

Passive-solar Design

(in 10 simple steps)

by Andy Lemann

Passive-solar Design (in 10 simple steps)

FUNDAMENTAL PRINCIPLES

- Passive Solar Design is a simple and commonsense approach to **energy efficiency**.
- When done correctly it can be a highly cost-effective way of keeping buildings **warm in winter** and **cool in summer**.
- It requires a basic understanding of **HOW THE SUN MOVES** through the sky at different times of the day and year.
- And it requires a **HOLISTIC APPROACH** to design. The 10 simple steps outlined in this class ALL need to be considered and applied correctly for a passive solar design to work properly.
- If even one of the steps is done incorrectly serious problems can arise and the resulting building can be hard to heat in the winter and/or hard to keep cool in the summer.

Passive-solar Design (in 10 simple steps)

FUNDAMENTAL PRINCIPLES

SUN MOVEMENT SPECIFICS

- Go to **Google Earth** to find latitude, longitude, and elevation of the site (bottom left hand corner)
- Go to **susdesign.com** and use their sun angle calculator to find the exact sun angles for any time and day of the year.
- Armed with this information you are ready to begin your Passive Solar Design.

A screenshot of the 'SunAngle' calculator website. The page has a green header with 'SUSTAINABLE BY DESIGN' and 'SEATTLE, WASHINGTON'. Below the header is a navigation menu with 'tools', 'consulting', 'about', 'contact', and 'solar cooking'. The main content area is titled 'SunAngle' and includes a brief description of the tool. Below this is a 'TIP' box. The 'INPUTS' section contains several dropdown menus and text boxes for 'longitude', 'latitude', 'date', 'year', 'elevation', 'time', 'time zone', 'time basis', 'daylight saving', and 'zero azimuth'. A green 'Calculate' button is located below the inputs. The 'OUTPUTS' section displays the results for 'altitude angle', 'azimuth angle', 'clock time', 'solar time', 'hour angle', 'declination', 'equation of time', 'time of sunrise', and 'time of sunset'.

Passive-solar Design (in 10 simple steps)

THE 10 STEP PROGRAM

- 1 - SITE SELECTION for solar access and shelter from winds
- 2 - ANGLE (orientation) for max. solar gain
- 3 - FENESTRATION for heat gain and control
- 4 - EAVE OVERHANGS for winter sun/summer shade
- 5 - ROOM LAYOUT for natural light and sun
- 6 - VENTILATION for air quality, summer cooling, and heat distribution
- 7 - INSULATION for heat retention and comfort
- 8 - THERMAL MASS for heat storage
- 9 - AIR SEALING for energy efficiency
- 10 - LANDSCAPING for shade and shelter

Passive-solar Design (in 10 simple steps)

STEP 1 – SITE SELECTION

THE 10 STEPS

- 1- SITE SEL-
ECTION
- 2- ANGLE
- 3- FENEST-
RATION
- 4- EAVE
OVERHANGS
- 5- ROOM
LAYOUT
- 6- VENTILATION
- 7- INSULATION
- 8- THERMAL
MASS
- 9- AIR SEALING
- 10- LAND-
SCAPING

- Choose a site with **GOOD SOLAR ACCESS**.
- Preferably a gentle **SOUTH SLOPE** with pleasant views to the south.
- Look for **PROTECTION** from **PREVAILING WINDS** and from **HOT AFTERNOON SUN** in summer.
- **BEWARE** of tantalizing **VIEWS** to the **WEST** and/or **NORTH**.
- Preferably choose an **INFILL SITE** in an already developed area to reduce sprawl, preserve open space/agricultural land/habitat, maximize use of existing infrastructure, and reduce driving.

Passive-solar Design (in 10 simple steps)

STEP 1 – SITE SELECTION

Examples

THE 10 STEPS

- 1- **SITE SELECTION**
- 2- ANGLE
- 3- FENESTRATION
- 4- EAVE OVERHANGS
- 5- ROOM LAYOUT
- 6- VENTILATION
- 7- INSULATION
- 8- THERMAL MASS
- 9- AIR SEALING
- 10- LANDSCAPING



BIG HORN STUDIO (looking south)

- + Great solar access
- + Great views of mountains to the South
- Slight slope to the North
- Exposed to winds from North and West
- Out of town on unspoiled agricultural land with no existing infrastructure. Developing the site requires major earthworks for electrical and water supply, driveway, septic system, etc. Living on the site requires much driving to and from town.



