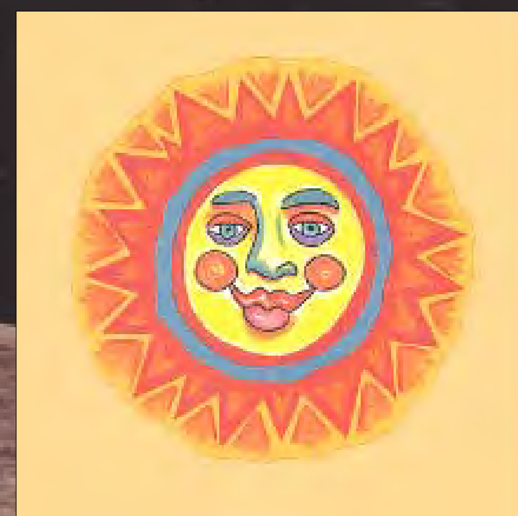
Resilient Design for Smaller Buildings

Thomas Brown, Architect



Overview

This workshop will highlight basic design principles and construction methods that enable smaller structures to perform well in cold climate regions, such as the upper Midwest.

Passive design fundamentals will be explored and illustrated, along with options for high-performance building envelopes.

Learning Objectives

- understand the importance of proper orientation of a structure on a building site.
- understand the use of proper shading techniques to optimize passive solar performance.
- understand the application of selective glazing for different building orientations.
- understand how passive cooling strategies might be applied to smaller buildings.
- understand the basic principles of daylighting and the use of borrowed light.
- understand the limitations and weaknesses of conventional wood-frame construction.
- understand simple modifications to wood-frame building details that can enhance performance.

Partially-interchangeable terms:

- Energy-efficient design
- Energy-conserving design
- Energy-conscious design
- Alternative design
- Passive solar design
- High-performance design
- Zero-energy design

- Earth-friendly design
- Environmental design
- Environmentally-conscious design
- Environmentally-responsible design
- Environmentally-responsive design
- Sustainable design
- Green design

- **Resilient design**

- Restorative design

What is Sustainability?

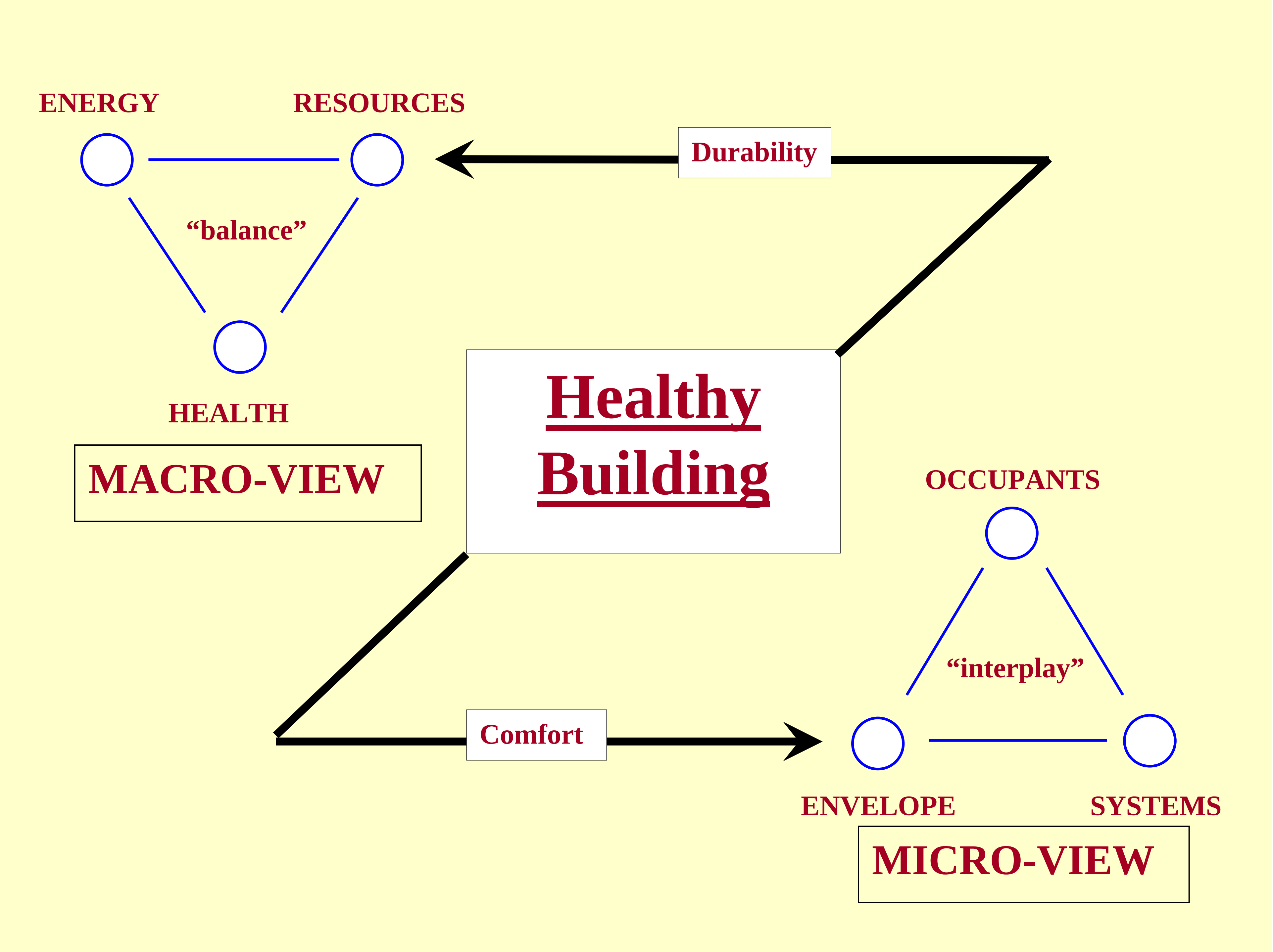
Sustainable development meets the needs of the present without compromising the ability of future generations to meet their needs.

- Brundtland Report, World Commission on Environment and Development, 1987

What is Green Design?

Design and construction practices that significantly reduce or eliminate the negative impact of buildings on the environment and occupants in five broad areas:

– Sustainable site planning
– Safeguarding water and water efficiency
– Energy efficiency and renewable energy
– Conservation of materials and resources
– Indoor environmental quality


ENERGY
RESOURCES
Durability
"balance"
HEALTH
MACRO-VIEW
Healthy
Building
OCCUPANTS
"interplay"
Comfort
ENVELOPE
SYSTEMS
MICRO-VIEW

Getting Started:

The design process should involve an analysis of how to prioritize choices leading to higher levels of sustainability, breaking down:

“design” choices
vs.
“materials and systems” choices
vs.
"methods" choices.

Design Issues

- Orientation for sun & wind
- Shape for sun & natural light
- Height for passive ventilation

Materials & Systems Issues

- Building envelope choices
- Structural systems
- Heating, cooling & ventilation systems
- Exterior & interior materials
- Exterior & interior finishes

Methods Issues

- Site disturbance
- Material handling & storage
- Construction waste management
- Construction indoor air quality

Resilient Design

"Resilience is the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance.
It is the capacity to bounce back after a disturbance or interruption of some sort."

Resilient Design Institute
resilientdesign.org

Resilient Design

"Resilient Design ….. is the intentional design of buildings, landscapes, communities, and regions in response to vulnerabilities to disaster and disruption of normal life."

Resilient Design Institute

resilientdesign.org

"the key function of a resilient design is to protect the contents inside from the environment outside …… to achieve reliable, secure, energy-efficient, robust buildings."

Househam Henderson Architects (UK)

househamhenderson.com/resilient-design

Resilient Design

"resilient design is a complex and many-faceted paradigm that involves long-term thinking about worst-case disaster scenarios, as well as more common, everyday wear.

Though the variables which contribute to resilience are many, and often complicated – the larger lesson is simple: buildings need to be resilient in order to be truly sustainable.

Photovoltaics and low-flow toilets are not enough for 'sustainability' – a building needs to be able to stand the test of time.

As architect Carl Elefante once said, "The greenest building is the one that's already built." So our goal should be … to design buildings that last longer than we do.

Jill Fehrenbacher, InHabitat

inhabitat.com/resilient-design-is-resilience-the-new-sustainability/

Resilient Design Resources

RESILIENT DESIGN INSTITUTE

resilientdesign.org

BuildingGreen.com

Environmental Building News
buildinggreen.com

Resilient Design Principles

- 1 **Resilience transcends scales.** Strategies to address resilience apply at scales of individual buildings, communities, and larger regional and ecosystem scales; they also apply at different time scales—from immediate to long-term.
- 2 **Resilient systems provide for basic human needs.** These include potable water, sanitation, energy, livable conditions (temperature and humidity), lighting, safe air, occupant health, and food; these should be equitably distributed.
- 3 **Diverse and redundant systems are inherently more resilient.** More diverse communities, ecosystems, economies, and social systems are better able to respond to interruptions or change, making them inherently more resilient. While sometimes in conflict with efficiency and green building priorities, *redundant* systems for such needs as electricity, water, and transportation, improve resilience.
- 4 **Simple, passive, and flexible systems are more resilient.** Passive or manual-override systems are more resilient than complex solutions that can break down and require ongoing maintenance. Flexible solutions are able to adapt to changing conditions both in the short- and long-term.
- 5 **Durability strengthens resilience.** Strategies that increase durability enhance resilience. Durability involves not only building practices, but also building design (beautiful buildings will be maintained and last longer), infrastructure, and ecosystems.

Resilient Design Principles

- 6 **Locally available, renewable, or reclaimed resources are more resilient**. Reliance on abundant local resources, such as solar energy, annually replenished groundwater, and local food provides greater resilience than dependence on nonrenewable resources or resources from far away.
- 7 **Resilience anticipates interruptions and a dynamic future.** Adaptation to a changing climate with higher temperatures, more intense storms, sea level rise, flooding, drought, and wildfire is a growing necessity, while non-climate-related natural disasters, such as earthquakes and solar flares, and anthropogenic actions like terrorism and cyberterrorism, also call for resilient design. Responding to change is an opportunity for a wide range of system improvements.
- 8 **Find and promote resilience in nature.** Natural systems have evolved to achieve resilience; we can enhance resilience by relying on and applying lessons from nature. Strategies that protect the natural environment enhance resilience for all living systems
- 9 **Social equity and community contribute to resilience.** Strong, culturally diverse communities in which people know, respect, and care for each other will fare better during times of stress or disturbance. Social aspects of resilience can be as important as physical responses.
- 10 **Resilience is not absolute.** Recognize that incremental steps can be taken and that *total resilience* in the face of all situations is not possible. Implement what is feasible in the short term and work to achieve greater resilience in stages.

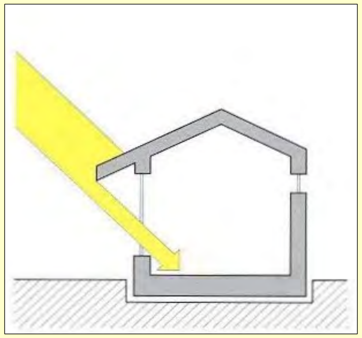
Resilient Design Principles (applied to small buildings)

➔ 4 **Simple, passive, and flexible systems are more resilient.** Passive or manual-override systems are more resilient than complex solutions that can break down and require ongoing maintenance. Flexible solutions are able to adapt to changing conditions both in the short- and long-term.

➔ 5 **Durability strengthens resilience.** Strategies that increase durability enhance resilience. Durability involves not only building practices, but also building design (beautiful buildings will be maintained and last longer), infrastructure, and ecosystems.

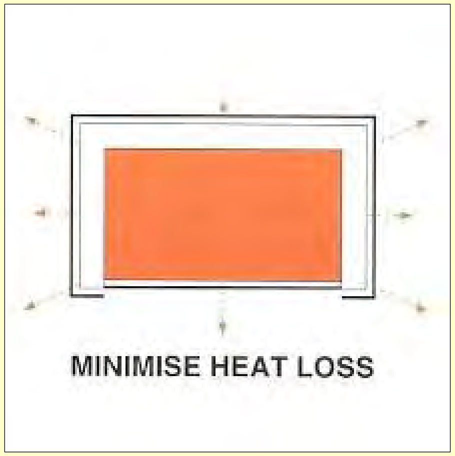
➔ 6 **Locally available, renewable, or reclaimed resources are more resilient.** Reliance on abundant local resources, such as solar energy, annually replenished groundwater, and local food provides greater resilience than dependence on nonrenewable resources or resources from far away.

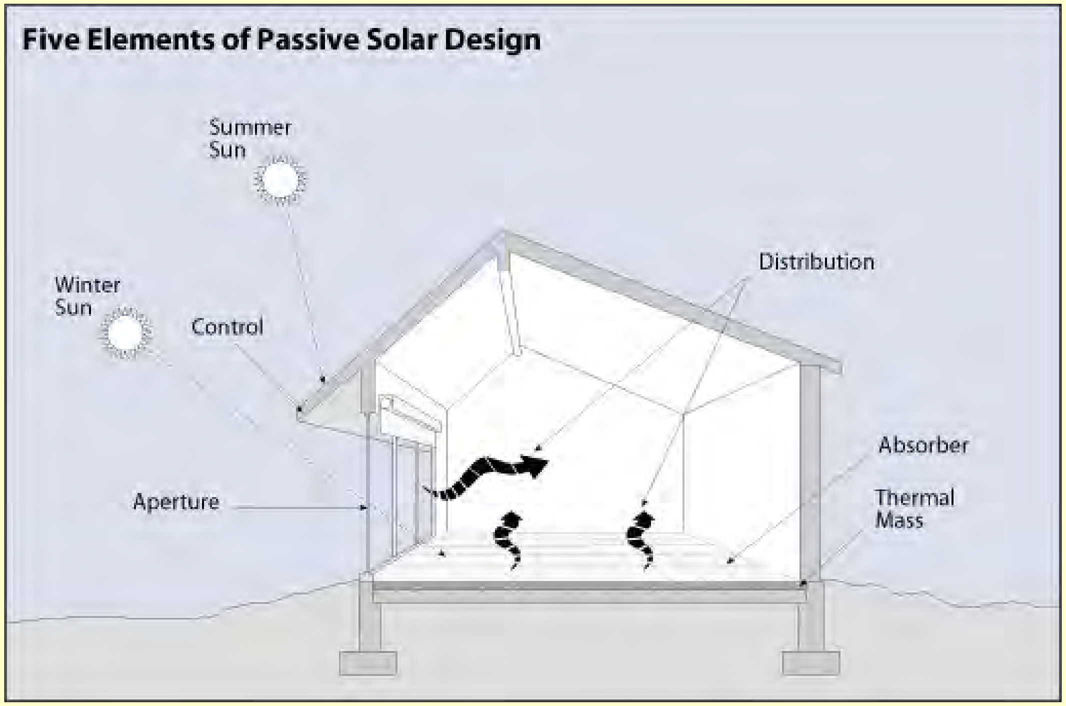
Orientation



Passive Solar

Passive Solar

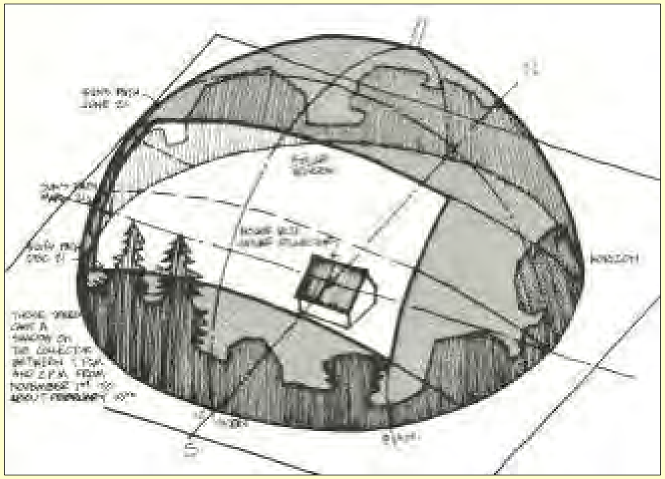


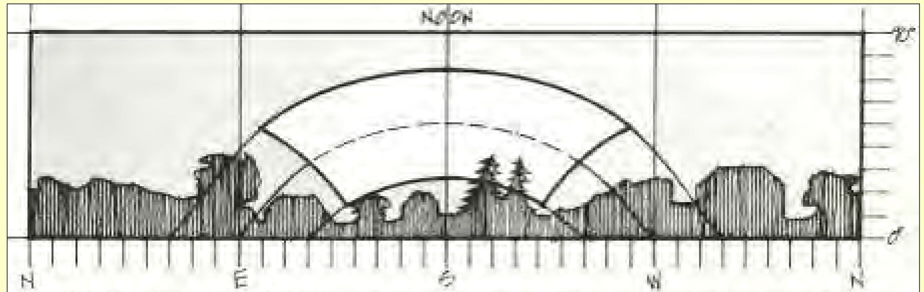


- Source: IKLIM-Turkey-website-passive-types-1.jpg

Passive Solar

– Sun Chart





PANORAMA OF THE SKY DOME As with the spherical earth, the spherical sky dome with its "solar window" can be mapped using a Mercator projection, in which all latitude and longitude lines are straight lines. Such a map is very useful for comparing the site surroundings with the "solar window" outline, since both can be easily plotted on the map. Any elements surrounding the site that intrude into the "solar window" will cast shadows on the collector.

SIDE VIEW OF SKY DOME WITH "SOLAR WINDOW" A side view of the sky dome from the east illustrates the relative position and angle of the sun throughout the year that defines the boundaries of the "solar window."

ANGLE OF INCIDENCE, a term often used in solar collector design, is the angle measured from the normal of the collector surface to the line indicating the sun's altitude at a particular time. The diagram specifically identifies the angle of incidence for June 21.

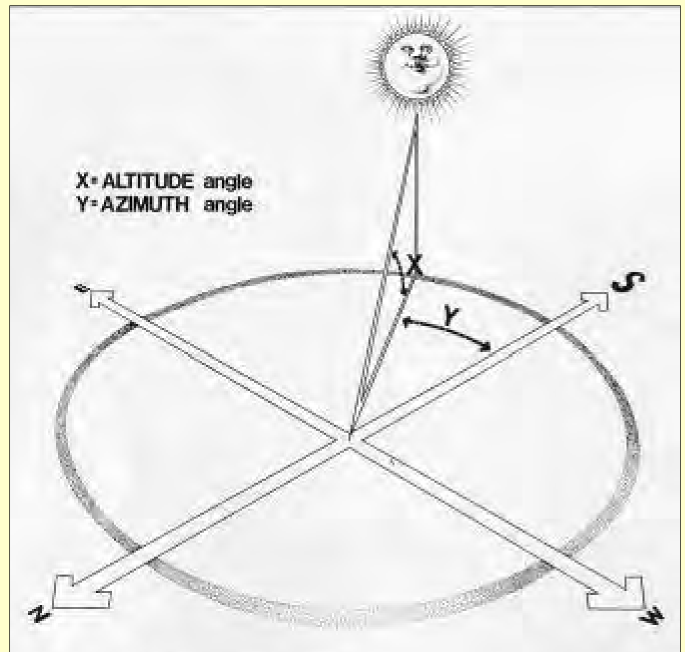
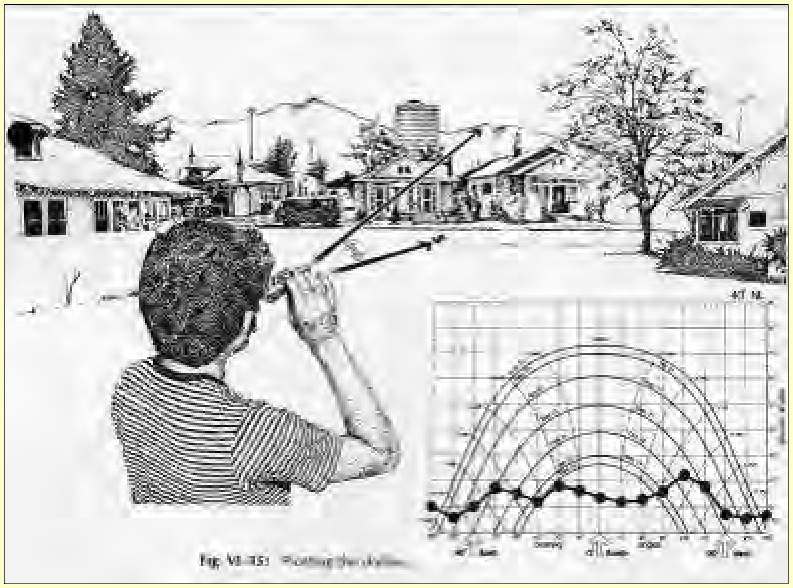


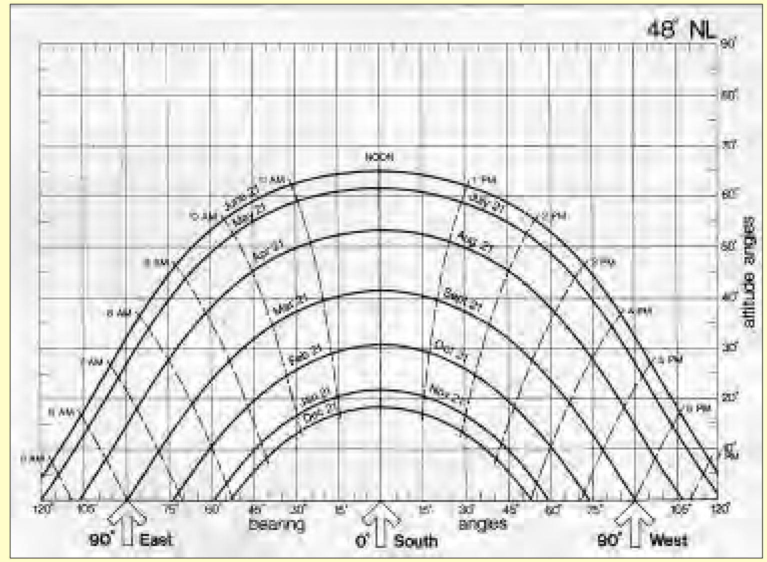
Fig. VI-2: Altitude and azimuth angles.

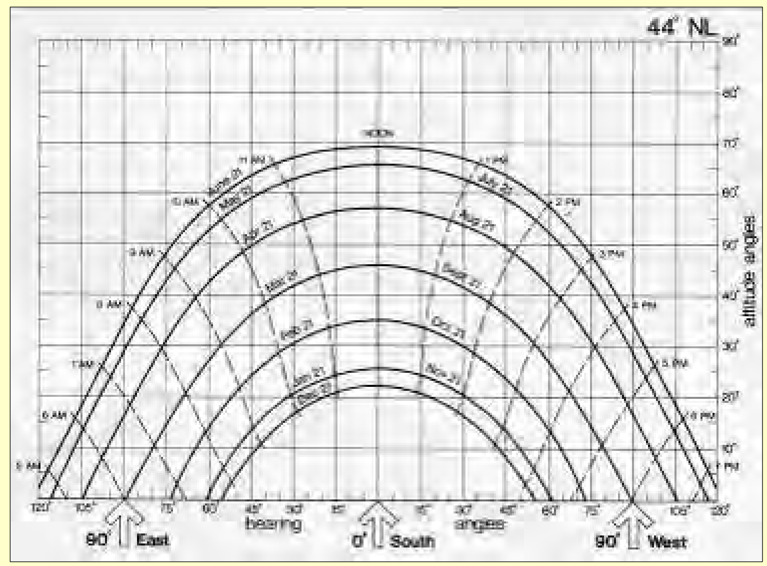
- Source: Basics-Solar-Heating-Hot-Water-AIA-p-9a.jpg

Passive Solar

– Sun Chart







- Source: Passive-Solar-Mazria-Sun-Path-44.jpg

Passive Solar

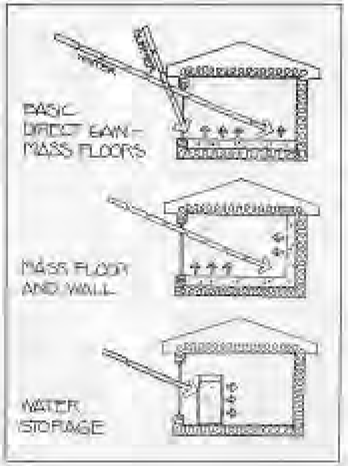
– Types

Direct gain

A direct-gain passive solar system can be as simple as proper location of a south-facing window. Locate the storage mass so it is exposed to sunlight. Insulate windows at night to retain stored heat. In direct-gain passive solar systems, living spaces directly heated by the sun become "live-in" collectors.

