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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

BETTER BUILDINGS BY DESIGN | 2011

Efficiency Vermont

Learning Objectives

At the end of this program, participants will be able to:

- *Understand an overview of the Passive House Energy Standard*

- *Employ design strategies to achieve Passive House standards*

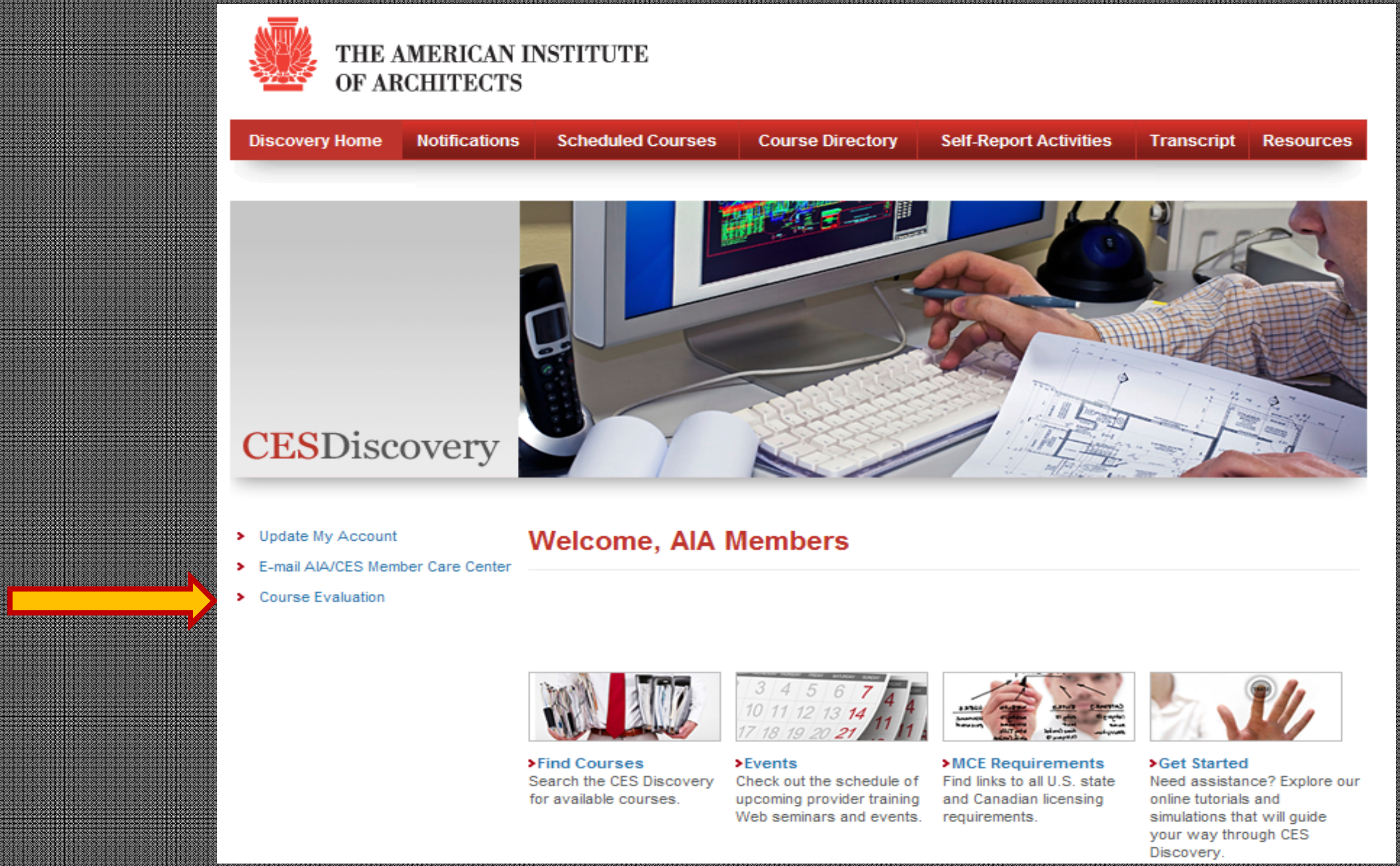
.

- *Be knowledgeable in the case study of two homes; the typical Habitat Cape and the new Passive House design*

- *Evaluate the benefits of modular building, including cost, quality, and the ability to replicate designs.*

Course Evaluations

In order to maintain high-quality learning experiences, please access the evaluation for this course by logging into CES Discovery and clicking on the Course Evaluation link on the left side of the page.



Getting to Passive House in the Northeast

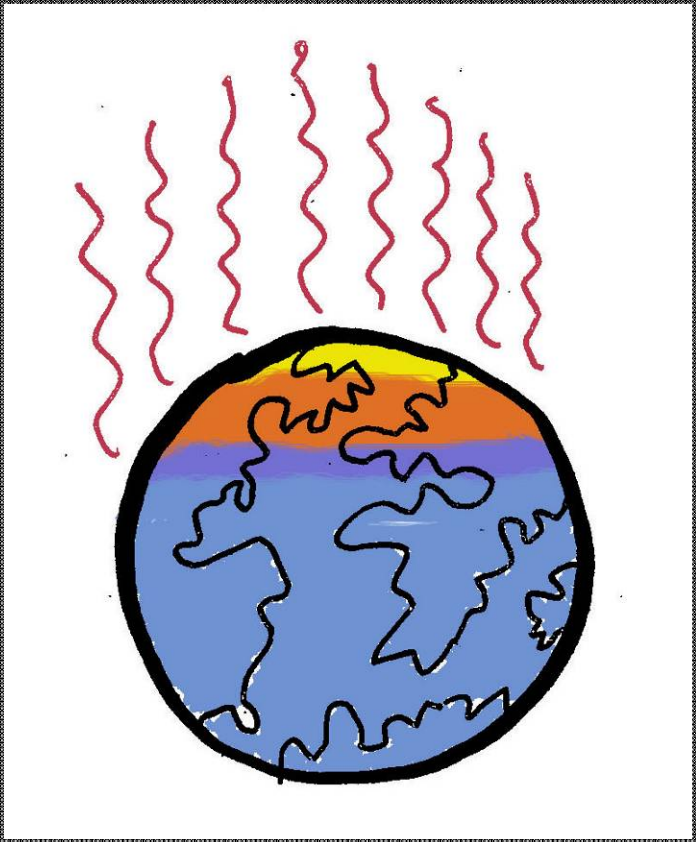
& Re-defining Affordable Housing

J.B. Clancy, Albert, Righter & Tittmann Architects
Peter Schneider, Vermont Energy Investment Corporation

Green Mountain Habitat for Humanity Partners

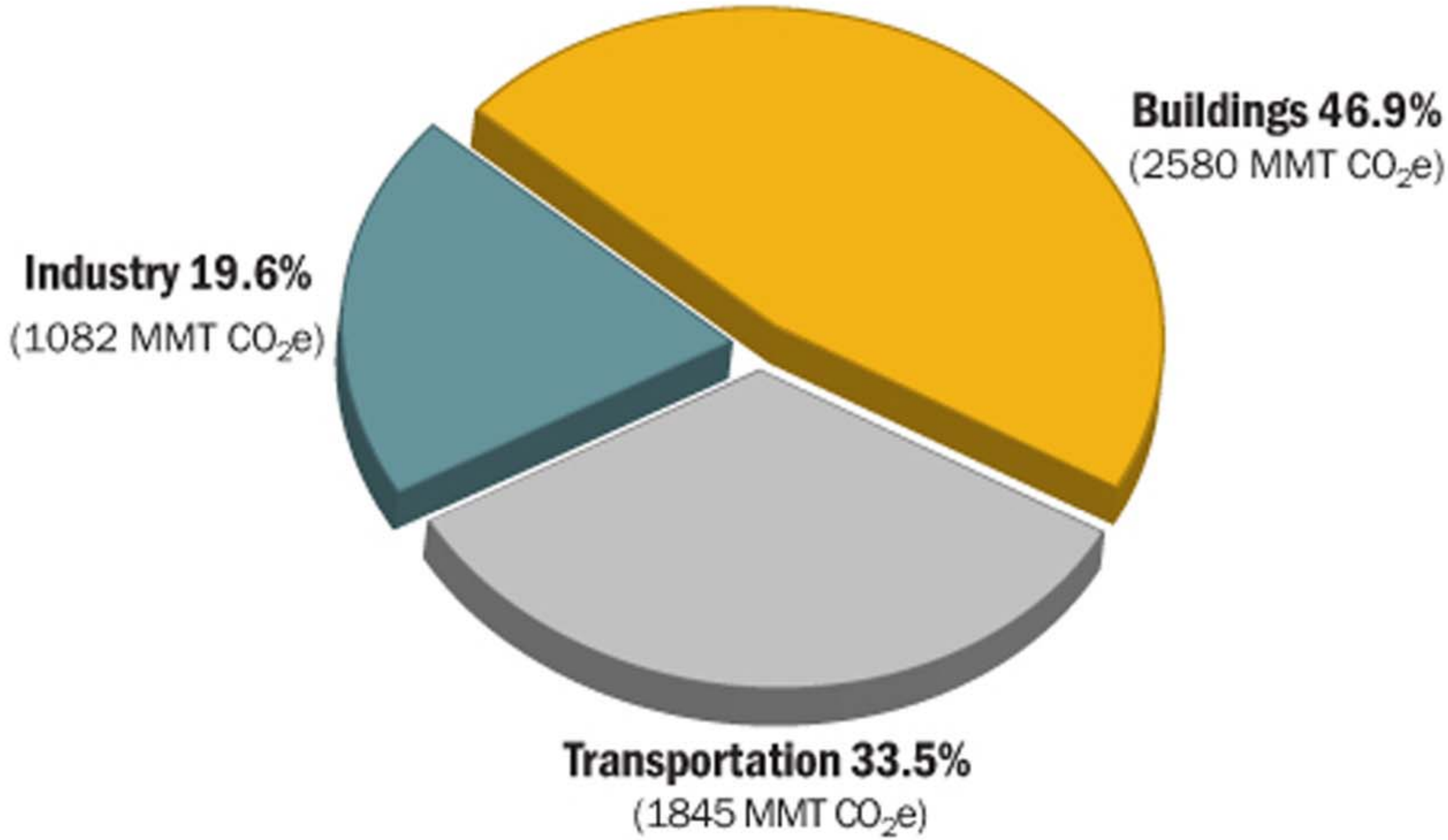
Albert, Righter & Tittmann Architects, Inc.
Vermont Energy Investment Corp.
Preferred Building Systems
Thermotech Windows
Artisan Engineering
Sunward
Zehnder
Whirpool Corporation
Bosch
Building Energy
DOW

21st Century Energy Context



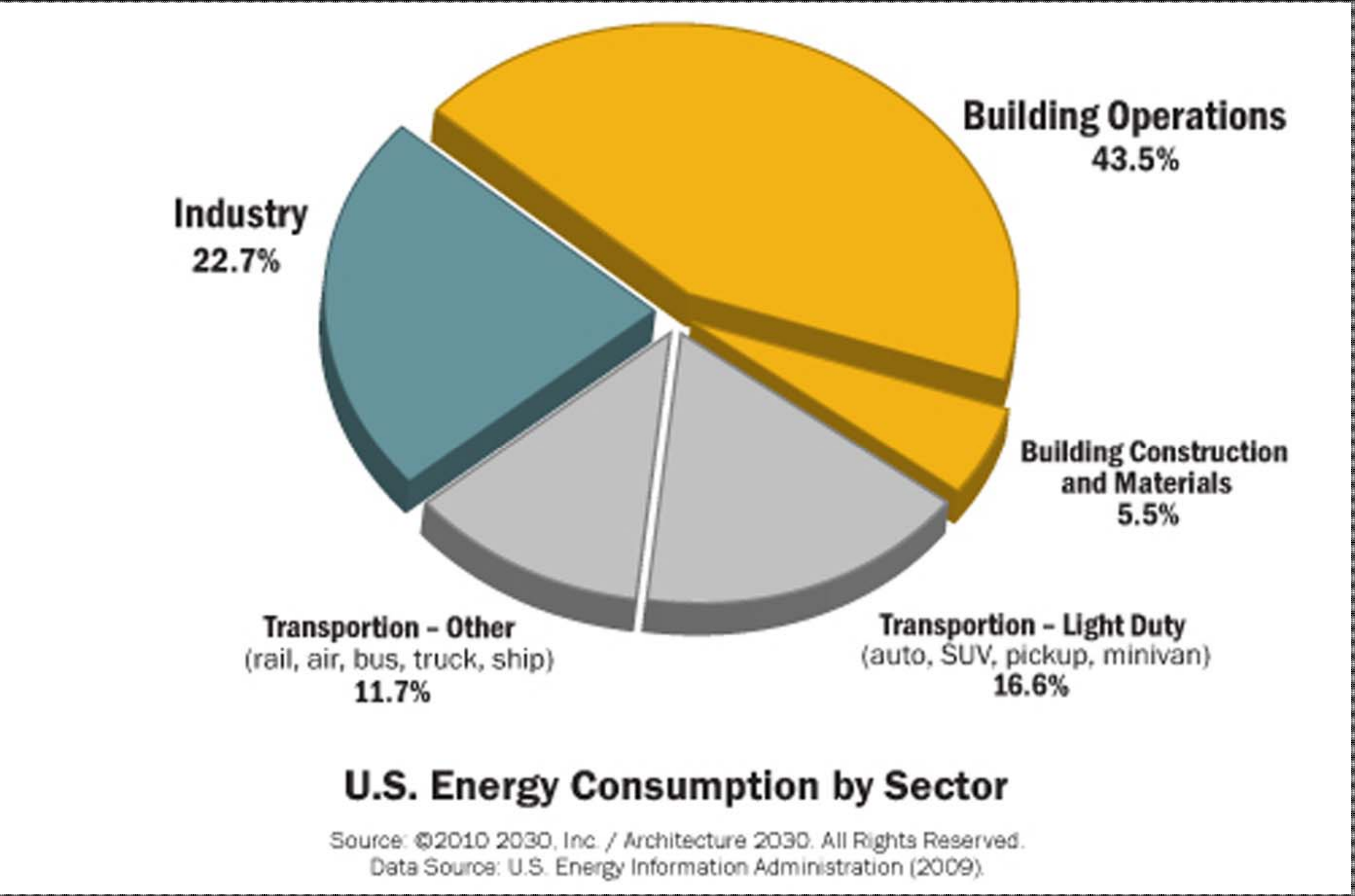
THE PROBLEM:

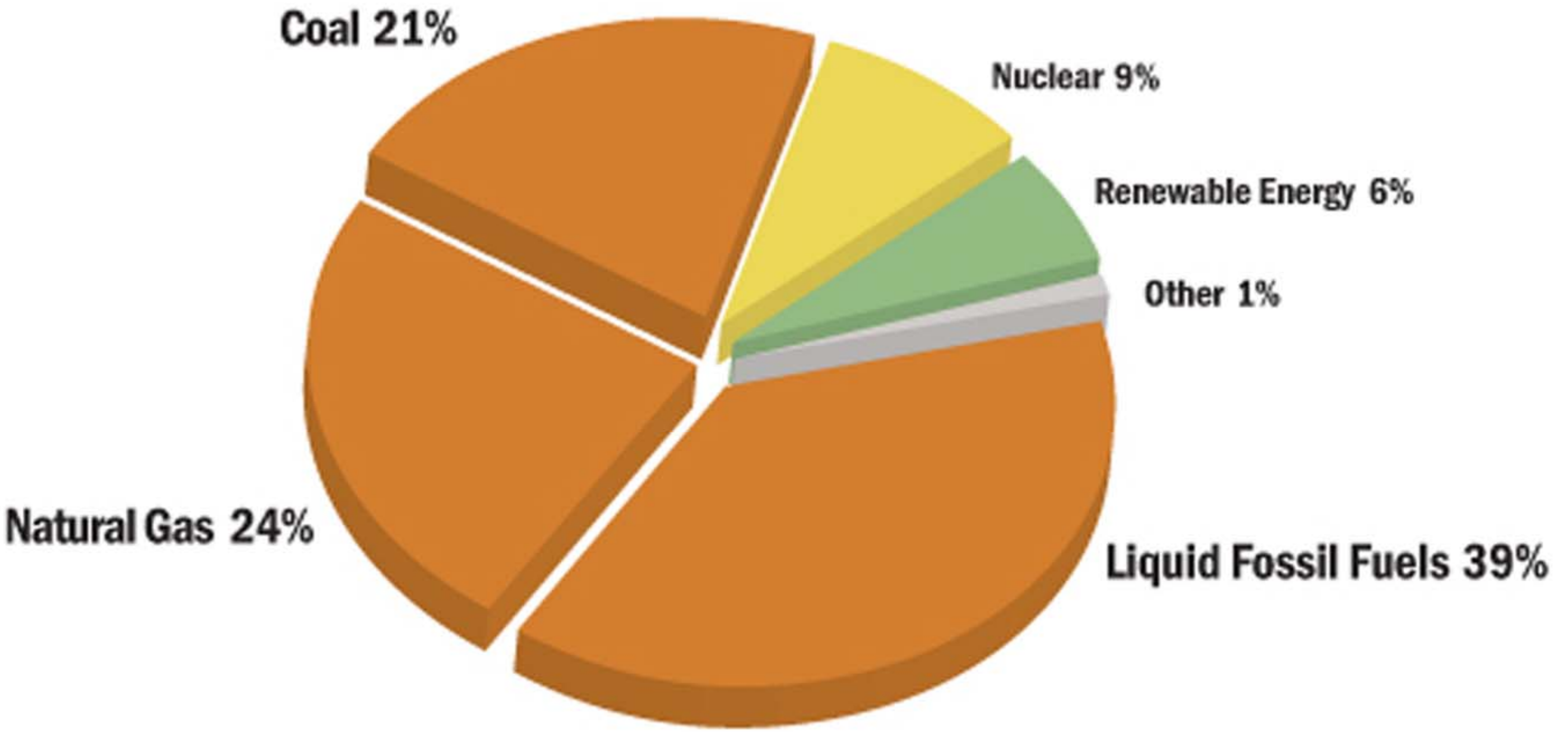
Buildings are the largest contributor to climate change.



U.S. CO_2 Emissions by Sector

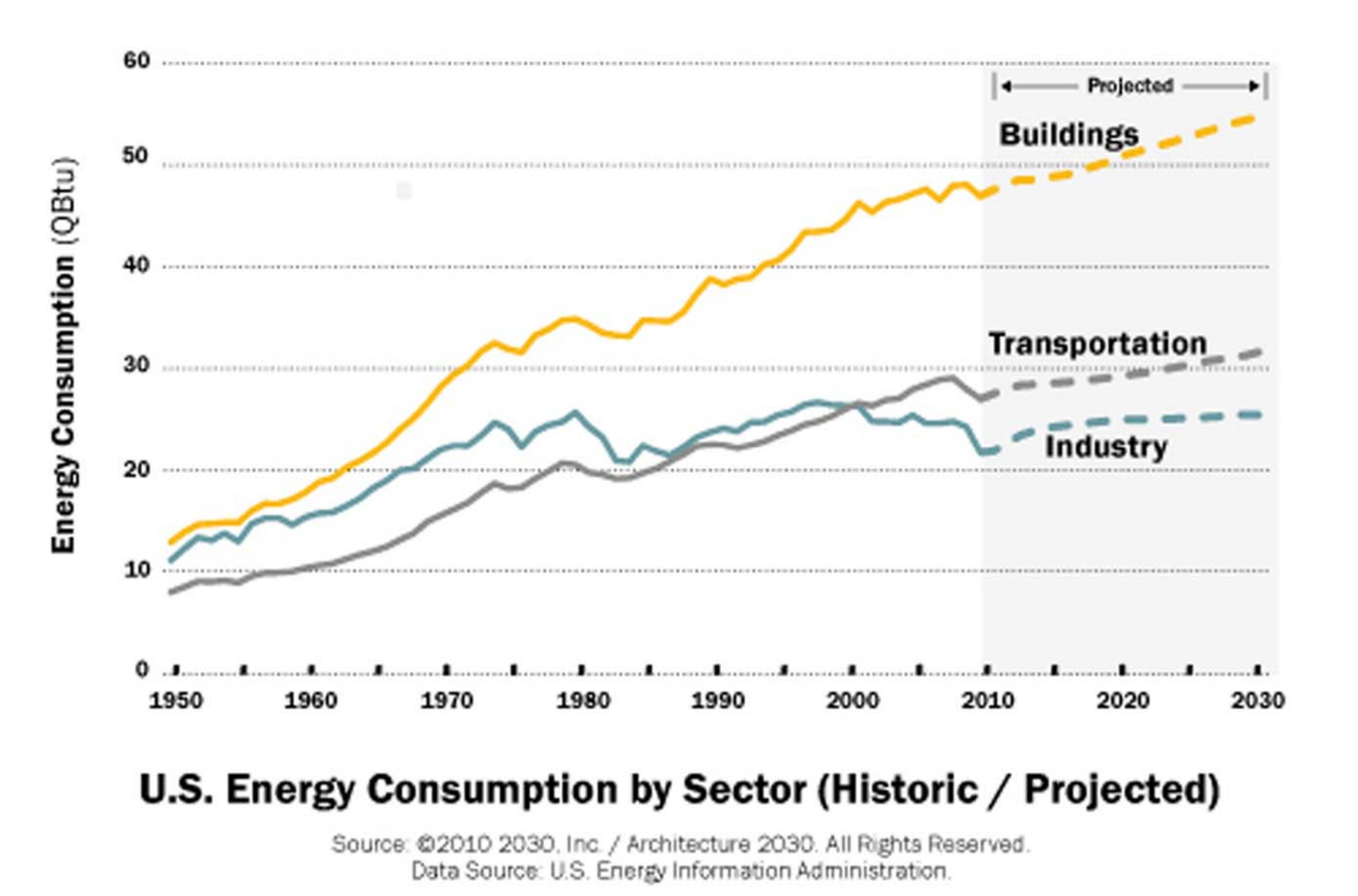
Data Source: U.S. Energy Information Administration (2009).

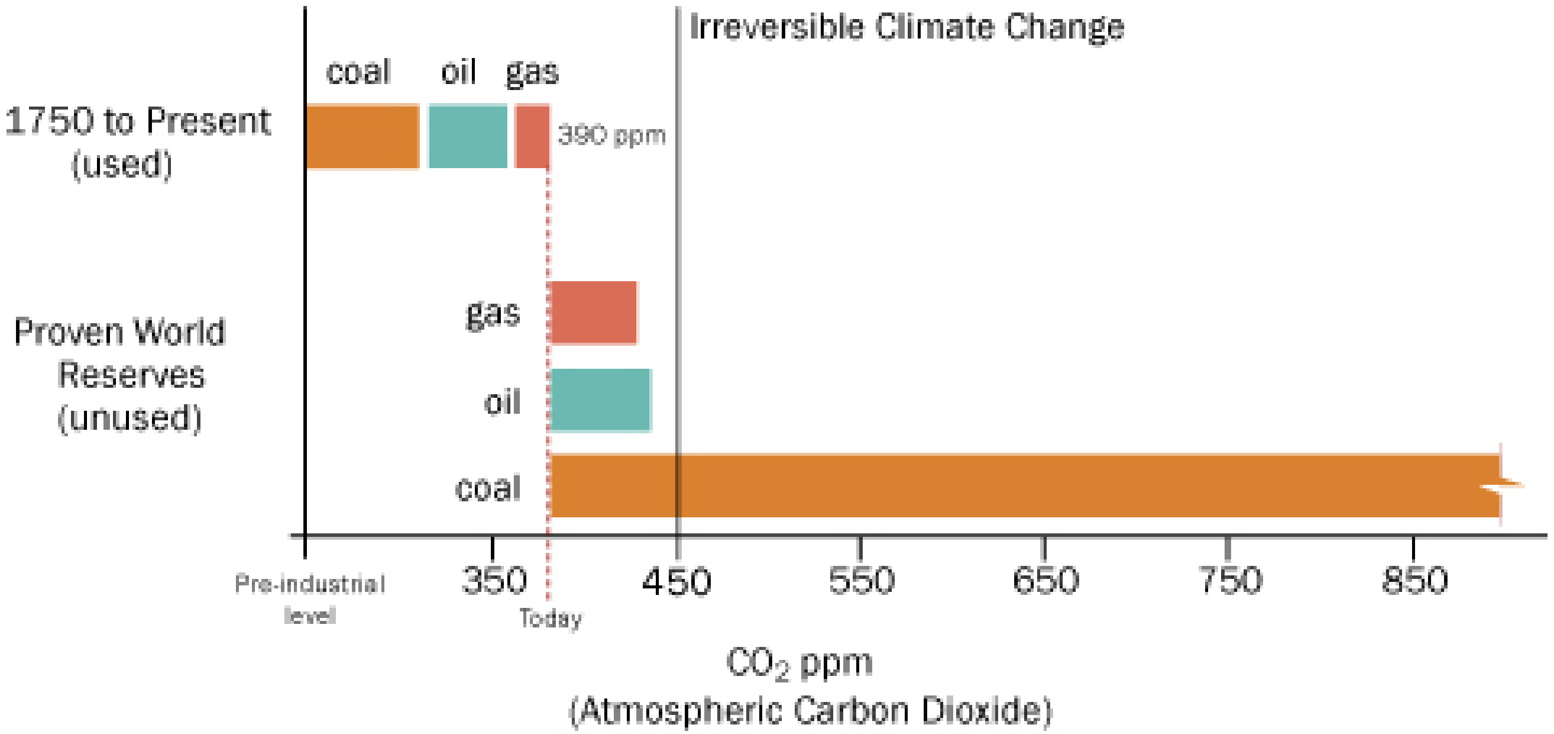

Building Operations
43.5%
Industry
22.7%
Building Construction
and Materials
5.5%
Transportion – Other
(rail, air, bus, truck, ship)
11.7%
Transportion – Light Duty
(auto, SUV, pickup, minivan)
16.6%
U.S. Energy Consumption by Sector
Source: ©2010 2030, Inc. / Architecture 2030. All Rights Reserved.
Data Source: U.S. Energy Information Administration (2009).