SHERIDAN HOUSE (looking north-west)

- + Excellent solar access due to streets on South and East sides
- + Long side of lot runs E-W
- + Pleasant streetscapes to South and East.
- + Protected from winds from the North and West.
- + Infill site in town with existing infrastructure (previous house burnt down), short walk or bike ride to all services and businesses, access to public transportation (very little need to drive).

Passive-solar Design (in 10 simple steps)

STEP 2 – ANGLE (of orientation)

THE 10 STEPS

- 1- SITE SELECTION
- 2- ANGLE
- 3- FENESTRATION
- 4- EAVE OVERHANGS
- 5- ROOM LAYOUT
- 6- VENTILATION
- 7- INSULATION
- 8- THERMAL MASS
- 9- AIR SEALING
- 10- LANDSCAPING

- Orient the building with the long axis facing solar south to **MAXIMIZE SOLAR GAIN** for the south wall.
- To find **SOLAR SOUTH** 1) Drive tall stake into ground (make sure it is plumb). 2) Observe shadow of stake at high noon (1pm during daylight savings time). 3) That's it...the shadow of the stake points directly north/south.

Passive-solar Design (in 10 simple steps)

STEP 2 – ANGLE (of orientation)

Examples

THE 10 STEPS

- 1- SITE SELECTION
- 2- **ANGLE**
- 3- FENESTRATION
- 4- EAVE OVERHANGS
- 5- ROOM LAYOUT
- 6- VENTILATION
- 7- INSULATION
- 8- THERMAL MASS
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BIG HORN STUDIO

+ Square plan with one side facing directly towards solar south.



SHERIDAN HOUSE

+ Rectangular plan with long side facing directly toward Solar South

Passive-solar Design (in 10 simple steps)

STEP 3– FENESTRATION

THE 10 STEPS

- 1- SITE SELECTION
- 2- ANGLE
- 3- FENESTRATION
- 4- EAVE OVERHANGS
- 5- ROOM LAYOUT
- 6- VENTILATION
- 7- INSULATION
- 8- THERMAL MASS
- 9- AIR SEALING
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- Arrange windows so that the following percentages of glass area to floor area are met.
- **South wall 7-12%** (depending on the amount of Thermal Mass – discussed in Step 8)
- **North wall <4 %**
- **East wall <4 %**
- **West wall <2 %**
- Use the highest performance (**lowest U-value**) windows that you can afford. For south windows use higher Solar Heat Gain Coefficient (SHGC) windows. (Visit energetechs.com/resources) to view a chart comparing window performances and costs)
- Don't forget to add insulating blinds!

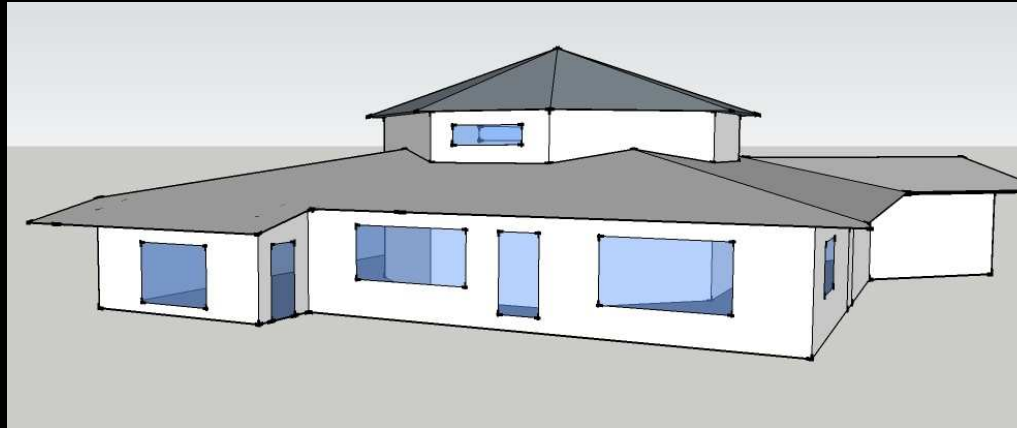
Passive-solar Design (in 10 simple steps)

STEP 3 – FENESTRATION

Examples

THE 10 STEPS

- 1- SITE SELECTION
- 2- ANGLE
- 3- FENESTRATION
- 4- EAVE OVERHANGS
- 5- ROOM LAYOUT
- 6- VENTILATION
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Big Horn Studio – Sketchup model (looking North-west)

BIG HORN STUDIO

(percentages of glazing to floor area by wall)

