



Module 6: Infrastructure Networks

THE CHANGING CLIMATE'S IMPACT ON THE TRANSPORTATION
AND ENERGY SECTORS

Overview

1. What are the primary impacts of climate change on infrastructure networks?
2. What are the key climate-related challenges and issues to consider in transportation and energy infrastructure planning?
3. Have there been recent, successful municipal efforts to create more resilient infrastructure networks?
4. Are there any resources to assist infrastructure planners?

Primary impacts of climate change on transportation and energy infrastructure networks

Overview of Municipal Infrastructure Impacts

Climate change-related challenges to infrastructure networks

- ✓ Infrastructure may be exposed to weather extremes not accounted for in original design. Construction often assumes past climate extremes will represent future conditions
- ✓ Severe weather causes shorter infrastructure life span and reduced overall performance, as well as increased maintenance and operating costs
- ✓ Climate change may disrupt municipal transit and power operations, compromising public safety
- ✓ Severe and unanticipated economic losses can occur due to damaged/overwhelmed infrastructure
- ✓ Climate related risks are further aggravated by:
 - Aged infrastructure that has exceeded normal service life
 - Frequent co-location and interdependency of multiple structures
 - Decline in public spending
 - Ballooning populations



Climate-Specific Factors to Consider

1. Accelerated freeze and thaw cycles, with snow & ice variability
2. Hotter & drier summers
3. Extreme rain and flooding events
4. Variable Great Lakes levels
5. Problems stemming from increased salt usage
6. More pronounced repercussions in small communities (example: Wawa, Ontario)

For freeze and thaw forecasts for your area, visit the Midwestern Regional Climate Center's website, <http://mrcc.isws.illinois.edu/>, or check out NOAA's National Weather Service Climate Prediction Center at <http://www.cpc.ncep.noaa.gov/index.php> to find seasonal temperature and precipitation forecast data. The Great Lakes Hydro-Climate Dashboard is another useful site that shows real-time data for Great Lakes water levels, as well as offering historic climate and hydrological information. Visit it here: <http://www.glerl.noaa.gov/data/dashboard/GLHCD.html>



Accelerated freeze and thaw cycles

Accelerated freezing and thawing cycles have been implicated in destabilizing paved and built structures. This may impede automotive, railway, and other forms of transportation, and can undermine motorist, passenger and pedestrian safety. The following infrastructure elements may be negatively impacted:

- Ditches, culverts and drains
- Ramps, bridges, highways, railway lines and tunnels
- Sea walls, locks, lighthouses and water retention structures
- Power lines, generators and digital service towers

This may result in :

- Increased maintenance, repair and reconstruction costs
- Pavement bleeding, cracking and rutting, leading to traffic redirection
- Deterioration of motor, rail and seaways; damage to underground subway lines
- Electricity outages and cell phone service disruption



Road crews in Toronto attempt to clean up cracked pavement in January 2014

Climate Change and Transportation

Impacts to motorways

The transportation sector is one of the largest generators of greenhouse gas (GHG) emissions, and contributes to climate change, which then impacts the transportation sector even further. In 2011, transportation represented approximately **27 percent** of total U.S. GHG emissions.

Challenges posed to roads and motorists

The US Department of Commerce estimates that 70% of automobile accidents resulting in death are snow or ice-related. Driving conditions in severe weather can be extremely perilous. Evidence from climate models suggests that an increase in overall severe storm and weather events is likely.

- Damage to paved surfaces from extreme heat, cold and excessive water may result in:
 - Increased danger to motorists from potholes, less stable bridges, visibility impairments (from blowing snow/dust), lessened vehicle traction, lane obstructions and/or submersion
 - Potentially higher repair and maintenance costs, including salting and plowing
 - Reduced life expectancy of roads
- Increased rainfall can heighten flooding, leading to traffic delays, health risks, erosion, infrastructure washout, landslides
- Temperature extremes (fast freezes, etc.) and flooding can also damage vehicles themselves



Climate Change and Transportation

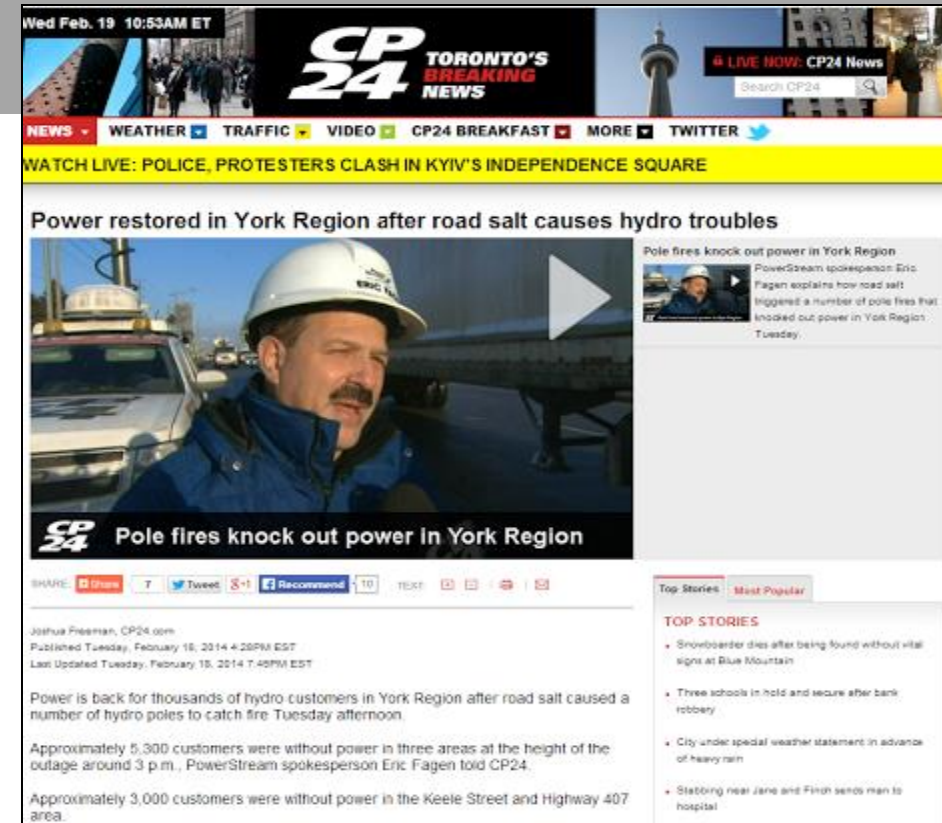
Road Salt Usage

Extreme precipitation events can lead to school, work and small business closures, with a resulting loss of productivity and profit. One way municipalities have traditionally combatted these challenges is with the use of road salt.

