Institute for Catastrophic Loss Reduction
Building resilient communities

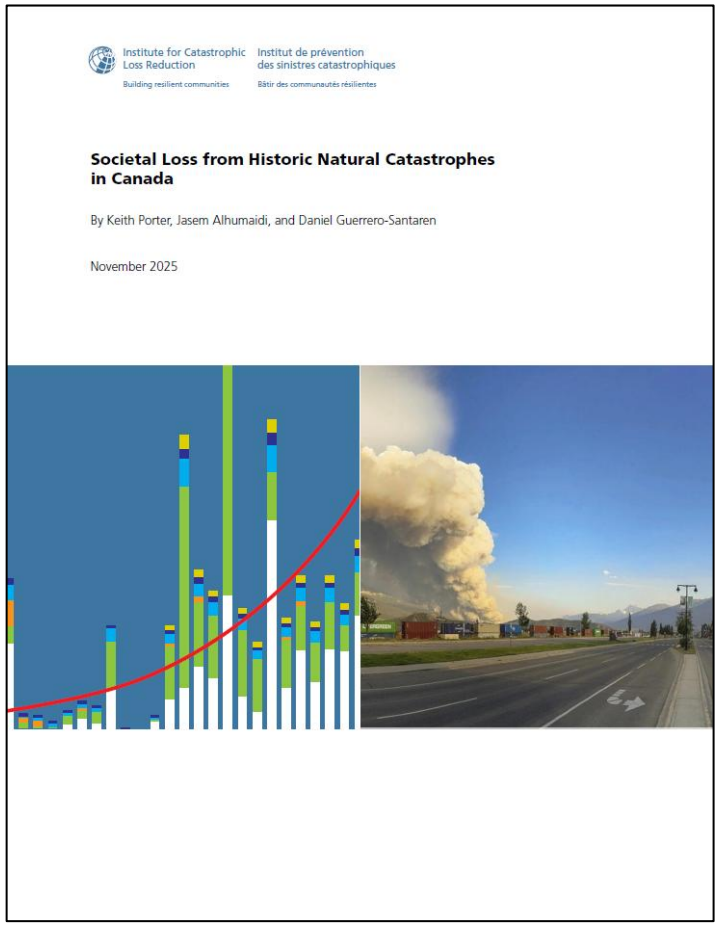
Institut de Prévention des Sinistres Catastrophiques
Bâtir des communautés résilientes

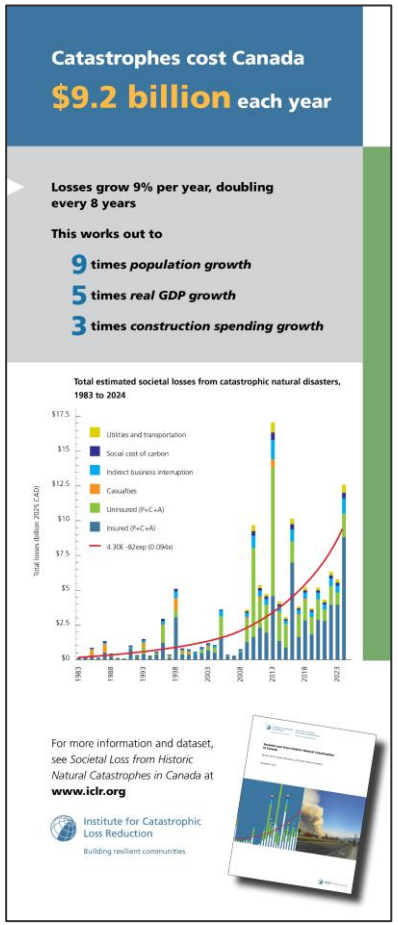
ICLR's New Canadian Catastrophe History

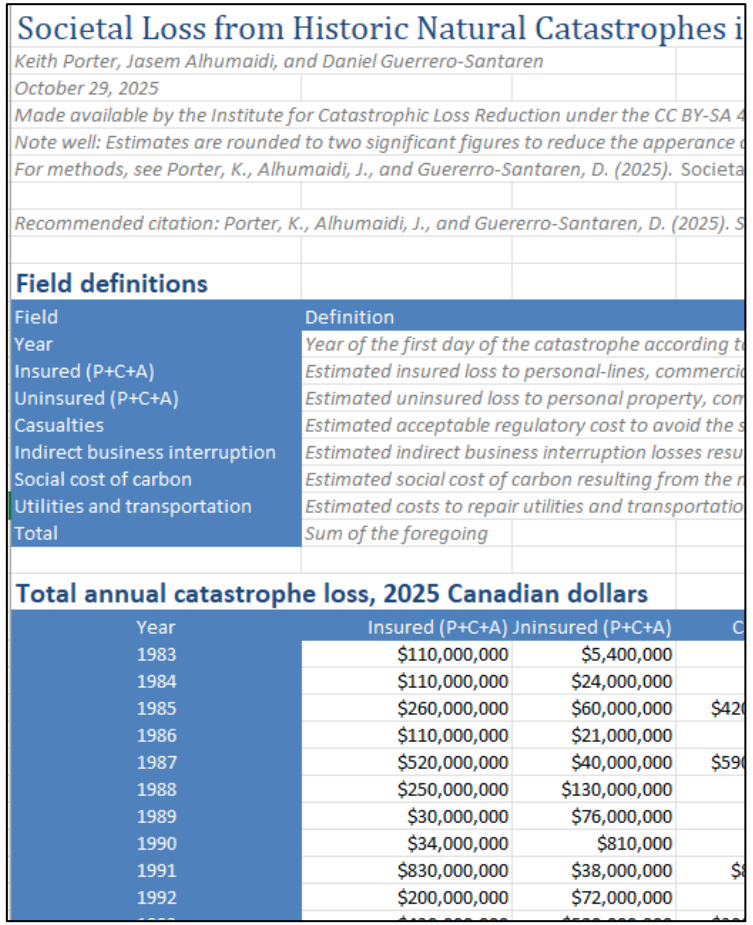
Dr. Keith Porter

March 13, 2026

ICLR's cat history & my co-authors







J. Alhumaidi

D. Guerrero-Santaren

https://www.iclr.org/researchpapers/ or search "iclr.org societal loss"

Introduction

ICLR aims to inform and persuade. A cat history helps with both.

