The Passivhaus Standard:

The Next Step for High Performance Schools

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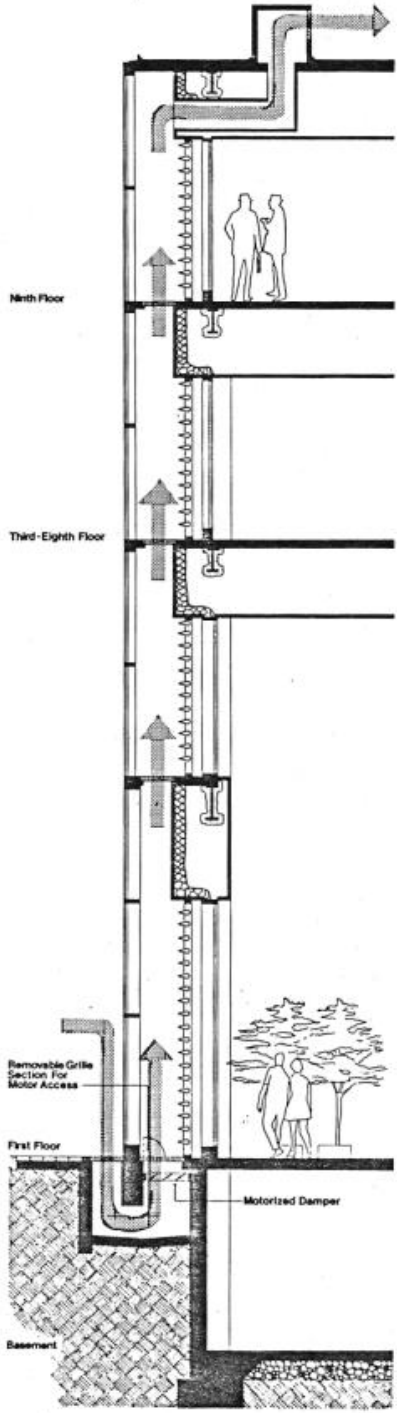
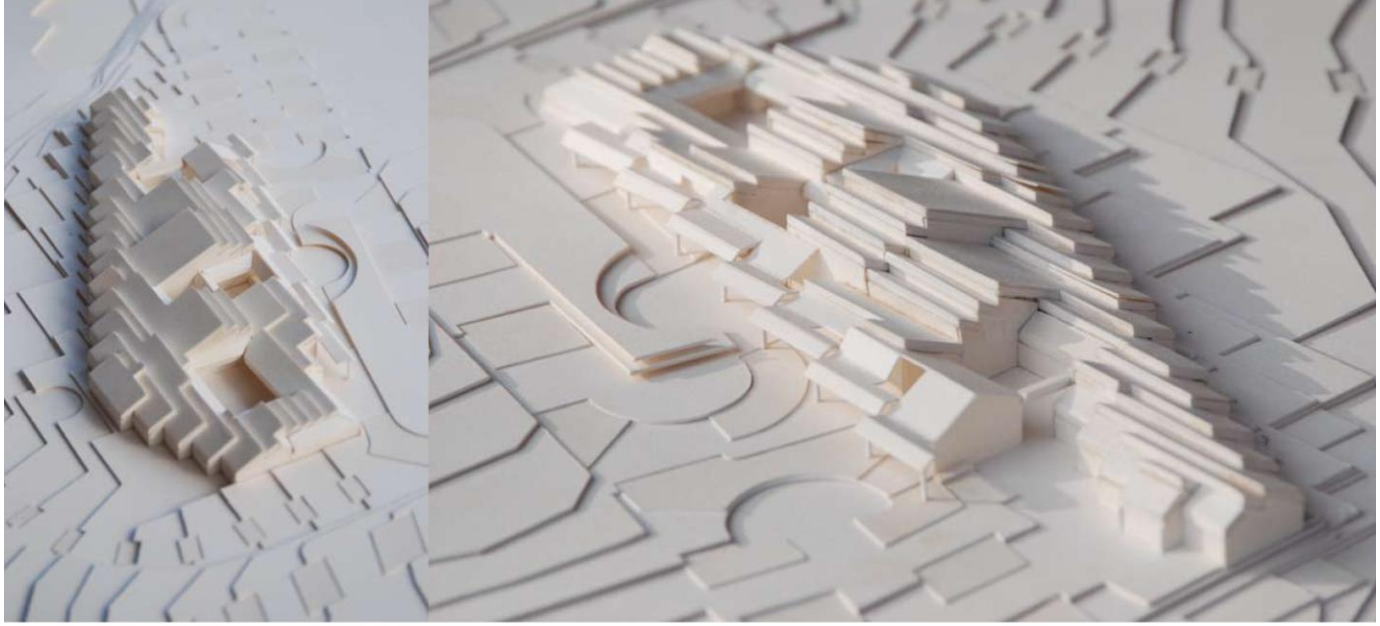
DESIGN STUDIO

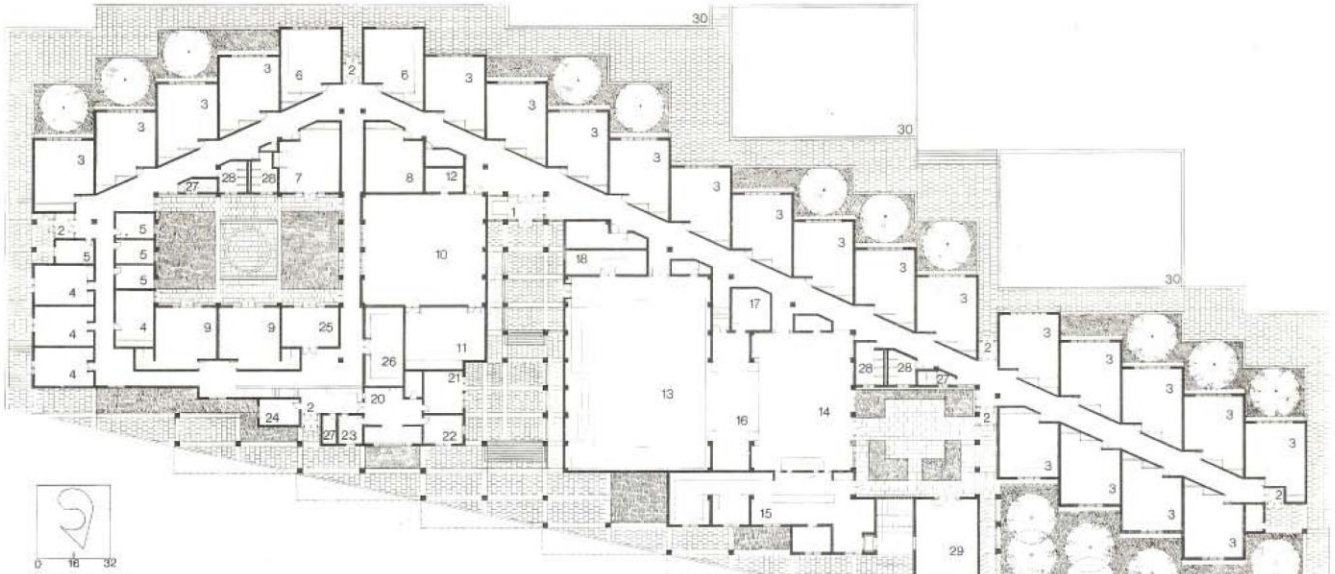
www.cscdesignstudio.com

STRUCTURES
Building with integrity

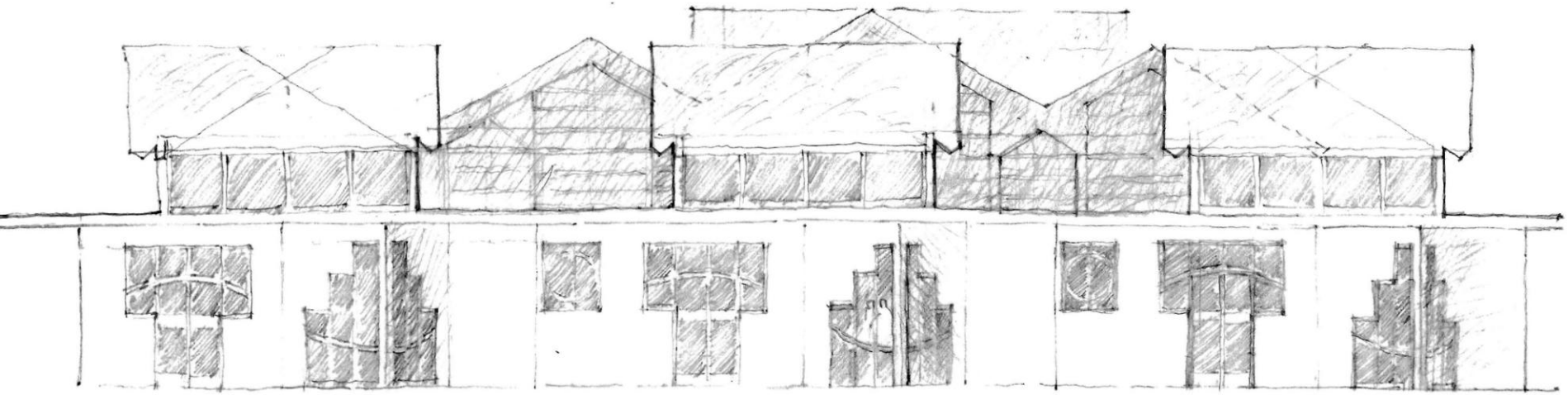
www.stucturesdb.com

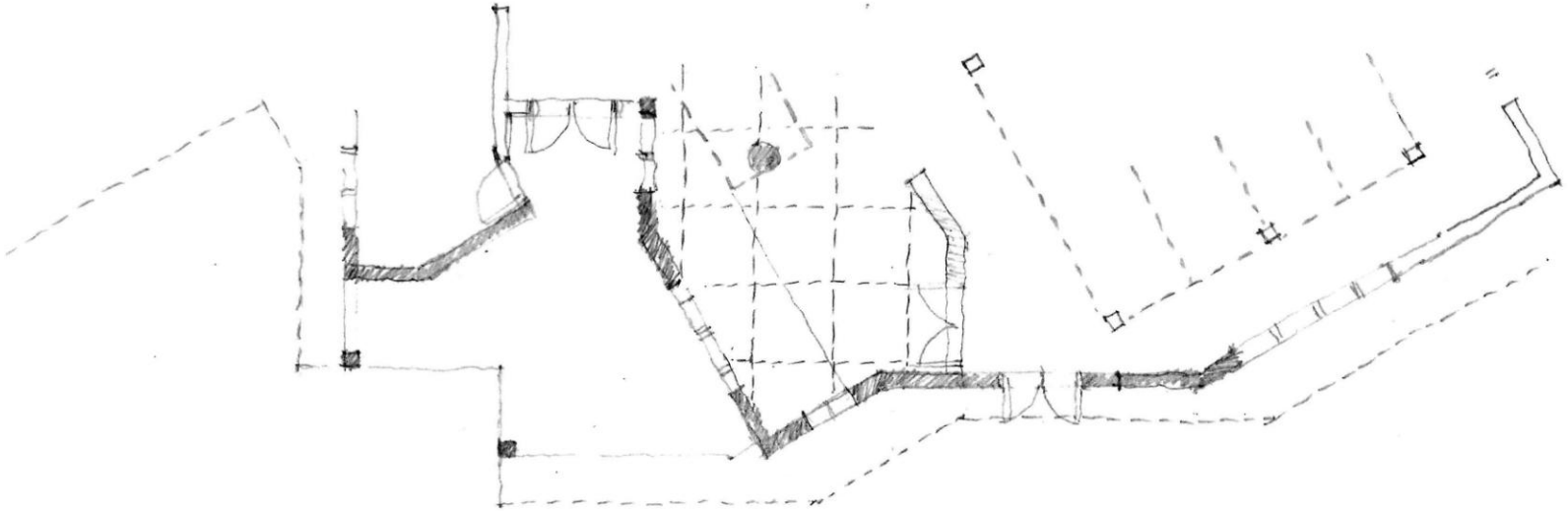

Ninth Floor
Third-Eighth Floor
Removable Grille Section For Motor Access
First Floor
Motorized Damper
Basement

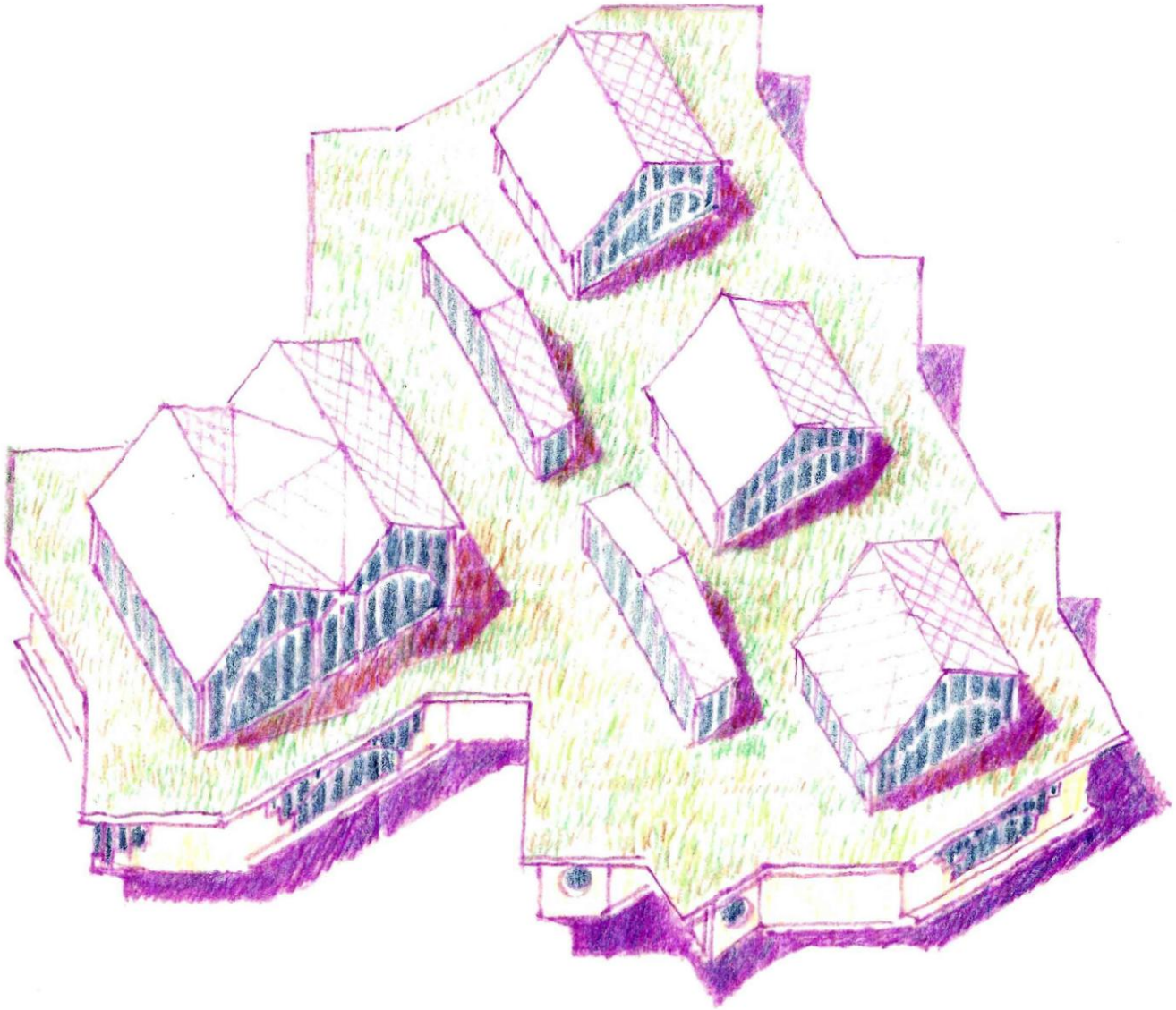




1 main entrance
2 secondary entrance
3 basic classroom
4 special classroom
5 special use classroom
6 music classroom
7 art classroom
8 computer classroom
9 kindergarten classroom
10 library main media room
11 library media equipment
12 librarian
13 gymnasium
14 cafeteria dining
15 kitchen
16 stage
17 stage storage
18 chair storage
19 supply storage
20 administration
21 conference
22 principle
23 health room
24 guidance office
25 teacher's lounge
26 teacher's workroom
27 faculty restroom
28 student restroom
29 mechanical room
30 outdoor playground





