Actionable, Cost-Effective Passive Building Strategies

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Objectives

Part 1:
- Conceptual Passive House Theory
- Climate Specific Standards
- Impacts on Cost

Part 2:
- Performance Criteria Analysis
- Characteristics of Cost-Effective Assemblies
- Examples

So, What About Cost?

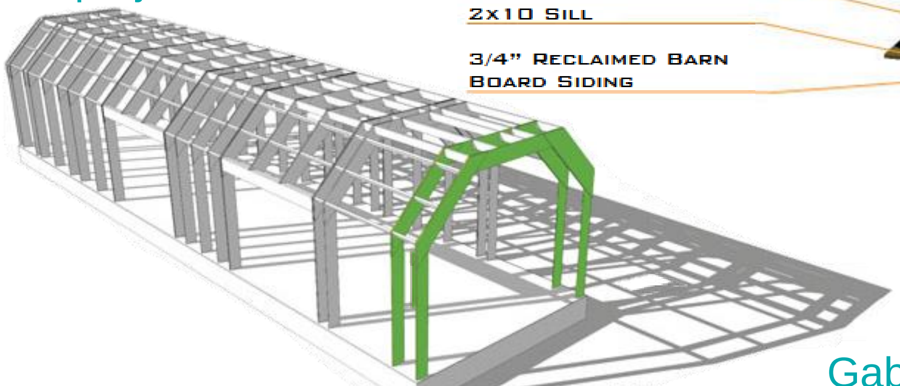
- Cost is a driver for every project
- There is a cost to build ANYTHING – not just a passive house
- Affordability is (still?) challenged
  - Interest Rates
  - Materials
  - Labor Costs
- Is there a PH Premium?
  - Climate Dependent, but typically added costs for:
    - Mechanical Systems
    - Incremental Insulation
    - High Performance Windows and Door
    - Air Sealing

How many construction methods can one person try?

14 years ago: I presented at my first PhiusCon

Since then, I have worked on projects that have used just about every possible type of assembly

Also, I was the Phius Certification Manager for approx. 3 years and still review projects for Phius



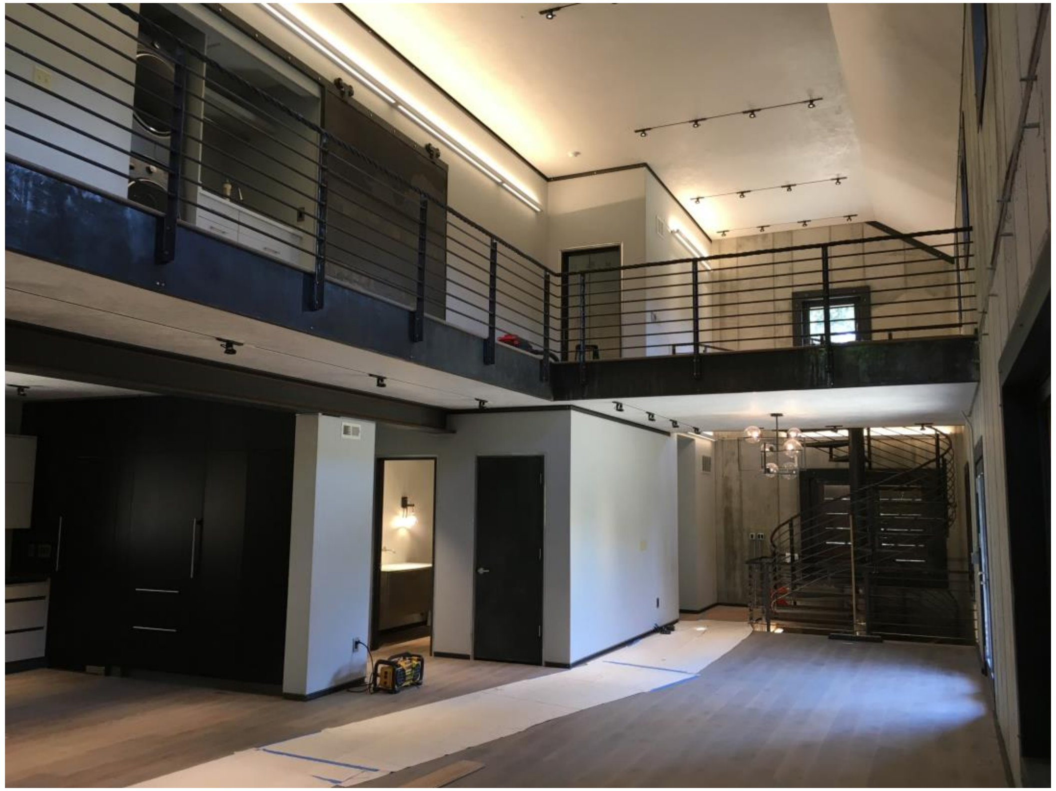
Lamboo Framing Perspective

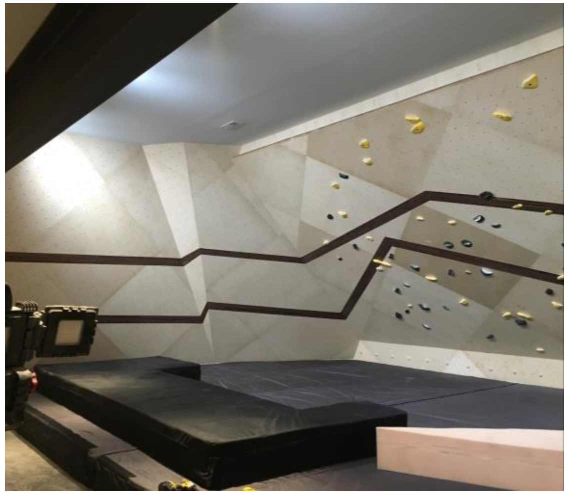
Gable Home
University of Illinois 2009

How many construction methods can one person try?

Techstyle Haus
Photo: Julia Hass 2015

How many construction methods can one person try?





Cast-in-place Concrete

Exterior Foam Insulation

Vented Attic

Wildwood, MO

How many construction methods can one person try?

CRETE House
Washington University in St. Louis, MO – 2017 US DOE Solar Decathlon
Precast Concrete: footings, floors, walls, roof, gutters, planters

How many construction methods can one person try?

Loughran Home

Goreville, IL – PHIUS+ 2015 Source Zero Certified

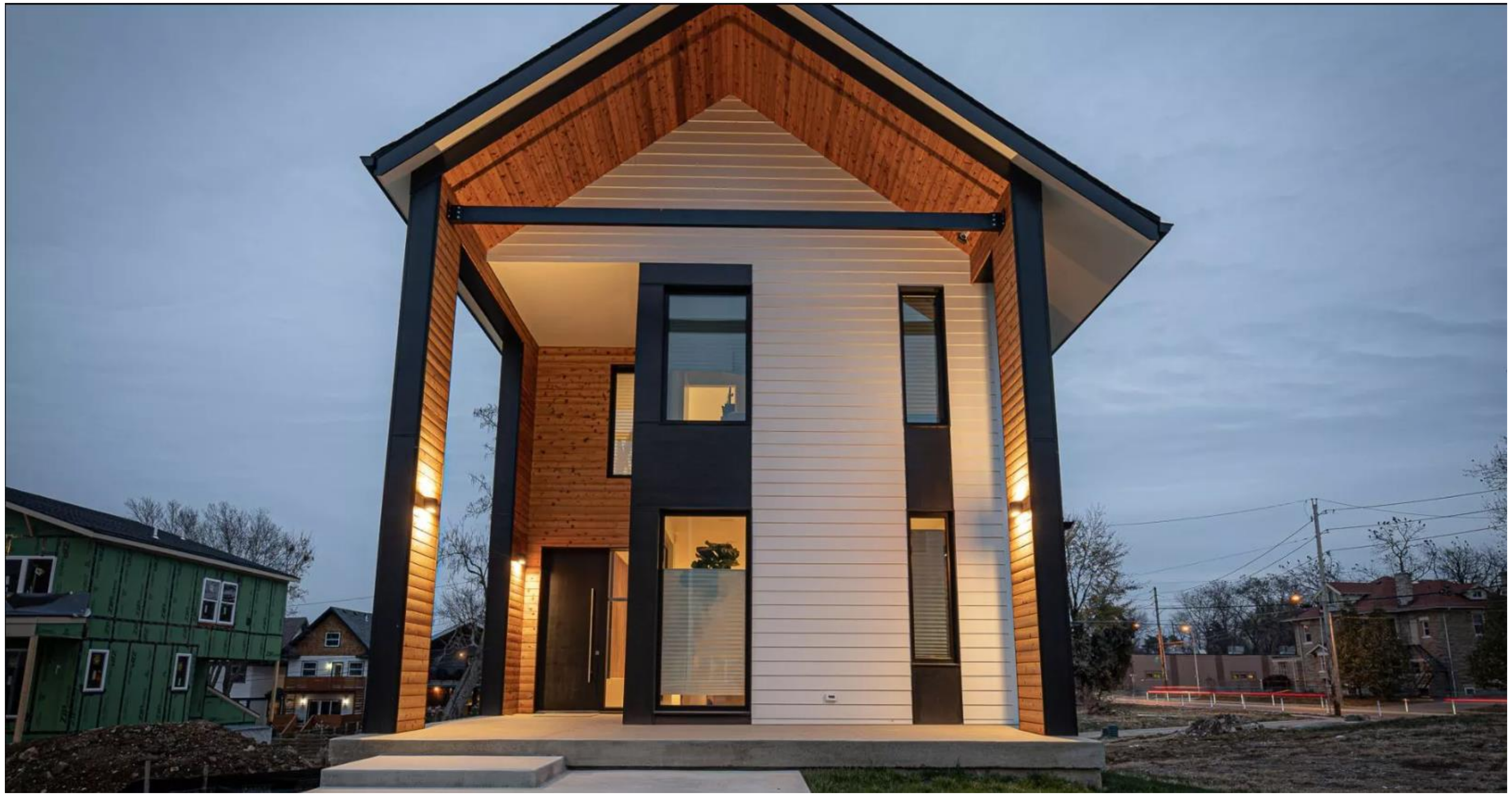
SIPS wall/roof on Timber Frame

Kala Forest Ave Passive House

Kansas City, MO – Phius Core 2021 Certified

SIPS w/ Interior Stud Wall, Vented attic

Builder: Kala Performance Homes



How many construction methods can one person try?

