Intro to Advance Building Science: Enclosure Design Principals of Energy Efficient Buildings

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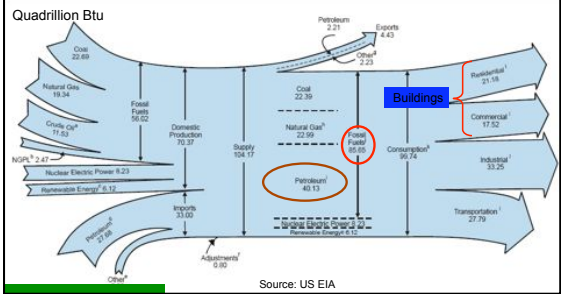
Overview

- A couple of problems
  - Climate change
  - Energy security
- Solutions?
  - Use less energy
  - Generate renewable energy
  - Switch to low carbon (NG) & sequester CO2

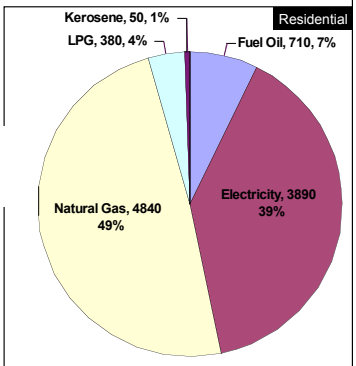
Total Energy

Domestic Supply almost 70%
40% of total supply is petroleum
23%of total supply is Nat gas
Buildings are #1 use (40%)
Urban planning? Embodied Energy?



Building Energy

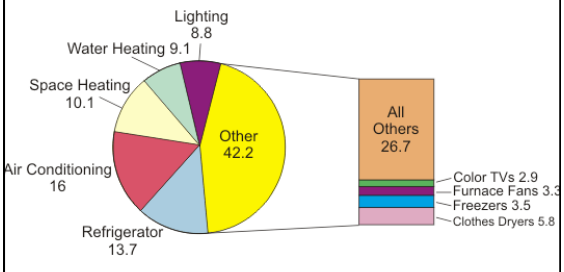
Mostly NG (heating, hotwater) and electricity (cooling, lighting, etc)



Building Science 2008

Building *Electrical* Use

Residential

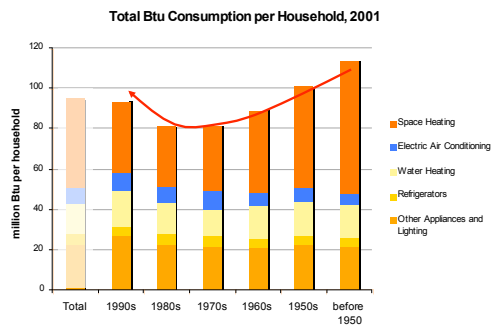


Source: Energy Information Administration, Form EIA-457A, B, C, E, and H of the 2001 Residential Energy Consumption Survey.

Low Energy Buildings

- Conservation / efficiency is lowest cost clean source of energy in America
- Efficiency = useful output / input
- Size matters
  - 4000 sf 3 BDR house is not really "efficient"

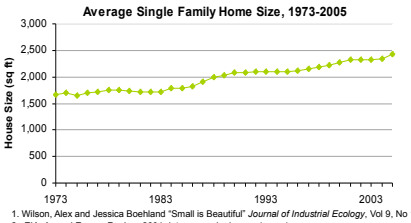
Old & New Houses Energy Use



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

More Efficient, but Bigger

- Average House Size in **1940**: **~1100 sq ft**[1]
- Average House Size in **1973**: **1660 sq ft**[2]
- Average House Size in **2005**: **2434 sq ft**



1. Wilson, Alex and Jessica Boehland "Small is Beautiful" *Journal of Industrial Ecology*, Vol 9, No 1-2. 2005
2. EIA, Annual Energy Review, 2001 data: www.eia.doe.gov/emeu/aer

