Passiv for the Masses

Part I: LOGIC — Matthew O'Malia, GO

Part II: LOGIC — Alan Gibson, GO

Part III: SCIENCE — Adam Cohen, PASSIV

NESEA BUILDING ENERGY 16 CONFERENCE BOSTON, MARCH 9TH, 2016

GO Logic

GO Logic is a 28 person architecture and construction firm in Belfast, Maine, committed to designing and building passive house level buildings. Founded in 2008 by Contractor, Alan Gibson and Architect, Matthew O'Malia

GO Logic designs and builds a mix of projects including residential, multi-family and institutional, and has certified 6 passive houses and is currently in the process of certifying its 7th.

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G·OLOGIC

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WARREN WOODS
North America's First Passive House Laboratory
Completed in Michigan, 2014


the GO HOME
PassiveHaus Certified Home


ECOVILLAGE
36 family complex of
Near-Zero structures

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LITTLE HOUSE THE FERRY
Three season summer home


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GOOD WILL HINCKLEY
Historical Masonry Renovation

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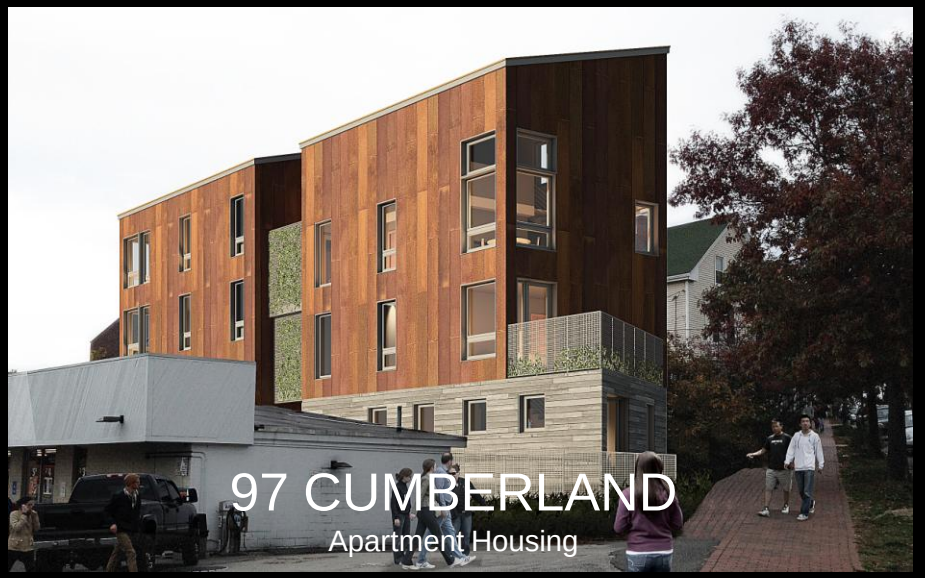
COMSTOCK
Passive house level residence


97 CUMBERLAND
Apartment Housing


QUNICY HOUSE
PasPassive house level residence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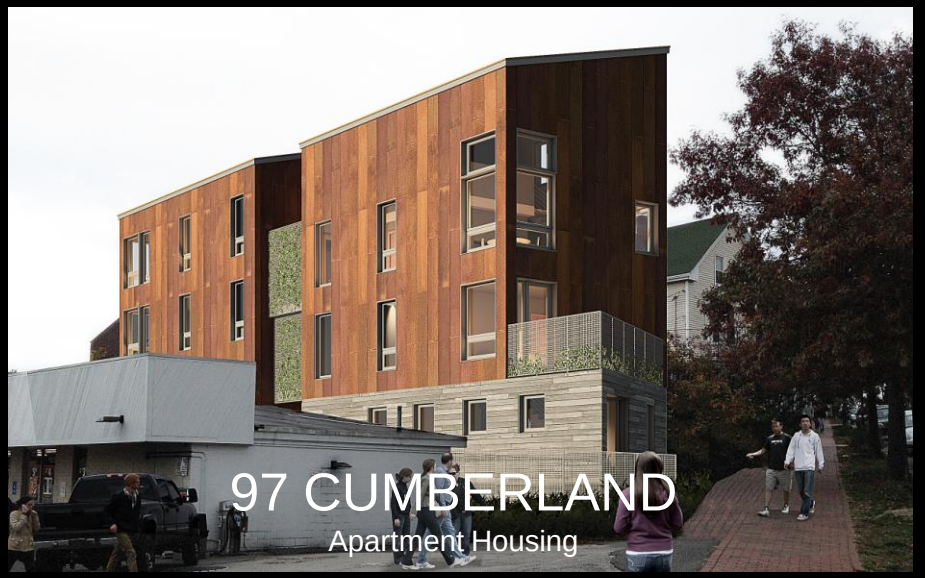
97 CUMBERLAND
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CORNERSPRING MONTESSORI
Elementary School


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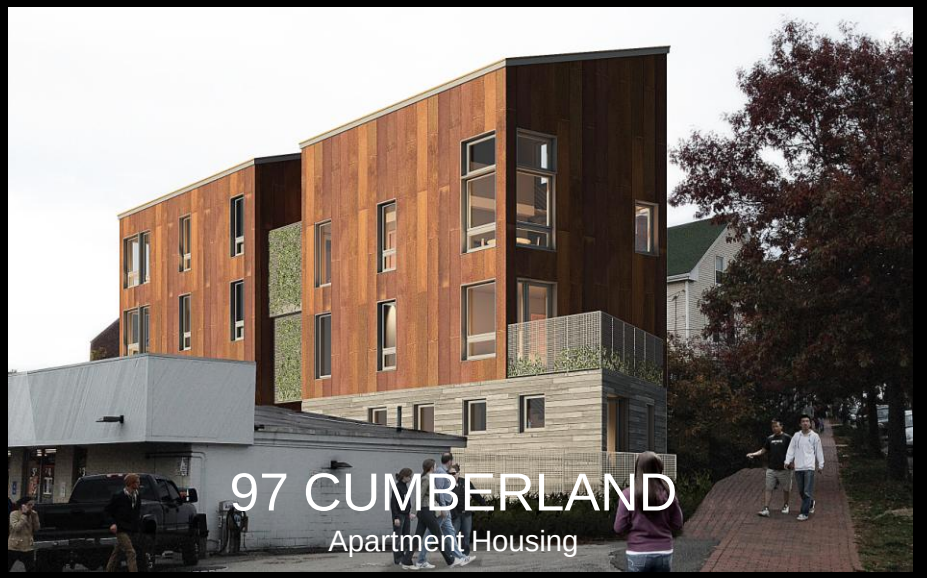
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CORNERSPRING MONTESSORI
Elementary School


SHELDON CALVARY CAMP
Dining Facility - Ohio

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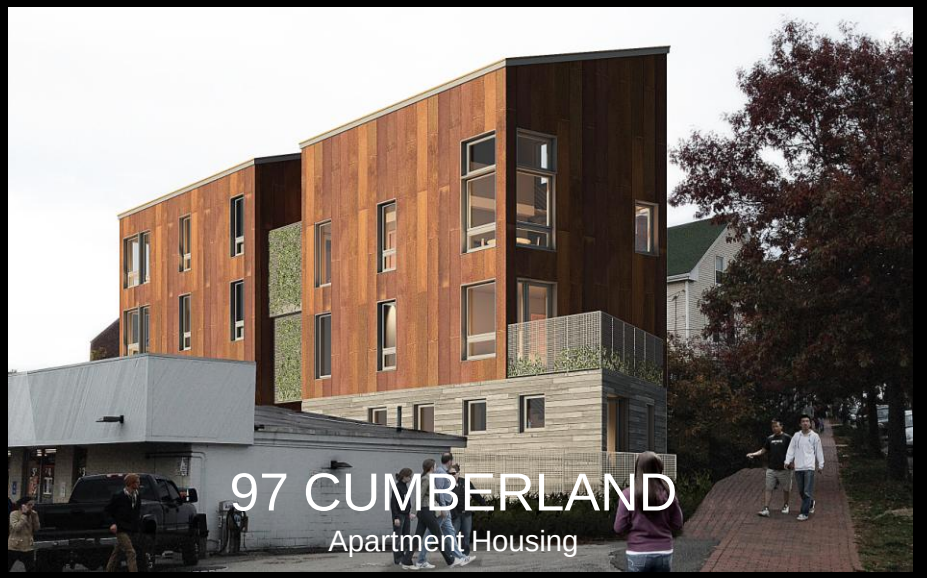
COMSTOCK
Passive house level residence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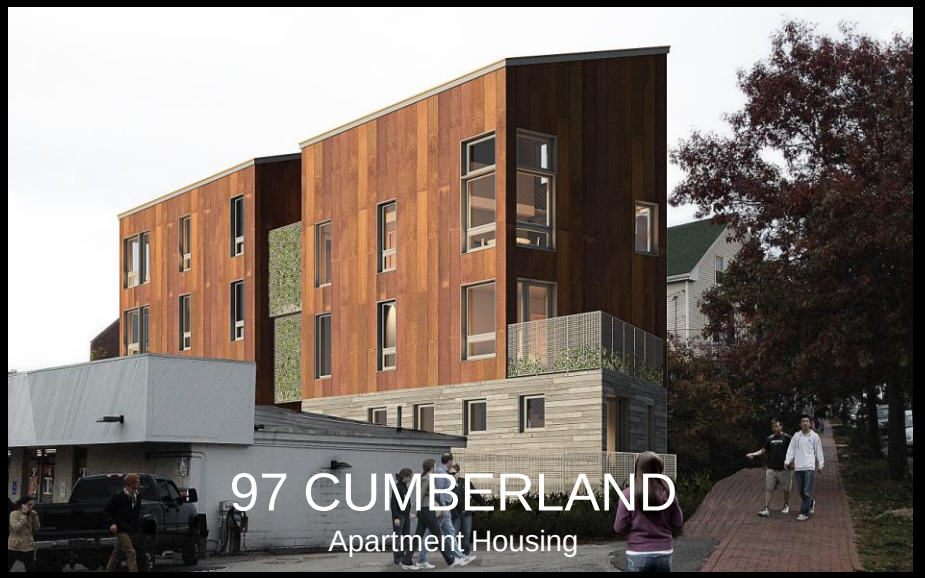
GATHERING CENTER
PassiveHaus certified Pending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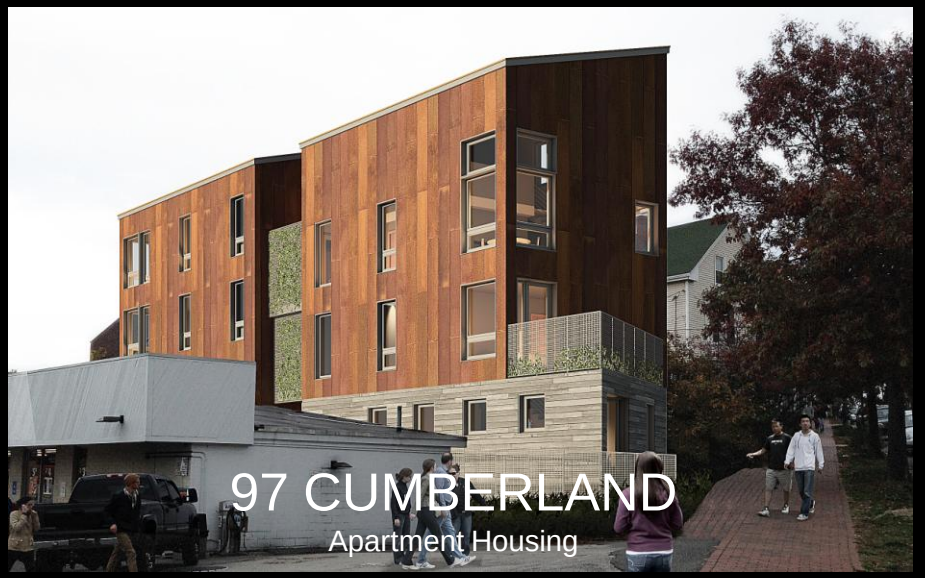
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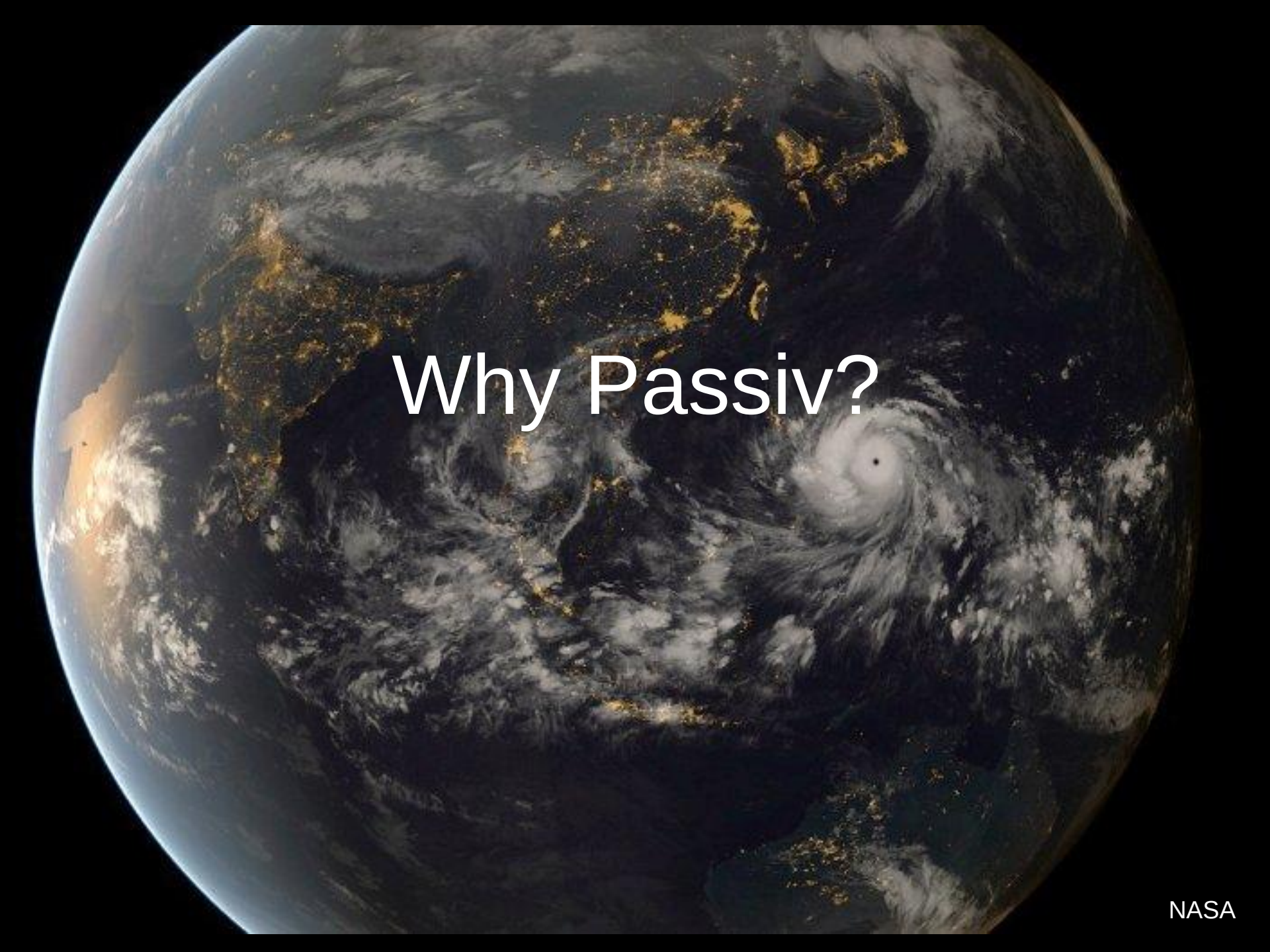
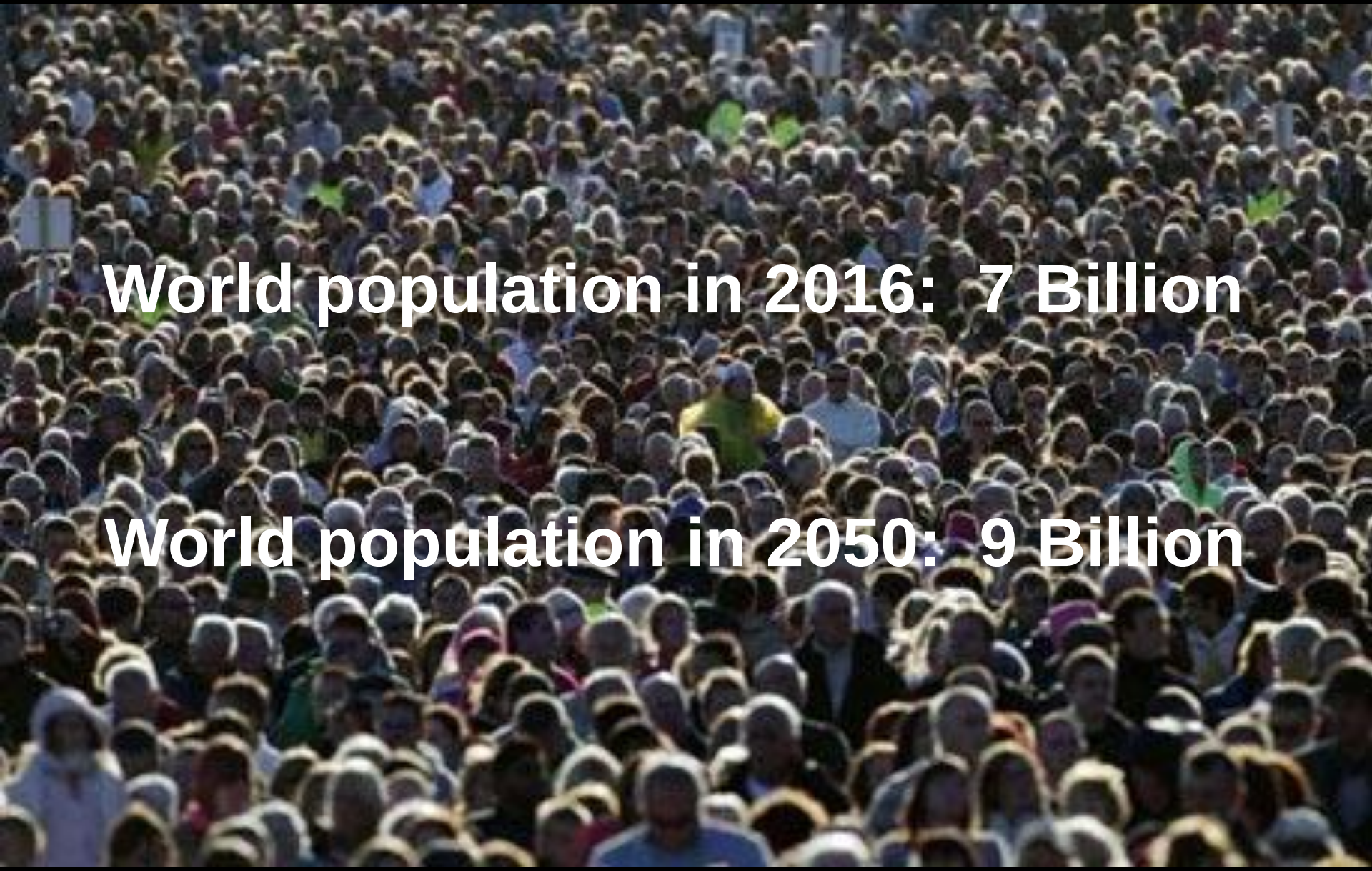

Why Passiv?
NASA

Reuters



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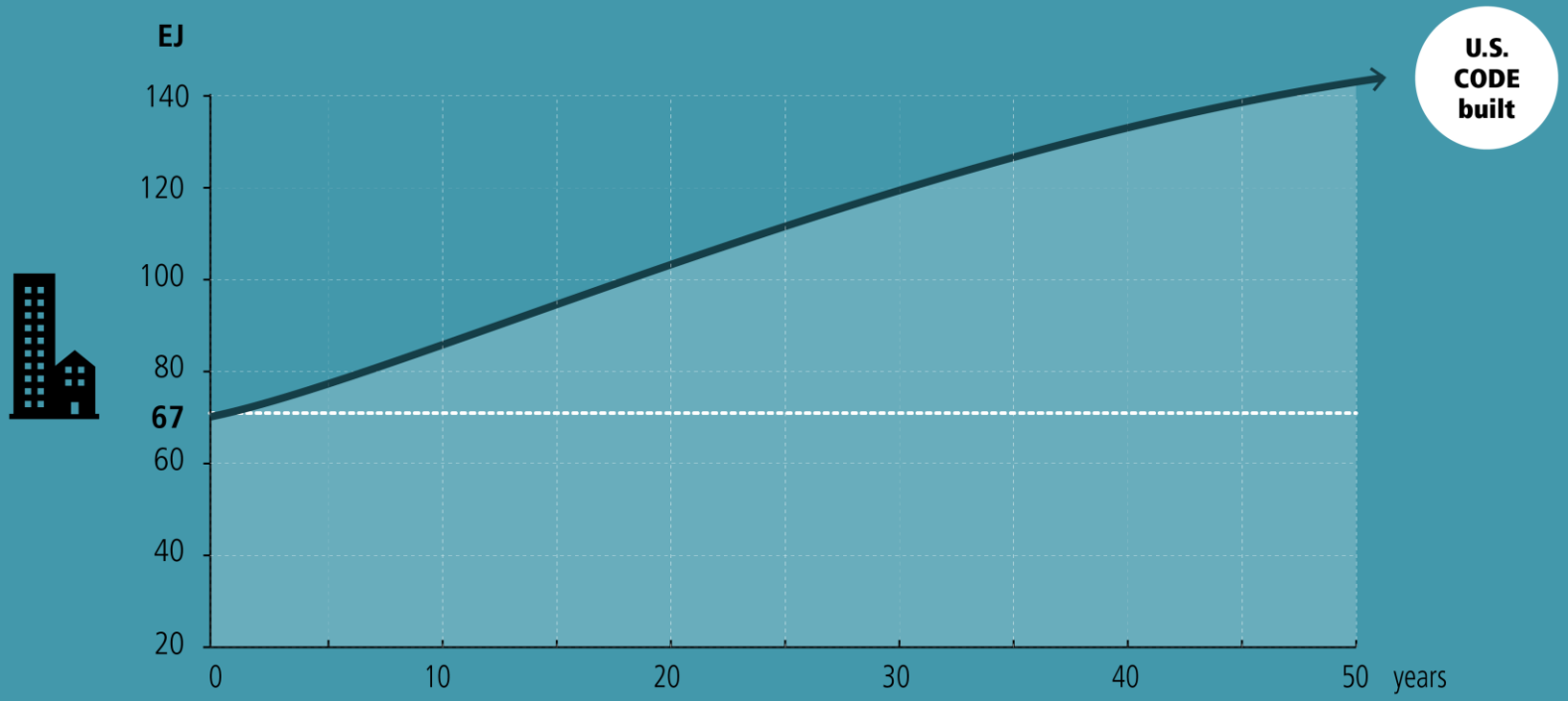
Reuters

THE LOCK IN EFFECT



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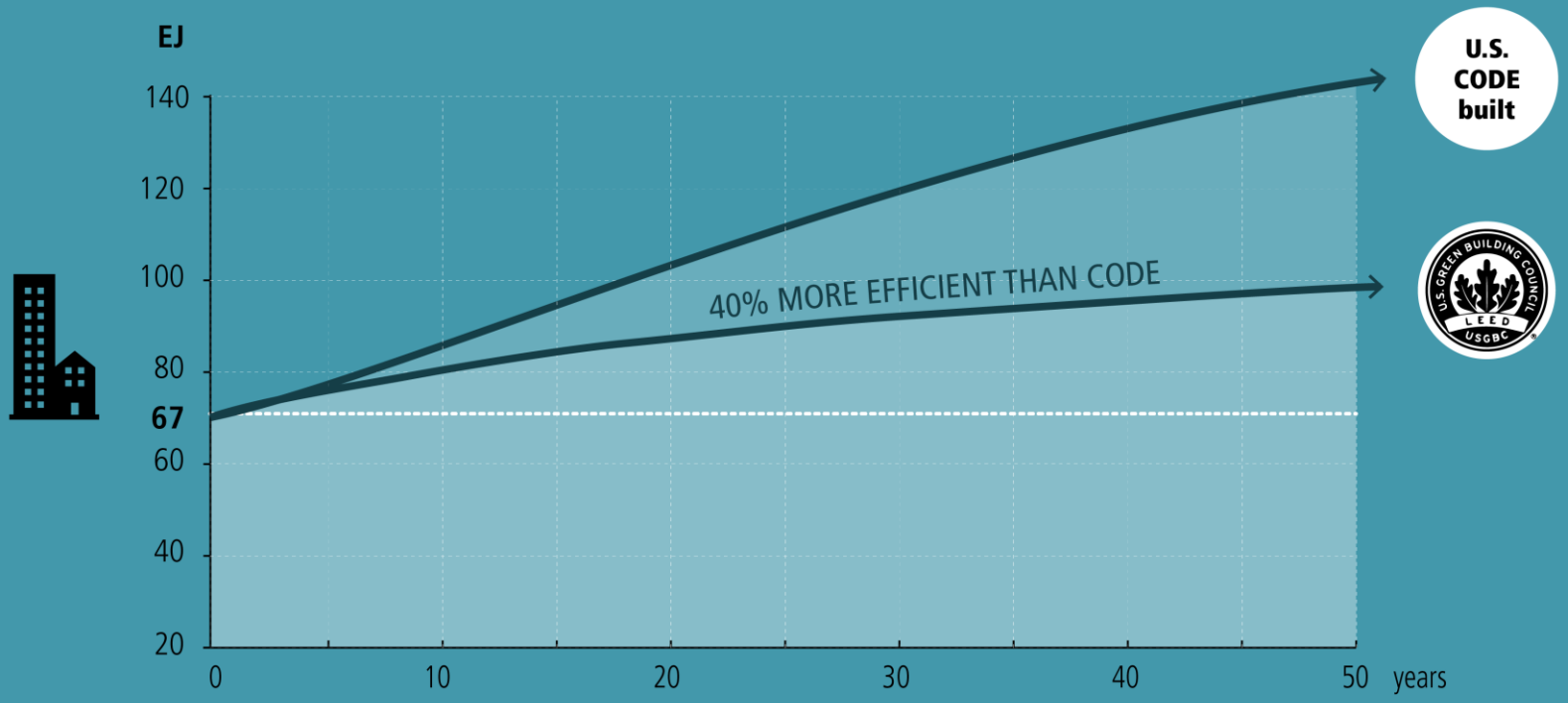

