Kohta Ueno

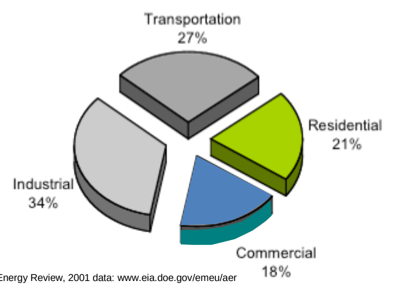
Massachusetts Deep Energy Retrofit Program: Lessons Learned

September 15, 2011

Introduction

Building Energy Use

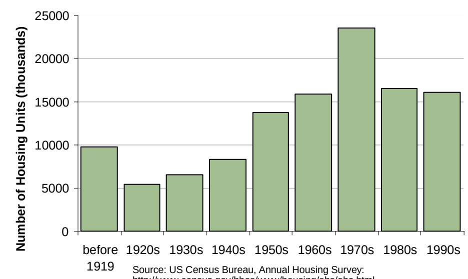
Primary Energy Consumption by Sector, 2001



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

Existing Housing Stock

Age of US Housing Stock (all unit types)



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

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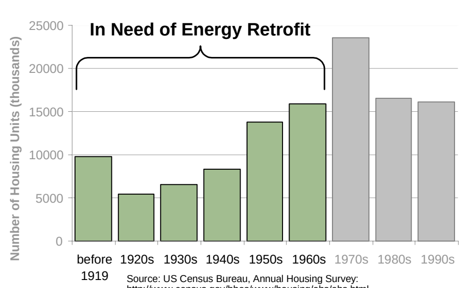

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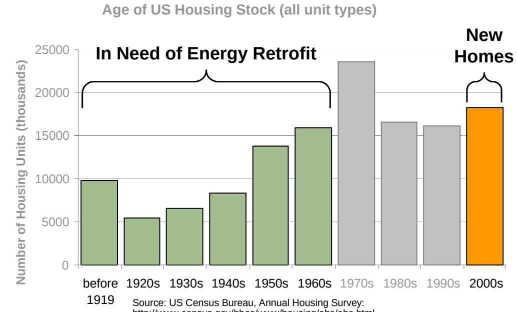

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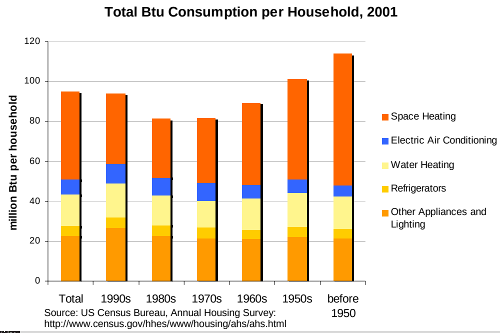
How Old and New Houses Use



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Enclosure Retrofit

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

Deep Energy Retrofits

- Significant upgrades are incrementally less expensive
  - Small upgrades very cost effective, but small (10-25% reductions)
  - mid-range upgrades (15-50%) usually really expensive per energy saved
- Deep retrofits (>50%) secure buildings future
  - Allow for new styles, use, etc.
  - Leap frog current housing

National Grid DER Pilot Program

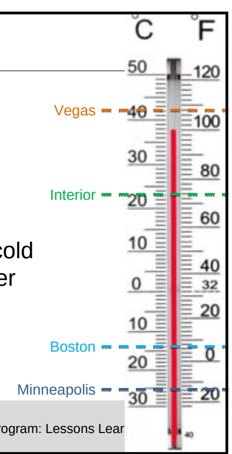
- Residential deep energy retrofit (DER) pilot program
- Incentives ~$35 to $60 K
- R-60 roof, R-40 walls, R-20 bsmt wall, U≤0.2 windows
- Eight completed projects
- 27 current active projects
- BSC provides technical guidance for program

nationalgrid THE POWER OF ACTION

Las Vegas ≠ New England

Delta T Comparisons

- ΔT is what drives heat loss/gain—therefore R values, energy paybacks, etc.
- "Dominant load" (heating vs. cooling dominated climates)
- Dominant ΔT much higher in cold climates (New England)—higher R value targets



