University of Waterloo

The role of Building Science in Past and Future Low Energy Buildings

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www.BuildingScience.com

What is Building Science?

- *The collection of knowledge surrounding the prediction and understanding of building performance*
  - Not structural, not quite HVAC, not air quality….
  - Not just enclosures: "envelopes"
  - Canadian focus: moisture, energy, air quality
  - European building physics: add fire, sound, light
- Must combine physics with field experience
- Much more development needed to reach sophistication of structural engineering

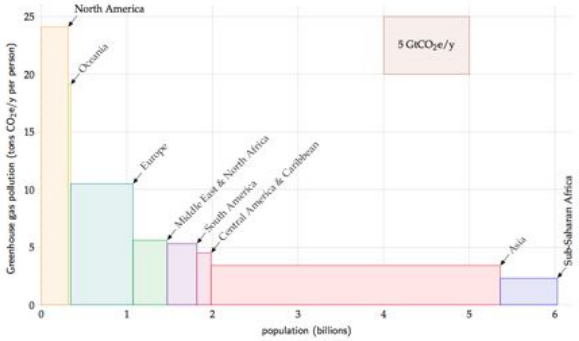
Global MegaTrends

- Global population is growing
- Global affluence is growing
- Demand for all resources growing as **Population × Resources**
- This drives up prices
- *Buildings consume more energy and resources than any other single human activity*
- **Hence, Sustainability and Energy**

In the next 40 yrs …

- 2.3 Billion *more* people to support
- 2.9 Billion *more* people become "urban"
  - E.g., need to accommodate *double* the urban population
  - More than all the urbanization of WW2 to today
- Almost all growth in less developed countries
  - Essentially zero population growth in more developed countries

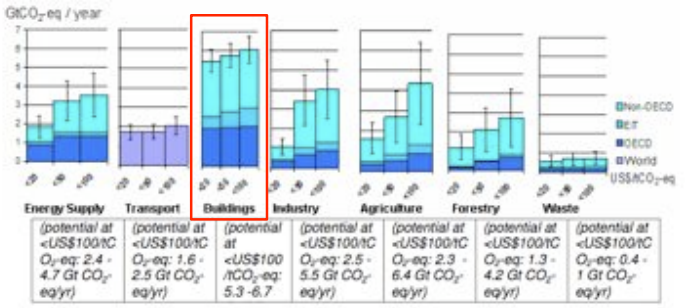
CO_2 by population



From: McKay, D. Sustainable Energy with the hot air. 2009

United Nations IPCC Mitigation Report May 2007

"Biggest & Cheapest CO2 reduction are in buildings"



Energy Supply	Transport	Buildings	Industry	Agriculture	Forestry	Waste
(potential at <US$100/tC O_2-eq: 2.4 - 4.7 Gt CO_2-eq/yr)	(potential at <US$100/tC O_2-eq: 1.6 - 2.5 Gt CO_2-eq/yr)	(potential at <US$100 /tC$O_2$-eq: 5.3 -6.7	(potential at <US$100/tC O_2-eq: 2.5 - 5.5 Gt CO_2-eq/yr)	(potential at <US$100/tC O_2-eq: 2.3 - 6.4 Gt CO_2-eq/yr)	(potential at <US$100/tC O_2-eq: 1.3 - 4.2 Gt CO_2-eq/yr)	(potential at <US$100/tC O_2-eq: 0.4 - 1 Gt CO_2-eq/yr)

Figure SPM 6: *Estimated sectoral economic potential for global mitigation for different regions as a function of carbon price in 2030 from bottom-up studies, compared to the respective baselines assumed in the sector assessments. A full explanation of the derivation of this figure is found in 11.3.*

Future Challenges

- Developed World
  - Renew buildings and infrastructure
  - Transition energy supplies
  - Develop renewable materials/systems
- Reduce waste / increase efficiency
  - Design for efficiency
  - Measure and report performance
  - Develop ability to predict performance

Infrastructure & Buildings

- Inefficient buildings with inefficient systems
  - Consume 40-50% of world energy / resources
  - Require large energy, water, waste infrastructure
  - Consume significant resources and emit significant pollution
- Transit / transport
  - Consume about 30% of world energy
- High efficiency = less demand = smaller infrastructure

Future Buildings

- Massive reductions in energy and resource intensity needed
  - Between factor 4 and factor 10
  - www.factor10-institute.org
- All solutions will be needed
  - Reduced demand by new efficiency + **retrofit**
  - Renewable energy: massive deployment
  - Transition fuels and systems

Trends in Buildings

- The past
  - On time, on budget, to spec/ code
- The Future: performance
  - Measureable outcomes. Aesthetics are subjective.
- Now: LEED, Energy Star
- Architecture 2030
- Actual energy use?

Building Science Today

- Building Science= tool kit for performance
- Problems
  - Environmental damage/consumption
  - Buildings don't work well
    - Comfort, durability, leaks, maintenance
  - Buildings often cost too much
  - Buildings can make us sick/puke
- Lots for Building Science to do!

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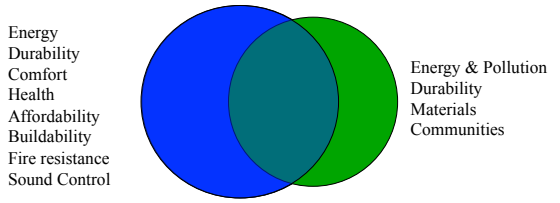
Building Science=Green Buildings

