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Building AMERICA
 U.S. Department of Energy
 Research Toward Zero Energy Homes

Retrofits

Commercial Institutional

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 Building Science Corp & University of Waterloo

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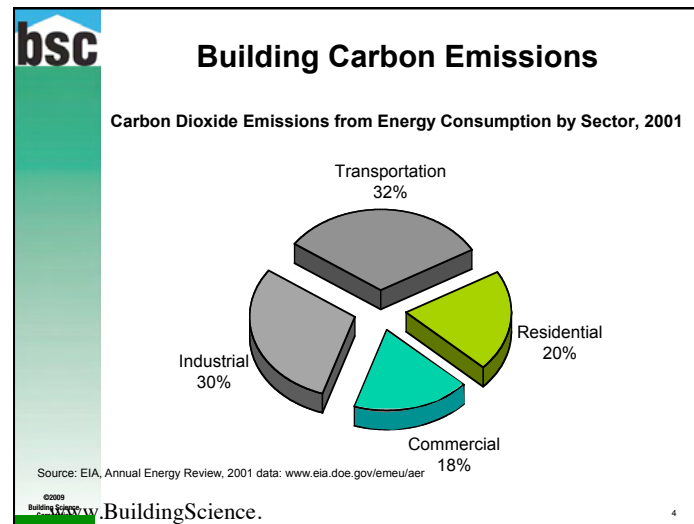
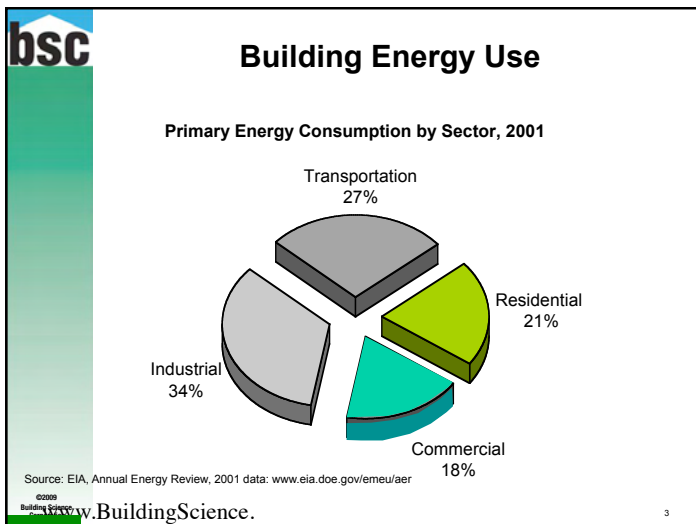
Assessing the Impact of US Housing

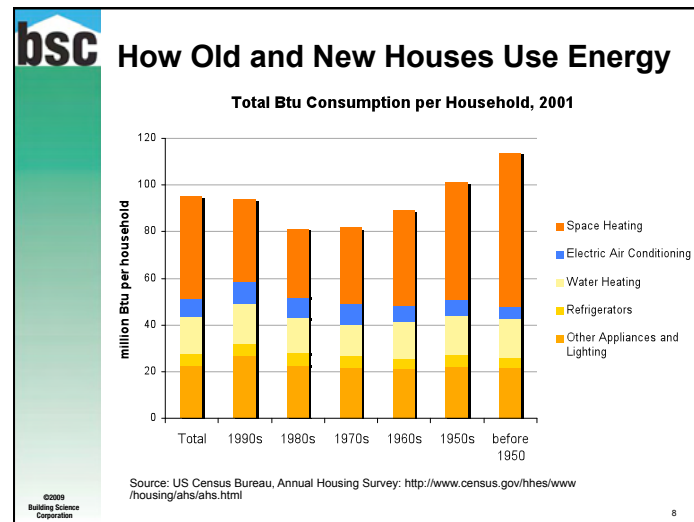
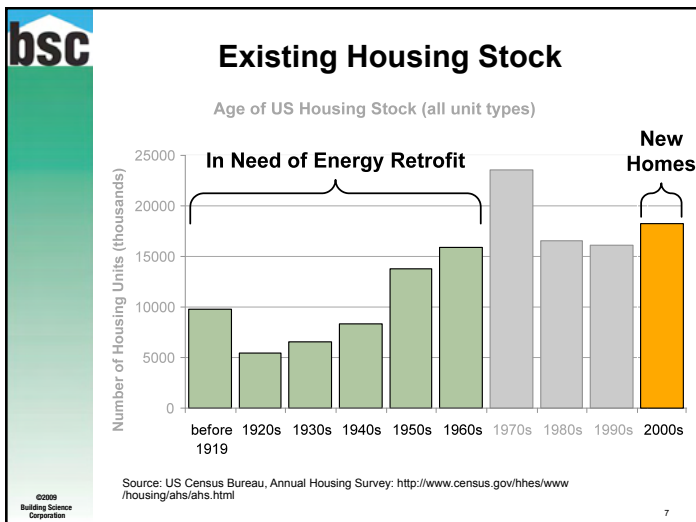
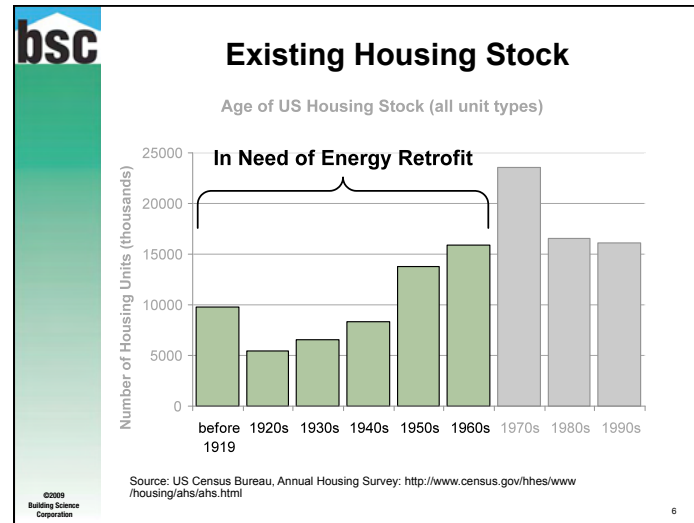
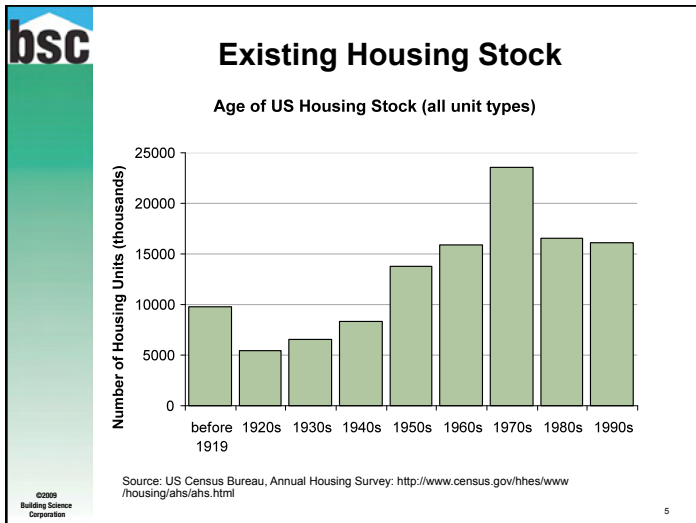
Background:

- Total Housing Units in 2001 (millions):**

Single-Family Homes	73.7
Apartments (all buildings)	26.5
Mobile Homes	6.8
Total	107.0 million units¹
- Total Residential Primary Energy Use in 2001:**
 7,200,462 million Btu²

1. Energy Information Administration, Residential Energy Consumption Survey, 2001 data: www.eia.doe.gov/emeu/recs
 2. EIA, Annual Energy Review, 2001 data: www.eia.doe.gov/emeu/aer





bsc **Commercial Buildings**

- Universities, Schools
- Shops
- Warehouse conversions
- Significant energy consumers

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bsc **Title**

- Points

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bsc **The Whole Building Approach**

- Performance Issues driving Retrofit:
 - Comfort
 - Health
 - Durability
 - Operating Costs
 - Energy Efficiency

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bsc **Expansion of space**

- Points

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bsc **Integrated Design Process Overview**

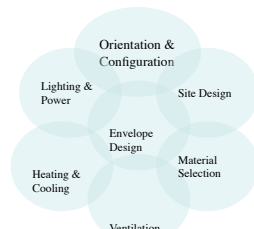
Successful energy efficient retrofit project requires effective management which includes:

1. Bring consultants on board at beginning – structural, mechanical, electrical, building envelope, energy simulator etc.
2. Determine scope of work – Failures? Mould? IAQ? Code requirements?
3. Perform full building audit – invasive investigation of problem areas to minimize assumptions.
4. Manage Client expectations, audit may introduce ‘scope creep’.

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bsc **Integrated Design Process Overview**

5. Suggest prime consultant be present at all audits.
6. Follow-up review meeting with client with all consultants present.
7. Commissioning



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bsc **Choices**

- **Changing mechanical systems is least invasive**
 - often near end of life (20 yrs)
 - 10% eff improvement = 10% operating savings = easy
- **Lighting and ventilation**
 - Many buildings have too many inefficient lights that are on for too long
 - Most buildings have too much ventilation with too little control
 - Can be major savings (30-50%)
- **MUST have clear idea of enclosure upgrades before deciding on mechanical!**

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bsc **Mechanical Retrofit**

- **After enclosure upgrade**
 - Much smaller and quieter systems can be chosen
- **Air-based can be replaced with hydronic**
- **Steam-based can be replaced hotwater**
- **Low-temperature (more efficient) systems can be used**
- **For high ventilation load add HRV**
 - Schools, meeting rooms, etc
- **Variable speed fans and CO₂ controls**
- **Convert CAV to VAV**

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Enclosure Retrofit

- **Important target for many buildings**
 - Airtightness
 - Windows
 - Insulation
 - Roof
 - Walls
 - Basement
 - Slabs
- **Prioritize by Ease and Impact**

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Retrofit Strategy

- Eg a 125 ft x 50 ft storey mill building
- 12 ft flr to flr, 9 ft basement 40% window

Component	Area (ft2)	U= 1 / R	Loss Btu/hr/F
Roof	6250	0.05 = 1/R20	312.5
Wall	7560	0.25 = 1/R4	1890
Windows	5040	1.0 = 1/1	5040
Air Leakage	0.3 ACH@ service		
Basement	3150	Dbl R (2*R3)	525
Slab	6250	Triple (3*1.5)	1388