U.S. Energy Consumption by Fuel Type

Data Source: U.S. Energy Information Administration (2009).


60
50
40
30
20
10
0
1950
1960
1970
1980
1990
2000
2010
2020
2030
Energy Consumption (QBtu)
Projected
Buildings
Transportation
Industry
U.S. Energy Consumption by Sector (Historic / Projected)
Source: ©2010 2030, Inc. / Architecture 2030. All Rights Reserved.
Data Source: U.S. Energy Information Administration.



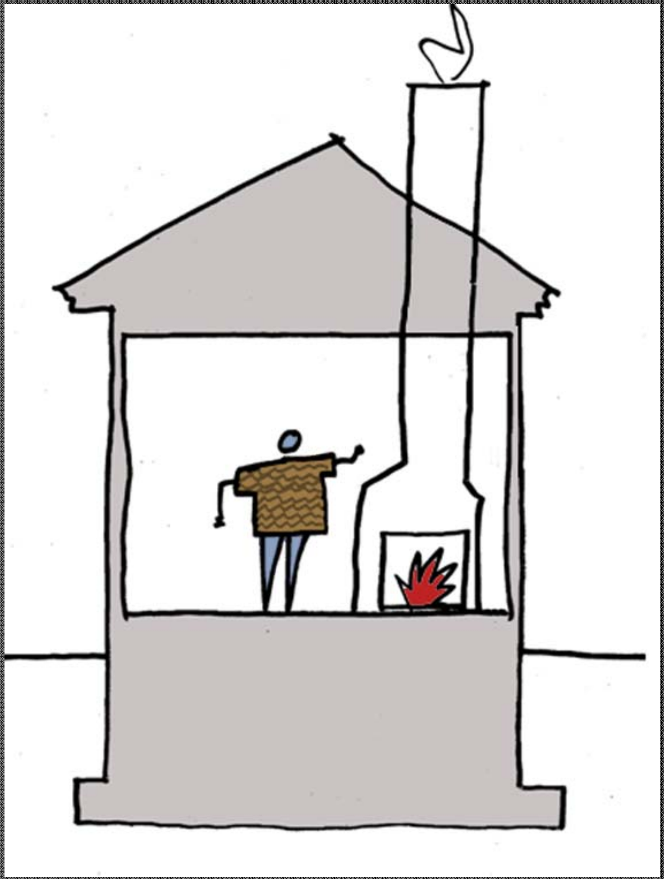
Global Fossil Fuel Resources & CO_2 Emissions

Data Source: Adapted from J.Hansen et al.: Dangerous human-made interference with climate. 2007.

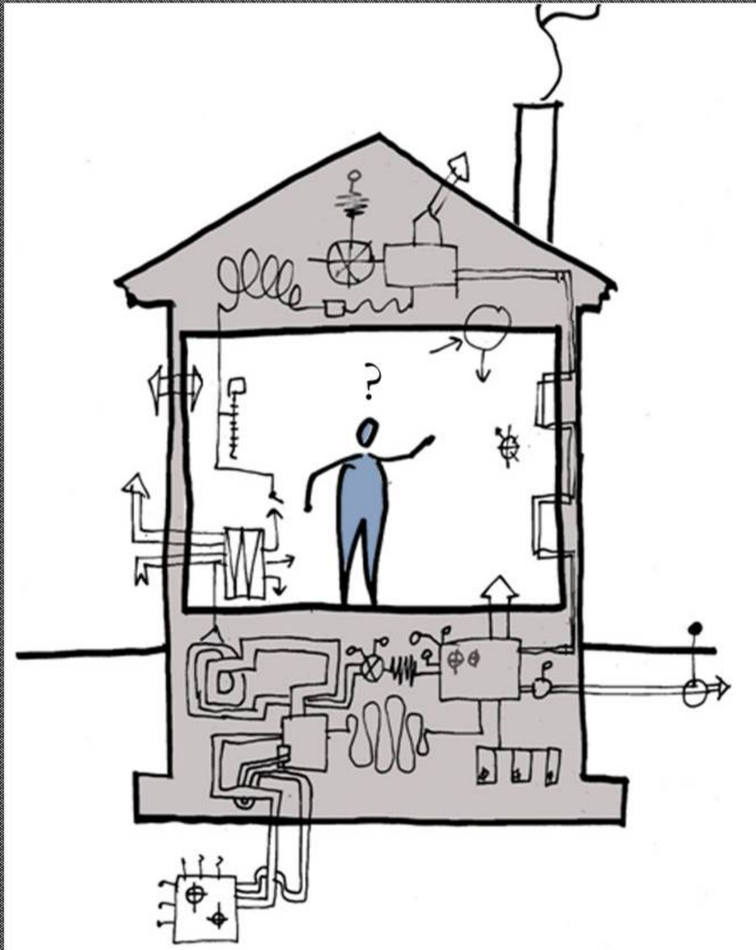
THE SOLUTION:

Make buildings that don’t contribute to climate change.

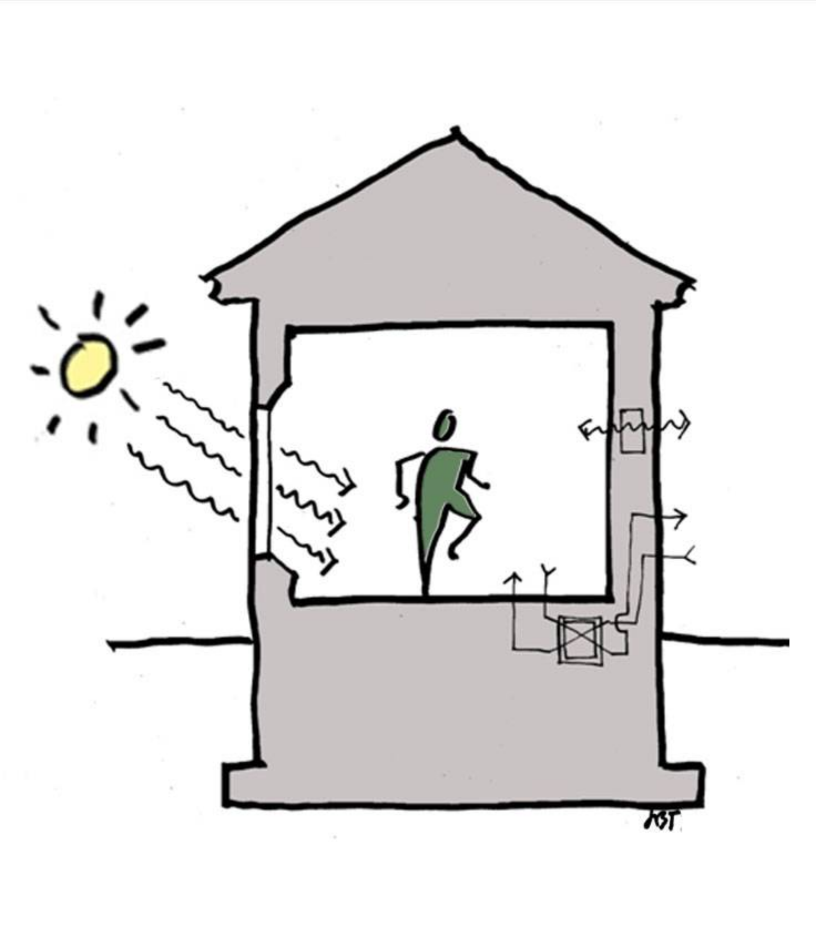
Moving Towards Simplicity:
19th Century



Moving Towards Simplicity:
20th Century



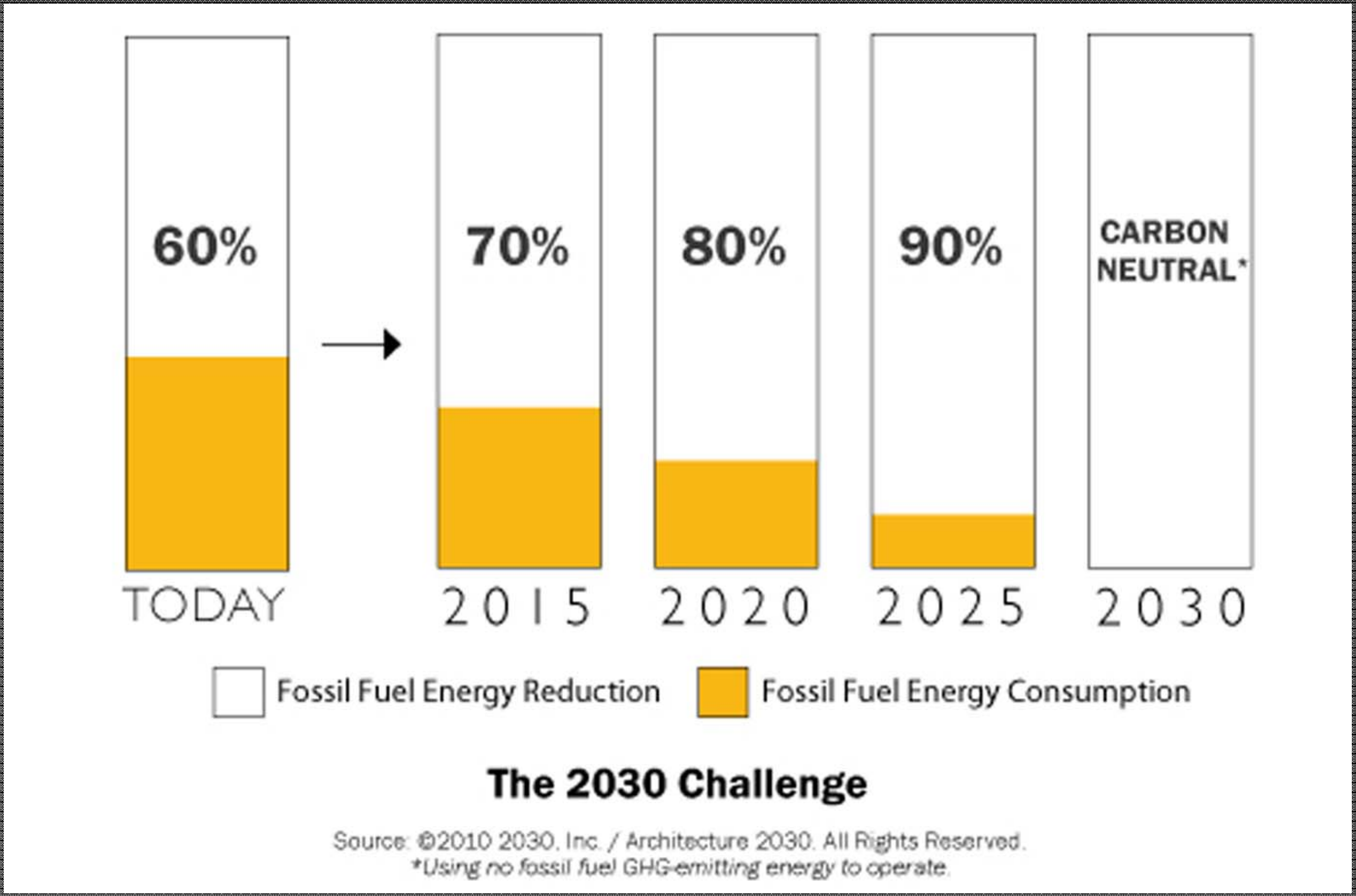
Moving Towards Simplicity:
21st Century



GETTING TO PASSIVE HOUSE in VERMONT

Albert, Righter, & Tittmann Architects & Vermont Energy Investment Corporation

Energy Goal:
Architecture 2030 Challenge



Energy Standard to Achieve Goal

Passivhaus Institut
Darmstadt, Germany

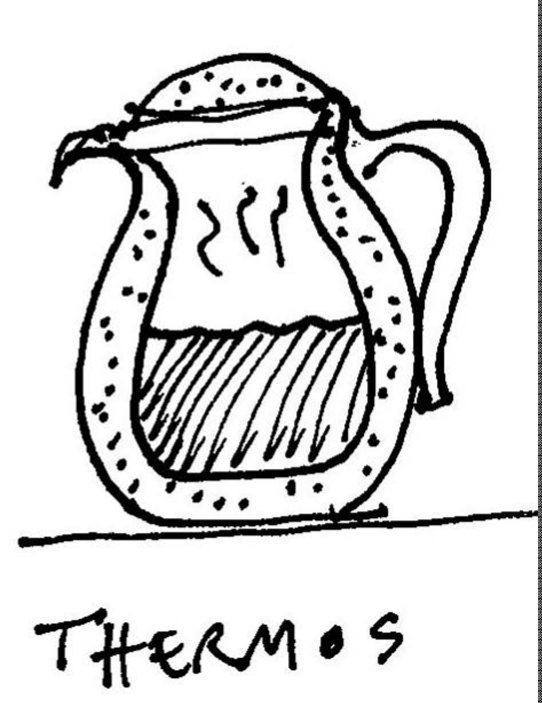
Passive House Institute US
Urbana, Illinois

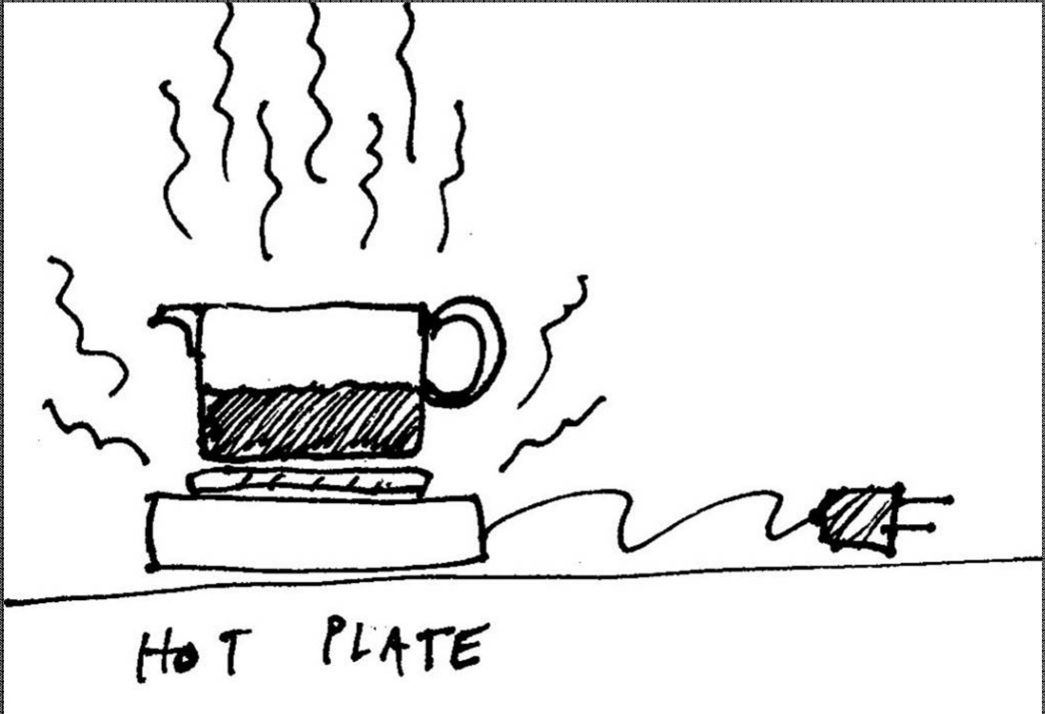
Passivhaus Principle:

- Today's highest energy standard applicable to all building types
- Focuses on energy conservation through building envelope optimization
- Utilizes energy modeling software to inform design decisions
- 20,000 structures built in Europe

Passivhaus Principle:

Maintain the temperature using insulation, rather than by using energy.





Passivhaus Results:

Passive House Institute US

- Dramatic reduction in energy consumption
- Superior indoor air quality
- Occupant comfort
- Lower annual energy costs
- Smaller carbon footprint
- More durable construction details

Passivhaus Energy Standard

Heating Load (Site): 4.75 kBTU/SF/YR

Cooling Load (Site): 4.75 kBTU/SF/YR

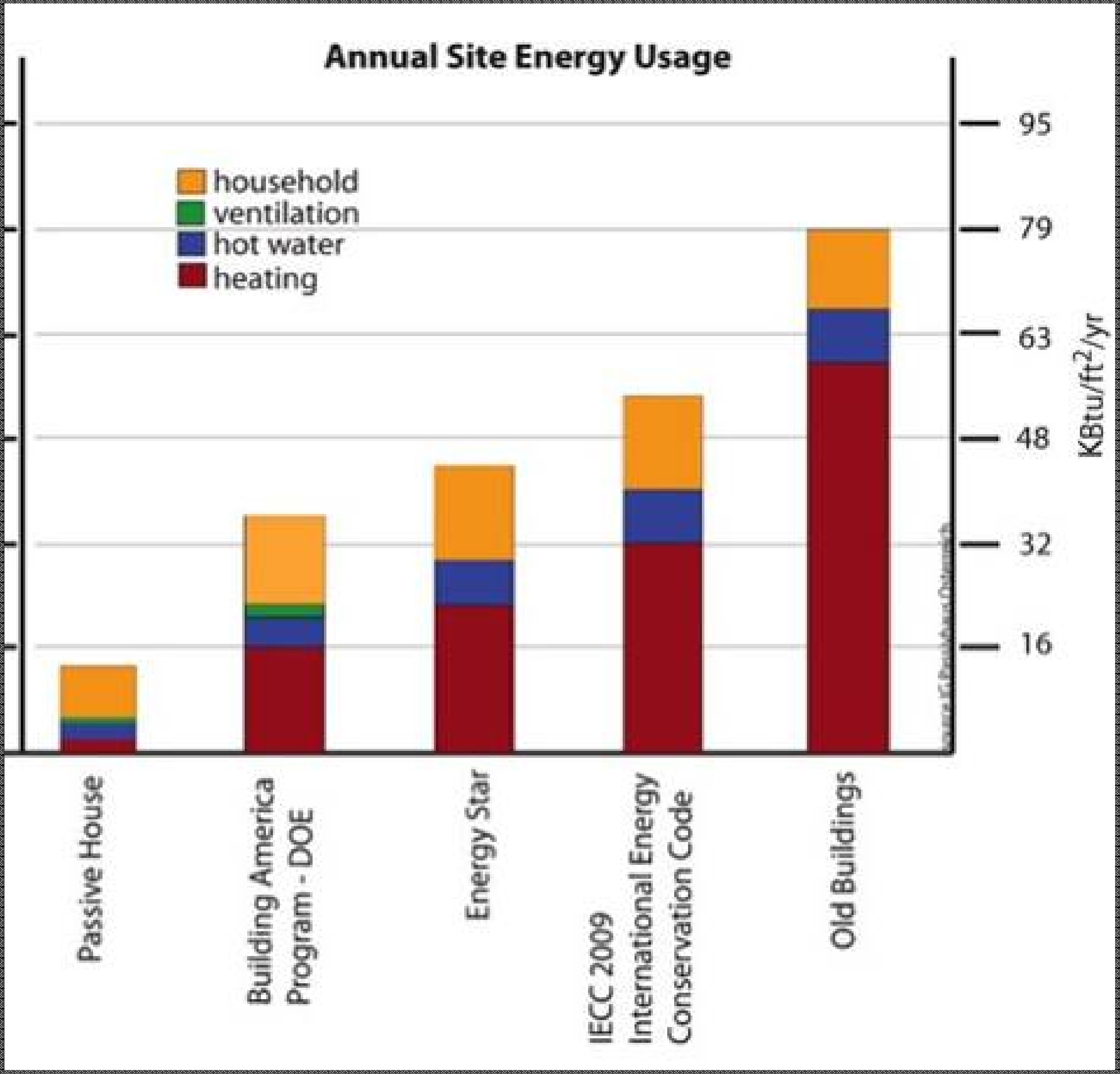
Total Energy Demand (Source): 38 kBTU/SF/YR

Air Tightness: .6 ACH @ 50pa

PHIUS

Passive House Institute US

Comparison of Energy Standards

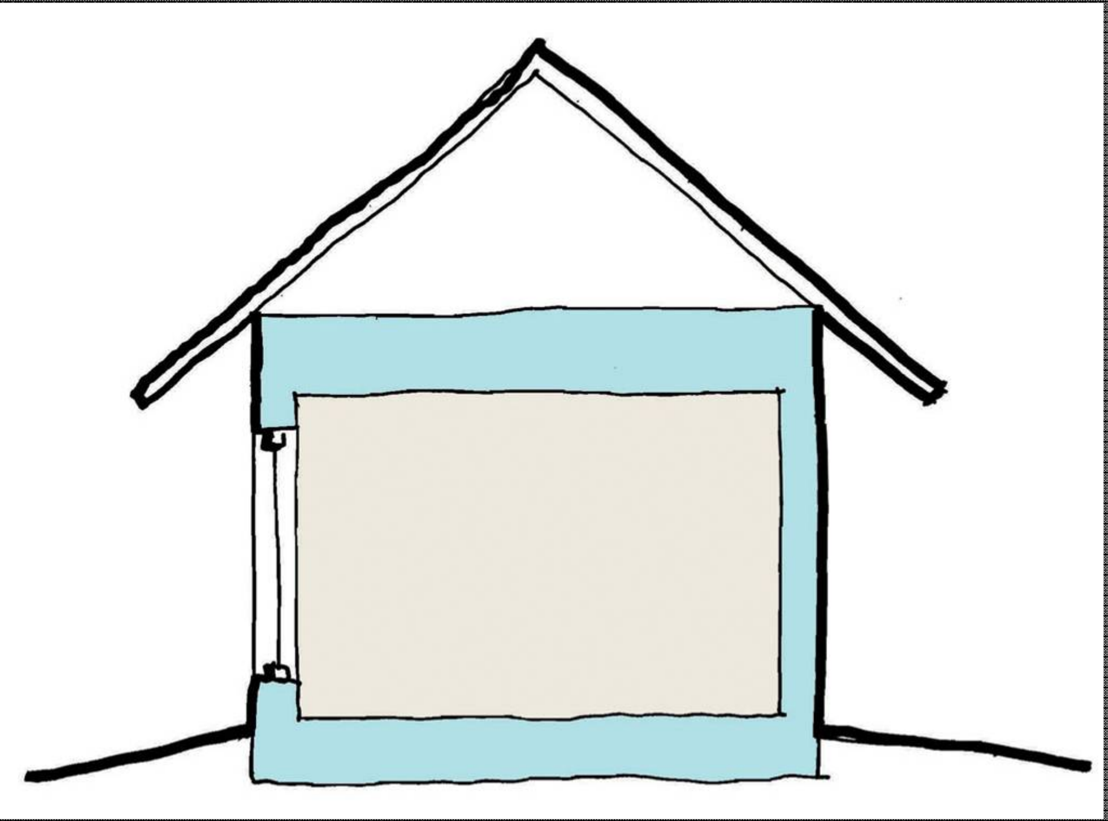


THE STRATEGY:

How to Make a 21st Century Building.