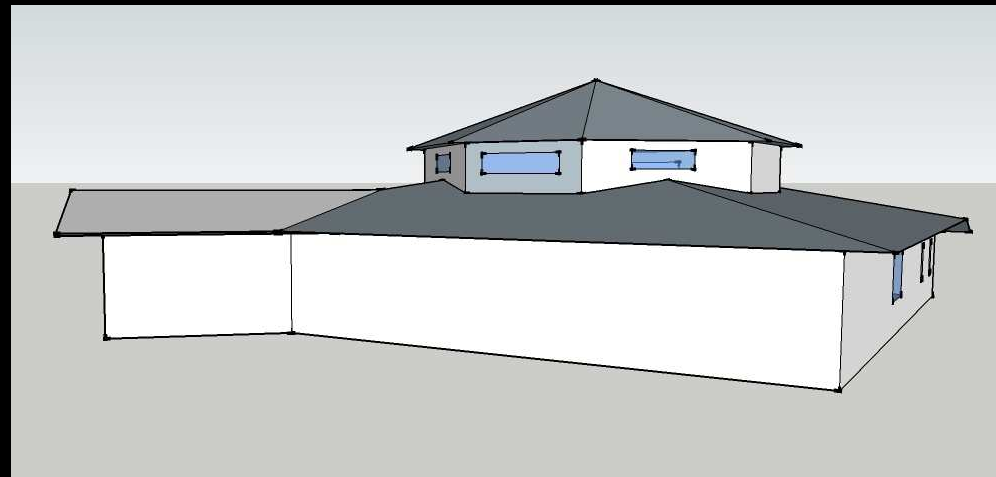
SOUTH WALL 7%
EAST WALL 2%

Google Sketchup® is a great free software for making 3D models and includes built-in sun study tools – check it out!

BIG HORN STUDIO

(percentages of glazing to floor area by wall)

NORTH WALL 1%
WEST WALL 1%



Big Horn Studio (looking South-east)

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Passive-solar Design (in 10 simple steps)

STEP 4 – EAVE OVERHANGS

THE 10 STEPS

- 1- SITE SEL-
ECTION
- 2- ANGLE
- 3- FENEST-
RATION
- 4- **EAVE
OVERHANGS**
- 5- ROOM
LAYOUT
- 6- VENTILATION
- 7- INSULATION
- 8- THERMAL
MASS
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SCAPING

How to determine the correct eave overhang.

- Find the building site on Google Earth and record the latitude, longitude, and elevation figures from the bottom left hand corner.
- Enter the location figures into the Sun Angle Calculator on susdesign.com/sunangle
- Find the sun angles for the site for the 21st of each month (this will include the summer solstice (Jun21), winter solstice (Dec21), and the equinoxes (Mar21/Sep21).
- Draw an accurate, scaled cross-section through the south wall and window(s) of the building.
- Use the calculated sun angles on the cross section to determine the desired amount of eave overhang so that the sun comes in when you want it and stays out when you don't.
- Highly Recommended – make a 3D model using Google's free Sketchup® software and perform sun studies for different times of the year, looking at different faces of the building, and both inside and outside. This will give you a very good idea of how the sun will affect your building, and it's easy and free!

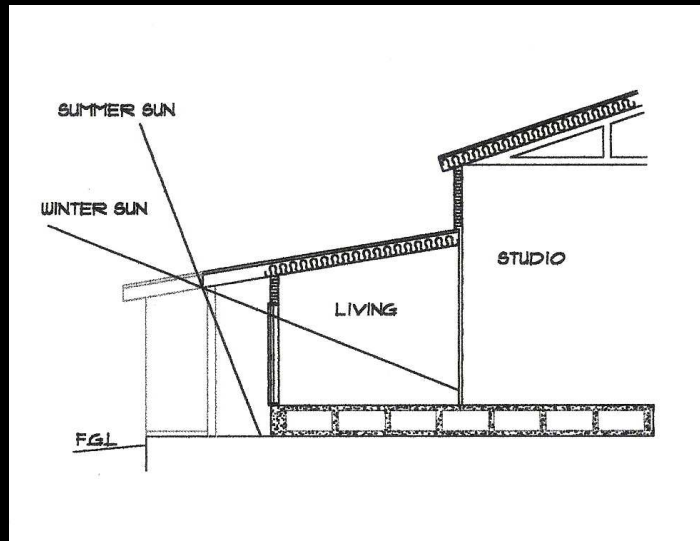
Passive-solar Design (in 10 simple steps)

