real estate (e.g. rail ways and yards) - Active citizens' alliances - Local producers - Municipal Development Plan
ENERGY	- Stresses: increases in demand; rising global energy prices as a result of peak oil - Shocks: brownouts; cascading network collapses; crippling spikes in global prices	- Most energy from distant, single group of power plants - Aging infrastructure - Reliance on dirty coal power	- ENERGY EXCHANGE CENTRES - Low-rise, high density mixed-use developments - Building modifications	- Availability of real estate (e.g. rail ways and yards) - Civic participation - Alberta a renewable leader (e.g. wind energy; Drake Landing) - New transmission lines
TRANSPORTATION	- Stresses: Peak Oil; cars taking the off ramp + insufficient infrastructure to meet demand for transit and cycling - Shocks: spikes in oil prices; interruptions in oil supply	- Carbon dependency - Dependence on shipping	- Ring Road electric bus system - Extension and addition of LRTs - High-profile bikeway system - Upgrade regional rail network	- Existing infrastructure (e.g. wide roads; outlets for electrical cars; Inner Ring Road) - Municipal Development Plan
MISCELLANEOUS		- Demographics (greater demand for municipal services)		- Demographics (growing tax-base) - Education and training system - Knowledge capital and skilled labour force - Stakeholder interest in key issues

2.1 THREATS

2.1.1 Water

In the long-term, due to the effects of climate change, we anticipate that disturbances to Edmonton's water capacity will increase significantly in the next one to two decades. Peaks in demand will increase in number and magnitude as summer weather becomes more prolonged and more extreme. Long-term stresses, such as decreasing average yearly rainfall and snowpack,[6] as well as rising vulnerability to extended drought,[7] will exert pressures on the system that it is not currently prepared to cope with. It is reasonable to expect that occasionally these stresses will manifest in the form of acute shocks to the water system. Coupled with peaks in demand, aging infrastructure, and the possibility of accidents such as chemical spills or wastewater contamination that undermine its single source of water, Edmonton is on a trajectory that seriously threatens not only its water system but the resilience of its most critical systems.

2.1.2 Food

For a manifold number of reasons, global prices of food staples including most grains like corn and rice as well as meats, are on a steady march upward. Between 2007 and 2008, the world experienced what is referred to as a "food price crisis." Increasing demand caused by the production of biofuels like corn-fuelled ethanol, changing diets among the emerging middle classes of developing countries, and general population increases, combined with decreasing supply caused by land and water constraints and rising input prices, are conspiring to form what might become a perfect storm that could potentially imperil the food supply of import-dependent cities like Edmonton. In 2008, raw food prices rose 22% over the previous year.[8] While this clearly caused significant depravation and destabilization in the developing world, the developed world was not immune from shortages and moderate price shocks. For example, the amount of U.S. grain stored for following seasons relative to consumption was the lowest on record in 2008.[9] Here in Canada, food prices increased substantially more than inflation, with flour increasing by 33%, macaroni by 31%, bread by 18%, and bananas by 15%.[10]

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6 "Snowpack and rainfall have been below average to much below average throughout the watershed over the last several years, affecting surface and groundwater quantity and quality in the watershed." Environment Canada, "Case study: North Saskatchewan Watershed in Alberta," (2004), available at: http://www.ec.gc.ca/eau-water/default.asp?lang=En&n=CC09EDA0-1

7 Alberta Environment, 2002: South Saskatchewan River Basin Water Management Plan, Phase One -Water Allocation Transfers: Appendices, Alberta Environment, Edmonton, Alberta.

8 Alia McMullen, "Forget oil, the new global crisis is food," *Financial Post* (7 January 2008), available at: http://www.financialpost.com/story.html?id=213343

9 Alia McMullen, "Forget oil, the new global crisis is food," *Financial Post* (7 January 2008), available at: http://www.financialpost.com/story.html?id=213343

10 Becky Lipton, "Food Security for Edmonton: Is It Really Something We Should Care About?" 2010 City of Edmonton – Way We Green Discussion Paper #7, available at: http://www.edmonton.ca/city_government/city_wide_initiatives/discussion-papers.aspx

2.1.3 Energy

Long-term stresses on Edmonton's energy system include steadily rising demand among all sectors of the economy and, as peak oil approaches, rising global energy prices, which are profitable for the energy industry but hurt the average Albertan household and ultimately weaken the entire provincial economy. Shocks to the energy system include rolling brownouts and, in a future scenario, the possibility of blackouts, as well as potentially crippling spikes in the price of a barrel of oil.[11] But the economic impact of increasing oil is not the only potential shock that might be experienced in the energy sector. Like the 2003 blackout that left 50 million people in Ontario and parts of the northeastern United States without electricity was caused by the unexpected failure of a single power plant, which triggered failures along its transmission lines and across much of the North American energy grid, aging and at capacity transmission infrastructure also set up the potential for a similar cascading energy network collapse.[12] Moreover, since Edmonton and much of Alberta depend heavily for their electricity on a grouping of power plants in the north of the province, the threat to the city's energy resilience is especially pronounced.

2.1.4 Transportation

The City's Transportation Master Plan identifies some possible future conditions that could stress the transportation system, including: a burgeoning, aging population; growth in the suburbs (forecasted to be 80% of total growth); and congestion, which is growing at a faster rate than population growth; and volatile fuel prices.[13] In the long run, as peak oil pushes up the price of fuel, as more commuters seek economically viable (and possibly environmentally responsible) means of transportation, and as people begin to relocate to the downtown to escape the increasing cost of commuting, overall transportation priorities will shift. Fewer people will own cars, and more people will look towards clean, (relatively) low cost mass transit, cycling, and walking to fill the void. Moreover, if peak oil is experienced as a sudden wave of successive price shocks, it will likely catch cities with less developed mass transportation infrastructure off guard, and subsequent disruptions to flows of people and goods carry the potential to severely undermine economic activity and quality of life. This potential also exists if oil supply is interrupted, such as in the event of an embargo or major spill.

11 Dina O'Meara, "Possible brownouts heat up Alberta power debate," *The Calgary Herald,* 25 September 2009, available at: http://www.nationalpost.com/opinion/story.html?id=2031720

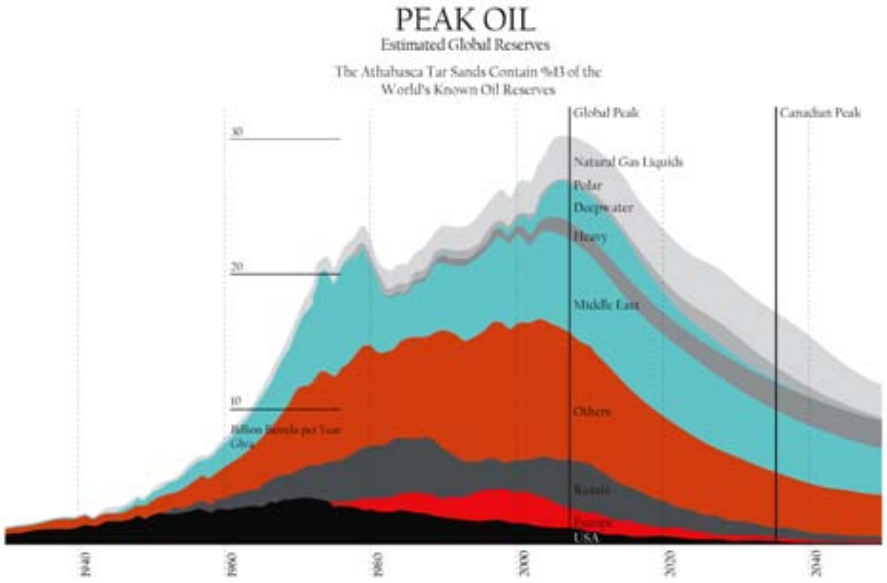
12 CBC News, "In-depth: Power outage," last updated 19 November 2003, available at: http://www.cbc.ca/news/background/poweroutage/

13 City of Edmonton, "The Way We Move: Transportation Master Plan," September 2009.

More about Peak Oil

We acknowledge that "the end of oil" may not be just around the corner. The City of Edmonton's discussion paper on fossil fuels and impacts for Edmonton contends that, "currently estimated economic reserves will last about 70 years or more, and potentially economic resources at least 200 years or more."[14] Nevertheless, the author of this paper concurs with the assertion by economists like Jeff Rubin15 and oil industry commentators like Richard Heinberg that the price per barrel of oil will be highly unstable in coming years as demand pressures and rising "supply inflexibility" (which refers to the difficulties associated with finding and extracting reserves that are increasingly scarce and hard to get to market) foster an unpredictable short-term dynamic on global oil markets. Supply inflexibility means that new reserves may not necessarily be able to replace the shortfall of quickly depleting existing reserves. For example, as the price of oil rose between 2005 and 2008, production remained stagnant. Although new sources of oil came online, they only barely made up for falls in production in existing fields due to depletion.[16] Many experts see the writing on the wall.

Figure 4 – Peak oil estimated global reserves



Source: Kelly Doran by permission of author

14 Chris Bataille, "Peak oil: The Future for Fossil Fuels and Impacts for Edmonton," 2010 City of Edmonton – Way We Green Discussion Paper #5, available at: http://www.edmonton.ca/city_government/city_wide_initiatives/discussion-papers.aspx

15 Rubin predicts that oil prices will hit triple-digit levels by the fourth quarter of 2010 and surpass the high-water mark of $147 per barrel of oil by sometime next year. Jeff Rubin, "Expect a new peak for oil next year," *Jeff Rubin's Small World blog at The Globe and Mail* (31 March 2010), available at: http://www.theglobeandmail.com/report-on-business/commentary/jeff-rubins-smaller-world/expect-a-new-peak-for-oil-next-year/article1517154/. See also, Jeff Rubin, *Why Your World is About to Get a Whole Lot Smaller*, Toronto: Random House, 2009.