Passivhaus Concept

Controlling Heat Loss… INSULATION

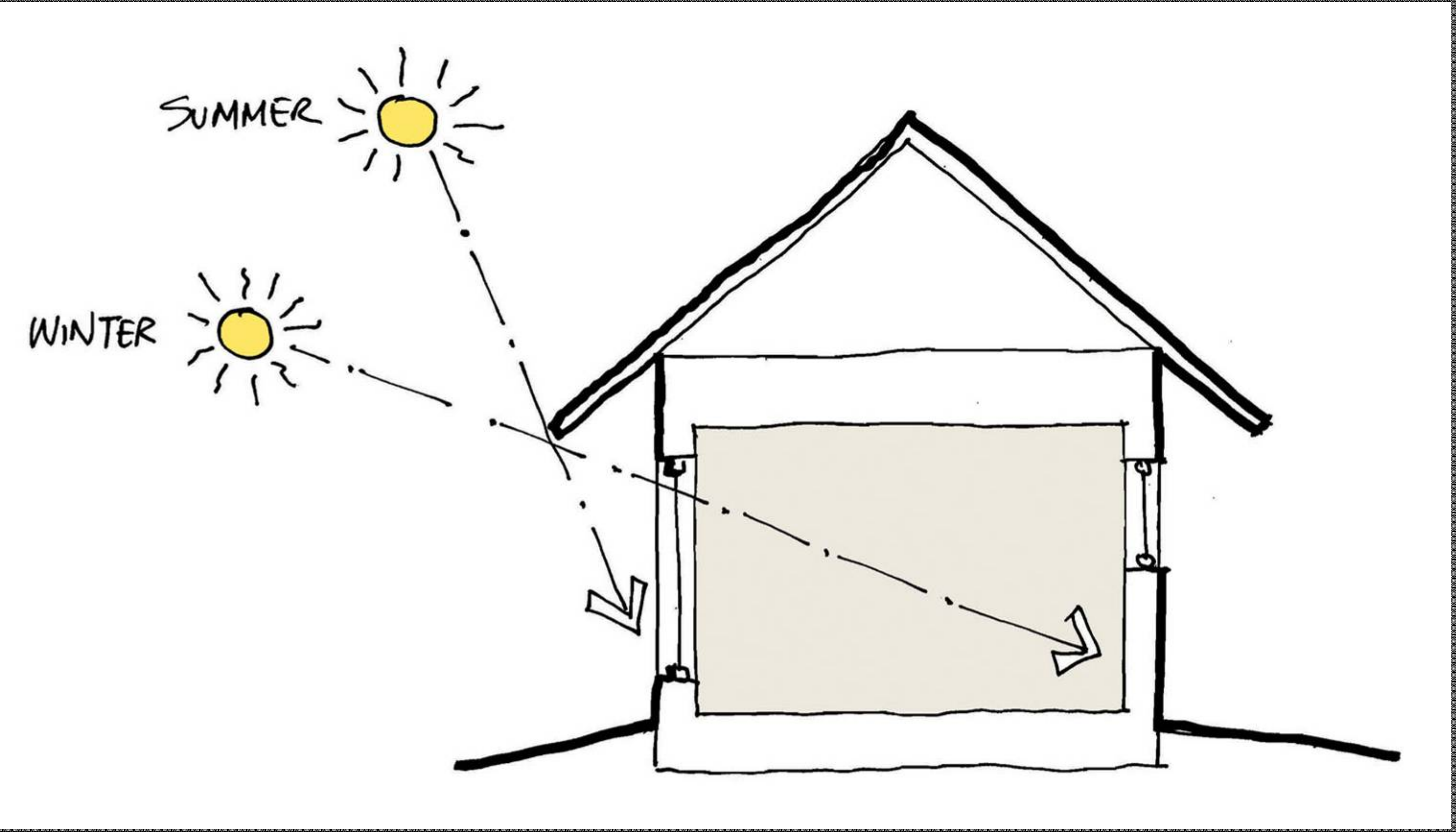


R60 WALLS: R90 CEILING: R60 SLAB

High Performance WINDOWS U value 0.16

Passivhaus Concept

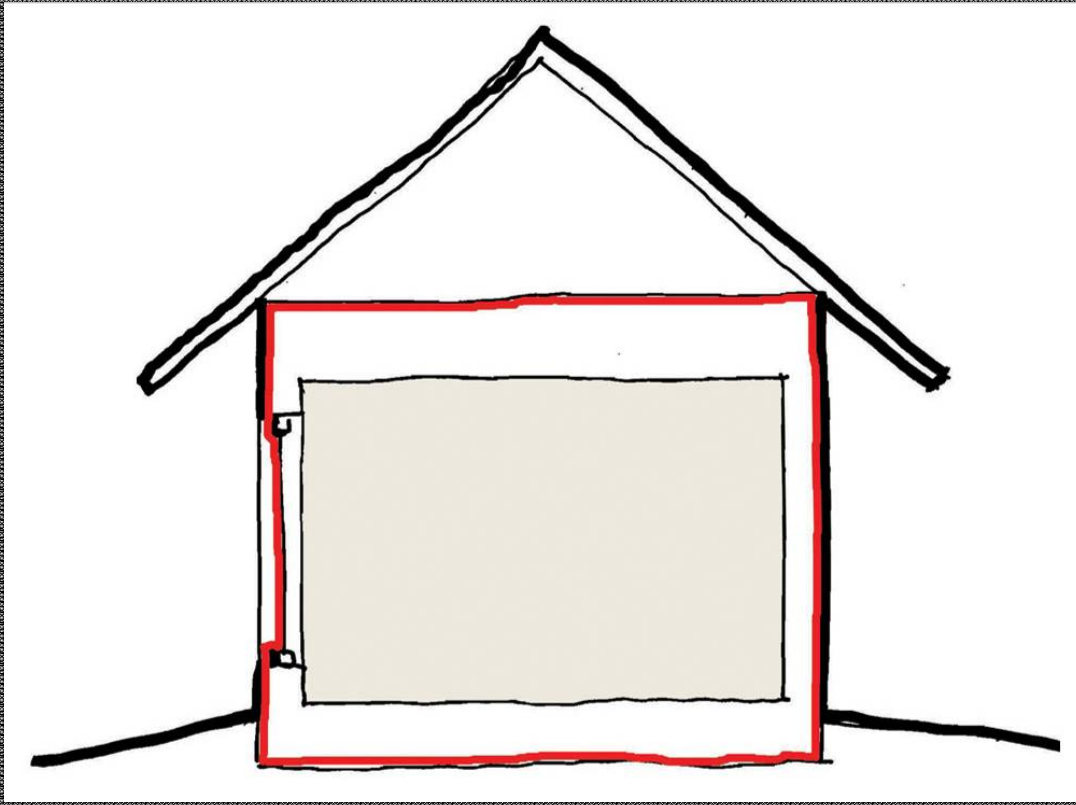
Controlling Gains Seasonally… WINDOWS AND ORIENTATION



U VALUE .16: TRIPLE GLAZED: >.61 SHGC ON SOUTH WINDOWS

Passivhaus Concept

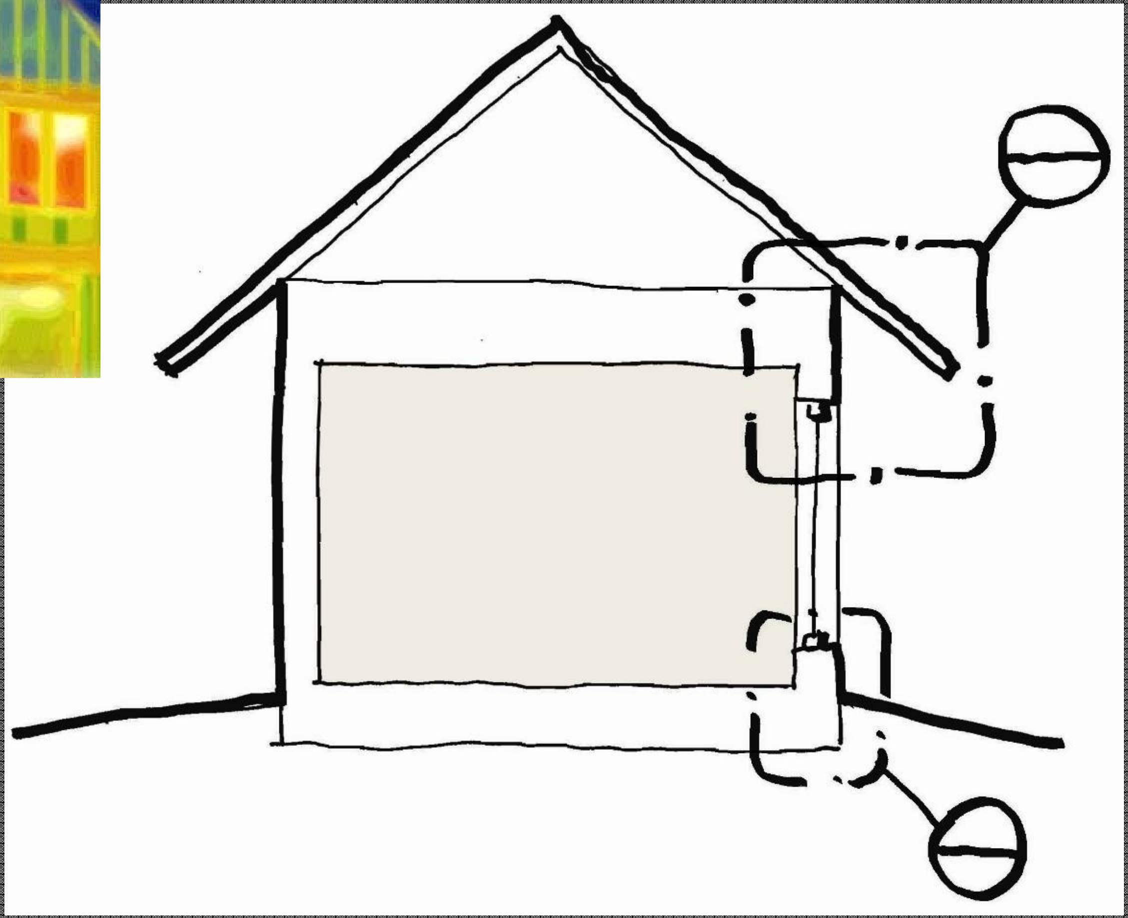
Controlling Heat Loss... REDUCE AIR INFILTRATION



.6 ACH @ 50 PA

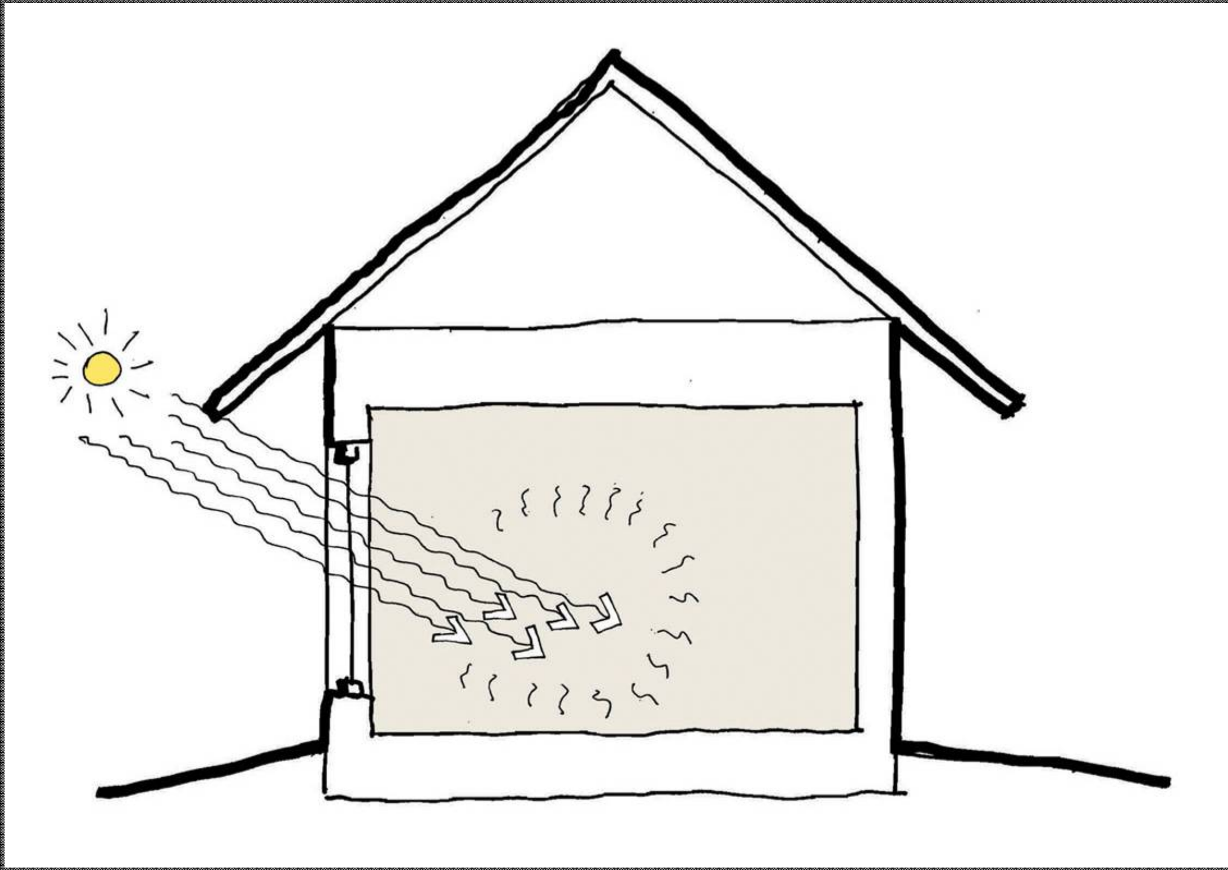
Passivhaus Concept

Controlling Heat Loss… ELIMINATE THERMAL BRIDGES



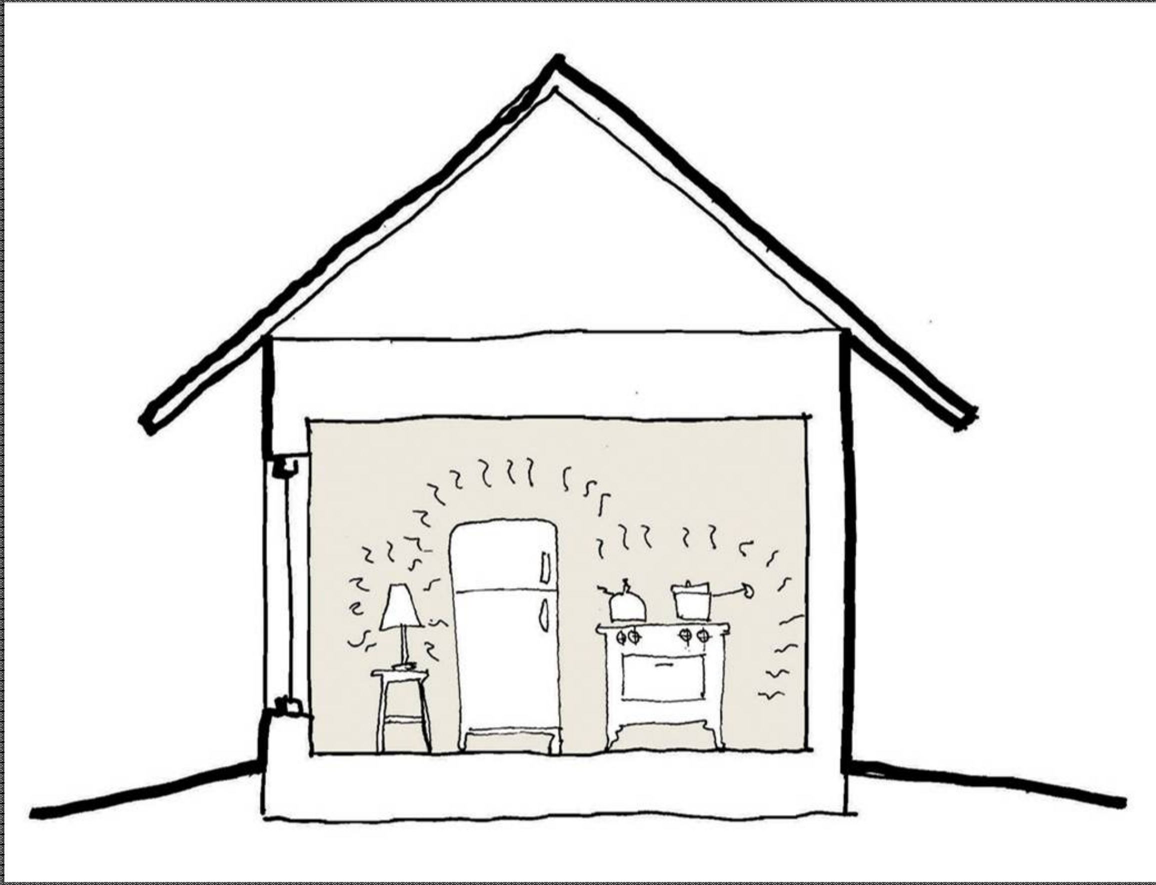
Passivhaus Concept

Capturing Heat Gains... SOLAR ENERGY



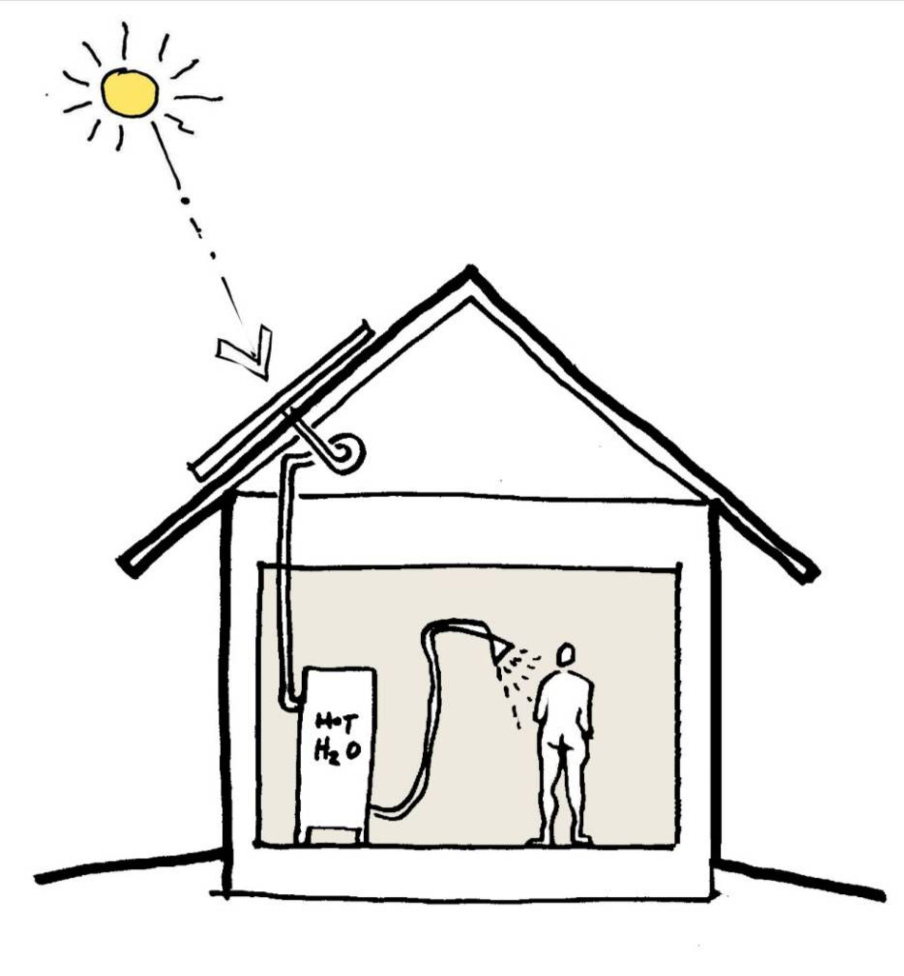
Passivhaus Concept
Capturing Heat Gains… PEOPLE

