Breathing New Life into Aging Homes

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Assessing the Impact of US Housing

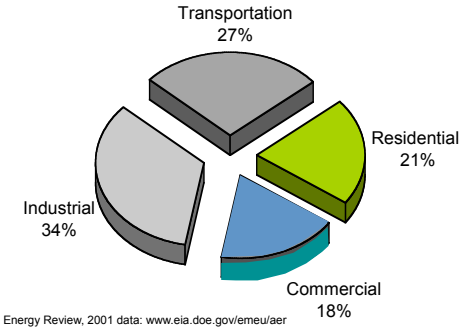
- Background:
- Total Housing Units in 2001 (millions):
- Single-Family Homes 73.7
- Apartments (all buildings) 26.5
- Mobile Homes 6.8
- 107.0 million units[1]

- Total Residential Primary Energy Use in 2001:
- 7,200,462 million Btu[2]

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

Building Energy Use

Primary Energy Consumption by Sector, 2001



Source: EIA, Annual Energy Review, 2001 data: www.eia.doe.gov/emeu/aer

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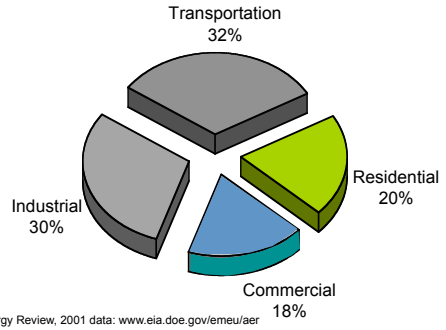
Building Carbon Emissions

Carbon Dioxide Emissions from Energy Consumption by Sector, 2001



Source: EIA, Annual Energy Review, 2001 data: www.eia.doe.gov/emeu/aer

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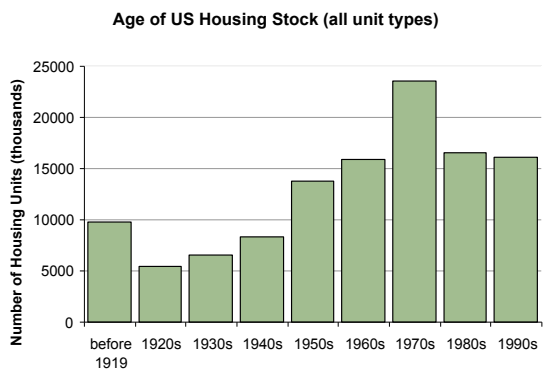
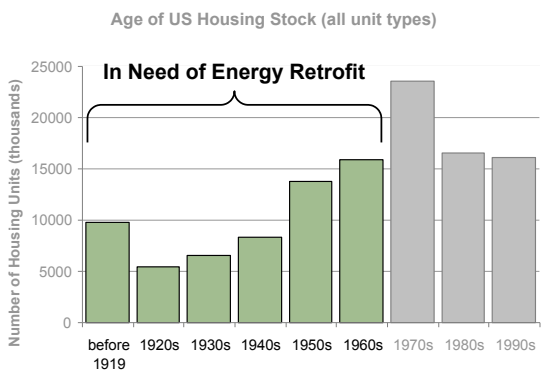
Existing Housing Stock



Source: US Census Bureau, Annual Housing Survey: http://www.census.gov/hhes/www/housing/ahs/ahs.html

Existing Housing Stock



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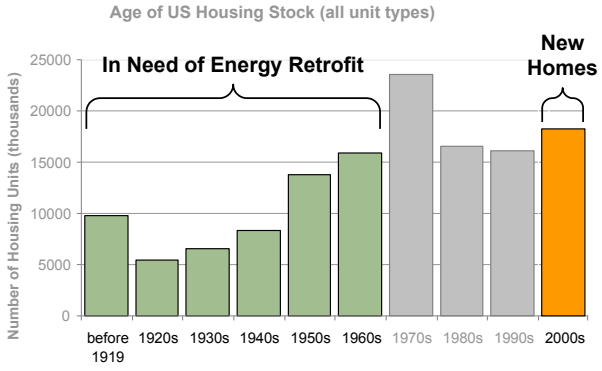
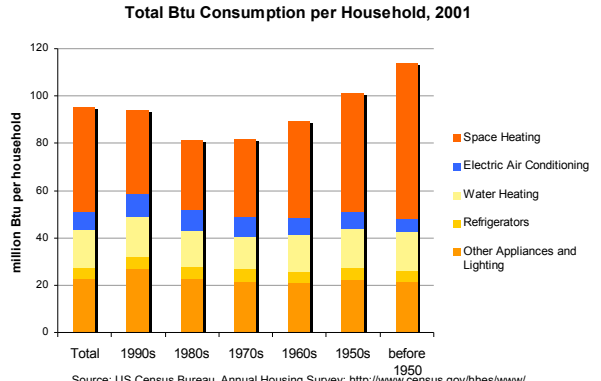
Existing Housing Stock



Source: US Census Bureau, Annual Housing Survey: http://www.census.gov/hhes/www/housing/ahs/ahs.html

How Old and New Houses Use Energy



Source: US Census Bureau, Annual Housing Survey: http://www.census.gov/hhes/www/housing/ahs/ahs.html

Existing buildi

- About ¼ of all households were built before 1950
- Almost ¾ before 1980
- 80% of residential energy is consumed by homes built 1980 or earlier
- This is a *huge* energy consumption sector
- Retrofit solutions need to address this!
- Good news: some low-hanging fruit
  - Attics, airtightening, efficient furnaces, windows, insulated over clad

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National Policy Implication

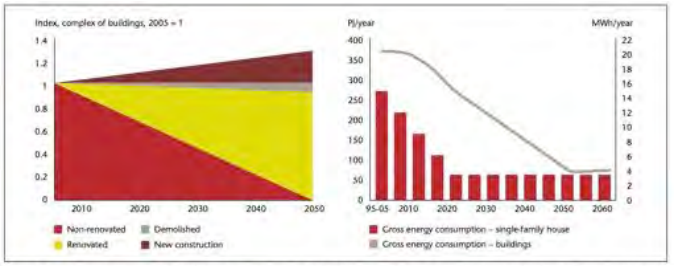


Figure 8: Possible future energy savings in Denmark's housing stock (left), and gross energy consumption in buildings during the same period (right).

California

- Residential Energy Consumption
- California
  - 5746 Btu/Degree Day
- National
  - 3262 Btu/Degree Day

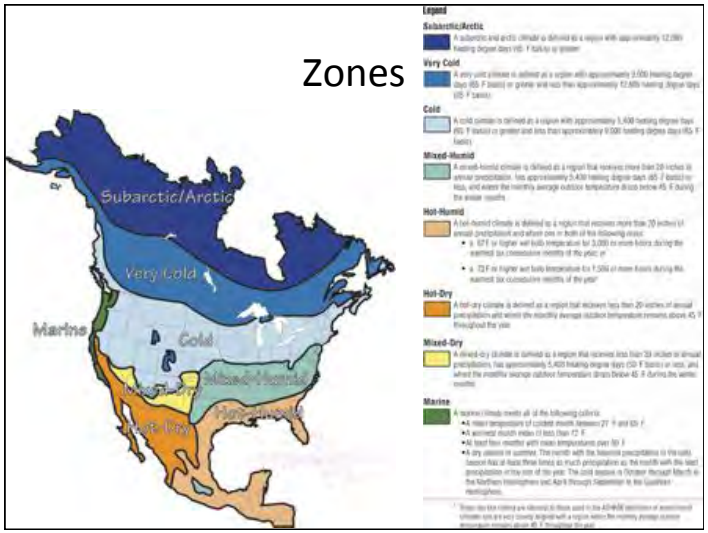
Energy Economics

More than 12 times increase since 1970
Compound annual rate 6.8% per year
Future?

Table 2. Residential Sector Energy Price and Expenditure Estimates, Selected Years, 1970-2008, California

Year	Primary Energy: Coal	Primary Energy: Natural Gas [a]	Primary Energy: Petroleum: Distillate Fuel Oil	Primary Energy: Petroleum: Kerosene	Primary Energy: Petroleum: LPG [b]	Primary Energy: Petroleum: Total	Biomass: Wood [c]	Biomass: Total [c]	Retail Electricity	Total Energy [d]
	Prices in Dollars per Million Btu									
1970	1.01	0.93	1.27	2.57	2.67	[R] 2.43	0.52	0.69	6.59	1.01
1975	—	1.66	2.80	5.98	4.46	[R] 4.14	1.62	[R] 1.62	13.86	3.19
1980	3.13	3.37	8.92	13.04	8.19	[R] 8.14	4.15	[R] 3.53	17.16	[R] 6.79
1985	4.54	3.91	5.28	11.15	6.98	[R] 6.56	4.39	[R] 3.58	12.62	[R] 6.84
1990	3.77	5.82	5.70	7.44	12.68	[R] 11.62	6.79	[R] 6.77	09.26	12.36
1995	3.79	5.35	6.62	5.91	12.50	[R] 11.96	3.86	[R] 5.42	94.02	[R] 14.96
1998	4.03	5.23	7.84	5.32	11.16	[R] 12.61	9.43	[R] 6.31	33.25	[R] 14.79
1997	3.71	6.70	8.10	4.95	13.73	[R] 12.83	8.41	[R] 6.73	33.71	[R] 15.65
1998	3.68	6.85	8.89	6.63	12.49	[R] 11.68	3.62	[R] 6.67	51.94	13.63
1999	3.68	6.52	7.88	6.58	12.77	[R] 12.19	3.52	[R] 6.60	51.31	13.94
2000	3.72	8.56	10.77	9.97	16.26	[R] 15.36	3.88	[R] 8.76	31.92	16.56
2001	3.68	10.27	19.09	9.96	15.56	[R] 16.21	8.62	[R] 10.01	39.43	16.40
2002	3.67	[R] 6.86	6.75	9.19	15.87	[R] 15.04	5.09	[R] 7.15	37.26	[R] 16.81
2003	3.77	[R] 8.85	13.84	9.10	16.40	[R] 17.05	6.11	[R] 9.21	50.84	[R] 18.21
2004	3.81	[R] 8.67	12.60	11.81	20.86	[R] 20.07	6.88	[R] 10.08	39.77	[R] 18.47
2005	3.98	[R] 11.58	16.90	13.75	24.13	[R] 23.25	8.20	[R] 12.17	36.65	[R] 20.62
2006	3.73	[R] 11.53	18.32	22.13	27.56	[R] 26.92	10.80	[R] 12.34	42.01	[R] 23.04
2007	—	11.43	25.73	24.26	29.83	[R] 28.25	11.62	[P] 12.29	42.27	[R] 23.15
2008	—	12.36	29.71	[P] 37	33.90	33.61	14.43	11.63	46.44	23.98

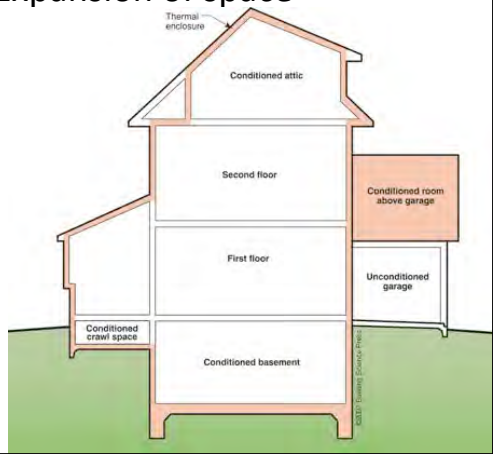
Zones



Drivers of Retrofits

- Performance/Needs not Energy $ drive Retrofit:
  - **Comfort**
  - **Health**
  - **Durability**
  - **New/better uses**
  - **Marketing / Aesthetics**
  - **Operating Costs**
  - **Energy Efficiency**

Expansion of space



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Retrofit: How to reduce energy?

