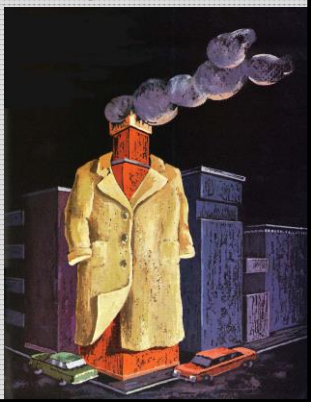
The Importance of Being Insulated

"…not only reduces consumption of energy…leads to better quality, and on occasion, lower cost construction."
—Thomas Fisher

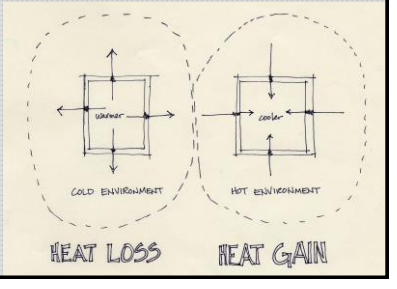
…plus it improves thermal comfort



1

Three unsurprising facts:

- All heat loss/gain occurs on the "path" through the building skin.
- Heat transfer is always from hot to cold.
- The weather and the internal load determine if heat loss or heat gain is occurring.

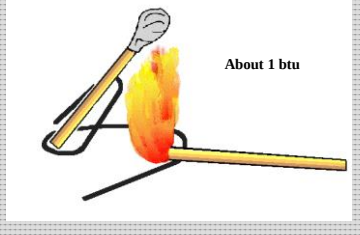


2

Introduction to a British Thermal Unit (Btu)

Heat to raise 1 pound of water 1°F

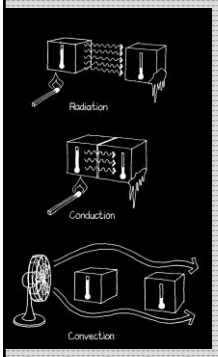
Rate of heat transfer is measured in Btu per hour [Btuh]



[The rest of the world measures heat transfer in Watts (3.41 Btuh).]

3

Methods of heat flow



1 no-touchy

radiation—by electromagnetic wave

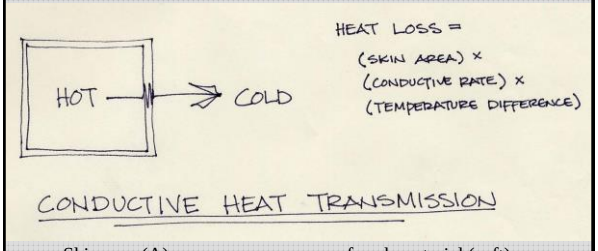
2 touchies

conduction—thru a solid medium

convection—thru a fluid

4

Basic conduction



Skin area (A)	area of each material (sqft)
Conductive rate (U)	U-value (btuh/sqft°F) (1/R-value)
Temperature differential (ΔT)	between inside and outside (°F)

$HL = A \times U \times \Delta T$

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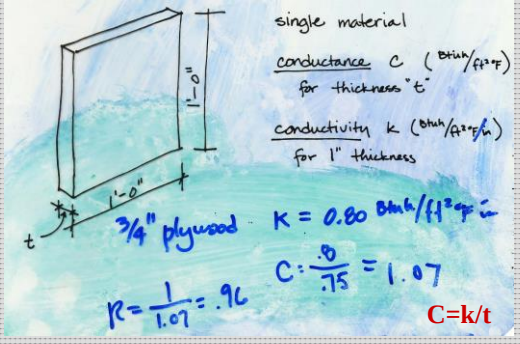
To reckon the U-Value—look up C or k



1. For a specific thickness (t) look up Conductance, C (btuh/ft²°F)
2. For a unit of thickness (1") look up Conductivity, k (btuh/ft²°F/in)

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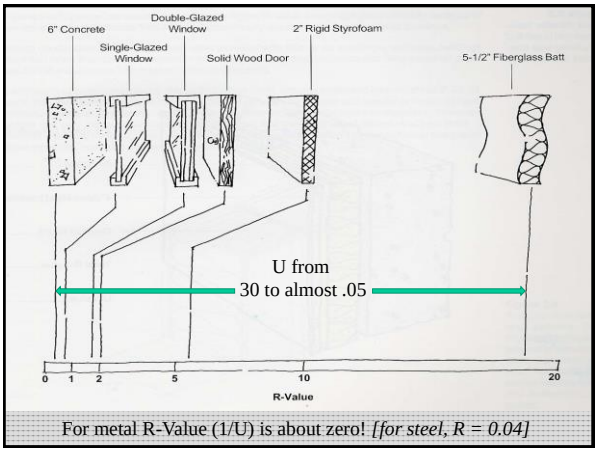

