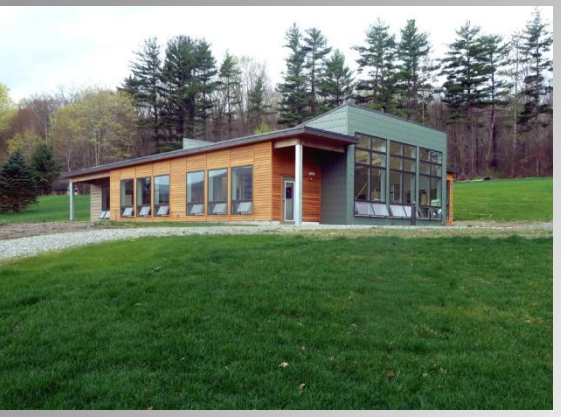


The Perfect Wall

Report from the field on practical external insulation strategies pros, cons, details & issues

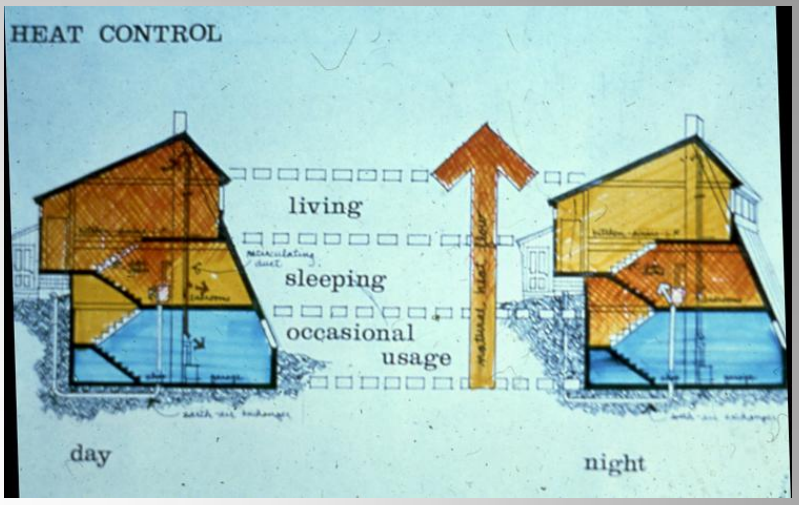
JOHN RAHILL
BLACK RIVER DESIGN
MONTPELIER, VT

BLACK RIVER DESIGN
ARCHITECTS

OUTLINE

1. Introduction
2. “energy efficient design” – Some History
3. A brief history of changes in envelope design & moisture control/learning from failing
4. The science behind the perfect wall: Moisture Migration Theory, Conductivity, Air Barrier Theory
5. A few tricky & important details
6. Increased durability and other side benefits of exterior insulation
7. Cost comparison to conventional cavity insulation
8. Limitations and potential drawbacks
9. Aesthetic bonuses
10. When you can’t get the perfect wall – WUFI, a hygrothermal modeling tool to avoid moisture problems.

THE 1970's BROUGHT FOCUS ON USING RENEWABLE ENERGY, NOT ON SAVING ENERGY



ACTIVE SOLAR!

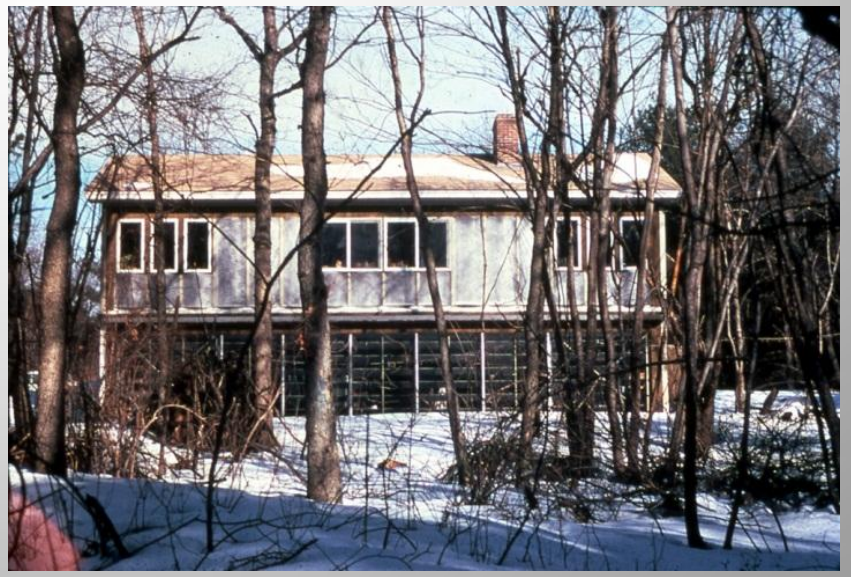
- Green lumber
- 2x6 framing, fiberglass insulation
- No insulation around the foundation or under slab
- Full 8" of insulation between framing in roof

Cardboard Model

Green Lumber Framing

BLACK RIVER DESIGN ARCHITECTS

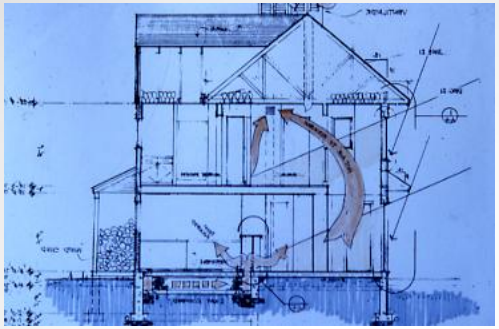
NEXT REVELATION: PASSIVE, NOT ACTIVE SOLAR DIRECT ABSORPTION HEAT SINKS, AND SHADING