Global Buildings Performance Network

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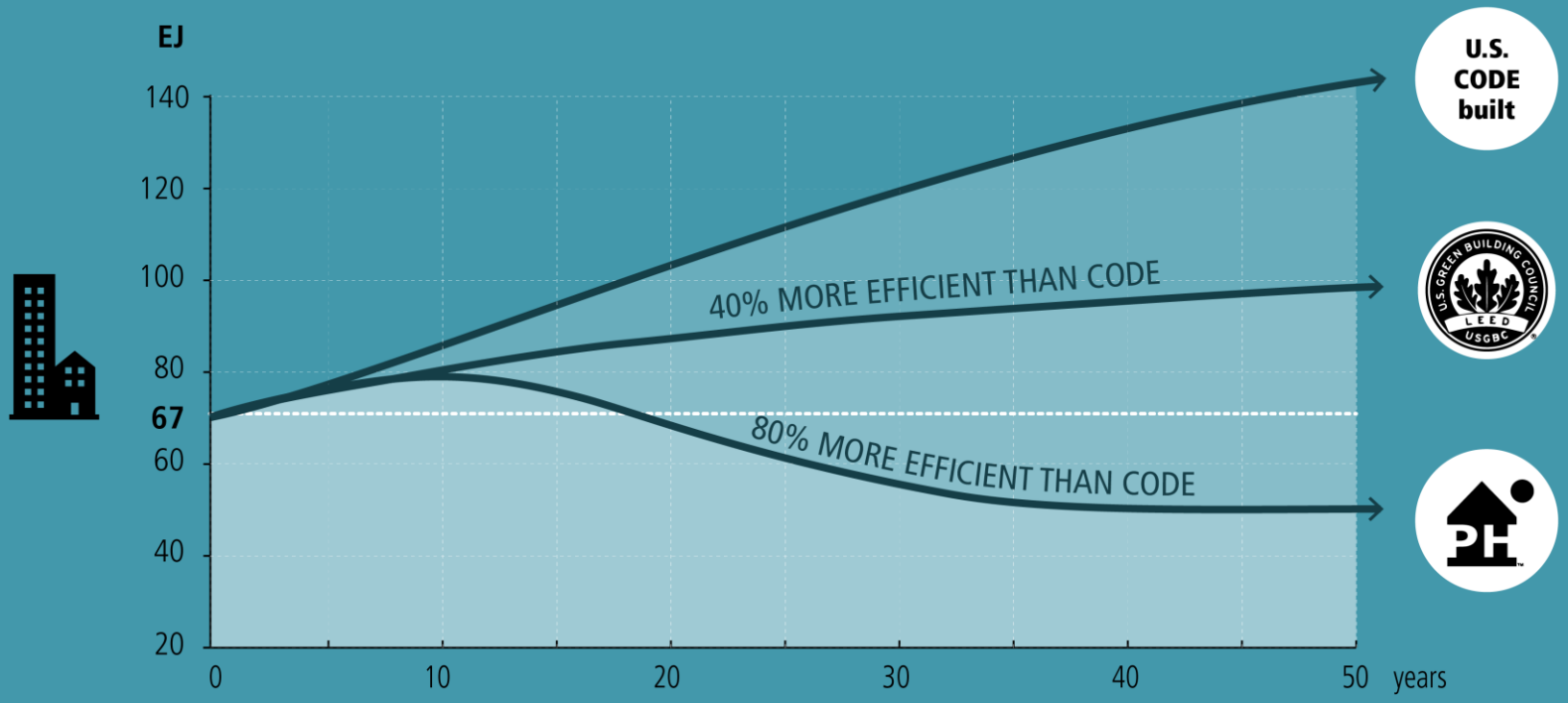

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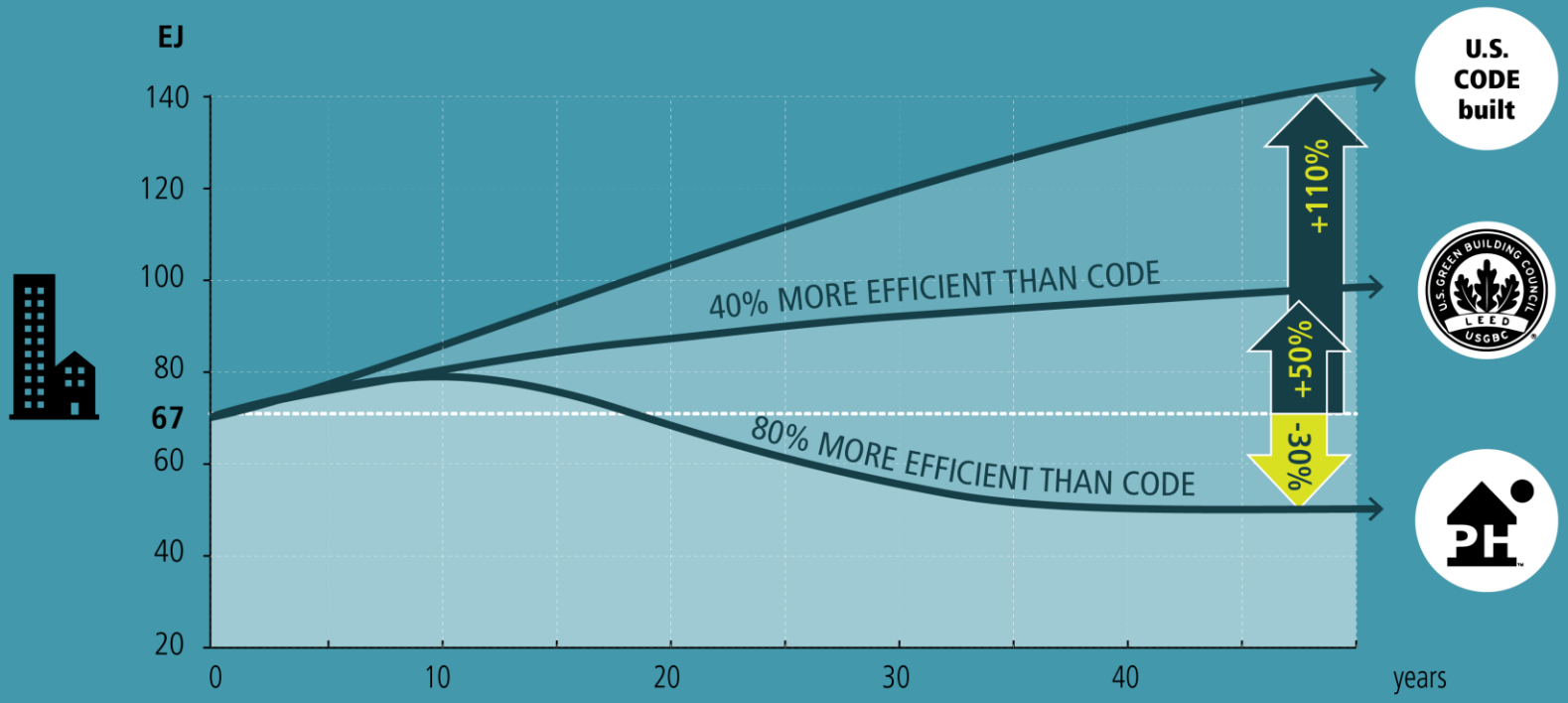

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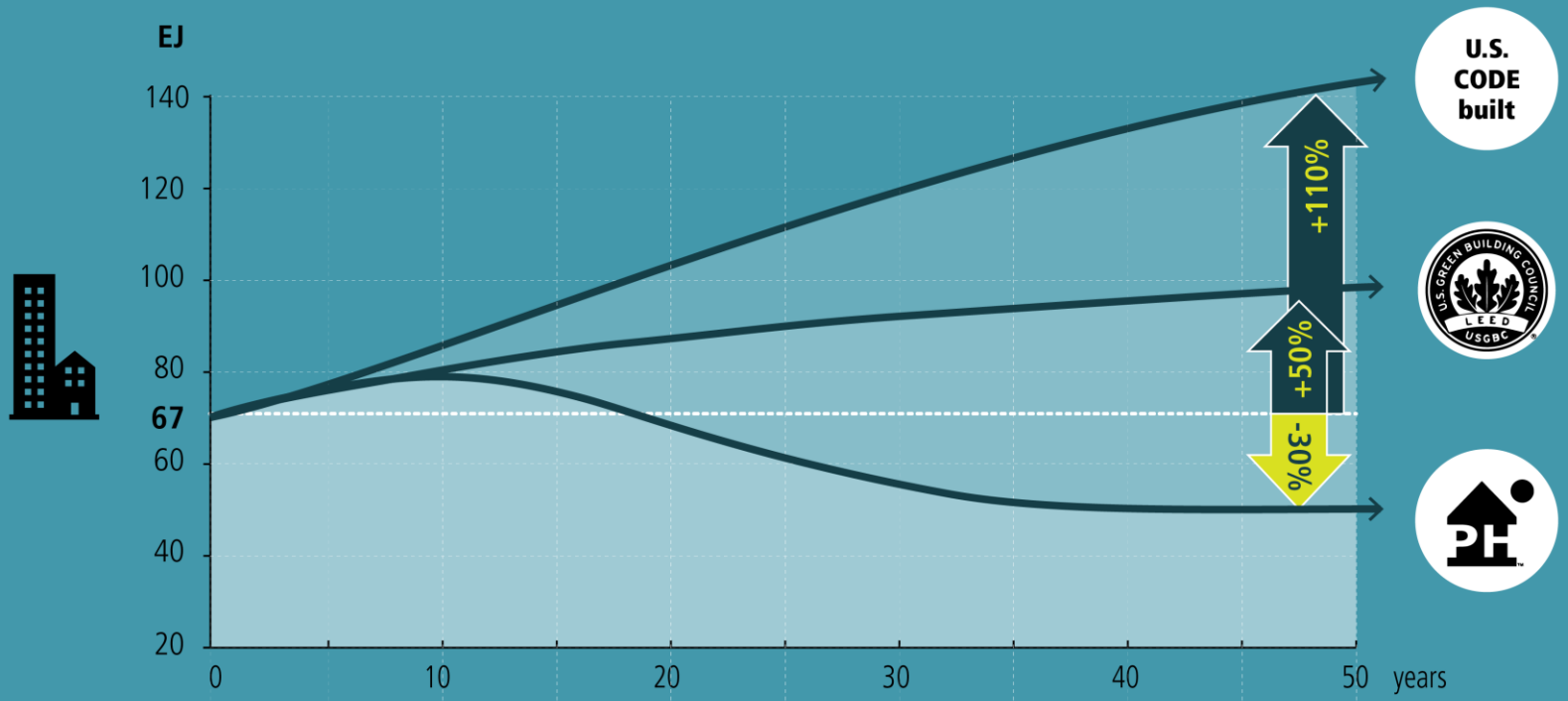
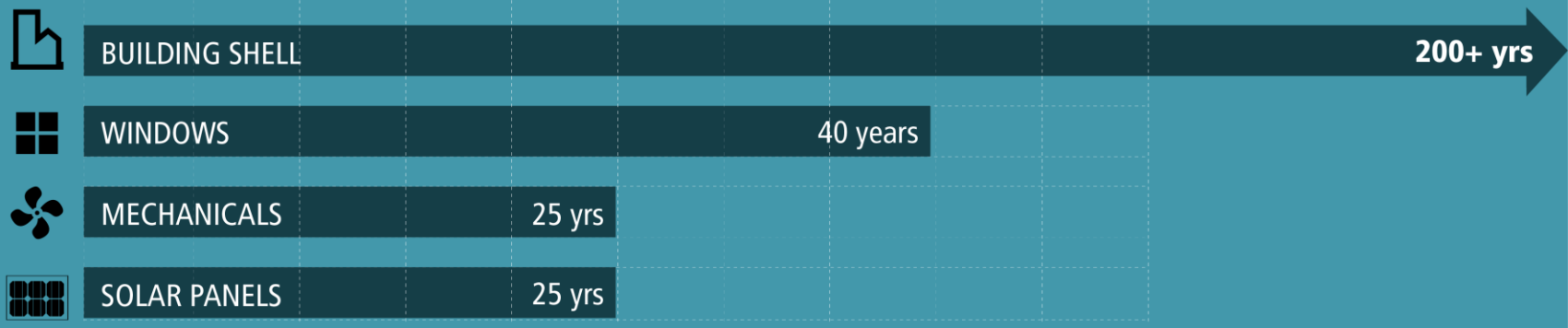


LIFESPAN OF BUILDING COMPONENTS



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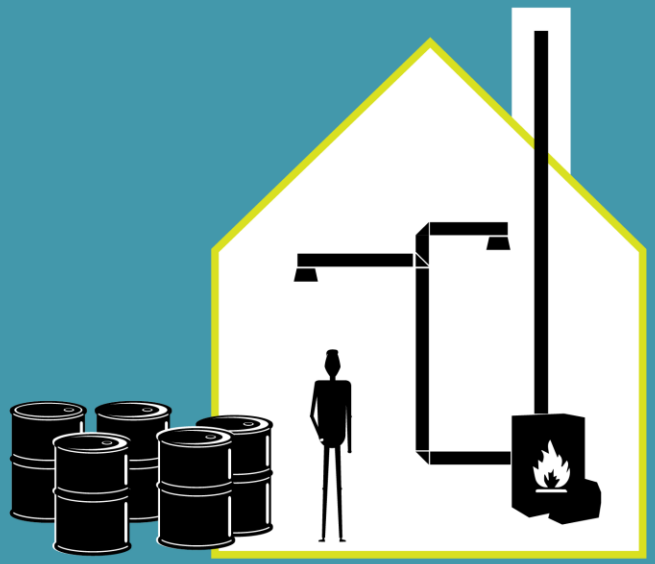
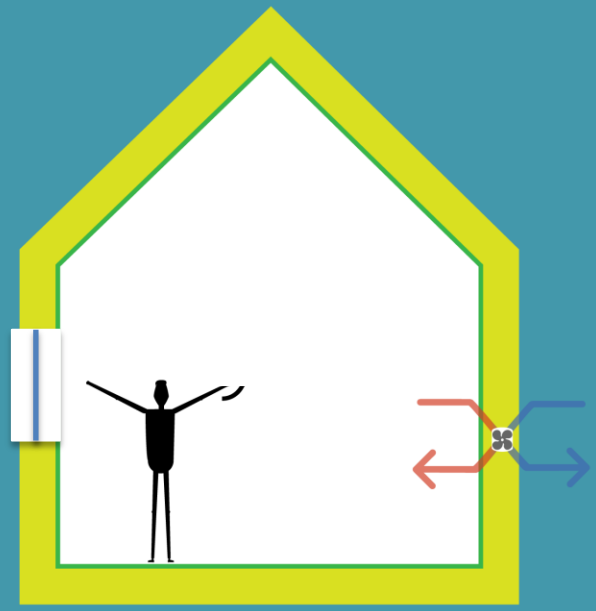
PASSIVE HOUSE 101

- HIGHLY INSULTATED BUIDLING SHELL: BUILDINGS THAT ARE 80% MORE EFFICIENT THAN STANDARD COSNTRUCTION
- NEARLY AIR TIGHT BUILDING ENCLOSURE
- VENTIALTION WITH HEAT RECOVERY FOR IMPROVED INDOOR AIR QUALITY
- A COST-EFFECTIVE BUILDING SOLUTION FOR COLD CLIMATES

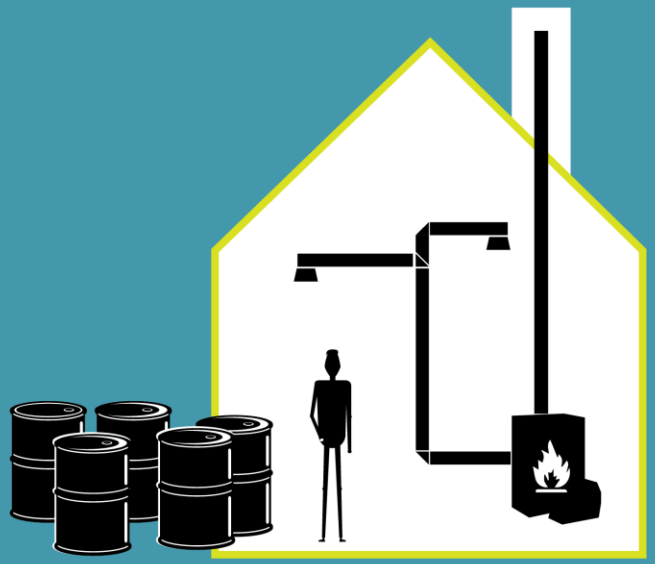
Standard house v. Passive house

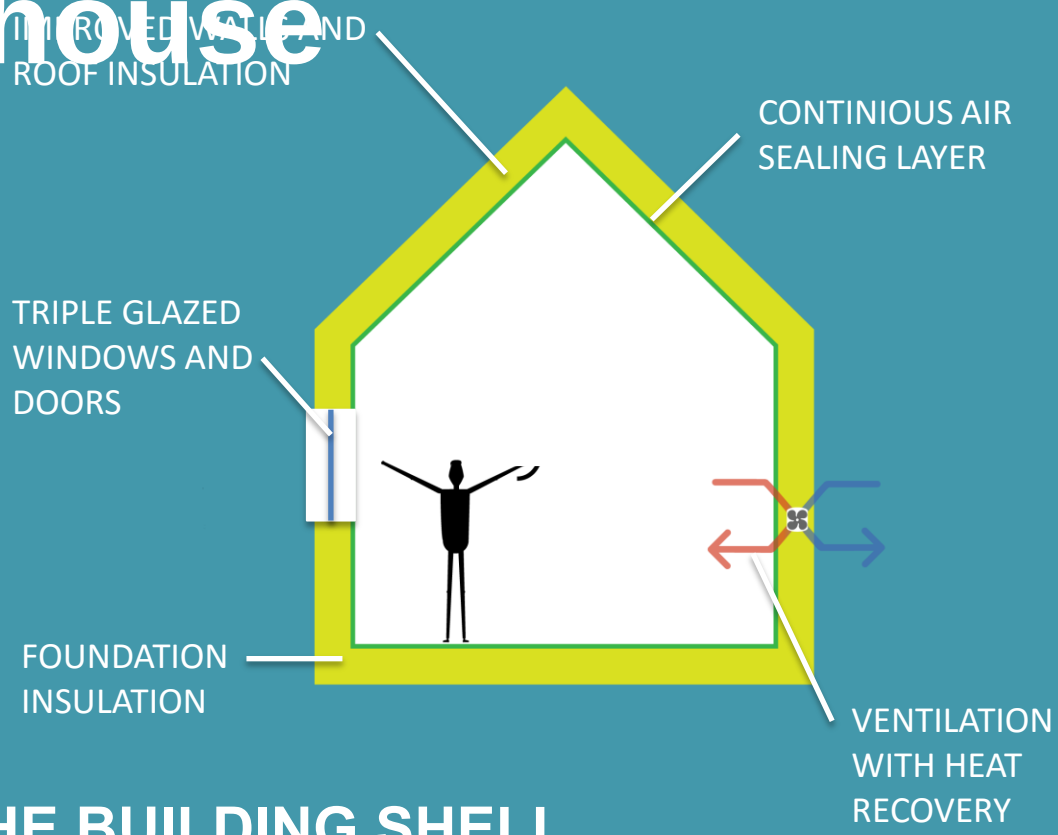




INVEST IN THE BUILDING SHELL….

Standard house v. Passive house





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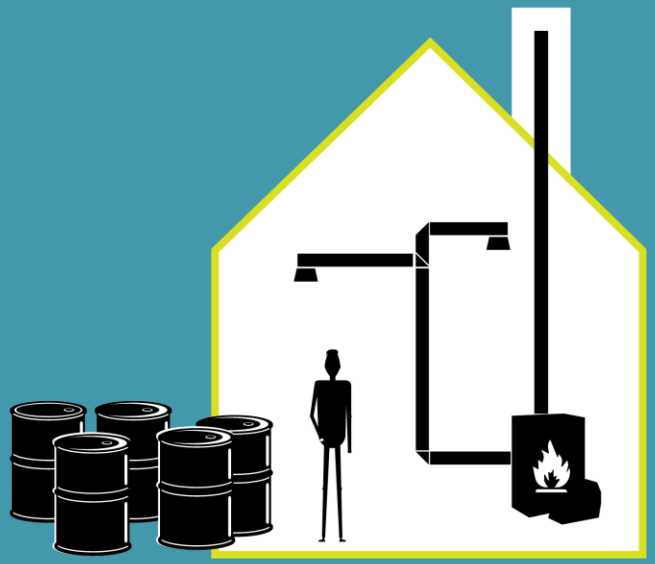
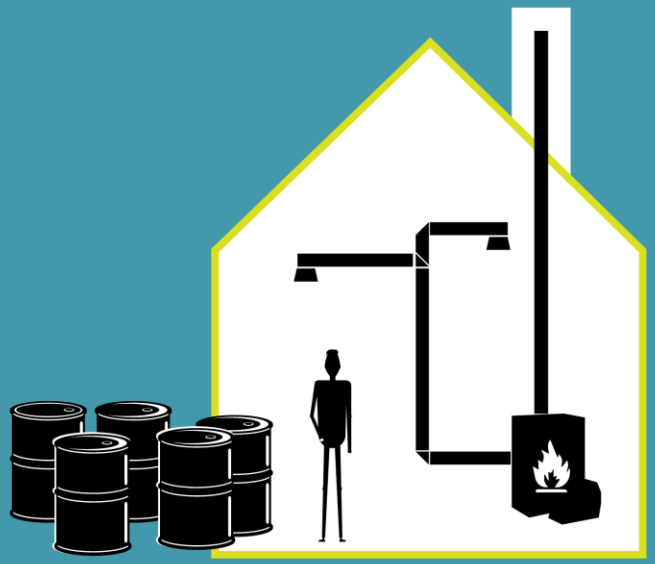


INVEST IN THE BUILDING SHELL….
AND REDUCE THE HEATING SYSTEM TO A HAIR DRYER-

Standard house v. Passive house



$ = $

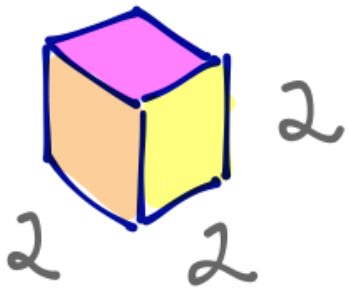
INVEST IN THE BUILDING SHELL….
AND REDUCE THE HEATING SYSTEM TO A HAIR DRYER-
…THE SAVINGS IN MECHANCIAL SYSTEMS PAYS FOR THE INSULATION

PASSIVE DESIGN CONCEPTS FOR A COLD CLIMATE: MODELING TAKE-AWAYS

- FORM FACOTOR- COMPACT BUILDING FORM HELPS
- PASSIVE SOLAR- GREAT WHEN YOU CAN GET IT- NOT ALL SITES ALLOW FOR IT. E
- INSULATION LEVELS DEPEND ON THE BUILDING- ONE SIZE DOES NOT FIT ALL
- IN A COLD CLIMATE, TRIPPLE GLAZED WINDOWS ARE REQUIRED
- OCCUPANCY HAS A MAJOR IMPACT ON INTERNAL GAINS
- LARGER BUILDINGS MAKE MEETING THE PH STANDARD EASIER THAN SMALLER BUIDLINGS

FORM FACTOR: COMPACT BUILDING FORM IS A GOOD STA

CUBE:



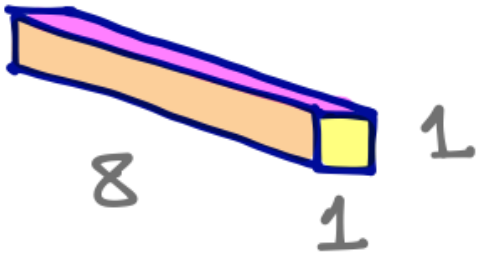
Volume:

$2 \times 2 \times 2 = 8$

Area:

$4 \times 6 = 24$

RECTANGLE:



Volume:

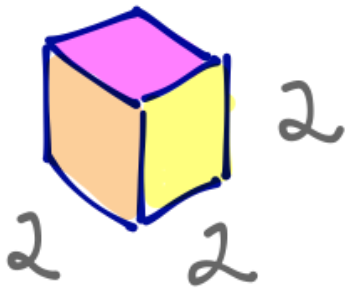
$1 \times 1 \times 8 = 8$

Area:

$4 \times 8 + 2 \times 1 = 34$

FORM FACTOR: COMPACT BUILDING FORM IS A GOOD STA

CUBE:



Volume:

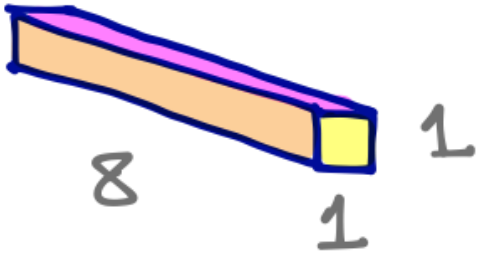
$2 \times 2 \times 2 = 8$

Area:

$4 \times 6 = 24$

30% GREATER HEAT LOSS!