16 Richard Heinberg, "Peak oil Day," Post Carbon Institute Blog (3 July 2009), available at: http://www.postcarbon.org/blog-post/40804-peak-oil-day

Last year, Raymond James Associates, a prominent brokerage specializing in energy investments, issued a report that concluded "peak oil on a worldwide basis seems to have taken place in early 2008," a finding that is being echoed by other analysts.[17]

The peak in estimated global reserves is shown in the above graph, which also shows Canada's oil reserves peaking at some point in the 2030s. The 2010 report from the UK Industry Taskforce on Peak oil and Energy Security warns that, "oil shortages, insecurity of supply, and price volatility will destabilize economic, political and social activity within five years," when, it predicts, world production from existing reserves will go into permanent decline.[18] More importantly, since it is indisputable that oil is a non-renewable resource, the question about peak oil is therefore ultimately not if, but when. Even if it remains somewhat far off, the time lag between deciding to prepare for peak oil and being prepared for it suggests that it would only be prudent that cities should begin to prepare sooner rather than later.

Summary of Key Impacts of Peak Oil

1. Much higher cost of oil and all fossil fuels as supply and production peak
2. Automobiles become uneconomical for everyday transportation needs
3. Much greater need for pubic mass transit
4. Re-localization of agriculture / food production
5. Re-localization of manufacturing as off-shoring becomes less viable
6. Transformation and/or demise of suburbs

17 Richard Heinberg, "Peak oil Day," Post Carbon Institute Blog (3 July 2009), available at: http://www.postcarbon.org/blog-post/40804-peak-oil-day

18 The Peak oil Group, "Industry Taskforce on Peak oil and Energy Security," last accessed on 13 May 2010, available at: http://peakoiltaskforce.net/

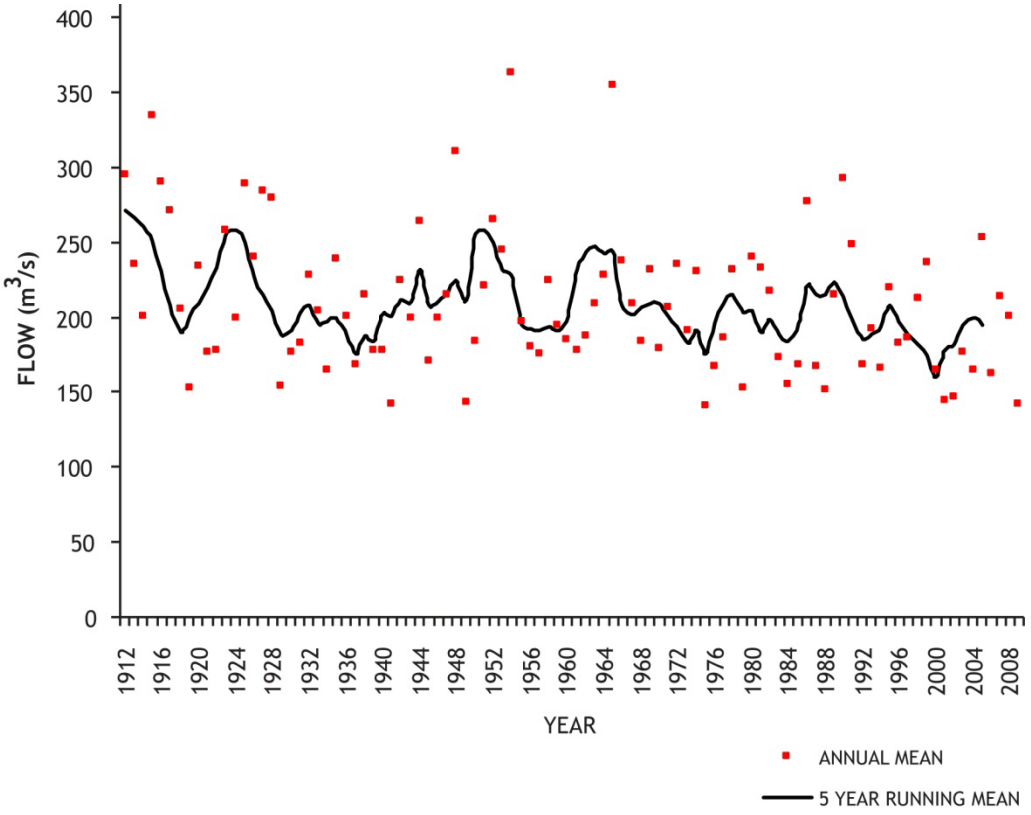
2.2 WEAKNESSES

2.2.1 Water

Our research for this paper indicates that Edmonton's most critical weakness is its dependence on a single, and depleting source of water: the North Saskatchewan River Basin (NSRB).

Over 100 municipalities are situated in the NSRB,[19] and water use is forecasted to increase by 21% in 2015 and by 37% in 2025 relative to 2005, which will place increasing stress on the basin despite declining per capita household consumption.[20]

Figure 5 – Mean Annual North Saskatchewan River Flows and Five Year Running Averages, 1912 to 2009

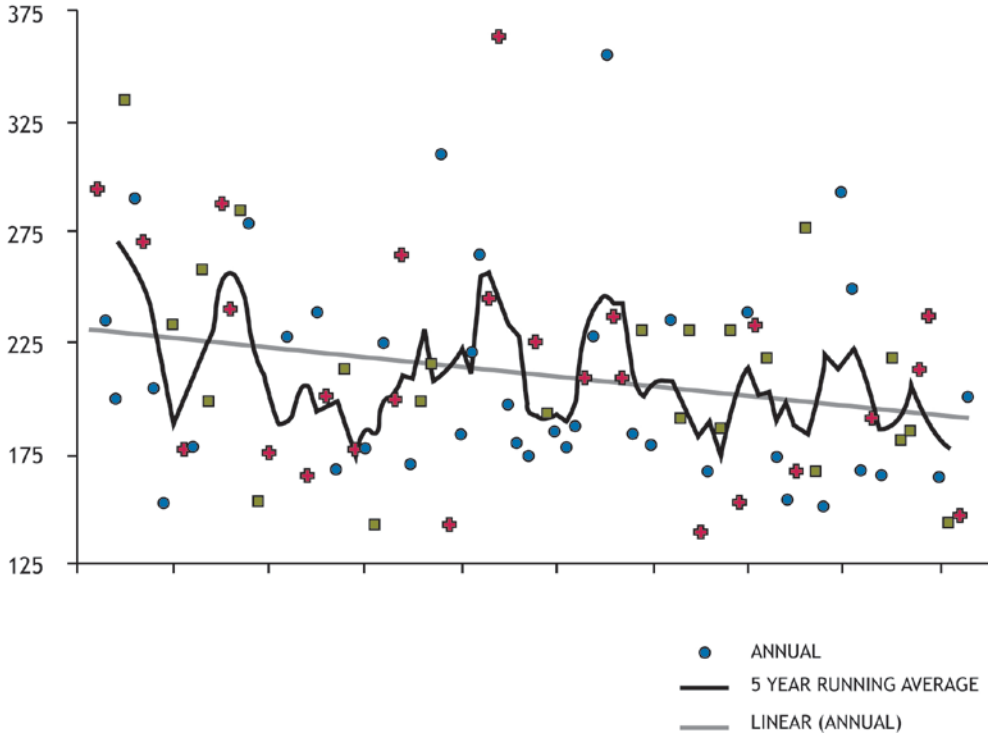


Source: Cindy Shepel, Steph Neufeld, and Robert Raimondo, "The Need for Sufficient Water Supply," 2010 City of Edmonton – Way We Green Discussion Paper, p. 6

19 Sharon Reedyk, IWMP Steering Committee Chair, "NSWA Integrated Watershed Management Plan Update Presentation," available at: http://nswa.ab.ca/content/presentations

20 John Thompson, AMEC Consulting, "Current and Future Water Use in the North Saskatchewan River Basin," available at: http://nswa.ab.ca/content/presentations

Figure 6 – North Saskatchewan River Flow at Edmonton, 1911-2003



Source: North Saskatchewan Watershed Alliance, "State of the North Saskatchewan Watershed Report 2005 A Foundation for Collaborative Watershed Management", p.26

Three points need to be taken into consideration.

1. *The flow of Edmonton's only water source appears to be diminishing*, although the authors of the "Need for Sufficient Water Supply" discussion paper are careful to add that they cannot say the trend is significantly negative based on a trend analysis. The authors summarize some of the key findings of the Prairie Adaptation Research Collaborative (PARC), which researches future effects of climate change on water yield in the NSRB:

    - "There has been a decreasing flow trend over the past 50 years. This can be attributed in part to a natural cycle; however, the trend is also consistent with a warming climate.

    - The modeling of future river flows under climate change suggests that the total volume of water in the basin (mean annual flow) may not change significantly; however, more of the flow will occur in winter and spring. As peak flow shifts to earlier in the year and glaciers mass continues to decline, there is potential for significantly lower summer flows. These shifts in river flow correspond to climate change scenarios that project wetter warmer winters and longer drier summers.