Passivhaus Concept
Capturing Heat Gains... EQUIPMENT



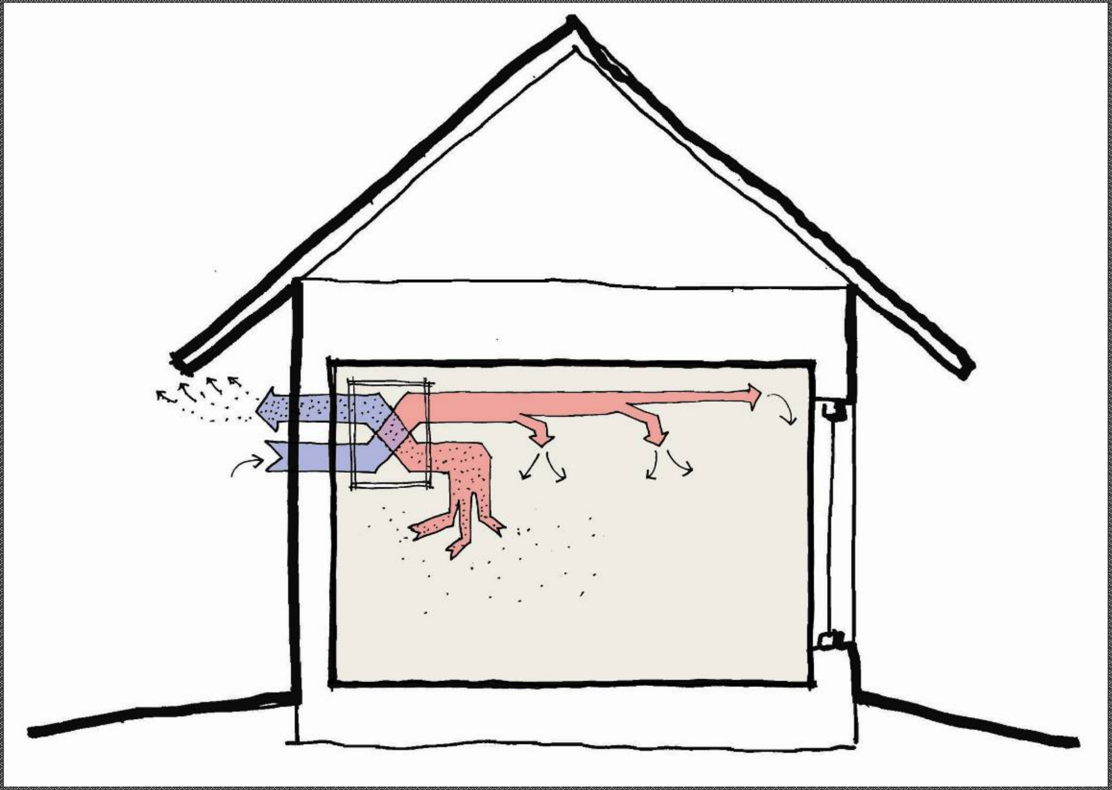
Passivhaus Concept

Controlling Gains Seasonally... SOLAR THERMAL



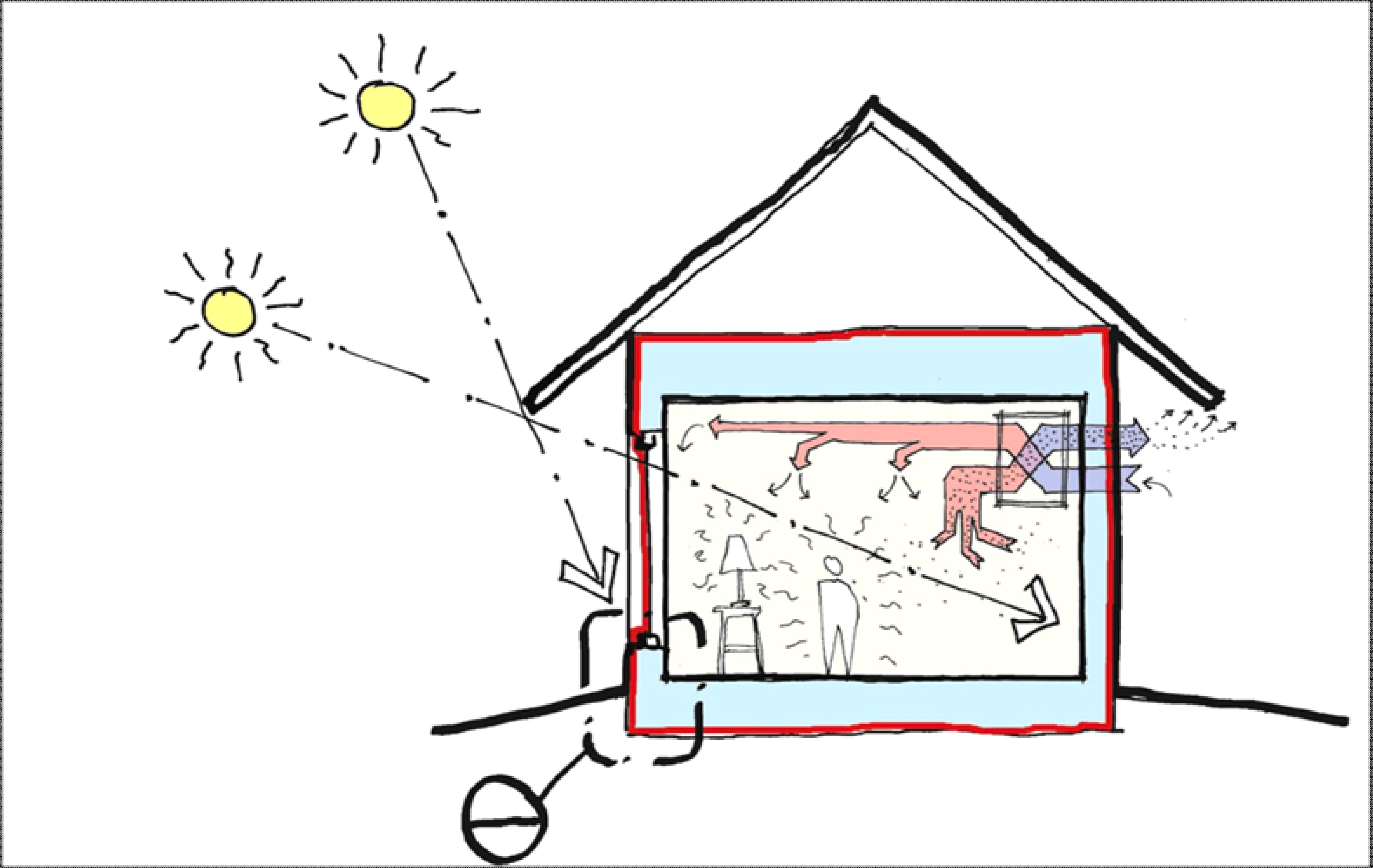
Passivhaus Concept

Providing Fresh Air... HEAT RECOVERY VENTILATION

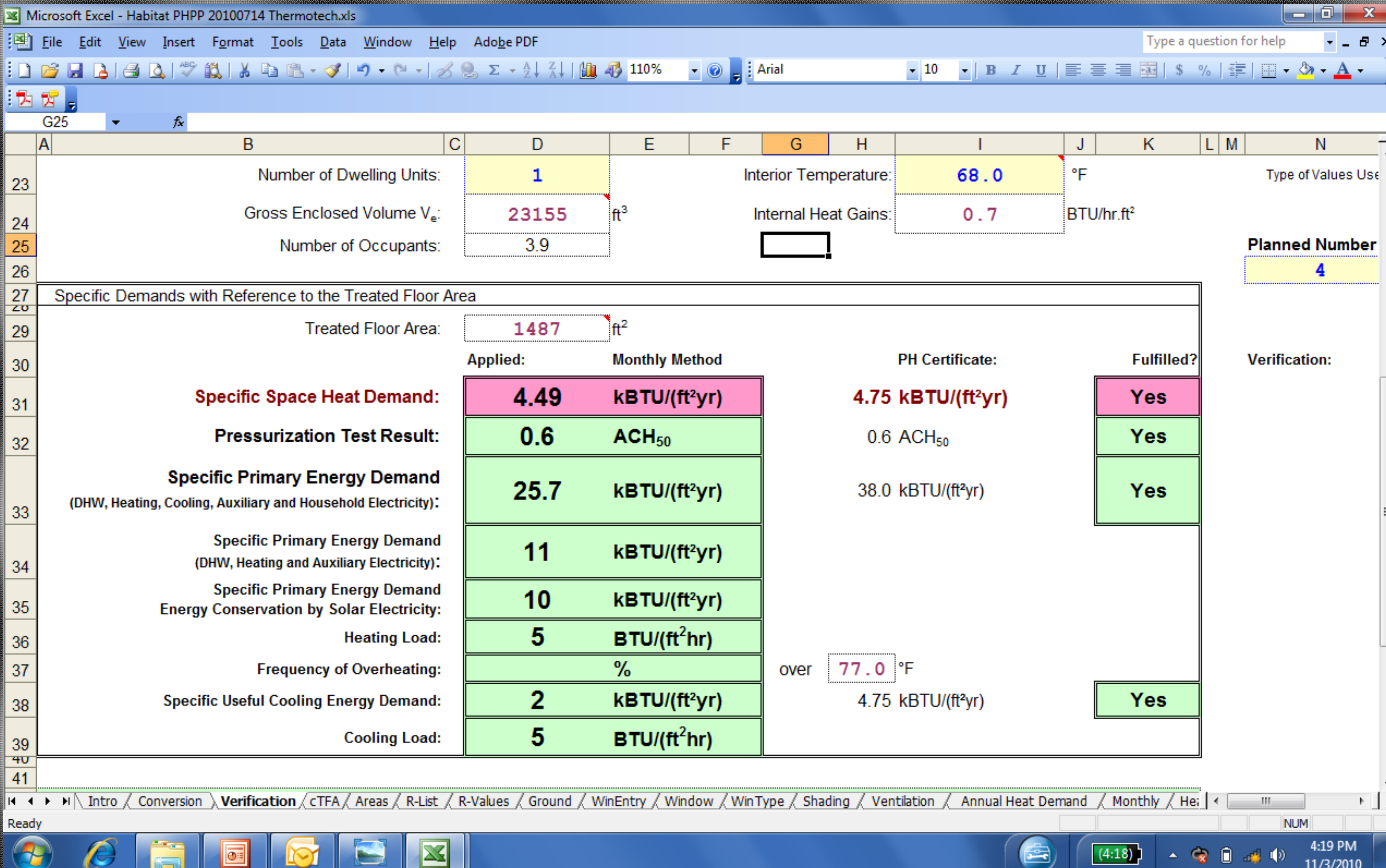


MINIMUM .35 ACH

Passivhaus Concept
INTEGRATED



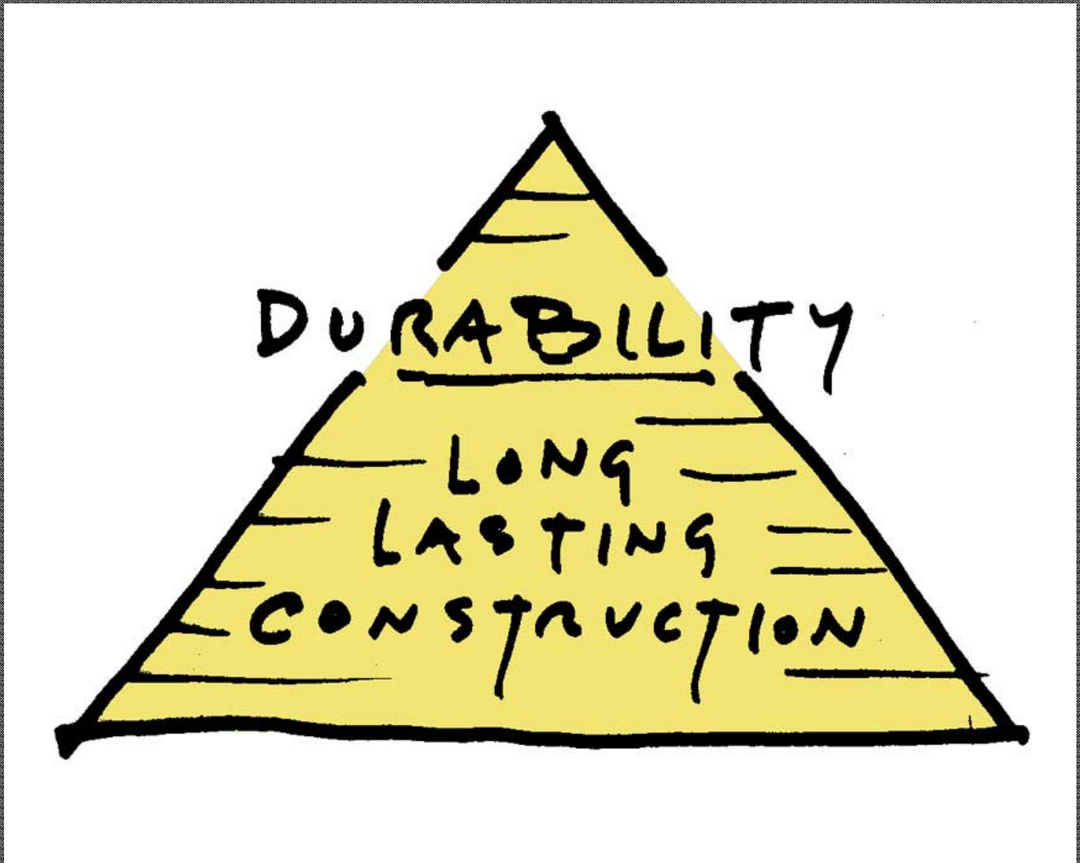
Energy Modeling Software:



