

Blue, Green and Grey Infrastructure: Examples and Benefits

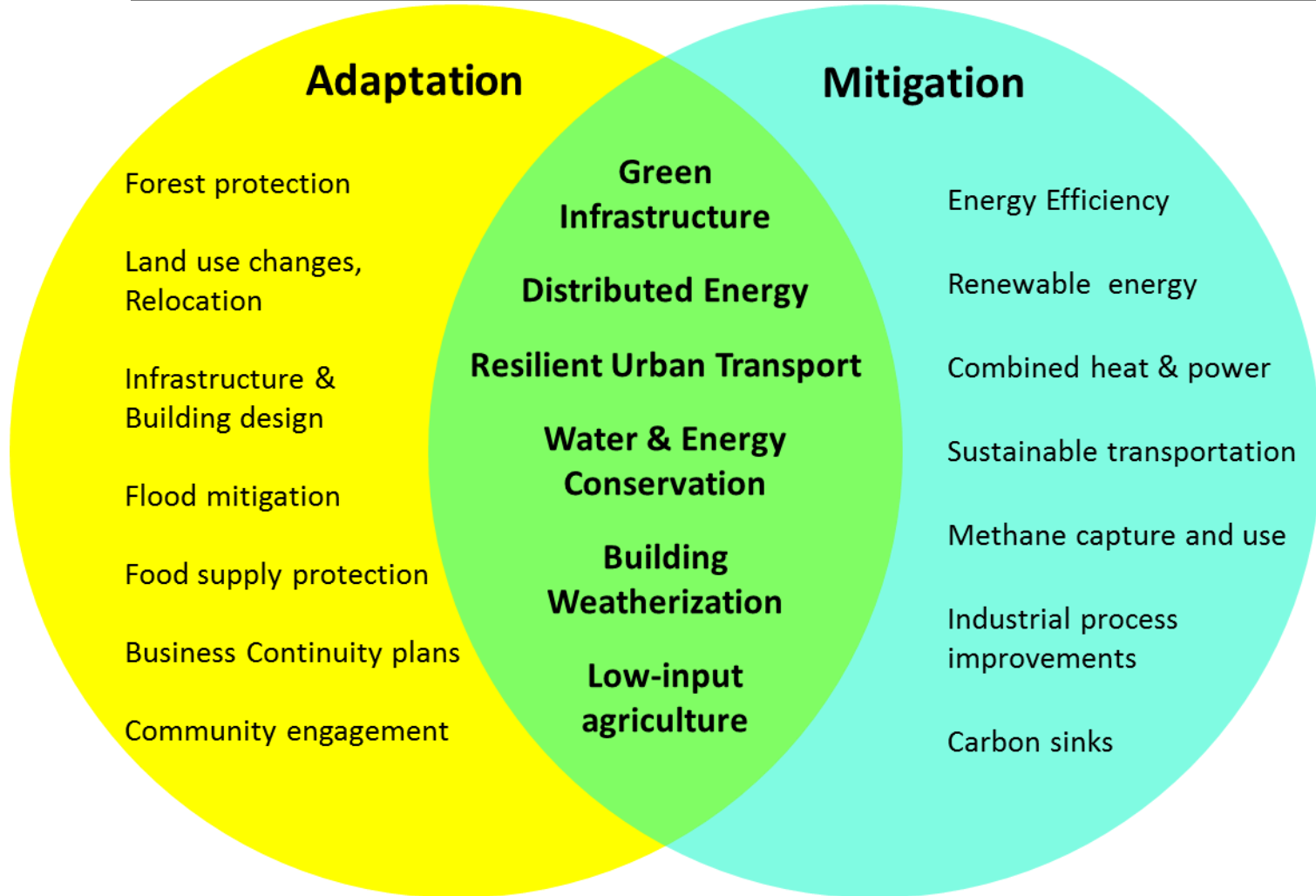
Steve Winkelman | September 18, 2017

Livable Cities Forum, Victoria, BC





Green Resilience: Adaptation + Mitigation Synergies



Green Resilience Strategies (2017)

Graphic concept modified with acknowledgement of David MacLeod, City of Toronto.



Green Roofs: capture rainwater

- Can reduce annual stormwater run-off by 50-60%
 - 1-2,000 kWh to treat 1 M million gallons of rainwater
- Washington DC study: full penetration of green roofs could reduce CSOs by 6-15% and CSO water volumes by 26%
- Toronto study: full penetration could save > \$300 million



Mountain Equipment Coop green roof (Toronto)

http://farm9.staticflickr.com/8152/7304625336_2d59d237fc_b.jpg



Green Roofs: reduce energy use



Chicago City Hall green roof and adjacent building with black asphalt roof.