For metal R-Value (1/U) is about zero! *[for steel, R = 0.04]*

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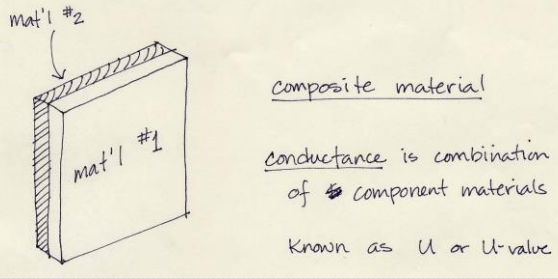
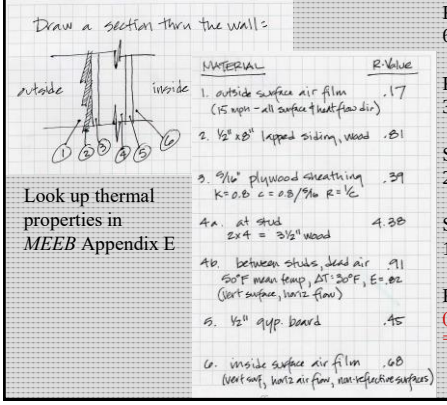
Most skin elements are composites:



Mathematically, it's not as simple as adding conductance (C).
Conductance (U-Value (btu/hr°Fft^2) is a speed
You can add times, though. R = 1/C (hr/btu°Fft^2)
Resistance (R-Value) is a time

8

Typical composite residential wall



Look up thermal properties in *MEEB* Appendix E

R-Value @ stud
6.88

R-Value between
3.41

Studs @ 16"o.c.
20% framing

Studs @ 24"o.c.
15% framing

R-Value average
(6.88)(.2)+(3.41)(.8)
= 4.10

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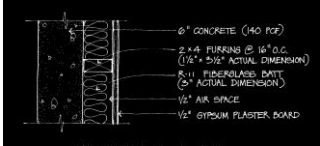
Each skin element is slightly different and must be calculated.



CALCULATION OF U VALUE

	R @ gap	R @ stud
Outside air film (assume wind = 15 mph)	.17	.17
Concrete (k = 9, x = 6" x/k = 6/9 = .67)	.67	.67
Stud (x/k = 3.5/1.0 = 3.5)	-	3.5
Fiberglass (glass batt)	11.00	-
Air space (50°F mean temp, 30°ΔT, ε = .82)	.90	-
½" gypsum board	.32	.32
Inside air film (still air, ε = .90)	.68	.68
$R_{tot} = \Sigma R =$	13.74	5.34

Weighted average R-value:

(13.74)(.80) + (5.34)(.20) = 12.06

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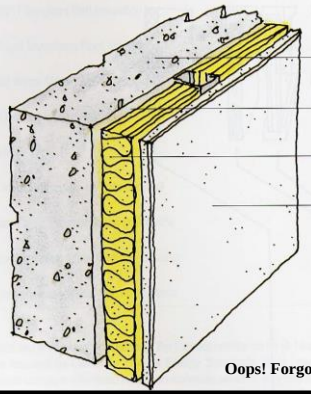
Total R-Value = $R_1 + R_2 + R_3 + \ldots + R_n$ or $\sum (R_n)$



	R-Value
8" Exterior Concrete Wall	0.8
Air Space	0.7
4" Semi-Rigid Insulation	13.0
Gypsum Board	0.6
Total R-Value	**15.2**
U-Value	**0.07**

$U = 1/ R_{total}$

Oops! Forgot about insulating air films!

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You can also compare performance of competing insulation strategies

Compare the performance of an uninsulated concrete wall (R-3) to that of a similar uninsulated, ground-coupled concrete wall (R-3) and a built-to-code frame wall (R-20). Assume that the thermostat temperature is 65°F, the outside temperature is 35°F, and the earth temperature is 55°F.

The rate of heat loss, UAΔT, for one square foot of each wall is:

1. The uninsulated concrete wall—

   UAΔT = (1/3)(1)(30) = 10 btuh/ft²

2. The earth-coupled concrete wall—

   UAΔT = (1/3)(1)(10) = 3.33 btuh/ft²

3. The built-to-code frame wall—

   UAΔT = (1/20)(1)(30) = 1.33 btuh/ft²

As you can see, the earth-coupled concrete wall outperforms its uninsulated sibling, but is similarly left in the dust by the code-compliant wall.