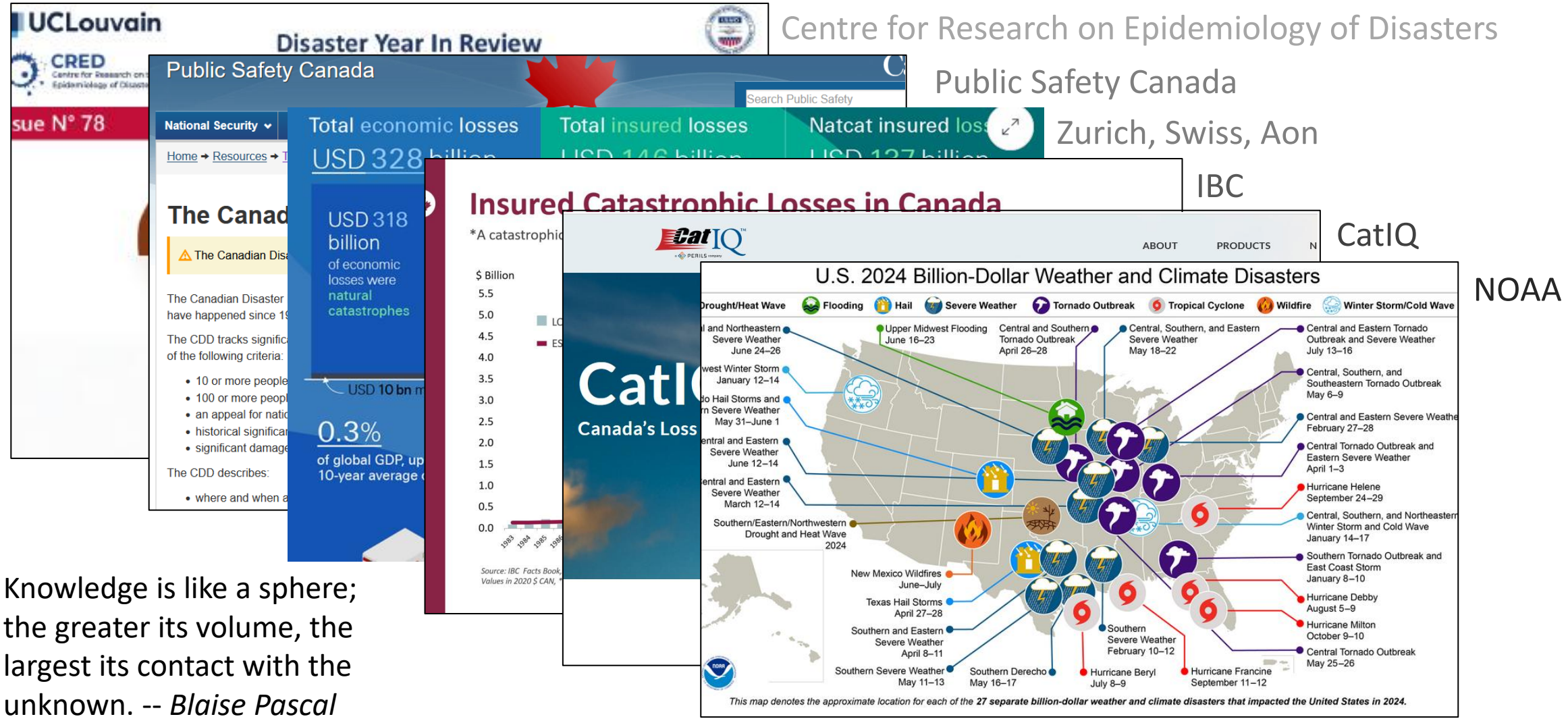
Leading source for resilience info

Information by hazard:

Information by role:

Improve safety & reduce damage

A well-trodden path



Centre for Research on Epidemiology of Disasters

Public Safety Canada

Zurich, Swiss, Aon

IBC

CatIQ

NOAA

Knowledge is like a sphere; the greater its volume, the largest its contact with the unknown. -- *Blaise Pascal*

Objectives: L_1 – L_{10} in Canada catastrophes since 1983

L_1	insured personal property repair costs, additional living expenses
L_2	insured commercial property repair costs, direct business interruption
L_3	insured auto repair costs
L_4	uninsured personal property repair costs, additional living expenses
L_5	uninsured commercial property repair costs, direct business interruption
L_6	uninsured auto repair costs
L_7	value of deaths and injuries
L_8	indirect business interruption losses
L_9	externalized social cost of greenhouse gas emissions from repairs
L_{10}	costs to repair utilities and transportation infrastructure

Methodology

Method, very briefly

Table 2. Brief sketch of the proposed methodology

Item	Meaning	Source
L_1	Insured personal property repair costs and additional living expenses	CatIQ after 2008; IBC before 2008
L_2	Insured commercial property repair costs and direct business interruption	CatIQ after 2008; IBC before 2008
L_3	Insured auto repair costs	CatIQ after 2008; IBC before 2008
L_4	Uninsured personal property repair costs and additional living expenses	L_1 factored by insurance penetration F_1, estimated as the ratio of total number of dwellings to number of insured personal-lines risks, less L_1
L_5	Uninsured commercial property repair costs and direct business interruption	L_2 factored by insurance penetration F_2, estimated as the ratio of total business establishments to number of insured commercial-lines risks, less L_2
L_6	Uninsured auto losses	L_3 factored by insurance penetration F_3, estimated as the ratio of total registered vehicles to insured auto risks, less L_3
L_7	Value of deaths and injuries	Canadian Disaster Database deaths and injuries multiplied by the acceptable regulatory costs to avoid statistical deaths and injuries
L_8	Indirect business interruption losses	Property losses L_1 through L_6 multiplied by a factor reflecting indirect business interruption to property loss, using Multi-hazard Mitigation Council (2019)
L_9	Externalized social cost of greenhouse gas emissions required to perform repairs	Property losses multiplied by a factor that reflects the social cost of carbon per unit of property value
L_{10}	Costs to repair utilities and transportation infrastructure	Property losses multiplied by a factor that reflects public expenditures on lifeline repairs implied by the Disaster Financial Assistance Arrangement

Insured personal, commercial, and auto losses L_1, L_2, and L_3

From IBC before 2008, CatIQ after

Uninsured personal property loss and additional living expenses L_4

Uninsured personal = insured personal scaled up by penetration

$$L_4 = \frac{L_1}{F_1} - 1$$

F_1 = personal-lines penetration rate

$N_{1i,j,k}$ = personal property policies (CatIQ)

$M_{1i,j}$ = total private dwellings (StatsCan)

i = index to catastrophes

j = index to province or territory

k = index to perils in i (hail etc.; CatIQ)

$$F_{1i,j,notsewer} = \left(\prod_{k=1}^{Perils}\left(\frac{N_{1i,j,k}}{M_{1i,j}}\right)\right)^{\frac{1}{Perils}} : k \neq \text{sewer (STSB)}$$

$$F_{1i,j,water} = \frac{N_{1i,j,water}}{M_{1i,j}}$$

Uninsured commercial property loss and direct business interruption L_5

Uninsured commercial = insured commercial scaled up by penetration

$$L_5 = \frac{L_2}{F_2} - 1$$

$$F_{2i,j} = \left(\prod_{k=1}^{Perils}\left(\frac{N_{2i,j,k}}{M_{2i,j}}\right)\right)^{\frac{1}{Perils}}$$

F_2 = commercial-lines penetration rate

$N_{2i,j,k}$ = commercial property policies (CatIQ)

$M_{2i,j}$ = business establishments (StatsCan)

Uninsured auto L_6

Uninsured auto = insured auto scaled up by penetration rate

$$L_6 = \frac{L_3}{F_3} - 1$$

$$F_{3i,j} = \left(\prod_{k=1}^{Perils}\left(\frac{N_{3i,j,k}}{M_{3i,j}}\right)\right)^{\frac{1}{Perils}}$$

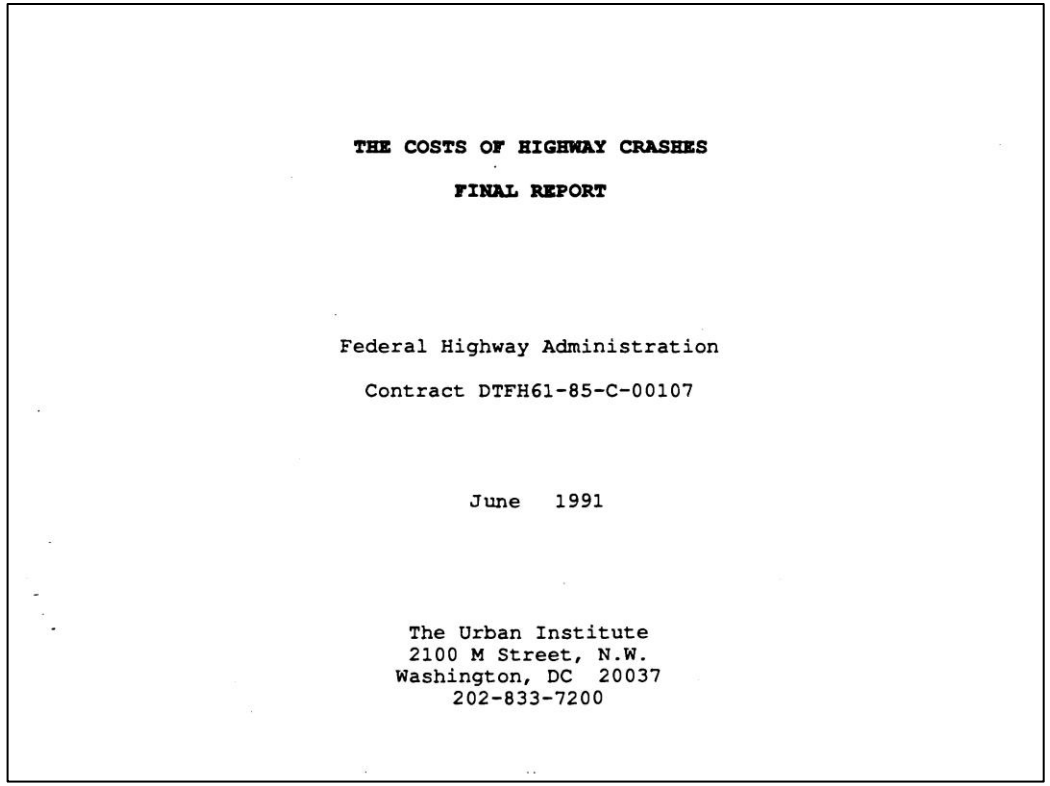
$N_{3,i,j,k}$ = number of auto policies (CatIQ)