However, the chloride in road salt is toxic to aquatic vegetation, wildlife, soils, groundwater, rivers and lakes. Anti-caking agents in salt often contain cyanide, which the EPA classed as a toxic pollutant in 2003. Cold-weather states use 10-15 million tons of road salt every winter, according to the American Association of State Highway and Transportation Officials. Salt alternatives include sand, molasses, beet juice and cheese brine – some of which can cause their own set of environmental impacts.

Road salts may negatively impact ecosystem health (vegetation, wildlife, freshwater habitats, soil pH) and urban green spaces, including trees and parks. Even residents' pets may be harmed. Public drinking water security and private wells are at risk of salt contamination, and concrete infrastructure and railway crossings are often corroded by salt.

Road salt in high traffic areas results in a spray that may get inside electrical equipment and cause short circuiting. Excess salt accumulation can cause traffic signal box malfunctions and contribute to roadway congestion and accidents.



In York, Ontario, over 5000 customers were without power due to salt-created fires on utility poles.

Climate Change and Transportation

Impacts to Rail Networks



Derailed train in Ohio

Challenges posed to railway infrastructure

Climate affects railroad safety and operations, efficiency, scheduling and demand. The viability of railway transit impacts many passengers, as well as businesses whose bottom line depends on a smooth-running railway system.

Railway tracks can buckle in instances of extreme temperatures, causing repair delays and even derailments. Crossings and bridges are particularly vulnerable. Severe weather may require sudden stops and even re-routing of common train routes.

Subways and below-ground transportation infrastructure are especially prone to risk of flooding. High-speed crosswinds can be particularly hazardous for train operators and travelers. Hazardous cargo may spill if trains derail.

Adaptation strategies may include:

- Increase forecasting capability with real-time data and additional monitoring stations. Improve operational responses to severe weather (avalanches, etc.)
- Identify high-risk earthworks, flooding sites, extreme temperature and high wind zones, and aging infrastructure. Example actions; raise sea walls, increase drainage capacity, increase vegetation of surrounding areas.

Climate Change and Transportation

Impacts to Air Travel



Severe flooding at Chicago's O'Hare International Airport in July 2014 caused the delay and cancellation of many flights.

(Source: abc7Chicago.com)

Challenges posed to airlines

- Extreme weather can lead to the grounding of flights
- Runway and aircraft damage may occur with extreme temperatures and excessive precipitation
- Increased business costs (fuel, electricity, insurance, service disruption, ground transportation and lodging for displaced or stranded passengers)
- Sudden (or gradual) changes in demand
- Unhappy customers (and consequent economic losses)

Adaptation strategies may include:

Infrastructure reinforcement, such as sea walls and coastal protection, diversified local supplies/resources (fuel, electricity, water), storm water improvements (like better drainage, pumping, storage), enhanced response programs for disruptions, and Emergency Management Plans.

Climate Change and Transportation

Impacts to Public Transit

Challenges posed to the public transportation sector

Climatically hazardous conditions pose a threat to transit operators/drivers as well as passengers. Emergency vehicle operators such as ambulance drivers, fire fighters are particularly at risk, and vital emergency services may slow or stop completely. Increased precipitation may flood bus and train storage lots, as well as subway tunnels, and power outages could disrupt traffic control signals for all transit types.

Climatic factors will likely cause increased delays for transit users and economic losses for the public transportation sector. Low-income populations, seniors and disabled citizens, who may be disproportionately reliant on public transportation, will be more affected by transit interruptions.

Adaptation strategies may include:

- Sealing street-level vents and manholes; protecting underground pump rooms, circuit breaker houses and other underground facilities that provide power to subways;
- Purchasing buses or ferries that are able to withstand adverse weather conditions, and upgrading emergency communication systems.



Severe flooding stalls a Michigan school bus.

Climate Change and Transportation

Impacts to Marine Transport and Shipping

Challenges posed to waterway systems

80 percent of the world's volume in trade is carried by sea (UNCTAD). Harbors and docks are vulnerable to rising coastal water levels and higher storm surges.

Higher temperatures and/or increased sediment deposition from flooding may lead to reduced channel depth and lessened clearance under bridges. With shallower channels, more stringent size and weight restrictions will be enforced. Additionally, the operability of locks is influenced by floods and droughts.

The Great Lakes Basin Program for Soil Erosion and Sedimentation has a Soil Erosion & Sediment Control Task Force in every state:

<http://projects.glc.org/basin//>

Adaptation strategies may include:

Identification and reinforcement of vulnerable areas (by adding breakwaters, for example, or increasing dredging), increased monitoring and data collection at the local level, and compilation of case/studies & best practices.

Please see the “Ports, Harbors and Marinas” and “Water” module for more in-depth information on this topic.



Motorboat in the UK stuck under bridge.

Climate Change and Transportation

Extreme Rain and Flooding

Increase in frequency and severity of:

- Drainage issues and erosion threats to road and bridge structures
- Collapsed culverts, wash out/ inundation of causeways, bridges, low-lying roads
- Pavement and bridge joint expansion and road asphalt softening; compromised bridge structure integrity, due to high winds and channel flow
- Soil moisture, unstable slopes and landslides that cause road and bridge damage, along with service disruption

Modeling and projections can be predictive:

A DOT-funded vulnerability assessment for transportation systems in New Jersey, completed in 2011, was predictive of many of the areas actually flooded by Hurricane Irene and Superstorm Sandy. Similarly, the transportation sections of the City of New York's adaptation plan, completed in 2010, anticipated much of the flooding and damage that actually occurred, particularly the disastrous consequences of flooding highway and subway tunnels into Manhattan.



Climate Change and Transportation:

Hotter and drier summers

Increase in frequency and severity of:

- Pavement softening and buckling; distortion in wheel paths
- Reduced maximum loads among municipal, transport and residential transport vehicles on paved surfaces
- Reduced ride quality and performance, increased maintenance costs
- Reduced overall life span of roads, rail, bridges and culverts



Climate Change, Energy and Electricity

An Introduction

The energy sector is a major contributor to global climate change, with renewable energy -- wind and solar fuels in particular -- contributing the least. The operation of traffic signals, airline flight control decks, and public transit hubs all require energy to operate.

