FUTURE PROOFING CITIES

STRATEGIES TO HELP CITIES DEVELOP CAPACITIES TO ABSORB FUTURE SHOCKS AND STRESSES

BY CRAIG APPLEGATH, FRAIC // FOUNDER OF RESILIENTCITY.ORG // 2012
Craig Applegath, a Principal with DIALOG, is an accomplished architect and urban designer. Since earning a Master of Architecture in Urban Design from Harvard University, Craig has garnered a reputation for successfully leading complex institutional planning and design projects. He is recognized for his design and business acumen, advocacy of environmentally integrated design, and thought leadership in the field of urban resilience.

In addition to his project and practice responsibilities, Craig is extra-ordinarily active within his industry and the community at large. He is a sought after writer and lecturer who regularly presents at major conferences in Toronto, Montreal, Chicago and San Francisco. As a futurist and leader, Craig is passionate about finding design solutions that make sense in a world of energy scarcity and climate change. He was a founding Board Member of Sustainable Buildings Canada and served as the President of the Ontario Association of Architects. These and other accomplishments led to Craig being named a Fellow of the Royal Architectural Institute of Canada.

Most recently, Craig has been credited with boldly articulating and advancing the resilient cities approach. He is currently a member of the Canadian Green Building Council and a founding member and current moderator of the ResilientCity.org website. The Resilient Cities Toolkit content and unique participatory design are informed by Craig’s research, professional practice and desire to truly engage urbanites in conversations that celebrate cities while finding solutions for tomorrow’s challenges.
Cities are variously embracing sustainability principles, yet it is ever more apparent that they will face external shocks and stresses regardless.

Rising energy prices are creating economic reverberations as global demand rapidly outstrips supply. Severe Category 5 weather events have increased tenfold. Debt-laden governments struggle to replace aging urban infrastructures. Cities face a myriad of potential future shocks—sudden, major breakdowns—and stresses—slow, insidious cracks.

To meet these challenges, cities must become more resilient. The notion of resilience in ecology was first introduced by the Canadian ecologist Dr. C.S. “Buzz” Holling. In the book *Resilience Thinking, Sustaining Ecosystems and People in a Changing World*, Brian Walker and David Salt define resilience as: “The capacity for a system to absorb disturbance and still retain its basic function and structure.” At ResilientCity.org we define urban resilience as “the capacity of a city’s economic, social, political and physical infrastructure systems to absorb shocks and stresses and still retain their basic function and structure.”

This toolkit outlines six approaches to increasing resilience capacity that planners and designers can deploy to build more resilient cities. It comprises a set of conceptual tools to kick start the thinking and DIALOG required to implement action. There are other approaches to increasing the resilience capacity of a city—emergency response, communication systems, etc.—but this toolkit is focused on the approaches that can be directly implemented or influenced by planners and designers. The format is modular—it can be taken apart, rearranged, added to, or subtracted from.
WHAT IS A RESILIENT CITY?

+ CHALLENGES TO RESILIENCE
  - Population growth + migration
  - Climate change
  - Energy scarcity
  - Income disparity
  - Socio-political
  - Environmental degradation

ATTRIBUTES OF RESILIENCE
  - Flexibility
  - Redundancy
  - Diversity
  - Decoupling
  - Decentralization
  - Environmental integration

APPROACHES FOR RESILIENCE
  - Growth + Density
  - Energy Performance
  - Local Food Production
  - Modularization Key Infrastructure
  - Integrated Metabolism
  - Infrastructure ‘Hardening’

It is important to note that this is not an attempt to create an ersatz taxonomy for a very complex set of interrelationships. Building the capacity for resilience is an emergent behaviour and the six proposed approaches are not exhaustive. They are simply the evolution of our thinking to date in response to the six big challenges we see and the six attributes of resilience we have gleaned. That they are all sixes is coincidental and certainly not symbolic. We hope they are the first step toward developing a series of lenses for understanding and platforms for action.
WHY?
Some 50% of the world’s population lives in cities, and about 75% of the world’s energy consumption occurs in urban areas. However, dense urban centres use 1/3 the energy of suburbs. As the global population swells to an estimated 9 billion people in the next 25 years, it will be critical to embrace density. Density lowers the per capita costs of infrastructure capital and operating costs, and reduces per capita use of all types of energy—including energy for transportation and heating and cooling buildings. In this sense, density is the keystone of resilience.