$M_{3i,j}$ = registered vehicles (StatsCan)

k, Perils exclude water/sewer backup

Deaths and injuries L_7 (value of life safety)

Urban Institute & FHWA willingness to pay for safety



THE COSTS OF HIGHWAY CRASHES

FINAL REPORT

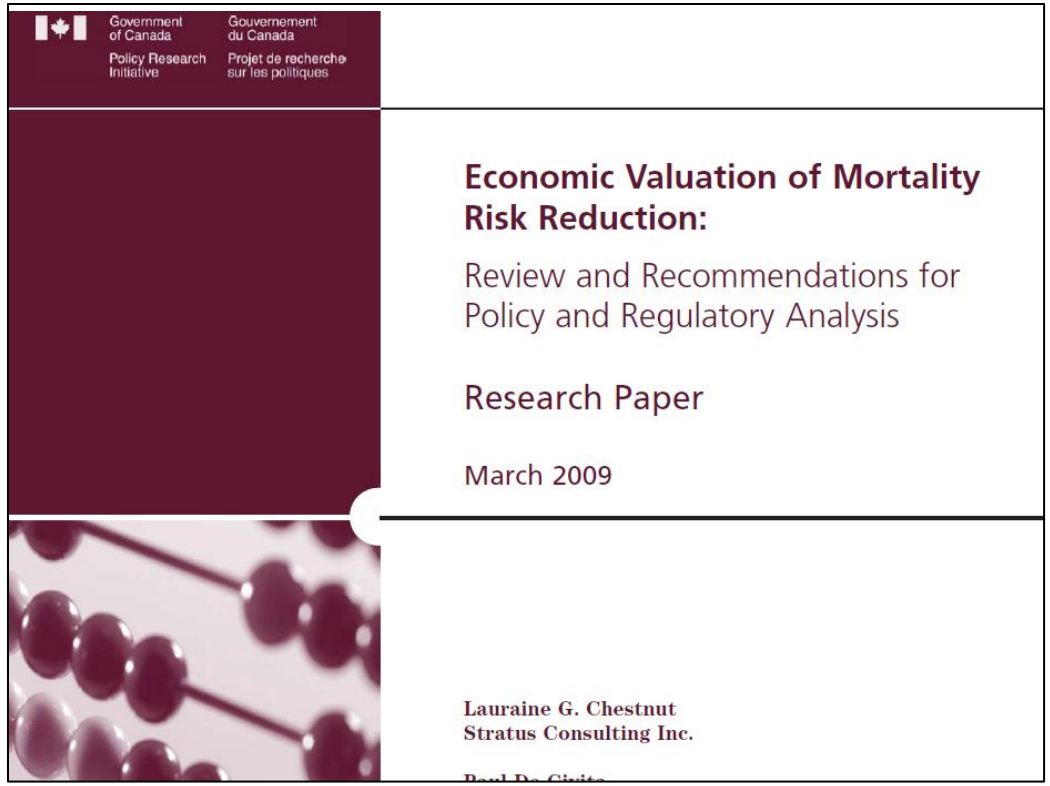
Federal Highway Administration

Contract DTFH61-85-C-00107

June 1991

The Urban Institute
2100 M Street, N.W.
Washington, DC 20037
202-833-7200

Chestnut & de Civita



Government of Canada / Gouvernement du Canada
Policy Research Initiative / Projet de recherche sur les politiques

Economic Valuation of Mortality Risk Reduction:

Review and Recommendations for Policy and Regulatory Analysis

Research Paper

March 2009

Lauraine G. Chestnut
Stratus Consulting Inc.

Deaths and injuries L_7

Death & injury loss = acceptable reg. cost to avoid that many statistical deaths & injuries

$$L_{7i} = \left(N_{AIS6,i} + N_{AIS3,i} \cdot F_{7,AIS3}\right) \cdot VSFA_{CD}$$

$N_{AIS6,i}$ = deaths (Canadian Disaster DB)

$N_{AIS3,i}$ = injuries (Canadian Disaster DB)

$F_{7,AIS3}$ = 0.0575 (USDOT)

$VSFA_{CD}$ = value of statistical fatality avoided (Chestnut & De Civita)

= 2007 CAD $6.3 million

Indirect business interruption L_8

Indirect BI = property & casualty loss × a factor from US input-output analysis

$$L_8 = F_8 \cdot (L_1 + L_2 + L_3 + L_4 + L_5 + L_6 + L_7)$$

F_8 = IBI as % of losses $L_1 - L_7$
= 0.10 (NIBS 2019)

Peril, *k*	F_{8k}	Comment
Hail	10%	Multi-Hazard Mitigation Council (2019) Figure 2-22
Flood	3.9%	Multi-Hazard Mitigation Council (2019) Figure 2-21
Windstorm	10%	Multi-Hazard Mitigation Council (2019) Figure 2-22
Lightning	10%	Multi-Hazard Mitigation Council (2019) Figure 2-22
Water	10%	Multi-Hazard Mitigation Council (2019) Figure 2-22
Winter storm	10%	Multi-Hazard Mitigation Council (2019) Figure 2-22
Fire	2.1%	Multi-Hazard Mitigation Council (2019) Figure 2-19
Earthquake	17%	Multi-Hazard Mitigation Council (2019) Figure 2-24

Social cost of carbon L_9 (carbon embodied in repairs)

Magwood et al. (2023) 505 kg CO_{2e}/m^2

RMI

The Hidden Climate Impact of Residential Construction

Zeroing In on Embodied Carbon Emissions for Low-Rise Residential Buildings in the United States

ECCC (2023) $0.266/kg CO_{2e} (2024 CAD)

Government of Canada | Gouvernement du Canada

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Canada.ca › Environment and natural resources › Climate change › Climate science

Social cost of greenhouse gas emissions

Official title: Social Cost of Greenhouse Gas Estimates – Interim Updated Guidance for the Government of Car

On this page

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  - 2.3. Analyses involving multiple GHGs
  - 2.4. Sensitivity analysis
  - 2.5. Break-even analysis
- 3. Estimating the SC-GHG
  - 3.1. Background
  - 3.2. History

Social cost of carbon L_9

Social cost of carbon = property loss × its embodied carbon cost

$$L_9 = F_9 \cdot (L_1 + L_2 + L_3 + L_4 + L_5 + L_6)$$

F_9 = (carbon/property)
× (property/total)
= 4.2% × 97% (PL) or
= 4.2% × 92% (CL)
≈ 0.04

Utilities & transportation infrastructure L_{10}

U&TI = property loss × apparent long-term ratio

$$L_{10} = F_{10} \cdot (L_1 + L_2 + L_3 + L_4 + L_5 + L_6)$$

F_{10} = (U&T repairs)/(property loss)
= DFAA 2009-2015 ×
(U&T as % of total) ÷
(property loss 2009-2015)
= \$4.5B × 0.5 ÷ \$45B
= 0.05

Inflation

Inflate building losses using shelter CPI
Inflate everything else using all-items CPI

$$F_{4i,j} = \frac{CPI_{Shelter,now,j}}{CPI_{Shelter,i,j}}$$

F_4 for buildings (L_1, L_2, L_4, L_5, L_9)

$$F_{5i} = \frac{CPI_{AllItems,now}}{CPI_{AllItems,i}}$$

F_5 for all others

Results

Sample intermediate results by catastrophe (*not published*)

Table 6. First five catastrophes in the database, showing losses in millions of 2024 CAD by loss category

Catastrophe	Name	Insured personal	Insured comm	Insured auto	Unins personal	Unins comm	Unins auto	Casual-ties	Indirect BI	Carbon	Util & transp	Total
Redacted	Redacted	$88.4	$14.6	$8.0	$9.8	$7.5	$1.2	$0.0	$12.9	$5.2	$6.5	$154
Redacted	Redacted	$108.9	$12.8	$122.9	$6.9	$8.9	$2.5	$0.0	$26.3	$10.5	$13.1	$313
Redacted	Redacted	$27.0	$5.8	$11.0	$4.8	$0.1	$0.1	$0.0	$4.9	$1.9	$2.4	$58
Redacted	Redacted	$47.1	$4.5	$21.0	$2.0	$0.0	$2.9	$0.0	$7.8	$3.1	$3.9	$92
Redacted	Redacted	$50.6	$17.5	$4.5	$15.1	$7.9	$0.9	$0.0	$9.6	$3.9	$4.8	$115