STEP 4 – EAVE OVERHANGS

THE 10 STEPS

- 1- SITE SELECTION
- 2- ANGLE
- 3- FENESTRATION
- 4- **EAVE OVERHANGS**
- 5- ROOM LAYOUT
- 6- VENTILATION
- 7- INSULATION
- 8- THERMAL MASS
- 9- AIR SEALING
- 10- LANDSCAPING

Examples



BIG HORN STUDIO (simplified for clarity)

- Scaled cross-section shows roof height and pitch, wall height, floor, window height and location in wall, and eave overhang distance.
- 4' overhang on south side provides adequate shading in summer and ample solar penetration in winter.
- Ideally this study will include the sun angles on the 21st of each month throughout the year. The eave overhang can then be adjusted to control when the sun enters the building and when it stays out.



SHERIDAN HOUSE

- Sunspace with roll-up, glass door on south side provides winter solar collector and summer shaded porch.

Passive-solar Design (in 10 simple steps)

STEP 5 – ROOM LAYOUT

THE 10 STEPS

- 1- SITE SEL-
ECTION
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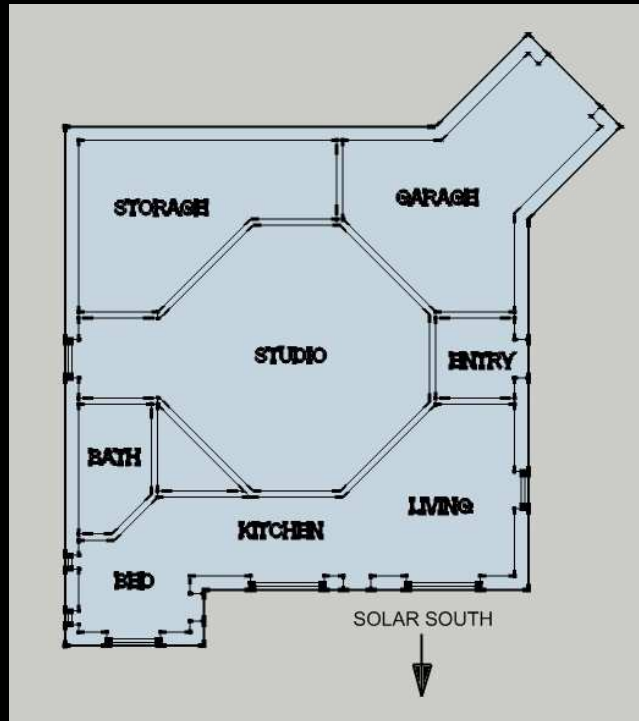
- In general, place rooms that are used during the **day** on the **south** side of the house and rooms that are used at **night** on the **north** side (e.g. South Side - Living Rooms and Kitchens. North Side – Bedrooms, Bathrooms, Dining Rooms)
- Utility Rooms and Mechanical Rooms don't usually need sun so can go on the North Side.
- Give thought to morning and afternoon sun. Some people like to wake up with the sun shining in their room so their Bedroom would go on the East Side.
- All of the above **depends on the specific site and client preferences.**

Passive-solar Design (in 10 simple steps)

STEP 5 – ROOM LAYOUT

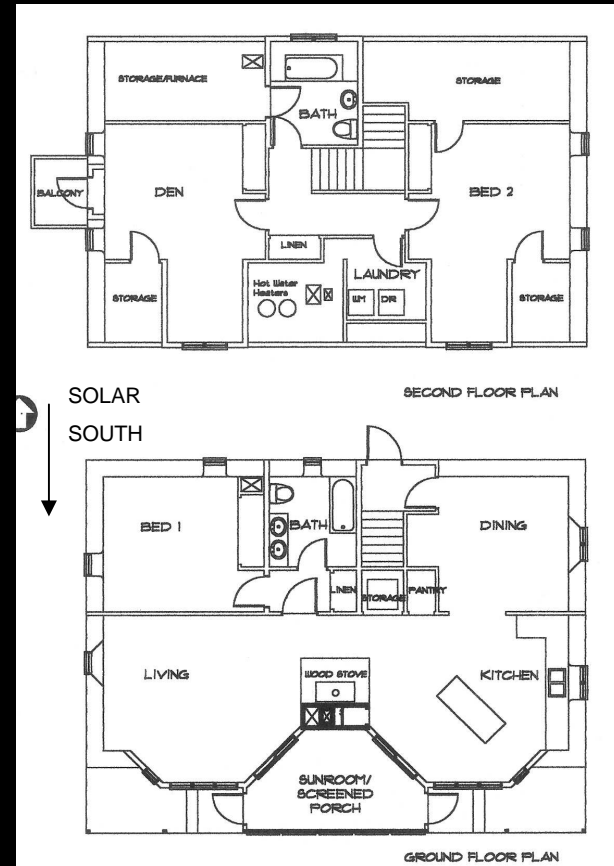
THE 10 STEPS

- 1- SITE SELECTION
- 2- ANGLE
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BIG HORN STUDIO

- Living Room, Kitchen, Bedroom on South
- Garage and Storage on North
- Studio in center with high north windows.