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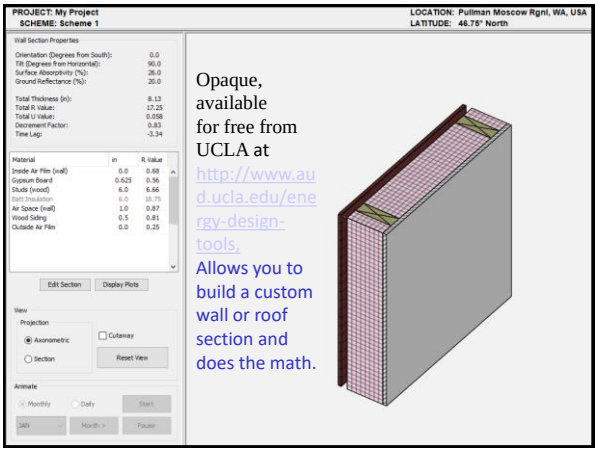

Opaque, available for free from UCLA at http://www.aud.ucla.edu/energy-design-tools, Allows you to build a custom wall or roof section and does the math.

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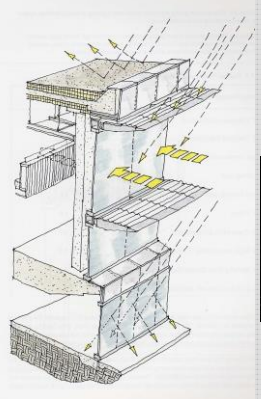
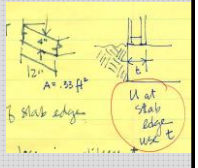
Whole Building Conductive Heat Loss (or Gain)



$$HL_C = \sum (U \times A \times \Delta T)$$

Infiltration

Slab Edge Loss



Moreover

$HL_{tot} = HL_C + HL_I + HL_{SE}$

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Surface temperature

You can measure surface temperature with a spot pyranometer or an infrared camera.

RAYTEK SPOT PYRANOMETER

INFRARED CAMERA

Lightly insulated 1920s bungalow loses heat through its walls (green)

Solar radiation raises surface temperature in Ed Bldg

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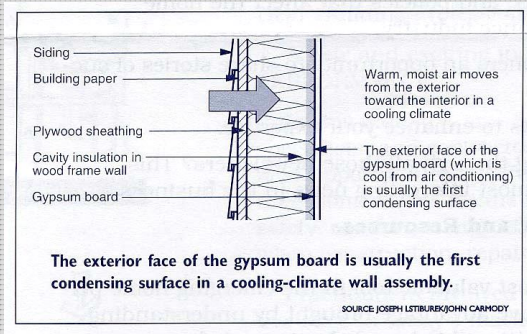
Thermal Gradients can predict:

1. the wall's radiant temperature
2. the dew point location



The exterior face of the gypsum board is usually the first condensing surface in a cooling-climate wall assembly.

SOURCE: JOSEPH LSTIBUREK/JOHN CARMODY

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First how to do it:

theoretically

$$R_{TOT}\,\Delta T = R_1\Delta T + R_2\Delta T + \cdots + R_N\Delta T$$

or

$$\Delta T = \frac{R_1\Delta T + R_2\Delta T + \cdots + R_N\Delta T}{R_{TOT}}$$

or

$$\Delta T = \frac{R_1\Delta T}{R_{TOT}} + \frac{R_2\Delta T}{R_{TOT}} + \cdots + \frac{R_N\Delta T}{R_{TOT}}$$

and we can rename each factor

$$\Delta T_1 = \frac{R_1\Delta T}{R_{TOT}}$$

or

$$\Delta T = \Delta T_1 + \Delta T_2 + \cdots + \Delta T_N$$

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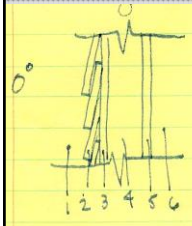
The infamous uninsulated stud wall:



	R
1. outside air	.17
2. siding	.81
3. sheathing	.39
4. air space	.91
5. gyp. board	.45
6. inside air	.68
	3.41

R-Value = 3.41 between studs

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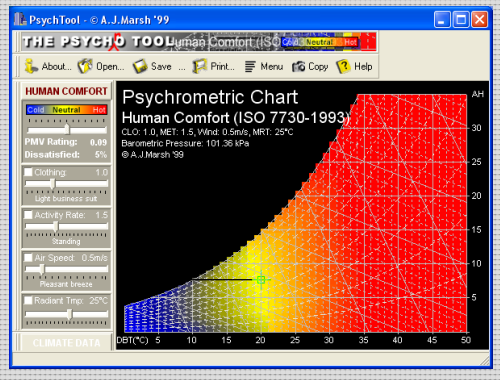
Determine the Dew Point from psych chart



Here 10°C or 50°F

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On a cold day in Helena, MT (0°F),

