BUILDINGENERGY 13
CONFERENCE + TRADE SHOW FOR RENEWABLE ENERGY AND GREEN BUILDING PROFESSIONALS
MARCH 5-7 2013, SEAPORT WORLD TRADE CENTER, BOSTON MA

How Much Insulation is Too Much?

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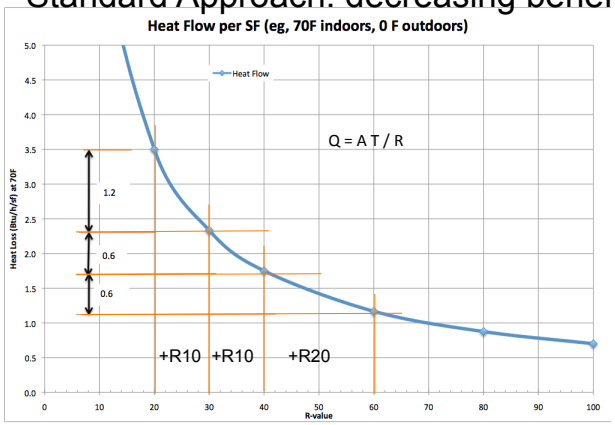
- **Description: Used to be that the answer to "How do I increase building energy performance?" was to add insulation and do more air-sealing, just about every time. Now with growing code minimums, lower renewable energy costs, and an acceptance of super insulation, a more careful analysis may be justified. Building component insulation, airtightness, window performance, renewable energy costs, occupant life style and mechanical system efficiencies all need to be considered. When is "more insulation" too much? What are the best mechanical and renewable systems? How should occupants be factored in? This session will revisit some popular assumptions about how to design the optimal energy efficient home.**

Context: How much Insulation?

- The wrong question
  - How much thermal control do I need?
- Insulation ≠ Thermal control
  - Thermal bridging
  - Air leakage
  - Thermal mass
- Minimum levels of thermal control needed
  - Comfort
  - Condensation

Standard Approach: decreasing benefit

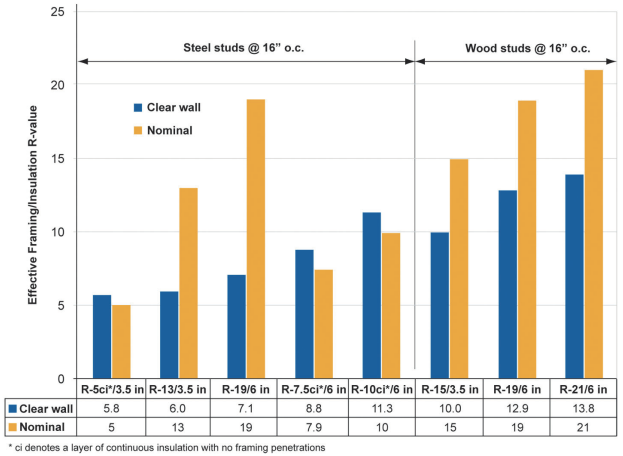


Calculating "payback"

- Why apply economics to insulation?
  - Usually don't apply it to other choices
- Interest / time value of money
  - 4% mortgage? 7%? 15%ROI?
- Fuel escalation rate
  - Which fuel? 5% 7% 10% increase
- Incremental cost
  - Price varies by region, material, job, contractor
- Other functions
  - Some insulations are water, vapor air barriers
  - How to value comfort?

True R-value is what matters

- Adding insulation may not help if it is bridged
  - Focus is moving to managing thermal bridging
  - True-R of 2x6 w/R21 is about R15 +/-
  - True R of 11.5" double stud is R36 +/-



	R-5ci*/3.5 in	R-13/3.5 in	R-19/6 in	R-7.5ci*/6 in	R-10ci*/6 in	R-15/3.5 in	R-19/6 in	R-21/6 in
Clear wall	5.8	6.0	7.1	8.8	11.3	10.0	12.9	13.8
Nominal	5	13	19	7.9	10	15	19	21