SHERIDAN HOUSE

- Living Room, Sunspace, and Kitchen on South
- Bedroom, Bath, Dining Room on North
- Bedrooms upstairs with south facing dormers.

Passive-solar Design (in 10 simple steps)

STEP 6 – VENTILATION

THE 10 STEPS

- 1- SITE SELECTION
- 2- ANGLE
- 3- FENESTRATION
- 4- EAVE OVERHANGS
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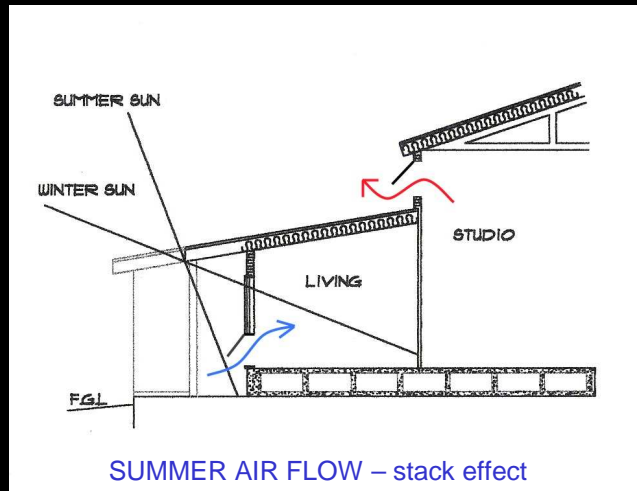
- Ventilation is very important for:
- **INDOOR AIR QUALITY**. Heat Recovery Ventilation removes stale humid air, captures the heat, and transfers it to the incoming constant supply of fresh air.
- **HEAT DISTRIBUTION**. Without some form of air movement it can be difficult to move heat from the south side when the sun is shining to the rest of the building.
- **SUMMER COOLING**. In Montana, summer cooling is best accomplished by closing the house up during the day and opening it up during the night to allow cool air to flow through.

Passive-solar Design (in 10 simple steps)

STEP 6 – VENTILATION

THE 10 STEPS

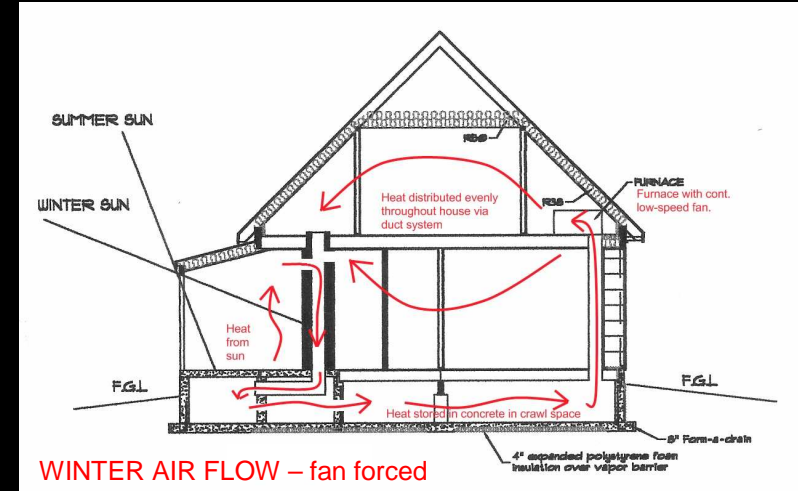
- 1- SITE SELECTION
- 2- ANGLE
- 3- FENESTRATION
- 4- EAVE OVERHANGS
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SUMMER AIR FLOW – stack effect

BIG HORN STUDIO

- WINTER – continuous, low-flow exhaust fan in storage area creates slight negative pressure which draws in fresh air from outside and helps to distribute heat from the sun.
- SUMMER – night time cooling - high windows in studio allow warm air to escape which draws cool air in down low (stack effect).