There are several ways to reduce temperature fluctuations in solar-heated homes. Since the angle of the sun (declination) is higher during the summer than during the winter, overhangs can shade the house during the summer to limit the amount of sunlight entering the house without blocking sunlight during the winter. Moveable shades can also be used as night insulation during winter and limit amount of solar heat gain during the summer.

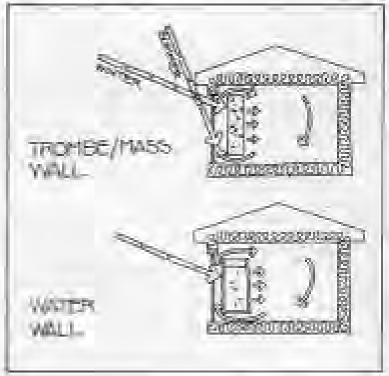
Also consider methods and materials which will prevent excessive glare. Some fabrics exposed to sunlight may fade, so use fabrics that resist fading or limit time fabrics are exposed to sunlight.



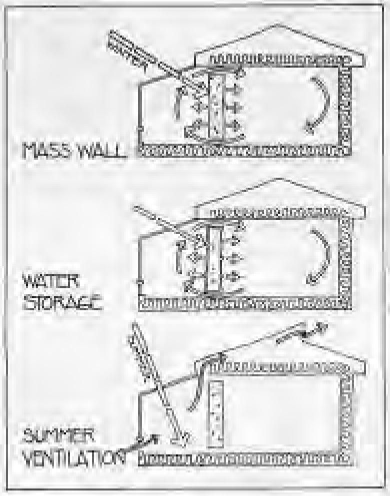
Indirect gain

In indirect-gain systems, sunlight does not travel through the living space to storage. Instead, a massive wall directly behind the collector glazing intercepts sunlight and stores heat. Indirect-gain systems reduce temperature fluctuations which can occur with direct-gain systems.

Two types of storage walls are used in direct-gain systems: mass storage walls or Trombe walls (pronounced *trohm*) and water storage walls. Both types of walls may or may not have vents. Vents help air circulate naturally between the glazing and the wall to the living area. Vents help warm room air more quickly in the morning. Proper shading and night insulation for windows help control heat gain and heat loss from the building.



Isolated gain



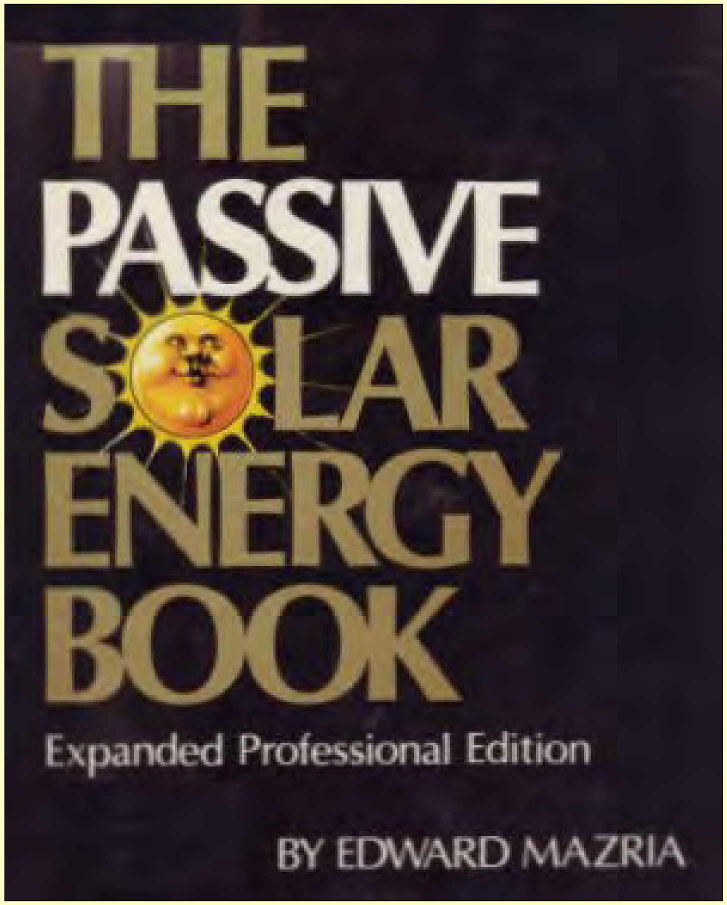
Isolated-gain systems collect solar energy in a secondary space separate from the living area, areas such as an atrium, greenhouse, solarium, sun porch or sun room. The collector space must be arranged so heat can flow to the storage area and be distributed later. Heat from the collection area may be distributed to storage by conduction (a system similar to the indirect-gain mass wall); it can flow naturally by convection through vents, adjustable windows or convective loops; or heat can be mechanically blown or pumped to storage.

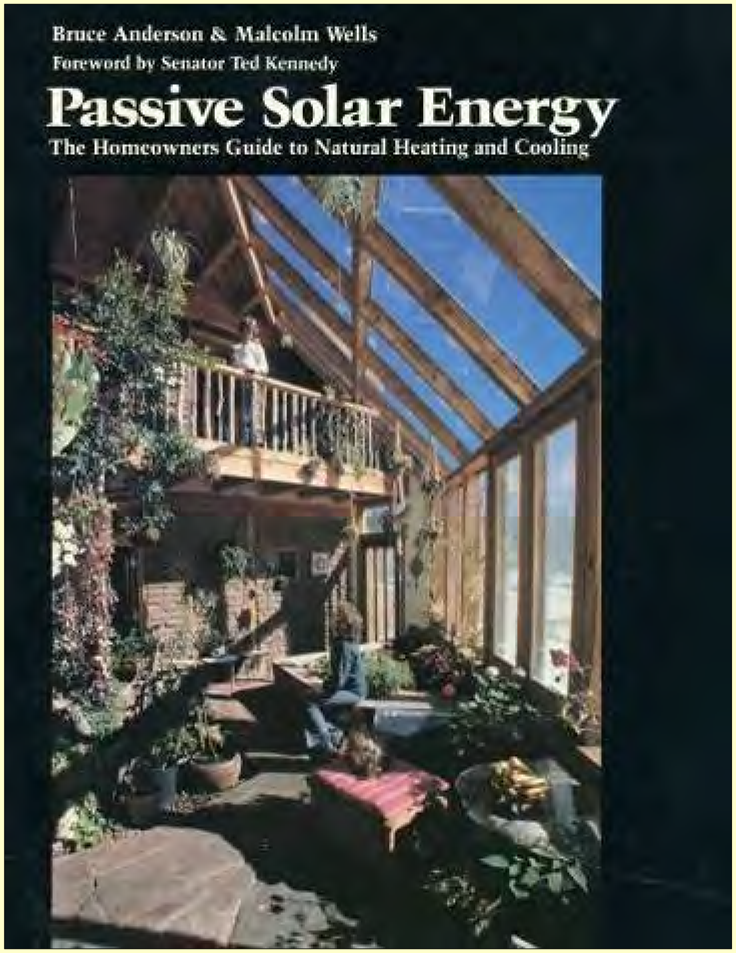
Carefully plan how to control heat flow between the collector and the living area so the right amount of heat is available at the right time.

- Source: WI-Passive-Guide-p3b.jpg

Passive Solar

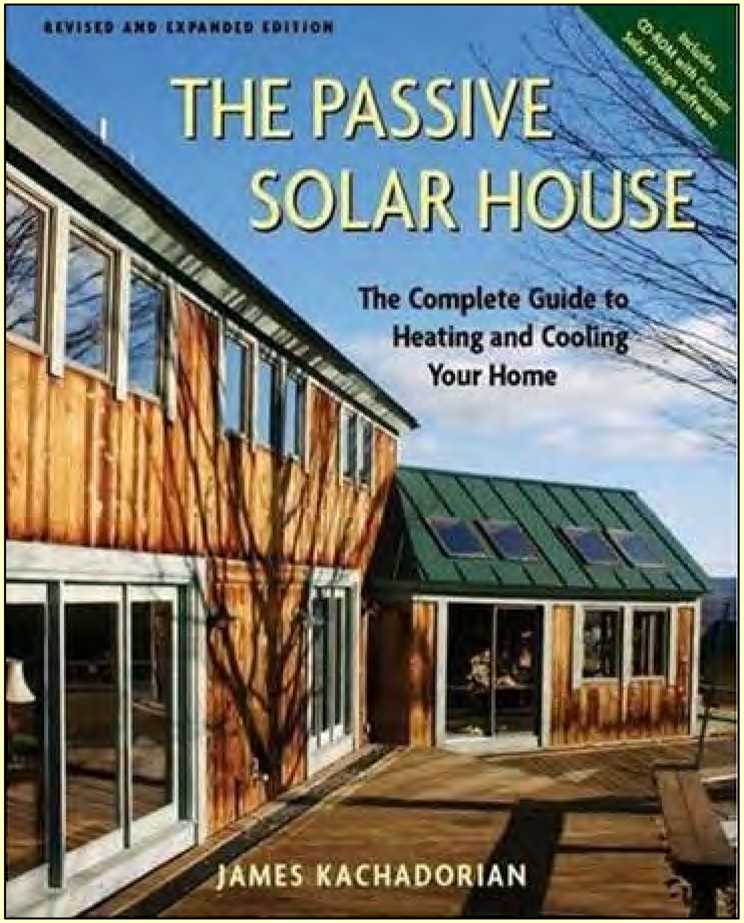
– Resources

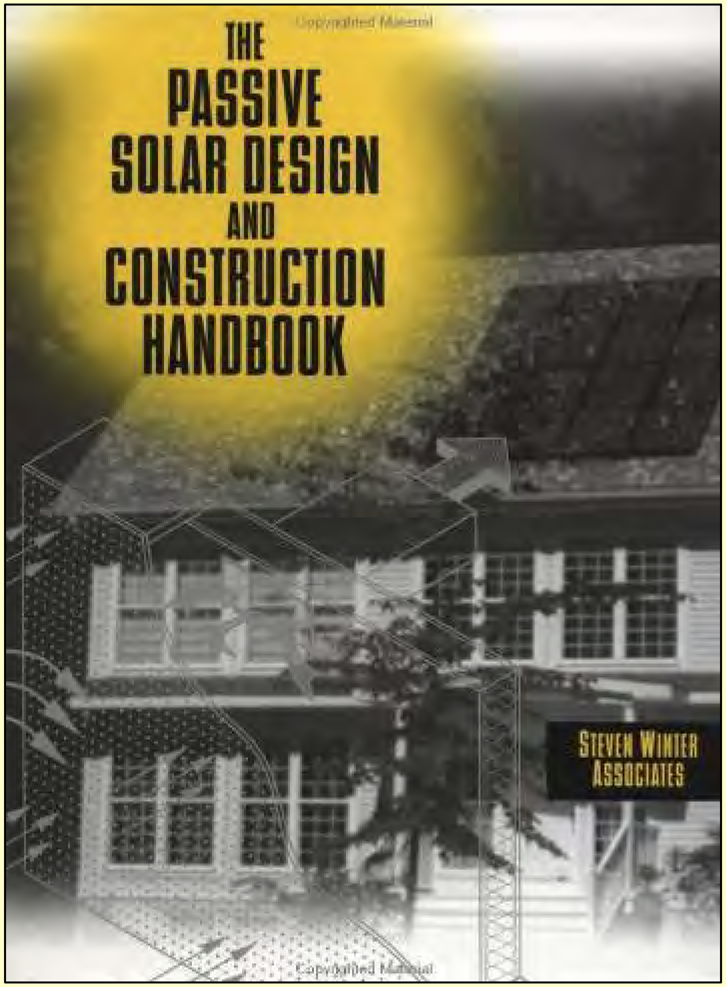




Passive Solar

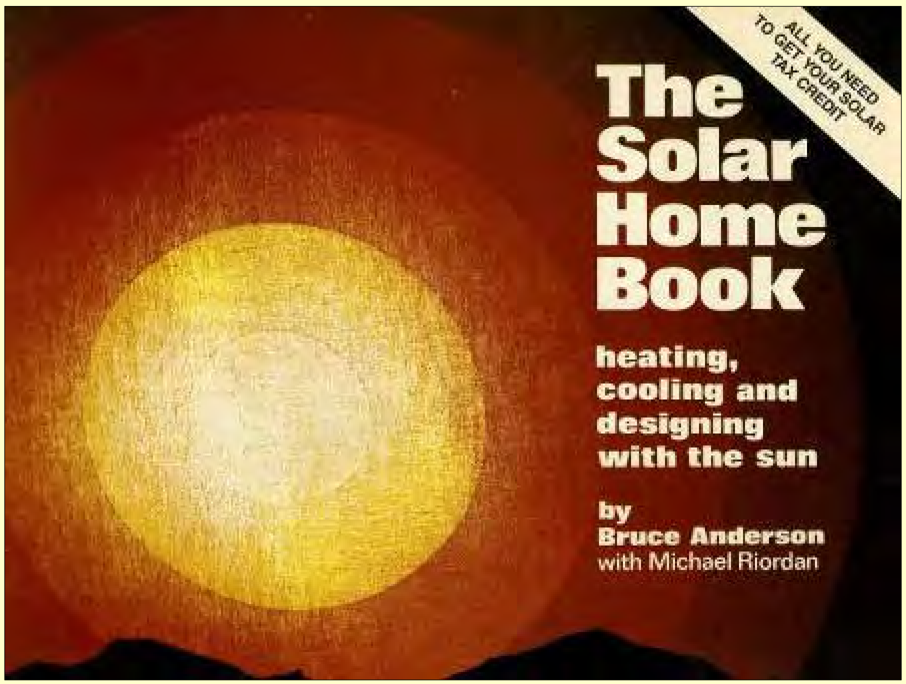
– Resources

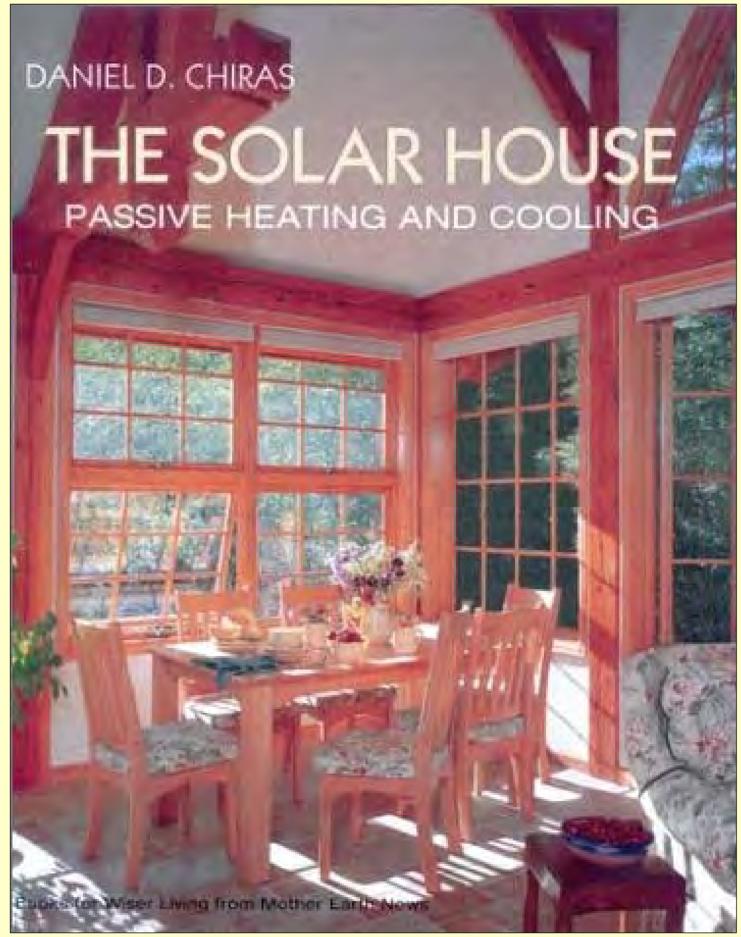




Passive Solar

– Resources





- Source: Solar-Home-Book-Anderson-cover-1.jpg
- Source: Solar-House-Chiras-cover.jpg

Passive Solar

– Concepts

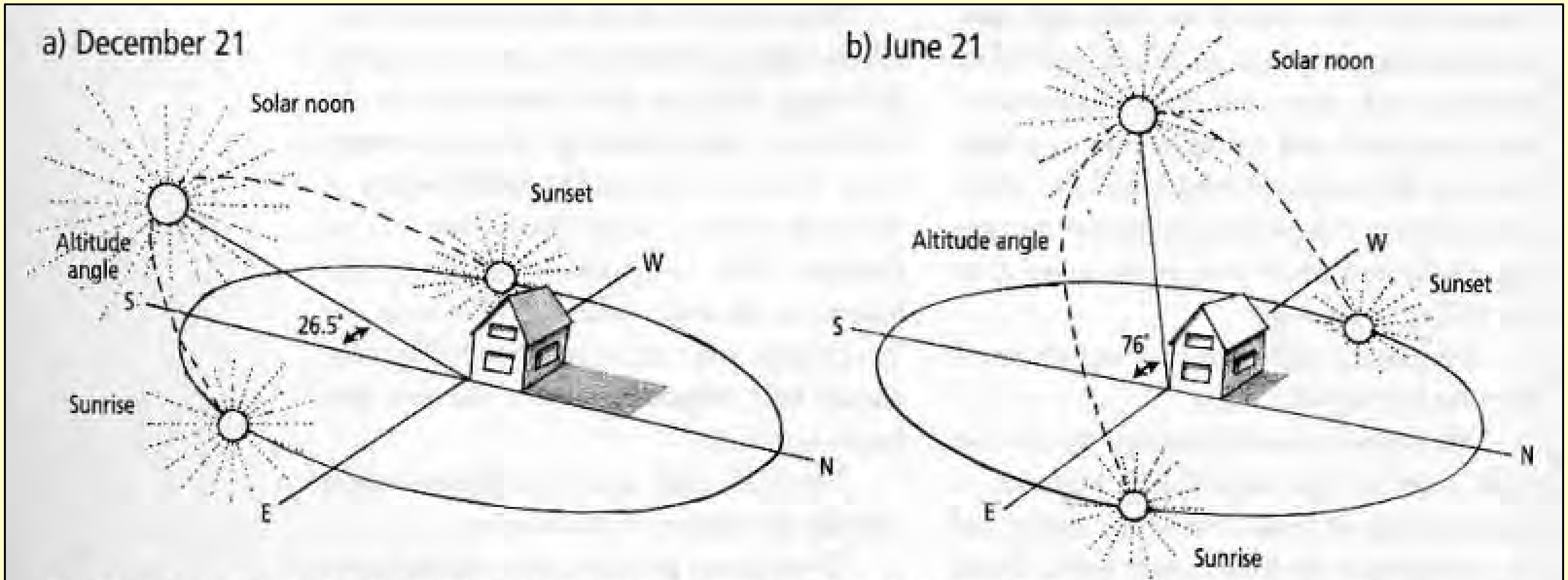
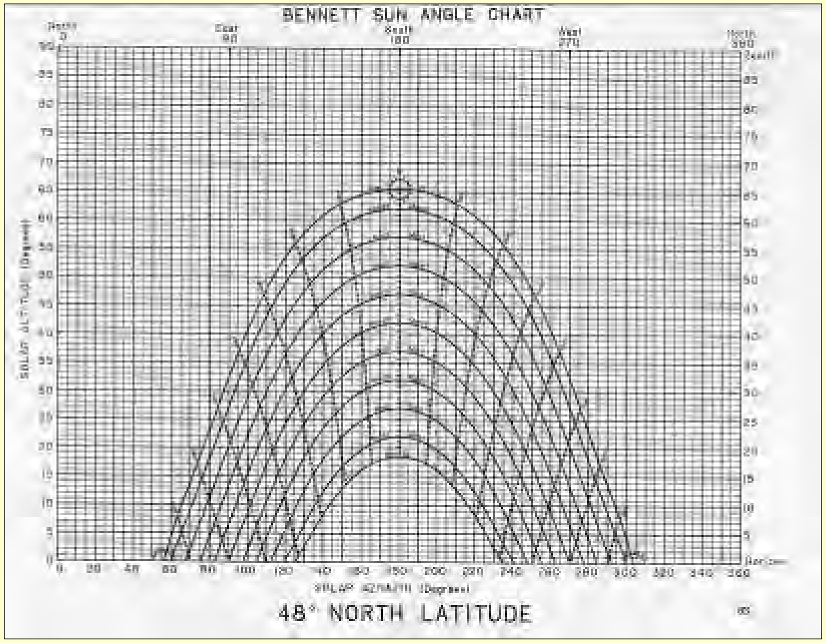


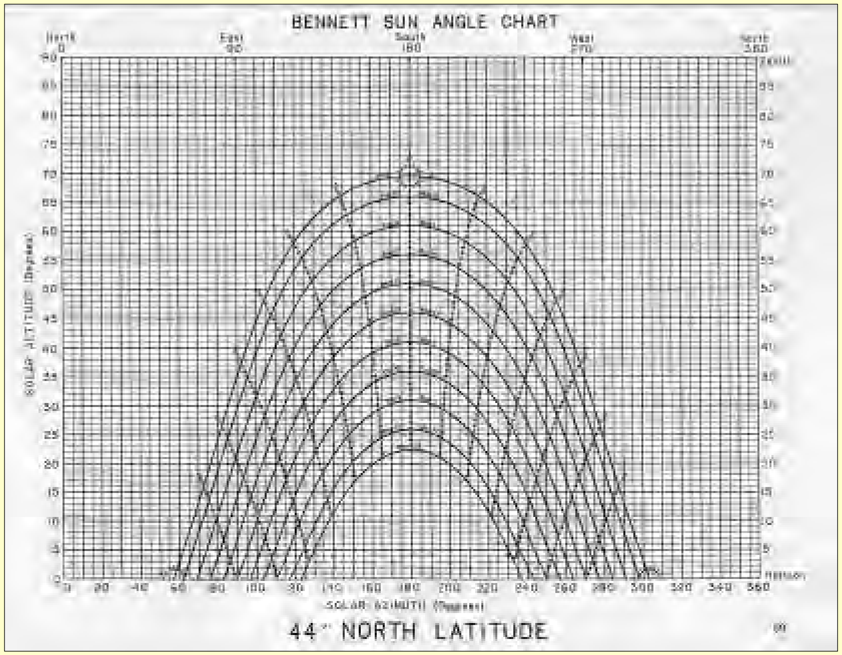
Fig. 4-1: In a passive solar home, the low-angled winter sun penetrates south-facing windows to heat the home. During the summer, the high-angled sun shines on the roofs of houses, reducing heat gain.