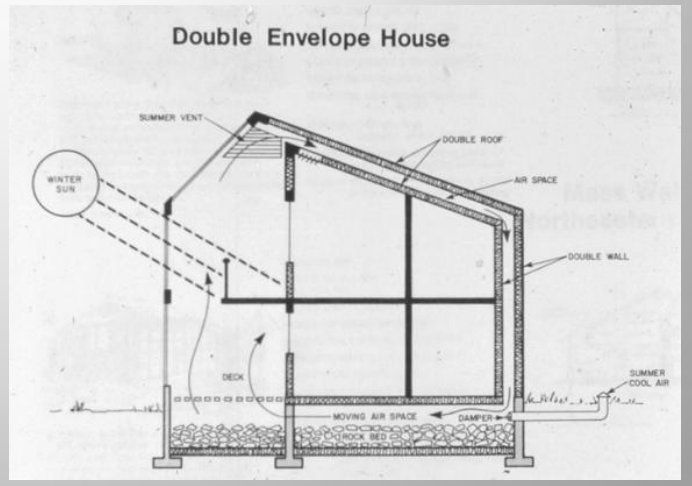
BLACK RIVER DESIGN ARCHITECTS

THINGS WENT THROUGH A COMPLICATED PHASE

- The double envelope house
- Passive venting through heat sinks
- Trombe walls



Rock Storage

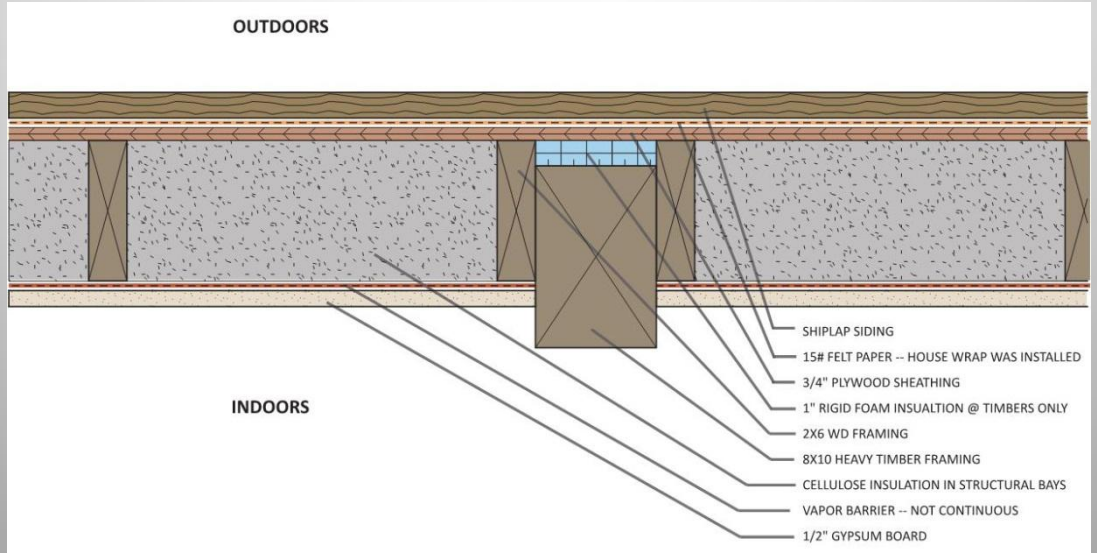


BLACK RIVER DESIGN ARCHITECTS

WHICH HOUSE WAS AHEAD OF IT'S TIME?

The greatest advancements in understanding how buildings perform has been in the envelope and in reducing heat loss, not in renewable energy and technological advances

THE TIGHTER THE HOUSE, THE MORE VULNERABLE TO MOISTURE PROBLEMS



BLACK RIVER DESIGN ARCHITECTS

AVOIDING MOISTURE PROBLEMS AS WE REDUCE HEAT LOSS

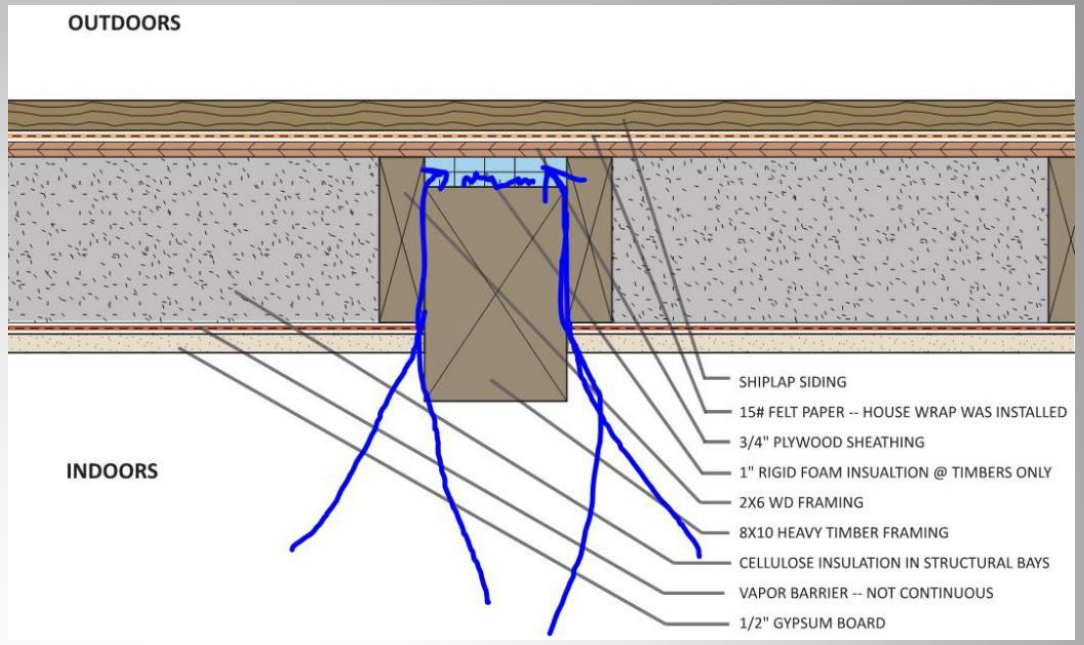
Increased vapor barrier awareness – primitive moisture theory based on all moisture problems coming from inside moisture.

A FEW YEARS LATER:
When design fails, everyone's opinion is valid.

Why is the paint peeling?

1. Wrong Brand of Paint
2. Should have used stain
3. Should have back primed
4. Should not have used a vapor barrier –it needs to be removed

IN THIS CASE WE DID NOT NEED TO WAIT 10 YEARS TO SEE THE PROBLEMS



BLACK RIVER DESIGN ARCHITECTS

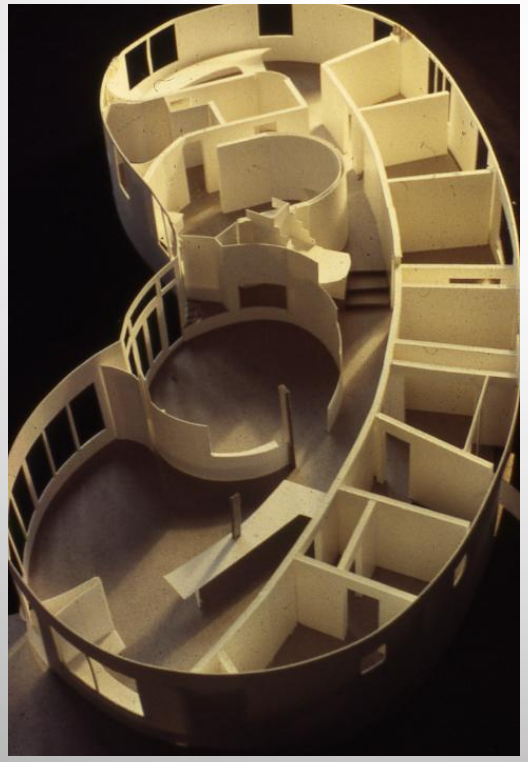
OUR FIRST EXPERIMENT WITH RIGID FOAM INSULATION: 1992

With insulation in the ceiling plane (cold attic) how are we going to prevent violations in thermal envelope?

