Holistic Whole-Building Calibrated Analysis of the Performance Gap:
Using a BC Case Study Green Building

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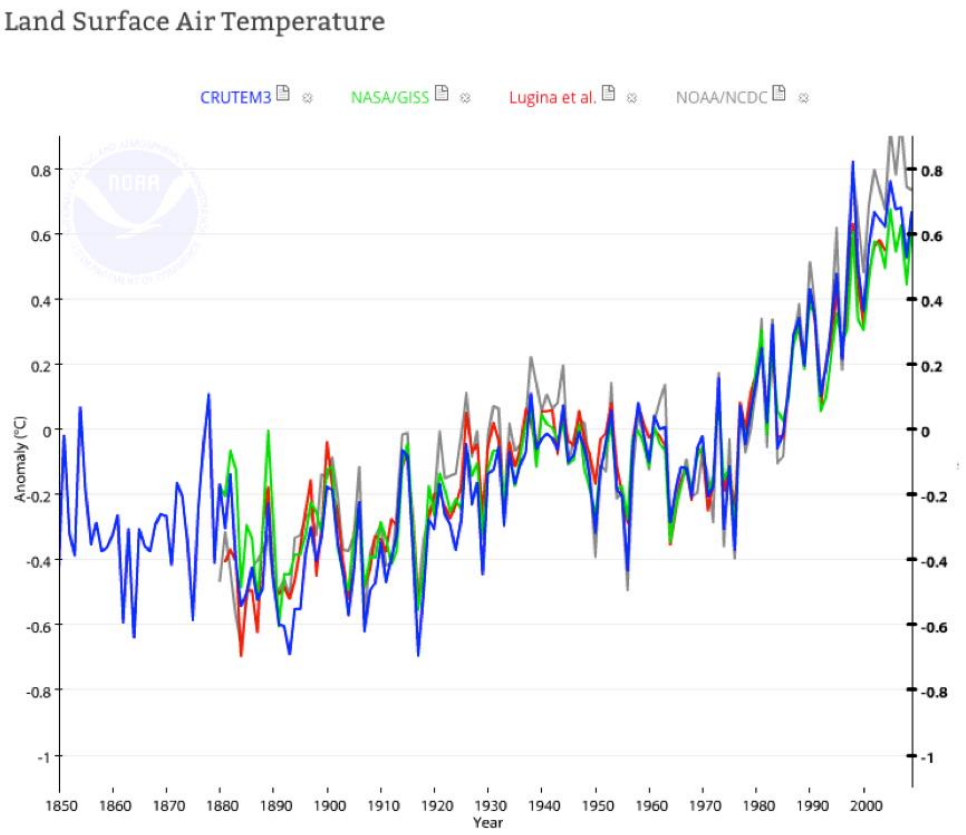
Climate Change and its very real impacts



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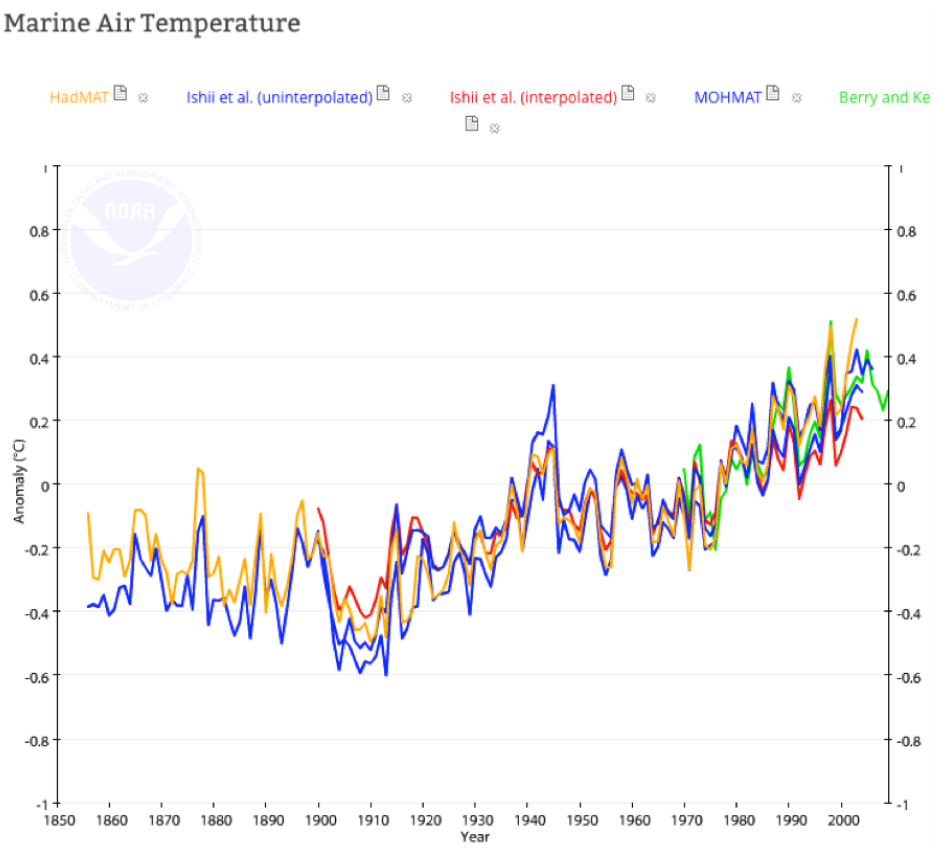