- Source: Solar-House-Chiras-cover.jpg

Passive Solar

– Sun Chart

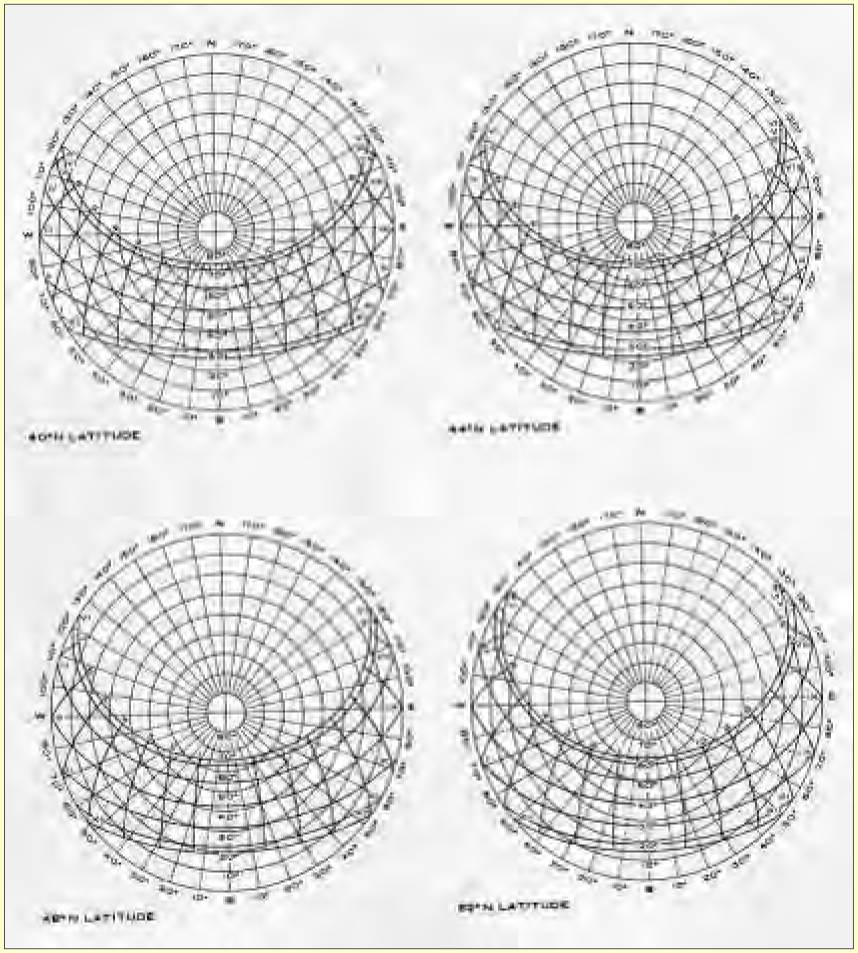




- Source: Sun-Angles-Design-Bennett-48.jpg

Passive Solar

– Solar Chart



Solar Radiation on South Walls on Sunny Days *

Date	Solar Time AM	Solar Time PM	Solar Radiation, Btus per hour per square foot — Latitude (North) 24	32	40	48	56	64
Jan 21	7	5	31	1	0	0	0	0
	8	4	127	115	84	22	0	0
	9	3	176	181	171	139	60	0
	10	2	207	221	223	206	153	20
	11	1	226	245	253	243	201	81
	12		232	253	263	255	217	103
	Daily Totals		1766	1779	1726	1478	1044	304
Feb 21	7	5	46	38	22	4	0	0
	8	4	102	108	107	96	69	19
	9	3	141	158	167	167	151	107
	10	2	168	193	210	217	208	173
	11	1	185	214	236	247	243	213
	12		191	222	245	259	255	226
	Daily Totals		1476	1644	1730	1720	1598	1252
March 31	7	5	27	32	35	35	32	25
	8	4	64	78	89	96	97	89
	9	3	95	119	138	152	154	153
	10	2	120	150	176	195	205	203
	11	1	135	170	200	223	236	235
	12		140	177	208	232	246	246
	Daily Totals		1022	1276	1484	1632	1700	1656

* Courtesy ASHRAE, *Handbook of Fundamentals*

144

- Source: Passive-Solar-Anderson-Wells-Sun-Path-1.jpg

Passive Solar Design

- Guidelines
- Mid-month Sun Angles – 12 noon

Superior, WI

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
21.87	29.27	40.47	52.37	61.87	66.37	64.67	57.27	46.07	34.17	24.67	20.17

Stevens Point, WI

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
24.07	31.47	42.67	54.57	64.07	68.57	66.87	59.47	48.27	36.37	26.87	22.37

Madison, WI

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
25.53	32.93	44.13	56.03	65.53	70.03	68.33	60.93	49.73	37.83	28.33	23.83

Passive Solar Design

- Guidelines
- Mid-month Sun Angles – 12 noon

Duluth, MN

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
24.58	31.98	43.18	55.08	64.58	69.08	67.38	59.98	48.78	36.88	27.38	22.88

Minneapolis, MN

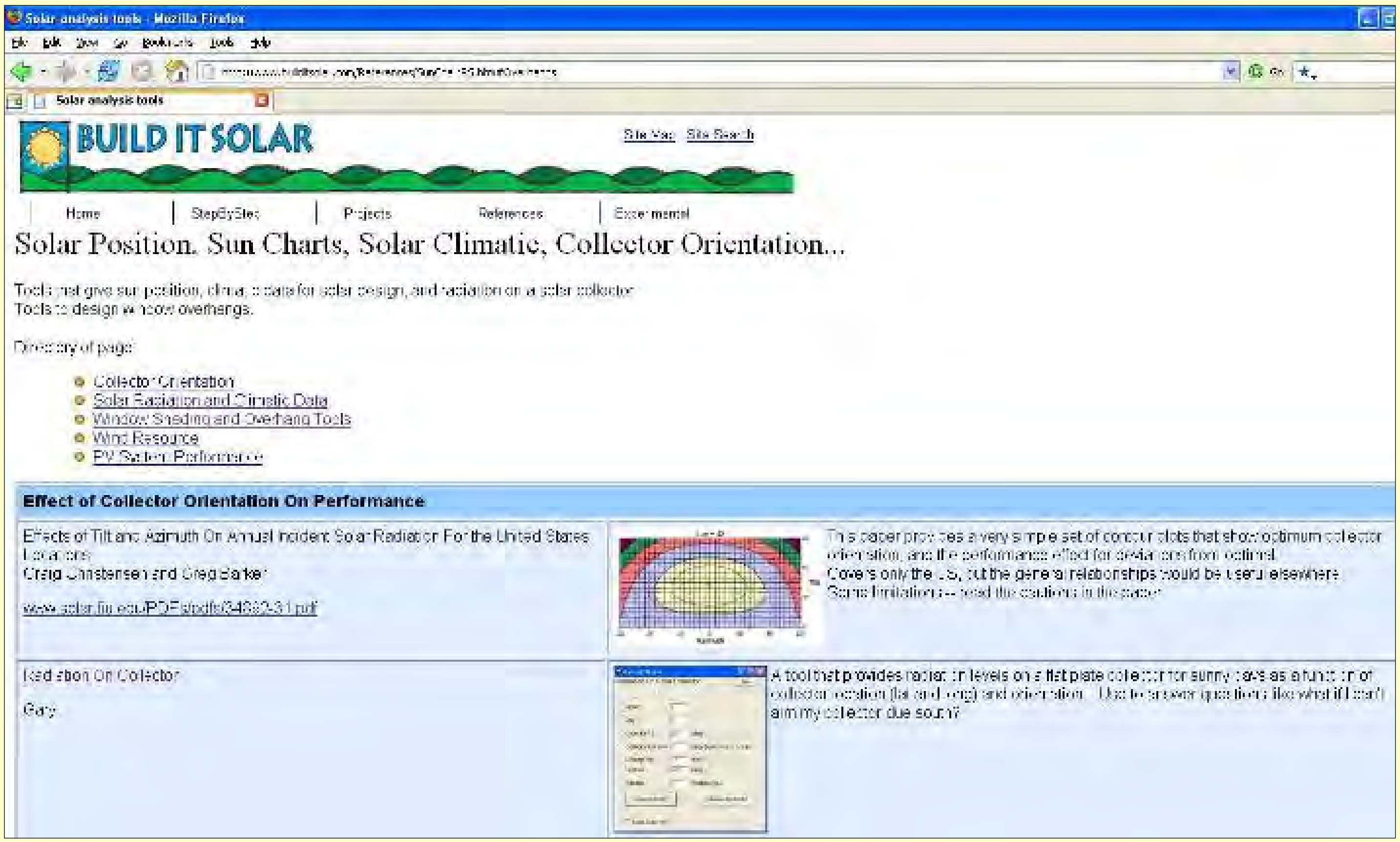
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
23.62	31.02	42.22	54.12	63.62	68.12	66.42	59.02	47.82	35.92	26.42	21.92

Rochester, MN

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
21.82	29.22	40.42	52.32	61.82	66.32	64.62	57.22	46.02	34.12	24.62	20.12

Passive Solar

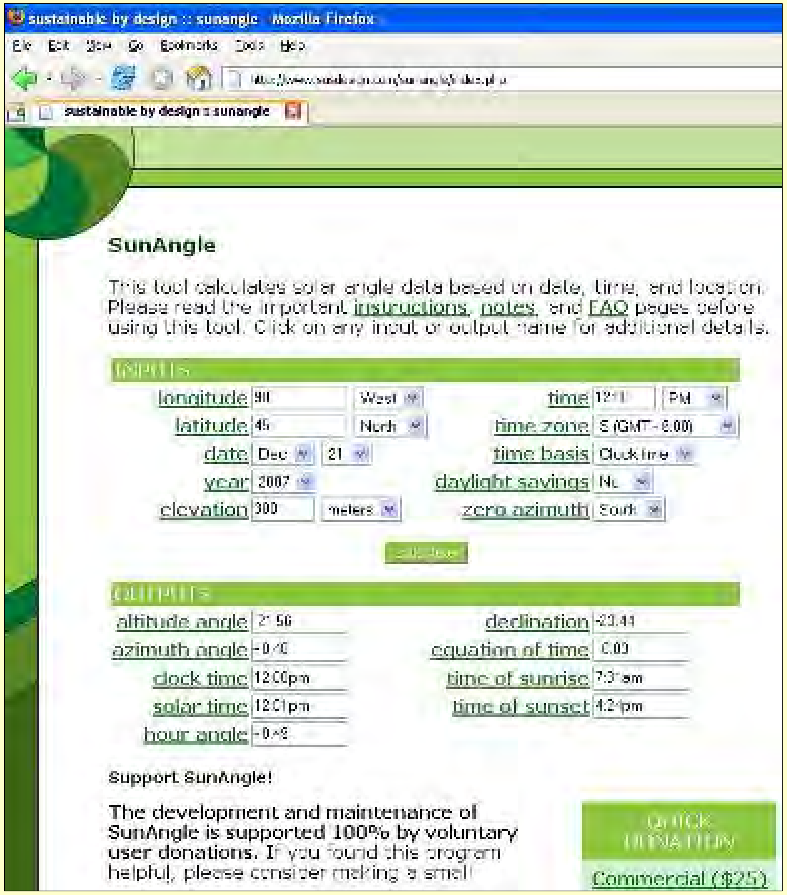
- Web Tools
- builditsolar.com



- Source: Build-it-Solar-website-solar-resources-1.jpg

Passive Solar

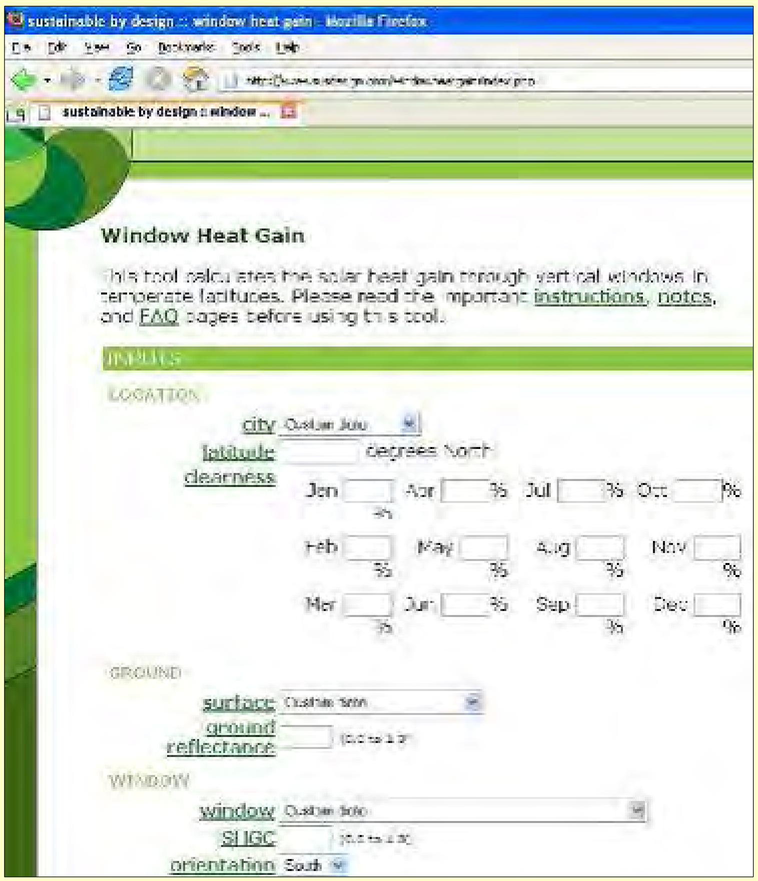
- Web Tools
- susdesign.com



- Source: Sustainable-by-Design-website-Sun-Angle-45-90.jpg

Passive Solar

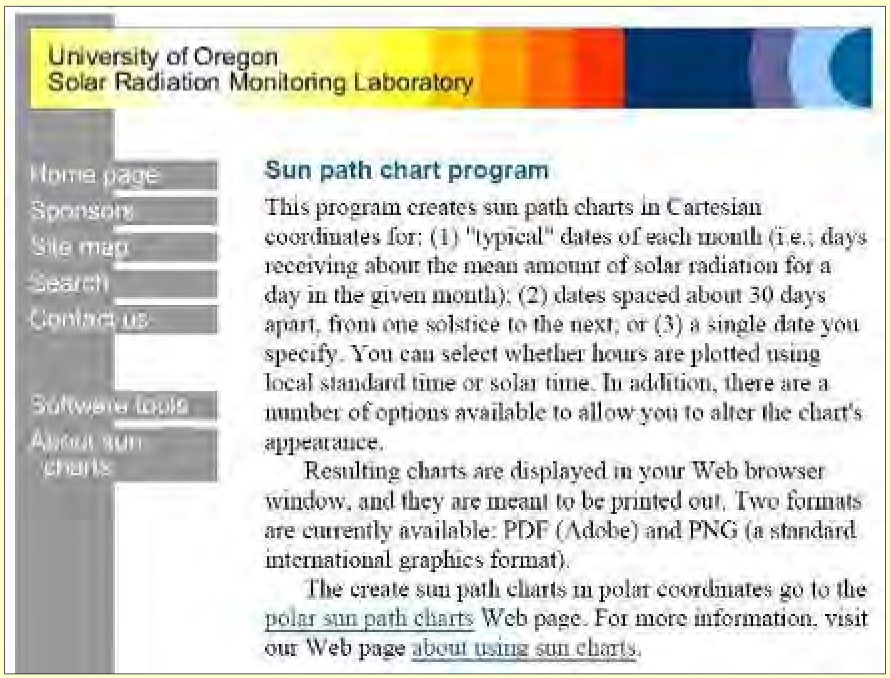
- Web Tools
- susdesign.com

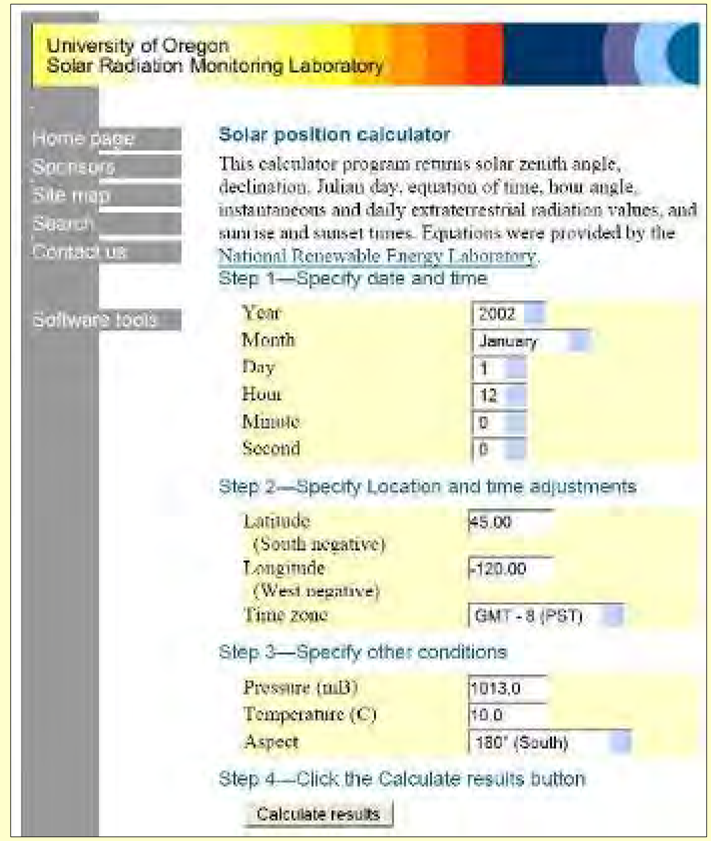


- Source: Sustainable-by-Design-website-Window-Heat-Gain-1.jpg

Passive Solar

- – Web Tools
- – Solardat.uoregon.edu/
- – SolarChartProgram

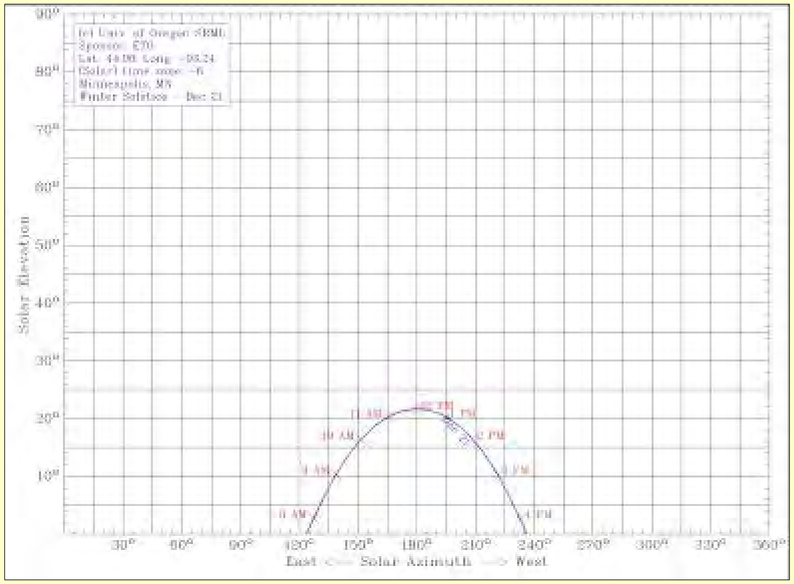




- Source: U-Oregon-Solar-Sun-Path-Chart-website-1.jpg
- Source: U-Oregon-Solar-Calculator-website-1.jpg

Passive Solar

- Web Tools
- Solardat.uoregon.edu/
- SolarChartProgram



- Source: U-Oregon-Solar-Sun-Path-Chart-Mpls-MN-6-21.jpg

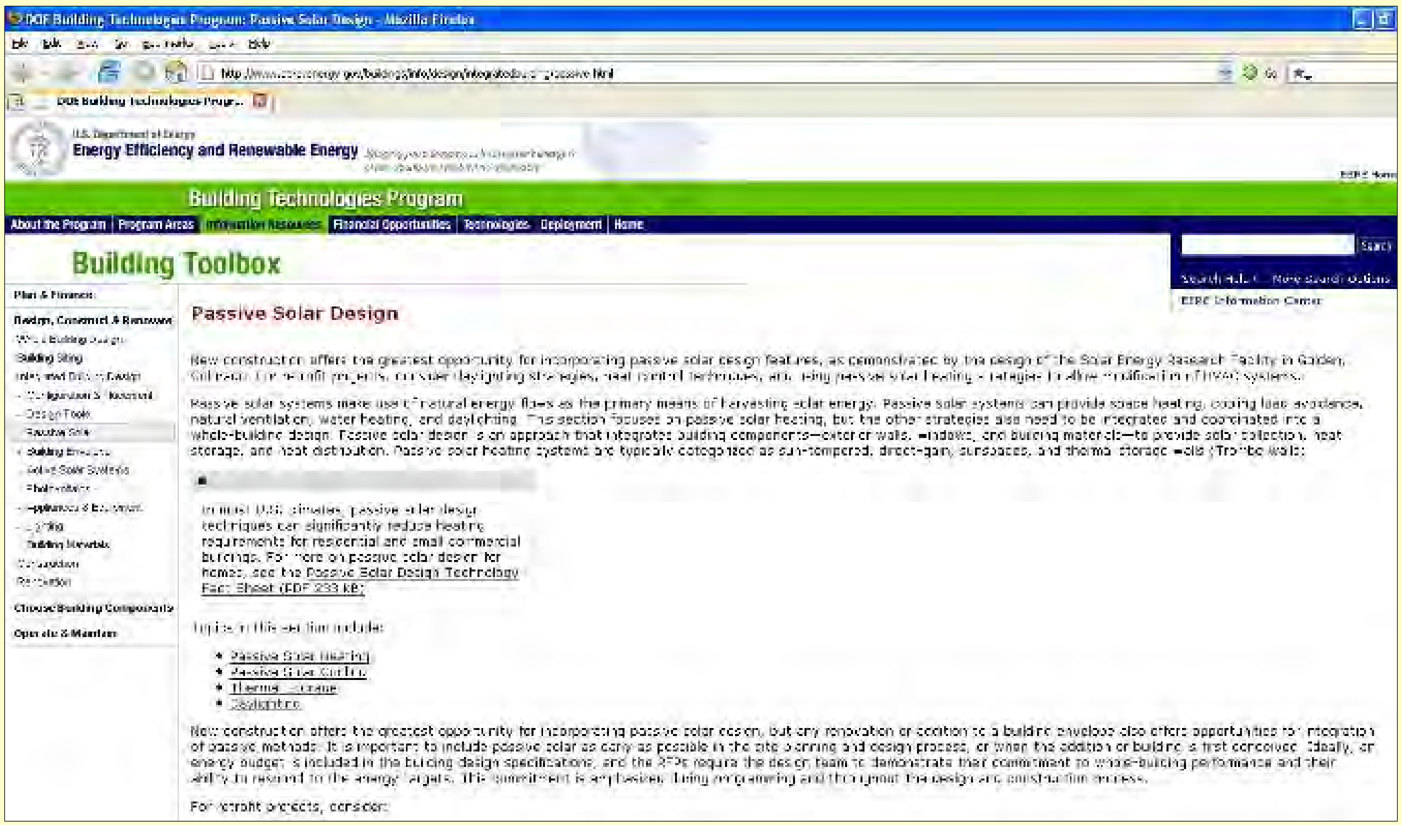
Passive Solar

- Web Tools
- csbr.umn.edu.org
- msbg.umn.edu
- msdg.umn.edu

- Source: CSBR-U-Mn-Center-Sustainale-Bldg-Research-website.jpg

Passive Solar

- Web Tools
- U.S. Dept. of Energy - Office of Energy Efficiency & Renewable Energy
- energy.gov/eere/energybasics/articles/passive-solar-building-design-basics