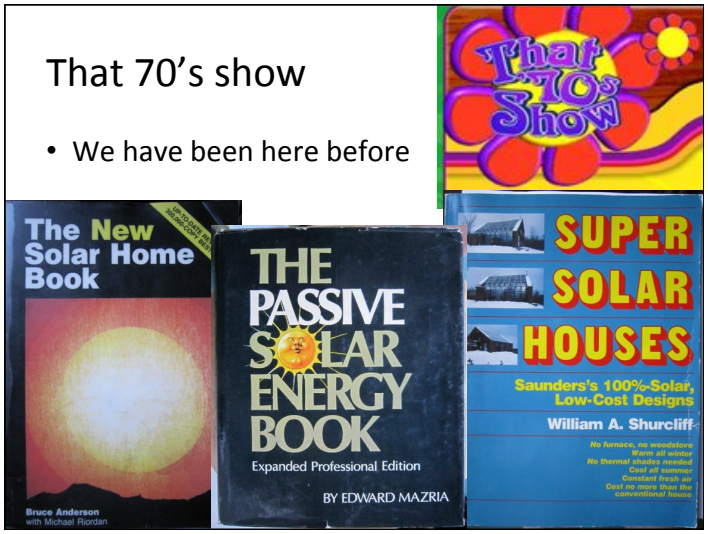
- Building Science?
  - The science of making buildings that work
- Green Buildings?
  - Buildings that reduce environmental damage

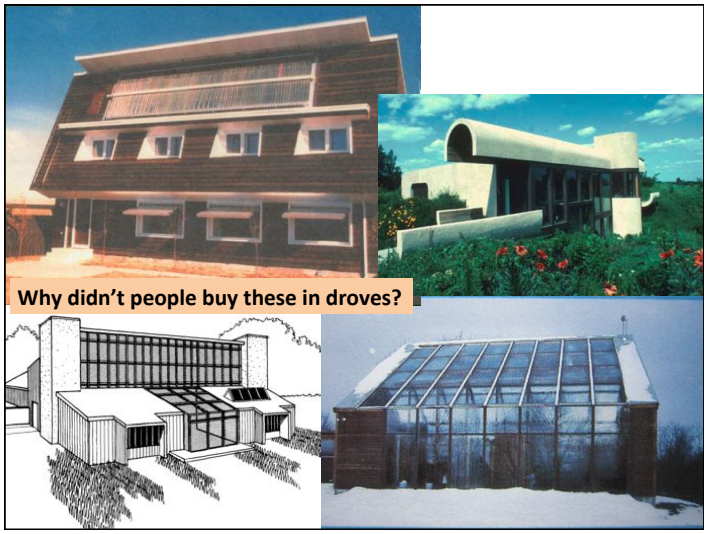


- Less impact for same function = **efficient**

That 70's show

- We have been here before





What we learned

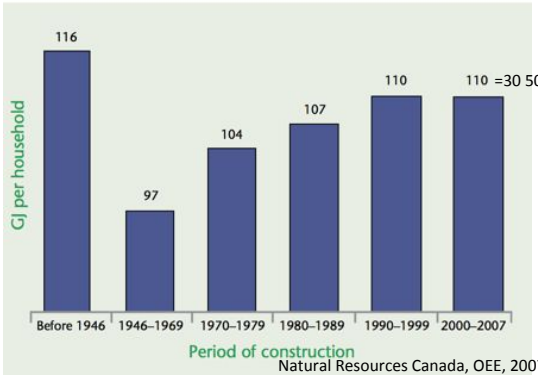
- Most people don't like weird stuff
- Most people don't like discomfort
- Complex and mechanical things break
- Insulation does not wear out or break
- Airtightness is critical
- Balance energy with comfort and aesthetics
- House is a system: durability, IAQ can be compromised by focus on energy

Lessons applied to today

- Lots of airtightness and insulation
- Exceptional rain control, more drying capacity
- Windows are critical, beware over-glazing
- Make it look mostly normal

How did we do?

Chart 9. Energy consumption by year of construction, 2007 (GJ per household)



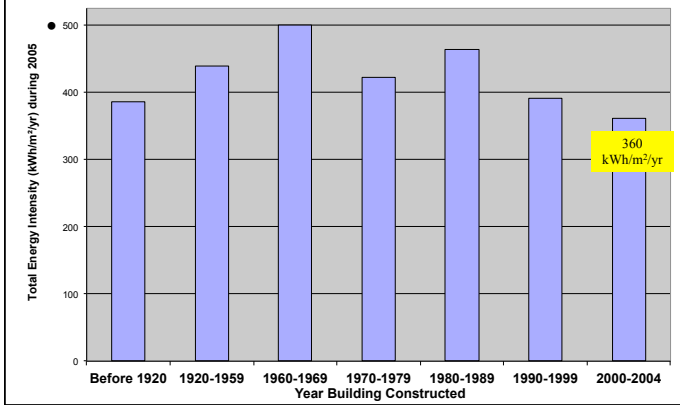
Natural Resources Canada, OEE, 2007 Survey

How did we fail?

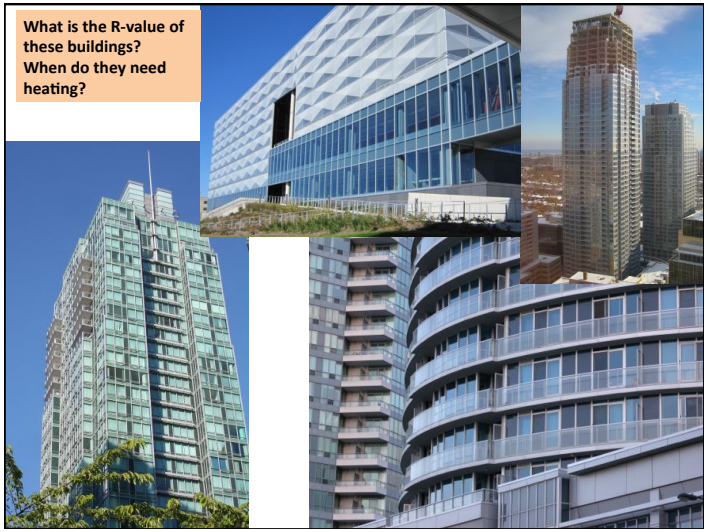
- Low energy prices
- Increased house size / complexity
  - Significant increases in 50 years
- Failed to increase insulation
  - Most codes languishing
- Failed to adopt window technology
  - "good" windows are still R3 or so.
- We did airtighten and improve combustion