RECTANGLE:



Volume:

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Area:

$4 \times 8 + 2 \times 1 = 34$

ENERGY MODELING CASE STUDY

INFILL PROJECT IN PORTLAND, ME

TIGHT SITE WITH POOR SOLAR ACCESS

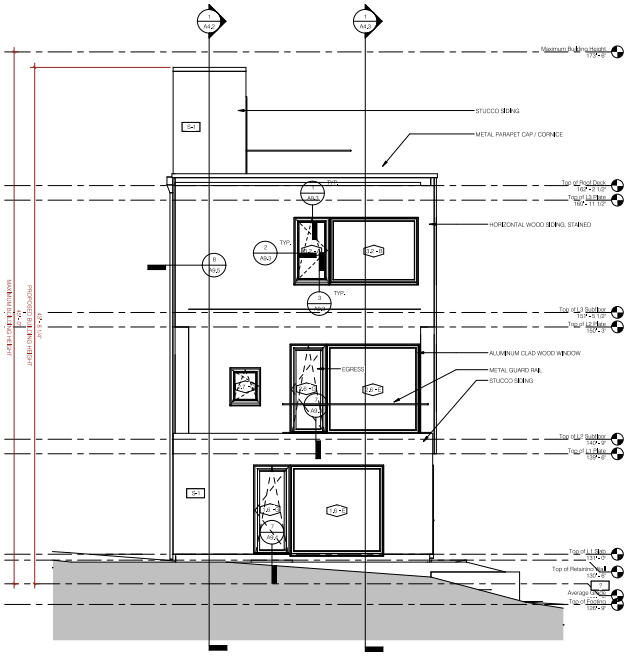
GOAL OF NEAR PASSIVE HOUSE LEVEL OF PEROFRMANCE

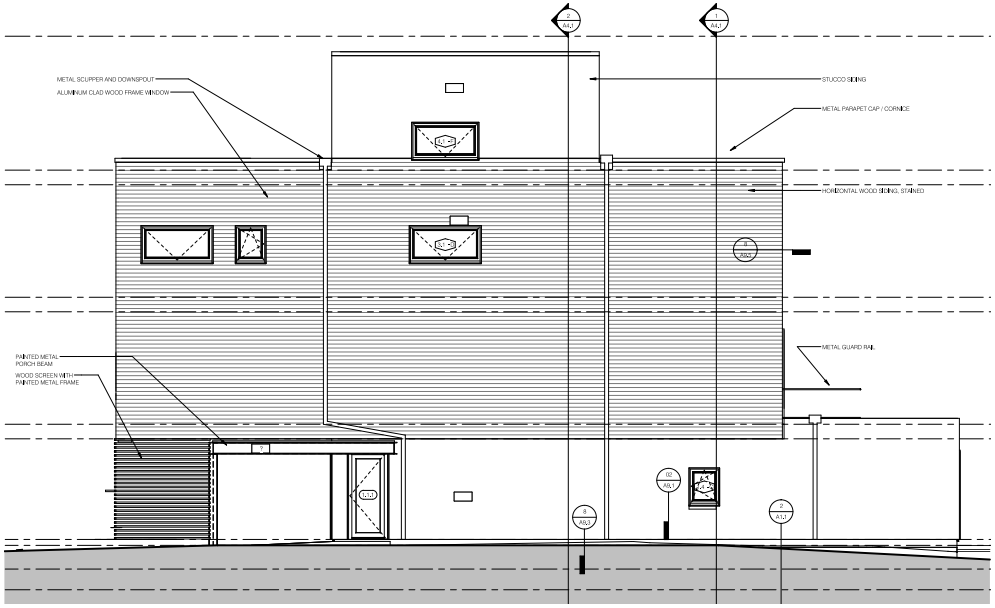
ENERGY MODEL USED TO HELP IMPROVE CLIENT DECISIONS ON BUILIDNG SHELL DESIGN AND MECHANCAL SYSTEMS

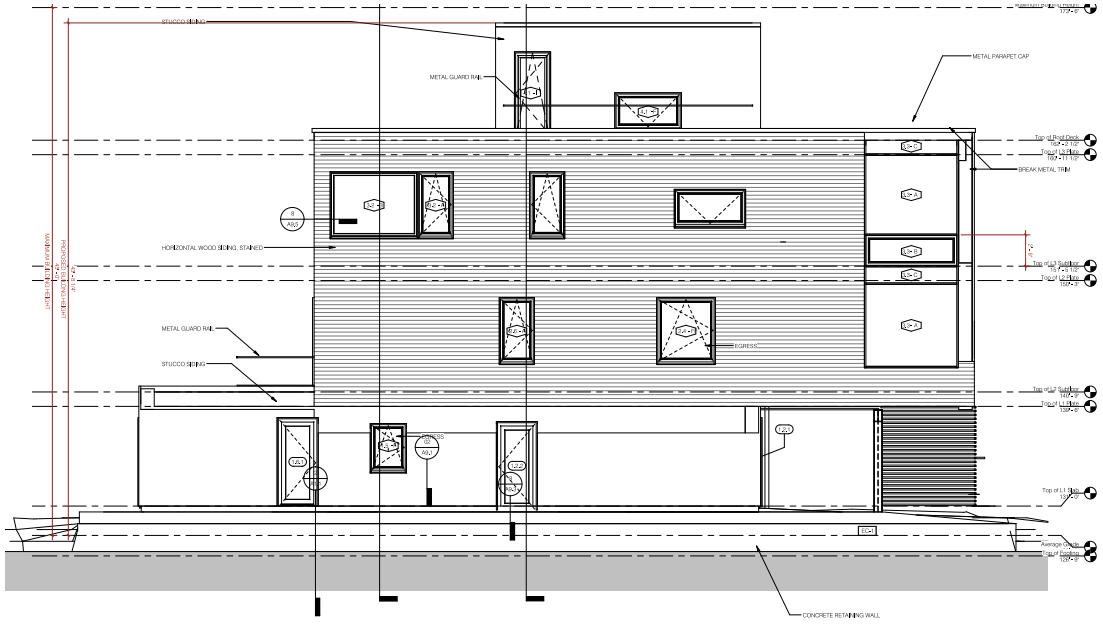
RESIDENTIAL PROJECT, PORTLAND, ME

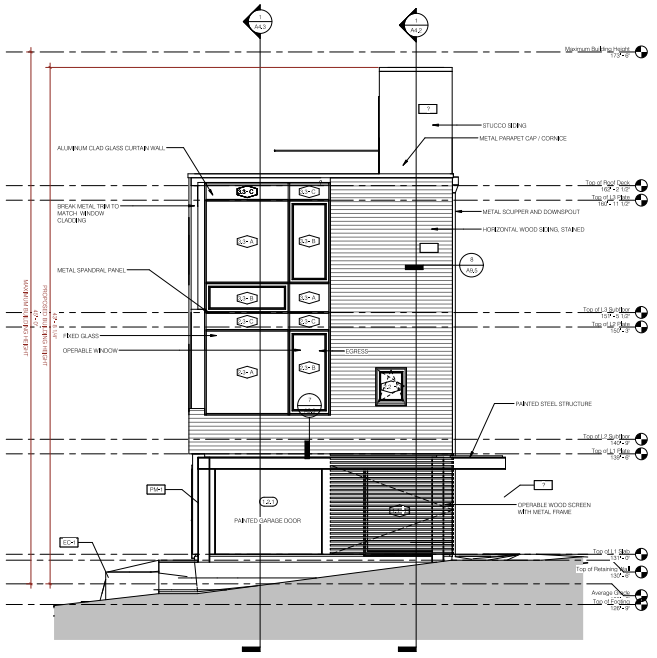
RESIDENTIAL PROJECT, PORTLAND, ME

1. Roof: R80
   U-Value – 0.061
   W/m²K
2. HRV system-
   83% efficient
3. Triple glazed
   windows:
   Passive solar
   g-Value – 0.5
   /0.6
   U_g-Value – 0.7
4. Wall: R50
   U-Value – 0.111
   W/m²K
5. Slab on grade:
   R30
   U-Value – 0.138
   W/m²K


STUCCO SIDING
METAL PARAPET CAP / CORNICE
HORIZONTAL WOOD SIDING, STAINED
ALUMINUM CLAD WOOD WINDOW
EGRESS
METAL GUARD RAIL
STUCCO SIDING


METAL SCUPPER AND DOWNSPOUT
ALUMINUM CLAD WOOD FRAME WINDOW
STUCCO SIDING
METAL PARAPET CAP / CORNICE
HORIZONTAL WOOD SIDING, STAINED
PAINTED METAL PORCH BEAM
WOOD SCREEN WITH PAINTED METAL FRAME
METAL GUARD RAIL


STUCCO SIDING
METAL GUARD RAIL
METAL PARAPET CAP
BREAK METAL TRIM
HORIZONTAL WOOD SIDING, STAINED
METAL GUARD RAIL
STUCCO SIDING
EGRESS
CONCRETE RETAINING WALL


ALUMINUM CLAD GLASS CURTAINWALL
STUCCO SIDING
METAL PARAPET CAP / CORNICE
BREAK METAL TRIM TO MATCH WINDOW CLADDING
METAL SCUPPER AND DOWNSPOUT
HORIZONTAL WOOD SIDING, STAINED
METAL SPANDREL PANEL
FIXED GLASS
OPERABLE WINDOW
EGRESS
PAINTED STEEL STRUCTURE
PAINTED GARAGE DOOR
OPERABLE WOOD SCREEN WITH METAL FRAME

GOL PH / LEED / CODE COMPARISON

	PH Building Envelope Data			Comparison Data	
				Option 1:	*Option 2:*
Option Title:	**6" Mineral Wool / PH Windows**			**LEED**	**Code**
	Area [SF]	**R-Value**			
Above Grade					
Windows & Glazed Doors	978	6.00	*PH Typ. R Value = 6*	3.36	2.80
North	304.985	**SHGC**		**SHGC**	**SHGC**
East	363.31	0.50	*PH Typ = .6*	0.30	0.30
South	222.08	0.50	*PH Typ = .6*	0.30	0.30
West	87.625	0.50	*PH Typ = .6*	0.30	0.30
Doors (opaque)	93.1	5.00	*PH Typ. R Value = 5*	3.00	2.50
Net Wall	4535.3	50.00	*PH Typ. R Value = 50*	18.00	15.00
Skylights	0	0.00	*PH Typ. R Value = 5*	1.00	1.00
Roof	1523.5	80.00	*PH Typ. R Value = 80*	58.80	49.00
Floor (ambient / cantilever)	685.56	65.00	*PH Typ. R Value = 60*	36.00	30.00
Foundation Wall (above grade)	0	0.00	*PH Typ. R Value = 30*	1.00	1.00
Below Grade					
Foundation Wall (below grade)	0	0.00	*PH Typ. R Value = 20*	1.00	1.00
Slab (On Grade)	822.1	30.00	*PH Typ. R Value = 30*	8.70	8.70
Foundation Edge	96.3	30.00	*PH Typ. R Value = 30*	8.70	8.70
Slab (Below Grade)	0	0.00	*PH Typ. R Value = 18*	0.00	0.00

			LEED	Code
Efficiency of HRV [%]	84	*PH Typ. Efficiency = 84%*	60.00	60.00
Infiltration Rate [ACH]	0.04	*PH Typ. Rate = 0.04*	0.10	0.20
Heat Pump COP	2.5	*PH Typ = 2.5*		
Proposed Occupancy	4	*Often # of bedrooms*		
Total Floor Area [SF]	2,676.18			
Treated Floor Area [SF]	2,554.83			
Building Volume [CF]	33,557			

Solar Data

Total Heating Degree Days [deg. F]	6,689	*5 year average from www.degreedays.net*
Days of Heating	240	*Maine Typ = 240*
Percent Reduction for Shading		
East	60	*%*
South	90	*%*
West	50	*%*
Available Roof Area for Solar Panels	300 sf	*Note: sloped roof area within 15deg. of solar south*
Sensible Gains [BTU/hr]	250 BTUs/hr	*PH Typ. = 250 BTU/hr*
Glass of windows + doors [%]	70	*PH Typ. = 70*
Hours of Sun per Year [hrs]	1234	*Maine Typ = 1234*

Note: The following values (Solar Factor and %Sun) can be found in the solar book on Gunther's desk

	South Solar Factor	East Solar Factor	West Solar Factor	% Sun	Heating Degree Days
Sept	1144	1144	787	47	168
Oct	1098	1098	582	47	410
Nov	983	983	399	38	750
Dec	895	895	307	37	1053
Jan	1004	1004	405	41	1248
Feb	1184	1184	603	44	1054
Mar	1206	1206	829	43	913
Apr	1128	1128	1000	44	580

Heating Data

Comparison Data

		2" Foam / Loewen Triple	2" Foam / PH Windows
FUEL TYPE:	Grid Electric	Grid Electric	Grid Electric

	% Inflation	cost per unit	
PV	0%	$0.00	*WATT*
Natural Gas	3%	$1.45	*THERMS*
#2 Oil	3%	$3.66	*GAL*
LP	3%	$3.22	*GAL*
Grid Electric	5%	$0.15	*KWH*
Heat Pump	5%	$0.15	*KWH*
Firewood	3%	$200.00	*CORDS*
Pellets	3%	$300.00	*TONS*

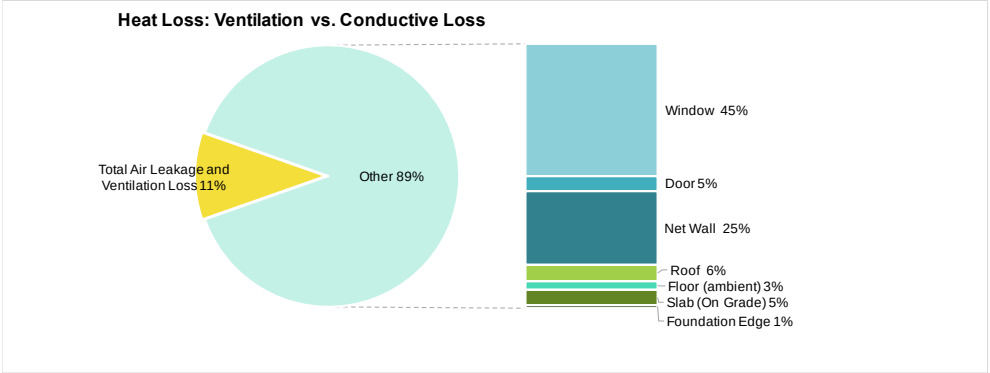
(GOL) PASSIVE HOUSE PERFORMANCE

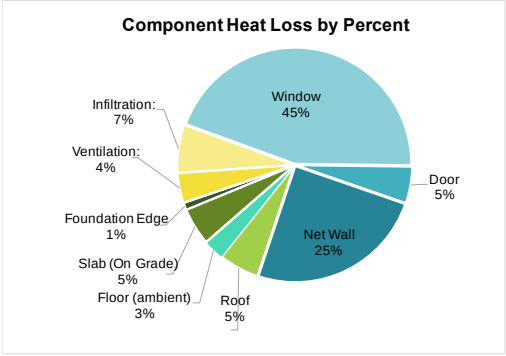
ENVELOPE (CONDUCTIVE LOSSES)

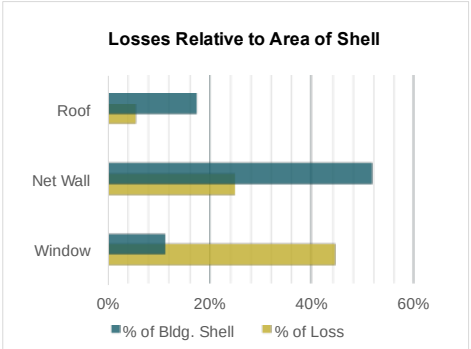
Region	Area [SF]	R-Value [hr-SF-°F/Btu]	Heat Loss [Btu/hr]	% of Loss	% of Gross Wall
Window	978	6.0	10106	45%	11%
Door	93.1	5.0	1154	5%	1%
Floor (Ambient)	685.56	65.0	654	3%	8%
Net Wall	4535.3	50.0	5624	25%	52%
Roof	1523.5	75.0	1259	6%	17%
Foundation	96.3	26.1	229	1%	1%
Slab	822.1	26.1	1172	5%	9%
			Total Envelope Loss:	*89%*	

INFILTRATION AND VENTILATION LOSSES

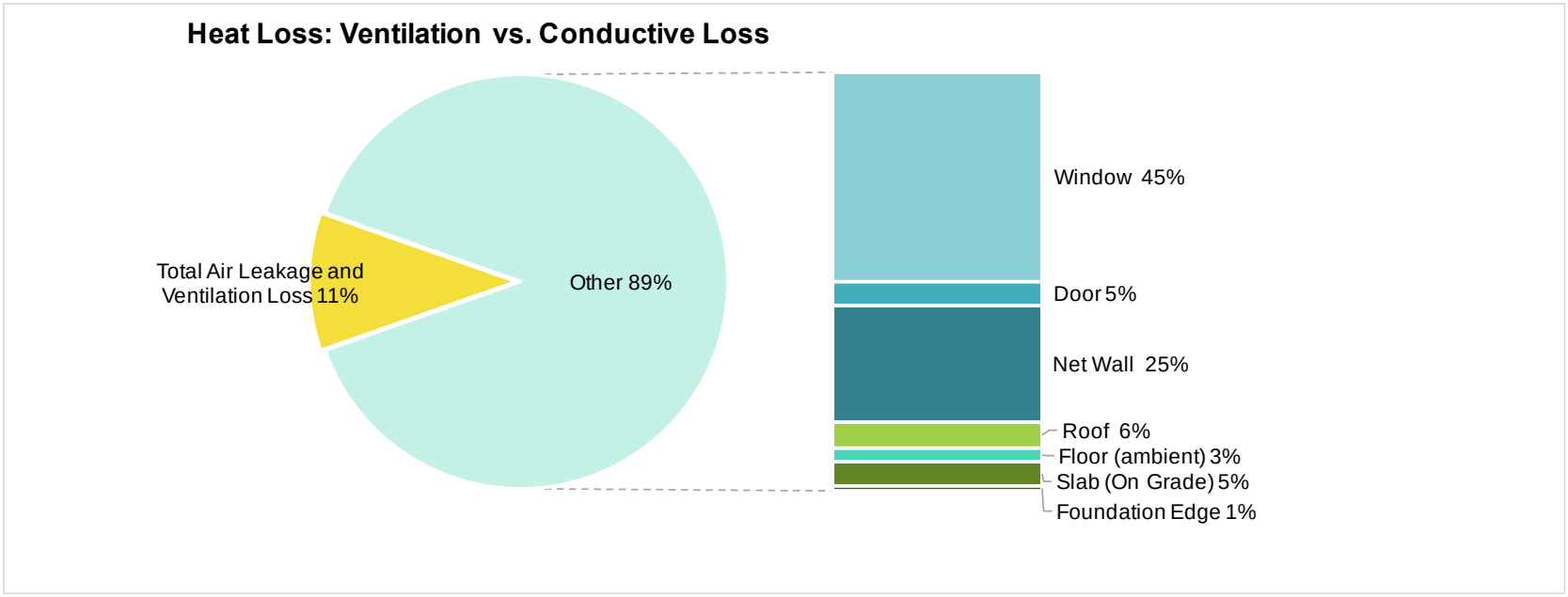
	Ventilation Rate [CFM]	Efficiency of HRV (%)	Heat Loss [Btu/hr]	% of Loss
Ventilation:	86.7618	84	934	**4%**
	Building Volume [CF]	**Infiltration Rate [ACH]**	**Heat Loss [Btu/hr]**	**% of Loss**
Infiltration:	33557	0.04	1505	**7%**
		Total Air Leakage and Ventilation Loss		*11%*