HOW?
Density does not mean a monolithic city of skyscrapers. We need to optimize density throughout the city. There is much debate around how little density is appropriate but, as a rule of thumb, a minimum of 50 dwellings per hectare is necessary to support public transit. This is acceptable at the outskirts of a city, but densities should increase closer to the core to allow for medium rise densities of four to six stories. Core densities should be as high as the market will allow, with densification development providing the revenues for associated infrastructure renewal.

WHO?
In the 1930s, Max Kleiber discovered the law of animal metabolism: as life gets bigger its metabolism tends to decrease exponentially. Intrigued by this finding, theoretical physicist GEOFFREY WEST applied the formula to cities. It turns out cities are just big organisms, with infrastructure such as transportation, road surfaces, electrical cable, water piping and sewers all scaling according to Kleiber’s law. Given a city’s population, West can estimate the dimensions of its sewer system, the income of its citizens, the crime rate, or even the number of patents per capita with 85% accuracy.

WHAT?
Transit Oriented Development (TOD) is occurring in cities across the world, particularly in Europe and North America. Land within two blocks of transit arteries is zoned for high-density development and retail, with density tapering off the further away one is situated. A number of Canadian cities have embraced TOD including Hamilton, Edmonton, and Calgary. Vancouver has a history of developing along its SkyTrain corridor with regional town centres at its hubs. In Toronto, development has occurred along the Yonge Street subway line, particularly at hubs like Yonge-Eglinton and Yonge- Sheppard.
Demand for all forms of energy is projected to soar in the coming years with a growing and increasingly affluent global population. We are particularly reliant upon oil, for both transportation and product manufacture, and with the uncertain shadow of Peak Oil looming there is reason for concern about our ability to meet that demand. The energy performance of a city’s infrastructure and building fabric is a key determinant of its capacity for resilience. Reducing a city’s per capita energy consumption is critical in reducing the impact of shocks or stresses associated with future energy costs.

Buildings and transportation should be the primary focus. Energy retention technologies must be designed into all new buildings. Older buildings will need to be re-clad with a highly insulating building envelope made ZEB-ready (Zero Energy Building) for the future addition of renewable energy infrastructure such as solar water heating and photovoltaics. Sun shades and light shelves amplify the benefits. In transportation, there are vast differences in fuel efficiencies between modes—a modern streetcar/tram uses just 0.11 kWh/passenger mile compared with 1.4 kWh/passenger mile for a typical SUV. Enabling walking and bicycling extends these energy gains.

LORRAINE GAUTHIER and ALEX QUINTO of Work Worth Doing have developed a project called Now House, a process for retrofitting older houses into net zero energy homes that annually produce as much energy as they use. The pair have focused on renovating wartime houses—first in Toronto and more recently in Windsor—because the houses have a relatively standard footprint and there are about a million of them across Canada. Retrofitting is a critical given the fact that some 66% of the houses that will exist in 2050 are already standing.

Net zero projects are occurring on many scales. BedZed in England is a housing development designed to rely solely on renewable energy generated on site, including 777 m² of solar panels as the main source of power and a cogeneration plant to provide district heating and electricity. In Toronto, Project Neutral is helping two established neighbourhoods transition to carbon neutrality by first developing a baseline of greenhouse gas emissions, then engaging the communities to formulate a carbon reduction plan that will be tracked on an annual basis.
Halves Oil Produced

Individual Wells

Hubbert Curve for Region

Hubbert’s "Peak Oil" Curve
WHY?
Future energy price increases will directly impact the cost of food due to agriculture's heavy reliance on oil in all aspects of food production and the cost to transport food north from southern growing regions. Food price inflation is being accelerated by the global diversion of crops for the production of biofuels. In 2011, food prices increased 4.4% in Canada—1.5 times the general rate of inflation. Moreover, potential disruptions in food production as a result of climate change, or a sharp rise in energy costs could potentially seriously disrupt the economics of food supply to cities.