Vapor barrier?

Ridge vent?

Eave vents?

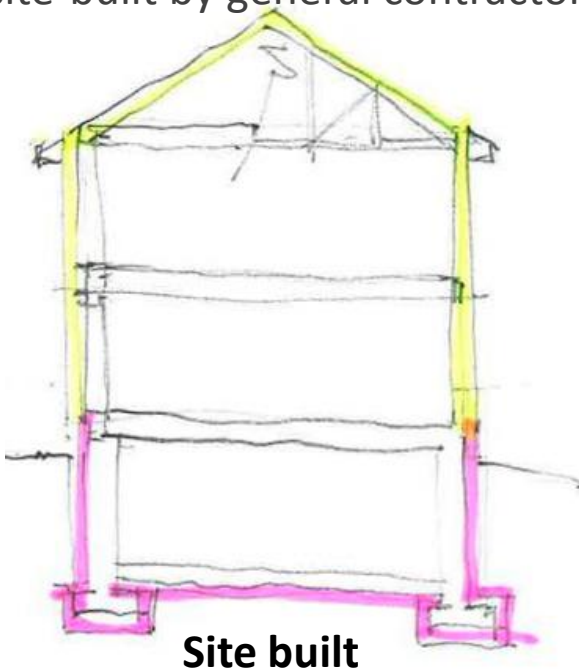


BLACK RIVER DESIGN ARCHITECTS

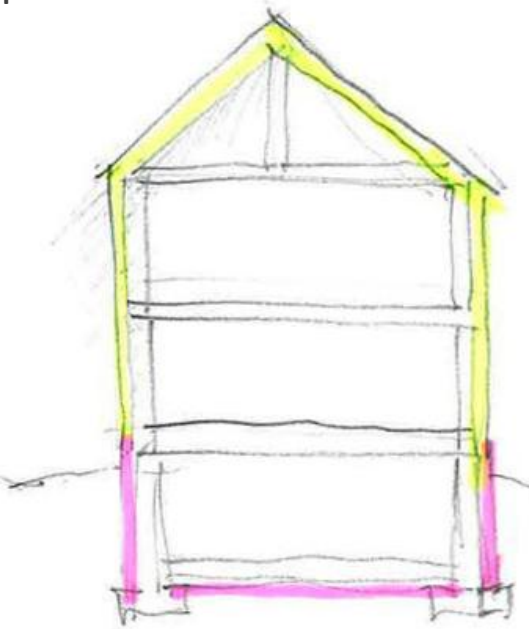
OUTSULATION: SITE BUILT EXTERIOR INSULATION

Building insulation system that wraps the building in rigid foam, continuously and with minimal thermal interruptions.

Similar to SIPS only
site-built by general contractor

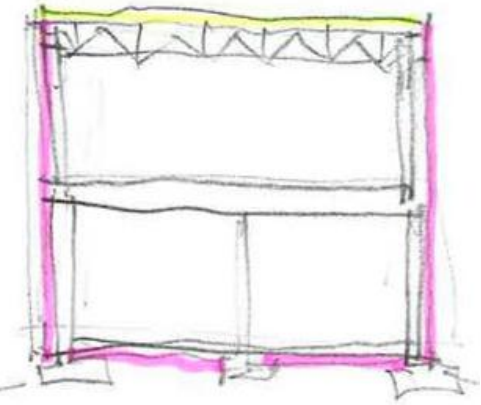


Site built
"Outsulation"



