Solar Passive House

Basic Calculations Intro

When designing a solar passive house, it is important to consider various heating and cooling loads. These loads may be external, such as those caused by the building's envelope (walls, roof, windows), or internal, such as those caused by occupants, equipment, and lights. The total heating and cooling load is made up of two components: sensible, which affects the dry bulb temperature, and latent, which affects the moisture content. Heat enters the home through solar radiation, conduction through walls and roofs, and internal sources such as occupants and equipment. Sensible heat gains involve conduction, convection, and radiation, while latent gains involve moisture from ventilation, respiration, and appliances. The balance between external and internal loads varies depending on the building type, climate, and design.

Sources of Sensible Heat Gain:

- Conduction, convection, and radiation through building elements (floors, ceilings, walls).
- Occupant's body heat.
- Heat generated by appliances and lighting.
- Solar heat gain through glass.
- Infiltration of outside air.
- Air is introduced through ventilation.

Sources of latent heat gain:

- Moisture-laden outside air from infiltration and ventilation.
- Heat produced by occupant respiration and activities.
- Moisture is generated by equipment and appliances.

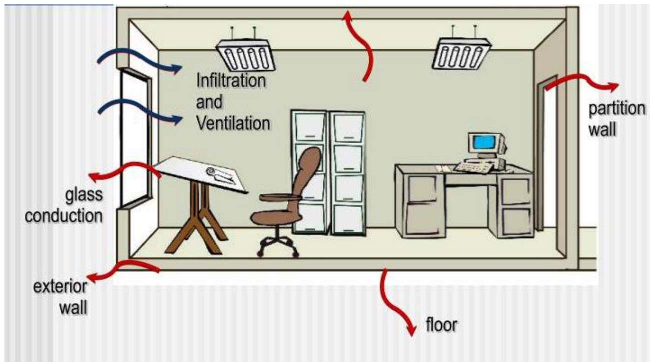


Figure 1: Heating Load Components (Berryman, https://www.slideserve.com/Patman/heat-loss)

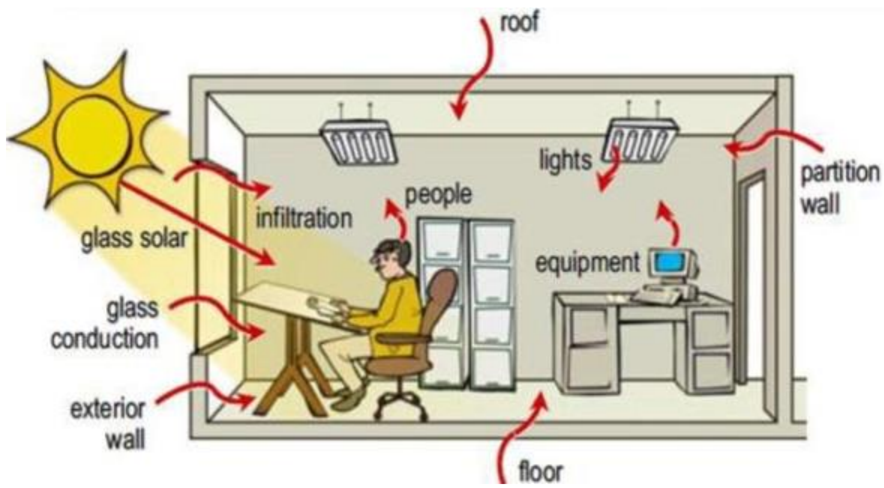


Figure 2: Cooling Load Components (H M Hashim, 2023)

Codes and Standards for Energy Efficiency in Solar Passive House

To make energy-efficient buildings that promote sustainability and a healthy indoor environment, building codes must include Passive House standards. These standards are helpful in reducing carbon emissions and enhancing energy efficiency. Passive House principles provide a blueprint for constructing zero-energy buildings that align with broader environmental goals.

ASHRAE sets guidelines for energy efficiency in solar passive houses, helping to shape codes and standards. These guidelines establish minimum efficiency criteria for building construction and operation. They emphasize solar passive principles, covering building envelope design, HVAC systems, and lighting to ensure that solar passive houses follow the best industry practices. Complying with ASHRAE codes contributes to the sustainability of solar passive homes, promoting a greener and more energy-efficient built environment.

Table 11. Ventilation Air Requirements, from ASHRAE Standard 62.2–2003

a. (IP) Outdoor Air Required, cfm						b. (SI) Outdoor Air Required, L/s					
Floor Area	No. of Bedrooms					Floor	No. of Bedrooms				
(ft^2)	0-1	2–3	4–5	6–7	>7	Area (m^2)	0–1	2–3	4–5	6–7	>7
< 1500	30	45	60	75	90	< 139	14	21	28	35	42
1502–3000	45	60	75	90	105	139.1–279	21	28	35	42	50
3001–4500	60	75	90	105	120	279.1–418	28	35	42	50	57
4501–6000	75	90	105	120	135	418.1–557	35	42	50	57	64
6001–7500	90	105	120	135	150	557.1–697	42	50	57	64	71
> 7500	105	120	135	150	165	> 697	50	57	64	71	78

Figure 3: Example of ASHRAE Standard

COOLING/HEATING LOAD ESTIMATION

The heat loss and gain in a solar passive house are affected by several factors. Heat loss occurs due to building envelope, foundation perimeter, infiltration, ventilation, and fenestration. On the other hand, heat gain involves building envelope, infiltration, ventilation, fenestration, and internal sources, such as occupants, lighting, power equipment, and appliances. It is also essential to consider thermal mass and comfort, as it plays a crucial role in maintaining optimal air temperature (19-27°C), humidity (30-60% relative humidity, not exceeding 12gm/kg of dry air), airspeed impact, and ensuring clean, fresh air supply for indoor spaces.