$\Delta T = 65°$ outside temp = 0°

$\Delta T_1 = \frac{R_1 \Delta T}{R_{TOT}} = \frac{.17(65)}{3.41} = 3.24°F$ 3.24°F

$\Delta T_2 = \frac{R_2 \Delta T}{R_{TOT}} = \frac{.81(65)}{3.41} = 15.44°F$ 18.68°F

$\Delta T_3 = \frac{R_3 \Delta T}{R_{TOT}} = \frac{.39(65)}{3.41} = 7.43°F$ 26.11°F

$\Delta T_4 = \frac{R_4 \Delta T}{R_{TOT}} = \frac{.91(65)}{3.41} = 17.35°F$ 43.46°F ← dew pt.

$\Delta T_5 = \frac{R_5 \Delta T}{R_{TOT}} = \frac{.45(65)}{3.41} = 8.58°F$ 52.04°F wall temp

$\Delta T_6 = \frac{R_6 \Delta T}{R_{TOT}} = \frac{.68(65)}{3.41} = 12.96°F$ 65.00°F

You want it to be 65°F indoors.

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Insulation (R-11 batt)

1.	outside air	.17
2.	siding	.81
3.	sheathing	.39
4.	insulation	11.00
5.	gyp board	.45
6.	inside air	.68
	R_{TOT} =	13.50

Add Insulation!

$\Delta T_1 = \frac{R_1 \Delta T}{R_{TOT}} = \frac{.17(65)}{13.50} = .82$ .82°F

$\Delta T_2 = 3.90$ 4.72°F

$\Delta T_3 = 1.88$ 6.60°F ← Dew Point

$\Delta T_4 = \frac{11.00(65)}{13.50} = 52.96$ 59.56°F

$\Delta T_5 = \frac{.45(65)}{13.50} = 2.17°$ 61.73°F Wall Temp.

$\Delta T_6 = \frac{.68(65)}{13.50} = 3.27°$ 65.00°F

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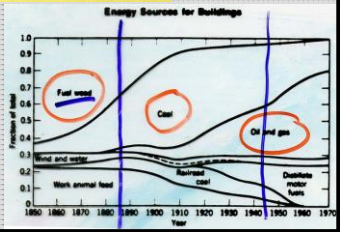
The nutshell history of heating buildings
two step history

1. Originally all bldgs were heat with local materials that included wood, sheep and sun

2. As populations grew more concentrated and trade lines were established the concept of importing fuel was born first from countryside to city now from OPEC to USA

…until 1973…
The OPEC oil embargo stimulated energy conservation:
2 philosophies arose



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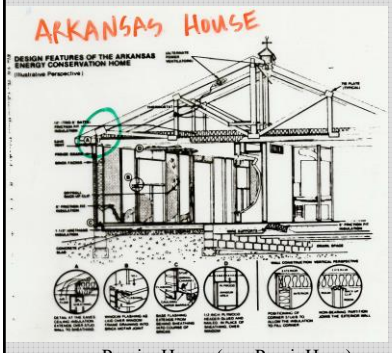
Light and Tight vs.



- 8% glass max.
- Max insulation
- Tight construction

Impressive energy savings at low cost!

Homes less in touch with nature than the energy wasters they seek to replace.

…now PassiveHouse (nee PassivHaus)

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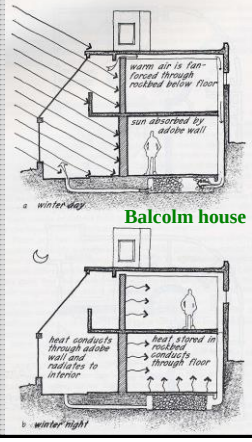
Glass and Mass

(aka Passive Solar)

- >20% glass for solar gain
- Thermal mass within

Impressive energy savings at low cost!

Homes in tune with natural conditions.



Balcolm house

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Who won?

Energy codes developed to embrace both.

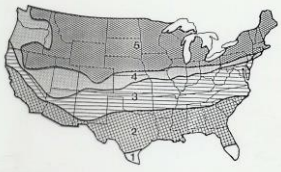
Surpassing the code requirements came to be known as superinsulation.

Prescription-based standards

New Model Energy Code

The first major action on energy related issues occurred last January when the new Model Energy Code was adopted. MIMA along with many other organizations and individuals worked with the Congress of American Building Officials (CABO) to revise the Code. Under the new code, minimum thermal values for insulation have been changed.

The nation has been divided into five thermal zones with the recommended R-Values for ceiling insulation varying from R-19 for new homes in hottest climates (see chart) to R-49 for those in northern frost and ice belts.