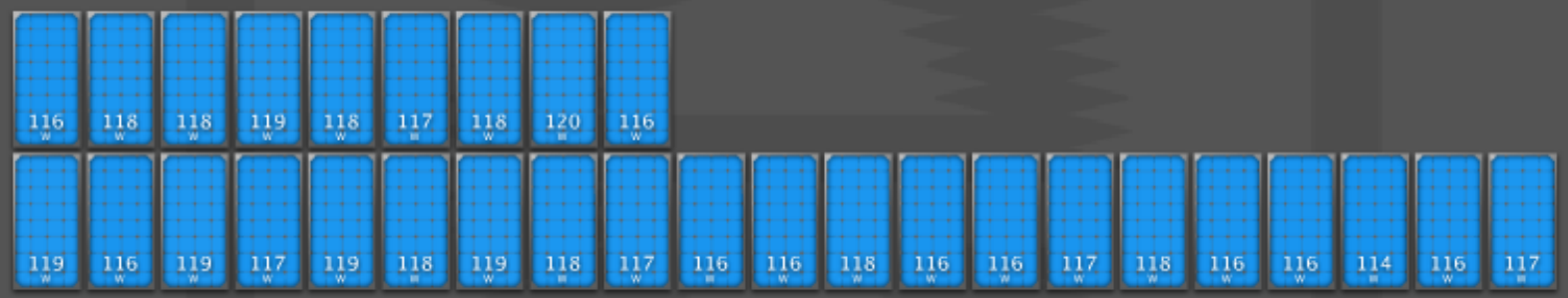


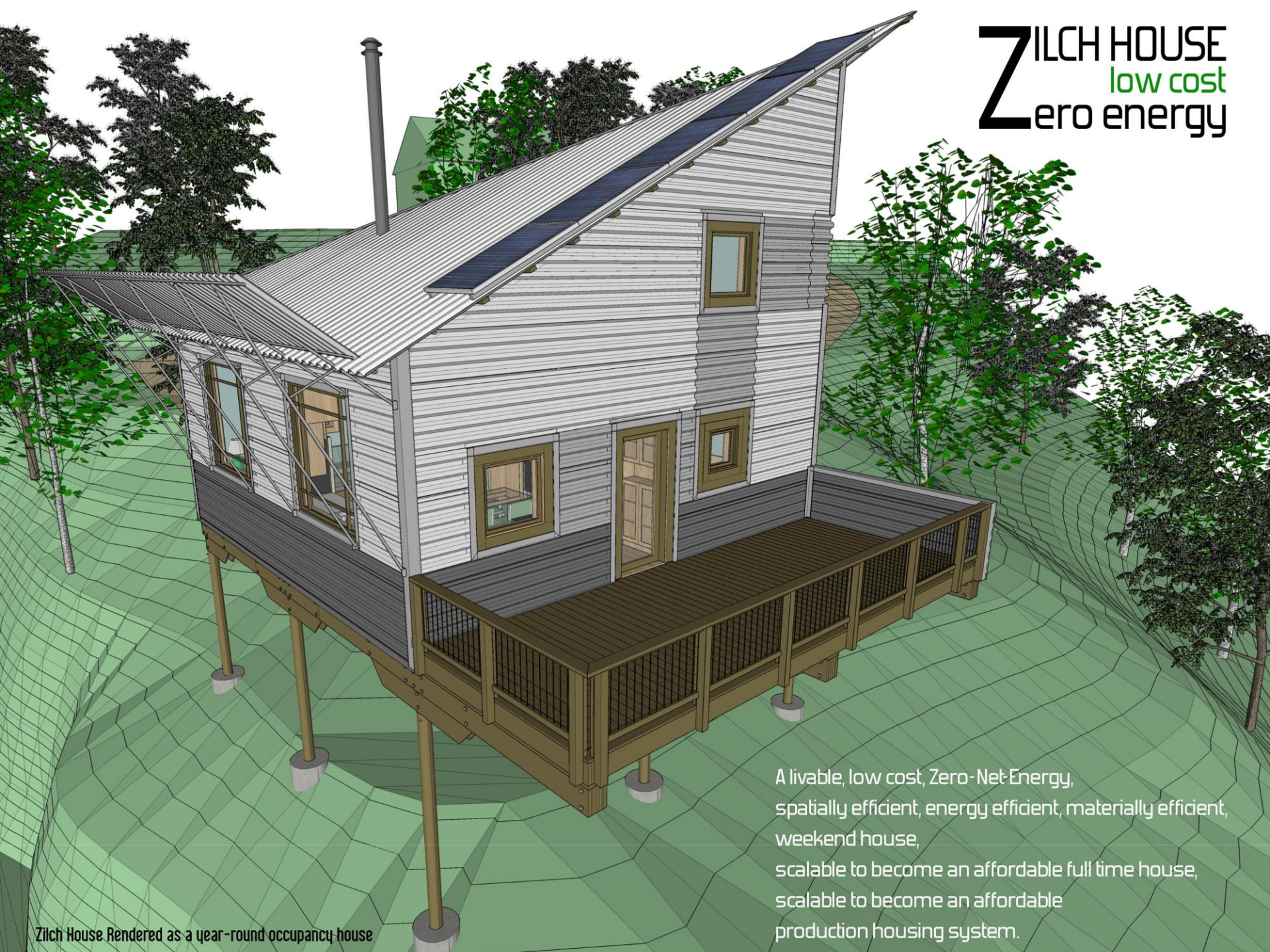
Status	Power Production:	Today's Energy:	Calendar Month:	Lifetime:	Local Weather
no issues	3.5 kW	4.6 kWh	114.2 kWh	1.4 MWh	72 F
	Today's Peak: 3.5 kW				

CSC Design Studio Net-Zero System PV Arrays

Current Power | Today's Energy | Monthly Energy | Lifetime Energy | Time-lapse: | Today's Power | Power Last 7 day

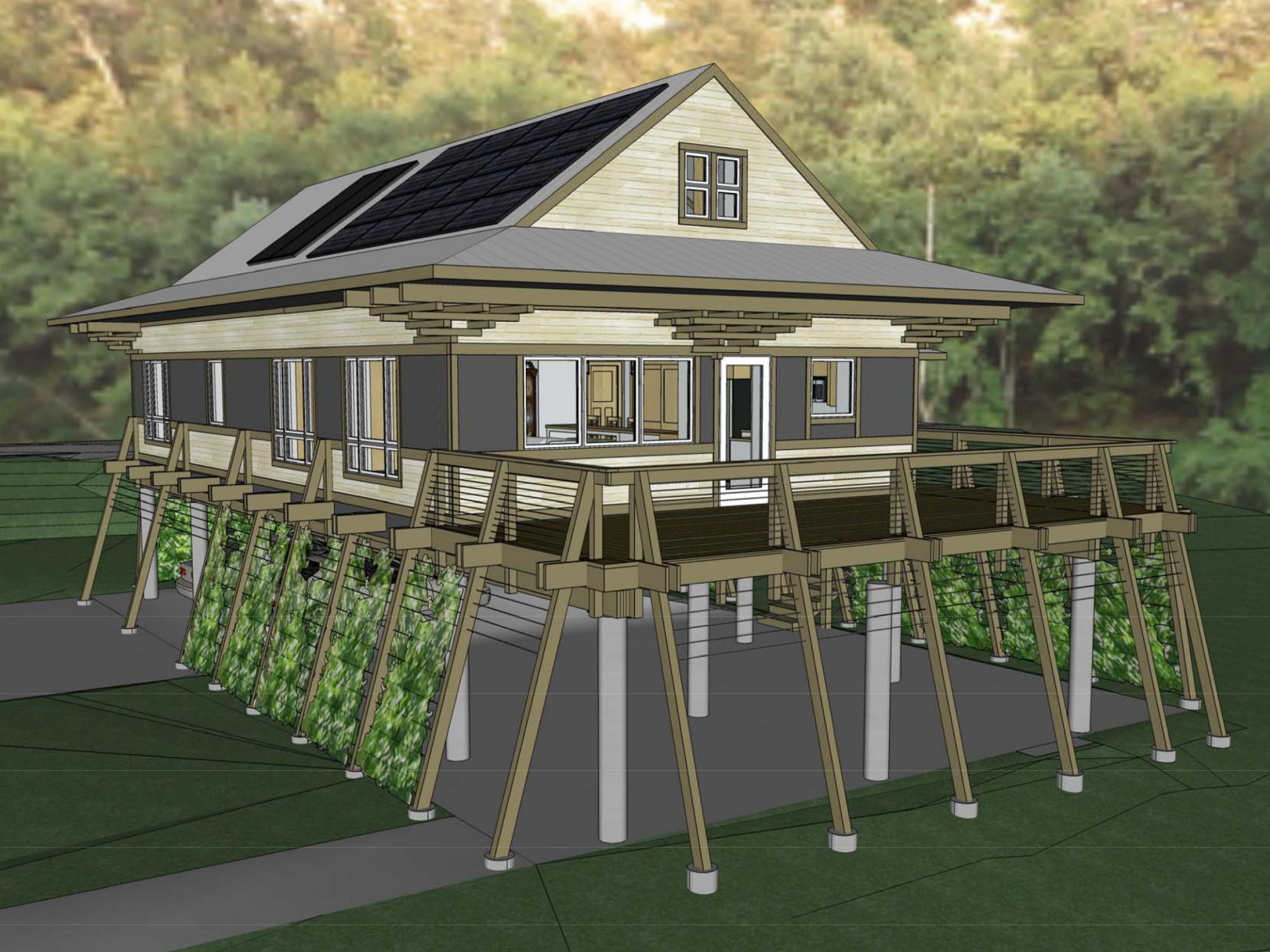
Mon Apr 5 10:55:00 GMT-0400 201





Zilch House Rendered as a year-round occupancy house

3M
All Weather
Flashing Tape 8067
3M
All Weather
Flashing Tape 80



The BioHaus – 2006, MN

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Montessori School Germany

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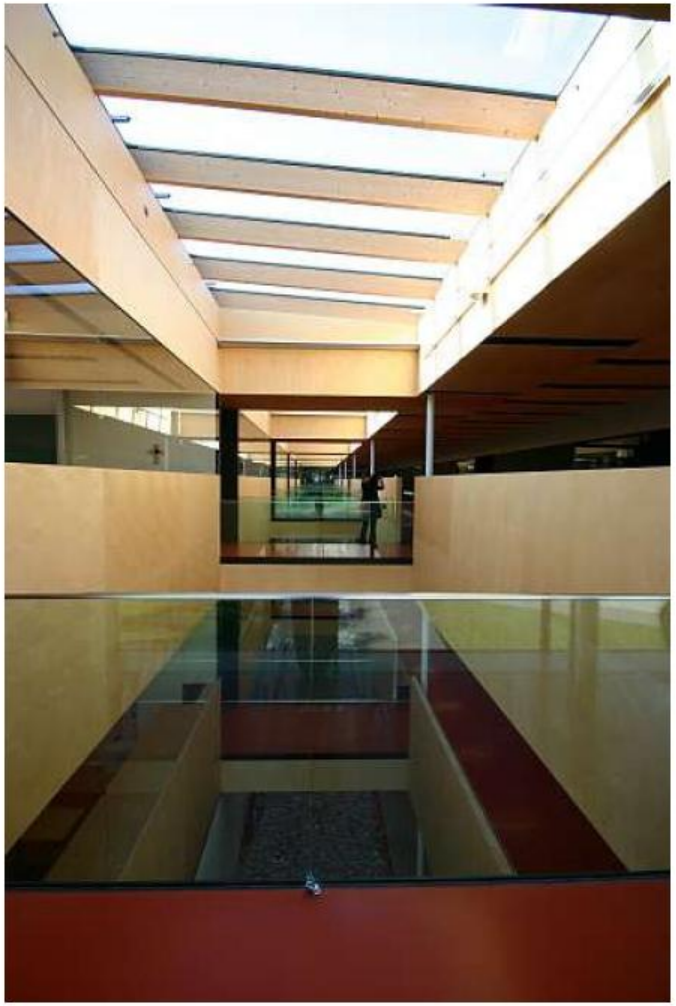

School Vorarlberg Austria, Architects Dietrich | Untertrifaller.

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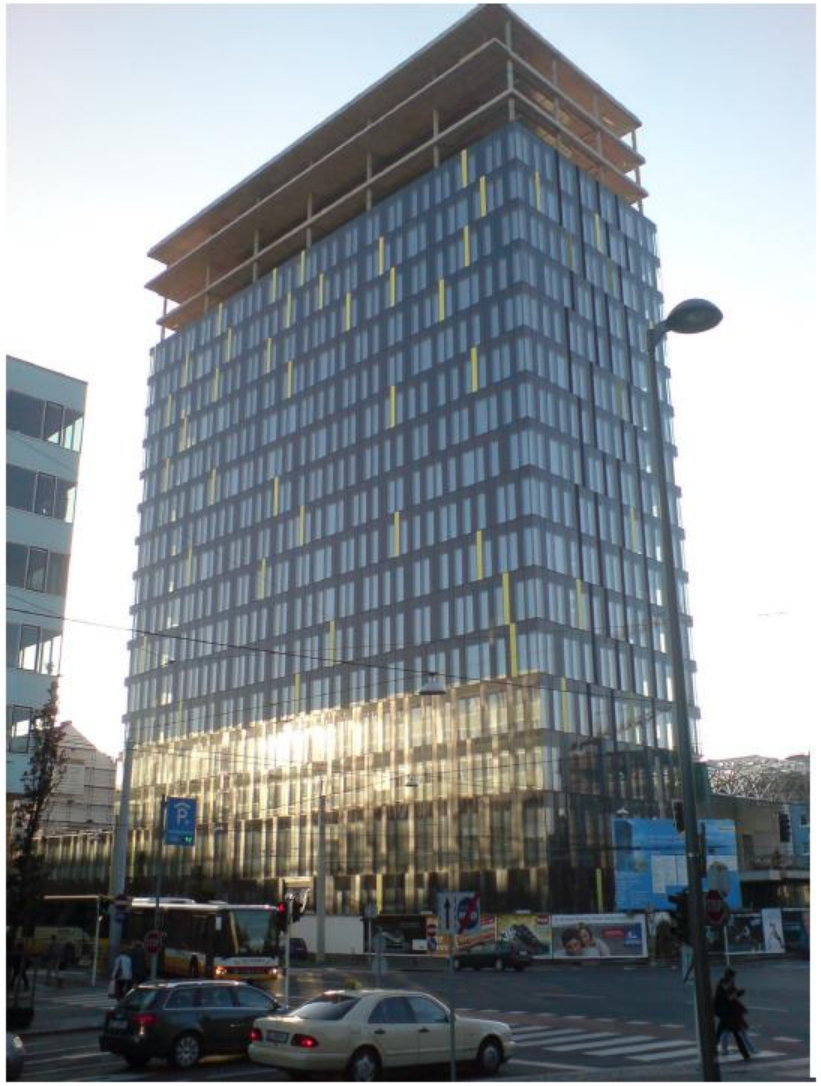

Energie Agentur Oberoesterreich,
75 m tall office tower,
Linz Austria

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Zero Energy Buildings (ZEB) Definitions

- **Net Zero Site Energy:** A site ZEB produces at least as much energy as it uses in a year, when accounted for at the site.
- **Net Zero Source Energy:** A source ZEB produces at least as much energy as it uses in a year, when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site. To calculate a building's total source energy, imported and exported energy is multiplied by the appropriate site-to-source conversion multipliers.
- **Net Zero Energy Costs:** In a cost ZEB, the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.
- **Net Zero Energy Emissions:** A net-zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources.