HOW?
In North America, approximately two acres is required to feed a person for a year. As such, a city the size of Toronto would require 6 million acres to feed its inhabitants. Even if the suburbs were returned to traditional agricultural uses, they would still not provide northern cities with sufficient food supplies during winter months. The answer to local, urban food production lies in a vertical approach to farming that contrasts with land-intensive methods. A high-efficiency hydroponic farm needs just 0.1 acres to feed a person for a year, a 95% reduction in acreage.

WHO?
GORDON GRAFF is a leading proponent of high-efficiency urban farming. His 2006 design concept for a high rise “Sky Farm” comprised 59 floors, 2.7 million square feet of floor space and 9.5 million square feet of growing area, feeding 40 thousand people annually, equivalent to a thousand acres farmed traditionally. A biogas plant would collect methane from plant waste, grass “silage” growing on the farm’s south-facing wall, and the city’s sewers, with the gas powering an electric generator. A “living machine” would filter water, recycling it back into the farm.

WHAT?
The Science Barge was a prototype, sustainable urban farm and environmental education center created by NY Sun Works and docked in Manhattan in 2007 and Yonkers in 2008. At the time it was the only fully functioning demonstration of renewable energy supporting sustainable food production in New York City. The Science Barge grew tomatoes, cucumbers, and lettuce with zero net carbon emissions, zero chemical pesticides, and zero runoff. A large portion of its surface area was dedicated to solar panels to provide the energy requirements of a high-efficiency urban farm.
160 TONS OF FOOD WASTE

59,120 LETTUCE PLANTS

18 KG OF NUTRIENTS

16 TONS OF DIGESTATE

INPUTS

OUTPUTS

CO2

H2O

2,200 THERMS OF METHANE

64,000 KWH

20,295 L

7,145 KG WATER VAPOUR

12,240 KG DEPLETED WATER

DEHUMIDIFIERS

BIOLOGICAL WATER FILTRATION

ELECTRIC GENERATORS

ANAEROBIC DIGESTERS

INPUTS

OUTPUTS

100 TONS OF FOOD WASTE

59,120 LETTUCE PLANTS

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With Permission of Gordon Graff 2010
MOduLARIZATION

Key infrastructure systems such as power, water, communications, and sewage waste processing are vital to an effectively functioning city. The incapacitation or failure of any one of these systems would have serious consequences. However, most of our important infrastructure systems are currently both at the end of their useful service life and, in their current configurations, almost without redundancy and modularization. Any significant damage to one part of a system has the potential to create cascading failures through its adjacent parts, the most vivid example of this being the Northeastern power outage of 2003.

HOW?

An excellent example of modular and redundant infrastructure is co-generated district heating whereby power and heat are generated by the same system, in a single, locally distributed plant. Each plant provides power for its surrounding area but also can be called upon to provide excess power to back up neighboring plants when a failure occurs. Furthermore, a failure at one plant is less costly and disruptive and is favoured by the market, the book argues that a resilient energy system is feasible, and it is at odds with U.S. domestic energy policy. The book was released in 2001 following the September 11 attacks. In the preface to the book, Lovins stated that little had changed during the two decades between publications.

Germany is a leader in creating decentralized modular energy systems. The Kombikraftwerk or Combined Power Plant is an initiative that links 36 wind, solar, biomass and hydropower installations throughout Germany. Turbines and solar modules generate electricity and are connected into a smart grid. Biogas and hydropower are converted into electricity to balance out short-term fluctuations. Another project, E-Energy, is creating the “Internet of Energy”, a comprehensive digital network optimizing the energy system.

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WHO?