Green Strategies

- 1. Keep it simple (compact) & small, orient to sun
- 2. Reduce heat loss and gain
  - Lots of **insulation**, avoid thermal bridges (true R-values)
  - Use not too many, very good, **windows** (heat and solar)
  - **Airtight**, then control ventilation properly (don't over vent)
- 3. Avoid energy use
  - Efficient heating, cooling, lighting, elevators, fans, appliances
  - Use daylighting, motion sensors, etc. Off=very efficient.
- 4. Durable
  - Moisture control: Drained, airtight, drying capacity
- 5. Only then, generate renewable energy
  - Passive solar then active

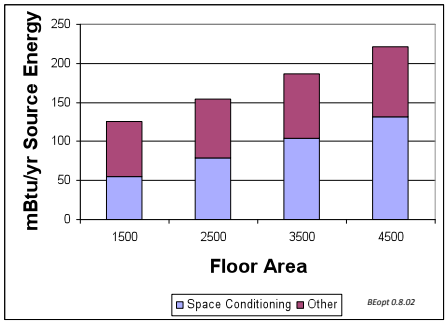
Keep it Simple

2000 ft², 16% window to floor area ratio

Design: Betsy Petit, Building Science Corporation

Small houses use a smaller fraction of total energy for space conditioning than larger homes

Source: Dr Ren Anderson DOE NREL



(2 Story House in Phoenix: SEER 18 AC, R19 Walls, R30 Ceiling, Low e/Low SHGC Windows)

2. Reduce Heat Loss / Gain

- Increasing resistance to heat flow
  - Better insulation values
  - Reduced thermal bridges
  - Better air leakage resistance
  - Better windows
  - Better solar control
- But, there is an impact of above on moisture & durability

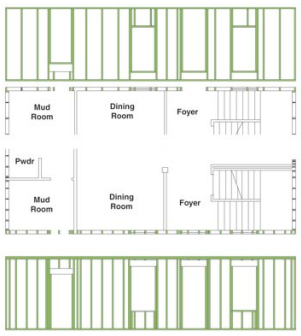
Better Insulation

- Stud-fills cannot get us to high R walls
  - 5.5" of insulation is not enough
- Typical walls are 25% wood (R5)
- Must add insulation outside of framing to achieve high R *and* durability

Different Lifespans

- Equipment lasts 15 to 25 yrs
  - Easy to change out, upgrade
- Insulation last 50++ yrs
  - Upgrade often impractical
- Renewable technologies improving quickly
  - What will PV cost in 10 yrs
- Therefore invest heavily in insulation, then choose good equipment, then consider PV

Cavity insulation about 50-60%



Wall 1 (2x6 24"o.c.)

Plate	36'-0"	2
Stud	8'-0"	20
Jack	7'-9 1/4"	6
Jack 2	6'-8 1/2"	2
Cripple 2	1'-2 1/2"	2
Cripple 3	2'-1"	3

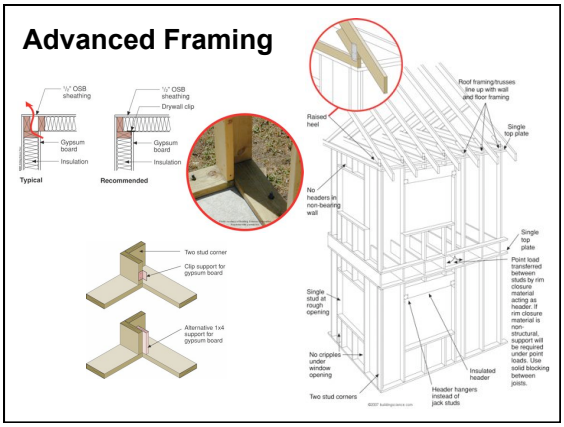
Gross wall area	327 ft²
Window area	74 ft²
Opaque area	45.17 ft²
Cavity area	207.83 ft²

Wall 1 (2x6 16"o.c.)