Source: Chicago Climate Action Plan report.



Infrared image of the roofs.

Green roof: 23 °C

Black asphalt roof: 66 °C

Source : Chicago Climate Action Plan.

- **40% higher life-cycle net-present value**
- **15 - 45% energy savings (mainly cooling)**
- **White roofs can save 65% energy costs**

Green Resilience Strategies

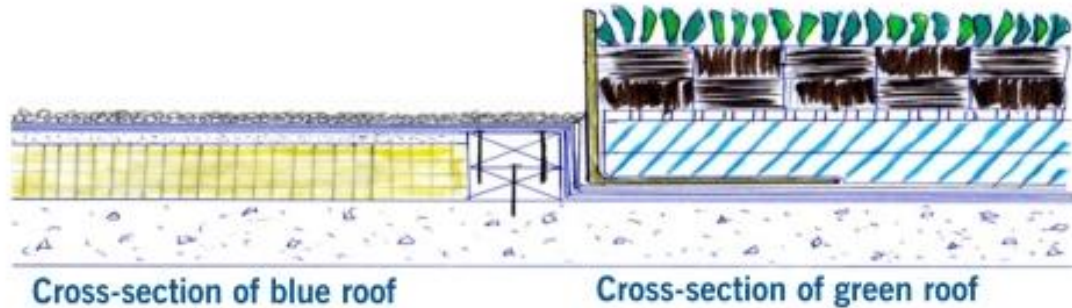




Blue vs Green roofs

■ Blue Roofs

- Can store 50% of annual precipitation
- \$4 / sq ft vs \$24 for green roofs
- \$0.16 - \$0.32 per gallon captured (NPV) vs. \$3.33 for green roof



[NYC](#)



Permeable and Reflective Pavements

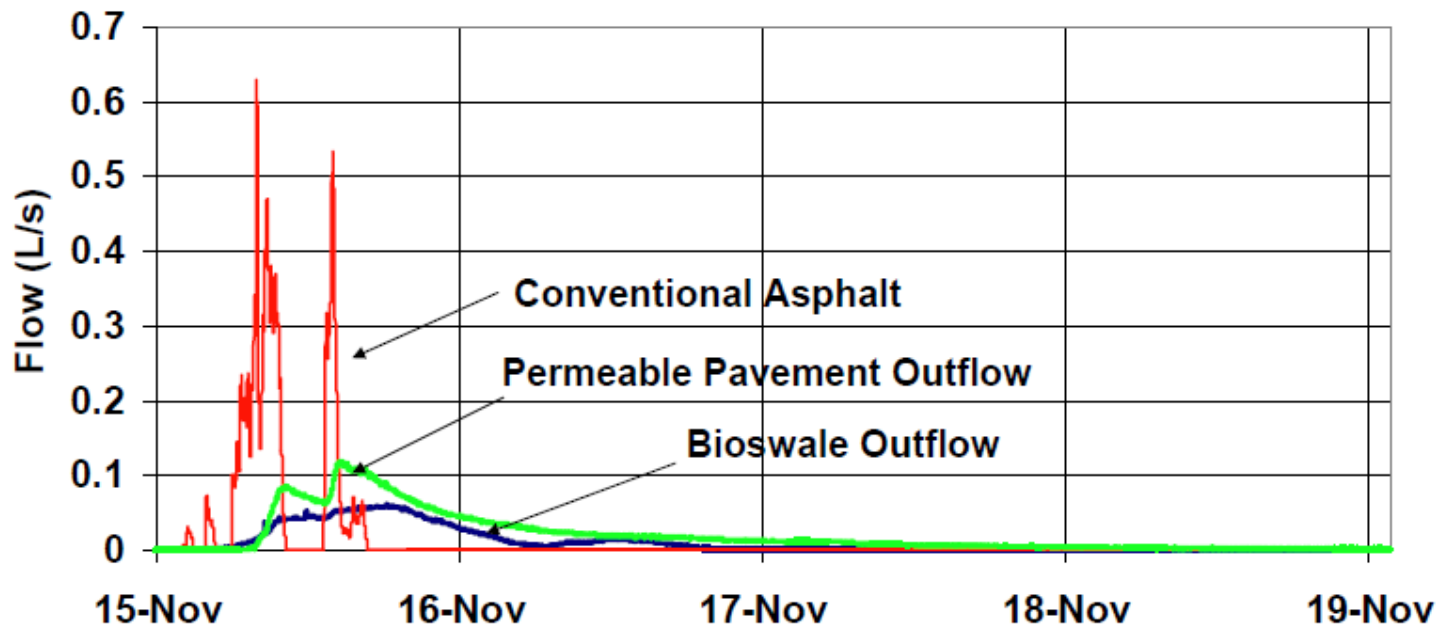
- **Permeable pavement can reduce storm-runoff volume by 70-90%,**
 - similar to a meadow or forest.
- **Increasing pavement reflectivity by 10-35% could save \$90 million (energy, air pollution)**
 - 0.8°C decrease in Urban Heat Island temperature