In 1982, the American environmental scientist AMORy LOVINS penned the book Brittle Power: Energy Strategy for National Security with his then wife L. Hunter Lovins. Originating as a study for the Pentagon, the book argues that U.S. domestic energy infrastructure is vulnerable to disruption, and that a resilient energy system is feasible, costs less, works better, and is favored by the market, the book argues that a resilient energy system is feasible, and it is at odds with U.S. domestic energy policy. The book was released in 2001 following the September 11 attacks. In the preface to the book, Lovins stated that little had changed during the two decades between publications.

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MODULARIZATION

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THE RESILIENCE CENTRE

COMBINED DISTRICT POWER, HEAT, WASTE, WATER RECOVERY, FOOD PRODUCTION CENTRE. THIS PLAN WOULD BE SCALABLE - FROM NEIGHBOURHOOD CENTRES TO DISTRICT CENTRES.

BY CRAIG APPLEGATH
BASED ON IDEAS OF JOHN TODD AND GORDON GRAFF
INTEGRATED METABOLISM

WHY?
Contemporary cities rely upon infrastructure systems conceived of and in some cases implemented in the 19th Century. Power, water, food and waste infrastructure systems are all separate, and do not take advantage of the inherent natural connections between them. The production of food requires both water and energy. Sewage as the byproduct of consumed food and water retains energy that can be released through anaerobic digestion. Wastewater can be reprocessed into potable water with plants and sunlight. These are natural cycles that, if harnessed properly, can reduce a city’s net demand for both water and energy.

HOW?
Integrating a city’s metabolism—energy, water, food and sewage—would reduce the per capita energy and water required to produce the same amounts of electrical power and potable water, and also decrease the per capita amount of non-usable organic waste. This would be accomplished by grouping these systems such that water used in the production and consumption of food could be reclaimed from sewage, and power could be generated from the digestion of waste. The byproducts of this cycle would feed back into the food production as a source of nutrients.

WHO?
In 1974, biologist JOHN TODD designed and built “An ARK for P.E.I.” at the behest of the Canadian government. The ARK was a test bed of many of the principles that would become the “living machine”, an ecologically engineered technology developed to restore, conserve, or remediate sewage or other polluted water by replicating and accelerating the natural purification processes of streams, ponds and marshes. The company Todd founded now produces an Eco-Machine where all the major groups of life are represented, including microscopic algae, fungi, bacteria, protozoa, and zooplankton, on upward to snails, clams, and fishes.

WHAT?
The “Resilience Centre” is an as-yet unrealized concept of integrated infrastructure systems that builds upon the thinking of John Todd and Gordon Graff. Developed by DIALOG and proposed for the City of Edmonton as part of its Way We Green strategy, each centre comprises district heating, food growing greenhouses, and “living machine” waste water treatment facilities, harnessing natural, interconnected processes to reduce per capita energy and water consumption. The flexibility of the Resilience Centre’s design allows for components to be added and subtracted as needed, depending on micro-level conditions.
INTEGRATED METABOLISM

