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"Great spirits have always been met with violent opposition from mediocre minds."
- Albert Einstein

"To achieve results never before accomplished, we must employ methods never before attempted."
- Sir Francis Bacon

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Enlosures and Energy: What's Working

Dr John Straube, P.Eng.
Dupont Young Professor
Associate Professor
School of Architecture & Dept Civil Engineering

University of Waterloo
Waterloo, Canada

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Why Green? Why Energy?

- Climate Change
- Energy Security
- Environmental Damage

- Good investments
- Comfort
- Durability

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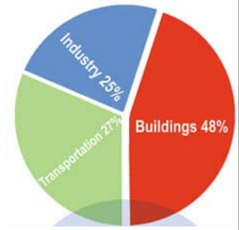
www.buildingscience.com Chevron Energy Ad 2005

www.buildingscience.com

Energy Supply

- Fossil fuels becoming unreliable
  - Supply?
    - Cheap oil has run out
    - Oil sands and American oil wont help
    - Major oil field in decline
  - Political disruptions
- Energy increasingly substitutable
  - Oil switch to natural gas
  - Food or fuel
  - Biomass for boilers or ethanol
  - Plug-in cars compete with buildings



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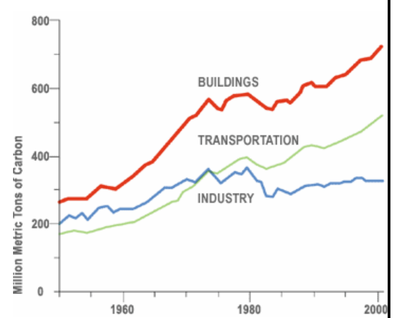
Climate Change

- Even Exxon now says it is happening
- Reducing climate change by
  - Reducing energy=reducing carbon
  - Absorbing carbon
  - Generating C-free energy
- Easiest, lowest cost:
  - Passive energy savings



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See Mazria's www.architecture2030.org

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"Green" Buildings

- Recognize buildings have an impact
- Minimize or eliminate:
  - non-renewable resource use
  - non-renewable energy consumption
  - damage to the local and global ecology
  - production of waste and pollutants

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"Good" Buildings Are "Green"

- No magic material, widget
- A systems approach is required
- Trade-offs, compromises of systems
- *Optimal* design requires a broad understanding:
  - people and their behavior
  - city planning
  - transportation
  - ecology
  - materials & production
  - building science & technology

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Energy and Green

- Current Buildings
  - Energy use is easy to measure
  - Vast majority of damage done by energy consumption *during operation*
- ***Operational energy reduction is key***
- Material choices less significant
  - Nice to choose lower energy lower polluting alternatives

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Buildings, Energy, Pollution

- Buildings consume ***68%*** of all electricity
- Operation of US buildings
  - 560 million tons of CO_2 per year
  - 36% of US total and 9% of global CO_2 production
  - 49% of US total SO_2

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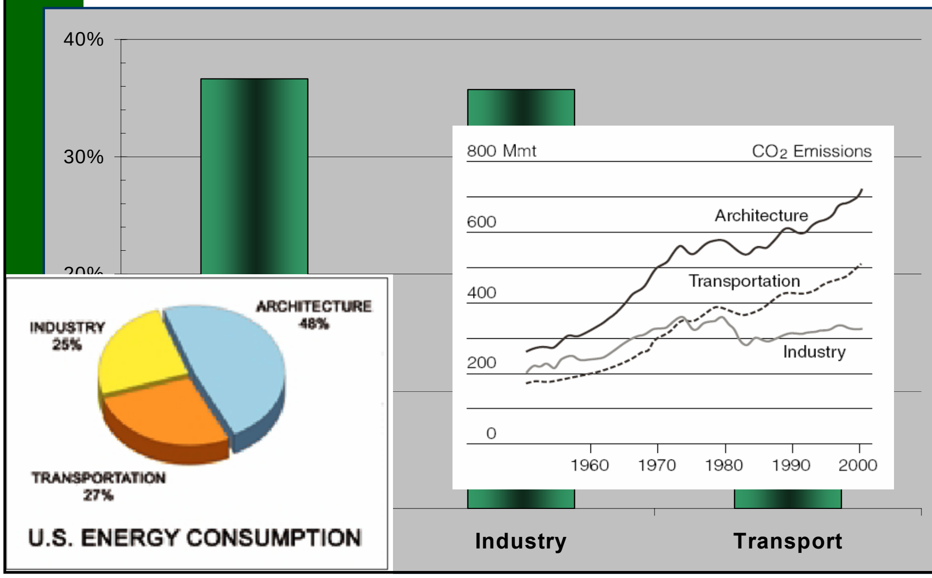
Building Operational Energy: Growing Rapidly



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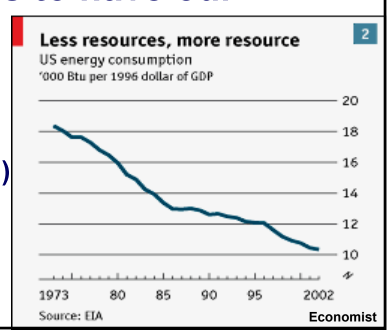
Energy & Efficiency

- People want services not energy
  - Warm house, not gas
  - Light, not electricity
- Hence, efficiency allow us to have our cake and eat it
- Energy reductions after ’73 / ’79
- California brownouts(2001)
  - 14% cut in 6 months simply by citizen action



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The new “buzz” words

- Net Zero Energy
- Carbon-neutral
- LEED
- “xx% below code”

- How about good buildings?
  How about reducing energy use?
  How about REAL NUMBERS?

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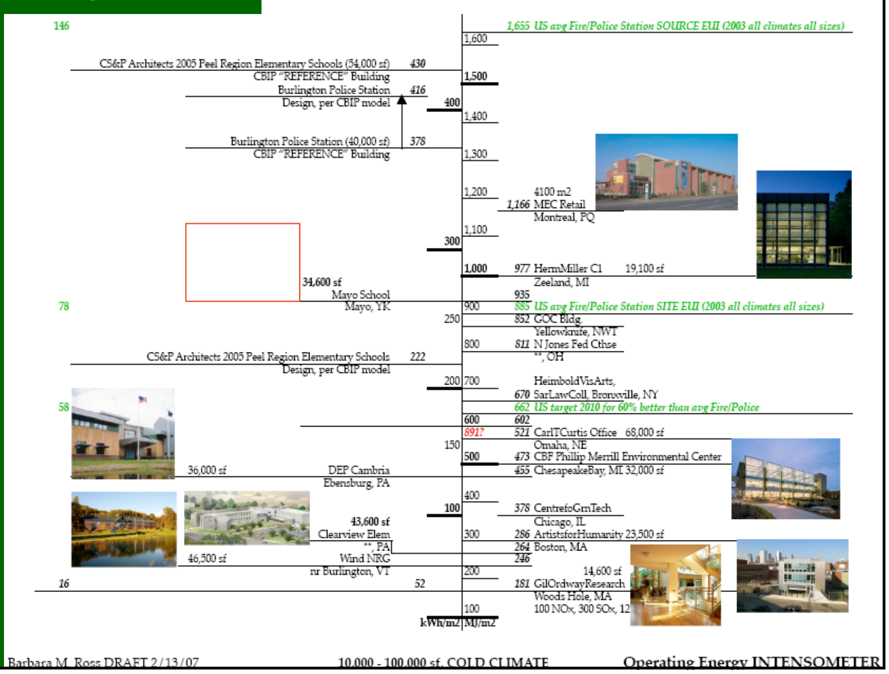