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Moisture Balance

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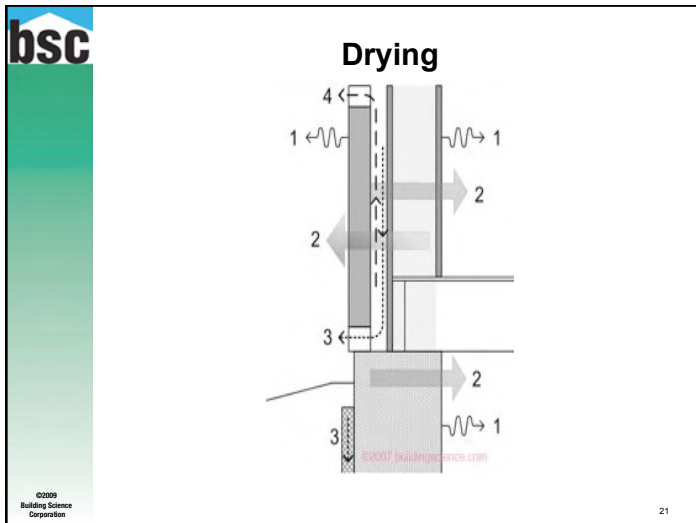
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Wetting

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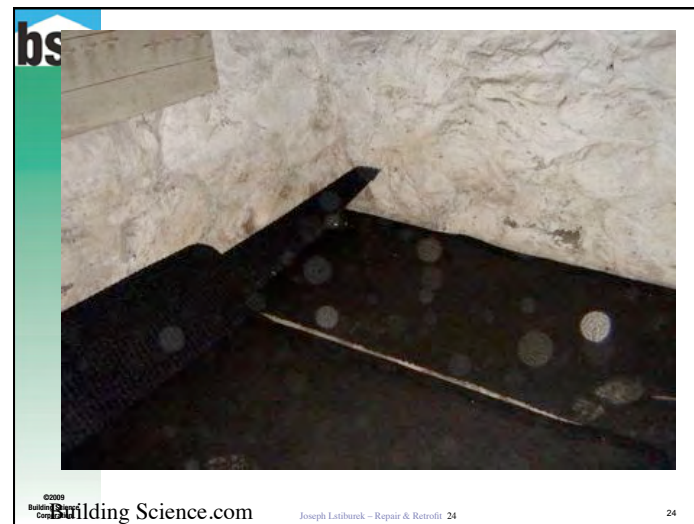
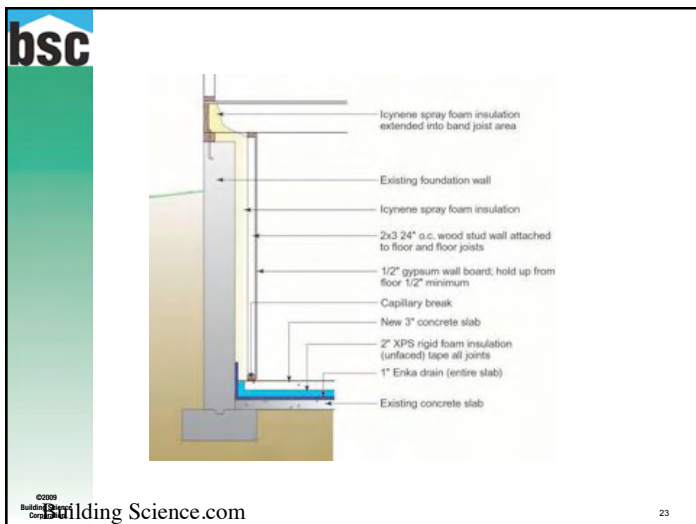
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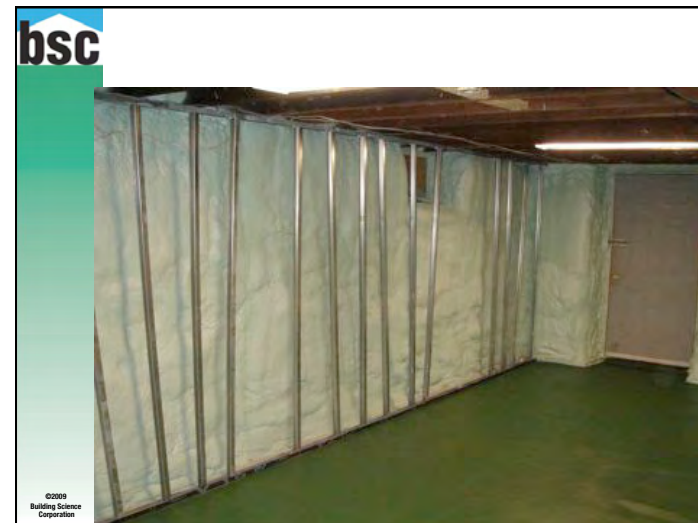
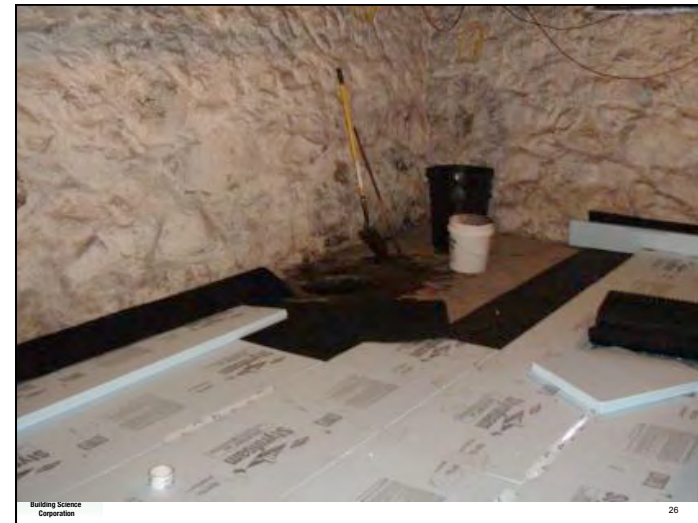