Permeable Pavement and Bioretention



Permeable Pavement and Bioretention, King City: 31 mm rain event



Tim Van Seters: Toronto and Region Conservation



Urban Trees

- **Net economic benefits of mature urban trees range \$30-90 per year for each tree (ROI of 1.5 – 3.0)**
- **+ 20% tree canopy: household ↓ cooling costs 8-18%, ↓ heating costs 2-8%**
- **Value of street trees in Wash, DC: \$10.7 million/yr**
- **Manchester UK study: +10% green cover would keep temperature below historic levels under future climate scenarios**



Green Infrastructure: Benefits increase with scale

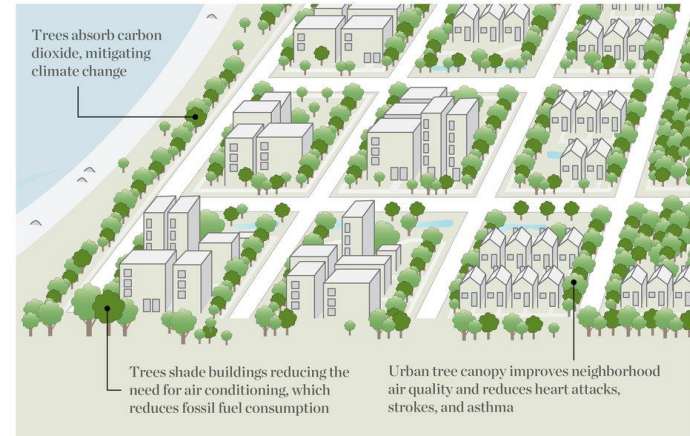
- ↓ Energy
- ↓ Flood
- ↓ Urban Heat
- ↑ Habitat
- ↑ Water Quality
- ↑ Health
- ↑ Beauty



NRDC: [GI in Washington DC](#)



Urban Tree Canopy



[The Nature Conservancy](#)



NACTO: [perVIOUS pavement](#)



Multiple Benefits of Green Infrastructure

Benefit	Reduces Stormwater Runoff				Increases Available Water Supply	Increases Groundwater Recharge	Reduces Salt Use	Reduces Energy Use	Improves Air Quality	Reduces Atmospheric CO ₂	Reduces Urban Heat Island	Improves Community Livability					Improves Habitat	Cultivates Public Education Opportunities
	Reduces Water Treatment Needs	Improves Water Quality	Reduces Grey Infrastructure Needs	Reduces Flooding								Improves Aesthetics	Increases Recreational Opportunity	Reduces Noise Pollution	Improves Community Cohesion	Urban Agriculture		
Practice																		
Green Roofs	●	●	●	●	○	○	○	●	●	●	●	●	◐	●	◐	◐	●	●
Tree Planting	●	●	●	●	○	◐	○	●	●	●	●	●	●	●	●	◐	●	●
Bioretention & Infiltration	●	●	●	●	◐	◐	○	○	●	●	●	●	●	◐	◐	○	●	●
Permeable Pavement	●	●	●	●	○	◐	●	◐	●	●	●	○	○	●	○	○	○	○
Water Harvesting	●	●	●	●	●	◐	○	◐	◐	◐	○	○	○	○	○	○	○	●

