"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

Enlosures and Energy: What’s Working

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Why Green? Why Energy?

- Climate Change
- Energy Security
- Environmental Damage
- Good investments
- Comfort
- Durability

The world consumes two barrels of oil for every barrel discovered.

The fact is, the world has been finding less oil than it's been using for decades now. We may not demand more, but the oil we've never used doesn't cumber. The oil that is stored in the world is at the very end of the cycle. The current rate of oil production is expected to peak within the next 15 years. The world's oil reserves are estimated to be at their lowest level in decades. The demand for oil continues to grow, and the supply is limited. The world needs to find alternative sources of energy to meet its growing energy needs.

The energy industry needs to develop new energy sources, while continuing to develop new technologies. It must strive to improve fuel efficiency and reduce greenhouse gas emissions. Technological improvements are needed to lower costs, make oil and gas production more efficient, and make production more environmentally friendly.

The world needs to develop alternative energy sources to meet its growing energy demands. Consumers must demand and be willing to pay for these alternative sources, while politicians and industry leaders work together to find solutions.

Chevron Energy Ad 2005
Energy Supply

- Fossil fuels becoming unreliable
  - Supply?
    - Cheap oil has run out
    - Oil sands and American oil won't 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

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
"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

"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
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

Buildings, Energy, Pollution

- Buildings consume **68%** of all electricity
- Operation of US buildings
  - 560 million tons of CO₂ per year
  - 36% of US total and 9% of global CO₂ production
  - 49% of US total SO₂
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
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?
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”)

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)
Insulation - History

- R2
- R6
- R6
- R4
- R3
- R4
- R4
- R5

Us Commercial Building Energy Use

kBtu/sf

Series 1

Before 1920
1920 to 1945
1946 to 1959
1960 to 1969
1970 to 1979
1980 to 1989
1990 to 1999
2000 to 2003
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

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?
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

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
Find the thermal bridge

Heat bridging through steel studs
Internal Stack Effect

- Gaps in batt insulation on both sides
- Cold air = heavy
- Hot air = light
- Result: Air Flow

Steel studs provide conduits

- Gaps in batt insulation on both sides
- Cold air = heavy
- Hot air = light
- Air gaps

Cool Exterior

Hot Interior
R-value Comparison

- **2x4 @16” w/R11**
  - R_{ws}
  - R_{wag} (steel framing)
  - R_{wag} (wood framing)

Adding studspace insulation is not helpful!

- **Add R2**
  - Get R0.6

- **Add R2**
  - Get R0.5

Wall Configuration (Stud Size and Spacing and Cavity Insulation R-value)
Impact of Insulating Sheathing

2x4 @16” w/R11

Thermal Bridge Examples
- Balcony, etc
- Exposed slab edge,
Thermal Bridging: Common Problems

Not Just Energy: Comfort and Condensation/mold

- Corners - thermal bridging and less airflow
- Exterior closets - little airflow, insulating clothes
- Poorly insulated window frames and glass
- Behind furniture - poor airflow and insulating material

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
**Thermal bridge problem**

**Solution: exterior insulation**

**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
Windows, Insulated Enclosures

High tech?  Low tech?

High Performance

Southwall  Kawneer  Visionwall
How much glass?

Total Heat Flow
Curtain Wall Plan View

flanking frame
centre of glass
edge of glass

glazing system U-value

R2.5
R4
R4
R12

BEG
Building Engineering Group
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)

Low-e Coatings

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

<table>
<thead>
<tr>
<th>Coating</th>
<th>Emissivity</th>
<th>Radiation Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncoated Glass</td>
<td>0.84</td>
<td>-</td>
</tr>
<tr>
<td>Low-e 0.2</td>
<td>0.20</td>
<td>62%</td>
</tr>
<tr>
<td>Low-e 0.1</td>
<td>0.10</td>
<td>79%</td>
</tr>
<tr>
<td>Low-e 0.03</td>
<td>0.03</td>
<td>93%</td>
</tr>
</tbody>
</table>
Gas Fills

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

<table>
<thead>
<tr>
<th>Fill</th>
<th>Conductivity W/mK</th>
<th>Conductivity R/inch</th>
<th>Reduction in Conduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>0.0241</td>
<td>6.0</td>
<td>-</td>
</tr>
<tr>
<td>Argon</td>
<td>0.0162</td>
<td>8.9</td>
<td>33%</td>
</tr>
<tr>
<td>Krypton</td>
<td>0.0086</td>
<td>16.8</td>
<td>64%</td>
</tr>
<tr>
<td>Xenon</td>
<td>0.0051</td>
<td>28.3</td>
<td>79%</td>
</tr>
</tbody>
</table>

Double IGU

- ¼”
- ½”
- ¾”
Triple Glazing: Use in cold climate when WWR>50%
e.g., when the budget allows this high a window area

Comfort

- Warmer windows = more comfort!

Source: Lawrence Berkeley National Laboratory (Lyons and Arasteh).
More Frames = More Heat Loss

OVERALL WINDOW U-VALUE (Uw)
For fixed window configurations as shown with height (h) equal to width (w).

**SEALING UNIT GLAZING TYPE**
- A = 6mm clear / 0.1" air / 6mm clear / metal spacer
- B = 6mm clear / 0.1" air / 6mm low-e / metal spacer
- C = 6mm clear / 0.1" argon / 6mm low-e / metal spacer
- D = 6mm clear / 0.1" argon / 6mm low-e / halogen thermally broken spacer
- E = 6mm clear / 0.1" argon / 6mm low-e / low-e thermally broken spacer
- F = 6mm clear / 0.1" argon / 6mm low-e / Edgebond Super Spacer®

Kawneer Isoport 518
BEG
Building Engineering Group

Solar Gains - July 21 @45 N

Solar Gain (W/m²)

Hour of the Day
Mother Nature is trying to tell you something...
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 don’t

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

376 kWh/yr = 122 kBtu/sf/yr

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
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

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
Concept Design

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

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
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?

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
Green on the Grand
Enermodal Engineering

- much lower energy consumption
- <= 40 kBtu/sf/yr w/high occupant density
- much lower resource consumption
- better air quality
- lower first cost

Waterloo Dorset Apartments

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

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

Andy Shapiro - Consultant
Summary good targets

- **Airtightness**
  - 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

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,
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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