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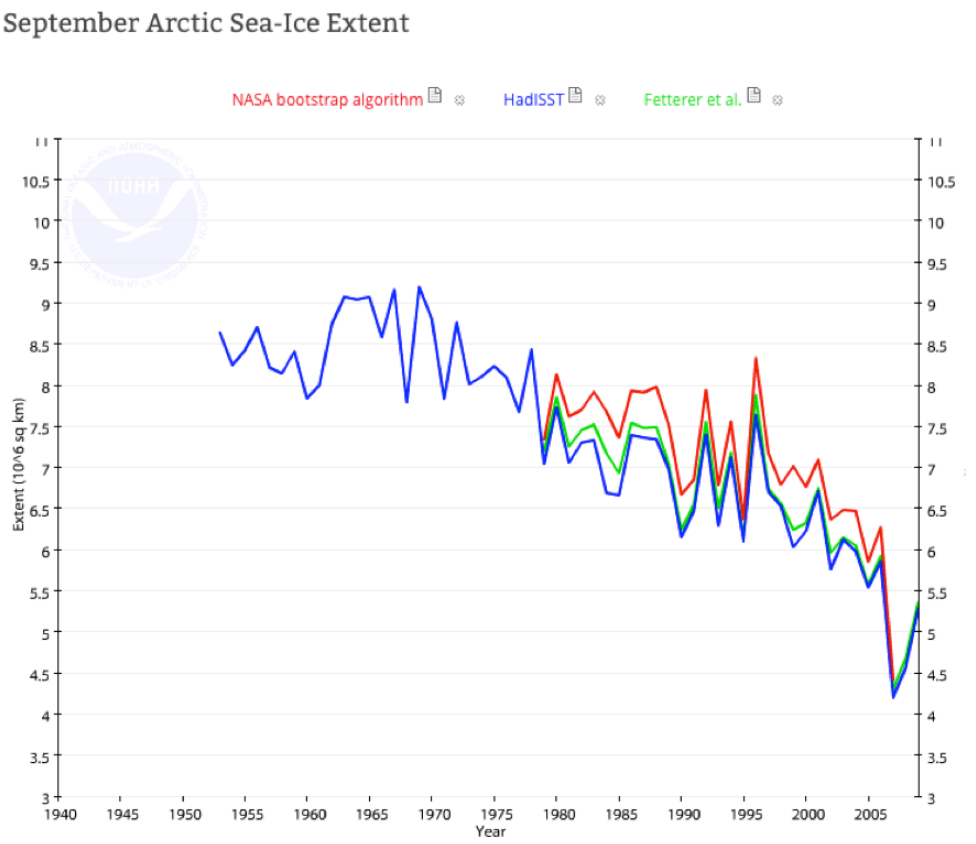

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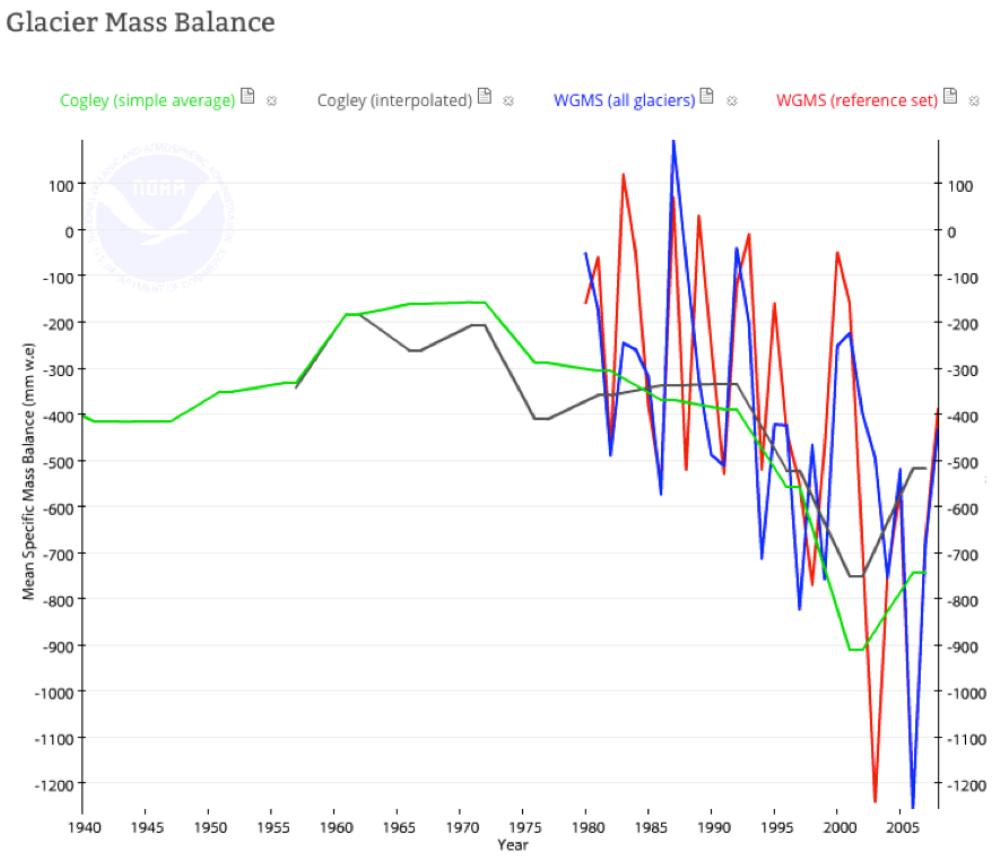