GETTING TO PASSIVE HOUSE in VERMONT

Albert, Righter, & Tittmann Architects & Vermont Energy Investment Corporation

H_2O
Efficiency


DURABILITY
LONG
LASTING
CONSTRUCTION

MATERIALS

LOW EMBODIED ENERGY

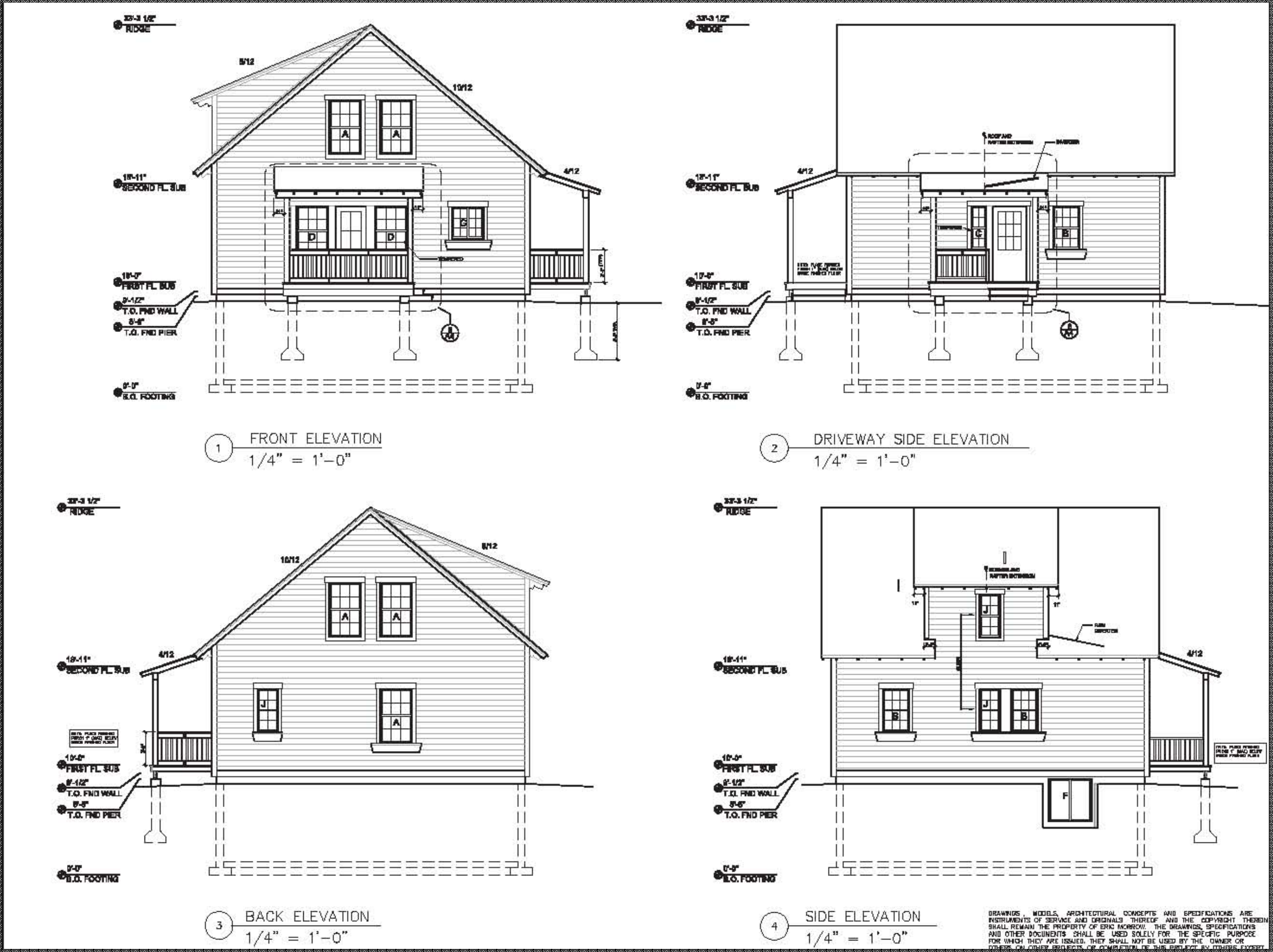
A Tale of Two Houses

Same plan, Same site, Different results

Cape

Passive House

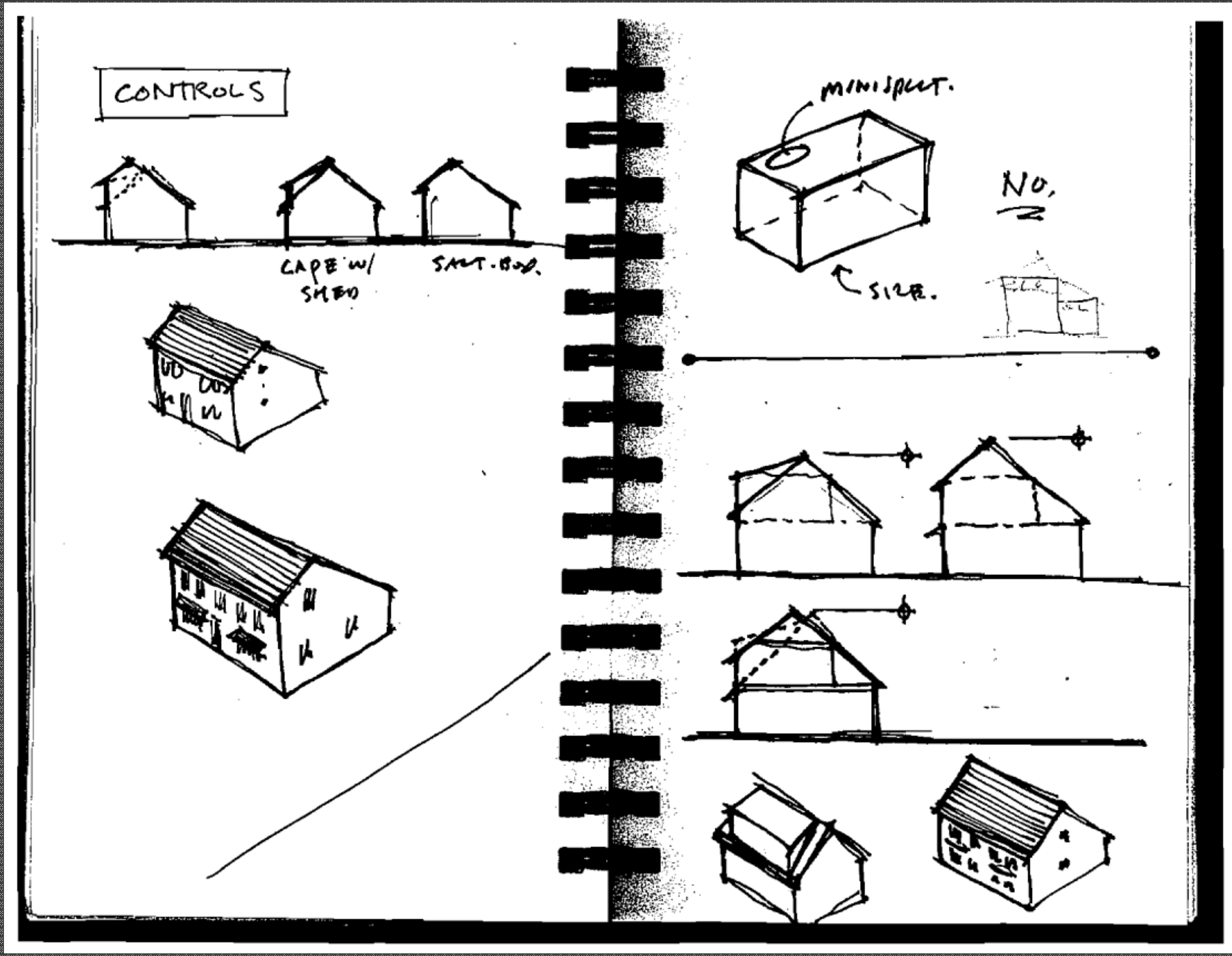
Initial Cape Design



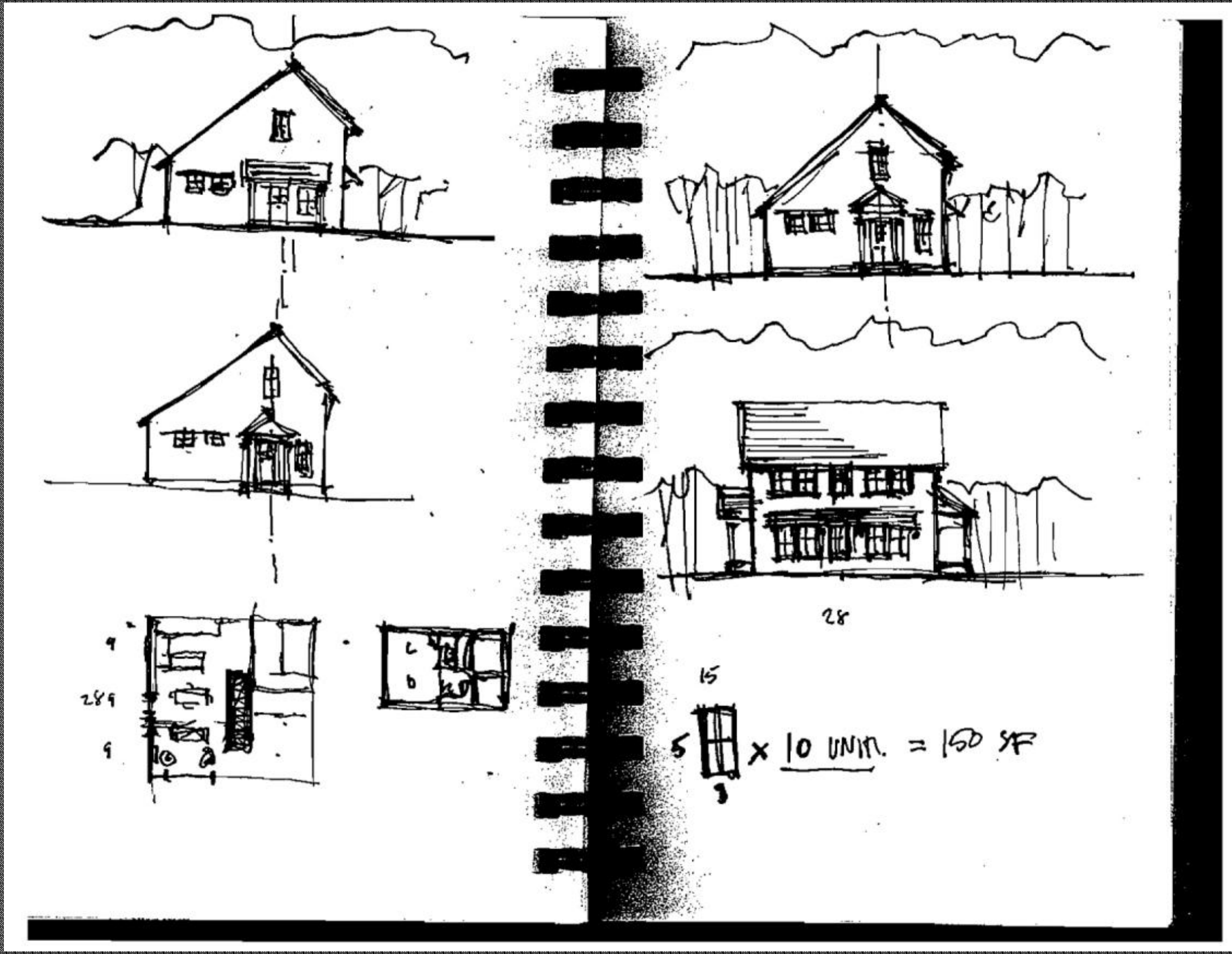
GETTING TO PASSIVE HOUSE in VERMONT

Albert, Righter, & Tittmann Architects & Vermont Energy Investment Corporation

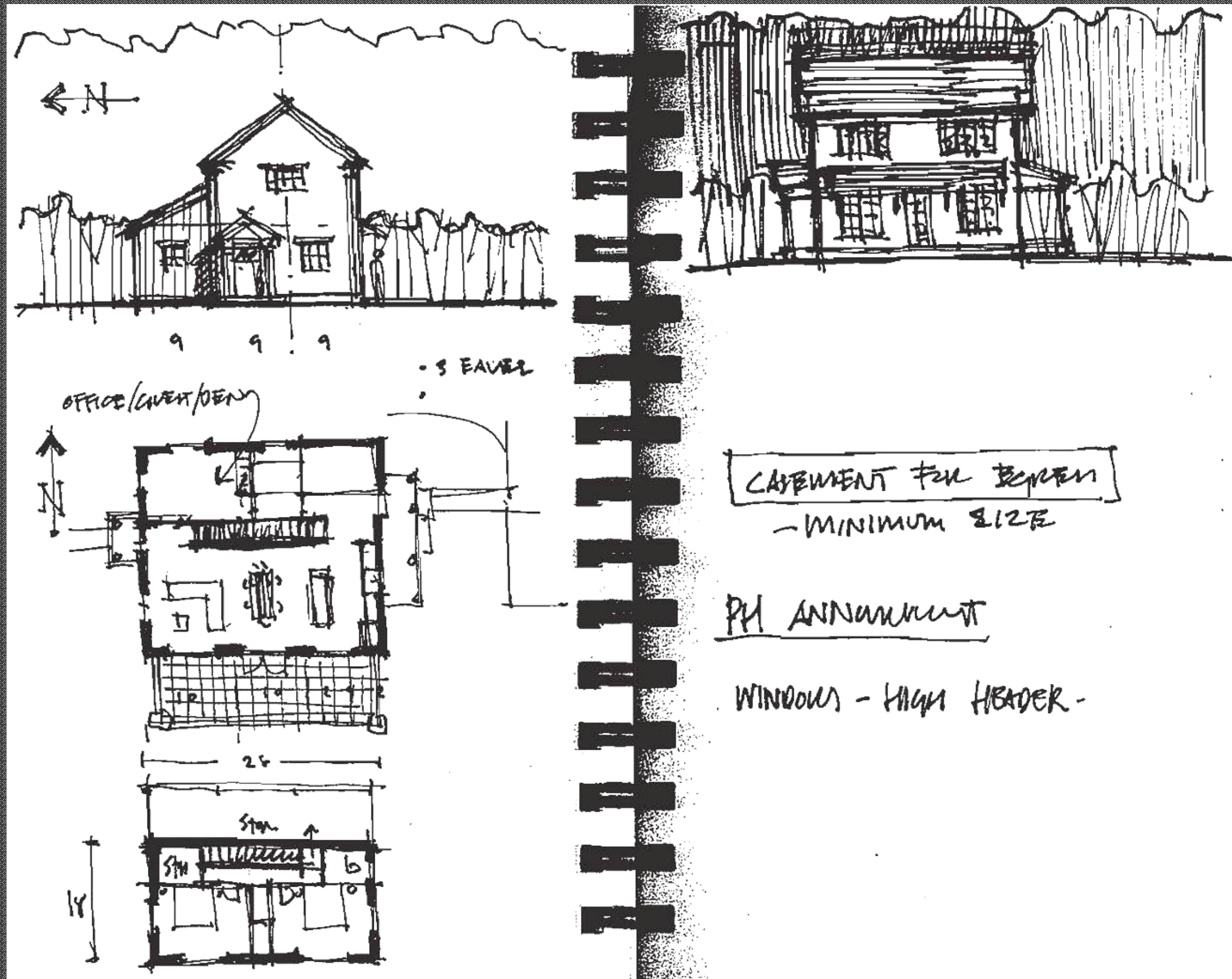
Preliminary Passive House Sketches



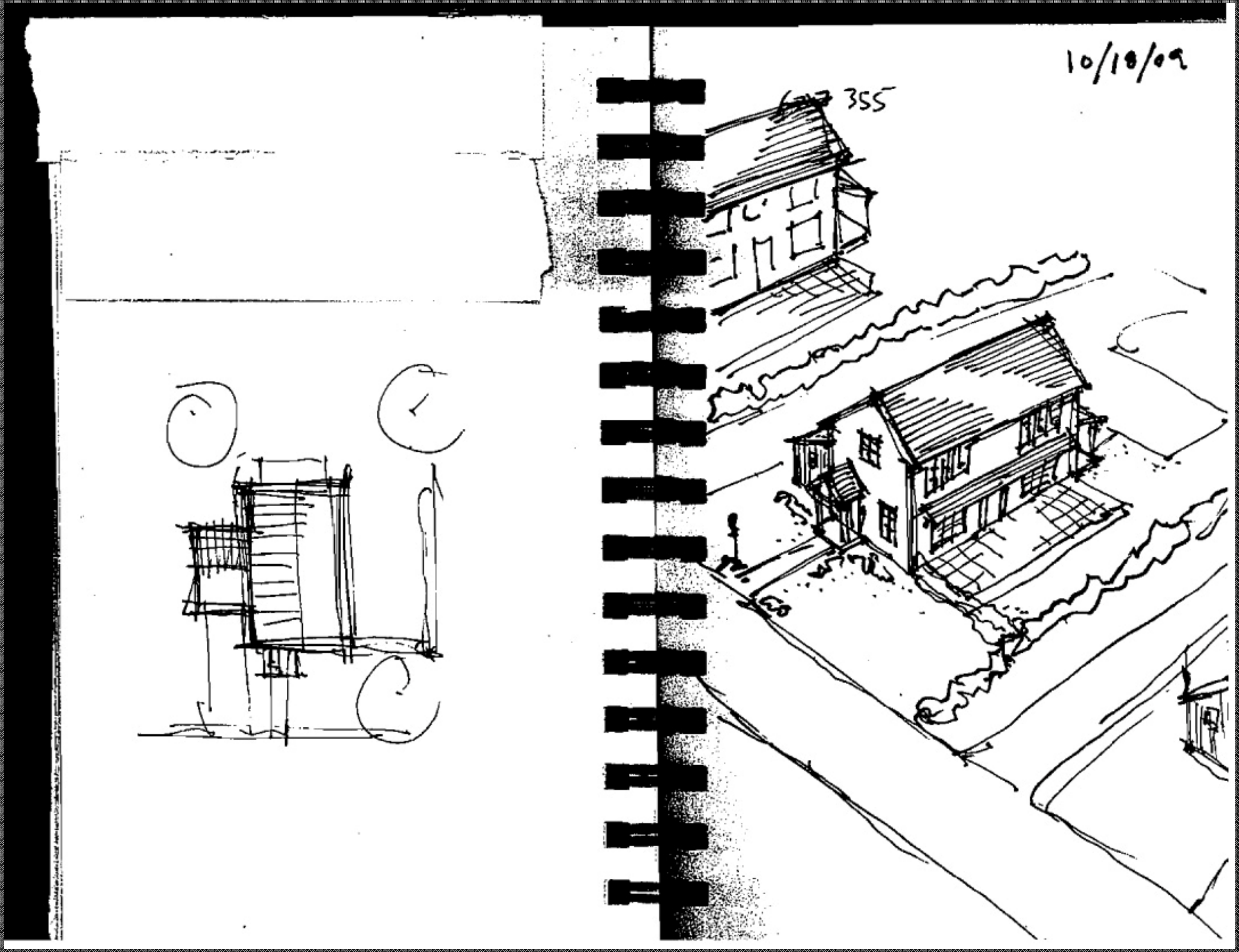
Preliminary Passive House Sketches



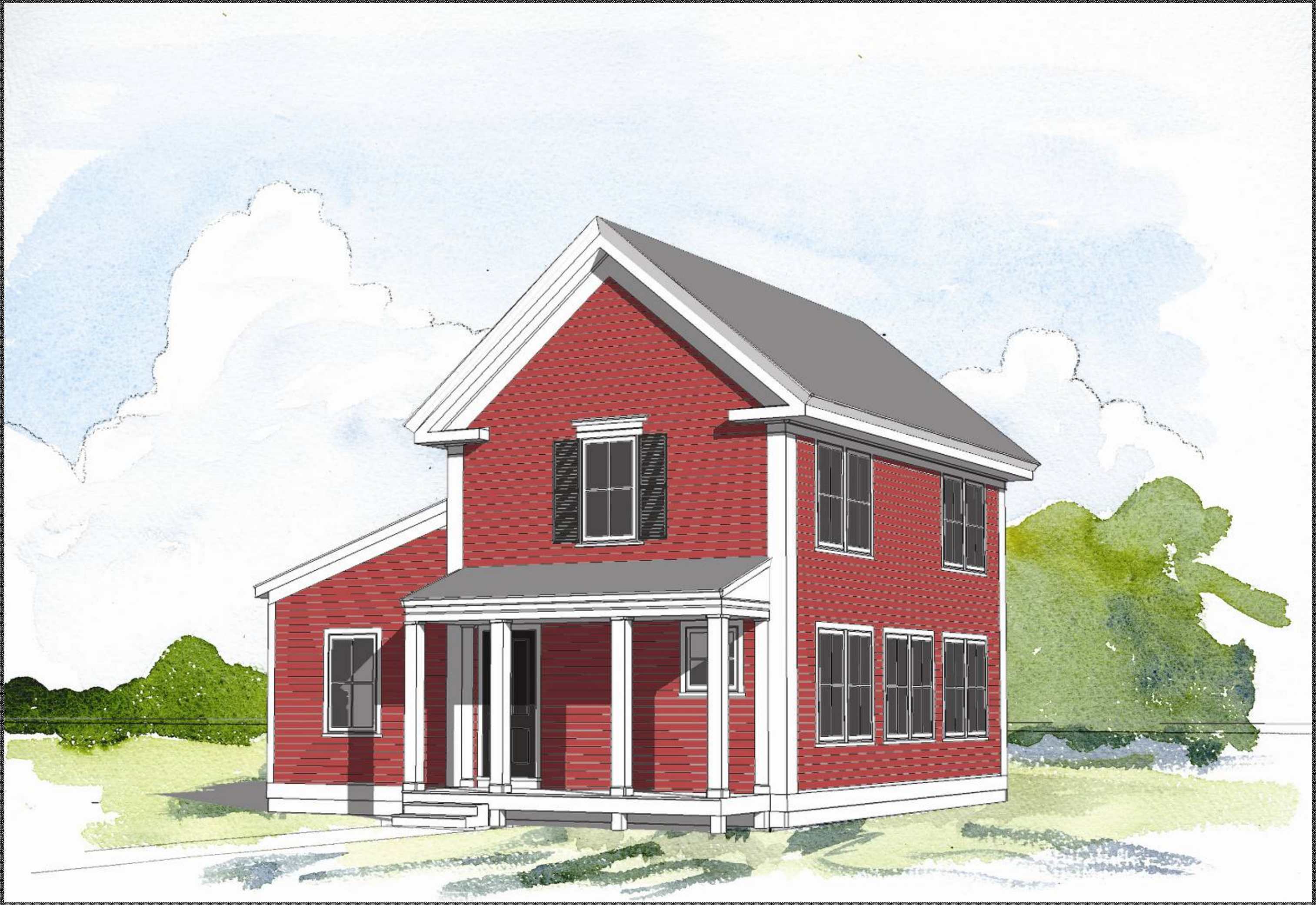
Preliminary Passive House Sketches



Preliminary Passive House Sketches



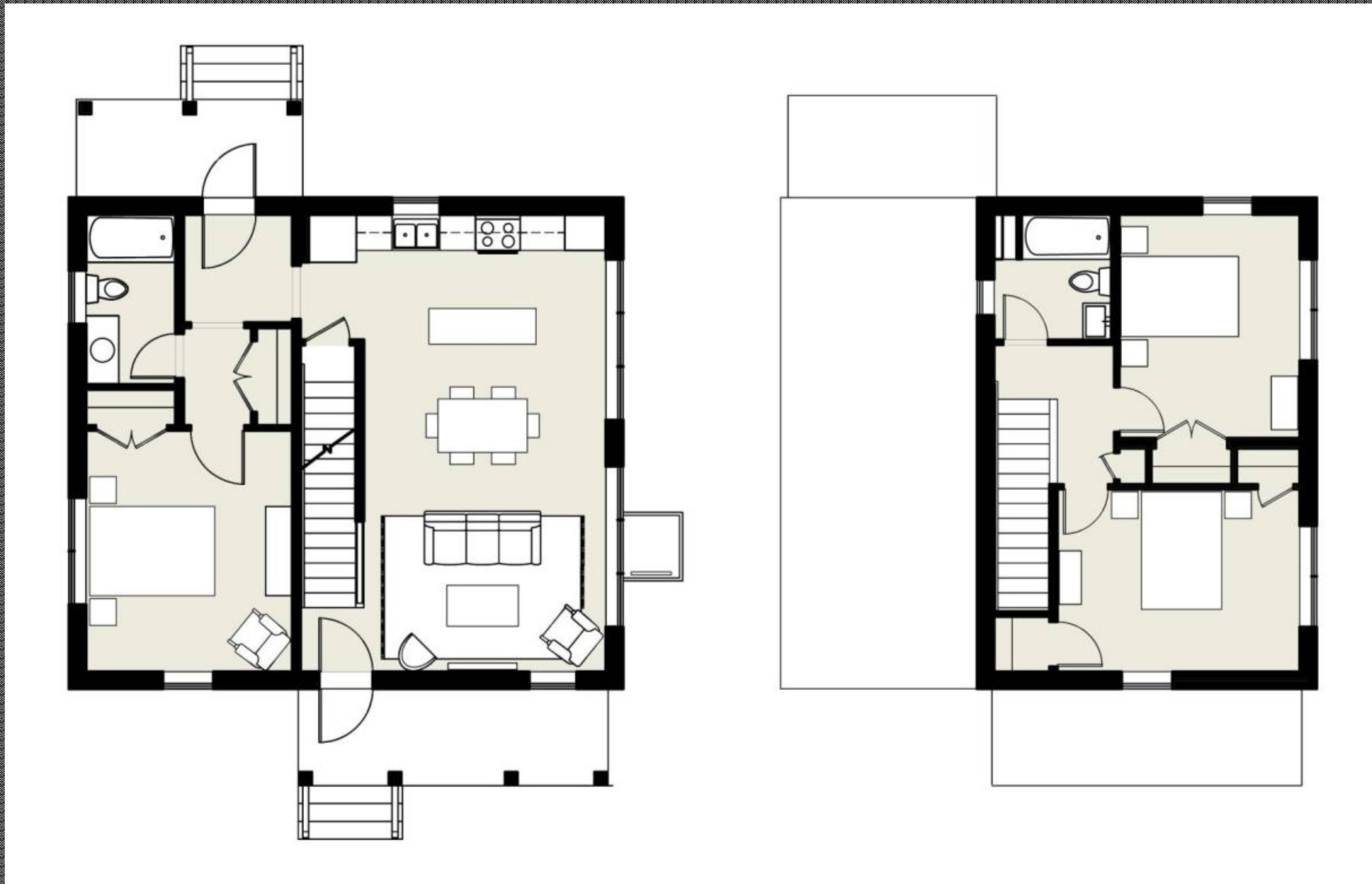
Habitat for Humanity Passive House



GETTING TO PASSIVE HOUSE in VERMONT

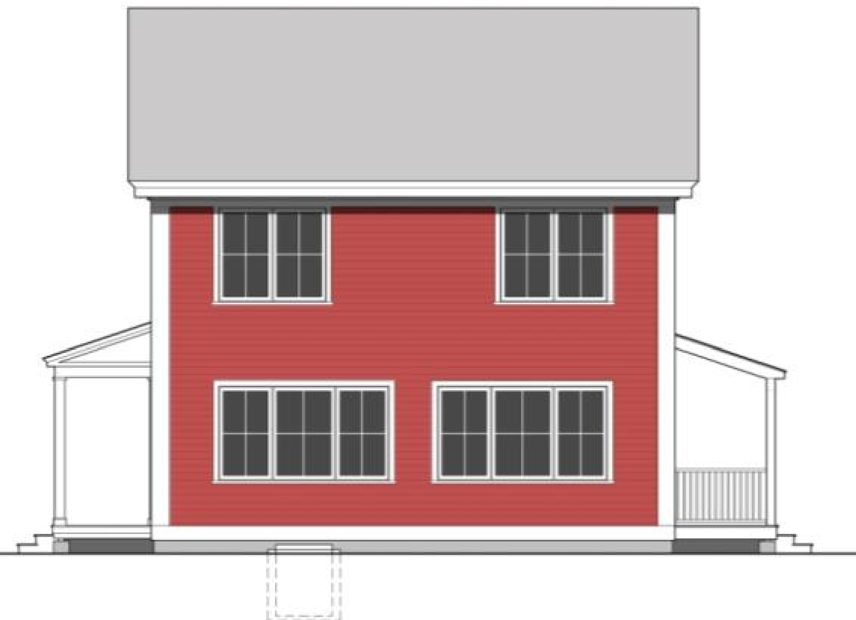
Albert, Righter, & Tittmann Architects & Vermont Energy Investment Corporation

Habitat Passive House Floor Plan



Habitat for Humanity Passive House

WEST ELEVATION



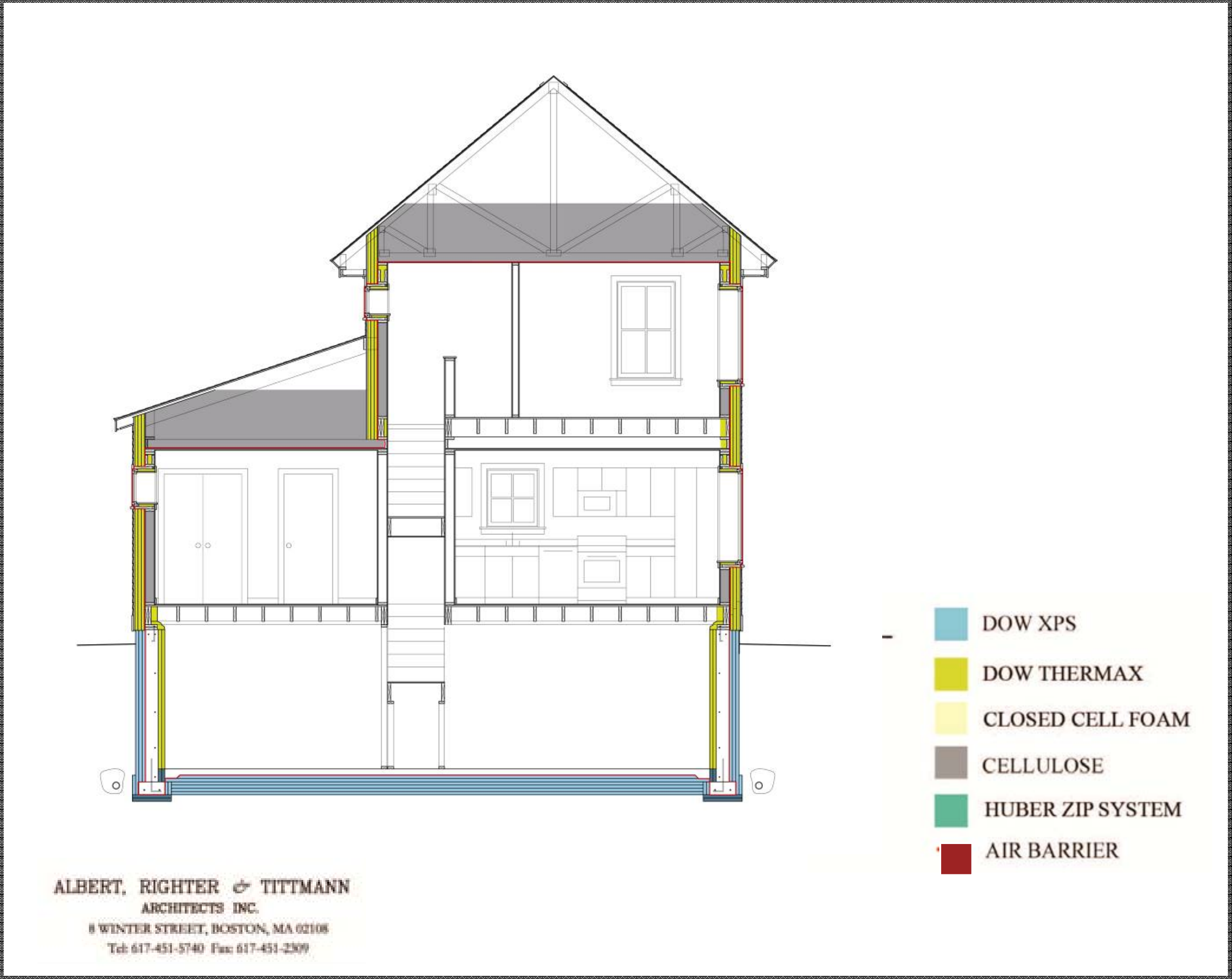
SOUTH ELEVATION

Habitat for Humanity Passive House

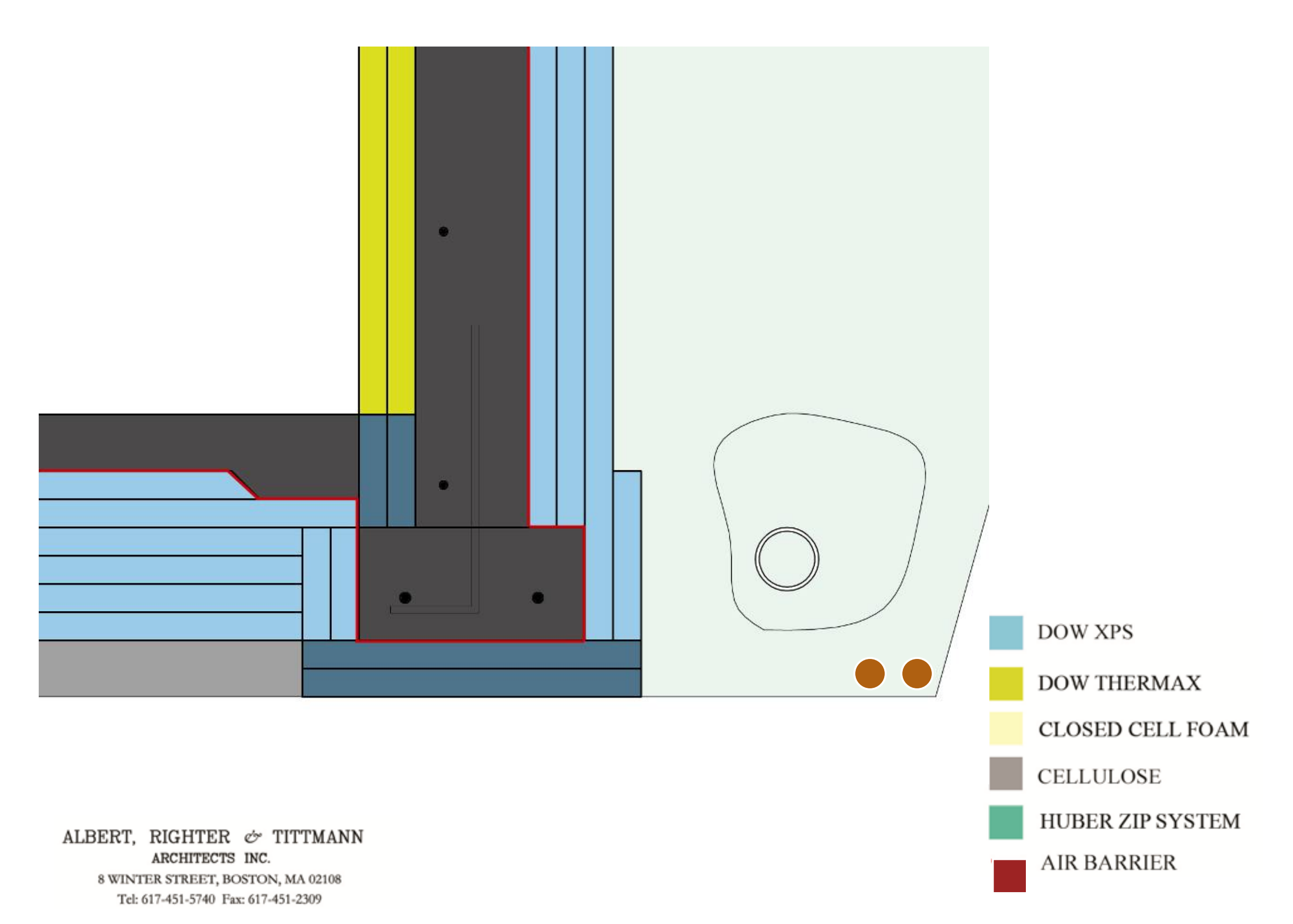
EAST ELEVATION

NORTH ELEVATION

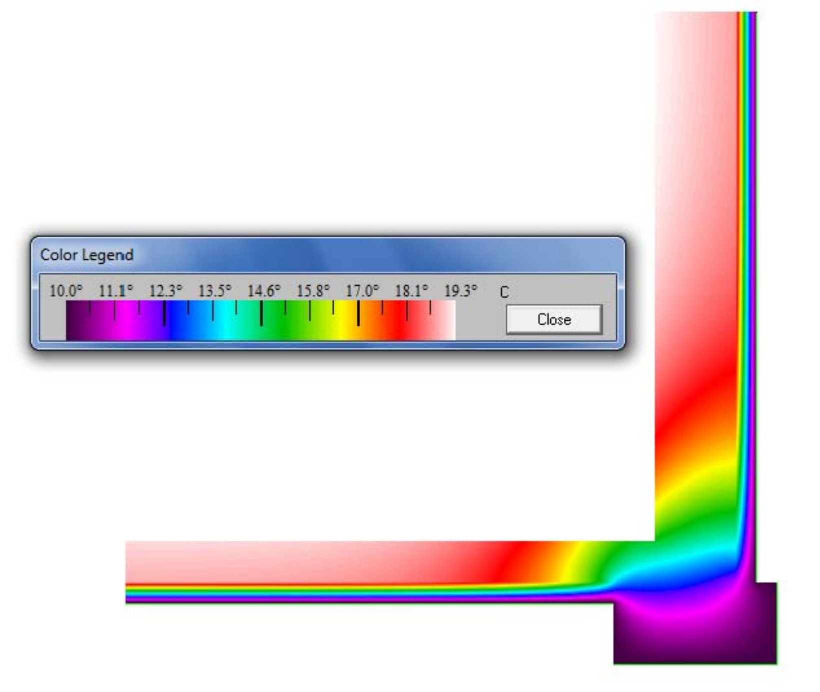
Habitat Passive House – Section



Habitat for Humanity Passive House Footing Detail

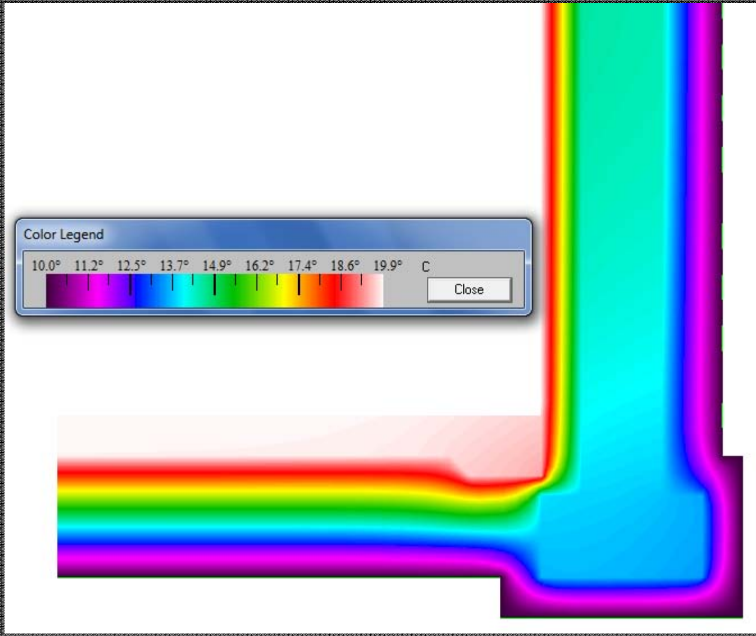


Therm Model of Foundation Details

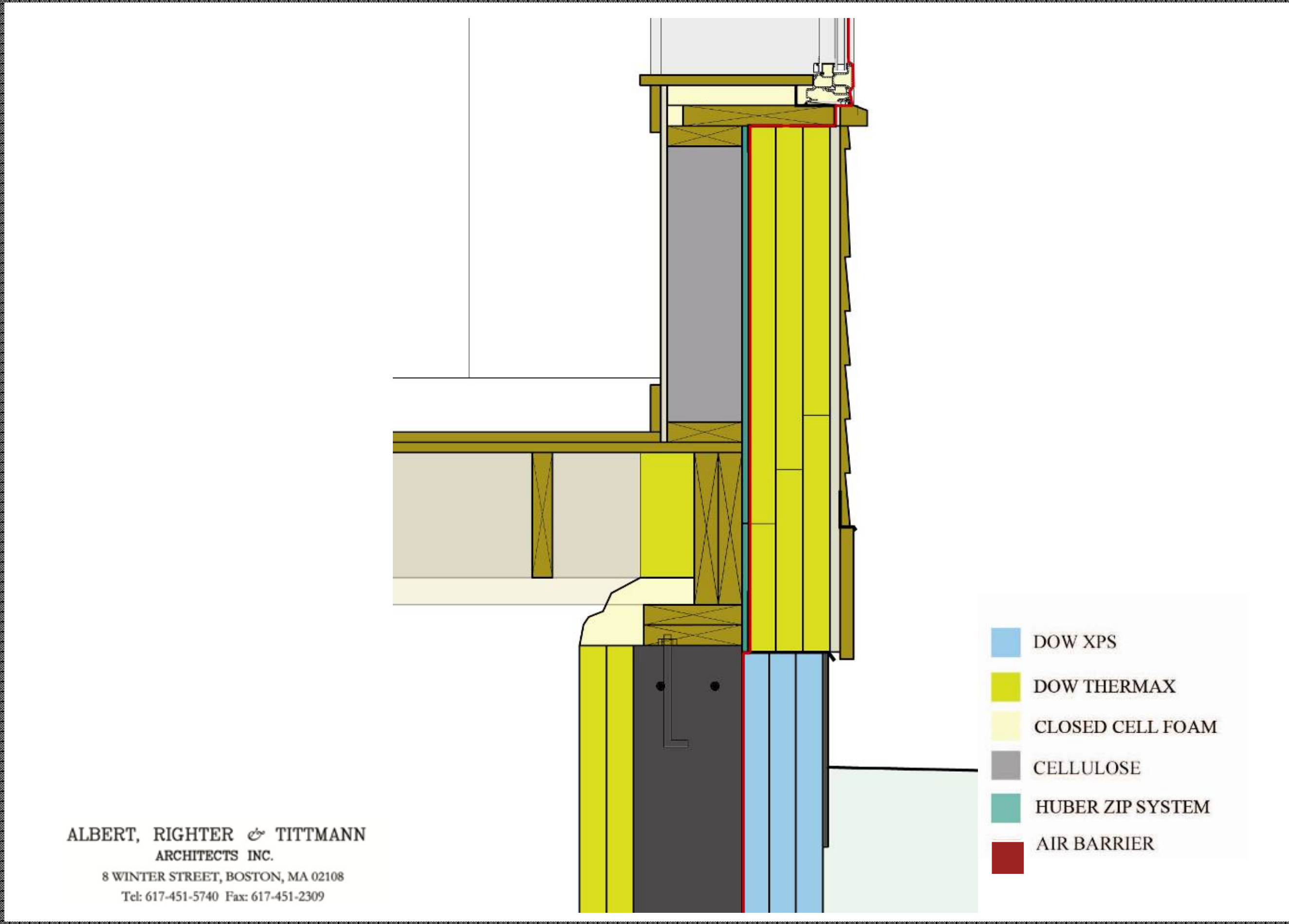


Code Insulation – 2” XPS Under Slab & on Wall (1.553 W/mK)