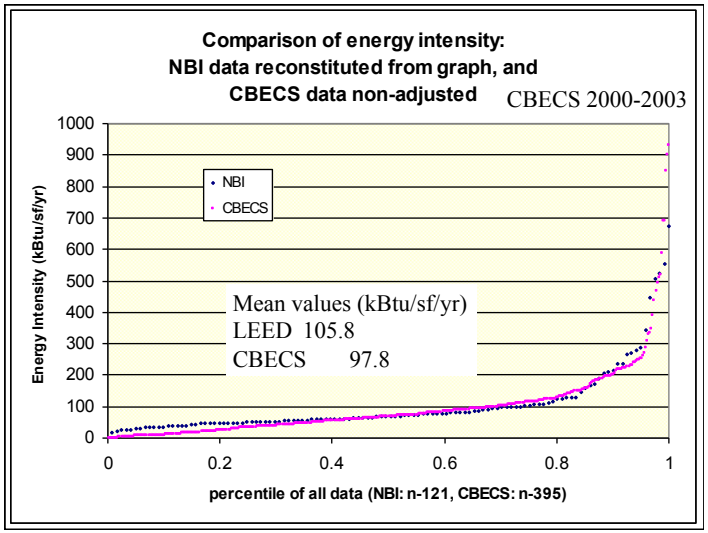
How did we do? - Commercial

Actual Energy Consumption of Canadian Commerical and Institutional Buildings



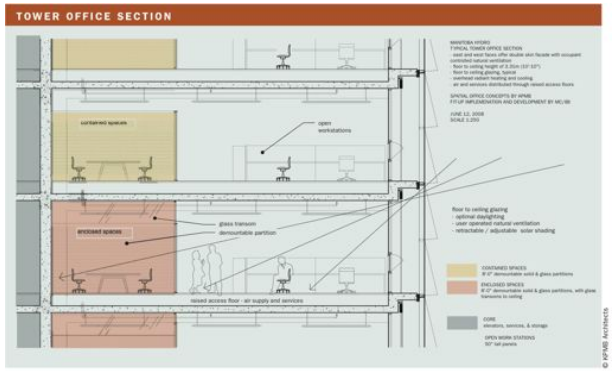
What is the R-value of these buildings? When do they need heating?



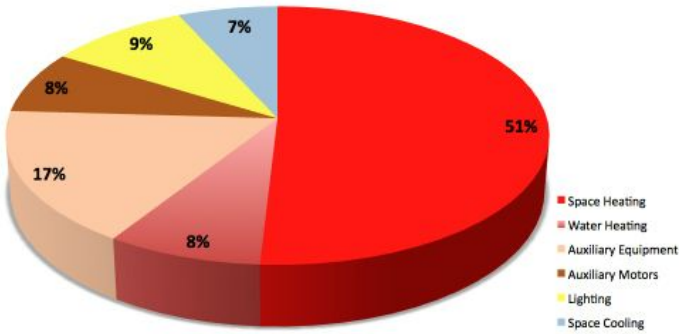


Daylighting Myths

Floor to Ceiling Glass Walls ARE NOT useful (often harm) good daylighting



Canadian Office Buildings 2007



What uses Energy?

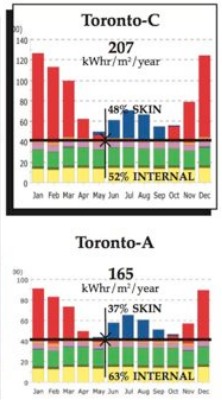
MD40SQ-C
4-storey, square floor plate
50,000 sf GFA
40% w-w-r (N, S, E, & W)
Enclosure "C-Institutional"

Space Heating | Space Cooling
Water Heating | Ventilation Fans
Pumps & Auxilliary | Plug & Miscellaneous
Task Lighting | Area Lighting

MD40SQ-A
similar to above, except:
Enclosure "A-Exemplary"

From: Ross, B., "Design with Energy in Mind", M.Arch. Thesis, University of Waterloo, 2009.

Typical market
Building in Toronto
55% heat+cool



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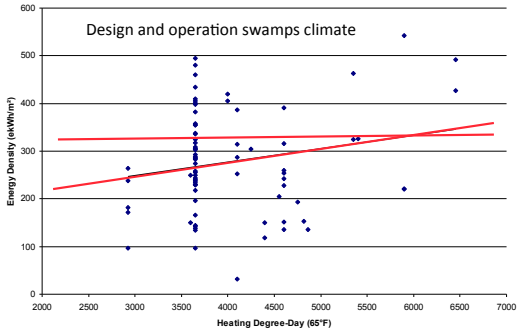
Reality check

- Real performance is what matters
- Sometimes understanding can't keep up
- Real measured performance needed
  - Real buildings
  - Real test walls, windows, roofs, heat pumps
- Need feedback to guide science
- Need feed forward to code
  - E.g. vapour barriers

MURBS:Vancouver vs Edmonton

- How much does climate really matter?