1. Heat gain through exterior walls and roofs

The building envelope calculates heat loss using non-solar windows, doors, floors, roofs, and walls, as well as sunlit counterparts for heat gain, which is referred to as fabric heat gain or loss depending on the direction of heat transfer. Heat gain from exterior walls and roofs is calculated using the following equation:

$$\mathbf{Q}_{\text{exterior walls}} = \mathbf{U} \times \mathbf{A} \times \mathbf{CLTD}_{\text{ext walls}}$$

$$\mathbf{Q}_{\text{roof}} = \mathbf{U} \times \mathbf{A} \times \mathbf{CLTD}_{\text{roof}}$$

Where,

U=Overall Heat Transfer Coefficient

A= Cross-Sectional Area

CLTD= Cooling Load Temperature Difference

CLTD is a theoretical temperature difference that accounts for the combined effects of inside and outside air temperature difference, daily temperature range, solar radiation, and heat storage in the construction assembly or building mass.

2. Heat gain through interior partitions, ceilings, and floors

Heat gain from partitions, ceiling and floors is calculated as:

$$\mathbf{Q}_{\mathrm{Partition}} = \mathbf{U} \times \mathbf{A} \times \Delta T$$

$$\mathbf{Q}_{\mathrm{Ceiling/Floor}} = \mathbf{U} \times \mathbf{A} \times \Delta T$$

Where,

U=Overall Heat Transfer Coefficient

A = Cross-Sectional Area

ΔT = Temperature Difference Between Conditioned Space and Adjacent Space.

Normally Adjacent Room Temperature Is Considered As 5 Degrees Above the Conditioned Space or Average of Indoor Conditioned Space and Outdoor Temperature.

3. Heat gain through ventilation and infiltration

Ventilation is the controlled supply of outdoor air to maintain indoor air quality. It's done using equipment like fans and blowers. Whereas, Infiltration is uncontrolled leakage caused by pressure differences. Both are calculated to ensure acceptable air quality.

Ventilation and infiltration are calculated as:

$$\mathbf{Q}_{\mathbf{sensible}} = \mathbf{m_a} \times \mathbf{C_p} \times (\mathbf{T_o} - \mathbf{T_i})$$

$$\mathbf{Q}_{\mathbf{latent}} = \mathbf{m_a} \times \mathbf{h_l} \times (\mathbf{w_o} - \mathbf{w_i})$$

$$\boldsymbol{Q_{total\ loss}} = \boldsymbol{m_a} \times (\boldsymbol{h_o} - \boldsymbol{h_i})$$

Where, ma= Mass of Air Entering the Space

$\mathbf{C_p}$ = Specific Heat Capacity of The Air Entering the Space

$\mathbf{h_l}$ = Latent Heat of Vaporization

$\mathbf{w_o}$ = Relative Humidity of Outside/Ambient Air

$\mathbf{w_i}$ = Relative Humidity of Indoor Air

4. Heat gain by occupants

Occupants generate both sensible and latent heat, with higher activity leading to a slight increase in sensible heat and a dramatic increase in latent heat due to perspiration. The combined sensible and latent loads produced by occupants can be calculated as:

$$\mathbf{Q_{sensible} = N \times sensible\ heat\ gain \times CLF}$$

$$\mathbf{Q_{latent} = N \times latent\ heat\ gain}$$

Where,

N = Number of People in Space

CLF = Cooling Load Factor

5. Heat gain by lights

Heat gain by light is calculated as:

$$\mathbf{Q_{light} = W \times F_{ul} \times F_{SA} \times CLF}$$

Where,

W = Watts Input from the Lighting Equipment

F_{ul} = Lighting Use Factor, as Appropriate

F_{sa} = Special Allowance Factor, as Appropriate

CLF = Cooling Load Factor

6. Heat gain by power equipment

Heat gain by power equipment is calculated as:

$$\mathbf{Q_{power\ equipment} = P \times E_F \times CLF}$$

Where,

P = Horsepower Ratings from Manufacturer

Ef = Efficiency Factor

CLF = Cooling Load Factor

7. Heat gain by appliances

Heat gain by appliances is calculated as:

$$\mathbf{Q_{appliance} = Q_{input} \times F_U \times F_R \times CLF}$$

Where,

Q_{input} = Rated Energy Input

F_u = Usage Factor

F_R = Radiation Factor

CLF = Cooling Load Factor

8. Heat gain through fenestration

Fenestration refers to any opening in a building's structure, which includes the glass material. It connects to the outdoors and allows solar radiation. It adds heat by direct solar gain and glass conduction, which can be calculated as:

$$\mathbf{Q_{solar\ heat\ gain} = A \times SC \times SCL}$$

Where,

A = Area of Transparent Surface

SC = Shading Coefficient

SCL = Solar Cooling Load Factor

Heat transfer through transparent surface can be calculated as:

$$\mathbf{Qglass\ loss/gain = U \times A \times CLTD_{glass}}$$

9. Foundation Perimeter Heat Loss

To calculate the total foundation heat loss from slabs-on-grade, basements, and insulated crawlspaces, you need to multiply the perimeter by the appropriate heat loss factor and the change in temperature. You can find the heat loss factors in the thermal properties table provided by various standards.

$$\mathbf{Q_{foundation\ loss} = Perimeter \times U \times \Delta T}$$

Note: ASHRAE publications provide various parameter values, such as SC (shading coefficient), SCL (solar cooling load factor), Q_{input} (rated energy input), FU (usage factor), FR (radiation factor), CLF (cooling load factor), P (horsepower ratings from the manufacturer), EF (efficiency factor), W (watts input from lighting equipment), Ful (lighting use factor), Fsa (special allowance factor), U (overall heat transfer coefficient), A (cross-sectional area), and CLTD (cooling load temperature differential). These values can be used to understand and calculate different aspects of building design and performance.

10. Cooling Load Estimations Basic Numerical

To estimate cooling load for the facility given in the drawing.

Building specifications for a college laboratory.