Source: Zero Energy Buildings: A Critical Look at the Definition--Paul Torcellini, Shanti Pless, and Michael Deru, National Renewable Energy Laboratory, Drury Crawley, U.S. Department of Energy

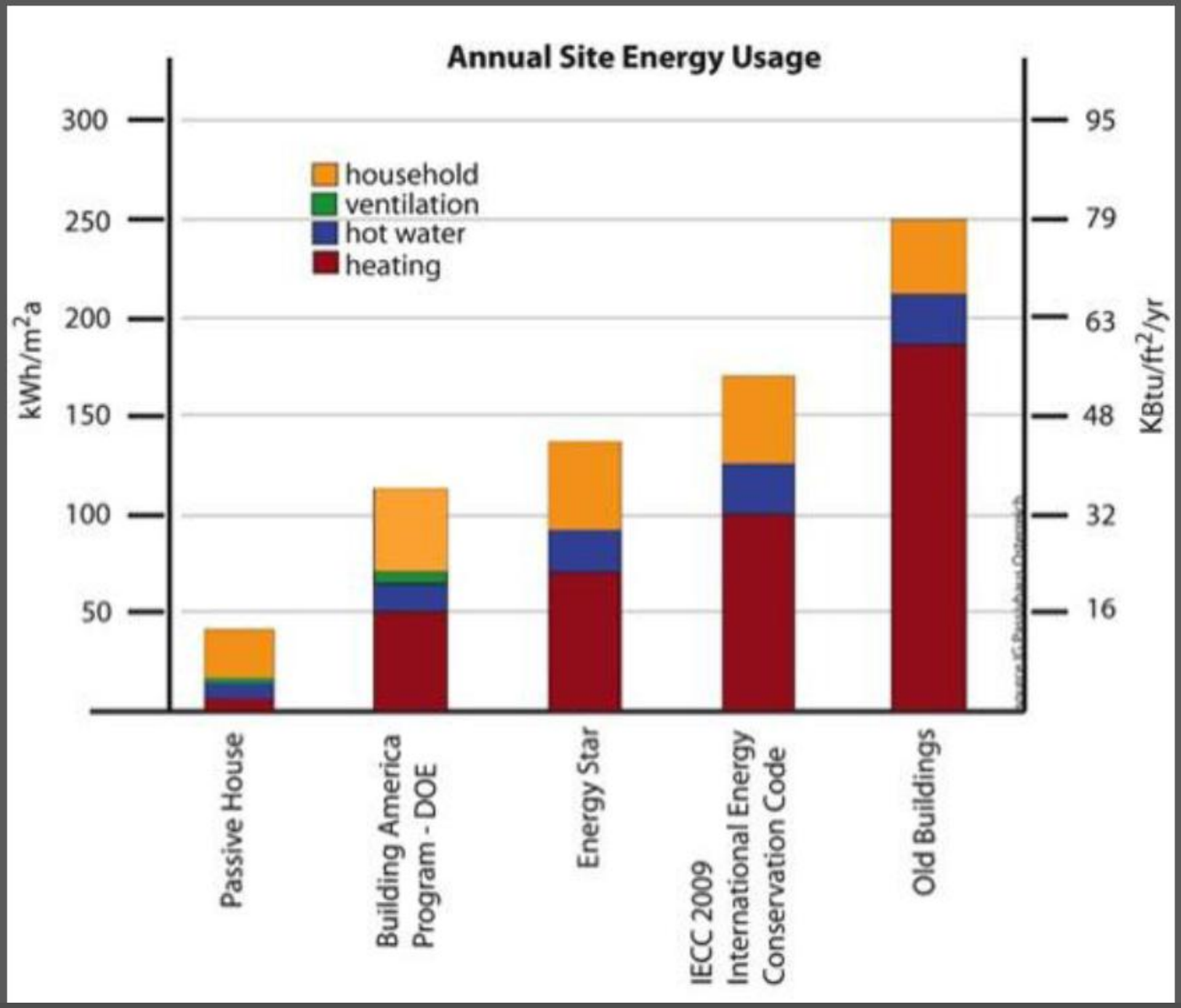
The Passivhaus Standard

- 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: 0.6 ACH @ 50pa

* Square footage referenced to "treated floor area" not gross

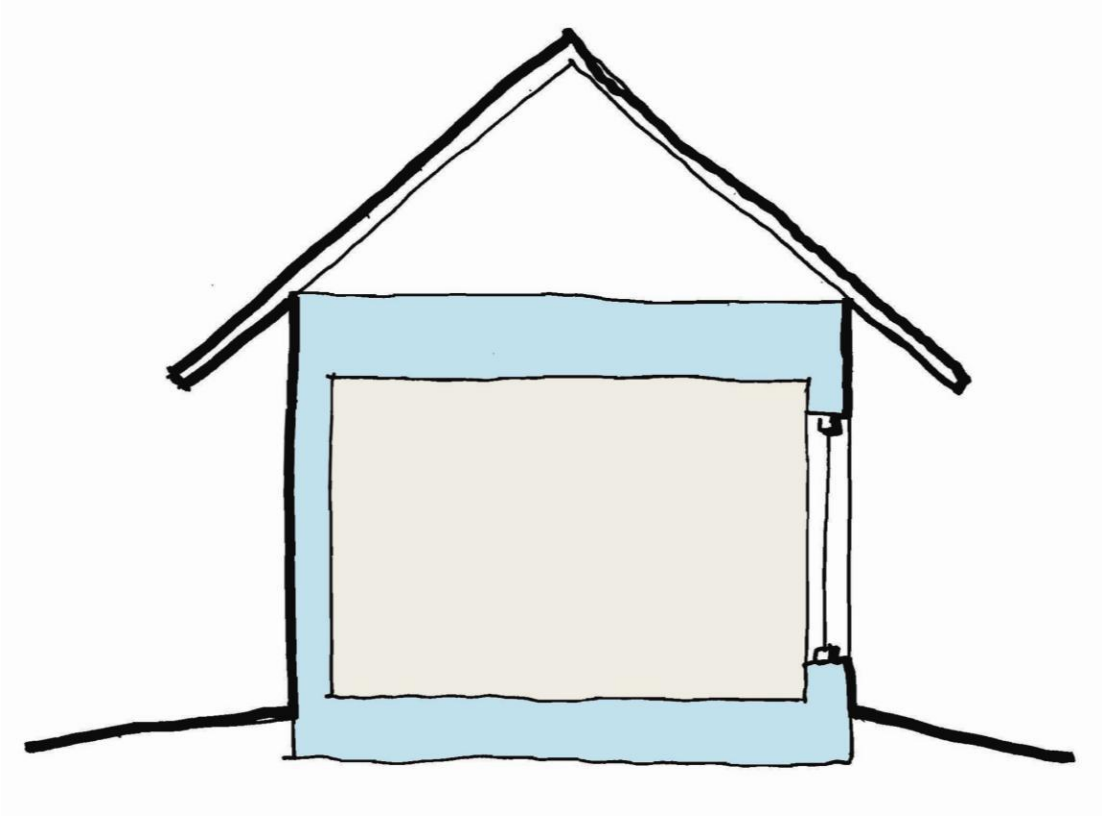
- A prescriptive standard—any number of strategies may be employed so long as the building meets these performance criteria
- 80-90% reduction in heating and cooling cost and 65%-75% reduction in total energy use compared to typical new construction

Standards Comparison



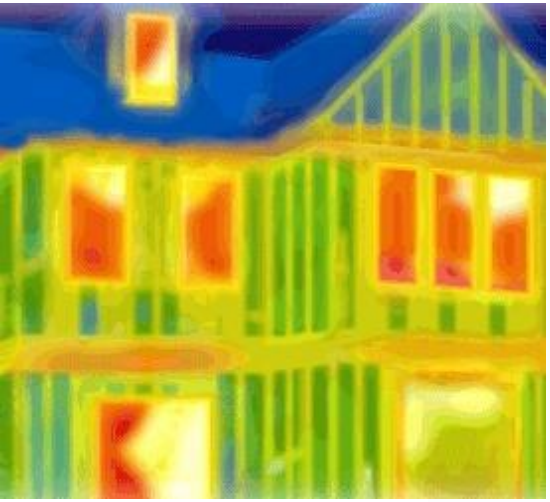
Passivhaus Concept

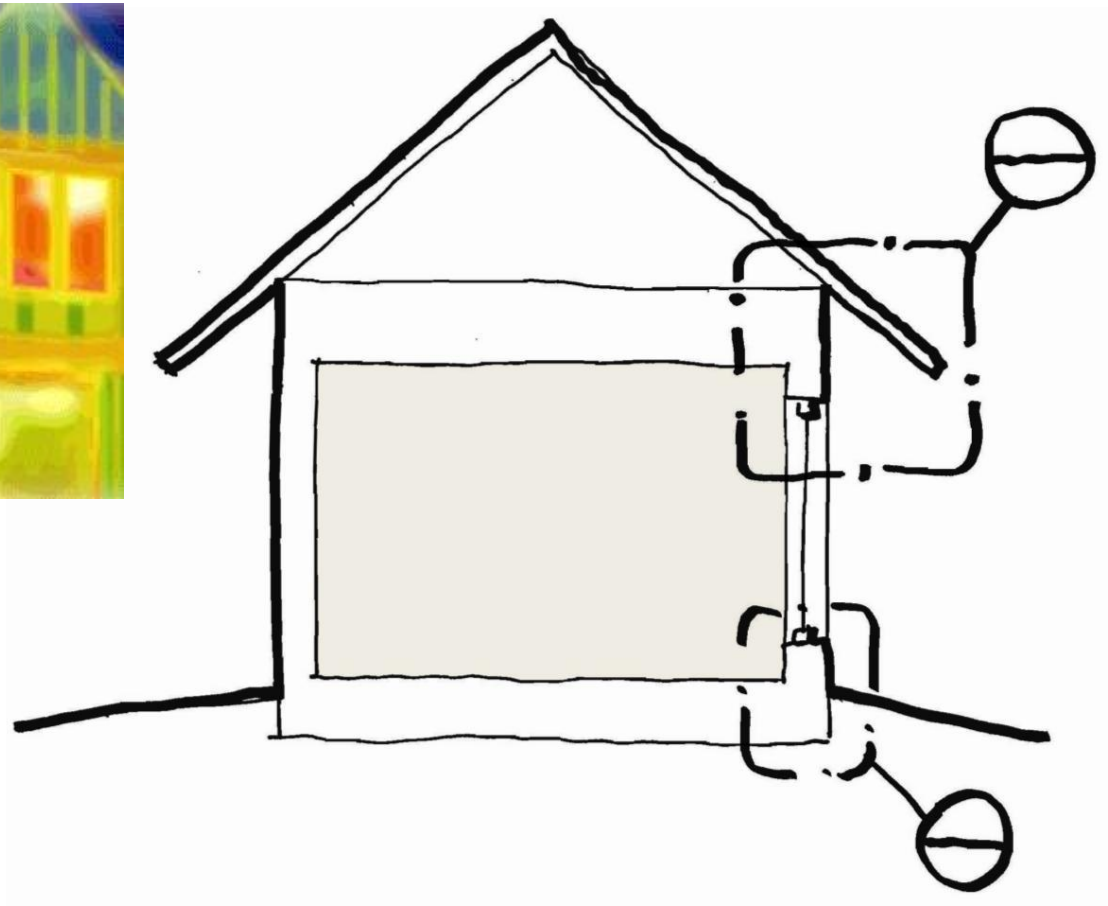
Controlling Heat Loss… INSULATION



Passivhaus Concept

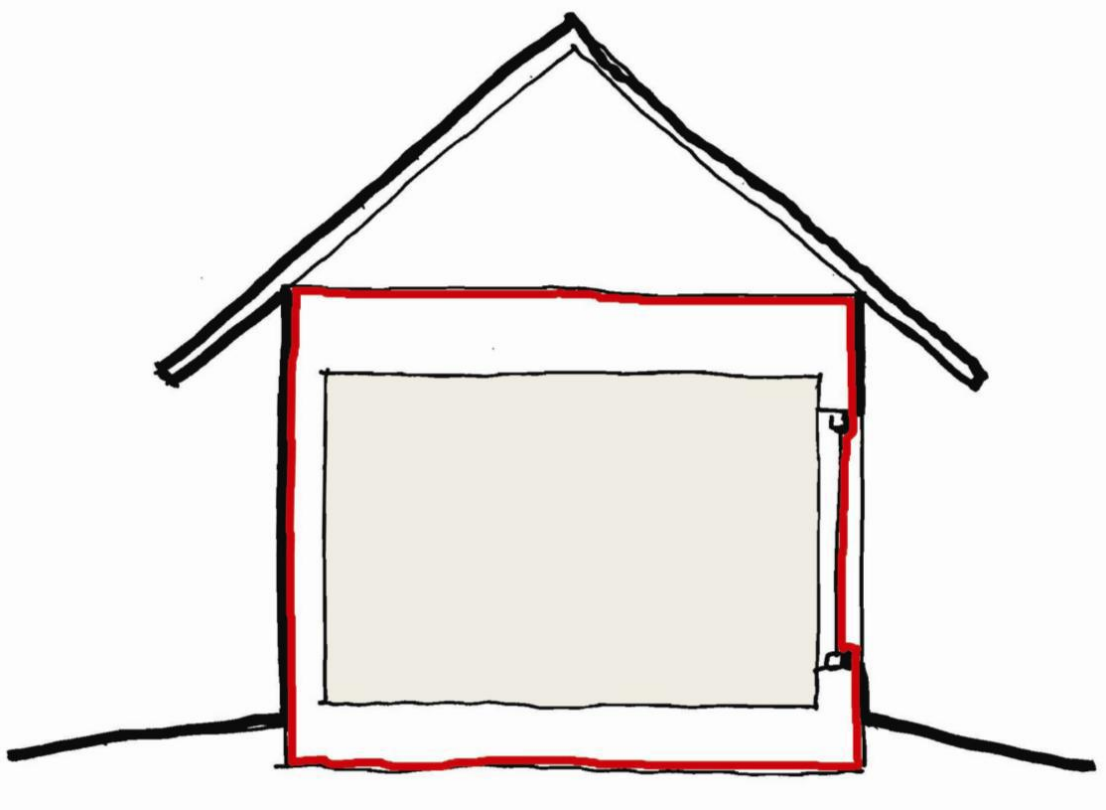
Controlling Heat Loss… ELIMINATE THERMAL BRIDGES





Passivhaus Concept

Controlling Heat Loss… REDUCE AIR INFILTRATION



.6 ACH @ 50 PA

Principles of good passive house insulation:

1. ***Thick enough!*** (depending on climate)
2. ***Thermal bridge-free!*** (Thermal bridge coefficient <= 0.01W/(mK))
3. ***Airtight!***
4. ***Wind tight!*** (House wrap)
5. ***No gaps!*** (No voids > 5mm or 1/4 inch)

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Wall Construction Components

Wall Type	*Insulation Type*
Structural insulated panel (SIP)	foam
Insulated Concrete Form (ICF)	
Double stud wall	cellulose, fiberglass, foam, cotton, wool, etc
Wooden I-Joist	
Straw Bale	Straw

No 'best' method, just must meet the thermal resistance requirements of the building in the specific climate

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Larsen Truss

LION EAS

Mineral wool exterior insulation finish system:

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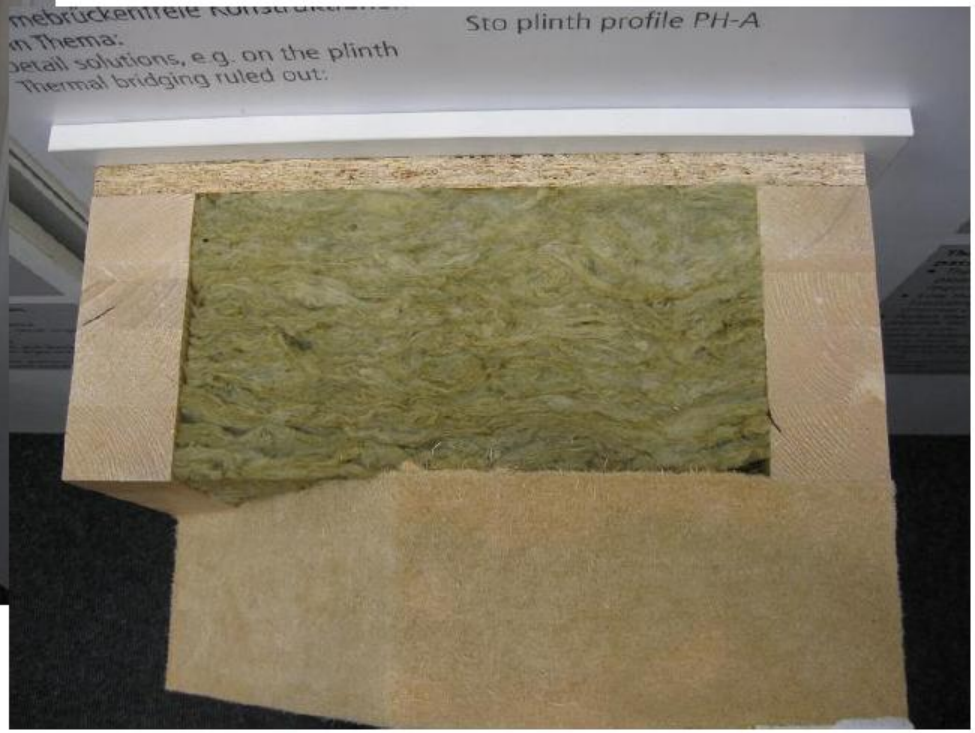

