Dwight Look College of ENGINEERING
TEXAS A&M UNIVERSITY

International Perspective on Clean Air and Energy Efficiency in Buildings

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Architectural Engineering at Texas A&M

- New Bachelor of Science in Interdisciplinary Engineering with Specialization in Architectural Engineering (Fall'17)

An interdisciplinary learning environment to develop engineers ready to meet industry demands for high-performance, green and safe buildings

Mechanical Systems for Buildings

Structural Systems for Buildings

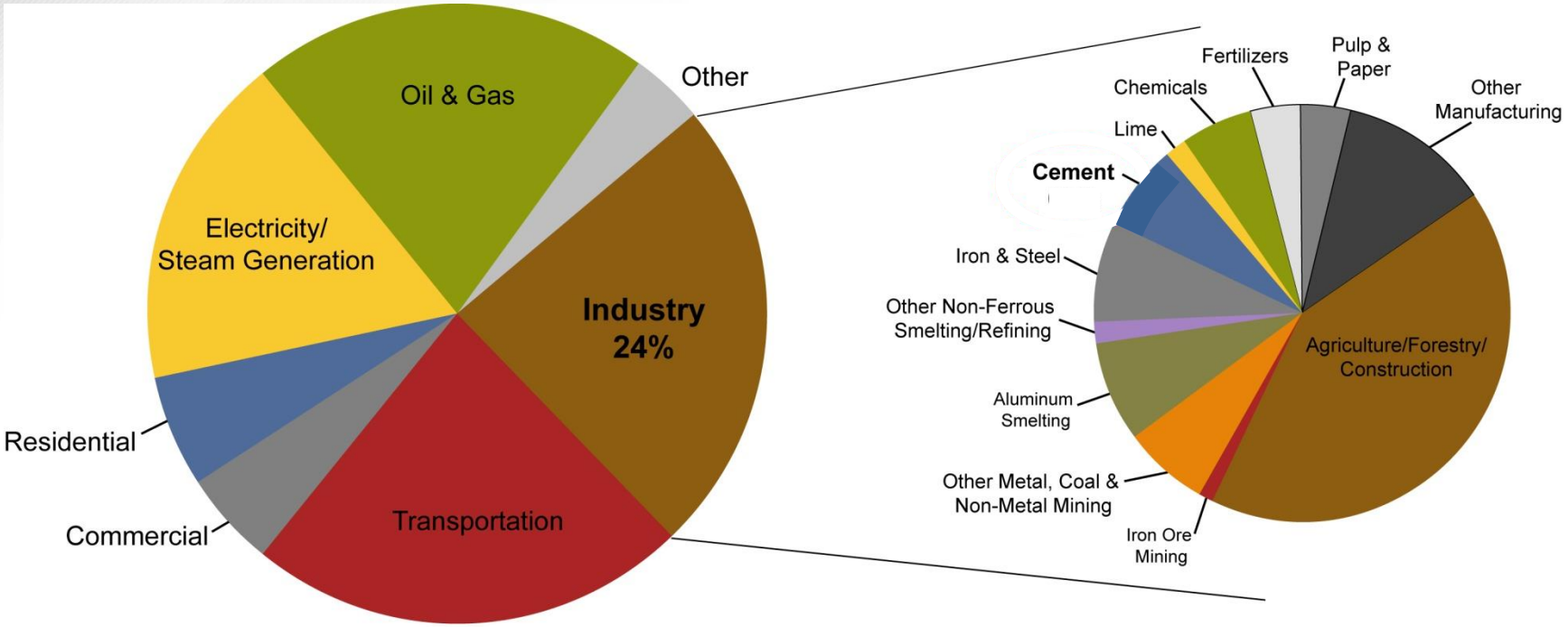
Scope of International Projects & Perspectives

- National Research Council of Canada
  - Institute for Research in Construction
  - Construction Portfolio
  - Indoor Environment Research
- International Energy Agency
  - Energy Conservation in Buildings & Community Systems (26 countries)

Buildings: Environmental and Resource Loadings

- 30-40 % of energy use
- > 30 % of GHG emissions
- 25 –40% solid waste (Construction)
- > 50 % primary resources (Construction)