- Height: 10 feet
- Door: Glass door, measuring 6 feet x 3 feet

Windows:

- Window 1: 6 feet x 4 feet
- Window 2: 4 feet x 2 feet

Materials:

- Wall: Brick wall, 9 inches thick with a thermal conductivity of 1.6 W/mK
- Window: 2 inches thick glass with a thermal conductivity of 0.96 W/mK and a shading coefficient of 0.9

Heat Transfer Coefficients:

- Inside convective heat transfer coefficient: 10 W/m²K
- Outside convective heat transfer coefficient: 30 W/m²K

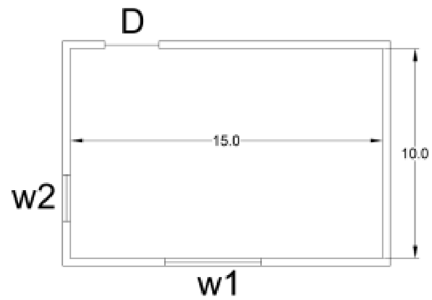
Additional Factors:

- Location Parameters: Latitude 40° North (July), Wall no: 1, Zone type A for CLTD calculation
- Infiltration: 0.2 air changes per hour (ACH)
- Lighting: 5 CFL lamps, each with a capacity of 10 W
- Occupancy: 5 people engaged in moderate activity work

Environmental Conditions:

- Outdoor Weather: 35°C Dry Bulb Temperature (DBT), 25°C Wet Bulb Temperature (WBT)
- Indoor Design Conditions: 24°C, 50% relative humidity (rh)

Note: Roof and floor losses are not considered in this scenario.



1. <u>Starting from the wall conduction/convection solar</u>

$$\frac{1}{U} = \frac{1}{hi} + \frac{1}{ho} + \frac{L}{K}$$

Direction	Area (in²)	U	CLTD	Q=U*A*CLTD (W/m²)
N	15*10-6*3=132	3.62	16	0.706
S	15*10-6*4=0126	3.62	19	0.8054
E	10*10=100	3.62	16	0.538
W	10*10-4*2=92	3.62	44	1.36

CLTD values of walls and roofs from ASHRAE Fundamentals, Chapter 28

Table 32 July Cooling Load Temperature Differences for Calculating Cooling Load from Sunlit Walls 40°North Latitude

Wall Face	Wall Number 1																							
	Hour																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	1	0	−1	−1	−2	−1	4	6	6	7	9	12	14	15	16	16	16	16	15	9	6	4	3	2
NE	1	0	−1	−1	−2	1	13	23	26	24	19	16	15	16	16	16	15	13	11	8	6	4	3	2
E	1	0	−1	−1	−1	1	16	28	34	36	33	27	20	17	17	17	16	14	11	8	6	4	3	2
SE	1	0	−1	−1	−2	0	8	18	26	31	32	31	27	22	18	17	16	14	11	8	6	4	3	2
S	1	0	−1	−1	−2	−1	0	2	6	12	18	24	28	29	28	24	19	15	11	8	6	4	3	2
SW	1	0	−1	−1	−1	−1	0	2	4	7	9	14	22	29	36	39	38	34	25	13	7	4	3	2
W	1	1	−1	−1	−1	−1	1	2	4	7	9	12	15	23	33	41	44	44	34	18	9	5	3	2
NW	1	0	−1	−1	−1	−1	0	2	4	7	9	12	14	16	21	28	34	36	31	16	8	5	3	2

2. <u>Fenestration (Conduction & Convection)</u>

$$\frac{1}{U} = \frac{1}{hi} + \frac{1}{ho} + \frac{L}{K}$$

Direction	Area (in²)	U	CLTDglass	Qglass=U*A*CLTD (W/m²)	SC	SCL	Qfens=SC*SCL*A
N	6*3=18	5.36	7	0.063	0.9	98	0.1475
S	6*4=24	5.36	7	0.083	0.9	98	0.196
E	0	5.36	7	0	0.9	82	0
W	4*2=8	5.36	7	0.027	0.9	605	0.404
Total				0.172	Total		0.747

Table 34 Cooling Load Temperature Differences (CLTD) for Conduction through Glass

Solar Time, h	CLTD, °C	Solar Time, h	CLTD, °C
0100	1	1300	7
0200	0	1400	7
0300	−1	1500	8
0400	−1	1600	8
0500	−1	1700	7
0600	−1	1800	7
0700	−1	1900	6
0800	0	2000	4
0900	1	2100	3
1000	2	2200	2
1100	4	2300	2
1200	5	2400	1

Figure 4: Table for CLTDglass

Table 36 July Solar Cooling Load For Sunlit Glass 40°North Latitude

Glass Face	Zone Type A																							
	Hour											Solar Time												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	0	0	0	0	3	79	85	88	101	110	120	126	126	123	113	98	98	113	38	19	9	3	3	0
NE	0	0	0	0	6	268	406	422	353	236	173	151	139	126	117	101	82	57	22	9	6	3	0	0
E	0	0	0	0	6	293	495	583	576	485	334	211	167	142	123	104	82	57	22	9	6	3	0	0
SE	0	0	0	0	3	148	299	413	473	473	413	306	198	154	129	107	85	57	22	9	6	3	0	0
S	0	0	0	0	0	28	54	79	129	202	268	306	302	265	198	132	98	63	25	13	6	3	0	0
SW	0	0	0	0	0	28	54	76	95	110	123	202	318	419	476	479	419	293	110	54	25	13	6	3
W	3	0	0	0	0	28	54	76	95	110	120	126	205	359	498	589	605	491	180	85	41	19	9	6
NW	3	0	0	0	0	28	54	76	95	110	120	126	126	158	265	381	450	410	145	69	35	16	9	3
Hor	0	0	0	0	0	76	217	378	532	665	759	810	816	772	684	554	394	221	91	44	22	9	6	3

Figure 5: Table for Solar Cooling Load factor (SCL)