R-Value Targets

Climate Zone	Wall	Vented Attic	Compact Roof	Basement Wall	Exposed floor	Slab edge[1]	Windows (U/SHGC)	Sub-slab[2]
1	10	40	35	5	10	none	yes	none
2	15	50	40	10	20	5	0.35/<.25	none
3	20	50	45	10	20	7.5	0.30/<.3	5
4	25	60	45	15	30	7.5	0.30/<.35	7.5
5	30	65	50	15	30	10	0.24/<.50	7.5
6	35	75	60	20	40	10	0.18/--	10
7	40	90	65	25	45	15	0.15/--	15
8	50	100	75	35	50	20	0.15/--	20

Table 2: Current Recommended "True" Minimum R-value (+/-)[3] including thermal bridging

- "True" R value: R-13 2x4 wall ≈ R-8; R-19 2x6 wall ≈ R-12
- Estimated targets—will vary with local construction costs, energy costs, client targets

Source: RR-1005: High R-Value Enclosures for High Performance Residential Buildings in All Climate Zones

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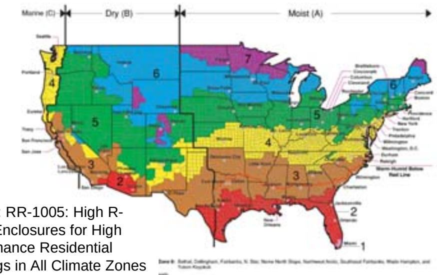
Airtightness targets

- Zones 1-3: 0.25 CFM 50 per sf enclosure area
- Zones 4-6: 0.20 CFM 50 per sf enclosure area
- Zones 7-8: 0.15 CFM 50 per sf enclosure area



Source: RR-1005: High R-Value Enclosures for High Performance Residential Buildings in All Climate Zones

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Construction Differences

But this talk is about New England deep energy retrofits…

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Walls

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Exterior Insulation Retrofits

- Going beyond nominal R-13/R-19 walls = thicker walls
- Exterior retrofit advantages
  - Insulation outboard of vulnerable structure
  - Interior is habitable during retrofit
  - Retain interior finishes (lose exterior finishes)
  - No loss in interior square footage
  - Can inspect condition of enclosure (during cladding removal)
  - Interior stairwells (code minimum widths)

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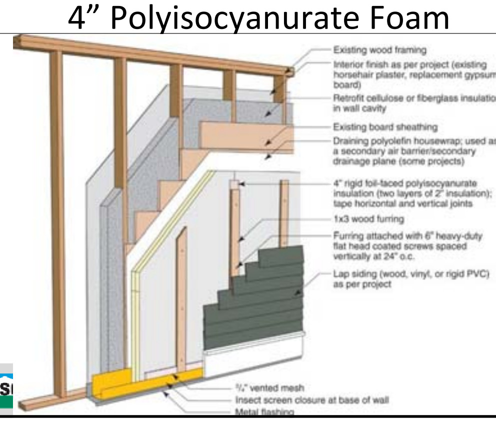
4" Polyisocyanurate Foam



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4" Polyisocyanurate Foam

4" Polyisocyanurate Foam

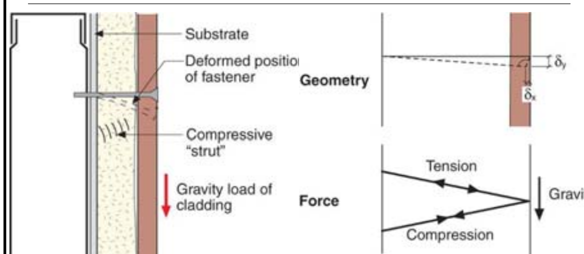
Foam Sheathing Cladding Attachment

250 lbs/113 kg load (7.8 psf): <0.003" deflection

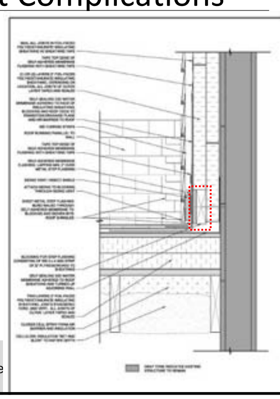
Wood siding ~2 psf
Fiber cement 2-3 psf
Stucco 8-10 psf