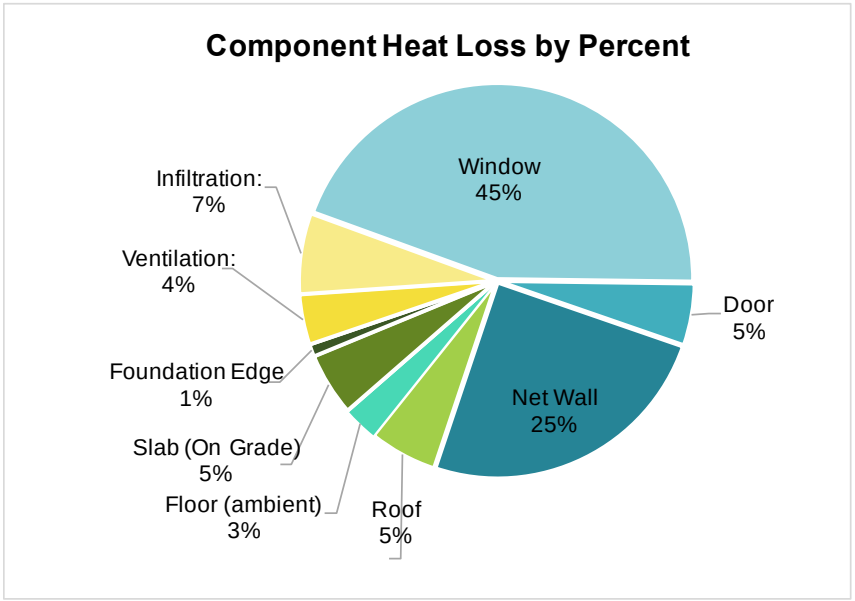


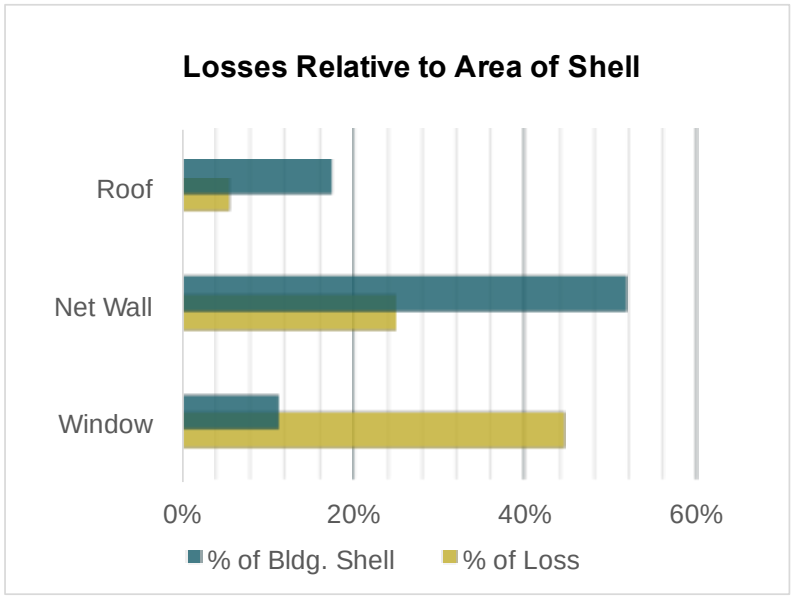




(GOL) PASSIVE HOUSE PERFORMANCE







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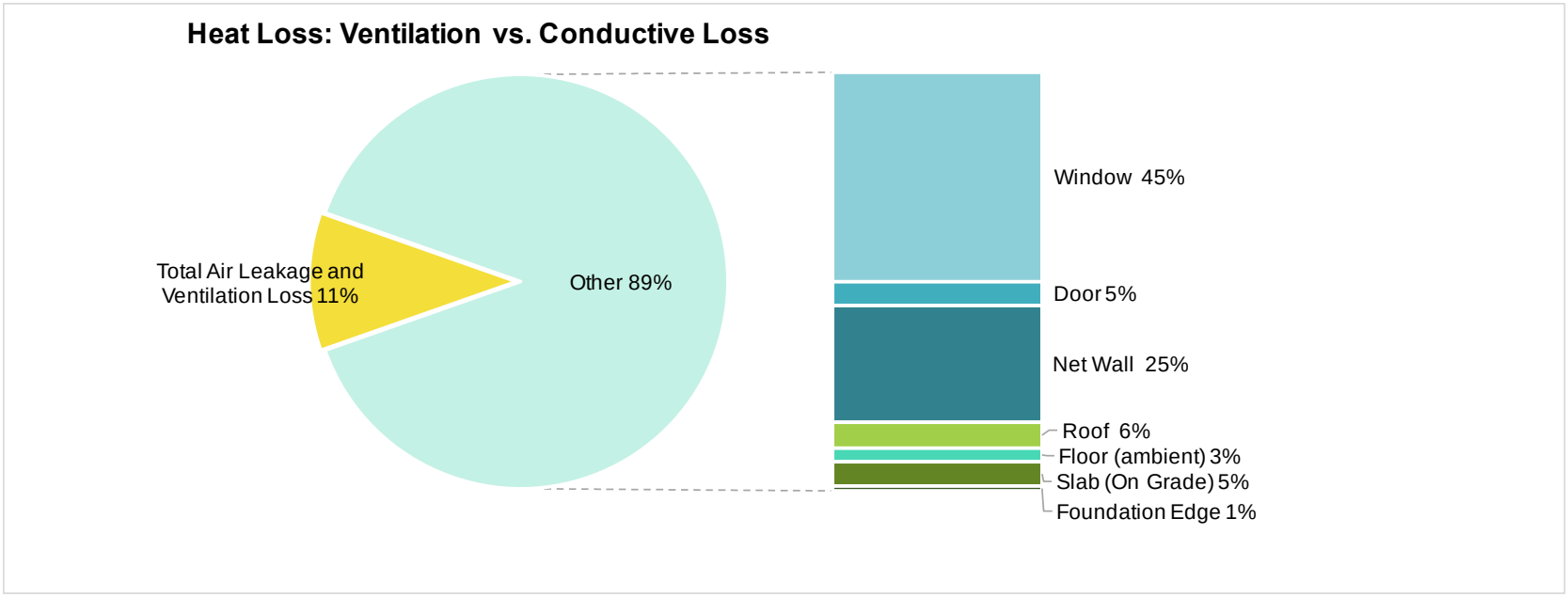
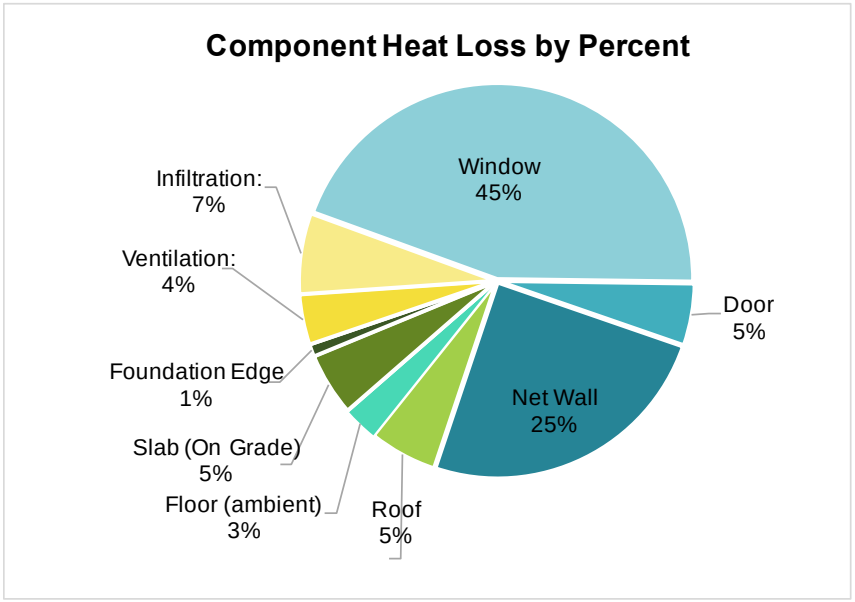
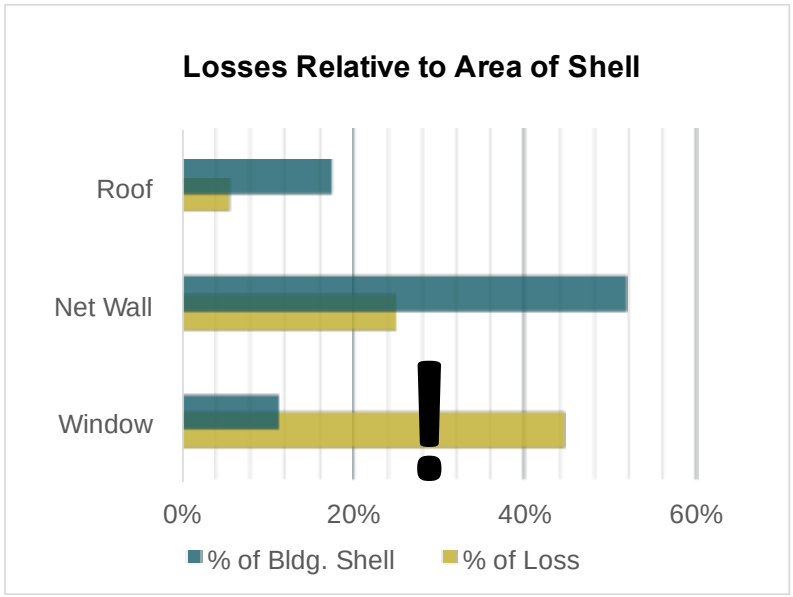
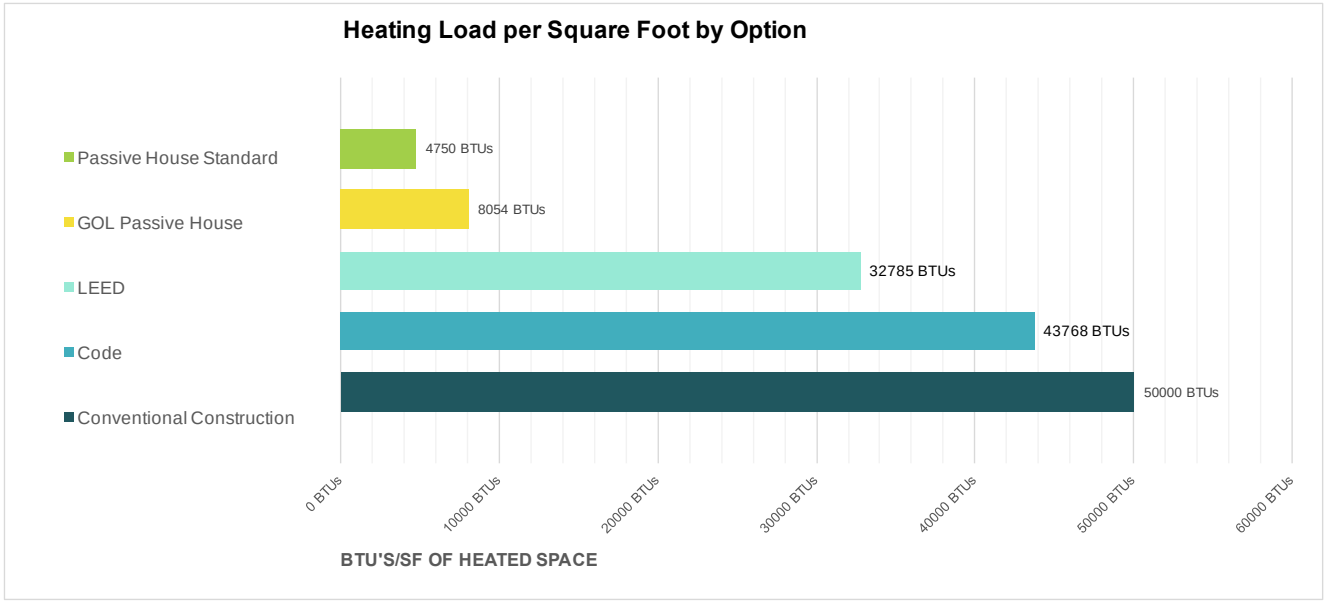
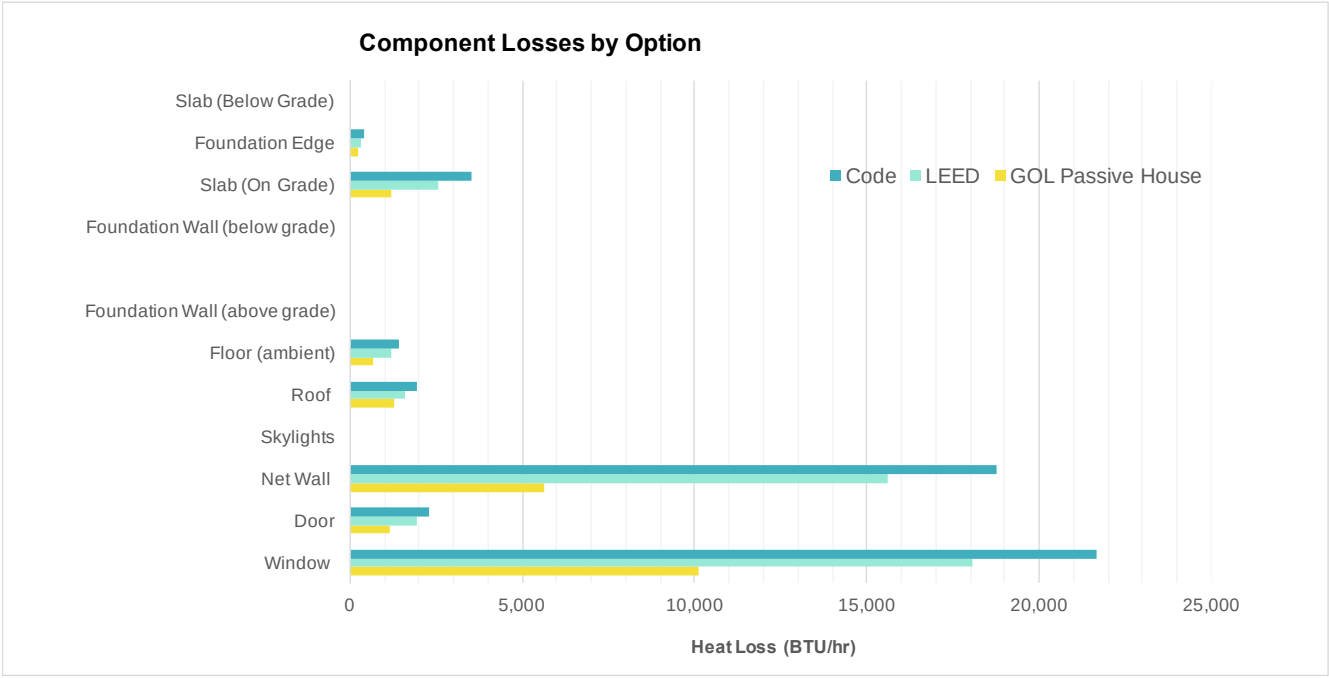






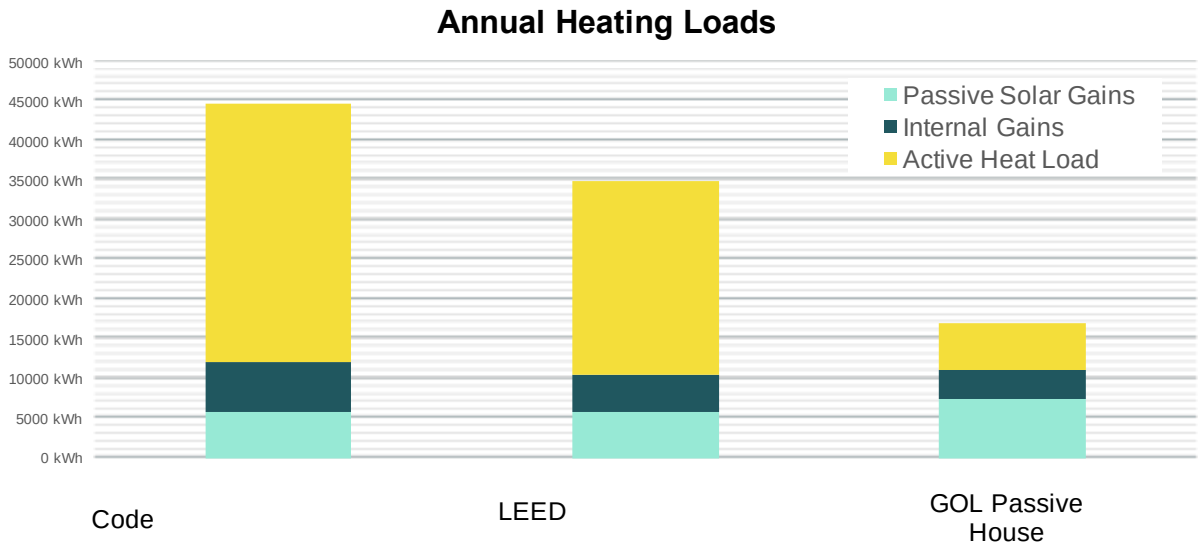
(GOL) PH / LEED / CODE COMPARISON

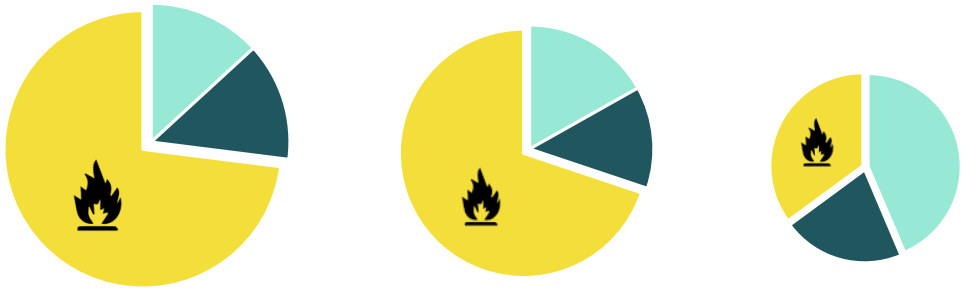




(GOL) PH / LEED / CODE COMPARISON

	Code	LEED	GOL Passive House
Passive Solar Gains	5917 kWh	5917 kWh	7490 kWh
Internal Gains	6201 kWh	4675 kWh	3658 kWh
Active Heat Load	32772 kWh	24549 kWh	6031 kWh





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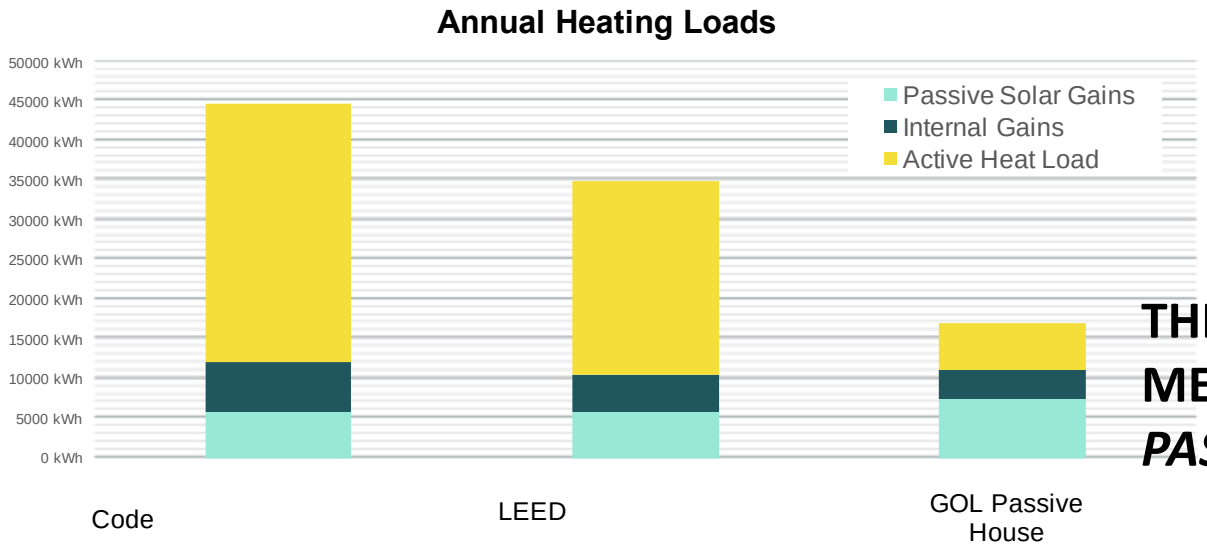
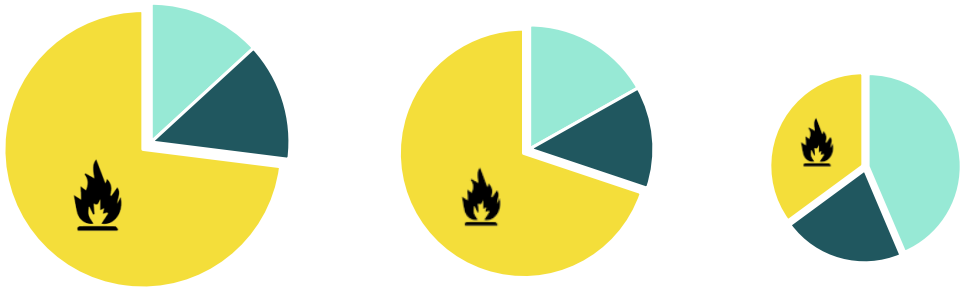
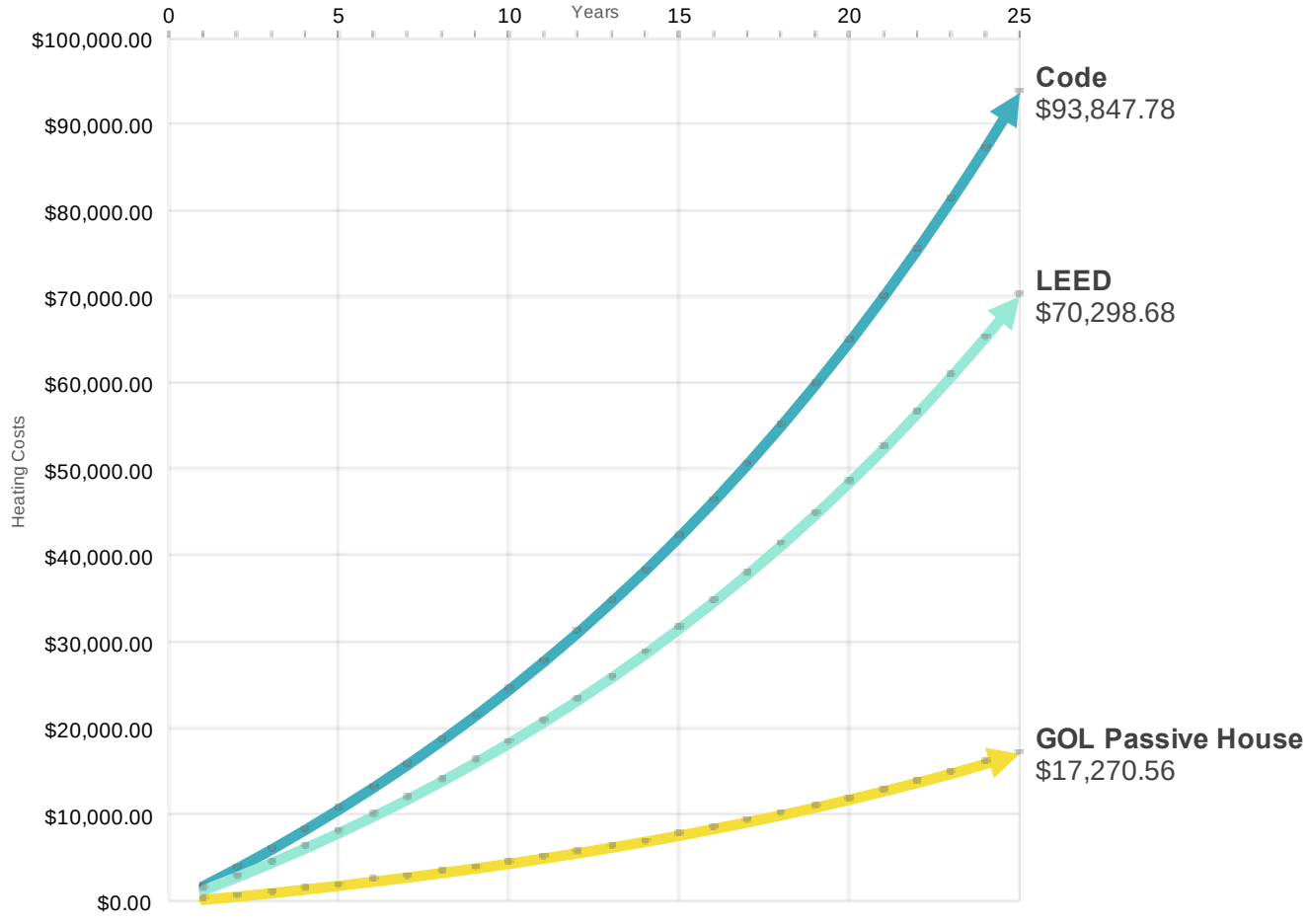


THIS IS WHAT IT MEANS TO BE *PASSIVE*



(GOL) PH / LEED / CODE COMPARISON

	Code	LEED	GOL Passive House
Fuel Type	Heat Pump	Heat Pump	Heat Pump
Annual Operating Costs:	$1,966.34	$1,472.93	$361.86
Operating Costs after 25 Years:	**$93,847.78**	**$70,298.68**	**$17,270.56**
Difference from PH	$76,577.22	$53,028.12	



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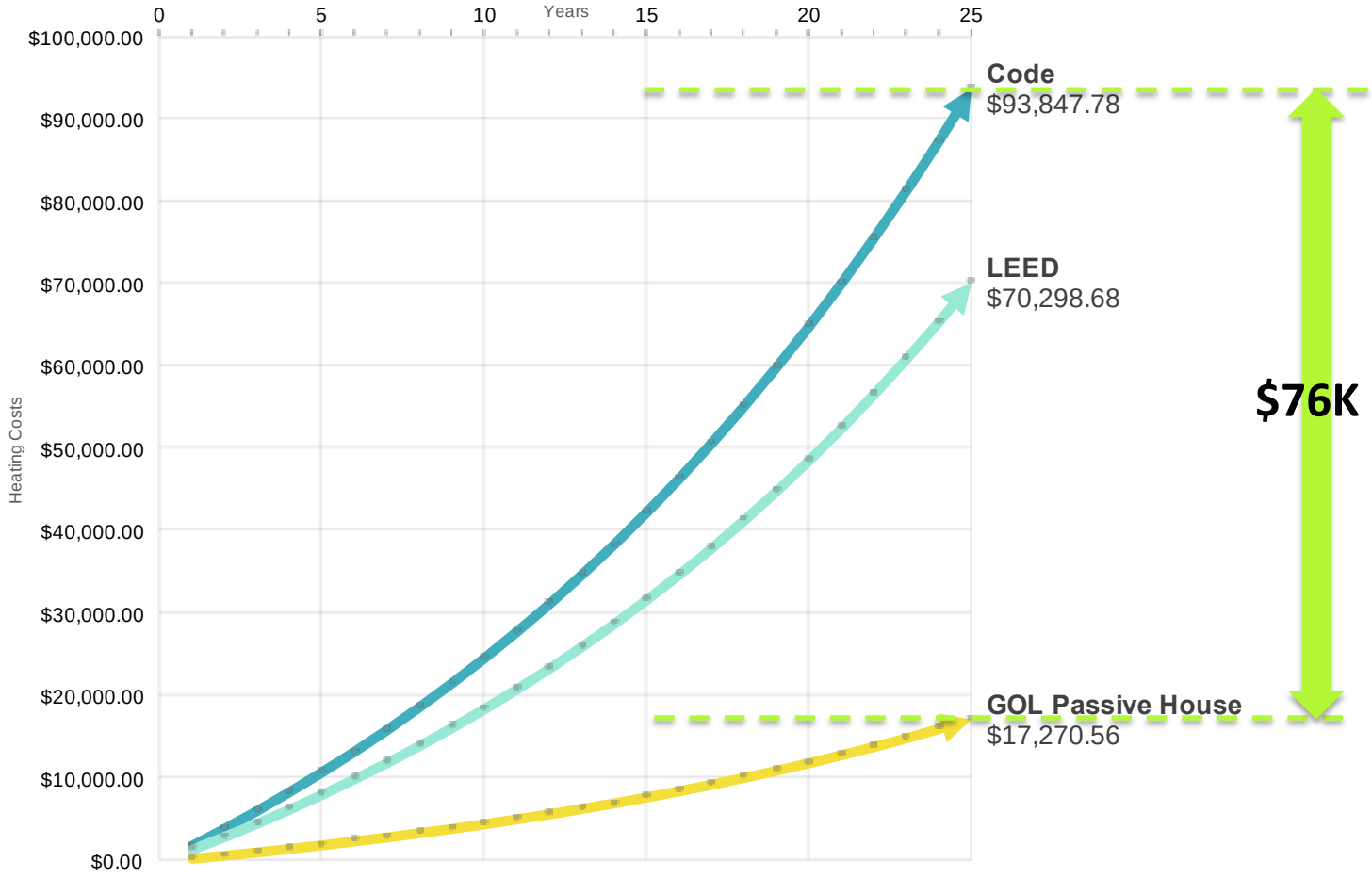
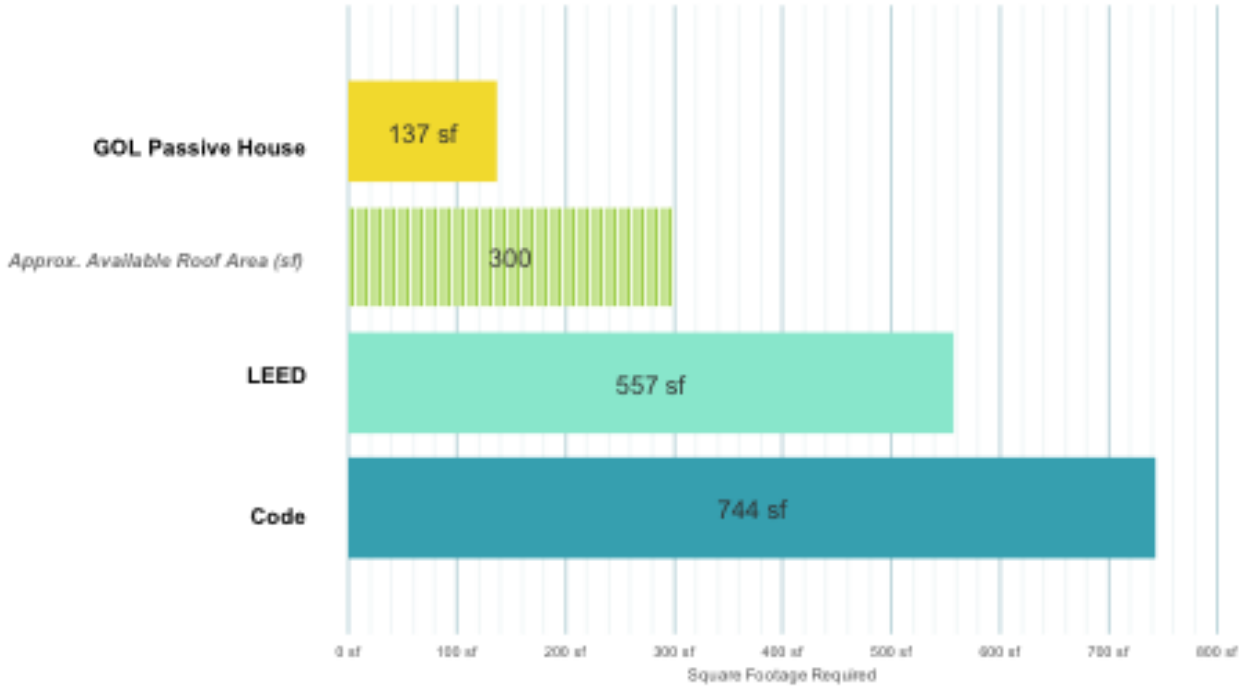


(GOL) PH / LEED / CODE COMPARISON

	Code	LEED	GOL Passive House	*Each Panel:*
kW required	10.62	7.96	1.95	*sf:* 70
SF array required (sf)	744 sf	557 sf	137 sf	*kw:* 1
Approx. Available Roof Area (sf)	300	300	300	*panel:* 250w
Cost of Installed Array	$42,492.52	$31,829.93	$7,819.79	*cost / kw:* $4,000

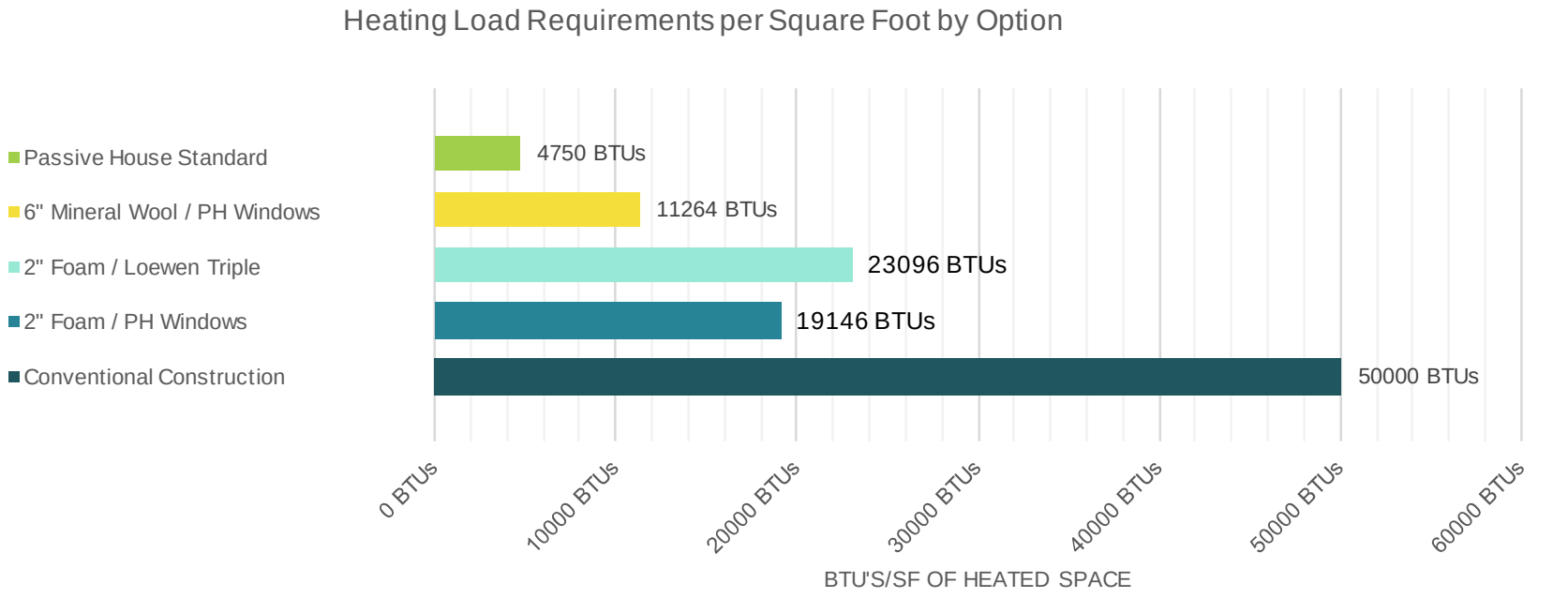


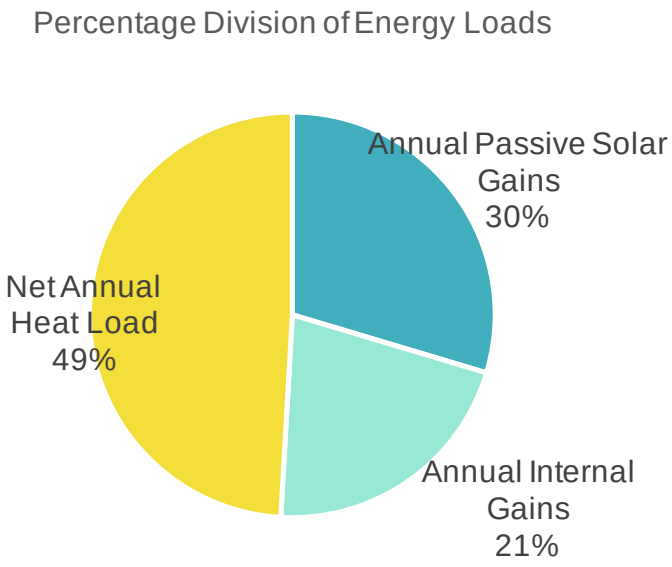
PV Requirements for the annual heating demand, shown against the roof area available