- Source: DOE-EERE-website-passive-1.jpg

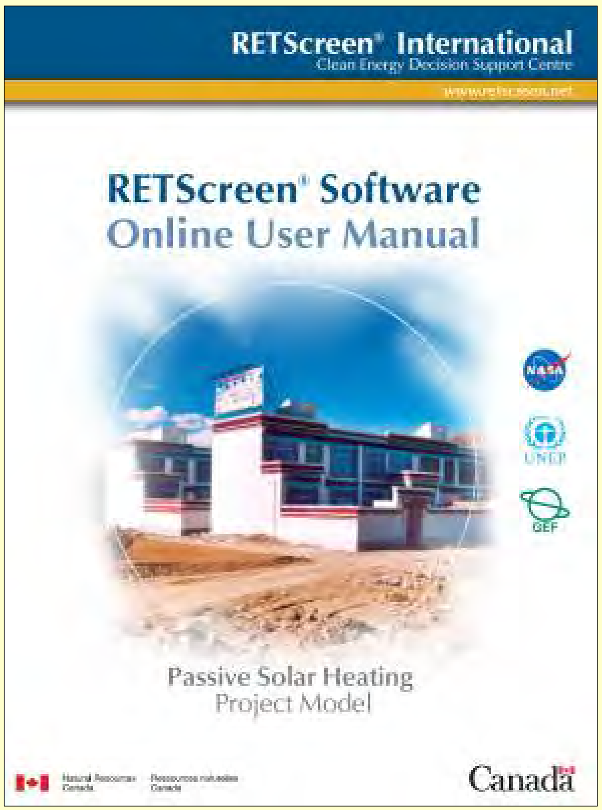
Passive Solar

- Web tools
- efficientwindows.org

- Source: __EWC-Efficient-Windows-Collaborative-website.jpg

Passive Solar

- Web Tools
- retscreen.net



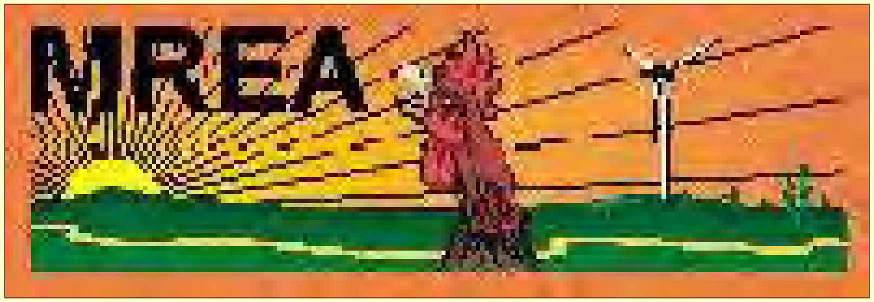
- Source: Retscreen-website-Tools-1.jpg

Midwest Renewable Energy Association

Renewable Energy & Sustainable Living Fair

Third Weekend in June, every year

www.the-mrea.org



Solar Tour of Homes & Businesses

Early October, every year

American Solar Energy Society

www.ases.org

Minnesota Renewable Energy Society

Workshops & Resources

www.mnrenewables.org

Solar Tour of Homes & Businesses

Early October, every year

American Solar Energy Society

www.ases.org

Passive Solar

- ReArch resources
- Fact sheets
- rearch.umn.edu


Re-Arch: The Initiative for Renewable Energy in Architecture

Fact Sheet

Technology: Passive Solar Design


Re-Arch: The Initiative for Renewable Energy in Architecture

Fact Sheet

Technology: Integrated Whole-Building Design


Re-Arch: The Initiative for Renewable Energy in Architecture

Fact Sheet

Technology: Daylighting


Re-Arch: The Initiative for Renewable Energy in Architecture

Fact Sheet

Technology: Glazing Selection

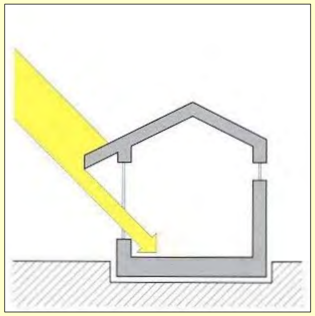

Re-Arch: The Initiative for Renewable Energy in Architecture

Fact Sheet

Technology: Shading and Sun Control

Passive Solar

– Rules of Thumb



General

- In winter, the sun rises in the southeast and sets in the southwest, with a low noontime sun angle of about 23 degrees in December. The low angle allows good solar penetration.
- In summer, the sun rises in the northeast and sets in the northwest, with a high noontime sun angle of about 69 degrees in June. The high angle allows good summer shading with overhangs.
- The sun is in the same position in spring and fall. In spring, the west sun is sometimes welcome, in fall it often is not.
- The west afternoon sun is not of value in the winter and can be a liability in the summer, presenting a cooling and shading problem

Passive Solar

– Rules of Thumb

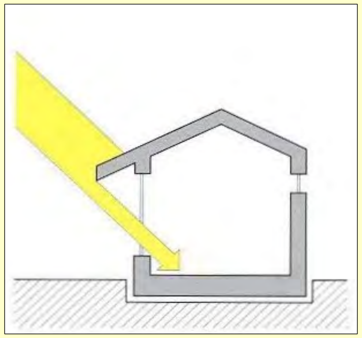
Building Shape

- Elongated shape along east-west axis
- Easier to shade south-facing glazing
- Less exposure to summer sun in east and west

Building Orientation

- Elongated building axis facing south
- Up to 30 degrees east or west of south acceptable
- Southeast orientation provides earlier winter warm-up
- Southeast orientation lessens summer cooling load from west sun

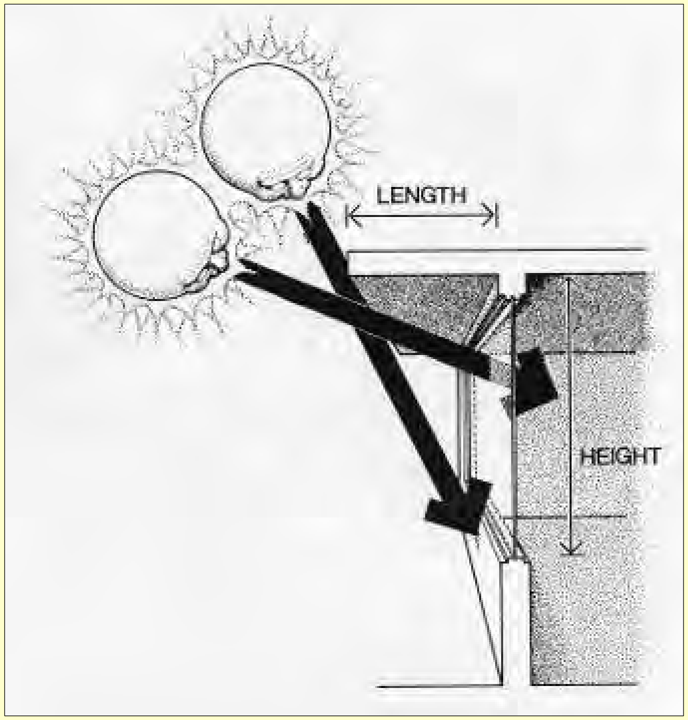
Shading

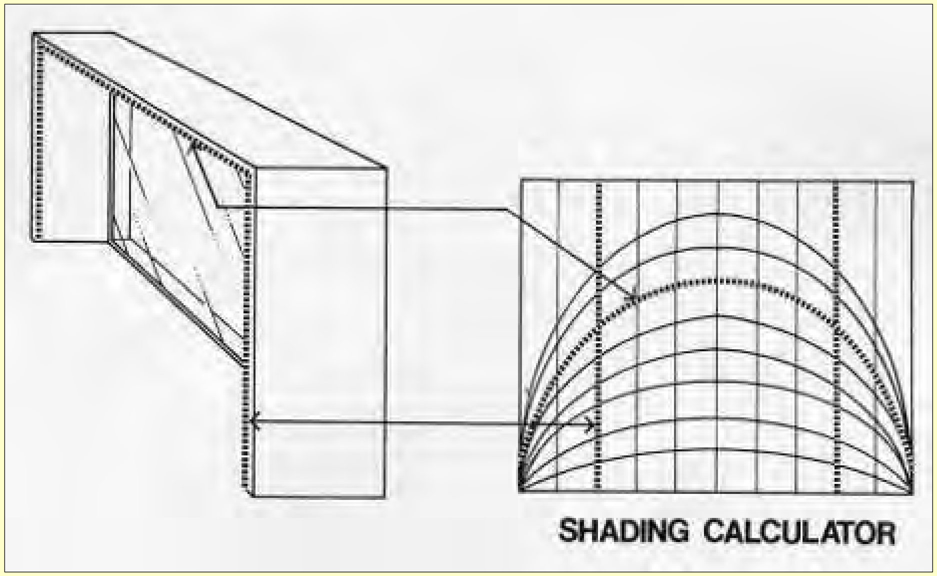


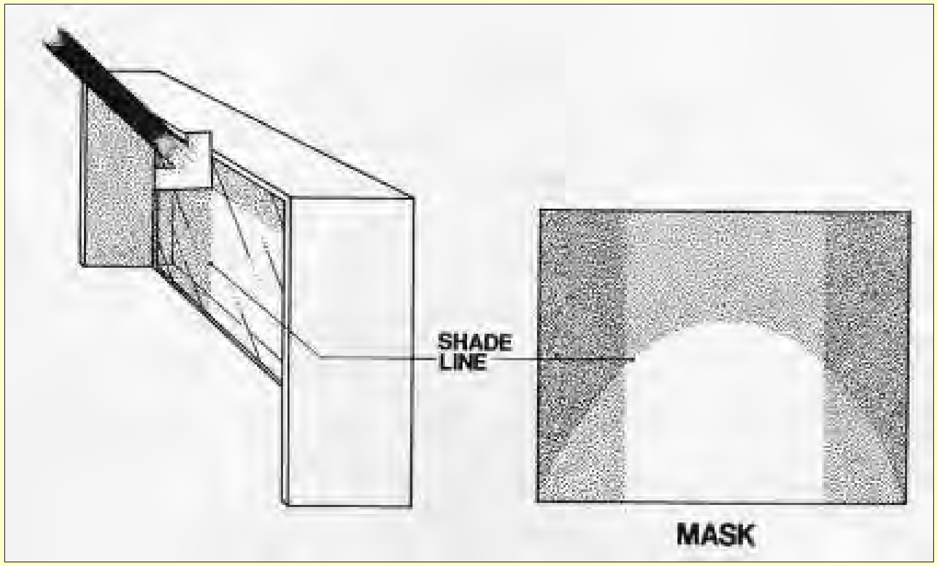
Passive Solar

Shading

– Overhang



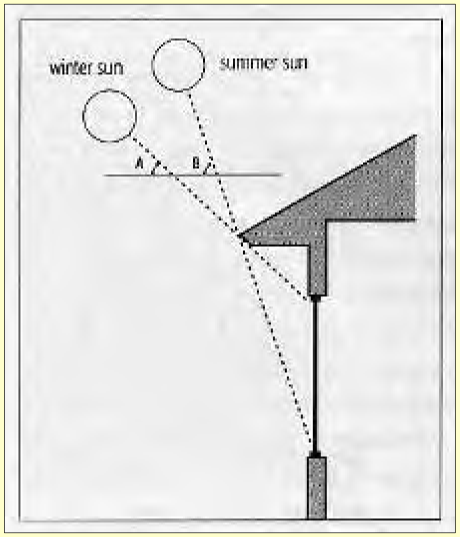




- Source: Passive-Solar-Mazria-Overhangs-1a.jpg

Shading

– Overhangs



Designing Overhangs

Overhangs control the solar heating season, that is, the beginning and end of the period of solar gain through south-facing glazing. Fixed overhangs should be designed so there is a separation between the top of the window and the underside of the projecting surface, as shown in figure 3-17. This feature, combined with the length of the overhang, allows the low-angled winter sun (angle A in the drawing) to penetrate the interior, while blocking the high-angled summer sun (angle B) from gaining entrance at the end of the heating season. To determine the length of the overhang projection, use the following formula:

length of projection (L) = height of window opening (H)/F factor.

In this equation, the F factor is a number that varies with the latitude. It is determined from table 3-2. For example, suppose you are building a home in Wisconsin at 44° north latitude. Suppose your windows are 6 feet high. To determine the overhang, you would simply divide 6 feet by the F factor, which in this case is 2 to 2.7. As you can see, F factors are expressed in a range, which allows some design flexibility. If you want more sunlight, use the larger number in the range. Knowing your heating requirements (heating degree days) and solar availability (average daily solar radiation by season) will assist you in making this determination.

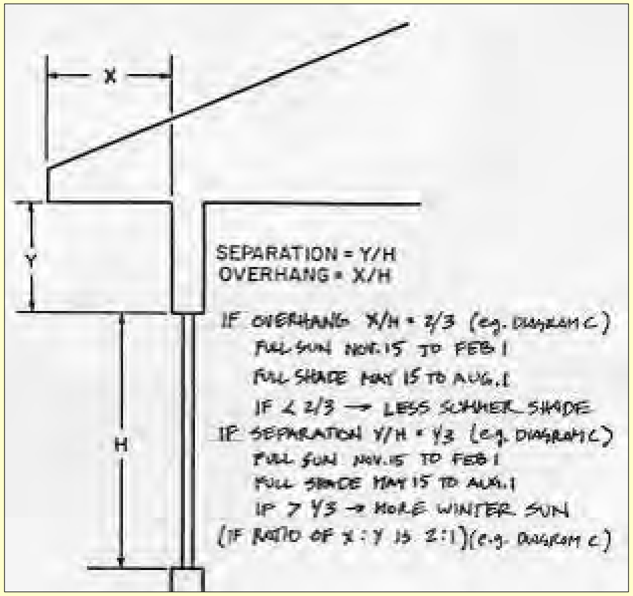
F Factor Used to Determine Length of Overhang Projection in All Passive Solar Designs

NORTH LATITUDE	F FACTOR
20°	5.6 - 11.1
32°	4.0 - 6.3
36°	3.0 - 3.5
40°	2.5 - 3.4
44°	2.0 - 2.7
48°	1.7 - 2.2
52°	1.5 - 1.8
56°	1.5 - 1.5

- Source: Chiras-Solar-House-7c-overhangs.jpg

Shading

– Overhangs



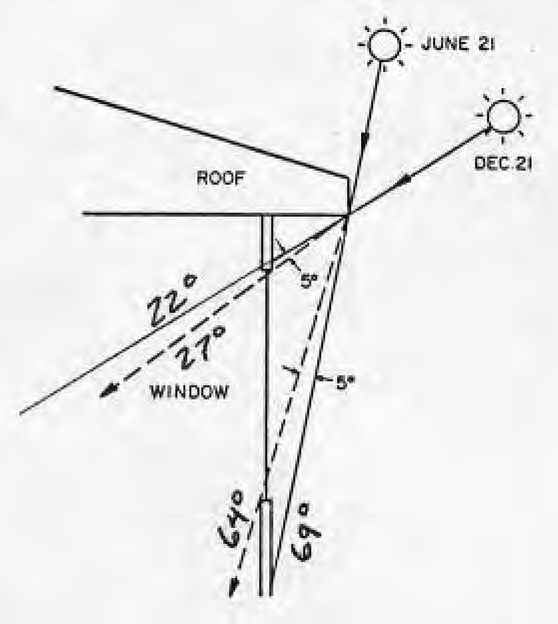
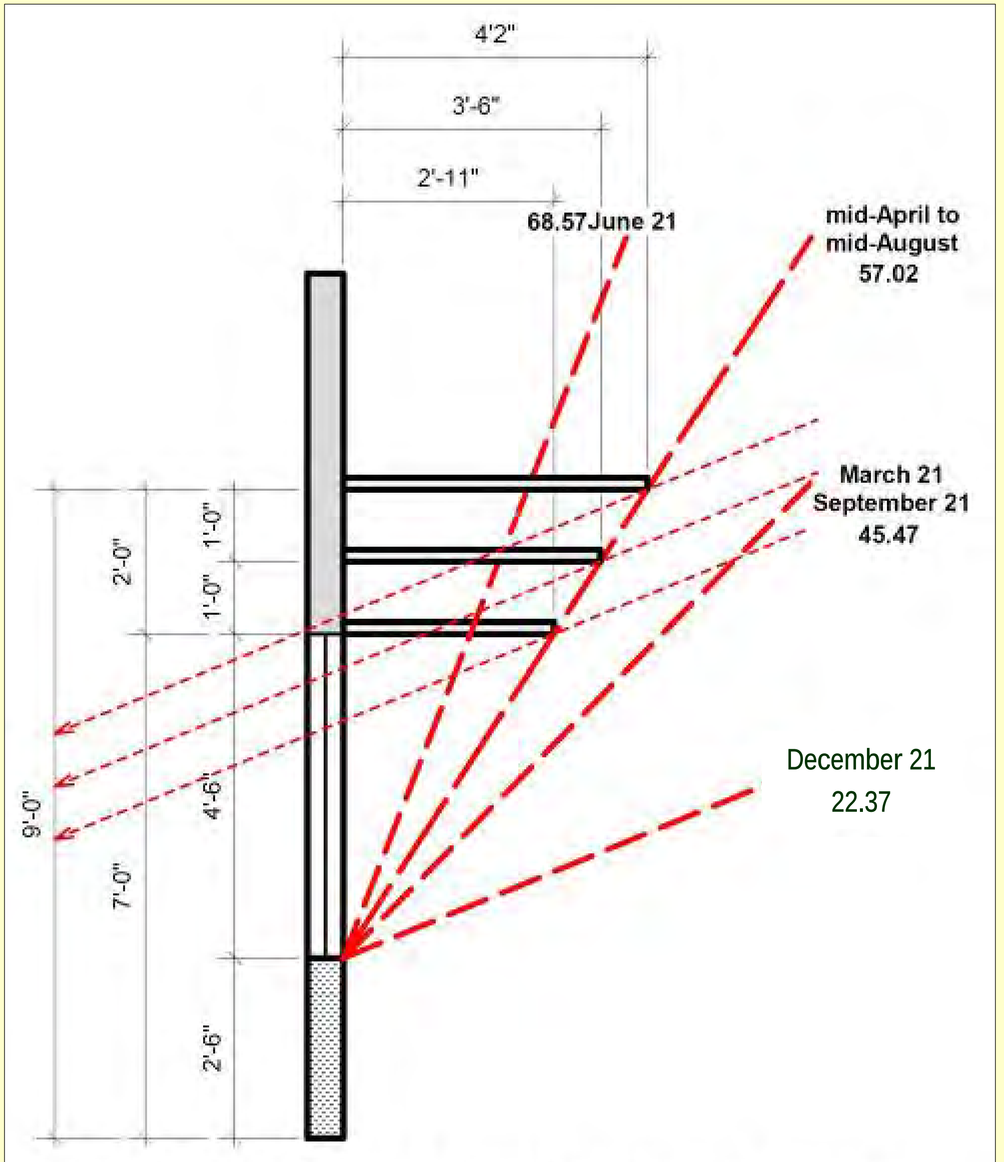


Fig. E-56.
An example showing how roof overhang geometry can be modified to provide desired summer shading and winter solar gain. The 5° allowances shown extend the desired effects over a ten-week season.

- Source: DOE-Passive-Handbook-vol-2-overhang-1.jpg

Shading

- Overhang Example
  - Summer Solstice
  - April-August
  - Spring-Fall Equinox
  - Winter Solstice
  - Stevens Point, WI



Stevens Point, WI -- 7' View Window (no transom)

Passive Solar Design

– Guidelines

– Summer Shading Sun Angles – April to August

Superior, WI

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-	-	-	X	X	**54.82**	X	X	-	-	-	-

Stevens Point, WI

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-	-	-	X	X	**57.02**	X	X	-	-	-	-

Madison, WI

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-	-	-	X	X	**58.48**	X	X	-	-	-	-

Passive Solar Design

– Guidelines

– Summer Shading Sun Angles – April to August

Duluth, MN

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-	-	-	X	X	**57.53**	X	X	-	-	-	-

Minneapolis, MN

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-	-	-	X	X	**56.57**	X	X	-	-	-	-

Rochester, MN

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-	-	-	X	X	**54.77**	X	X	-	-	-	-

Shading

– Rules of Thumb

Shading

- For south-facing glazing provide exterior overhangs
- A higher, longer overhang provides better winter sun penetration and summer shading.
- For south-facing gable end roofs, provide a skirt overhang at base of gable.
- For east or west-facing windows, use hip roof overhangs or provide a skirt overhang across the base of gable-end roofs
- For east or west-facing windows, consider vertical wings or fins
- For north-facing glazing provide fins or no shading
- Avoid overhangs tight to top of glazing.

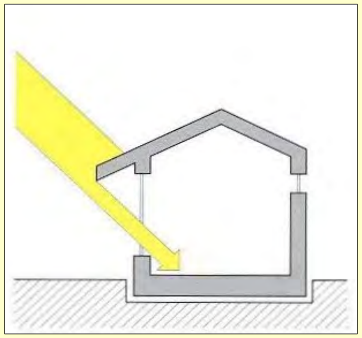
Shading

– Rules of Thumb

Building Construction

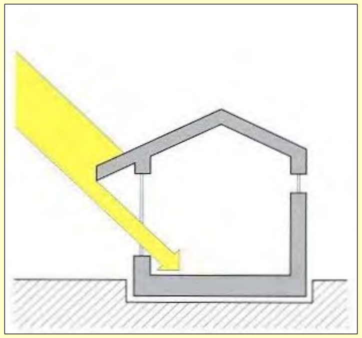
- Avoid standard truss or rafter framing, where exterior overhang soffits are tight to the top of the windows.
- Use raised-heel energy trusses, where the exterior soffit is at or near the interior ceiling height.
- For conventional stick-built framing, set rafters on a plate on top of ceiling joists, instead of on wall top plate.

