Energy Efficiency and the Future of Building Science

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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**

Changes are coming

- Canadians are demanding cleaner use of energy
- Energy costs are rising
  - Brazil, Russia, India, China will make sure of that
- California will pay 3 times as much for BC electricity as BC Hydro charges consumes
  - Why waste it here?
- Regulation is responding

Role of Building Science

- Change in building enclosure design, material, or construction *involves risk*
- We do not have the ability to reliably predict performance "near the edge"
- Field performance still the ultimate test
- Need to apply science (e.g. physics) with field experience to generate low risk solutions

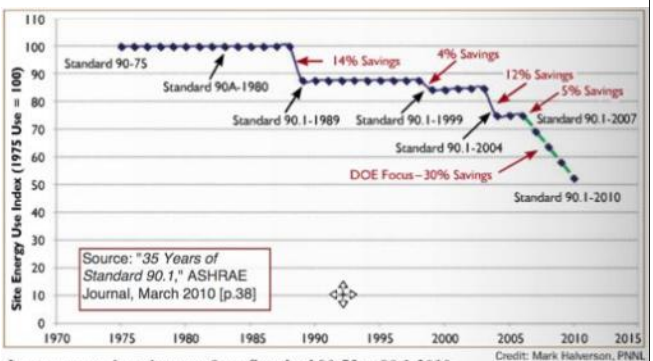
The Last Time….

- The last time small changes were adopted across the industry …

  outcomes were “unexpected”
- Still don’t fully understand the condo disaster
  - What factors played what role?
- BC Industry is now very good at dealing with water

Change is coming again to BC

- Stricter codes for commericial
  - E.g., ASHRAE 90.1- 2010
- Net Zero “Ready” for housing by 2020



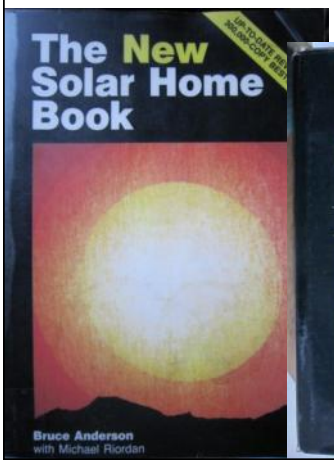
Improvements in stringency from Standard 90-75 to 90.1-2010.

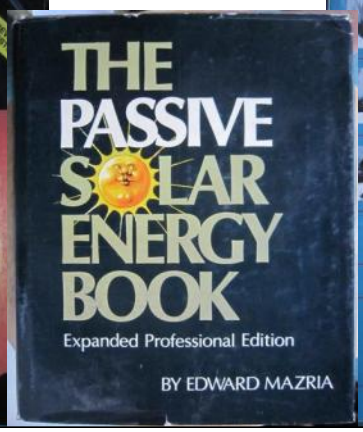
The Past Cycle (1973)

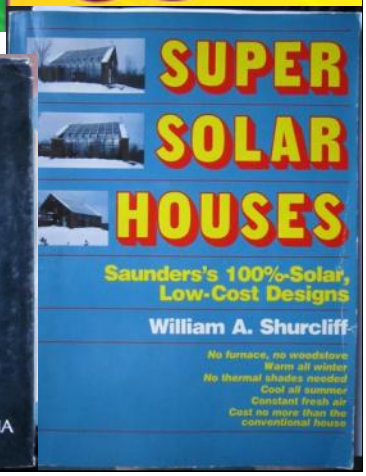
- Energy prices spiked, people worried about supply
- Environmentalists raised alarms about pollution and habitat destruction
- Society responded with research, incentive programs, new products, new codes

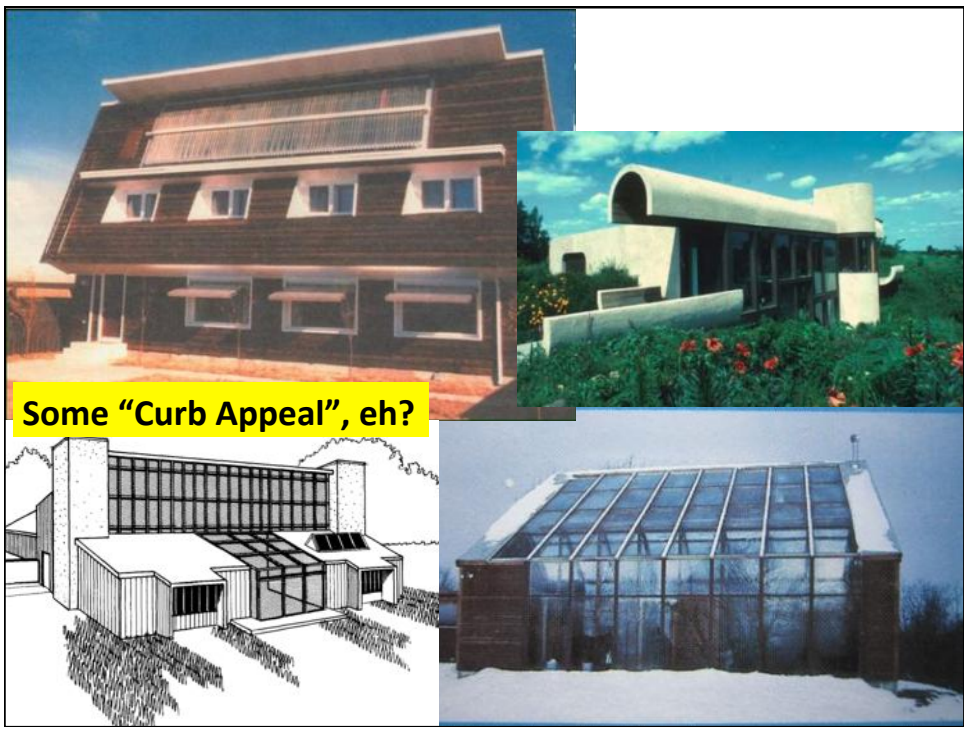
That 70's show

- We have been here before









What we (should have) 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 (and rarely breaks)
- Airtight / highly-insulated assemblies often more susceptible to moisture flaws

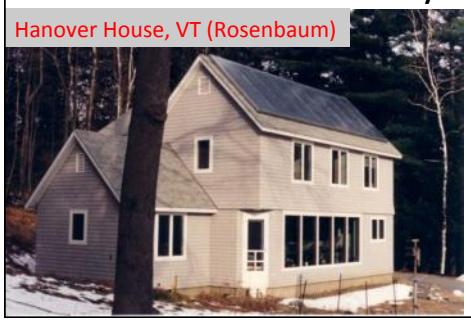
The Prime Directives

- House is a system: durability, IAQ, safety must not be compromised by a focus on energy
- Balance energy savings with comfort, aesthetics to gain widespread acceptance

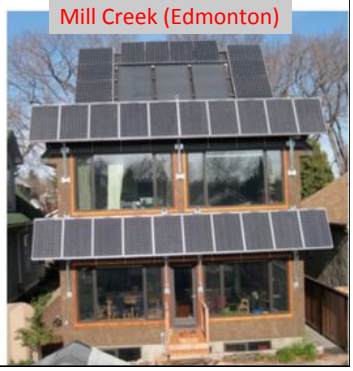
Past lessons applied today

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

Hanover House, VT (Rosenbaum)