- Climate change modeling also suggests that the range of flows could increase such that drought and flooding can be expected with greater frequency and severity."[21]

2. *The larger regional and global pictures appear to suggest an increased risk to all sources of water*. David Schindler, professor of Ecology at the University of Alberta, observes that at the same time water use and demand is growing, river flows in Alberta in summer are only 40 to 70 percent of historical values.[22] Most large glaciers in the headwaters of the NSR have shrunk by roughly 25% in the last century.[23] Research by Schindler and W.F. Donahue also indicates that predicted warming could increase evaporation by up to 55% in some regions of the western Prairie Provinces.[24] The Intergovernmental Panel on Climate Change says that over-allocated water systems in western Canada that rely on capturing snow runoff could be particularly vulnerable to the effects of climate change.[25] Projected future water shortages recently led the CEO of EPCOR to state that water management is a growing concern at home and abroad.[26]

3. *Collapse can happen precipitously and with little warning*. Melbourne, Australia, for example, saw its water reserves decline from 100% in 1997 to 30% today.[27]

   Edmonton currently has no reservoirs under its direct control. Typically, in most Canadian municipalities, ground level reservoirs and elevated tanks provide the necessary capacity to permit a constant rate of pumpage, with demand in excess of pumpage being provided from the reservoir system and surplus being transmitted to the reservoir system. In the short term, distribution storage facilities are important for meeting peak demands and allowing continued service when supply is interrupted, or in the event of catastrophic shocks such as large scale toxic chemical spills. To meet these basic short-term priorities, environmental engineering experts recommend that distribution storage volume, depending on system size and type, range from about one-half the average daily use, to the maximum daily use, to a 2- or 3-day supply.[28] However, there are presently no

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21 Cindy Shepel, Steph Neufeld, and Robert Raimondo, "The Need for Sufficient Water Supply," 2010 City of Edmonton – Way We Green Discussion Paper, available at: http://www.edmonton.ca/city_government/city_wide_initiatives/discussion-papers.aspx

22 David Schindler, "The Myth of Abundant Canadian Water," Canada Foundation for Innovation (1 March 2006), available at: http://www.innovationcanada.ca/en/articles/the-myth-of-abundant-canadian-water

23 David Schindler and W.F. Donahue, "An Impending Water Crisis in Canada's western prairie provinces," National Academy of Sciences, 103:19 (9 May 2006)

24 David Schindler and W.F. Donahue, "An Impending Water Crisis in Canada's western prairie provinces," National Academy of Sciences, 103:19 (9 May 2006)

25 Intergovernmental Panel on Climate Change, "Climate Change and Water: IPCC Technical Paper VI," IPCC Working Group II, p.102

26 Bill Mah, "'Scarcity of water is huge:' EPCOR CEO," The Edmonton Journal (7 May 2010), available at: http://www.calgaryherald.com/story_print.html?id=3000670&sponsor=

27 Phil Mercer, "Parched Perth embarks on water rescue," *BBC News* (2 February 2009), available at: http://news.bbc.co.uk/2/hi/science/nature/7859590.stm

28 Joseph Salvato, *Environmental Engineering and Sanitation*, New York: John Wiley and Sons (April 1992).

reservoirs within the City of Edmonton to ensure continued flow in case of shocks to the water system.

Edmonton's dependence on a single water source is therefore a major weakness in its capacity for future resilience to water related shocks and stresses, and a problem that is amplified by its aging infrastructure. For example, most components of the storm and sewer system were installed between 50 and 100 years ago, and in many areas of the City of Edmonton, storm surges can cause storm water to mix with waste sewers and overflow into the North Saskatchewan, thereby threatening the health and safety of residents. Outside of Edmonton's jurisdiction, the river basin does have two major water storage reservoirs, Brazeau Reservoir and Lake Abraham, but even these are experiencing shortages. As of 10 May 2010, the two reservoirs were at 3% and 15%, respectively, of total volume capacity, numbers that are consistent with measurements taken the previous year.[29] However, these reservoirs are not directly controlled by the City of Edmonton, and have no alternative means of access to water should the river between the City and the reservoir become compromised or contaminated.

All of these weaknesses are exacerbated by Edmonton's location in a naturally-occurring drought zone. Schindler notes that the prairie provinces have been plagued by drought for centuries.[30] In fact, the twentieth century was the wettest century of at least the last two millennia, and it is extremely unlikely that this anomaly will be repeated in the twenty-first century.

2.2.2 Food

Edmonton's capacity for resilience in its food system is significantly limited by both its geography and its climate. The average North American city has a two to three-day supply of fresh food in the event of a food shock such as a severe drought or widespread transport interruptions.[31] Although there are no studies that look at Edmonton specifically,[32] it is reasonable to think that due to its short growing season and substantial losses of its arable farmland area, it would depend more on food imports than the average Canadian city and probably have less than a two to three-day reserve of fresh food. Drought is also taking its toll on the resilience of the food system. A drought in the summer of 2009 caused stunted pasture growth and shortages of winter feed, which led Alberta beef farmers to consider thinning some of their herds even further just in order to stay in business.[33] And growing conditions around Edmonton are deteriorating.

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29 Alberta Environment, "Status of Major Water Storage Reservoirs," 10 May 2010.

30 David Schindler, "The Myth of Abundant Canadian Water," Canada Foundation for Innovation (1 March 2006), available at: http://www.innovationcanada.ca/en/articles/the-myth-of-abundant-canadian-water

31 Greater Edmonton Alliance, "The Way We Eat," available at: http://www.greateredmontonalliance.com/e107/page.php?9

32 Becky Lipton, "Food Security for Edmonton: Is It Really Something We Should Care About?" 2010 City of Edmonton – Way We Green Discussion Paper #7, available at: http://www.edmonton.ca/city_government/city_wide_initiatives/discussion-papers.aspx. p.4

33 Rod Nickel, "Drought could thin Alberta cattle herd," *Reuters* (26 June 2009), available at: http://www.canada.com/Life/Drought+could+thin+Alberta+cattle+herd/1737650/story.html

The droughts of 2003 and 2004 forced Alberta feedlot operators to import more grain than normal from the U.S. and other Canadian provinces.[34] In the long run, Barrow and Yu estimate that temperatures in Alberta could rise 2 to 4 degrees by 2020, 4 to 7 degrees by the 2050s, and 5 to 11 degrees by the 2080s.[35] Any rise in this range has the potential to drastically curtail Edmonton's ability to feed itself.

In addition to its position as a northern city in a drought zone, a lack of forward planning by past municipal administrations has also worsened Edmonton's capacity for resilience. Although Edmonton was blessed with good soils, it has seen 74% (17,000 Ha) of its Class 1 soils disappear since 1982, most of it under asphalt and suburban sprawl.[36]

2.2.3 Energy

The potential for rotating brownouts in Alberta is already a real weakness in Edmonton's capacity for energy resilience.[37] As Edmonton's population increases, and as the industrial heartland northeast of Edmonton continues to grow, the level of strain on the city's energy capacity will approach a critical point. The latest AESO analysis forecasts that demand for electricity in central and southern Alberta will grow by roughly 125 megawatts (MW) every year, the equivalent of adding a city the size of Red Deer (pop. 86,000) to the grid each year.[38] The AESO concludes that rising demand is stressing the existing system so much that capacity will fall short of its reliability requirements by 2014.[39] Edmonton's energy capacity is also weakened by its reliance on a small, remote grouping of power plants. As of 2007, generation facilities in Alberta's north accounted for three quarters of all power production in the province.[40] And much of this production comes from dirty coal-fired power plants. In fact, burning coal generates about 63% of Alberta's energy.[41] No other province consumes more coal to produce electricity than Alberta.[42]

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34 Alberta Barley Commission, "Welcome news on fusarium head blight," last accessed on 11 May 2010, available at: http://www.albertabarley.com/barley/feed/feed_research.html

35 Debra Davidson, "Climate Change: Projections & Implications for Edmonton," 2010 City of Edmonton – Way We Green Discussion Paper #6, available at: http://www.edmonton.ca/city_government/city_wide_initiatives/discussion-papers.aspx

36 Greater Edmonton Alliance, "The Way We Eat," available at: http://www.greateredmontonalliance.com/e107/page.php?9

37 Dina O'Meara, "Possible brownouts heat up Alberta power debate," *The Calgary Herald,* 25 September 2009, available at: http://www.nationalpost.com/opinion/story.html?id=2031720

38 AESO, "Edmonton to Calgary Transmission Reinforcement: Information Overview Brochure," available at: http://www.aeso.ca/transmission/15347.html

39 AESO, "Update: Edmonton to Calgary Project Background Information – July 2009," available at: http://www.aeso.ca/transmission/15347.html

40 AESO, "Edmonton to Calgary Transmission Reinforcement: Information Overview Brochure," available at: http://www.aeso.ca/transmission/15347.html

41 EUB Alberta Energy and Utilities Board, Vision 2006 http:// www.eub.ca/ docs/ products/ STs/ st41-2007.pdf

42 Tim Weis and Kristi Anderson, Pembina Institute, "Greener Energy Opportunities and Priorities for the City of Edmonton," 2010 City of Edmonton – Way We Green Discussion Paper #14, available at: http://www.edmonton.ca/city_government/city_wide_initiatives/discussion-papers.aspx

2.2.4 Transportation

Like most North American cities, Edmonton's transportation system is highly carbon-dependent, with automobile transportation being the primary means of transportation for both residents and goods and services. This presents a definite threat to the continued future flow of people and goods in the city's confines. However consideration also needs to be given to what impact peak oil will have on regional shipping and trade. As the Report of the City of Portland's Peak Oil Taskforce observes, "Transportation of freight will become more costly and either decline or shift modes from air and truck to rail and boat."[43] This will make land-locked cities like Edmonton particularly susceptible to supply shocks. Part of the solution to this problem requires diversifying sources of critical goods like food. But Edmonton will also have to consider ways to prepare for a world in which transoceanic and transcontinental trade will be different in kind (e.g. fewer trucks, more trains) and lower in intensity.

2.3 OPPORTUNITIES

2.3.1 Three Steps to Resilience: Mitigation, Preparation, and Adaptation

To help us better understand the existing opportunities in Edmonton, we outline three steps for developing the capacity for increased resilience: mitigation, preparation, and adaptation.