Zone	Heating Degree Days	Ceiling R-Value	Wall R-Value	Floor R-Value
1	up to 500	R-19	R-12	R-11
2	501-3,000	R-30	R-19	R-11
3	3,001-5,000	R-38	R-19	R-14
4	5,001-6,000	R-38	R-19	R-22
5	6,001 up	R-49	R-22	R-25

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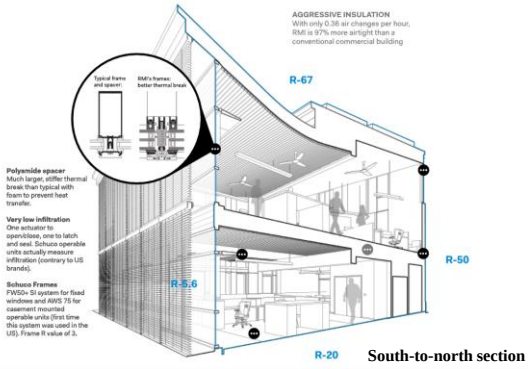
Rocky Mountain Institute's Innovation Center: Less than Zero

Sponsored by WOOD.

BUILDING DIAGRAM

Performance-based compliance: Not all walls need to be equal….



South-to-north section

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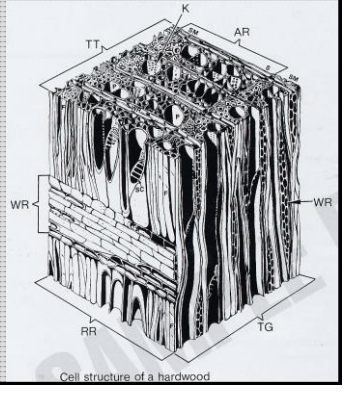
Techniques for superinsulation

- Double walls
- Wall trusses
- Straw bale walls
- Stress skin panels
- Radiant barriers



Cell structure of a hardwood

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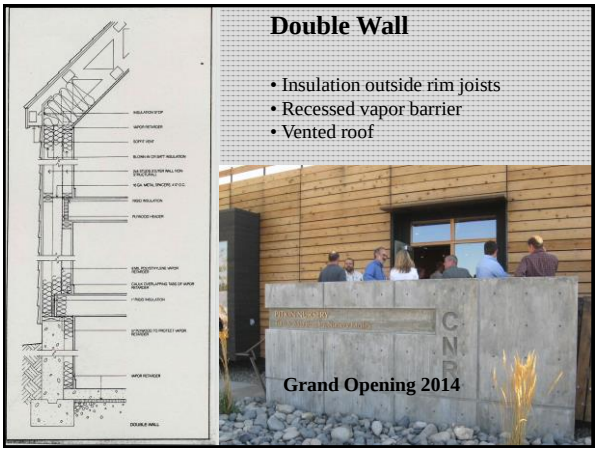
Double Wall
• Insulation outside rim joists
• Recessed vapor barrier
• Vented roof
Grand Opening 2014

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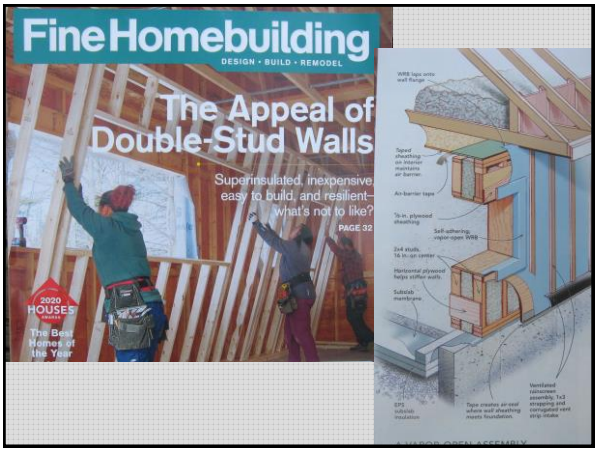
Fine Homebuilding
DESIGN • BUILD • REMODEL
The Appeal of Double-Stud Walls
Superinsulated, inexpensive, easy to build, and resilient—what's not to like?
PAGE 32
2020 HOUSES
The Best Homes of the Year

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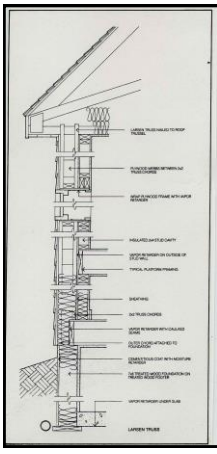
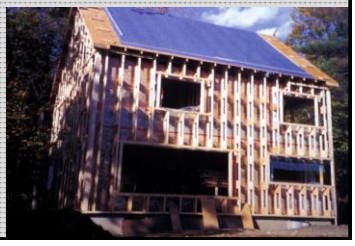
Soft insulations choices (all ~R-3 per inch):
• Fiberglas
• Mineral wool
• Denim
• Lamb's wool
UltraTouch
Denim Insulation
When you choose UltraTouch® Denim Insulation, you are making a Sound decision. With excellent acoustic control properties and thermally efficient performance, UltraTouch® is the natural choice. And because it's from Bonded Logic, UltraTouch® is safe for you and our environment!