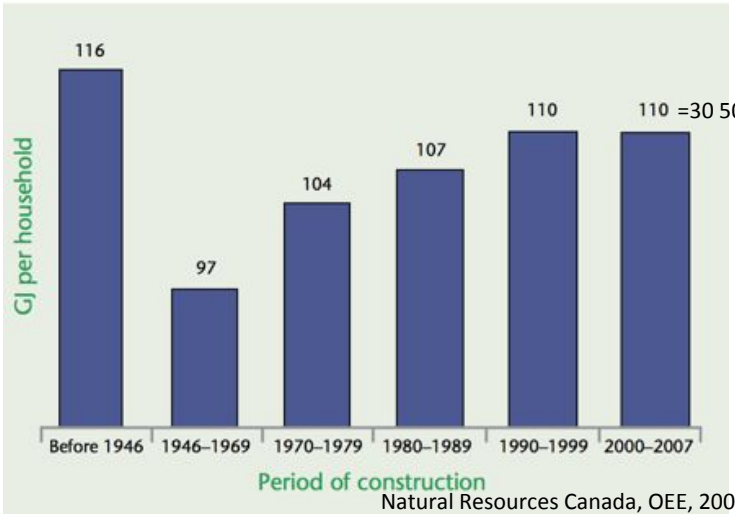


Mill Creek (Edmonton)



How did we do

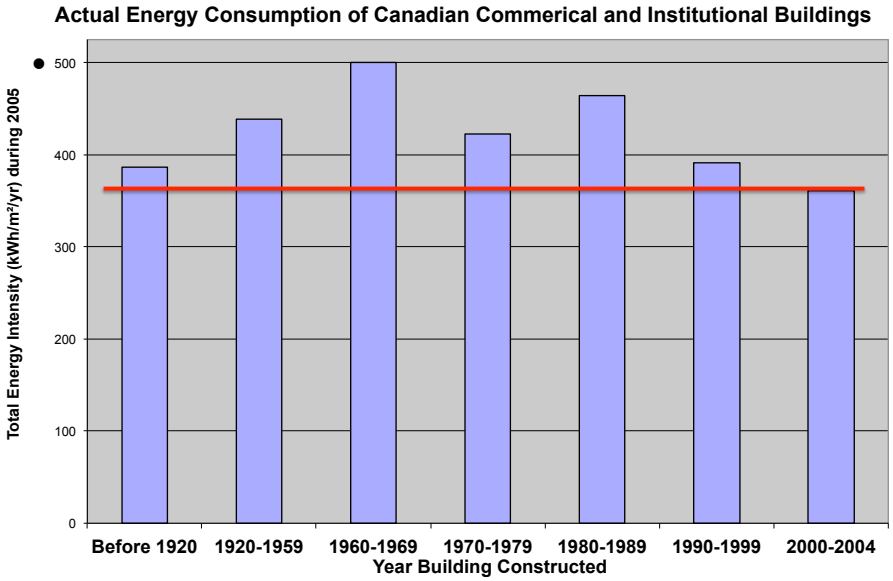
Chart 9. Energy consumption by year of construction, 2007 (GJ per household)



=30 500 kWh

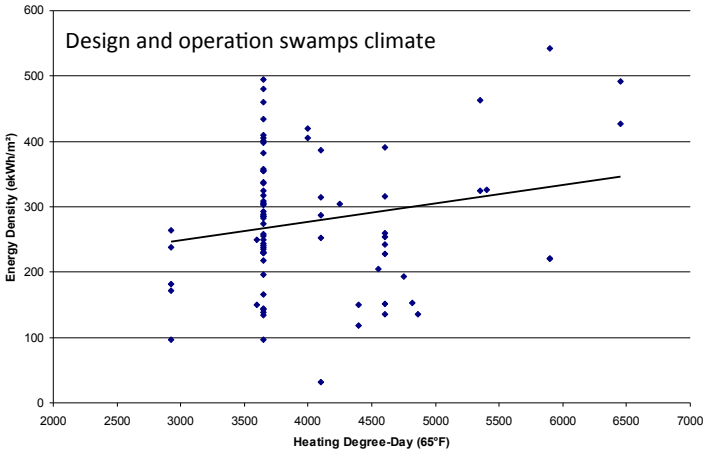
Natural Resources Canada, OEE, 2007 Survey

Commercial Buildings by yr built



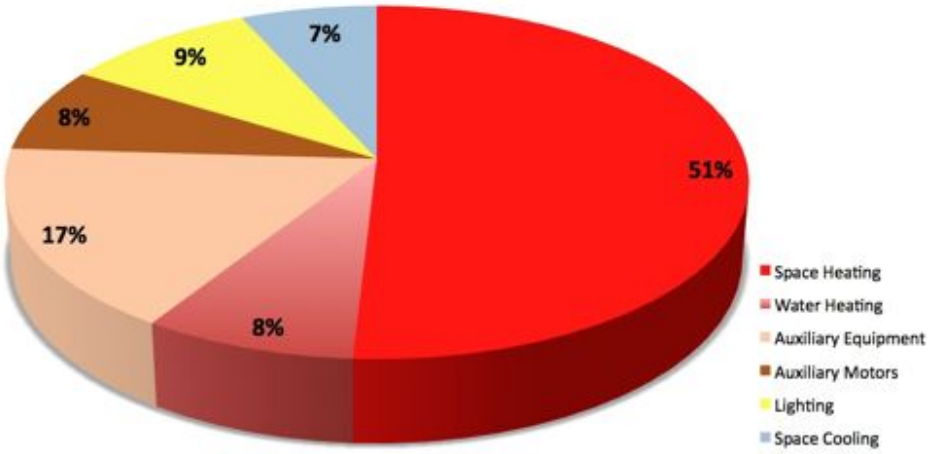
MURBS:Vancouver vs Edmonton

- How much does climate really matter?



John Strau

Canadian Office Buildings 2007



Actual Energy use

Good estimates for lower Mainland:

- Single Family housing lower mainland
  - 130 kWh /m^2 / yr or 22 000 kWh/household
- Condominium High-rise
  - 215 kWh/m^2/yr or 22 000 kWh/unit

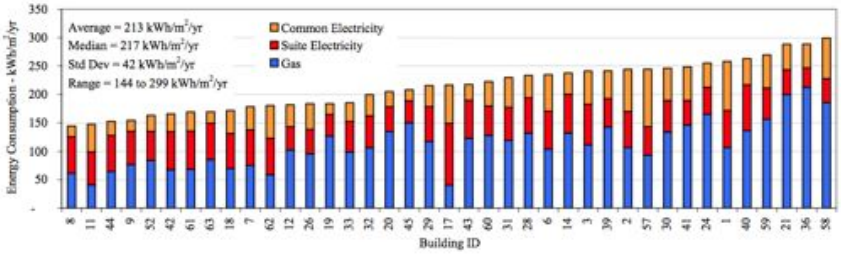


Fig. 3.1.1 Total Energy Usage per Gross Floor Area – Sorted Low to High, Split by Electricity (Common & Suite) and Gas.

The Goal? Net Zero

- Should it be?
- Who will pay for the grid?
- Who will pay for the peak power plants?

Photovoltaics

- Ideally oriented, 1 kW rated PV in Vancouver generates about 1100 kWh/year (750 on wall)
- Current PV has about 7.75 m^2/kW_p (12 W_p/ft^2)
- Typical household uses 22 000 kWh energy
  - 22 000/ 1100 * 7.75 = 155 m^2
- Forget economics …
  Where do I get 155 m^2 of 45° sloped surface per 110 m^2 unit?

This or That?

- Which looks better?

Integration on single family homes probably be solved

Moderate density Net Zero development may be possible

Rolf Disch, Freiburg Germany (wikipedia)

Rolf Disch, Freiburg Germany (wikipedia)

How to get to low-energy Buildings

- The new focus for Building Science
  - Durability, comfort, AND energy efficiency
- Less prescriptive buildings, more “designed”
- Will require trade-off analysis
- Choices between different Mechanical and Electrical choices need to be made
- Many M&E know even less about BS than BS know about M&E

We must reduce!