Passive House Insulation – 12” XPS Under Slab & 10” on Wall (0.05 W/mK)

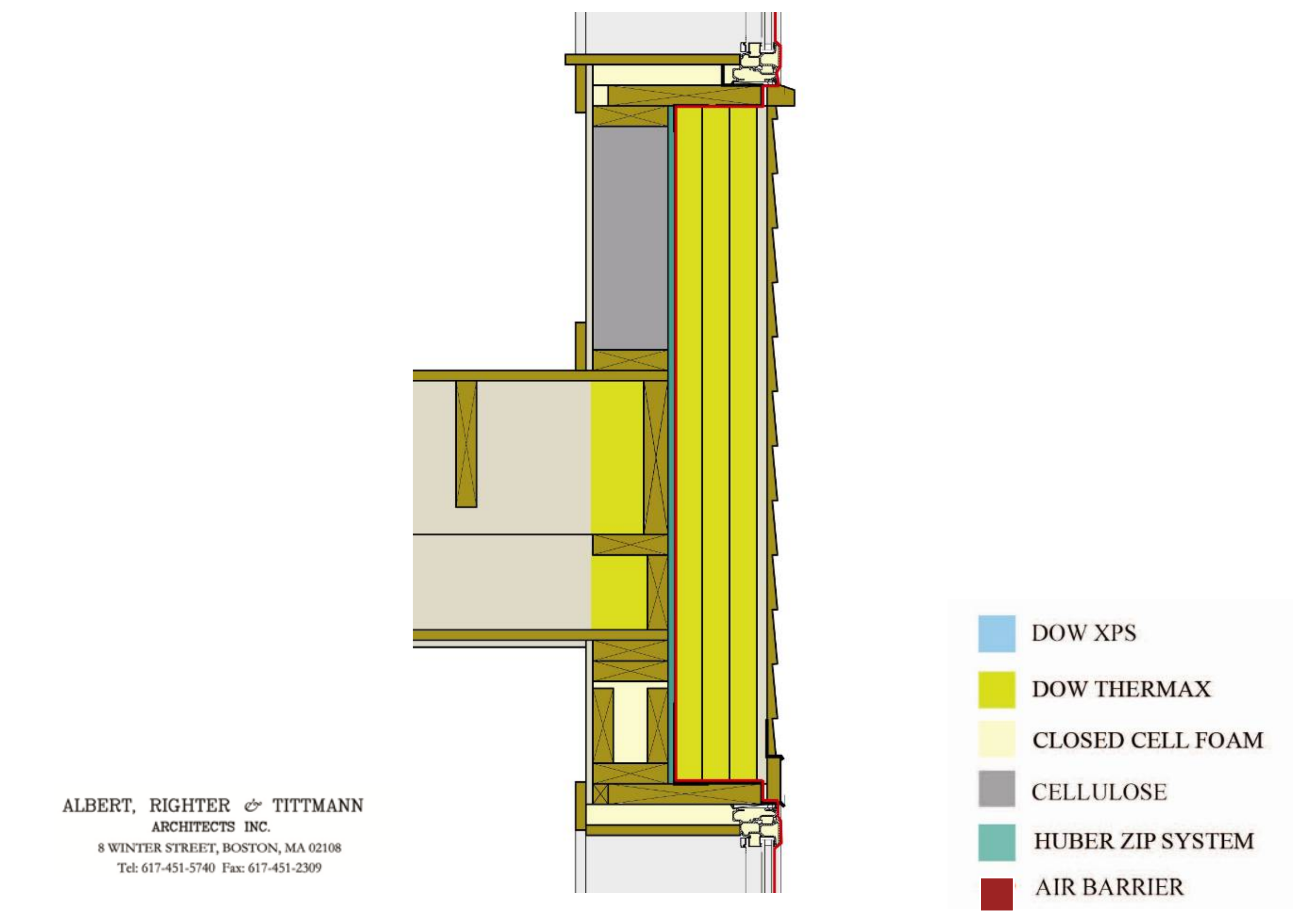


Habitat for Humanity Passive House
Sill Detail

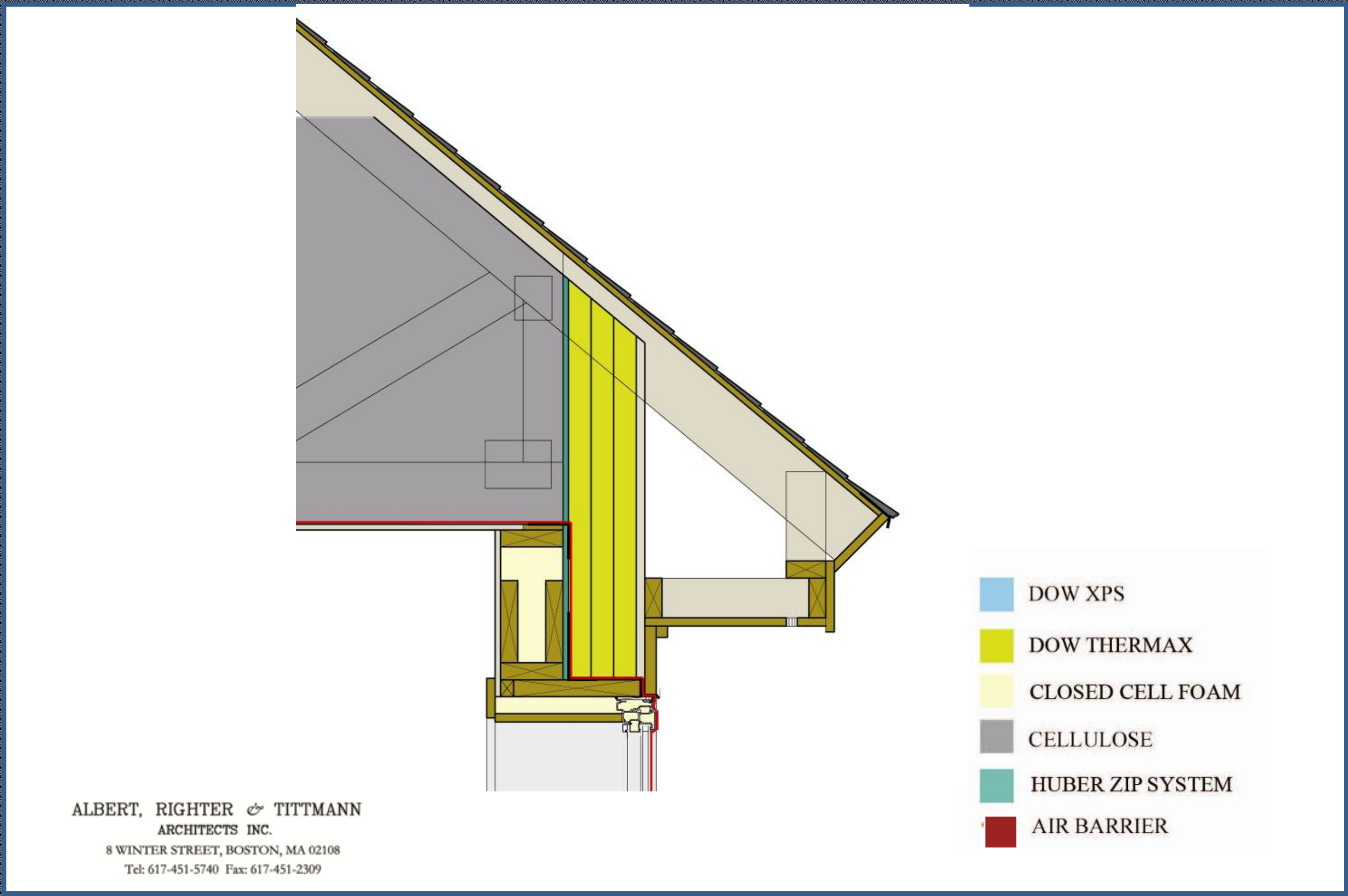


Habitat for Humanity Passive House

Habitat for Humanity Passive House Second Floor Platform Detail



Habitat for Humanity Passive House Eave Detail



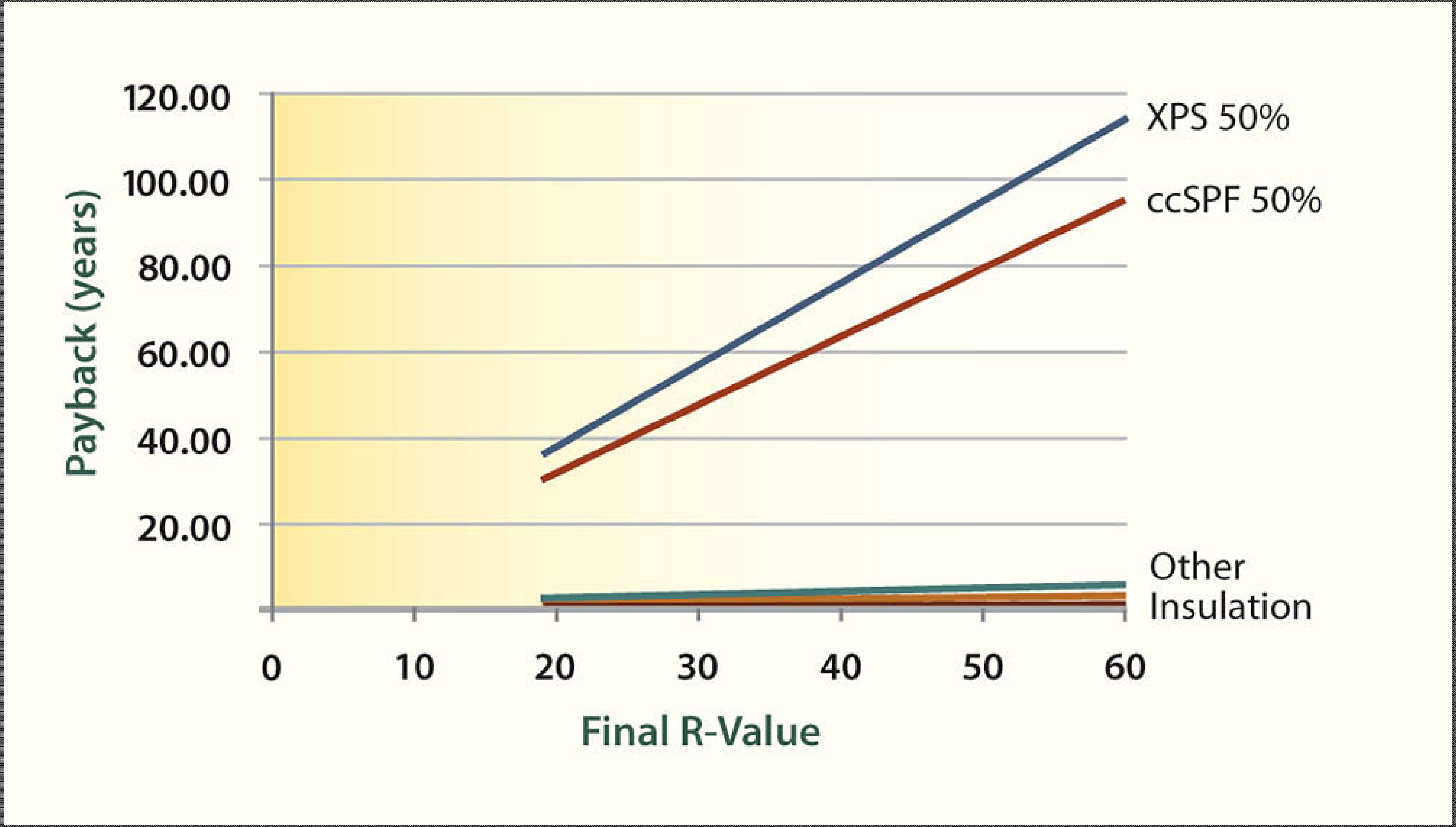
GWP of Insulation Materials

Insulation Material	R-value R/inch	Density lb/ft^3	Emb. E MJ/kg	Emb. Carbon $kgCO_2/kg$	Emb. Carbon $kgCO_2/ft^2 \cdot R$	Blowing Agent (GWP)	Bl. Agent kg/kg foam	Blowing Agent GWP/ bd-ft	Lifetime GWP/ $ft^2 \cdot R$
Cellulose (dense-pack)	3.7	3.0	2.1	0.106	0.0033	None	0	N/A	0.0033
Fiberglass batt	3.3	1.0	28	1.44	0.0165	None	0	N/A	0.0165
Rigid mineral wool	4.0	4.0	17	1.2	0.0455	None	0	N/A	0.0455
Polyisocyanurate	6.0	1.5	72	3.0	0.0284	Pentane (GWP=7)	0.05	0.02	0.0317
Spray polyurethane foam (SPF) – closed-cell (HFC-blown)	6.0	2.0	72	3.0	0.0379	HFC-245fa (GWP=1,030)	0.11	8.68	1.48
SPF – closed-cell (water-blown)	5.0	2.0	72	3.0	0.0455	Water (CO_2) (GWP=1)	0	0	0.0455
SPF – open-cell (water-blown)	3.7	0.5	72	3.0	0.0154	Water (CO_2) (GWP=1)	0	0	0.0154
Expanded polystyrene (EPS)	3.9	1.0	89	2.5	0.0307	Pentane (GWP=7)	0.06	0.02	0.036
Extruded polystyrene (XPS)	5.0	2.0	89	2.5	0.0379	HFC-134a[1] (GWP=1,430)	0.08	8.67	1.77

1. XPS manufacturers have not divulged their post-HCFC blowing agent, and MSDS data have not been updated. The blowing agent is assumed here to be HFC-134a.

www.buildinggreen.com

Payback of XPS Insulation



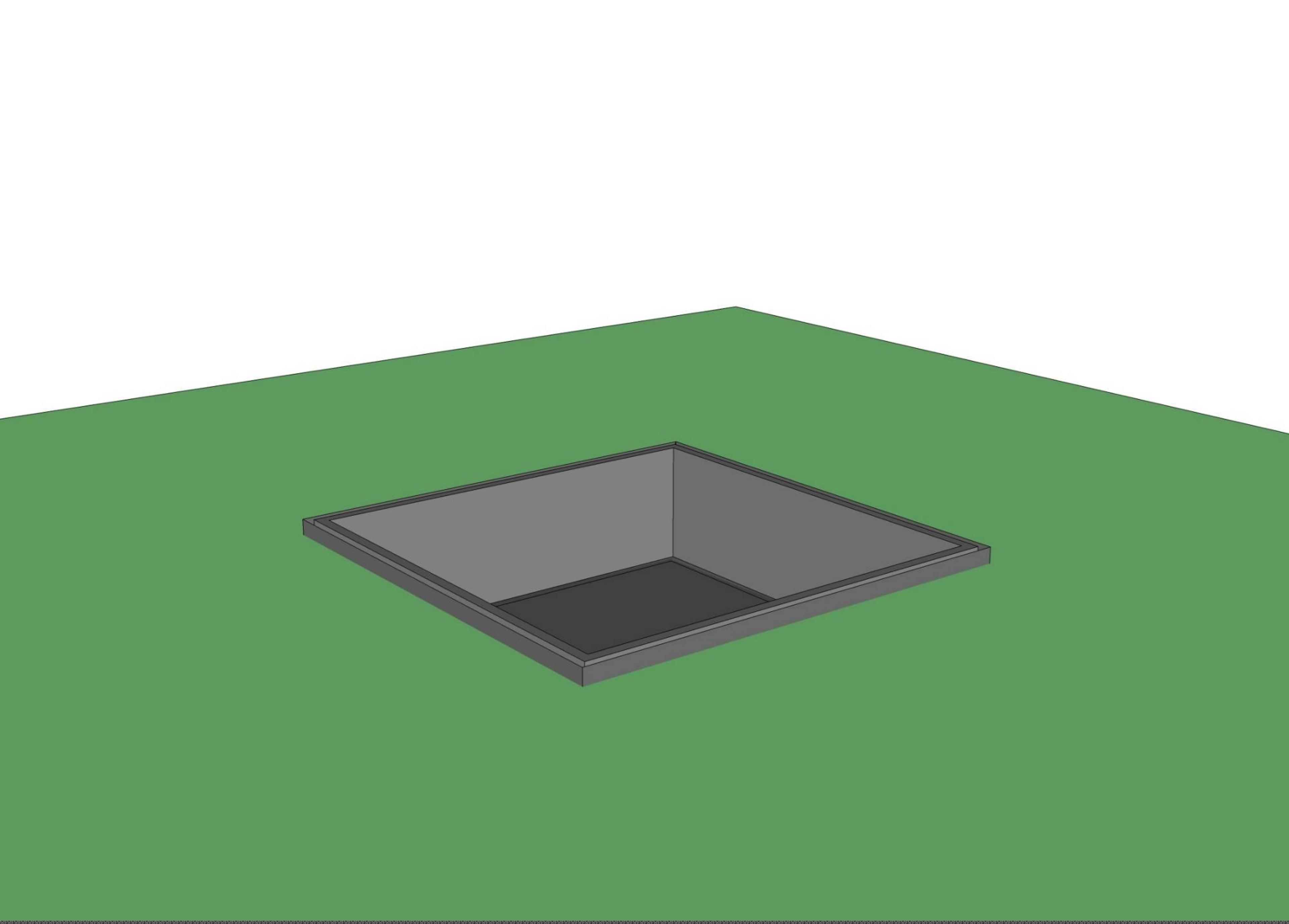
www.buildinggreen.com

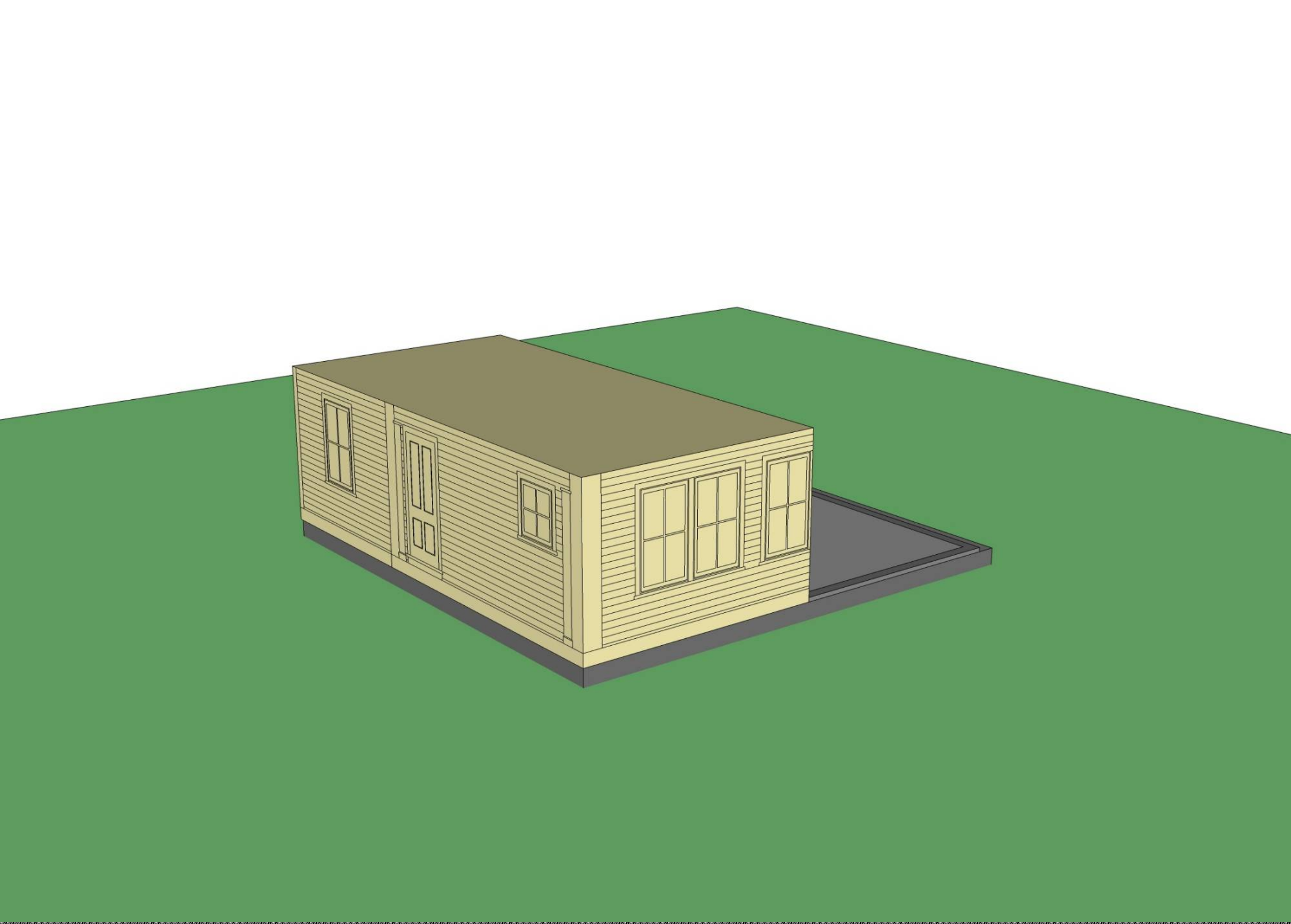
Habitat for Humanity Passive House Windows