The Full List of Walls:

Laminated Bamboo 1x10's
TJI Studs (no CI / CI)
2x4 with ext. Hanging TJI (Klingenberg Wall)
2x6 with Rigid Foam CI
2x6 with int. 2x4 w/ 2" Mineral Wool CI w/ stucco
2x6 with Zip R as Insulated Sheathing
2x6 with 4-6" EPS Nailbase w/ stucco
Insulated Light Frame Steel w/ 4" Rigid Foam CI
Structural Steel Frame with Fabric Enclosure

Pre-Cast Concrete Sandwich Panels
Cast-in-Place Concrete w/ ext. Foam
Insulated Concrete Form (Basement Only)
Insulated Concrete Form (Full Walls)
Concrete block walls in Tropical Climate
SIP panels as Structure
SIP panels on a TimberFrame
CLT and Timberframe w/ pre-fab wood walls
Historic Masonry – Interior Retrofit

Slabs:

Concrete with EPS
Concrete with XPS
Concrete with Foam Glass Aggregate

Roofs:

Vented Attic with fibrous insulation
Conditioned Roof with exterior foam
Conditioned Roof mix of cavity and deck insulation
Conditioned Roof with spray foam

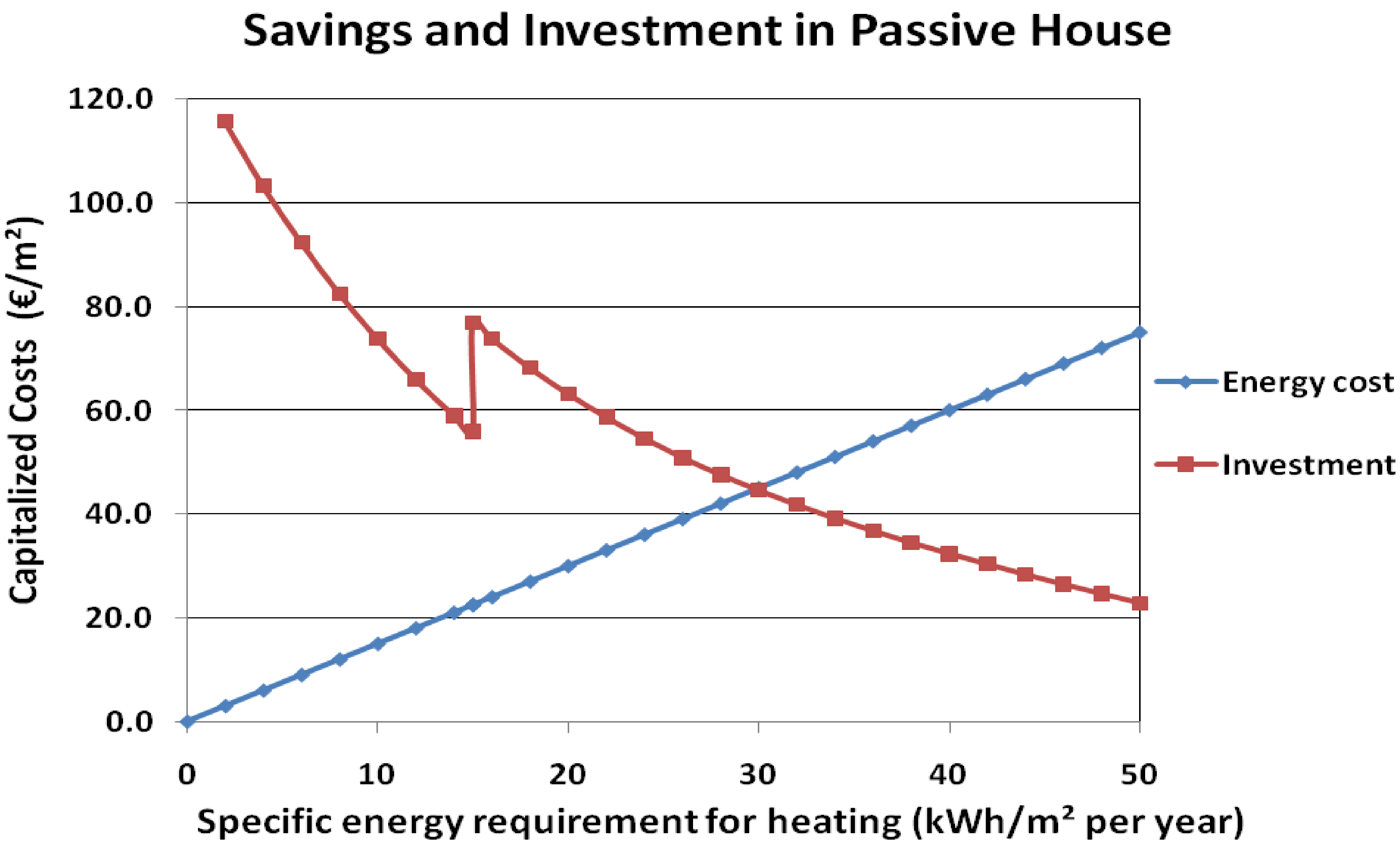
Peak Heat Load Design Concept

A quick history lesson:

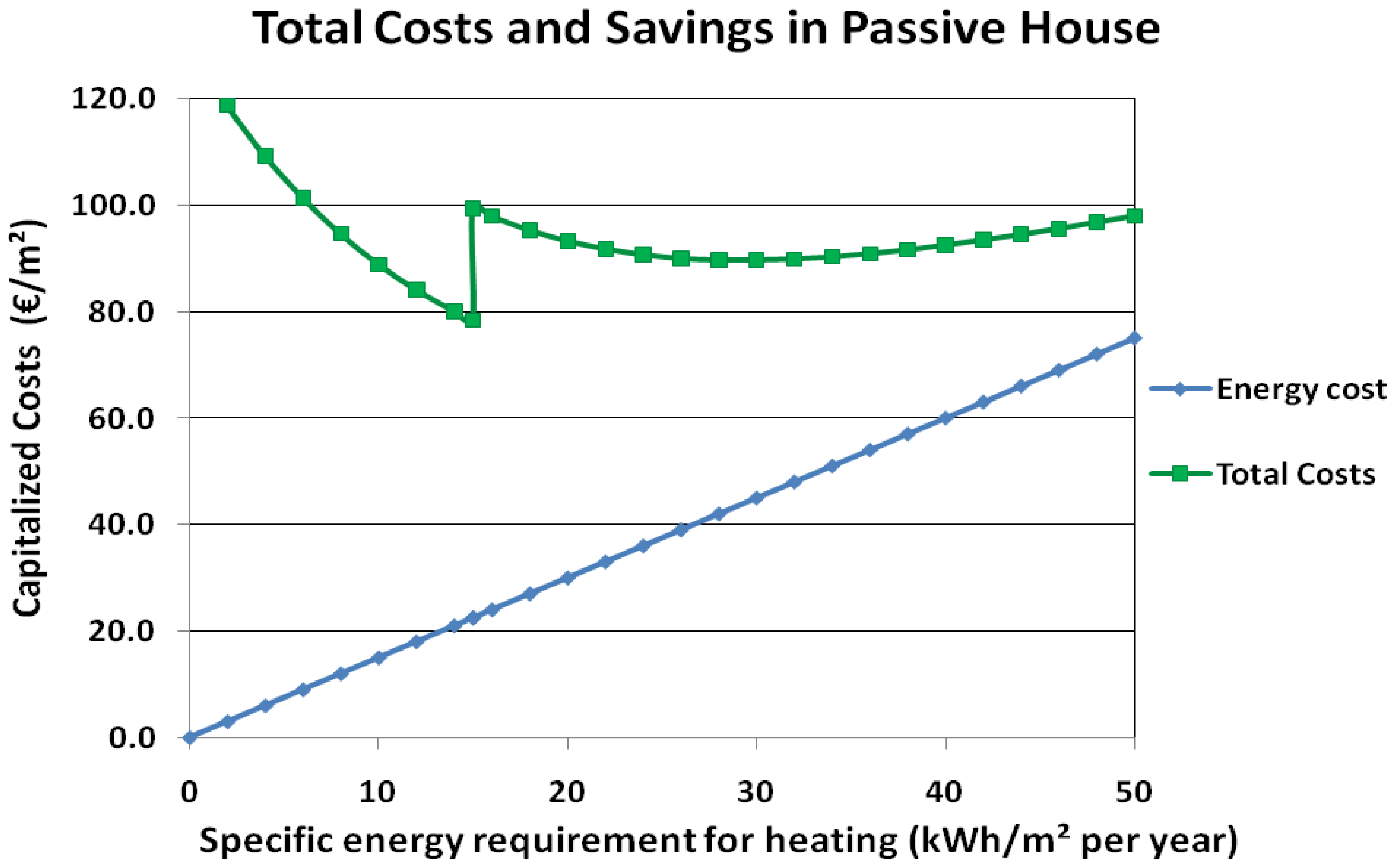
- Original PHI Criteria was developed by limiting the Peak Heating Load to the amount of heat that could be carried at the airflow required for fresh air ventilation by the building occupants
- This "removed" the traditional heating system resulting in cost savings

Certification Criteria	Certification Values
Annual Heating Demand:	4.75 $kBTU/ft^2yr$
Peak Heating Load:	**3.17 $BTU/hr.ft^2$**
Annual Cooling Demand:	4.75 $kBTU/ft^2yr$
Peak Cooling Load:	3.17 $BTU/hr.ft^2$
Primary Energy Demand:	38.1 $kBTU/ft^2yr$
Air Tightness:.	0.6 ACH_{50}

Passive House Costs (Europe)



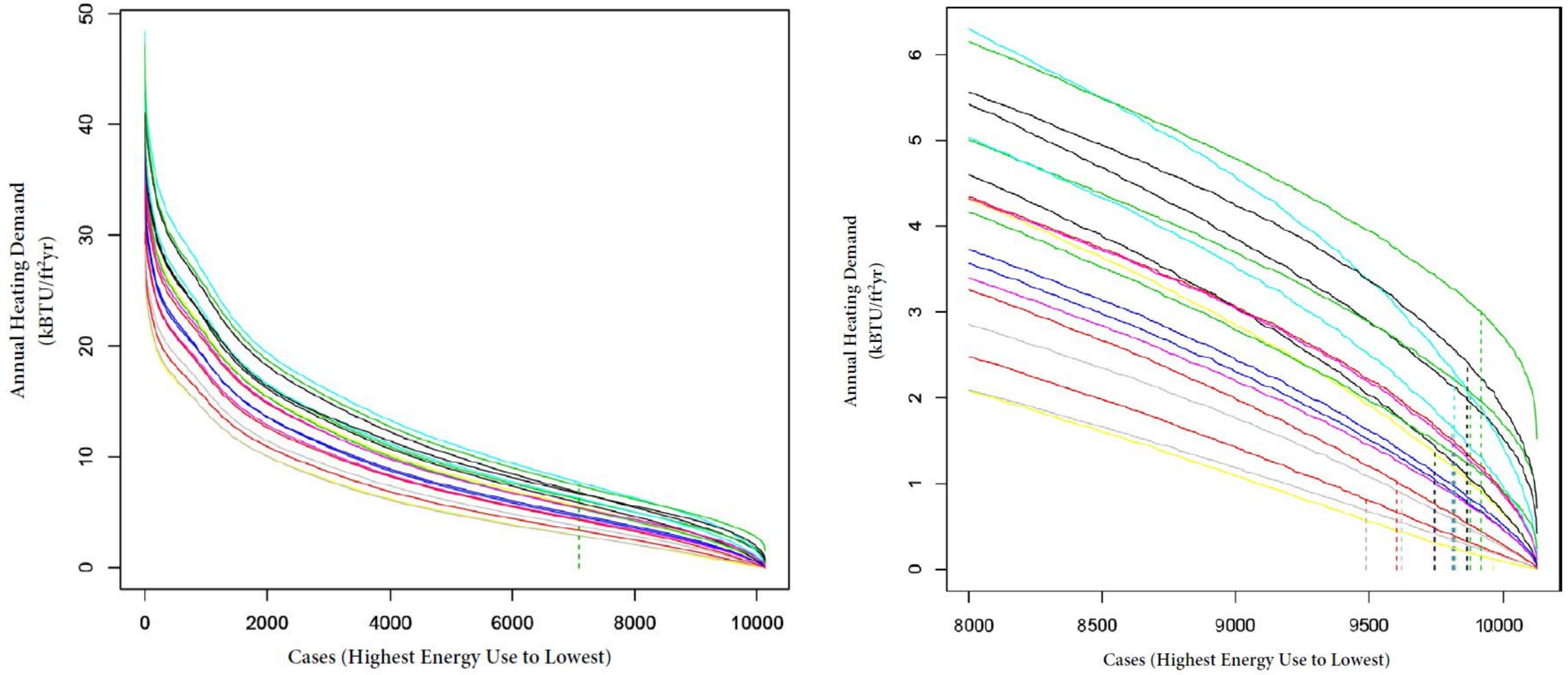
Passive House Costs (Europe)



Climate Specific Passive House Standard

A CRITICAL ANALYSIS OF THE PASSIVE HOUSE STANDARD FOR THE CLIMATES OF THE UNITED STATES

Ryan Abendroth's Thesis for Master of Architecture at University of Illinois in 2013



There is not a scientific reason to stop insulating in most climates.