- Efficiency is critical
  - Perhaps conservation will be fashionable?
- Building Enclosure
  - Part of the equation, but actually “solved”
- Appliances
  - Important unsolved piece of puzzle
- Domestic Hotwater
  - Needs to be improved

Zone 4 ASHRAE 90.1-2010

Prescriptive Enclosure Tables

Opaque Elements	Nonresidential		Residential	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roofs				
Insulation Entirely above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.
Metal Building[a]	U-0.055	R-13.0 + R-13.0	U-0.055	R-13.0 + R-13.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0
Walls, Above-Grade				
Mass	U-0.104	R-9.5 c.i.	U-0.090	R-11.4 c.i.
Metal Building	U-0.084	R-19.0	U-0.084	R-19.0
Steel-Framed	U-0.064	R-13.0 + R-7.5 c.i.	U-0.064	R-13.0 + R-7.5 c.i.
Wood-Framed and Other	U-0.089	R-13.0	U-0.064	R-13.0 + R-3.8 c.i.
Walls, Below-Grade				
Below-Grade Wall	C-1.140	NR	C-0.119	R-7.5 c.i.

R-11.2 to R-15.6

Zone 5 ASHRAE 90.1 -2010

Opaque Elements	Nonresidential		Residential	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roofs				
Insulation Entirely above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.
Metal Building[a]	U-0.055	R-13.0 + R-13.0	U-0.055	R-13.0 + R-13.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0
Walls, Above-Grade				
Mass	U-0.090	R-11.4 c.i.	U-0.080	R-13.3 c.i.
Metal Building	U-0.069	R-13.0 + R-5.6 c.i.	U-0.069	R-13.0 + R-5.6 c.i.
Steel-Framed	U-0.064	R-13.0 + R-7.5 c.i.	U-0.064	R-13.0 + R-7.5 c.i.
Wood-Framed and Other	U-0.064	R-13.0 + R-3.8 c.i.	U-0.051	R-13.0 + R-7.5 c.i.
Walls, Below-Grade				
Below-Grade Wall	C-0.119	R-7.5 c.i.	C-0.119	R-7.5 c.i.

R-15.6 to R-19.6

90.1-2010 is not that demanding

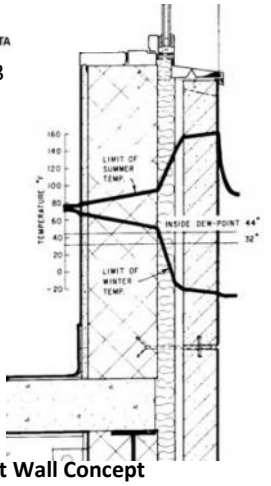
- Continuous insulation of R7.5 is pretty easy
- Will require changing techniques of cladding installation
- Lots of options available but few commonly used

DBR Research in 60's and 70's

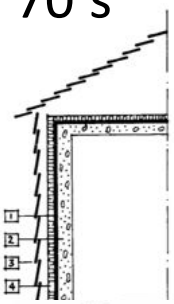
WALLS, WINDOWS AND ROOFS
FOR THE
CANADIAN CLIMATE

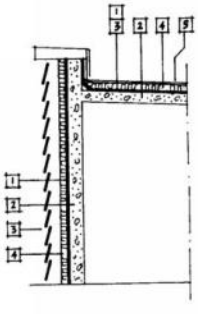
BY
J.K.LATTA

1973



The Perfect Wall Concept

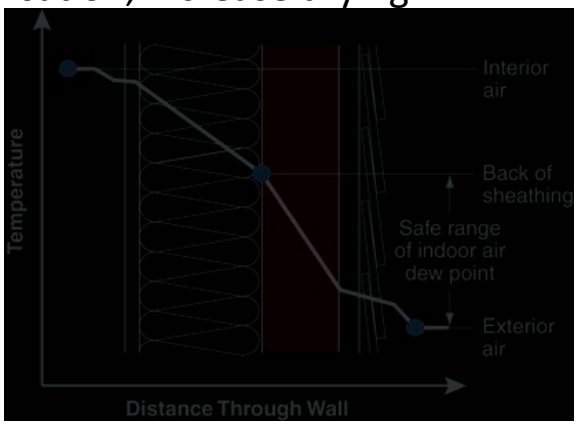


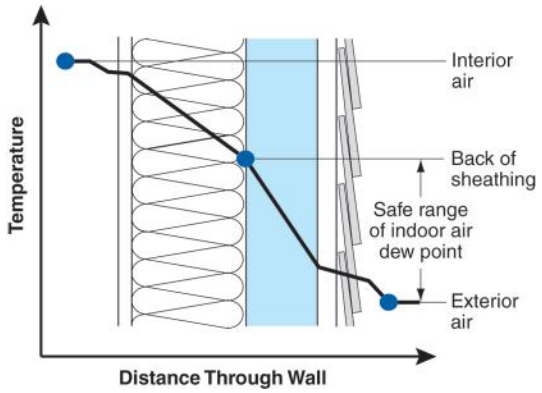


Exterior Insulation: More then energy

- Reduces moisture risks if done right
- Reduce condensation, increase drying

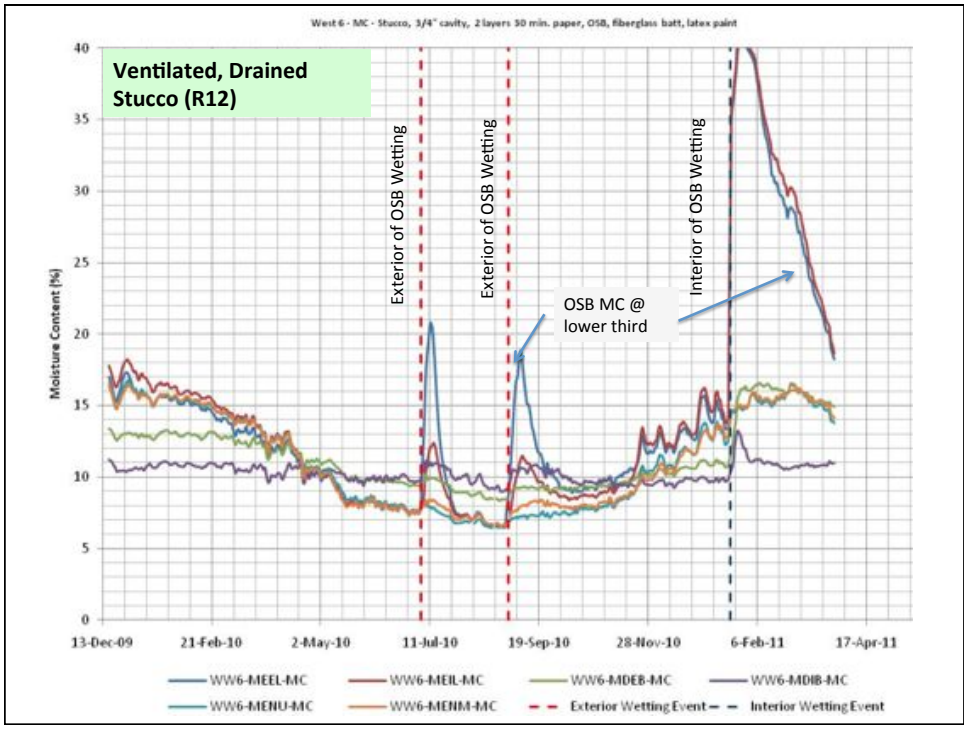
- **Back of Sheathing defined by R-value ratio**
- **Indoor dewpoint defined by ventilation rate**