Sample results table at https://www.iclr.org/researchpapers/

Total annual catastrophe loss, 2025 Canadian dollars

Year	Insured (P+C+A)	Uninsured (P+C+A)	Casualties	Indirect business interruption	Social cost of carbon	Utilities and transportation	Total
1983	$110,000,000	$5,400,000	$0	$11,000,000	$4,500,000	$570,000	$130,000,000
1984	$110,000,000	$24,000,000	$0	$13,000,000	$5,200,000	$650,000	$150,000,000
1985	$260,000,000	$60,000,000	$420,000,000	$74,000,000	$30,000,000	$3,700,000	$850,000,000
1986	$110,000,000	$21,000,000	$0	$13,000,000	$5,400,000	$670,000	$150,000,000
1987	$520,000,000	$40,000,000	$590,000,000				
1988	$250,000,000	$130,000,000	$0				
1989	$30,000,000	$76,000,000	$0				
1990	$34,000,000	$810,000	$0				
1991	$830,000,000	$38,000,000	$8,000,000				
1992	$200,000,000	$72,000,000	$0				
1993	$430,000,000	$520,000,000	$300,000,000				
1994	$150,000,000	$82,000,000	$2,100,000				
1995	$380,000,000	$140,000,000	$0				
1996	$1,200,000,000	$1,200,000,000	$92,000,000	$250,000,000	$100,000,000	$13,000,000	$2,900,000,000
1997	$130,000,000	$180,000,000	$0	$32,000,000	$13,000,000	$1,600,000	$360,000,000
1998	$3,100,000,000	$570,000,000	$820,000,000	$450,000,000	$180,000,000	$22,000,000	$5,100,000,000
1999	$380,000,000	$200,000,000	$120,000,000	$69,000,000	$28,000,000	$3,500,000	$790,000,000
2000	$370,000,000	$78,000,000	$190,000,000	$63,000,000	$25,000,000	$3,200,000	$730,000,000

Societal Loss from Historic Natural Catastrophes in Canada

Societal Loss from Historic Natural Catastrophes in Canada: Dataset

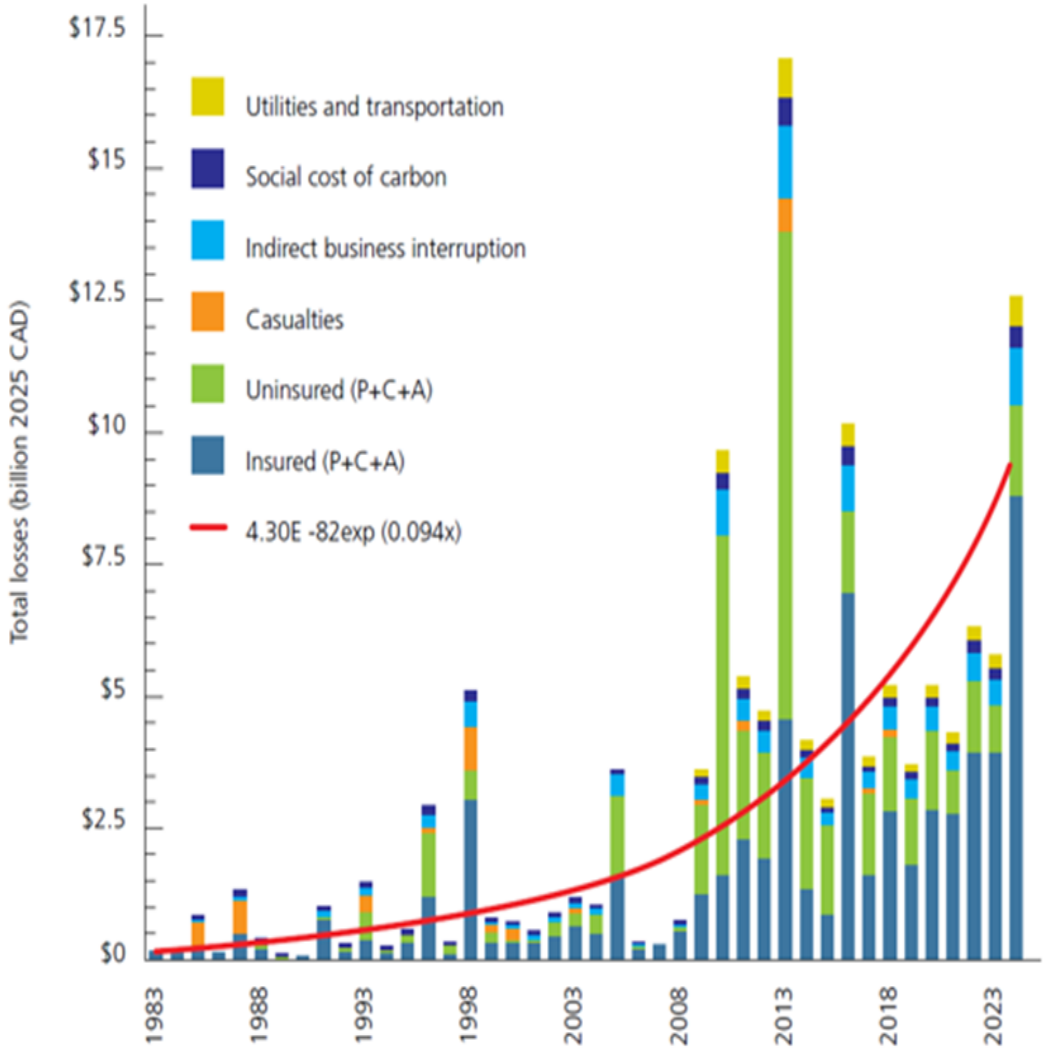
Keith Porter, Jasem Alhumaidi, and Daniel Guerrero-Santaren,

November 2025

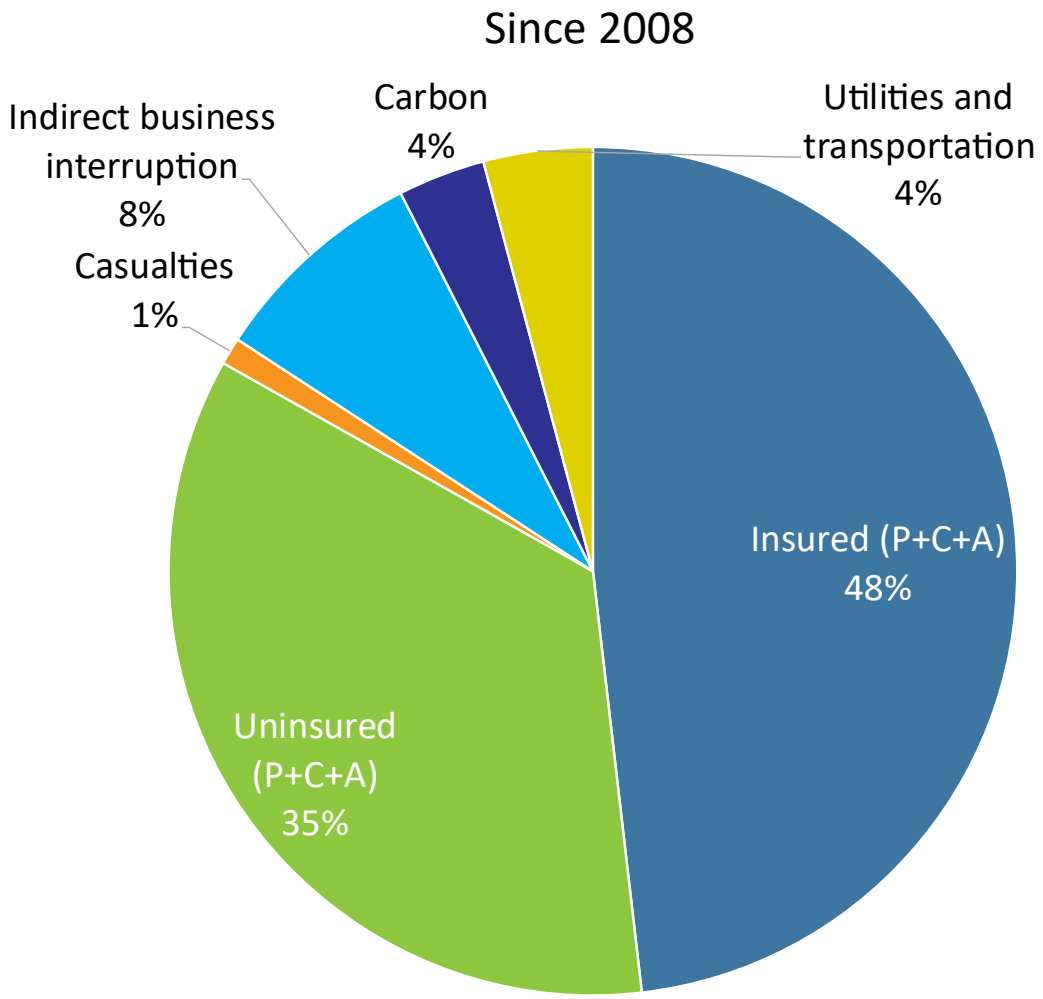
ICLR Research Paper Series – No. 82

Numbers are rounded to 2 significant figures to reduce the appearance of excessive accuracy.