More Insulation = Less Heat Loss

Diminishing returns of insulation ARE in-effect and ARE significant, but still – more is more.

Climate Specific Passive House Standard

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Climate-Specific Passive Building Standards

Graham S. Wright and Katrin Klingenberg
Passive House Institute US

July 2015

Climate-Specific Passive Building Standards

Building America Report - 1405
July 2015
G. Wright (PHIUS), K. Klingenberg (PHIUS), Betsy Pettit, FAIA

Climate Specific Passive House Standard

So how was the standard set?

COST

Climate Specific Passive House Standard

Factors:

Construction Cost

Climate Data

Utility Cost

Occupancy

Envelope Area

Interior Conditioned Floor Area

What increases the cost to build Passive?

Envelope
- Insulation
- Air sealing
- Membranes
- Specialty Envelope Products
- Windows
- Doors

Systems
- Ventilation
- Heating / Cooling
- DHW
- Appliances
- Exhausts / Make-up Air

Service Fees
- CPHC
- Rater
- Phius Certification Fee
- Extra Design Services

Quick Code Comparisons

Code requirements are trending towards greater energy efficiency every cycle

Buildings built to current codes use ~50% less energy than the 1975 Baseline

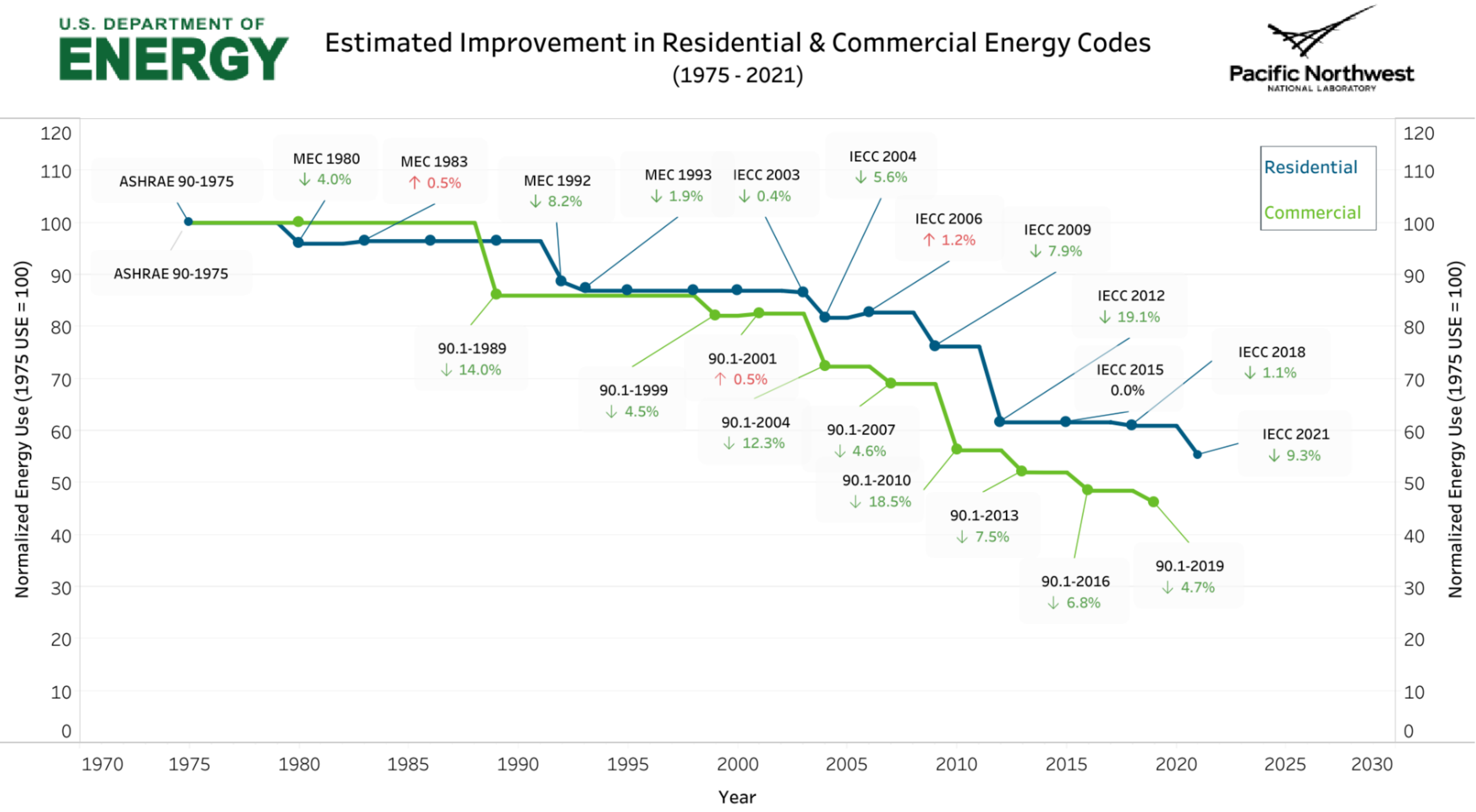


Image credit: U.S. Department of Energy

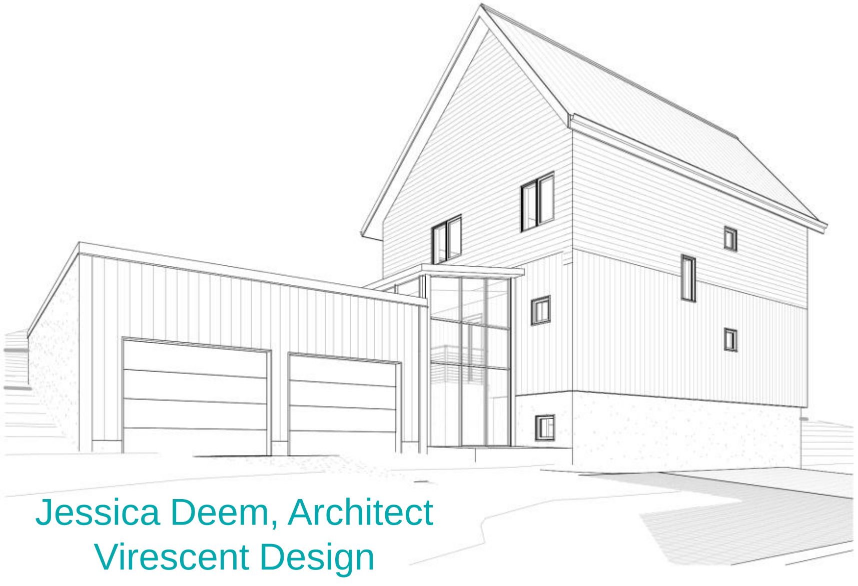
Quick Code Comparison – CZ4: St. Louis

TABLE 402.1.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

	CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
IECC 200	4 except Marine	0.35	0.60	NR	38	13	5/10	19	10 /13	10, 2 ft	10/13
IECC 20	4 except Marine	0.35	0.55	0.40	49	20 or 13+5[h]	8/13	19	10/13	10, 2 ft	10/13
IECC 201	4 except Marine	0.35	0.55	0.40	49	20 or 13+5[h]	8/13	19	10/13	10, 2 ft	10/13
IECC 201	4 except Marine	0.32	0.55	0.40	49	20 or 13+5[h]	8/13	19	10/13	10, 2 ft	10/13
IECC 202	4 except Marine	.30	0.55	0.40	60	30 or 20&5ci[h] or 13& 10ci[h] or 0&20ci[h]	8/13	19	10ci or 13	10ci, 4 ft	10ci or 13

Quick Code Comparison – CZ4: St. Louis

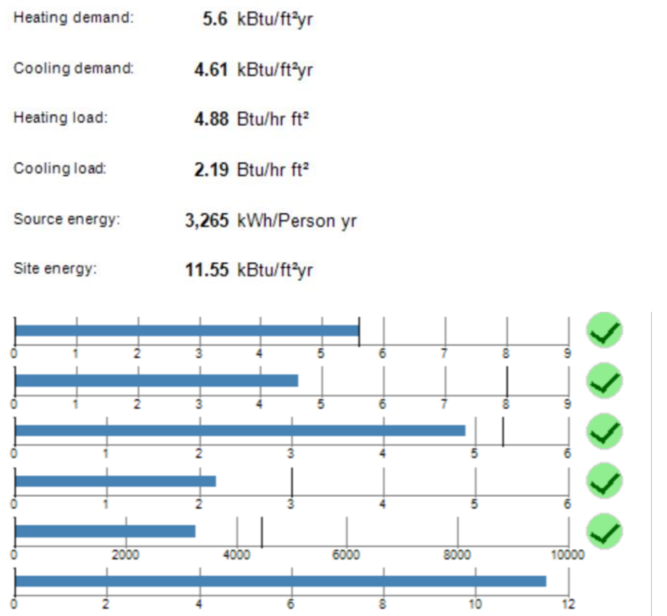
	CLIMATE ZONE	FENESTRATION *U*-FACTOR[b, i]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[g]	MASS WALL *R*-VALUE[h]	FLOOR *R*-VALUE	BASEMENT[c,g] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c,g] WALL *R*-VALUE
IECC 2021	4 except Marine	.30	0.55	0.40	60	30 or 20&5ci[h] or 13& 10ci[h] or 0&20ci[h]	8/13	19	10ci or 13	10ci, 4 ft	10ci or 13
Most Recent Project: St. Louis, MO		0.16 24-cont.	n/a n/a	.386 cog	60		35		n/a	n/a	26



Jessica Deem, Architect
Virescent Design

From Code to Passive House

Much better window performance
A bit more wall insulation
A bit more basement wall insulation
Insulate full slab
Airtightness about 5x tighter than code



Quick Code Comparison – CZ2: Austin

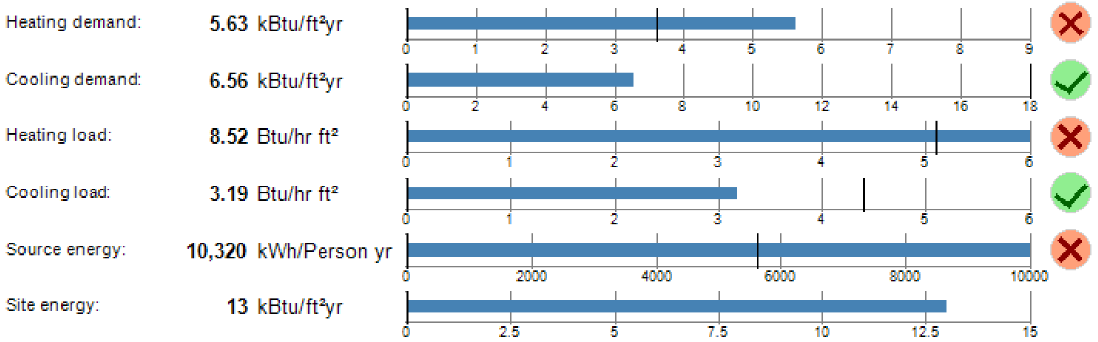
TABLE 402.1.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

	CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
IECC 200	2	0.65[j]	0.75	0.30	30	13	4/6	13	0	0	0
IECC 201	2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
IECC 201	2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
IECC 201	2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
IECC 202	2	0.40	0.65	0.25	49	13 or 0& 10ci	4/6	13	0	0	0

Quick Code Comparison – CZ2: Austin

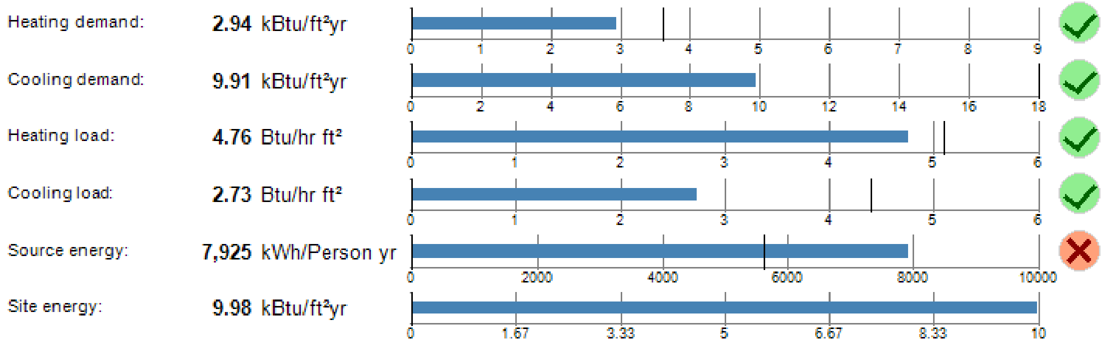
	CLIMATE ZONE	FENESTRATION *U*-FACTOR[b, i]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[g]	MASS WALL *R*-VALUE[h]	FLOOR *R*-VALUE	BASEMENT[c,g] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c,g] WALL *R*-VALUE
IECC 2021	2	0.40	0.65	0.25	49	13 or 0& 10ci	4/6	13	0	0	0
Austin TX Code Compliant (ish)		0.25 .42	0.25	.25 cog	38		18.1		n/a	n/a	n/a
Austin TX Optimum (ish)		0.25 4.42	0.25	.25 cog	49		24.3		n/a	n/a	n/a

Austin TX Code Compliant (ish)



Air Infiltration Limit:
0.215 cfm_{50}/ft^2
3.00 ACH_{50}

Austin TX Optimum (ish)



Air Infiltration Limit:
0.06 cfm_{50}/ft^2
0.83 ACH_{50}

Cost Analysis – CZ2: Austin

IECC 2021

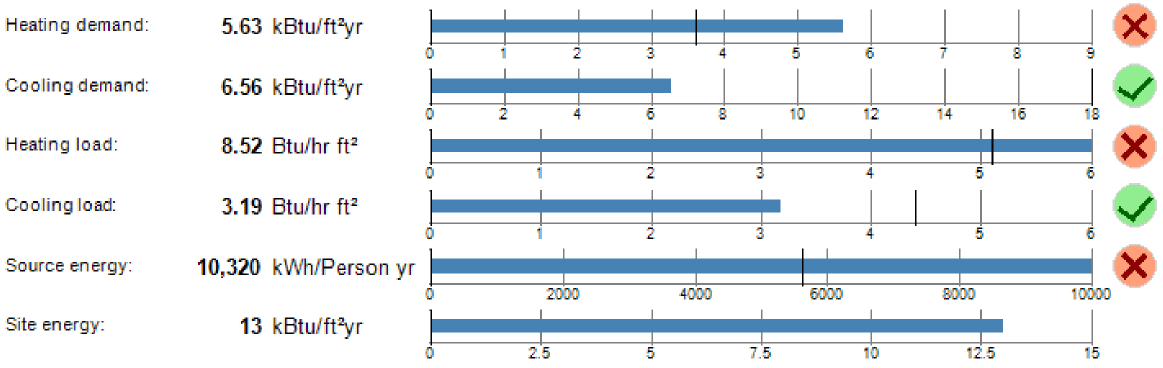
CLIMATE ZONE	FENESTRATION *U*-FACTOR[b, i]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[g]	MASS WALL *R*-VALUE[h]	FLOOR *R*-VALUE	BASEMENT[c,g] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c,g] WALL *R*-VALUE
2	0.40	0.65	0.25	49	13 or 0& 10ci	4/6	13	0	0	0

Assembly	**Case 1 Minimum**	**Case 2 Base Case**	**Case 3 Optimized**	**Case 4 Optimized + R4.2 Slab Ins.**
Slab	4” Concrete Slab = R 0.42	4” Concrete Slab = R 0.42	4” Concrete Slab + 1” XPS NGX Perimeter	4” Concrete Slab + 1” EPS Underslab
Walls	R13 (2x4 w/ Batt Insulation)	R21 (2x6 w/ Zip R3)	R24 (2x6 + Zip R6)	R24 (2x6 + Zip R6)
Roof	R38 (Not including framing)	R38 (Not including framing)	R49 (Not including framing)	R49 (Not including framing)
Windows	U-Value 0.4 BTU/ft^2 h F SHGC 0.25	U-Value 0.25 BTU/ft^2 h F SHGC 0.25	U-Value 0.2 BTU/ft^2 h F SHGC 0.25	U-Value 0.2 BTU/ft^2 h F SHGC 0.25
Airtightness	ACH50: 5 per hour CFM50: 0.36 per ft^2 (Envelope Area)	ACH50: 3 per hour CFM50: 0.215 per ft^2 (Envelope Area)	ACH50: .83 per hour CFM50: 0.06 per ft^2 (Envelope Area)	ACH50: .83 per hour CFM50: 0.06 per ft^2 (Envelope Area)
[illegible]	38993.07 kWh	34764.64 kWh	28491.12 kWh	26076.03 kWh
Energy Cost (Monthly in $)	$454.92	$405.59	$332. 40	$304.22
PV Required for Zero	39,000 kWh	34,800 kWh	28,500 kWh	26,100 kWh
Estimated DC System Size	26.4 kW	23.6 kW	19.3 kW	17.7 kW
Estimated Number of [illegible]				

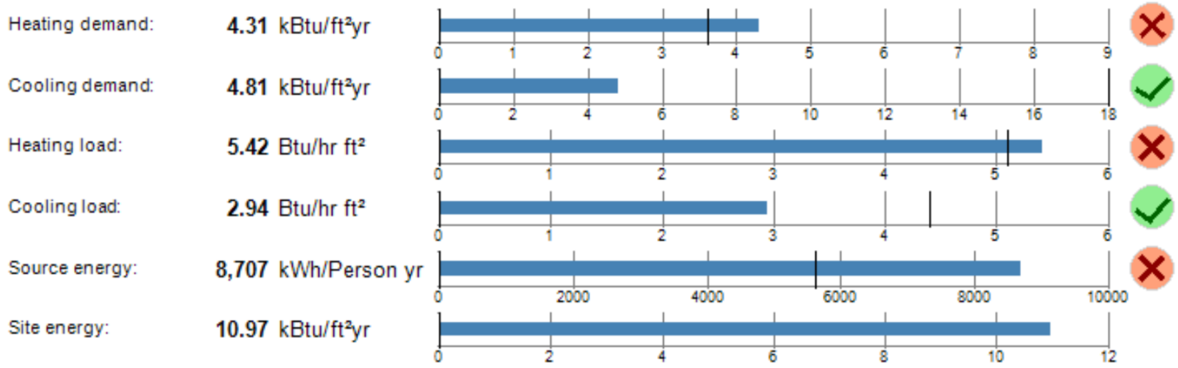
Cost Analysis – CZ2: Austin

	CLIMATE ZONE	FENESTRATION *U*-FACTOR[b, i]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[g]	MASS WALL *R*-VALUE[h]	FLOOR *R*-VALUE	BASEMENT[c,g] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c,g] WALL *R*-VALUE
IECC 2021	2	0.40	0.65	0.25	49	13 or 0& 10ci	4/6	13	0	0	0
Austin TX Code Compliant (ish)		0.25 .42	0.25 n/a	.25 cog	38		18.1		n/a	n/a	n/a

Air Infiltration Limit:
0.215 cfm_{50}/ft^2
3.00 ACH_{50}



Air Infiltration Limit:
0.06 cfm_{50}/ft^2
0.83 ACH_{50}



Energy savings due to Air Tightness: 5376 kwh/year of site energy

Results in a 15.6% energy savings for the building and a cost savings of $806.40/year or $67.20/month @ $0.15/kwh

Cost Analysis – CZ2: Austin

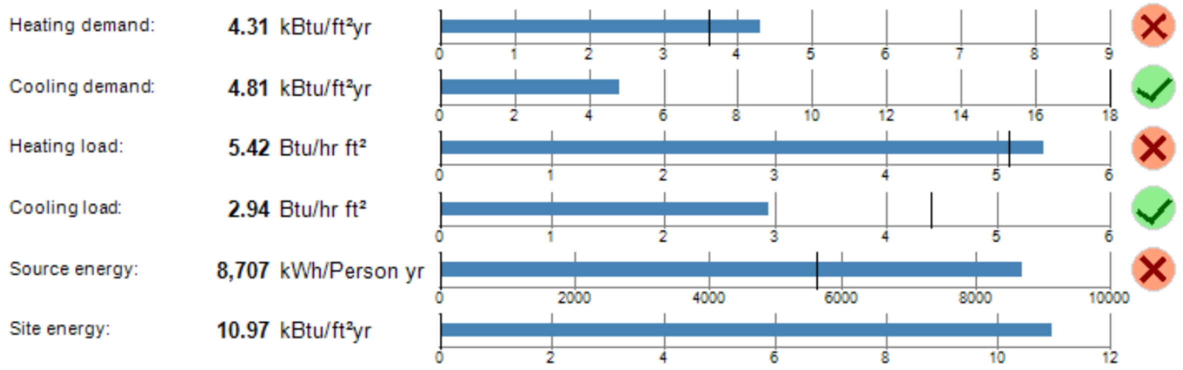
IECC 2021

CLIMATE ZONE	FENESTRATION U-FACTOR[b, i]	SKYLIGHT[b] U-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING R-VALUE	WOOD FRAME WALL R-VALUE[g]	MASS WALL R-VALUE[h]	FLOOR R-VALUE	BASEMENT[c,g] WALL R-VALUE	SLAB[d] R-VALUE & DEPTH	CRAWL SPACE[c,g] WALL R-VALUE
2	0.40	0.65	0.25	49	13 or 0& 10ci	4/6	13	0	0	0