Glazing

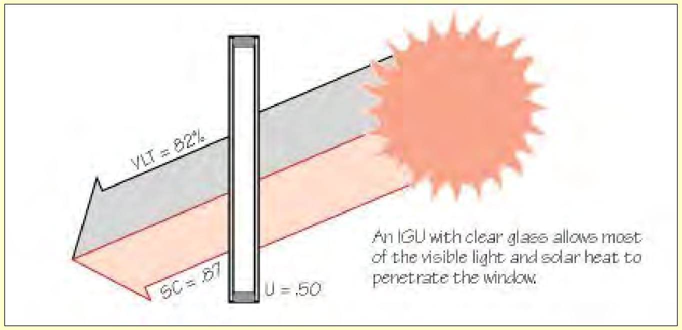


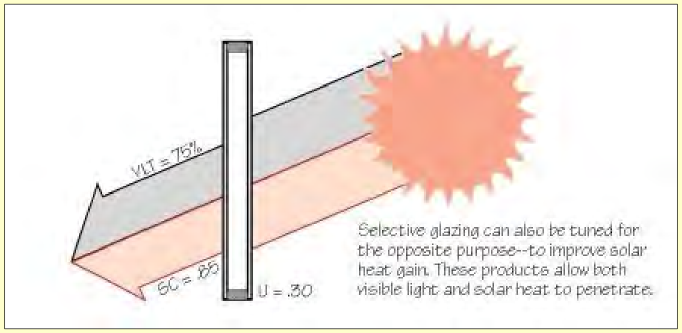
Passive Solar

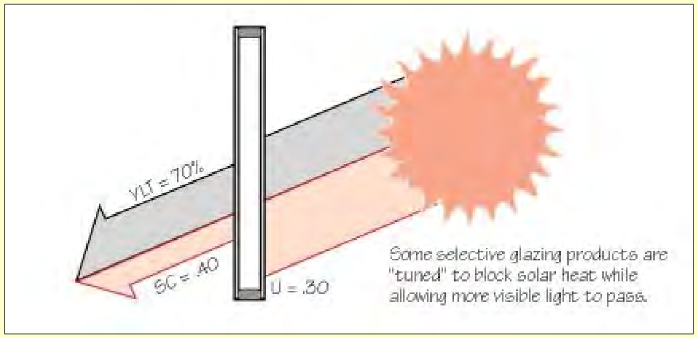
Glazing



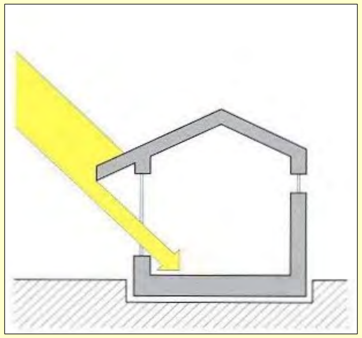
Passive Solar



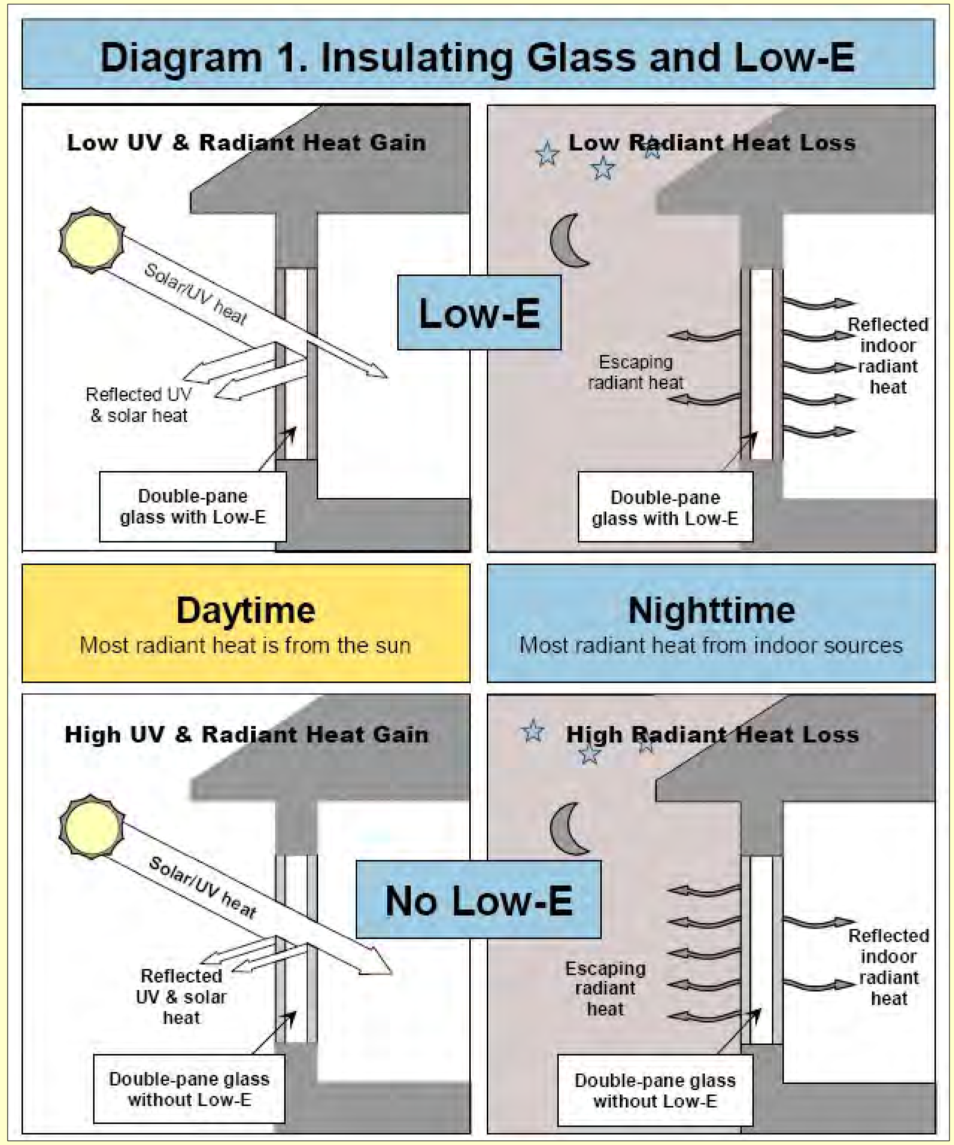




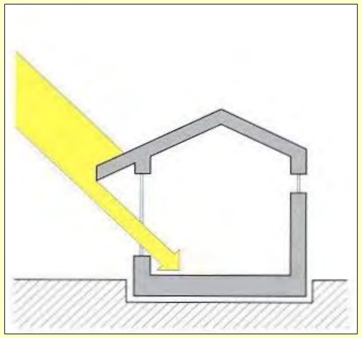
Glazing



Passive Solar



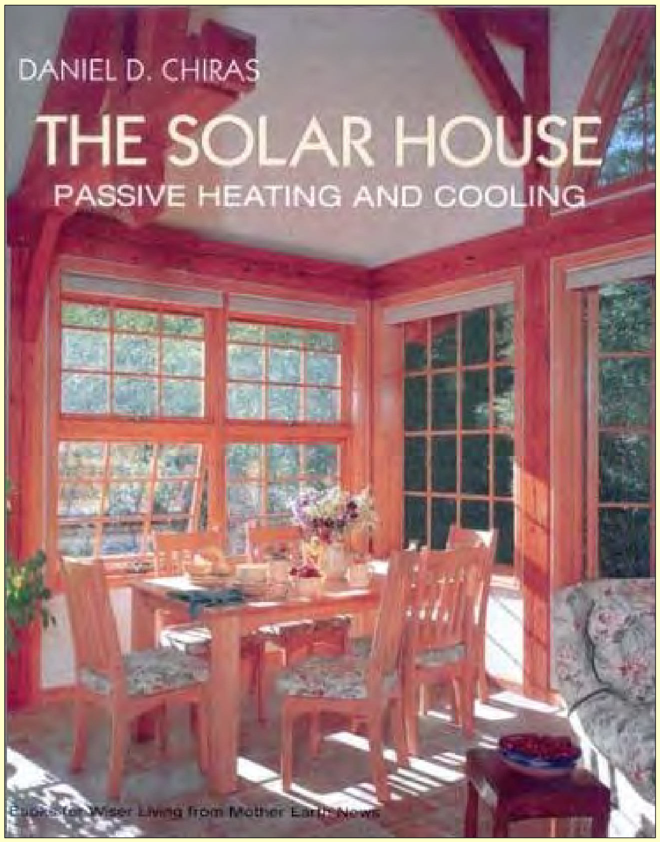
Glazing



Passive Solar

Glazing

– Rules of Thumb



WINDOW ALLOCATIONS IN DIRECT-GAIN SYSTEMS

Solar glazing–7 to 12%

North-facing glass–no more than 4%

East-facing glass–no more than 4%

West-facing glass–no more than 2%

Percentages are based on total square footage of a home. Window space is glass area (total window space minus frame).

- Source: Solar-House-Chiras-cover.jpg

Glazing

– Rules of Thumb

<u>Glazing Type</u>

- Use clear or low-e gas-filled insulating glazing
- Use higher Solar Heat Gain Coefficient (SHGC) on south-facing glazing, or use clear south-facing glazing
- Use lower SHGC on east, west & north-facing glazing
- Avoid un-shaded overhead glazing
- Use high clerestory or transom windows, instead of skylights, to increase daylight penetration & facilitate shading
- Minimize large expanses of west-facing windows and glazing

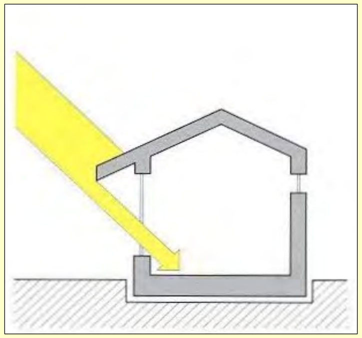
Glazing

– Rules of Thumb

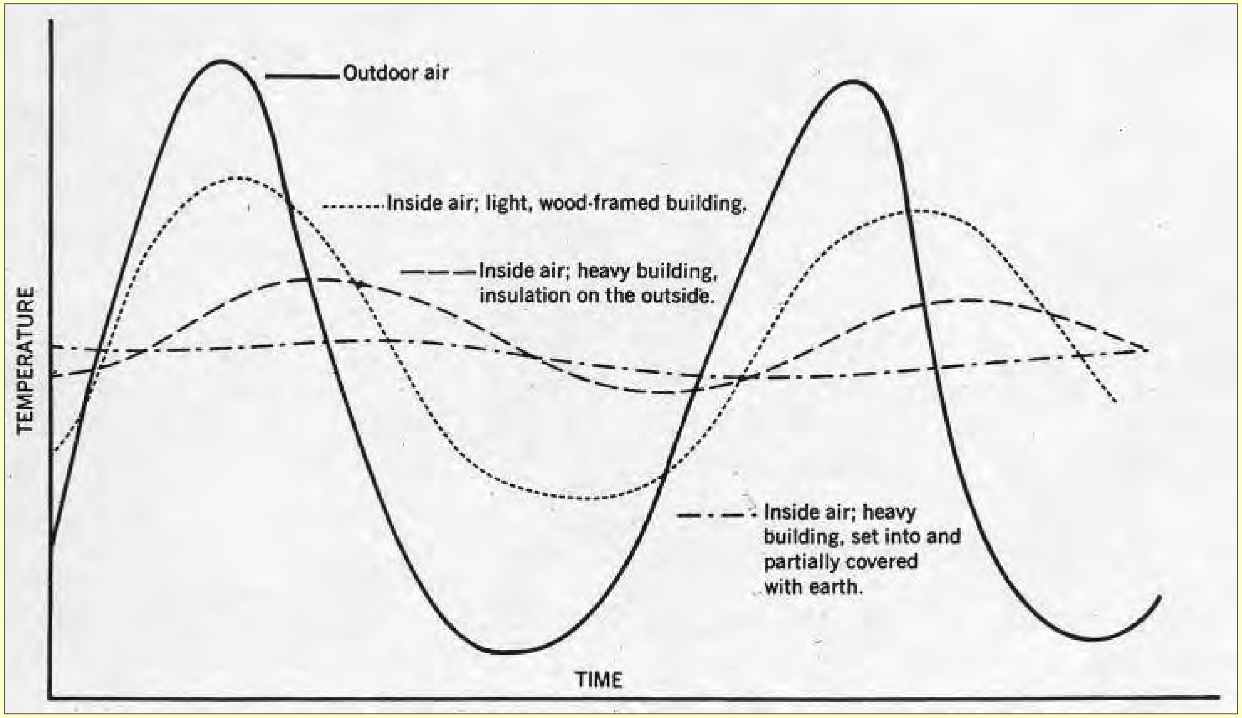
Glazing Area

- Allocate 50% of the overall glazing to walls within 30 degrees of south
- Allocate 50% or less of window area to the north, east and west faces
- Provide 10-15% of floor area in south-facing glazing
    - Less glazing if building constructed of lightweight materials
    - More glazing if building constructed of heavier materials
- Limit east or west-facing glazing to less than 5% of floor area

Thermal Mass

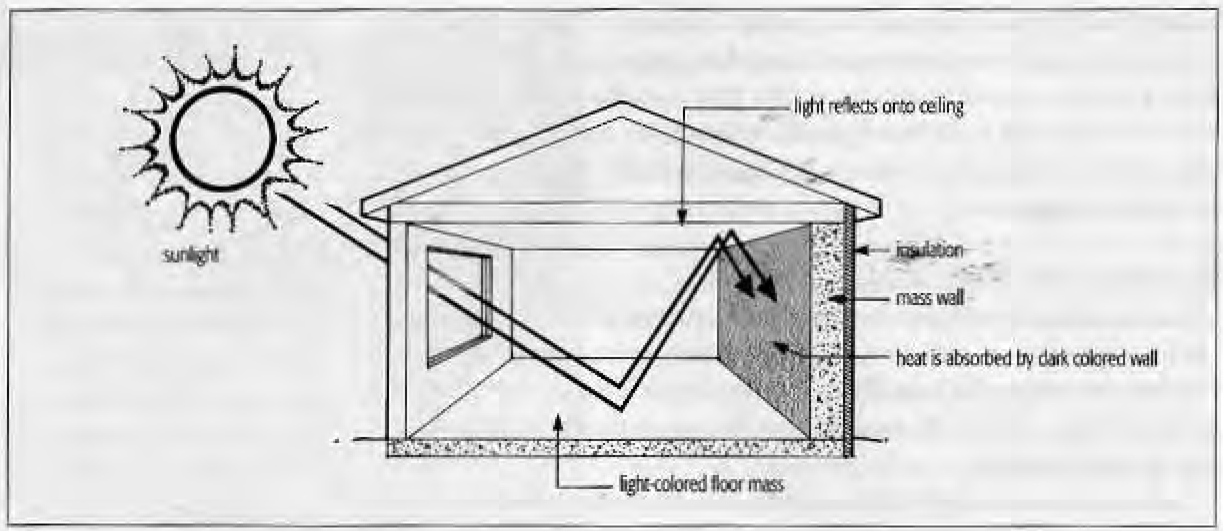


Passive Solar



Thermal Mass

– configuration



Sunlight is often reflected off light-colored mass toward the south side of a passive solar home onto darker, heat-absorbing mass situated deeper in the structure.

- Source: Solar-House-Chiras-cover.jpg

Thermal Mass

– Rules of Thumb

Thermal Mass

- High-mass buildings provide thermal fly-wheel effect and respond slowly to temperature spikes and dips
- Surface area of thermal mass is more important than thickness
- Provide 3-4 sq ft of thermal mass for each 1 sq ft of south-facing glazing for areas exposed to direct sunlight
- Provide 9-12 sq ft of thermal mass for each 1 sq ft of south-facing glazing for remote areas not exposed to direct sunlight
- Incorporate heavier materials into construction wherever possible
  - Concrete slabs, ceramic tile, stone, pavers
  - Thicker or multi-layer gypsum board, thin-coat plaster
  - Masonry veneer, CMU partition walls

Daylighting and natural light

Natural Light

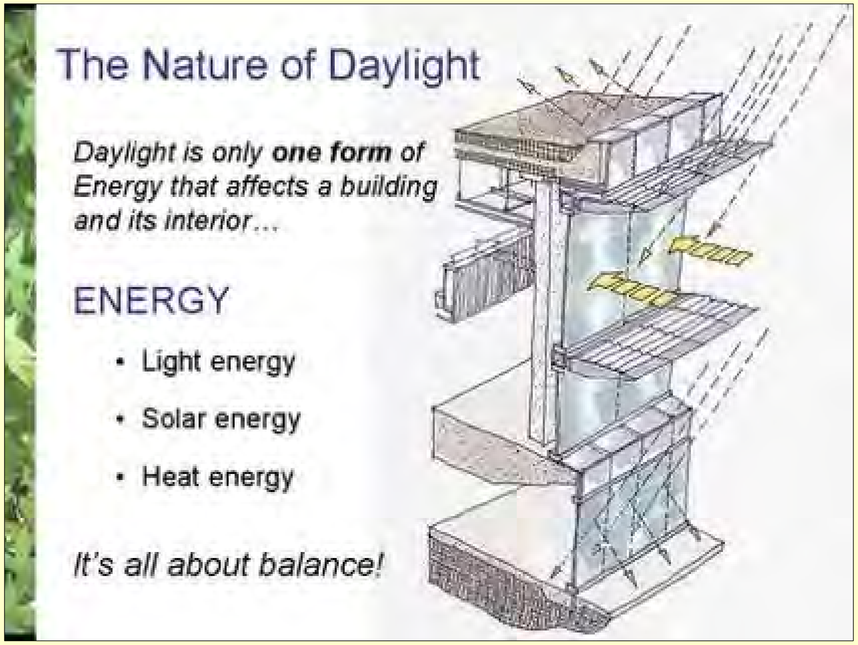
Side-lighting

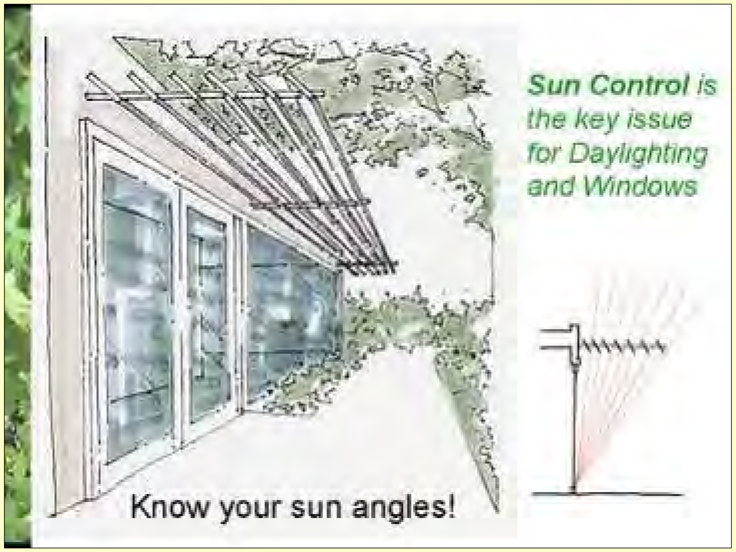
Top-lighting

Core-lighting

Daylighting

– Fundamentals





- Source: BD+C-12-7-06-daylight-nature-1.jpg

Daylighting

– Fundamentals

Elements of Integrated Daylighting

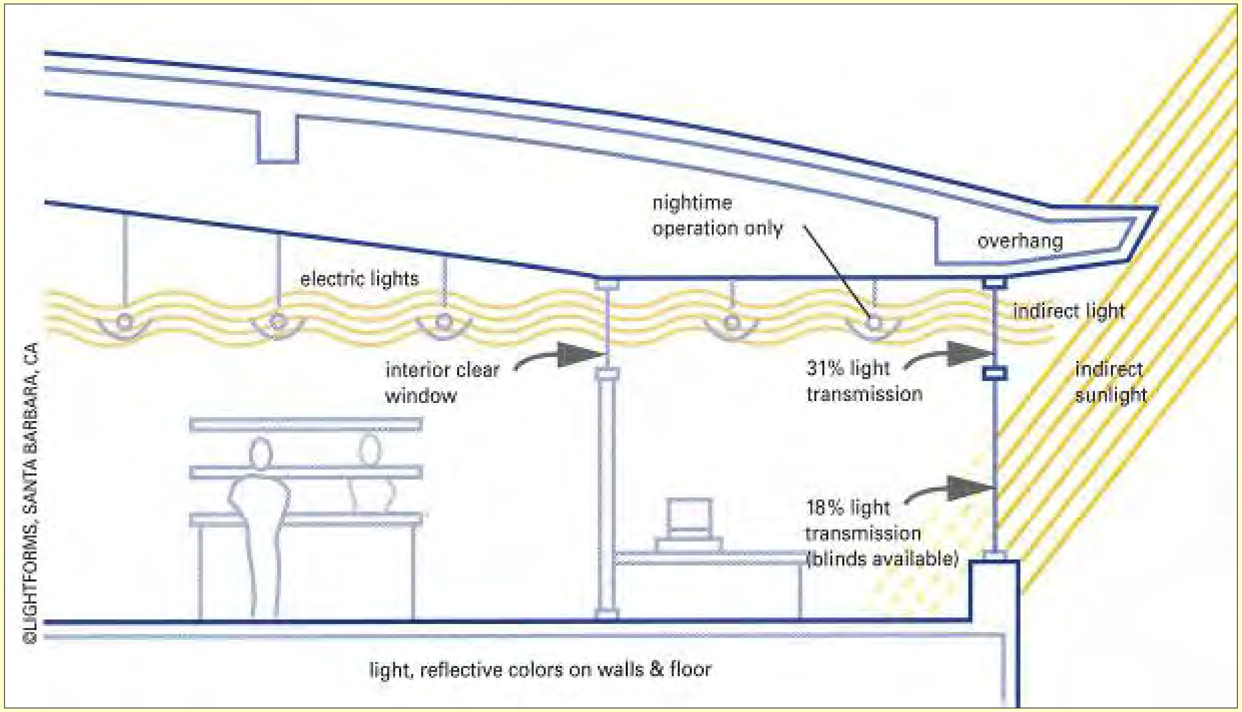
- Daylight Source
- Building Massing
- Building Orientation
- Window size & location
- Sun shading
- Glass types
- Space programming
- Interior surfaces
- Lighting design & control