Mitigation: Mitigation requires developing strategies for reducing the magnitude of potential disturbances by addressing their underlying causes before they become disturbances. Edmonton responded relatively early and pro-actively to climate change concerns with the establishment of the CO2RE program, which set the goal of 20% reduction in greenhouse gas emissions compared to 1990 levels by 2020.[44] Last year, Edmonton took another positive step on this matter by passing a resolution urging federal action on climate change in advance of the world leaders climate summit in Copenhagen.[45] Many cities around the world are taking the lead in reducing their emission of greenhouse gases (GHG), sometimes in the absence of action by regional and national governments. Jan Corfee-Morlot et al. of the Organization of Economic Cooperation and Development note in a recent paper on cities, climate change and multilevel governance, that cities such as London, New York, and Tokyo have all set ambitious targets for reducing their contribution to global emissions.[46] The authors observe that cities have a wide range of policy options at their disposal for this purpose, such as encouraging savings in energy use, promoting renewable energy resources,

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43 Peak Oil Taskforce, "Descending the Oil Peak: Navigating the Transition from Oil and Natural Gas," Report of the City of Portland (March 2007).

44 Debra Davidson, "Climate Change: Projections & Implications for Edmonton," 2010 City of Edmonton – Way We Green Discussion Paper #6, available at: http://www.edmonton.ca/city_government/city_wide_initiatives/discussion-papers.aspx

45 City of Edmonton resolution, "International Agreement on Climate Change," 24 November 2009, available at: http://www.davidsuzuki.org/what-you-can-do/call-for-leadership/municipalities-show-leadership/

46 Jan Corfee-Morlot et al., "Cities, Climate Change and Multilevel Governance," OECD Environmental Working Papers N° 14, 2009

investing in comprehensive public transportation, infrastructure design, land use planning and zoning, and waste and green procurement programs.

Preparation: Preparation requires the anticipation of, and planning for a foreseeable disturbance before its effects are manifested. In order to prepare and develop capacity the disturbance must be probable and comprehensible. Preparation is always fraught with uncertainty, and politically complicated because constituents are being asked to invest in capacity-building that may not always appear to have an immediate or provable benefit. It is therefore important to capitalize on those resilience-building strategies that have a perceived immediate benefit. However, of all three steps, preparation is the most effective phase for building resilience capacity because it provides the greatest opportunity for decreasing the harmful impacts of the disturbance to a SES, and typically with the least cost. For example, preparing for the significant economic impacts of peak oil by heavily investing in public mass transportation would have a much greater likelihood of increasing the capacity for resilience of a city like Edmonton than scrambling to compensate for the effects after the fact by building a comprehensive mass transportation system after the debilitating effects of peak oil are fully realized, with their concomitant costs to the economy of the city. The earlier that a city prepares for impending threats, the less costs and damages it will be likely to incur. Conversely, failing to create capacity in a timely manner will increase the probability of incurring greater costs and damages, up to the point of system collapse.

Adaptation: Adaptation requires coping with disturbances once they have occurred. In this step, it is widely accepted that some structural changes introduced by climate change and peak oil are, to an extent, inevitable features of our social-ecological systems. In a sense, disturbances are no longer disturbances, but simply part and parcel of a new reality. Unlike preparation, which looks forward to foreseeable, but potentially fixable disturbances, adaptation accepts the existence of "a new normal," the persistence of disturbances that were previously uncommon or non-existent.

To take but one example, some municipalities around the world have already had to adapt to the effects of prolonged drought induced by climate change. Australia has been experiencing what is essentially one prolonged drought for over a decade that has been attributed to changes in the global climate.[47] Several years ago, officials in Perth estimated that it had only a short amount of time before the city became "unlivable."[48] Melbourne, meanwhile, saw its water reserves decline from 100% in 1997 to 30% today. Both cities had to undertake extreme conservation measures and other capacity-building measures in order to avoid total collapse.

Since many climate scientists, geologists, and industry observers think that the earth is already past the point of no return with respect to climate change[49] and peak oil,[50] adaptation is

47 Susan Carpenter, "Australian water crisis offers clues for California," The Los Angeles Times (15 January 2010), available at: http://latimesblogs.latimes.com/greenspace/2010/01/australian-water-crisis-provides-clues-for-california-at-gday-usa.html

48 Phil Mercer, "Parched Perth embarks on water rescue," BBC News (2 February 2009), available at: http://news.bbc.co.uk/2/hi/science/nature/7859590.stm

49 Spence Reiss, "Climate Change is inevitable – it's time to adapt," Wired (9 November 2009), available at: http://www.wired.com/magazine/2009/11/st_essay_globalwarming/

something every city needs to think about very carefully. Compared to preparation and mitigation, adaptation tends to be riskier and more expensive. Riskier, because the window of opportunity is smaller given the immediate need to build capacity as soon as possible, and more expensive because solutions usually take the form of megaprojects that can reach the greatest number of people in the shortest amount of time, such as the massive desalination plants that were constructed in recent years to sustain Perth and Melbourne, Australia. Furthermore, if cities wait to adapt, and pass on the chance to prepare and mitigate, they risk developing insufficient capacity for resilience and straying dangerously close to the point of collapse. To many environmentalists, policies that take a narrow focus on adaptive solutions represent a *moral hazard* because they do not do enough to address the possibilities for mitigation. Conversely, taking efforts to prepare and mitigate can help make the transition to adaptation less painful because such efforts help establish an infrastructural foundation to build upon under more dire circumstances. Establishing the necessary policy infrastructure – regulations, zoning requirements, steering committees, and other governance tools – will be as important to lessening the costs of adaptation as building the real infrastructure – bike paths, mixed-use developments, etc. This is important because adaptation also tends to be the phase that is most difficult politically, as well as most damaging to quality of life. In Perth, many dissatisfied residents reported feeling "restriction fatigue" after the first wave of conservation measures were implemented, and were reluctant to cooperate any further. Yet more restrictions were necessary, with the average resident being limited to 35 to 40 gallons of water a day, a target that could be more easily achieved if residents reduced their showers from seven minutes to four.[51] So while it might appear painful now to mitigate and prepare for the worst effects of climate change and Peak oil, it pales in comparison to the crippling costs and restrictions that are necessitated by adaptation.

2.3.2 Water

Edmonton has a good opportunity to piggyback efforts to build capacity in water resilience on the need to replace aging infrastructure. It can also use the need to make critical infrastructure upgrades as an opportunity to make investments that integrate important new components, such as reservoirs and wastewater reprocessing plants that can be used to more effectively conserve water. As the Prairie Adaptation Research Collaborative suggests, reservoirs could help Edmonton manage its water needs by balancing excess spring runoff with summer shortages that are expected to worsen with climate change.[52] Edmonton could also take the opportunity of updating its aging wastewater and storm sewer infrastructure to implement the development of neighbourhood based biological waste-water reprocessing centres ("living machines") that would allow water to be more effectively conserved and re-used.[53]

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50 Melinda Wenner, "Study: 'Peak oil' Will be Reached by 2018," LiveScience (18 April 2007), available online at: http://www.foxnews.com/story/0,2933,266764,00.html

51 Susan Carpenter, "Australian water crisis offers clues for California," The Los Angeles Times (15 January 2010), available at: http://latimesblogs.latimes.com/greenspace/2010/01/australian-water-crisis-provides-clues-for-california-at-gday-usa.html

52 Cindy Shepel, Steph Neufeld, and Robert Raimondo, "The Need for Sufficient Water Supply," 2010 City of Edmonton – Way We Green Discussion Paper, available at: http://www.edmonton.ca/city_government/city_wide_initiatives/discussion-papers.aspx

53 For a description of how Living Machines work, see: Living Machine, "How it Works," last accessed on 12 May 2010, available at: http://www.livingmachines.com/about/how_it_works/

2.3.3 Food

Growing food locally can be good business for a city. The Greater Edmonton Alliance (GEA) recently examined shifts towards greater local food production in other cities to see how a similar shift might impact Edmonton.[54] For example, a 20% shift to local foods in Detroit and five nearby counties resulted in 35,822 jobs and $3.4 billion in increased output, $900 million in increased earnings, and $155 million in increased business taxes. Extrapolating these results to Edmonton would result in 21,396 jobs, increased output of $2.1 billion, $540 million in increased earnings, and $92 million in business taxes.

Furthermore, temperature increases resulting from climate change could actually stimulate a longer growing season. The discussion paper on climate change cites a study that says Edmonton may experience up to 20% more days per year above 5°C by the 2020s, increasing to 50% by the 2050s.[55] However this opportunity would most likely be offset by damage to vegetation caused by more extreme summer temperatures. Therefore, climate-controlled hydroponic greenhouses could prove to be the best option for expanding the local food industry in Edmonton.

2.3.4 Energy

To reduce overall energy demand, the City could use its powers of encouragement and enforcement to promote low-rise, high-density, mixed-use residential developments. As the cost of fuels rise due to peak oil economics, there will be greater pressures to develop the downtown of Edmonton with higher densities. Low-rise (4-6 stories), high-density, mixed-use developments will allow people to live close to where they work and not need to drive. It will also improve the economy of the downtown core of Edmonton, making it a much more livable and vibrant community. These developments are especially important to consider as offshore manufacturing contracts due to the effects of peak oil. Since economists like Jeff Rubin predict that manufacturing will be re-localized to North America as shipping costs become prohibitively expensive, it will be crucial to have a policy framework in place that can accommodate the return of industry in ways that are resilient and environmentally friendly.[56] The city can also take action to improve the energy efficiency of new and existing buildings. The Capital City Downtown Plan recommends that the city adopt a Green Building Strategy, that would include strategic actions such as adopting a LEED™ target for new municipal buildings and building performance targets appropriate to Edmonton's environment.[57]

With respect to energy supply, Edmonton needs to do two things: strengthen the capacity of the regional grid system on which it currently depends for the vast majority of its electricity, and diversify its sources of electricity. Creating so-called "smart grids" that use computer technology capable of balancing loads between production and

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54 Greater Edmonton Alliance, "The Way We Eat," available at: http://www.greateredmontonalliance.com/e107/page.php?9

55 Debra Davidson, "Climate Change: Projections & Implications for Edmonton," 2010 City of Edmonton – Way We Green Discussion Paper #6, available at: http://www.edmonton.ca/city_government/city_wide_initiatives/discussion-papers.aspx

56 See: Jeff Rubin, *Why Your World is About to Get A Whole Lot Smaller*, Toronto: Random House Canada, 2009.

57 City of Edmonton, "Capital City Downtown Plan – Draft," 23 April 2010. p.65

consumption peaks are an important component of generating energy from unpredictable renewable sources like wind and solar, which vary based on day-to-day conditions. It's also important to update transmission systems in order to move renewable energy from distant sources to the places where it's needed most. One component of building the capacity for energy resilience in Edmonton is already underway. The Edmonton to Calgary Transmission Reinforcement project calls for the construction of two high-voltage direct current (HVDC) transmission lines between the cities.[58] The proposal calls for building two lines, which will add capacity for resilience and facilitate access between renewable energy zones and consumer markets.