GHGs: Canadian Perspective*



* Natural Resources Canada

Policies & Measures for Building Energy Efficiency

- Energy Codes (Regulations)
  - Canada's Model Energy Code for Buildings
  - EU Energy Performance Building Directives
- Environmental Building Rating Tools
  - LEED, CASBEE (Jp), BREEM (UK), HQE (Fr)
- Building Energy Programs (demos)
  - Canada's R-2000; Housing Equilibrium
  - Buildings America (US)

Photo: Stefan Müller-Neumann, GWG Munich

Building Regulations in Canada – Shared Vision among Jurisdictions

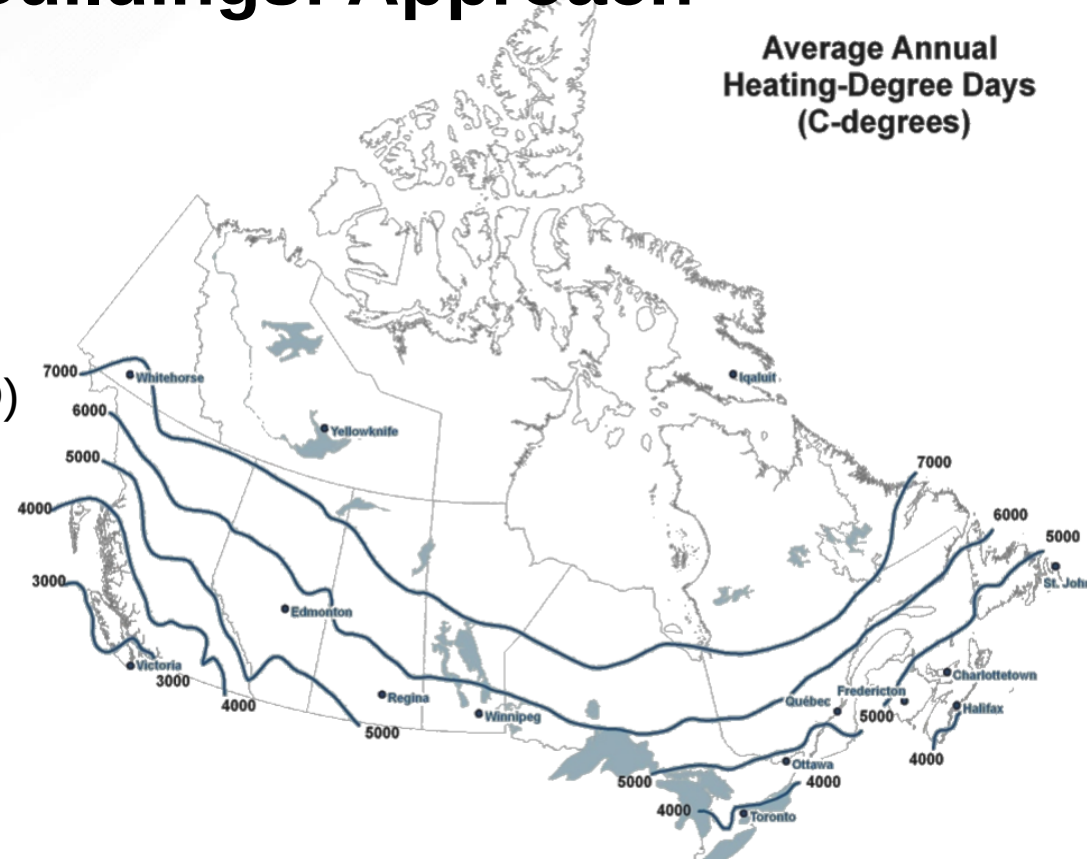
- 2007: Shared vision for energy
  - ✓ 7 strategic elements, including *promote energy efficiency and conservation*

- 2008: 5-Point plan on energy efficiency
  - ✓ Improve Energy Code for Buildings by 25% by 2011
  - ✓ Add energy efficiency as core objective in National Building Code

- 2011-15 Model Energy Code for Buildings

Energy Code for Buildings: Approach

- Energy used by building
  → energy source neutral
- Based on climatic zone-heating degree-days (HDD)
- No differentiation based on occupancy