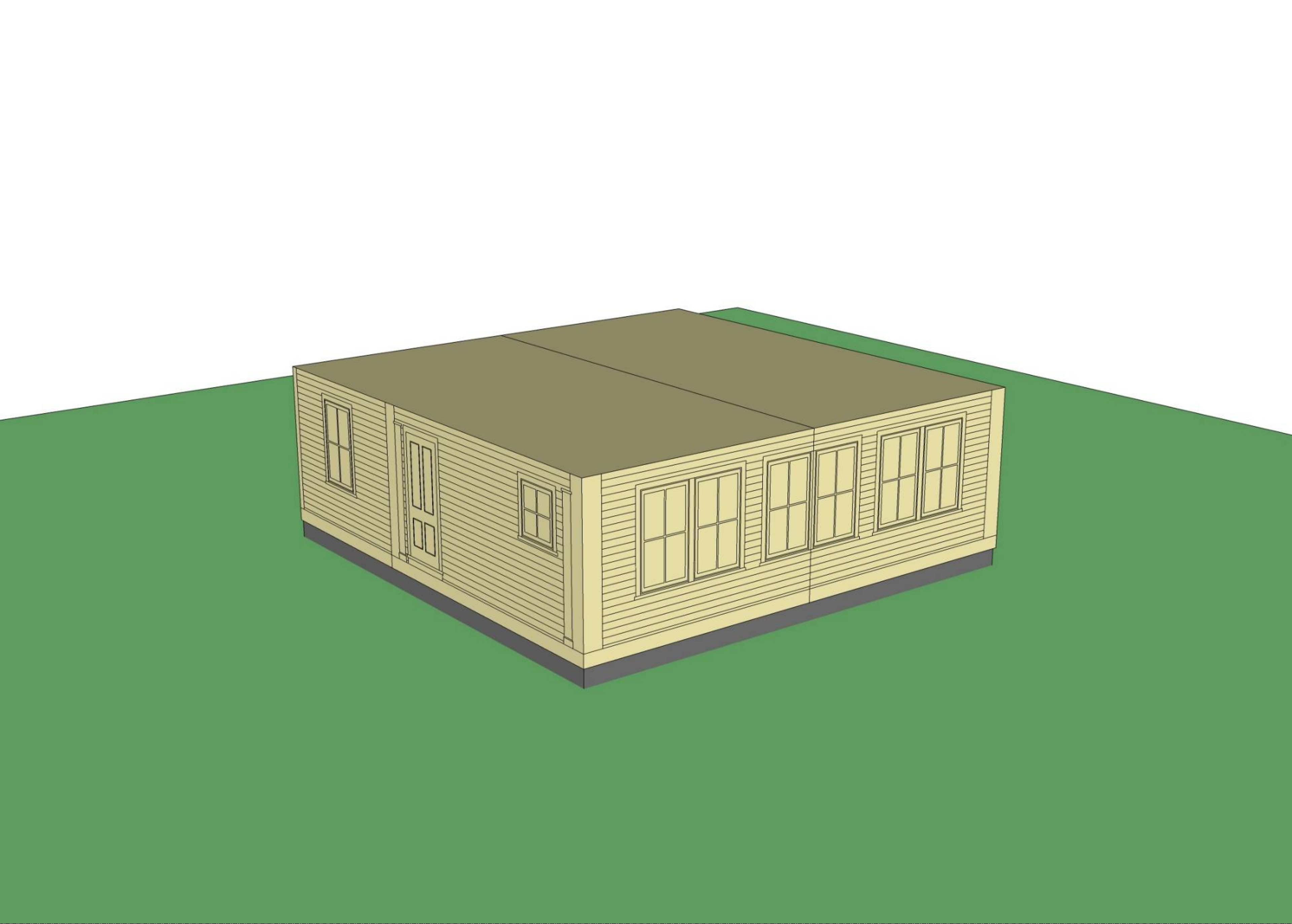
Thermotech
322 Gain+

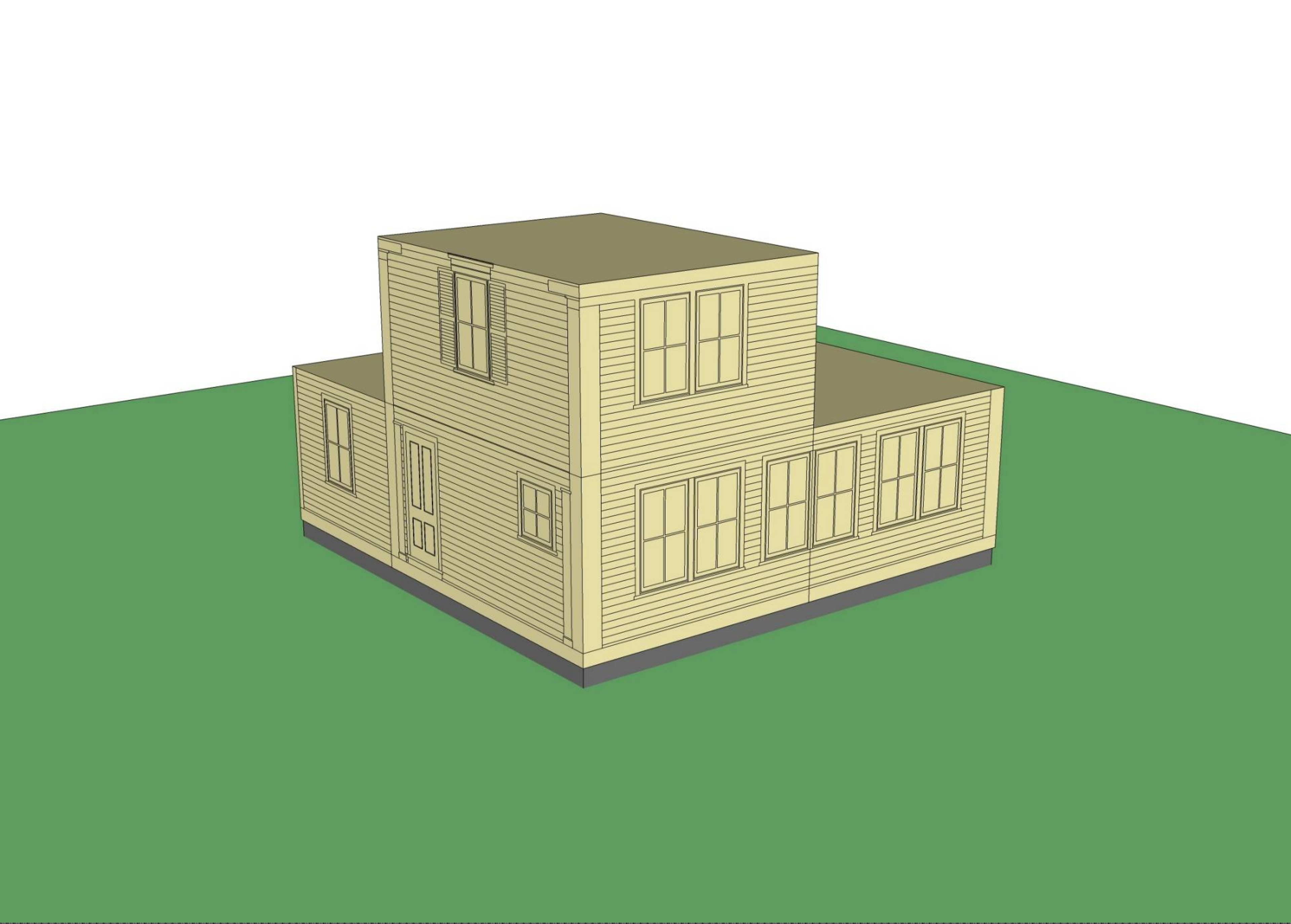
.61 SHGC

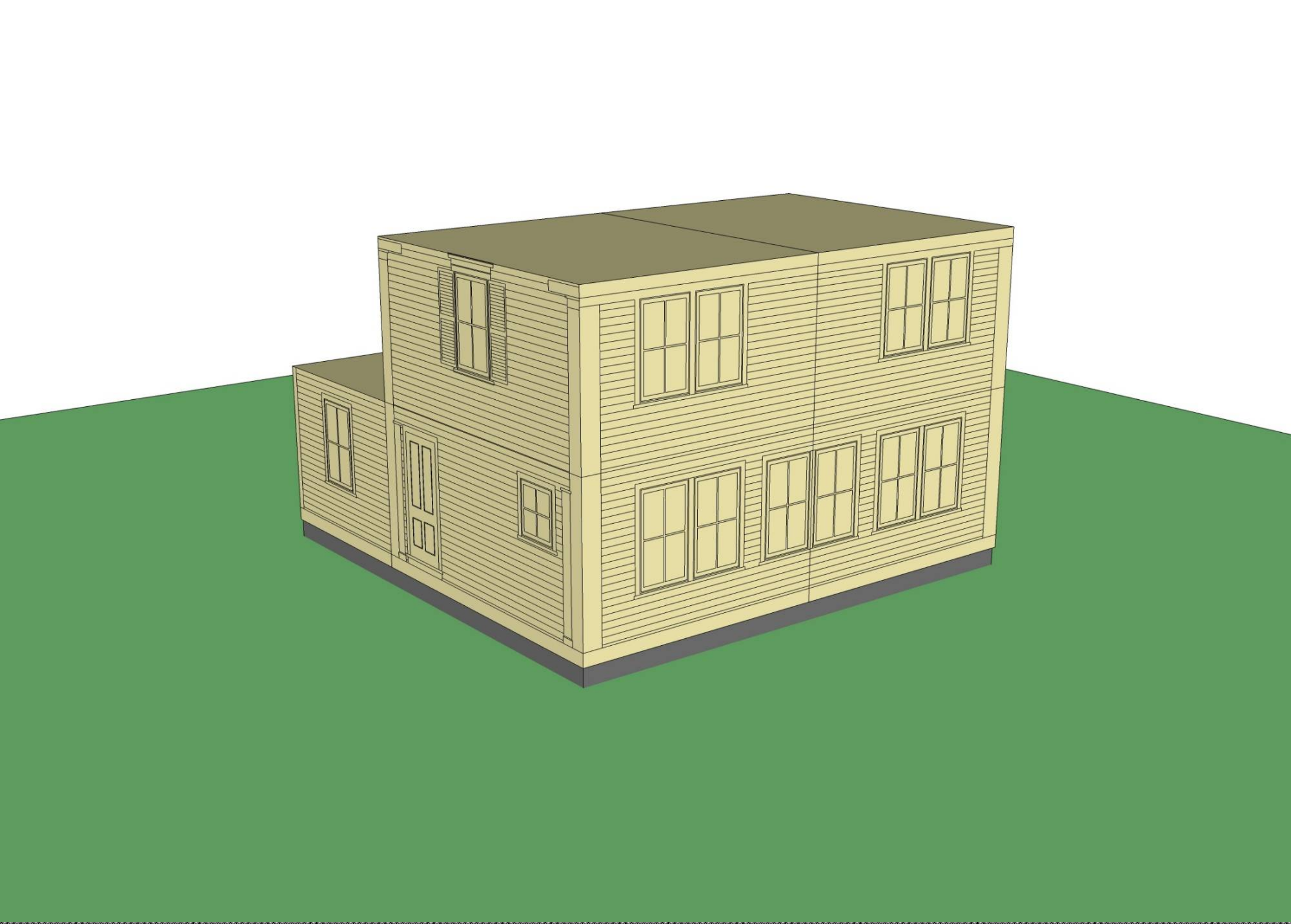
Glazing U-value .16
Frame U-value .16

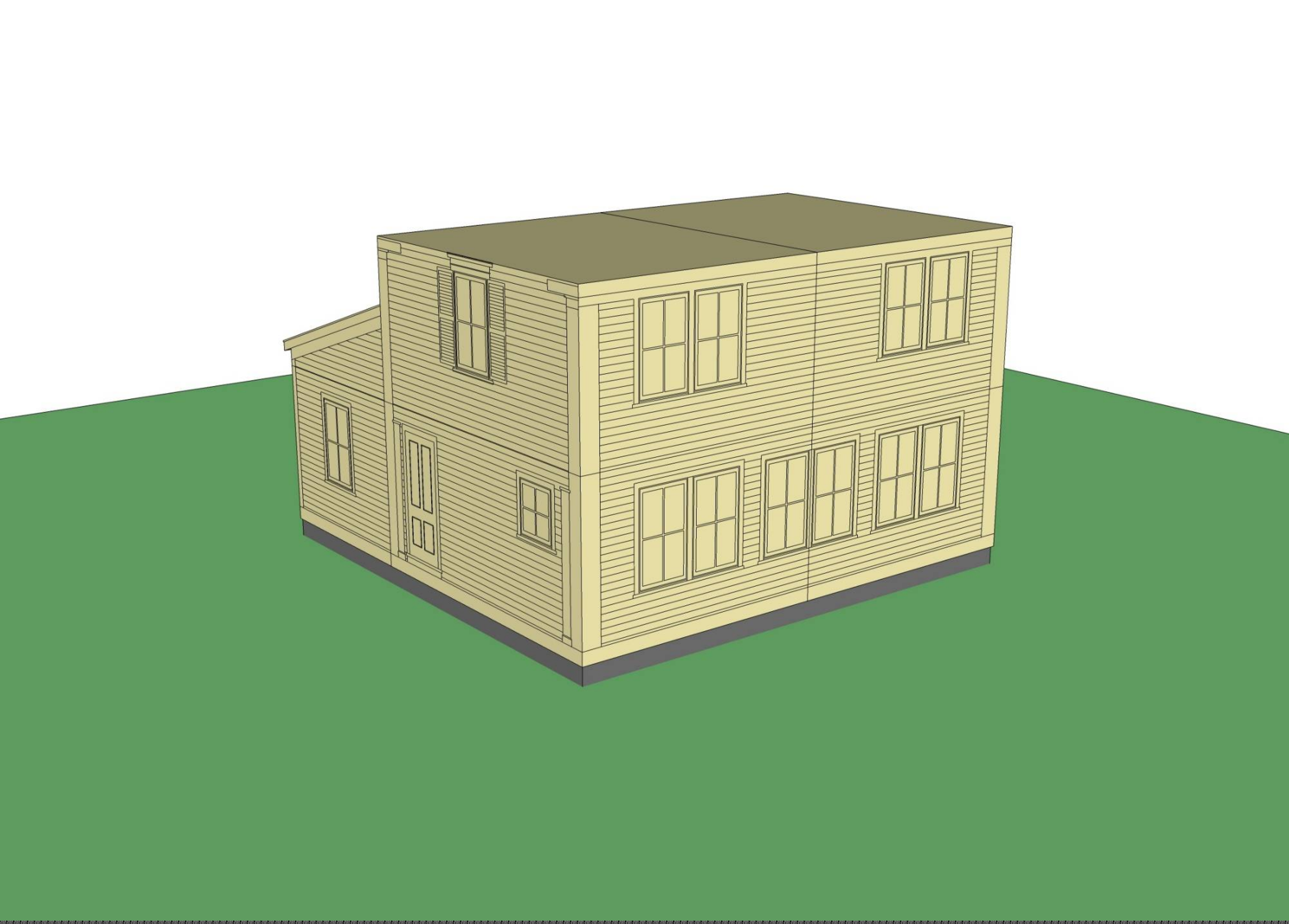


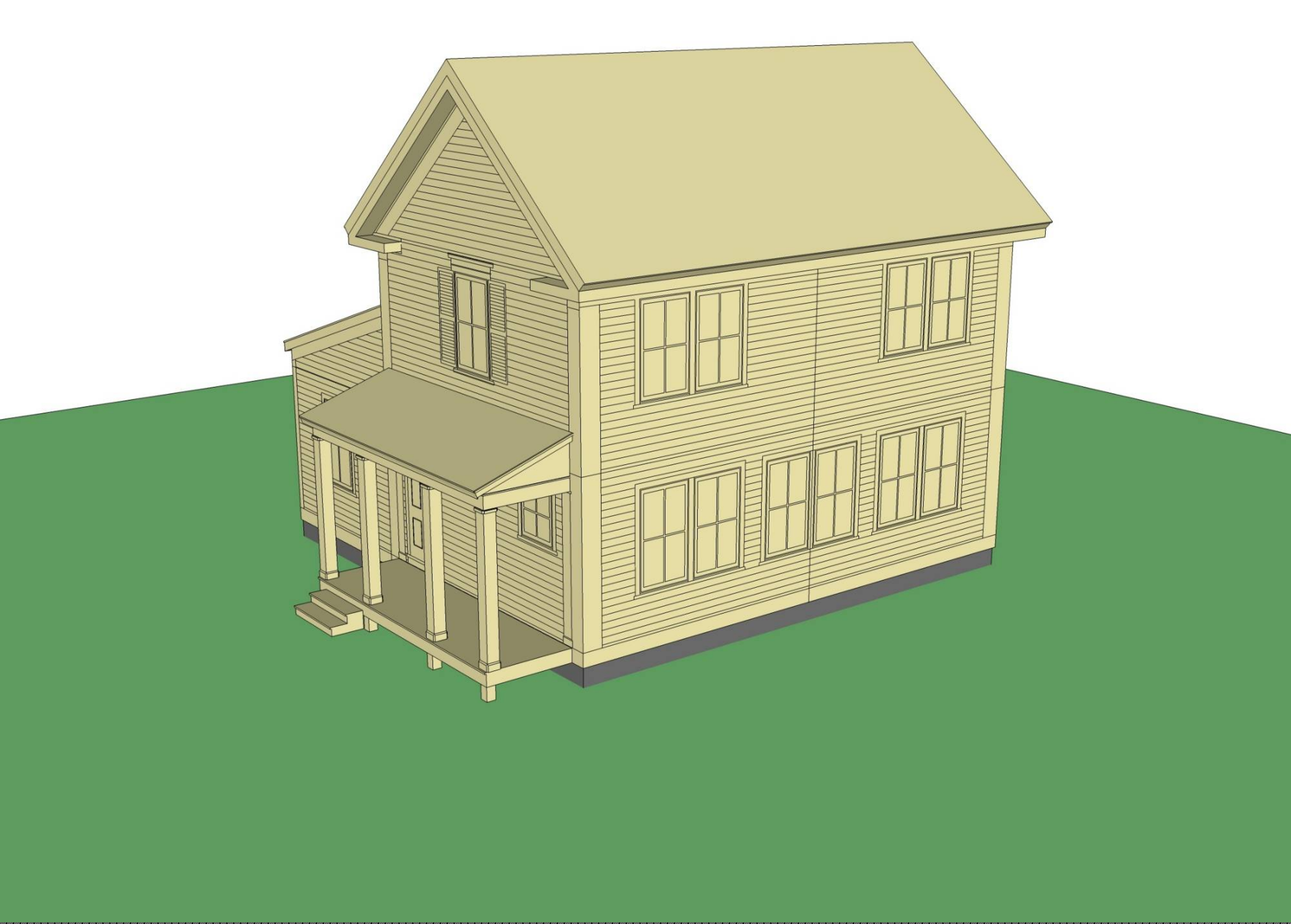












Habitat for Humanity Passive House HVAC System

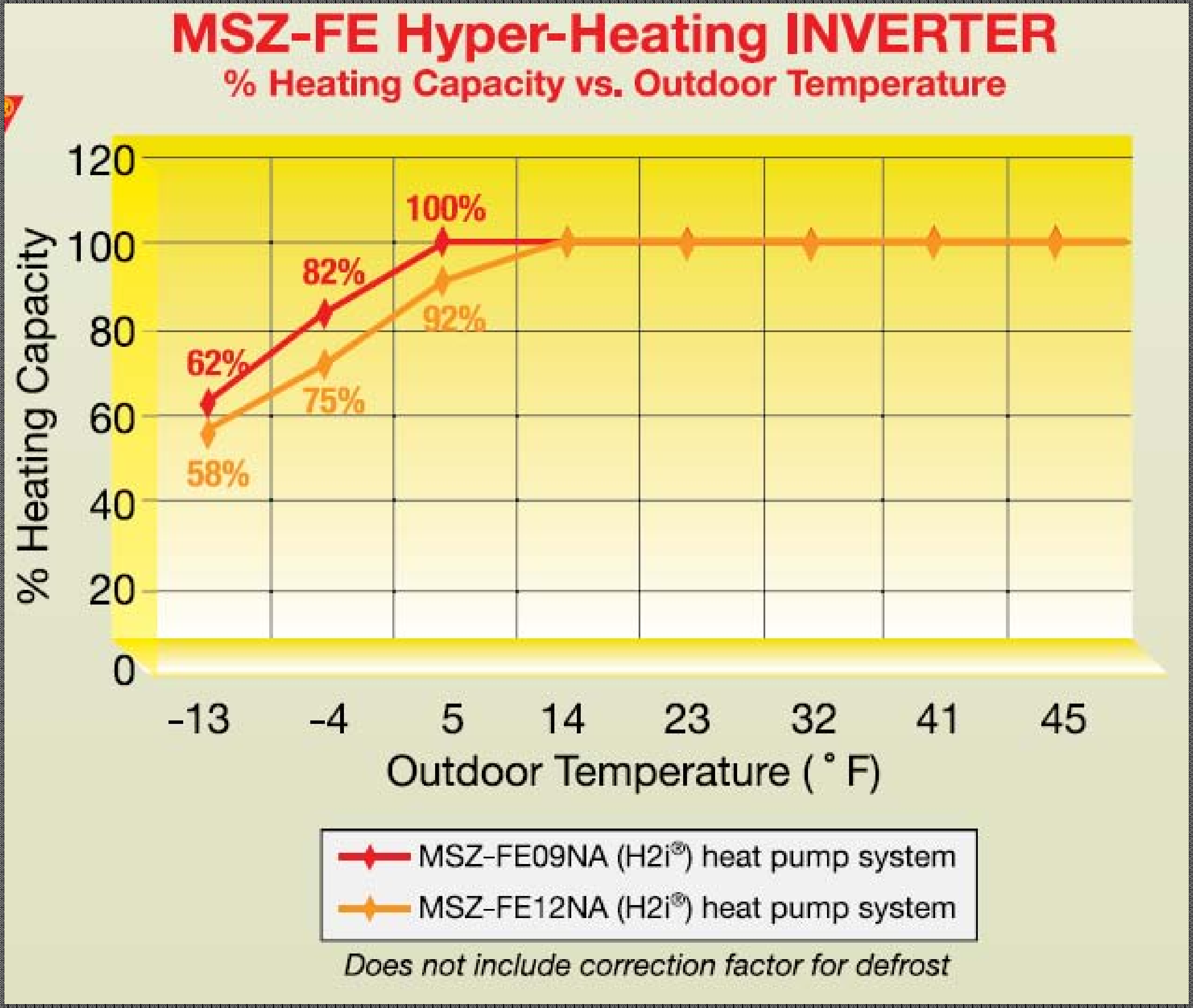
Air Source Heat Pump:
Mitsubishi Hyper-heat MSZ-MUZ FE12