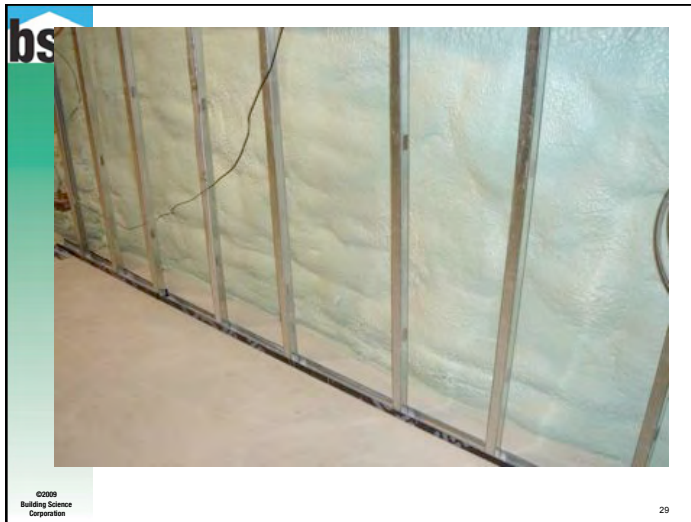
bsc **Basements**

- Easy to retrofit and improve from the interior
- Ceiling height is the big restriction for slab solutions

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Low-Slope Roofs

- Add insulation on top of membrane
- Add min R20

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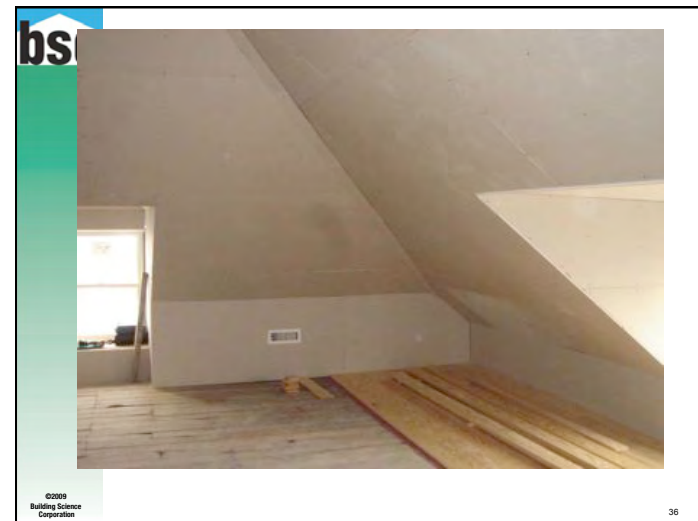
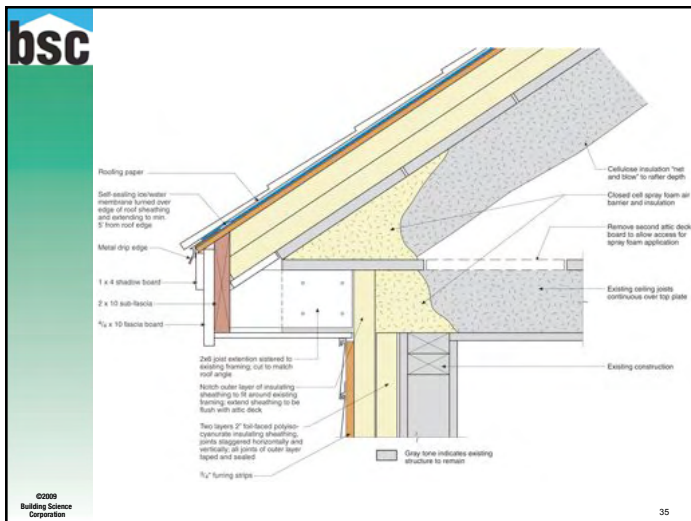
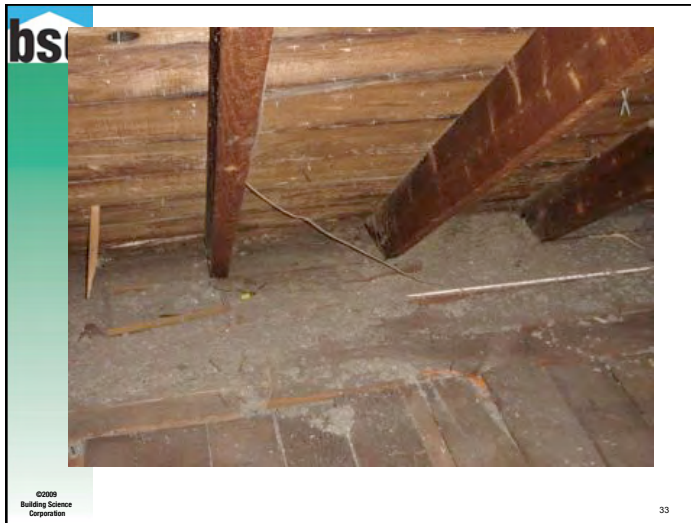
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Sloped Wood Roofs

- Usually require re-roofing and structural repair
- Deal with moisture, then add insulation
- If possible, keep ventilated attic
 - Inspect ceiling plane, plug all holes with caulking and foam
 - Consider 1" of spray foam air barrier
 - Blow in minimum R60 cellulose.
- If cathedral, insulate AND airtighten
 - Insulation on exterior is a benefit
 - airtighten

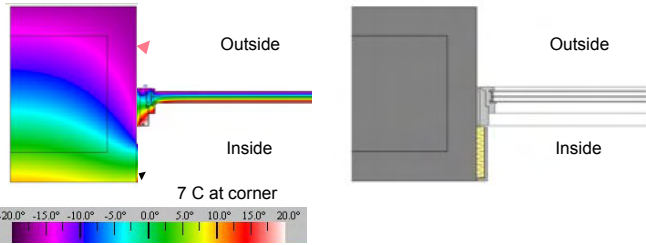
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bsc **Window Thermal Flanking**

Beware heat flow around window frame




The image shows two diagrams of a window frame cross-section. The left diagram, labeled 'Thermal Flanking', shows a color-coded heat map where the corner of the window frame is the warmest point, indicated by a red arrow and the text '7 C at corner'. A color scale below ranges from -20.0° to 20.0°. The right diagram, labeled 'Flanking Reduced', shows the same window frame with additional insulation applied to the side walls, significantly reducing the heat flow around the frame.