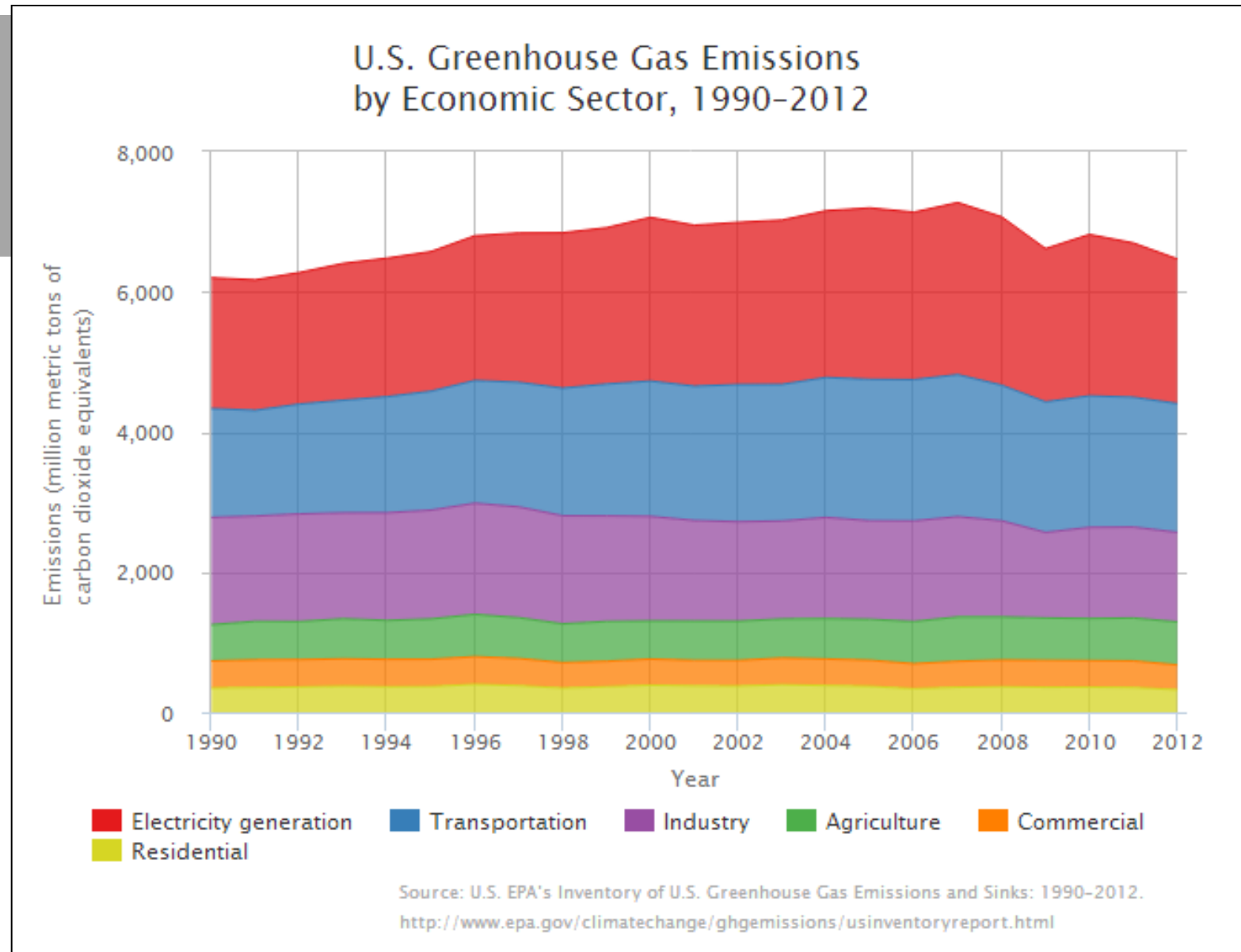
The National Resource Council and U.S. Global Change Research Program (USGCRP) found that **U.S. energy infrastructure is vulnerable to a range of climate change impacts**--particularly infrastructure in areas prone to severe weather, blackouts and water shortages.



Air traffic control hubs are one example of where climate change could impact the energy and transportation sectors.

Sector Emissions

According to the US Energy Information Administration, the electric power sector was the largest source of energy-related CO₂ emissions in 2009. The transportation sector was the second-largest source, contributing approximately 1/3 of the total emissions. Those emissions stem principally from the combustion of motor gasoline, diesel and jet fuel. Direct fuel use in residential and commercial sectors (mainly for heating) and the use of fuels...in the industrial sector together accounted for about ¼ of total CO₂ emissions in 2009. Energy and transportation sector emissions are projected to decline through 2020, while emissions from other sectors are predicted to increase.



Energy and Transportation Infrastructure:

Impacts and Management Strategies

Risks to infrastructure:

Buildings, roads, shipping channels, shoreline conditions, energy supplies and usage may all be affected by climate change, via stress on the power grid during hotter summers and colder winters. Additionally, crucial energy infrastructure elements may be damaged by extreme weather.



Adaptation strategies include:

- Manage power vulnerability;
- Diversify current energy sources to improve resiliency of existing system;
- Incorporate better ventilation, reduced energy use (efficiency, renewables);
- Manage fleet vulnerability with varied purchasing strategies and rotating maintenance schedules;
- Include climate change in new development and renovation planning;
- Set appropriate codes and standards.

Energy & Transportation Infrastructure

Transportation Energy Usage and Reduction

Key areas of concern (excerpted from www.cakex.org) :

“Resource extraction refineries and processing plants are often located near the coast, making them vulnerable to severe weather and sea level rise. With lessened oil and gas availability, transportation fuel sources may become more costly and less available.

Fuel transportation and storage infrastructure, including pipelines, barges, railways and storage tanks, is susceptible to damage from severe weather, melting permafrost, and increased precipitation.

Electricity generation and transmission infrastructures, such as power plants and power lines, are vulnerable to severe weather and/or water shortages, which can interrupt transportation operations.”

Adaptation strategies for reduced municipal energy usage:

- Shift primary power usage to off-peak hours and conduct energy audits routinely.
- Drinking and wastewater systems account for 25-40% of a municipality’s energy use. Proper equipment sizing, regular maintenance, and efficiency are an important consideration.
- One idea is to purchase electricity from landfill gas power plants.