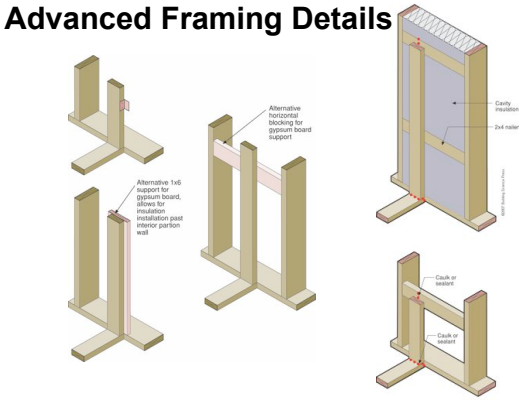
Plate	36'-0"	3
Stud	8'-8 1/2"	29
Jack	7'-8 1/2"	6
Jack 2	6'-8 1/2"	2
Cripple 1	0'-2 1/2"	6
Cripple 2	1'-2 1/2"	2
Cripple 3	2'-1"	8

Gross wall area	327 ft²
Window area	74 ft²
Opaque area	65.60 ft²
Cavity area	181.40 ft²

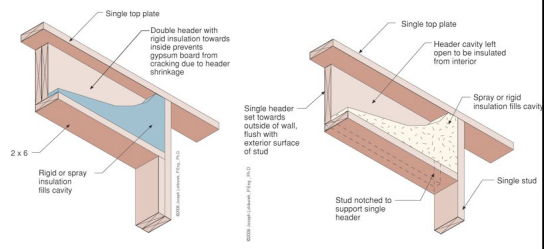
Advanced Framing



Advanced Framing Details



Advanced Framing Details

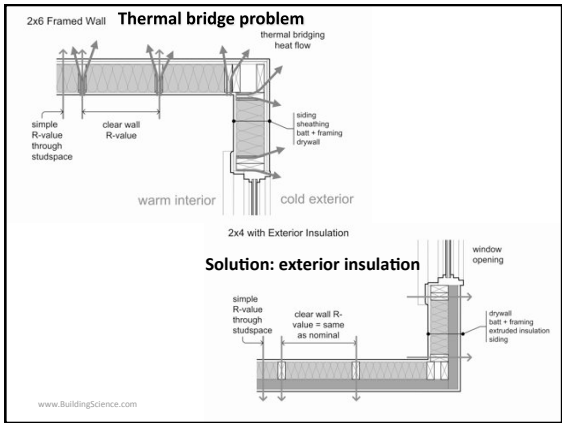


Insulation levels

- Target "real" R-value:
  - 15-20 in Zone 2,
  - R25-30 in Zone 3-4,
  - R30-40 Zone 5-6
- Roofs
  - R40 to R60 in attics (Zone 2-6)
- Basements
  - R10 to 20 (Zones 2-6)

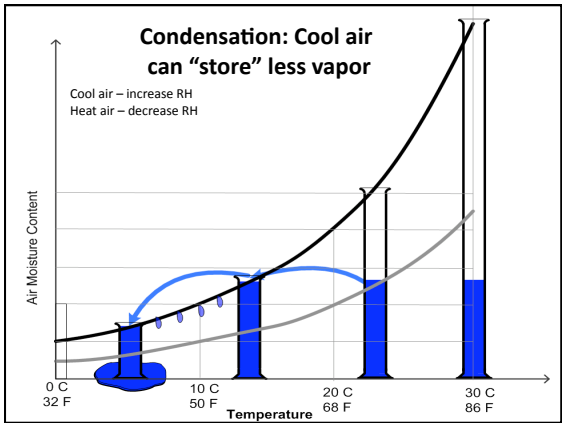
Thermal Bridging

- Leaks in the thermal enclosure
- Robs you of the insulation you installed

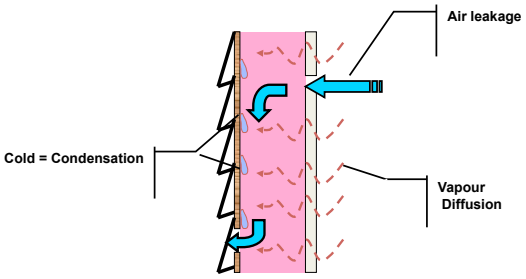


Advanced Framing System

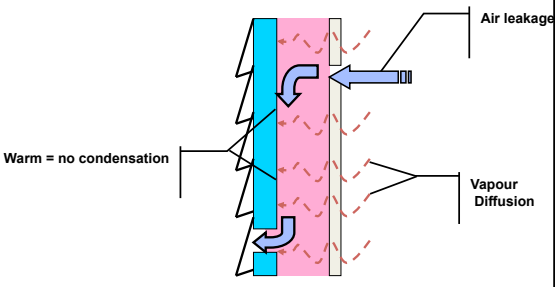
- Insulated headers
- No header necessary at non-bearing walls