c/o Weidt Group - Iowa DNR Sustainable Design Initiative

- Source: www.iowadnr.com/energy/sustainable/files/model.pdf

Daylighting

– Fundamentals



- Source: ED+C-7-00-Lightforms-Daylight-Diagram-1a.jpg

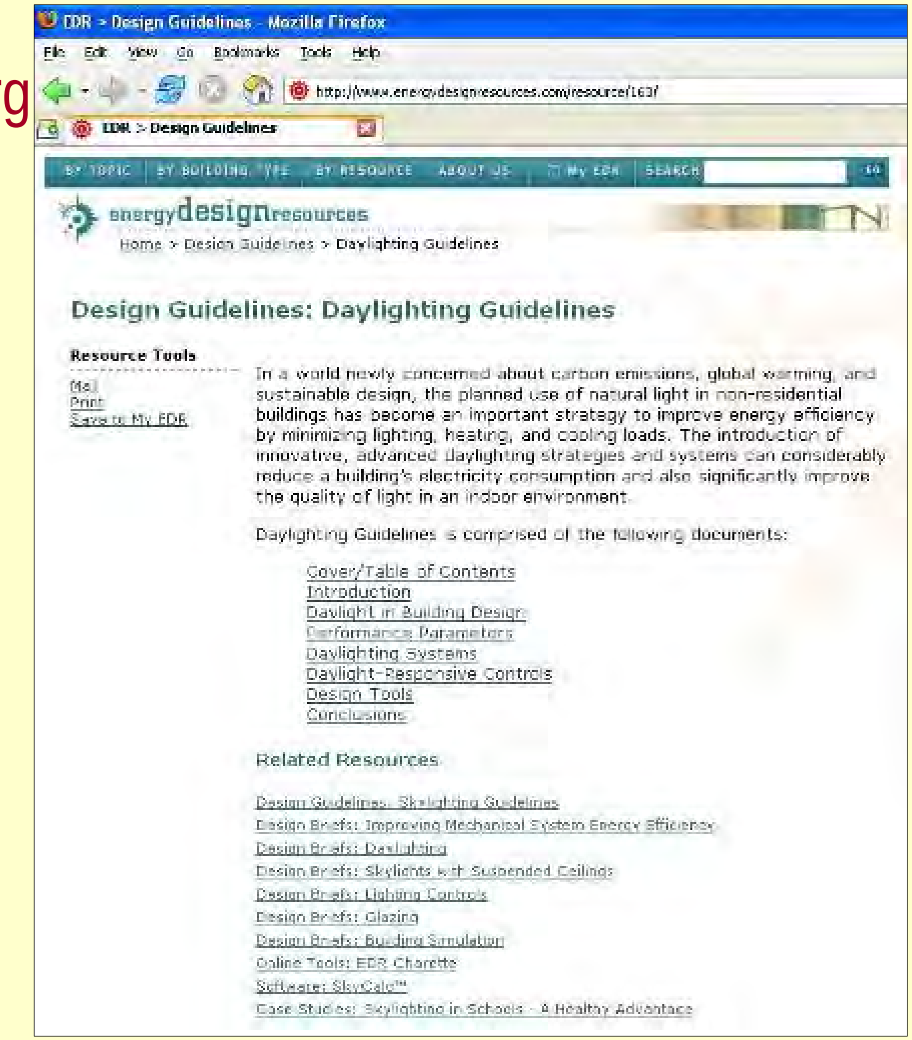
Daylighting

– Resources
– daylighting.org

- Source: _ECW-Daylighting-Collaborative-website.jpg

Daylighting

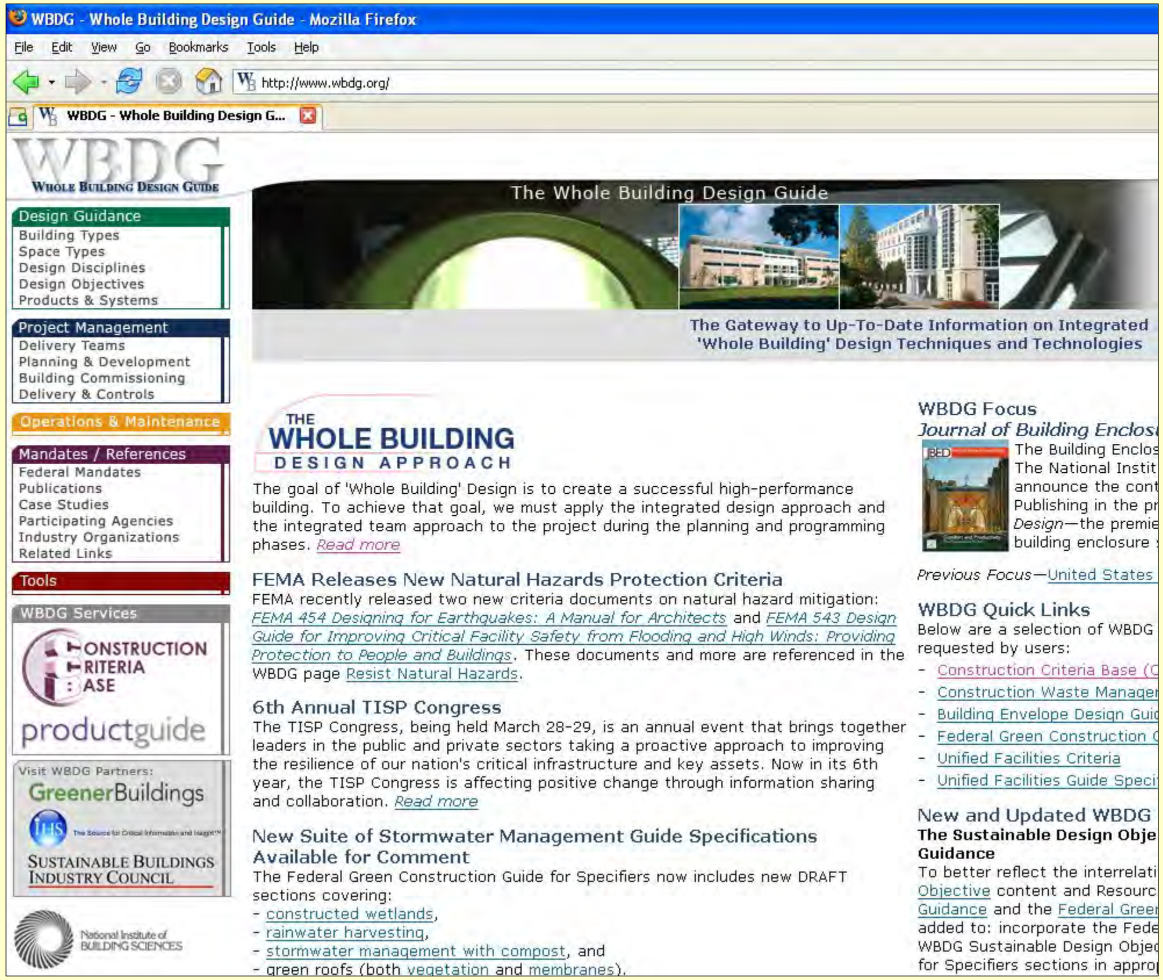
- Resources
- energydesignresources.org



- Source: _EDR-website-daylighting.jpg

Daylighting

– Resources
– wbdg.org

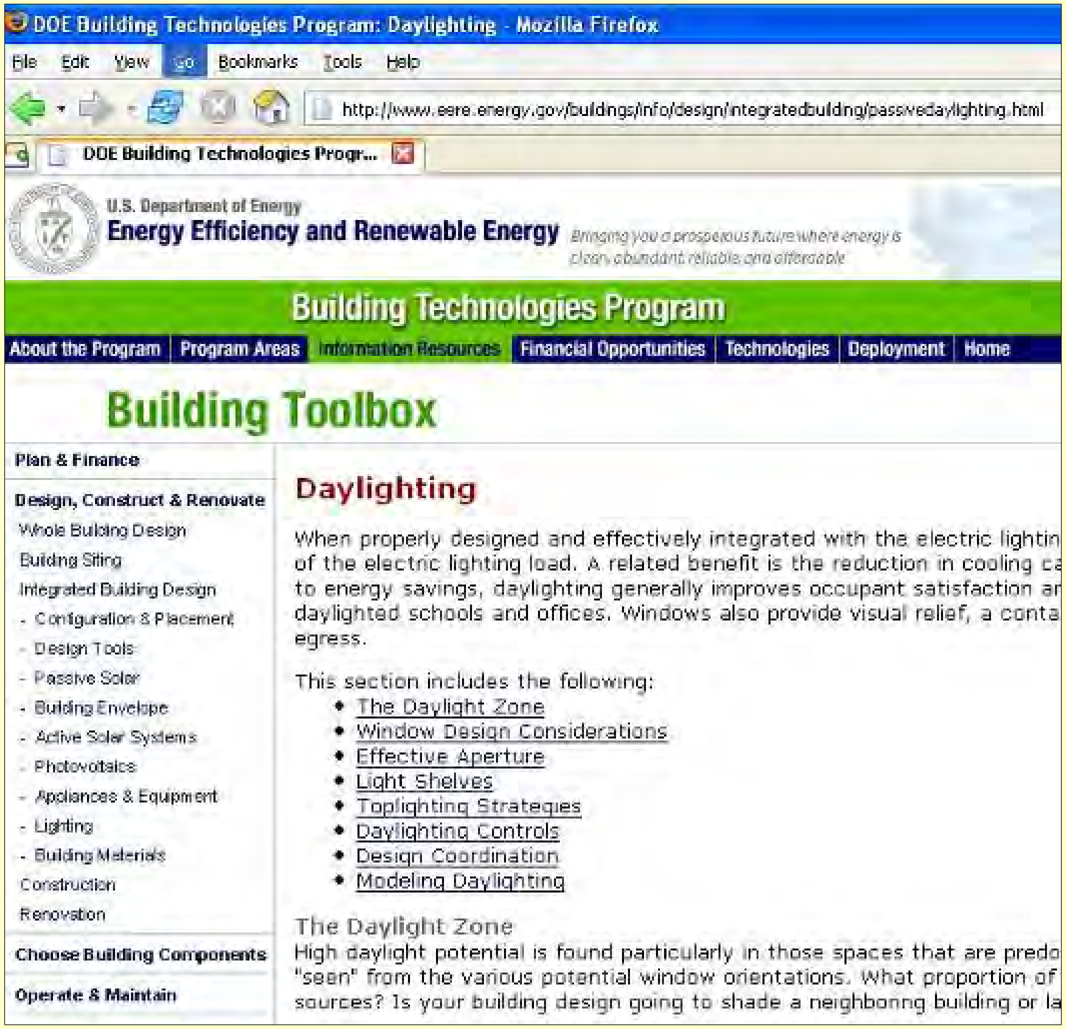


• Source: WDDG-Whole-Building-Design-Guide-website.jpg

Daylighting

– Resources

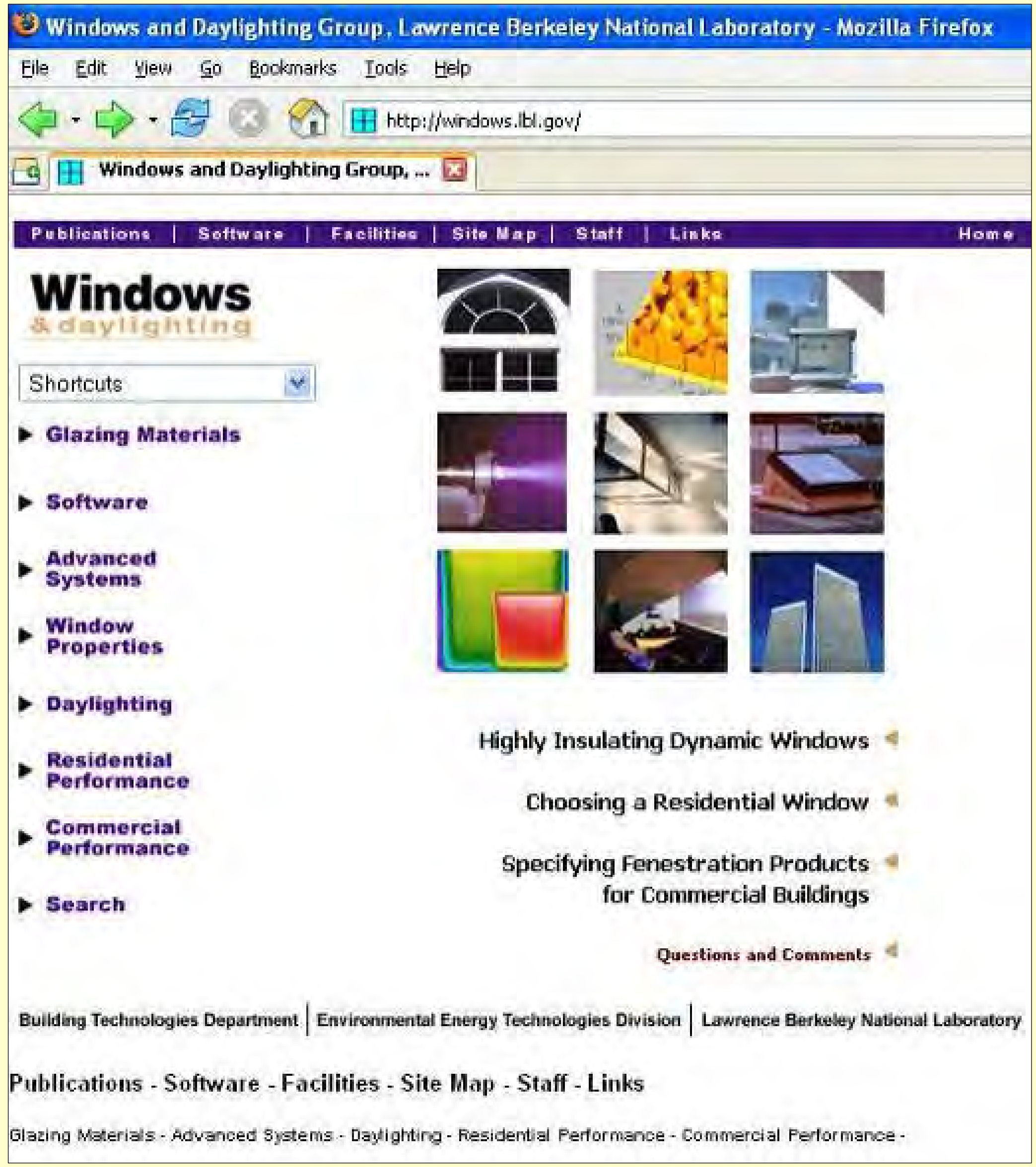
– eere.energy.gov



- Source: DOE-EERE-website.jpg

Daylighting

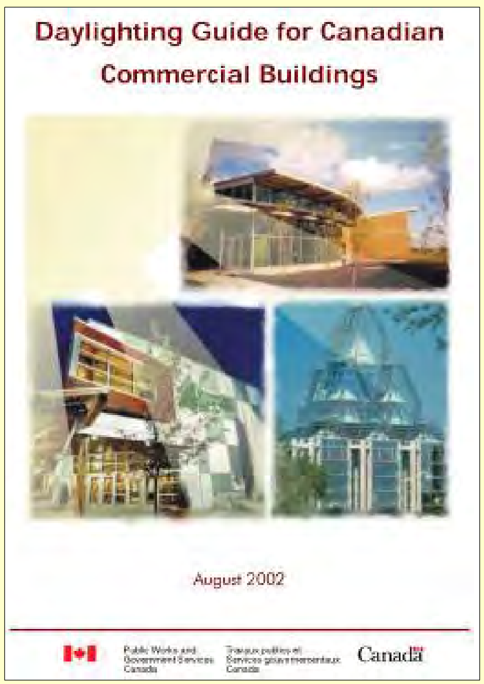
- Resources
- windows.lbl.gov



- Source: _LBL-Windows-Daylighting-website-1.jpg

Daylighting

- Resources
- enermodal.com/pdf/DaylightingGuideforCanadianBuildingsFinal6.pdf



- Source: Advanced-Buildings-Canada-website-1.jpg

Daylighting

– Best Practices

If you have...

no time

1. Minimize window area on east and especially on west.
2. Keep window area to a 30-40% window-to-wall ratio.
3. If tenants are unknown, use a strip window.
4. If tenants are known and punched windows are used, plan task areas to correspond with windows.
5. Keep interior finishes light-colored.
6. Try to increase surface area of window opening and splay these surfaces if possible.

a little time

In addition to above:

1. If preliminary glazing decision has been made, use engineer's early calculations to refine window area.
2. Explore envelope alternatives that could incorporate shading elements or light shelves.
3. Build a simple model and view it outdoors for lighting quality and glare.

more time

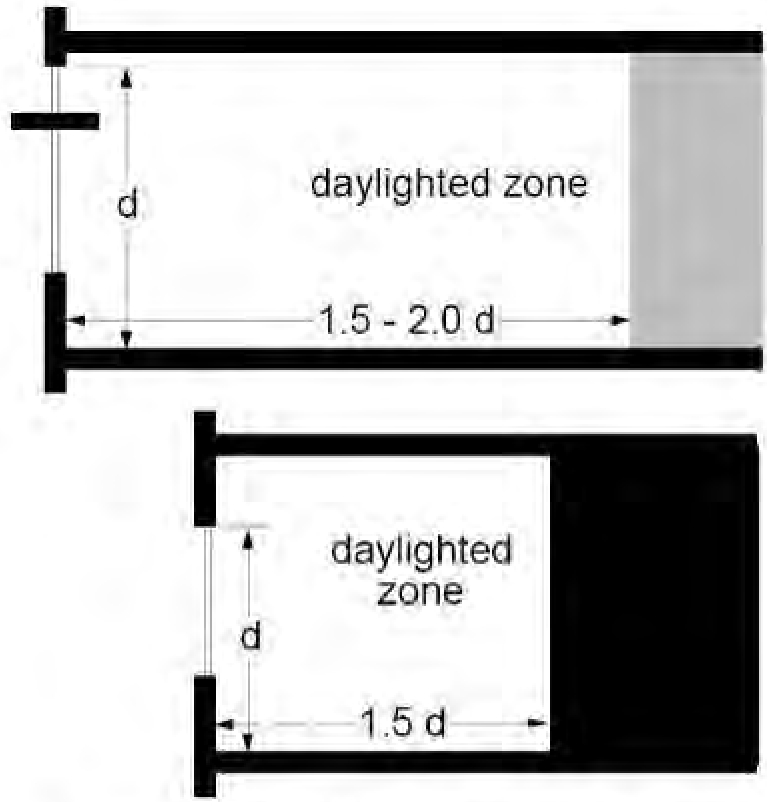
In addition to above:

1. Build a more accurate model and view/photograph outdoors. If photometric equipment is available, measure the daylight in the model. Refine design as necessary.
2. Mechanical engineer models variations in siting, form, footprint, and skin materials in an optimization study. Engineer looks for equipment downsizing opportunities.
3. Hire a daylighting consultant or investigate computer design tools.

- Source: LBL-Daylighting-Guide-checklist-text-4.jpg

Daylighting

– Best Practices
– Side-lighting

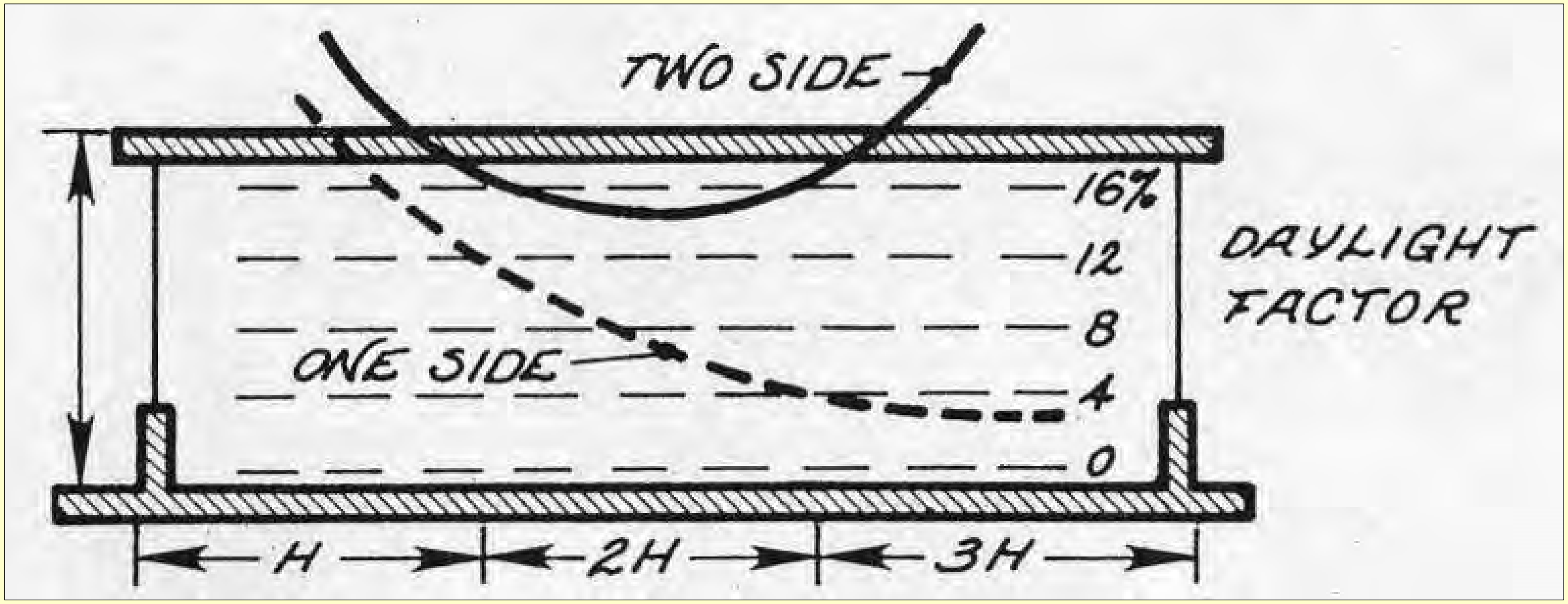


A rule of thumb for daylight penetration with typical depth and ceiling height is 1.5 times head height for standard windows, 1.5 to 2.0 times head height with light shelf, for south-facing windows under direct sunlight.

- Source: LBL-Daylighting-Guide-windows-9.jpg

Daylighting

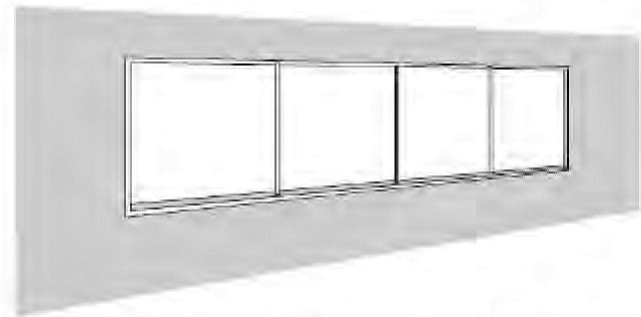
– Best Practices
– Side-lighting



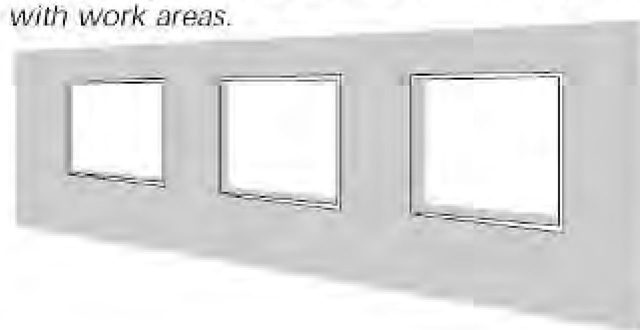
- Source: Solar-Architecture-Direct-Gain-Johnson-daylighting-1b.jpg

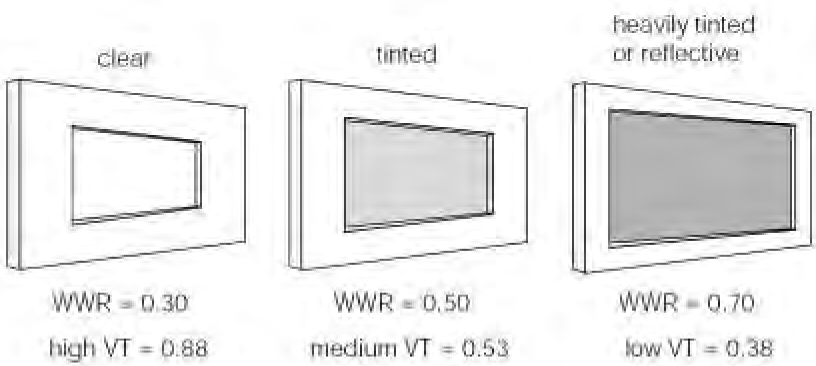
Daylighting

- Best Practices
- Side-lighting



Strip windows are an easy way for uniform daylighting. Punched windows should be paired with work areas.





Effective Aperture (EA) is visible transmittance (VT) x window-to-wall ratio (WWR). These three windows all have the same EA of 0.26.

- Source: LBL-Daylighting-Guide-windows-4.jpg

Daylighting

- Best Practices
- Side-lighting

When the window is behind your back, you may shade your task and make it too dark to see easily. However, your computer screen may be difficult to see if it reflects light from the window.