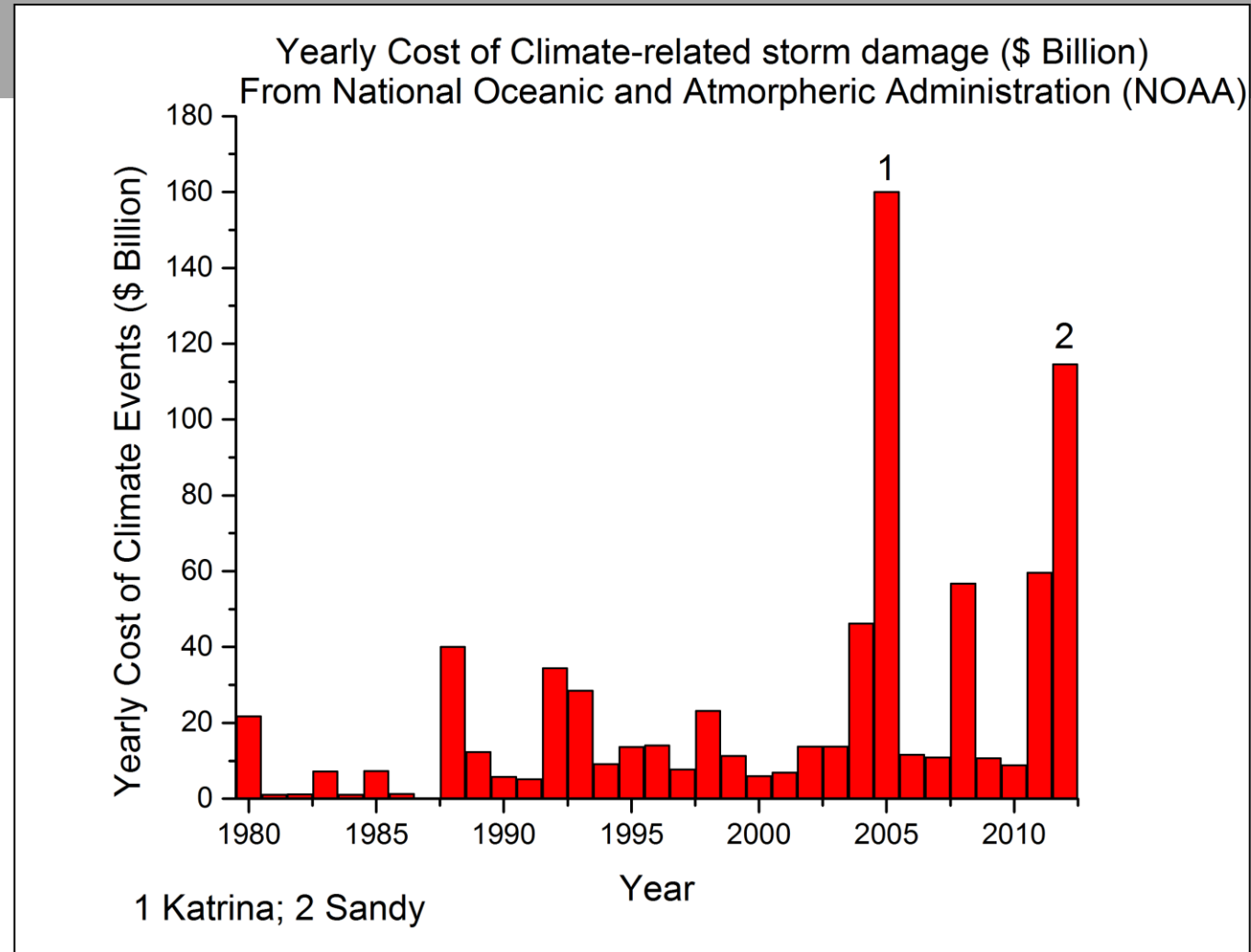
A worker attempts to repair a traffic light during a power outage after a severe storm.

Energy and Transportation Infrastructure

Financial implications

Municipalities may incur high costs related to the premature replacement of damaged infrastructure, or old and deteriorated infrastructure. The following financial considerations are important in the planning process:

- Increase in maintenance and operating costs;
- Expenditures set aside specifically for weather emergencies – response, evacuation and repair
- Increased insurance costs
- Loss of taxes and reduced income due to business disruptions
- Lawsuits stemming from transportation and energy grid safety issues



Source: NOAA

Infrastructure, Maintenance and the Law

Giuliani v. Halton, Milton Ontario

In April 1, 2003, Giuliani lost control of her vehicle on an icy road and travelled into oncoming traffic, colliding with another vehicle. In the three hours prior, 2cm of snow had fallen. The courts found that municipal authorities were lax in their roadway monitoring and clearing duties, and further, that the municipality was not in compliance with Minimum Maintenance Standards (2002) as they relate to snow accumulation and icy roadways. The standards stipulated that Milton authorities had a maximum of four hours to treat an icy roadway after becoming aware that the road was icy.

Failing to monitor the road conditions appropriately and in a timely fashion meant that de-icing did not commence on schedule. This implicated the municipality in the Giuliani incident.



Pronounced Effects in Smaller Communities

Wawa, Ontario

- October 25th 2012, excess rainfall of 100 mm in 12 hours
- Total flood damage exceeded \$10 million, with greatest damage to transportation infrastructure
- Severe damage to 3 bridges, plus one collapsed culvert
- Destroyed sections of a popular municipal biking and snowmobile trail



Photos by Chris Benka

Climate change-related strategies to consider in transportation and energy infrastructure planning

Adaptation Meets Mitigation

Walking and Bicycling

Alternative Transit Modes

Individual-level changes in transportation choices can add up to big impacts, improving local air quality and minimizing the urban heat island effect, for example.

- Private automobiles are responsible for 62% of transportation-related CO2 emissions (EPA 2006).
- Non-polluting forms of transportation such as biking and walking improve public health in several important ways. They:
 - reduce ground-level ozone;
 - lessen traffic congestion and minimize automobile accident risk;
 - offer the wellness benefits of physical activity.



Protected bike lane in Arlington, Virginia.

Adaptation Meets Mitigation

Electric Transit

Alternative Vehicle Types

Electric and hybrid vehicles help increase energy security, reduce emissions, improve fuel economy and reduce fuel costs. Since the electricity grid is available almost everywhere, electric vehicles are increasingly easy to charge. In fact, in 2014, the number of publicly accessible charging stations rose to more than 21,000 outlets.

Additional benefits include:

- Electric vehicles convert about 59–62% of the electrical energy from the grid to the wheels. Conventional gasoline vehicles only convert about 17–21% of the energy stored in gasoline to power their wheels.
- Evs are also quieter and, on average, require less maintenance than their gasoline-powered counterparts.