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bsc **Common paths : Curtainwall**

- Remove and replace**
When at or near end of life
- Upgrade IGU / spandrel insulation**
Often leaves large thermal bridges!
Confirm structural connection conditions
- Upgrade pressure plate**
fiberglass insulating PP provides thermal break
Insulate spandrels from inside
- Always airseal, esp. spandrel**



The image shows a modern building with a glass curtainwall. The building is multi-storied with a prominent glass facade reflecting the sky. It is situated on a green lawn under a clear blue sky.

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bsc **Common paths : Precast**

Problems:
thermal bridging, lack of airtightness, poor insulation


Confirm structural connections are sound

Clean and re-seal joints for rain control
Add drainage if possible

Airseal
spray or rigid foam, sealant, drywall

Insulate (combine with airsealing)
rigid board, spray foam, mineral fiber if careful
beware floor and roof thermal penetrations

Overclad is possible and high performance



The image shows the exterior of a long, low-rise building with a precast concrete facade. The building has a clean, industrial appearance with horizontal concrete panels.

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- interior



The image shows the interior of a building under construction. The walls are covered in pink insulation. Scaffolding is visible around a window opening. A blue tarp is on the floor in the foreground.

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bsc **Brick Veneer/Steel Studs**

Mostly 1980+
 Contain R12/R20 batt
 Thermal bridging nightmare
 Insulate on interior
 Leaves slabs as bridge
Overclad




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bsc **Overclad Options**

- Drained EIFS
- Drained & Ventilated metal sheets, panels, fiber cement
- Horizontal Lap Siding

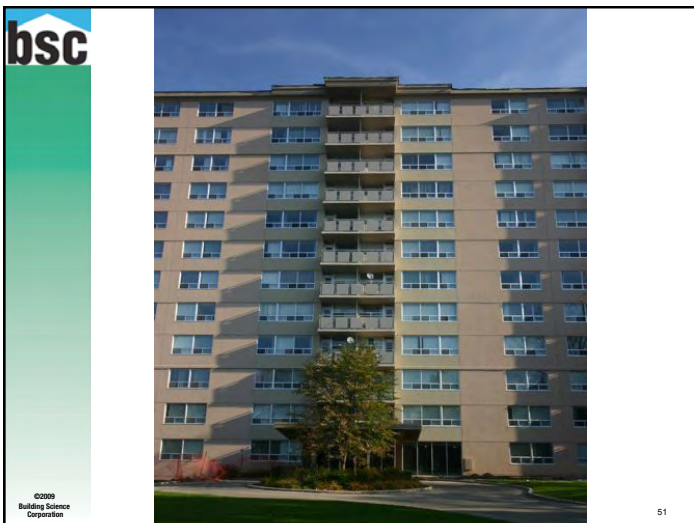
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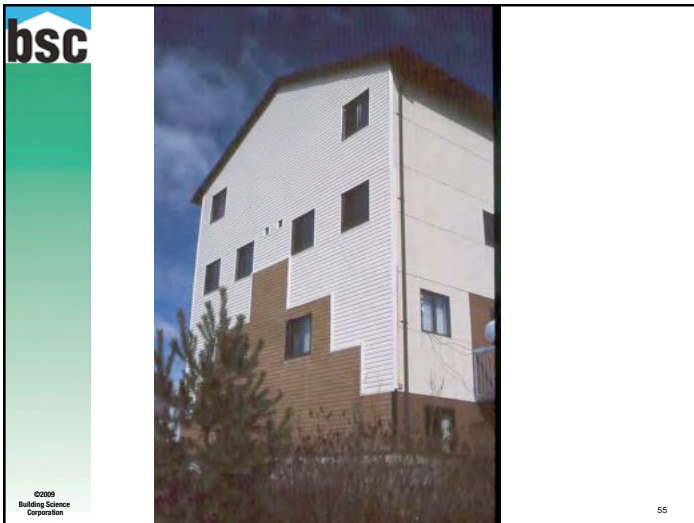
bsc **A wide range of aesthetics**