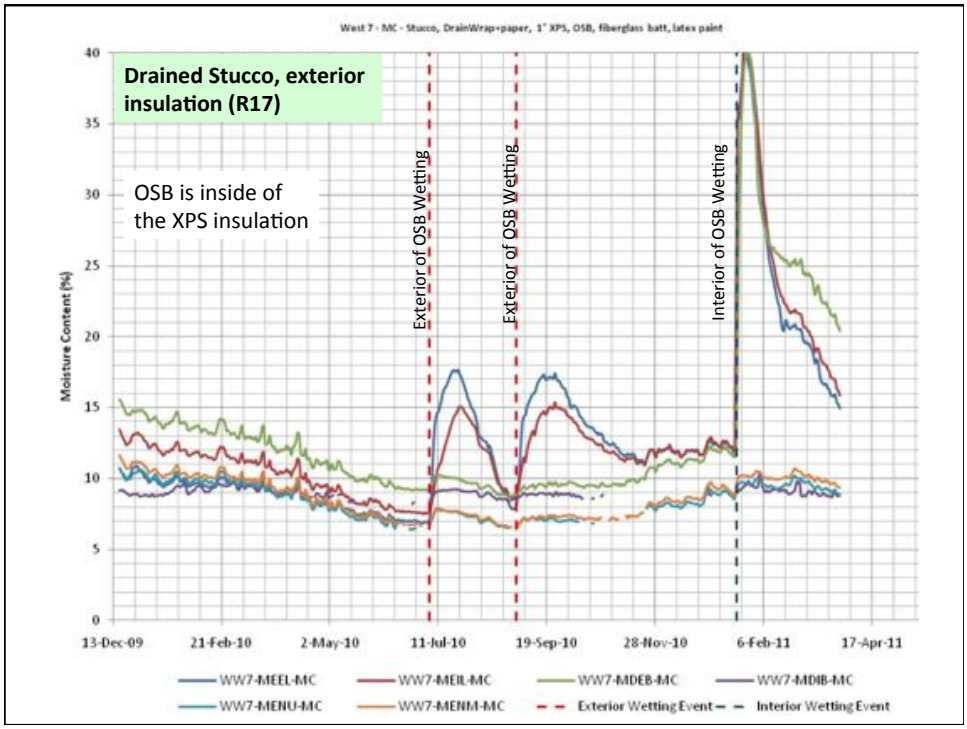



Interior air
Back of sheathing
Safe range of indoor air dew point
Exterior air
Temperature
Distance Through Wall

Wet Spots

- Add a calibrated Leak
- Lower third of wall
- Add 1.5 ounces,
  2 times / day
  5 days
  = 15 ounces
  = 425 ml

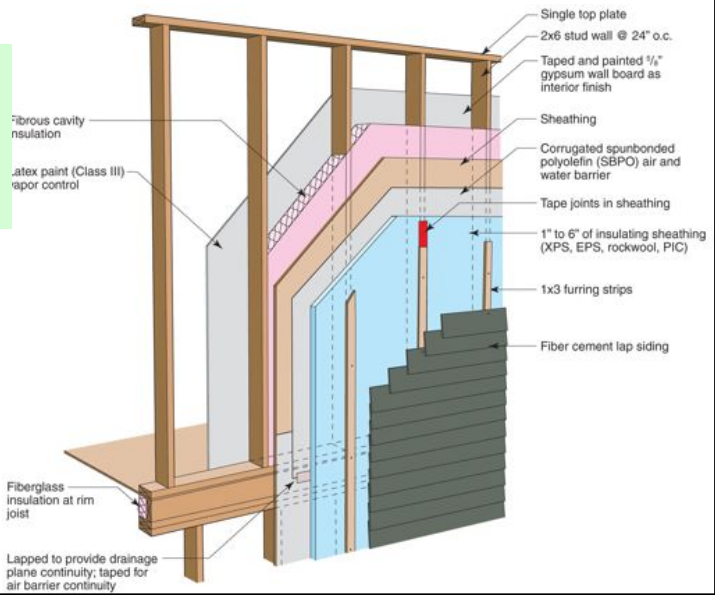




Wood Framed Furring

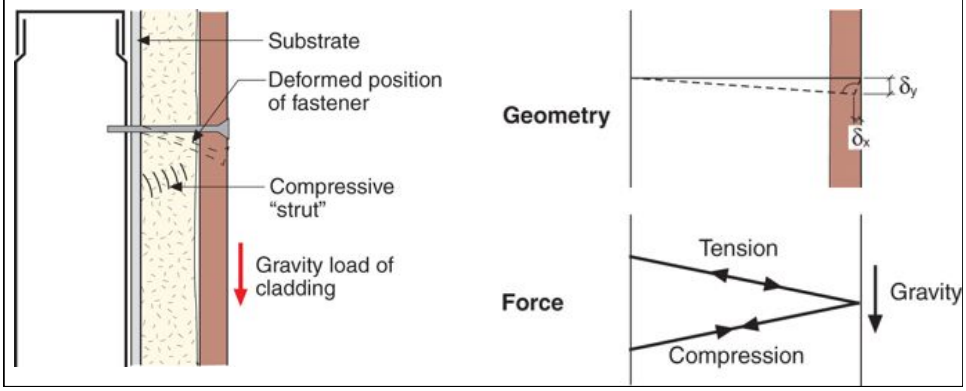
2x6 w/R5 exterior is for weenies
2x4 w/R7.5 for higher interior RH
2x6 w/R10-R15 is likely long-term answer

Increasing ratio of Exterior to Cavity insulation reduces risk and improves performance

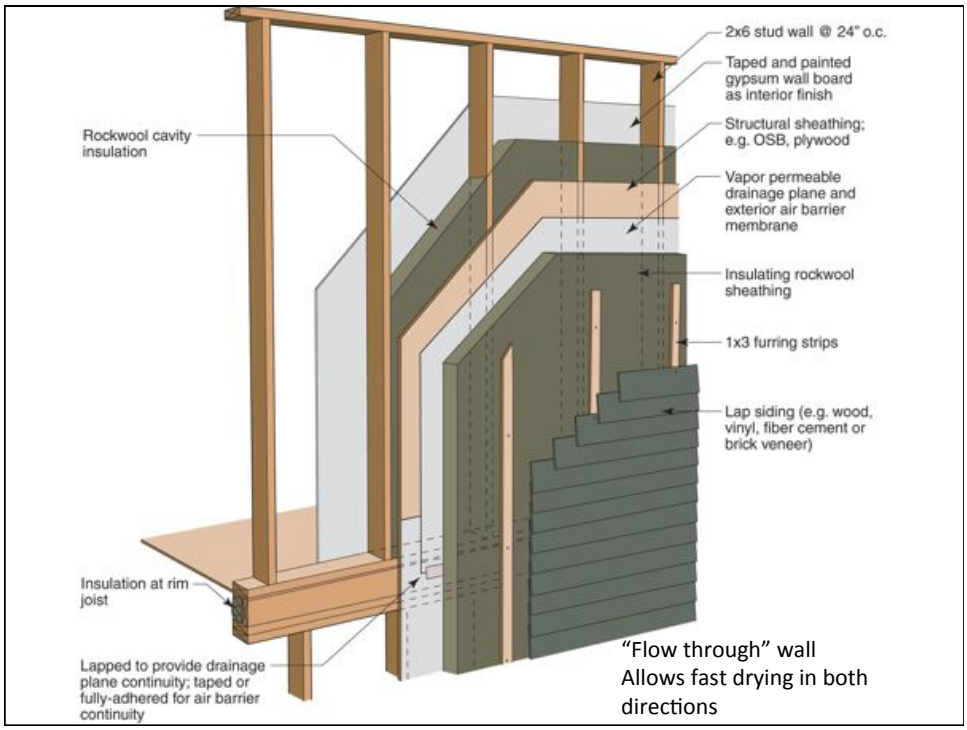


Exterior insulation

- Insulating on exterior is not a structural challenge … unless you use the wrong model
- Bending does matter, but only at high deflections