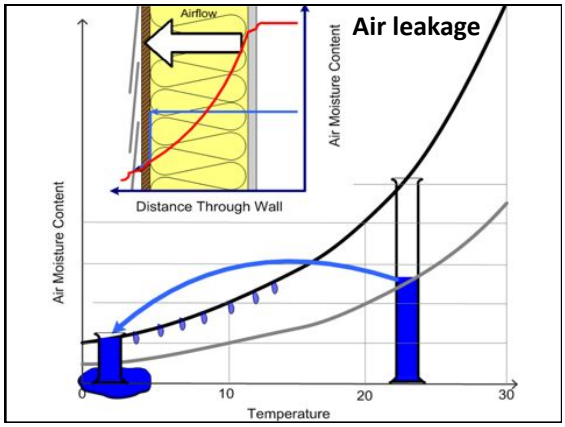


Wall w/o Insulated Sheathing

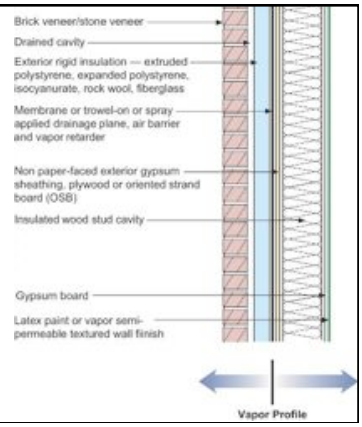


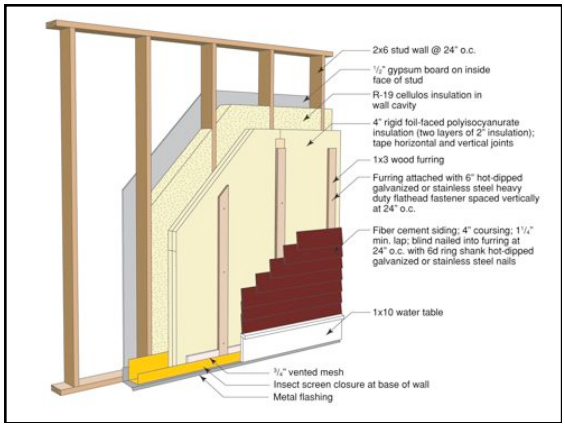
Wall with Insulated Sheathing





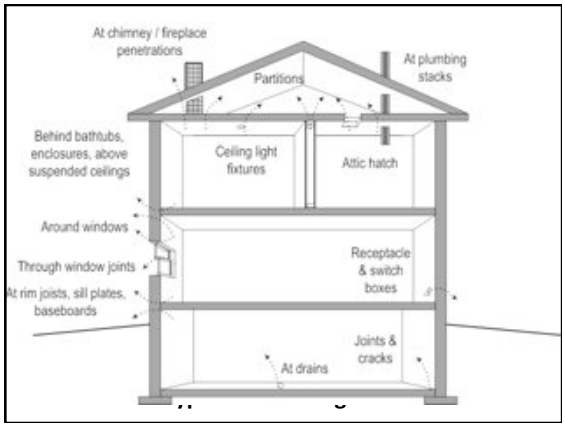
Exterior Insulation

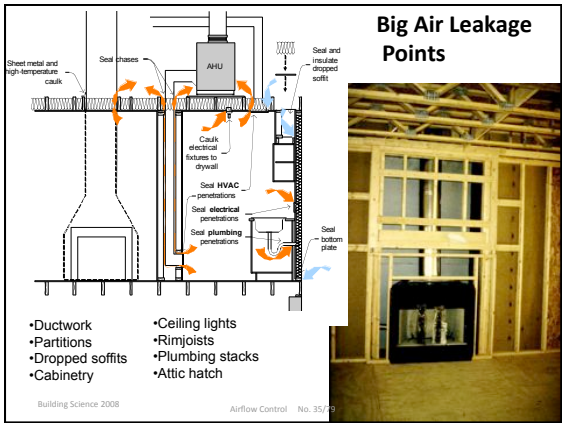


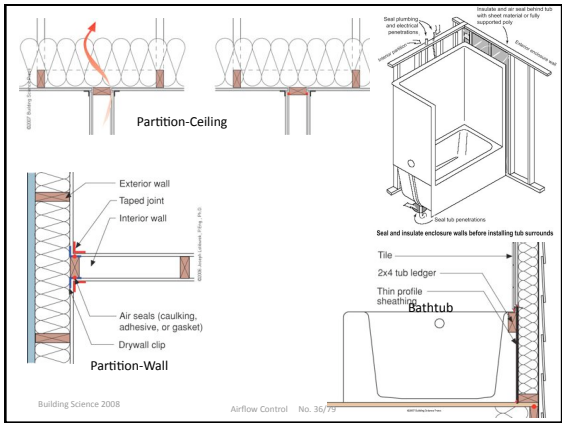


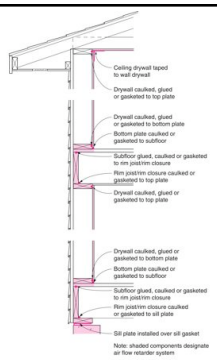
Airflow Control

- Stop airflow anywhere
- Can locate anywhere in enclosure
- Should be protected if possible
- Multiple layers are good
- Important in all climates

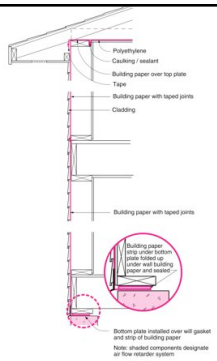




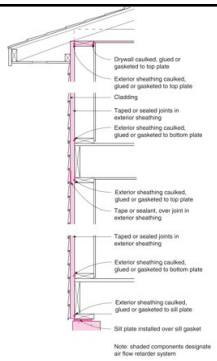




Interior Air Flow Retarder Using Drywall and Framing