* ci denotes a layer of continuous insulation with no framing penetrations

Insulation Choice

- Lowest cost insulation per R is the best, right?
  - Eg fill with loose fill cellulose (attic) and fiberglass batts (wall)

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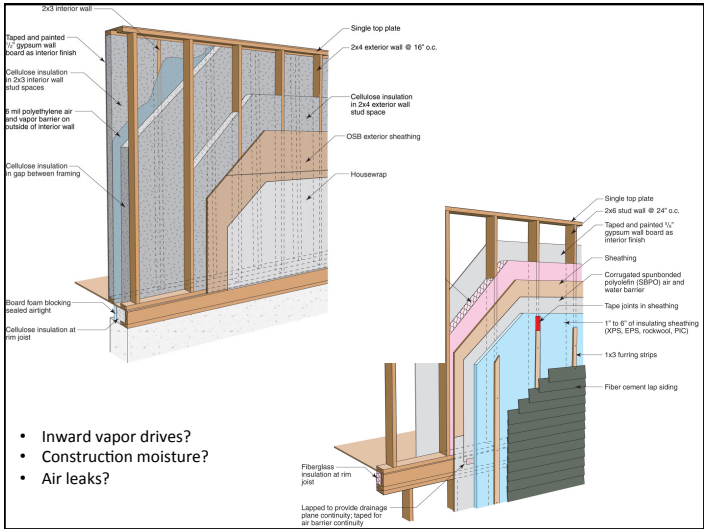
  - Eg fill with loose fill cellulose (attic) and fiberglass batts (wall)
- Wrong.
  - Lowest cost *for the same function*!

Different Insulations are Different

- Low-density glass and cellulose fiber require support, must be protected from wind, water, air
- High-density glass and rockwool can withstand water and wind but not stop them
- Closed-cell foam board can stop water and air, and limit vapor diffusion
- Cant substitute without thinking!

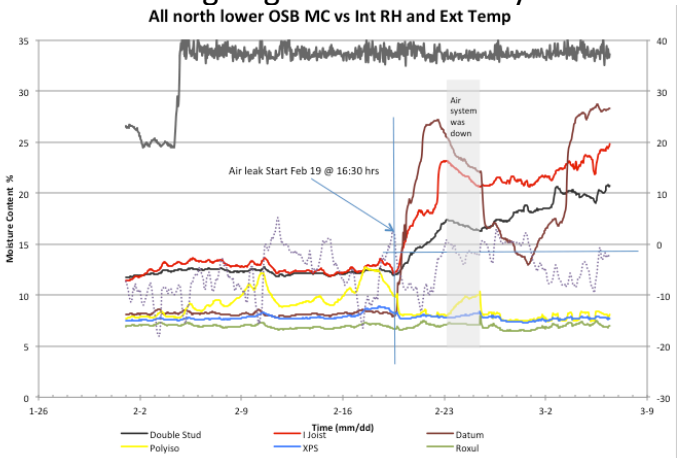
Where is the insulation?

- Location, location, location
- Lots of insulation inboard exposes all materials outboard to very cold (wet) conditions



- Inward vapor drives?
- Construction moisture?
- Air leaks?