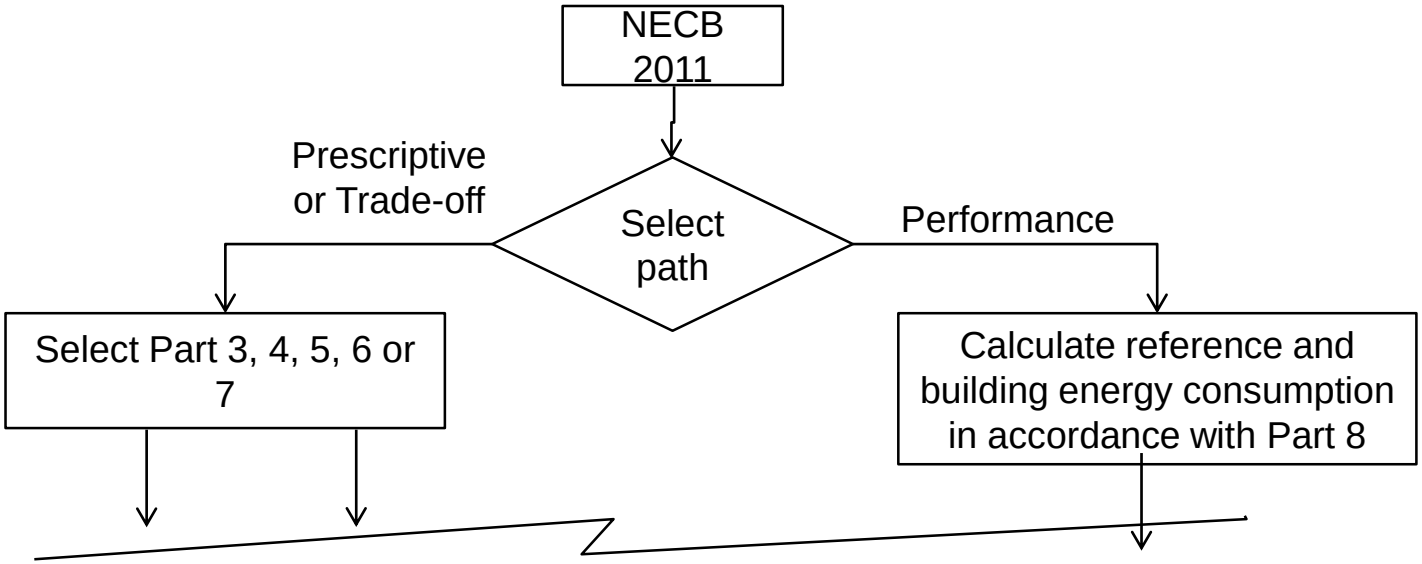


National Energy Code for Buildings-Content

- Part 3: Building Envelope
- Part 4: Lighting
- Part 5: Heating, Ventilating and Air-conditioning
- Part 6: Service Water Heating Systems
- Part 7: Electrical Power Systems and Motors
- Part 8: Performance Path

NECB compliance paths

- Mix and match simple prescriptive and trade-off paths
- Use trade-off within same Part only
- Cannot mix any other path with performance path



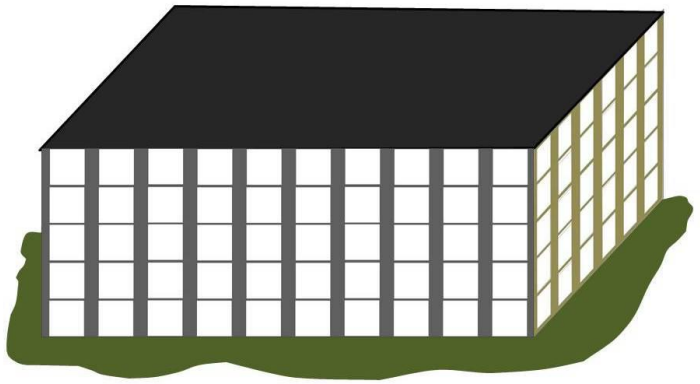
Energy Code Trade-off Paths

- Adds flexibility in design
- Available for :
  - Building Envelope – has two: a detailed and a simple
  - HVAC
  - Service water heating
  - Lighting

Energy Code Trade-off Paths

- Example: Trade–off for building envelope in Toronto

Prescriptive = 40%



Simple trade-off = 65%
(with better windows and walls)

Energy Code Performance Levels

- All paths: one consistent minimum and acceptable performance level
  - Required U-value and maximum fenestration-and-door-to-wall ratio for location's climatic conditions

Green Building Post-occupancy Evaluation*

- How do green buildings perform when occupied?
  - Energy and Water
  - Comfort
  - Environmental satisfaction
- Can credit systems be fine-tuned to ensure better performance?
- Multi-year field experimentation of green buildings