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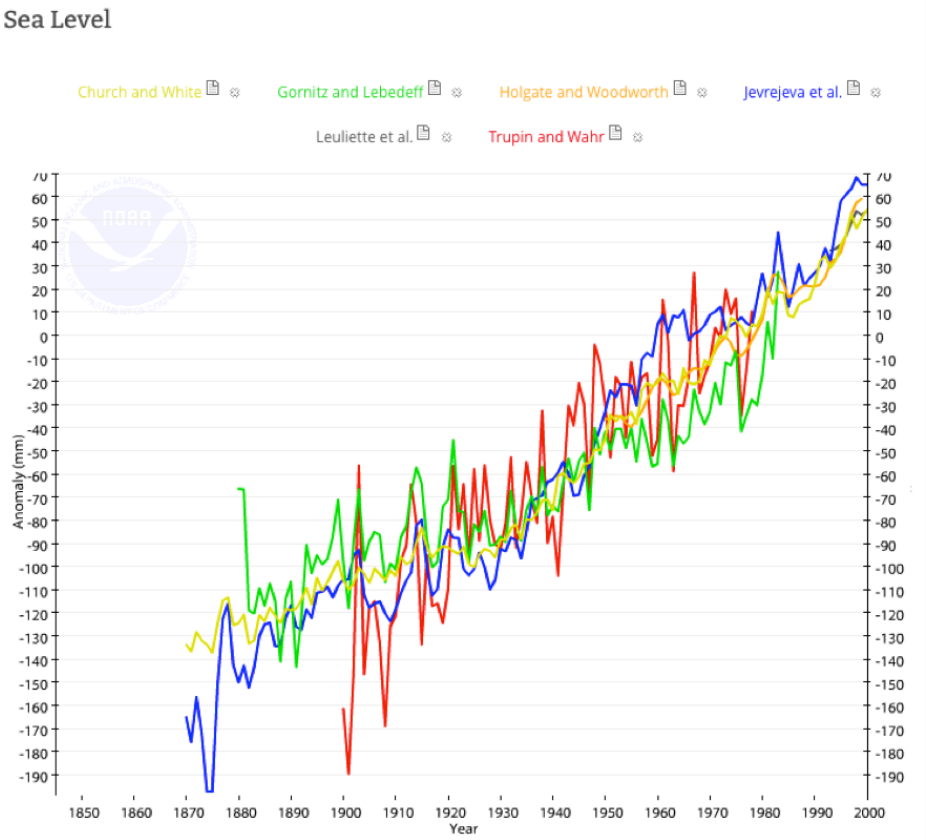

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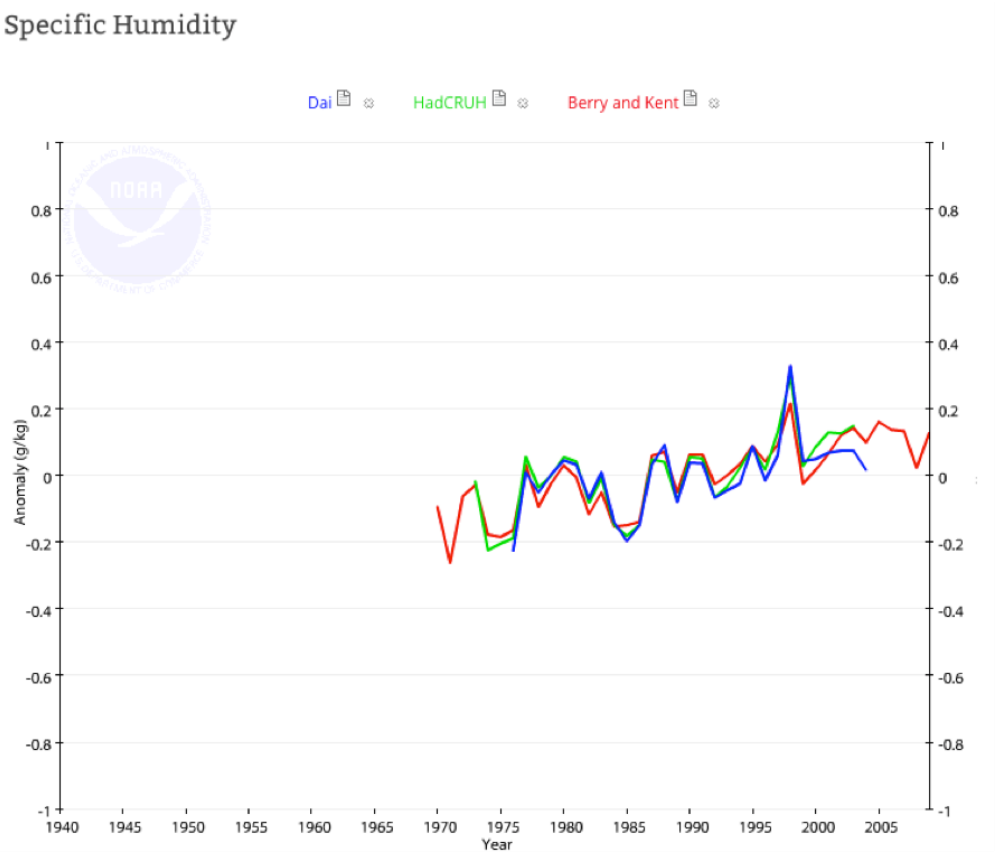

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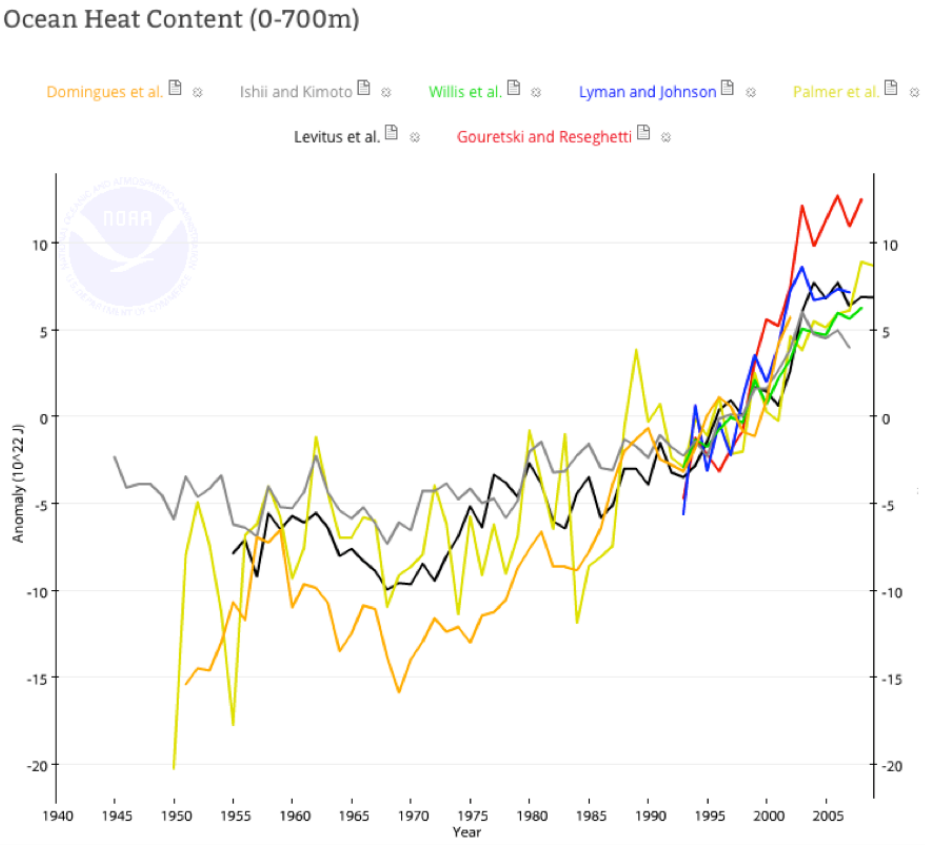