● Yes

◐ Maybe

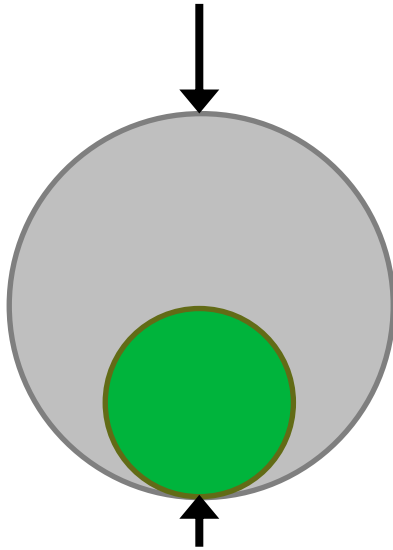
○ No



Green is Cheaper than Grey

Catskills / NYC

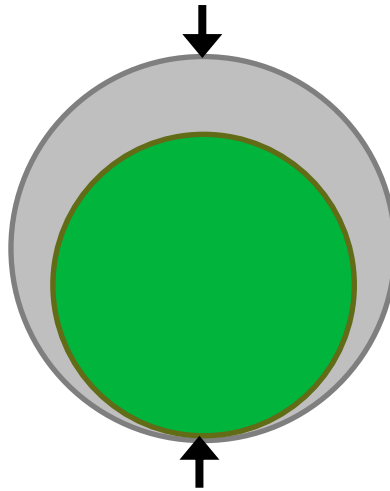
Water filtration
plant: \$6.2B



Protect
Catskills: \$1.5B

NYC

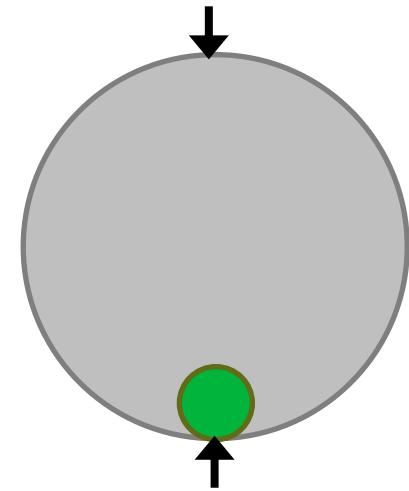
Tanks, tunnels, and
expansions for combined
sewer overflow: \$3.9B



Green
Infrastructure
Plan: \$2.4B

Portland, OR

Normal infrastructure
for storm water runoff:
\$350M



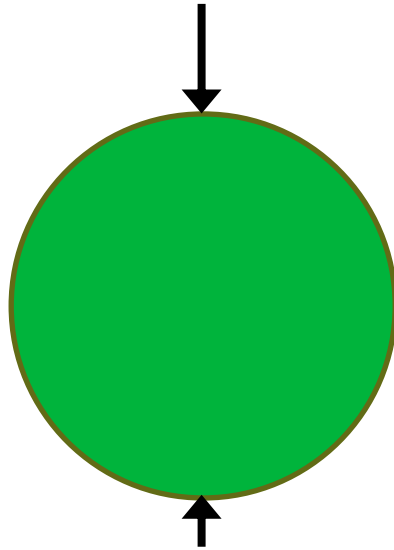
Green practices, (e.g.
Downspout Disconnection
program) \$12.75M