On-going Test house study



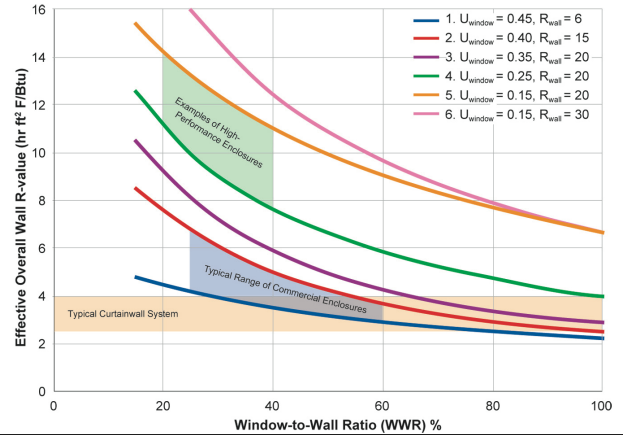
Assess Cost of Increasing Insulation

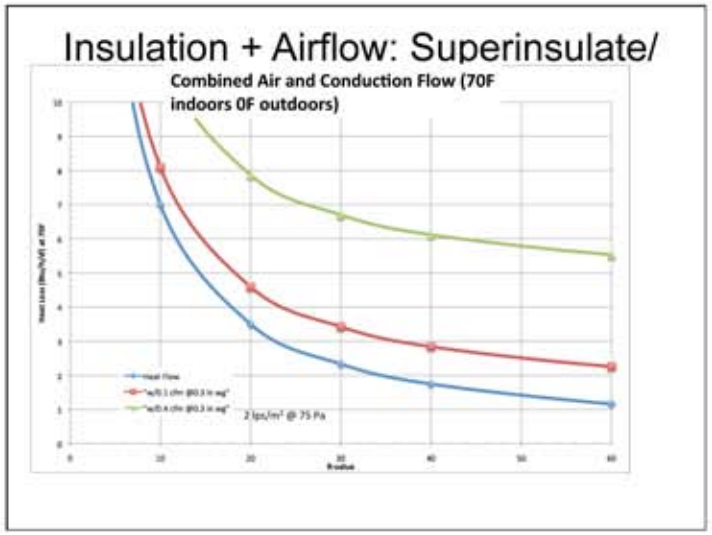
- Compare
  - Adding R7.5 to a 2x6 (R15) wall
    vs
  - Adding R60! to an R30 vented attic
- Same energy saved per square foot of area
- R60 blown cellulose often/usually cheaper than R7.5
- Consider cost difference if unvented roof
- Consider cost of windows going from R4 to R7.

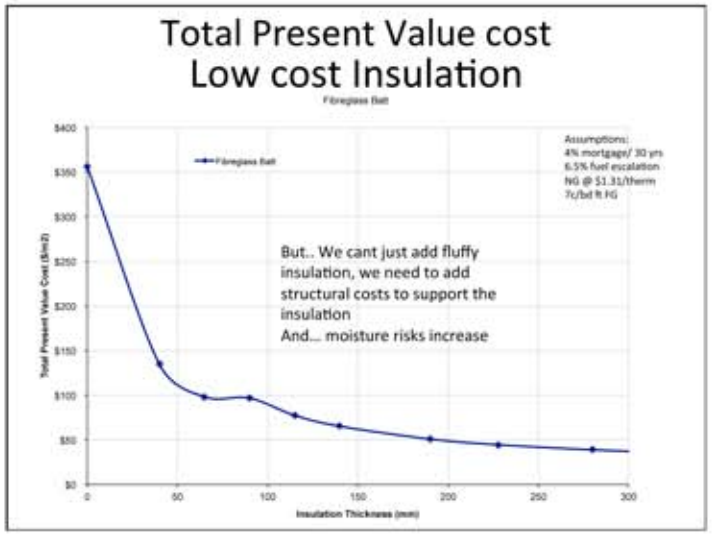
Other heat leaks

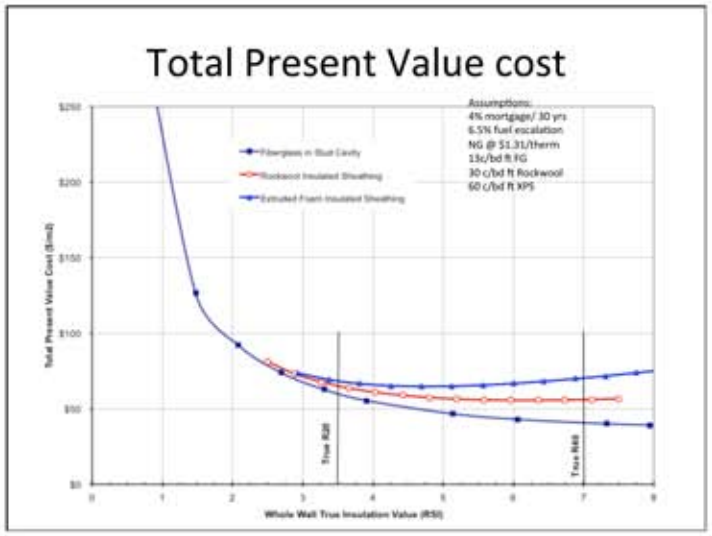
- Windows are major source of heat loss
- High-R windows are expensive
  - When are better worth the price
- Air leaks bypass insulation
  - When spend more effort ($) on airtightness?