WINTER AIR FLOW – fan forced

SHERIDAN HOUSE

- WINTER – heat from the sun is drawn down through the crawl space during the day where excess heat is stored in Thermal Mass. The furnace fan runs continuously on low speed to distribute heat evenly through the duct system. At night heat is drawn out of the crawl space to keep the house warm. The furnace only adds gas heat when necessary.
- SUMMER – the house is opened up at night and the fan draws cool air down into the crawl space. During the day the house is closed and the cool air from the crawl space is distributed through the ducts.

Passive-solar Design (in 10 simple steps)

STEP 7 – INSULATION

THE 10 STEPS

- 1- SITE SELECTION
- 2- ANGLE
- 3- FENESTRATION
- 4- EAVE OVERHANGS
- 5- ROOM LAYOUT
- 6- VENTILATION
- 7- **INSULATION**
- 8- THERMAL MASS
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Recommended levels of insulation for Montana

<u>Location</u>	<u>Code (IECC2003)</u>	<u>Better</u>
Ceiling	R49	R60
Wall	R21	R40
Floor	R21	R40
Basement wall	R11	R30
Crawl Wall	R20	R30
Slab perimeter	R13	R20
Under slab	-	R20
Crawl floor	-	R20

Note: Buildings in cold climates will perform best if there is insulation around the **ENTIRE THERMAL ENVELOPE** (that means under floors too).

Advice: Don't get too hung up on the groovy materials – by far the biggest environmental impact of a building is from the energy that it uses over its life so it's R-value that matters. And don't believe what mfg's tell you. [© Andy Lemann 2009](#)

Passive-solar Design (in 10 simple steps)

STEP 7 – INSULATION

THE 10 STEPS

- 1- SITE SELECTION
- 2- ANGLE
- 3- FENESTRATION
- 4- EAVE OVERHANGS
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- 7- **INSULATION**
- 8- THERMAL MASS
- 9- AIR SEALING
- 10- LANDSCAPING



Bale Insulated Floor (don't do it!)



Straw Bale Walls

BIG HORN STUDIO

- Bale Insulated Floor – BAD IDEA!
- Straw Bale Walls – GOOD IDEA – about R25+
- Recycled Cotton insulation in ceiling – R38 (not enough for Montana, new code min. is R49)



4" EPS Foam under crawl space floor.



Straw Bale Walls

SHERIDAN HOUSE

- Foam Insulated Floor – GOOD IDEA – R18
- Crawl space walls – R10 (not enough, we recommend min. R20)
- Straw Bale Walls – R25+
- Fiberglass Batt ceiling – R38 (not enough, we recommend R60)

Passive-solar Design (in 10 simple steps)

STEP 8 – THERMAL MASS

THE 10 STEPS

- 1- SITE SELECTION
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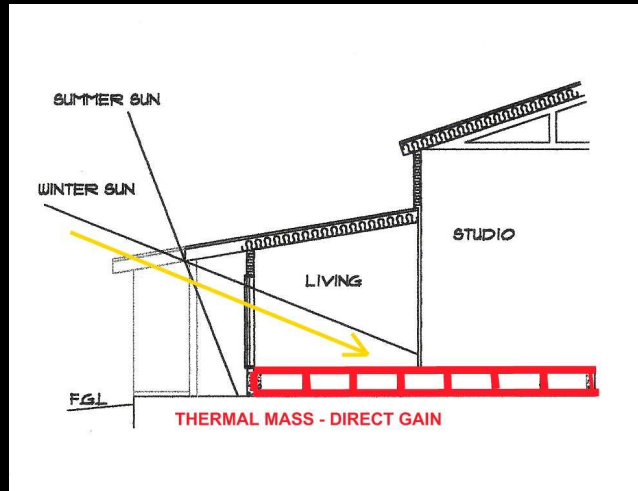
- Stores heat.
- Evens out temperature fluctuations (too little and the temp. goes up and down, too much and it's very hard to heat, 4-6" thick is best)
- Must be balanced with the amount of solar glazing.
- See "The Solar House" by Dan Chiras (Pp.102-104) for details of **Glass-to-Mass Ratios**

Passive-solar Design (in 10 simple steps)