3. <u>Ventilation</u>

$$Vvent = 5 * 5 + \frac{15 * 10 * 0.9}{10.76}$$

$\mathrm{M}vent = \frac{Vvent}{Sp.Vol}$

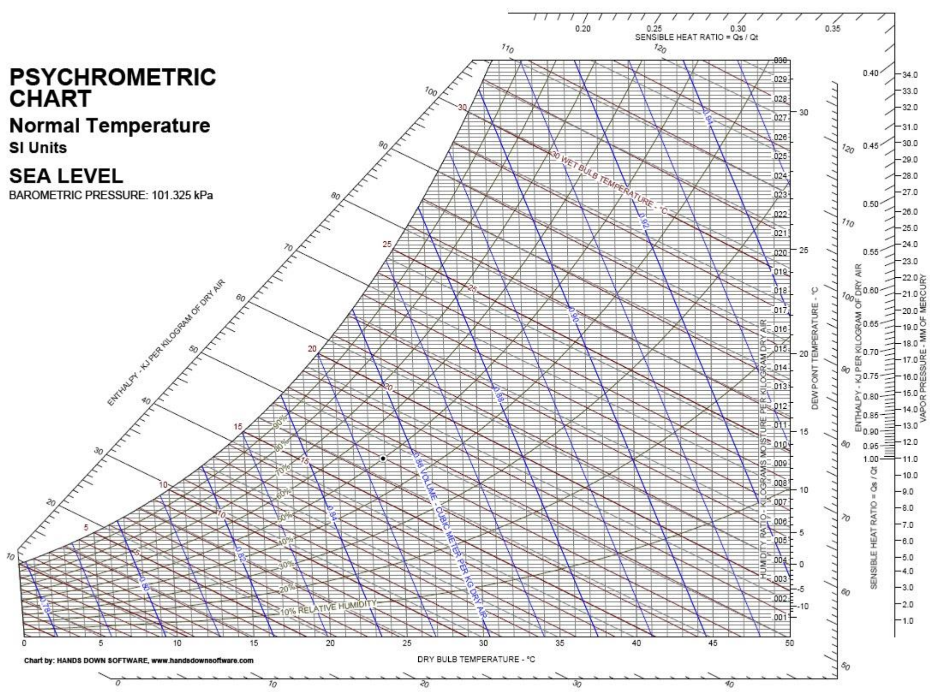
Qvent=Mvent*(h1-h2)

Note: Sp. Vol, h1, h2 are obtained from Psychometric Chart.

Portion of ASHRAE Standard 62.1 – 2019, www.ashrae.org

Table 6-1 Minimum Ventilation Rates in Breathing Zone *(Continued)*

	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Default Values
					Occupant Density
Occupancy Category	cfm/ person	L/s· person	cfm/ft²	L/s·m²	#/1000 ft² or #/100 m²
Educational Facilities (continued)					
University/college laboratories	10	5	0.18	0.9	25
Wood/metal shop	10	5	0.18	0.9	20
Food and Beverage Service					
Bars, cocktail lounges	7.5	3.8	0.18	0.9	100
Cafeteria/fast-food dining	7.5	3.8	0.18	0.9	100
Kitchen (cooking)	7.5	3.8	0.12	0.6	20
Restaurant dining rooms	7.5	3.8	0.18	0.9	70
Food and Beverage Service, General					
Break rooms	5	2.5	0.06	0.3	25
Coffee stations	5	2.5	0.06	0.3	20
Conference/meeting	5	2.5	0.06	0.3	50
Corridors	—	—	0.06	0.3	—
Occupiable storage rooms for liquids or gels	5	2.5	0.12	0.6	2



4. <u>Infiltration</u>

Infiltration=0.2*ACH

$$Vin = \frac{Vroom * Infiltration}{3600}$$

$$\mathrm{M}inf = \frac{Vinf}{Sp.\ vol}$$

Qinf=Minf*(h1-h2)

Note: Sp. Vol, h1, h2 are obtained from Psychometric Chart.

5. <u>Lightening</u>

Qlightening=Bulb power*no. of bulb

6. <u>Occupants</u>

Qoccupants= No. of People*Total Heat

Table 3 Rates of Heat Gain from Occupants of Conditioned Spaces

		Total Heat, W		Sensible Heat, W	Latent Heat, W	% Sensible Heat that is Radiant[b]	
Degree of Activity		Adult Male	Adjusted, M/F[a]			Low V	High V
Seated at theater	Theater, matinee	115	95	65	30		
Seated at theater, night	Theater, night	115	105	70	35	60	27
Seated, very light work	Offices, hotels, apartments	130	115	70	45		
Moderately active office work	Offices, hotels, apartments	140	130	75	55		
Standing, light work; walking	Department store; retail store	160	130	75	55	58	38
Walking, standing	Drug store, bank	160	145	75	70		
Sedentary work	Restaurant[c]	145	160	80	80		
Light bench work	Factory	235	220	80	140		
Moderate dancing	Dance hall	265	250	90	160	49	35
Walking 4.8 km/h; light machine work	Factory	295	295	110	185		
Bowling[d]	Bowling alley	440	425	170	255		
Heavy work	Factory	440	425	170	255	54	19
Heavy machine work; lifting	Factory	470	470	185	285		
Athletics	Gymnasium	585	525	210	315		

7. <u>Total Heat=Sum of all the Q above</u>

Portion of ASHRAE Standard 62.1 – 2019, www.ashrae.org

Table 6-1 Minimum Ventilation Rates in Breathing Zone *(Continued)*

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Default Values Occupant Density
	cfm/person	L/s·person	cfm/ft²	L/s·m²	#/1000 ft² or #/100 m²
Educational Facilities (continued)					
University/college laboratories	10	5	0.18	0.9	25
Wood/metal shop	10	5	0.18	0.9	20
Food and Beverage Service					
Bars, cocktail lounges	7.5	3.8	0.18	0.9	100
Cafeteria/fast-food dining	7.5	3.8	0.18	0.9	100
Kitchen (cooking)	7.5	3.8	0.12	0.6	20
Restaurant dining rooms	7.5	3.8	0.18	0.9	70
Food and Beverage Service, General					
Break rooms	5	2.5	0.06	0.3	25
Coffee stations	5	2.5	0.06	0.3	20
Conference/meeting	5	2.5	0.06	0.3	50
Corridors	—	—	0.06	0.3	—
Occupiable storage rooms for liquids or gels	5	2.5	0.12	0.6	2

11. Worksheet

Let's take a house (Jackson, Mississippi) as shown in figure below for a worksheet example, it is a single-family passive solar home with a total area of 1,504 square feet and an average ceiling height of 8.3 feet. The floor plan, building elevations, building sections, and other details are shown below.