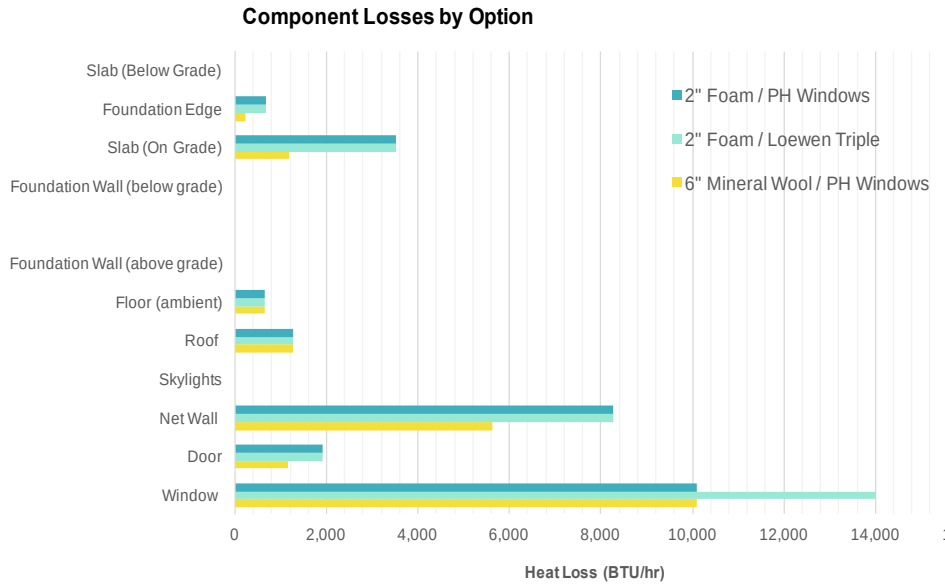
PH / REDUCED SHELL / REDUCED SHELL AND WINOW COMPAI

	PH Building Envelope Data			Comparison Data		T
				Option 1:	*Option 2:*	
Option Title:	6" Mineral Wool / PH Windows			2" Foam / Loewen Triple	2" Foam / PH Windows	% ti
Above Grade	**Area [SF]**	**R-Value**				
Windows & Glazed Doors	978	6.00	*PH Typ. R Value = 6*	4.33	6.00	
North	304.985	**SHGC**		**SHGC**	**SHGC**	
East	363.31	0.50	*PH Typ = .6*	0.30	0.30	
South	222.08	0.50	*PH Typ = .6*	0.30	0.30	
West	87.625	0.50	*PH Typ = .6*	0.30	0.30	
Doors (opaque)	93.1	5.00	*PH Typ. R Value = 5*	3.00	3.00	
Net Wall	4535.3	50.00	*PH Typ. R Value = 50*	34.00	34.00	
Skylights	0	0.00	*PH Typ. R Value = 5*	0.00	0.00	
Roof	1523.5	75.00	*PH Typ. R Value = 80*	75.00	75.00	
Floor (ambient / cantilever)	685.56	65.00	*PH Typ. R Value = 60*	65.00	65.00	
Foundation Wall (above grade)	0	0.00	*PH Typ. R Value = 30*	0.00	0.00	
Below Grade						
Foundation Wall (below grade)	0	0.00	*PH Typ. R Value = 20*	0.00	0.00	
Slab (On Grade)	822.1	26.10	*PH Typ. R Value = 30*	8.70	8.70	
Foundation Edge	96.3	26.10	*PH Typ. R Value = 30*	8.70	8.70	
Slab (Below Grade)	0	0.00	*PH Typ. R Value = 18*	0.00	0.00	
				2" Foam / Loewen Triple	**2" Foam / PH Windows**	
Efficiency of HRV [%]	84	*PH Typ. Efficiency = 84%*		78.00	78.00	
Infiltration Rate [ACH]	0.04	*PH Typ. Rate = 0.04*		0.04	0.04	
Heat Pump COP	2.5	*PH Typ = 2.5*				
Proposed Occupancy	4	*Often # of bedrooms*				
Total Floor Area [SF]	2,676.18					
Treated Floor Area [SF]	2,554.83					
Building Volume [CF]	33,557					

PH / REDUCED SHELL / REDUCED SHELL AND WINOW COMPAR

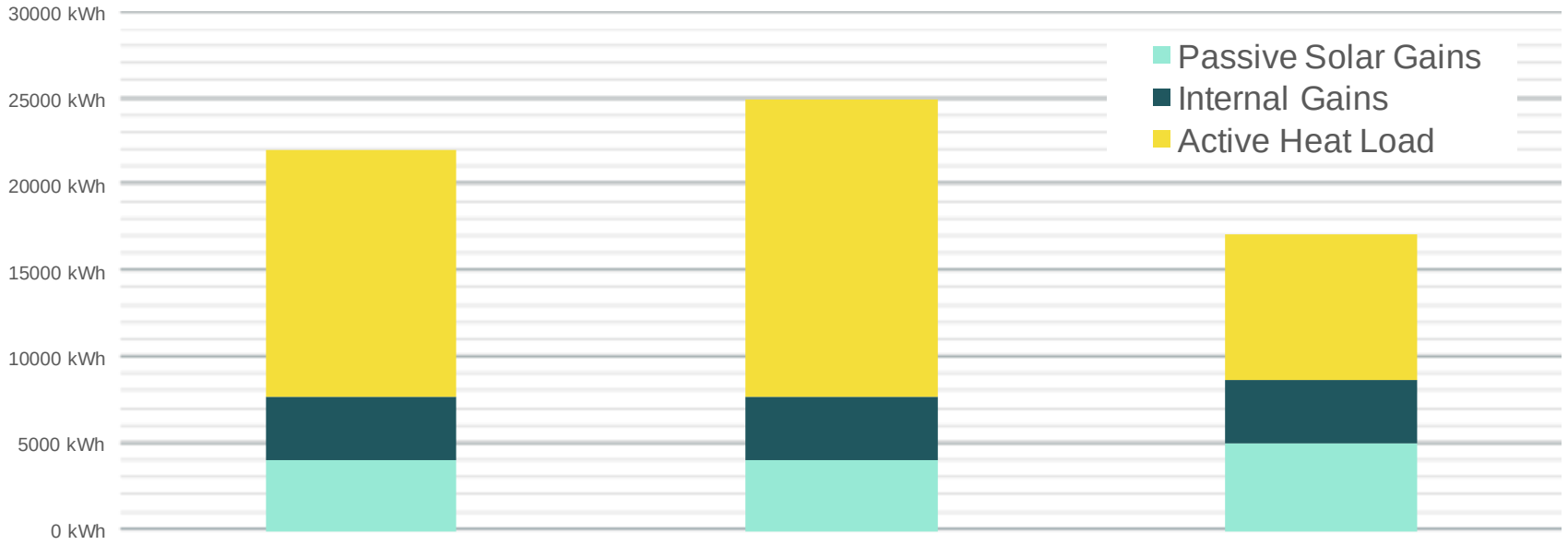






PH / REDUCED SHELL / REDUCED SHELL AND WINOW COMPAR

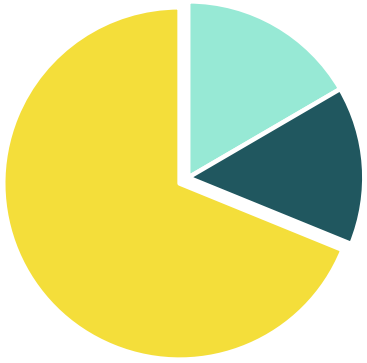
Annual Heating Loads



2" Foam / Loewen Double

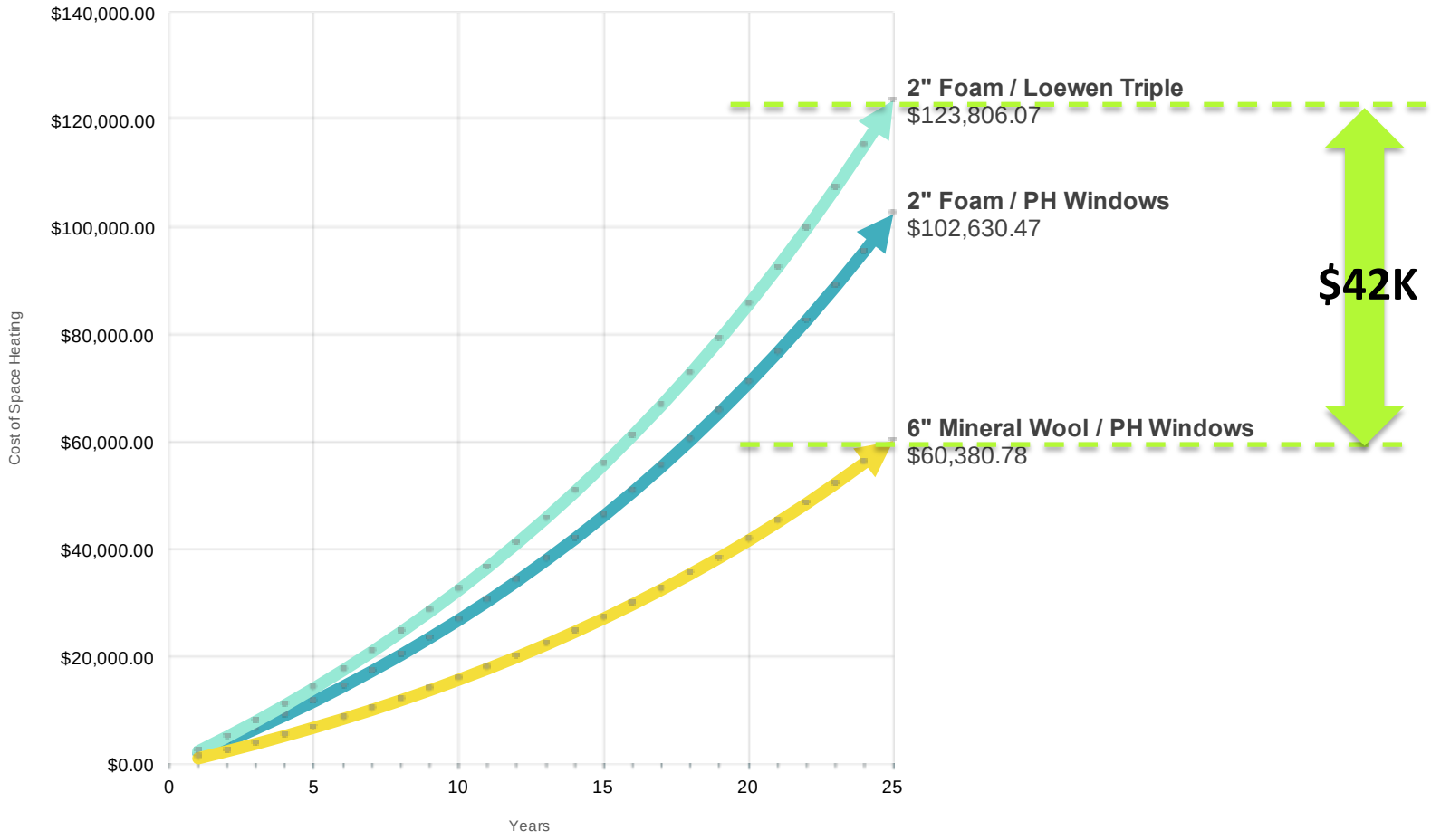
2" Foam / Loewen Triple

6" Mineral Wool / PH Windows



PH / REDUCED SHELL / REDUCED SHELL AND WINOW COMPAI

	2" Foam / PH Windows	2" Foam / Loewen Triple	6" Mineral Wool / PH Windows
Fuel Type	Grid Electric	Grid Electric	Grid Electric
Annual Operating Costs:	$2,150.36	$2,594.04	$1,265.13
Operating Costs after 25 Years:	**$102,630.47**	**$123,806.07**	**$60,380.78**
Difference from PH	$42,249.69	$63,425.29	



Massive Passiv Walls for the Masses

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Why Walls?

- In the land of passivhaus, walls are thick and complicated.
- They hold up the floor and the roof.
- They want to be as thin as possible to reduce cost and be acceptable to the architect.
- Architects are at the mercy of builders, and builders have their methods.
- They need to be evaluated on a number of criteria, including but not limited to:

Evaluation Criteria

- Load Path and Shear
- Bulk Moisture Control (given)
- Insulation value
- Airtightness (given)
- Thermal bridge-free (mostly given)
- Vapor Control
- Buildability and Cost

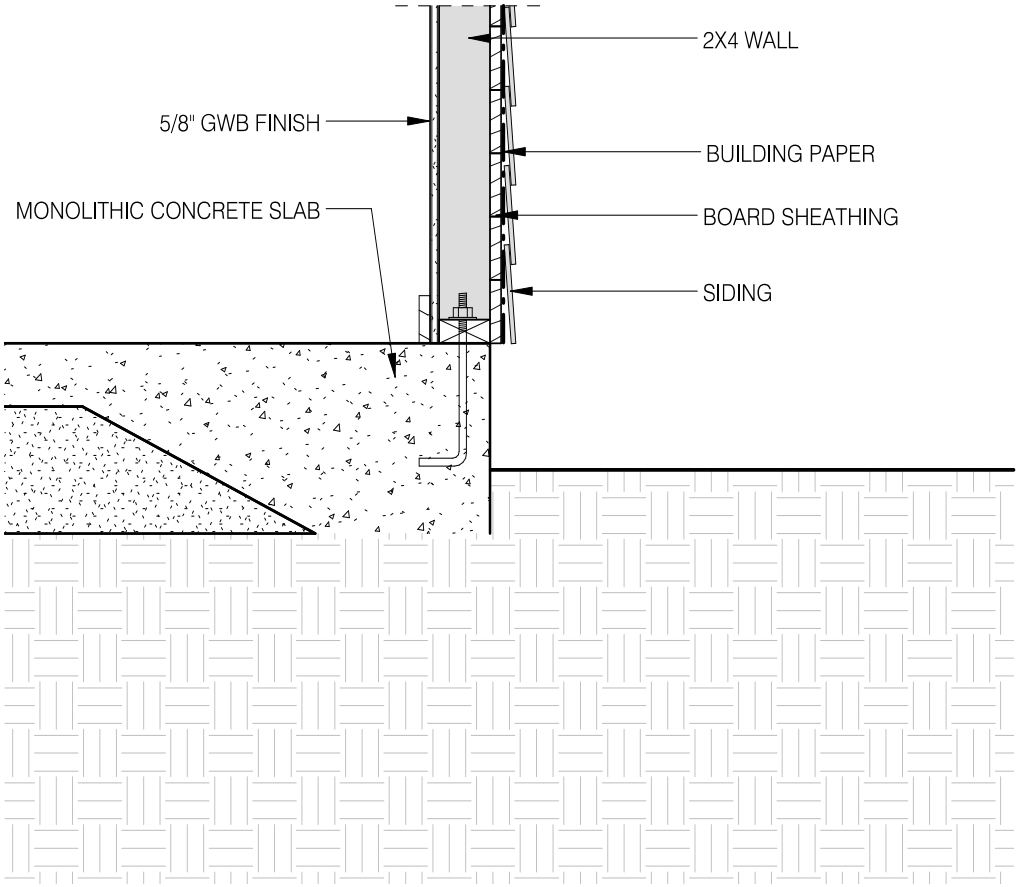
Assumptions

- There are many ways to build walls.
- Some are better than others.
- The walls I am presenting are generally for cold climates.
- The walls I am presenting are wood frame.

Passivhaus Wall Survey Results

1. Double Stud
   a. Not Good Way
   b. Better Way
2. Stud Wall with Exterior Insulation
   a. Foam/SIP
   b. Larsen Truss
   c. Mineral Wool
   d. Sorry, no spray foam here

In the beginning: simple stick framing. Life was good.



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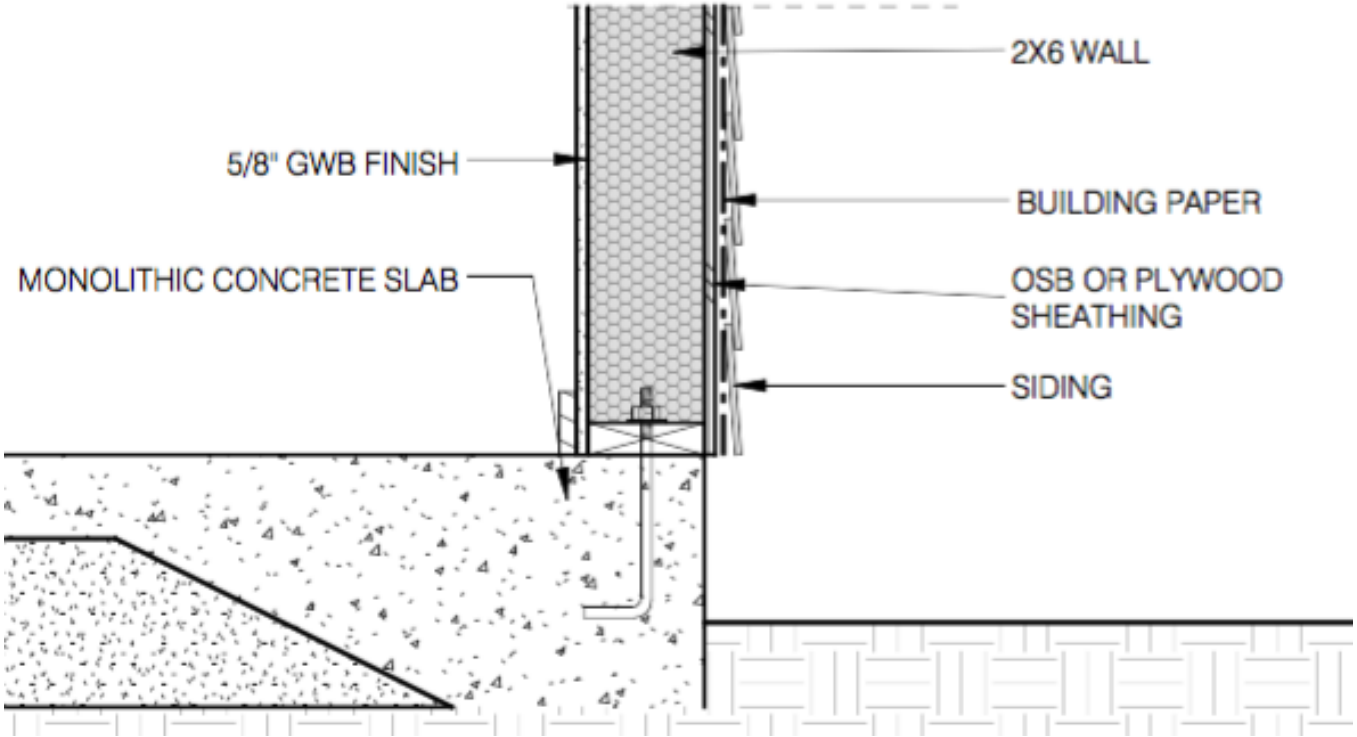
1977

Saskatchewan Conservation House

1980s: 2x6 wall with… poor insulation



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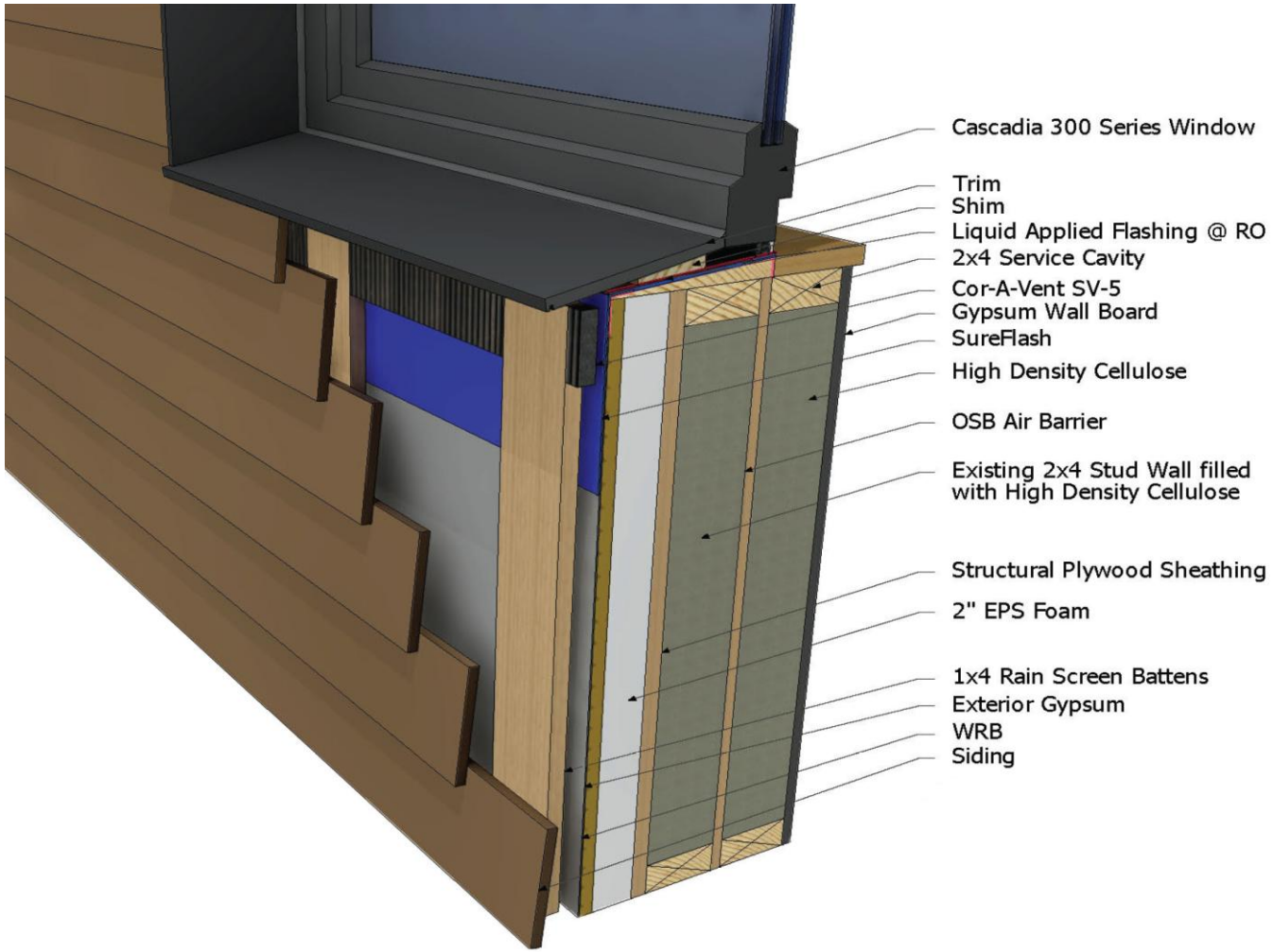
Fast Forward: Passivhaus:

Hello, R50

Standard insulation values: R 3.5-4/inch

Wall 14”-16” thick



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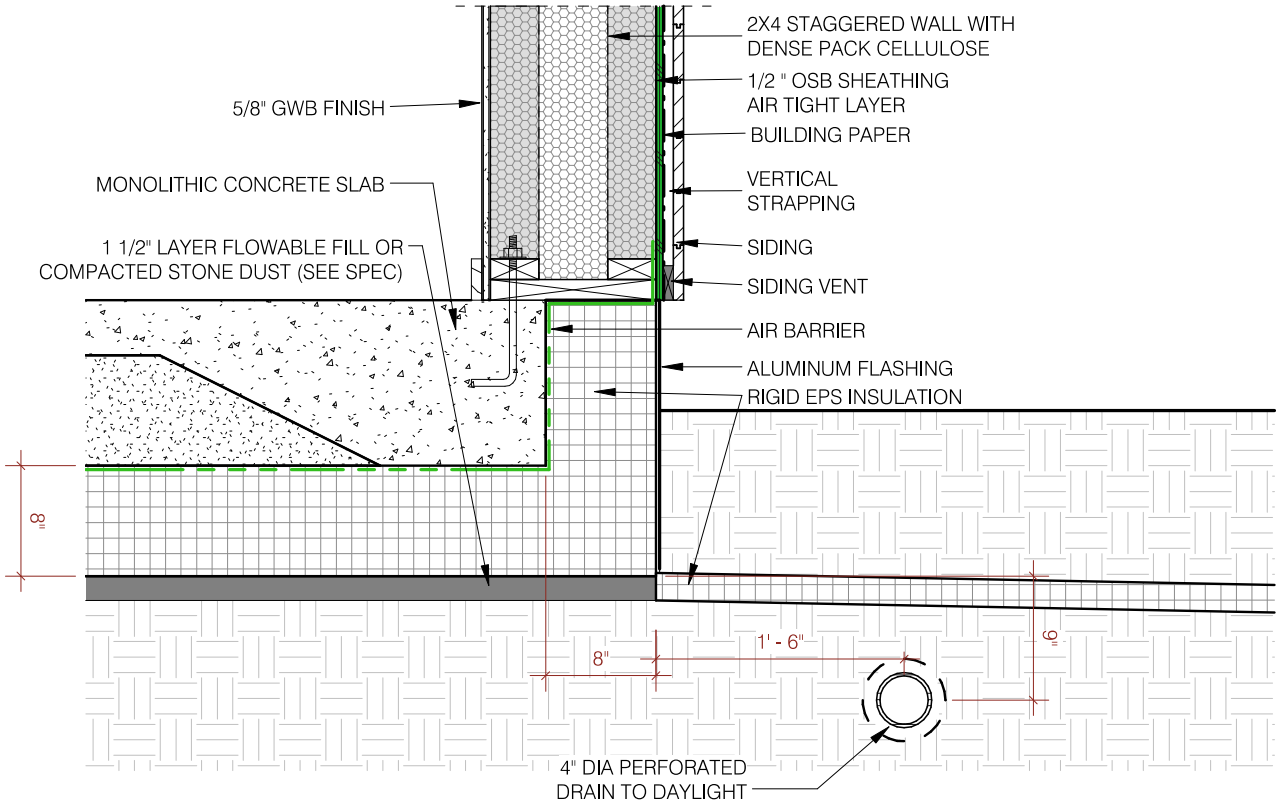
Double Stud: not good way