**** http://archive.nrc-cnrc.gc.ca/eng/projects/irc/post-occupancy.html***

Green Building Post Occupancy Evaluation*

24 Buildings: Conventional vs. “Green” Buildings

Multi-year measured data from each building:

1. Energy consumption: whole building; sub-systems

2. On-line questionnaire (N=2445)
   - environmental satisfaction
   - job satisfaction, health,
   - absenteeism, environmental attitudes

3. On-site measurements of physical environment (N=974)

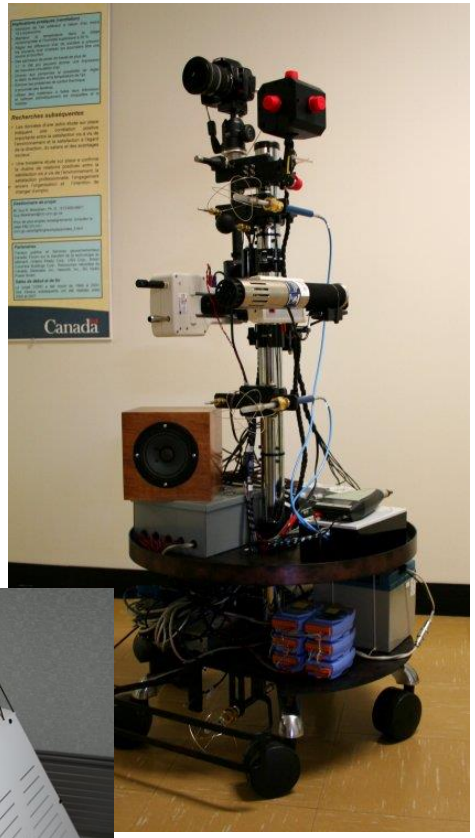
**** http://archive.nrc-cnrc.gc.ca/eng/projects/irc/post-occupancy.html***

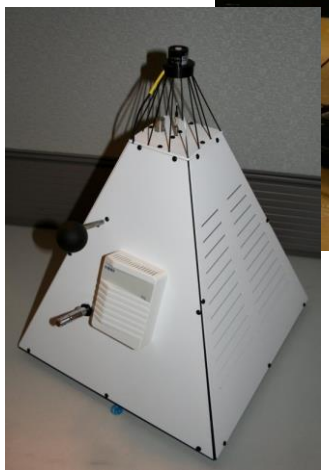
Green Building Post-occupancy Evaluation*

Field-Studies-Measurements*

- Spot measurements
  - Temperature, humidity, air speed, formaldehyde, particulates, TVOC, CO_2, light level, noise, Speech AI

- Longitudinal data
  - Temperature, humidity, air speed, CO_2 ,light level, noise