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Is it Green? Learning to count

- Depends on answers to:
  - Does it use less non renewable energy to operate?
  - Will it last longer? (less life-cycle resources)
  - Does it use fewer non renewable resources to build?
  - Does it pollute less?
- Compared to?:
  - Zero (sustainable)
  - Average (move forward, “green”)

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Changing heat flow control

- Better heat flow control required today and tomorrow
  - More environmental concerns re: energy
  - Comfort standards more demanding
  - Building materials & finishes are more resistant to condensation (& mold)

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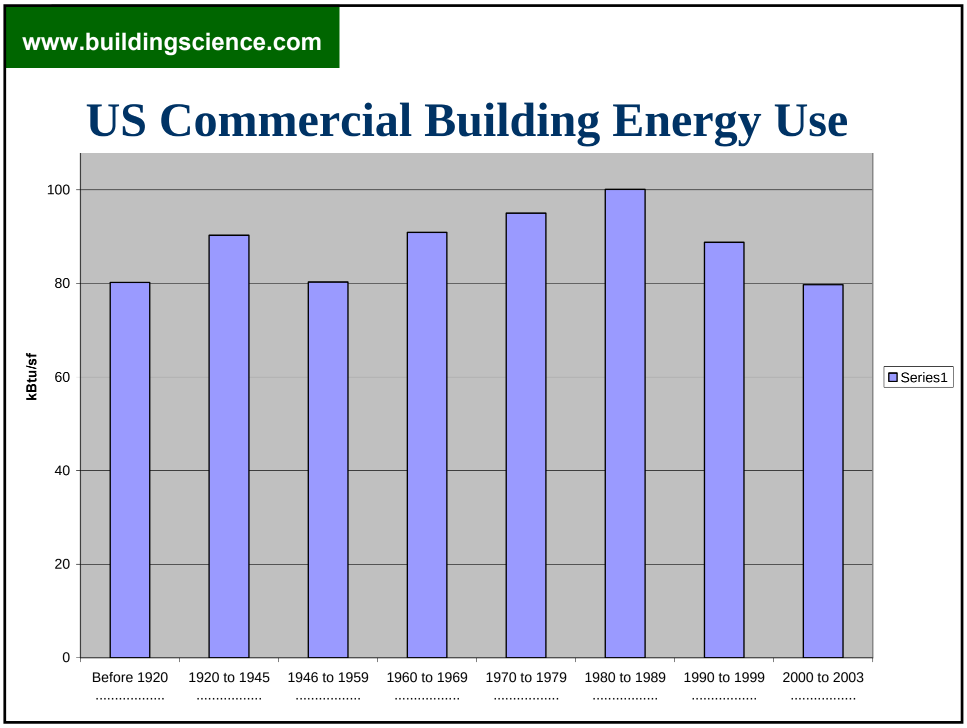
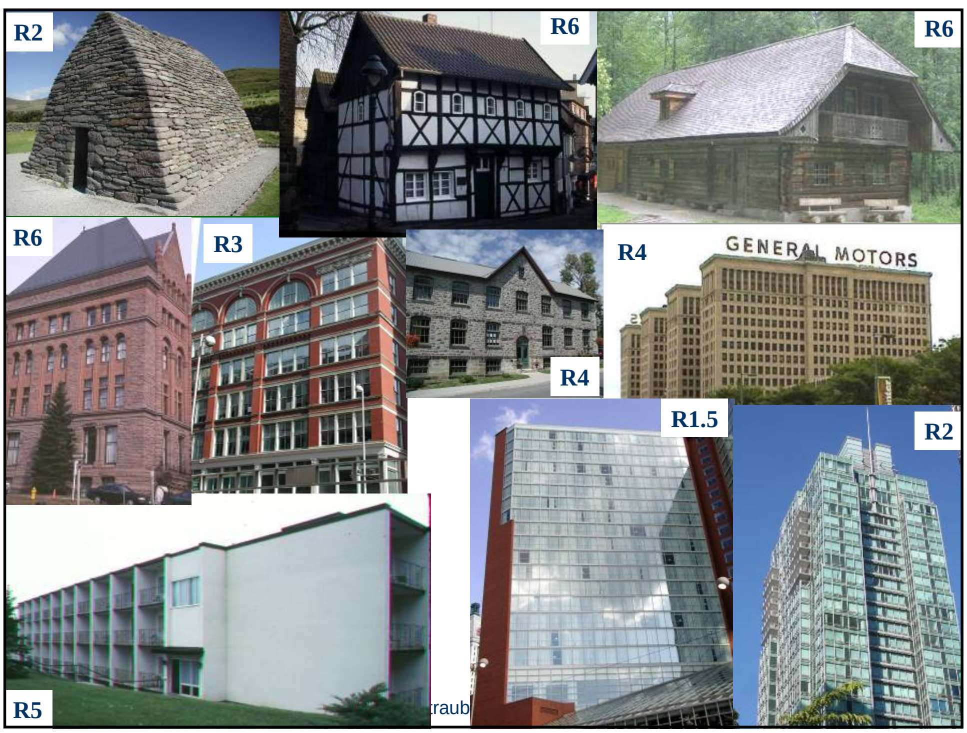

www.buildingscience.com
US Commercial Building Energy Use
kBtu/sf
100
80
60
40
20
0
Before 1920
1920 to 1945
1946 to 1959
1960 to 1969
1970 to 1979
1980 to 1989
1990 to 1999
2000 to 2003
Series1


R2
R6
R6
R6
R3
R4
R4
GENERAL MOTORS
R1.5
R2
R5

Technology to reduce energy+pollution

- Reduce heat loss and gain
  - Insulation
  - Avoid thermal bridges
  - Use good windows
  - Airtight
- Avoid energy use
  - Efficient appliances and elevators
  - Collect from sun
  - Use daylighting
- Then, generate renewable energy

Strategies

- Airtight
- Insulate well
  - Only small thermal bridges
- Good windows or few of them
  - Guidance
  - U< 0.33, WWR <25%
  - U<0.25, WWR < 50%
  - U<0.20, WWR >50%

How to do it

- We already know how! (energy reduction)
  - e.g. Good enclosure insulation / airtight (1/2)
  - E.g. Compact fluorescents, controls (1/4)
  - E.g. Highly performance windows (1/3)
  - E.g. Efficient HVAC and office equipment (1/2)
- Future
  - Superwindows, smart appliances
  - Renewable / bio-materials, low embodied energy
  - Building systems that allow recycling

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How much insulation?