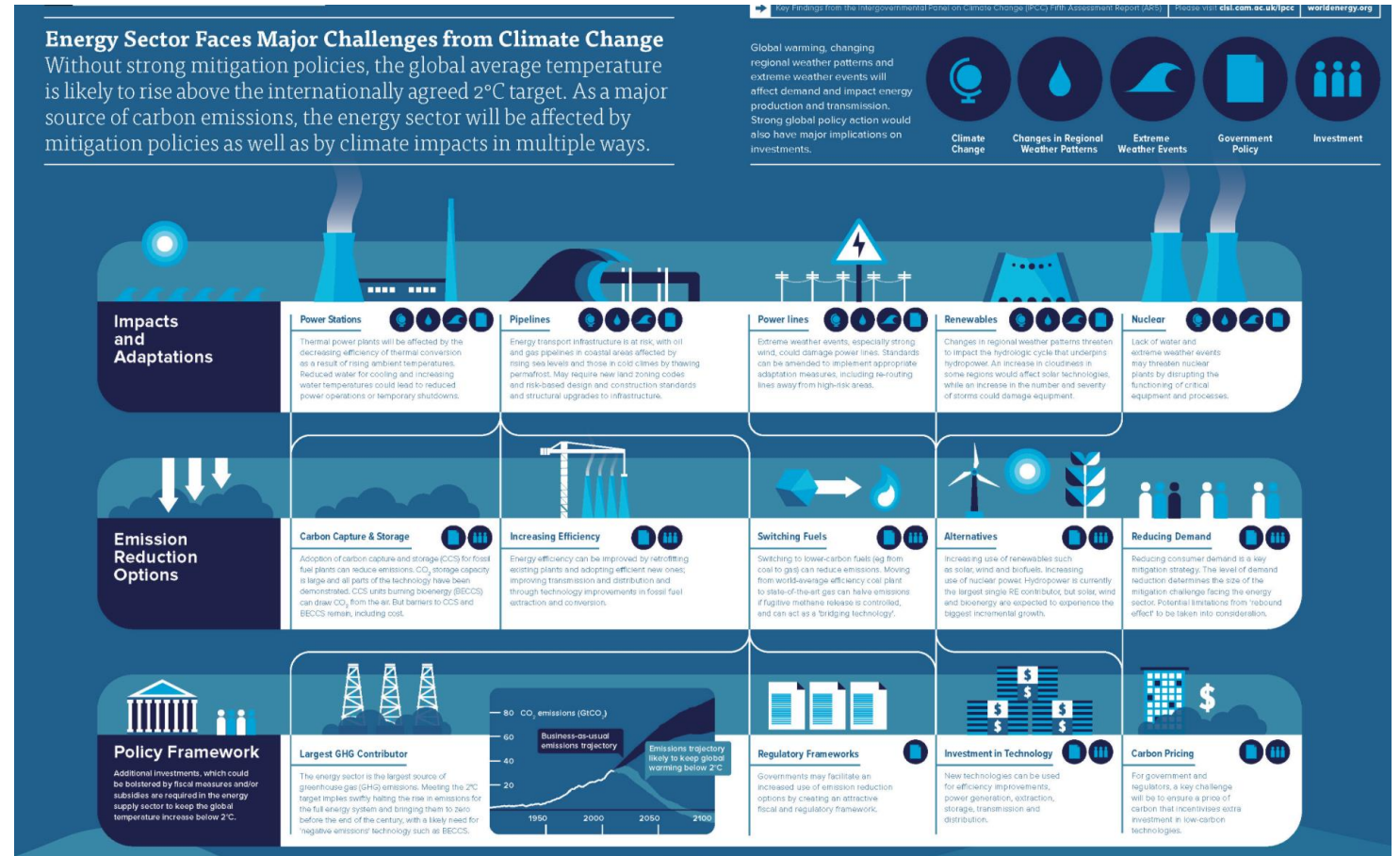
Electric car at a recharging station.

Infographic

[Here](#) is a link to an infographic that enumerates some of the mitigation and adaptation impacts of climate change to the energy sector.

Impacts may include:

- Reduced power plant operations, plant cooling, and fuel transportation vulnerabilities; rerouting of pipelines and power lines
- Changes to climate cycles which may impact renewable energy generation and production
- Implementing “negative emissions” technologies, and reducing overall consumer demand is one possible strategy.



Adaptation Meets Mitigation

The role of building codes

Zoning is a key important regulatory tool which can:

- Ensure that more pervious surfaces are created, which reduces water inundation of roadways and submersion of key infrastructure
- Increase mixed land use to shorten vehicle trips, thereby reducing wear and tear on road surfaces
- Require landscaping, mature tree preservation, and open spaces to mitigate temperature extremes that may damage infrastructure networks



Adaptation Meets Mitigation

Maintenance, the Low-Hanging Fruit

Routine maintenance of energy and transportation infrastructure is one of the easiest and most cost-effective strategies for dealing with the impacts of a changing climate. Additionally, providing information and training to employees can be beneficial in this regard as well.

- Establish a schedule for reviewing ingress and egress patterns, and identify highest priority repairs needed to culverts, power lines, roadways and facilities
- Identify areas at highest risk for flood and weather hazards
- Install warning signs and, when possible, barriers
- Conduct emergency drills and ensure evacuation plans are up to date and personnel are trained in emergency response measures
- Revise plowing guidelines, add emergency routes and revise weight and speed limits for winter road, bridge and railway use



Recent municipal efforts to create more resilient transportation and energy infrastructure networks

Case Study: Transportation

Ann Arbor, Michigan

Issues

- 24.7% of Ann Arbor's citizens use alternative transit modes to commute to work. This is higher than the national average (8%), but the City wished to do even better.
- Goal: discourage highway traffic, connect the City's existing bike paths, reduce traffic congestion and pollution, and encourage a healthier and more sustainable lifestyle among residents.

Adaptation Measure: Enhanced Bicycling Infrastructure

- Part of City's Climate Action Plan to incentivize residents to live within 2 miles of work
- City added over 4 lane miles of on-road bike lanes in 2012, bringing the total to over 71 lane miles.
- Offers ample bike parking, with 400+ bike hoops, 26 secured bike lockers and on-street bike parking racks, as well as fix-it stations
- Will begin offering bike sharing program, "ArborBike", in 2014



Bike lane, fix-it station and storage locker in Ann Arbor.

Case Study: Energy

San Francisco and Electric Cars

Issue

San Francisco sought to help reduce US dependency on fossil fuels, while simultaneously lowering smog and stimulating its local economy. To this end, the City is determined to become the electric vehicle (EV) capital of the US, and as such, has installed public charging infrastructure and is engaging in EV regional planning. The program is called “SF Electric Drive”.

Adaptation Measure: Electric cars and charging

- Offered FREE charging of EV vehicles at public stations through 2013, and provides maps of station locations so that drivers can quickly recharge
- Is Integrating EVs into City fleet and reducing fleet size, and now has the cleanest transit fleet in the nation. Is helping businesses transition to EV use through incentives programs
- Involved the private sector by piloting an EV car rental program through Hertz and Marriott
- Developed an EV Strategic Council as part of its SF Environment Department at the City of San Francisco. It also has a designated “Clean Transportation Team” that helps communicate news to the public and engender excitement about energy-saving shifts.