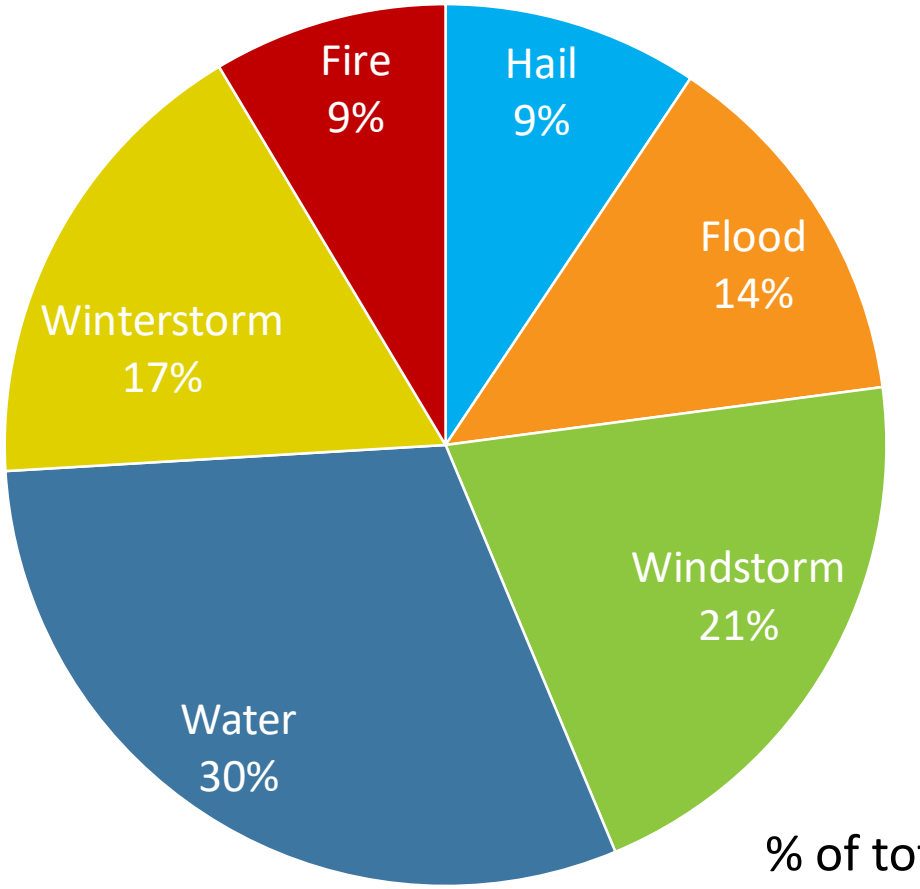
Yearly total losses in 2025 CAD



How big is each loss category?

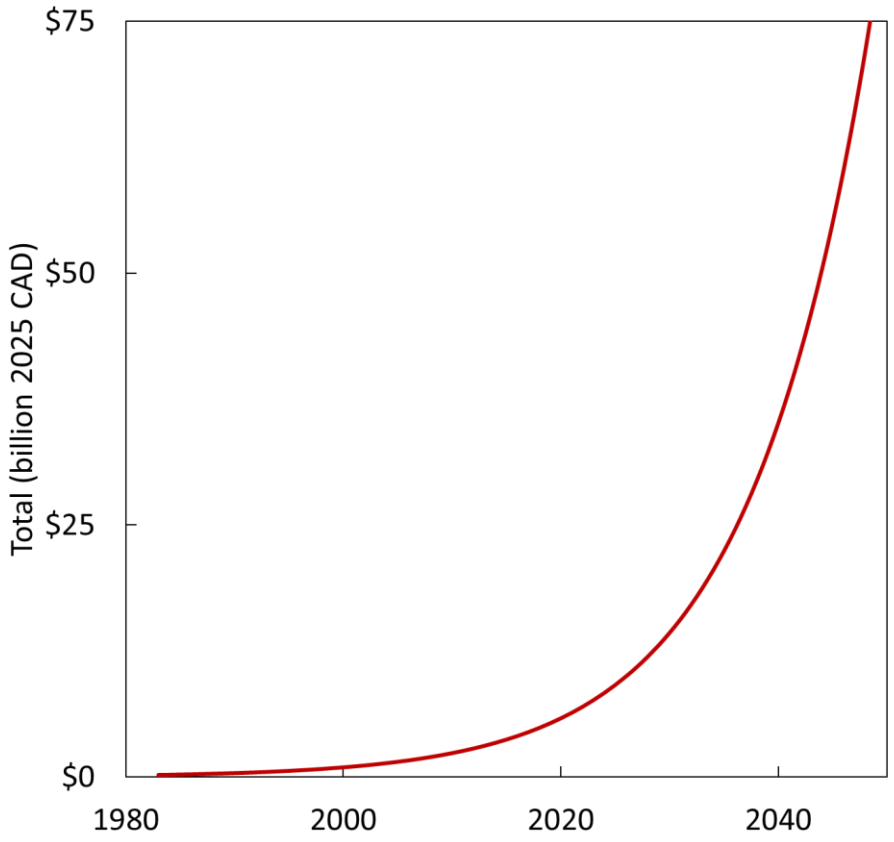


What are the leading hazards?



% of total that “involved” each peril. Big overlaps.

How fast is loss growing?