- Regardless of type, use *more*
- For Comfort & moisture control
  - True **R7-10 is enough!, but …..**
- For energy and the environment
  - As much as practical & economical
- Increased insulation should reduce HVAC capital cost as well as operating!
- Practical constraints often the limit
  - How much space available?

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R-values

- **Given as equivalent conductance**
- **Never intended to account for realities such as:**
  1. Thermal Bridges
  2. Thermal Mass
  3. Air Leakage
- **New methods and materials mean R-value often has less meaning**

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It's More Than Insulation!

- **Thermal bridges provide *a path for heat around insulation***
- **Heat passes through the structural members**
- **Common offenders**
  - **Floor and balcony slabs**
  - **Shear walls**
  - **Window frames**
  - **Steel studs**

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Find the thermal bridge

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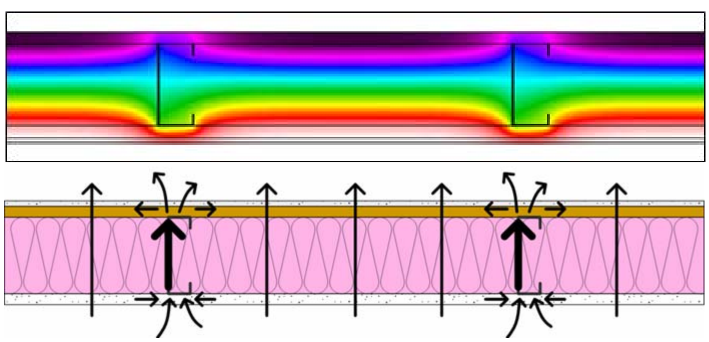
Heat bridging through steel studs