*** http://archive.nrc-cnrc.gc.ca/eng/projects/irc/post-occupancy.html**

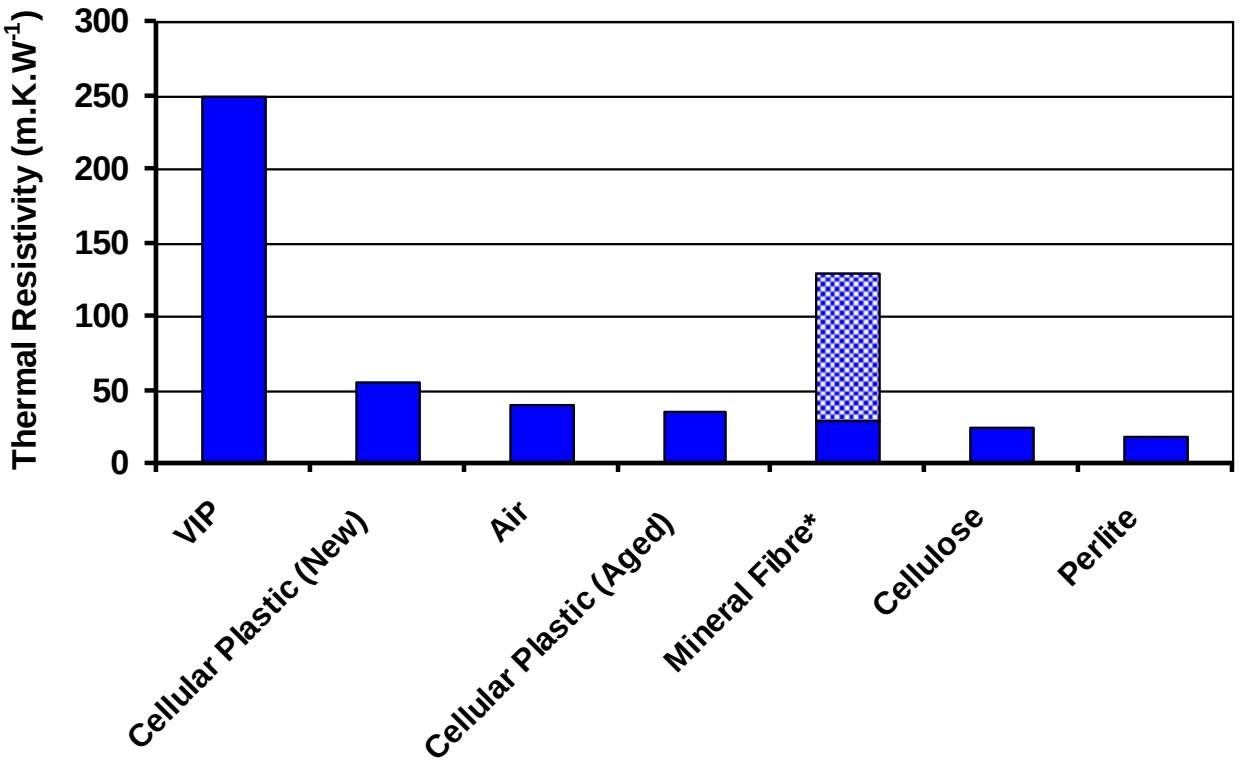
Green Building Post-occupancy Evaluation*

Results (highlights)- Energy Consumption

- Re-analysis of data from 100 LEED-certified buildings
  - On average, LEED buildings used 25% less than conventional counterparts
  - 1/3 of LEED buildings used more energy
  - Little correlation between energy credits and actual energy savings

http://archive.nrc-cnrc.gc.ca/obj/irc/doc/pubs/nrcc51142.pdf

High Performance Insulation for Building Envelopes*



Air Quality: An Enduring and Complex Issue

- Various contaminant sources
  - Indoors: human activity; building materials, furnishings; cleaning products, equipment (VOC, SVOC, mould)
  - Outdoors: Ozone, Particles, CO, CO2, NO, NO2, Radon
  - Ventilation, airtightness, environmental conditions
- Lack of data correlating contaminant concentrations with ventilation rates and human health
- Limited data on environmental and health Impacts

International Guidelines: Indoor Air Quality

Example: CO2 [ppm]*

Canada (2006)	WHO (2006)	U.S. EPA (2006)	Hong Kong (2003)	Finland (2001)	Germany (2007)	Singapore (1996)	U.S. (OSHA)	U.S. (NIOSH) (2005)	U.S. (ACGIH) (2004)	Germany (2005)
R	-	-	R + O	R + O	O	O	W	W	W	W
3,500			800 / 1,000 [8 hr]	1200	1,500 (mech. Vent.)	1,000 [8 hr]	5,000 [8 hr]	5,000 [10 hr] 30,000 [15 min]	5,000 [8 hr] 30,000 [15 min]	5,000 [8 hr]

A: Ambient Air; O: Offices; R: Residential Homes; W: Workplace
(Canada) – Health Canada; **(WHO)** – World Health Organization
(EPA) - U.S. Environmental Protection Agency
(OSHA) - U.S. Department of Labor, Occupational Safety and Health Administration
(MAK) - Maximum Concentrations Values (Germany)
(NIOSH) – National Institute for Occupational Safety and Health
(ACGIH) – American Conference of Governmental Industrial Hygienists
(Hong Kong) – The Government of the Hong Kong Special Administrative Region
(Finland) – Finnish Society of Indoor Air Quality and Climate
(German) – German Federal Environmental Agency
(Singapore) – Ministry of the Environment, Singapore

* Data compiled by NRC, 2007

Gov. of Canada's Air Quality Initiatives (2007-16)

Goal: Improve environment and health of citizens, by reducing greenhouse gas and air pollutant emissions

- Emissions: Source emission targets for transport, industry,
- Indoor Air Quality: Develop targets and IAQ solutions
  - Provide validated IAQ technical information to regulators
  - Support industry on validated energy-efficient IAQ solutions