- Changing mechanical systems is least invasive
  - Lifespan is moderate, say (20 yrs)
  - 10% eff improvement = 10% operating savings = easy
- Lighting appliances and ventilation
  - Change is easy at any time, lifespan <20 yrs
  - Appliances/ligjting often payback quickly
- Enclosures
  - Windows last 30-50 yrs
  - Insulation lasts 100+ yrs
  - Cladding lasts 35-200+ years
- MUST have clear idea of enclosure upgrades before deciding on mechanical!

Deep Retrofit

- Simple upgrades have great paybacks
- but have little impact
  - Small upgrades very cost effective, but small (10-25% reductions)
- Mid-range upgrades (15-50%)
- usually quite expensive per energy saved
- Deep retrofits (>50%) secure buildings future
  - Cost a lot, save a lot.
  - But … allow for new styles, repair/replace, more use, etc.
  - Leap frog current housing

Enclosure Retrofit

- An important target for many buildings
  - Walls
  - Roofs
  - Basements/Slabs
  - Windows
- Airtighten and control moisture
- Prioritize by Ease ($) and Impact (Energy and other benefits)

DANGER!

- House is a system
- Change the insulation, airtigtness, mechanical system, etc impacts
  - Durability
  - Health
  - Safety
  - Indoor Air Quality

Energy Efficiency & Durability

- Better insulation means
  - Cold exterior and/or interior surface
  - More extreme variations at exterior
  - Colder surfaces mean
    - more likely condensation
    - And/or higher RH = higher moisture content
    - And slower drying
- So… More insulation reduces durability!
- Air leakage dried as well as wets
  - Airtightness increases indoor humidity

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Enclosures

Building Components

- Buildings are made of several large systems
- The systems that make up a a building can be grouped in four categories
  - Superstructure
  - Enclosure
  - Service Systems
  - Fabric

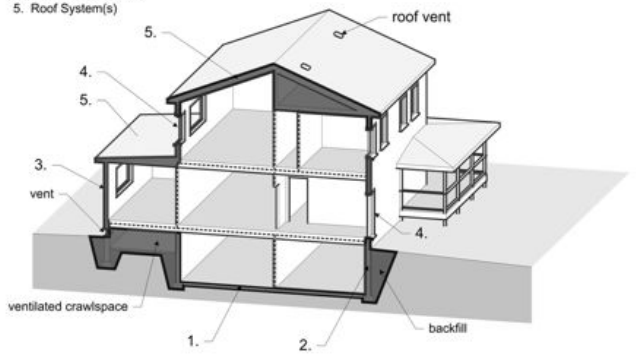
The Enclosure: An Environmental Separator

- The part of the building that physically ***separates*** the ***interior*** and ***exterior*** environments.
- Includes all of the parts that make up the wall, window, roof, floor, etc… from the innermost to the outermost layer.
- Sometimes, interior partition also are environmental separators (pools, rinks, etc.)

Where is inside?
Where is outside?

Building Enclosure Components:

1. Basement Floor System(s)
2. Foundation Wall System(s)
3. Above Grade Wall System(s)
4. Windows and Doors
5. Roof System(s)



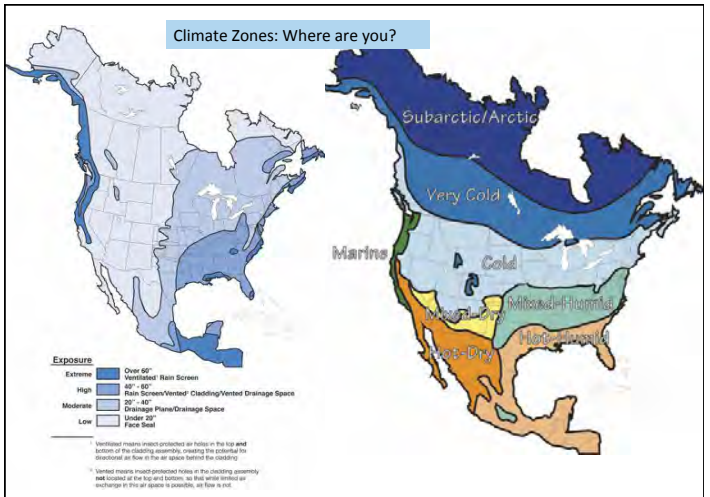
Climate Si

- Design for
  - Climate zone
  - Site
  - Building height, shape, complexity

Seattle ≠ Sacramento
Miami ≠ Minneapolis
Edmonton ≠ Toronto

Marcus Vitruvius Pollio

These are properly designed, when due regard is had to the country and climate in which they are erected. For the method of building which is suited to Egypt would be very improper in Spain, and that in use in Pontus would be absurd at Rome: so in other parts of the world **a style suitable to one climate, would be very unsuitable to another**: for one part of the world is under the sun's course, another is distant from it, and another, between the two, is temperate.



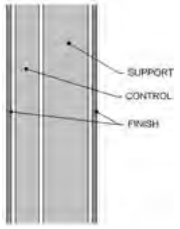
Climate Load Modification

- Building & Site (overhangs, trees…)
  - Creates microclimate
- Building Enclosure (walls, windows, roof…)
  - Separates climates
  - Passive modification
- Building Environmental Systems (HVAC…)
  - Use energy to change climate
  - Active modification

Basic Functions of the Enclosure

- 1. Support
  - Resist and transfer physical forces from inside and out
- 2. Control
  - Control mass and energy flows
- 3. Finish
  - Interior and exterior surfaces for people
- Distribution – a building function

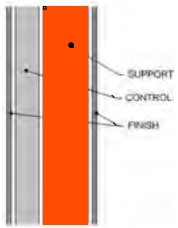
Functional Layers



Basic Enclosure Functions

- **Support**
  - **Resist & transfer physical forces from inside and out**
    - Lateral (wind, earthquake)
    - Gravity (snow, dead, use)
    - Rheological (shrink, swell)
    - Impact, wear, abrasion
- Control
  - Control mass and energy flows
- Finish
  - Interior and exterior surfaces for people

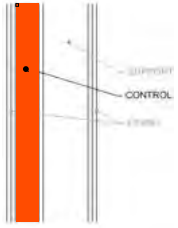
Functional Layers



Basic Enclosure Functions

- Support
  - Resist & transfer physical forces from inside and out
- **Control**
  - **Control mass and energy flows**
    - **Rain** (and soil moisture)
      - Drainage plane, capillary break, etc.
    - **Air**
      - Continuous air barrier
    - **Heat**
      - Continuous layer of insulation
    - **Vapor**
      - Balance of wetting/drying
- Finish
  - Interior and exterior surfaces for people

Functional Layers



Retrofit

- Need to assess what is doing what
- May be able to change functions of layers
- Often need to improve, replace, or add support, control or finish

Fundamental Enclosure Functions

- Support
- Control
  - Rain
  - Air
  - Heat
  - Vapor / condensation
  - Fire
- Finish

Walls

Walls

- Major aesthetic element
  - Curb appeal and satisfaction
- Expensive to change
  - Cant usually pay just for upgrade
- Usually need a reason to retrofit
  - Cladding past service life
  - Comfort / durability problems
  - Major interior renovations

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Targets

- R20-40+ True R-value
  - Climate and energy sources matter
- Airtightness
  - ACH@50 <3?? 2??
  - Depends on energy target
- R40 wall with 5 ACH50 makes little sense
- R20 wall with 1 ACH50 makes little sense

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Wood-framed Walls

- Can add insulation if voids empty
  - Experience with weatherization
  - Should do everytime as a start
- Airtightness & Insulation level improvements are limited
  - Hard to get to “modern” levels
    - R20+ and < 2 ACH@50
  - May be as far as some can afford
- Can’t improve RAIN control from inside cavity

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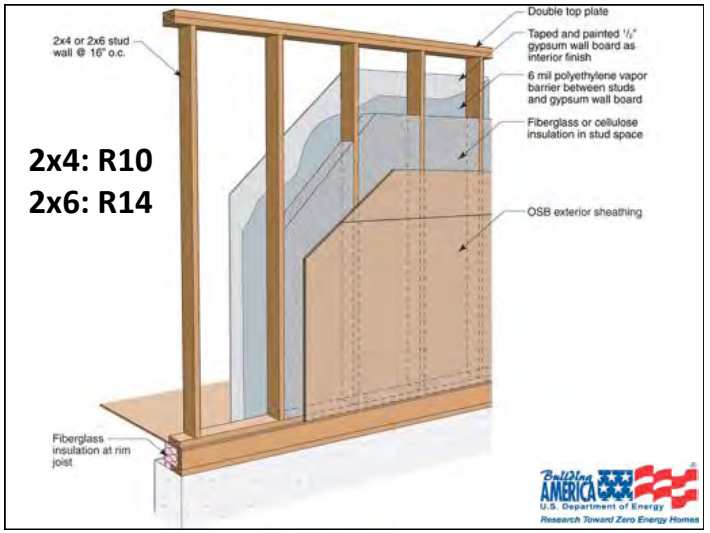
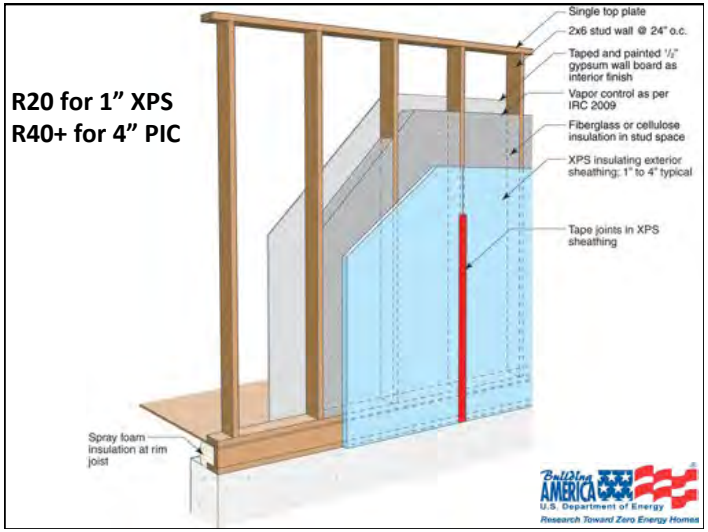
Above grade walls

- *Interior retrofit* limits improvements to airtightness, rain control,thermal bridge
- *Exterior retrofit* allows excellent improvements and increased durability
- Windows should be done at the same time! Risky
- Installation cost $200+/- so get good windows, eg vinyl triple glazed for $30/sf

2x4: R10
2x6: R14



R20 for 1" XPS
R40+ for 4" PIC



Exterior Insulation Retrofit

- Any reasonable level of insulation can be provided
  - Final R of 20, 30, 40, 50
- Almost all penetrations of air, heat, and rain can be improved
- New drainage plane
- Critical to deal with windows
- Significant reductions in moisture risk

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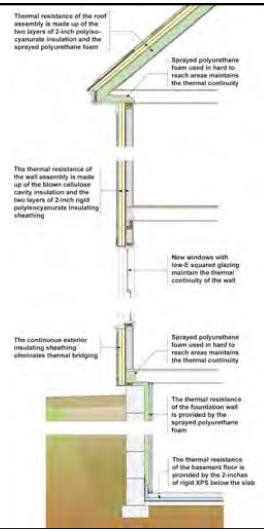
Thermal Continuity

•Continuous
•High R-values
•Warm& protect wood structure



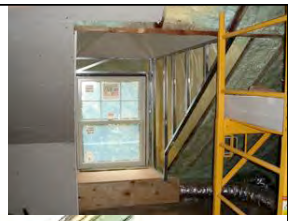
Thermal Continuity

The thermal resistance of the wall assembly is made up of the blown cellulose cavity insulation and the two layers of 2-inch rigid polyisocyanurate insulating sheathing

New windows with low-E squared glazing maintain the thermal continuity of the wall