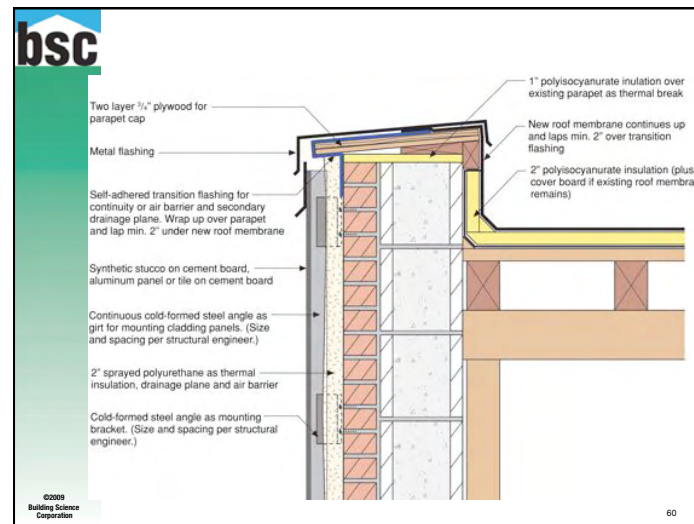
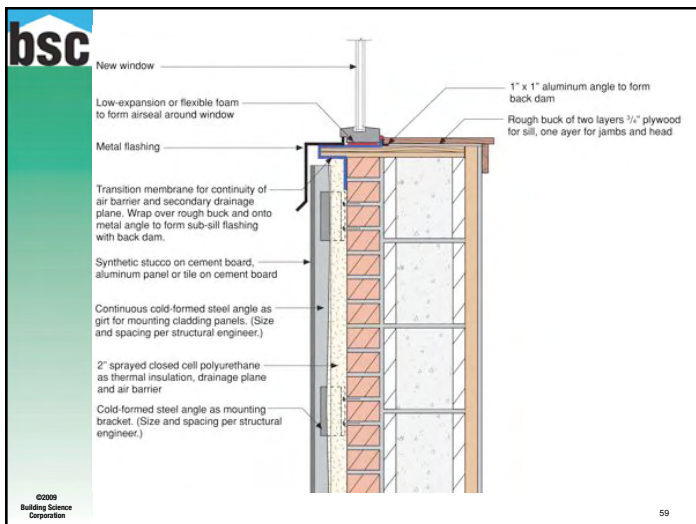
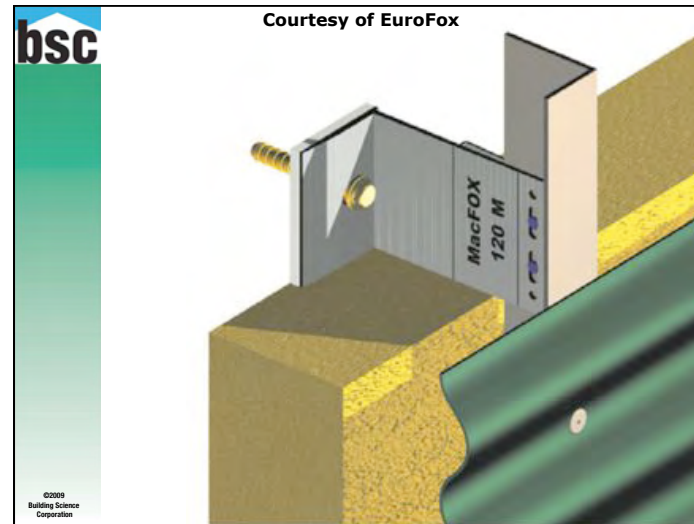
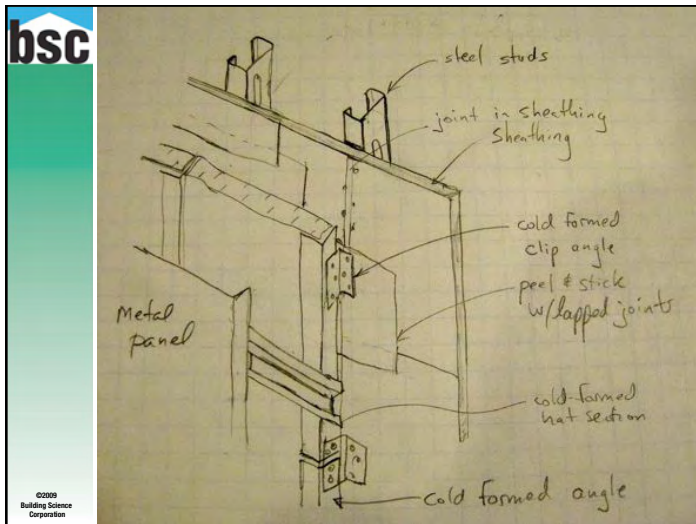


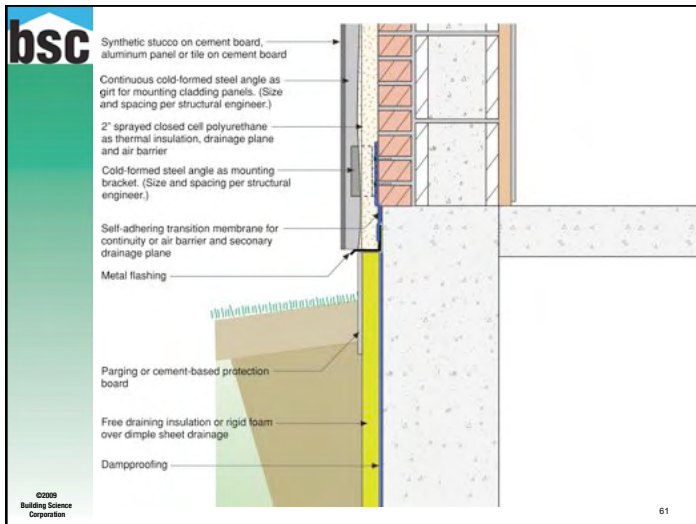
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Load Bearing Solid Masonry

- Large stock of desirable buildings
- Downtown
- Attractive
- Good bones
- Flexible Program
- Most want to keep brick exterior

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Solid Masonry: Interior Retrofit

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bsc Solid masonry

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bsc Drained ventilated cladding (no risk)
Require airtight parge