Case Study: Transportation

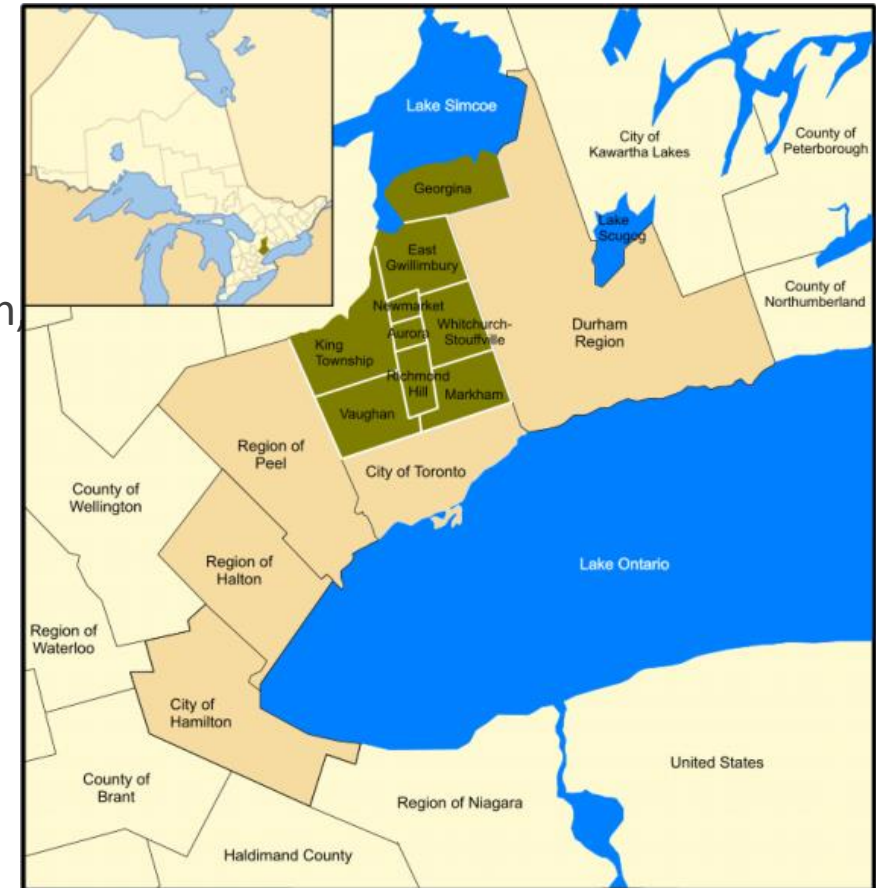
York Region, Ontario

Issues

- Increased population led to higher vehicle and road usage
- Increase in road widening, resulting in lack of space to store snow
- Increasing weather variability and extreme weather, particularly freezing rain, freeze/thaw and extreme cold
- Increase in road salting, posing risks to environment and watershed

Adaptation Measure: Salt Management Plan

- Pre treated Rock Salt
- Road Weather Information System (RWIS)
- Vehicle global positioning system (GPS)



Case Study: Energy

Power Grid “Hardening” in New York State

Issues

Severe weather, geothermal disturbances, even terrorist threats make power grids vulnerable to disruption. In the wake of Hurricane Sandy and other extreme weather events, New York is embarking on an ambitious plan to “harden” – or make more resilient- their existing energy infrastructure. The state has suffered nine federally-declared disasters in the last three years.

Adaptation Measures:

- New York Governor Cuomo has allocated \$1.37 billion to harden the state’s energy grid and create 10 “microgrids” at the community level
- Part of the “Reimagining New York for a New Reality” master plan
- The plan includes replacing and repairing aging bridges, installing an advanced weather detection system, and creating a Statewide Strategic Fuel Reserve that will enable gasoline-powered backup energy generation in the event of outages
- New coastal surge protection infrastructure will be built
- Citizens will be trained to become part of a Citizen First Responder Corps



Case Study: Transportation

Kingston, Ontario

Issues

- Aging road surfaces and increase in weather variability
- Increase in the incidences of large potholes, pavement surface cracks
- Increase in traffic jams due to road maintenance problems
- Soaring road maintenance costs

Adaptation Measure: Academic Partnership & Road Construction Standards

- Scientific testing and support by Queen's University Chemical Engineering Dept.
- Mandatory new standards in asphalt used in arterial and collector road construction and repaving
- Use of asphalt free of cheap and harmful additives and modifiers



Case Study: Transportation

Wisconsin Department of Transportation

Issue

Climate change in Wisconsin is projected to worsen smog and cause local vegetation to produce more pollen, increasing respiratory health threats such as allergies and asthma.

Adaptation Measure: Congestion Mitigation and Air Quality Improvement Plan

Wisconsin State's preparedness strategy includes:

- Measures to track and respond to air quality threats; expanded public health tracking
- Reduction of air pollution levels by increasing tree canopy, championing transportation alternatives and ridesharing, local power production, and lowering carbon fuels usage
- Outreach and education to county and city public health departments, school nurses, daycare centers, nursing homes, and other facilities about the Wisconsin statewide air quality notification system.
- Milwaukee's plan includes reduction of current levels of air pollution and improved air quality warning systems.



Case Study: Transportation

Sudbury, Ontario

Issue

Impact of climate change on performance of road and associated structures yet to be identified

Adaptation Measure: Assessment

PIEVC Engineering Assessment of Sudbury's road and associated structures

Assessment resulted in 104 recommendations:

- Remedial action ,10 recommendations
- Management action, 48 recommendations
- No further action, 34 recommendations
- Additional study, 12 recommendations

Vulnerabilities	
<i>Climate Effect</i>	<i>Infrastructure Component</i>
Increased frequency of high intensity rain	Washouts & damage of gravel road surfaces Surcharging / flooding of drainage systems
Rising temperatures (extreme / sustained summer)	Softening of asphalt road surfaces
Ice accretion	Functionality, operations, safety
Increased intensity / volume of rain > ground water table rise	Embankment failure; slope stability

Recommendations
• Review / revise design standards for drainage infrastructure • Review / revise maintenance procedures for roads / sidewalks • Improve materials / modify mix designs (asphalt, high temperature conditions) • Perform sensitivity analyses