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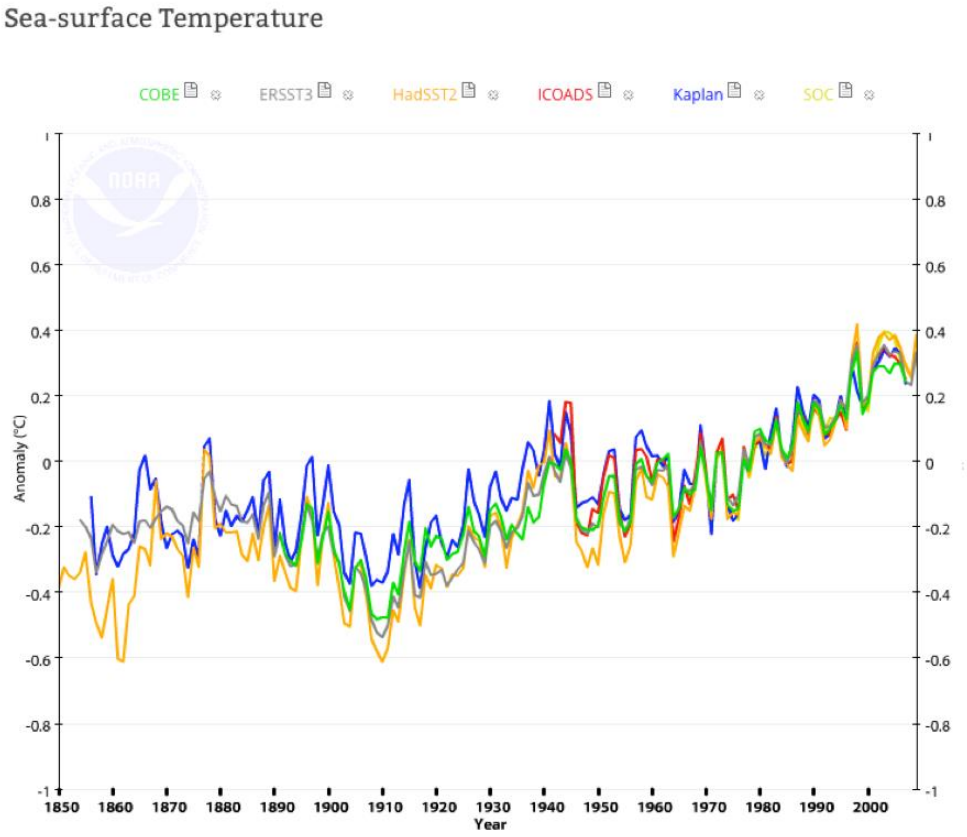

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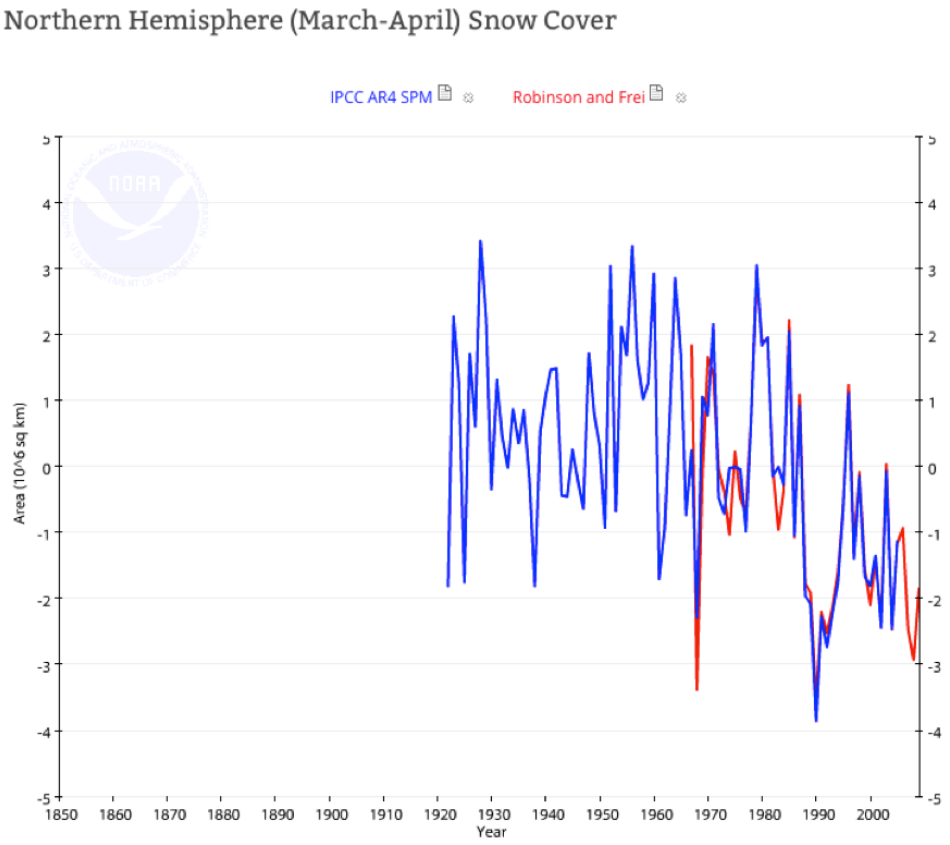