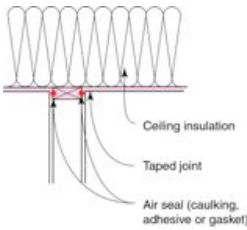


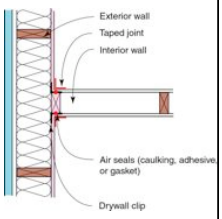
Exterior Air Flow Retarder Using Building Paper or Housewrap



Exterior Air Flow Retarder Using Exterior Sheathing

Air Sealing





Air sealing

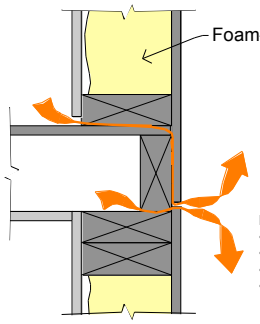
- Seal ALL penetrations to the outside

Air sealing

- **Airtight electrical boxes in exterior walls and ceilings**

Air sealing

- Seal ALL penetrations to the outside



Air Sealing Framed Walls with Foam: foam the details!

Most air leakage at
•rim joist
•windows
•penetrations
•bath rooms

Don't forget to air seal around windows

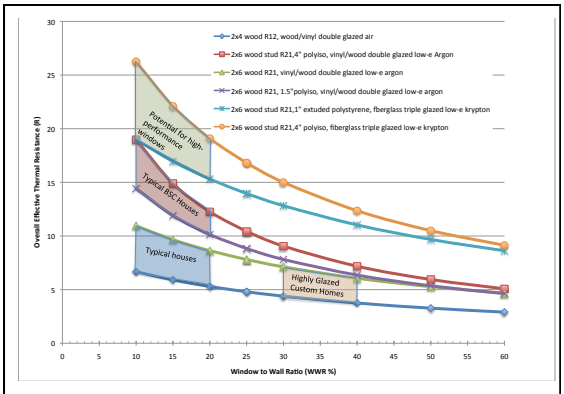
- **Foam**
- **Sealant w/ backer rod**
- **Taped joint?**