Green and Green-Grey blends increase Economic Benefits

Houston

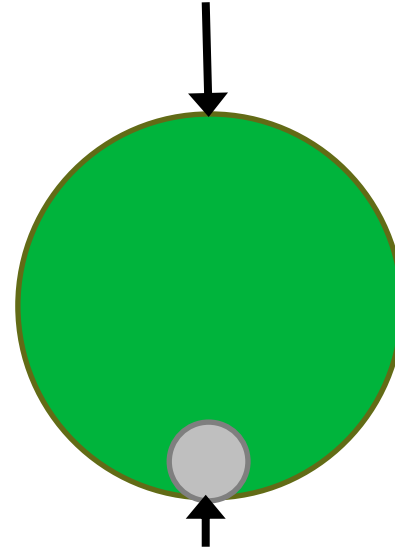
Stormwater benefit
from trees: \$1.3B



No trees: \$0B

Philadelphia

50% low impact
development: \$2.85B



Normal 30' tunnel:
\$0.12B



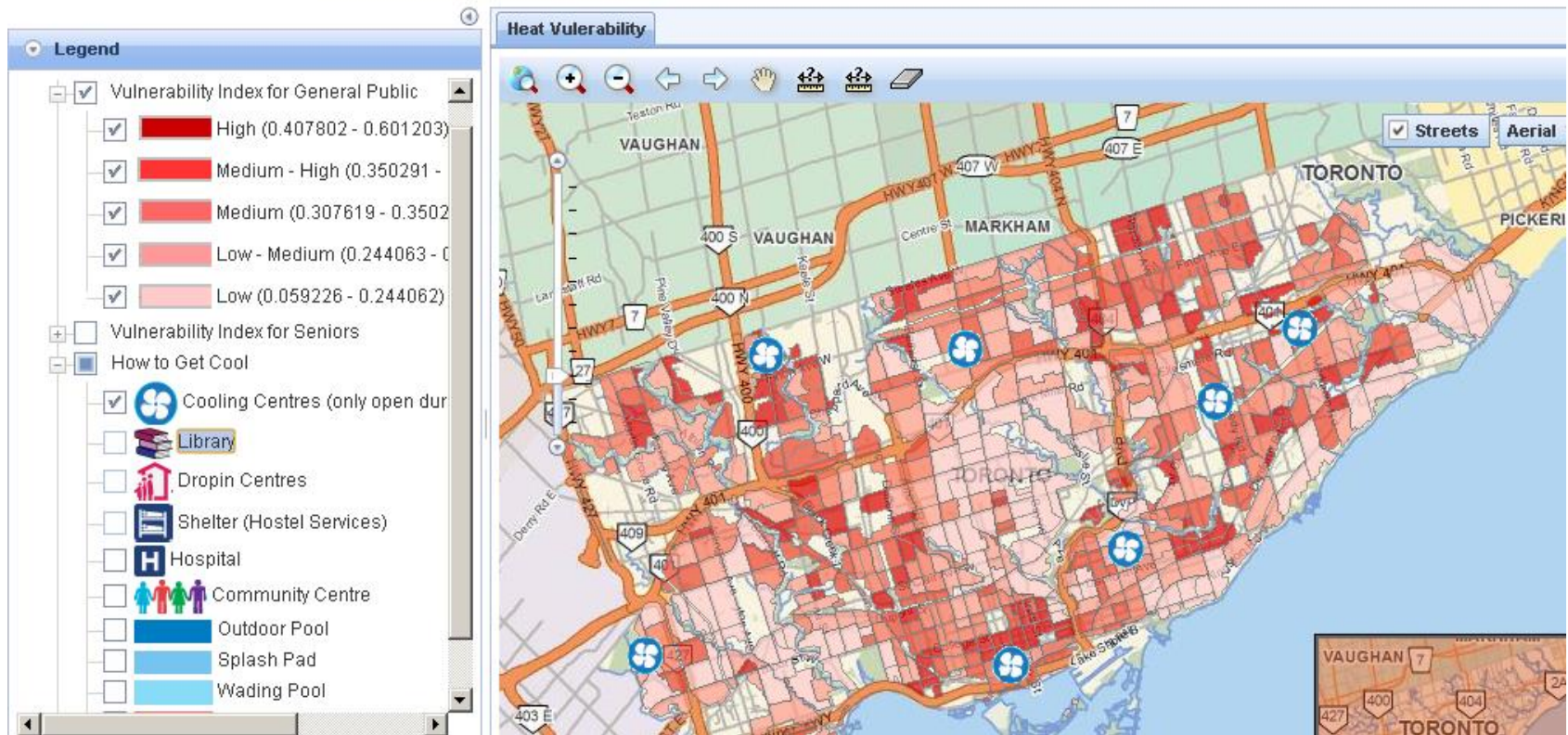
GIS to identify strategic green infrastructure locations (heat, flood, building shading, biodiversity...)



Toronto Public Health - Heat Vulnerability

[About Map](#)

Search by Name, Address, or Intersection

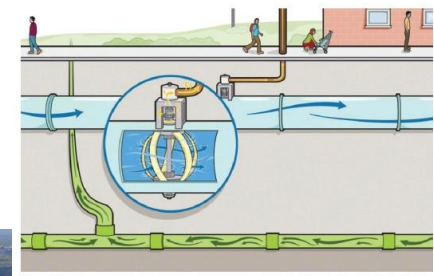
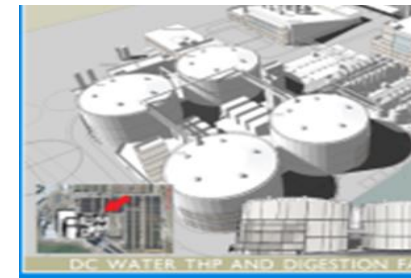