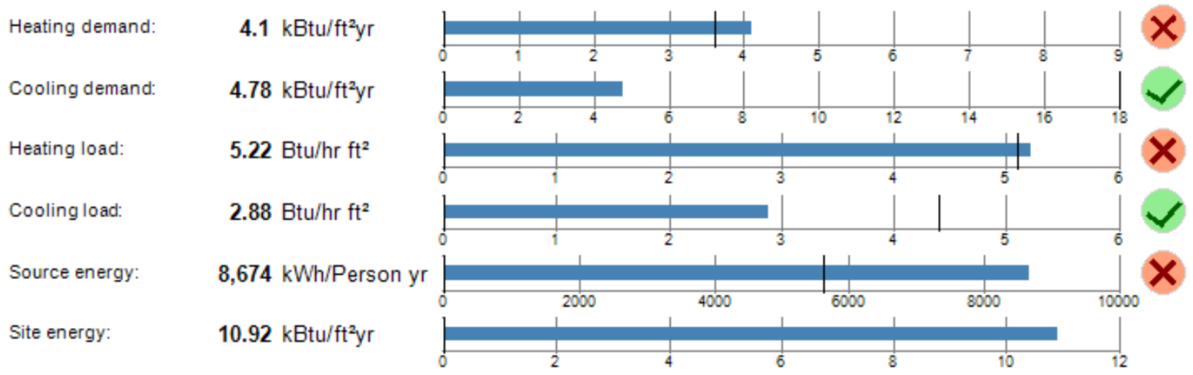
Baseline:
Slab R = .42
Wall R = 18.1
Roof R = 38
Slab Per. = R5, 2’

Window U = 0.25
Window SHGC= 0.25
Airtightness = 0.06 cfm_{50}/ft^2

Wall R-Value: 18.1



Wall R-Value: 21.2



Energy savings due to increased R-value: 109.8 kwh/year of site energy

Results in a 0.38% energy savings for the building and a cost savings of $16.47/year or $1.3725/month @ $0.15/kwh

Cost Analysis – CZ2: Austin

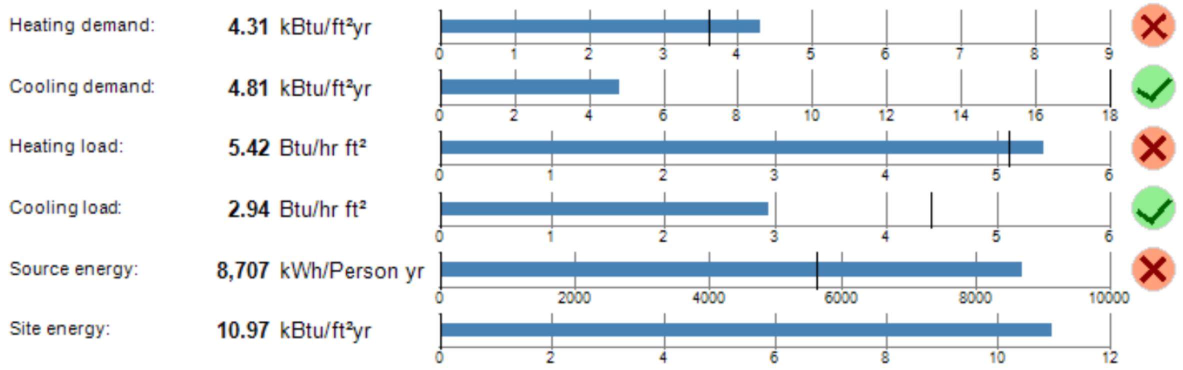
IECC 2021

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b, i]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[g]	MASS WALL *R*-VALUE[h]	FLOOR *R*-VALUE	BASEMENT[c,g] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c,g] WALL *R*-VALUE
2	0.40	0.65	0.25	49	13 or 0& 10ci	4/6	13	0	0	0

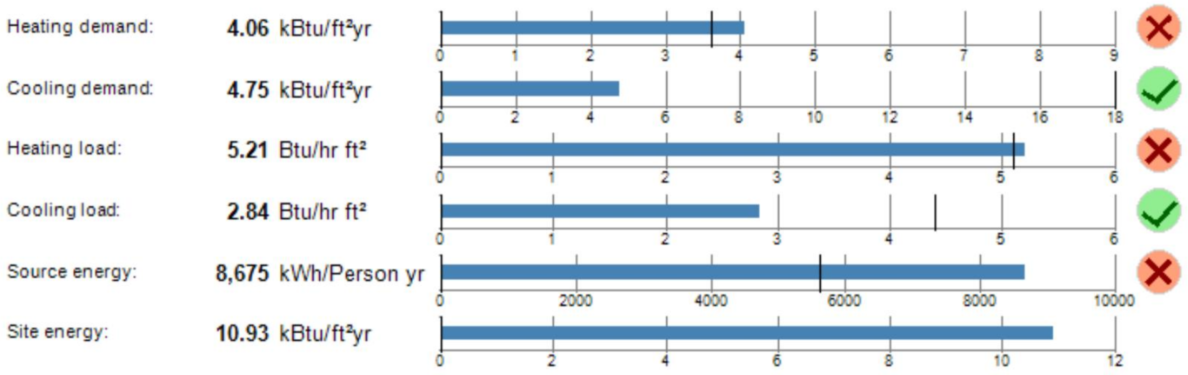
Baseline:
Slab R = .42
Wall R = 18.1
Roof R = 38
Slab Per. = R5, 2'

Window U = 0.25
Window SHGC= 0.25
Airtightness = 0.06 cfm_{50}/ft^2

Roof R-Value: 38



Roof R-Value: 49



Energy savings due to increased R-value: 106.3 kwh/year of site energy

Results in a 0.37% energy savings for the building and a cost savings of $15.95/year or $1.33/month @ $0.15/kwh

Cost Analysis – CZ2: Austin

IECC 2021

CLIMATE ZONE	FENESTRATION U-FACTOR[b, i]	SKYLIGHT[b] U-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING R-VALUE	WOOD FRAME WALL R-VALUE[g]	MASS WALL R-VALUE[h]	FLOOR R-VALUE	BASEMENT[c,g] WALL R-VALUE	SLAB[d] R-VALUE & DEPTH	CRAWL SPACE[c,g] WALL R-VALUE
2	0.40	0.65	0.25	49	13 or 0& 10ci	4/6	13	0	0	0

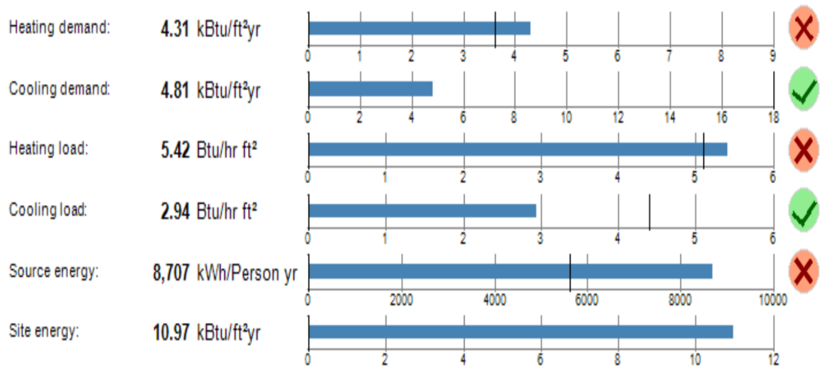
Baseline:
Slab R = .42
Wall R = 18.1
Roof R = 38
Slab Per. = R5, 2'

Window U = 0.25
Window SHGC= 0.25
Airtightness = 0.06 cfm_{50}/ft^2

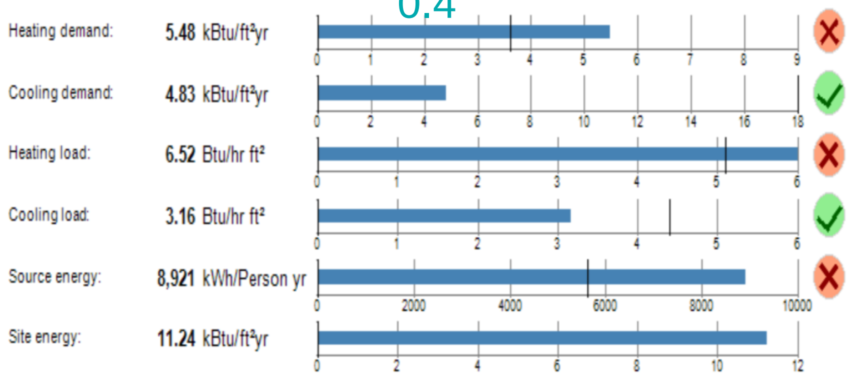
Energy **cost** due to **increased** U-value: 713.2 kwh/year of site energy

Results in a 2.46% energy **increase** for the building and a cost **increase** of $106.98/year or $8.92/month @ $0.15/kwh

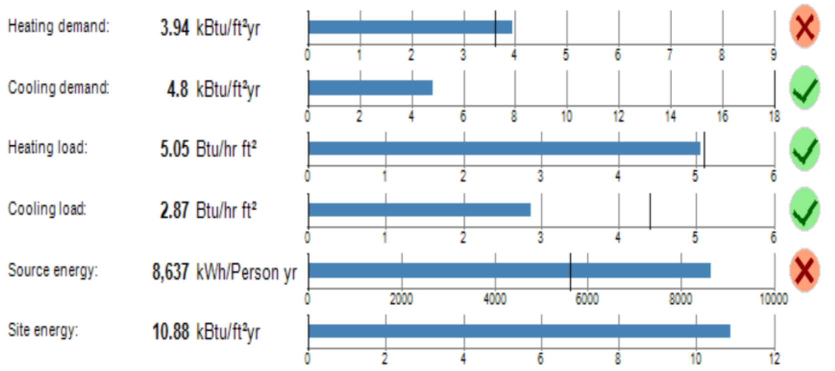
Window U-Value: 0.25



Window U-Value : 0.4



Window U-Value : 0.20



Energy savings due to decreased U-value: 230.9 kwh/year of site energy

Results in a 0.80% energy savings for the building and a cost savings of $34.64/year or $2.89/month @ $0.15/kwh

Saving $$$$ on Windows and Doors - Tips

- Work with the manufacturer!
  - Unilux Example
  - Alpen Example
  - Zola Example
  - These things are not unique but exist for all manufacturers and small tweaks can make a huge difference in price with minimal design impact
- Window Types
  - Fixed vs Operable
  - Material Dependent
- Doors
  - Should have multipoint locks.
  - Lift slide if sliding
  - Solid doors do not need to be from the window manufacturer

Cost Analysis – CZ2: Austin

TR6 Balanced

Calculation based on ISO 10077-2, EN 673, EN 410

Product name:	Alpen Tyrol TR6 Tilt Turn				Center-of-glass properties		
ASHRAE/IECC /DOE North American Climate Zone	South-facing	North, East, West - facing	PHIUS Passive House Institute US		Balanced-6 TGT	No Grids	
			Whole-window installed U-value			Ucog-Value	
Climate specific recommendations:			W/m2K	BTU/hr.ft2.F	SHGC	W/m2K	BTU/hr.ft2.F
8			0.92	0.16	0.386	0.677	0.119
7			0.91	0.16	0.386	0.663	0.117
6			0.91	0.16	0.386	0.658	0.116
5			0.91	0.16	0.386	0.660	0.116
4			0.91	0.16	0.386	0.665	0.117
Marine North		☑	0.92	0.16	0.386	0.668	0.118
Marine South	☑		0.92	0.16	0.386	0.673	0.119
3	☑		0.92	0.16	0.386	0.670	0.118
2 West			0.93	0.16	0.386	0.685	0.121
2 East			0.93	0.16	0.386	0.685	0.121