Image c/o Petersen Engineering

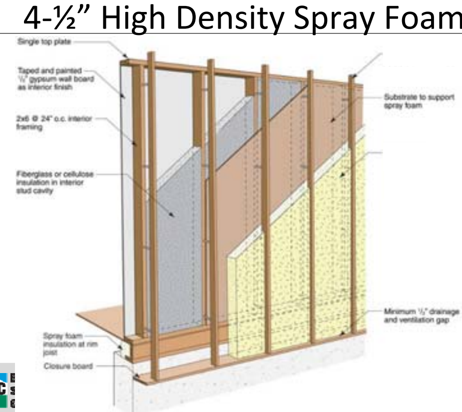
Foam Sheathing Cladding Attachment

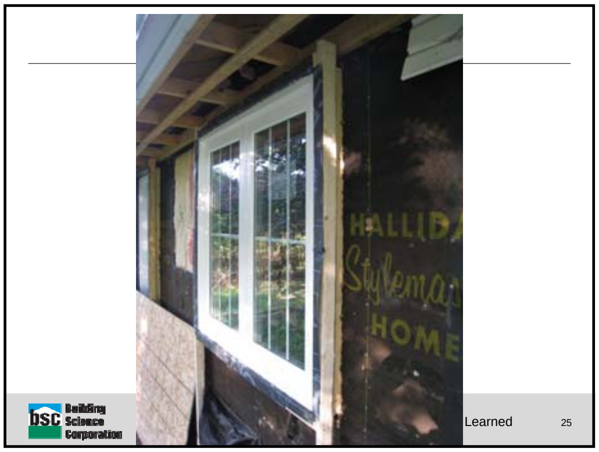


Exterior Retrofit Complications



4-½" High Density Spray Foam

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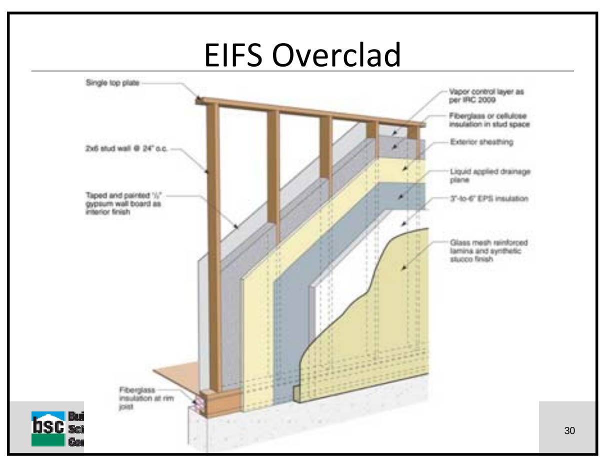
EIFS Overclad
Single top plate
2x6 stud wall @ 24" o.c.
Taped and painted ½" gypsum wall board as interior finish
Fiberglass insulation at rim joist
Vapor control layer as per IRC 2009
Fiberglass or cellulose insulation in stud space
Exterior sheathing
Liquid applied drainage plane
3"-to-6" EPS insulation
Glass mesh reinforced lamina and synthetic stucco finish
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EIFS Overclad

- Insulation
- Protection of existing wall
- Aesthetic improvement?