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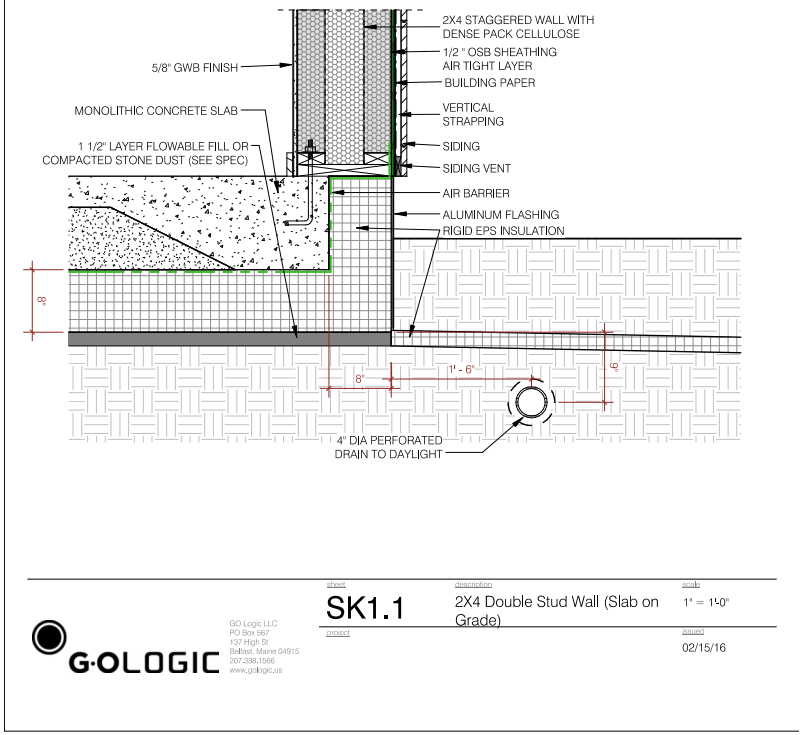
Double Stud: not good way

- Load Path, Shear
- Insulation value (R42)
- Airtightness
- Vapor Control
- Buildability and Cost—need to separate bays for cellulose; not as cheap as you think



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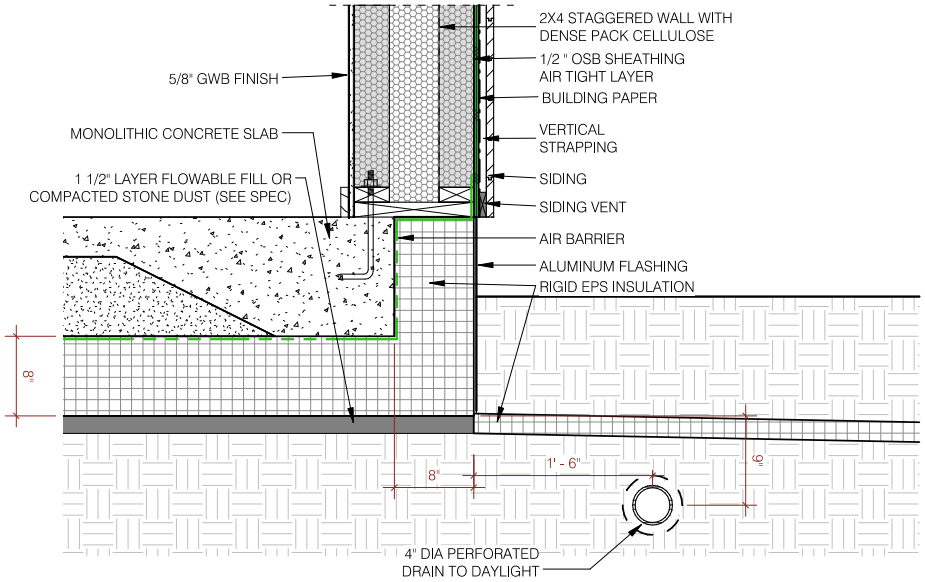
Vapor Control Basics

- Vapor drive is real. Moisture goes from more humid to less humid, just like heat moves from warm to cool.
- Walls must be able to dry to one side or the other. Winter condition in cold climate: keep moisture out of wall and away from condensing surface (typically the sheathing).
- This means exterior skin must be more vapor permeable than interior skin, by at least 5 times

Double Stud: not good way

Gwb (interior) perm rating: 50
o.s.b. (exterior) perm rating: 1
Must use vapor retarder on Interior, and make sure it's smart



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GO Logic LLC
PO Box 667
137 High St
Belfast, Maine 04915
207.338.1566
www.gologic.us

sheet	description	scale
SK1.1	2X4 Double Stud Wall (Slab on Grade)	1" = 1'-0"
project		issued
		02/15/16

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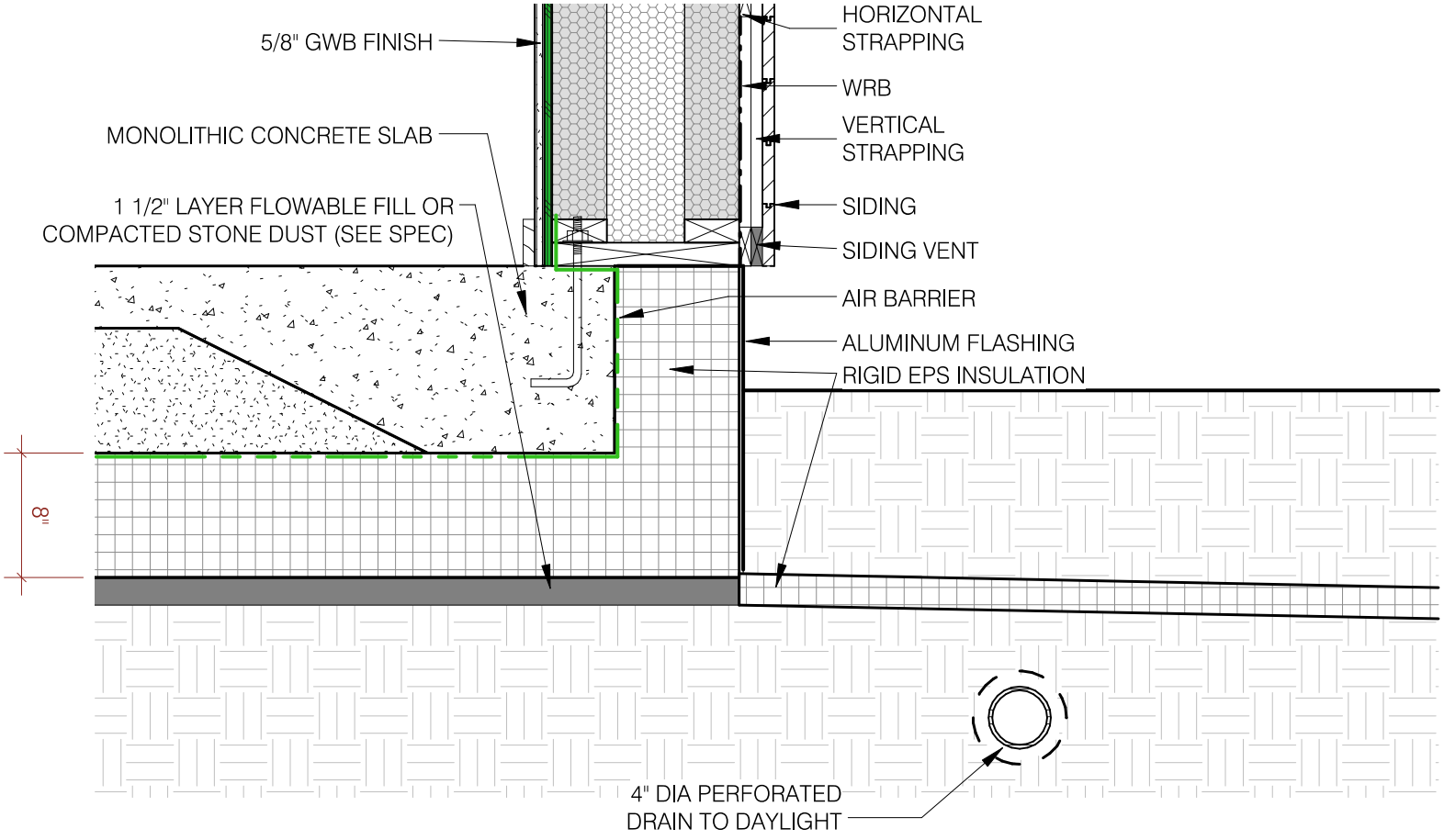
Double Stud Wall: Better Way 1



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Double Stud Wall: Better Way 1

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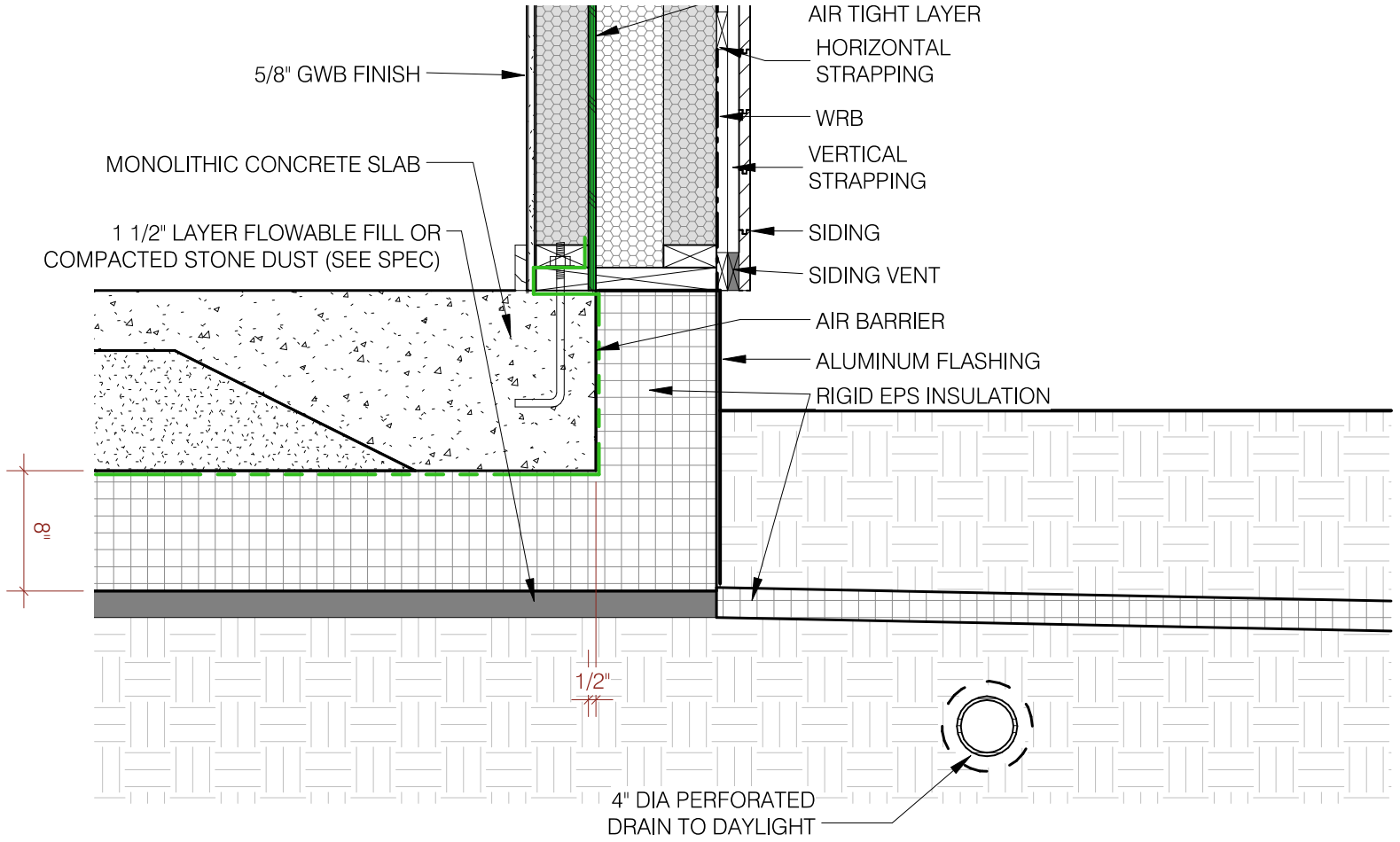
Double Stud Wall: Better Way 2



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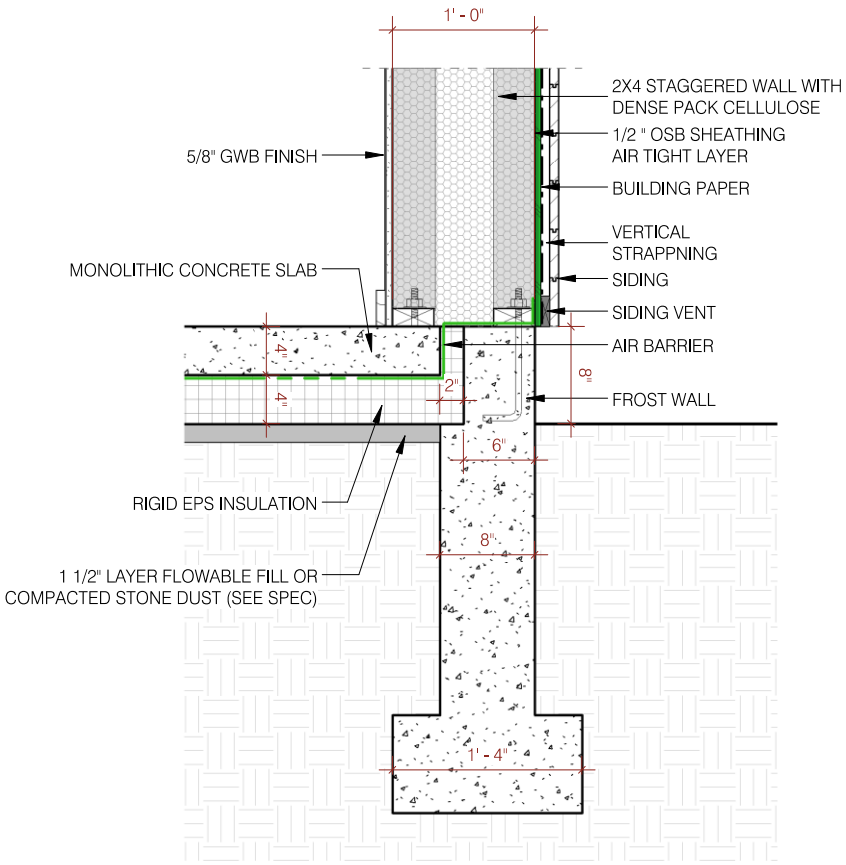
Double Stud Wall: Better Way 3



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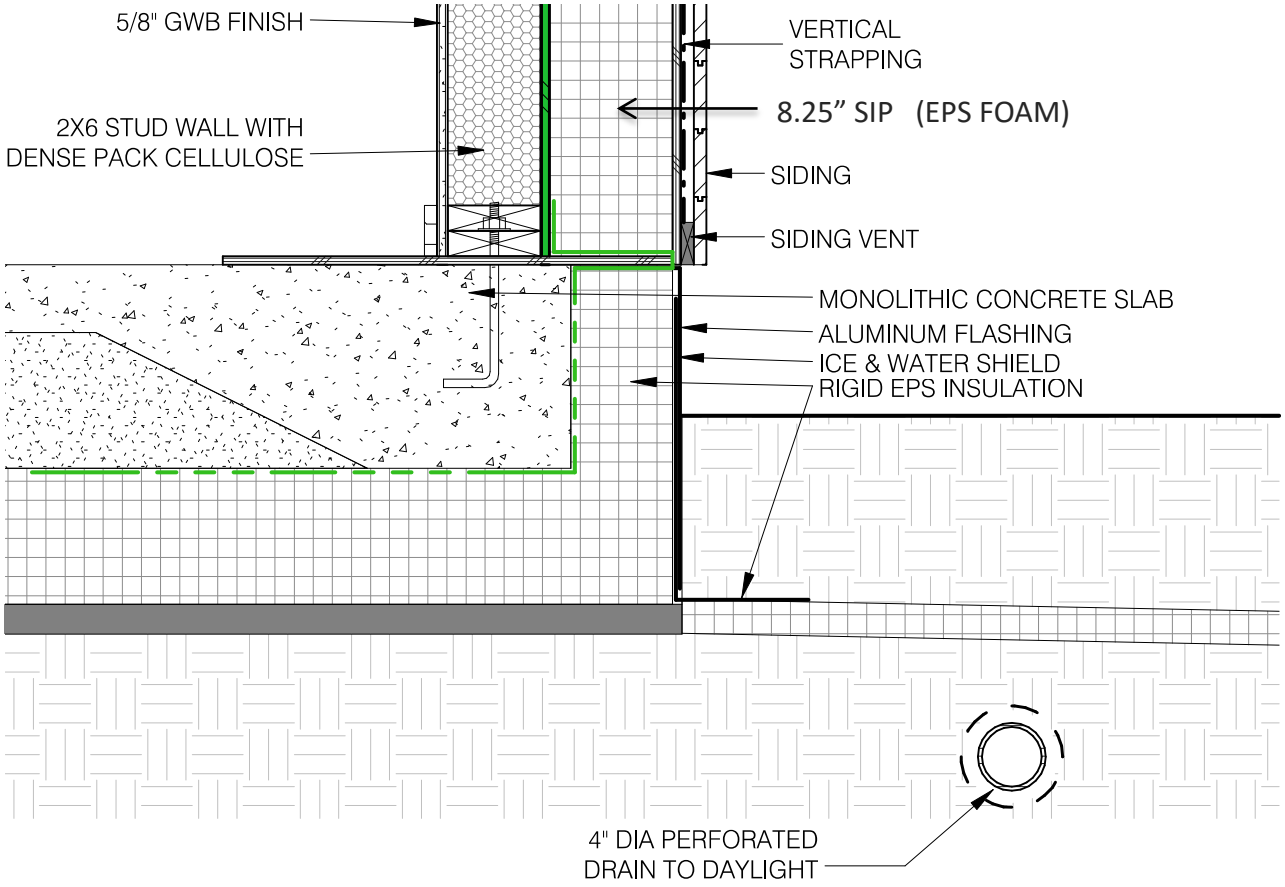
Stud Wall with Exterior Insulation



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Sheathing, foam, sheathing: SIP

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Naomi C. O. Beal

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Sheathing, foam, sheathing: SIP

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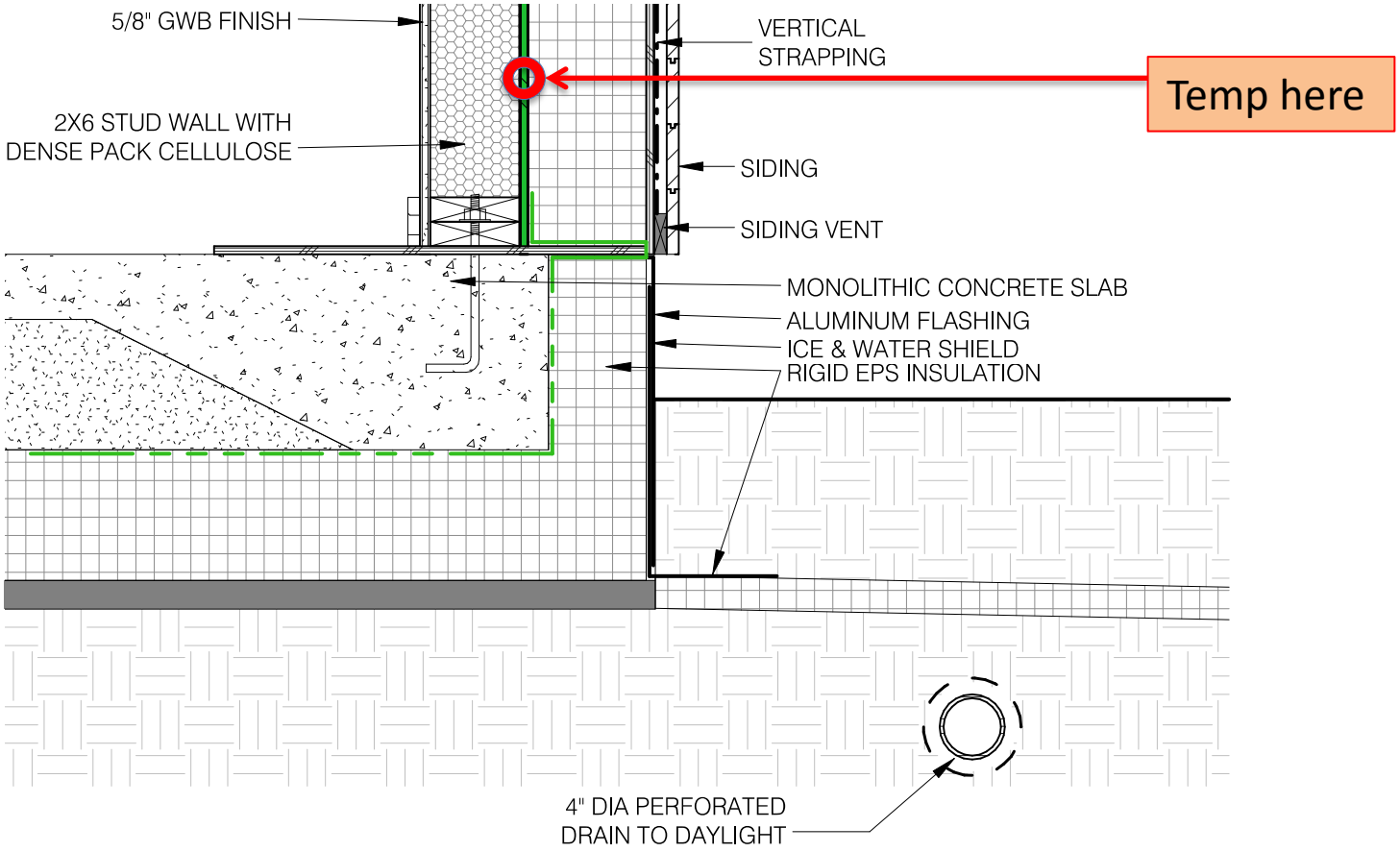
Stud Wall with Exterior Insulation



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Calculate temp inside the wall, and dew point