John Strat

Occupancy vs model

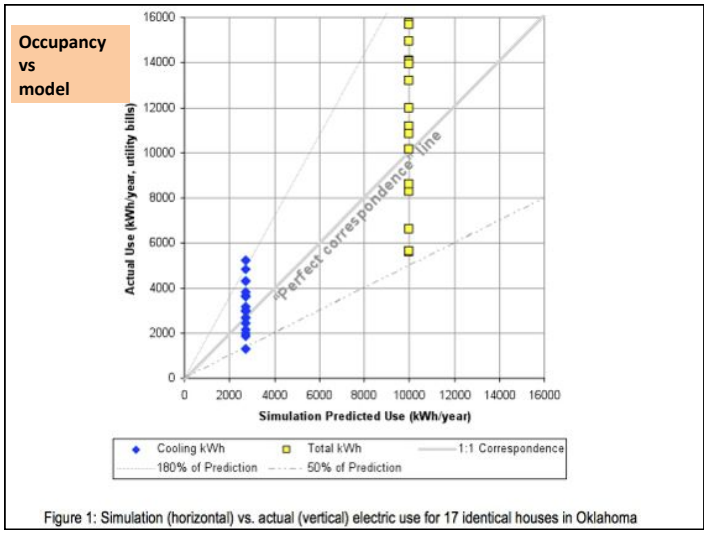
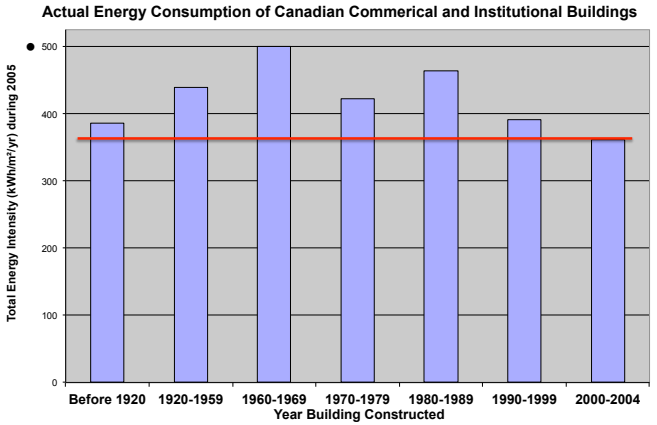
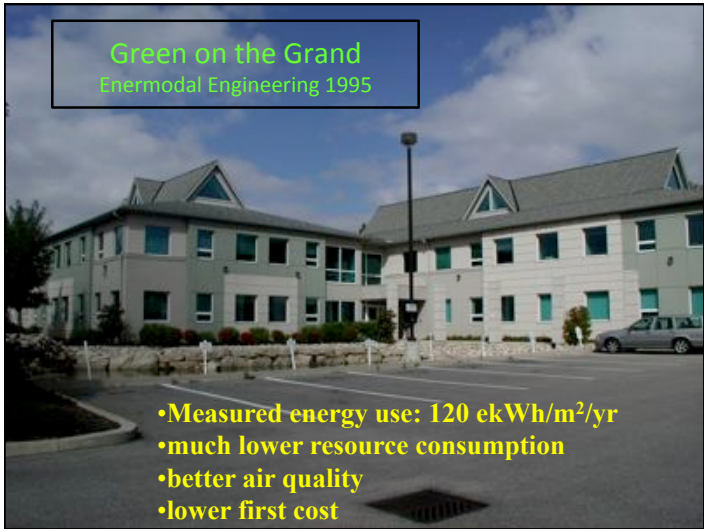


Figure 1: Simulation (horizontal) vs. actual (vertical) electric use for 17 identical houses in Oklahoma

Commercial Buildings by yr built

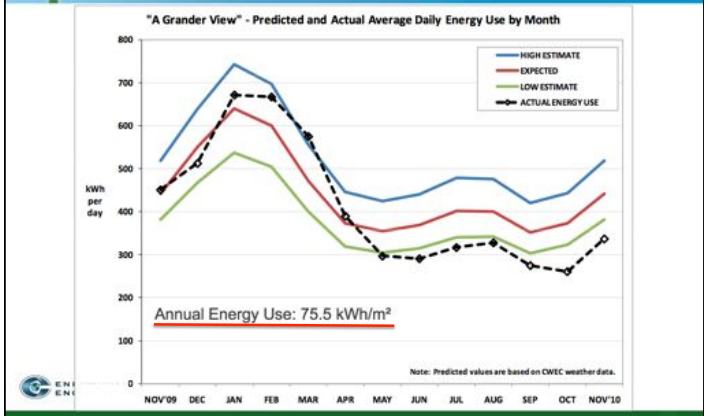




Grander View, 2010

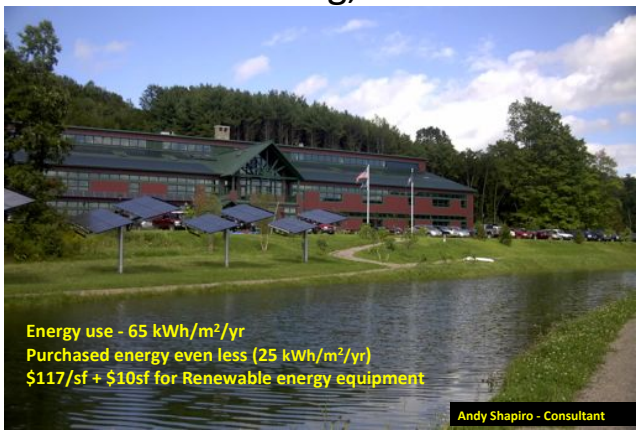
- Mostly simple, standard technology
- Modest cost premium

A Grander View Monitored Energy Use



Creating energy and resource efficient buildings

NRG Building, Vermont



Energy use - 65 kWh/m²/yr
Purchased energy even less (25 kWh/m²/yr)
$117/sf + $10sf for Renewable energy equipment

Andy Shapiro - Consultant

Waterloo Apartment / Office

- Built for median cost in 2005
- About 100 ekWh/m² (Ont avg around 250)
- All standard products

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Non-combustile ICF Structure