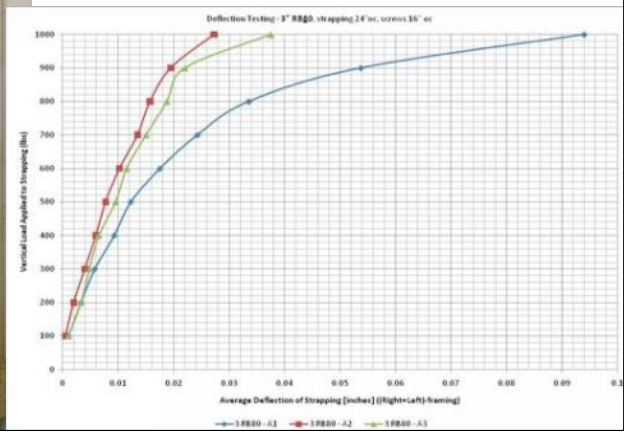
Foam sheathing field testing

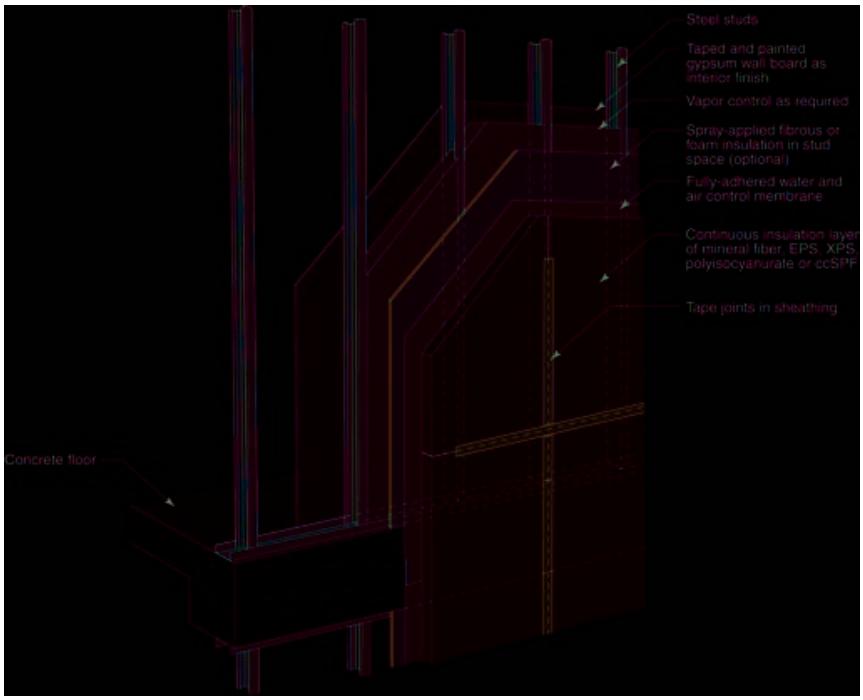


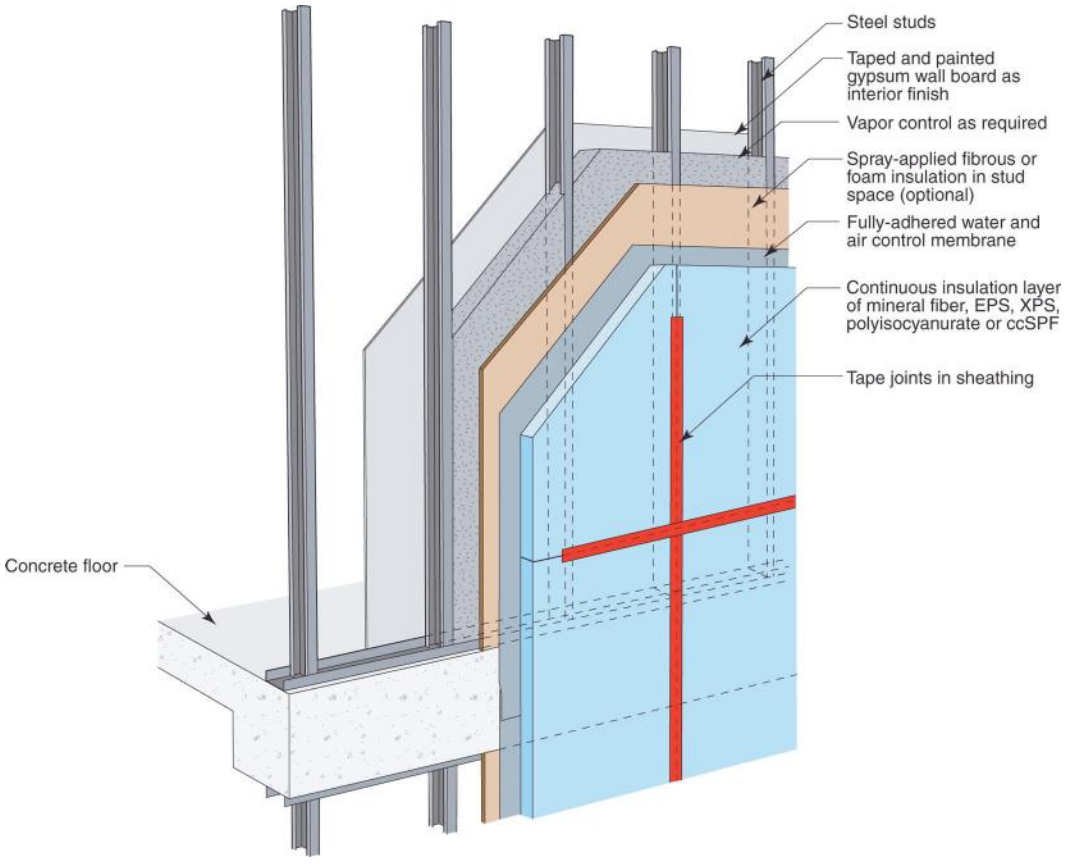
"Flow through" wall
Allows fast drying in both directions

Rockwool

1x3 furring @ 24” o.c.
#10 screws @ 16” o.c. vertically
Result: 20 psf cladding weight with < 2/100” deflection