As part of our Resilience Centre example, we consider how such localized, low-carbon electricity generation facilities can be integrated into the grid. A 2009 Electric Transmission Assessment Report on current and future transmission technologies commissioned by the Government of Alberta[59] found that underground or combined overhead-underground AC transmission lines, although imperfect, are well suited to short distance transmission in high-density urban environments where right-of-way for overhead is limited. Overhead-underground AC infrastructure already operates in Edmonton: underground cables connect the Bellamy Terminal Station near downtown Edmonton with the Argyll Transfer Station, which is linked by overhead cables to the Petrolia and Ellerslie substations. An advantage of underground transmissions is that they suffer from very few weather-related outages. Weatherproofing energy systems will become crucial for limiting the number of blackouts caused by extreme weather disturbances exacerbated by climate change. According to the Government report, underground transmission requires 100 per cent redundancy in the form of two parallel cable systems to ensure continued operation due to the considerable repair time if one of the cables malfunctions. As a key resilient design principle, we recommend that appropriate levels of redundancy be incorporated into all the generation and transmission systems that supply Edmonton's energy.

Furthermore, since these projects have to be sensitive to local impacts, we also recommend that Edmonton coordinate and collaborate with groups like Responsible Electricity Transmission for Albertans to ensure new energy developments have the endorsement of key stakeholders. The transmission of energy between local generation facilities should strive to minimize impacts and maximize public participation. This is consistent with the City's Municipal Development Plan, which sets out as an objective, "To promote citizens' quality of life in the planning and development of high voltage transmission lines."[60]

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58 Alberta Electric System Operator, "Edmonton to Calgary Transmission Reinforcement," last accessed on 10 May 2010, available at: http://www.aeso.ca/transmission/15347.html

59 Government of Alberta – Energy, "Electric Transmission Systems Study – Report Summary," available at: http://www.energy.alberta.ca/Electricity/1800.asp

60 City of Edmonton, "Municipal Development Plan," 20 January 2010.

2.3.5 Transportation

With respect to local transportation needs, the Edmonton's Transportation Master Plan identifies the need to expand existing Light Rail Transit (LRT) routes and add new ones. According to the master plan, "The ultimate LRT network could have six lines extending to the Northwest, Northeast, East, Southeast, South and West." The plan also has a focus on densification: "The LRT network has a focus to Downtown which aligns with The Way We Grow policies that aim to promote the growth of office employment opportunities across the city, with Downtown as the primary focus."[61] This will be an important resilience capacity-building development, as peak oil pushes up the cost of fuel and more people are forced to use public mass transit as their primary mode of transportation. Furthermore, the recently created Inner Ring Road highway system that provides a means of circulating traffic around the periphery of Edmonton provides the necessary infrastructure for the establishment of a high efficiency electric bus system that could serve as a collector system connecting to the radial branches of the existing and future LRT lines.

And more people can be expected to turn to active transportation, especially as measures are taken to encourage and support densification. In fact, surveys show that cycling trips in Edmonton have already increased by 150% between 1994 and 2005.[62] A key objective of Edmonton Transportation Master Plan is to make Edmonton a cycle-friendly city, and to that end, to improve the bicycle transportation network by integrating cyclists with the public transit system and provide end-of-trip facilities such as weather resistant storage facilities. The Capital City Downtown Plan proposes that a high profile bikeway system, featuring highly visible, segregated and shared cycling routes, should be a high priority for the city.[63]

At a regional level, we encourage the city to begin exploring ways that it can secure flows of people and goods. To the credit of the Transportation Master Plan, it identifies the need to effectively link its municipal transportation system into larger regional networks, with a special focus on rail: "For effective rail movements, efficient inter-modal facilities and travel throughout the city and Capital Region are required. The City will work cooperatively with its regional partners to facilitate this."[64] This is a positive step. Groups such as the US Association for the Study of Peak Oil & Gas (ASPO) recommend that our economies begin to switch as soon as possible from heavy diesel trucks to electric trains for our long-haul, overland transportation needs in order to prepare for peak oil and take advantage of the significant differences in their energy efficiencies. The ASPO estimates that every 20 British Thermal Units (BTUs) of diesel needed to ship freight by truck is equal to just 1 BTU of electricity need to ship the same freight by electric train.[65]

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61 City of Edmonton, "The Way We Move: Transportation Master Plan," September 2009. p.44

62 City of Edmonton, "Capital City Downtown Plan – Draft," 23 April 2010. p.133

63 "City of Edmonton, "Capital City Downtown Plan – Draft," 23 April 2010. p.38

64 City of Edmonton, "The Way We Move: Transportation Master Plan," September 2009. p.86

65 Alan Drake, "A 10% Reduction in America's Oil Use in Ten to Twelve Years," The Association for the Study of Peak Oil and Gas (9 July 2007), available at: http://www.aspo-usa.com/archives/index.php?option=com_content&task=view&id=168&Itemid=93

Eight Key Opportunities

As an immediate action plan, here are eight key opportunities that the City of Edmonton could explore for building the capacity for greater resilience that address the specific threats that the City faces in the future:

Opportunity 1: (Water) Edmonton could plan for the implementation of a comprehensive water reservoir system capable of providing a minimum 3-day water capacity for city residents.

Opportunity 2: (Water) Edmonton could plan for the implementation of neighbourhood based biological waste-water reprocessing ("living machines") that would allow water to be more effectively conserved and re-used.

Opportunity 3: (Food) Edmonton could develop a strategic plan for implementing local food production, which could include planning for the implementation of local food production greenhouses – these could possibly be associated with the co-gen district power stations (for heat and power). These local food production green houses could be scalable from a neighbourhood scale up to a district scale. A model for an urban 'Sky Farm' designed by Gordon Graff is one of many creative possibilities for boosting urban food production.[66]

Opportunity 4: (Energy) Edmonton could plan for encouraging and facilitating the development of low-rise (up to 5 storey), high-density, mixed-use residential in the downtown core to accommodate the shift of residents to the core in the future, as fuel prices rise.

Opportunity 5: (Energy) Edmonton could plan for facilitating the "re-skinning" of existing building to increase their energy conservation and reduce both their carbon footprint, and their operating costs. [67]

Opportunity 6: (Energy) Edmonton could plan for implementing small-scale district co-generation stations that can use mixed fuels (gas and biomass). These plants could be used in existing neighbourhoods, as well as in downtown neighbourhoods that would be increasing in density in the future.

Opportunity 7: (Transportation) Edmonton could plan for increasing mass transportation by supporting and accelerating the development of the LRT system, as well as implementing a future ring-road electric bus system that would serve to collect commuters from the more diffuse lower density residential neighbourhoods on the outer edges of the city, connecting them to the LRT lines at new intermodal stations that would link the LRT and bus routes together.

Opportunity 8: (General) Many cities have benchmark themselves against the Livable Cities Index. As a future leader in resilience, Edmonton could consider developing an index of future resilience to measure itself against other comparable cities.

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66 Murray Whyte, "Is highrise farming in Toronto's future?" *The Toronto Star* (27 July 2008), available online at: http://www.thestar.com/article/468023

67 ZeroFootprint Foundation, "Zerofootprint unveils winners in 2010 ," (24 March 2010), available at: http://www.zerofootprintfoundation.org/press/single/zerofootprint-unveils-winners-in-2010-building-re-skinning-awards/

RESILIENCE CENTRES

One proposed example of how some of the Opportunities for Resilience might be realized.

In the T.W.O.S. section above, we undertook a system-by-system examination of possible opportunities for building resilience capacity. In the example that follows, we would like to sketch out how the City of Edmonton might be able to implement some of the key opportunities discussed by implementing a city wide program for development of what we have termed "Resilience Centres" – neighbourhood infrastructure which integrates opportunities for capacity-building in three critical systems – water, energy, and food – into a single, self-contained unit.