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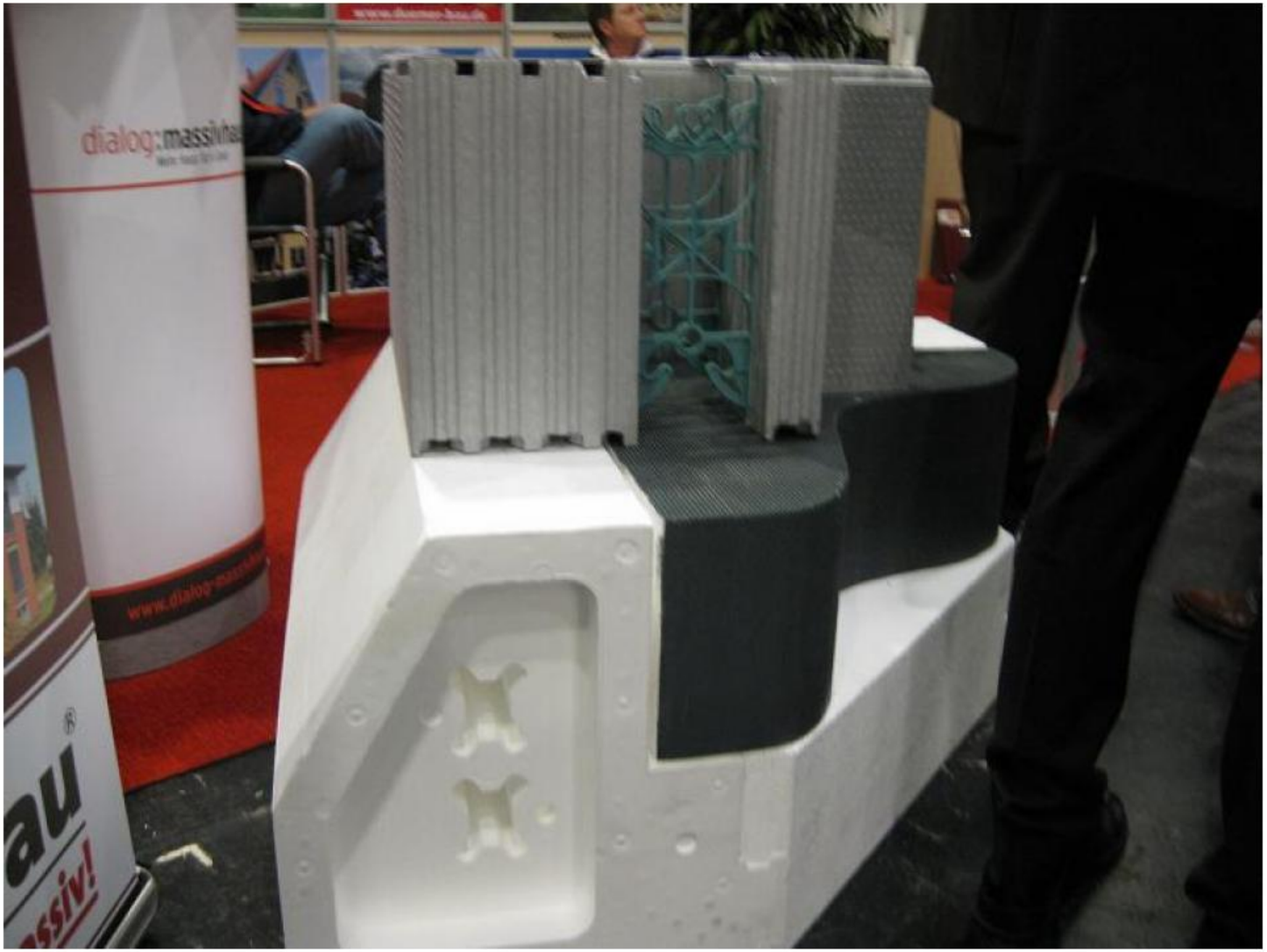

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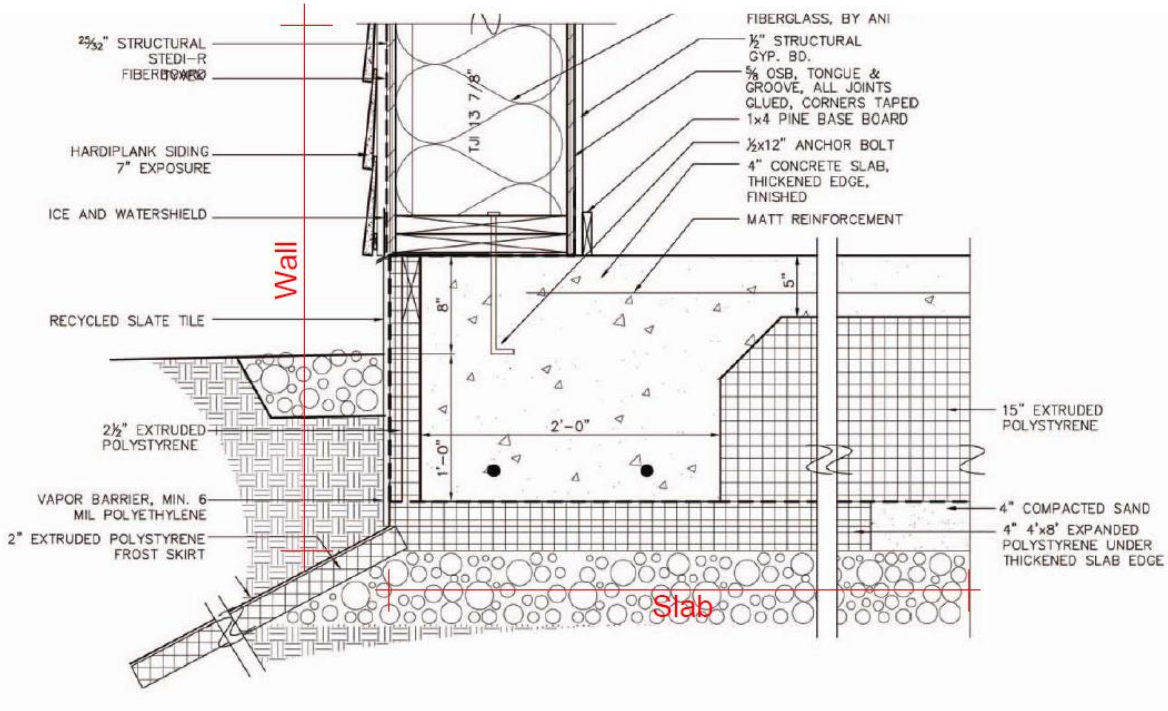
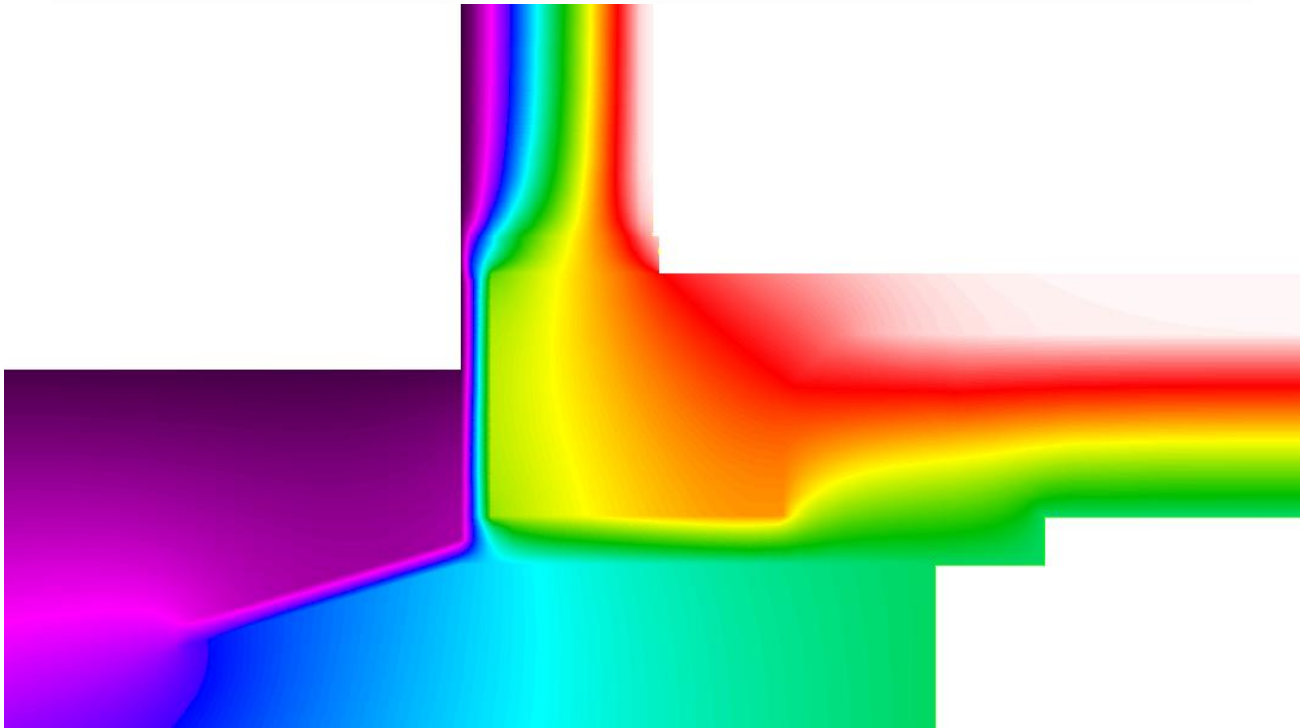
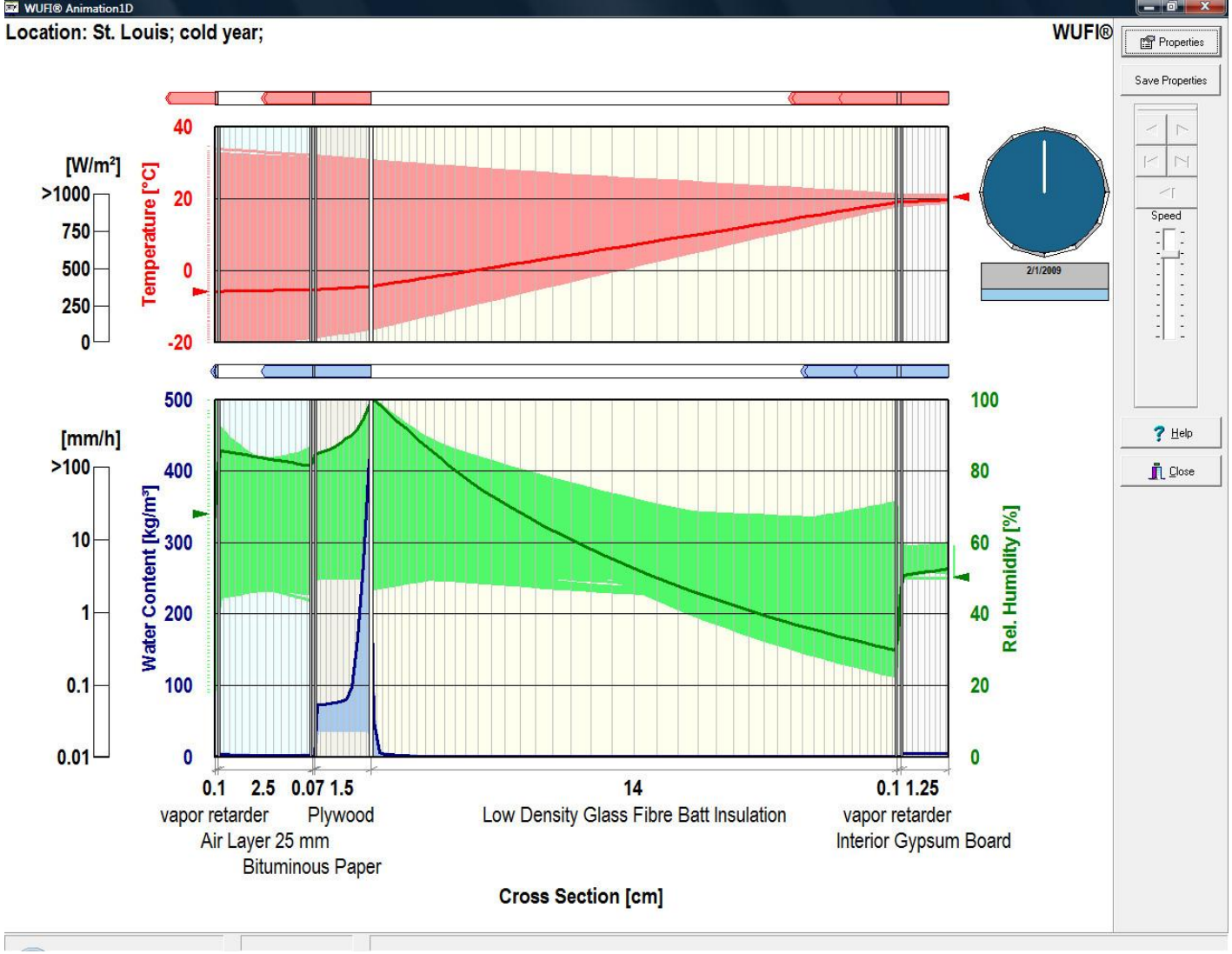
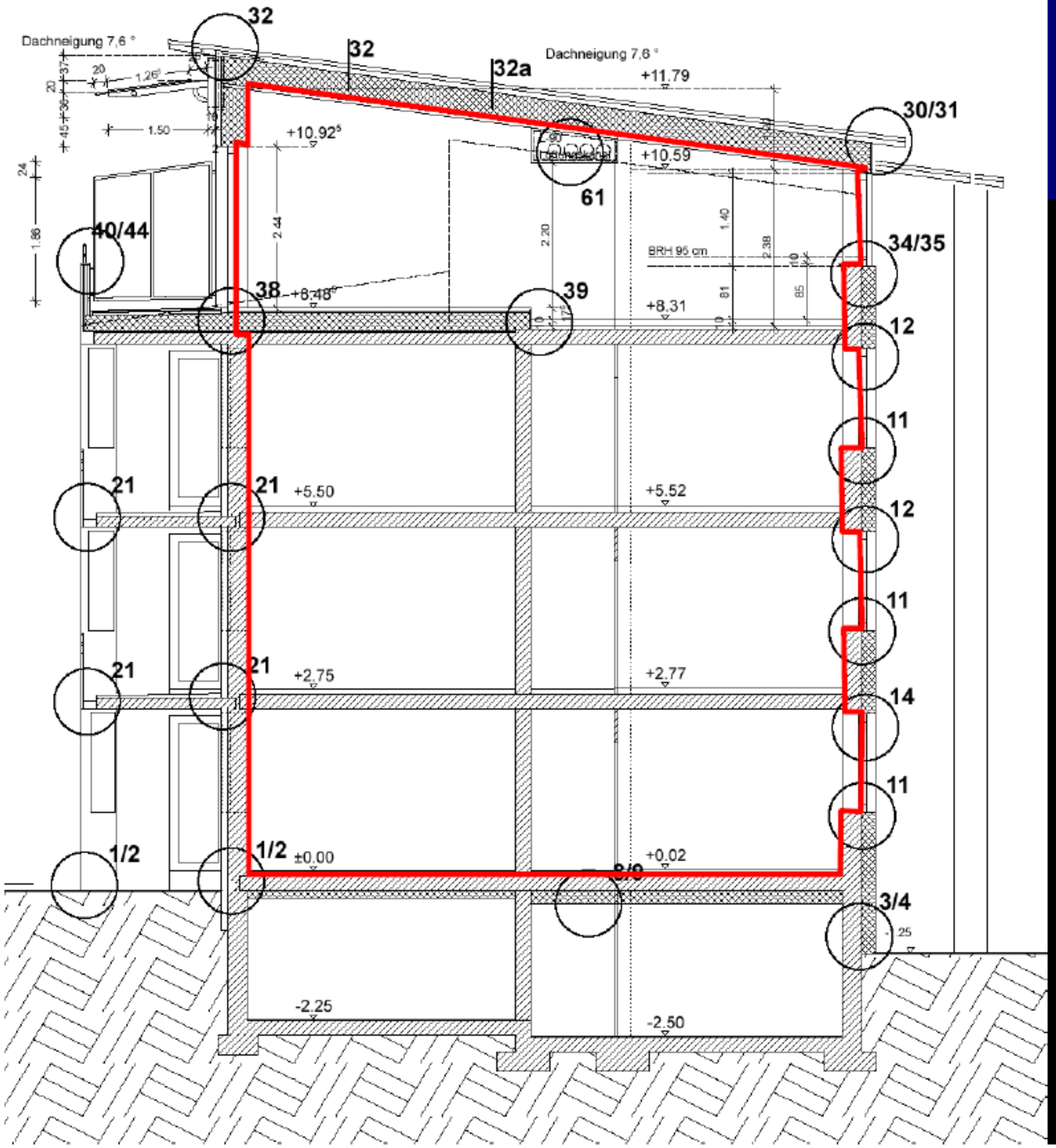
Thermal Bridge Analysis using THERM software