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bsc Moisture Balance

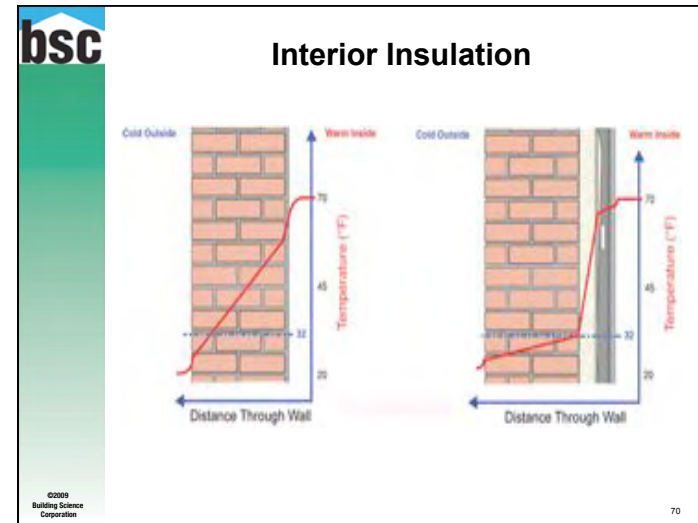
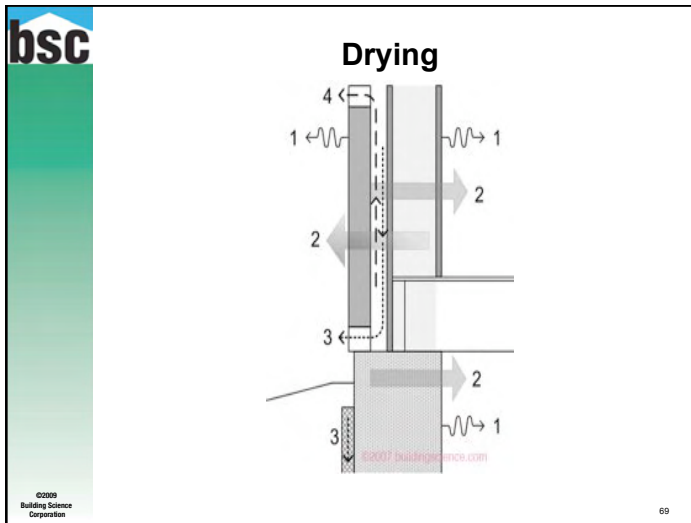
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bsc Wetting

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- bsc**
- ### Risks
- **Freeze-thaw**
 - **Salt and Osmosis**
 - **Rot of embedded wood**
 - **Damage to interior finish**
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Freeze-thaw

For a damaging F-T cycle one needs

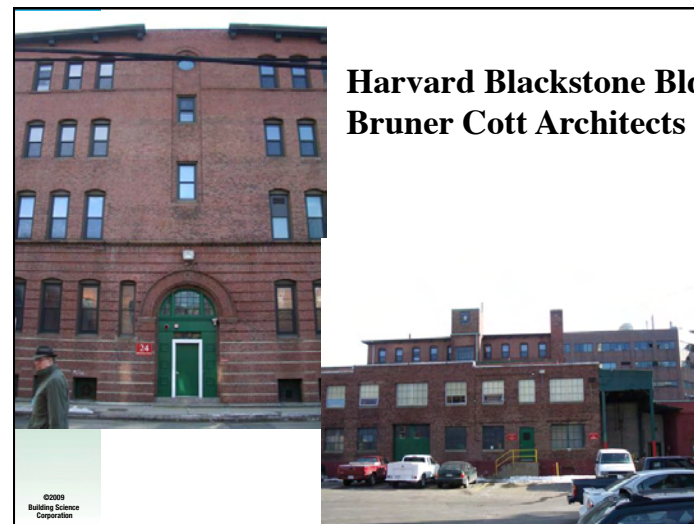
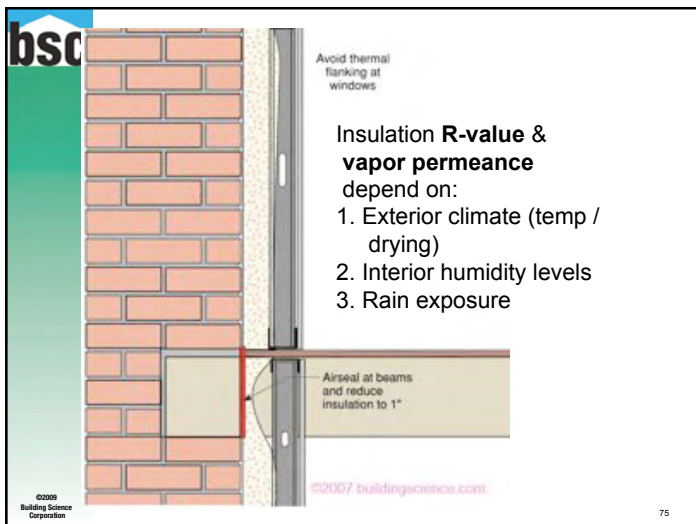
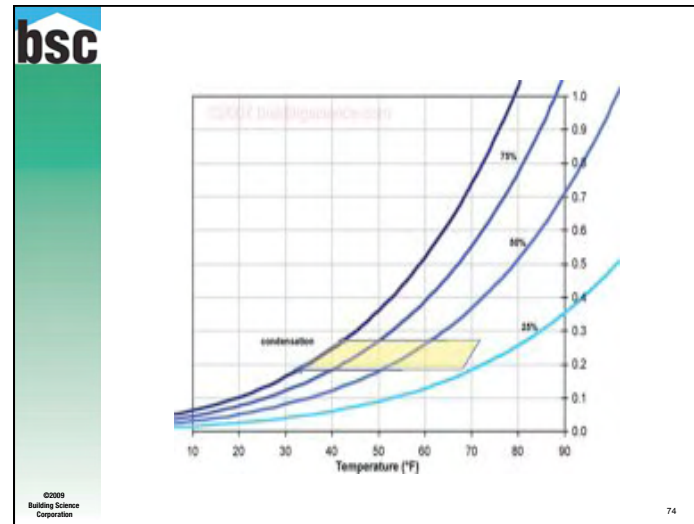
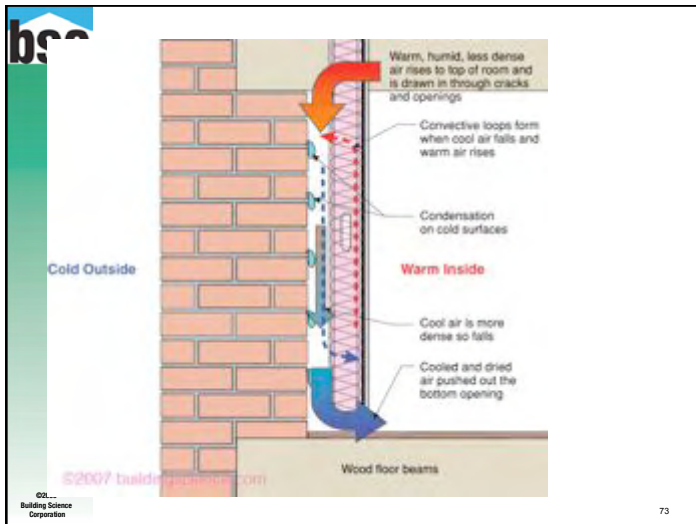
- A temperature drop below about -5 C / 20 F
- Nearly saturated moisture content
- Porous, brittle material