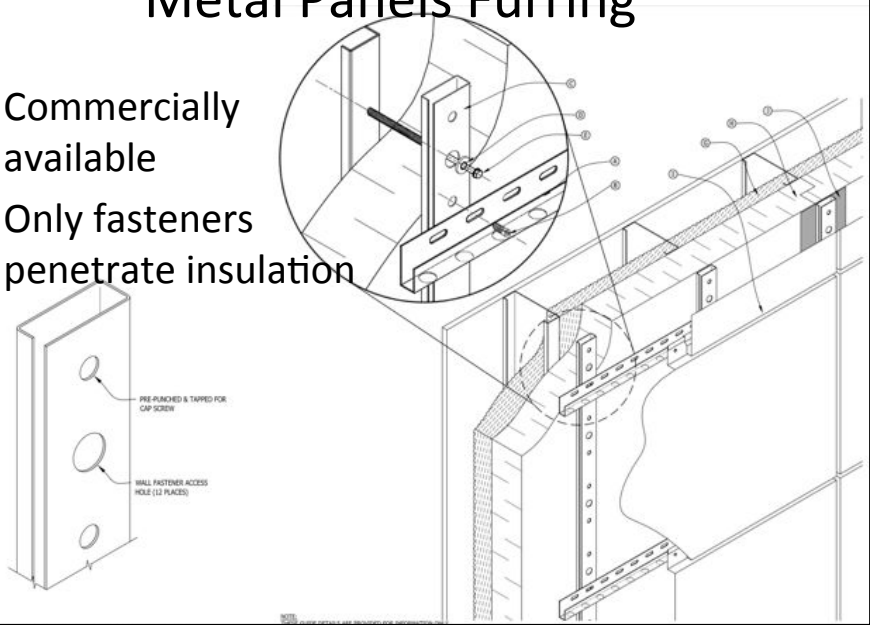


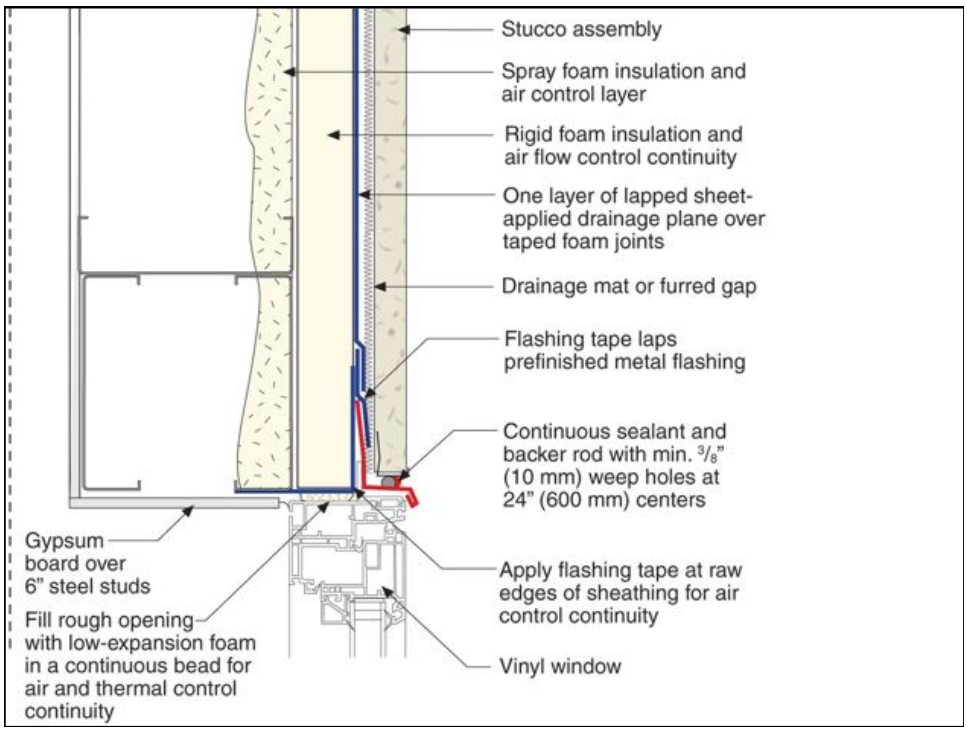



Steel studs
Taped and painted gypsum wall board as interior finish
Vapor control as required
Spray-applied fibrous or foam insulation in stud space (optional)
Fully-adhered water and air control membrane
Continuous insulation layer of mineral fiber, EPS, XPS, polyisocyanurate or ccSPF
Tape joints in sheathing
Concrete floor