HRV:
Zehnder ComfoAir 350

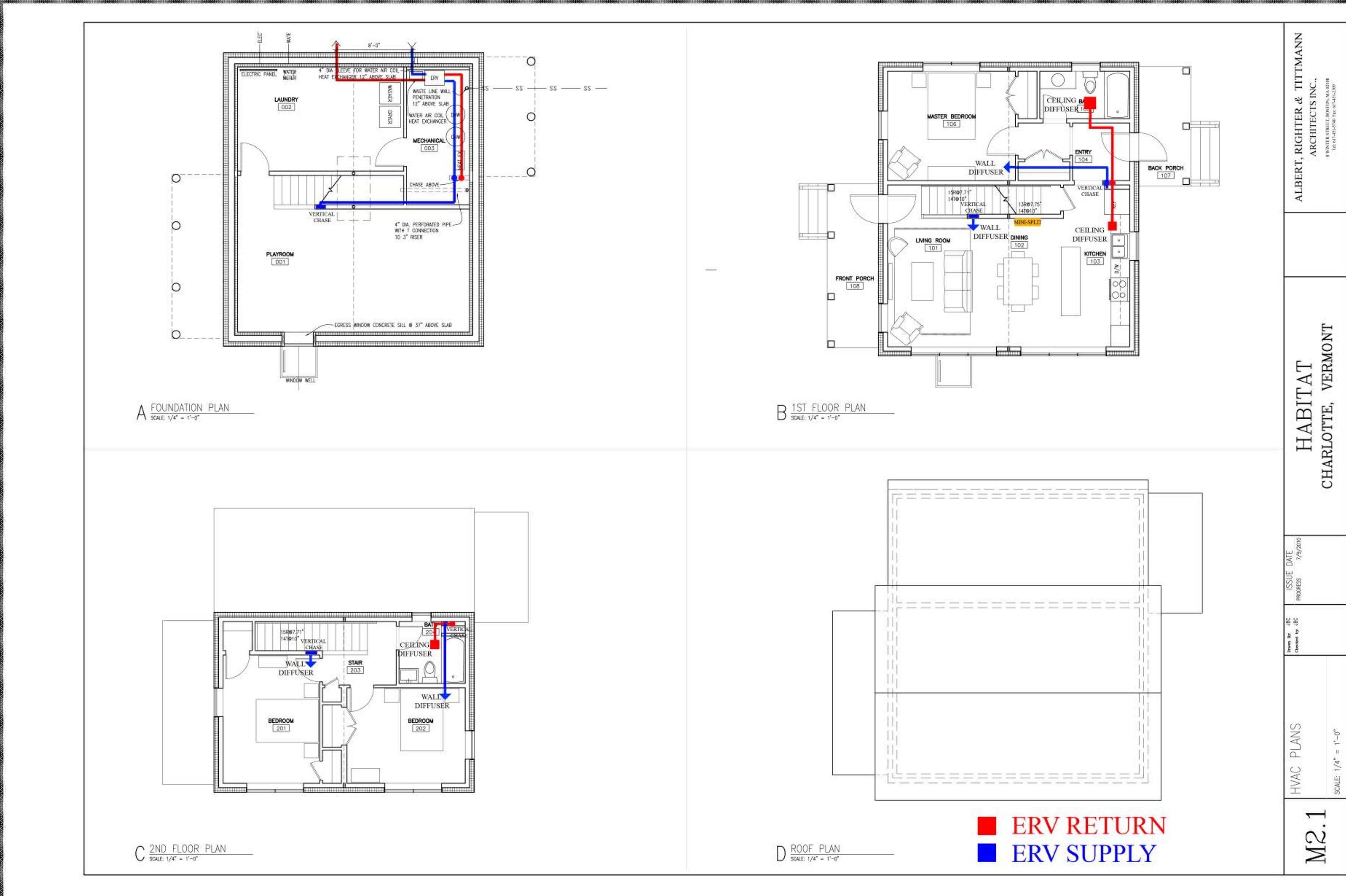
Soil heat exchange system:
Two 125' loops of 1" pex around the base of the footings filled with water/glycol mix & tied to Laing 30W AC Pump & water-to-air coil made by Zehnder (~40F Temp Rise)

Solar Hot Water:
Sunward Solar water heating system mounted on roof with 40g electric hot water heater as back-up

Air-to-Air Heat Pump Performance



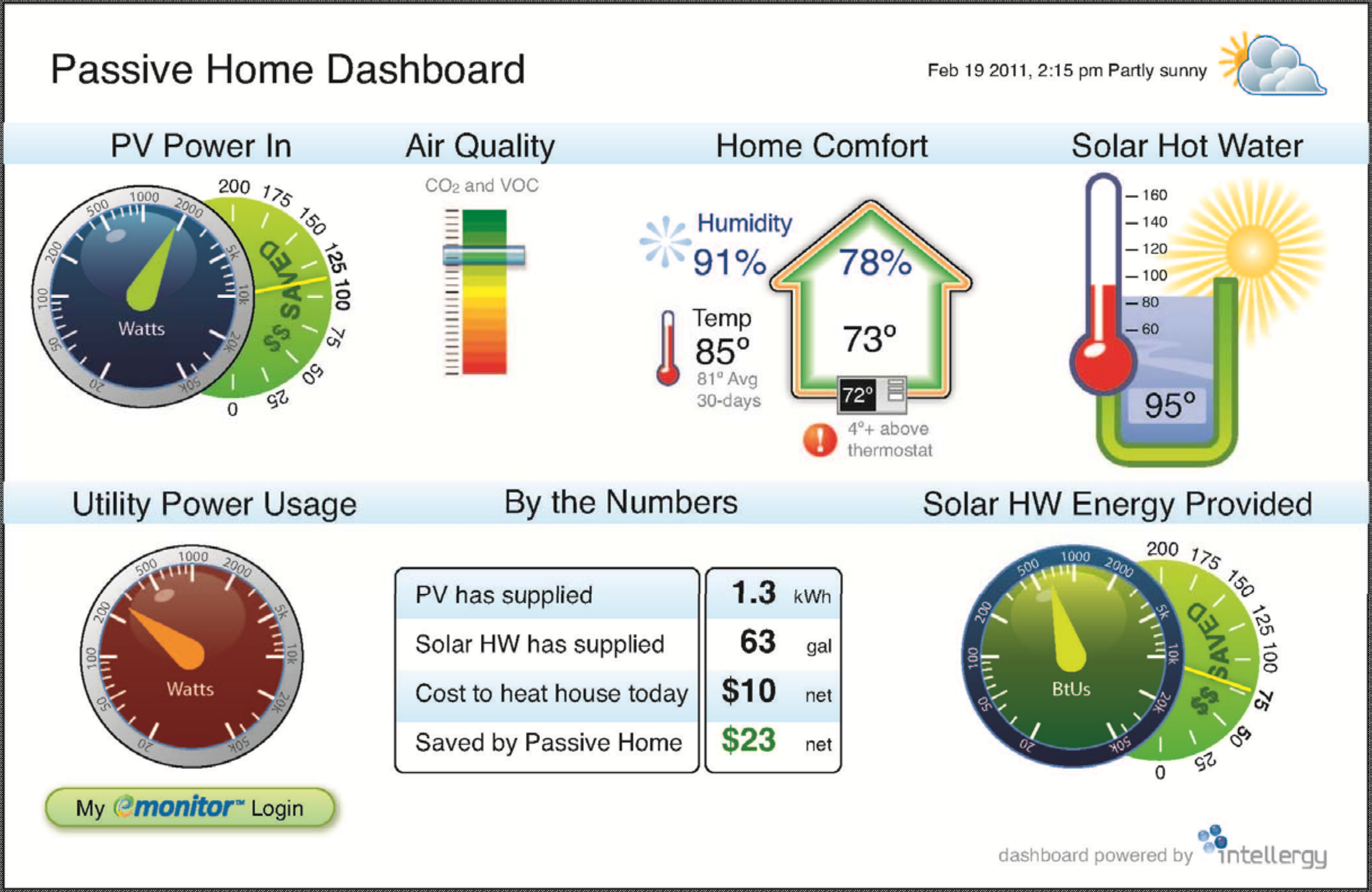
Duct Design



A FOUNDATION PLAN
SCALE: 1/4" = 1'-0"
LAUNDRY 002
MECHANICAL 003
PLAYROOM 001
ERV
VERTICAL CHASE
WINDOW WELL
B 1ST FLOOR PLAN
SCALE: 1/4" = 1'-0"
MASTER BEDROOM 106
CEILING DIFFUSER
WALL DIFFUSER
ENTRY 104
BACK PORCH 107
VERTICAL CHASE
MINI-SPLIT
LIVING ROOM 101
DINING 102
KITCHEN 103
FRONT PORCH 108
C 2ND FLOOR PLAN
SCALE: 1/4" = 1'-0"
STAIR 203
BEDROOM 201
BEDROOM 202
D ROOF PLAN
SCALE: 1/4" = 1'-0"
ERV RETURN
ERV SUPPLY
ALBERT, RIGHTER & TITTMANN ARCHITECTS INC.,
HABITAT
CHARLOTTE, VERMONT
HVAC PLANS
M2.1

Post-Construction Performance Monitoring

Post-Construction Performance Monitoring



GETTING TO PASSIVE HOUSE in VERMONT

Albert, Righter, & Tittmann Architects & Vermont Energy Investment Corporation

Appliances

Refrigerator

	Brand	Model	Volume (ft3)	Configuration	Ice?	KWH / Year	Federal std.	% Less Energy
	Whirlpool	W9RXXMFW*0*	18.92	Top Freezer	No	343	492	30%

Dishwasher

	Brand	Model	Size	KWH / Year	Gallons / Cycle	Energy Factor
	Whirlpool	GU3100XTV*	Standard	270	4.8	0.82

Clothes Washer & Dryer

Bosch
WTE86300US
Axxis
Condenser Dryer

Brand	**Model**	**Type**	**Volume (ft3)**	**KWH/ Year**	**MEF Energy**	**Water Factor**
Bosch	WFVC844*UC	Front Load	3.31	130	2.55	3.5

PHPP Model Verification Page

Microsoft Excel - Habitat PHPP 20100714 Thermotech.xls

Number of Dwelling Units:	1		Interior Temperature:	68.0 °F
Gross Enclosed Volume V_e:	23155 ft³		Internal Heat Gains:	0.7 BTU/hr.ft²
Number of Occupants:	3.9			

Type of Values Use

Planned Number: 4

Specific Demands with Reference to the Treated Floor Area

Treated Floor Area: 1487 ft²

	Applied:	Monthly Method	PH Certificate:	Fulfilled?
Specific Space Heat Demand:	4.49	kBTU/(ft²yr)	4.75 kBTU/(ft²yr)	Yes
Pressurization Test Result:	0.6	ACH_{50}	0.6 ACH_{50}	Yes
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):	25.7	kBTU/(ft²yr)	38.0 kBTU/(ft²yr)	Yes
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):	11	kBTU/(ft²yr)		
Specific Primary Energy Demand Energy Conservation by Solar Electricity:	10	kBTU/(ft²yr)		
Heating Load:	5	BTU/(ft²hr)		
Frequency of Overheating:		%	over 77.0 °F	
Specific Useful Cooling Energy Demand:	2	kBTU/(ft²yr)	4.75 kBTU/(ft²yr)	Yes
Cooling Load:	5	BTU/(ft²hr)		

Verification:

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PHPP Model Window Page

Passive House Planning

REDUCTION FACTOR SOLAR RADIATION, WINDOW U-VALUE

Building: Charlotte Habitat for Humanity

Annual Heat Demand: 4.16 kBTU/(ft²yr)

Heating Degree Days: 7260

Climate: Burlington, Vermont

Window Area Orientation	Global Radiation (Cardinal Points)	Shading	Dirt	Non-Perpendicular Incident Radiation	Glazing Fraction	SHGC	Reduction Factor for Solar Radiation	Window Area	Window U-Value	Window R-Value	Glazing Area	Glazing Area as % of Treated Floor Area	Average Global Radiation	Transmission Losses	Heat Gains Solar Radiation
maximum:	kBTU/ft²yr	0.75	0.95	0.85				ft²	BTU/hr.ft².F	hr.ft².F/BTU	ft²		kBTU/ft²yr	kBTU/yr	kBTU/yr
North	38	0.91	0.95	0.85	0.645	0.64	0.47	21.00	0.24	4.16	13.5	0.9%	38	879	243
East	99	0.95	0.95	0.85	0.746	0.64	0.57	22.17	0.22	4.53	16.5	1.1%	99	853	805
South	205	0.96	0.95	0.85	0.765	0.64	0.59	152.17	0.20	4.89	116.5	7.8%	205	5427	11827
West	106	0.95	0.95	0.85	0.754	0.64	0.58	36.33	0.22	4.57	27.4	1.8%	106	1385	1425
Horizontal	156	0.75	0.95	0.85	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.0%	156	0	0
Total or Average Value for All Windows.						0.64	0.58	231.67	0.21	4.72	173.94			8545	14300

Description	Nr	Deviation from North	Angle of Inclination from the Horizontal	Orientation	Window Rough Openings: Width	Window Rough Openings: Height	Installed: in Area in the Areas worksheet	Nr.	Glazing: Select glazing from the WinType worksheet	Nr.
		Degrees	Degrees		in	in	Select:		Select:	
N1W1A	1	0	90	North	36.00	24.00	North Wall	1	Thermotech 32	2
N1W2B	2	0	90	North	36.00	24.00	North Wall	1	Thermotech 32	2
N2W1A	3	0	90	North	24.00	18.00	North Wall	1	Thermotech 32	2
S1W1A	4	180	90	South	34.00	60.00	South Wall	2	Thermotech 32	2
S1W2B	5	180	90	South	34.00	60.00	South Wall	2	Thermotech 32	2
S1W3C	6	180	90	South	34.00	60.00	South Wall	2	Thermotech 32	2
S1W4D	7	180	90	South	34.00	60.00	South Wall	2	Thermotech 32	2
S1W5E	8	180	90	South	34.00	60.00	South Wall	2	Thermotech 32	2
S2W1A	9	180	90	South	34.00	60.00	South Wall	2	Thermotech 32	2
S2W2B	10	180	90	South	34.00	60.00	South Wall	2	Thermotech 32	2

Description	Frame: Select window from the WinType worksheet	Nr.	SHGC: Perpendicular Radiation	U-Value: Glazing	U-Value: Frames	R-Value: Glazing	R-Value: Frames	Window Frame Dimensions: Width - Left	Width - Right	Width - Below	Width - Above	Installation: Left 1/0	Right 1/0	Sill 1/0
	Select:		-	BTU/hr.ft².F	BTU/hr.ft².F	hr.ft².F/BTU	hr.ft².F/BTU	in	in	in	in			
N1W1A	Thermotech 32	2	0.64	0.16	0.16	6.29	6.10	2.68	2.68	2.68	2.68	1	1	1
N1W2B	Thermotech 32	2	0.64	0.16	0.16	6.29	6.10	2.68	2.68	2.68	2.68	1	0	1
N2W1A	Thermotech 32	2	0.64	0.16	0.16	6.29	6.10	2.68	2.68	2.68	2.68	1	1	1
S1W1A	Thermotech 32	2	0.64	0.16	0.16	6.29	6.10	2.68	2.68	2.68	2.68	0	1	1
S1W2B	Thermotech 32	2	0.64	0.16	0.16	6.29	6.10	2.68	2.68	2.68	2.68	0	0	1
S1W3C	Thermotech 32	2	0.64	0.16	0.16	6.29	6.10	2.68	2.68	2.68	2.68	1	0	1
S1W4D	Thermotech 32	2	0.64	0.16	0.16	6.29	6.10	2.68	2.68	2.68	2.68	0	1	1
S1W5E	Thermotech 32	2	0.64	0.16	0.16	6.29	6.10	2.68	2.68	2.68	2.68	0	0	1
S2W1A	Thermotech 32	2	0.64	0.16	0.16	6.29	6.10	2.68	2.68	2.68	2.68	0	1	1
S2W2B	Thermotech 32	2	0.64	0.16	0.16	6.29	6.10	2.68	2.68	2.68	2.68	1	0	1

Intro / Conversion / Verification / cTFA / Areas / R-List / R-Values / Ground / WinEntry / Window / WinType / Shading / Ventilation / Annual Heat Demand / Monthly / Heat Load / Summer / Shading-S / Su

PHPP Model Heat Demand

		Q_T kBTU/yr		Q_V kBTU/yr		Reduction Factor Night/Weekend Saving		kBTU/yr	kBTU/(ft²yr)
Total Heat Losses Q_L	(	19984	+	3593	)	1.0	=	23577	15.86

Orientation of the Area	Reduction Factor See Windows Sheet		SHGC (perp. radiation)		Area ft²		Radiation HP kBTU/(ft²yr)		kBTU/yr
1. North	0.47	*	0.64	*	21.00	*	38	=	243
2. East	0.57	*	0.64	*	22.17	*	99	=	805
3. South	0.59	*	0.64	*	152.17	*	205	=	11827
4. West	0.58	*	0.64	*	36.33	*	106	=	1425
5. Horizontal	0.40	*	0.00	*	0.00	*	156	=	0

Available Solar Heat Gains Q_S — Total: 14300 kBTU/yr; 9.62 kBTU/(ft²yr)

	kh/d		Length Heat. Period d/a		Spec. Power q_I BTU/hr.ft²		A_{TFA} ft²		kBTU/yr	kBTU/(ft²yr)
Internal Heat Gains Q_I	0.024	*	205	*	0.67	*	1487	=	4859	3.27

			kBTU/yr	kBTU/(ft²yr)
Free Heat Q_F	$Q_S + Q_I$	=	19159	12.88
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.81	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	91%	
Heat Gains Q_G	$\eta_G * Q_F$	=	17372	11.68
Annual Heat Demand Q_H	$Q_L - Q_G$	=	6205	**4.17**

Limiting Value: 4.75 kBTU/(ft²yr) — **Requirement met?** (Yes/No): **Yes**

PHPP Model Heating Load

Total Room Risk

Appraisal and Advice

Total Heating Load P_L

		P_L 1		P_L 2
		BTU/hr		BTU/hr
$P_T + P_V$	=	11108	or	10835

	Orientation the Area	Area ft²		SHGC (perp. radiation)		Reduction Factor (see Windows worksheet)		Radiation 1 BTU/hr.ft²		Radiation 2 BTU/hr.ft²		P_S 1 BTU/hr		P_S 2 BTU/hr
1.	North	22	*	0.6	*	0.5	*	6	or	6	=	42	or	42
2.	East	23	*	0.6	*	0.6	*	14	or	8	=	122	or	67
3.	South	161	*	0.6	*	0.6	*	37	or	14	=	2256	or	884
4.	West	38	*	0.6	*	0.6	*	17	or	6	=	244	or	88
5.	Horizontal	0	*	0.0	*	0.4	*	22	or	11	=	0	or	0

Solar Heat Gain, P_S

Total	=	2665	or	1082

Internal Heat Gains P_I

Spec. Power BTU/hr.ft²		A_{TFA} ft²		P_I 1 BTU/hr		P_I 2 BTU/hr
0.51	*	1487	=	754	or	754

Heat Gains P_G

		P_G 1		P_G 2
		BTU/hr		BTU/hr
$P_S + P_I$	=	3419	or	1836
$P_L - P_G$	=	7689	or	8999

Heating Load P_H

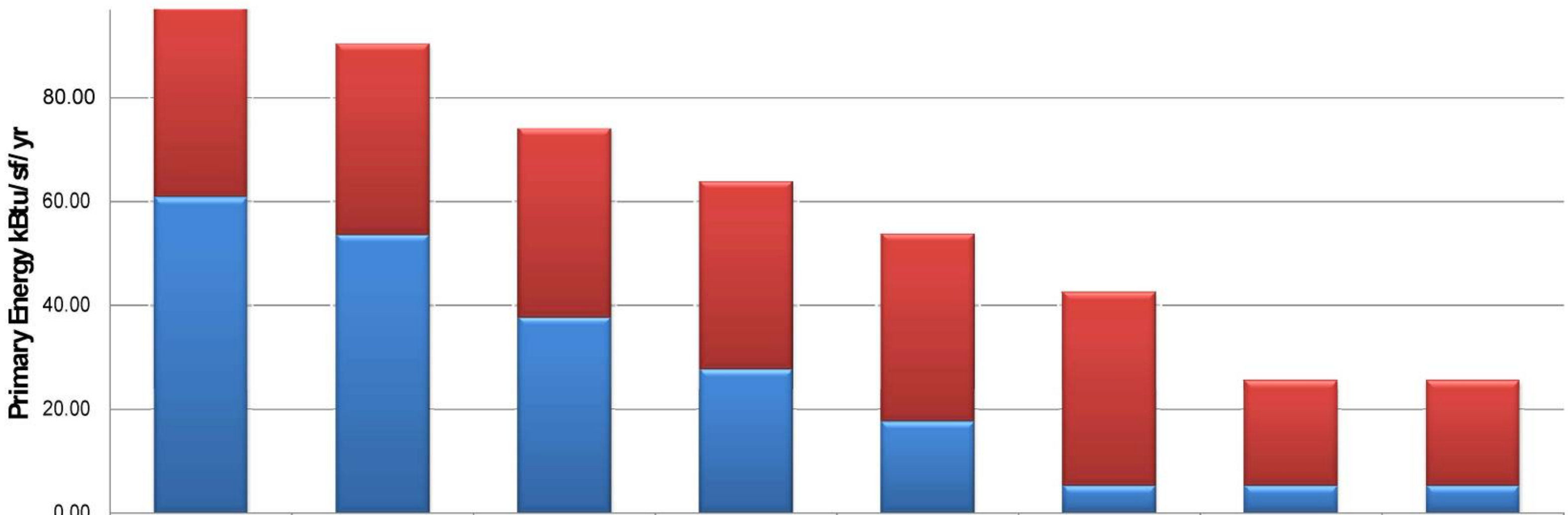
= **8999** BTU/hr

Specific Heating Load P_H / A_{TFA}

= **6.1** BTU/hr.ft²

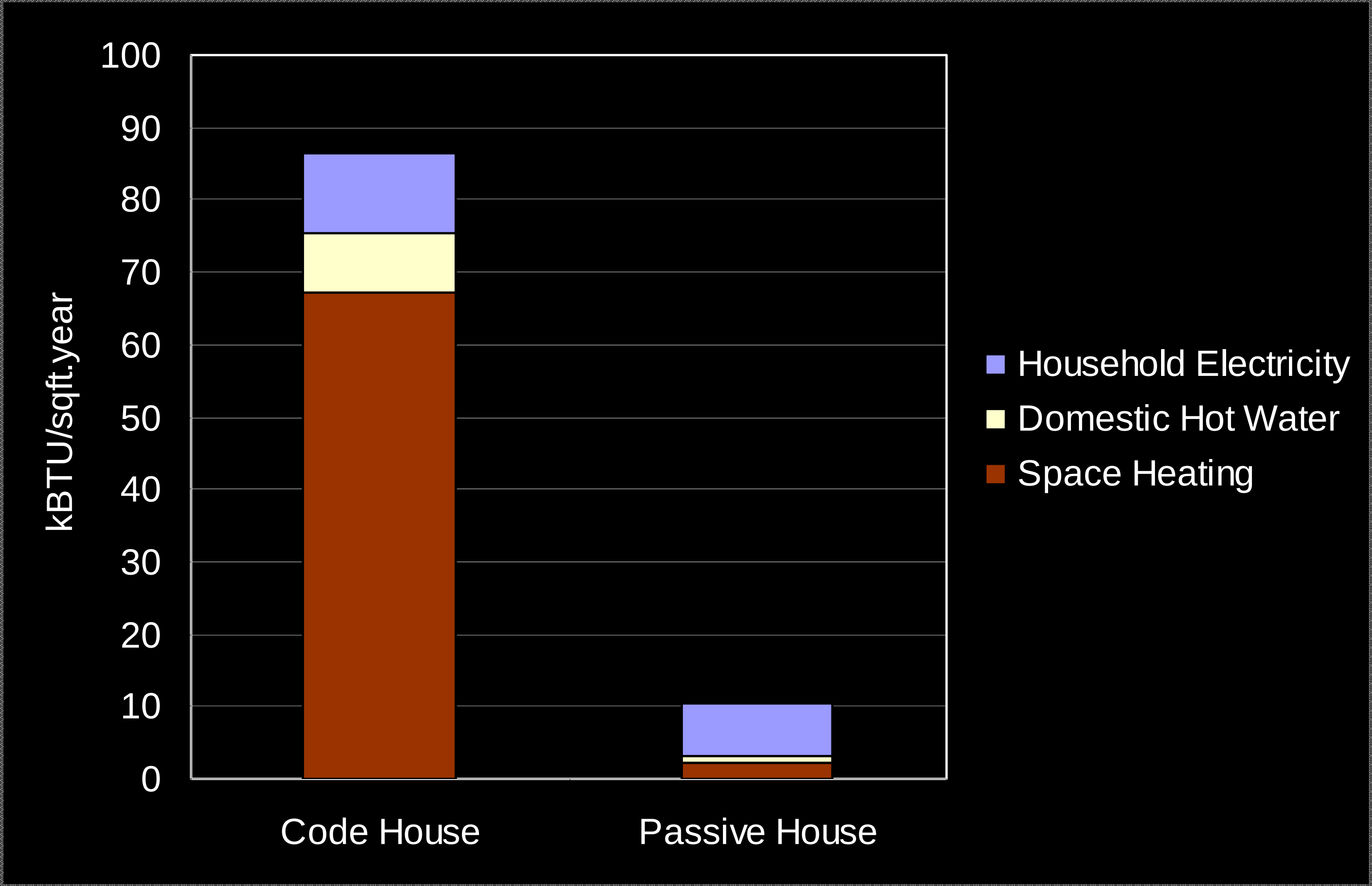
Input Max. Supply Air Temperature	126	°F			°F	°F
Max. Supply Air Temperature $\vartheta_{Supply,Max}$	126	°F	Supply Air Temperature Without Heating	$\vartheta_{Supply,Min}$	60	60

Parametric Analysis



	Code	New Massing and Window Location	Thermotech Windows	Eliminate Thermal Bridges	Air Tightness High Eff ERV	PH Insulation with Heat Pump no setback	Solar Hot Water System	Final Passive House
Primary Energy Demand w/o Heat	37.20	36.80	36.40	36.20	36.10	37.20	20.20	20.20
Primary Heat Demand	60.80	53.60	37.70	27.70	17.70	5.30	5.30	5.30

How much energy is used in houses?



Habitat for Humanity Passive House

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