Thermal bridge / drainage

ccSPF air, water, thermal

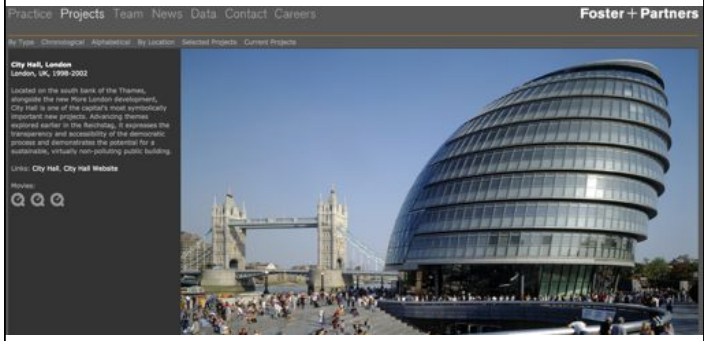
Range of finishes

Waterloo Region Health & Welfare

- Built 1990. 160 ekWh/m^2/yr. Less than half national average

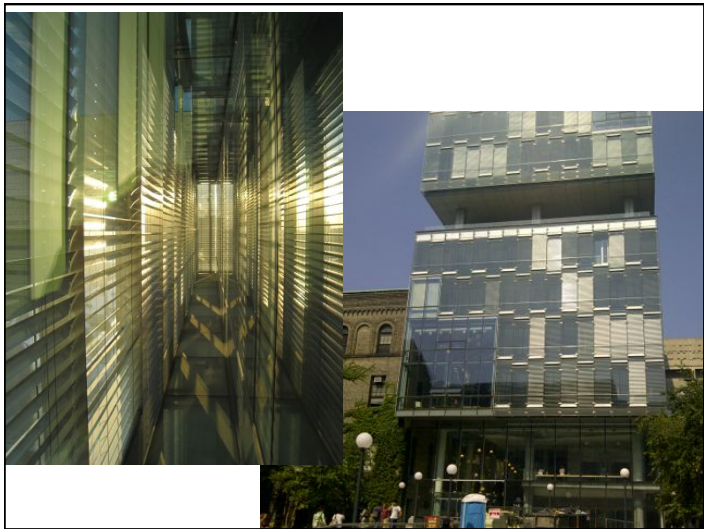
London City Hall

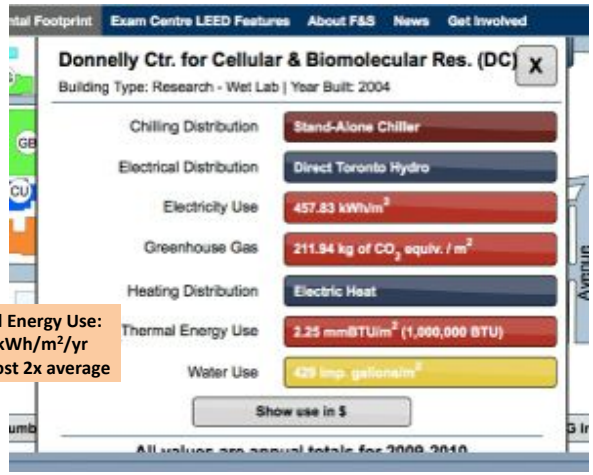
"Greenest city hall in the world" 2002
"Virtually non-polluting" 2011



London UK City Hall

- Measured: 376 kWh/m^2/yr

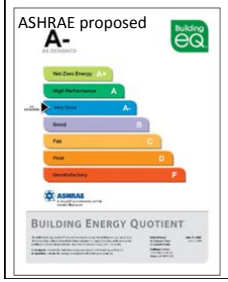


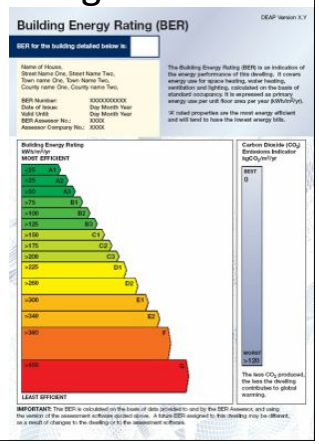


Total Energy Use:
659 kWh/m²/yr
Almost 2x average

Energy Labeling

- Can cut through fluff
- Real data not promises, points or plaques



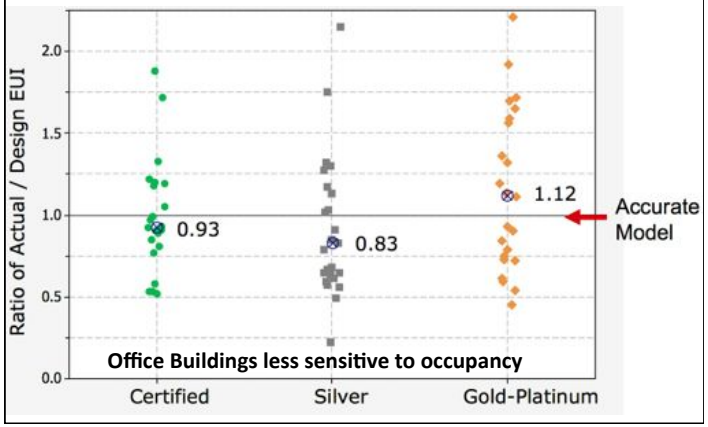


Energy Models

- Are critical to guide energy-efficient design
  - Mostly used as compliance tools (LEED)
  - Need more design guidance, esp early stage
- GIGO Garbage in = garbage out
- No control of quality/accuracy
- Need to compare measured results to modeled results!

More Complex Models are *rarely* more accurate or more useful

Energy Model vs Measured Data



How to get to Low energy

- Stop wasting
  - Good insulation, no thermal bridges
  - Airtight
  - Efficient Appliances
  - Efficieny Heating & cooling
- Don't build too big

Innovation: Nice but not necessary

- Insulation
  - Some new products, e.g. BASF Neopor
  - VIPs may become available
  - ICFs (structure, air + thermal + vapor)
  - Spray insulation, (air + water) control
- Fluid applied (air + water +vapor? control)
- Doing what's right is the innovation needed
- **But**, we *can* get 2x-5x R-value by
  - Continuity (blunt thermal bridges), and
  - adding thickness

Need more than technology

- We need different
  - Values
    - E.g. performance matters, long term thinking
  - Skills
    - E.g. reliable prediction, test performance
  - Knowledge & Understanding
    - Developed by education, training, experience
    - Need research to feed into this process!

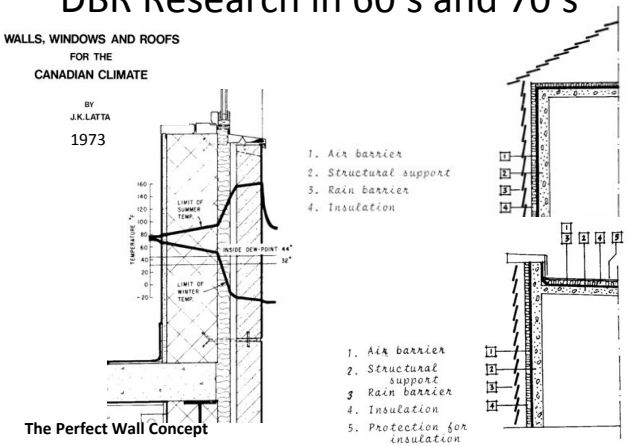
We know how

- Getting to ½, even ¼ is possible, mostly practical
- BUT, requires
  - Knowledgeable, integrated design team
  - Performance tracking during design
  - owner who cares
- Does NOT need
  - Expensive new widgets, complex HVAC, controls
  - Checklists aka LEED