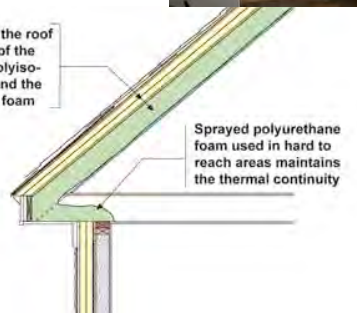
Today, we would recommend triple-glazed with compression seals for airtightness

Roof to wall

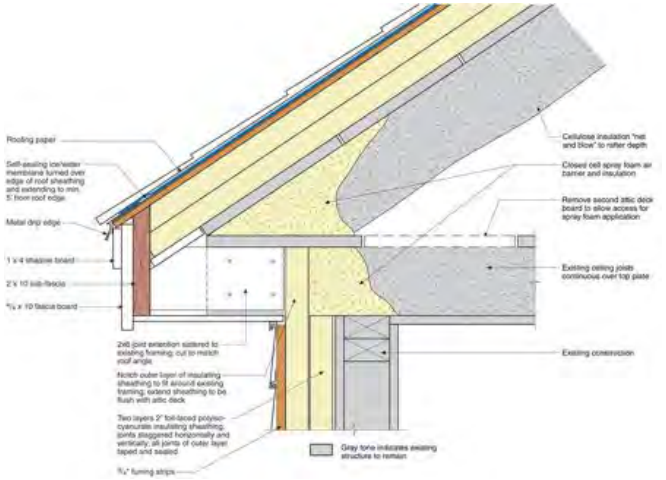


Thermal resistance of the roof assembly is made up of the two layers of 2-inch polyiso-cyanurate insulation and the sprayed polyurethane foam

Normally we would use blown cellulose or fiberglass in rafter space, foam for airsealing



Sprayed polyurethane foam used in hard to reach areas maintains the thermal continuity



Exterior Insulation Retrofit

- Challenges
  - How to attach cladding
  - How to detail windows
  - Porches
  - Overhangs
  - Foundation transition

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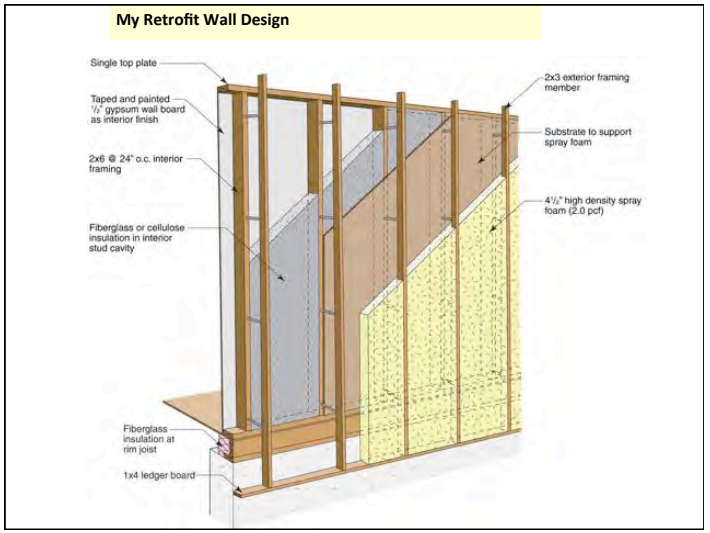
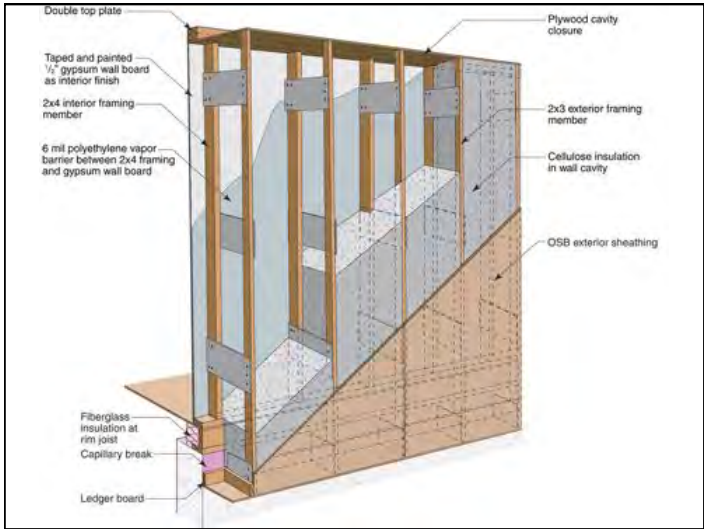
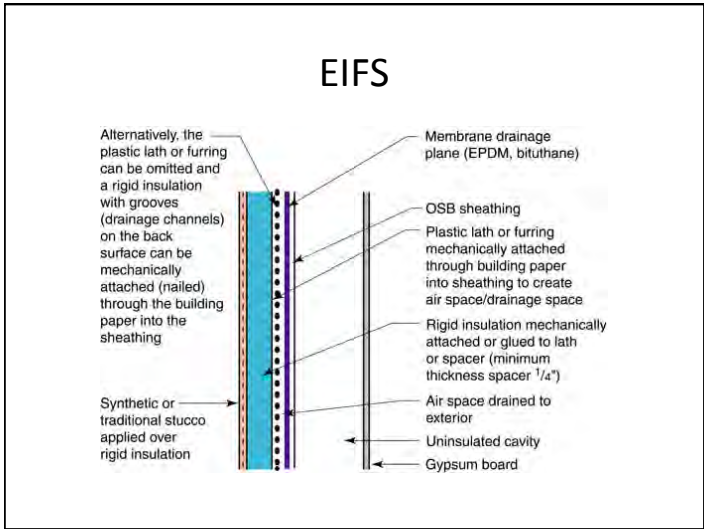
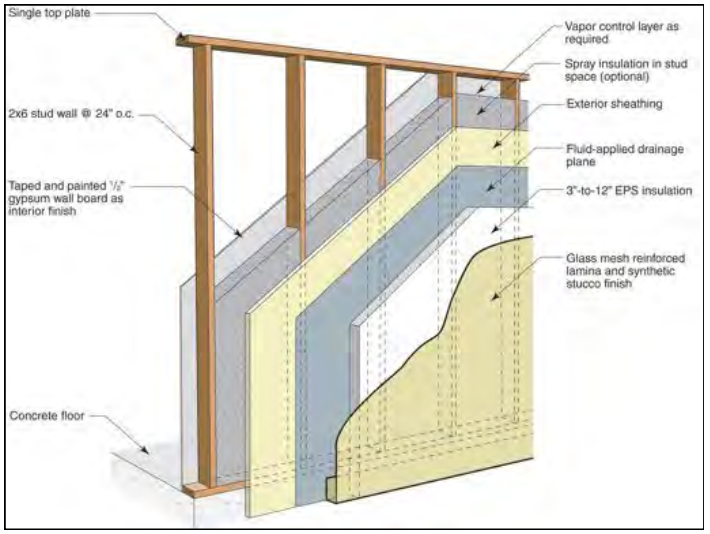
My retrofit

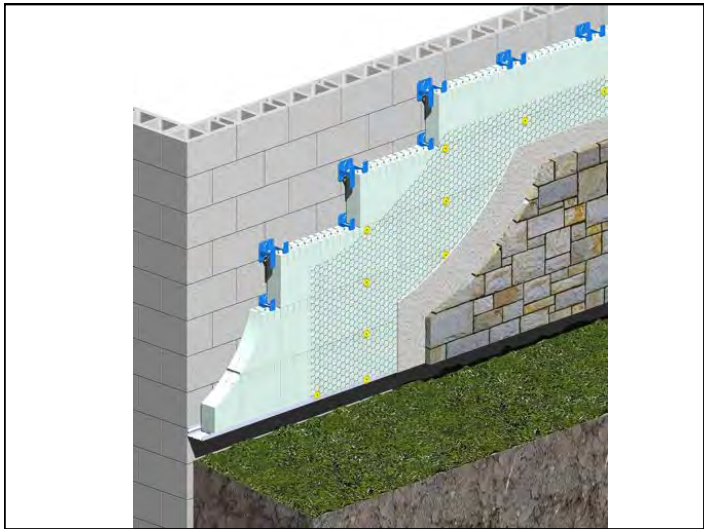
My Retrofit Wall Design




Double top plate
Plywood cavity closure
Taped and painted ½" gypsum wall board as interior finish
2x4 interior framing member
2x3 exterior framing member
6 mil polyethylene vapor barrier between 2x4 framing and gypsum wall board
Cellulose insulation in wall cavity
OSB exterior sheathing
Fiberglass insulation at rim joist
Capillary break
Ledger board


EIFS
Alternatively, the plastic lath or furring can be omitted and a rigid insulation with grooves (drainage channels) on the back surface can be mechanically attached (nailed) through the building paper into the sheathing
Membrane drainage plane (EPDM, bituthane)
OSB sheathing
Plastic lath or furring mechanically attached through building paper into sheathing to create air space/drainage space
Rigid insulation mechanically attached or glued to lath or spacer (minimum thickness spacer 1/4")
Synthetic or traditional stucco applied over rigid insulation
Air space drained to exterior
Uninsulated cavity
Gypsum board

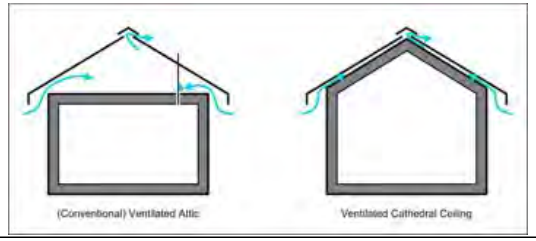

Single top plate
2x6 stud wall @ 24" o.c.
Taped and painted ½" gypsum wall board as interior finish
Concrete floor
Vapor control layer as required
Spray insulation in stud space (optional)
Exterior sheathing
Fluid-applied drainage plane
3"-to-12" EPS insulation
Glass mesh reinforced lamina and synthetic stucco finish



Roofs

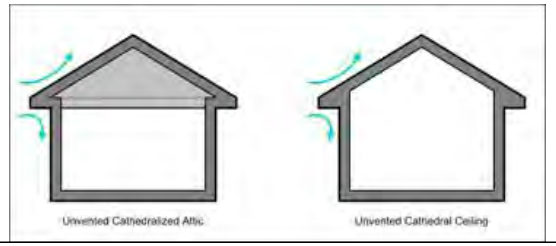
Pitched Roof Types

- Vented Attic
  - Insulation/air barrier at ceiling plane
- Cathedral Ceiling
  - Insulation/air barrier at roof plane



Pitched Roof Types

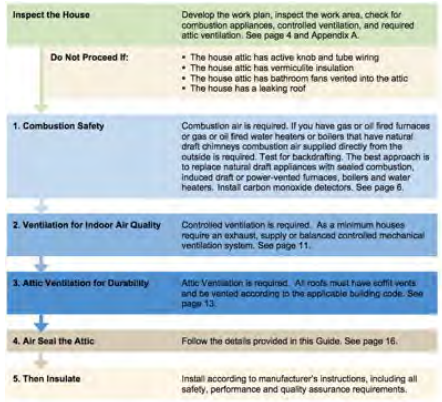
- Unvented Cathedralized Attic
  - As cathedral but no venting above insulation
- Unvented Cathedral