Alpen Tyrol TR6 Tilt Turn Super Spacer S2 Premium	FRAME				Psi-spacer		Psi-opaque
	Frame height		U-frame		□		
	mm	in	W/m2K	BTU/hr.ft2.F	W/mK	BTU/hr.ft.F	W/mK
Head	117	4.61	0.97	0.17	0.032	0.018	0.156
Sill	117	4.61	0.97	0.17	0.032	0.018	BTU/hr.ft.F
left jamb	117	4.61	0.95	0.17	0.032	0.018	0.090
right jamb	117	4.61	0.95	0.17	0.032	0.018	Grade C

Valid through May 2025

TR6 PH+ Balanced

Calculation based on ISO 10077-2, EN 673, EN 410

Product name:	Alpen Tyrol TR-6 Thin Glass Triple Tilt-Turn				Center-of-glass properties		
ASHRAE/IECC /DOE North American Climate Zone	South-facing	North, East, West - facing	PHIUS Passive House Institute US		Alpen Balanced-6 PH+ TGT	No Grids	
			Whole-window installed U-value			Ucog-Value	
Climate specific recommendations:			W/m2K	BTU/hr.ft2.F	SHGC	W/m2K	BTU/hr.ft2.F
8			0.90	0.16	0.386	0.664	0.117
7			0.88	0.16	0.386	0.630	0.111
6			0.85	0.15	0.386	0.578	0.102
5			0.84	0.15	0.386	0.564	0.099
4		☑	0.83	0.15	0.386	0.555	0.098
Marine North		☑	0.83	0.15	0.386	0.558	0.098
Marine South	☑		0.83	0.15	0.386	0.563	0.099
3	☑		0.83	0.15	0.386	0.560	0.099
2 West			0.84	0.15	0.386	0.573	0.101
2 East			0.84	0.15	0.386	0.573	0.101

Alpen Tyrol TR-6 Thin Glass T Triseal Premium	FRAME				Psi-spacer		Psi-opaque
	Frame height		U-frame		Ψ		
	mm	in	W/m2K	BTU/hr.ft2.F	W/mK	BTU/hr.ft.F	W/mK
Head	117	4.61	0.94	0.17	0.030	0.017	0.152
Sill	117	4.61	0.94	0.17	0.030	0.018	BTU/hr.ft.F
left jamb	117	4.61	0.93	0.16	0.030	0.018	0.088
right jamb	117	4.61	0.93	0.16	0.030	0.018	Grade B

Valid through December 2021

I find this upgrade generally makes sense!

Cost Analysis – CZ2: Austin

TR6 PH+ Balanced

Calculation based on ISO 10077-2, EN 673, EN 410

Product name: **Alpen Tyrol TR-6 Thin Glass Triple Tilt-Turn**

Center-of-glass properties: Alpen Balanced-6 PH+ TGT, No Grids

ASHRAE/IECC /DOE North American Climate Zone	South-facing	North, East, West - facing	Whole-window installed U-value W/m2K	BTU/hr.ft2.F	SHGC	Ucog-Value W/m2K	BTU/hr.ft2.F
Climate specific recommendations:							
8			0.90	0.16	0.386	0.664	0.117
7			0.88	0.16	0.386	0.630	0.111
6			0.85	0.15	0.386	0.578	0.102
5			0.84	0.15	0.386	0.564	0.099
4		✓	0.83	0.15	0.386	0.555	0.098
Marine North		✓	0.83	0.15	0.386	0.558	0.098
Marine South	✓		0.83	0.15	0.386	0.563	0.099
3	✓		0.83	0.15	0.386	0.560	0.099
2 West			0.84	0.15	0.386	0.573	0.101
2 East			0.84	0.15	0.386	0.573	0.101

Alpen Tyrol TR-6 Thin Glass T Triseal Premium	FRAME: Frame height mm	in	U-frame W/m2K	BTU/hr.ft2.F	Psi-spacer Ψ W/mK	BTU/hr.ft.F	Psi-opaque W/mK
Head	117	4.61	0.94	0.17	0.030	0.017	0.152
Sill	117	4.61	0.94	0.17	0.030	0.018	BTU/hr.ft.F
left jamb	117	4.61	0.93	0.16	0.030	0.018	0.088
right jamb	117	4.61	0.93	0.16	0.030	0.018	Grade B

Valid through December 2021

TR9 PH+ Balanced

Calculation based on ISO 10077-2, EN 673, EN 410

Product name: **Alpen Tyrol TR-9 PH+ Tilt Turn**

Center-of-glass properties: Alpen Balanced-9 PH+, No Grids

ASHRAE/IECC /DOE North American Climate Zone	South-facing	North, East, West - facing	Whole-window installed U-value W/m2K	BTU/hr.ft2.F	SHGC	Ucog-Value W/m2K	BTU/hr.ft2.F
Climate specific recommendations:							
8			0.75	0.13	0.333	0.417	0.074
7			0.74	0.13	0.333	0.397	0.070
6		✓	0.72	0.13	0.333	0.376	0.066
5		✓	0.72	0.13	0.333	0.373	0.066
4		✓	0.72	0.13	0.333	0.376	0.066
Marine North		✓	0.72	0.13	0.333	0.378	0.067
Marine South	✓		0.72	0.13	0.333	0.381	0.067
3	✓		0.72	0.13	0.333	0.379	0.067
2 West			0.73	0.13	0.333	0.388	0.068
2 East			0.73	0.13	0.333	0.388	0.068

Alpen Tyrol TR-9 PH+ Tilt Tur SS-D	FRAME: Frame height mm	in	U-frame W/m2K	BTU/hr.ft2.F	Psi-spacer Ψ W/mK	BTU/hr.ft.F	Psi-opaque W/mK
Head	117	4.61	0.86	0.15	0.047	0.027	0.157
Sill	117	4.61	0.86	0.15	0.047	0.027	BTU/hr.ft.F
left jamb	117	4.61	0.85	0.15	0.047	0.027	0.091
right jamb	117	4.61	0.85	0.15	0.047	0.027	Grade C

Valid through April 2022

I find this upgrade generally doesn't make sense (CZ4 and below)!

Window Comparison

Window Comparison							spec lower 0.25	spec. 0.2 - 0.25						
Manufacturer	Type (uPVC, Wood, Wood/Alu, Alu)	Total incl. Shipping	Glass Tempered or anneald	Color int	Color Ext	U Value	SHGC	Fixed	Operable	spacer	VT	Shipping	Total incl. Shipping	
Shhh It's a Secret	Wood	$ 122,536.00	annealed	Timber	Timber	0.11	0.32			black, technoform	70-73	$ 12,000.00	$ 122,536.00	
	uPVC	$85,116.74 double Approx. $97,884 triple	annealed	White	White	0.26	window quote: 0.28, data sheet 0.38		0.2494-0.2655	white or black	69	$ 3,500.00	$85,116.74 double Approx. $97,884 triple	
	Aluminium	$123,422 double $ Triple (about 6k higher)	Tempered	White	White	0.09	0.34	0.89-0.96	1.1-1.4	black	61	$ 7,000.00	$123,422 double $ Triple (about 6k higher)	
	uPVC	$ 121,233.26	Tempered	White 9016	White 9016	0.17	0.23			steel brushed/black	0.48		$ 121,233.26	
	Wood/Alu	$ 148,554.11	annealed	natural	black	0.09	0.317		0.63	black	56		$ 148,554.11	
	uPVC	$ 102,043.00		White	White		0.37 operable, 0.44 fixed	0.25	0.26	grey	53-63	$ 5,800.00	$ 102,043.00	
	uPVC	$60,594 (double) $66,572		White	White		0.24-0.36 0.23-0.34	0.25 0.14-0.18	0.25 0.14-0.18		41-61 37 -56	900	$60,594 (double) $66,572	

Takeaways:

1. Price different manufacturers - its all over the place
2. Triple Pane is more expensive – may not be worth it in some climates (see above)
   - Some manufacturers have very small premium to upgrade to triple pane
   - Acoustics and Comfort must be considered.
3. UPVC frames are cheaper than wood, aluminum clad wood, or aluminum

Cost Analysis – CZ2: Austin

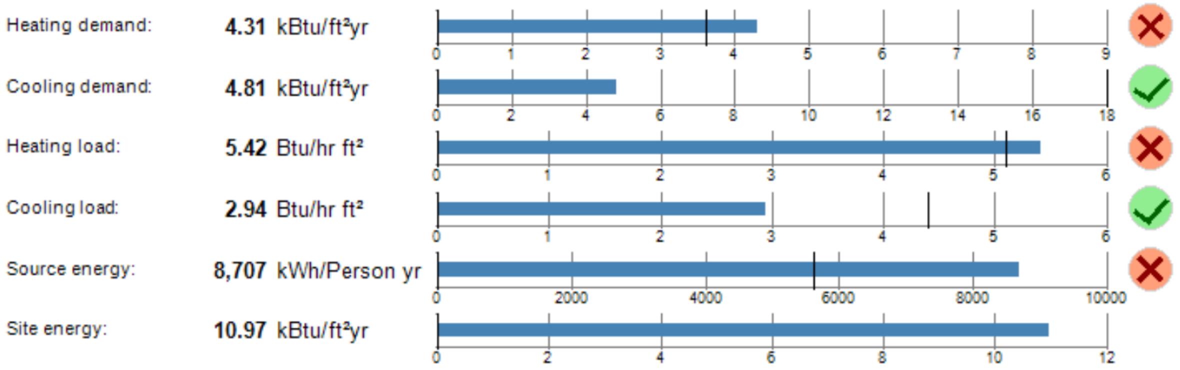
IECC 2021

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b, i]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[g]	MASS WALL *R*-VALUE[h]	FLOOR *R*-VALUE	BASEMENT[c,g] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c,g] WALL *R*-VALUE
2	0.40	0.65	0.25	49	13 or 0& 10ci	4/6	13	0	0	0

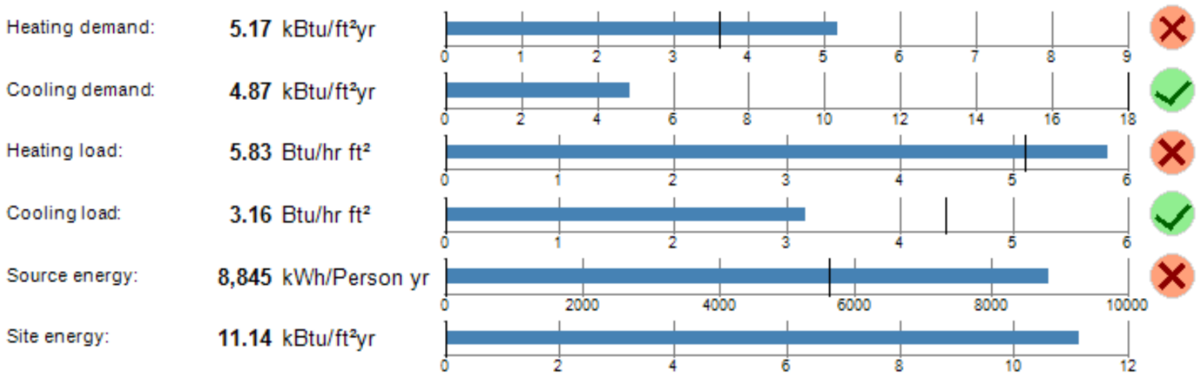
Baseline:
Slab R = .42
Wall R = 18.1
Roof R = 38
Slab Per. = R5, 2'