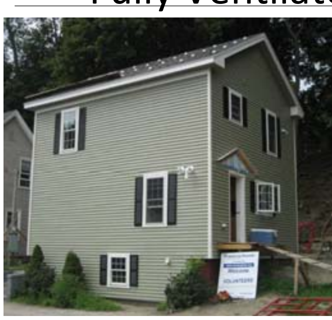
Metal Panel Overclad

Roofs

Fully Ventilated Attics

- Can re-roof whenever, with whatever
- Deal with moisture, then add insulation
  - Rain leaks, air leaks
- 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, R75-R100 sensible

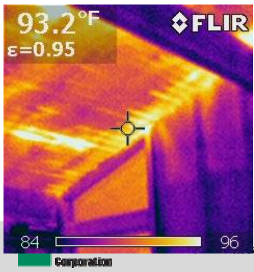
Fully Ventilated Attics

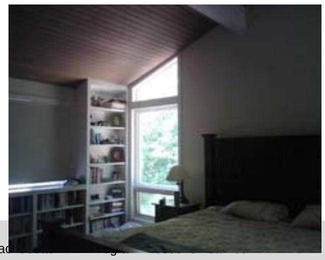


Fully Ventilated Attics

Why an Unvented Roof?

- Difficult air barrier to retrofit @ ceiling plane?
- Leaky ductwork and AHU in attic?
- More space (dormers, bedrooms in attic)?





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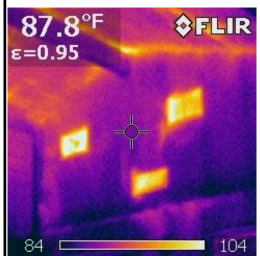

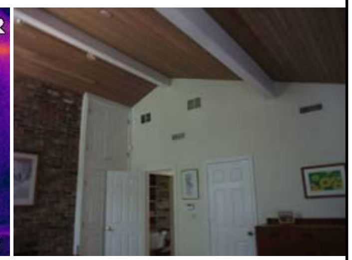

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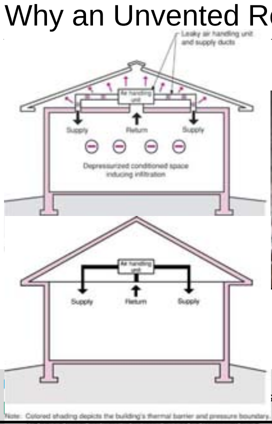
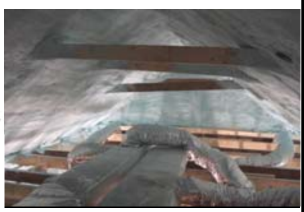
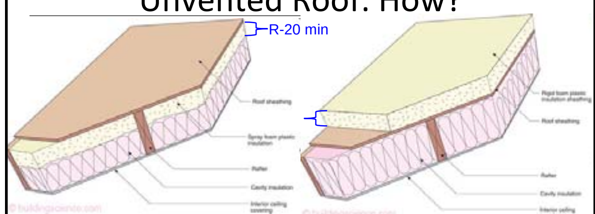




Unvented Roof: How?



- 2006 IRC: R806.4 Unvented attic assemblies
- Minimum R-value of "air impermeable insulation"
- Zone 2B/3B + tile roof: none required
- Nail base needed with rigid foam on roof deck

Windows

Water Control: Pan Flashings



- Deep energy retrofits (addition of insulation at existing wall) can make the wall more vulnerable to water leakage
- Previously "survivable" leaks may no longer be able to dry out.

Retrofitting "Superwindows"

U=0.25 to ~0.18 for triple glazed + low E films + Krypton fill gas + warm edge spacers

Comparison U=0.35 double glazed, low E, fill gas (?)

"Innie" and "Outie" Windows

"Innie" vs. "Outie" Windows

- "Outie" Advantages
  - Simpler drainage plane connections/geometry
  - Lower cost (extension trim is interior material)
  - Similar appearance to conventional construction

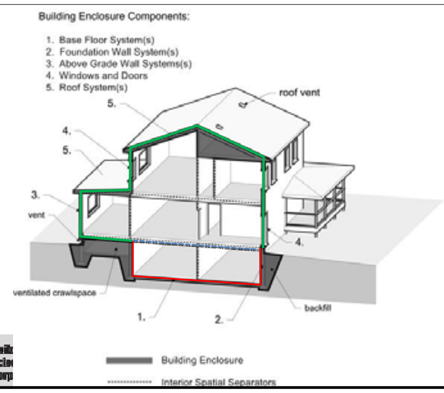
"Innie" vs. "Outie" Windows

- "Innie" Advantages
  - Window supported by lumber frame (foam install)
  - Greater protection from wind-driven rain (inset)
  - Less condensation risk (?)
  - Can use existing window trim
  - Solar shading (advantage or disadvantage)