These "Resilience Centres" would consist of the integrated use of a district co-generation, able to burn both natural gas and biomass as fuel; a biological waste water reprocessing unit (often referred to as a Living Machine); and a hydroponic greenhouse for food production. These centers could be implemented at either a neighbourhood scale or a district scale, or both. These Resilience Centres would provide the following benefits:

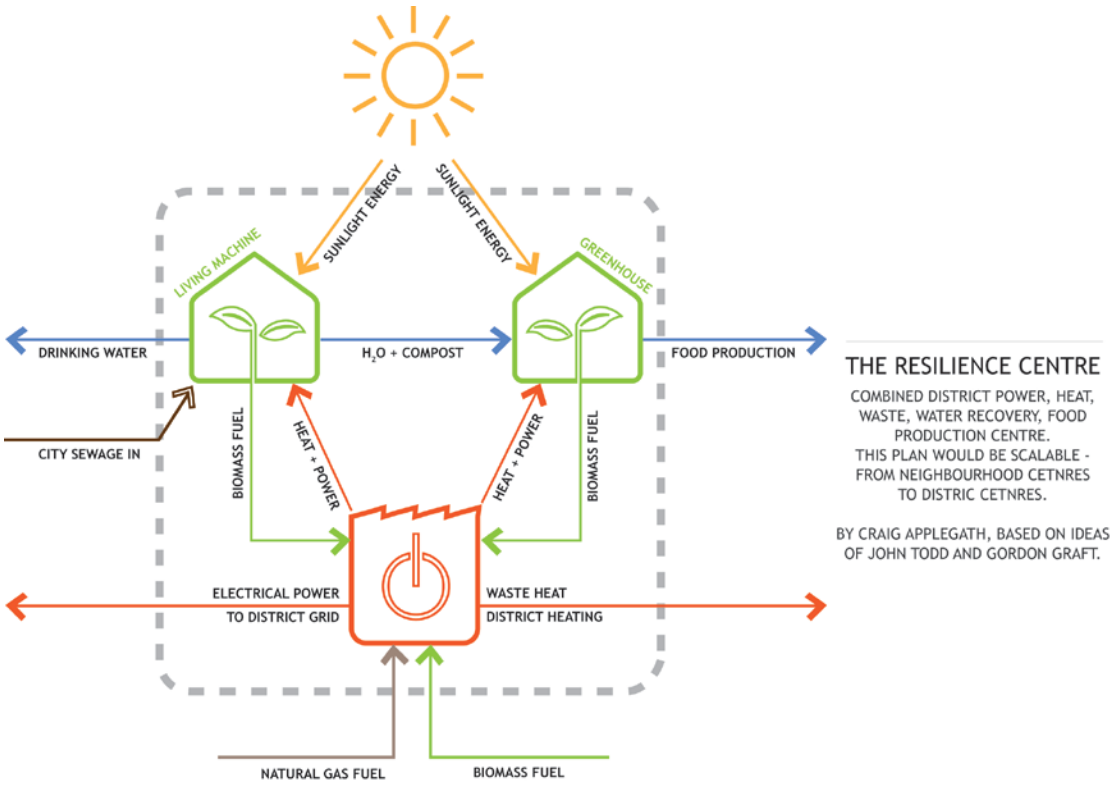
- Reprocessing and conservation of water – potable water could be extracted from waste water.
- Creation of biomass for use as fuel and as compost
- Creation of district electrical power – from either natural gas or biomass
- Creation of district heat – as a biproduct of the creation of electricity
- Creation of food – as a bi-product of waste heat, and compost.

Tim Weis and Kristi Anderson note in their discussion paper on green energy opportunities in Edmonton that there is an abundance of wood pellets produced in northern Alberta, much of which is currently shipped to Scandinavia, that could be used for biofuel in a district heating system much like the one we propose. They also point to Enoch reserve, just west of the city, which contains a massive quantity of wood waste that could be used to power this system.[68]

A diagram of how this Resilience Centre would function is shown in Figure 7.

68 Tim Weis and Kristi Anderson, Pembina Institute, "Greener Energy Opportunities and Priorities for the City of Edmonton," 2010 City of Edmonton – Way We Green Discussion Paper #14, available at: http://www.edmonton.ca/city_government/city_wide_initiatives/discussion-papers.aspx

Figure 7 – Resilience Centre Diagram

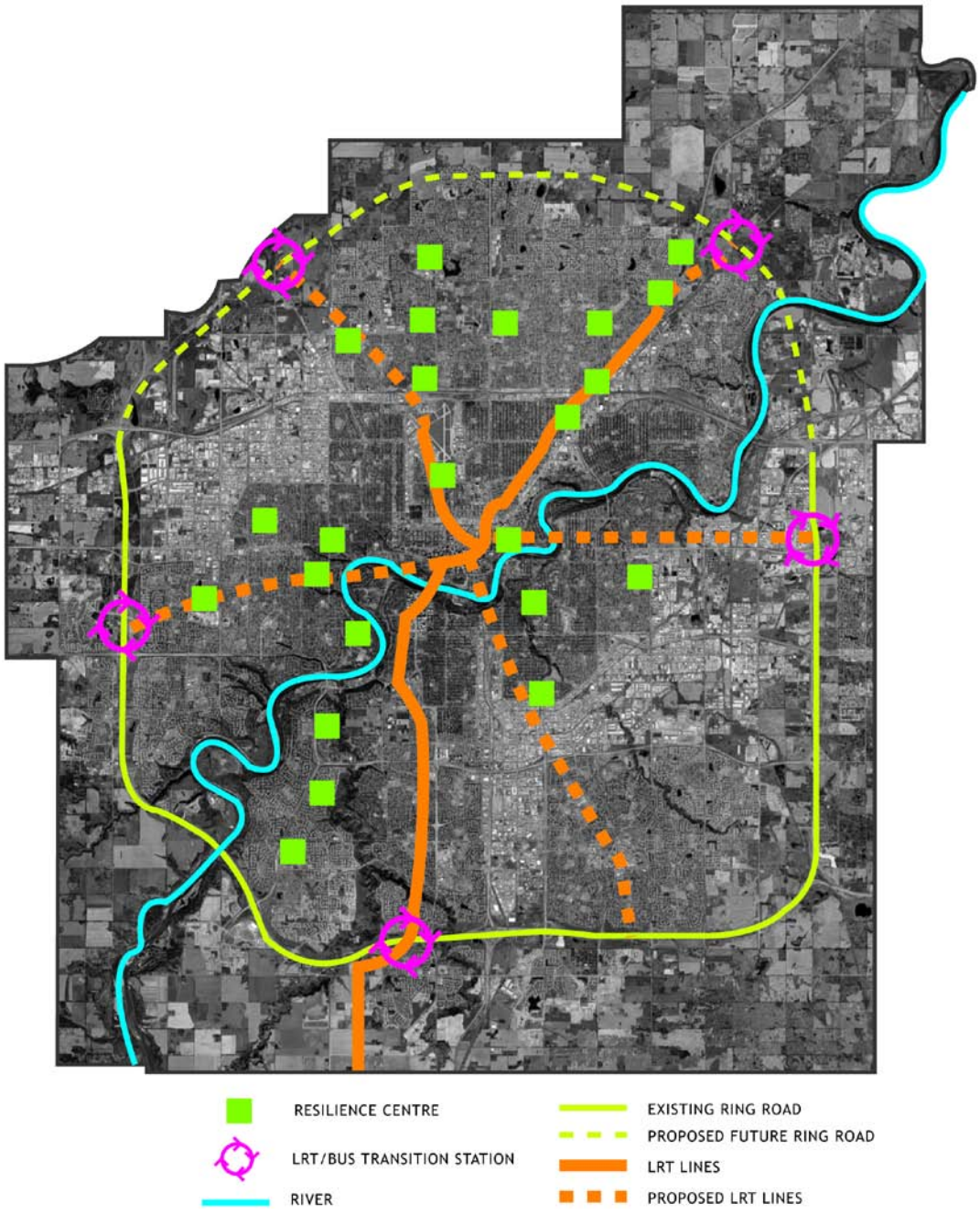


The development of Resilience Centres would not only contribute to the mitigation of climate change-related disturbances, they would also prepare the city's core systems for the emerging post-carbon economy. They would add redundancy and diversity to the city's critical systems – key principles of resilient design. They would also incorporate key principles of urban design in resilient cities. Resilience Centres support higher densities and aging infrastructure, as well as the impending need for food re-localization. The flexibility of Resilience Centre's design allows for components to be added and subtracted as needed, depending on micro-level conditions. For example, the extensive oil refinery operations in Refinery Row in the South West end of Edmonton produce a tremendous amount of hot water that could be used for district heating. In fact, just next-door is Sherwood Park, an industrial park that could be heated with this waste heat. A modified Resilience Centre could take advantage of this wasted heat, capturing it for greenhouses that could be set up for the production of food. As a discussion paper by the Pembina Institute observes, this kind of co-generation offers considerable potential for reducing emissions because it is highly efficient, loses less power from transmission, and burns biomass or natural gas, which produces as much as 50% fewer greenhouse gas emissions than coal-burning.[69] And the emphasis on district power provides the city a chance to promptly address priority areas with more urgent problems instead of waiting for larger, more distant power plants

69 Tim Weis and Kristi Anderson, Pembina Institute, "Greener Energy Opportunities and Priorities for the City of Edmonton," 2010 City of Edmonton – Way We Green Discussion Paper #14, available at: http://www.edmonton.ca/city_government/city_wide_initiatives/discussion-papers.aspx

to come online. For example, the South West and North East of Edmonton has experienced brownouts due to insufficient power supply. Using a Resilience Centre to provide district power in the four quadrants of Edmonton would allow the city to address this problem immediately.

Figure 8 – Strategy Map showing location of machines



2.4 STRENGTHS

2.4.1 Water

Edmonton's inclining block pricing system for water has been credited with encouraging conservation among households, and as a result the city has one of the lowest per capita water consumption rates of any Canadian municipality, 15% lower than the national average.[70] The average Edmontonian uses 230 litres per person, per day for indoor and outdoor use.[71] While impressive, these indicators mask serious threats to Edmonton's water capacity. Also, since industry greatly exceeds households in quantities of water consumed, household gains in conservation make a relatively small impact overall.[72]

Another strength is the existing governance framework for the NSRB, and in particular the North Saskatchewan Watershed Alliance. There is broad acknowledgement from key stakeholders that management of the NSRB needs to reflect impending threats and existing weaknesses. This is reflected in the Government of Alberta's 2009 Water for Life strategy paper, which states that the province, "will address vulnerabilities by fostering municipal resiliency through sustainable waterworks infrastructure, effective operations, and preparedness." The paper features several "Key Actions" that pertain directly to the resilience of the province's water supply, notably Action 3.2: "Develop strategies to deal with the management of changing future water supplies through the provincial Climate Change Adaptation Strategy."[73]

2.4.2 Food

"The Way We Eat," a recent report from the Greater Edmonton Alliance (GEA),[74] finds that 17% of Alberta land is good for farming, mostly in the Edmonton to Calgary corridor along with 75% of Alberta's population. It also finds that within its city limits, Edmonton is gifted with prime agricultural soils (Class 1, 2, & 3), a longer growing season than anywhere else in Central or Northern Alberta, and more moisture than southern Alberta. While much of the black soil has been paved over, pockets still remain that could be used for urban greenhouses as well as rooftop and outdoor community gardens exist throughout the city.