The house has an attached sunspace with a four-inch-thick slab-on-grade floor made of quarry tile set in a mortar bed. The sunspace is separated from the rest of the house by sliding glass doors and a masonry fireplace wall. Awning windows located at the top and bottom of the south wall provide ventilation for the sunspace.

The south-facing windows in the dining area, kitchen, and master bedroom provide direct gain solar heating. The south-facing glazing in the kitchen and dining area provides heat to an exposed slab-on-grade. The eastern part of the house is built on a slab-on-grade, while the great room and master bedroom suite are raised floor construction. The kitchen and dining area floor are finished with ceramic tiles, allowing it to function as thermal mass.

The exterior doors are made of metal with a foam core center.

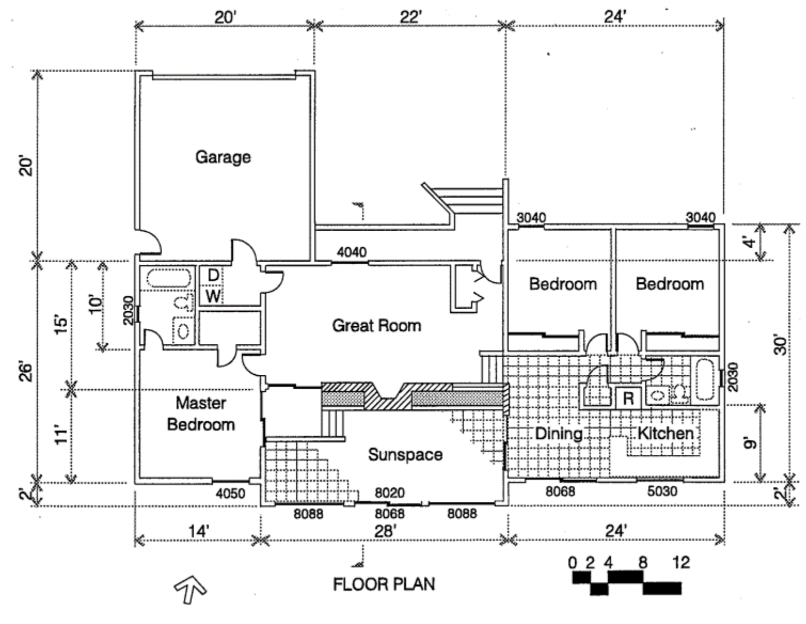


Figure 6: House Floor Plan (Jackson, Mississippi)

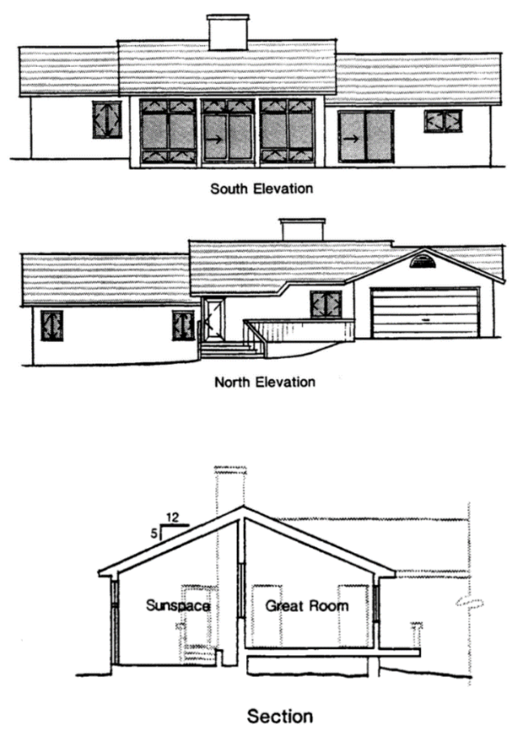


Figure 7: Section View of House (Jackson, Mississippi)

Table 1: Worksheet Sample (Jackson, Mississippi)

Conservation Performance Level

A. Envelope Heat Loss

S.N.	Envelope	Construction Description	Area (1)	R-Value (Table A) (2)	Heat Loss (Btu/°F-h) (1)/ (2)
1	Ceilings/Roofs	R-30 in Attic	1084	35.9	30
		R-30 in Cathedral Ceiling	420	24.5	17
2	Walls	R-19 + R-7 Sheathing	992	24.7	40
		R-19 at Garage	140	17.7	8
3	Insulated Floors	R-19 in Floor Over Vented Crawlspace	784	25.8	30
4	Non-Solar Glazing	Double Glazed Wood Frame 1/2" Air Gap	52	1.8	29
5	Doors	Metal with Foam Core	40	5.9	7
Total					161

B. Foundation Perimeter Heat Loss

S.N.	Envelope	Construction Description	Perimeter (1)	Heat Loss Factor (Table B) (2)	Heat Loss (1) *(2) (Btu/°F-h)
1	Slabs-on-Grade	R-7	82	0.3	25
Total					25

C. Infiltration Heat Loss

S.N.	Building Volume (1)	Air Changes Per Hour (2)	Factor (3)	Heat Loss (1) *(2) *(3) (Btu/°F-h)
1	12483	0.5	0.18	112

D. Total Heat Per Square Foot

S.N.	Total Heat Loss (A+B+C) (1)	Floor Area (2)	Factor (3)	Heat Loss Per Sq. Foot (1) *(3)/ (2) (Btu/DD-sf)
1	298	1504	24	4.76

E. Conservative Performance Level

S.N.	Total Heat Loss per Sq. Foot	Heating Degree Days (Table C)	Heating Degree Day Multiplier (Table C)	Total (Btu/yr-sf)
	4.76	3703	0.97	17.097

F. Comparison Conservative Performance (From Table D)	25.360 Btu/yr-sf

The Worksheets booklet is a valuable tool for designers who work on building designs. It simplifies the process of evaluating a design's performance, allowing designers to compare a specific design with a typical one built by the same builder.