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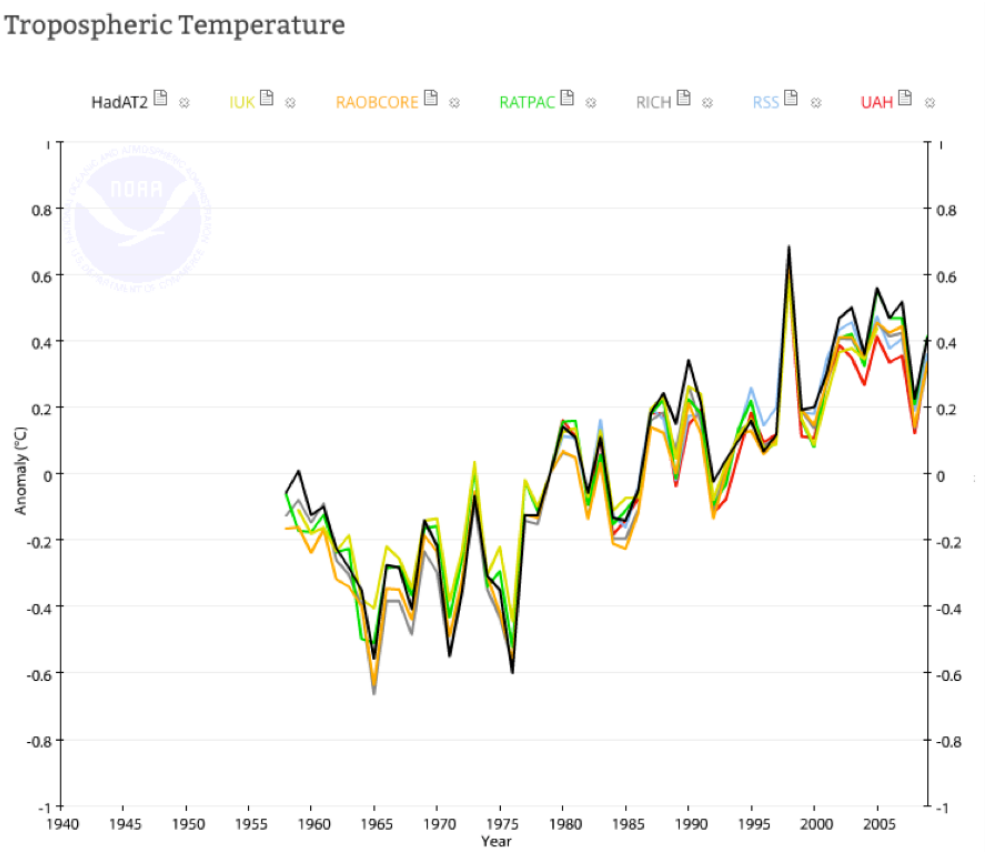
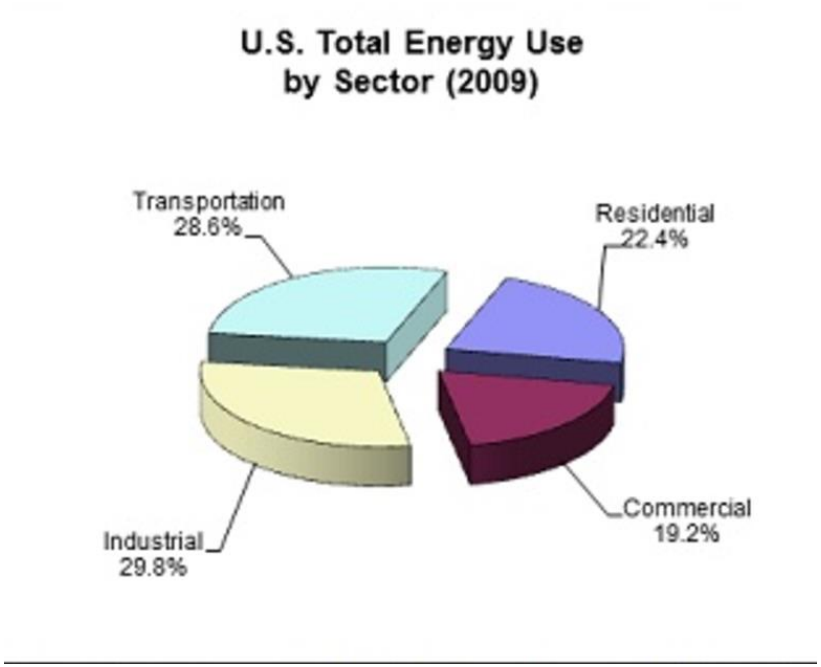


Buildings and their impact

What part do buildings play in contributing to our changing climate?

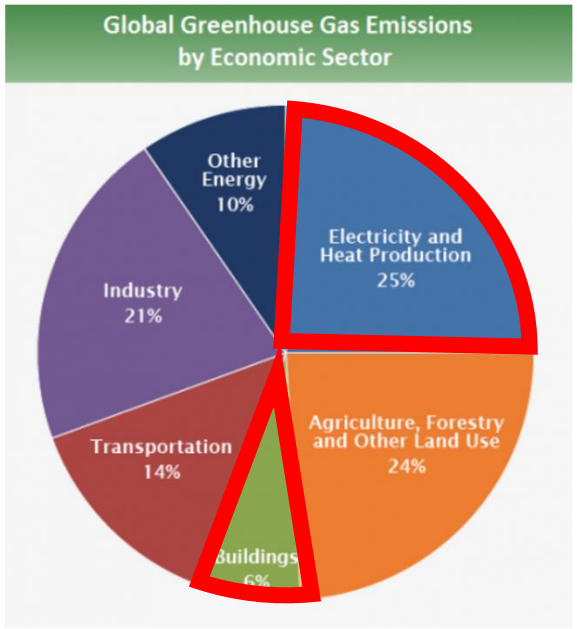
Buildings and energy

- Canada, the EU, and the United States: 40%
- Hong Kong: 60%
- 20% of energy use world-wide