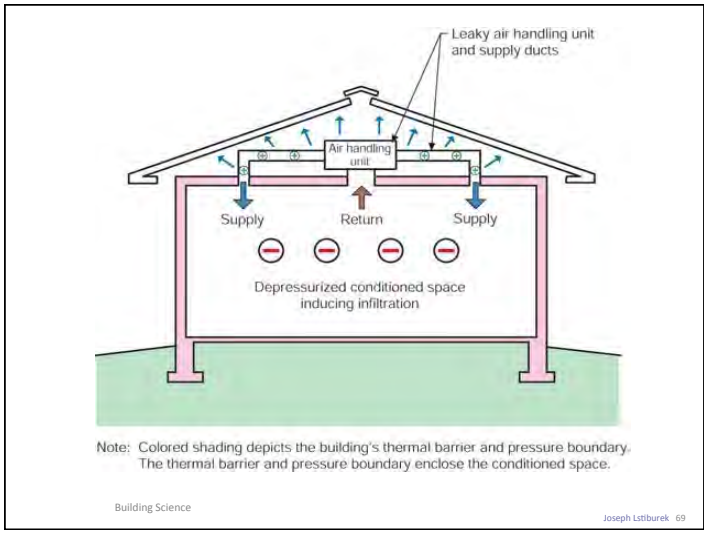


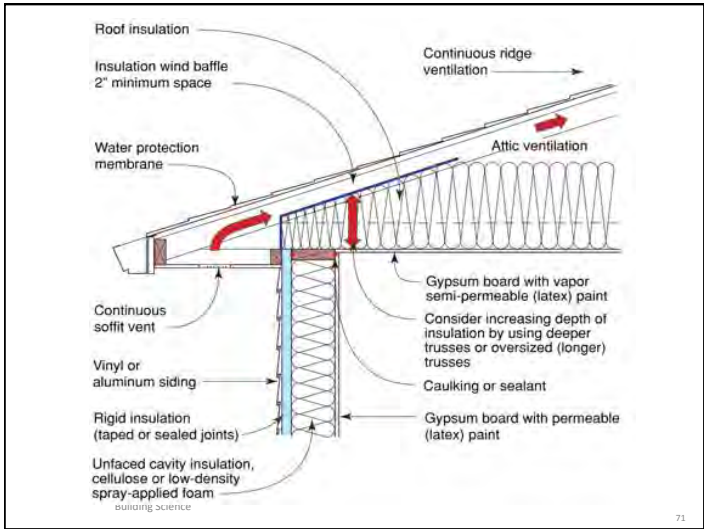
Fully Ventilated Attics

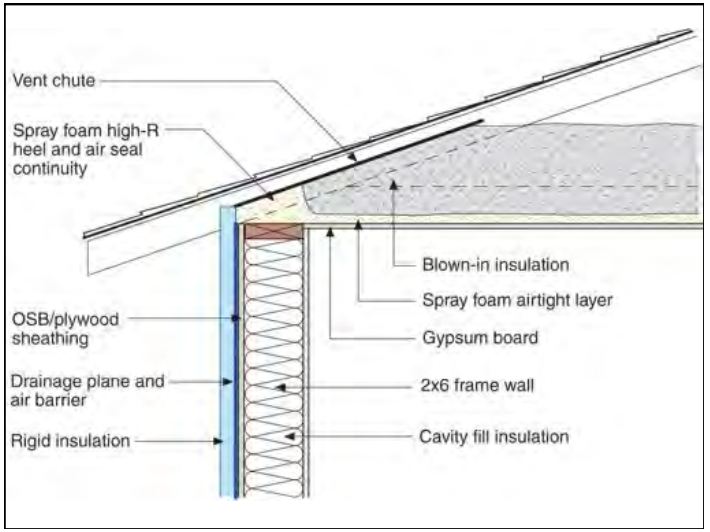
- Can re-roof whenever, with whatever
- Deal with moisture, then add insulation
  - Rain leaks, air leaks
- Easy to upgrade by adding blown insulation
- Challenge: Low height at eaves
  - Solution: spray foam and vent chutes
- If possible, keep ventilated attic
  - Inspect ceiling plane, plug all holes with caulking and foam
  - Consider 1" of spray foam ceiling air barrier
  - Blow in minimum R60 cellulose, R75-R100 sensible

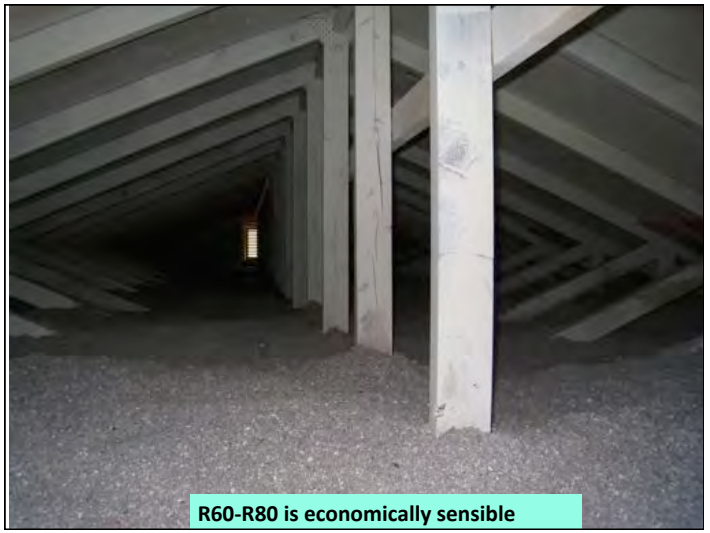
BuildingScience.com Attic Sealing Guide

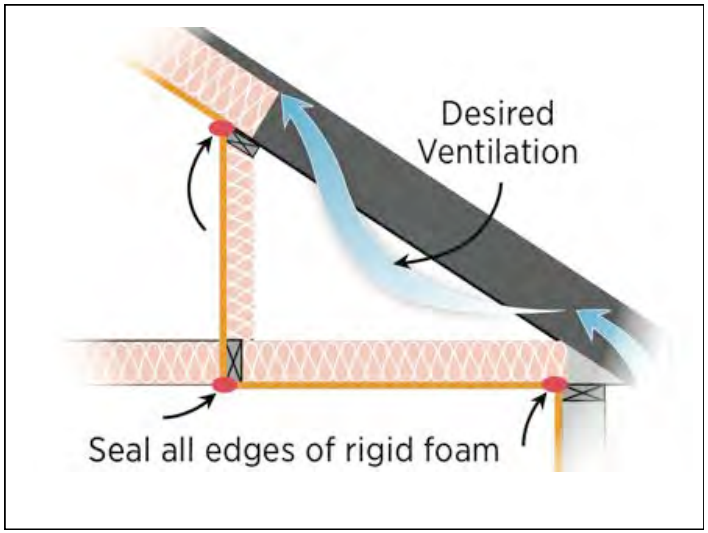


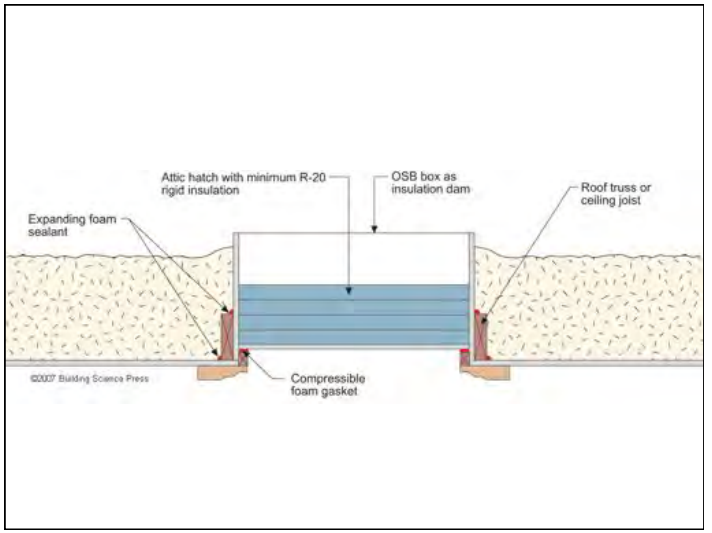

Leaky air handling unit and supply ducts
Air handling unit
Supply
Return
Supply
Depressurized conditioned space inducing infiltration
Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.
Building Science
Joseph Lstiburek 69

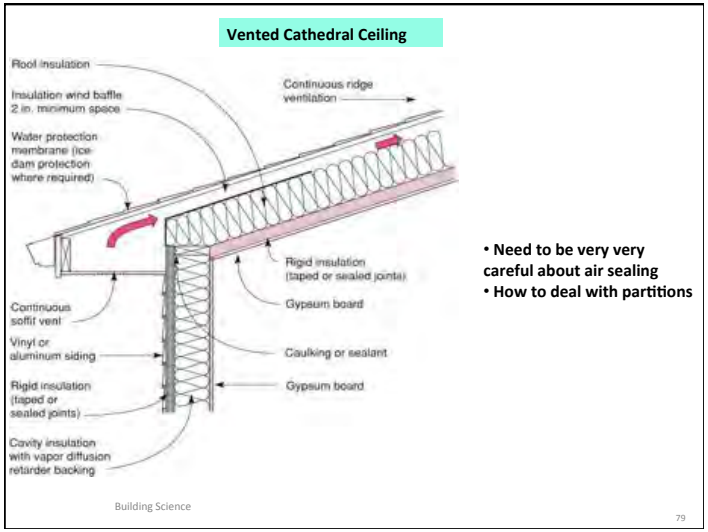

Roof insulation
Insulation wind baffle 2" minimum space
Continuous ridge ventilation
Water protection membrane
Attic ventilation
Continuous soffit vent
Gypsum board with vapor semi-permeable (latex) paint
Consider increasing depth of insulation by using deeper trusses or oversized (longer) trusses
Vinyl or aluminum siding
Caulking or sealant
Rigid insulation (taped or sealed joints)
Gypsum board with permeable (latex) paint
Unfaced cavity insulation, cellulose or low-density spray-applied foam
Building Science
71


Vent chute
Spray foam high-R heel and air seal continuity
Blown-in insulation
Spray foam airtight layer
OSB/plywood sheathing
Gypsum board
Drainage plane and air barrier
2x6 frame wall
Rigid insulation
Cavity fill insulation


R60-R80 is economically sensible







- **Need to be very very careful about air sealing**
- **How to deal with partitions**

Conditioned Attics

- Needs a good new roof
  - Top quality underlayment needed
- Unvented roofs best for complex shapes
  - Air sealing is critical
- Venting if you can easily achieve this
  - Ensure real venting!

Vented complex roof

Building Science 2008

Unvented Cathedralized Attics

- Move air and insulation control from ceiling plane to roof plane
- Moves HVAC into conditioned space
  - Saves lots of energy, reduce problems with comfort, extends life of equipment
- Avoids wind blown rain, snow, and burning wildfire embers

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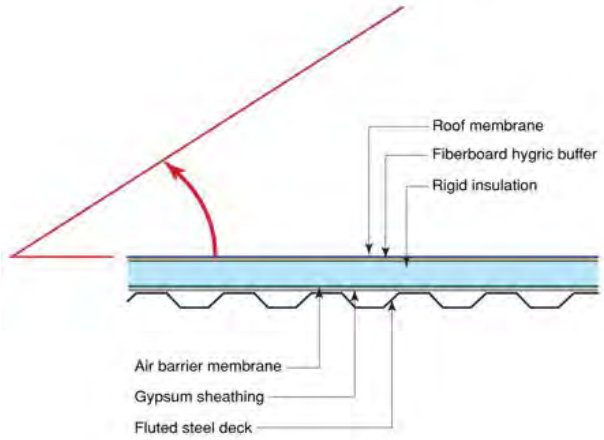
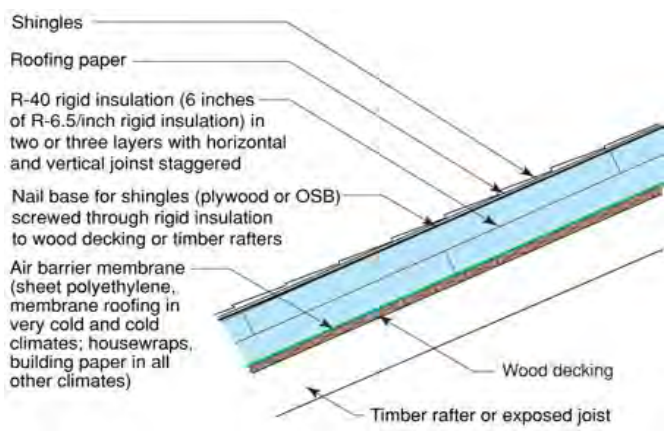
Unvented Cathedral Ceilings