http://map.toronto.ca/maps/map.jsp?app=TPH_HVMAP



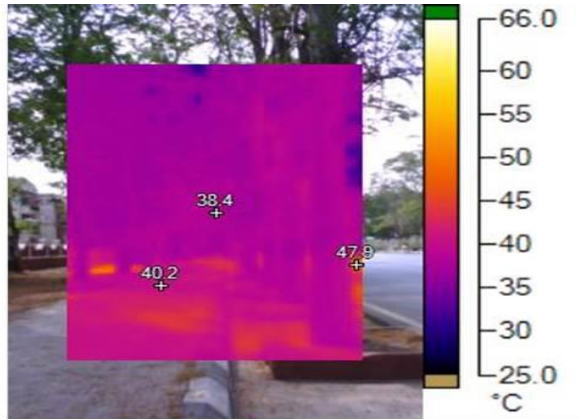
Water: Green Resilience Solutions

- **Water efficiency and conservation**
 - ↓ Energy use for pumping, treatment
 - ↑ Drought resilience
- **Re-use of treated wastewater**
 - ↑ Drought resilience
- **Distributed Energy Generation**
 - Biogas → combined heat and power
 - Micro-hydro from distribution pipes
- **Wetland treatment of water**
 - 50% cost of conventional treatment
- **Flood proofing waste/water facilities**
 - Water quality and resilience benefits





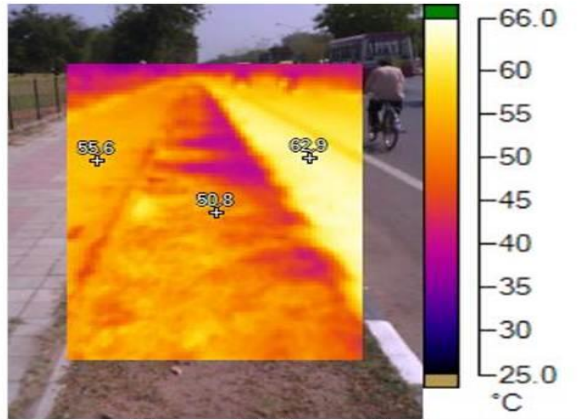
Green Infrastructure for Transportation: Shade Pedestrian and Cycling Facilities



Thermal Infrared Image
3:20:18 PM



Visible Light Image
3:20:18 PM



Thermal Infrared Image
3:29:28 PM



Visible Light Image
3:29:28 PM



Grey infrastructure: help reduce subway flooding



Portable barriers (ACSE)

NYC subway flooding after a 2007 storm.
Source: MTA NYC Transit



Partial Solution: Raise ventilation grates



Inflatable tunnel plug (NYC)



COURTESY ARCADIS



Grey: Culvert maintenance and redesign saves \$\$\$ and GHGs (reconstruction)



A 2005 storm in **Toronto** caused \$647 million in damages, including destruction of this culvert (left, \$4 million) in losses, which was replaced with a larger, more resilient culvert (right). Source: Toronto Environment Office.

Photo credit for damaged culvert: Jane-finch.com.



Photo credit for new culvert: City of Toronto Transportation Services.



Urban design and topography are key



Richard Carson (Reuters)

<https://www.cnbc.com/2017/08/28/the-stunning-images-from-record-setting-flooding-in-houston-texas.html>