WASTE

FOOD

ENERGY

WATER

WASTE TREATMENT
+ BIOGAS PLANT

CENTRALIZED PRODUCTION MODEL

INTEGRATED/DISTRIBUTED PRODUCTION MODEL

DISTRIBUTED/INTEGRATED PRODUCTION MODEL

WASTE

With Permission of Che Biggs 2011
According to Munich Re, the number of annual Category 5 storms has tripled between the years 1980 and 2008. In Toronto, the 2005 flooding of Finch Avenue resulted in $624 million in insurance claims. University of Western Ontario climatologist Gordon McBean suggests the type of rain event that occurred every 20 years in 1990 could occur every 10 years by 2050. Moreover, warming trends suggest a Northerly migration of tornado zones, increasing the likelihood of events in southern Canada. As such, we would be well advised to ‘harden’ our key infrastructure and building assets. One way to address building durability is to look at the living past—structures that have resisted the impacts of time. Whether it be 3000-year-old Bronze Age tombs, Roman stone arch aqueducts, or adobe churches in New Mexico, these buildings all share the characteristic durability of their materials, all—not coincidentally—of high thermal mass. Building codes have a role to play, raising minimum standards and placing greater emphasis on material lifespan and maintenance as well as the need to brace against more frequent severe storm events. TED KESIK, Professor of Building Science at the University of Toronto, is a leading advocate of returning to walls with higher durability/thermal mass and punched windows. In a 2011 paper entitled “The Glass Condo Conundrum”, he criticized the use of glass curtain walls in Toronto condos, citing energy inefficiency as well as poor durability and air and water leakage. Kesik suggests, boldly, that building performance has regressed during the past 50 years even as costs have risen. At the time of the paper’s publication, Toronto had the most condos under development in North America. DIALOG has been exploring recladding strategies and protective metal shutters as ways of retrofitting glass window-wall buildings to make them more resilient. In New York’s Chelsea district, a recently constructed building designed by Shigeru Ban features metal shutters echoing those that protect neighbourhood shop windows. Storefront shutters were widely adopted in New York after the 1977 blackout and the ensuing looting. In the context of a residential building, the shutters modulate light for energy efficiency and provide privacy to residents as well as serving the traditional purpose of protecting the more fragile glass structure.
INTEGRATED DURABILITY

SERVICE QUALITY × SERVICE LIFE = DURABILITY

- MINIMUM SPECIFIED QUALITY
- MINIMUM ACCEPTABLE QUALITY (REPLACEMENT/RETROFIT REQUIRED)

COMPONENT NO.1

COMPONENT NO.2

SOURCE: TED KESIK
WORKSHEET
RESILIENT APPROACH

TRANSFORMING UNDERSTANDING INTO ACTION

ANALYSIS
A classic strategic planning analysis method is the SWOT, referring to Strengths, Weaknesses (internal), Opportunities and Threats (external). We suggest reordering the analysis under the acronym TWOS, examining issues before solutions, and prioritizing the external over the internal as resilience focuses on preparing for largely external shocks and stresses; the Threats section will be informed by the six challenges of: population, climate change, energy scarcity, income disparity, socio-political and environmental degradation. One should assess all aspects of a city's infrastructure: water, energy, waste, building fabric, etc.

PROBABILITIES + IMPACTS VS COST
Quadrant maps can help visualize the probability of a shock or stress occurring and its economic impact, mapping these against the cost of building the capacity for resilience. This exercise will help prioritize strategies and tactics.

STRATEGIES + TACTICS
When creating a series of strategies and tactics to execute each resilience approach, the 6 attributes of resilience should be used to assess the quality of any given strategy or tactic.

Ask:
> How much flexibility does it allow for?
> How will it facilitate redundancy in the system?
> How does it support the increase of diversity in the system?
> How can dependency of systems be reduced?
> How decentralized is the solution?
> How integrated is the system with its environmental context?

Strong strategies and/or tactics can answer many of these questions and can serve more than one approach, so be sure to cross-pollinate your worksheets.
## Resilient Approach Worksheet

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### Strategy + Associated Tactics

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### Probability of Threat vs. Cost of Building Capacity for Resilience

- **I**: High Probability, Low Cost
- **II**: High Probability, High Cost
- **III**: Low Probability, Low Cost
- **IV**: Low Probability, High Cost

### Economic Impact of Threat vs. Cost of Building Capacity for Resilience

- **I**: High Economic Impact, Low Cost
- **II**: High Economic Impact, High Cost
- **III**: Low Economic Impact, Low Cost
- **IV**: Low Economic Impact, High Cost
I am very grateful to a great many individuals who have been directly or indirectly very helpful in bringing this toolkit into being. Thanks particularly should go to:

THOMAS HIRSCHMANN – For co-writing and editing this toolkit, but more importantly, for his enthusiasm for the notion that a toolkit that could inspire a more focused discussion of resilience;

KAREN NG-HEM – for her masterful graphic design of this toolkit which would not have been possible without her;

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JEFF RANSON – for his continuing feedback on all things related to resilient and sustainable cities;

GREGORY GREEN – for his continuing interest in and exploration of how best to communicate the ideas of resilience through video and web media;

And of course, I would like to thank my partner JANE THOMPSON for all of her thoughtful strategic advice, constant encouragement and support on this project.