30



Larsen Truss Wall

- Non-structural trusses
- Interior 2x4 structure
- Insulation outside rim joists
- Recessed vapor barrier
- Vented roof



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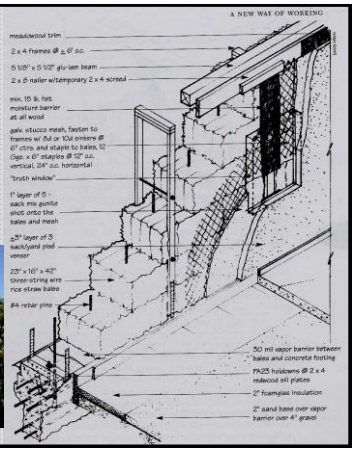
Straw Bale Wall

- Structure and insulation combined
- Breathing walls
- Cheap local material
- Tests at ~R-27

Real Goods—Sim van der Ryn



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Hempcrete is structural insulation!

IT'S NOT ROCKET SCIENCE
IT'S BUILDING SCIENCE

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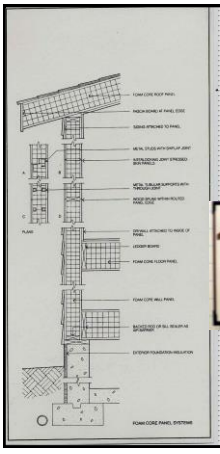
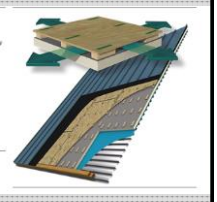


Structural Insulating Panels (SIPs)

- Insulated panel is structural
- No vapor barrier
- Un-vented roof*
- Wiring and plumbing issues



*Hunter Cool-Vent is the exception.

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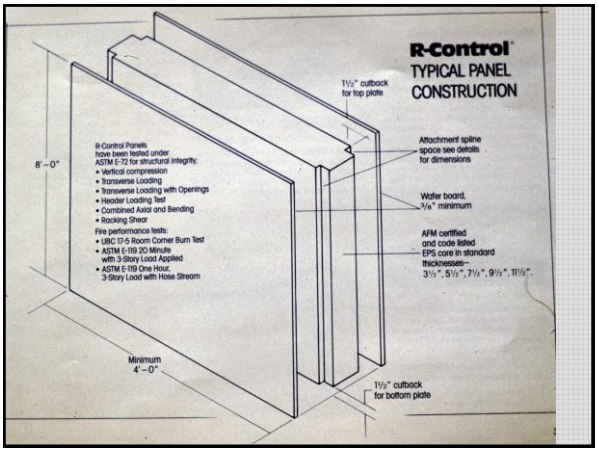

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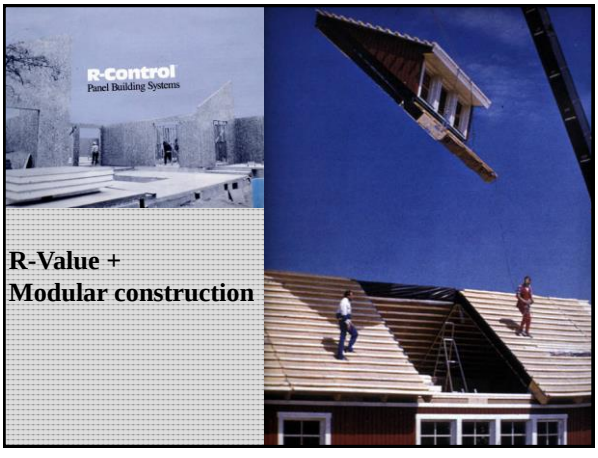