2007-16 Indoor Air Quality: R&D Objectives*

- Expand expertise for lab and field measurements
- Establish relationship between ventilation and IAQ, health
- Develop technical standards/best practices for IAQ solutions
- Enable industry to develop IAQ solutions

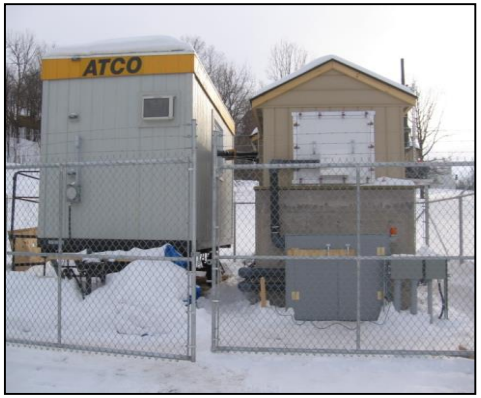
* Initiative led on behalf of the Government of Canada

1.A. Building Facilities Indoor Air Quality Experimentation*

Mycology Laboratory

Analytical Laboratory

Radon Test Facility



HRV/ERV Test Rig

In-duct Filtration & Purification

Emission Chambers

* Labs of the NRC's Indoor Air Quality Group

1.B New Indoor Air Research Laboratory*

Field-measurement of IAQ technologies under realistic and controlled conditions

Key features

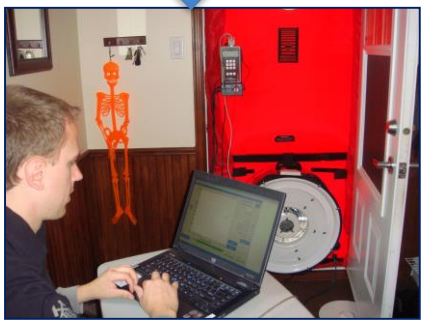
- Flexible architecture
- Building automation system
- Multiple ventilation systems
- Variable envelope air leakage
- Tracer gas (SF_6, CO_2, N_2O)
- IEQ sensors
- Particle image velocimetry

* Labs built by the Indoor Air Quality Group

1.C. Field Measurements on IAQ with Health Agencies*

Physical	Chemical	Biological

• Air & wall temp
• IR thermography
• PM
  • fine
  • ultrafine
• Housing and HVAC characterisation
• Air exchange rate
• Airtightness
	• O_3
	• NO_2
	• Aldehydes
	• CO_2
	• VOC
	• SVOC (dust)
	• RH
		• Mould spores
		  • Air
		  • Dust
		• Settling mould spores
		• Endotoxin (dust)
		• Ergosterol (dust)
		• Allergens (dust)
		• Glucans (dust)



Partnerships with medical R&D and health agencies for field studies

* Labs of the NRC's Indoor Air Quality Group

2. Three-Year Field Study: IAQ, Ventilation and Health*

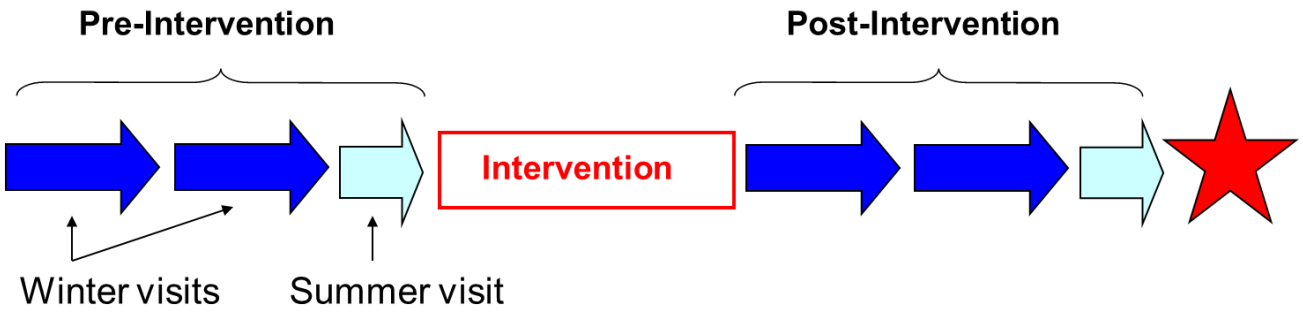
Will increased home ventilation decrease asthmatic symptoms in children?