The GEA and other groups such as Just Food Edmonton represent a groundswell of public interest and activity in locally produced food. The Community Garden Network has grown from just 11 community gardens in 1998 to 51 gardens in 2006. Overall, these

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70 City of Edmonton, "City's Water Pricing and Conservation Wins National Acclaim," 24 February 2009, available at: http://www.edmonton.ca/city_government/news/11469.aspx

71 EPCOR, "Average household water use," last accessed 10 May 2010, available at: http://www.epcor.ca/en-ca/customers/water-customers/efficiency-tools-tips/water-efficiency-tips/pages/average-household-water-use.aspx

72 John Thompson, AMEC Consulting, "Current and Future Water Use in the North Saskatchewan River Basin," available at: http://nswa.ab.ca/content/presentations

73 Government of Alberta, "Water for Life: Action Plan," (November 2009).

74 Greater Edmonton Alliance, "The Way We Eat," available at: http://www.greateredmontonalliance.com/e107/page.php?9

gardens represent over 530,000 square feet of land in the city and are cared for by an estimated 2,500 people each season.[75] The city has taken positive steps towards using its governance capacity to strengthen this local food movement. City council recently passed motions ensuring strategies to preserve remaining farmland will be instituted before the land can be re-zoned or developed. Specifically, approval for developments in the northeast, southeast, and southwest sections of the city can only be granted following council acceptance of and adherence to the City Wide Food and Agriculture Strategy.[76] Furthermore, the Municipal Development Plan directs Edmonton to work collaboratively with the community to create and endorse an Edmonton Food Charter, and with regional partners including the Government of Alberta to develop a Regional Food Policy Council and Food Charter.[77]

As the food security discussion paper notes, Alberta is rich in farming know-how. Although the average farmer is getting older, the paper is hopeful that sustainable agriculture apprenticeship programs can generate interest in innovative, small-scale, local farming among urbanites.[78]

2.4.3 Energy

Edmonton has great potential for generating clean energy locally. Spaces around the city that were once railroads and rail yards would make ideal locations neighbourhood-scaled district power stations that could be powered with a combination of natural gas and biomass fuels. The city's northern climate should not be treated as an insurmountable barrier to developing integrated networks of renewable energy in the city. In fact, Edmonton has a better solar energy resource than a city as far south as Toronto; it also has better solar potential than Berlin or Tokyo.[79] The Drake Landing Solar Community[80] in Okotoks, Alberta amply demonstrates that a social-ecological system situated in a climate like Edmonton's is capable of meeting its heating needs using locally produced renewable energy. The community is supported by 800 solar panels situated across its 52 energy-efficient homes. A district heating system stores surplus energy underground during summer months and transfers it to the homes for space heating during winter months. Even in the case of unusually harsh winters, the community supplies between 80 and 90 per cent of its heating needs with solar energy. In fact, Alberta is already somewhat of a green energy leader compared to other Canadian provinces.

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75 Scott Harris, "This is the new Green Revolution," *Vue Weekly* (1 June 2006) available at: http://www.vueweekly.com/article.php?id=3910

76 Just Food Edmonton's Blog, "Protecting Edmonton's Food Security," 23 November 2009, available at: http://justfoodedm.wordpress.com/2009/11/23/protecting-our-ability-to-produce-local-food/

77 City of Edmonton, "Municipal Development Plan," 20 January 2010. p.100, 101

78 Becky Lipton, "Food Security for Edmonton: Is It Really Something We Should Care About?" 2010 City of Edmonton – Way We Green Discussion Paper #7, available at: http://www.edmonton.ca/city_government/city_wide_initiatives/discussion-papers.aspx

79 Tim Weis and Kristi Anderson, Pembina Institute, "Greener Energy Opportunities and Priorities for the City of Edmonton," 2010 City of Edmonton – Way We Green Discussion Paper #14, available at: http://www.edmonton.ca/city_government/city_wide_initiatives/discussion-papers.aspx

80 For more information, see: The Drake Landing Solar Community homepage, available at: http://www.dlsc.ca/index.htm

For example, Alberta is a national leader in wind generation, with about 5% of its generated from wind farms.[81] The participation of active citizens' groups like Responsible Electricity Transmission for Albertans is also considered an important strength in this area because they demonstrate grassroots interest in the development of safe, clean energy.

2.4.4 Transportation

There are numerous strengths Edmonton can capitalize on to improve its capacity for resilience in transportation. A major strength is its existing infrastructure. This includes the Inner Ring Road, which could in future facilitate an integrated network of electric buses; a system of wide roads that could be repurposed to incorporate mass public transit and active transportation; and electrical outlets in a majority of parking facilities(which now support traditional internal combustion engines from freezing during winter) but could also eventually serve as recharge points for electric cars.

2.4.5 A Strong Community: The key to a Resilient City

Beyond the strengths that pertain directly to its critical systems, we find a number of other impressive community attributes that make Edmonton well positioned to mitigate, prepare for, and adapt to impending shocks and stresses of climate change and peak oil. There are encouraging signs of densification, as construction in the downtown rose considerably between 2001 and 2006, representing 26% of total growth in the city compared to just 5% in the previous five years.[82] Also, it is anticipated that the City of Edmonton's population will exceed one million people in the next thirty years, while the Census Metropolitan Area will expand to roughly 1.6 million people.[83] While this influx of new residents will place more strain on existing infrastructure and public services, a growing population will also add to the tax-base and give the city an opportunity to invest in new infrastructure that could help build capacity.

Edmonton also has a strong system of education, training, and research institutions, including the University of Alberta and Northern Alberta Institute of Technology (NAIT). As a result, Edmonton has a large, skilled labour force and a strong concentration of knowledge capital. Debra Davidson's paper on climate change implications for Edmonton notes that 20% of the city's adult population holds a university degree.[84] Davidson also observes that Albertans express high levels of civic commitment, with 77% of respondents in a recent study indicating that they were either 'likely' or 'very likely' to stay in their community in the event of a weather or economic crisis.[85]

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81 Claudia Cattaneo, "Irish like 'wind-rich' Alberta," *The National Post* (13 March 2009).

82 City of Edmonton, "Neighbourhood Profile – Downtown," (2006)

83 City of Edmonton, "The Way We Move: Transportation Master Plan," September 2009

84 Debra Davidson, "Climate Change: Projections & Implications for Edmonton," 2010 City of Edmonton – Way We Green Discussion Paper #6, available at: http://www.edmonton.ca/city_government/city_wide_initiatives/discussion-papers.aspx

85 Debra Davidson, "Climate Change: Projections & Implications for Edmonton," 2010 City of Edmonton – Way We Green Discussion Paper #6, available at: http://www.edmonton.ca/city_government/city_wide_initiatives/discussion-papers.aspx

EDMONTON LRT

Section 3 Moving Forward: Solidifying Edmonton as a Livable and more Resilient City

3.1 Resilience Capacity Building Prioritization Tools

All potential threats, stresses and shocks are not equal in either probability of occurrence, nor of their economic impact on a city. Therefore, some careful prioritization of how to allocate resources for building resilience capacity will be required of any government looking to create a more resilient municipality or region.

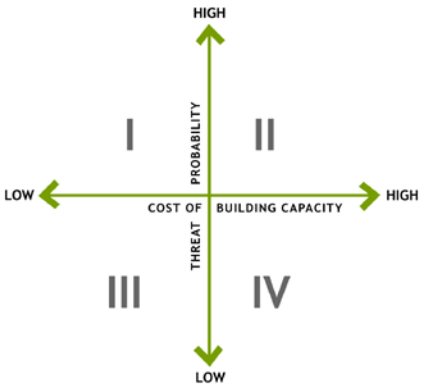
Although the scope of this paper is limited to a broad overview of defining the concept of resilience, and pointing to some of the key opportunities for increasing resilience capacity in the City of Edmonton, it is nevertheless worthwhile to at least suggest a couple of tools to assist the City in prioritizing the opportunities for building resilience as discussed in this paper.

We would suggest that as the City of Edmonton explores the various options for developing resilience, that it consider prioritizing these options based on the following three criteria:

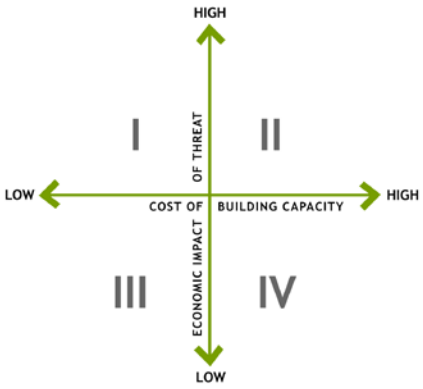
1. The probability of the threat (stress or shock) being considered
2. The economic impact of the threat
3. The cost to build the capacity for resilience

Particularly useful is to understand the relationship of criteria 1 and 2 in relation to criteria 3. This relationship produces to quadrant maps that can be helpful in prioritizing opportunities.

Figure 9 – Threat Impact Quadrant Diagrams



PROBABILITY OF THREAT
VS.
COST OF BUILDING CAPACITY
FOR RESILIENCE



ECONOMIC IMPACT OF THREAT
VS.
COST OF BUILDING CAPACITY
FOR RESILIENCE

Given that every government is faced with marshalling limited resources to accomplish the greatest benefit to society, as the opportunities are examined within the four quadrants of each map above, it is easier to see which opportunities might be most appropriate for acting upon.

In both maps, opportunities that fall into quadrant I are the first and best choices, with the opportunities that fall into quadrant II being as important and beneficial, but coming with a higher price tag.

Opportunities falling in quadrants III and IV should probably be avoided, as producing either too little benefit, or too little benefit with too high a cost.

Some careful thought should be given to establishing benchmarks for the quantification of these axises, something that is both a comparative exercise, and a political exercise.