The Conservation Performance Level worksheet helps estimate the amount of heat energy a building requires from solar and backup heating systems each year. The table and calculations in this worksheet estimate the yearly heat loss from inside the building to the outside, which is crucial for determining how much energy is required to maintain a comfortable temperature during the cold months. By examining the heat loss through different parts of the building, designers and builders can make informed decisions about energy efficiency and determine the appropriate size for the heating system.

This worksheet specifically deals with calculating heat loss, which is similar to the process used to determine the appropriate size for heating and cooling systems. However, it's important to note that the calculations do not include heat loss through passive solar systems, such as large windows or walls that separate the house from the sunspace. Trombe walls or water walls are also not taken into account. This way, designers can make well-informed decisions about energy efficiency and the size of the heating system.

Procedure (Jackson, Mississippi)

1. **Step A:** Calculating the heat loss through the building envelope. The building envelope includes walls, roofs, floors, non-solar windows, and doors that enclose the conditioned space. To determine the heat loss for each component, we divide its surface area by the total R-value. The total envelope heat loss is the sum of the heat loss for all components. We obtain R-values from tables specific to ceilings/roofs, walls, floors, windows, and doors. We consider different constructions, such as framed ceilings and walls with specific insulating materials, and use their associated areas and R-values to calculate heat losses.

1.1. For ceilings/roofs, we take into account two types of construction, each with its R-value, accounting for factors like attic buffering and framing effects.

A1–Ceilings/Roofs

Attic	Insulation R-value			
Construction	R-30	R-38	R-49	R-60
	27.9	35.9	46.9	57.9
Framed	Insulation R-value			
Construction	R-19	R-22	R-30	R-38
2x6 at 16"oc	14.7	15.8	16.3	–
2x6 at 24"oc	15.3	16.5	17.1	–
2x8 at 16"oc	17.0	18.9	20.6	21.1
2x8 at 24"oc	17.6	19.6	21.6	22.2
2x10 at 16"oc	18.1	20.1	24.5	25.7
2x10 at 24"oc	18.4	20.7	25.5	26.8
2x12 at 16"oc	18.8	21.0	25.5	30.1
2x12 at 24"oc	19.0	21.4	27.3	31.4

1.2. We consider two types of wall construction, one with insulating sheathing and one without. We use surface areas and R-values to calculate heat losses.

A2–Framed Walls

Single Wall Framing	Insulation R-value			
	R-11	R-13	R-19	R-25
2x4 at 16"oc	12.0	13.6	–	–
2x4 at 24"oc	12.7	13.9		–
2x6 at 16"oc	14.1	15.4	17.7	19.2
2x6 at 24"oc	14.3	15.6	18.2	19.8
Double Wall Framing	Total Thickness (inches)			
	8	10	12	14
	25.0	31.3	37.5	43.8

The R-value of insulating sheathing should be added to the values in this table.

1.3. We only consider the raised floor in this step, with different framing configurations and insulation values. We use areas and R-values to calculate heat losses.

A3–Insulated Floors

Framing	Insulation R-value R-11	R-19	R-30	R-38
2x6s at 16"oc	18.2	23.8	29.9	–
2x6s at 24"oc	18.4	24.5	31.5	–
2x8s at 16"oc	18.8	24.9	31.7	36.0
2x8s at 24"oc	18.9	25.4	33.1	37.9
2x10 at 16"oc	19.3	25.8	33.4	38.1
2x10 at 24"oc	19.3	26.1	34.4	39.8
2x12 at 16"oc	19.7	26.5	34.7	39.8
2x12 at 24"oc	19.6	26.7	35.5	41.2

These R-values include the buffering effect of a ventilated crawlspace or unconditioned basement.

1.4. For non-solar glazing, we calculate heat loss from non-solar glazing, excluding direct gain glazing and windows separating the house from the sunspace. We use the rough frame opening area and R-values specific to window types.

A4–Windows

	Air Gap 1/4 in.	1/2 in.	1/2 in. argon
Standard Metal Frame			
Single	.9		
Double	1.1	1.2	1.2
Low-e (e<=0:40)	1.2	1.3	1.3
Metal frame with thermal break			
Double	1.5	1.6	1.7
Low-e (e<=0.40)	1.6	1.8	1.8
Low-e (e<=0.20)	1.7	1.9	2.0
Wood frame with vinyl cladding			
Double	2.0	2.1	2.2
Low-e (e<=0.40)	2.1	2.4	2.5
Low-e (e<=0.20)	2.2	2.6	2.7
Low-e (e<=0.10)	2.3	2.6	2.9

These R-values are based on a 3 mph wind speed and are typical for the entire rough framed opening. Manufacture's data, based on National Fenestration Rating Council procedures, should be used when available. One half the R-value of movable insulation should be added, when appropriate.

1.5. We consider exterior doors and use their total surface area and R-values to calculate heat losses.

A5–Doors	
Solid wood with Weatherstripping	2.2
Metal with rigid foam core	5.9

1.6. Sum of the all-heat losses for all components.

2. **Step B:** The objective is to estimate foundation heat loss from slabs-on-grade, basements, and insulated crawlspaces. This involves multiplying the perimeter length by a specific heat loss factor obtained from Table B.