Green Resilient Neighbourhoods: Vancouver

Multiple benefits → multiple funding opportunities

Northeast False Creek – *Planning in progress*

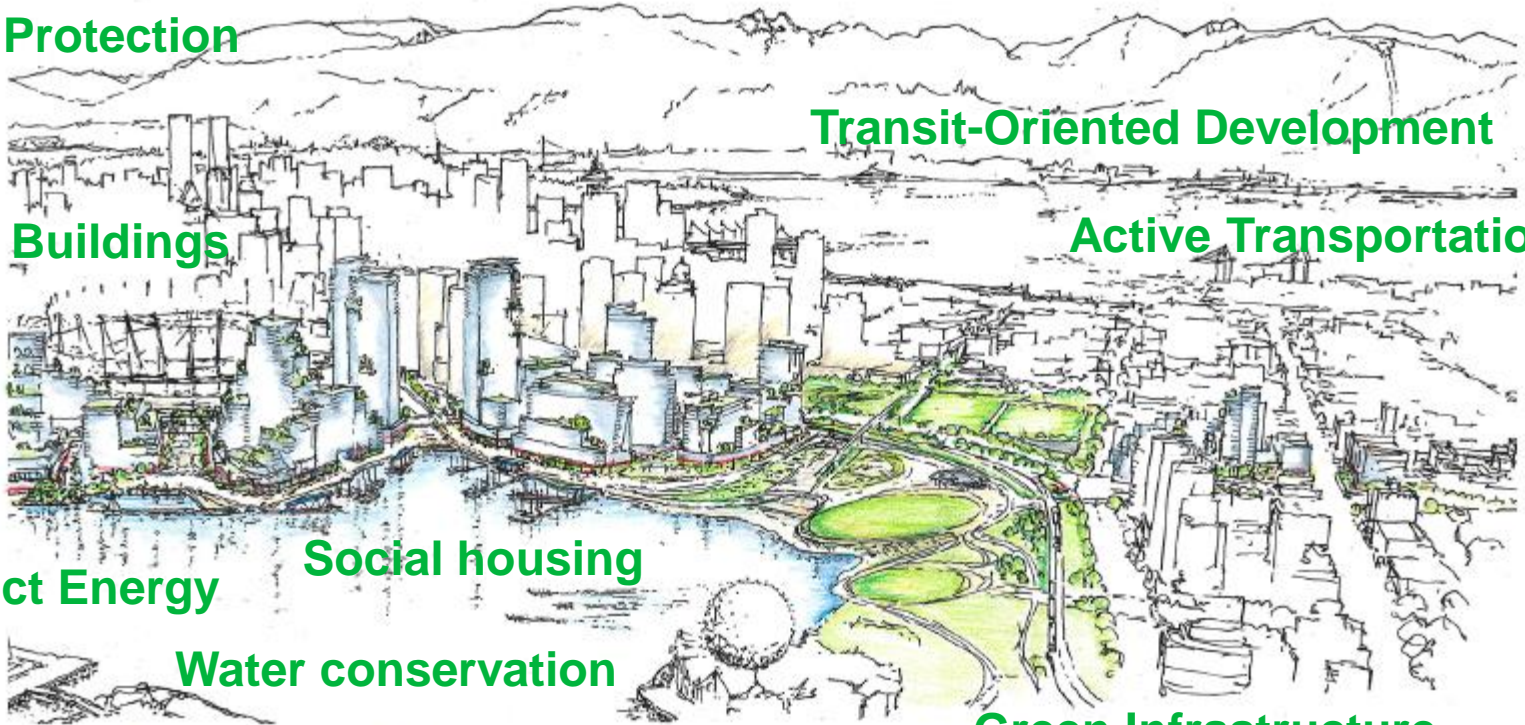
<http://vancouver.ca/home-property-development/northeast-false-creek.aspx>

Flood Protection

Transit-Oriented Development

Green Buildings

Active Transportation



District Energy

Social housing

Water conservation

Green Infrastructure
Ecosystem expansion

Perspective sketch showing potential 20 year build out of Northeast False Creek



Green Resilient Neighbourhoods: **Vancouver**

Northeast False Creek seawall – *rendering*:

Flood protection embedded into the urban design, with a re-naturalized shoreline, thereby protecting the “technology” of the low-carbon neighbourhood.



Image source: Brad Badelt, City of Vancouver



Green & Resilient Neighbourhoods: NYC

The Big U: New York City (Rebuild by Design)



