LL97 and High-Rise Retrofit

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What Generates Carbon

• Construction & Materials
• Space heating, cooling, ventilation
  – Enclosure (walls, roof, windows, basement, air leak)
  – Mechanical equipment (meets load from enclosure)
• Domestic hot water
• Lights, elevators, appliances......
Reducing Carbon Emissions

Reducing need for energy
Better windows, insulation, airtightness, controls

Use Energy Efficiently
i.e., don’t waste

Low Carbon Energy Supply

LL97: Energy → Carbon

• Electric 0.637 lb CO$_2$e per kWh
• Natural gas 0.117 lb CO$_2$e per kbtu
  – 1 kbtu = 0.293 kWh
• #2 Fuel oil 0.164 lb CO$_2$e per kbtu
• District steam 0.099 lb CO$_2$e per kbtu

• How will these change 2025, 2030?
Fuel switching

• A good heat pump with COP=2.5
  – 0.075 lb CO₂ to deliver 1000 Btu heat
• A typical NG boiler with 82% efficiency
  – 0.142 lb CO₂ to deliver 1000 Btu heat
• Therefore switching NG to heatpump reduces carbon by a factor of 2
• Fuel oil @80% vs nat gas at 92%... Saves 40%

LL97 Carbon limits → Energy

• Vary with Building type
• B Office: 18.75 lb CO₂e per square foot
  – 29.4 kWh/sf for all electric 315 kWh/m²
• R-2 Residential: 14.87 lb CO₂e per square foot
  – 23.3 kWh/sf for all electric 250 kWh/m²
• Using heat pumps, NG increases allowable energy use above these targets
Retrofit Economics

- Tweaks & Repairs
  - Fix controls, replace weather stripping
- Upgrades & Improvements
  - Add controls, weather stripping, fuel switch?
- Retrofit & Renewal
  - Glazing/roof/façade replacement
  - Boiler/chiller
- Gut rehab

Timing is everything

- Energy efficiency / carbon reduction best timed with major replacements / renewal
- Have a plan for each major equipment replacement ....
- And how that fits into long-term plan
Planning

• All buildings will spend big $ on replacement
  – Boilers, windows, chillers, water heater

• But... When? And replaced with what?
• Too often replaced when if fails (panic) and with like-for-like
The Victoria... an example of the challenges

Levels of Intervention

- Well developed lower steps
Deep Retrofits / Renewals

• For buildings with failing / end of life enclosures (windows / walls, curtainwall)
  – Opportunity for a major intervention

The Empire State Building Retrofit

• A famous local example
• Part of a $550M overhaul
  – Around $200/sf overhaul
  – $106M energy-related
ESB Retrofit

- Rocky Mountain Institute Case Study
- Coherent plan
- Many components working together
- Priority made considering the costs and benefits

See [www.rmi.org](http://www.rmi.org) for more

Thousands of buildings

Precast and ugly

Concrete and Brick
Enclosure Retrofit Choices

Exterior retrofit always technically better!!

But, if we have to, can do interior

- beware floors, partitions, etc.
- Freeze-thaw, corrosion
Exterior Retrofit

- Preferred Building Science solution
  Great for ugly buildings

- Controls rain, heat, *and* air
- Protects existing structure and cladding
- ... while providing a new finish

- Historically, retrofit was a major reasons modern **EIFS** was developed post WW2
- Many different lightweight cladding products now available
Drained EIFS: nice but not always needed
EIFS Retrofit Advantages

• Best building science location for insulation, air and water barrier
• Lightweight = flexible
• Like-New looks
Modernization increases asset values, rents and payback periods

Not covering all of building... Phased approach?
Drained EIFS, Window Detail

Window Details are usually the most crucial & difficult

- Brick
- Hollow concrete block
- Plywood blocking
- Fluid air-water barrier

Architect: Walter Fedy
Drawing: Shantz Windows, Elmira, ON
Window Head: Note EIFS Drain opening

1970’s University Admin / Library building
Base insulation over membrane, cement board protection

4” Brick veneer bonded over 8” CMU

Air-water barrier over brick

New Windows

Better window airsealing at inorganic shims required
Retrofit while in use
Panel Cladding Retrofit

Many cladding types:
- Fiber cement
- HDL
- Metal panel
- Metal sheets

Diagram:
- New window
- Low-expansion or flexible foam to form airspace around window
- Metal flashing
- Transition membrane for continuity of air barrier and secondary drainage plane. Wrap over rough back and onto metal angle to form sub-sill flashing with back dam.
- Synthetic stucco on cement board, aluminum panel or tile on cement board
- Continuous cold-formed steel angle as girder for mounting cladding panels. (Size and spacing per structural engineer)
- 2" sprayed closed cell polyurethane as thermal insulation, drainage plane and air barrier
- Cold-formed steel angle as mounting bracket. (Size and spacing per structural engineer)
Metal Overclad -- reshape

Window Overclad
Interior Insulation

- Creates cold exterior surfaces
Interior Insulation

- Reduced drying = risks
- Reduced effectiveness thermal bridging

ccSPF on interior
Non-foam solutions

Ensuring airtightness is the critical factor for durability, and hard to do!

Cavity walls

• Interior insulation does not solve many of the problems!
• Often need repairs
  – Leaks because of failed flashing
  – Cracked bricks
• Economics—exterior is often better... if improved air and water tightness matters
Expensive, Difficult, error prone
Federal Building
Cleveland, OH
Celebrezze

Energy Bills were high
Quality of space was low
Much of the glass & stainless was still in good shape
Limited blast resistance
Expensive, but it works

Case Study: One Wall Center
Failure Mechanisms and Re-Glazing of an all Glass Tower

Thanks to Brian Hubbs, P.Eng
RDH Building Science
Fogged & Corroded Glazing Units

Condensation – Hot sunny day?
Glass options were approved by the City and ultimately chosen by the developer.

- Triple glazed 6 mm clear tempered with Viracon VY-30 coating on surface #2, and Sunguard Light Blue 63 on surface #5, Argon filled.

Design – Final Structural Silicone/Tape Detail

Final Design for re-glazing and Installation
2 redundant structural adhesive joints (1 in factory, 1 on site)
All Weather Work Platform (60km/hr wind)

Custom Suspended Scaffolding
Custom Suspended Scaffolding

All work is completed from the suspended stage or from the interior. Anchors through vent openings pinned to the structure keep the stage secure.

5-6 IGUs per crew day

Windows

- A major issue in retrofits!
- Usually leak heat, air and water
  - Must address at some time
- Leaving leaky windows in good retrofit wall limits performance
  .... Could cause problems!
Air sealing
• New technology available for retrofitting
  – Sealing ducts
  – Sealing enclosures

→ Aerobarrier

4 Sit back and watch the envelope get tighter.
Planning as a System

• Many opportunities lost without planning
• Change boilers, windows, walls, roof
  – What order?
• System thinking
  – Easy to add PV, condensing boilers require a system design

Conclusions

• Enclosure/Equipment Energy retrofits rarely pay for themselves w/savings
• Controls and equipment have limited impact, and just comfort and energy
• Enclosure upgrades affect durability, comfort, energy and re-sale / rent values
• Plan ahead, co-ordinate with required renewals