Window U = 0.25
Window SHGC= 0.25
Airtightness = 0.06 cfm_{50}/ft^2

Slab Perimeter: R5,2



Slab Perimeter: None



Energy Cost due to removal of Slab Edge Insulation: 460.7 kwh/year of site energy

Results in a 1.59% energy increase for the building and a cost increase of $69.10/year or $5.76/month @ $0.15/kwh

Cost Analysis – CZ2: Austin

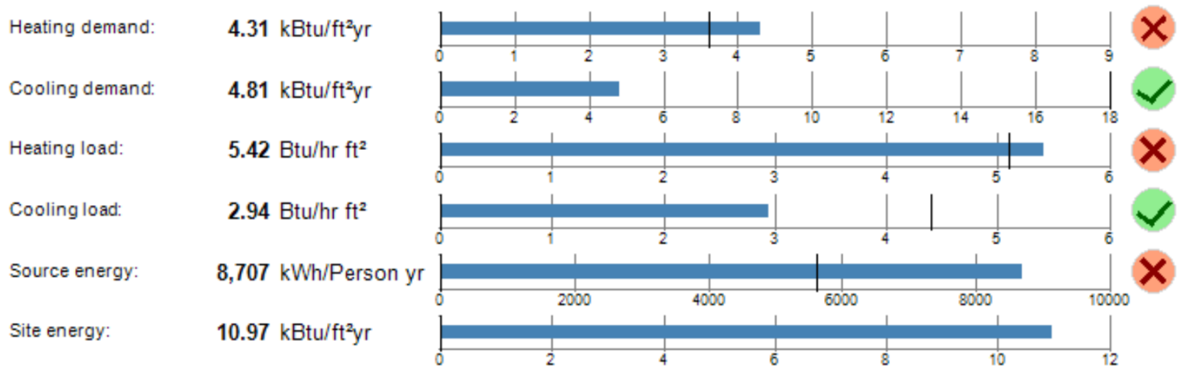
IECC 2021

CLIMATE ZONE	FENESTRATION U-FACTOR[b, i]	SKYLIGHT[b] U-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING R-VALUE	WOOD FRAME WALL R-VALUE[g]	MASS WALL R-VALUE[h]	FLOOR R-VALUE	BASEMENT[c,g] WALL R-VALUE	SLAB[d] R-VALUE & DEPTH	CRAWL SPACE[c,g] WALL R-VALUE
2	0.40	0.65	0.25	49	13 or 0& 10ci	4/6	13	0	0	0

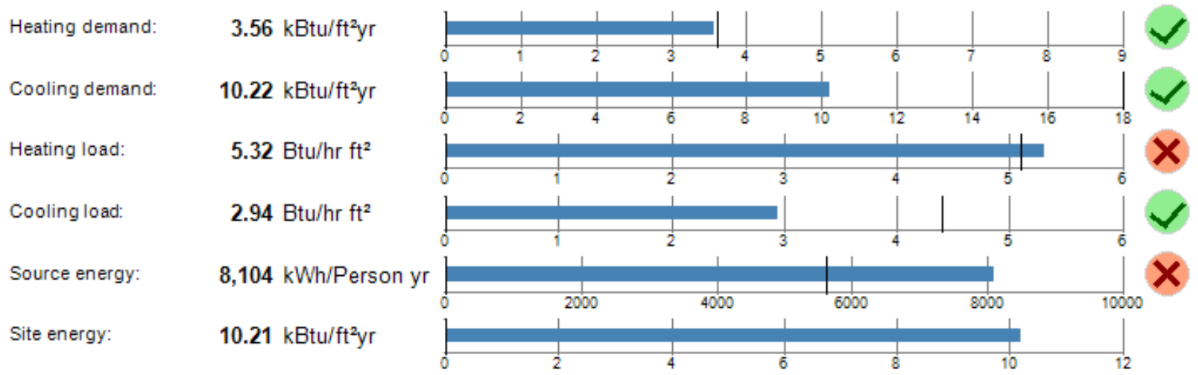
Baseline:
Slab R = .42
Wall R = 18.1
Roof R = 38
Slab Per. = R5, 2'

Window U = 0.25
Window SHGC= 0.25
Airtightness = 0.06 cfm_{50}/ft^2

Slab R-Value: None (.42)



Slab R-Value: 4.42



Energy savings due to increased R-value: 2007.8 kwh/year of site energy

Results in a 6.92% energy savings for the building and a cost savings of $301.17/year or $25.10/month @ $0.15/kwh

Characteristics of a Cost-Effective Slab

- “Proper” amount of sub-slab insulation
- Drainage gravel and radon mitigation system (where required)
- Membrane between insulation and concrete slab.
- Mitigate/Eliminate Perimeter Thermal Bridge

- Sub-slab insulation choices:
  - EPS
  - XPS
  - Foam Glass Aggregates

Characteristics of a Cost-Effective Slab

- Defining the "Proper" amount of sub-slab insulation
  - Use energy modeling to increase or decrease the insulation
  - Look at the change between Heating and Cooling Demands
  - Also compare the Site/Source total energy – You may be surprised.

- Start with the assumption that there should always be some sub-slab insulation – even in Hot Climates CZ 1-3!

A little look under the hood:

Phius used BeOpt as part of the Phius Certification standard setting process in 2015,2018, and 2021. Looking at a limited data sample of the BeOpt runs, the optimizer chose an uninsulated slab in only 2.22% of cases nationwide!

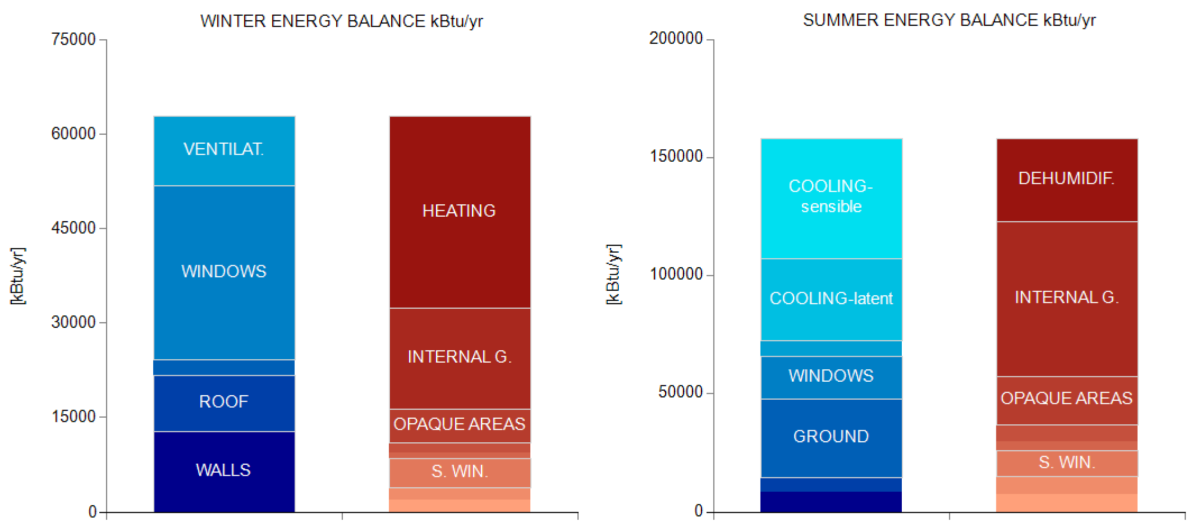
(specific locations in HI, CA, FL, TX, LA, GA)

Characteristics of a Cost-Effective Slab

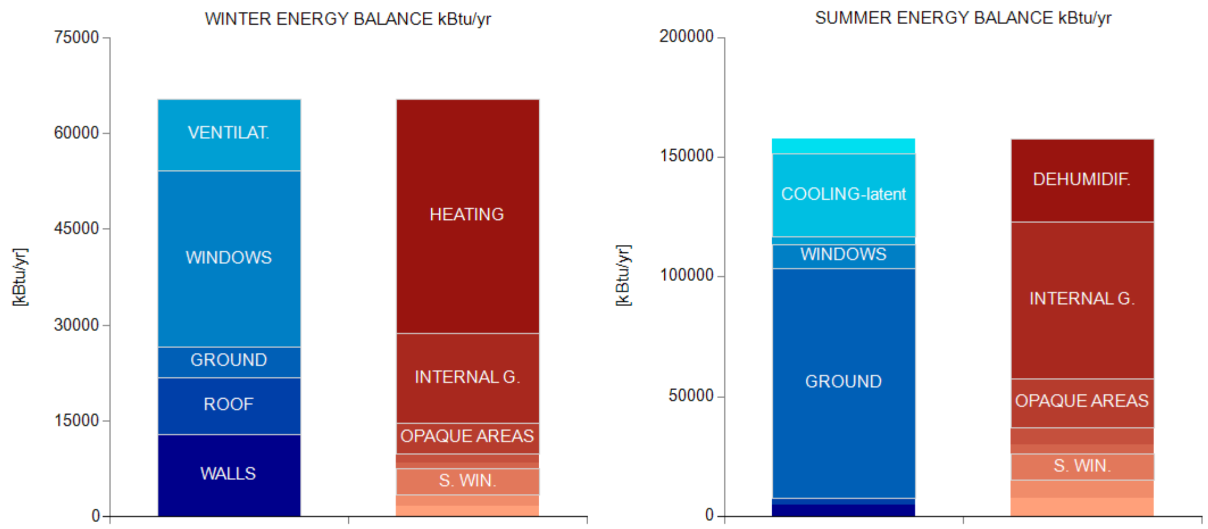
What happens when a slab is insulated?

Heat loss through the slab is reduced

- In the winter, this heat loss to the ground adds to the heating demand
- In the summer, this heat loss to the cool ground is beneficial
- The heat loss to the ground is sensible heat loss
- The latent heat demand stays the same, but sensible has been cut dramatically
- The demands are similar, but the efficiency of the mechanical system determines the annual source energy use!!