SIPS

Similar to commercial construction

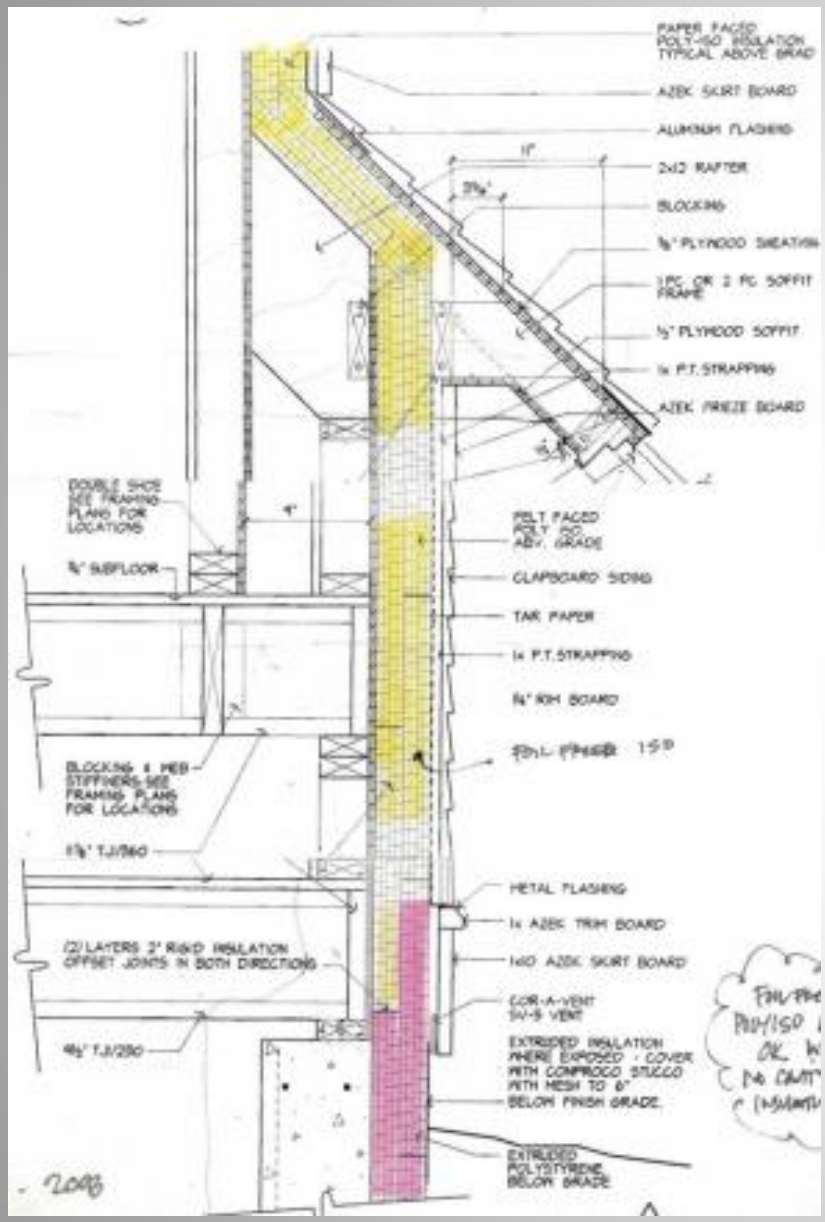


Masonry with Commercial roof

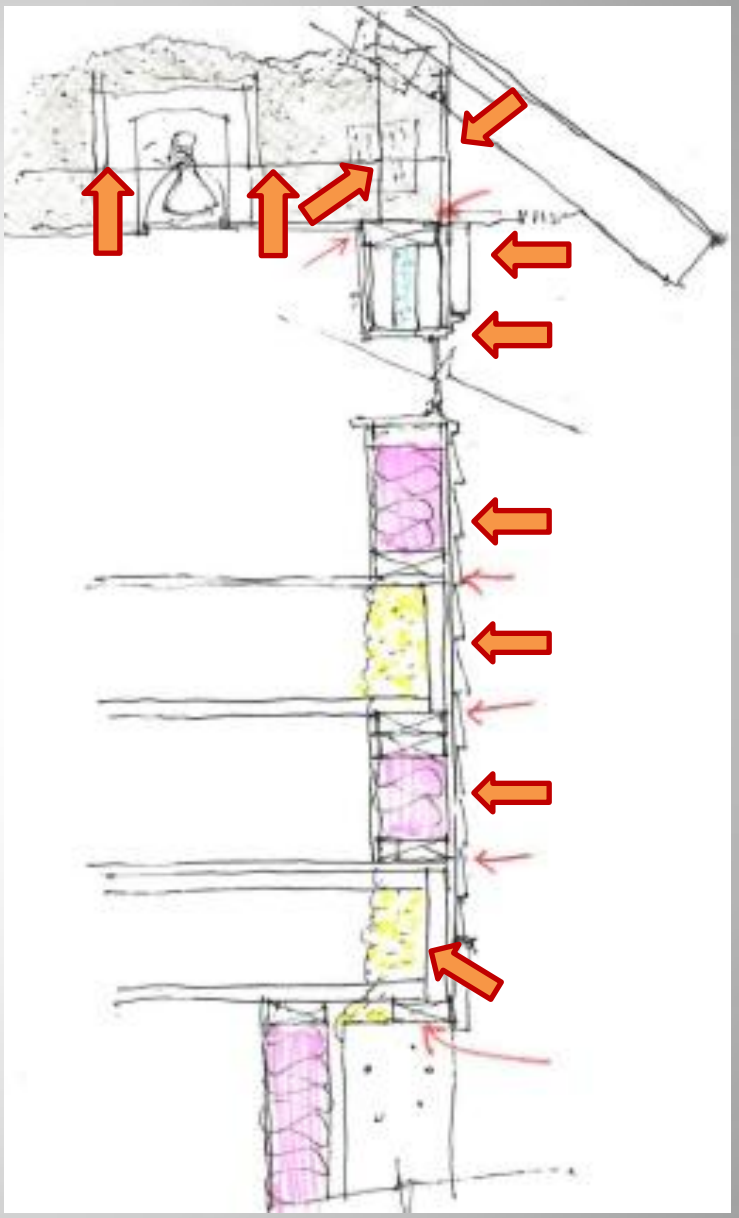
WHAT'S SO IMPORTANT ABOUT IT:

- Designed for continuity, practicality, durability
- Designed to prevent moisture damage