For brick, degree of saturation of 0.80 to 0.95

Insulating reduces masonry temperature

Therefore keep MC below 80% of saturation during cold weather

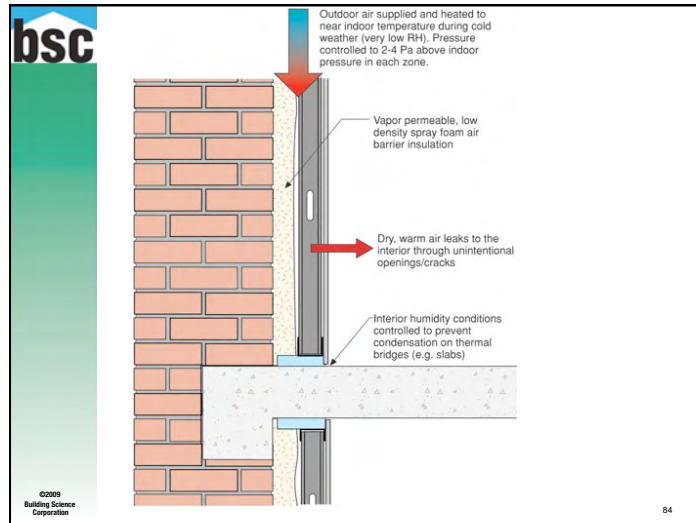
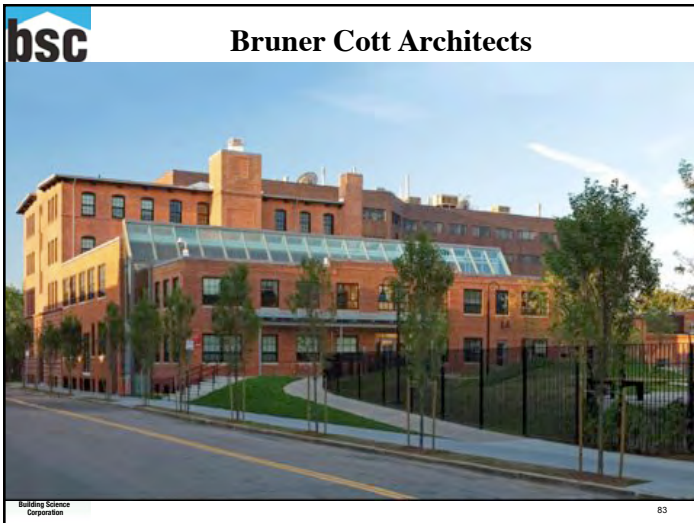
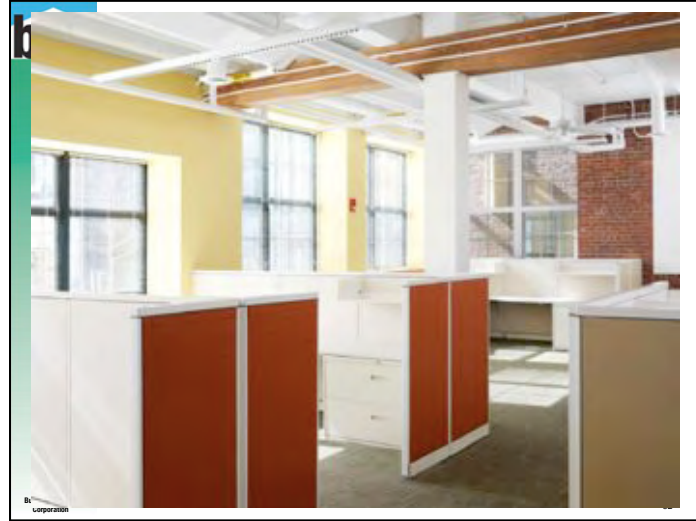
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Conclusions

Interior Insulation Retrofits of Load-bearing Masonry are possible

Accept that masonry gets much colder

Great care required to

- enhance drying as much as possible,
- reduce wetting more than drying is reduced

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