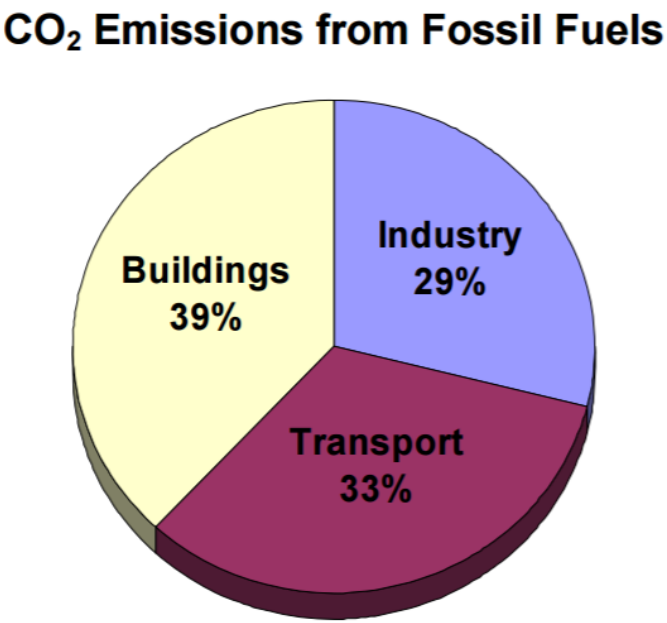
Buildings and emissions

Globally



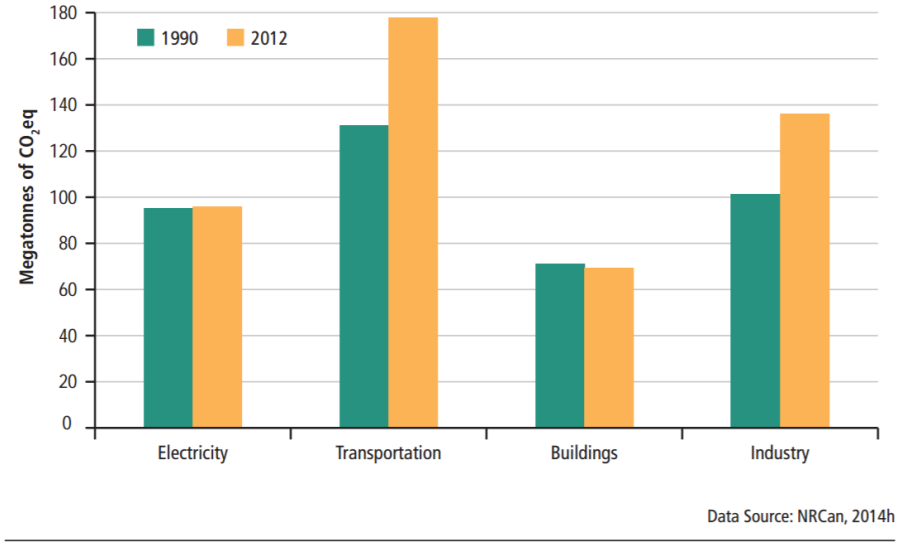
Source: IPCC (2014); EXIT based on global emissions from 2010. Details about the sources included in these estimates can be found in the *Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. EXIT