BLACK RIVER DESIGN ARCHITECTS



Outsulation



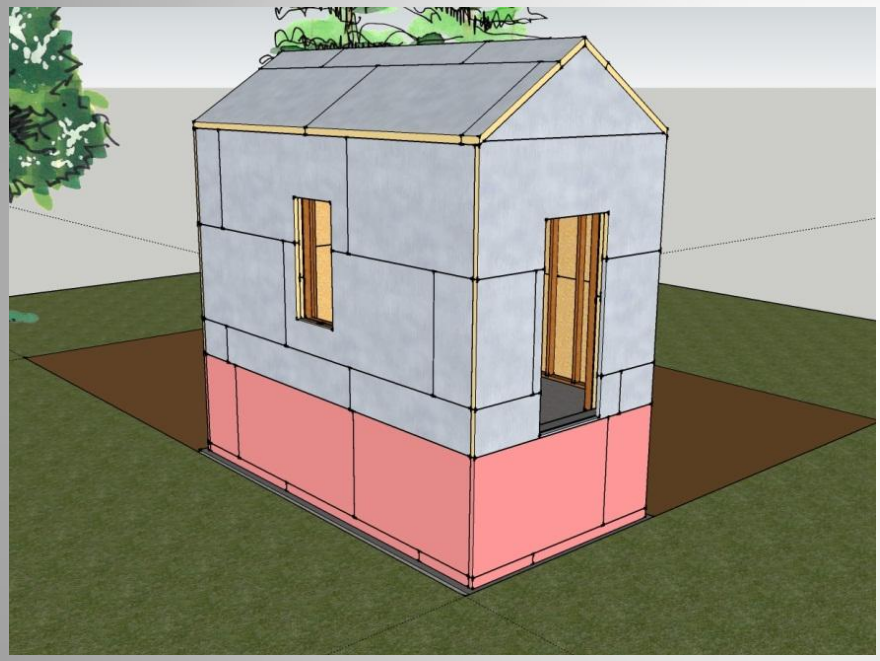
Conventional insulation

BLACK RIVER DESIGN ARCHITECTS

CONTINUOUS INSULATION – MINIMIZES THERMAL BRIDGING

BLACK RIVER DESIGN ARCHITECTS

SECOND LAYER OF INSULATION



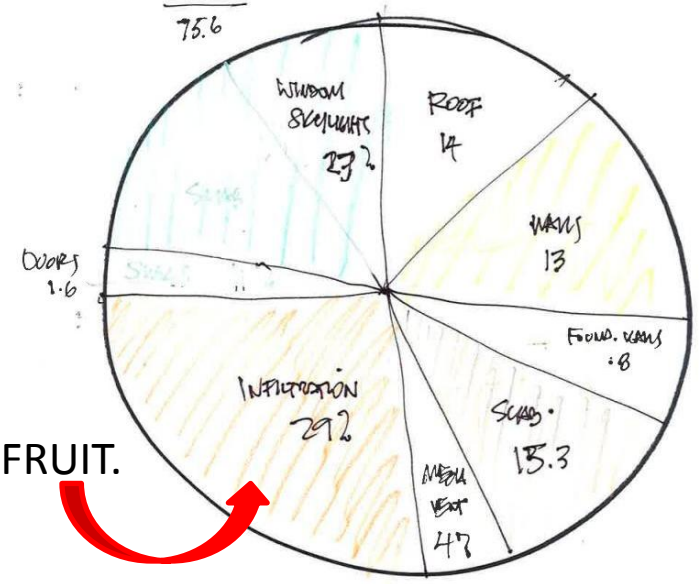
Exterior layer of insulation becomes drainage plane

In this case, the first layer is asphalt covered polyiso

BLACK RIVER DESIGN ARCHITECTS

B. AIR LEAKAGE: A SIGNIFICANT COMPONENT OF HEAT LOSS

	Rahill	% of TOTAL
EATING SEASON (MMBtu/yr)		
Ceilings/Roofs	10.5	14
Rim/Band Joists	1.1	1.5
Above Grade Walls	8.6	11.5
Foundation Walls	0.6	.8
Doors	1.2	1.6
Windows/Skylights	17.2	23
Frame Floors	0.0	
Crawl Space/Unht Bsmt	0.0	
Slab Floors	11.5	15.3
Infiltration	22.1	29
Mechanical Ventilation	2.9	3.8
Ducts	0.0	
Active Solar	0.0	
Sunspace	0.0	
Internal Gains	-16.3	
Total	59.3	
	+16.3	
	75.6	



AIR INFILTRATION IS THE LOW HANGING FRUIT.

AIRTIGHTNESS IS ACHIEVABLE

THERMAL BENEFITS

BLACK RIVER DESIGN ARCHITECTS

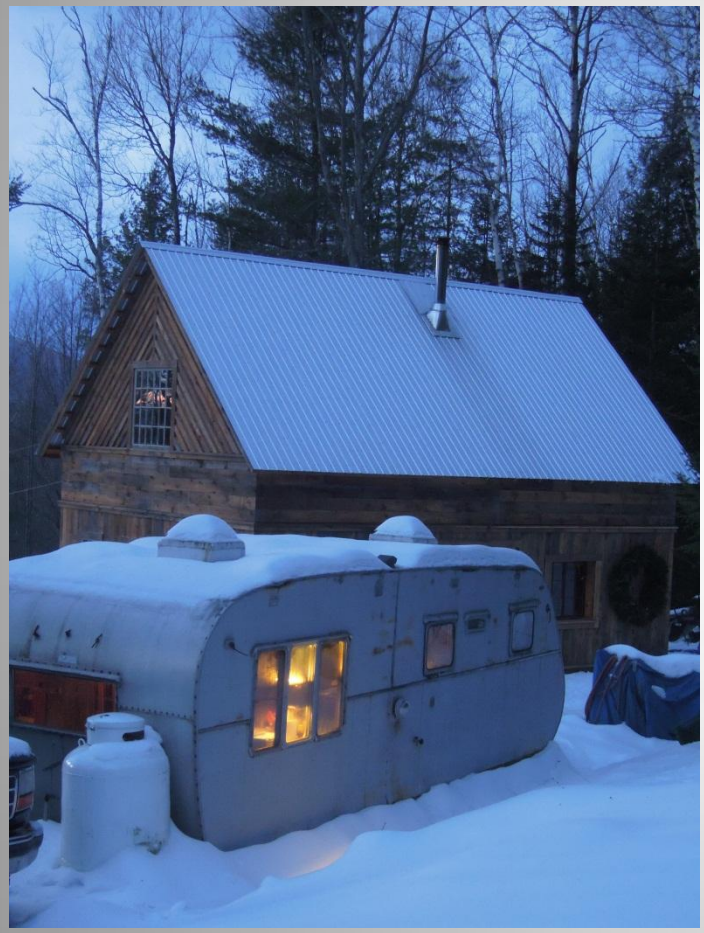
AIRTIGHTNESS IS ACHIEVABLE

25% IMPROVEMENT IN AIR TIGHTNESS IN 3 HOURS OF WORK….

TRICKY AND IMPORTANT DETAILS

BLACK RIVER DESIGN ARCHITECTS

CONTINUOUS INSULATION – MINIMIZES THERMAL BRIDGING



R-12 OUTSULATION VERMONT GUEST HOUSE

R-7 OUTSULATION RESIDENCE

THERMAL BENEFITS

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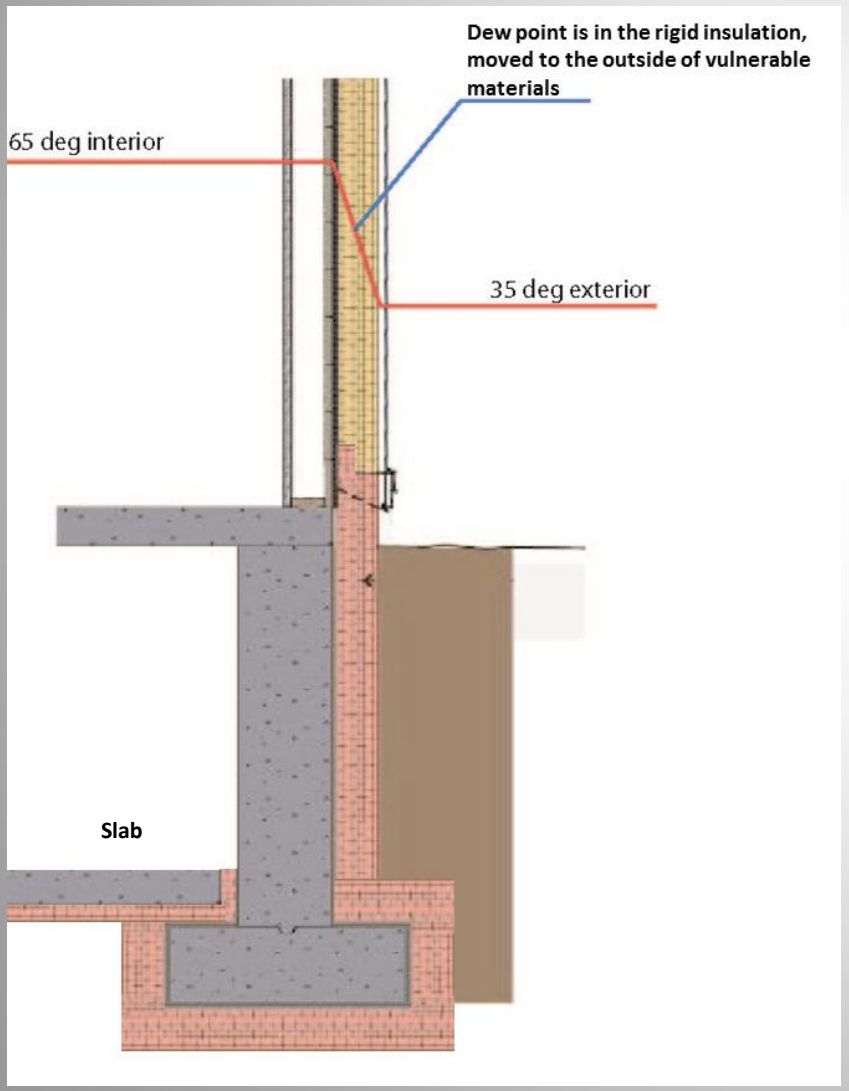
ARCHITECTS