$9B/year = 3% of construction spending

= 2 weeks of construction

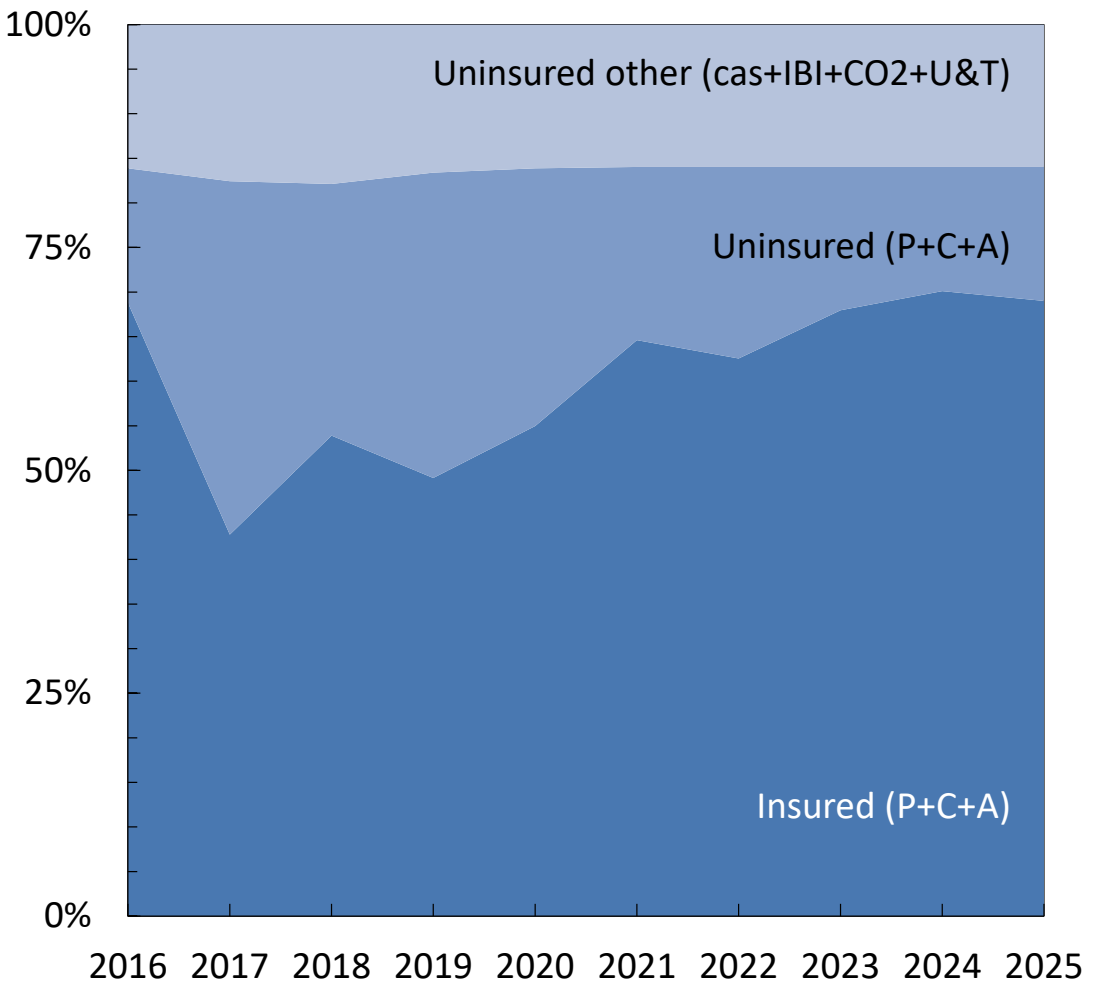
9.2% real annual growth in cat losses

= 9x population growth

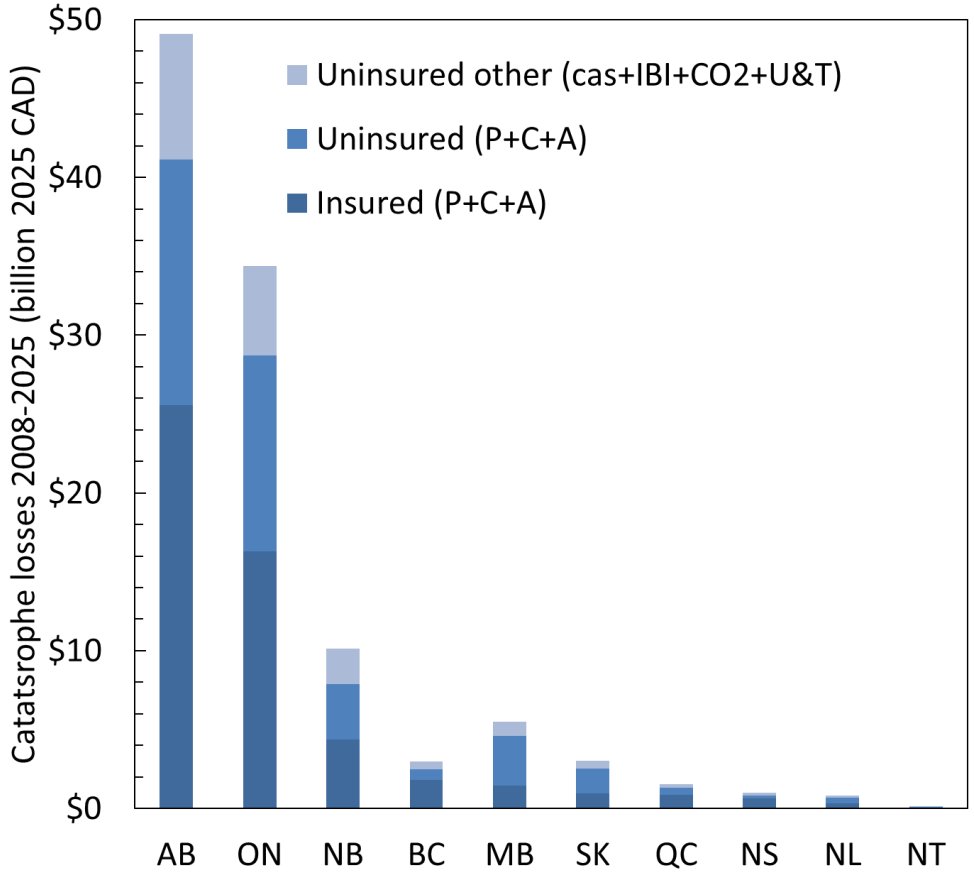
= 5x real (after-inflation) GDP growth

= 3x real construction spending growth

How much insurance protection gap?



What are the riskiest provinces?