"Outie" Window Installation Options

Foundations

Basement Insulation Location



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Basement Insulation Location

- 4.6 ACH50; 2129 CFM 50 total; 1100 CFM 50 through floor
- 8.5 ACH50; 3590 CFM 50 total; 1740 CFM 50 through floor

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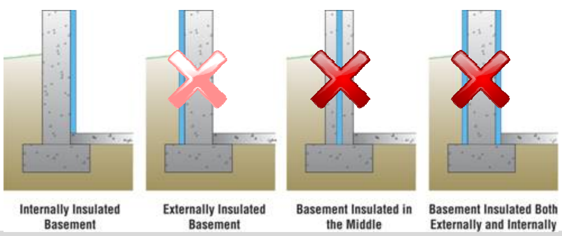
Insulation Location Choices

- Retrofits: interior insulation is often the only available option



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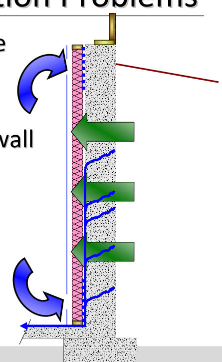
Basement Insulation Problems

- Wintertime interior moisture condensation (like above-grade walls)
- Condensation at bottom of wall (thermal lag of soil)
- Lack of drying of assembly (moisture from concrete and soil); soil is at 100% RH
- Liquid water through wall



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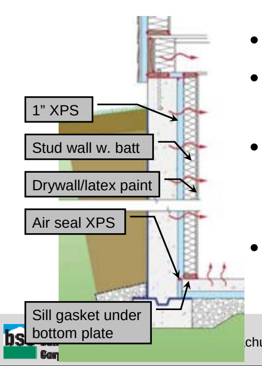
Recommended Wall Assembly



- XPS is moisture tolerant
- Wintertime condensation controlled
- Summertime (bottom of wall) condensation controlled
- Concrete can dry through XPS at a safe rate

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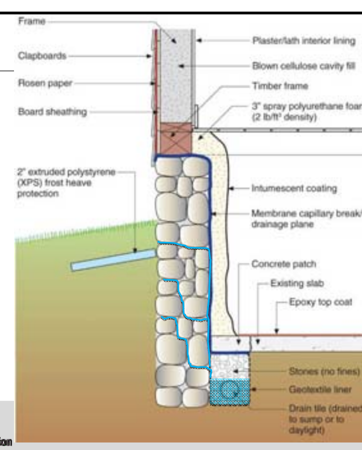

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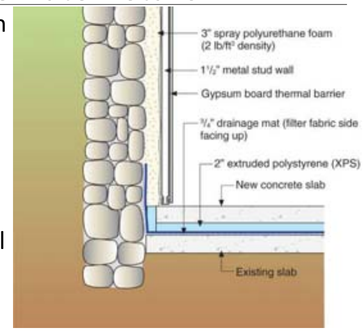
Interior Rubble Retrofit

Alternate Details

- Insulated slab on top of existing slab
- No membrane up wall surface
- Wet vs. dry basement?
- Light gauge steel framing interior wall



Spray foam basement insulation

- Open cell
  - Climate specific
- Closed cell

Spray Foam "Bathtub"

Air Barriers

Retrofitting Exterior Air Barriers

Bedford, MA "Farmhouse"

6.2 ACH 50

No secondary air barrier (housewrap w. connections); mediocre roof-wall connections

Arlington, MA "Duplex"

5.0 ACH 50

Basement compartmentalized? (1000 CFM 50 vs. 2129 CFM 50 total)

Jamaica Plain, MA

2.4 ACH 50

Vented space under existing slate roof; spray foam. All spray foam basement ("bathtub"). No clear failure points.