Hygrothermal Analysis of Assemblies over Time Modeled using WUFI software



Air-tightness

$n_{50} \leq 0{,}6\ h^{-1}$

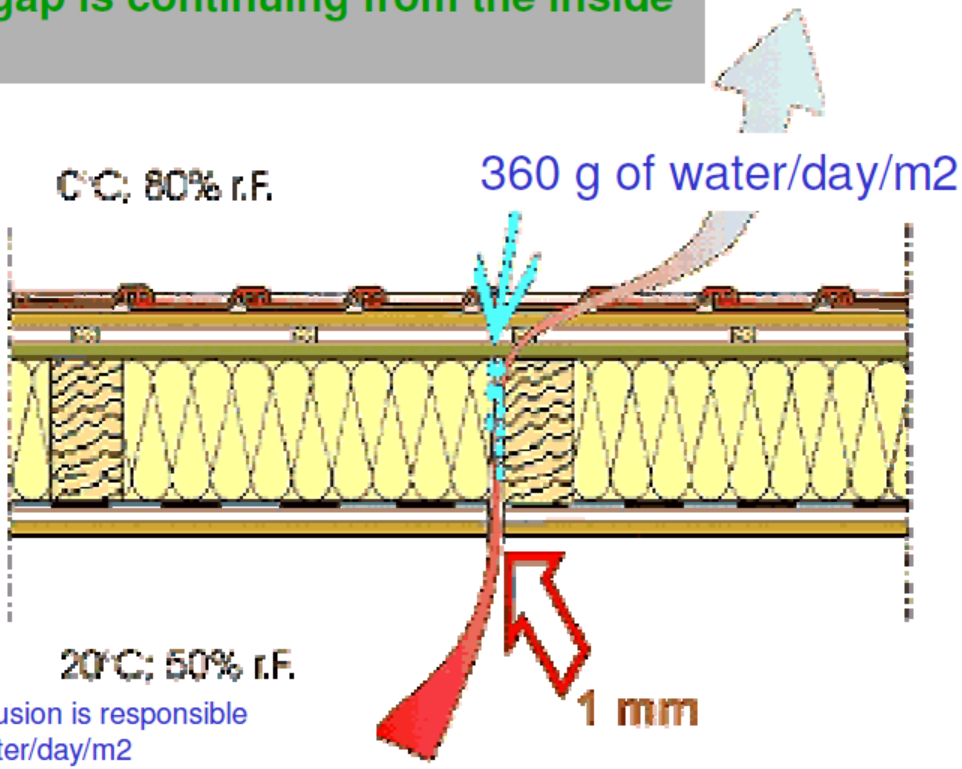
[.6 ACH @50 Pa]

Burkhard Schulze Darup

Multifamily 2008 Brooklyn

Air Tightness Principle:

Problem: the gap is continuing from the inside to the outside



Comparison: diffusion is responsible only for 1g of water/day/m2

Image Source PHI: www.passivhaustagung.de/Passivhaus_D/luftdicht_06.html

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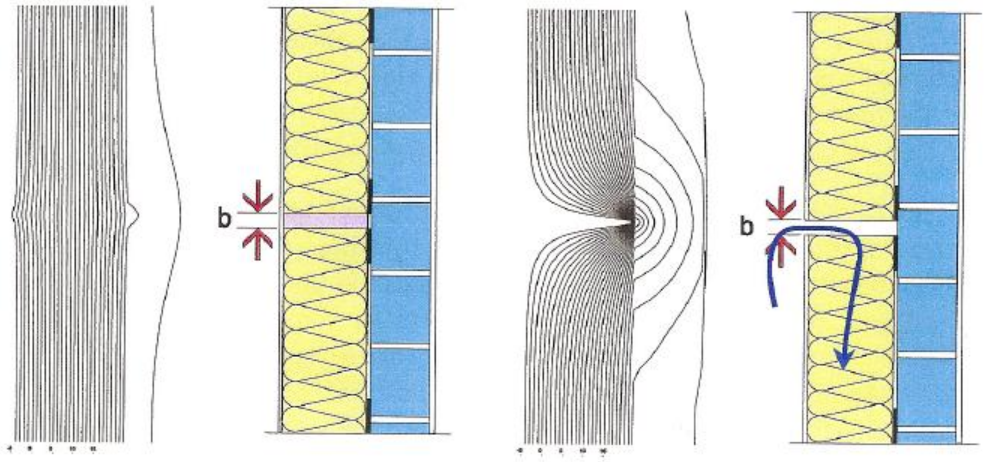
Wind Tightness Principle:



Enclosed gap in Insulation (10 mm)

Ψ = 0,017 W/(mK)

Gap in Insulation (10 mm) open to the outside

Ψ = 0,32 W/(mK)

Image Source: PHI Protokollband Nr. 18 (2008)

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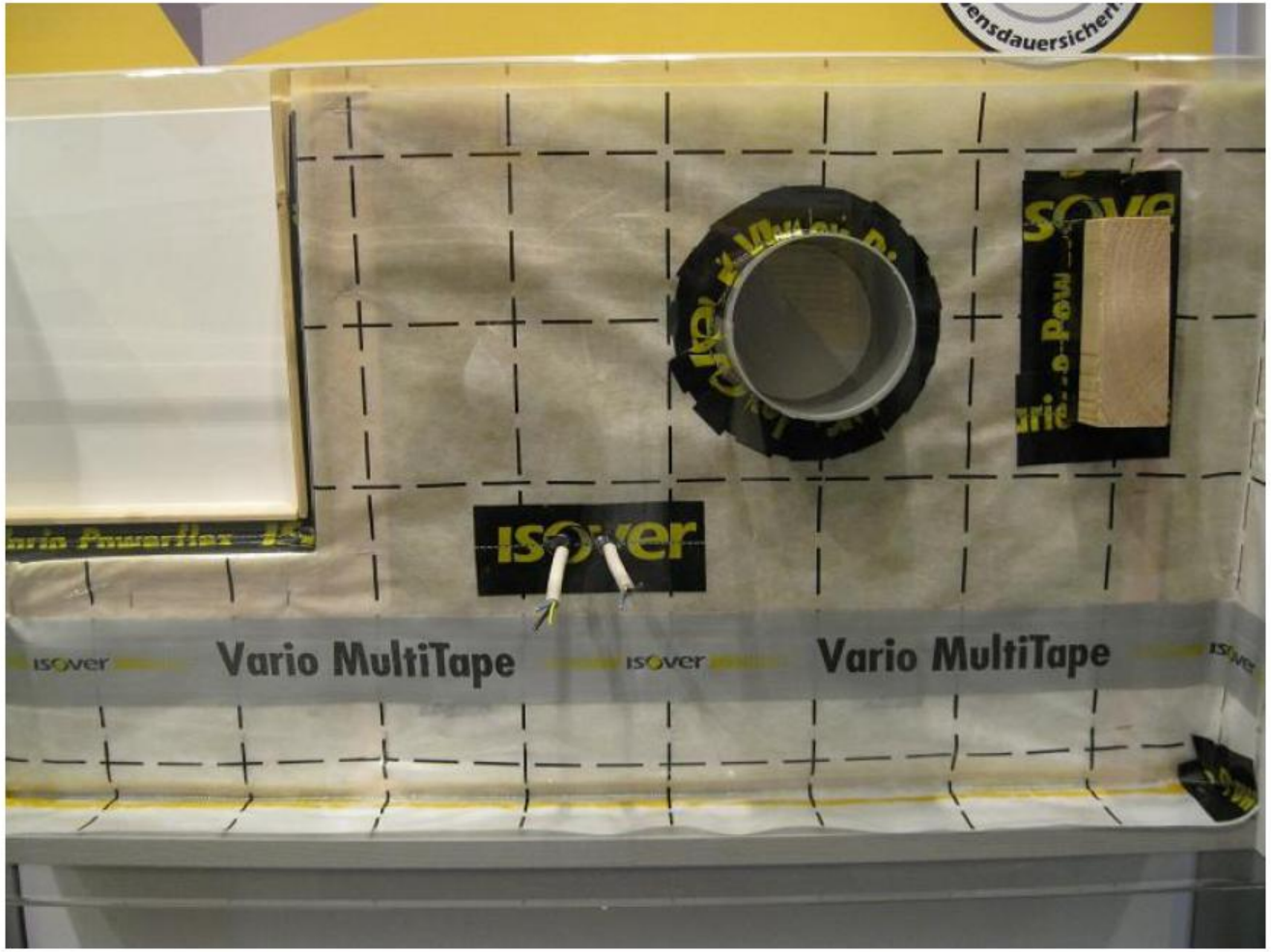
Boots and tapes– for envelope penetrations



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Site-made EPDM rubber gaskets for Air Barrier penetrations

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Continuous air barrier is applied to achieve…

…Air Leakage (@ 50 Pa) of less than 0.6 house volumes per hour!

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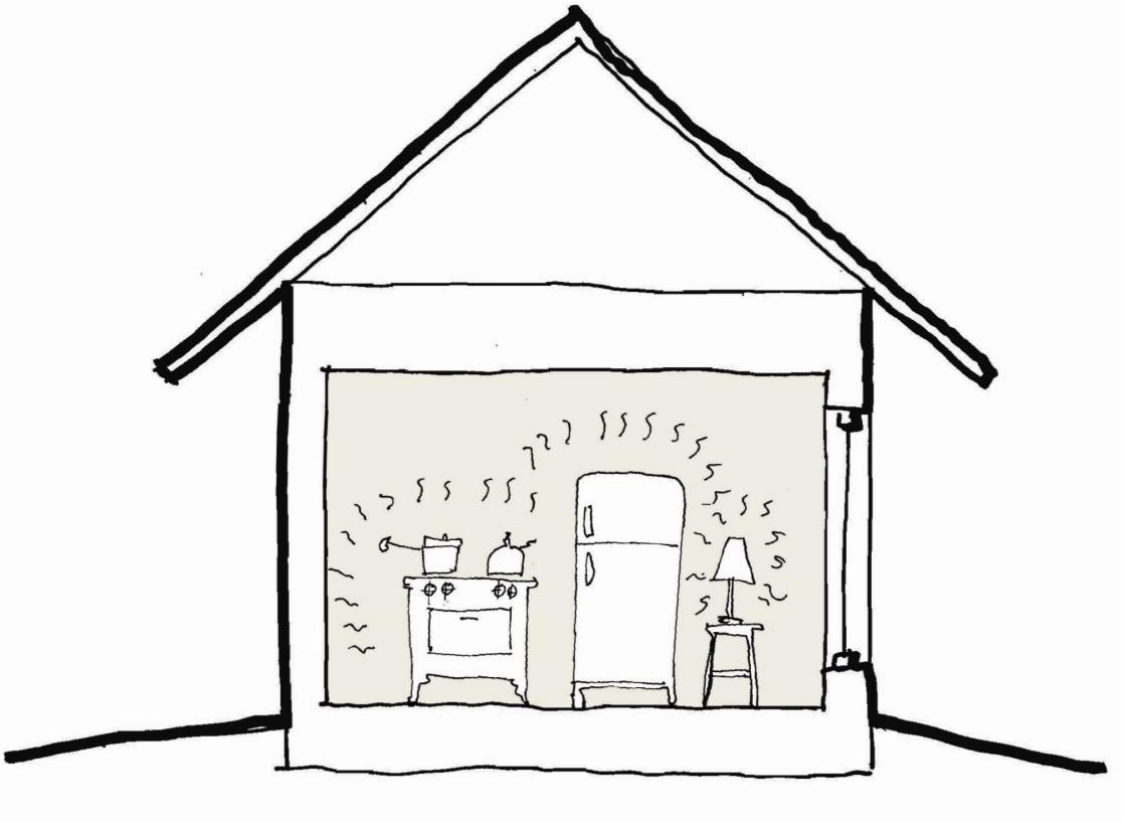
Passivhaus Concept

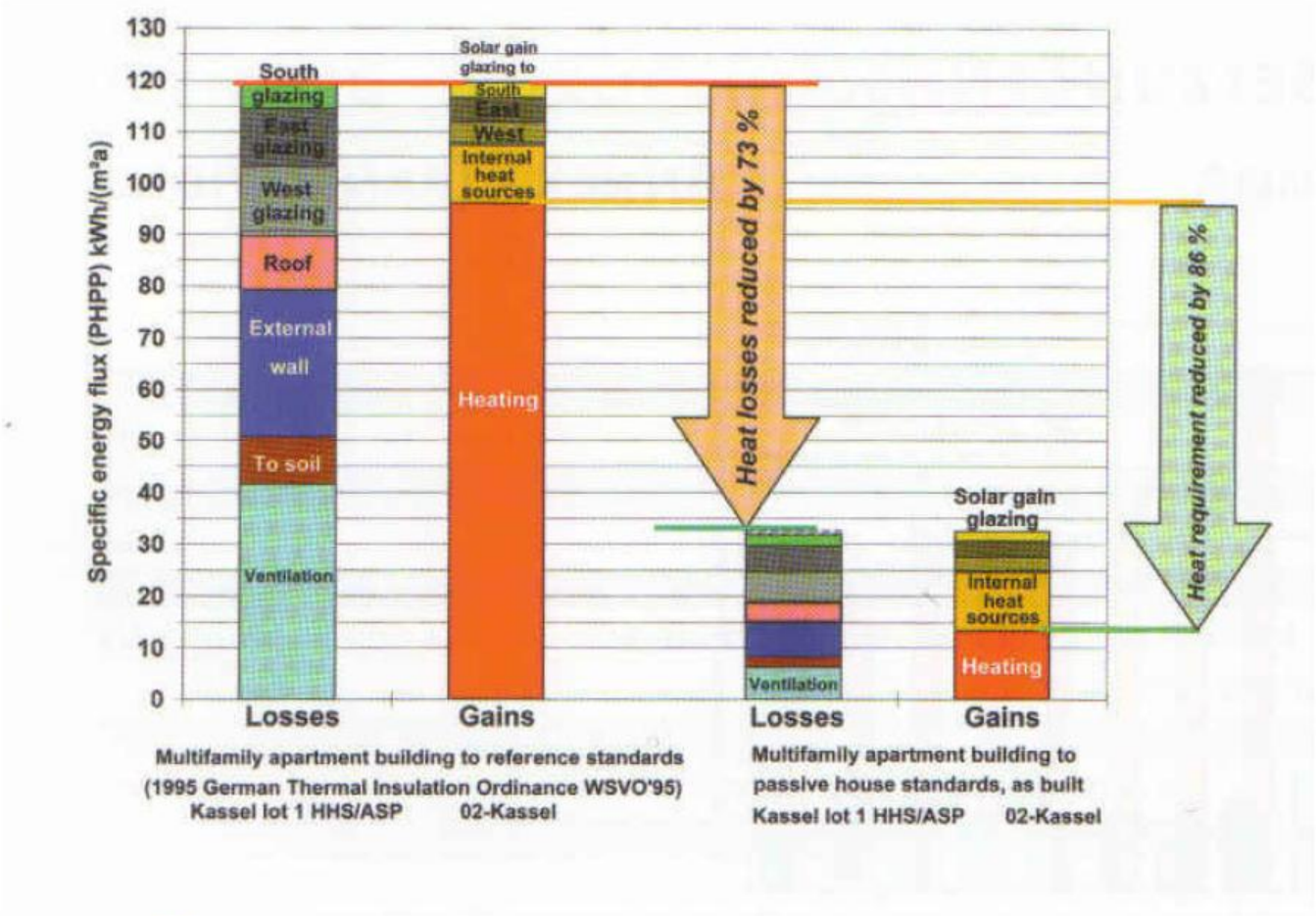
Capturing Heat Gains… PEOPLE

Passivhaus Concept

Capturing Heat Gains… EQUIPMENT



Minimimize Losses First-
Maximize Gains



(Krapmeier and Drossler 2001)

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Optimize Heat Gains: Indoor Environmental Heat Gains