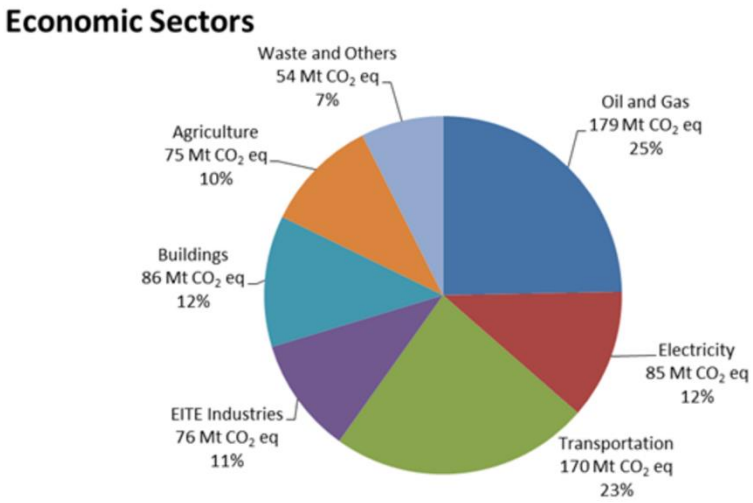
United States



Buildings and emissions

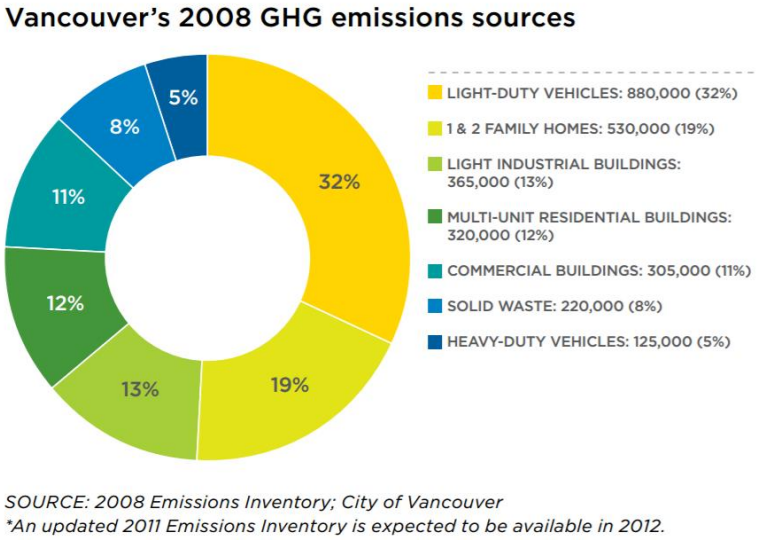
Canada





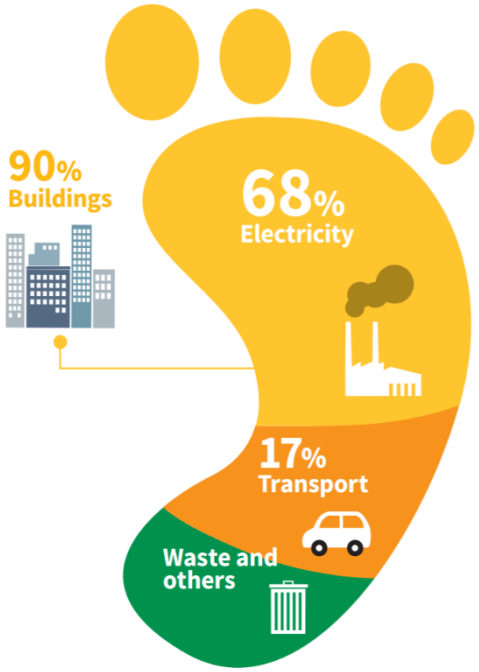
Buildings and emissions

City of Vancouver



SOURCE: 2008 Emissions Inventory; City of Vancouver
**An updated 2011 Emissions Inventory is expected to be available in 2012.*

Hong Kong



Buildings and emissions

When compared to sectors like transportation or oil and gas, buildings are:

- Easiest
- Fastest
- Most efficient
- Least expensive

means of reducing greenhouse gas emissions

"Building energy efficiency is not low-hanging fruit, it is fruit that is lying on the ground rotting!" - Stephen Selkowitz of Lawrence Berkeley National Laboratory, 2008

The solution? Green Building Certifications

Benchmarking

- Energy Star: compared to CBECS

Performance

- Living Building Challenge
- Passive House
- WELL standard

Assessment

- LEED
- Green Globes
- SITES
- BCA Green Mark
- BEAM
- BREEAM
- CASBEE
- EDGE

LEED Canada

Energy savings of **6,503,647** eMWh which is enough to power **220,702** homes in Canada for a full year.

A **1,261,016** C02e tonne reduction in greenhouse gas emissions which equates to taking **238,377** cars off the roads for a year.

Water savings totalling over **12.8 billion** litres, the equivalent of **5,131** Olympic sized swimming pools.

Installing **231,608** sq metres of green roofs, or an area the size of **153** NHL hockey rinks, to reduce the urban heat island effect and mitigate storm water flows in urban areas.

Recycling over **1.6 million** tonnes of construction/demolition waste which represents **491,174** garbage trucks.

The Performance Gap

Do green buildings perform as intended?

The Performance Gap

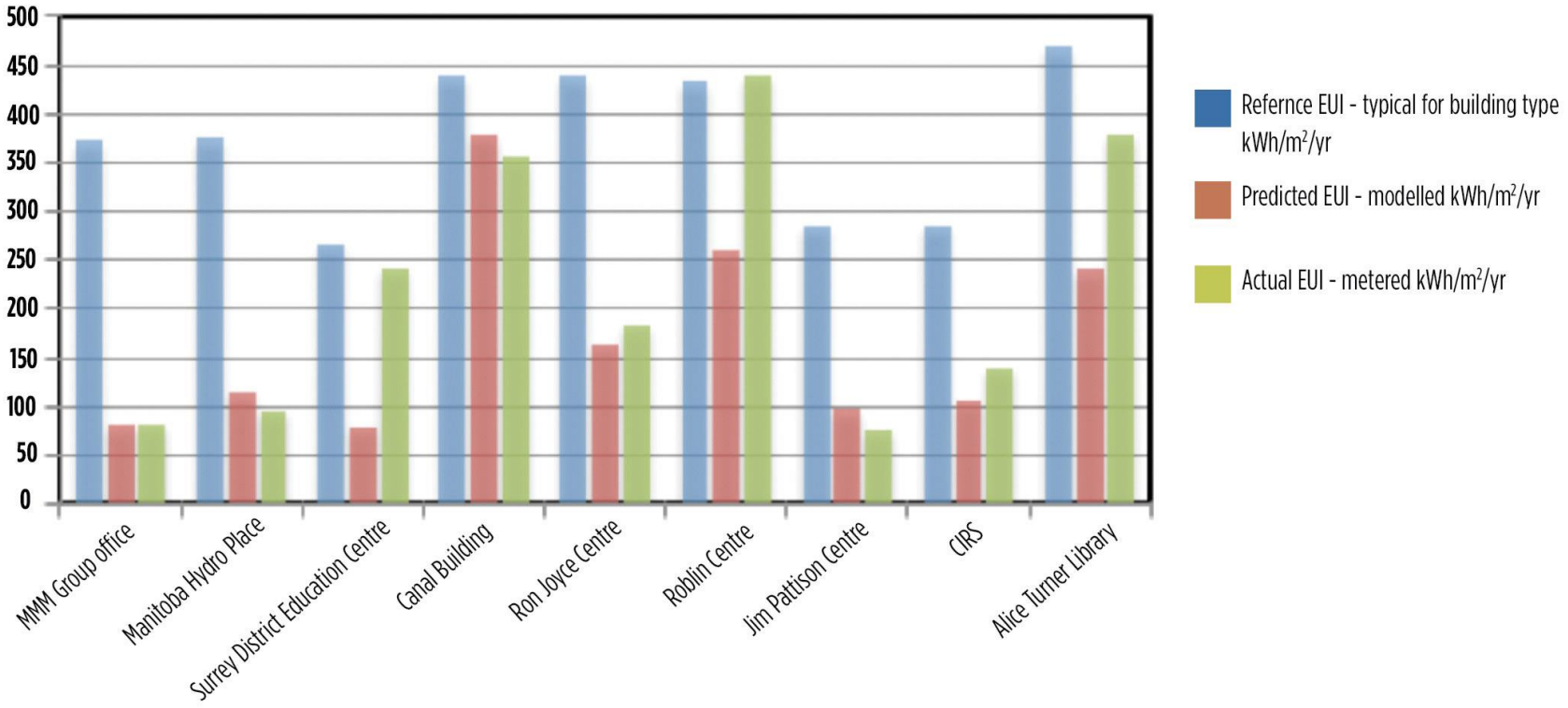
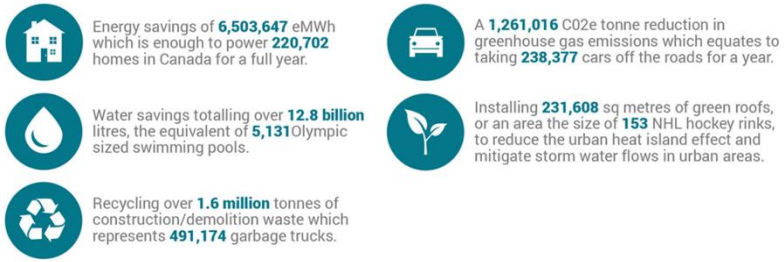


