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

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Cascadia Windows & Doors
Climate Change and its very real impacts
Climate Change and its very real impacts
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Glacier Mass Balance

[Graph showing the Glacier Mass Balance over time, with data points for Cogley (simple average), Cogley (interpolated), WGMS (all glaciers), and WGMS (reference set).]
Climate Change and its very real impacts
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Climate Change and its very real impacts

Ocean Heat Content (0-700m)

Domingues et al.  Ishii and Kimoto  Willis et al.  Lyman and Johnson  Palmer et al.
Levitus et al.  Gurevski and Reseghetti
Climate Change and its very real impacts

![Graph showing sea-surface temperature trends](image-url)
Climate Change and its very real impacts
Climate Change and its very real impacts

Tropospheric Temperature

![Graph showing changes in tropospheric temperature over time.](image-url)
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

United States

CO₂ Emissions from Fossil Fuels

Building 39%

Transport 33%

Industry 29%

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

Canada

![Graph showing emissions in different sectors (Electricity, Transportation, Buildings, Industry) and a pie chart showing economic sectors with percentages like Waste and Others (54 Mt CO₂ eq), Agriculture (75 Mt CO₂ eq), Buildings (86 Mt CO₂ eq), etc. Data Source: NRCan, 2014h.](image-url)
Buildings and emissions

City of Vancouver

Vancouver’s 2008 GHG emissions sources
- Light-Duty Vehicles: 880,000 (32%)
- 1 & 2 Family Homes: 530,000 (19%)
- Light Industrial Buildings: 365,000 (13%)
- Multi-Unit Residential Buildings: 320,000 (12%)
- Commercial Buildings: 305,000 (11%)
- Solid Waste: 220,000 (8%)
- Heavy-Duty Vehicles: 125,000 (5%)

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

Hong Kong

- 90% Buildings
- 68% Electricity
- 17% Transport
- Waste and others

Organisers:
- Construction Industry Council
- HKGBC
- SBE Series
- CIIB
- iiSBE

International Co-owners:
- Global Alliance for Buildings and Construction
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
<table>
<thead>
<tr>
<th>The solution? Green Building Certifications</th>
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</thead>
<tbody>
<tr>
<td><strong>Benchmarking</strong></td>
</tr>
<tr>
<td>• Energy Star: compared to CBECS</td>
</tr>
<tr>
<td><strong>Performance</strong></td>
</tr>
<tr>
<td>• Living Building Challenge</td>
</tr>
<tr>
<td>• Passive House</td>
</tr>
<tr>
<td>• WELL standard</td>
</tr>
<tr>
<td><strong>Assessment</strong></td>
</tr>
<tr>
<td>• LEED</td>
</tr>
<tr>
<td>• Green Globes</td>
</tr>
<tr>
<td>• SITES</td>
</tr>
<tr>
<td>• BCA Green Mark</td>
</tr>
<tr>
<td>• BEAM</td>
</tr>
<tr>
<td>• BREEAM</td>
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<td>• CASBEE</td>
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<td>• EDGE</td>
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LEED Canada

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

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

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

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

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.
The Performance Gap

Do green buildings perform as intended?
The Performance Gap
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

- Energy savings of 6,593,647 eMWh which is enough to power 220,702 homes in Canada for a full year.
- Water savings totalling over 12.8 billion litres, the equivalent of 5,137 Olympic sized swimming pools.
- Recycling over 1.6 million tonnes of construction/demolition waste which represents 491,174 garbage trucks.
- A 1,261,016 CO2e tonne reduction in greenhouse gas emissions which equates to taking 238,377 cars off the roads for a year.
- 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.
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

<table>
<thead>
<tr>
<th>Type</th>
<th>Initial</th>
<th>Ongoing / continuing</th>
<th>Retro- / re-</th>
</tr>
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<tbody>
<tr>
<td><strong>Role of Commissioning</strong></td>
<td>Ensure design meets performance targets, ensure as-built building represents designed building</td>
<td>Ensuring building continues to perform as intended</td>
<td>Identify the reasons for performance issues</td>
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<td></td>
<td>Quality Control</td>
<td>Quality Control &amp; Diagnostic</td>
<td>Diagnostic</td>
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<tr>
<td><strong>Reasoning</strong></td>
<td>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</td>
<td>Makes sure that the systems continue to operate as intended, and that issues discovered and fixed quickly and efficiently</td>
<td>Identifies and fixes issues in existing buildings, when obvious performance deficits have been identified by building owners or users</td>
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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
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
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.eia.gov/outlooks/ieo/buildings.cfm
- https://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=02D095CB-1#BR-Sec2
- https://www.eia.gov/tools/faqs/faq.php?id=86&t=1
- https://www.canadianarchitect.com/features/the-heat-is-on/
Thank you