1 candle = 30W

1 incandescent light bulb = 100W

1 person = 100W

1 hair dryer = 1500W

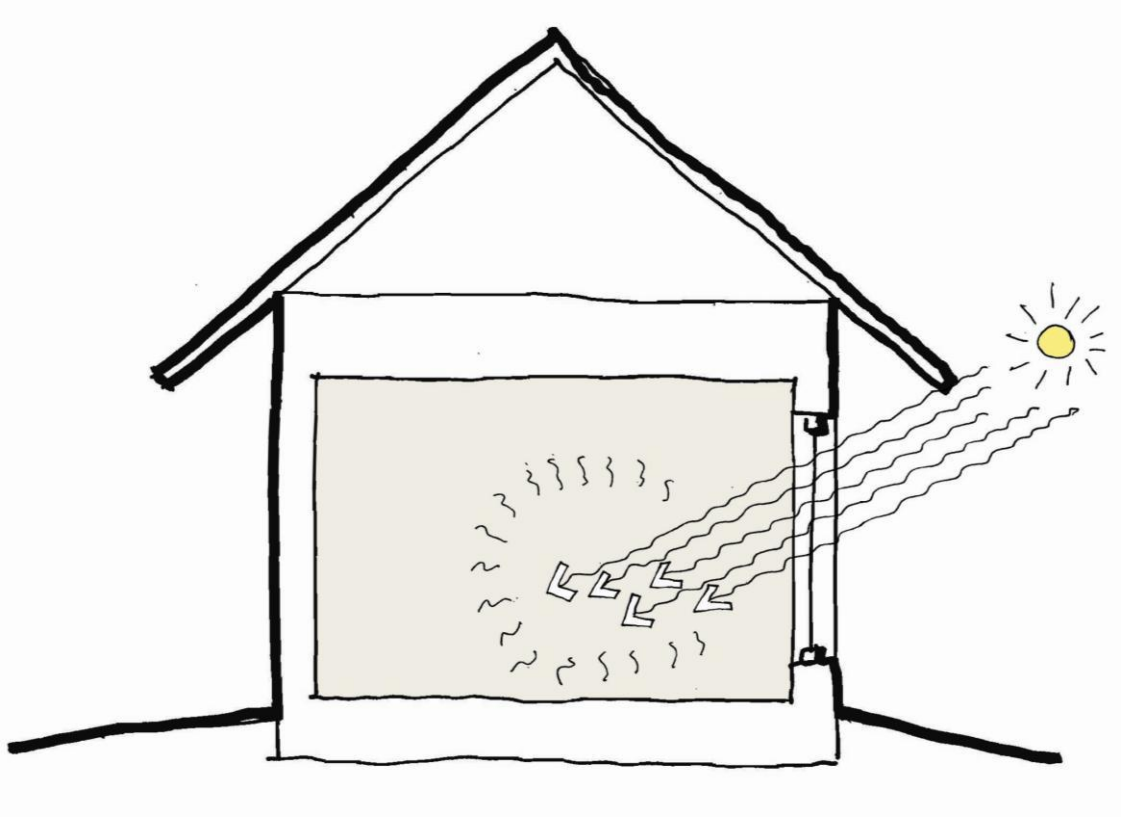
What is the Peak Heating Load for a 1200 sq. ft. Passive House?

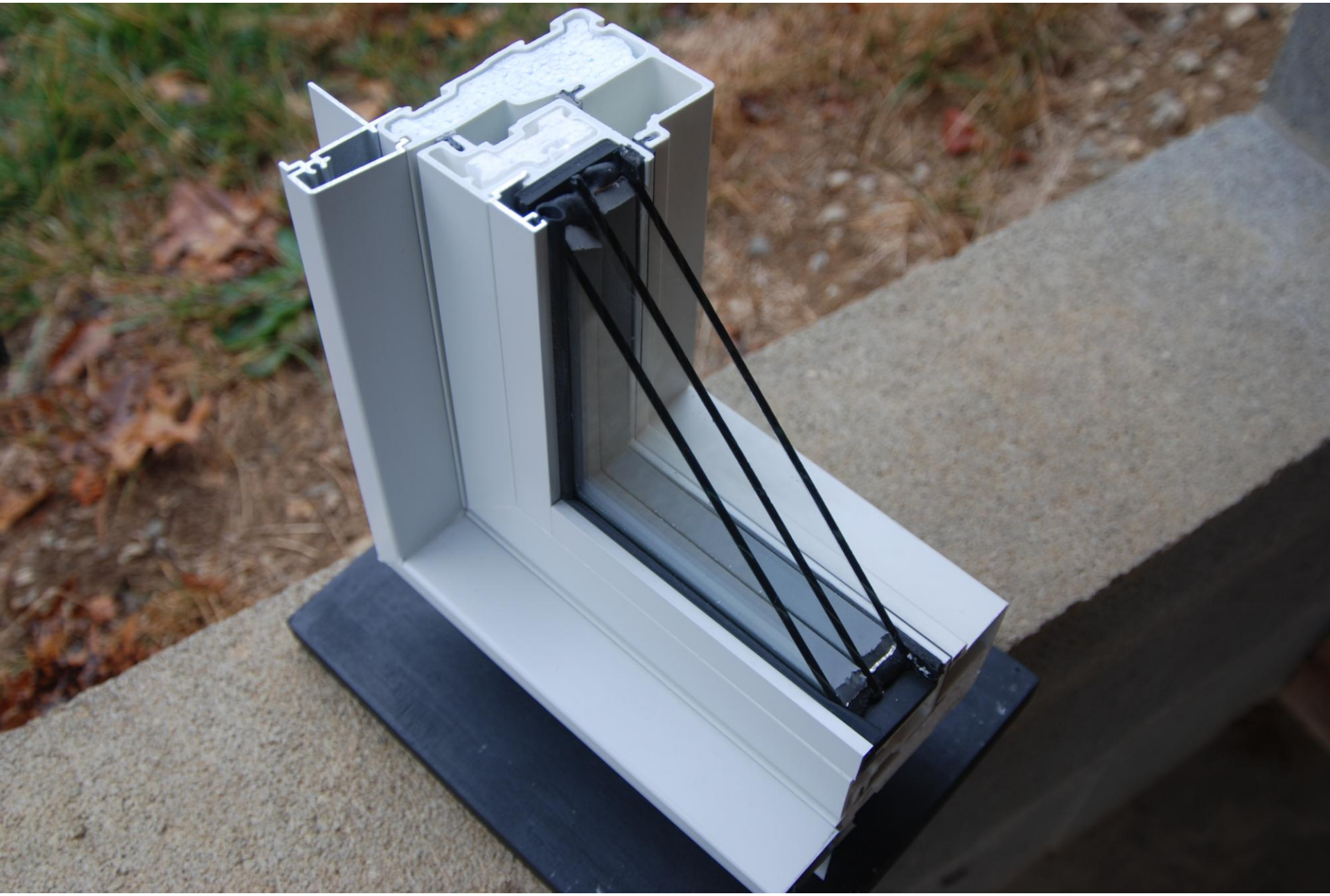
Roughly 5200 BTU/hr or about 1500W

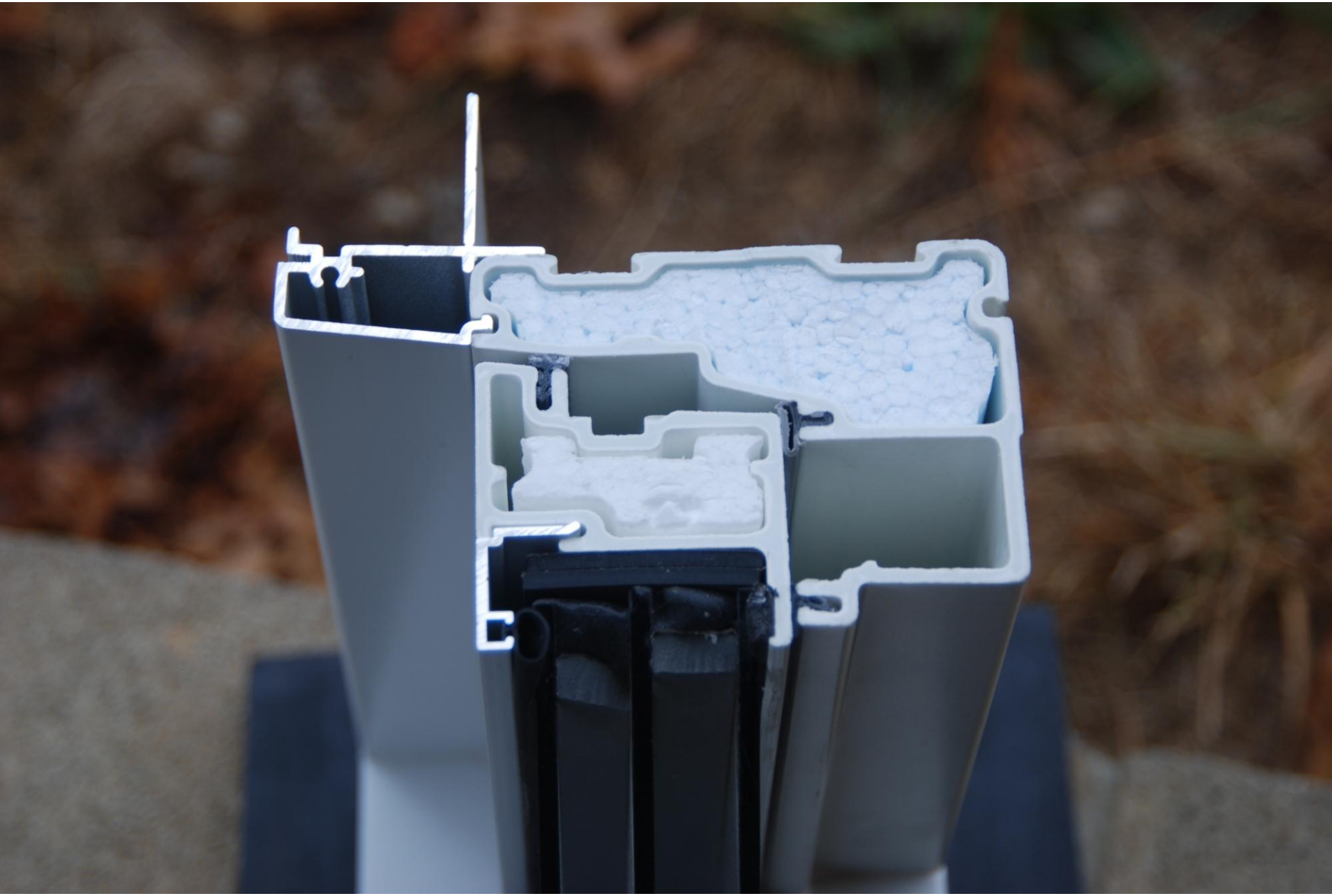
Equivalent to 15 people or 50 candles or 1 hair dryer!

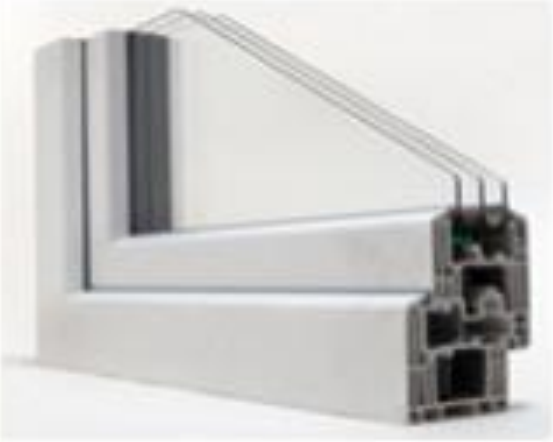
Passivhaus Concept

Capturing Heat Gains… SOLAR ENERGY





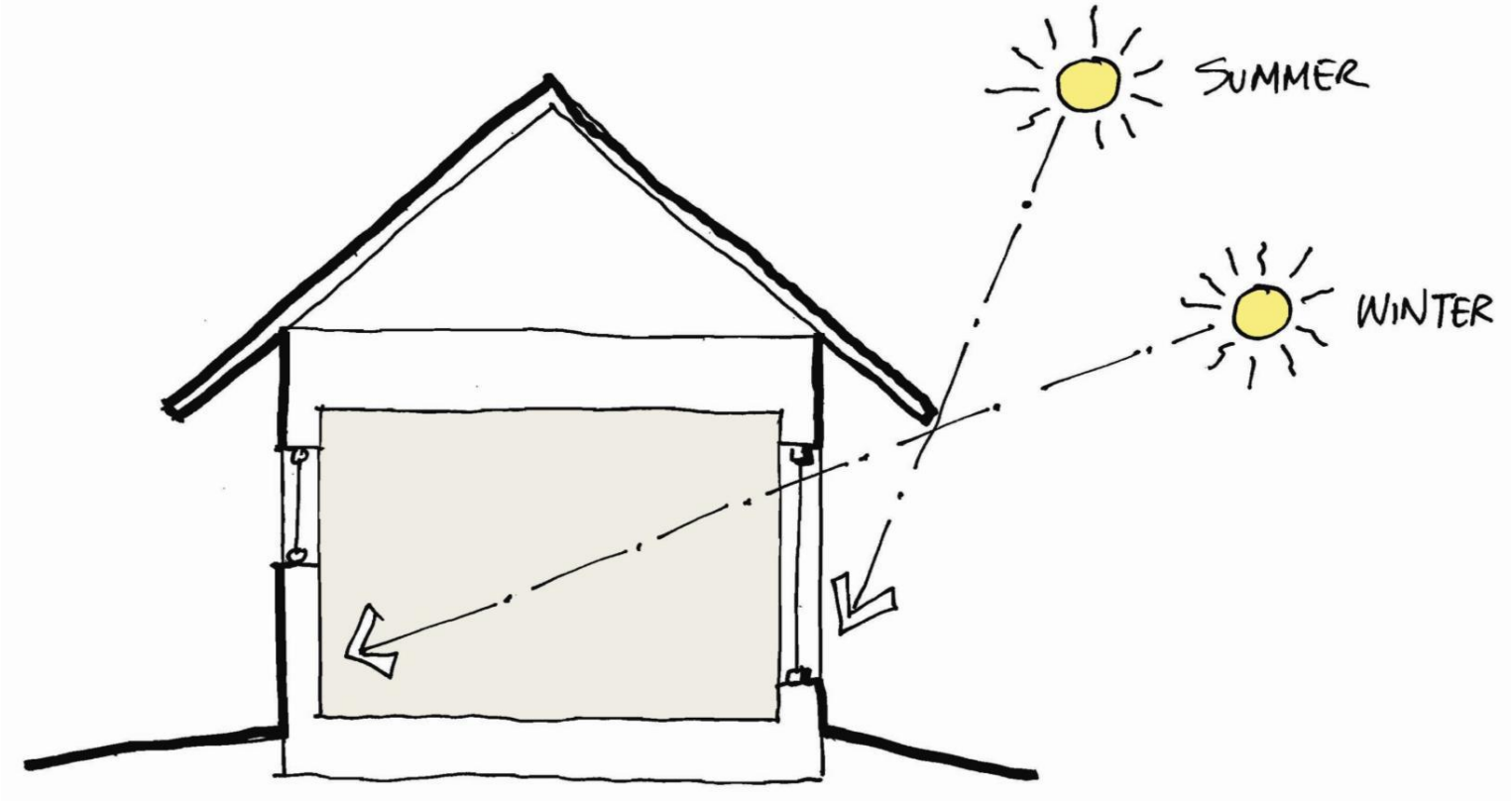




Daylighting

Passivhaus Concept

Controlling Gains Seasonally… WINDOWS, SHADING & ORIENTATION



>.5 SHGC ON SOUTH WINDOWS

SUMMER SHADING

Windows that perform better than walls?

In a sense…YES!