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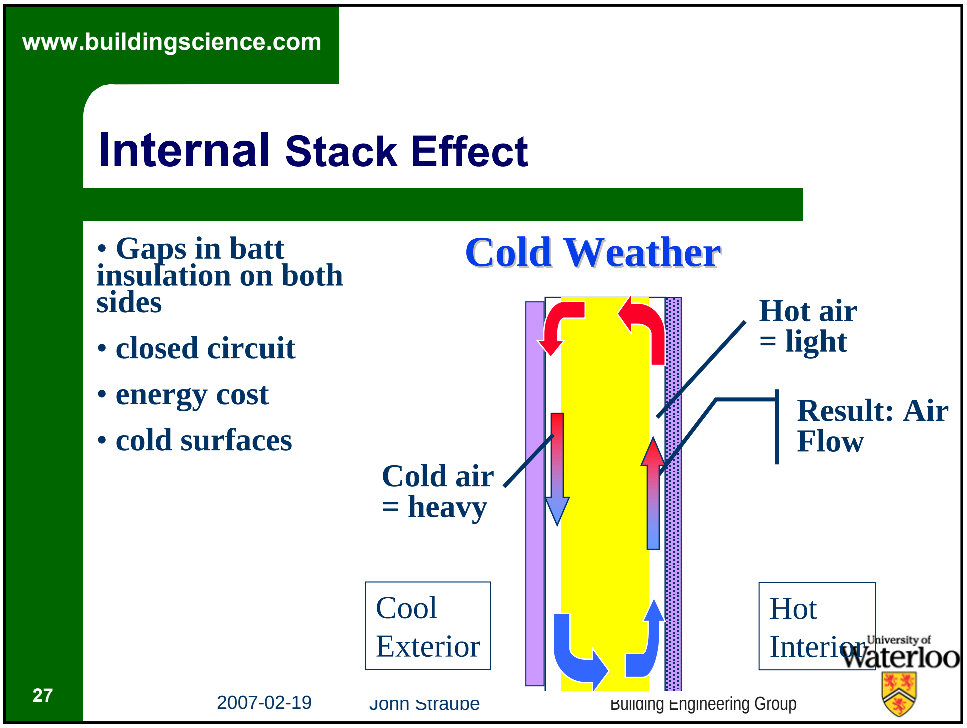
www.buildingscience.com
Internal Stack Effect
• Gaps in batt insulation on both sides
• closed circuit
• energy cost
• cold surfaces
Cold Weather
Hot air = light
Result: Air Flow
Cold air = heavy
Cool Exterior
Hot Interior
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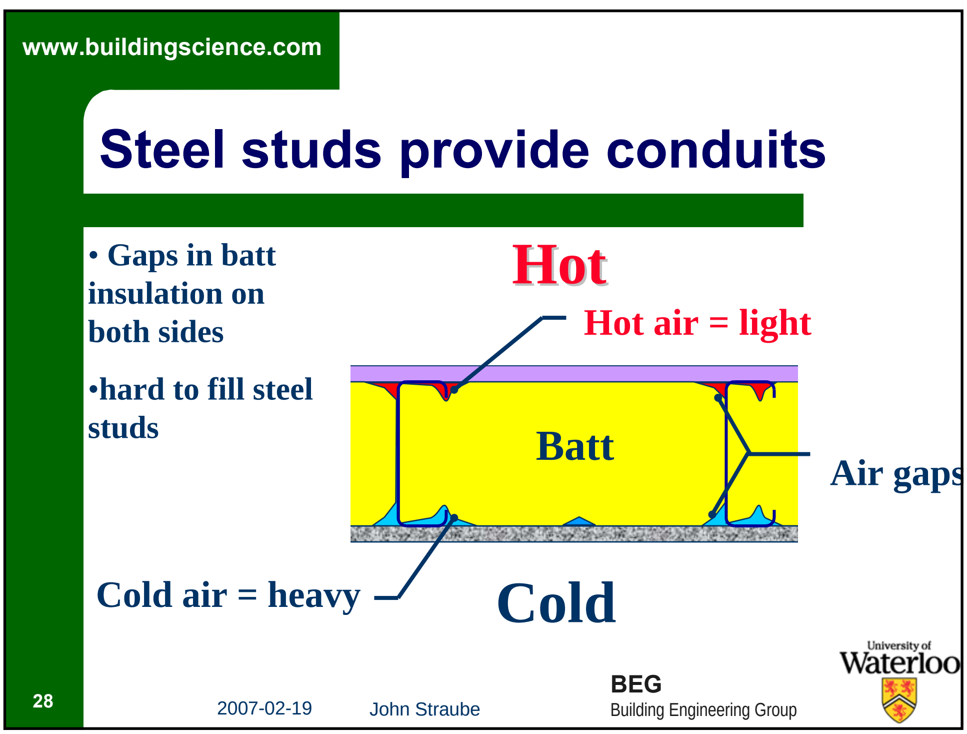
www.buildingscience.com
Steel studs provide conduits
• Gaps in batt insulation on both sides
•hard to fill steel studs
Hot
Hot air = light
Batt
Air gaps
Cold air = heavy
Cold
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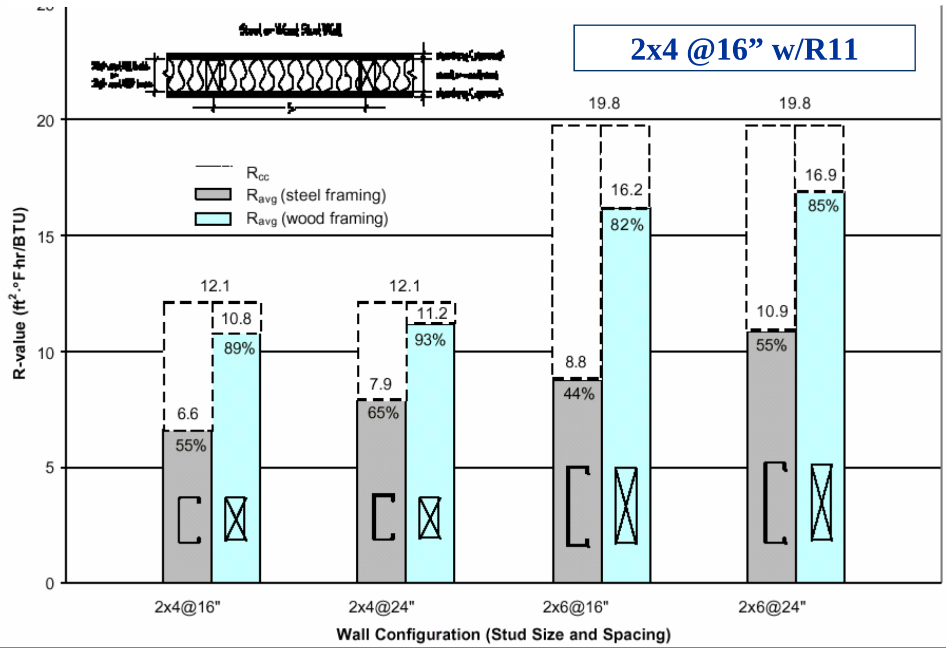
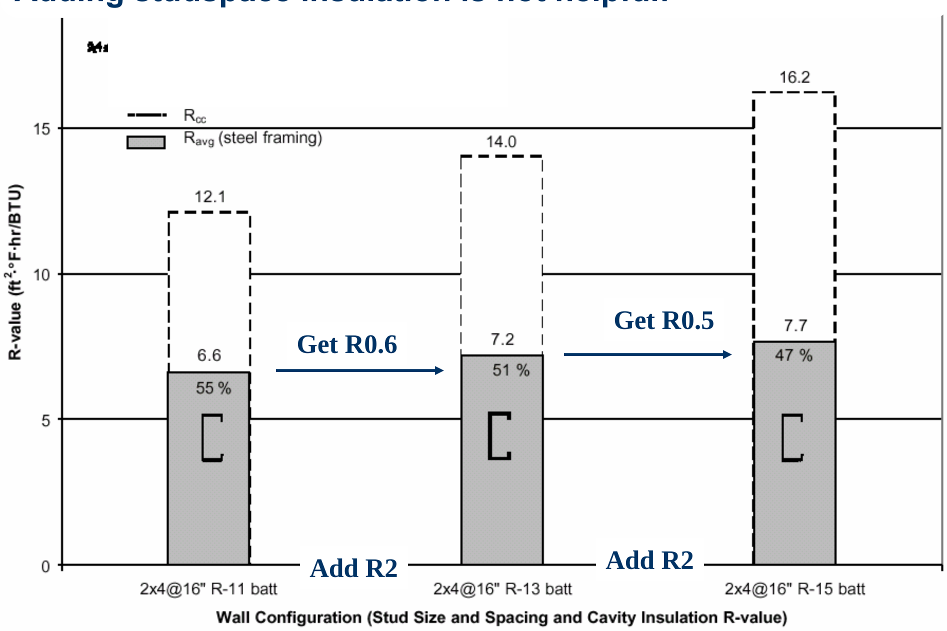
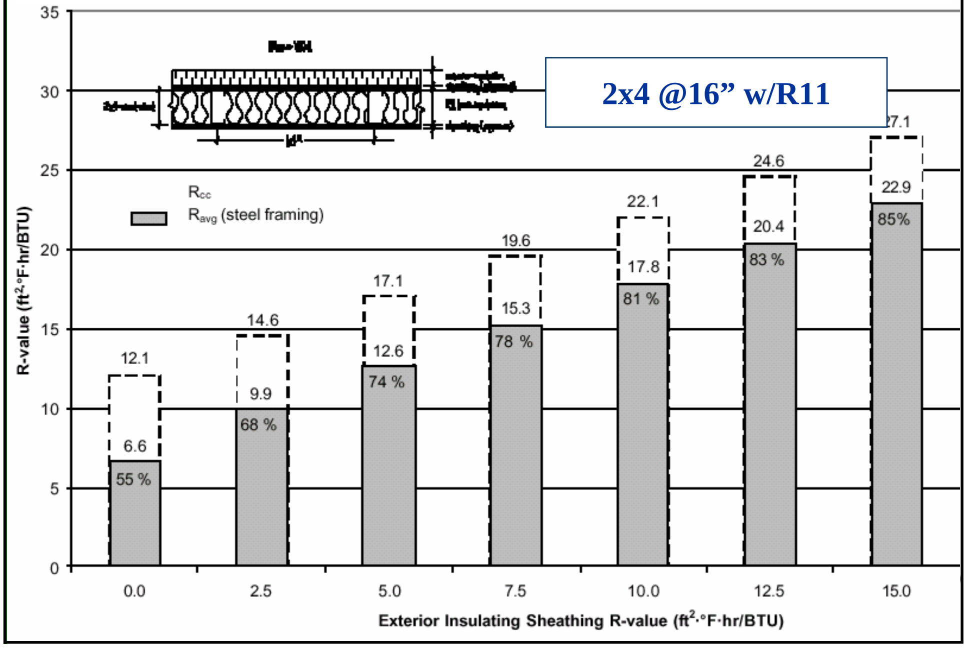
R-value Comparison



Adding studspace insulation is not helpful!



Impact of Insulating Sheathing



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Thermal Bridge Examples

- Balcony, etc
- Exposed slab edge,

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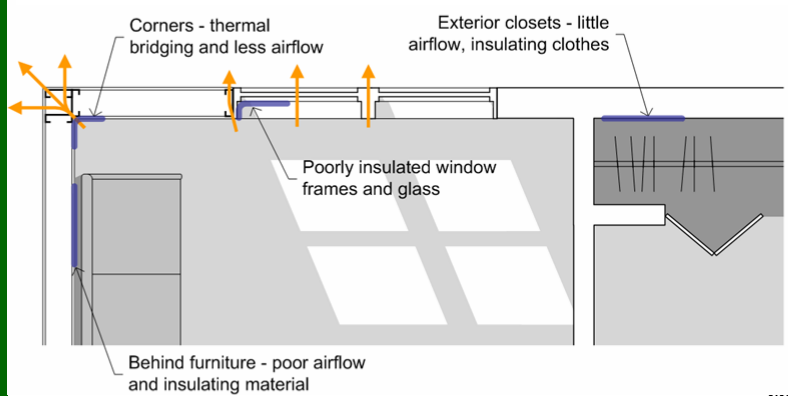
Thermal Bridging: Common Problems

Not Just Energy: Comfort and Condensation/mold



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Solving Thermal Bridging / Energy Waste