- Not absolutely necessary to vent if airtight and vapour tight material,
  - e.g. spray foam.
  - Or insulated sheathing
- May be most practical in retrofit
- If no wetting, little drying required
  - Demands very high performance
  - >R40, no penetrations
  - spray foam is a practical solution
  - beware thermal bridges

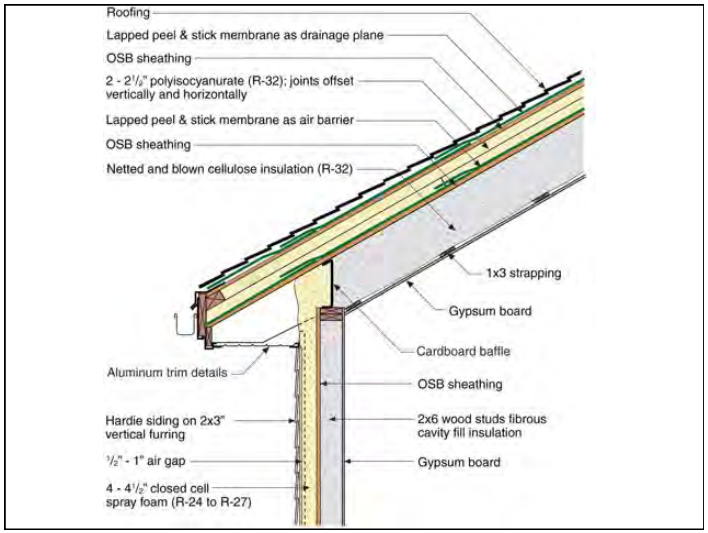
Building Science.com

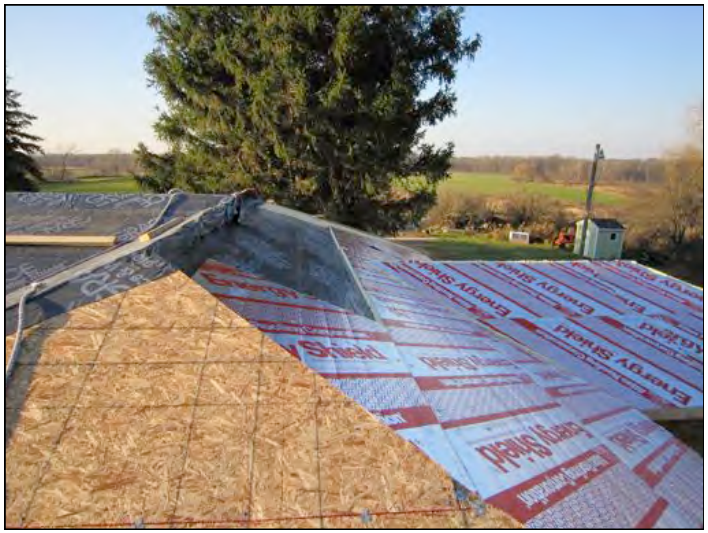


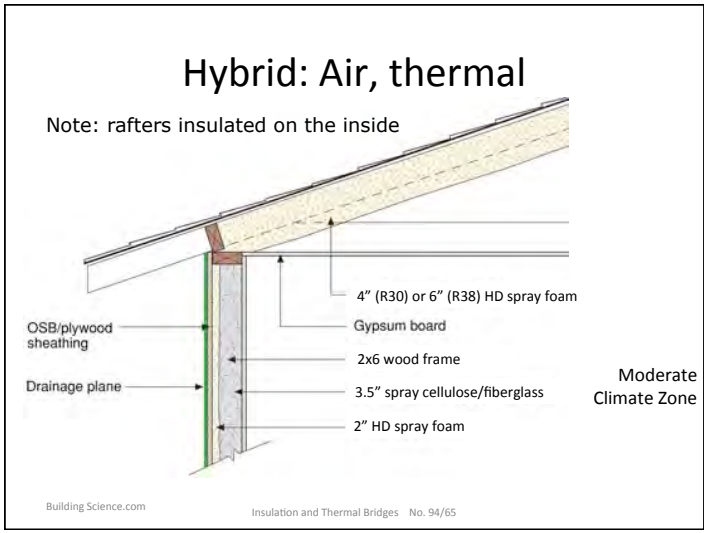
Building Science.com – Roofs 87

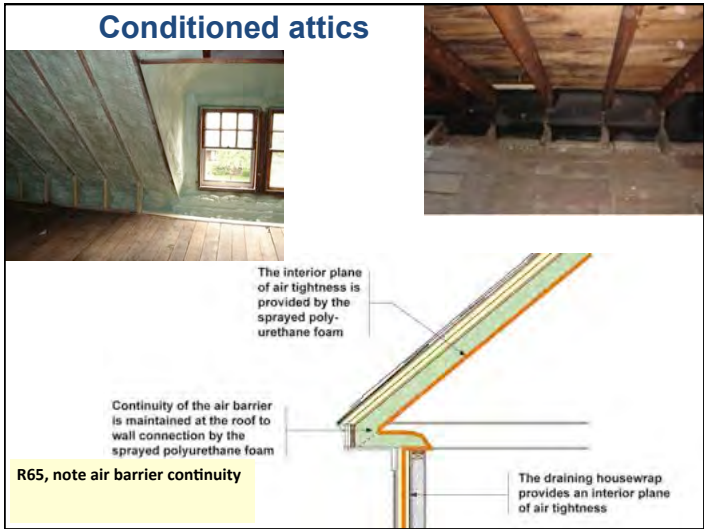


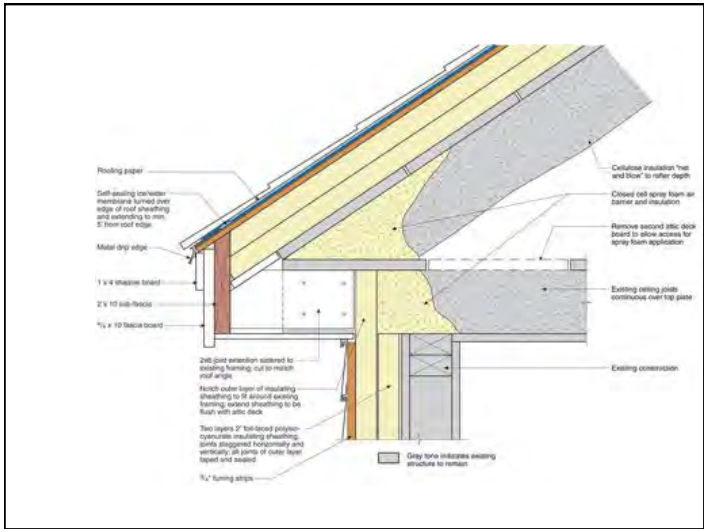
Building Science 2008 Joseph Lstiburek – Roofs 88

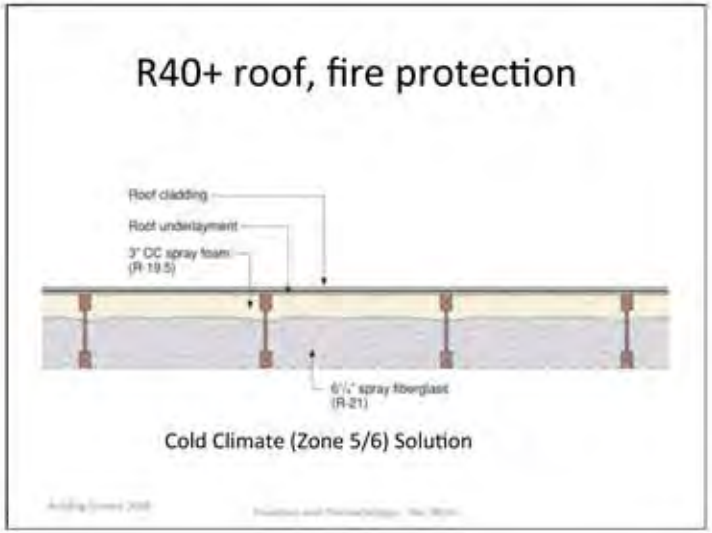

Roofing
Lapped peel & stick membrane as drainage plane
OSB sheathing
2 - 2 1/8" polyisocyanurate (R-32); joints offset vertically and horizontally
Lapped peel & stick membrane as air barrier
OSB sheathing
Netted and blown cellulose insulation (R-32)
1x3 strapping
Gypsum board
Cardboard baffle
Aluminum trim details
OSB sheathing
Hardie siding on 2x3" vertical furring
2x6 wood studs fibrous cavity fill insulation
1/2" - 1" air gap
Gypsum board
4 - 4 1/2" closed cell spray foam (R-24 to R-27)

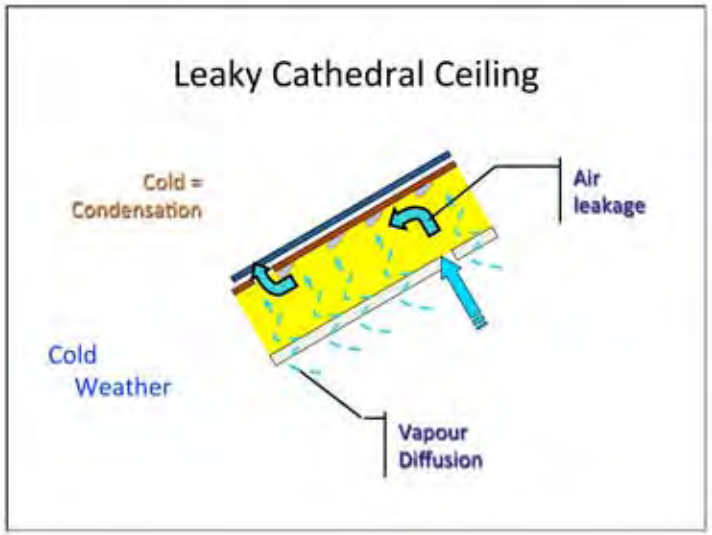



Hybrid: Air, thermal
Note: rafters insulated on the inside
4" (R30) or 6" (R38) HD spray foam
Gypsum board
OSB/plywood sheathing
2x6 wood frame
Drainage plane
3.5" spray cellulose/fiberglass
2" HD spray foam
Moderate Climate Zone
Building Science.com
Insulation and Thermal Bridges No. 94/65


Conditioned attics
The interior plane of air tightness is provided by the sprayed poly-urethane foam
Continuity of the air barrier is maintained at the roof to wall connection by the sprayed polyurethane foam
The draining housewrap provides an interior plane of air tightness
R65, note air barrier continuity

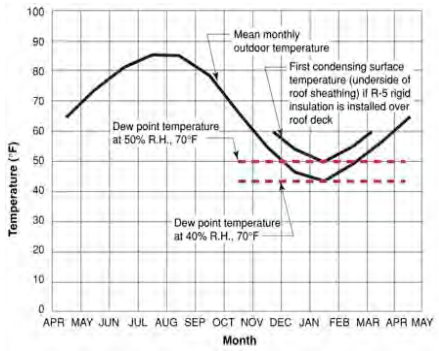



R40+ roof, fire protection
Roof cladding
Roof underlayment
3" CC spray foam
(R-19.5)
6"/" spray fiberglass
(R-21)
Cold Climate (Zone 5/6) Solution


Leaky Cathedral Ceiling
Cold =
Condensation
Air
leakage
Cold
Weather
Vapour
Diffusion


Roof with Insulated Sheathing
Warm = no
condensation
Air
leakage
Cold
Weather
Vapour
Diffusion
Stop thermal bridging
Insulated underside of eave!