Optimize Heat Gains: Passive Solar Heat Gains→ Net Gain Windows

Window Area Orientation	Transmission Losses	Heat Gains Solar Radiation
maximum:	kBTU/yr	kBTU/yr
North	825	338
East	1374	1339
South	4560	11518
West	550	548
Horizontal	0	0
	7308	13743

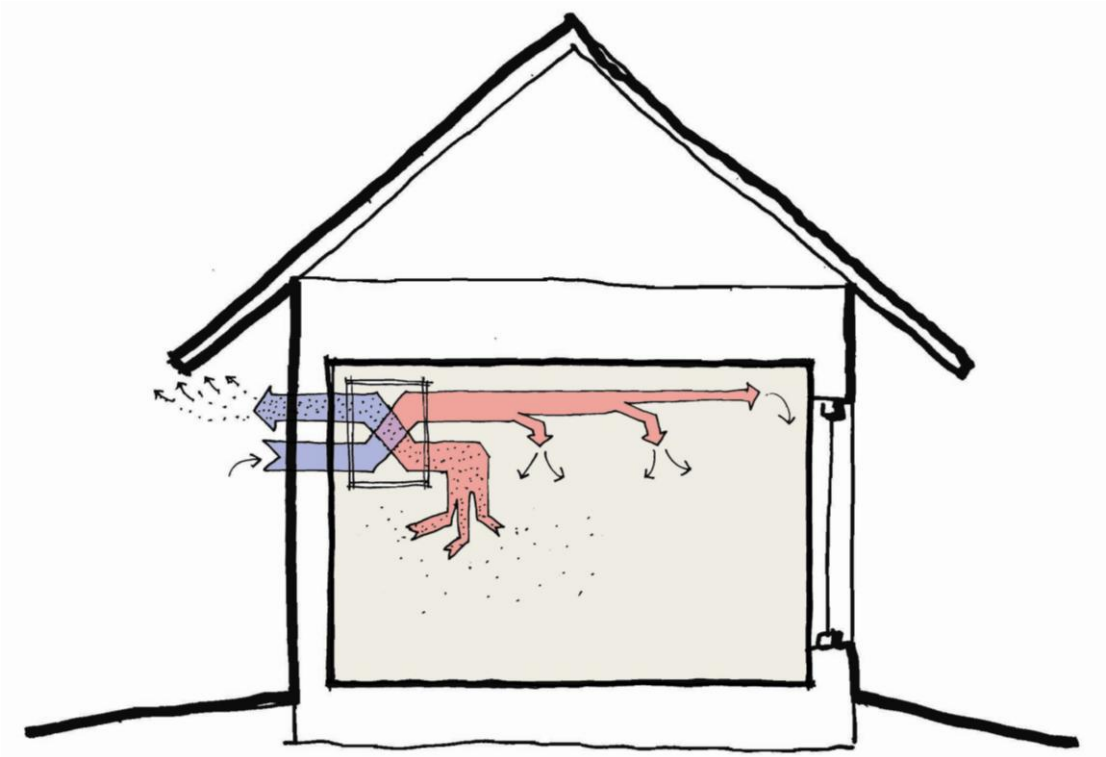
Recipe for a Net-Gain Window:

- Very low U-value
- Very High Solar Heat Gain Coefficient

Glass Code, Low e type*	Glass Properties						Frame Properties (for PHPP)				Window Properties					
	G (SHGC)	Ug_{EU}**		Ug_{NA}***		Visible Trans.	Frame Height (m)	Uf_{SP}****		psi****	SHGC	U		R	ER	
		W/m²K	BTU/ft²F	W/m²K	BTU/ft²F			W/m²K	BTU/ft² F	W/mK		W/m²K	BTU/ft²	ft²/BTU	old	new
322 Gain+, Kr	0.63	0.74	0.13	0.81	0.14	0.63	0.048	1.50	0.26	0.00	0.54	0.90	0.16	6.3	19	52
322 Gain+, 44mm	[illegible]	*0.82*	[illegible]	*0.88*	*0.15*	*0.63*	*0.048*	*1.33*	*0.23*	*0.00*	*0.54*	*0.94*	*0.17*	*6.0*	[illegible]	[illegible]
322 Gain+	0.63	[illegible]	0.16	[illegible]	0.16	0.63	0.048	1.50	0.26	0.00	0.54	0.98	0.17	5.8	18	50
322 Gain+, air	[illegible]	1.13	[illegible]	1.09	0.19	0.63	0.048	1.48	0.26	0.00	0.54	1.15	0.20	4.9	[illegible]	[illegible]
322 Gain, Kr	0.60	0.74	0.13	0.81	0.14	0.62	0.048	1.50	0.26	0.00	0.51	0.90	0.16	6.3	17	49
322 Gain	0.60	0.87	0.15	0.90	0.16	0.62	0.048	1.50	0.26	0.00	0.51	0.98	0.17	5.8	15	48
322 Gain, air	0.60	1.05	0.18	1.08	0.19	0.62	0.048	1.49	0.26	0.00	0.51	1.14	0.20	5.0	12	45
322 Shade, Kr	0.28	0.51	0.09	0.61	0.11	0.41	0.048	1.53	0.27	0.00	0.24	0.74	0.13	7.7	1	38
322 Shade	0.28	0.70	0.12	0.71	0.13	0.41	0.048	1.51	0.27	0.00	0.24	0.82	0.14	6.9	-1	36
322 Shade,air	0.28					0.41	0.048			0.00	0.24					
321 Gain	0.64	1.19	0.21	1.20	0.21	0.68	0.048	1.51	0.27	0.00	0.55	1.24	0.22	4.6	12	44
321 Shade	0.44	1.20	0.21	1.09	0.19	0.55	0.048	1.56	0.27	0.00	0.30	1.15	0.20	4.9	-4	32
300 Clear	0.69	1.84	0.32		0.00		0.048		0.00	0.00						
211 Gain	0.71			1.72	0.30	0.74	0.048	1.79	0.31	0.00	0.61	1.73	0.31	3.3	5	37
211 Shade	0.38			1.47	0.26	0.60	0.048	1.83	0.32	0.00	0.33	1.52	0.27	3.7	-10	25
404 Shade**	0.4194	0.51	0.09	0.51	0.09	0.5219	0.048	2.52	0.44	0.00	0.36115	0.75754	0.13	7.49533	8	44

Passivhaus Concept

Providing Fresh Air… BALANCED ENERGY RECOVERY VENTILATION



CO2 Sensor Controls so that ventilation matches occupancy levels

>87% Heat Recovery (by US testing methods)

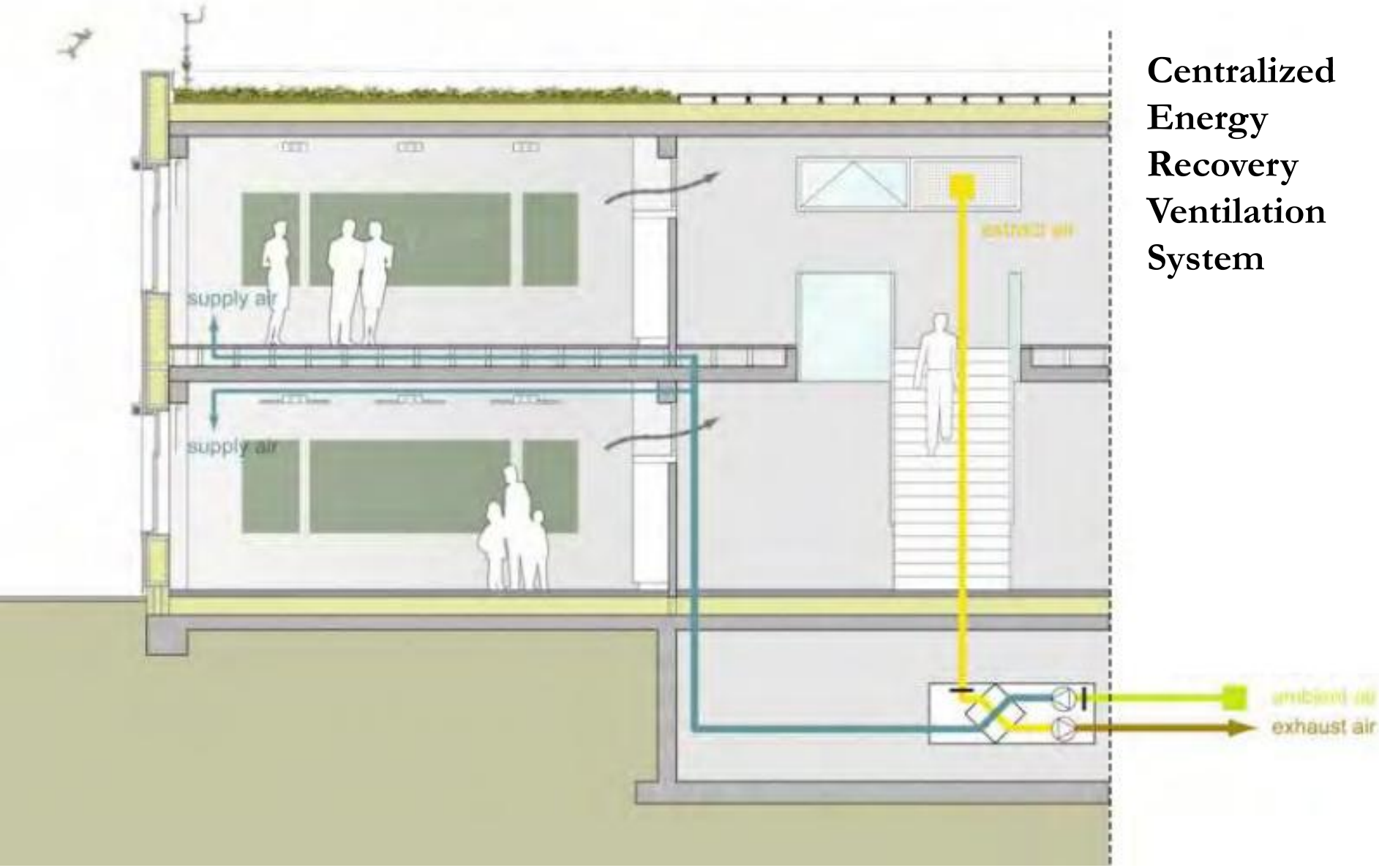
>75% Heat Recovery (by European testing methods)

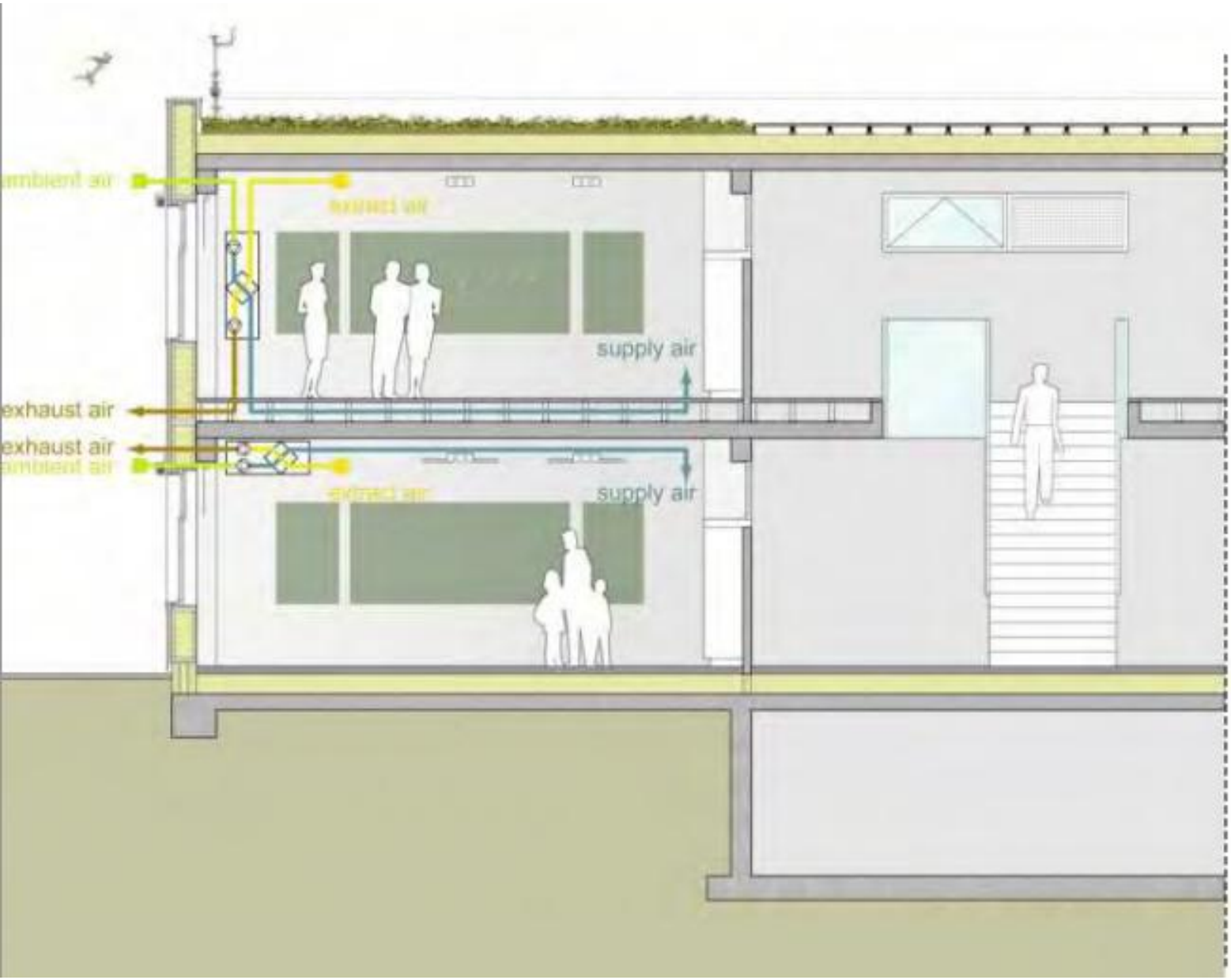
Why Ventilate?

- CO2
- Volatile Organic Compounds (VOCs)
- Sick Building Syndrome
- Radon

"I am certain that no air is so unwholesome as air in a closed room that has been often breathed and not changed." –Benjamin Franklin

Centralized Energy Recovery Ventilation System





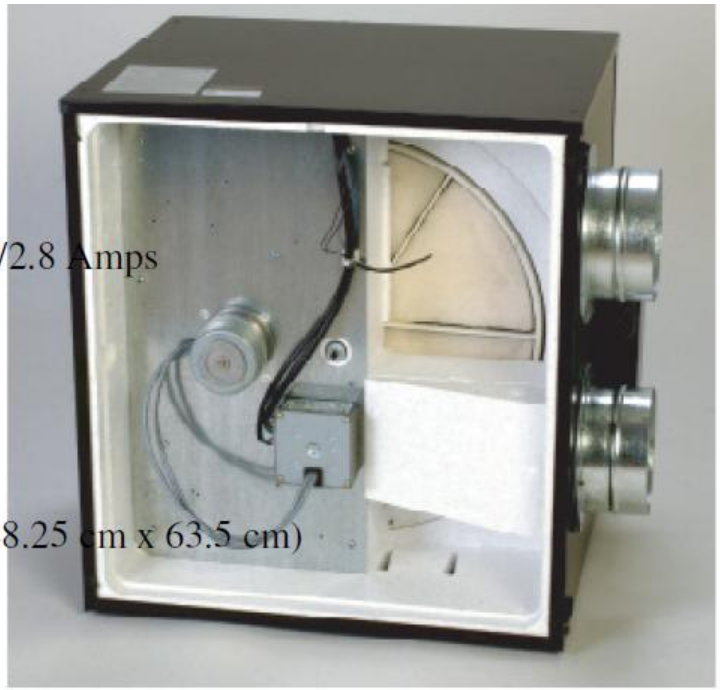
Decentralized Energy Recovery Ventilation System