- **Insulate the thermal bridge**
  - **Exterior insulation solves most thermal bridges**
  - **Inside insulation: difficult to cover structural penetrations**
- **Common Fix**
  - **Lower interior RH to stop condensation**

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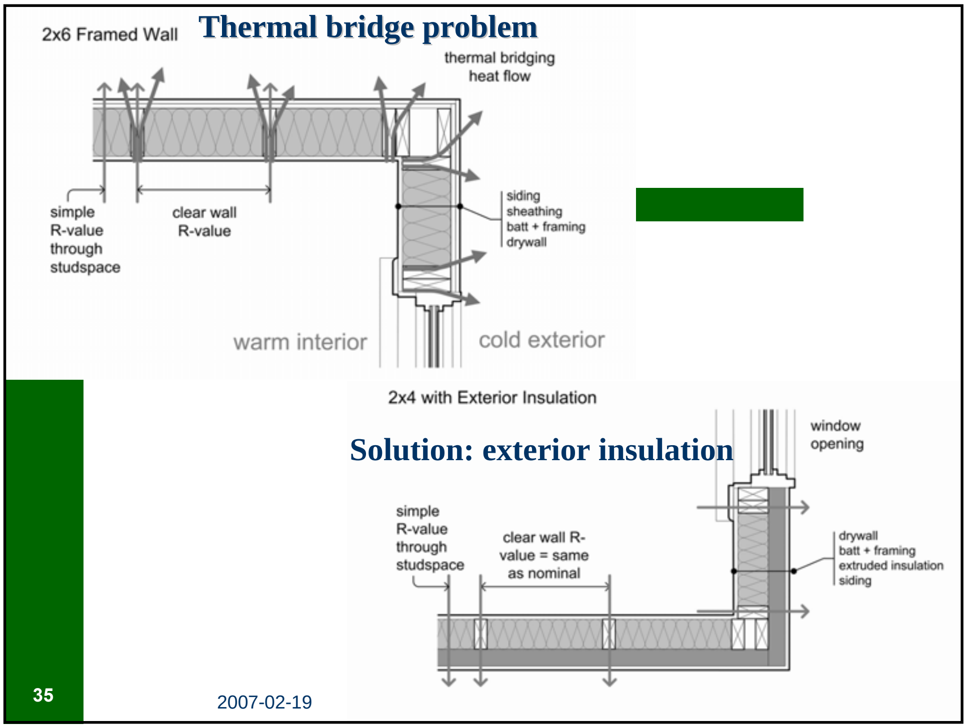
2x6 Framed Wall
Thermal bridge problem
thermal bridging
heat flow
simple
R-value
through
studspace
clear wall
R-value
siding
sheathing
batt + framing
drywall
warm interior
cold exterior
2x4 with Exterior Insulation
Solution: exterior insulation
window
opening
simple
R-value
through
studspace
clear wall R-
value = same
as nominal
drywall
batt + framing
extruded insulation
siding
35
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All on the exterior

Windows & Curtainwalls

- Our most expensive thermal bridges
- U-value 0.33 = R3
- U-value 0.50 = R2

Performance Issues and Metrics

- Heat Flow (R,U)
- Solar Heat Gain Coefficient (SHGC)
- Visual Transmittance (VT)
- Condensation resistance (CRI)
- Air Leakage
- Water penetration
- Impact and Blast


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Windows, Insulated Enclosures
R3
R2
R4
39
High tech?
Low tech?


High Performance
R12
Southwall
R8
R6
R24
Kawneer
Visionwall
40
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How much glass?

41

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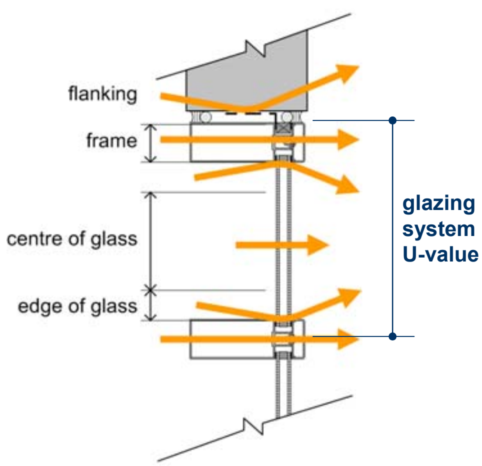
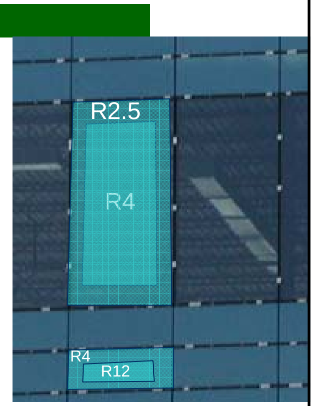
Total Heat Flow

Curtain Wall Plan View





ube

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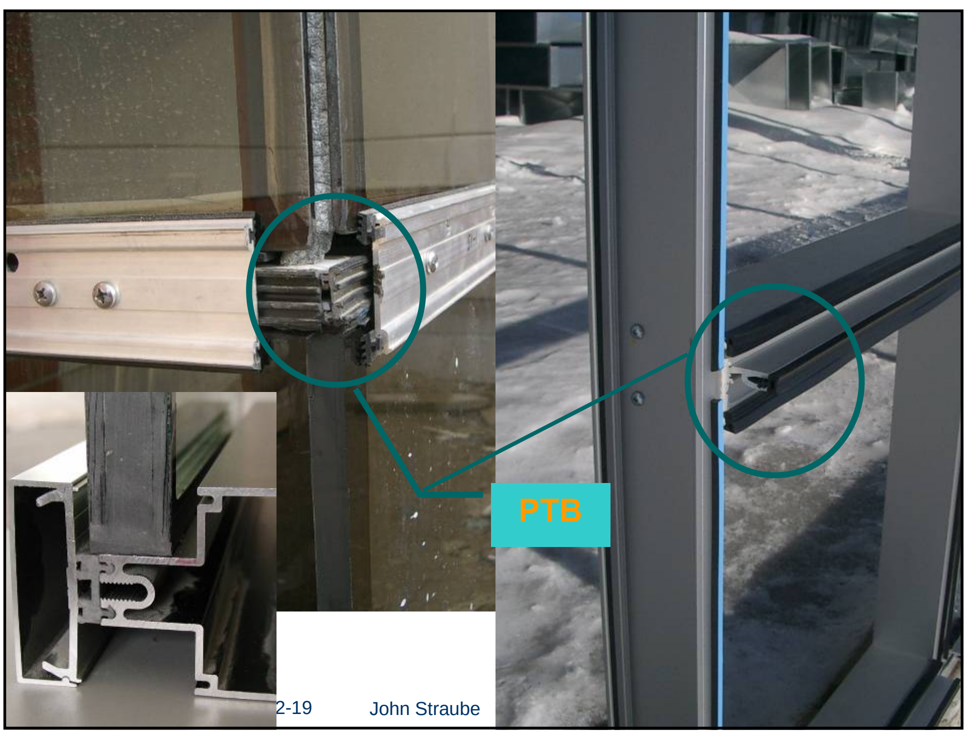
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Overall U-Value