Table B–Perimeter Heat Loss Factors for Slabs-on-Grade and Unheated Basements (Btu/h-F-ft)

Perimeter Insulation	Slabs-on-Grade	Heated Base-ments	Unheated Base-ments	Insulated Crawl-spaces
None	0.8	1.3	1.1	1.1
R-5	0.4	0.8	0.7	0.6
R-7	0.3	0.7	0.6	0.5
R-11	0.3	0.6	0.5	0.4
R-19	0.2	0.4	0.5	0.3
R-30	0.1	0.3	0.4	0.2

3. **Step C:** The objective is to calculate the amount of heat lost due to infiltration or air leakage. This is done by multiplying the building volume by the air changes per hour and a heat loss factor of 0.018. For instance, the building in question has an estimated infiltration rate of 0.50, based on local experience. To determine the building volume, you need to multiply the average ceiling height of 8.3 feet by the conditioned floor area of 1,504 square feet (excluding the garage and sunspace), resulting in a volume of 12,483 cubic feet.

4. **Step D:** The total heat loss of a building is calculated by adding up the heat loss from the building envelope (Step A), foundation perimeter (Step B), and infiltration (Step C). This value typically ranges between 200 and 500 Btu, which represents the heat loss per hour when the outside temperature is one degree Fahrenheit colder than the inside temperature. It's important to note that this total doesn't include any heat loss from solar systems.
   The result of Step D gives the annual heat loss per degree day per square foot. To get this value, we multiply the total heat loss by 24 (hours per day) and divide it by the conditioned floor area.

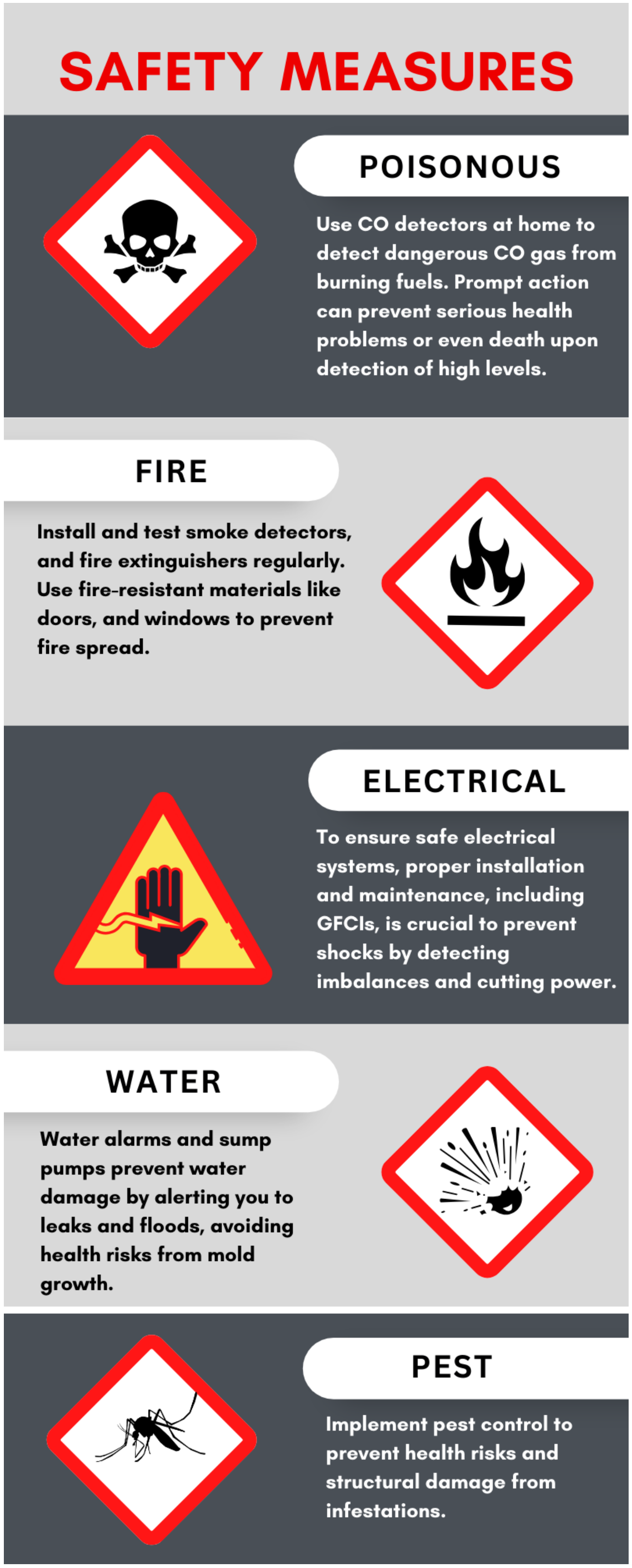
5. **Step E:** We determine the conservation performance level by multiplying the total heat loss per square foot (from Step D) by the product of heating degree days and the heating degree day multiplier. To calculate the heating degree days, we refer to Table C1 based on the specific location. For the heating degree day multiplier, we look at Table C2, which takes into account both the total heat loss per square foot and the passive solar glazing area per square foot of floor area (Worksheet II, Step A). Once we have these values, we can compare the resulting conservation performance level to the base case conservation performance level in the subsequent step.

6. **Step F:** The proposed design's energy conservation performance level is compared to the base case performance level for the area, as listed in Table D (Base Case: 25.38 Btu/sq.ft). Alternatively, it can be compared to other building designs that are typical for the region. If the energy conservation performance level of the proposed building (Step E) exceeds that of the base case or typical design level, the designer is advised to consider including additional building insulation or reducing the non-solar glass area.

Table D–Base Case Conservation Performance (Btu/yr-sf)

Base Case	25,380

SAFETY MEASURES



Ensuring safety in a solar passive house is of utmost importance for the well-being of its occupants. Safety measures should include installing smoke detectors, fire extinguishers, and fire-resistant materials to prevent fire hazards. Proper installation and maintenance of electrical systems, as well as the use of GFCIs, can prevent electrical shocks. Carbon monoxide detectors, water alarms, and sump pumps can address the threat of CO and water damage respectively. Handrails can prevent falls, and regular inspections can maintain the house's structural integrity. Other important safety considerations include radon detection, window safety, emergency exit plans, natural disaster preparedness, pest control, non-slip surfaces, security measures, air quality monitoring, appliance safety, and childproofing. By incorporating these measures, we can create a comprehensive approach to occupant safety and well-being.