Enclosures

- Most important for single-family houses, even rowhouses
- About half the challenge in large commercial, industrial, MURB
  - Need good HVAC

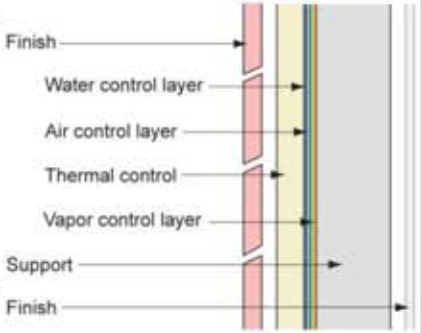
DBR Research in 60's and 70's



The Perfect Wall Concept

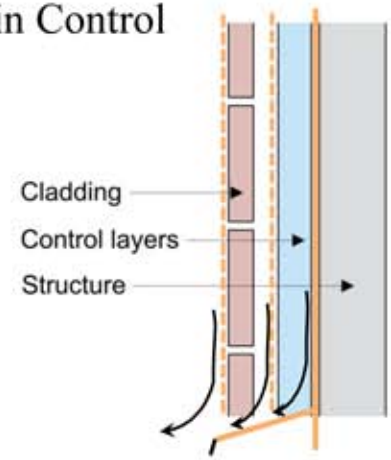
The "Perfect Wall"

- Finish of whatever
  - May need ventilated
- **Control continuity is the key**
  - Water: Drainage gap + drainage plane
  - Air: Air barrier
  - Heat: Insulation
  - Vapor: vapor barrier



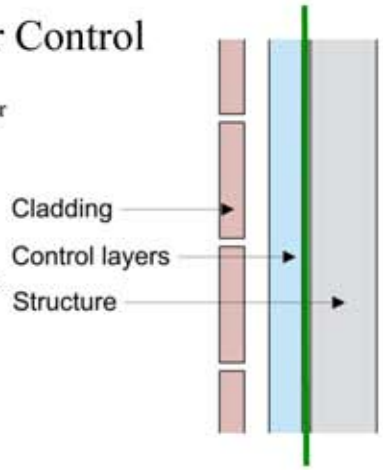
Rain Control

- Rain shedding
- Drainage
- Must integrate with flashing, drainholes
- Overlap everything
- No holes



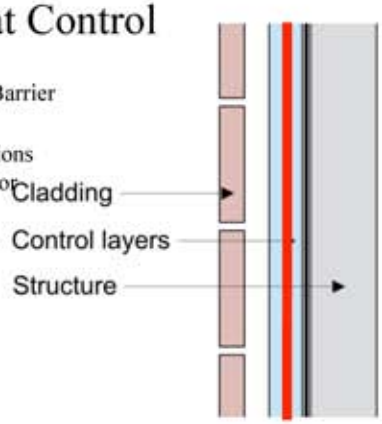
Air Control

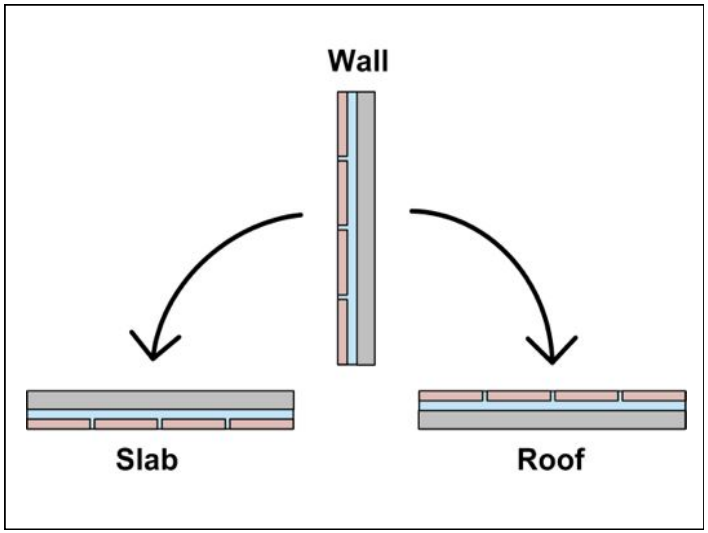
- Continuous Air Barrier
  - Continuous
  - Stiff
  - Strong
  - Durable
  - Air Impermeable
- Only very small holes tolerable