Case Study: Transportation

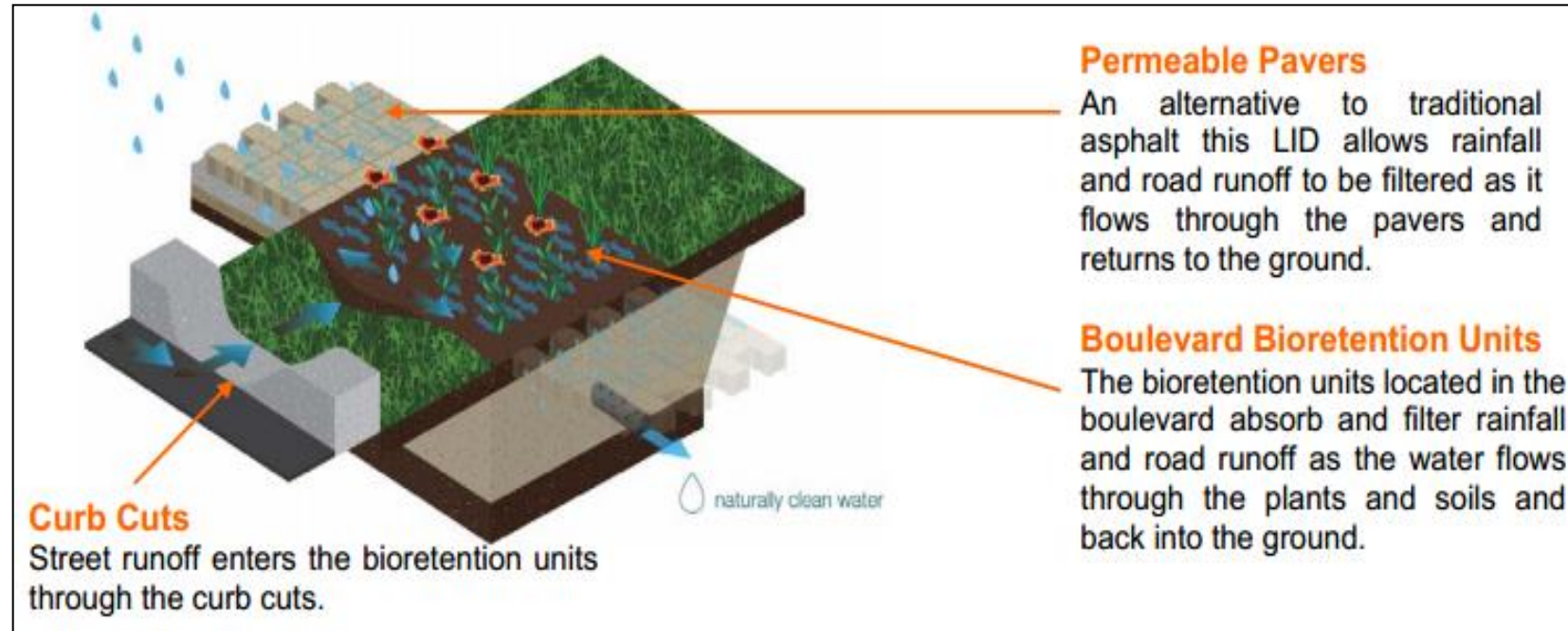
Peel Region, Ontario

Issue

Rainfall and runoff management

Adaptation Measure: LID Road Retrofits

- LID stands for “Low-Impact Development”
- LID retrofits are intended to help capture stormwater runoff
- LIDs help to calm traffic by reducing road width, thereby improving pedestrian safety



Resources to assist infrastructure planners

Reports

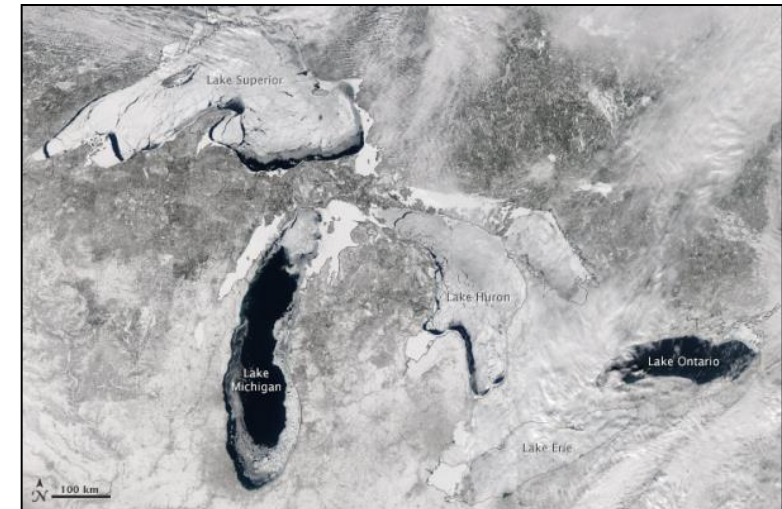
GLISA:

1. http://glisa.umich.edu/media/files/NCA/MTIT_Transportation.pdf

- a. Assesses current literature on potential impacts of climate change on transportation systems in the Midwestern region of the United States. Four sections follow:
- b. Synopsis of recent research on general transportation impacts
- c. Current climate projections for different parts of the Midwest, to assess levels of risk for transportation impacts from climate change
- d. Assessment of ongoing transportation adaptation measures
- e. Gaps in knowledge and research are discussed

2. Impacts discussed: Temperature and precipitation change, snow, water levels.

3. Ongoing efforts were highlighted, in areas including Chicago, Wisconsin, Iowa and Michigan



Reports



EPA: Climate Impacts on Energy

1. <http://www.epa.gov/climatechange/impacts-adaptation/energy.html>

2. Impacts discussed:

1. Temperature, energy demand and energy supply
2. Water availability and energy
3. Sea level rise, storm surge and extreme events
4. Wind speed, cloud cover and renewable energy

3. Climate changes will affect energy production, delivery, distribution and consumption in the US.

4. Problems like the cost of creating new infrastructure or updating old fixtures and facilities, as well as lesser known issues of competition, economic and population growth, and land use are addressed.