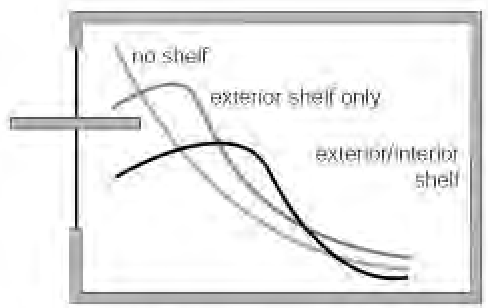
The most comfortable seating is with the window to the side—task is well illuminated and the source is not in direct line of sight.

Facing the bright window creates a harsh contrast in comparison to your relatively dark task—this is very tiring for the eye to have both in the same field of view.

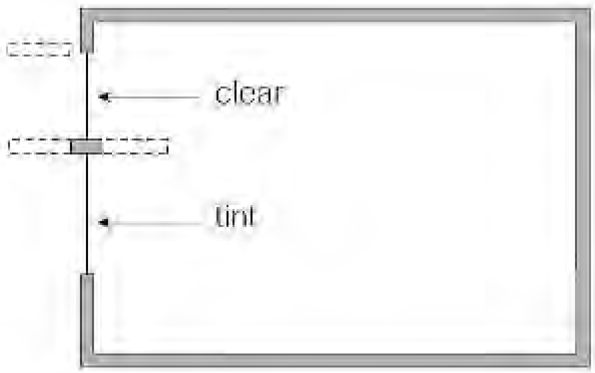
- Source: LBL-Daylighting-Guide-windows-15.jpg

Daylighting

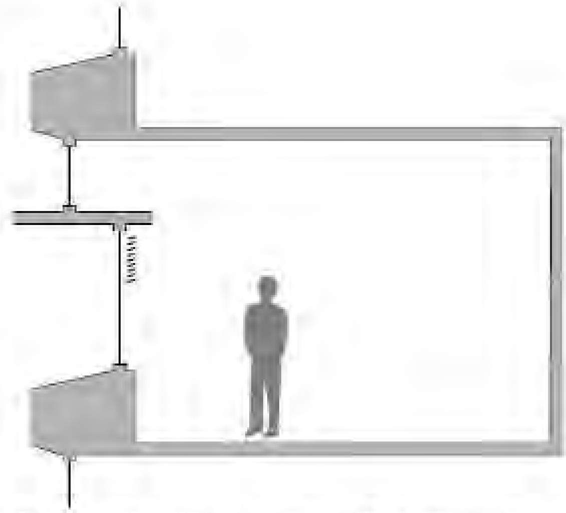
– Best Practices
– Side-lighting



A light shelf improves distribution of daylight. Notice the softer gradient with a light shelf.



Different apertures for daylight and view: clear glazing above for maximum daylight, tinted glazing below for glare control. The structure between the two provides a visual break and an opportunity to attach a light shelf or shading device.

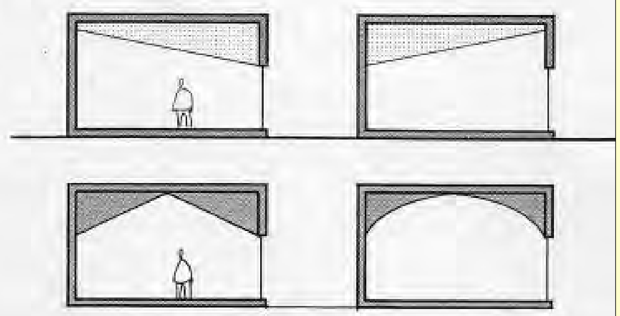

Deep wall section provides self-shading, allows easy integration of light shelf, creates surfaces that mitigate glare, and reduces noise transmission. Sloped surfaces also help soften glare.

- Source: LBL-Daylighting-Guide-windows-5.jpg

Daylighting

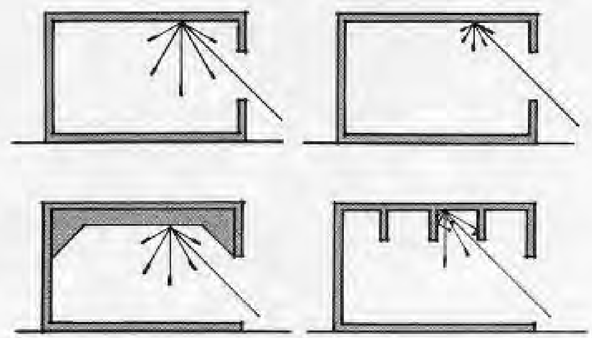
- Best Practices
- Side-lighting

6–12. Ceilings that slope up from the aperture improve illumination uniformity when the back wall is white. Sloping ceilings downward from the aperture increases the average illumination level but keeps the light closer to the window and makes the illumination less uniform.



6–13. Some ceiling shapes are better than a single slope.

6–10. A highly reflectant ceiling cavity is necessary for efficient utilization of light.



6–11. Highly articulated ceilings have a lot of surface area and trap light (right). Simpler ceilings, with less surface area, distribute light more efficiently (left).

- Source: Sunlighting-Lam-sidelighting-4b.jpg

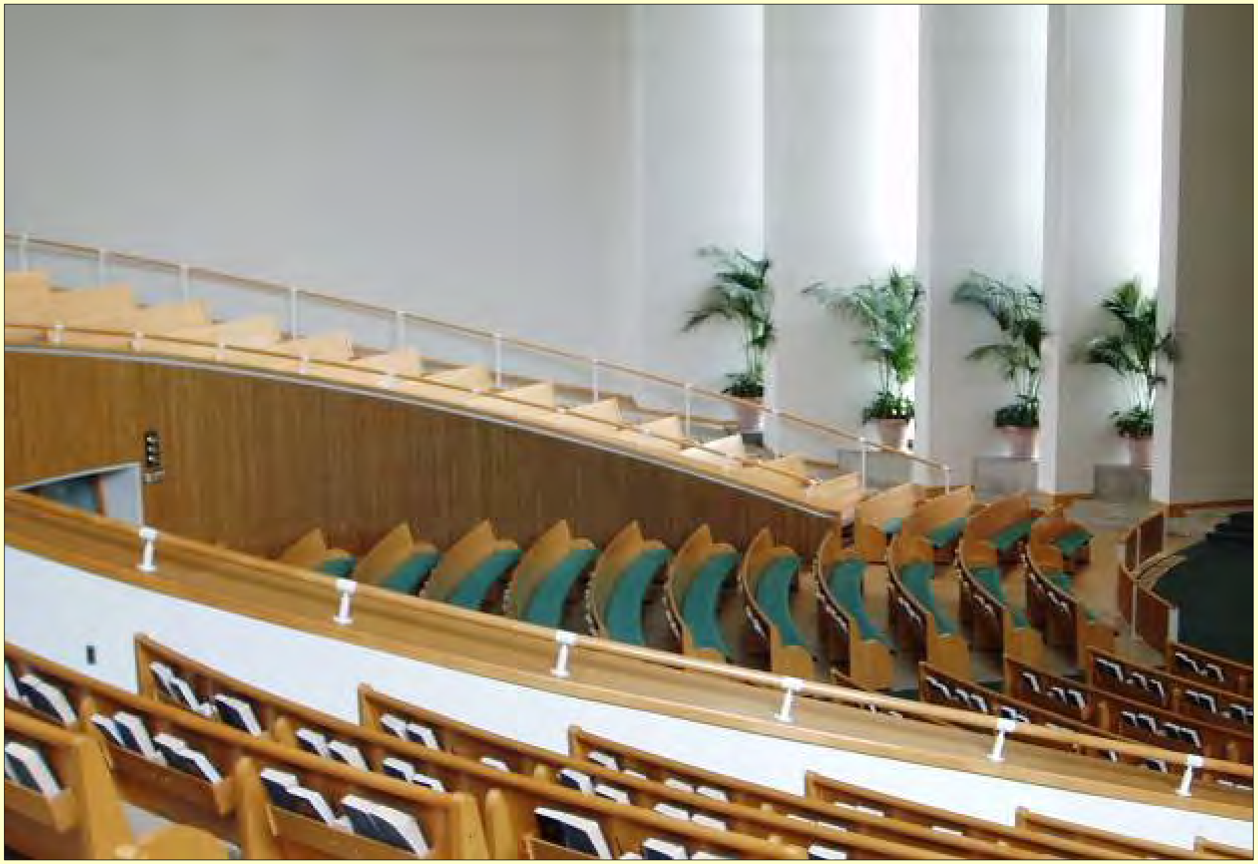
Daylighting

– Best Practices
– Side-lighting

• Source: Columbus-IN-St-Bartholemew-Church-1.JPG

Daylighting

- Best Practices
- Side-lighting



- Source: Columbus-IN-St-Peters-Lutheran-Church-1.JPG

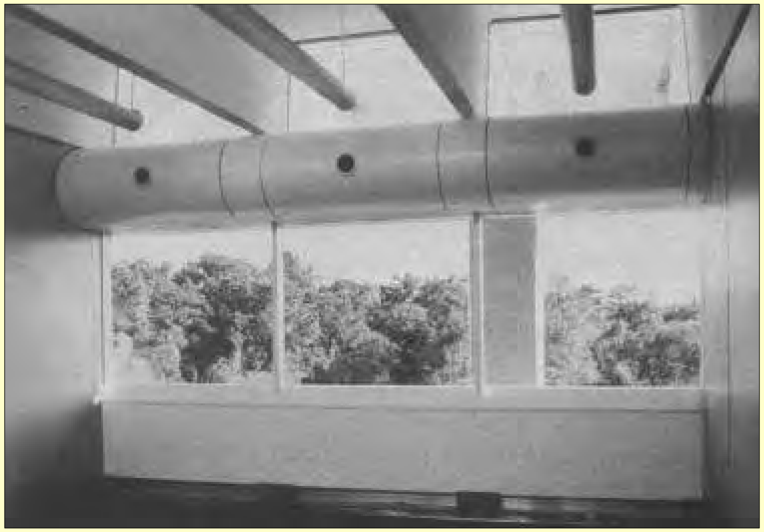
Daylighting

- Best Practices
- Side-lighting
- Light Shelves

- Source: Johnson-Diversey-Racine-WI-1.JPG

Daylighting

- Best Practices
- Side-lighting
- HVAC/Light Shelves



- Source: Daylighting-Design-Analysis-Robbins-lightshelf-TX-1.jpg
- Source: Sunlighting-Lam-TVA-Complex-TN-2a.jpg

Daylighting

- Best Practices
- Side-lighting
- Selective Apertures

- Source: Columbus-IN-Cummins-Main-HQ-Office-3.JPG

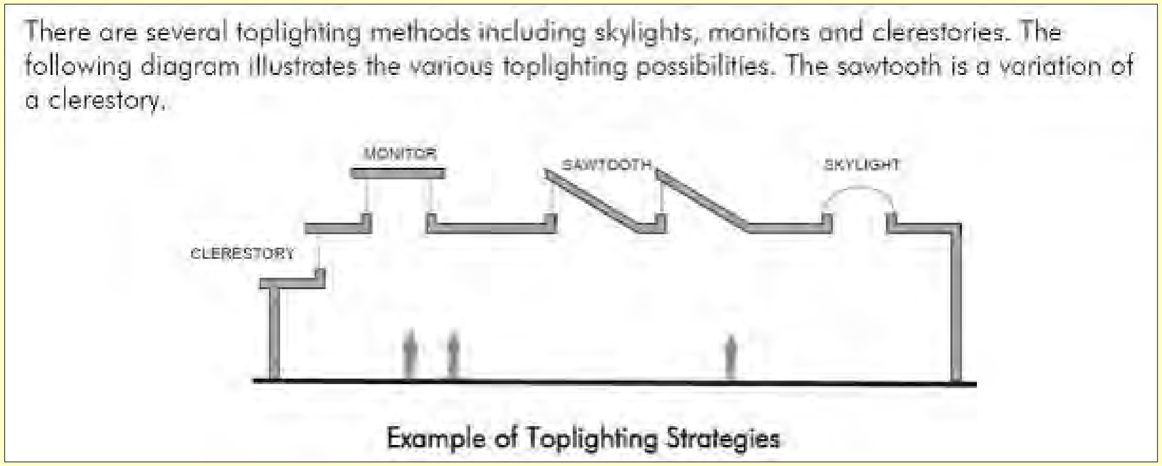
Daylighting

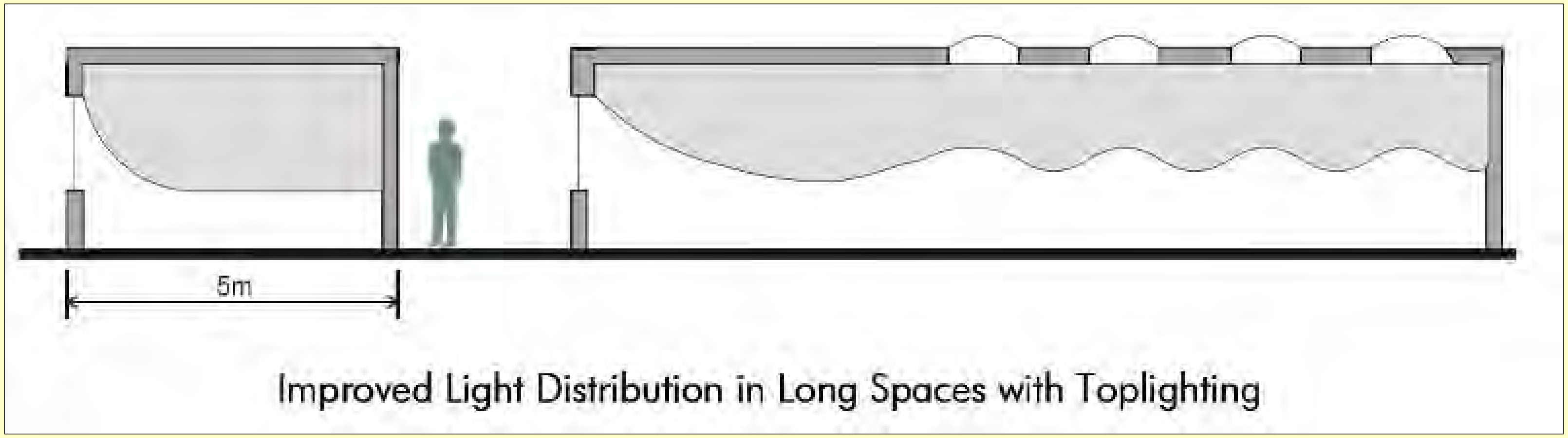
- Best Practices
- Side-lighting
- Reflection

- Source: Columbus-IN-Cummins-Main-HQ-Office-5.JPG

Daylighting

– Best Practices
– Top-lighting



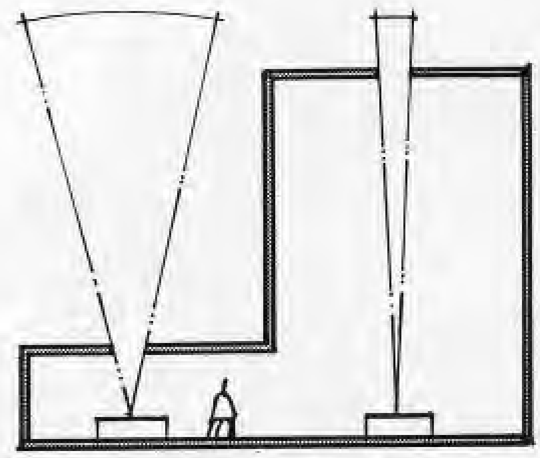


- Source: Canada-Daylighting-Guide-toplighting-1.jpg

Daylighting

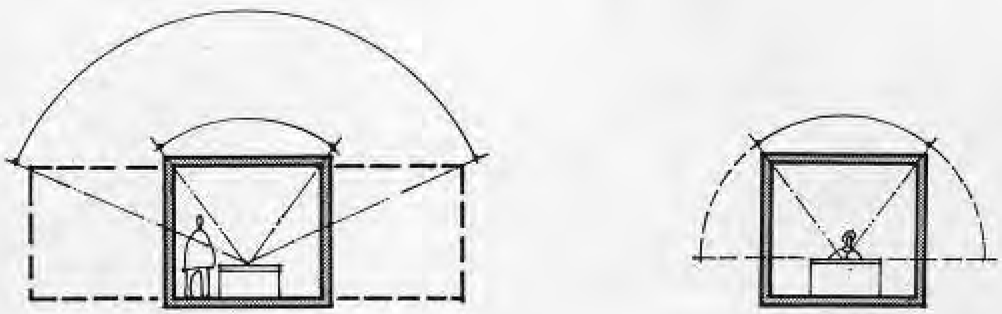
– Best Practices

– Top-lighting



3–2. The characteristics of a light source are relative to its distance from the viewer. At a distance of forty feet, a 4′ × 4′ skylight is a point source; at a few feet, it is an area source.

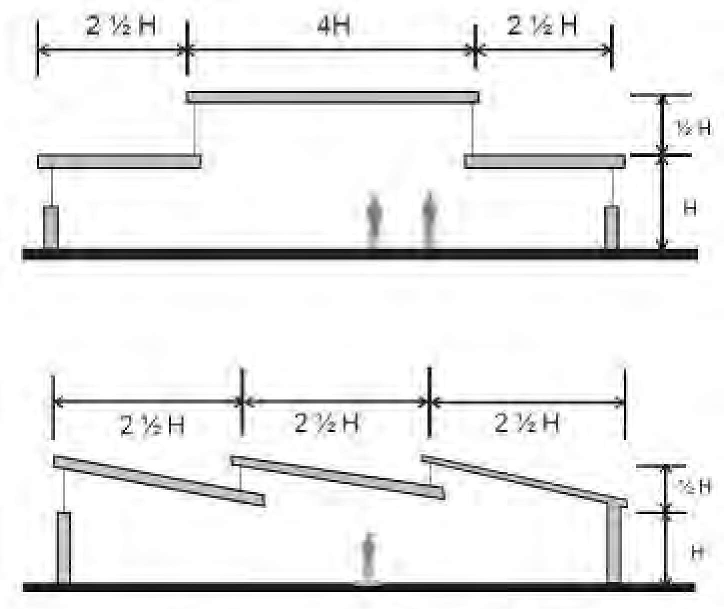
3–6. The ceiling of a small room must have a much higher luminance than that of a large room with wider proportions to produce equal illumination.



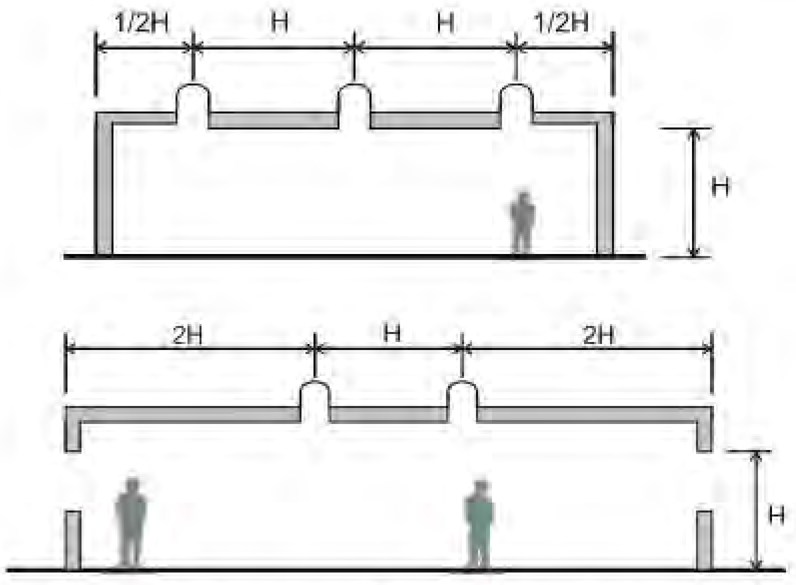
- Source: Sunlighting-Lam-sources-1a.jpg

Daylighting

- Best Practices
- Top-lighting



Clerestory Spacing as a Function of Building Height

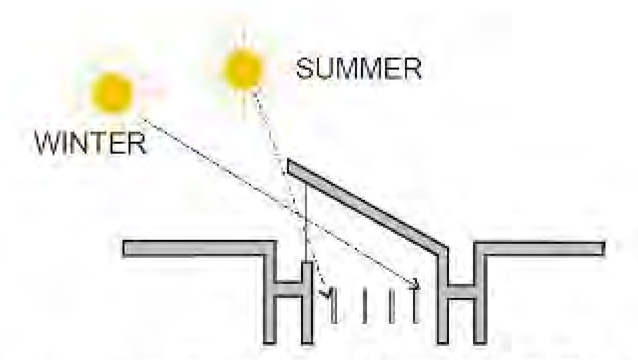


Skylight Placement as a Function of Building Height

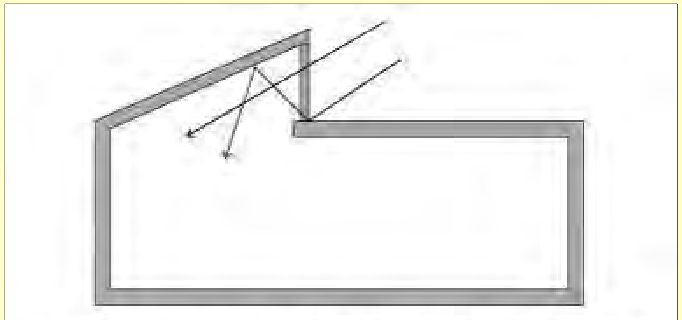
- Source: Canada-Daylighting-Guide-toplighting-3.jpg

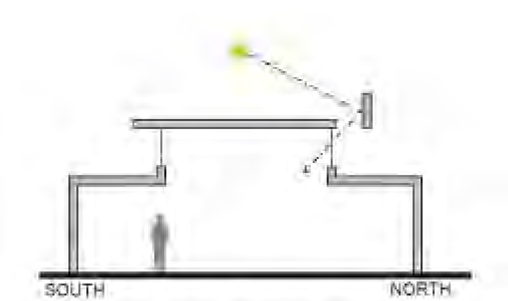
Daylighting

- Best Practices
- Top-lighting

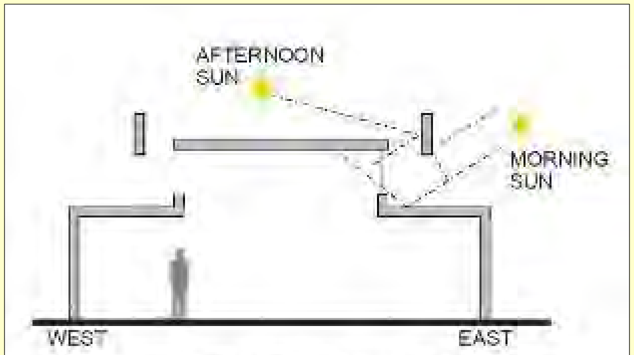


Minimize Clerestories Glare with Baffles and Overhangs


Clerestories Avoid Many of the Problems of Horizontal Skylights



Suncatcher Baffles with North/South Clerestories

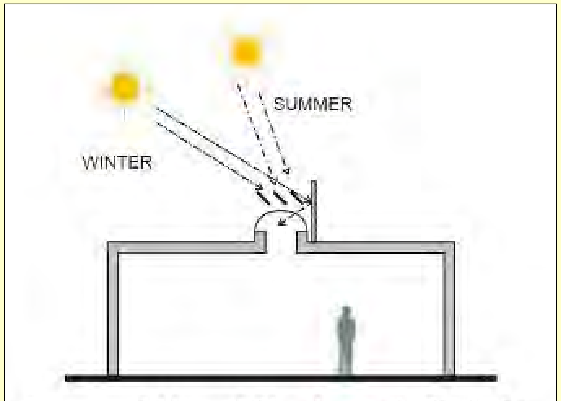


Suncatcher Battles With East/West Clerestories

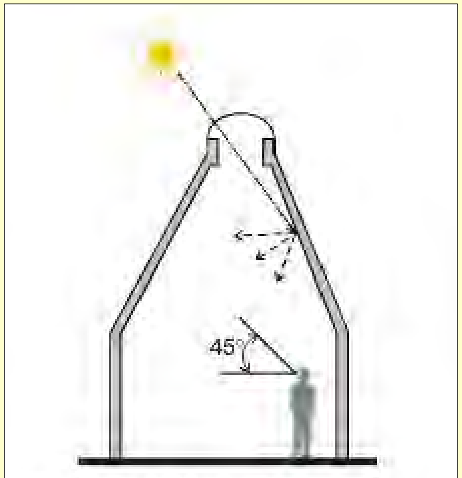
- Source: Canada-Daylighting-Guide-clerestories-2.jpg