Metal Panels Furring

- Commercially available
- Only fasteners penetrate insulation

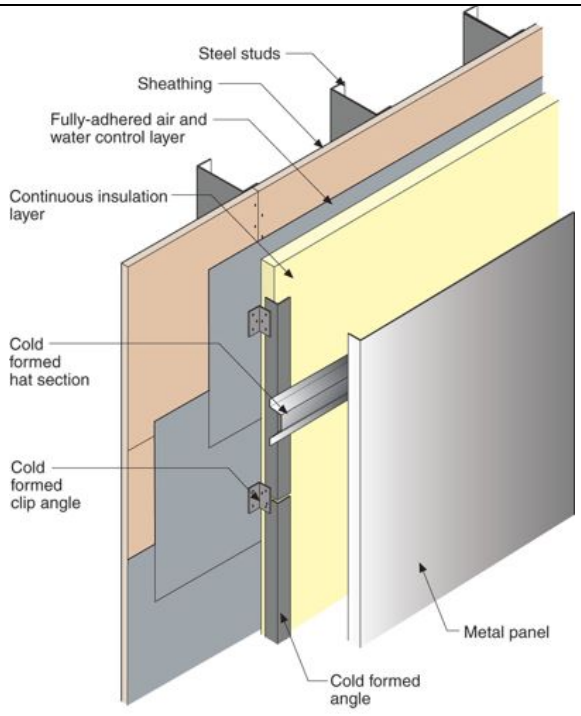


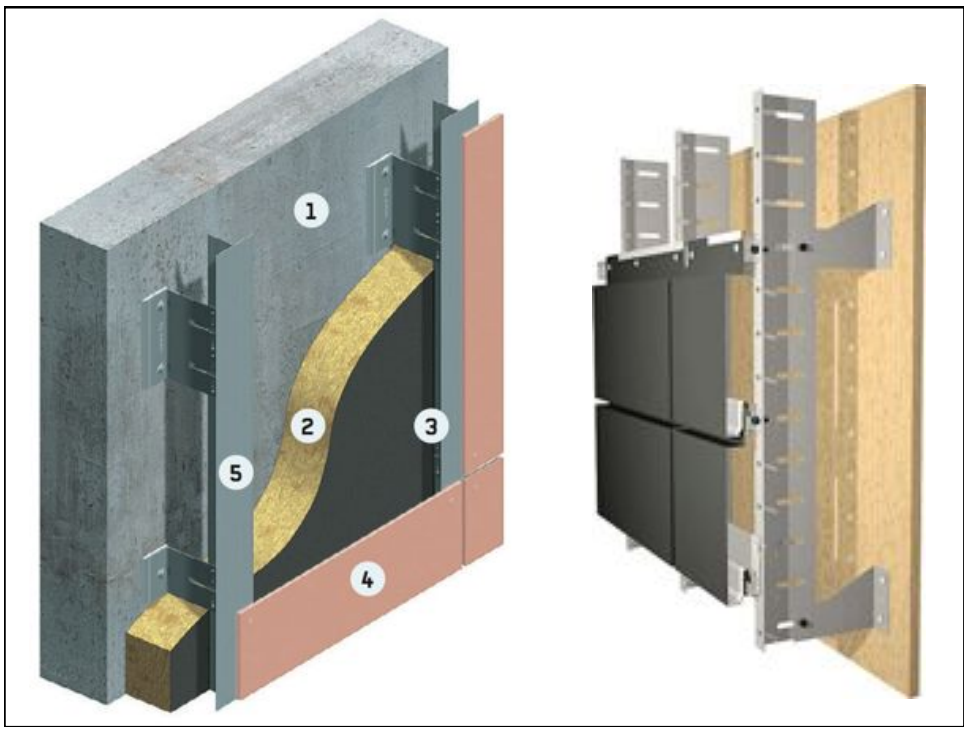


Metal Clips

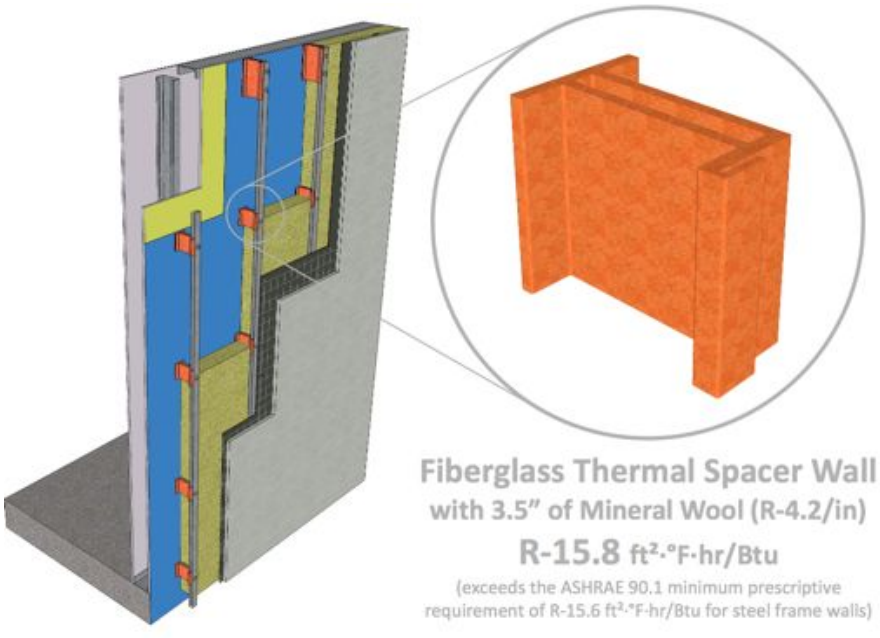
- Use of stainless steel clips and structural sufficient clips reduces R-value impact to about 10-20%

Based on 16 ga by 5" stainless clips at 32" o.c. through R20

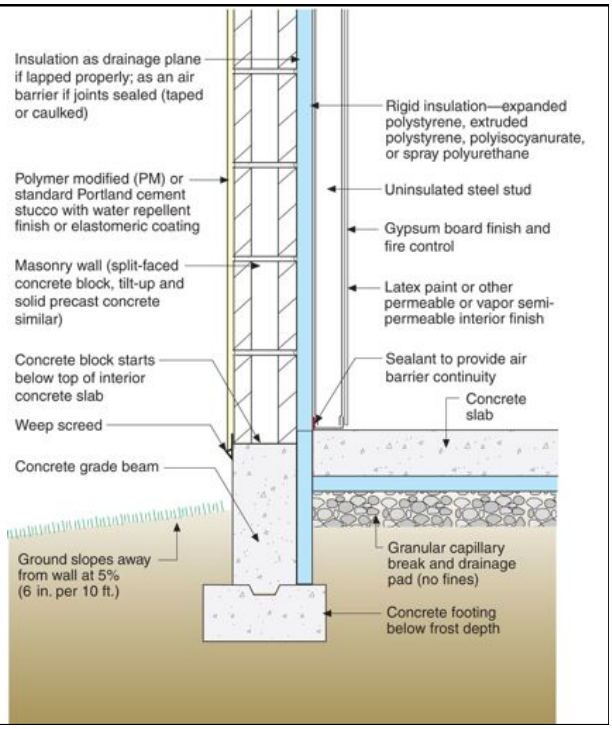


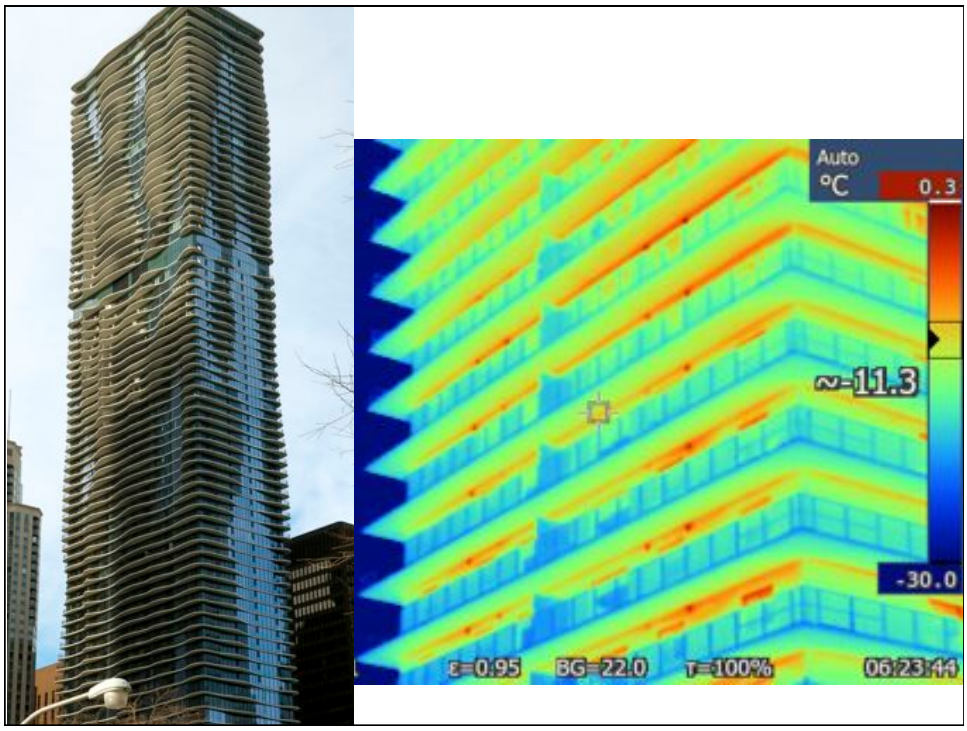


Local Invention



- Tilt-up & exposed block low-rise solution





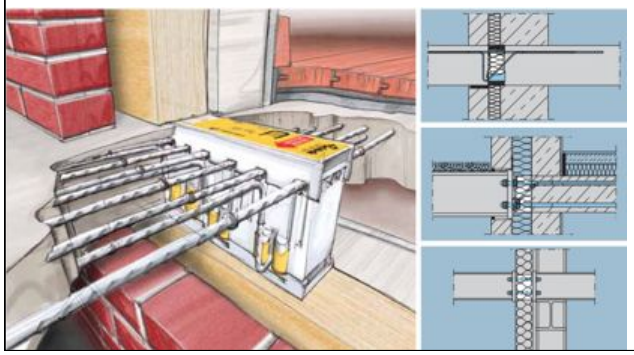
High-rise ICF

Excellent continuous insulation (True R-15 and more available)
+ Excellent airtightness
+ Modest window area
= low energy

Structural cost premium is near zero

Specialist Solutions

- Analysis of heat loss is included with expensive products
- "Generic" solutions are usually lower cost, but require analysis of "True R-value"



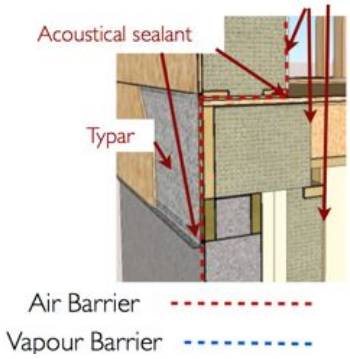
R20 wall is reduced to R16 in cavity wall example

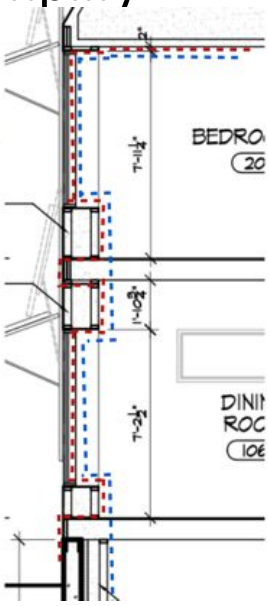
Innovation: Nice but not necessary

- Insulation
  - Some new products, e.g. BASF Neopor
  - VIPs *may* become available, but cheap?
  - 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

We need to simplify

- Air / Vapour Barrier
  - Makes use of common materials
  - Easiest, most opportunistic route





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!