MAINTAINANCE

Passive solar heating is incorporated into a building's design during its initial construction. Therefore, it requires minimal maintenance or attention beyond what is necessary for the building envelope in general. However, it is important to ensure that areas intended to receive solar heat are not obstructed by the growth of landscaping or other objects, which requires regular maintenance.

Passive Solar House Maintenance Checklist

Location	
Building	
Completed By	
Date	

Maintenance Task	Frequency	Comments	Done
Inspect and Clean Windows	Monthly	Check windows for damage or gaps. Clean them for better sunlight.	
Check Exterior Shading Devices	Bi-annually	Verify the functionality of exterior shading devices, such as shades or overhangs. Ensure they are positioned correctly to provide shade during peak sunlight hours.	
Evaluate Ventilation Systems	Annually	Ensure proper ventilation by regularly cleaning vents and ducts to maintain air quality.	
Thermal Mass Check	Annually	Inspect thermal mass (concrete floors, walls, etc.) for any damage or deterioration.	
Ventilation System Inspection	Bi-annually	Examine ventilation system for proper functioning. Clean or replace filters as needed.	
Energy Usage Monitoring	Monthly	Regularly monitor energy usage to identify areas for improvement. Adjust thermostat settings if necessary.	
Landscape Maintenance	Seasonally	Prune trees and shrubs to maximize sunlight reaching the house.	
Night Window Insulation	Annually	Check and ensure night window insulation is in place over double-pane windows.	
Trombe Walls Inspection	Bi-annually	Inspect Trombe walls for darkness to maximize solar absorption.	

Furniture Placement Check	Bi-annually	Ensure storage mass is not covered with furniture, rugs, or wall tapestries.	
Mass Distribution Evaluation	Annually	Check and redistribute mass in the room for even distribution and improved comfort.	
Overhang Size Inspection	Annually	Inspect overhangs based on latitude to ensure optimal shading in summer and sunlight in winter.	
Ventilation for Cooling	Seasonally	Assess and optimize ventilation to minimize energy use for cooling.	

Tools Required for Maintenance

Maintaining a solar passive house requires certain tools to ensure its energy efficiency and performance. Here are the tools required for maintenance:

1. Soft brushes or cloths:

   These tools are useful for cleaning the solar panels which are crucial components of a solar passive house. Any dirt or debris on the panels can hinder their efficiency. By using a soft brush or cloth, you can help maintain their performance.

2. Insulation tester:

   An insulation tester, also known as a megohmmeter or a "megger," is a specialized electrical test instrument used to measure the electrical resistance of insulating materials.

   An insulation tester checks the condition of insulation in a solar passive house. Insulation keeps the heat inside the house during winter and outside during summer, making it key to the energy efficiency of the building. An insulation tester identifies any areas where insulation may be damaged or missing, allowing you to make necessary repairs or replacements.

3. Multimeter:

   A multimeter is used to test electrical systems in a solar passive house, including solar panels, electrical outlets, and other electrical components. This tool helps identify any issues affecting the performance of the electrical system.

4. Screwdrivers:

   Screwdrivers are basic hand tools used to tighten loose screws or make repairs in a solar passive house. They may be used to tighten screws on solar panels, repair or replace insulation, or make other minor repairs.

5. Caulking gun:

   A caulking gun applies sealant around gaps or joints to fill them. In a solar passive house, it may be used to seal gaps around windows and doors to maintain the energy efficiency of the building.

6. Ladder:

   A ladder helps to access high areas of the building, including the roof for cleaning or inspecting solar panels. It may also be used to access other high areas of the building for maintenance or repairs.

7. Pruning shears or other gardening tools:

   Landscaping around a solar passive house can affect its energy efficiency. Pruning shears or other gardening tools can be used to maintain landscaping, ensuring it functions as intended.

8. Socket set or wrench set:

   These tools are used to loosen or tighten bolts and nuts that may be necessary during maintenance of a solar passive house. For example, they may be used to make repairs to mechanical systems such as geothermal systems or air conditioning units.

9. Hammer and nails:

   These basic tools fasten materials together and may be used to make repairs or hang pictures or other items in a solar passive house.

10. Level:

    A level ensures objects are properly aligned. In the context of maintaining a solar passive house, it may be used to ensure solar panels or other objects are properly aligned and level.

11. Pliers:

    Plier's grip and hold objects and may be used to tighten or loosen bolts and nuts in a solar passive house.

12. Utility knife:

    A utility knife cuts materials and may be used to cut insulation, trim excess sealant, or make other small cuts as needed in a solar passive house.

13. Flashlight:
    A flashlight illuminates dark areas and may be useful in illuminating areas that are difficult to see, such as crawl spaces or attics.

14. Personal Protective Equipment (PPE): PPE is essential during maintenance on a solar passive house. Safety goggles, glasses, and hard hats safeguard against workplace hazards and injuries, particularly when working on the roof or in elevated areas.

Bibliography

Cooling Load Calculations [Journal] / auth. H M Hashim E Sokolova, O Derevianko, D B Solovev // IOP. - 2023.

Heat Loss [Online] / auth. Berryman Dr.. - https://www.slideserve.com/Patman/heat-loss. - 10 2023. - https://www.slideserve.com/Patman/heat-loss.

Passive Solar Building Design Strategies in Lalitpur, Pokhara and Dharan cities of Nepal [Conference] / auth. Prativa Lamsal Sushil B. Bajracharya // Proceedings of IOE Graduate Conference. - 2016.

Passive Solar Design Strategies: Guidelines for Home Building [Report] / auth. Jackson, Mississippi . - [s.l.] : Passive Solar Industries Council, NREL.