MOISTURE PROBLEMS

Moisture problems are minimized (in theory they are eliminated.)
All vulnerable wall material remains at room temperature.



BLACK RIVER DESIGN ARCHITECTS

BUILDING THERMALLY BROKEN ROOF OVERHANGS

BLACK RIVER DESIGN ARCHITECTS

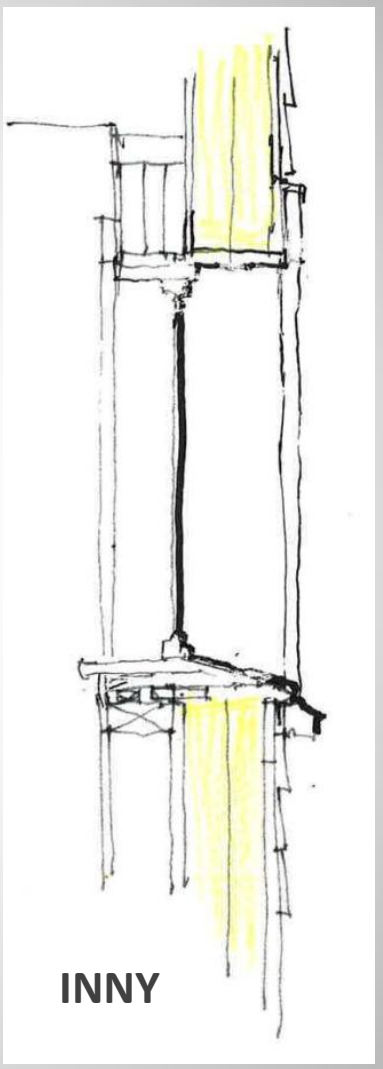
WINDOW INSTALL

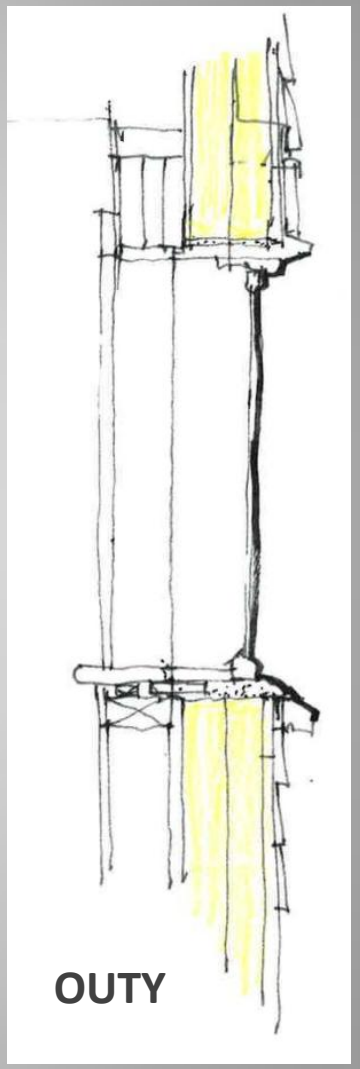
Installing windows and doors in the plane of insulation, or in the plane of structure

5 support systems:

1. Nailing flange
2. Window straps
3. Support under window (if you can)
4. Foam
5. Insulation down to footing

And if that is not enough - add a 2x4 under the window





BLACK RIVER DESIGN ARCHITECTS

FLASHING ABOVE DOOR AND WINDOWS

Take flashing way back, do not rely on tape alone….

Tarpaper or building wrap is useful to insure moisture is diverted out, but is not effective in increasing air tightness, in our experience