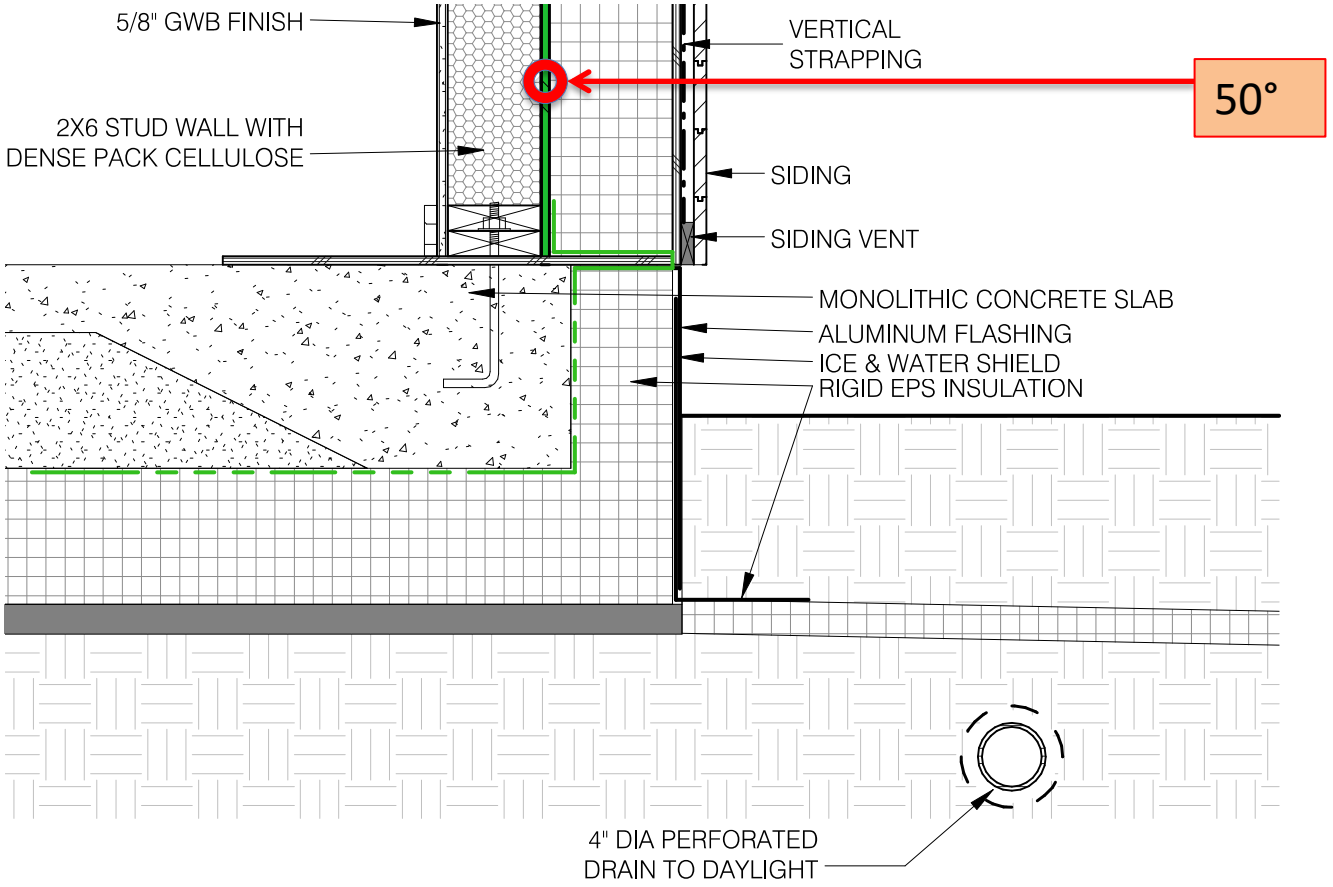
$$T_{si} = T_i - \left(\frac{R_{interior}}{R_{total}} \right) \times \Delta T$$

$$T_{si} = T_i - \left(\frac{R_{interior}}{R_{total}} \right) \times \Delta T$$

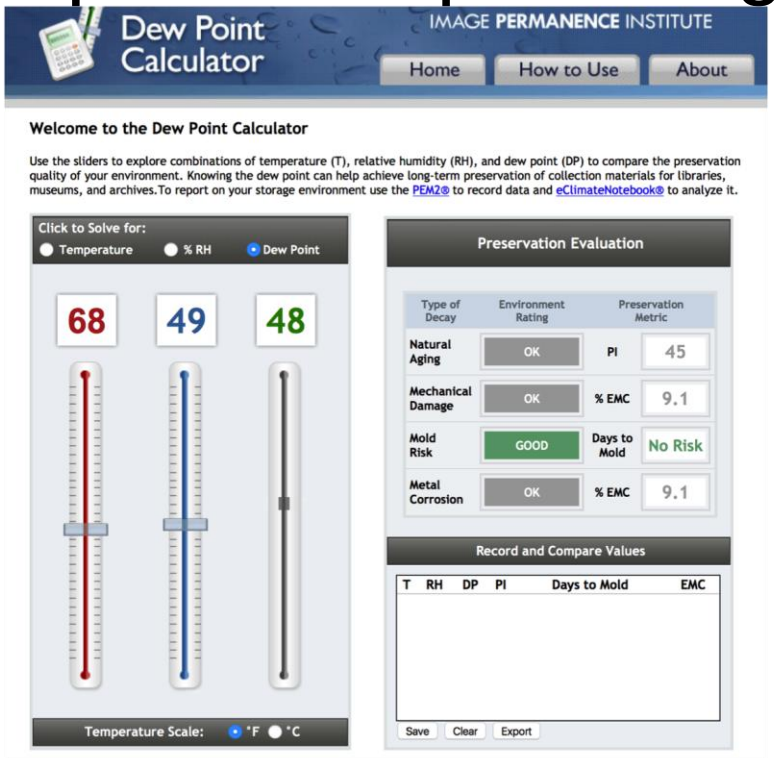
$T_{si} = 68° - (19/52) \times 48°$

$T_{si} = 50°$

Stud Wall with Exterior Insulation



Online Dew Point Calculator: http://www.dpcalc.org/



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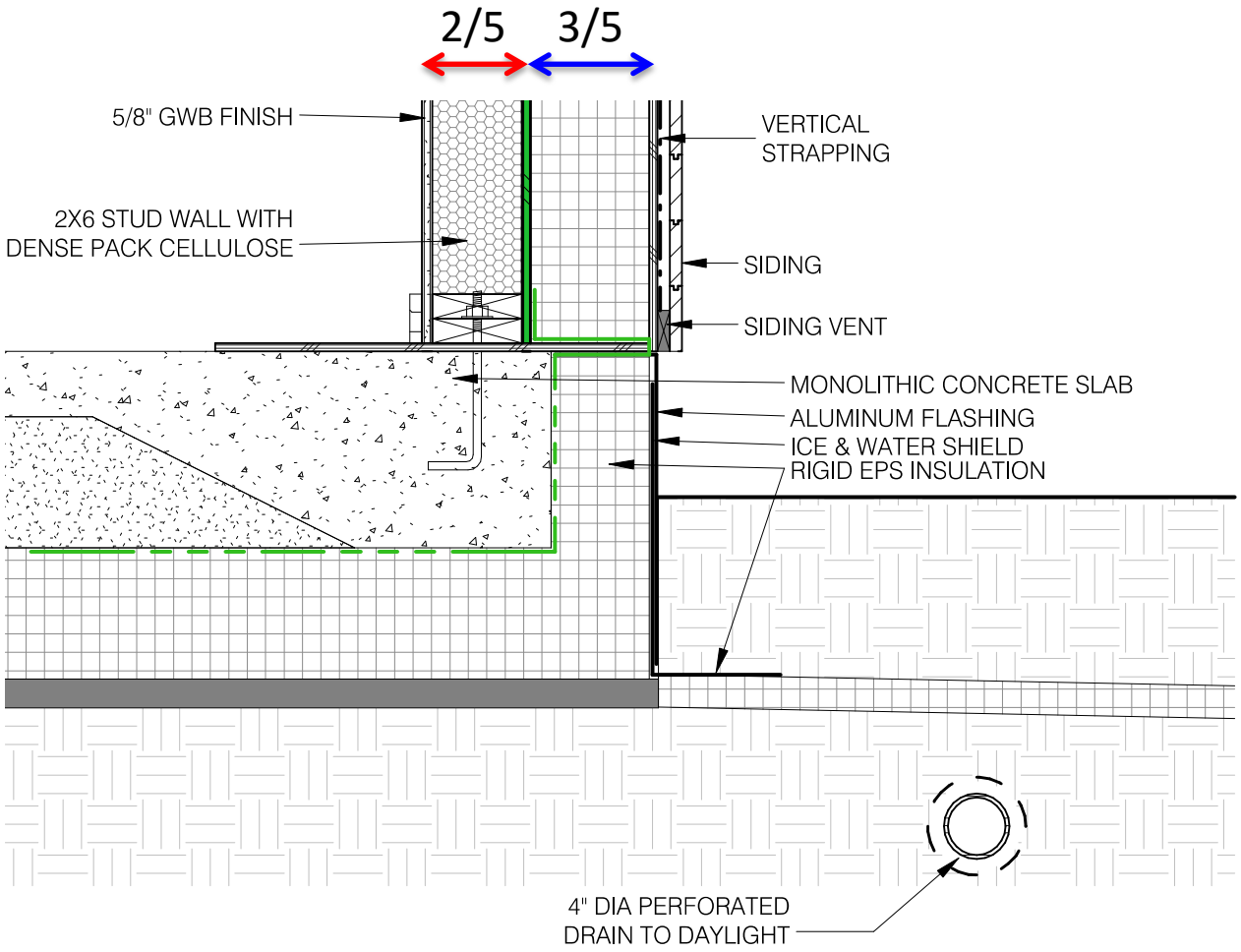
2/5 Rule: put sheathing no more than 2/5 of the total R value into the wall (from the interior).



IRC Code

R702.7.1 Class III vapor retarders.
Class III vapor retarders shall be permitted where any one of the conditions in Table R702.7.1 is met.

TABLE R702.7.1 CLASS III VAPOR RETARDERS

CLIMATE ZONE	CLASS III VAPOR RETARDERS PERMITTED FOR:[a]
Marine 4	Vented cladding over wood structural panels. Vented cladding over fiberboard. Vented cladding over gypsum. Insulated sheathing with *R*-value ≥ 2.5 over 2 × 4 wall. Insulated sheathing with *R*-value ≥ 3.75 over 2 × 6 wall.
5	Vented cladding over wood structural panels. Vented cladding over fiberboard. Vented cladding over gypsum. Insulated sheathing with *R*-value ≥ 5 over 2 × 4 wall. Insulated sheathing with *R*-value ≥ 7.5 over 2 × 6 wall.
6	Vented cladding over fiberboard. Vented cladding over gypsum. Insulated sheathing with *R*-value ≥ 7.5 over 2 × 4 wall. Insulated sheathing with *R*-value ≥ 11.25 over 2 × 6 wall.
7 and 8	Insulated sheathing with *R*-value ≥ 10 over 2 × 4 wall. Insulated sheathing with *R*-value ≥ 15 over 2 × 6 wall.

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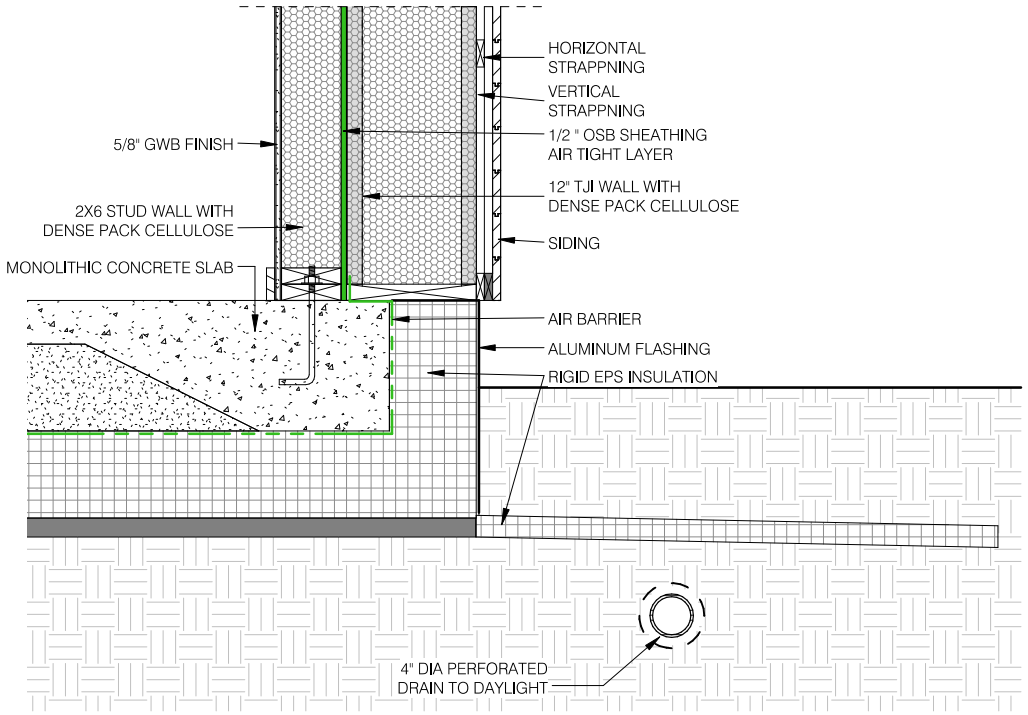
2x6 stud wall with TJI Larsen Truss



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GO Logic LLC
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Belfast, Maine 04915
207.338.1566
www.gologic.us

sheet	description	scale
SK1.5	2x6 Wall w/ 12" TJI	1" = 1'-0"

project

issued
02/15/16

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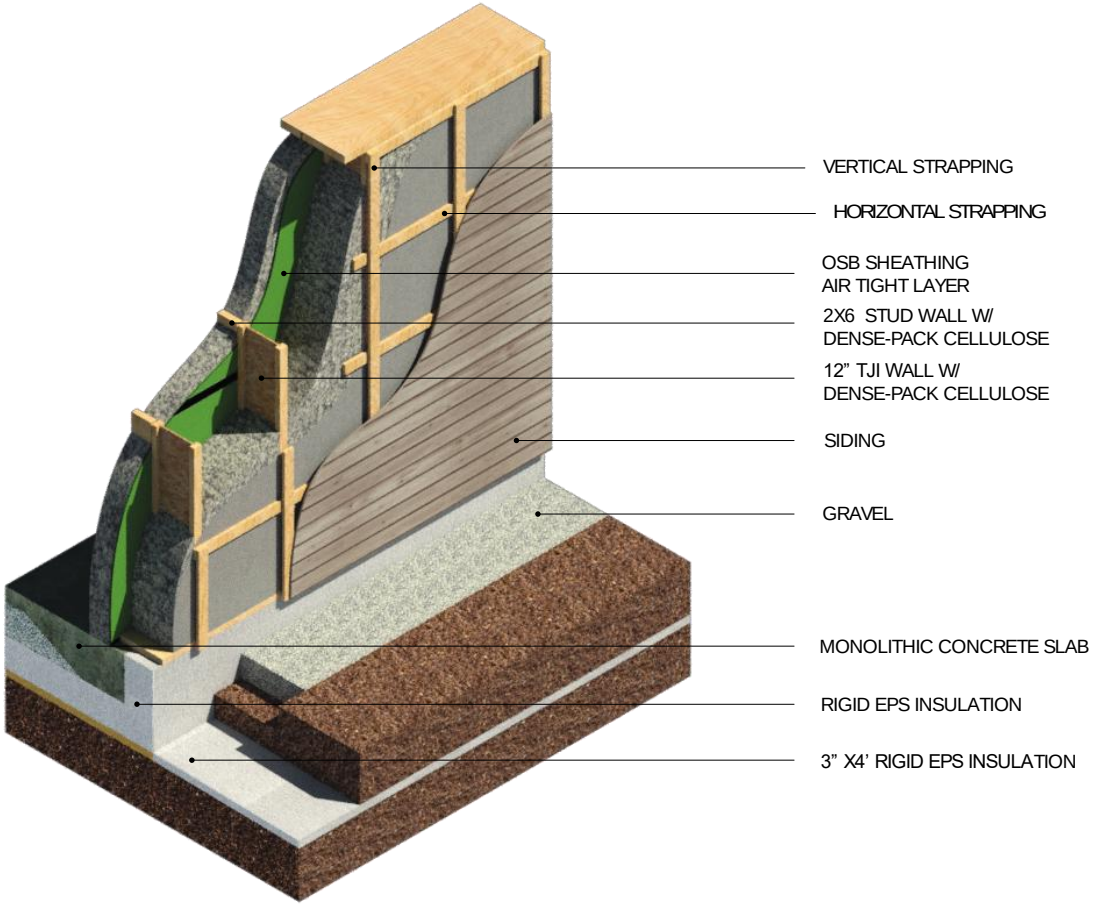
2x6 stud wall with TJI Larsen Truss



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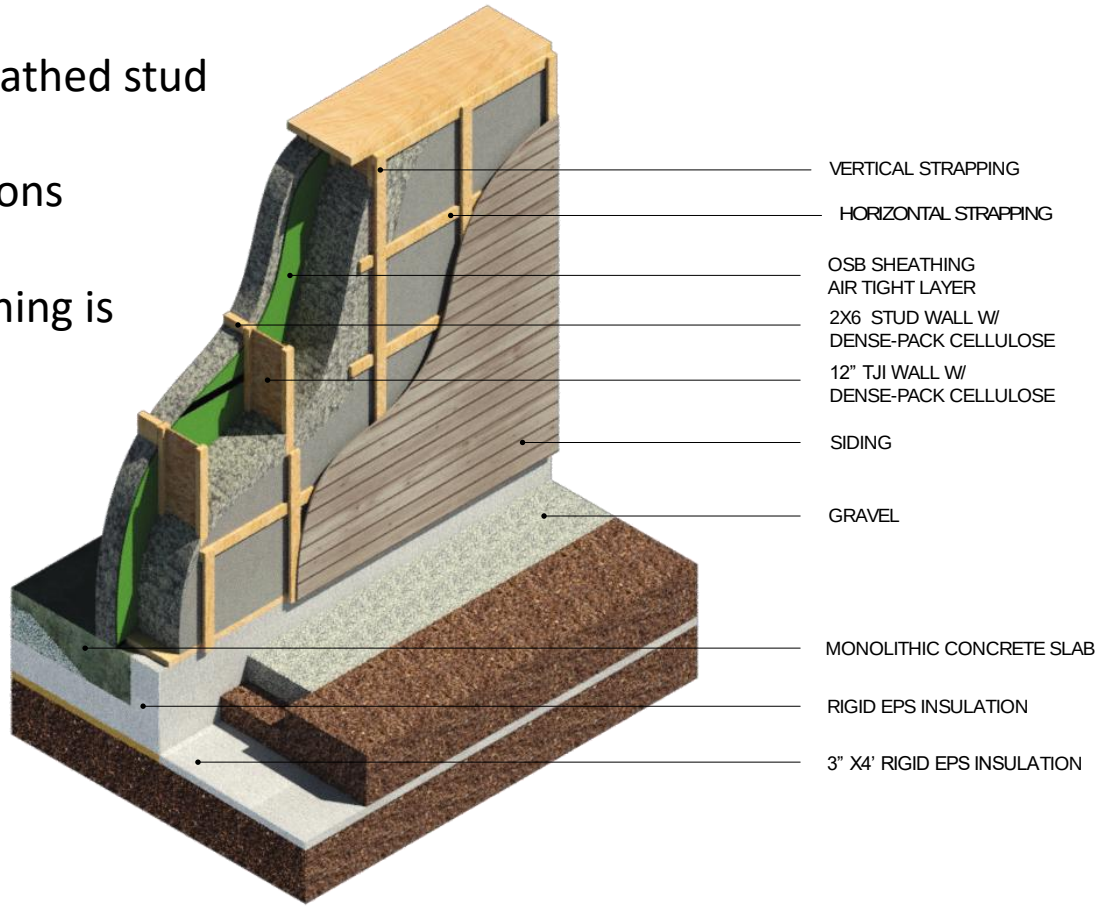
2x6 stud wall with 12” TJI Larsen Truss

Pros

- Load and shear resolved in sheathed stud wall
- TJI’s provide structure for bolt-ons
- R 63
- No dewpoint concerns—sheathing is warm, exterior vapor open



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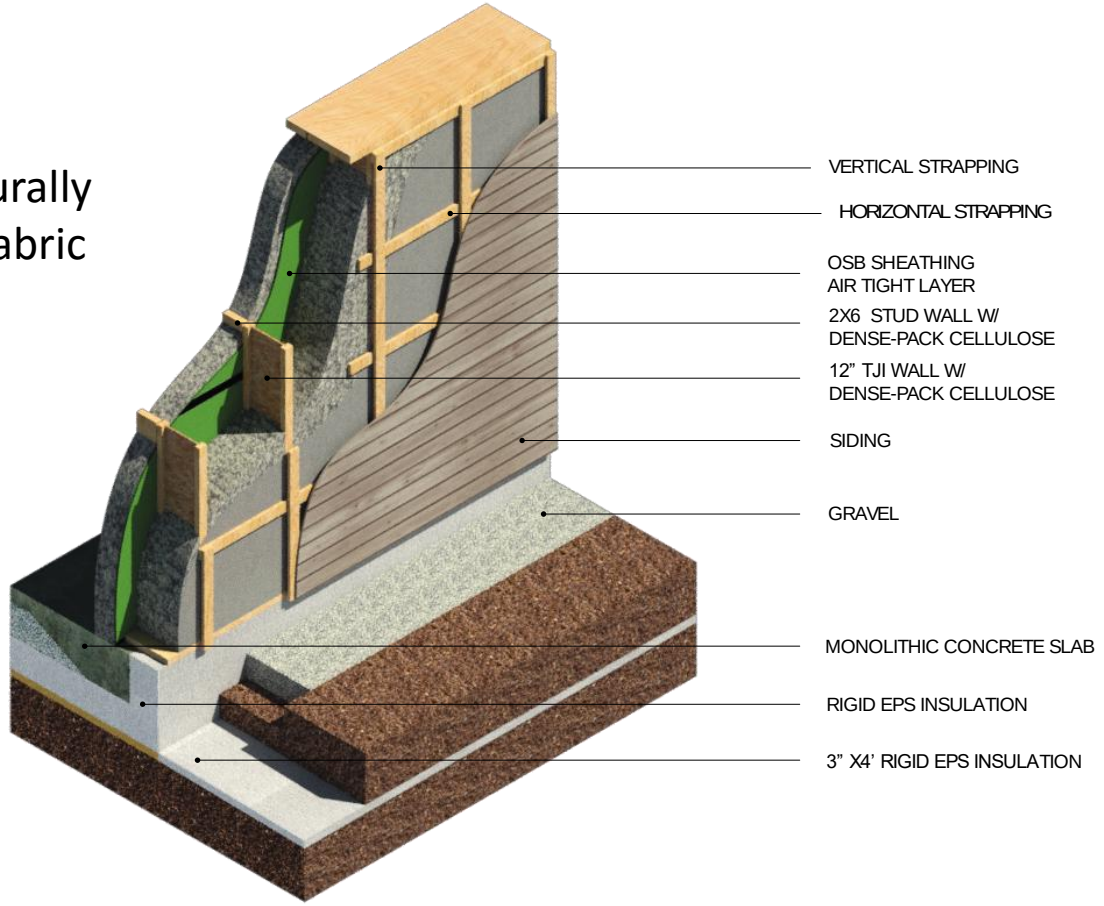
2x6 stud wall with TJI Larsen Truss

Cons

- Too fat?
- 2x4 wall limited structurally
- Fluffy stuff held in by fabric
- Getting expensive



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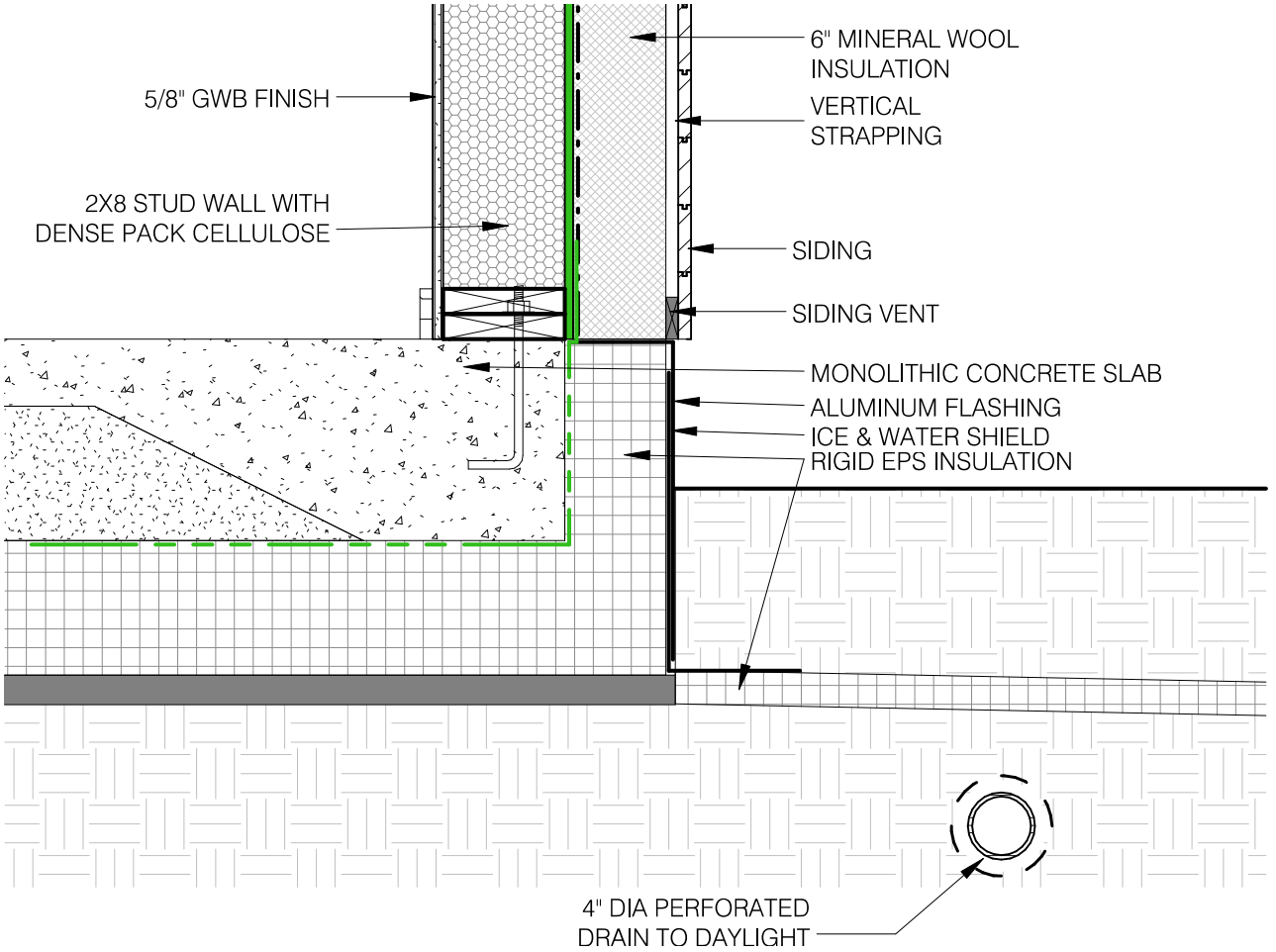
2x8 wall with exterior mineral wool