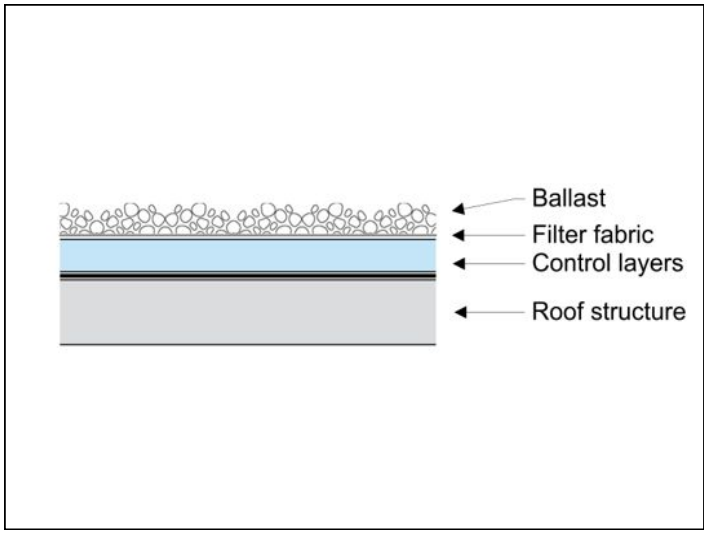


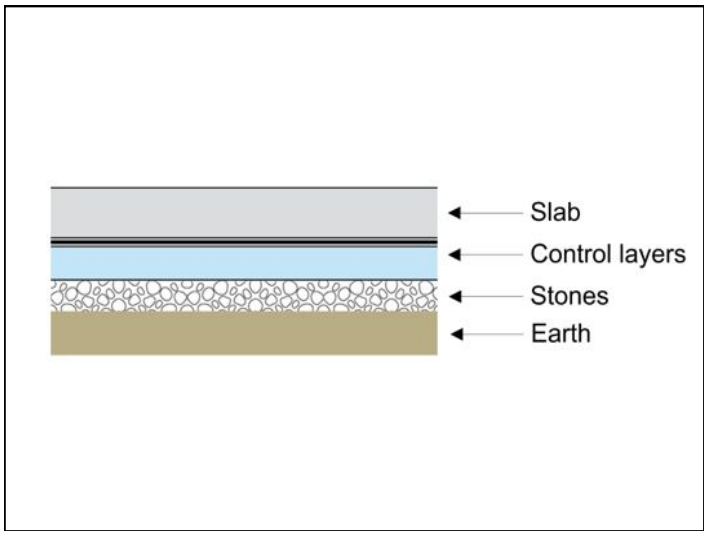
Heat Control

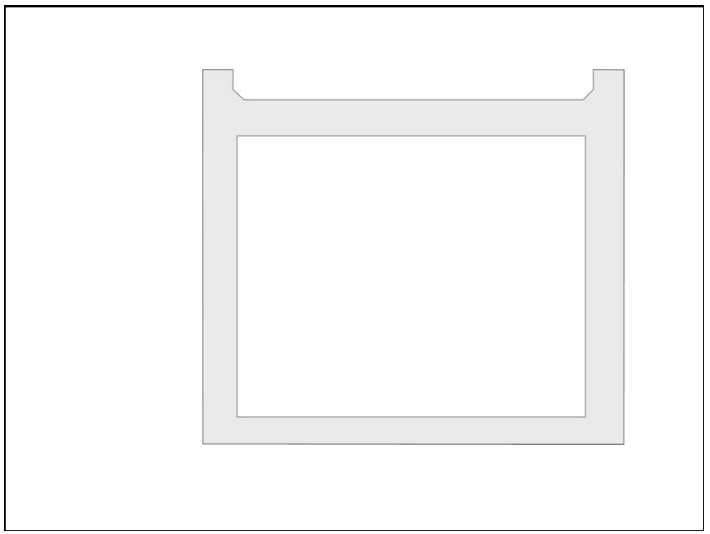
- Continuous Thermal Barrier
  - Even R10 is good
- Accept small penetrations as long as no comfort or durability issues
- Windows are a major concern
  - Heat loss/gain
  - Solar gain