Retrofitting Exterior Air Barriers



St. Agatha, ON	Belmont, MA	Northampton, MA
~1 ACH 50	0.7 ACH 50	0.75 ACH 50
Spray foam on exterior; all windows well air sealed; casement/ awning typical	Rigid foam as air barrier, "chainsaw" retrofit of roof overhangs/eaves, meticulous air barrier, blower door tests in progress	Taped ZIP wall air barrier layer roof & walls; spray foam basement. 40% new construction

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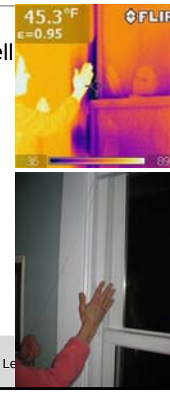
Retrofitting Exterior Air Barriers

- Other projects in 1.5 ACH 50 range; ~3-5 ACH 50 outliers, under 1 as well
- Roof-wall connections
- Roof geometries
- Wall-foundation connections
- Window air leakage
- Wall-window connections
- Porch/deck attachments
- Mechanical system penetrations
- Rigid air control layer on walls



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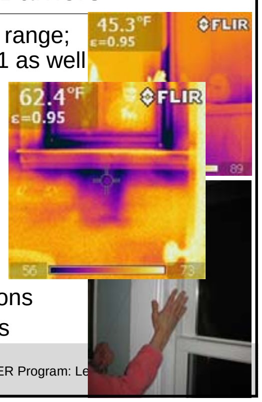

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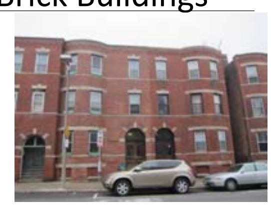
Air Barriers and Brick Buildings

- Pre-retrofit test
- Brick (2-wythe); front and rear exposed, party walls
- Vinyl replacement windows
- Whole-building test
  - 11.7 ACH 50
  - 0.9 CFM 50/sf enclosure
- Roof, chimneys, window-wall interfaces?

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Mechanicals

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Mechanical Retrofit

- Range of approaches
- Often similar to new construction
- After enclosure upgrade
  - Much smaller and quieter systems can be chosen
- Air-based can be replaced with hydronic
- Low-temperature (more efficient) systems can be used (e.g., steam → hot water)
- For ventilation load add HRV (or ERV)

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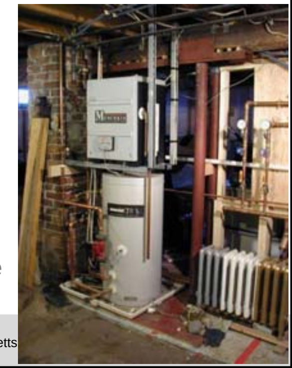
Heating: Steam to Hydronic

- Removed hazardous material
- Freed valuable floor space
- More even control
- Efficient, sealed combustion
- Provided option for more efficient water heater



Heating: Steam to Hydronic

Manifold Distribution – home run to every radiator

Heating: Steam to Hydronic

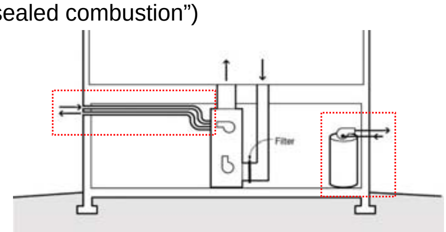
PEX tubing:
Minimally destructive distribution

Heating: Steam to Hydronic

Thermostatic Radiator Valves (TRVs): every radiator its own zone

Combustion Safety

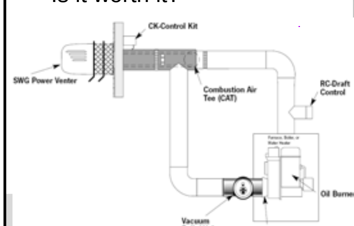
- Backdrafting risk in tighter houses
- Combustion air should be drawn from outside ("sealed combustion")



Sealed Combustion

Retrofit atmospherically vented?

- Maybe boilers
- Not water heaters
- Is it worth it?