STEP 8 – THERMAL MASS

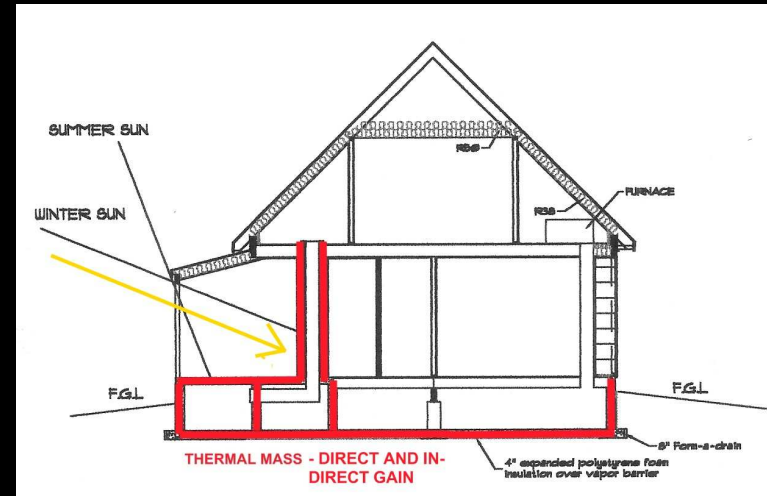
THE 10 STEPS

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- 2- ANGLE
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BIG HORN STUDIO

- Thermal Mass concrete in floor – small area gets direct gain from the sun shining on it.
- Rest is heated by hydronic in-floor heating system.
 - Hard to distribute heat evenly
 - Hard to make changes or repairs in future.



SHERIDAN HOUSE

- Thermal Mass brick wall at back of sunspace plus concrete walls and floor in crawl space.
- Some direct gain in sunspace, rest is indirect gain via air distribution system.
 - + Even heat distribution
 - + More mass utilized for heat sink
 - + Easy to make changes and repairs in future.

Passive-solar Design (in 10 simple steps)

STEP 9 – AIR SEALING

THE 10 STEPS

- 1- SITE SEL-
ECTION
- 2- ANGLE
- 3- FENEST-
RATION
- 4- EAVE
OVERHANGS
- 5- ROOM
LAYOUT
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- 7- INSULATION
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MASS
- 9- AIR SEALING
- 10- LAND-
SCAPING

- Essential for energy efficiency
- Insulation by itself is ineffective without good air-sealing (think of a blanket with holes in it).
- And air sealing by itself is ineffective without good insulation (think of a plastic bag in the snow).
- Air sealing should be tested with a blower door during and after construction.
- Good air sealing (less than 2.0ACH50) demands the use of a Heat Recovery Ventilation system (see our web-site for more info. at energetechs.com).
- To achieve good air-sealing there should be a continuous air barrier around the entire thermal envelope (see example).

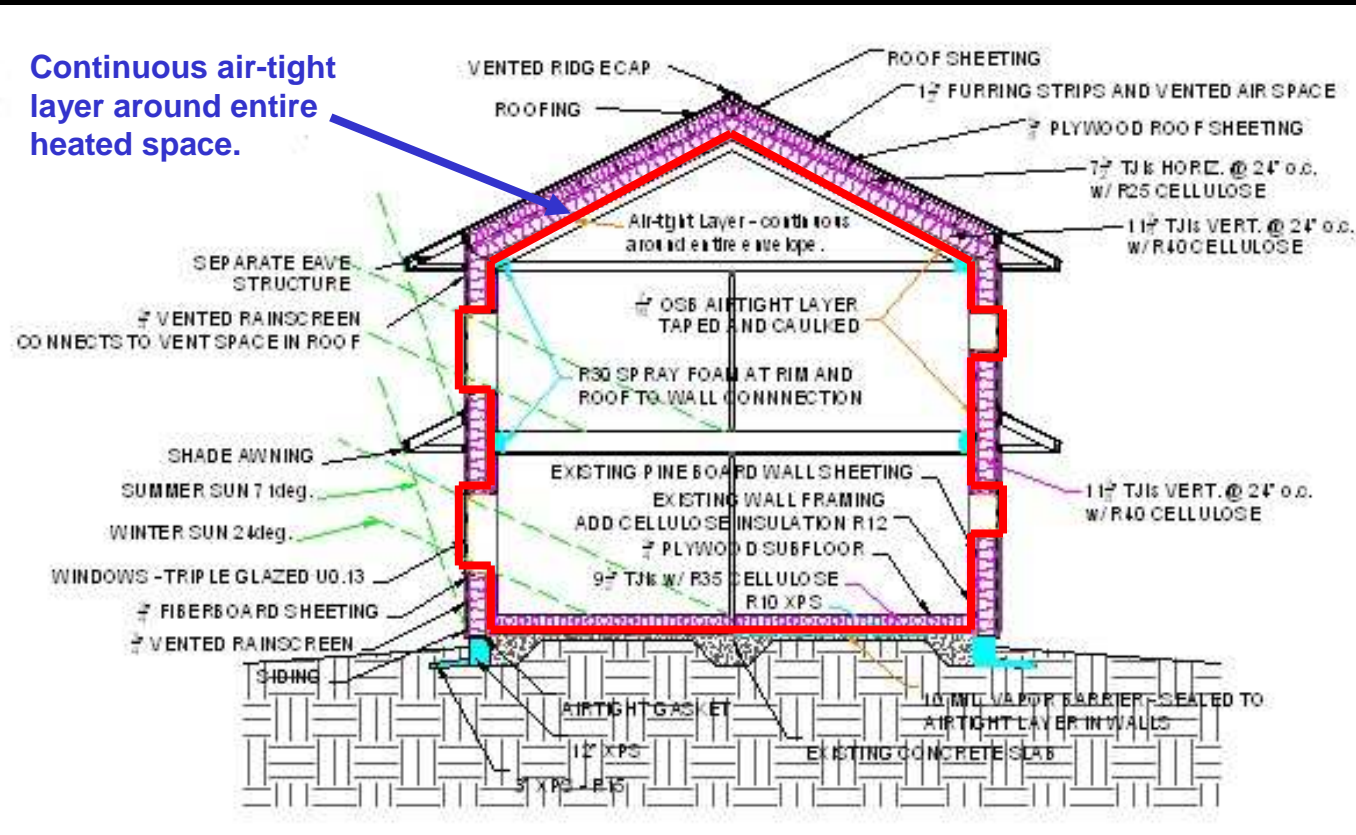
Passive-solar Design (in 10 simple steps)