R-Value +
Modular construction

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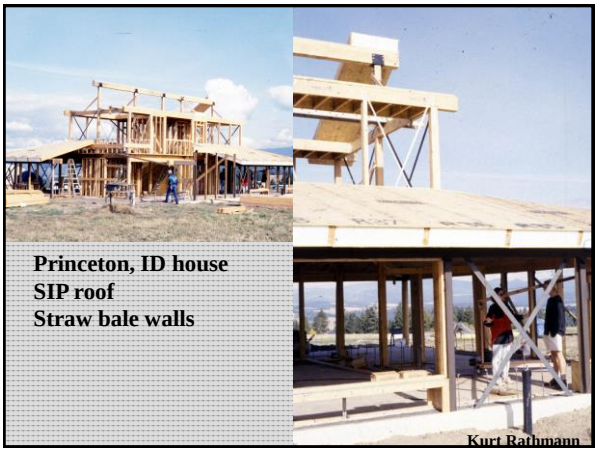
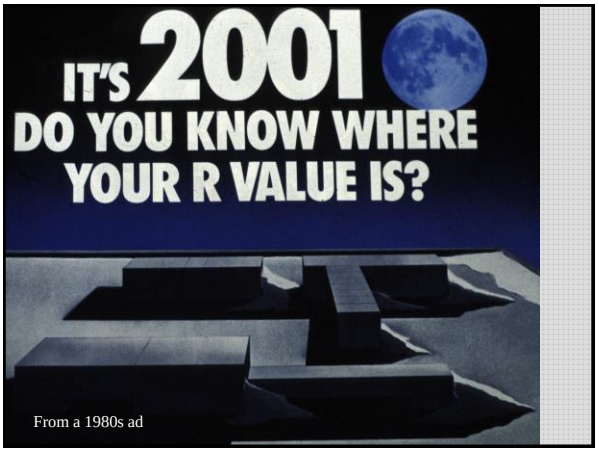

Princeton, ID house
SIP roof
Straw bale walls
Kurt Rathmann

37


IT'S 2001
DO YOU KNOW WHERE
YOUR R VALUE IS?
From a 1980s ad

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2017 Update: Do you know if
your insulation is flammable?
Grenfell Tower fire
12 June 2017 in London
Rydon fitted the 24-storey tower with a cheaper, less fire-resistant
aluminium composite panels with a plastic core.

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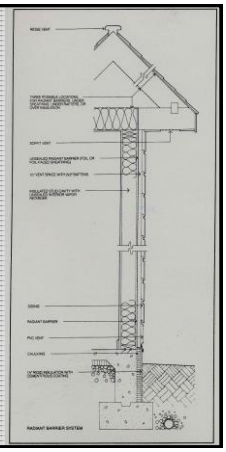
Radiant Barriers

- Vented air space behind siding
- Vapor barrier inside
- Radiant barrier outside
- Vented roof

Suitable for hot humid climates!



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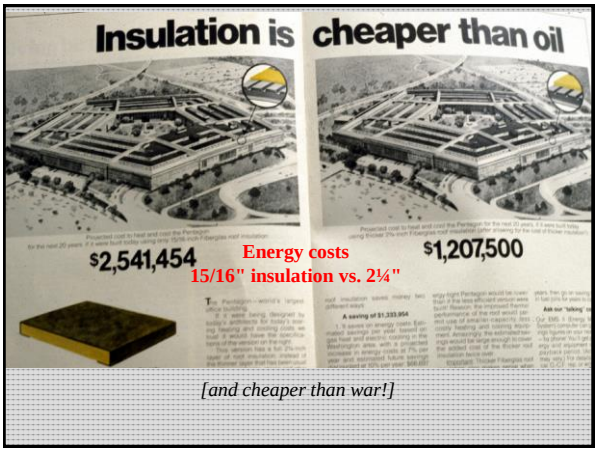
How do you attain great performance without superinsulation?

A research project?

41

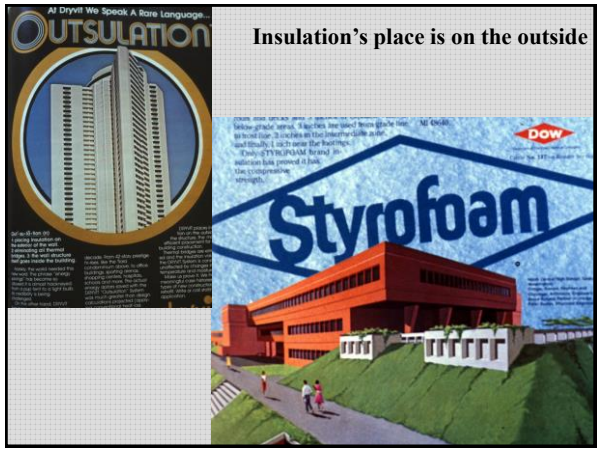


[and cheaper than war!]