E.g. Calculation



Hybrid Roofs with code levels of insulation

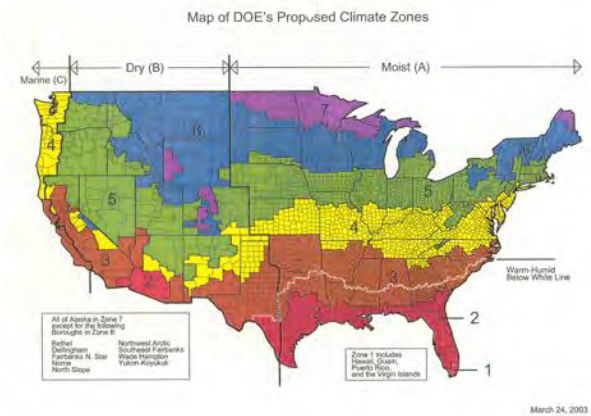
- IRC

TABLE R806.4
INSULATION FOR CONDENSATION CONTROL

CLIMATE ZONE	MINIMUM RIGID BOARD OR AIR-IMPERMEABLE INSULATION R-VALUE [a]
2B and 3B tile roof only	0 (none required)
1, 2A, 2B, 3A, 3B, 3C	R-5
4C	R-10
4A, 4B	R-15
5	R-20
6	R-25
7	R-30
8	R-35

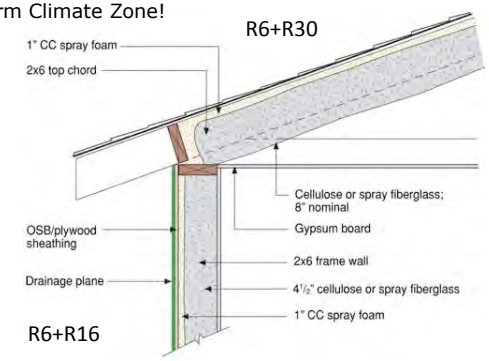
a. Contributes to but does not supersede Chapter 11 energy requirements.

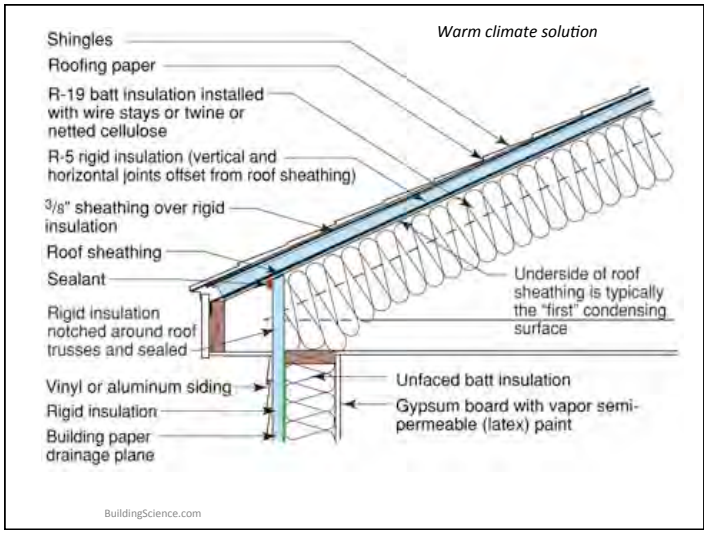
… or air impermeable insulation

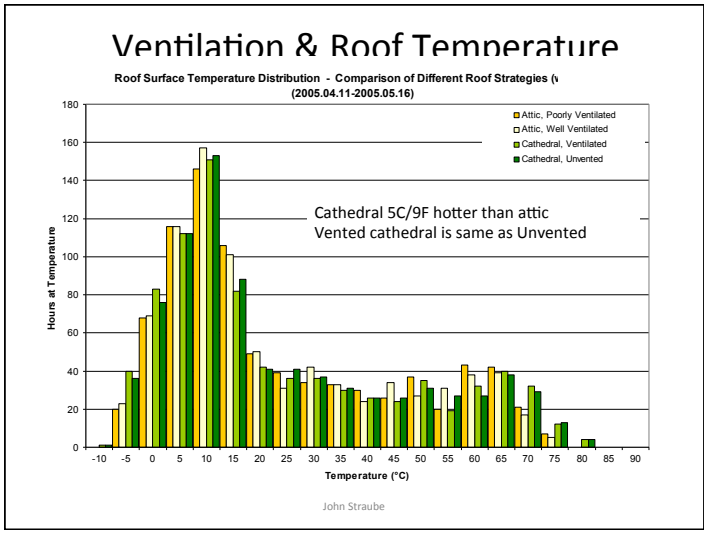


Hybrid: Air, thermal, fire

Warm Climate Zone!




Warm climate solution
Shingles
Roofing paper
R-19 batt insulation installed with wire stays or twine or netted cellulose
R-5 rigid insulation (vertical and horizontal joints offset from roof sheathing)
3/8" sheathing over rigid insulation
Roof sheathing
Sealant
Rigid insulation notched around roof trusses and sealed
Vinyl or aluminum siding
Rigid insulation
Building paper drainage plane
Underside of roof sheathing is typically the "first" condensing surface
Unfaced batt insulation
Gypsum board with vapor semi-permeable (latex) paint
BuildingScience.com

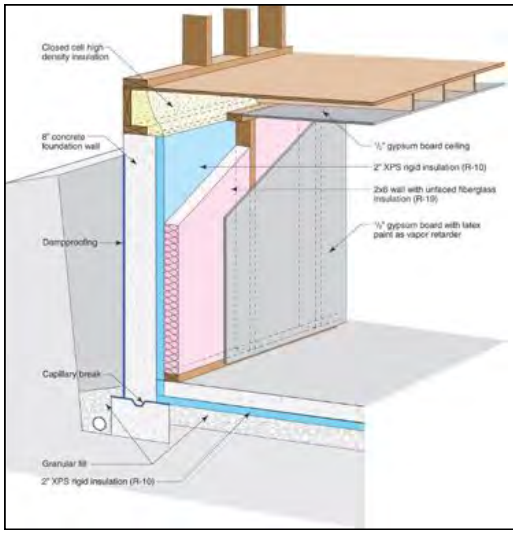

Ventilation & Roof Temperature
Roof Surface Temperature Distribution - Comparison of Different Roof Strategies (
(2005.04.11-2005.05.16)
Attic, Poorly Ventilated
Attic, Well Ventilated
Cathedral, Ventilated
Cathedral, Unvented
Cathedral 5C/9F hotter than attic
Vented cathedral is same as Unvented
Hours at Temperature
Temperature (°C)
John Straube


Low slope roof upgrade

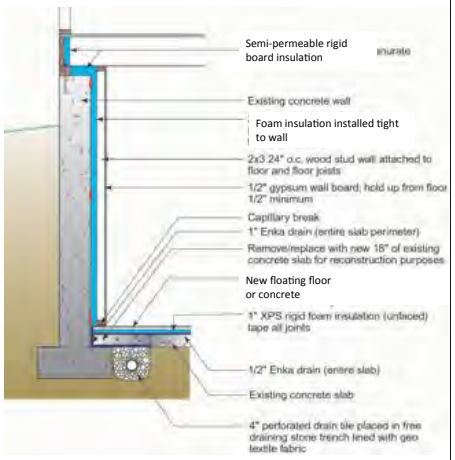
Below Grade

Basements & Crawlspaces

- Easy to retrofit and improve from the interior
- Ceiling height is the big restriction for slab solutions
- Crawlspaces: best to seal & Condition
- Slabs: insulate, control moisture



- Retrofit
- Solves slab wetness & cold

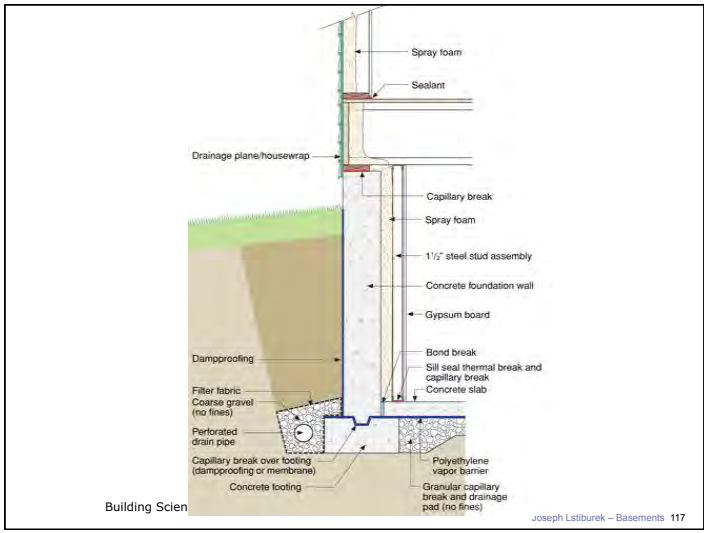


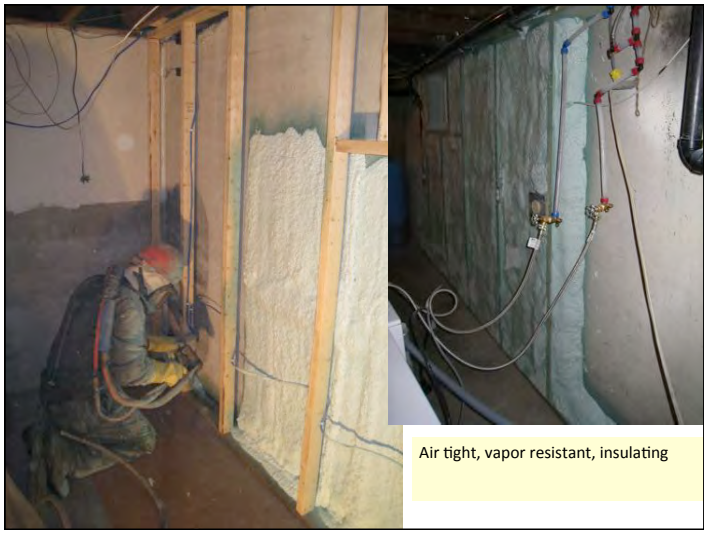
www.BuildingScience.com

Basements No. 115/73

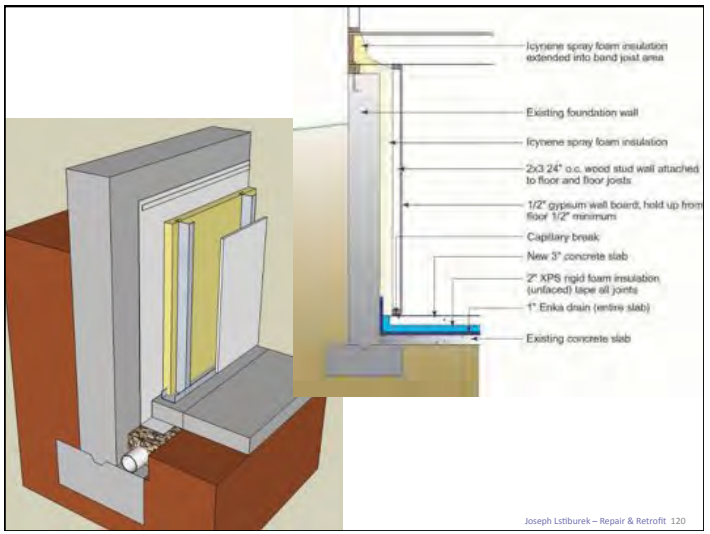
Building Science

Joseph Lstiburek – Basements 116

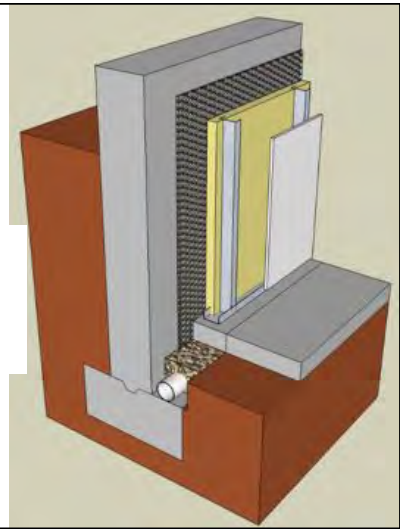

Spray foam
Sealant
Drainage plane/housewrap
Capillary break
Spray foam
1½" steel stud assembly
Concrete foundation wall
Gypsum board
Dampproofing
Bond break
Sill seal thermal break and capillary break
Concrete slab
Filter fabric
Coarse gravel (no fines)
Perforated drain pipe
Capillary break over footing (dampproofing or membrane)
Concrete footing
Polyethylene vapor barrier
Granular capillary break and drainage pad (no fines)
Building Scien
Joseph Lstiburek – Basements 117