STEP 9 – AIR SEALING

THE 10 STEPS

- 1- SITE SELECTION
- 2- ANGLE
- 3- FENESTRATION
- 4- EAVE OVERHANGS
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- 6- VENTILATION
- 7- INSULATION
- 8- THERMAL MASS
- 9- AIR SEALING
- 10- LANDSCAPING

Continuous air-tight layer around entire heated space.



PASSIVE HOUSE DETAILS (Source: energetechs.com)

- Pay careful attention to sealing around windows, doors, lights, outlets, mechanical equipment, and plumbing penetrations.
- Good air sealing requires careful thought and attention to detail.

Passive-solar Design (in 10 simple steps)

STEP 10 – LANDSCAPING

THE 10 STEPS

- 1- SITE SELECTION
- 2- ANGLE
- 3- FENESTRATION
- 4- EAVE OVERHANGS
- 5- ROOM LAYOUT
- 6- VENTILATION
- 7- INSULATION
- 8- THERMAL MASS
- 9- AIR SEALING
- 10- LANDSCAPING

- Correct landscaping and planting can help to **maximize the performance** of a Passive Solar Design and can help **solve all sorts of problems** with imperfect situations.
- Deciduous trees and vines in the right place can help to shade the building in the summer while letting in sun in the winter.
- Evergreen trees to the north and north-west can help to shelter the building from cold winter winds.
- Incorrect landscaping can render a Passive Solar design almost useless (e.g. if a row of tall evergreen trees were planted across the south side of the building).

Passive-solar Design (in 10 simple steps)

STEP 10 – LANDSCAPING

THE 10 STEPS

- 1- SITE SELECTION
- 2- ANGLE
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- 4- EAVE OVERHANGS
- 5- ROOM LAYOUT
- 6- VENTILATION
- 7- INSULATION
- 8- THERMAL MASS
- 9- AIR SEALING
- 10- **LAND-SCAPING**



BIG HORN STUDIO

Excavation and retaining walls were used to compensate for the slight north slope of the site. In the process they have created very comfortable and sheltered outdoor spaces.



SHERIDAN HOUSE

The finished house is very nicely sheltered from the north and northwest by the existing trees and hillside while being open to the south and east for maximum solar gain.

Passive-solar Design Photo Gallery

Big Horn Studio



Passive-solar Design Photo Gallery

Big Horn Studio



Passive-solar Design Photo Gallery

Big Horn Studio



Passive-solar Design Photo Gallery

Big Horn Studio



Passive-solar Design Photo Gallery

Big Horn Studio



Passive-solar Design Photo Gallery

Big Horn Studio



Passive-solar Design Photo Gallery

Big Horn Studio



Passive-solar Design Photo Gallery

Big Horn Studio



Passive-solar Design Photo Gallery

Sheridan House



Passive-solar Design Photo Gallery

Sheridan House



Passive-solar Design Photo Gallery

Sheridan House



Passive-solar Design Photo Gallery

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