CRITICAL DETAIL: INSECT SCREEN AND BARRIER

Place an insect barrier to prevent infestation

Insect Barrier

Drainage Plane Insect Screen

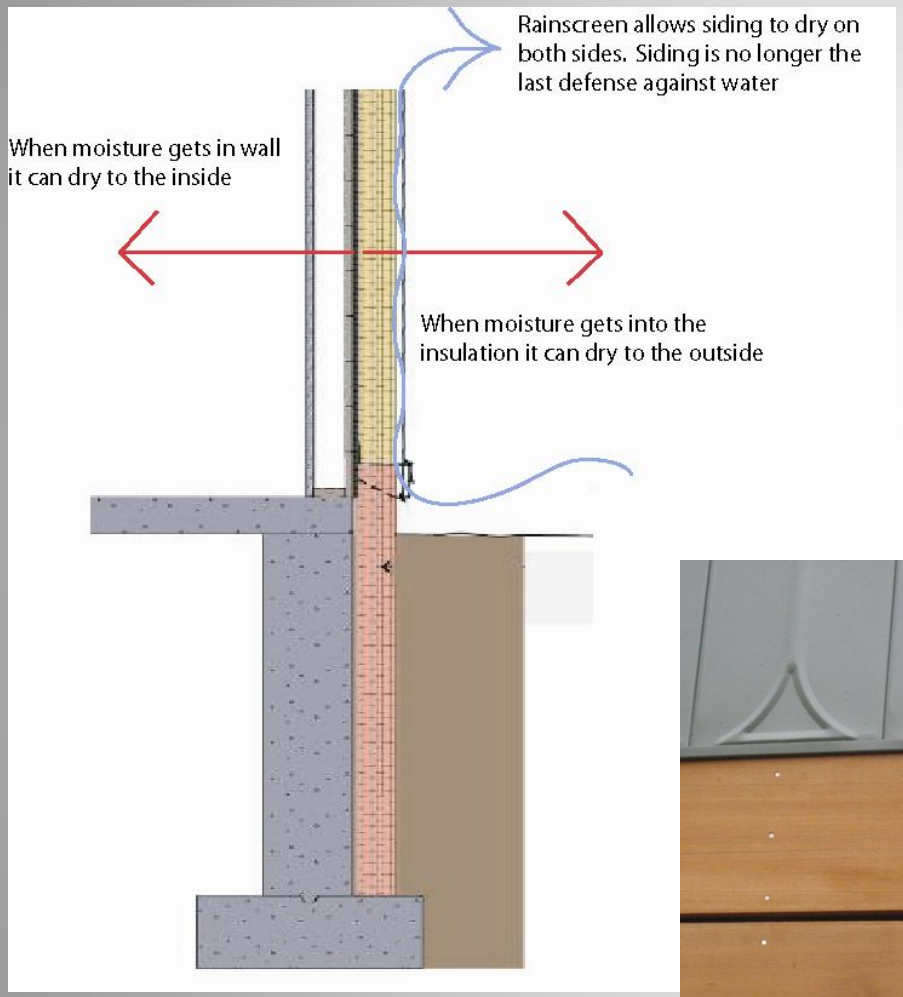
BLACK RIVER DESIGN ARCHITECTS

OUTSULATION:

WHEN COMPLETED – YOU CAN'T TELL IT'S ANY DIFFERENT BY LOOKING AT THE BUILDING

BLACK RIVER DESIGN
ARCHITECTS

OTHER SIDE BENEFITS OF "OUTSULATION"



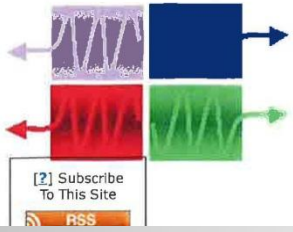
- Drying can occur to the inside
- Siding can dry to the outside
- Focus changes from "keeping water out" to "letting it dry."
- Insulation doesn't mind if it gets wet

BLACK RIVER DESIGN ARCHITECTS

ADVANTAGES FOR CONSTRUCTION SEQUENCE

	CONVENTIONAL INSULATION	OUTSULATION
Installer:	Specialist: cellulose/spray foam	Lowest paid worker on the GC crew, (like the fiberglass installer)
When:	After windows, wiring, plumbing, fire alarm, sprinkler	Very early in the job, right after framing
Who can ruin vapor barrier:	Plumber, electrician, insulator, homeowner	Nobody, there is no vapor barrier
After it is installed:	Add an outlet? Difficult.	Easy to move interior elements
Blower door	Typically near completion	After insulation is in, before dry wall

BLACK RIVER DESIGN ARCHITECTS



Insulation Guide

How Much Does Insulation Cost?

©Insulation-Guide.com

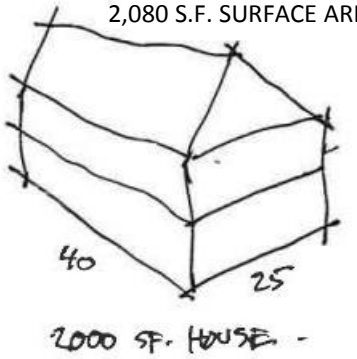
General Insulation Costs

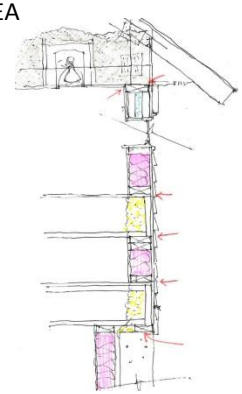
Insulation Type	R-value / inch	Thickness for R19	Installed Cost $/sq. ft. (R19)	Installed Cost $/bd.ft.	Installed Cost $/R-value	Material Cost (for DIY) $/sq. ft. (R19)	Material Cost (for DIY) $/bd.ft.	Material Cost (for DIY) $/R-value	Availability Installers	Availability for DIY
Closed-Cell Foam	6.5	2.9	3.02	1.03	0.16	Not Applicable			common	not available
Fiberglass Batt	3.2	5.9	0.88	0.15	0.05	0.43	0.07	0.02	common	hardware and home stores
Loose Fill Cellulose	3.6	5.3	0.73	0.14	0.04	0.31	0.06	0.02	common	hardware and home stores
Kit Foam (DIY)	6.0	3.2	Not Applicable			4.76	1.50	0.25	none	online
Cotton	3.5	5.4	0.92	0.17	0.05	Not Enough Data			not common	special order
Recycled Denim	3.5	5.4	Not Enough Data			1.37	0.25	0.07	note common	special order
Sheep's Wool	3.8	5.0	3.5	0.70	0.18	Not Enough Data			rare	special order
Cementitious (Air Crete)	3.9	4.9	2.45	0.50	0.13	Not Applicable			rare	not available
Mineral Wool, Rock Wool	4.0	4.8	1.2	0.25	0.06	0.51	0.11	0.03	rare	special order
Expanded Polystyrene (EPS)	4.0	4.8	4.04	0.85	0.21	1.14	0.24	0.06	common	hardware and home stores
Extruded Polystyrene (XPS)	5.0	3.8	4.37	1.15	0.23	1.82	0.48	0.10	common	hardware and home stores
Polyisocyanurate Board	7.2	2.6	3.17	1.20	0.17	1.61	0.61	0.08	common	hardware and home stores

BLACK RIVER DESIGN ARCHITECTS

"_____" (INSERT LEED, YOUR PRODUCT, ETC…) ONLY COSTS 5% MORE.