Figure 1

The Performance Gap – why is it important?

When we rely on green buildings to get it right, we can't afford to get it wrong



Literature Review: notable studies

- NBI study: analyzed 121 LEED certified buildings
  - On average, the buildings met predictions, but individually not the case
  - Half over-performed and half under-performed predictions, some quite significantly
- Oates and Sullivan performed an extension of NBI study to target more hot weather climates (in Arizona)
  - 15 buildings that on average performed 74% worse than predicted
- Centre for Interactive Research and Sustainability (CIRS) building at UBC:
  - 60-90% more energy than predicted (multiple studies resulted in different gaps)

Energy Modelling

- Meant for relative comparisons during design decision-making
- Not meant to be an accurate predictor of energy use
- Most green building certifications use energy model predictions for certification
- Usually requires “baseline” modelling to show improvements
- ASHRAE 90.1 performance path used for LEED

Commissioning

Type	Initial	Ongoing / continuing	Retro- / re-
Role of Commissioning	Ensure design meets performance targets, ensure as-built building represents designed building	Ensuring building continues to perform as intended	Identify the reasons for performance issues
	Quality Control	Quality Control & Diagnostic	Diagnostic
Reasoning	Checks that design meets performance targets and that assumptions made in determining predicted performance are correct, checks to see that construction of building matches design of building	Makes sure that the systems continue to operate as intended, and that issues discovered and fixed quickly and efficiently	Identifies and fixes issues in existing buildings, when obvious performance deficits have been identified by building owners or users

The Gulf Islands Operation Centre

Case study for in-depth research thesis

The Building

- Government building for Parks Canada on Vancouver Island
- Canada's first LEED Platinum certified building
- Experiencing issues:
  - Open loop ocean water heat exchange
  - Occupant comfort is an issue (drafty in winter, too hot in summer)
  - More energy use than anticipated


Parks Canada – Gulf Islands Operations Center
McFarland Marceau Architects Ltd. | Photo: Derek Lepper

Documentation

- Early design stage predictions for energy and emissions reductions
- Full drawings and specifications
- LEED documentation
- Original energy model
- Hydro bills for actual energy use
- Extensive monitoring and
- Change orders, emails, VE requests during construction phase
- Energy Audit from 2011
- Recommissioning report from 2011
- Access to major stakeholders involved in building process

The Research Plan

Phase one:

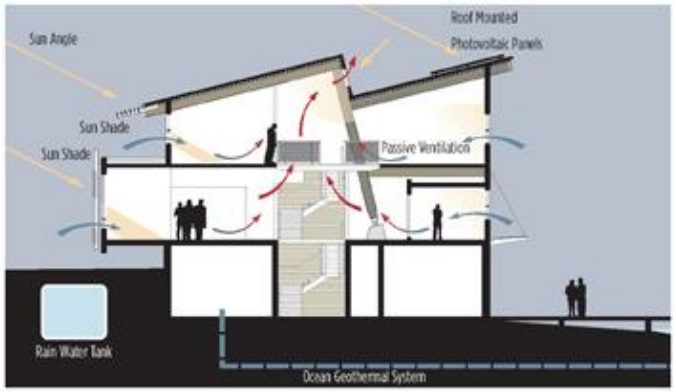
Calibrate an energy model to match actual performance

Phase two:

Perform a sensitivity analysis using the calibrated energy model

The Research Plan: Phase 1

- Create an energy model which closely matches performance
- Use documentation to get as fine a granularity as possible
- IES-VE Model



Section A-A: Ventilation patterns

The Research Plan: Phase 1.5

- By comparing original energy model to calibrated model:
  - Incorrect assumptions determined
  - Areas of under (or over) performance become obvious
  - Exact difference between predicted and actual performance, broken down by energy model input areas

The Research Plan: Phase 2

- Each difference assigned to process steps of completing a building
  - Planning and Design
  - Building Modelling
  - Commissioning
  - Construction
  - Operation and Occupancy
  - Certification
- Sensitivity analysis to determine which process step has most impact on overall building performance
  - Use calibrated model to input original assumptions to see impact on final performance

The Research Plan: Where I'm at

Firmly in Phase 0:

- Organizing the documentation
- Learning how to use IES-VE
- Mapping the existing energy model to something usable

Research Goals

- A methodology to use calibrated energy models to analyze building performance
- A quantification of which building process steps have the biggest impact on actual building performance, to better influence how we build buildings
- Feedback mechanism for all major stakeholders on any failures
- Clarification on the purposes, responsibilities, and impacts of building commissioning

Sources

- https://www.climaterealityproject.org/blog/10-indicators-that-show-climate-change
- https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data
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- http://www.lowenergybuildings.com/energy-use-ghg-emissions-in-buildings

Thank you