5. Useful links to many additional reports are provided.



Reports

Municipal:

Implementing Climate Change Adaptation in Prince George, BC:
Transportation Infrastructure

<https://www.ccadaptation.ca/en/component/k2/item/2794-implementing-climate-change-adaptation-in-prince-george-bc-transportation-infrastructure>

- Explores how Prince George is adapting its transportation infrastructure to climate change
 - Assesses climate change's impacts on road safety, conditions and vehicle crashes
 - City is considering using pervious paving to improve conditions

Implementing Climate Change Adaptation *in Prince George, BC*

Volume 5: Transportation Infrastructure



Ian Picketts

March 2012

Reports

GLISA:

Freezing-Rain in the Great Lakes

[http://glisacclimate.org/media/Freezing%20Rain%20in%20the%20Great%20Lakes%20\(6.7.13\)_0.pdf](http://glisacclimate.org/media/Freezing%20Rain%20in%20the%20Great%20Lakes%20(6.7.13)_0.pdf)

- a. A winter adaptation plan focused on Chicago
- b. Highlights the significant impacts from freezing-rain (issue stems from Chicago's proximity to Lake Michigan)



Additional Reports

Improved Data and Tools for Integrated Land Use-Transportation Planning in California Project

<http://ultrans.its.ucdavis.edu/projects/improved-data-and-tools-integrated-land-use-transportation-planning-california>

Up-to-date California-specific data on built environment-travel relationships allows decision-makers to consider the effects of transportation infrastructure and land use investment choices

FHWA's Climate Change and Extreme Weather Vulnerability Assessment Framework

<https://www.ccadaptation.ca/en/component/k2/item/2674-the-federal-highway-administrations-climate-change--extreme-weather-vulnerability-assessment-framework>

Guide for transportation agencies interested in assessing their vulnerability to climate change and extreme weather events. Provides overview of key steps in conducting vulnerability assessments and uses examples to demonstrate a variety of ways to gather and process information. The framework is comprised of three key steps: defining study objectives and scope; assessing vulnerability; and incorporating results into decision making.

Supplemental Slides:

Green Infrastructure Tools (EPA)

Green Infrastructure Tools available from EPA

Source: <http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm#tabs-3>



1. Cost-Benefit Resources

Help conduct cost benefit analyses of green infrastructure approaches. Includes completed analyses which demonstrate that green infrastructure's benefits and overall benefits can be well worth the investment.

2. Funding Opportunities

Green infrastructure serves many community purposes, and is thus eligible for an array of federal funding.

3. Policy Guides

Offers policy and planning strategies to encourage / require green infrastructure.

4. Design and Implementation Resources

Green infrastructure is most effective when the design is tailored to the context, when the installation follows the design, and when routine maintenance is performed.

5. Modeling Tools

Modeling tools are available to help assess the performance, costs, and benefits of green infrastructure, on a range of scales.

6. Federal Regulatory Programs

EPA encourages the use of green infrastructure in stormwater permits and Combined Sewer Overflow (CSO) enforcement agreements.

Supplemental Slides:

Green Infrastructure Tools – Valuation Tools Assessment

<http://publications.naturalengland.org.uk/publication/6264318517575680>

A report that highlights tools including:

- CAVAT: Capital Asset Value for Amenity Trees
- Green Infrastructure NorthWest's Green Infrastructure Valuation Toolkit
- Guide to valuing Green Infrastructure from the Centre for Neighborhood Technology Chicago
- Health Economic Assessment Tool for walking and cycling (HEAT);
- Helliwell
- i-Tree Design
- InVEST: Integrated Valuation of Environmental Services and Tradeoffs

Additional Resources

NOAA Factsheets:

- Civil Infrastructure:

http://www.ncdc.noaa.gov/sites/default/files/attachments/Civil%20Infrastructure_Low%20Rez.pdf

- Construction:

http://www.ncdc.noaa.gov/sites/default/files/attachments/Construction_Low%20Res.pdf

- Transportation:

http://www.ncdc.noaa.gov/sites/default/files/attachments/Transportation_Low%20Res.pdf

Other resources:

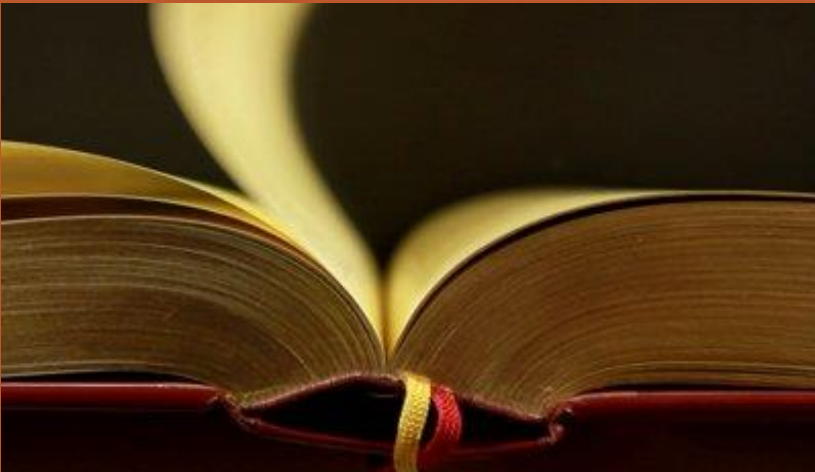
- NRC (2008). *The Potential Impacts of Climate Change on U.S. Transportation*. Research Board Special Report 290. National Research Council (NRC). <http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf>
Contains an in-depth study of the impacts of climate change on land, marine, and air transportation in the United States. The report recommends that state and local governments, as well as private infrastructure providers, incorporate climate change into long-term improvement plans, design, and operations and maintenance activities. It also discusses the potential benefits of using “smart” technologies for monitoring infrastructure, re-evaluating infrastructure design standards, updating maps used for flood insurance, and integrating climate change into transportation and land use planning.

- FCM/ CSA Infrastructure Adaptation Training:

<http://shop.csa.ca/en/canada/infrastructure-solutions/adapting-your-infrastructure-to-climate-change/inv/2703207wt/&bklist=icat,4,shop,training,infrastructuretrain>

- IISD Literature Review on Climate Adaptation and Canadian Infrastructure:

<http://www.iisd.org/publications/pub.aspx?pno=2854>



Additional Resources

Other resources:

- City of Toronto Vulnerability Assessment Info & RFP for project

http://www.merx.com/English/SUPPLIER_Menu.asp?WCE=Show&TAB=1&PORTAL=MERX&State=7&id=183752&print=Y&src=osr&ForceLID=&HID=&hcode=psexcgqiP32jggDNO6ttqA%3D%3D

- Road Construction Standards in Kingston:

http://www.thestar.com/news/gta/transportation/2014/01/15/potholefree_roads_yes_its_possible_with_better_asphalt_says_queens_university_professor.html

<http://www.chem.queensu.ca>

<http://www.cbc.ca/news/canada/ottawa/kingston-asphalt-program-takes-aim-at-potholes-1.2505845>

- Case Study of PIEVC Road Infrastructure Assessment in City of Sudbury:

http://www.pievc.ca/e/doc_list.cfm?dsid=3

- LID road retrofits in Peel Region

<http://www.creditvalleyca.ca/low-impact-development/showcasing-water-innovation-2/road-right-of-ways/>

- Case study of Prince George

http://princegeorge.ca/environment/climatechange/adaptation/Documents/2012_PGRAC_Transport_volume%20with%20Exec%20Sum.pdf

- York Region De-Icing Strategies

<http://www.cleanairpartnership.org/files/2%20Case%20Study.pdf>