With R4 Slab Insulation



Without Slab Insulation

Ryan’s Principles of Cost-Effective Building Envelope Design

1. Use standard (commonly available) materials and techniques
2. Limit thicknesses (especially CI layers, but also the cavity)
3. Limit “trips around the building” by limiting the number of layers and/or number of steps involved in installation
4. Work with the contractor and material suppliers

Other Priority:

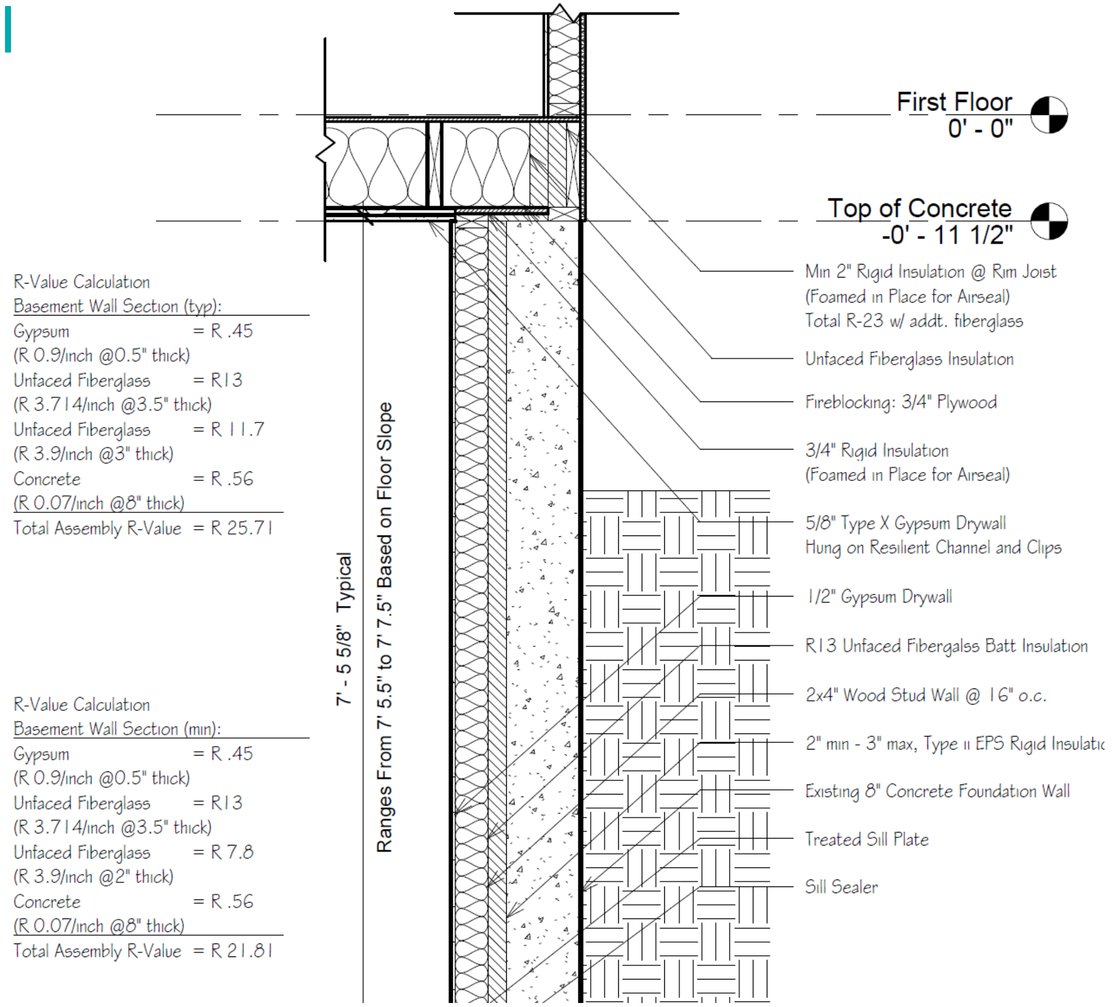
Reduce thermal bridging and increase airtightness by:

Aligning the insulation and airtight layers from component to component

Examples: between below grade wall and above grade wall, from wall to roof, slab to wall, wall to wall, etc.

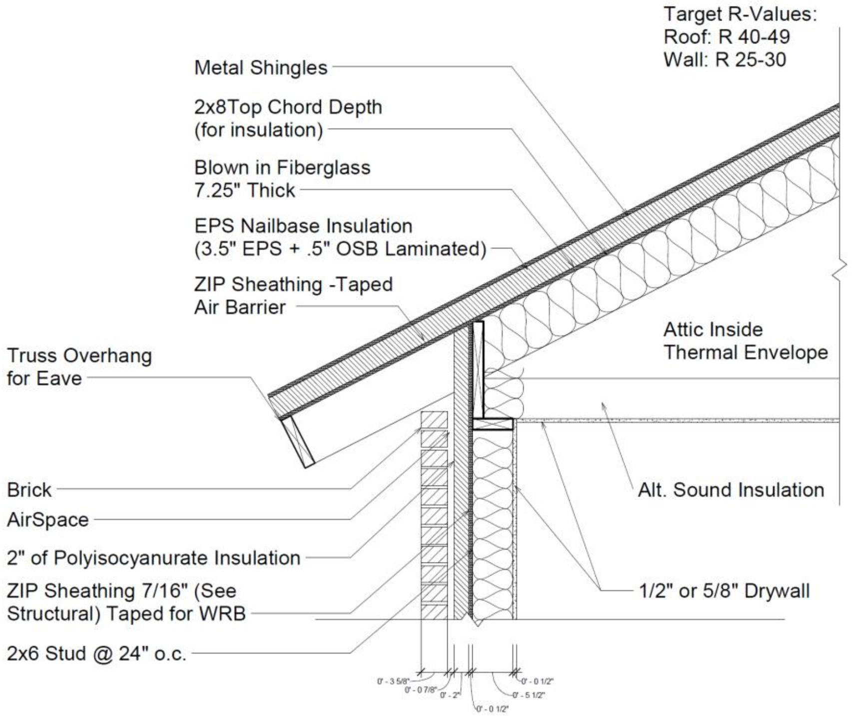
Characteristics of a Cost-Effective Basement

1. Insulation amount dialed in with energy model
2. Continuous Insulation + thermal bridging reduction
3. Connecting insulation
   - Slab to Basement Wall
   - Basement Wall to Above Grade Wall
4. Air barrier on concrete wall
   1. Connect to above grade wall on exterior
5. Manage Moisture
   1. Exterior Surface Ideal
   2. Unfaced Cavity Insulation (or none)
   3. Footing drain and radon mitigation system



Characteristics of a Cost-Effective Wall

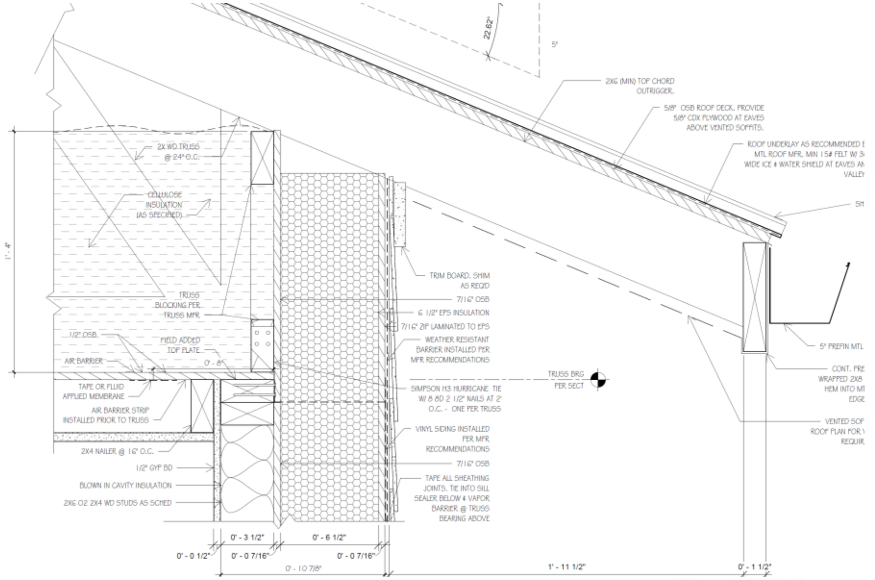
1. Insulation amount dialed in with energy model
2. Continuous Insulation + thermal bridging reduction
3. Insulation “in-plane” and contiguous with other assemblies (roof, rim joist, basement wall, slab, etc.)
4. Air barrier on sheathing
5. Moisture managed w/o use of specialty products
    1. Follows Phius’ Prescriptive Guidelines for Moisture Management.
6. Limits CI to 4” Maximum
    1. More CI creates potential window install issues
    2. Reveal shading can start to negatively effect energy balance
    3. At 4” and beyond Phius requires fastener correction
    4. 4” is often the limit for siding warranties
    5. 4” is also the typ max thickness of thermally broken brick ties
    6. Beyond 4”, fasteners get long/heavy, install is a problem and a facade system such as a fiberglass clip and rail is



Characteristics of a Cost-Effective Roof

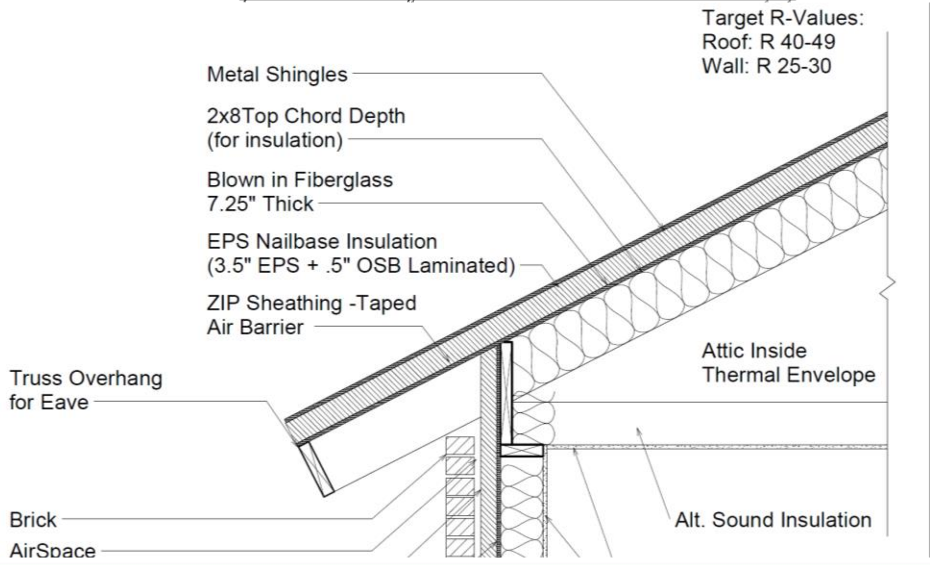
Method 1: Vented Attic – not conditioned

- Use underside of attic structure as air and vapor barrier
- A solid material (sheathing) is best, but membranes can work
- Drop ceiling can be used for electrical and mechanical
  - Might need to be overly large for certain systems – cost increase
- Biggest advantage is using cheaper blown in fibrous insulation



Method 2: Conditioned Attic – non-vented

- Use top side of roof structure (sheathing location as the air and vapor barrier.
- Use a “nailbase” product to protect the air barrier and meet the Phius Prescriptive Requirements for moisture management
- Split Insulation above and below roof deck
- This method works on flat roofs – replace nailbase with rigid



Ventilation

ERV with small homerun ducting (Zehnder / Brink)

1. Easy install, airtight ducts
2. Acoustical benefits – less sound transmission
3. Greater Static Pressure (UL Listing)
4. Equipment and duct material cost typically more than trunk + branch

ERV with Trunk + Branch ducting (Renewaire, Broan, Venmar, vane, Lifebreath, Fantech, Panasonic, etc.)

1. Duct system more difficult to fabricate and install
2. More acoustical concerns
3. More labor required
4. Equipment and duct material cost typically less than homeruns

Total cost depends on many factors but comes down to paying more in labor for the trunk + branch system or more in equipment for the homerun duct system and corresponding ERV.

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Domestic Hot Water

- Heat Pump Water Heater (tank)
  - Located inside the thermal envelope
- Save Cost with Limited Distribution
  - Cluster plumbing fixture
    - Eliminates long runs and/or recirculation system
    - RARE!
  - “On-Demand” Re-circulation Loop
    - I see this on many projects
    - Not as cost effective, but limits wasted water
    - Does not save energy, but saves water
    - Practically required for most projects to meet ZERH standards.

Rheem Performance Platinum

Consulting Costs

Has anyone (besides me):

- Used the # of refrigeration appliances to determine the CPHC Fee?
- Compared Appliances versus the PH Premium

Kidding, but Seriously

The Value of the CPHC and combining the Energy Model and Experience

Optimization

NO MORE and NO LESS than

what is required to meet the project goals.

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Thank You

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Build Zero Consulting