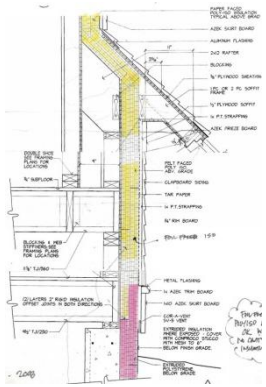
COST COMPARISON – R-24 WALL





CONVENTIONAL

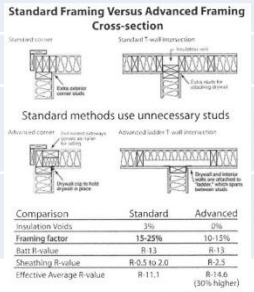
5.5" CELLULOSE INSULATION IN WALL CAVITY WITH 1 ½" RIGID ON THE EXTERIOR, TAPE SEAMS



OUTSULATION

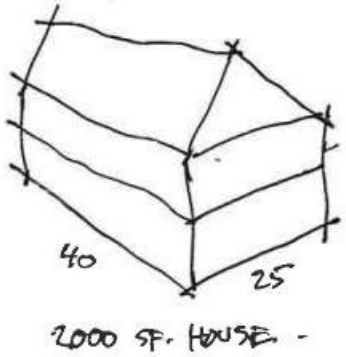
4" RIGID INSULATION, STAGGER AND TAPE SEAMS

	CONVENTIONAL	COST	OUTSULATION	COST
INSULATION	5.5" CELLULOSE @ $0.73 PER SF + 1 1/2" RIGID FOAM AT $1.80 PER SF	$5262.00	4" RIGID FOAM	$10,600.00
FRAMING	2X6 WALL FRAMING 16" OC TYP	$0.00	2X4 WALL FRAMING 16" OC TYP	-$420.00
GABLES	EITHER NEED TO INSULATE OR FIR OUT	$500.00	ADDED INSULATION @ GABLE WALL ENDS	$720.00
FOUNDATION	NO SAVINGS	$0.00	4" SMALLER BOTH DIRECTIONS	-$50.00
VAPOR BARRIER	$0.25 PER SF	$525.50	NO VB	$0.00
SPACE SAVINGS	NONE	$0.00	43 SF OF INTERIOR SPACE @ $100 PER SF (AT $200 PER SF = -$8,666.00)	-$4,333.00
TOTAL		**$6,287.50**		**$6,517.00**
OTHER POTENTIAL COSTS	WINTER CONDITIONS	$500-$3000		
	ADVANCED FRAMING	$500-$1000		



COST COMPARISON – R-32 ROOF

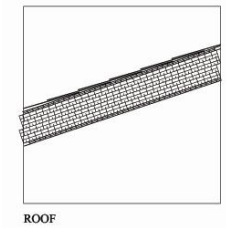
2,080 S.F. SURFACE AREA



CONVENTIONAL

12” CELLULOSE INSULATION BLOWN ACROSS TRUSS BOTTOM CHORD AND CEILING

OUTSULATION



5” RIGID INSULATION, ½” PLYWOOD SHEATHING ON THE OUTSIDE STAGGER AND TAPE SEAMS

	CONVENTIONAL	COST	OUTSULATION	COST
	CONVENTIONAL	COST	OUTSULATION	COST
INSULATION	$1.40 PER S.F.	$1,960.00	.	$7,280.00
SHEATHING		$0.00	ONE ADDITIONAL LAYER OF 1/2" PLYWOOD SHEATHING	$1,656.00
EAVE VENTS	NECESSARY ATTIC VENTING	$1,000.00	HOT ROOF (NO VENTING)	$0.00
ADD PROPER VENTS AT EAVES	NECESSARY ATTIC VENTING	$500.00		
RIDGE VENT/GABLE VENTS	NECESSARY ATTIC VENTING	$500.00	HOT ROOF (NO VENTING)	$0.00
AIR SEALING OF CEILING	?	$800.00	PRETTY TIGHT SANDWICH (TAPE PLYWOOD)	$0.00
TOTAL		**$4,760.00**		**$8,655.00**
			REMOVE ONE LAYER OF 1/2" SHEATING?	-$1,656.00

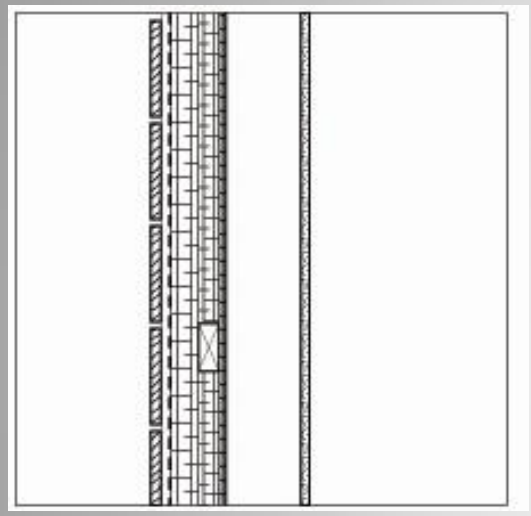
OTHER CONSIDERATIONS		
	WHAT TO DO WITH CATHEDRAL CEILINGS, KNEE WALL CONDITIONS?	600 S.F. OF WARM ATTIC SPACE (WHAT IS THIS WORTH?)
	SKYLIGHTS?	SKYLIGHTS IN THE PLANE OF INSULATION
	DORMERS, VALLEYS, WALL CEILING INTERSECTIONS?	ALL EXTERIOR AND CONTINUOUS
	RECESSED LIGHTS?	NO INSULATION TO FUSS WITH
	BATHROOM FANS?	NO INSULATION TO FUSS WITH
	CHIMNEYS?	NO INSULATION TO FUSS WITH

LIMITATIONS – POTENTIAL PROBLEMS

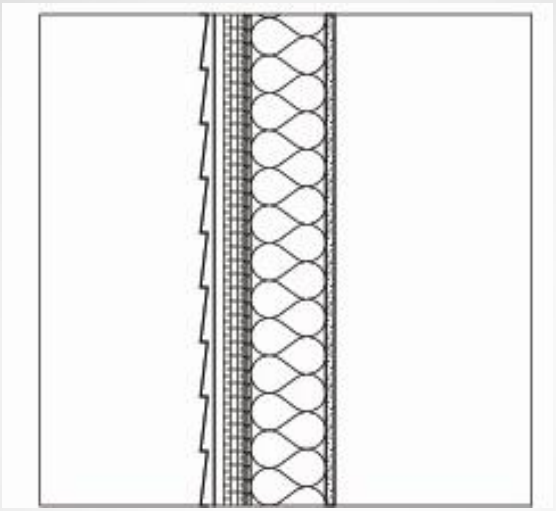
- Design limitations for roof overhangs and other exterior features?
- Thermal significance of heat loss through fasteners?
- Pollutants from rigid foam?
- Flashing above windows and doors can be tricky, how long will tape last?
- Foam shrinkage?
- How much do insects like rigid foam?

WUFI: A MODELING PROGRAM TO HELP WHEN REAL LIFE GETS IN THE WAY

Insulation strategy



After value engineering…..



Design walls that are "failure resistant"

BLACK RIVER DESIGN ARCHITECTS

AESTHETIC OPPORTUNITIES

- Thick walls allow for thermally broken deep recesses.
- Exposed interior framing
- Cathedral ceilings/ thermally broken skylights

BLACK RIVER DESIGN ARCHITECTS

QUESTIONS?

BLACK RIVER DESIGN ARCHITECTS