<http://www.rebuildbydesign.org/our-work/all-proposals/winning-projects/big-u>



Follow the Money: Package Projects for Multiple Funders and Investors

GHG Mitigation

- renewables
- building efficiency
- transit-oriented development

Climate Adaptation

- green infrastructure
- flood protection

Health

- active transport
- urban heat island
- air quality

Habitat protection

- trees planting for stream shading

Critical Infrastructure

- energy
- telecom
- water
- transportation

Economic Development

- Development Cost Levies
- Community Amenity Contributions



Perspective sketch showing potential 20 year build out of Northeast False Creek

Social equity

- affordable housing

Disaster prevention

- flood protection

Parks & Recreation

- waterfront access
- nature trails
- education

Community

- public art
- community engagement



Follow the Money: Build Green Infrastructure into Infrastructure Spending

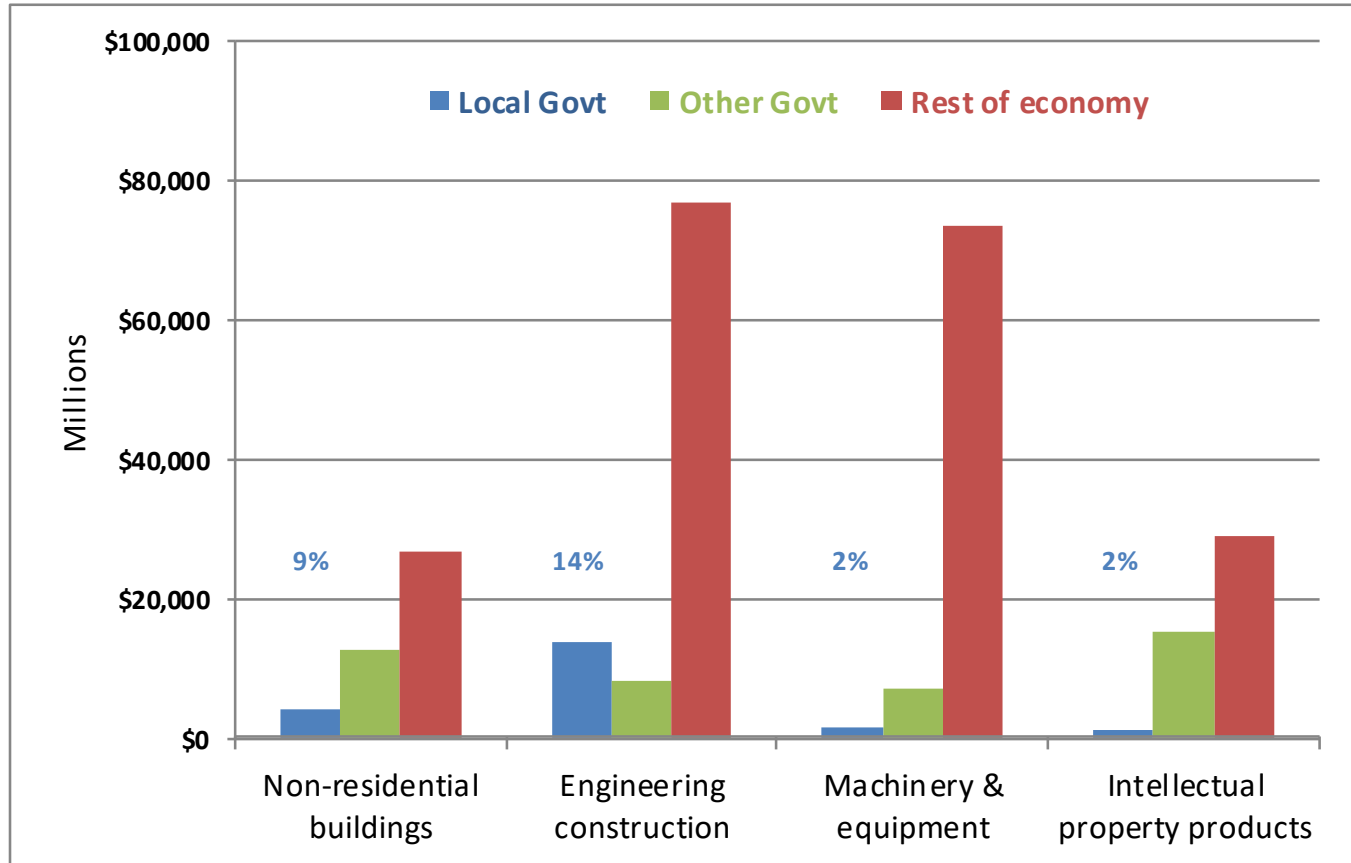
- **Review plans, policies & budgets for opportunities**
 - infrastructure, flood management, land use, transportation, housing, energy, health, education, ...





Follow the Money: Mobilize Private Investment (business & individual)

2015 Non-residential Capital Investment in Canada



Data Source: CANSIM 031-0005

Green Resilience Strategies, 2017



Comprehensive & Coordinated Policies

■ Guidelines and Regulations

- Design codes: streets, buildings
 - Washington DC: Green Area Ratio
- Rainwater harvesting
- More stringent stormwater regulation
- Smart growth and zoning changes

■ Incentives and Fees

- Downspout disconnect payments
- Green infrastructure on private property
- Stormwater fees
- Waiving storm-water fees for sites with greater permeability
- Development charges

Thank you



green
resilience
strategies

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Transportation
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Critical Infrastructure



stratégies de résilience verte

Merci