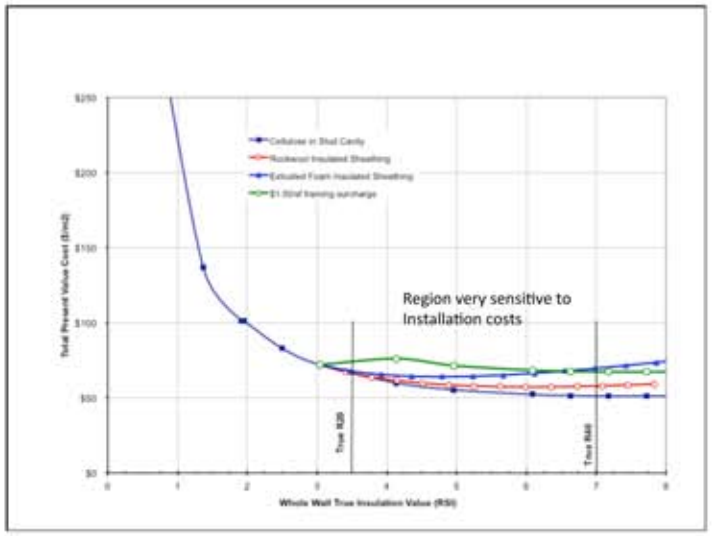
True R-values

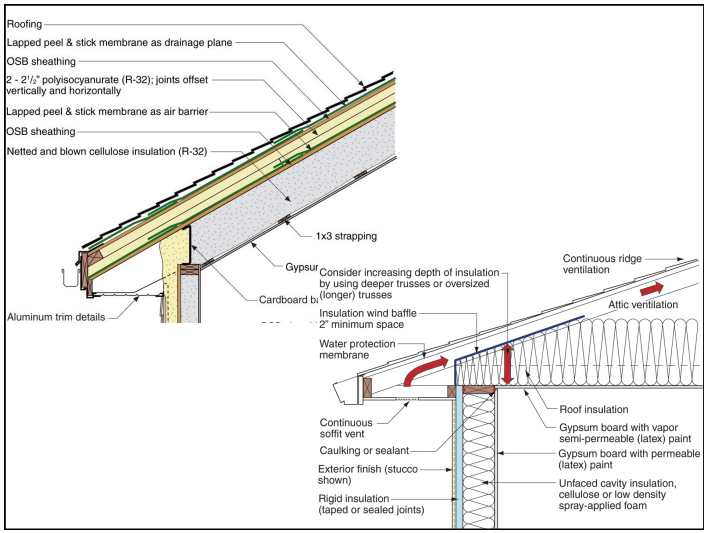



Insulation + Airflow: Superinsulate/
Combined Air and Conduction Flow (70F indoors 0F outdoors)
2 lps/m² @ 75 Pa

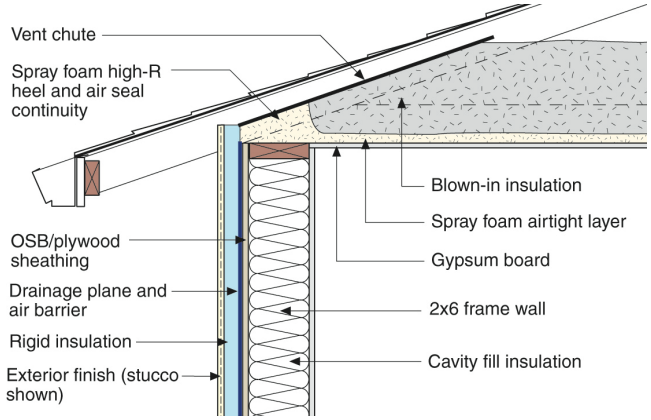

Total Present Value cost
Low cost Insulation
Fibreglass Batt
Assumptions:
4% mortgage/ 30 yrs
6.5% fuel escalation
NG @ $1.31/therm
7c/bd ft FG
But.. We cant just add fluffy insulation, we need to add structural costs to support the insulation
And... moisture risks increase
Insulation Thickness (mm)