I would like to extend particular thanks to my fellow principals at DIALOG for supporting my research on resilience, and more importantly, for creating the kind of studio environment where this kind of exploration could flourish. It is clear to me that research is only as good as the intellectual context from which it originates. DIALOG is an amazing place to explore new ideas in, and its mission for doing excellent work and making a difference has set the stage for real creativity and innovation.

ACKNOWLEDGEMENTS

Using 100% post-consumer recycled fibre, this toolkit produces the following environmental savings:

- 5 kg of waste
- 12 kg CO₂
- 313 L of water
- 82 km driven
- 38 showerheads
RESOURCES

WHAT CAN I DO NOW?

LEARN MORE ABOUT RESILIENCE

The following books and video provide a good foundation:

The Upside of Down by Thomas Homer Dixon
Climate Wars by Gwynne Dyer
Why Your World is About to Get a Whole Lot Smaller by Jeff Rubin
Arrival City - The Final Migration and Our Next World, by Doug Saunders
Triumph of the City by Edward Glaeser
The End of Suburbia (video) by Gregory Greene

Climate Change

Heat: How to Stop the Planet Burning by George Monbiot
Hot Air: Meeting Canada’s Climate Change Challenge by Jeffrey Simpson, Mark Jaccard and Nic Rivers
The End of Nature by Bill McKibben
The Revenge of Gaia by James Lovelock
The Vanishing Face of Gaia - A Final Warning by James Lovelock
Six Degrees: Our Future on a Hotter Planet by Mark Lynas

Ecology/Biology

Gaia: A New Look at Life on Earth by James Lovelock
The Future of Life by Edward O. Wilson
The New Green History of the World by Clive Ponting

Peak Oil

Beyond Oil - The View From Hubbert’s Peak by Kenneth S. Deffeyes
Carbon Shift edited by Thomas Homer-Dixon
Peak Everything by Richard Heinberg
The End of Oil - On the Edge of a Perilous New World by Paul Roberts
The Transition Handbook - From oil dependency to local resilience by Rob Hopkins

Sustainable / Green Design

Worldchanging: A Users Guide for the 21st Century edited by Alex Steffen
Biomimicry: Innovation Inspired by Nature by Janine M. Benyus
Cradle to Cradle by William McDonough
The Solar Economy - Renewable Energy for a Sustainable Global Future by Herman Scheer

Resilience and Resilient City Planning

Resilience thinking: Sustaining Ecosystems and People in a Changing World by Brian Walker and David Salt
The Resilient City: How Modern Cities Recover from Disaster by Lawrence J. Vale and Thomas J. Campanella
Climate Resilient Cities: A Primer on Reducing Vulnerabilities to Disasters by Neeraj Prasad, Federica Ranghieri, and Fatima Shah

Urban Design and Planning

On Streets edited by Stanford Anderson
The Economy of Cities by Jane Jacobs
Where Good Ideas Come From - The Natural History of In by Steven Johnson

WEBSITES

Resilience
http://www.resalliance.org
http://www.ecoinnovationlab.com

Climate Science and Environment
www.worldwatch.org
www.giss.nasa.gov/staff/jhansen.html
http://stephenschneider.stanford.edu
http://www.wri.org

Peak Oil
http://www.worldchanging.com
www.energybulletin.net
www.postcarbon.org
www.theoildrum.com

PRACTICE RESILIENCE

Walking through your city can generate a wealth of ideas when it is viewed through the lens of resilience thinking. The worksheet section of this toolkit is a template that can be used to make observations, test approaches, assess challenges, generate strategies and tactics, and formulate an implementation plan.

BUILD UPON THE APPROACHES PRESENTED HERE

These approaches are just one set of possible responses to the challenges our cities face. If our goal is to increase the resilience capacity of our cities, we believe an open source approach will be most effective. We’re hoping that by creating discussions about how to future proof our cities, that new, better ideas will emerge, providing—at the very least—a good conceptual map of how we can increase the resilience capacities of our cities. So please share your ideas and enter the annual Design Ideas competition at: ResilientCity.org