Mini-Splits

Mini-split non-ducted head

Mini-split short ducted system

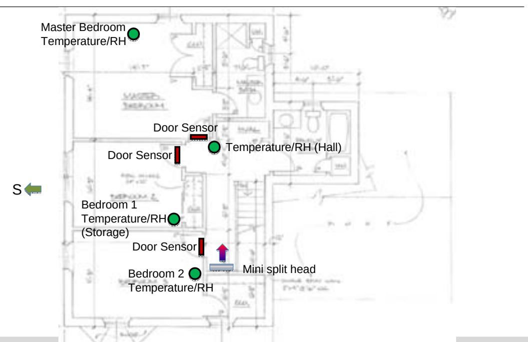
Mini-split outdoor unit

- Both heating & cooling
- Multi-splits (single outdoor unit)
- Systems with SEER=26 and HSPF=11 available

Mini-Splits Heating/Cooling in Cold Climate

- 1818 sf house, solar-oriented, superinsulated (12" spray foam walls, R-80 roof), triple glazed windows, very airtight
- Central Massachusetts location
- Net zero performance

Mini-Split Heat Pumps

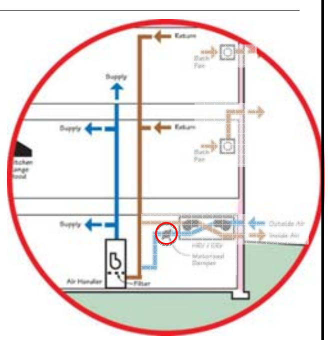


Mini Split Heating Conclusions

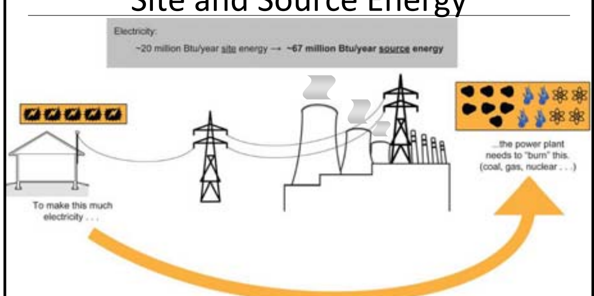
- Single point heating per floor can keep rooms close to setpoint (~5-7° F)
- Deep heating setbacks cause greater differences
- Leaving doors closed increases temperature differences
- Deep setbacks result in long runtimes for mini split heat pumps
- "Acceptable sizing" data inconclusive, but other practitioners in colder climates have hard data
- Effective trade-off for superinsulated enclosure

HRV Induced Flow

- AHU running, HRV not running→ unintended airflow
- Overall air leakage + duct leakage issues
- Need motorized damper in addition to backdraft dampers

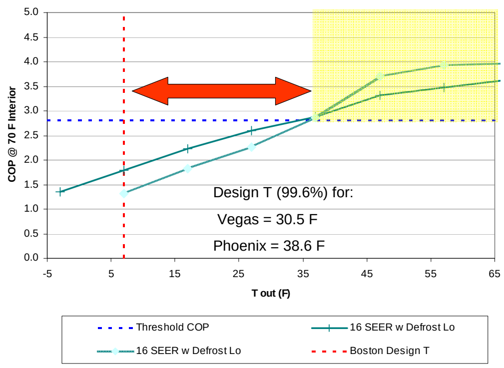


Site and Source Energy



- Site-source conversion changes based on location/grid, time of day, season
- Site-source number has change of improving with more renewable power

Heat Pump Behavior



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Questions?

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EEBA Course Description

- **Short Description:**

  A New England utility company has implemented a deep energy retrofit pilot program, with the goal of energy savings of over 50%. Several projects have been completed, with several more in progress and under construction. This session will cover measures implemented, savings achieved, and lessons learned in this program..

  Learning Objectives:
- Understand some of the benefits and risks of exterior wall retrofit insulation systems.
- Understand the pros and cons of including the basement within the conditioned space.
- Understand some of the challenges involved in retrofitting exterior air barriers to existing buildings.
- Understand the magnitude of savings achievable with these types of deep energy retrofits.

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