Individual Components: Ventilation

Subtract 12% from N. American Testing for PHPP

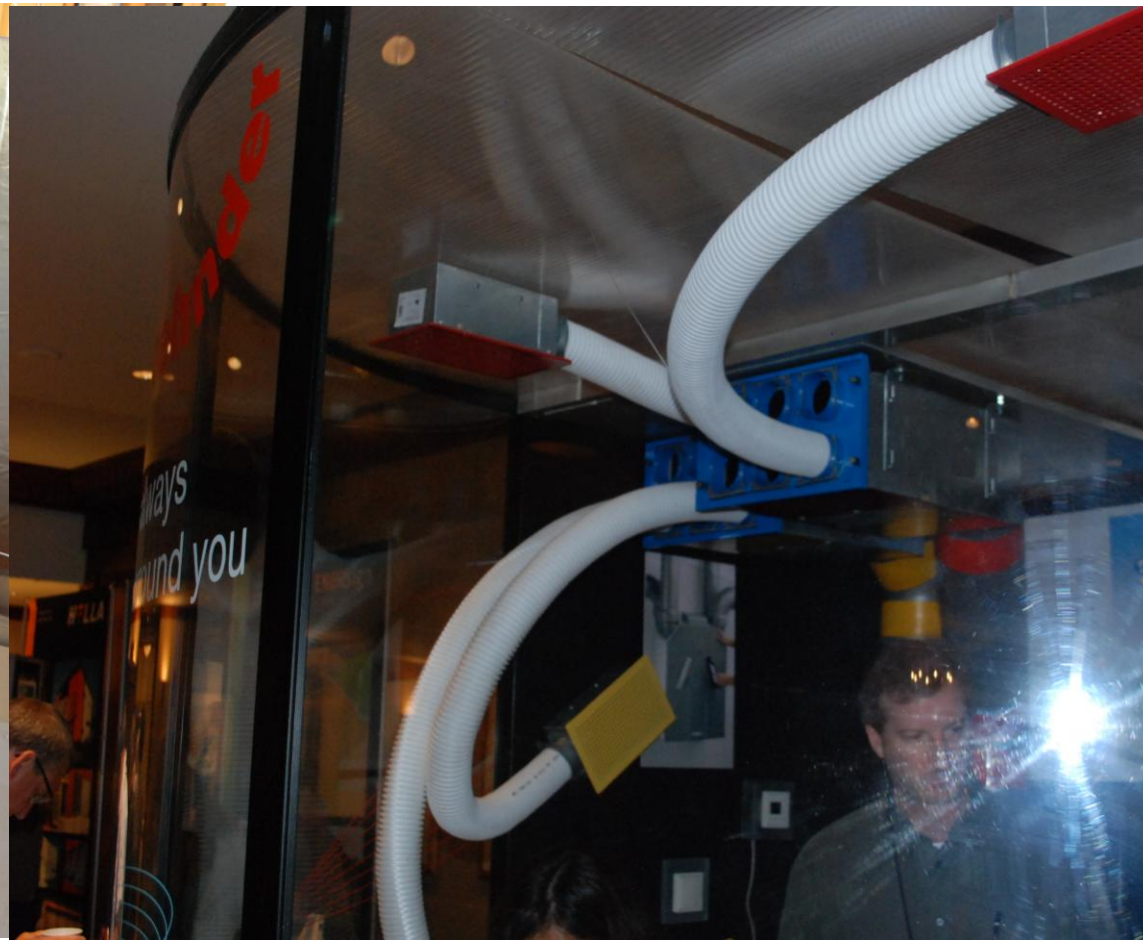
Must be greater than 75%

- 95% Efficiency
- Air flow: 70-210 cubic feet/minute (cfm)
- Motor: ECM brushless motors
- Electrical Rating: 120/240 volts, AC, 60/50 Hz, 5/2.8 Amps
- Average electrical consumption:
  - 210 cfm (360m3/h) — 200W
  - 60cfm —34 W
- Dimensions: 25" H x 19" W x 25" D (63.5 cm x 48.25 cm x 63.5 cm)
- Unit Weight: 72 lbs.
- Shipping Weight: 80 lbs.
- Mounting: Operates in vertical or horizontal position.
- Connects to 6" galvanized or flex ducts.



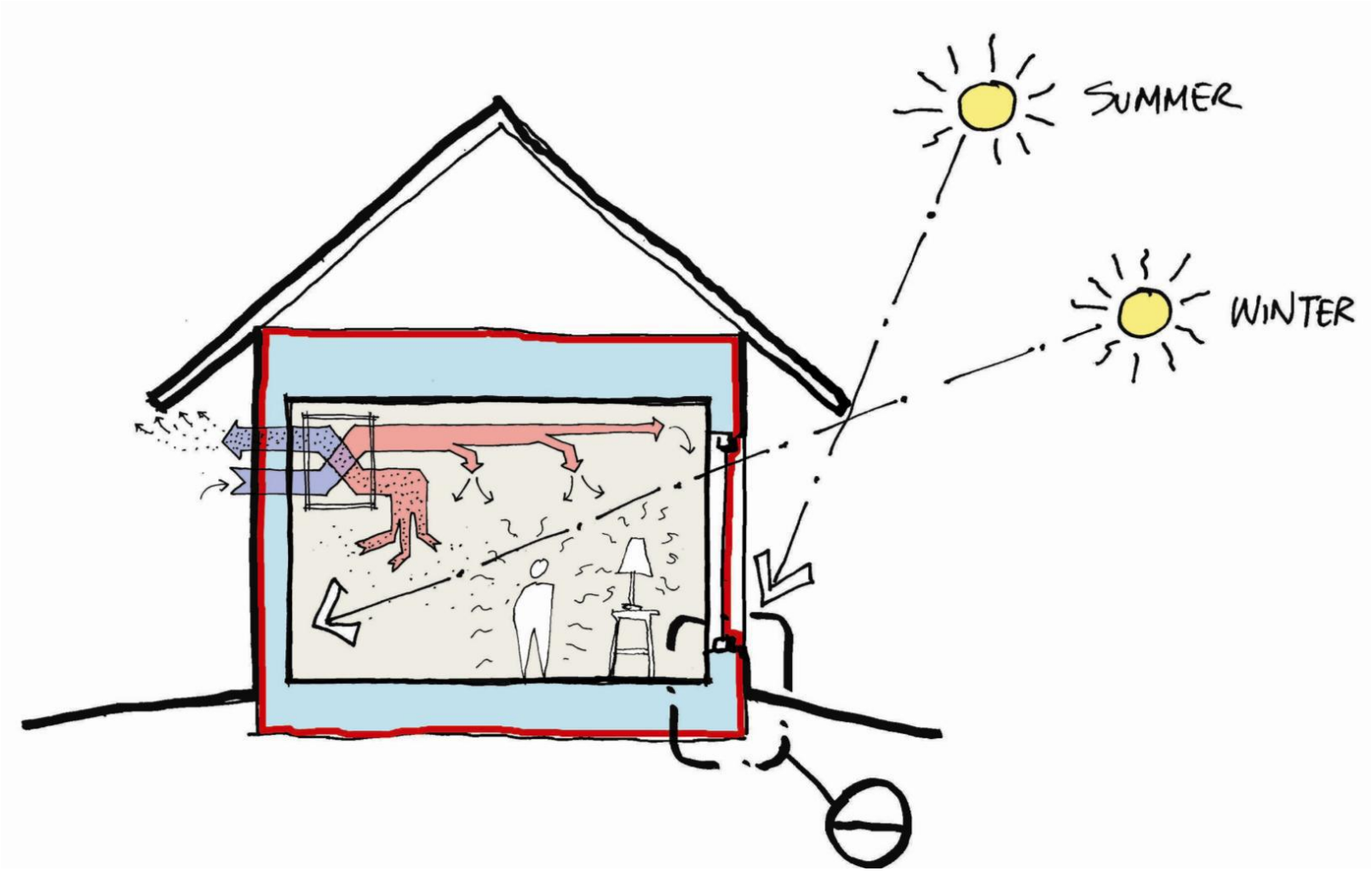
PHIUS

Passive House Institute US



Passivhaus Concept

INTEGRATED SYSTEMS



Passivhaus Concept

PASSIVE HOUSE PLANNING PACKAGE ENERGY MODELING

Year of Construction:	2010	
Number of Dwelling Units:	1	
Gross Enclosed Volume V_e:	19935	ft^3
Number of Occupants:	3.8	

Interior Temperature:	68.0	°F
Internal Heat Gains:	0.7	BTU/hr.ft²

Utilization Pattern:	Dwelling
Type of Values Used:	Standard

Planned Number of Occupants:

4 Verification

Specific Demands with Reference to the Treated Floor Area

Treated Floor Area: 1445 ft^2

	Applied:	Monthly Method	PH Certificate:	Fulfilled?
Specific Space Heat Demand:	4.66	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):	28.5	kBTU/(ft²yr)	38.0 kBTU/(ft²yr)	Yes
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):	14	kBTU/(ft²yr)		
Specific Primary Energy Demand Energy Conservation by Solar Electricity:	29	kBTU/(ft²yr)		
Heating Load:	5	BTU/(ft²hr)		
Frequency of Overheating:	3	%	over 77.0 °F	
Specific Useful Cooling Energy Demand:		kBTU/(ft²yr)	4.75 kBTU/(ft²yr)	
Cooling Load:	4	BTU/(ft²hr)		

Verification: Monthly Method

Specific Space Heat Demand, .

Specific Space Heat Demand, I

We confirm that the values given herein have been determined following the PHPP methodology and based on the characteristic values of the building. The calculations with PHPP are attached to this application.

Issued on:

signed:

Intro | Conversion | Verification | cTFA | Areas | R-List | R-Values | Ground | WinEntry | Window | WinType | Shading | Venti

THERMAL ENVELOPE DEFINITION

Building: Kennedy Residence Heat Demand: 5 kBTU/(ft²yr)

Basic Building Geometry

Treated Floor Area	1865	ft²	Gross Floor Slab Perimeter	66	ft
Gross Heated Building Footprint Area	840.006991	ft²	Envelope-Area-to-Treated-Floor-Area Ra	3.4	
Gross Enclosed Volume	23792	ft³			

Envelope Summary

Group Nr.	Area Group	Temp Zone	Area	Unit	Comments	Building Element Overview	Average R-Value [(hr.ft².F)/BTU]
1	Treated Floor Area		1865.00	ft²	*Living area or useful area within the thermal envelope*		
2	North Windows	A	24.11	ft²	Results are from the Windows worksheet.	North Windows	4.006
3	East Windows	A	17.44	ft²		East Windows	4.324
4	South Windows	A	320.44	ft²		South Windows	4.055
5	West Windows	A	5.44	ft²		West Windows	3.937
6	Horizontal Windows	A	0.00	ft²		Horizontal Windows	
7	Exterior Door	A	100.05	ft²	*Please subtract area of door from respective building element*	Exterior Door	2.913
8	Exterior Wall - Ambient	A	2168.08	ft²	*Window areas are subtracted from the individual areas specified in the "Windows" worksheet.*	Exterior Wall - Ambient	34.820
9	Exterior Wall - Ground	B	613.84	ft²	*Temperature Zone "A" is ambient air.*	Exterior Wall - Ground	34.168
10	Roof/Ceiling - Ambient	A	2160.02	ft²	*Temperature zone "B" is the ground.*	Roof/Ceiling - Ambient	59.998
11	Floor Slab	B	840.01	ft²		Floor Slab	29.750
12	Floor Slab 2	B	0.00	ft²	*Temperature zones "A", "B", "P" and "X" may be used. NOT "I"*	Floor Slab 2	
13			0.00	ft²	*Temperature zones "A", "B", "P" and "X" may be used. NOT "I"* — Factor for X		
14		X	0.00	ft²	*Temperature zone "X": Please provide user-defined reduction factor (0 < f < 1):* — 75%		
						Thermal Bridge Overview	[BTU/hr.ft.°F]
15	Thermal Bridges Ambient	A	0.00	ft	*Units in m*	Thermal Bridges Ambient	
16	Perimeter Thermal Bridges	P	0.00	ft	*Units in m; temperature zone "P" is perimeter (see Ground worksheet).*	Perimeter Thermal Bridges	
17	Thermal Bridges Floor Slab	B	0.00	ft	*Units in m*	Thermal Bridges Floor Slab	
18	Partition Wall to Neighbour	I	0.00	ft²	*No heat losses, only considered for the heat load calculation.*	Partition Wall to Neighbo	
Total Thermal Envelope			6249.44	ft²		Ave R-Value Therm Env	23.208

Inches to Decimal Fe		
1/12	=	0.083
2/12	=	0.167
3/12	=	0.250
4/12	=	0.333
5/12	=	0.417
6/12	=	0.500
7/12	=	0.583
8/12	=	0.667
9/12	=	0.750
10/12	=	0.833
11/12	=	0.917
12/12	=	1.000

Envelope Area Input

Area Nr.	Building Element Description	Group Nr.	Assigned to Group	Quantity	x (	a [ft]	x	b [ft]	+	User-Determined [ft²]	-	User Subtraction [ft²]	-	Subtraction Window Areas [ft²]	) =	Area [ft²]	Selection of the Corresponding Building Element Assembly	Nr.	R-Value [(hr.ft².°F)/BTU]
	Treated Floor Area	1	Treated Floor Area													1865			
	North Windows	2	North Windows													24.1	From Windows sheet		4.0
	East Windows	3	East Windows													17.4	From Windows sheet		4.3
	South Windows	4	South Windows													320.4	From Windows sheet		4.1
	West Windows	5	West Windows													5.4	From Windows sheet		3.9
	Horizontal Windows	6	Horizontal Windows													0.0	From Windows sheet		0.0
	Exterior Door	7	Exterior Door	5	x (	3	x	6.67	+		-		) -		=	100.1	R-Value Exterior Door		2.9
1	South Wall	8	Exterior Wall - Ambient	1	x (	21.00	x	60.00	+		-	277.50	) -	320.4	=	662.1	Double Stud Wall	1	34.8
2	North Wall	8	Exterior Wall - Ambient	1	x (	12	x	60.00	+		-	20	) -	24.1	=	675.9	Double Stud Wall	1	34.8
3	West Wall	8	Exterior Wall - Ambient	1	x (	21.00	x	24.00	+		-	20	) -	5.4	=	478.6	Double Stud Wall	1	34.8
4	East Wall	8	Exterior Wall - Ambient	1	x (	21	x	24.00	+		-	135	) -	17.4	=	351.6	Double Stud Wall	1	34.8
5	Roof	10	Roof/Ceiling - Ambient	1	x (	24.00	x	60.00	+	120	-		) -	0.0	=	1560.0	I-Joist Roof plus 2x4 ceiling	5	60.0
6	Floor Slab	11	Floor Slab	1	x (	24.00	x	35	+		-		) -	0.0	=	840.0	Foam Under 4" Slab	3	29.8
7	Ext. Wall Below Grade	9	Exterior Wall - Ground	1	x (	10.33	x	48	+		-		) -	0.0	=	495.8	Below Grade ICF Wall	2	34.2
8	Floor above Garage	10	Roof/Ceiling - Ambient	1	x (	25	x	24	+		-		) -	0.0	=	600.0	I-Joist Roof plus 2x4 ceiling	5	60.0
9	Insulated Slab Edge	9	Exterior Wall - Ground	1	x (		x		+	118	-		) -	0.0	=	118.0	Below Grade ICF Wall	2	34.2

Please complete in Windows worksheet only!

Additio

Exterior Absorptivity	Exteri

th
Inputs or
For consideratio

dy

Envelope and Thermal Comfort Principles

1. **Continuous Insulation-** creating steady indoor temperatures that won't drop below 50 degrees without heating source

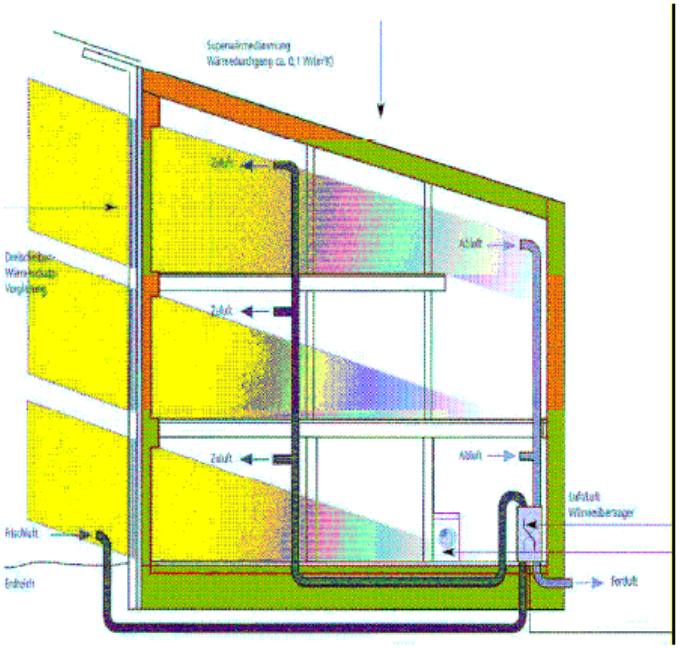
2. **Thermal Bridge Free Construction-** minimizes condensation/ building deterioration

3. **Compact Building Shape-** excellent surface-to-volume ratio (< 1)

4. **Airtightness-** minimizes moisture diffusion into wall assembly

5. **Balanced Ventilation with Heat Recovery with minimal Space Conditioning System -** exceptional efficiency, indoor air-quality and comfort

6. **Optimal Solar Orientation and Shading** – maximizing solar gains for winter, minimizing gains for the summer case



7. **Energy Efficient Appliances and Lighting-** highly efficient use of household electricity

8. **User Friendliness -** user manuals are recommended to be given homeowners

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Passivhaus Results

- **80-90% reduction** in heating and cooling loads when compared to Code
- **65%-75% reduction** in total energy demand
- Superior **indoor air quality**
- Occupant **comfort**
- **Increased student performance**
- **Lower** annual energy **costs**
- **Smaller carbon footprint**
- **Best Strategy to Net-Zero Energy: Reduce first, then produce renewable Energy**