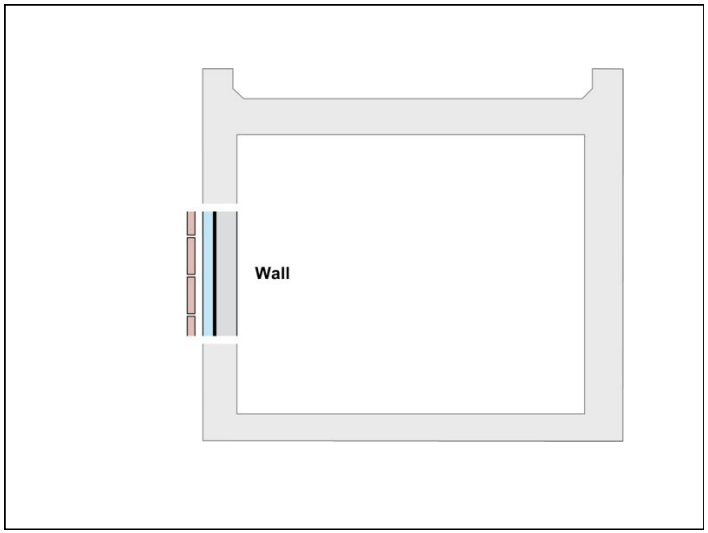


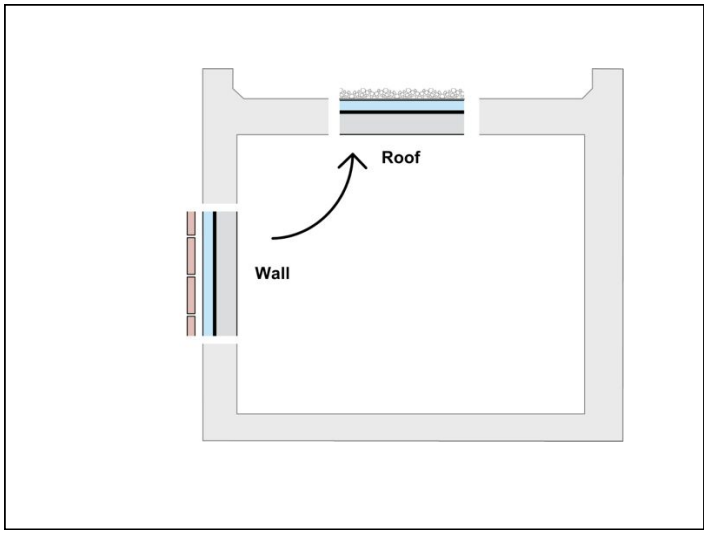

Wall
Slab
Roof

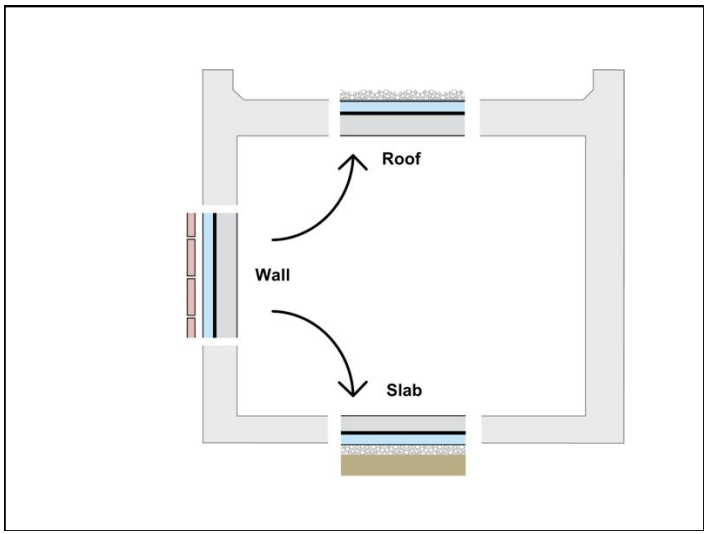

Ballast
Filter fabric
Control layers
Roof structure

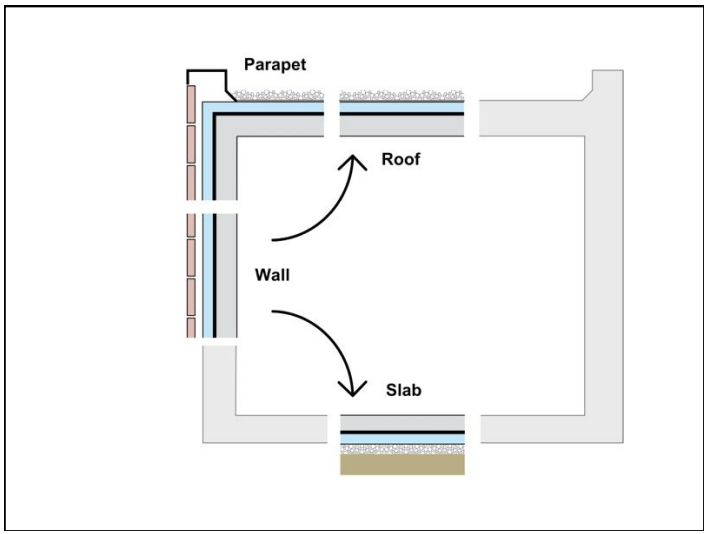

Slab
Control layers
Stones
Earth

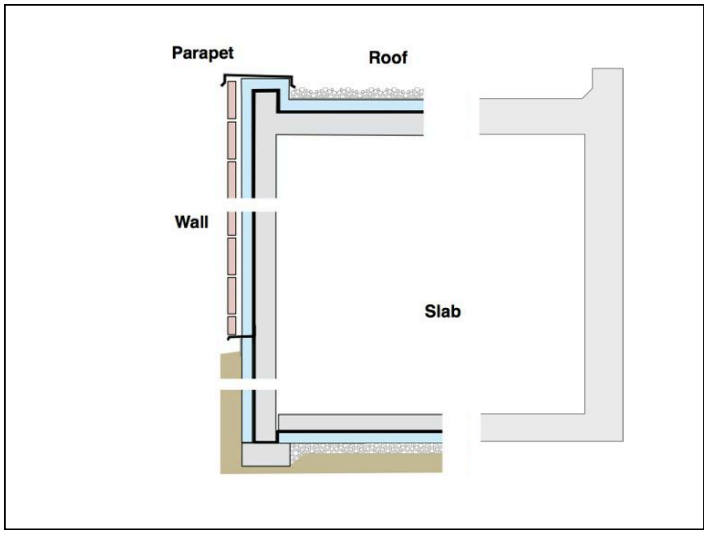


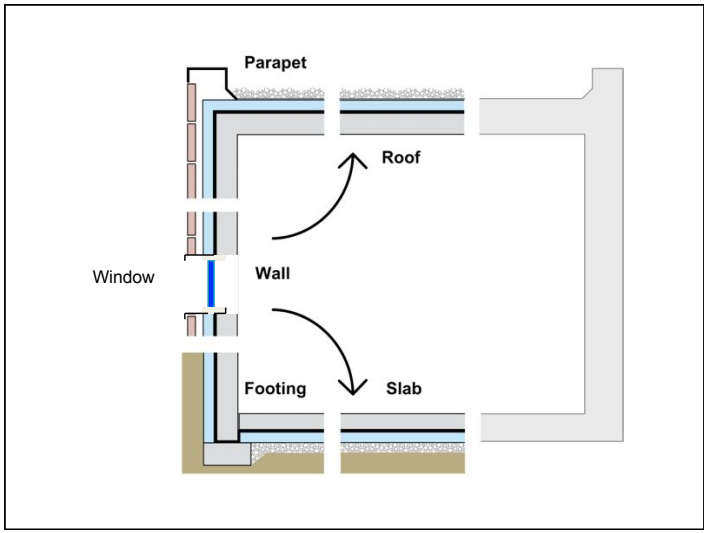

Wall


Roof
Wall


Roof
Wall
Slab

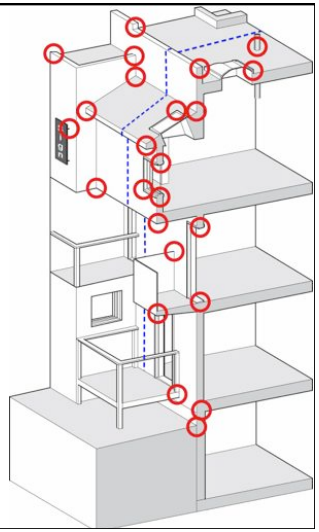

Parapet
Roof
Wall
Slab





Enclosure Design: Details

- Details demand the same approach as the enclosure.
- Scaled drawings required at ◯



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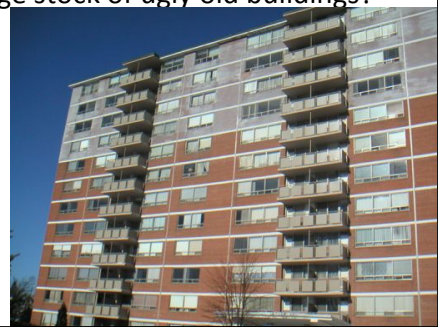
"Heritage" Buildings

- "Old buildings that are nice" = heritage
- What about huge stock of ugly old buildings?



Future

- We need much better buildings
- But we know most of how to go there
- Cant forget Indoor Air Quality, light, view, fire, cost, durability etc
- Need to apply good science mixed with good experience: building science
- Need to remove obstacles, work on implementation, deployment

Dialogue

- Passive Solar Heating
- Net Zero as a target
- Passive House
- Green Roofs
- Urban vs Rural