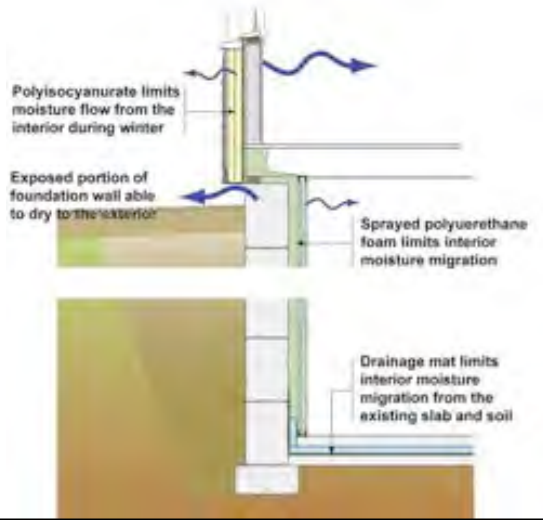

Air tight, vapor resistant, insulating


R24+, ready for drywall

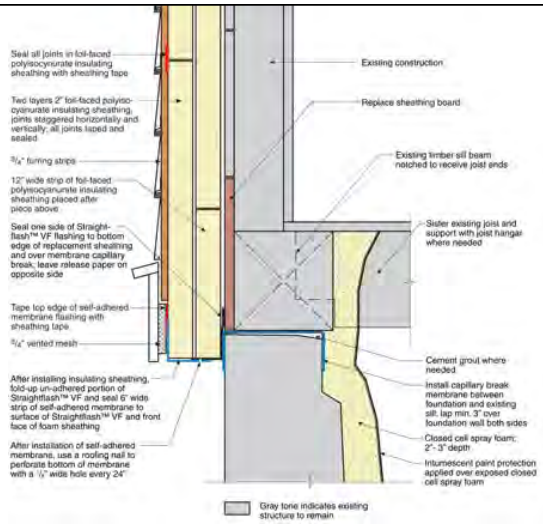

Icynene spray foam insulation extended into band joist area
Existing foundation wall
Icynene spray foam insulation
2x3 24" o.c. wood stud wall attached to floor and floor joists
1/2" gypsum wall board, hold up from floor 1/2" minimum
Capillary break
New 3" concrete slab
2" XPS rigid foam insulation (unfaced) tape all joints
1" Enka drain (entire slab)
Existing concrete slab
Joseph Lstiburek – Repair & Retrofit 120

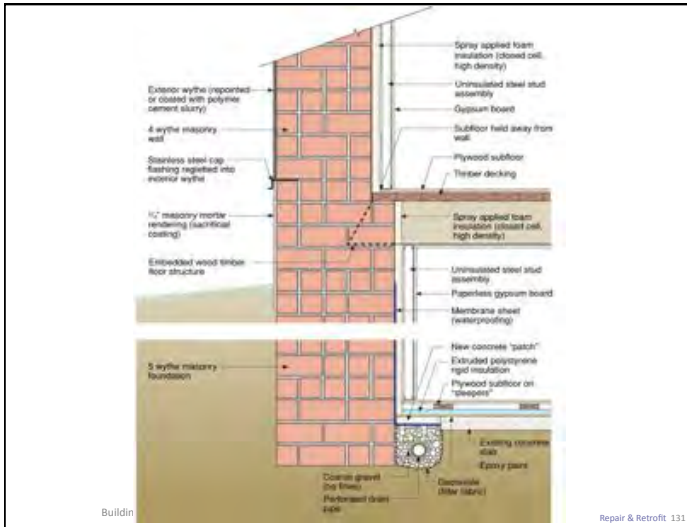
- Full drainage layer rarely needed
- Fasten lath through to masonry to increase adhesion of foam
- Beware leaching of lime if too much leakage is allowed





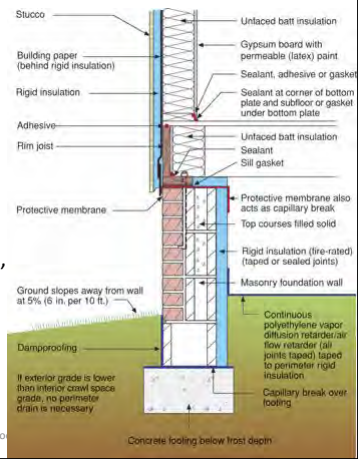

Sump pit basin in corner



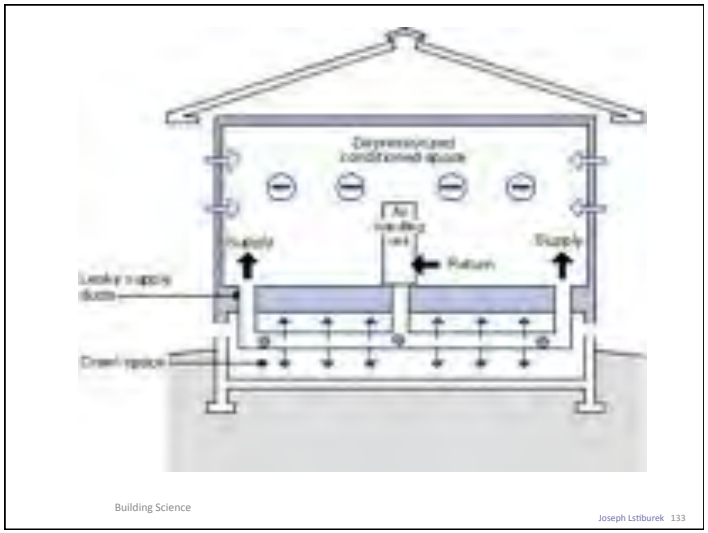


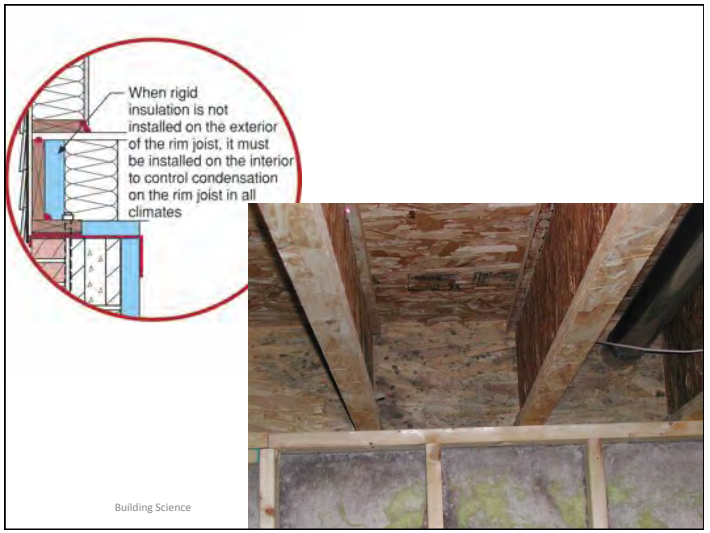
Crawlspace

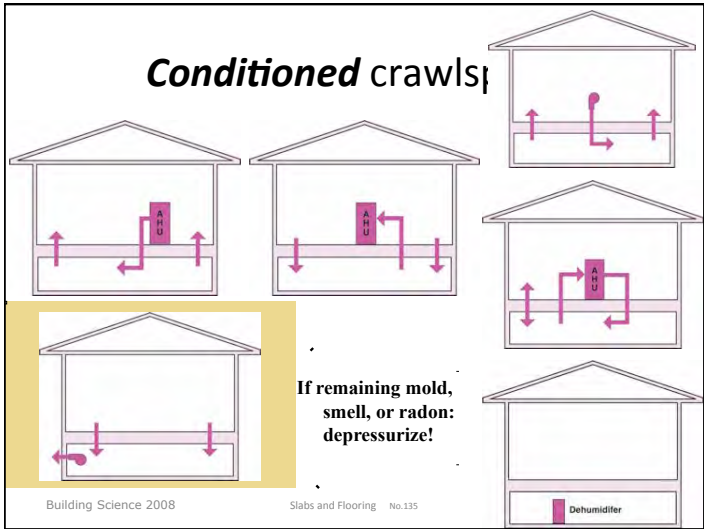
- Act as short basements
- Unvented
- But **Conditioned**!
  - Must have conditioned air to/from space
  - Air movement from conditioned space via fans, HVAC
- Airtight and vapor tight floor covering
- Floor drain?

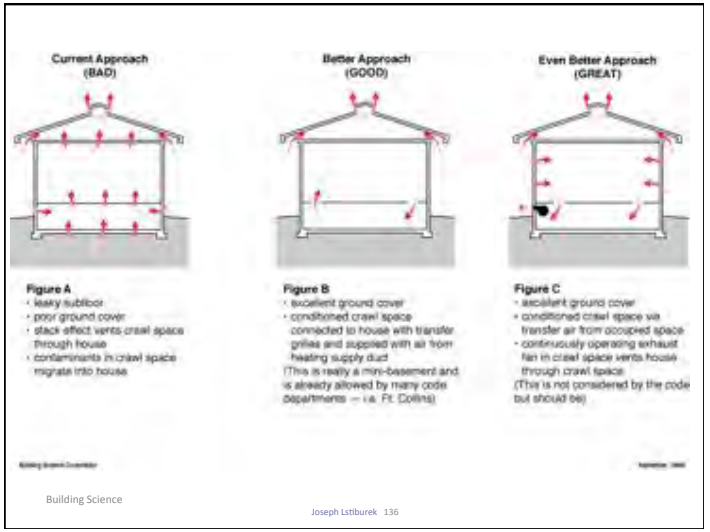


Building Science 2008 Slabs and Flo


Depressurized conditioned space
Return
Supply
Leaky supply ducts
Crawl space
Building Science
Joseph Lstiburek 133

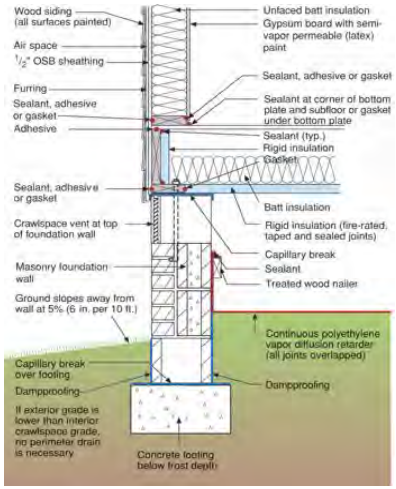

When rigid insulation is not installed on the exterior of the rim joist, it must be installed on the interior to control condensation on the rim joist in all climates
Building Science


Conditioned crawlsp
AHU
AHU
AHU
If remaining mold, smell, or radon: depressurize!
Dehumidifer
Building Science 2008
Slabs and Flooring No.135


Current Approach (BAD)
Better Approach (GOOD)
Even Better Approach (GREAT)
Figure A
Figure B
Figure C
Building Science
Joseph Lstiburek 136