Total Present Value cost
Assumptions:
4% mortgage/ 30 yrs
6.5% fuel escalation
NG @ $1.31/therm
13c/bd ft FG
30 c/bd ft Rockwool
60 c/bd ft XPS
Whole Wall True Insulation Value (RSI)

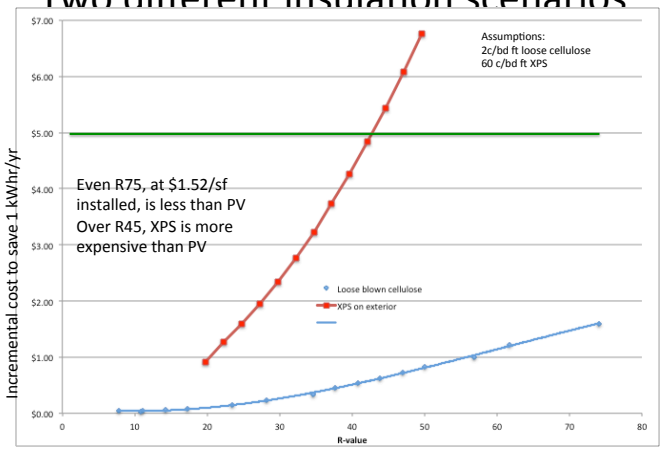

Region very sensitive to Installation costs
Whole Wall True Insulation Value (RSI)



SPF added to get better airtightness



Two different insulation scenarios



Mechanical systems savings

- Very small (eg residential) systems *are more expensive* than small commodity systems
  - Below about 30 kBtu/hr, it starts to cost more
  - Need to more clever
- Commercial systems can save a lot by reducing distribution (pipe, ducts ec)
  - Terminal unit elimination is a major saving
  - Eg perimeter heat @$30/lf can be eliminated

Renewable Energy Generation

- Easiest comparison is site PV
  - Capital $/kWhr produced per year
    - Eg $6000/kW / 1200 kWhr/yr = $5/ kWhr/yr
  - Capital $ to save 1 kWhr/yr
    - Eg $4000 insulation extra→ 2000 kWh/yr = $2/kWhr/yr
    - Eg $8400 window extra→ 1200 kWhr/yr= $7kWhr/yr
- Off-site wind generation
  - Usually at under $2-3 capital / kWhr/ yr

Summary of Methods

1. Make a lot of guesses, then calculate Present Value
2. Set a high bar: purchase energy up-front and compare cost of saving vs generation
   - Off-site energy can be a lot cheaper
3. Systems trade-off: pay for insulation by reducing mechanical costs
   - Rarely works in good houses
   - Works well in standard commercial buildings

Conclusions

- Analysis involves lots of variables
  - Not one-answer applies for target R-value
- *Very little risk of over-insulation* in today's market, but we are starting to see some
  - Perhaps some PassivHaus-type designs
- Avoiding over-insulation conserves financial resources for better alternatives
- Renewables can sometimes be better
  - Only at very high insulation levels
- Bigger problem is poor heat flow control
  - E.g. thermal bridges, air leakiness, poor solar control

Recommendations?

- Minimum: insulation level *and arrangement* to deliver comfort and durability
  - Should not fall below this level
- Upgrade in thermal control to save energy should rarely, if ever, cost more than the cost to generate same energy using unsubsidized photovoltaic (eg most expensive energy)
- Lower cost of energy production could/should be used depending on goals