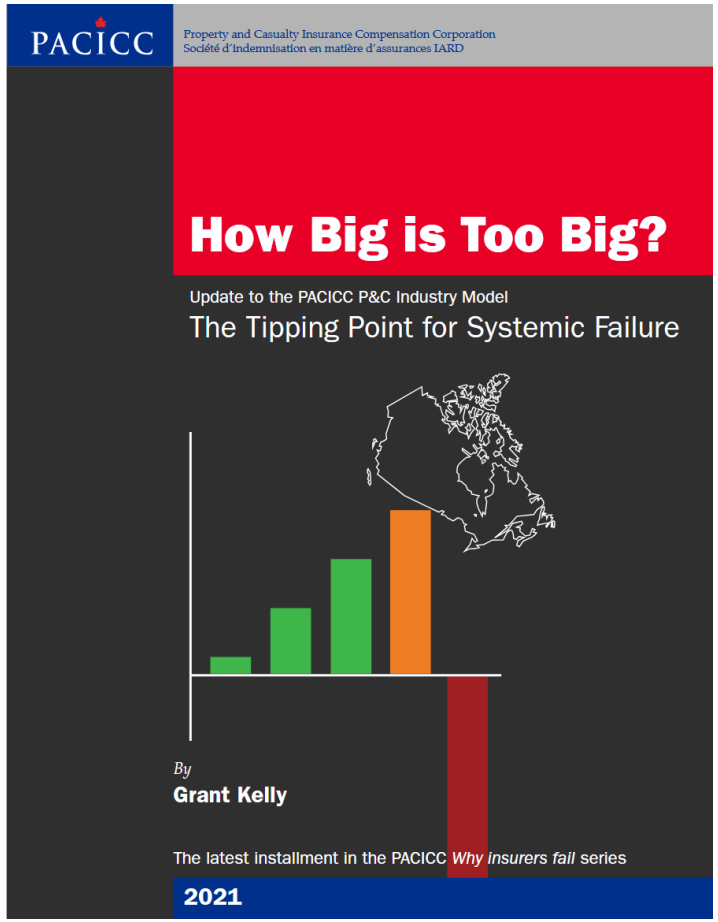


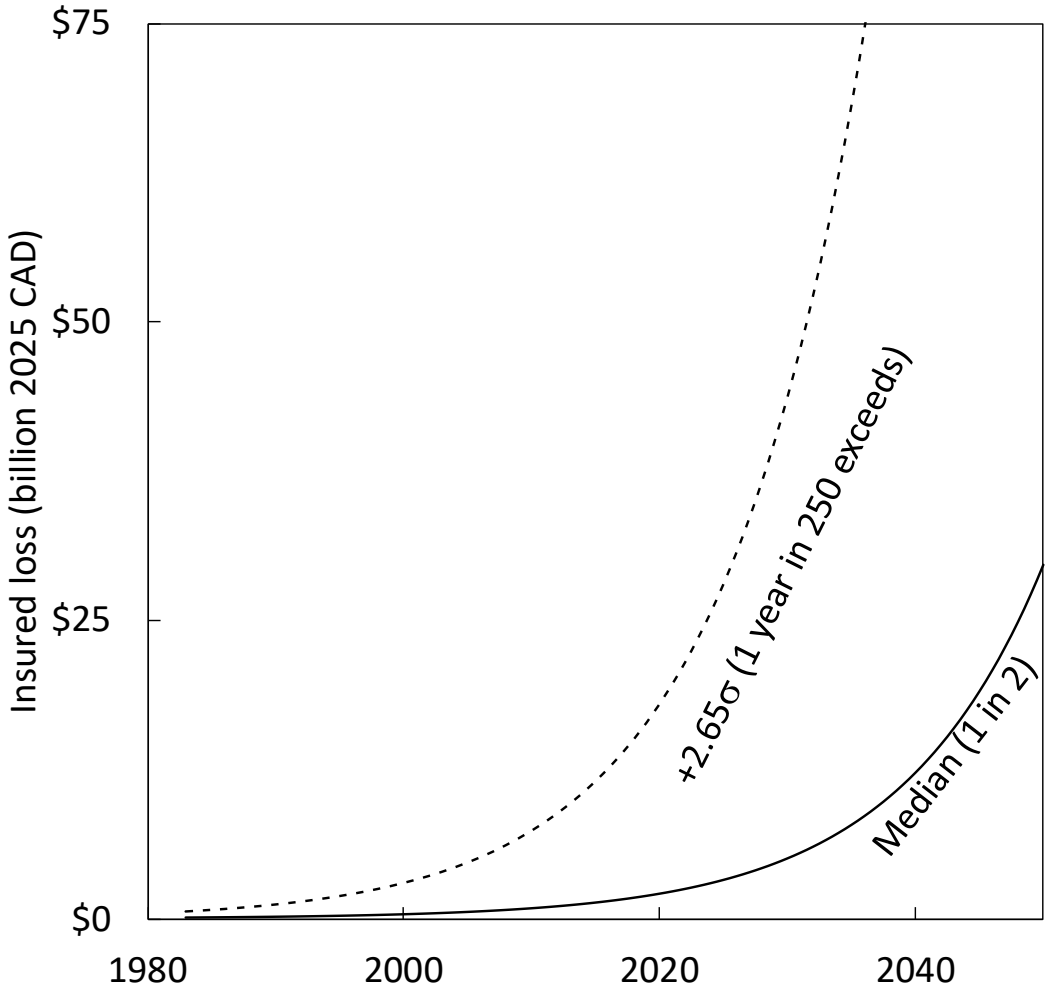
Quality assurance

- Spot checks of low, high, and middling samples agree with hand calcs
- Our $L_1 + L_2 + L_3$ for 2008+ agree with IBC; same origin
- Our total 2015-2024 ($24.3B USD) ≈ Swiss Re's $25B (Bevere 2025)
- Our estimated insurance projection gap (39%) ≈ Swiss Re's (37%)
- Sniff test by experts from CatIQ, Munich Re, and Climate Central

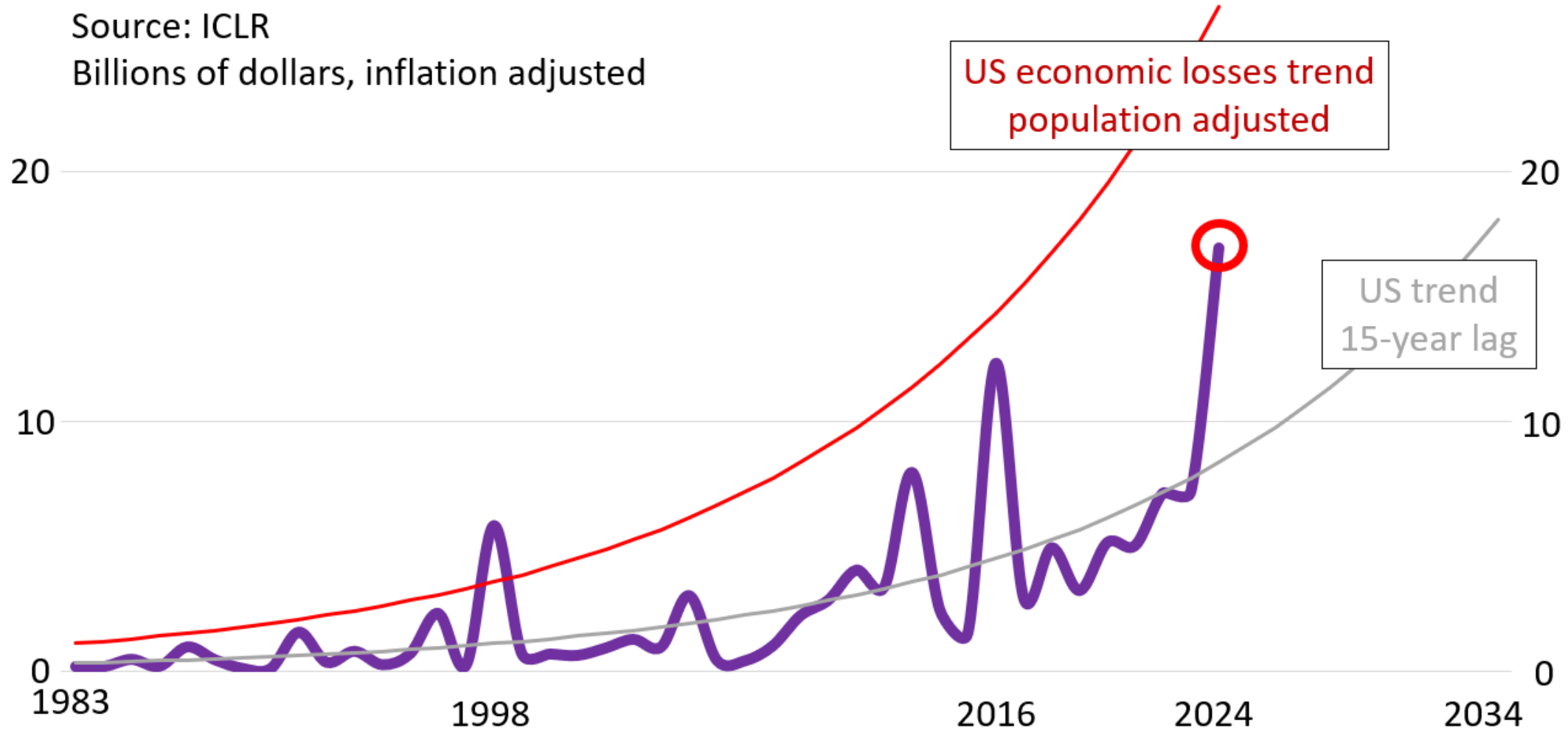
So what?

How much cat reinsurance required?

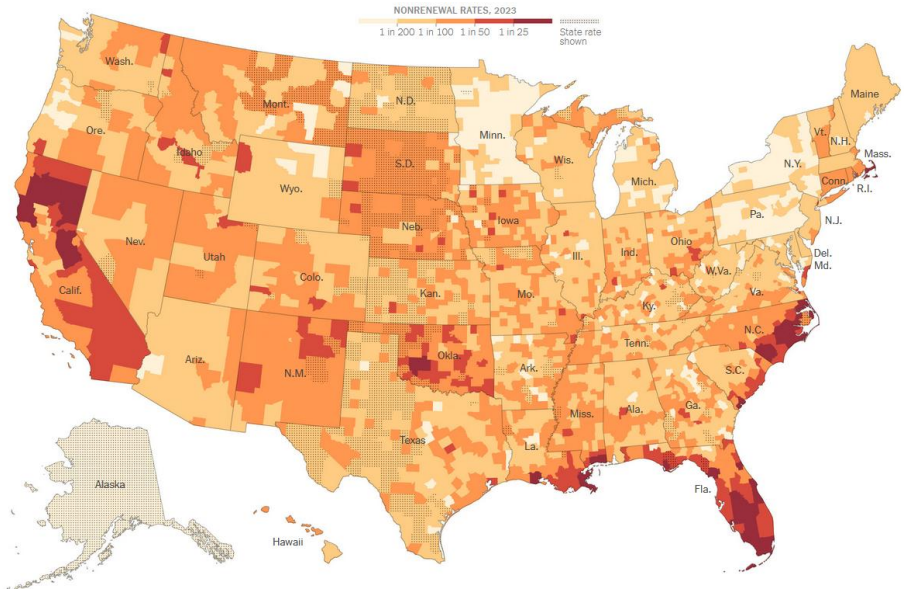




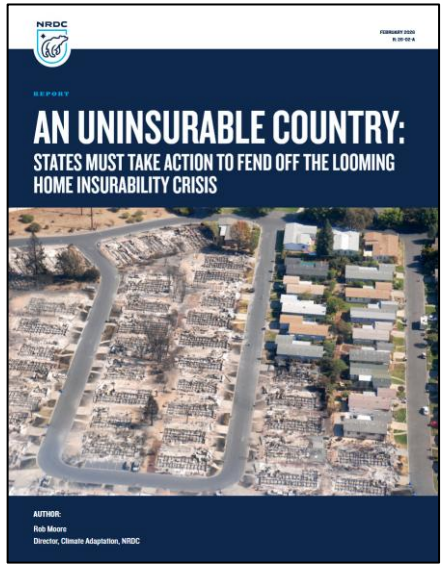
Can America's present tell us about Canada's future?