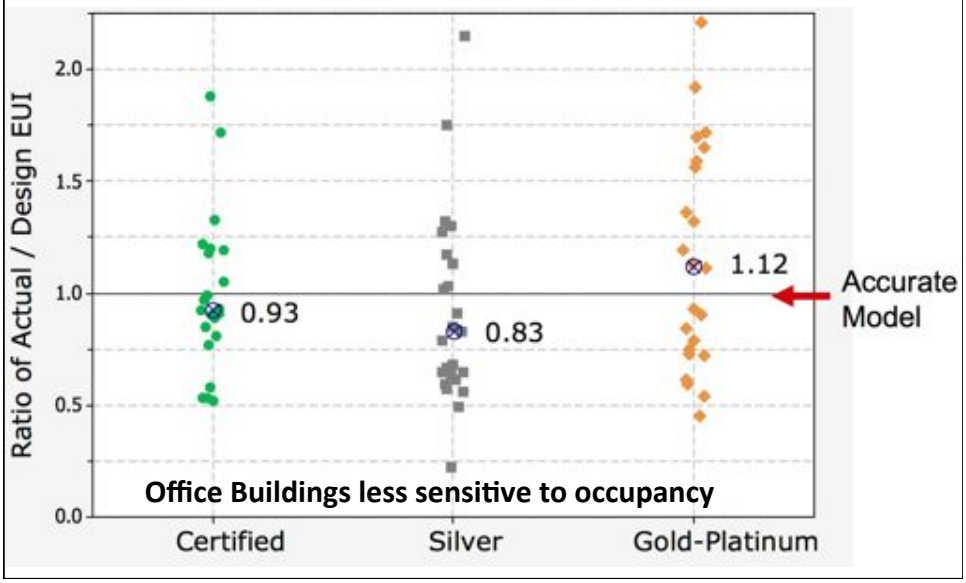
Reality check

- 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

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!
  - We need to tune our models, public info needed

Energy Model vs Measured Data



Occupancy vs model

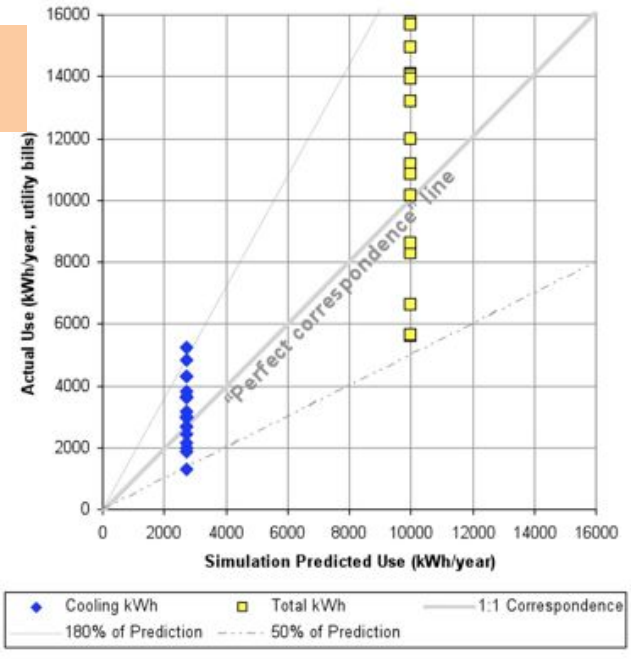
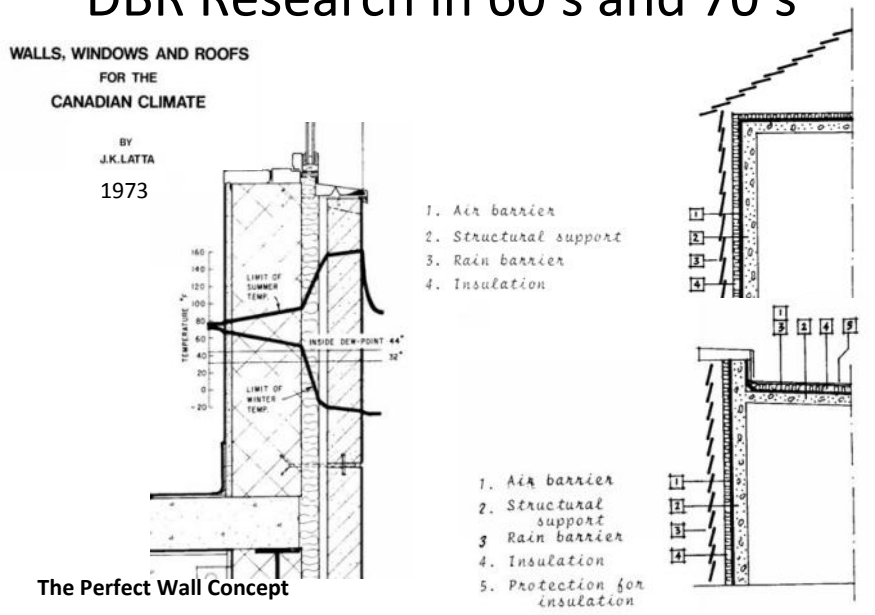


Figure 1: Simulation (horizontal) vs. actual (vertical) electric use for 17 identical houses in Oklahoma

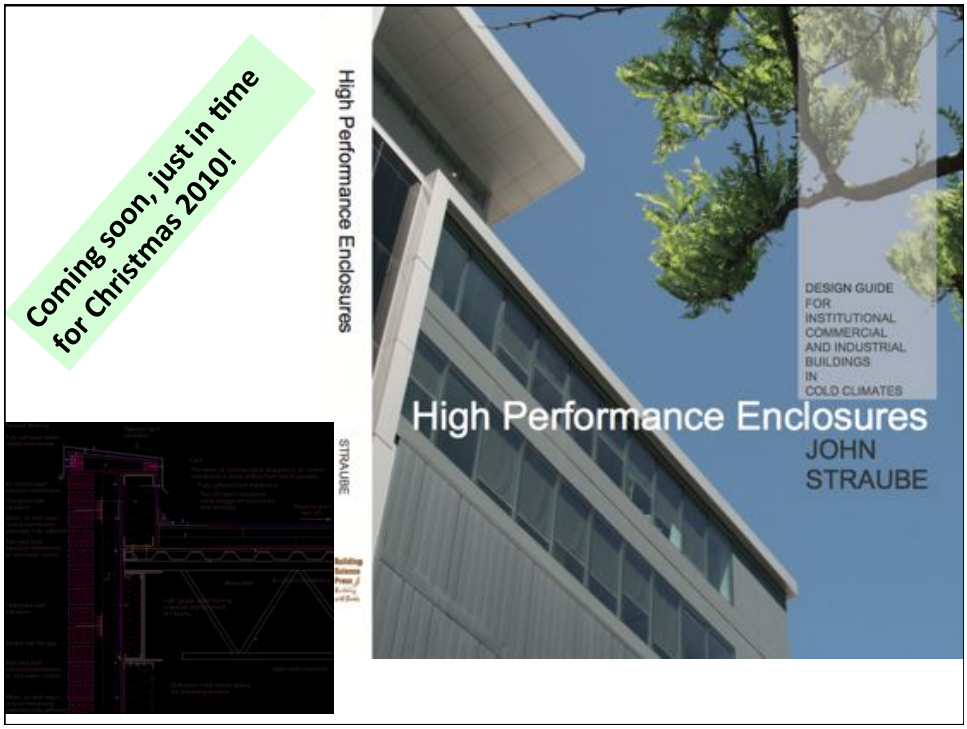
Conclusions

- We need much better buildings
- But we know most of how to get there
  - Perhaps exterior insulation, rain, water control
- Can't 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

DBR Research in 60's and 70's



The Perfect Wall Concept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