Windows

- Windows are expensive energy holes in our walls
- Use not too many very good windows

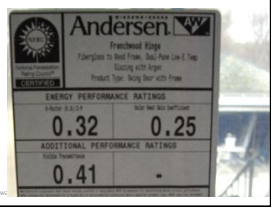
Window vs Wall Performance

	Window	Wall	Ratio
Conduction: Q_c=U ΔT	**U=0.33 / R3**	**U=0.05 / R20**	
T_{in}=70 F T_{out}=10 F	**Q_c= 20** Btu/sf/hr	**Q_c= 3** Btu/sf/hr	**6.6**
Solar: Q_s = SHGC I	**SHGC=0.60**	**SHGC=0.01**	
I_s= 250 Btu/sf/hr (bright sun)	**Q_s= 150** Btu/sf/hr	**Q_s=2.5** Btu/sf/hr	**60**
Alternate: solar control glazing	SHGC=0.30 Q_s= 75 Btu/sf/hr	**Q_s=2.5** Btu/sf/hr	30



NFRC Label

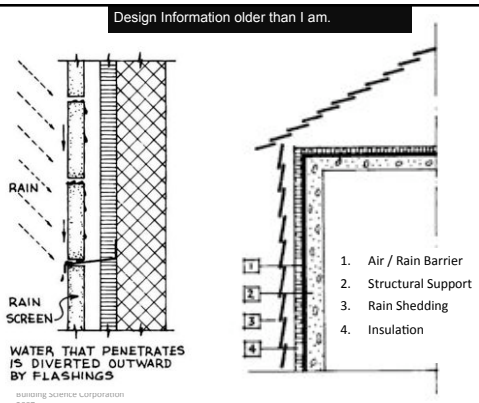
- Read the label
  - U-value (1/R)(<0.35)
  - SHGC (0.2-0.5) heating? Cooling?
  - VT (>0.40-0.50)
  - AL (NFRC opt.)(low!)
- www.NFRC.org



Durability

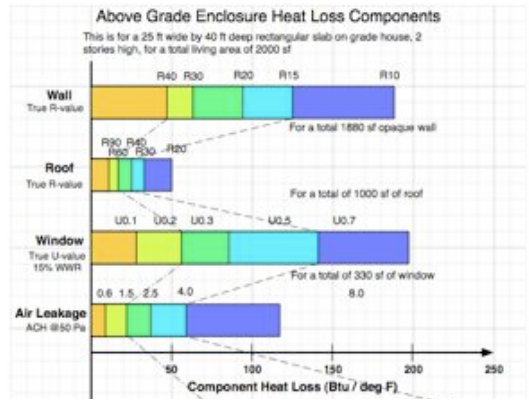
- Buildings must last and be healthy
- Materials have changed
  - OSB, particle board, gypsum not durable as boards, timber, plaster

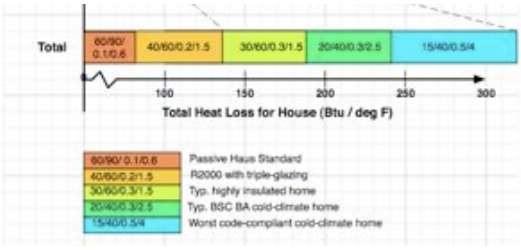
Design Information older than I am.



Energy Efficiency & Durability

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





Efficient Enclosures & HVAC

- Airtight buildings require ventilation systems
  - Don't over ventilate. Quality≠Quantity
- Better windows, insulation and lighting
  - = Low heat gain
  - = dehumidification, less sensible cooling
- Thermal mass matters more
- Different HVAC systems can now be applied
  - Simple systems, fewer zones

Appliances etc

- Appliances, computers, TVs, routers, game machines become a large proportion of the load
- Must do what we can to control these
- Hope for more stringent Energy Star rules

Conclusions

- Must consider several components to get to low energy buildings: wall, window, air, roof
- Advanced building science is not about advanced technology or physics
  - It is about putting many things together in context