3.2 Looking Forward

Urban Design Principles

To effectively meet the future stresses associated with climate change and peak oil the City of Edmonton will want to adopt urban planning and design principles that not only improve the livability of the city, but also significantly contribute to the building of future resilience. Many of the urban planning practices that most municipalities now take for granted, such as planning cities around automobile transportation, and zoning for single uses, are no longer economically and environmentally viable. To assist the City of Edmonton in building the capacity for future resilience we propose the following urban planning and design principles. [86]

3.2.1 Density, Diversity and Mixed-use

Resilient Cities and neighbourhoods will need to embrace density, diversity and mix of uses, users, building types, and public spaces.

Creating resiliency and reducing the carbon footprint of urban development requires the use of space and land to be maximized. Single use low-density residential neighbourhoods and suburban business parks are typically underutilized during long periods of the day. A vibrant and sufficiently densely populated urban environment, by contrast, is well used round-the-clock, all days of the week, and during all seasons. This results from a closely knit mix of uses (e.g. offices, residences, coffee shops etc.), with sufficient density, and which are accessible to a diversity of users (e.g. children, youth, seniors, high-income, low-income,etc.). Dense mixed-use neighbourhoods also support the effective functioning of all types of businesses, and social and cultural activities requiring much lower inputs of energy for transportation and logistics than low-density neighbourhoods, thus increasing the future resilience of these neighbourhoods to energy stresses and shocks.

86 from www.ResilientCity.org Urban Design Prinicples written by Craig Applegath and Antonio Gomez-Palacio 2009

3.2.2 Pedestrians First

Resilient cities and neighbourhoods should prioritize walking as the preferred mode of travel, and as a defining component of a healthy quality of life.

Reducing car dependency is a key objective and imperative. Luckily, the alternative modes of transportation – namely walking, cycling, and transit – result in more sustainable urban environments, and in an improved quality of life. It are the cities and neighbourhoods that have prioritized walking, that have created desirable locations to live, work, play, and invest in. (The term pedestrian, as used in these principles, includes persons with disabilities.)

3.2.3 Transit Supportive Planning

Resilient cities and neighbourhoods should be planned and developed to be transit supportive.

After walking and cycling, public transit is the most sustainable mode of transportation. Resilient cities will need to re-orient their way of thinking, by shifting from car oriented urban patterns (e.g. cul-de-sacs and expressways) to transit oriented urban patterns and developments (e.g. mobility hubs, and intensified corridors). Not only will pedestrian, and mass transportation friendly planning increase the quality of life of a cities, as fuel prices rise after peak oil, only cities that are viable without heavy dependence on the car will have the best chances of economic and social success.

3.2.4 Place-Making

To increase its resiliency, Edmonton should focus energy and resources on conserving, enhancing, and creating strong, vibrant places, which are a significant component of the neighbourhood's structure and of the community's identity.

All successful cities and successful neighbourhoods include vibrant places, with a strong sense of identity, which are integral to community life and the public realm: parks, plazas, courtyards, civic buildings, public streets, etc.

A resilient community, which reorients city-life to the pedestrian scale (a 500 m radius), must focus its efforts on creating a number of local destinations, which attract a critical-mass of users and activities. Sprawl has very little place-making, whereas traditional villages or an urban downtown, by contrast, have innumerable nocks and crannies, grand public spaces, beautiful streetscapes, which all contribute to making them desirable, successful, and sustainable.

Heritage resources – buildings, structures, and landscapes – represents a significant opportunity for place-making (i.e. through their cultural significance and identity), as well as a significant environmental investment (i.e. through their embedded energy) that should be conserved and leveraged.

3.2.5 Complete Communities

Resilient neighbourhoods should provide for the needs of daily living, within walking distance (a 500 m radius).

Resilient communities, reduce their carbon footprint by ensuring people opt to walk or cycle, instead of using a car. To achieve this, destinations must be accessible within a pleasant walking distance – people should be able and willing to walk from home to work, to school, to shop, to recreate, and to engage the activities of their everyday life. Longer distances should be achievable through transit.

Connectivity is central to making an area pedestrian oriented. Streets and pedestrian walkways must be enjoyable to walk, must link key destinations, and must operate at a fine scale. Communities must also be compact and concentrate a critical-mass of people and activities to support walking, and to support animated and vibrant place-making.

3.2.6 Integrated Natural Systems

Resilient cities and their neighbourhoods should conserve and enhance the health of natural systems and areas of environmental significance, and aim to mitigate the impacts of climate change.

Our individual and collective health is intricately tied to the health of air, water, land, and climate. How we choose to live, how we choose to move around, how we develop land, all have an impact on the quality of the air we breathe, the water we drink, and the weather we experience. Cities and neighbourhoods need to develop in a way that conserves and enhances the quality of the water flow and supply, likewise for the quality of air and land. Climate is, increasingly, a key driver to transforming our development patterns and living choices. Action on this front is imperative.

The health and integrity of wildlife and vegetation are also a priority. Protecting existing biodiversity, indigenous or endangered species, wetlands, the tree canopy, connectivity, are all a necessary aspect of securing healthy natural systems.

3.2.7 Integrated Technical and Industrial Systems

Resilient Cities and neighbourhoods should enhance the effectiveness, efficiency and safety of their technical and industrial systems and processes, including their manufacturing, transportation, communications and construction infrastructure and systems to increase their energy efficiency, and reduce their environmental footprint.

The economic health and vitality of cities is inextricably bound up with the effectiveness, efficiency and safety of its technical and industrial systems and processes. The importance of reducing negative environmental impacts of economic activities and processes, as well as reducing their dependence on fossil fuels will require us to develop more integrated and more highly efficient industrial processes and technical systems that ensure a maximum of efficiency in the use of both materials and energy resources, as well as the elimination of all wasteful and potentially harmful bi-products.

Technical and industrial uses need to be integrated into the city in ways that allow them to make the most efficient and synergistic connections and associations with similar and complementary uses that will design for waste products from one industry or technical process (such as heat energy) to be effectively used as a beneficial input in another industry or technical process, thus increasing the overall efficiency of the city as a system, while reducing the creation of harmful and/or wasteful bi-products.

The health and integrity of the neighbourhoods that these technical and industrial systems are part of is also a priority for a Resilient City. The strategic integration of industrial and technical systems into mixed use neighbourhoods should be planned so as to produce not only better economic performance, but also to create easily accessible and safe working environments, healthy surrounding neighbourhoods, and no negative impacts on the natural environment.

3.2.8 Local Sources

Resilient regions, cities, and neighbourhoods should support and encourage growing, producing, and manufacturing, the resources they need, in close proximity (200 kilometre radius).

The environmental cost of the movement of goods and energy increases every day. Thus, populations must seek to satisfy their consumption needs from local and regional sources. The '100-mile diet' has increased awareness of the importance of consuming local products, to decreasing our carbon footprint. The same principle that applies to food, also applies to the production of energy (e.g. district energy, district heating), recreation needs (i.e. 100-mile tourism), waste disposal, water management, and any other resource which we consume or dispose of.

3.2.9 Engaged Communities

The development of resilient cities and neighbourhoods will require the active participation of community members, at all scales.

From the seemingly trivial activities of everyday life (e.g. using a plastic bag) to the overtly transformational (e.g. growing the city), citizens have a role to play and a responsibility. It is only through the sum total of individual choices, of individual actions, that change will come about.

Residents and stakeholders must be part of planning and designing their cities and their communities. They must also be part of delivering a new vision: by choosing to walk, by engaging each other, by generating awareness, and by demanding higher standards.

3.2.10 Redundant and Durable Life Safety and Critical Infrastructure Systems

Resilient Cities and neighbourhoods should plan and design for redundancy and durability of their life safety and critical infrastructure systems. Planning and design of these systems will aim for levels of redundancy and durability that are commensurate with the increasing environmental, social, and economic stresses associated with the impacts of climate change and peak oil.

The physical, social and economic health of the Resilient City and its citizens is directly connected to the city's ability to maintain the effective functioning of its key life safety and critical infrastructure systems – especially during episodes of intense environmental stress (such as during severe storms, floods, or other weather related events). Key infrastructure systems such as drinking water supply, electrical power, and residential heating in winter, and key life safety systems, such as police, fire, and emergency

response services and their support systems, must be planned and designed for a level of redundancy and durability that will allow them to be durable enough to resist present and future environmental stresses, as well as to have enough redundancy built into their design to allow the system as a whole to remain sufficiently functional and intact that if one or more constituant parts of the system is compromised, the system as a whole will nevertheless remain operational and able to provide the necessary outputs or services.

3.2.11 Resilient Operations

Resilient cities and neighbourhoods should develop building types and urban forms that provide for reduced servicing costs, and reduced environmental footprints.

Urban sprawl is extremely expensive to service and maintain – the amount of land, roads, pipes, and infrastructure required per capita is disproportionately large. A compact, mixed-use urban environment, by contrast, is far more efficient in its demand for municipal services and infrastructure requirements. Resilient cities will not subsidize inefficient forms of development (e.g. building roads and assuming operating costs) and instead prioritize city patterns and built forms that have a reduced footprint on the environment and a reduced burden on municipal resources (e.g. directing growth to where services exist: infill).

Given the complexity of these issues discussed, we contained our paper to a high level overview of key ideas and possibilities. Therefore, we recommend that the City of Edmonton consider further exploration of resilience in terms of its needs and resources, and in consultation with important stakeholders, at a later date

Our proposals intend to lessen Edmonton's carbon footprint and help mitigate the impact of climate change and Peak Oil, as well as prepare the city for foreseeable disturbances ahead of the need to take more radical steps for adaptation – and, given the emerging consensus around peak oil and climate change, to better prepare the city for those adaptations that it eventually must make. Although our proposals focus predominantly on the opportunities to develop real infrastructure, we encourage the City of Edmonton to further explore what steps it can take to develop the policy infrastructure needed to implement these plans. ■