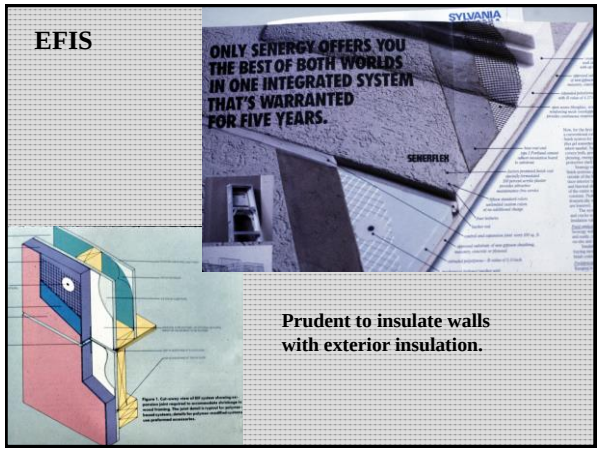
42


Which is thermally superior?

43


At Dryvit We Speak A Rare Language...
OUTSULATION
Insulation's place is on the outside
DOW
Styrofoam

44


EFIS
SYLVANIA
ONLY SENERGY OFFERS YOU THE BEST OF BOTH WORLDS IN ONE INTEGRATED SYSTEM THAT'S WARRANTED FOR FIVE YEARS.
SENERFLEX
Prudent to insulate walls with exterior insulation.

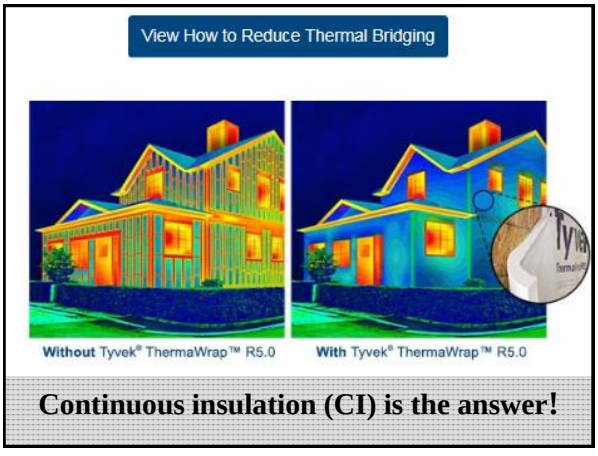
45


Combat the thermal bridge syndrome!
CALCULATED VALUES ARE FULL OF HOLES.
Sure, it's possible to arrive at some impressive U-values, if you take straight text-book calculations.

46


EVOLUTION
100% Thermally Broken
InsulTech™
Oldcastle Architectural

47


View How to Reduce Thermal Bridging
Without Tyvek® ThermaWrap™ R5.0
With Tyvek® ThermaWrap™ R5.0
Continuous insulation (CI) is the answer!

48

Sometimes an infrared camera isn't needed:

Structural insulation at work!
Before roof insulation project.

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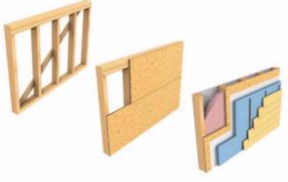
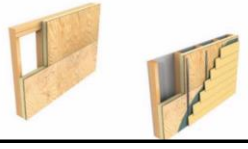
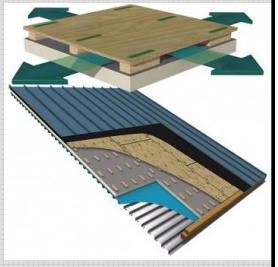
Traditional Construction Method



NEW Structural Insulated
Hunter Xci Ply or NB Construction Method

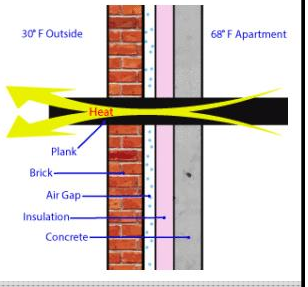


AAS roof remodel



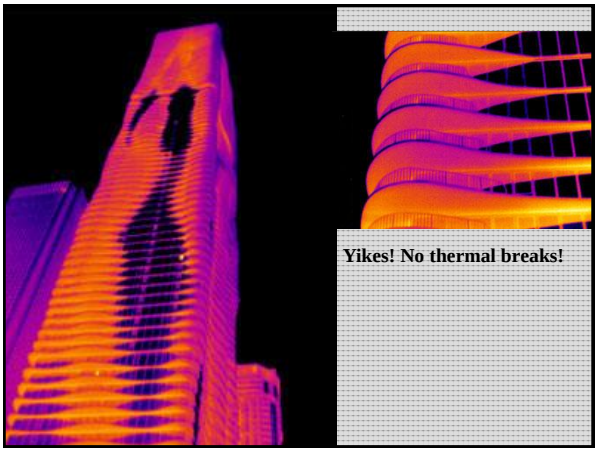
50

Decks are potential thermal bridges.



Aqua Tower, Chicago
Studio Gang

51



52

…but structural thermal break technology exists

53

Even metal garage doors can be insulated!
As can pet doors (Title 24 Compliant)!

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