- Correlate IAQ with ventilation rates
- Determine the effectiveness of ventilation interventions on IAQ and respiratory health
- Case Study: 111 homes in Quebec City

* Work performed by INSPQ NRC, CHUQ, in collaboration with CMHC

2. Three-Year Field Study: IAQ, Ventilation and Health*

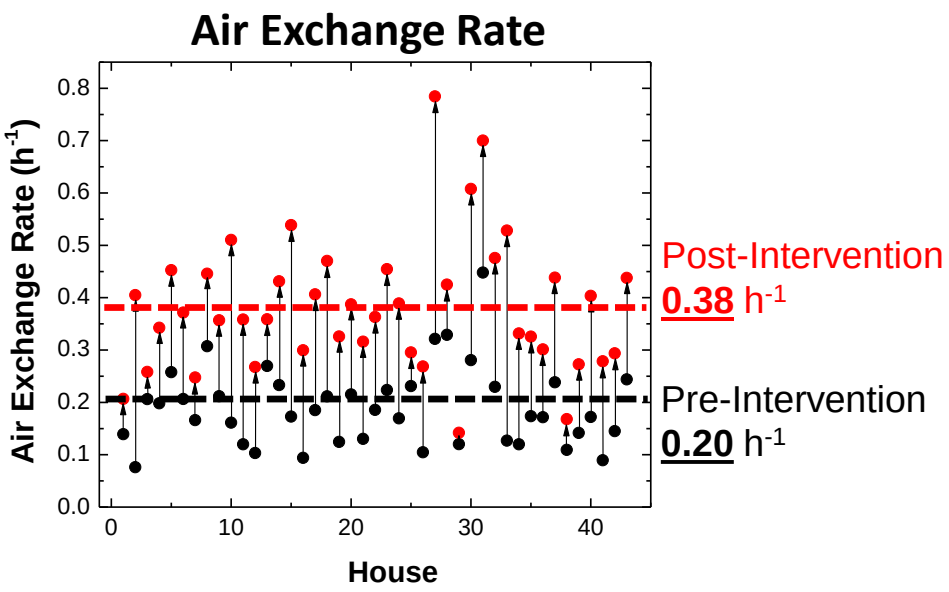
To demonstrate that improved ventilation improves IAQ and the respiratory health of asthmatic children

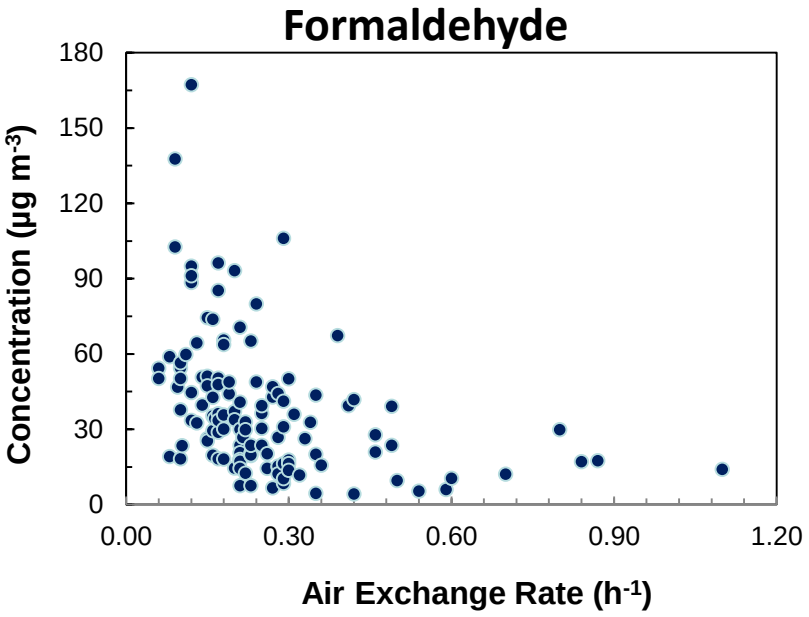


* Work performed by INSPQ NRC, CHUQ, in collaboration with CMHC

2. Three-Year Field Study: IAQ, Ventilation and Health*

Prescribed ventilation rates met through the use of H(E)RV which significantly reduced the concentration of IAQ relevant pollutants





Post-Intervention concentration reductions:

- Benzene ↓**15 %**
- Formaldehyde ↓**30 %**
- Airborne mould spores ↓**38%**

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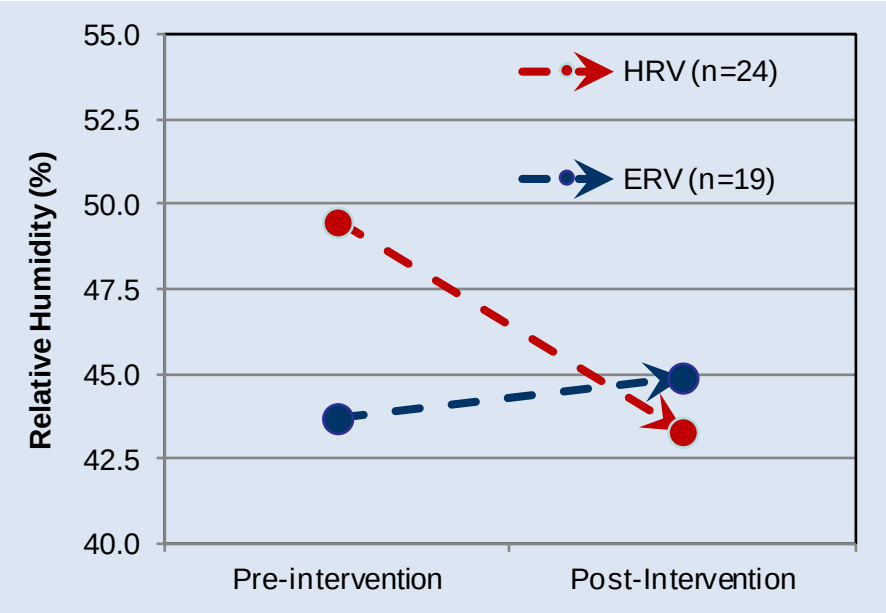
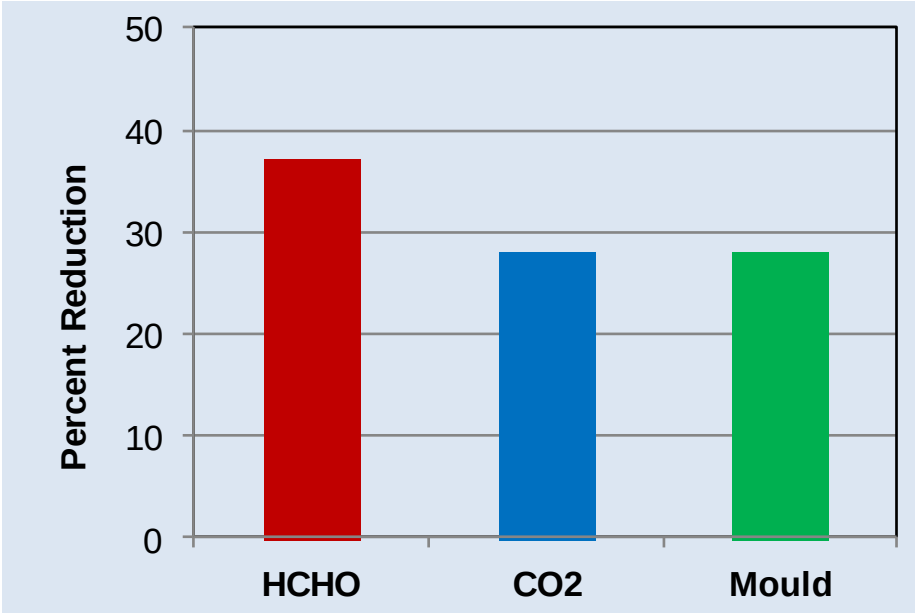
2. Three-Year Field Study: IAQ, Ventilation and Health*





83% of the homes were under-ventilated (ACH < 0.30 h-1).

HRV/ERV's intervention: increased ventilation

- improved IAQ.
- managed RH.

* Work performed by NRC,

Forecasts for 2025-30

- Urbanization: 70% will live in cities
- New Construction /Renovation
  - 50 % new construction in China
  - 50-60% of today's buildings will be still standing in 2030
- Energy market: 50-60% of global construction
- Lifestyle driving dynamic building energy load profiles
- Consumers: connected, and driving energy and comfort and health choices at home and workplace
- Smart grids, with smart meters & BMS in 60-70 % of North American homes/buildings; and energy-on-demand