- The overall thermal performance of the window depends on
  - Materials (Glazing, Coatings, Fills, Frame)
  - Geometry (Window, Frame)
  - Type of Window (Operable = more air leakage)
  - Installation (Position, Interface with walls)
- Generic overall U-values are provided in many text & handbooks (e.g. ASHRAE)
- U-value over 0.5 is bad!!- aim for U <0.33
- Most manufacturers publish overall U-values for their products (rated by the NFRC)

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Low-e Coatings

- Low-e coatings reduce the amount of heat transferred by radiation

Coating	Emissivity	Radiation Reduction
Uncoated Glass	0.84	-
Low-e 0.2	0.20	62%
Low-e 0.1	0.10	79%
Low-e 0.03	0.03	93%

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Gas Fills

- **Gas fills reduce the amount of heat transferred by conduction and convection through the space in the glazing unit**

Fill	Conductivity W/mK	Conductivity R/inch	Reduction in Conduction
Air	**0.0241**	**6.0**	**-**
Argon	**0.0162**	**8.9**	**33%**
Krypton	**0.0086**	**16.8**	**64%**
Xenon	**0.0051**	**28.3**	**79%**

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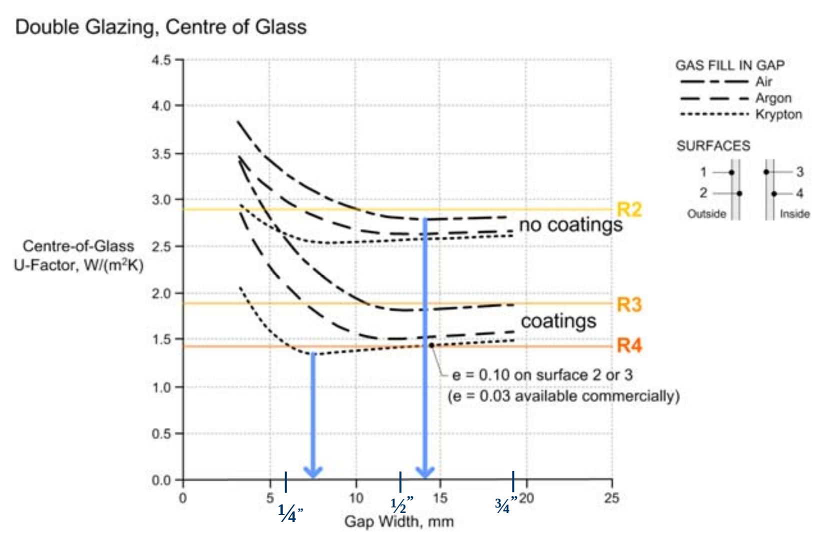

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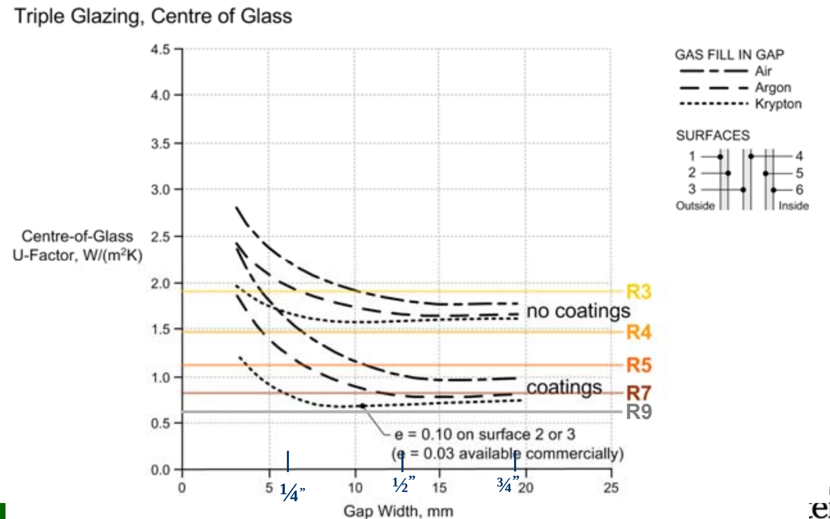
Triple Glazing: Use in cold climate when WWR>50%
e.g., when the budget allows this high a window area



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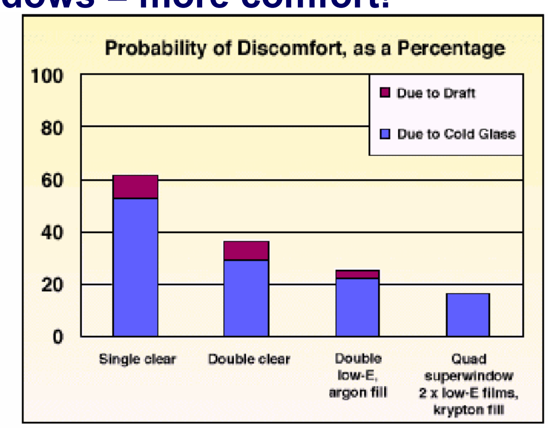
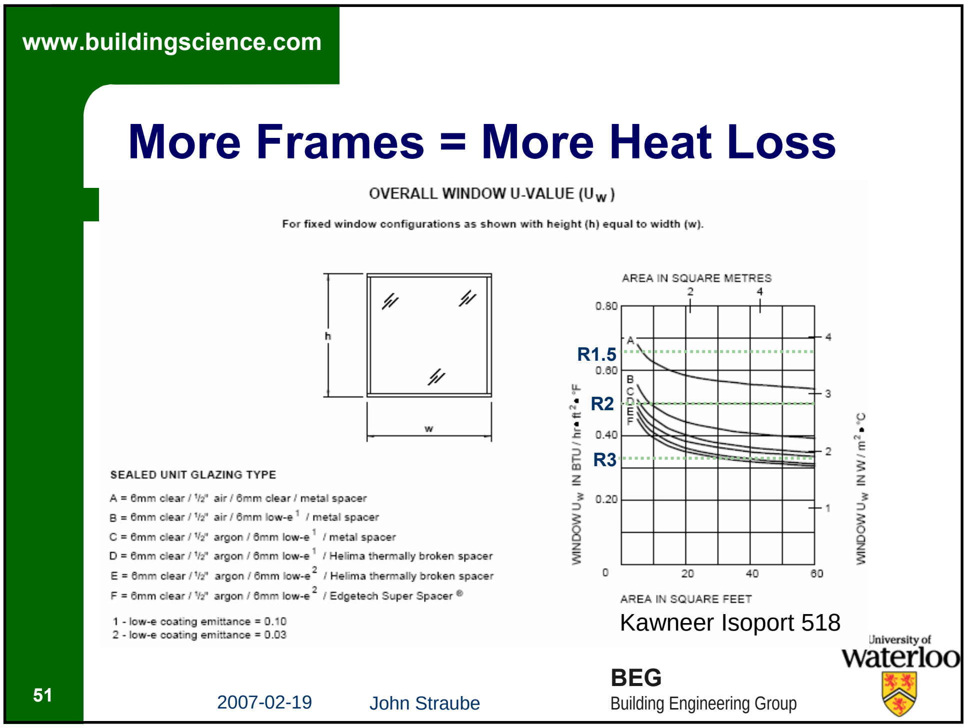
Comfort