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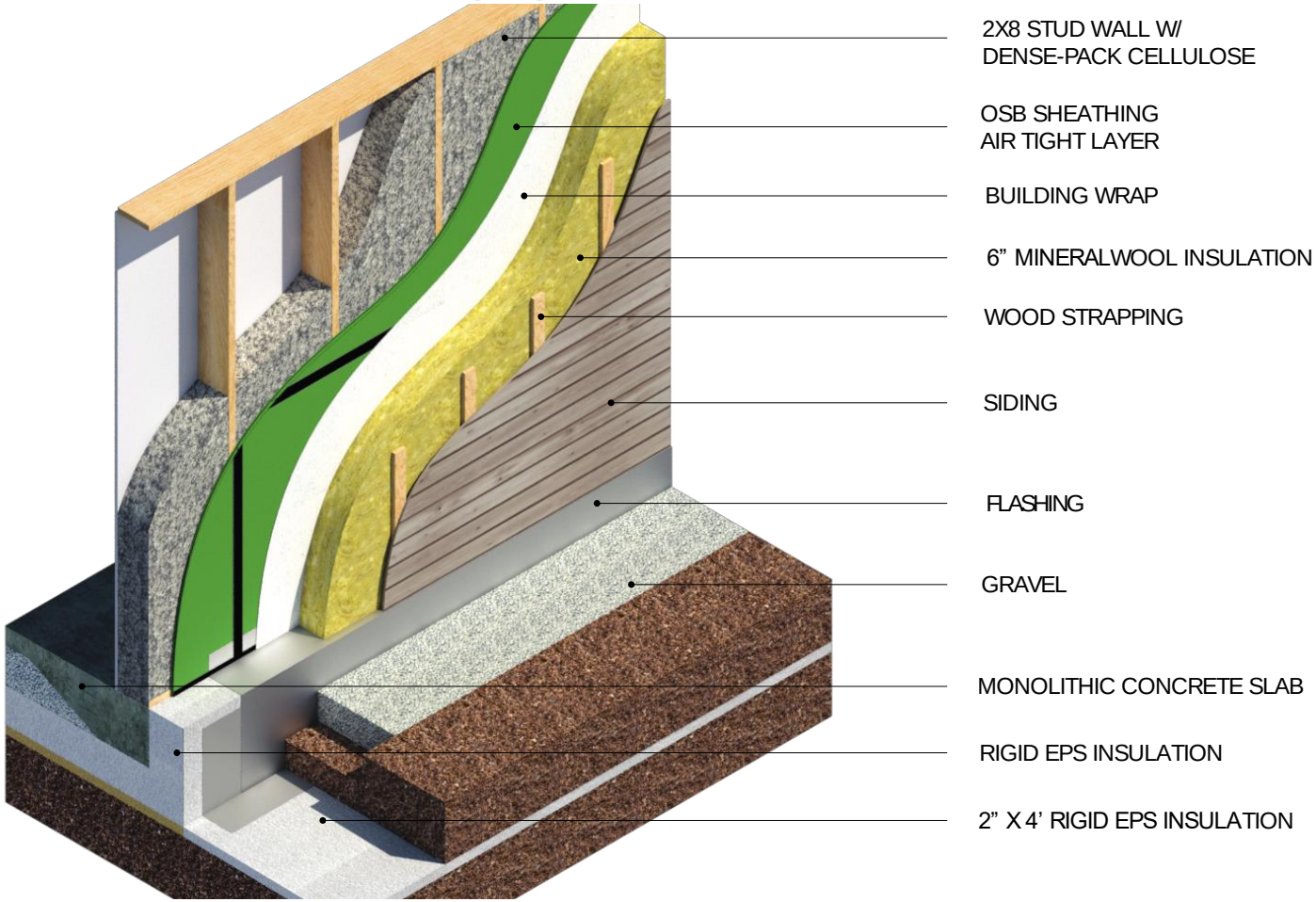
2x8 wall with exterior mineral wool



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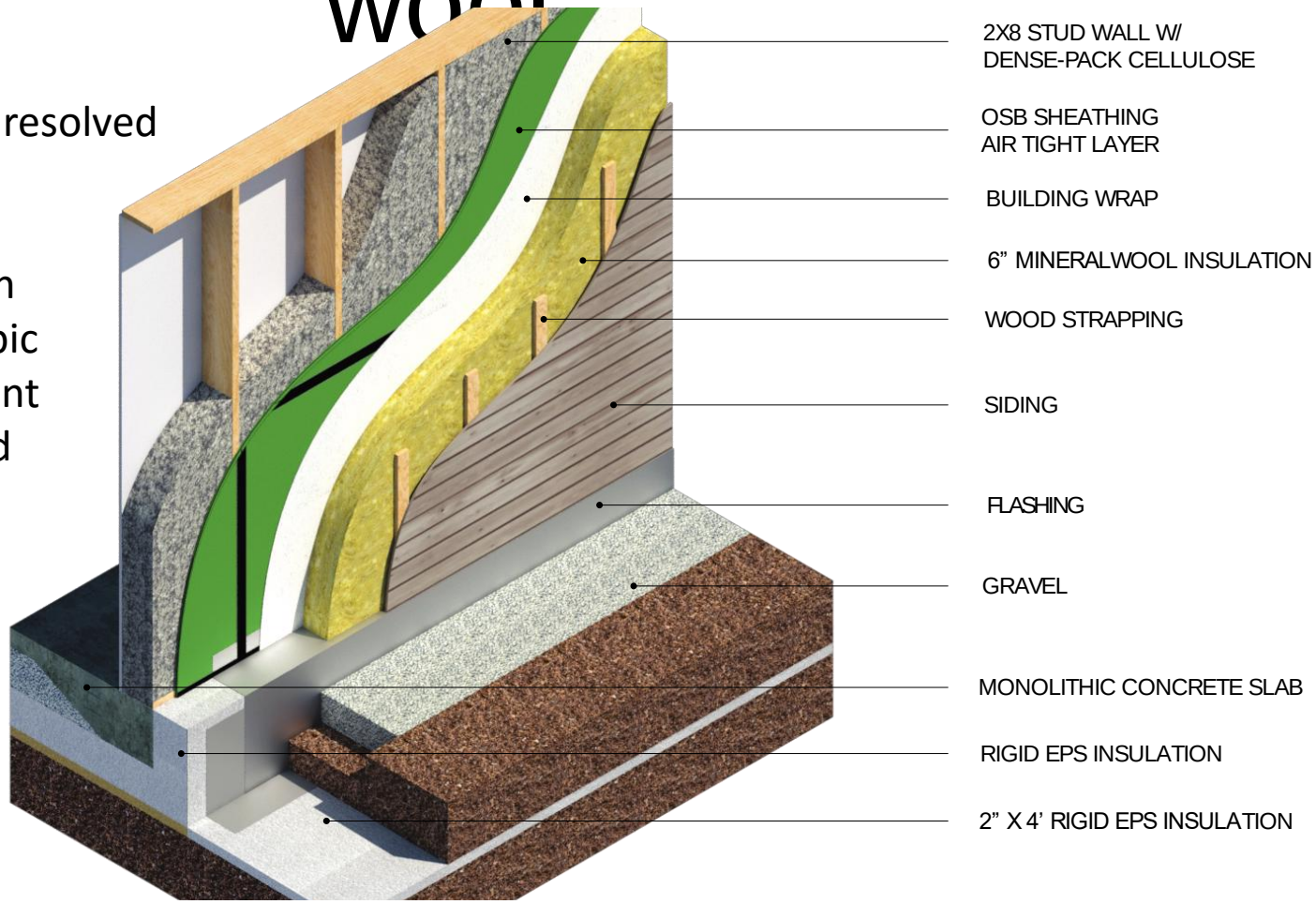
2x8 wall with exterior mineral wool

Pros

- Load and shear resolved
- R 52
- Mineral wool:
  - Vapor open
  - Hydrophobic
  - Fire resistant
  - Rigid board



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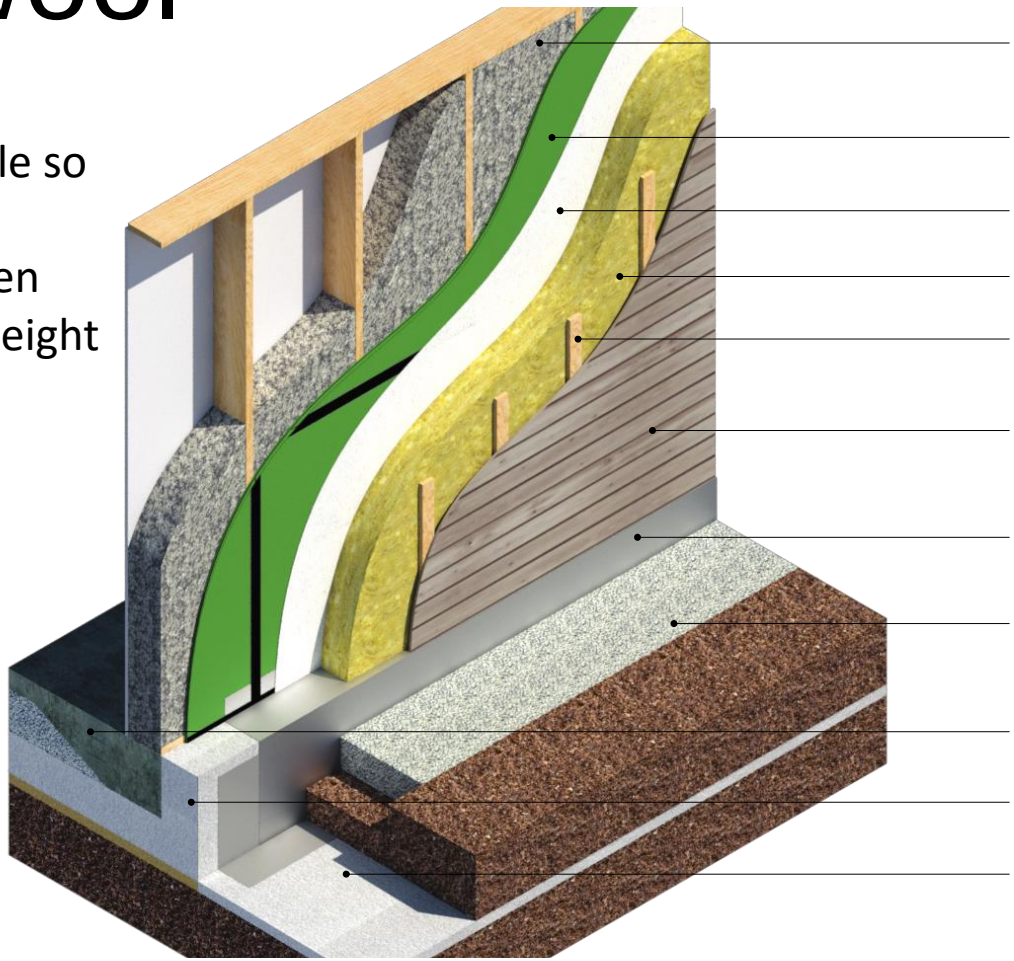
2x8 wall with exterior mineral wool

Cons

- Doesn't conform to 2/5 rule (but mineral wool is highly permeable so it's fine)
- Need to engineer connection between strapping and studs depending on weight of siding



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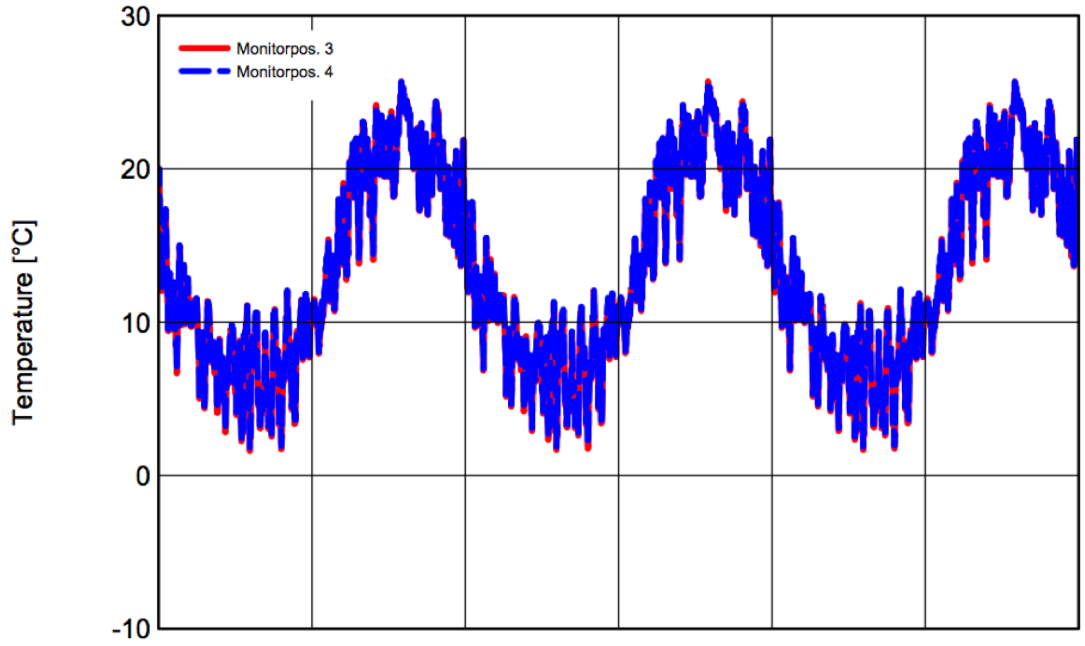
WUFI

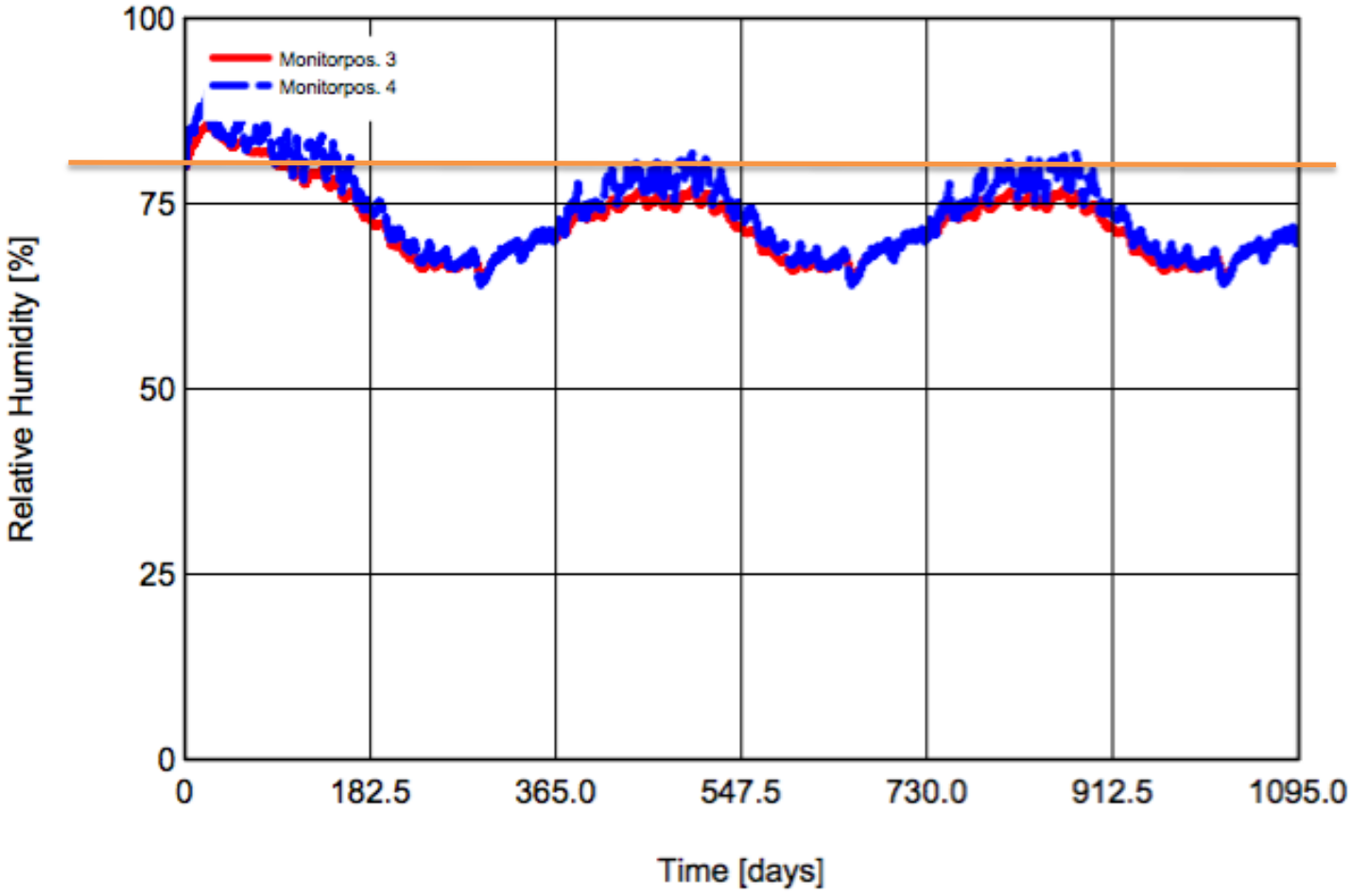
WUFI® Pro 5.2

Fraunhofer IBP

Temperature, RH (Monitor Position3, 4)



WUFI



80% RH: Danger Zone

Prefabrication

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Prefabrication

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The Cost Question

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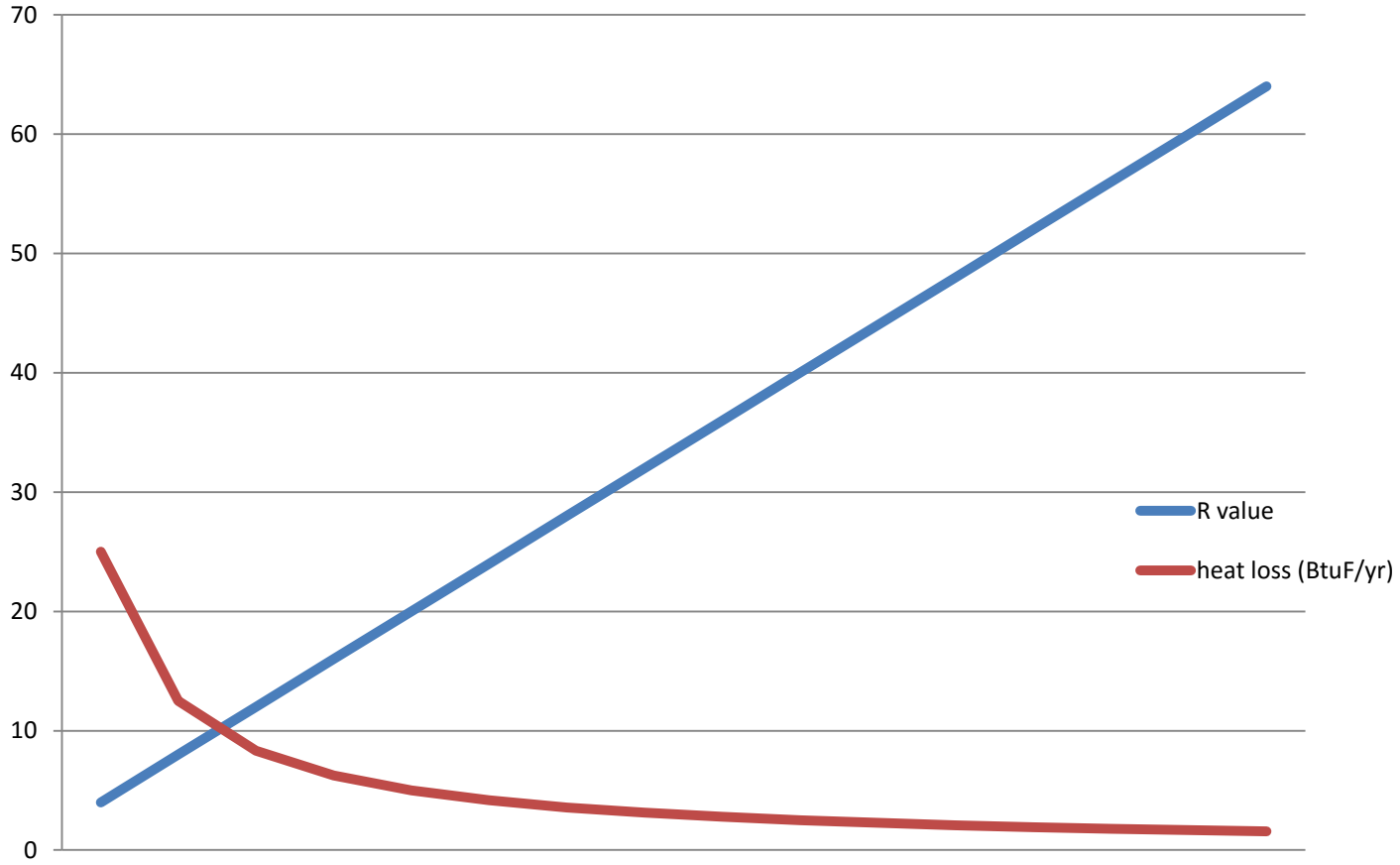
As R value increases, insulation's effectiveness decreases



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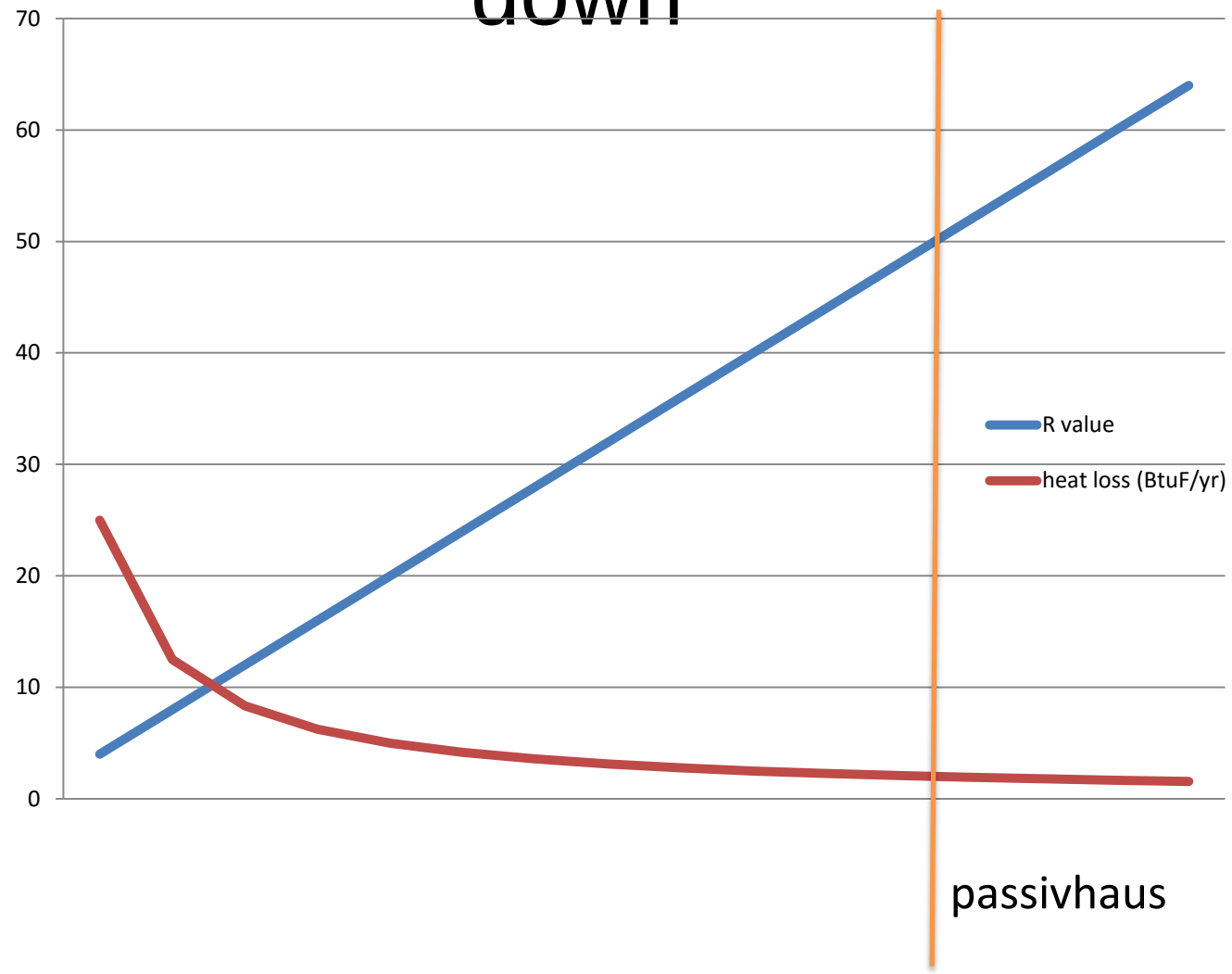
As R value increases, heat loss slows down



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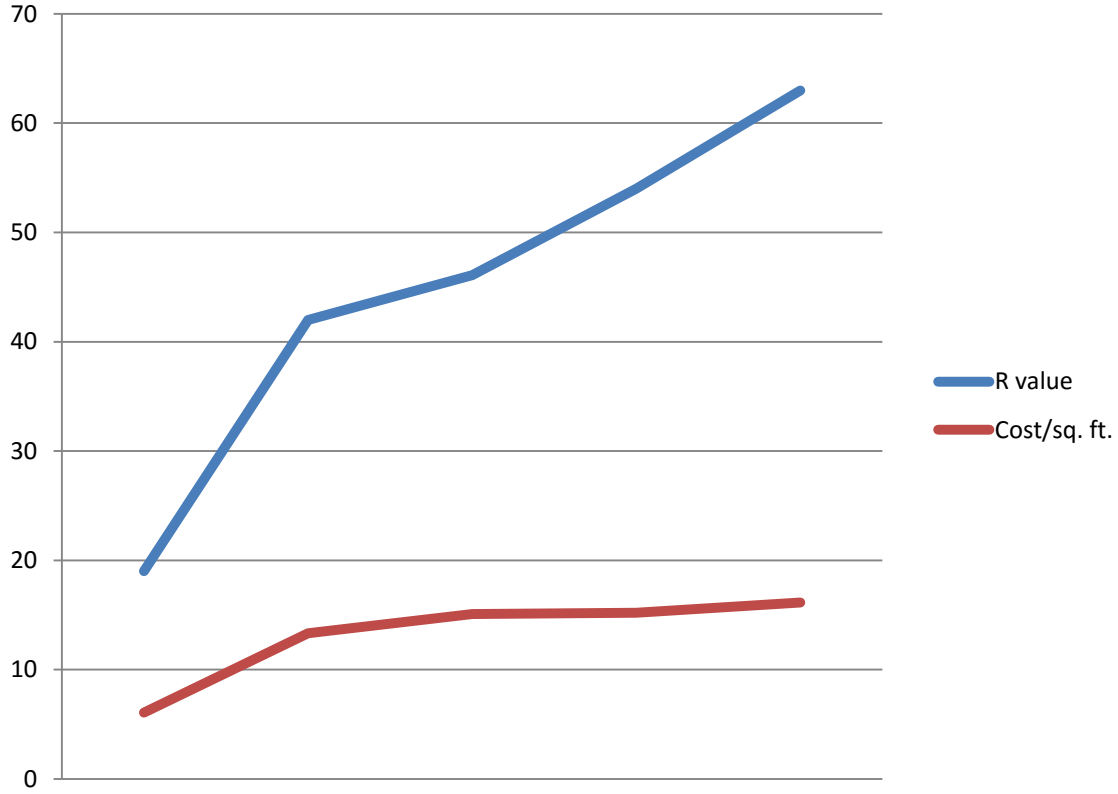
Cost

As R value increases, cost increases less



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Cost per square foot per R value

2x 6 wall with cellulose:	$.27
2x6 wall with 7.25” I-joist, fabric, cellulose:	$.33
2x6 wall with 9.25” I-joist, fabric, cellulose:	$.28
2x6 wall with 12” I-joist, fabric, cellulose:	$.26
12: double stud wall:	$.26
2x8 wall with 6” mineral wool:	$.26
2x6 wall with 8.25” SIP:	$.35

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Thank you.

Thanks to:

Martin Holladay, Green Building Advisor

Passive House Academy

Northeast Insulation

Albert Putnam, PE

Floris Keverling Buisman, 475 Building Supply