Vented

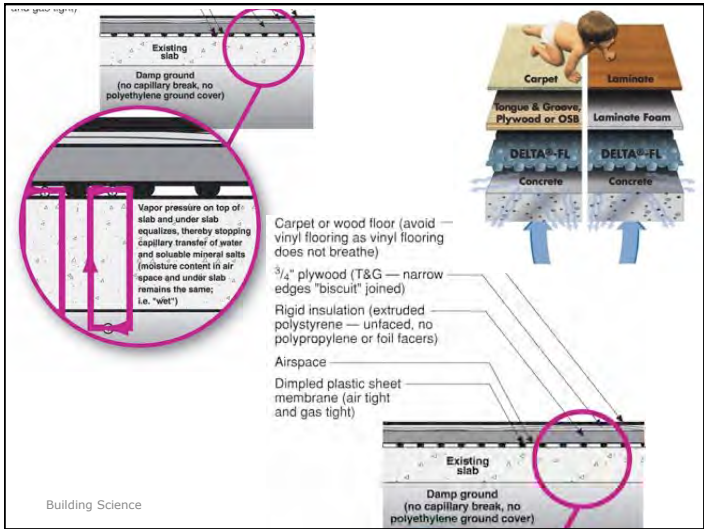
- Need to vent some times
- Poly on soil
- Wall upside down
- Flood drains
- Animal control



Building Science 2008 Slabs and Flooring No.137

Building Science Joseph Lstiburek 138

Building Science Joseph Lstiburek 139



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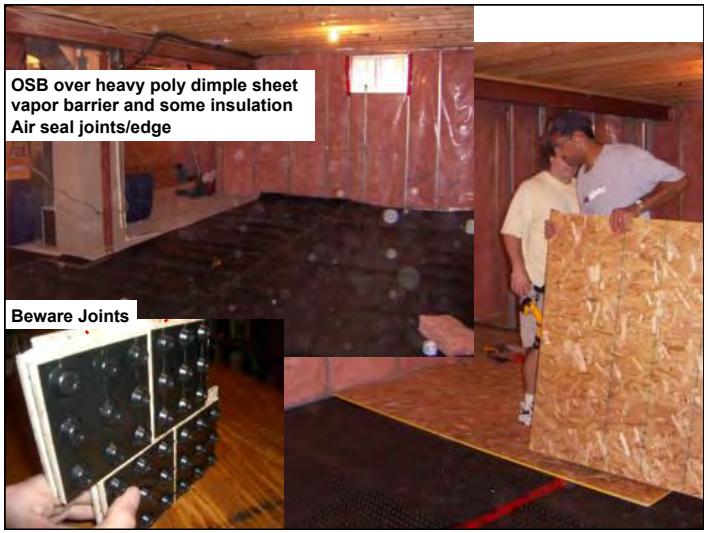
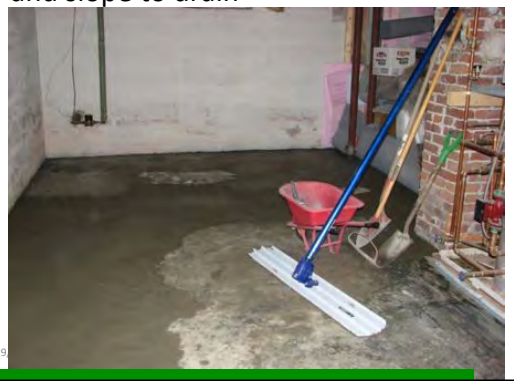


Slab Treatment – floor over existing slab

Step 1: add topping to smooth existing slab and slope to drain



10/19/

Slab Treatment – floor over existing slab

Step 2: install drainage mat with all seems and penetrations sealed

10/19/2009 143

Slab Treatment – floor over existing slab

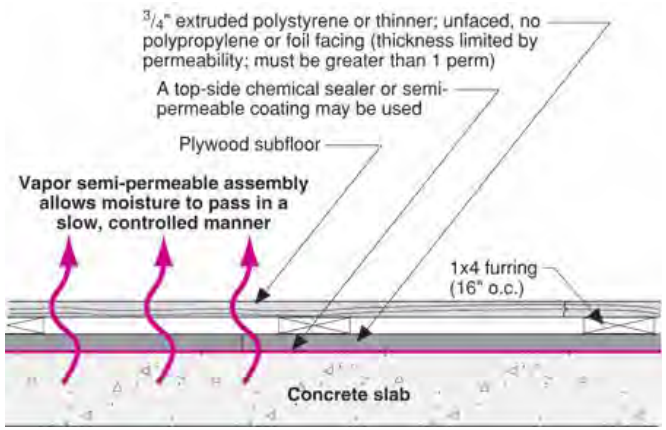
Step 3: install thermal control layer - air tight installation for condensation control

10/19/2009 144

Slab Treatment – floor over existing slab

Step 4: floating subfloor – tongue and groove sides, ends biscuit joined

10/19/2009 145



Building Science Slabs and Flooring No.146

Building Science 2006

Lowest cost

Floor can sound "clicky"
Not a lot of insulation

Building Science 2008

Windows

Replacement & Over-Insulation

- Details vary
  - "innie" OR "outie"
  - Flanged OR Unflanged
  - Drainage plane at sheathing OR insulation exterior face
- Eight variations

Drainage

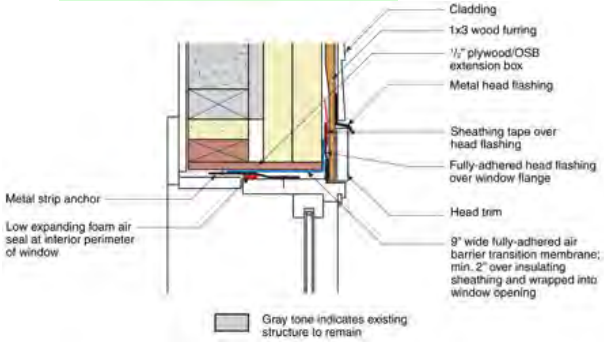
- Add subsill drainage when new windows installed

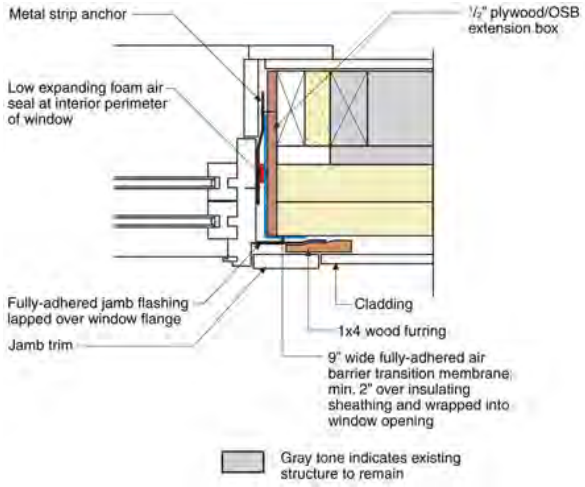
New Windows

Photos courtesy of Dan Morrison, *Fine Homebuilding Magazine*

New Windows

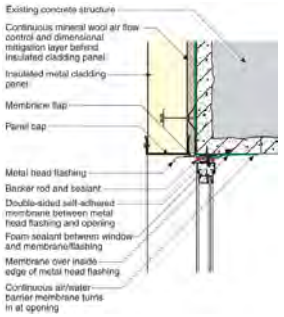
Windows: add a window buck is best
Control rain leakage, use subsill flashing





Deep Energy Retrofit Details

- Windows
  - Replacement in concrete wall



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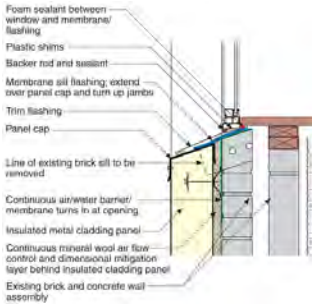
Deep Energy Retrofit Details

- Windows
  - Replacement in brick and CMU wall



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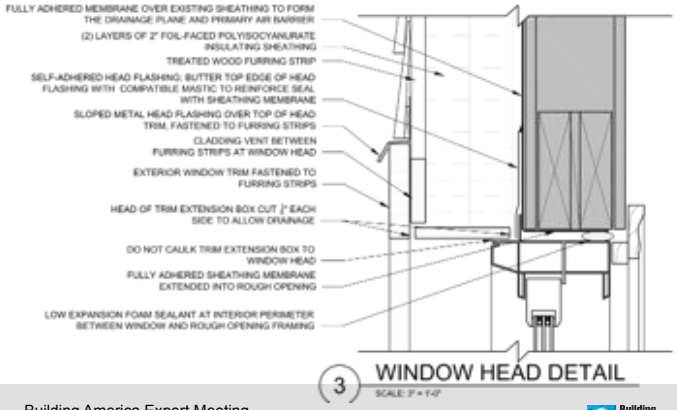
- Windows
  - Replacement in wood framed wall – with flange – "innie"



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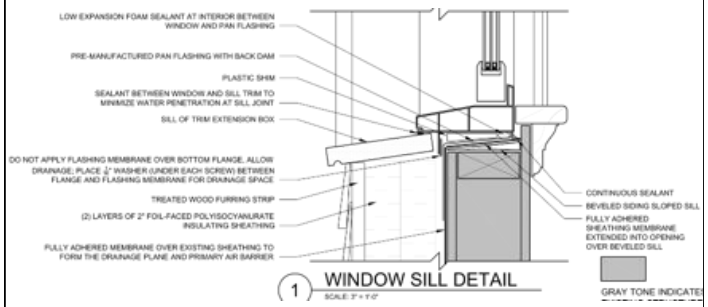
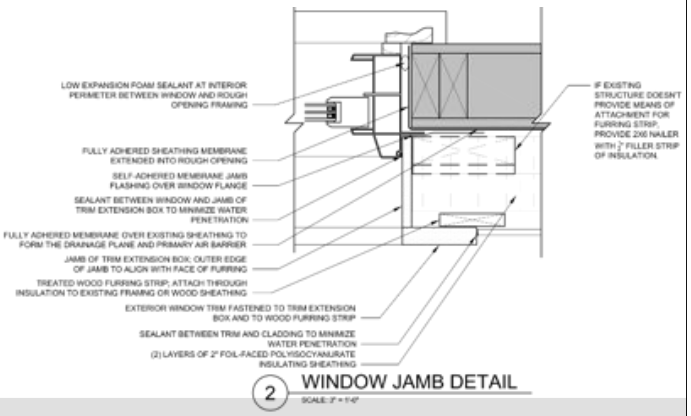
- Windows
  - Replacement in wood framed wall – with flange – "innie"

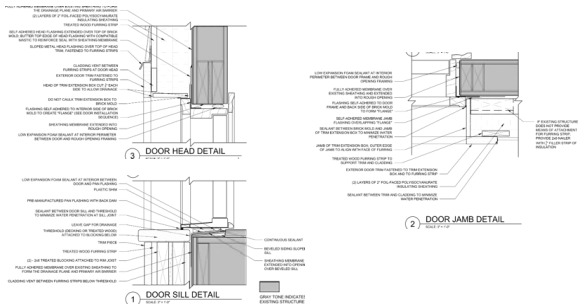


- Windows
  - Replacement in wood framed wall – with flange – "innie"



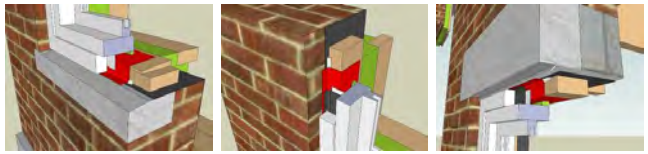
Deep Energy Retrofit Details

- Doors
  - Replacement in wood framed wall



Deep Energy Retrofit Details

- Windows
  - Replacement in brick wall



Storms

- Interior and Exterior
- Key issue is operability
  - Fixed are easy and high performance
- Can improve R1 single glazing to R3 with low-e interior storms
- Storms on interior must be tight
- Exterior must be leaky (5:1 ratio)

Storms

- Airtight interior low-e storms preferred

Vent Ratios

Outside Temp. °F	Minimum Ratio of Outside to Inside Air Flow to Window Space
40	7
20	9
0	16
-20	25
-40	41