- **Warmer windows = more comfort!**



50 2007-02-19 Source: Lawrence Berkeley National Laboratory (Lyons and Arasteh).


www.buildingscience.com
More Frames = More Heat Loss
OVERALL WINDOW U-VALUE (Uw)
For fixed window configurations as shown with height (h) equal to width (w).
SEALED UNIT GLAZING TYPE
A = 6mm clear / ½" air / 6mm clear / metal spacer
B = 6mm clear / ½" air / 6mm low-e 1 / metal spacer
C = 6mm clear / ½" argon / 6mm low-e 1 / metal spacer
D = 6mm clear / ½" argon / 6mm low-e 1 / Helima thermally broken spacer
E = 6mm clear / ½" argon / 6mm low-e 2 / Helima thermally broken spacer
F = 6mm clear / ½" argon / 6mm low-e 2 / Edgetech Super Spacer
1 - low-e coating emittance = 0.10
2 - low-e coating emittance = 0.03
AREA IN SQUARE METRES
AREA IN SQUARE FEET
R1.5
R2
R3
Kawneer Isoport 518
51
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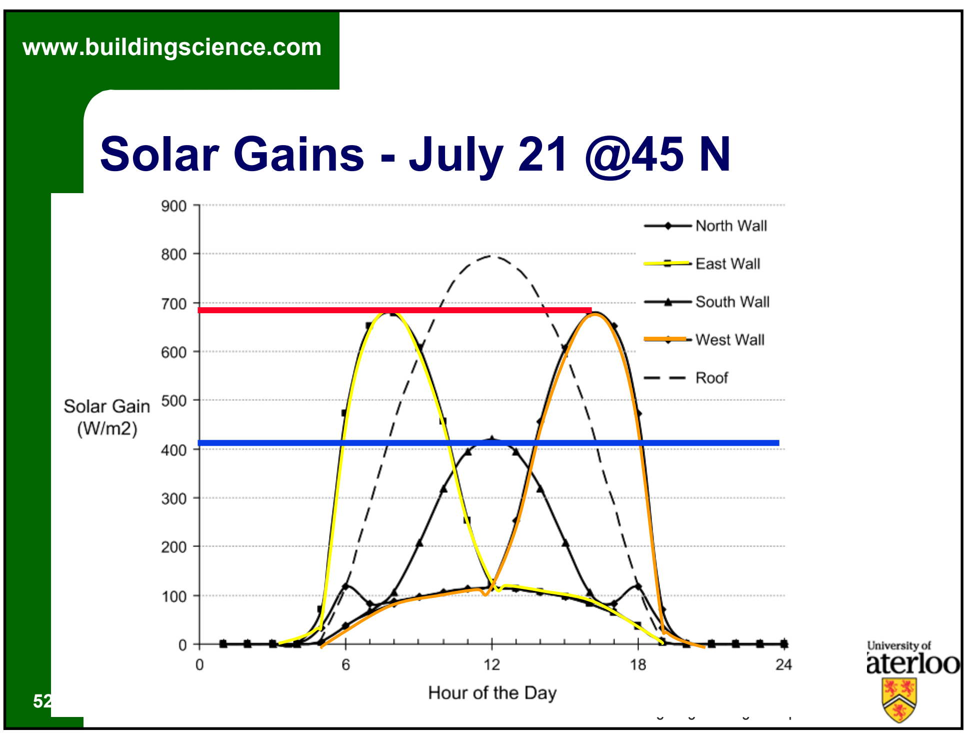
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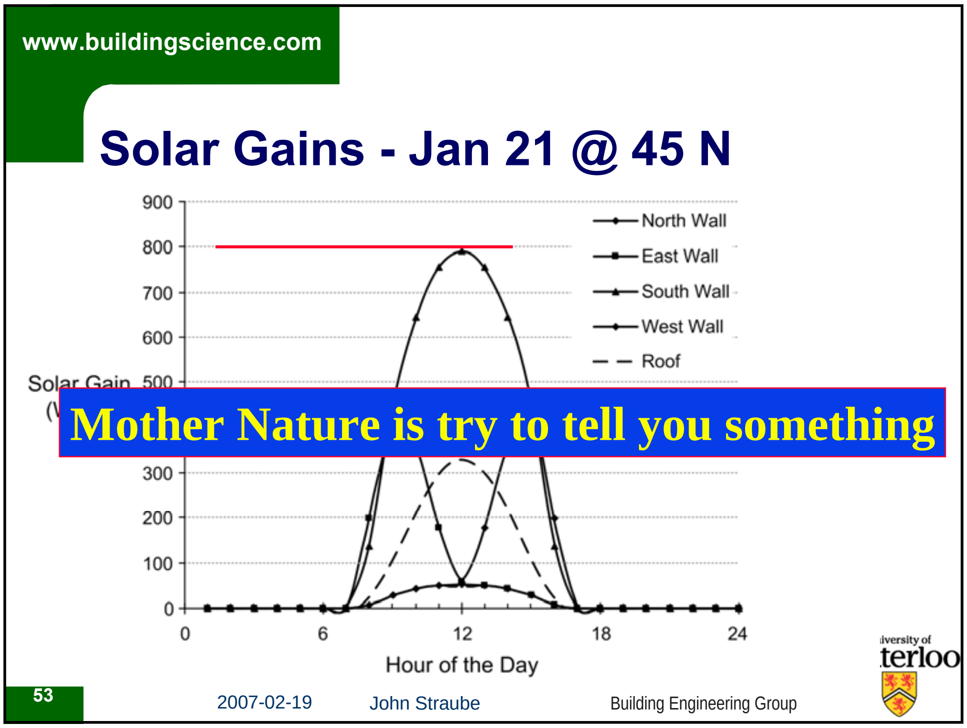
Solar Gains - July 21 @45 N
Solar Gain (W/m2)
Hour of the Day
North Wall
East Wall
South Wall
West Wall
Roof
52


www.buildingscience.com
Solar Gains - Jan 21 @ 45 N
900
800
700
600
500
300
200
100
0
0
6
12
18
24
Hour of the Day
North Wall
East Wall
South Wall
West Wall
Roof
Mother Nature is try to tell you something
53
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Shade
HILTON
54

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Solar Heat Gain

- Solar gain through glazing dominates cooling capacity installed
- Solar Heat Gain Coefficient
  - Ratio of solar heat available: penetrates
  - Clear double glass SHGC about 0.70
  - Spec < 0.50 if small window area
  - Spec <0.30 for larger window area
  - Exterior shades work, interior shades dont

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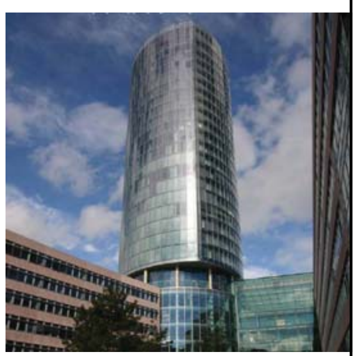
Double Facades

- "Controlling solar heat gain by placing building in a green house"
- Reported energy use high
- Research shows DF are energy pigs
- Great design is lipstick



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Adobe eSeminars for AEC

Building Design | the weekly paper for architects

2 February 2007

News

Levine Hall at U of Penn much higher:
almost 3 times a modern office (290 kBtu/sf)

Ken's gas guzzler

Building Design, Friday, July 29, 2005

London mayor's 'sustainable' City Hall is missing energy consumption targets by 50%

376 kWh/yr = 122 kBtu/sf/yr

By Ellen Bennett

Norman Foster's City Hall, which is billed as an exemplary sustainable building, uses 50% more energy than it was designed to do.