Recall 15-year US-Canada lag. Will Canada by insurable in 15 years?



New York Times 12/18/2024



NRDC 2026

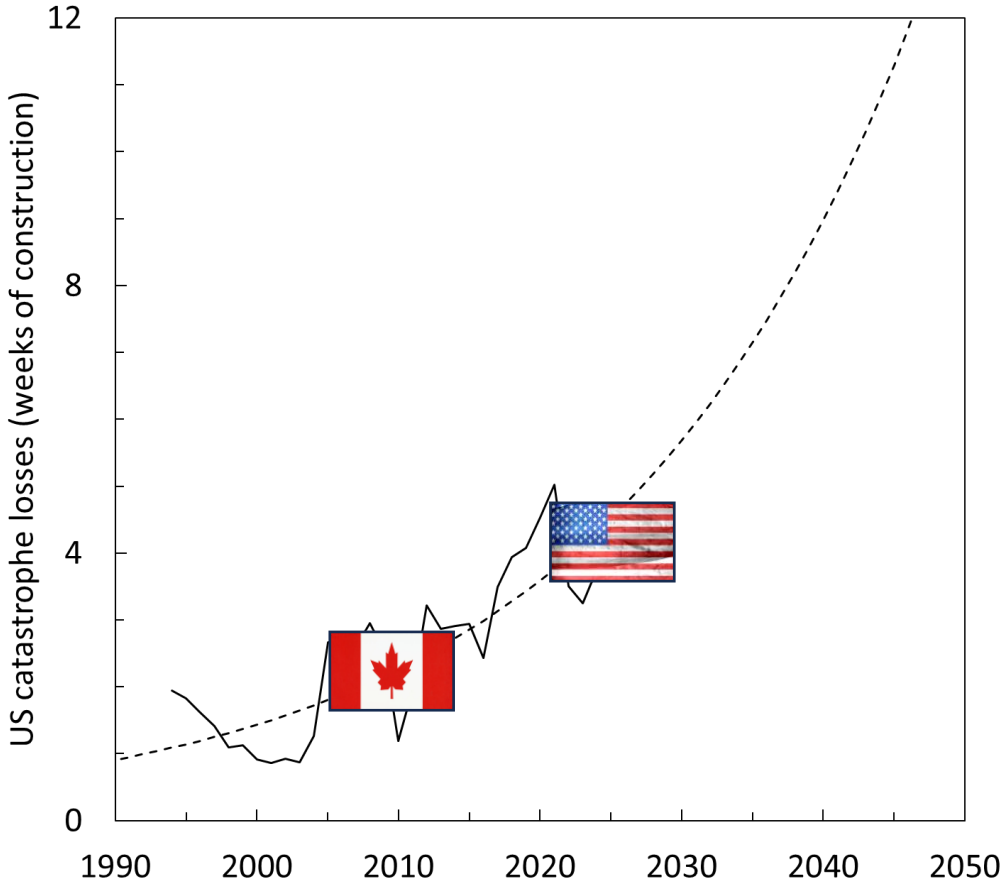
NRDC:

- 7-13% of US homes uninsured
- >1/3rd of manufactured homes
- Since 2020, 1.2 million US owners turned to state insurers

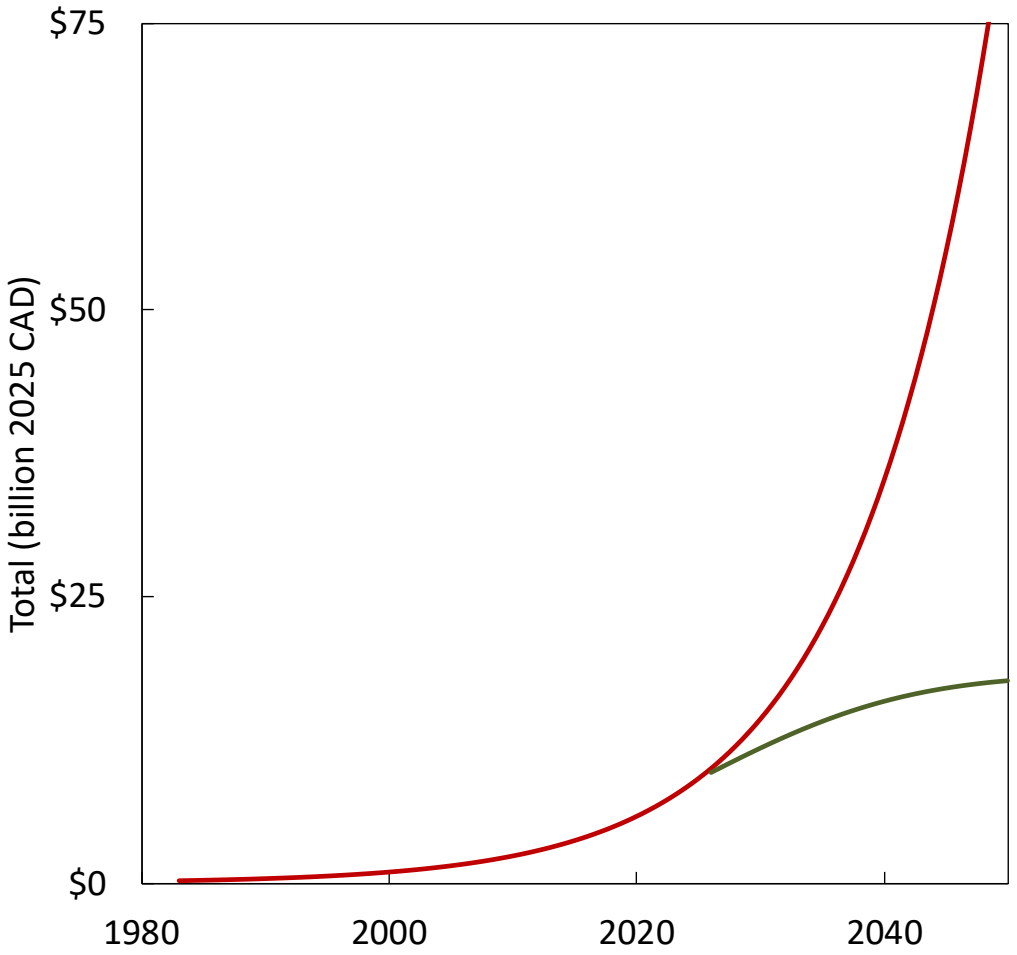
Interrupted FEMA work:

- $1T-$10T retrofit needed

Will Canada by insurable in 15 years?



What will it take to turn?



- Resilient building code, but:
  - Climatologists use 30 years of data
  - 10-20 years for a code change
  - 40 years for 50% new buildings
  - Relying just on code, already 50 years late
- $100B-$1T in retrofit
- Collaboration with finance, insurance, real estate, government, builders…

Limitations

Philosophical limitations to the study's persuasive power

- Measuring cats with money undervalues suffering of poor people
- L_1-L_{10} ignore potentially large losses
  - Psychological injuries
  - Domestic violence
  - Homelessness & consequent injuries
  - Smoke
  - Agriculture, livestock, pets
  - Indirect business interruption
  - Loss of productive business investment (an opportunity cost)
- Weak distinctions between loss from hail, rain, wind, & debris

Methodological limitations

- Inconsistent public record of utility & transportation infrastructure repair costs & emergency response costs
- Uses a constant factor for IBI, not input-output or CGE
- No treatment of uncertainty
- No treatment of disaster mitigation

Discussion

Do we share interests?

We serve different constituencies: insurers, the Canadian public, the US. But do our products reinforce each other, serving common interests?

Do we have an ambiguity aversion problem?

Different experts inevitably develop unique solutions. They can at least appear to disagree. People hate that. Have differences caused you problems, e.g., “CatIQ says this but Munich Re says that?”

Should we align methods or products?

Independent work accelerates innovation. E.g., ICLR might quantify economic drag from lost productive investment. But consensus helps persuade. What methods or products should we share?

Should we align dissemination?

We serve distinct audiences but share some too. What if any shared communication could advance our different missions?