Figures obtained by BD show that the home of London mayor Ken Livingstone and the Greater London Assembly actually used 376kWh/sq m in 2003/4 compared to the 236kWh/sq m it was designed to use.

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Strategies: Windows + Curtainwalls

- **High ratios almost always a problem**
- **Restrain use, or use very high performance- simple guidance:**
  - **WWR<0.25, U<0.35, SHGC <0.45 or shade**
  - **WWR<0.50, U<0.30, SHGC <0.30 or shade**
  - **WWR>0.50, U<0.25, SHGC<0.20 or shade**
- **Bias toward South-facing windows**
- **Beware west-facing**

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Solutions: Process

- Set goals and metrics
  - E.g. Mazria's 2030.org
  - 30, 50% reduction in energy? Carbon?
- Compare predictions to target
  - Early and often
  - Confirm concept plans can work
- Apply systems approach
  - Trade-off HVAC, enclosure, finishes, etc
  - Good insulation, airtighten, windows

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How to do it

- System integration
  - "Professional specialization" disease
  - Sub-system optimization
  - Non-optimal whole system design
- Real benefits come as a system, not individual
  - Airtight, shade and solar windows save AC costs, fans, and ducts
  - Better insulation can mean simple zoning, HVAC
  - Reduced power req'ts = alternative energy economical– Future Proofing

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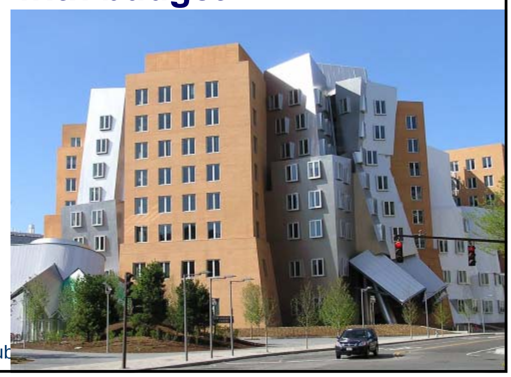
Concept Design

- Major cost / performance constraints imposed by concept design
- Anything possible with budget



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A note on Daylighting

- Good daylighting ≠ lots of glass
  - Glare! overbright
- Daylighting ≠ energy savings
  - unless controls are installed
- Window to wall ratios of 35-50% are in the optimum range for energy and daylighting
- More windows = more glare, energy costs, discomfort

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What about Renewable Energy?

"I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait 'til oil and coal run out before we tackle that."
--Thomas Edison 190?

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Renewable Energy

- **Renewable Energy**
  - **is often part of green / low-carbon buildings**
  - **is almost always more expensive**
  - **makes no sense if you waste energy**
- **Low energy buildings make RE work**
  - **e.g. 20 mpg @$2/gal > 45 mpg @$4/gallon**
- **On site production in distributed manner is part of a total solution**
  - **Balance loads**
  - **Reduce grids / transmission**

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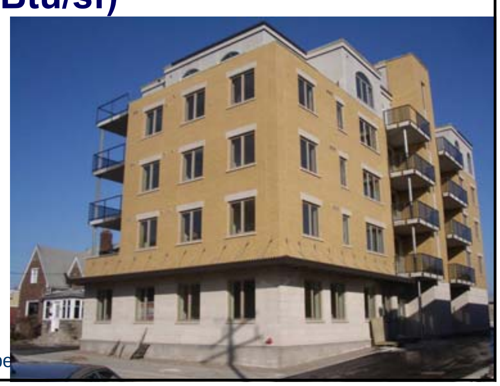
Waterloo Dorset Apartments

- Below average cost ($125/sf)
- About 1/3 average energy consumption (33 kBtu/sf)
- Better durability, quiet, healthy



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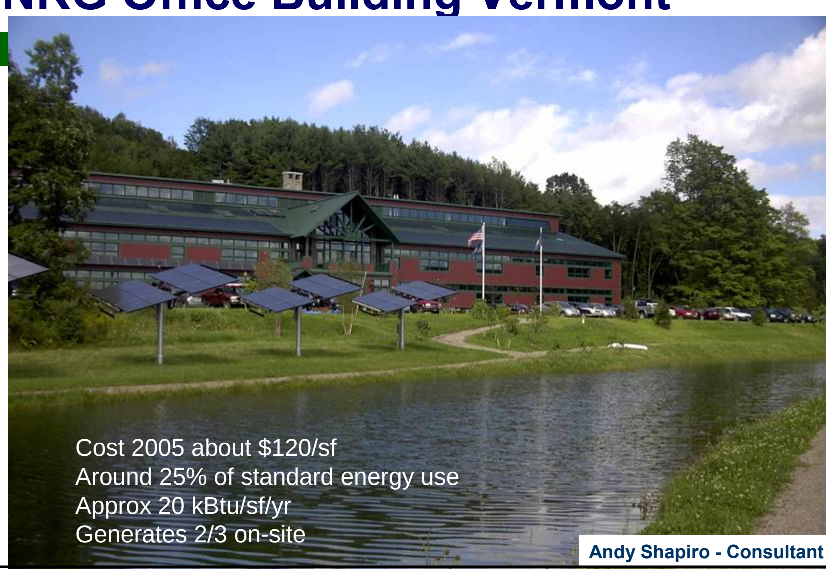

Cost 2005 about $120/sf
Around 25% of standard energy use
Approx 20 kBtu/sf/yr
Generates 2/3 on-site

68

Andy Shapiro - Consultant

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Summary good targets

- Airtighten
  - Tested under 2.5 ACH @50Pa
- Insulate well
  - R20+ opaque walls
  - Only small thermal bridges
  - Simple shapes (high floor area to enclosure area)
- Insulated windows, control solar gain, or use few of them,
  - WWR<0.25, U<0.35, SHGC <0.45 or shade
  - WWR<0.50, U<0.30, SHGC <0.30 or shade
  - WWR>0.50, U<0.25, SHGC<0.20 or shade

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The Future

- Paradigm shift from “least evil” to “as much good”
- Buildings must eventually
  - Produce energy
  - Clean air and water
  - Enhance local ecology
  - Reuse materials, low-damage recycle,

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Conclusions

- Energy control is getting more important
- Window U-values & R-value are often bogus
  - Thermal bridging
  - Installation
- Airtightness is critical

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