Daylighting

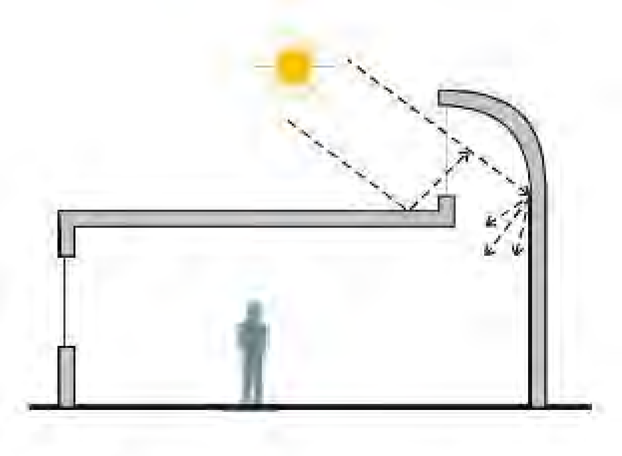
- Best Practices
- Top-lighting



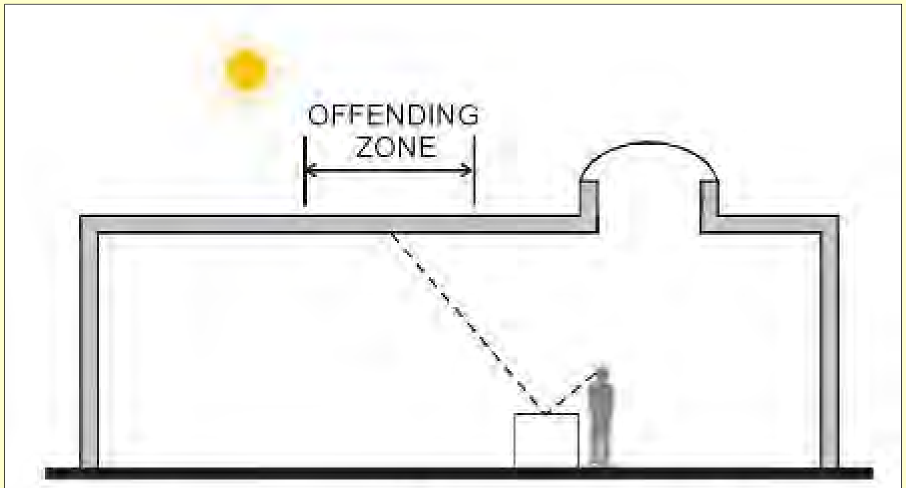
Seasonal Use of Shades with Skylights



Optimal Skylight Location



Diffuse Light with Interior Walls



Careful Location of Tasks to Avoid Direct Sunlight

- Source: Canada-Daylighting-Guide-skylight-diffusion-4.jpg

Daylighting

- Best Practices
- Top-lighting
- Roof Monitors

- Source: Columbus-IN-Richards-Elementary-School-1.JPG

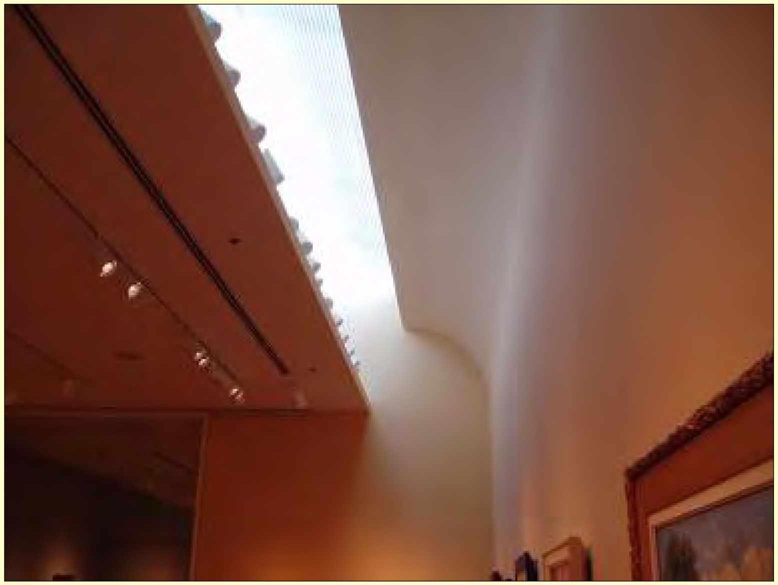
Daylighting

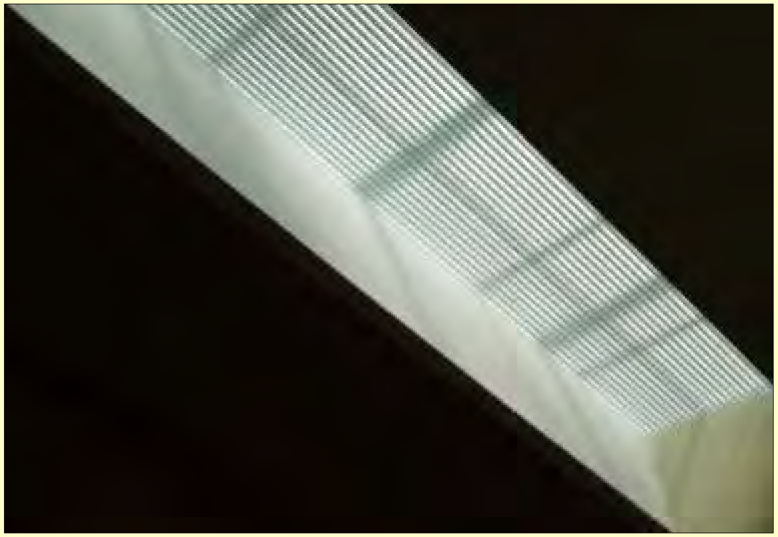
- Best Practices
- Top-lighting
- Roof Monitors

- Source: Sunlighting-Lam-Johnson-Controls-UT-2a.jpg
- Source: Daylighting-Performance-Ander-School-CA-3a.jpg

Daylighting

- Best Practices
- Top-lighting
- Roof Monitors
- Adjustable Blinds



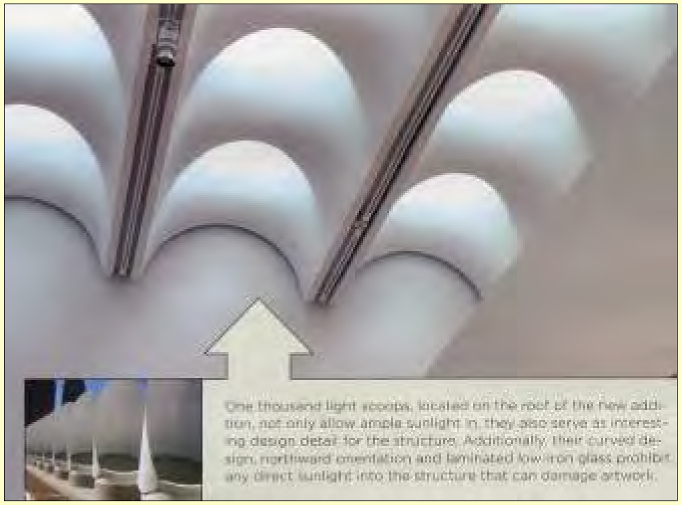


- Source: Indianapolis-Art-Museum-Gallery-1.JPG

Daylighting

- Best Practices
- Top-lighting
- Directional

  Light Scoops



- Source: High-Museum-Atlanta-Renzo-Piano-1.jpg

Daylighting

- Best Practices
- Top-lighting
- Side-lighting
- Clerestories
- Skylights w/diffusers

- Source: UW-Green-Bay-WI-Cofrin-Hall-classroom-1.jpg

Daylighting

- Best Practices
- Core-lighting
- Atrium
- Light Court
- Litrium

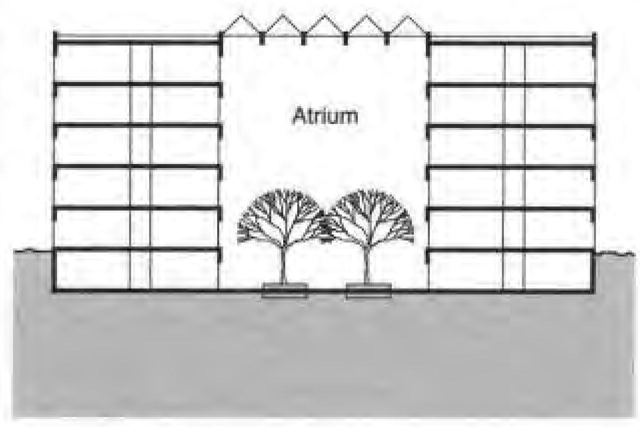


Figure 3-75. Atrium

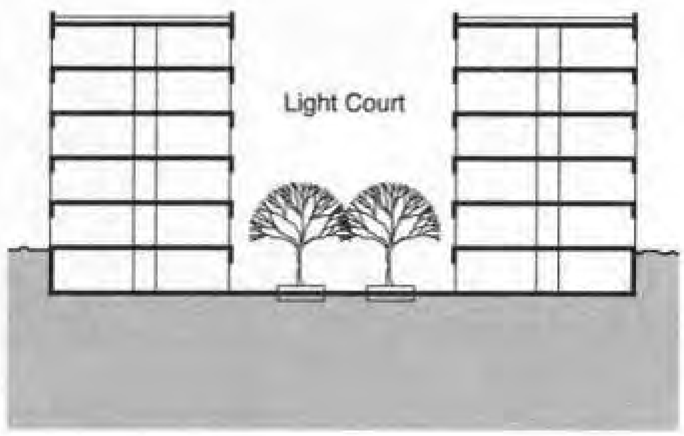


Figure 3-76. Light court

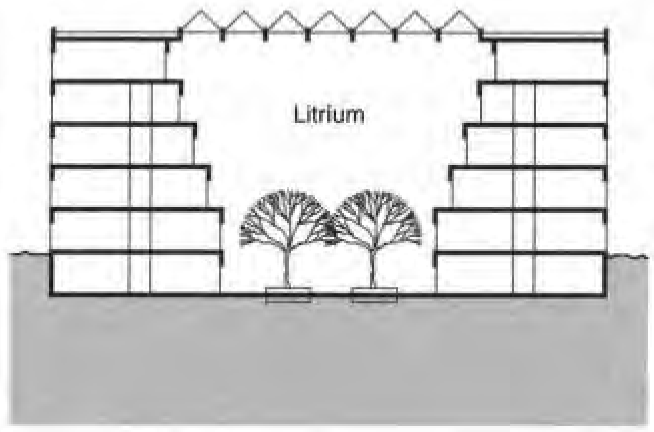
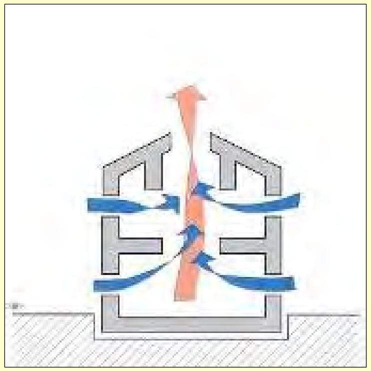


Figure 3-77. Litrium

- Source: Window-System-High-Performance-Bldgs-Carmody-Selkowitz-Corelighting-1a.jpg

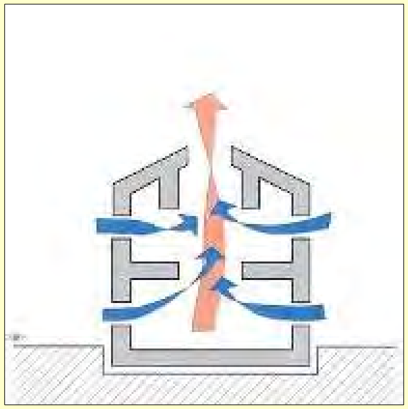
Ventilation and passive cooling

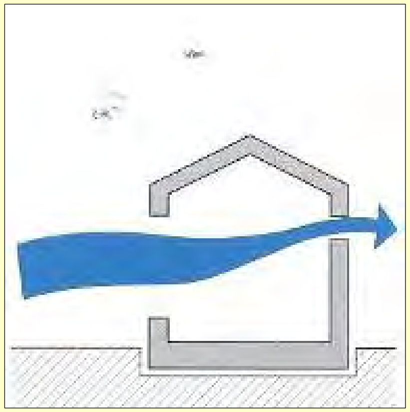


Stack Effect

Passive Ventilation

– Belvedere

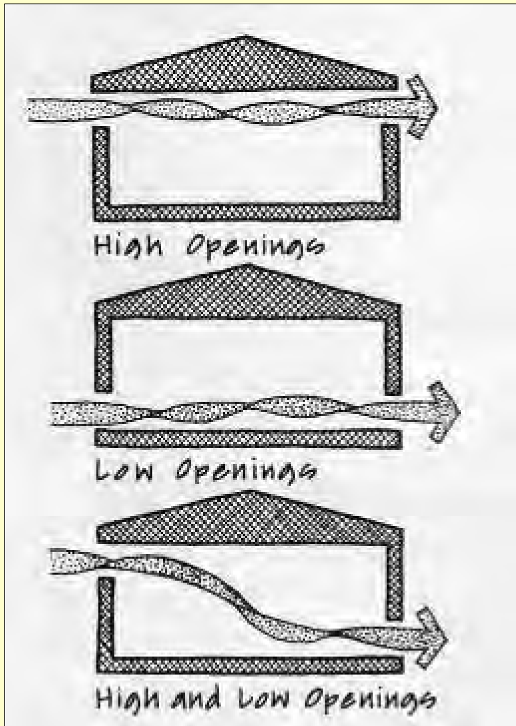




- Source: Hawkweed-Solar-House-belvedere-1.jpg

Passive Ventilation

- Cross-ventilation
- Opening area



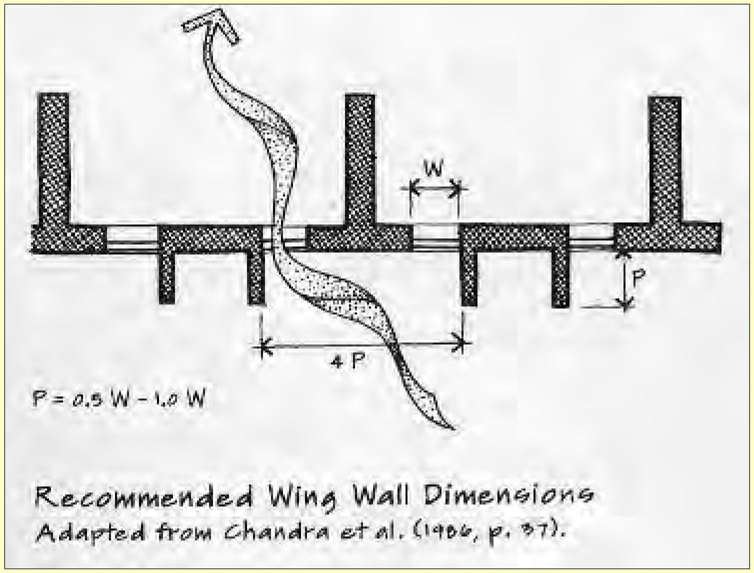
window height as a fraction of wall height	1/3	1/3	1/3
window width as a fraction of wall width	1/3	2/3	3/3
single opening	12-14%	13-17%	16-23%
two openings in the same wall	—	22%	23%
two openings in adjacent walls	37-45%	37-45%	40-51%
two openings in opposite walls	35-42%	37-51%	47-65%

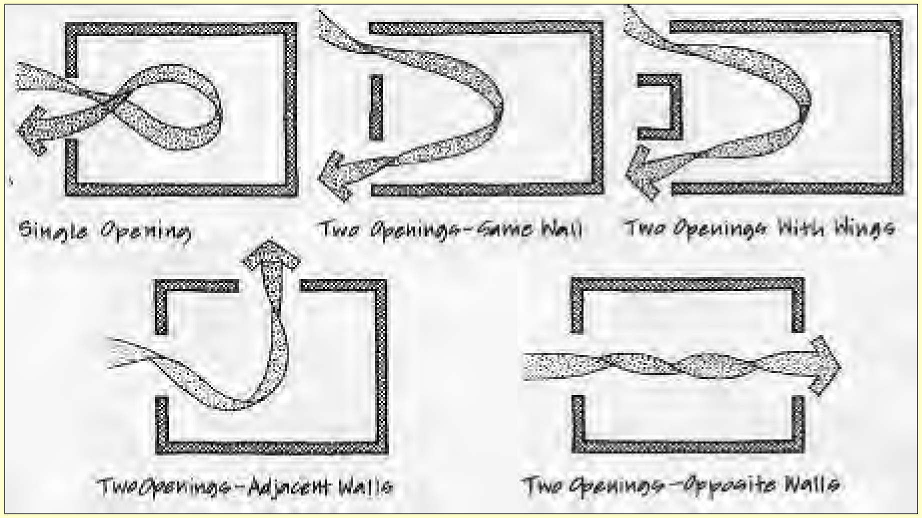
Average Interior Air Velocity as a Percentage of the Exterior Wind Velocity
range = wind 45° to perpendicular to opening

- Source: Sun-Wind-Light-Brown-DeKay-p242a.jpg

Passive Ventilation

- Cross-ventilation
- Configurations
- Wing Wall Deflection

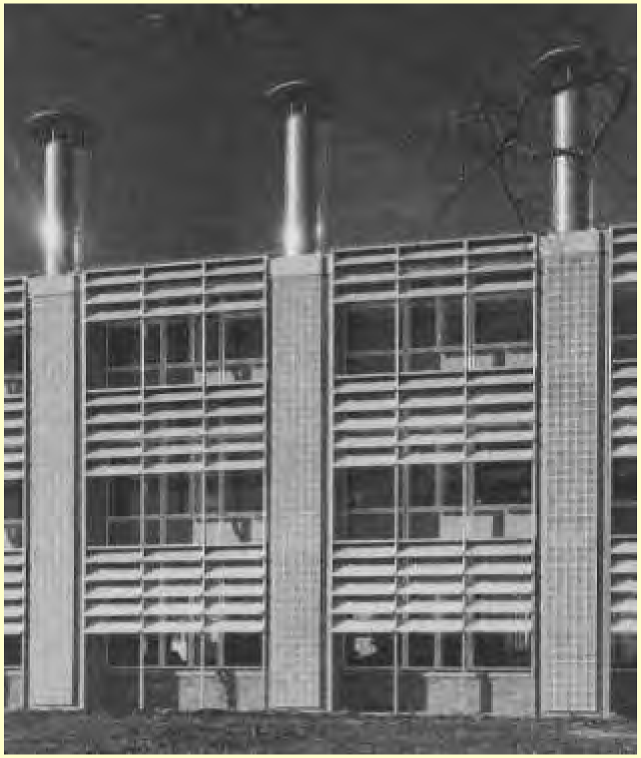


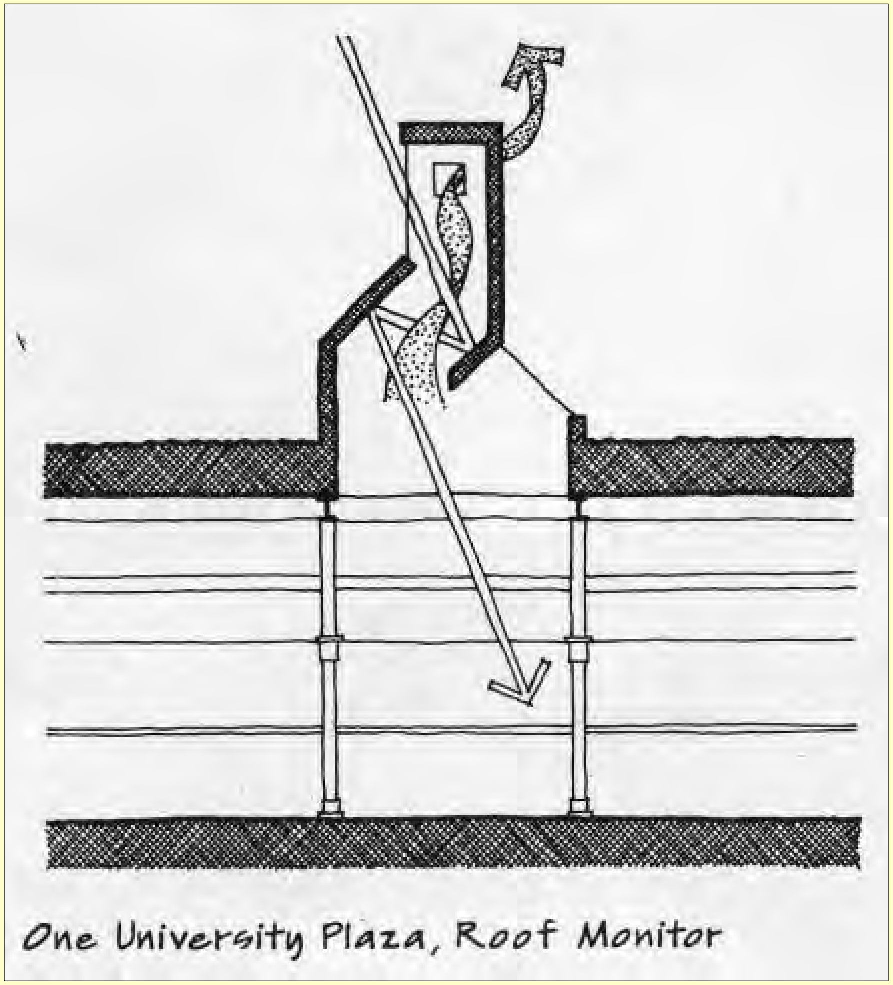


- Source: Sun-Wind-Light-Brown-DeKay-p242b.jpg

Passive Ventilation

– Solar Chimney
    – Stack Effect
    – Exterior Sunshades

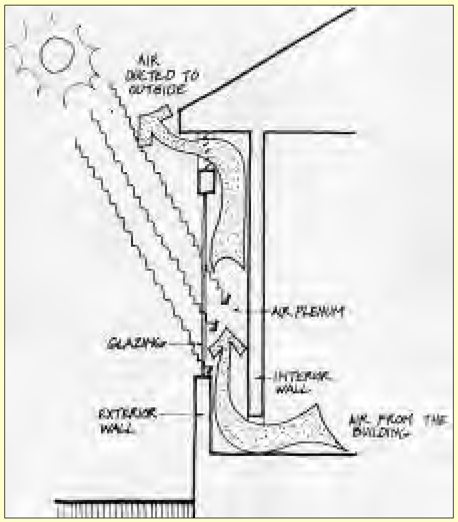


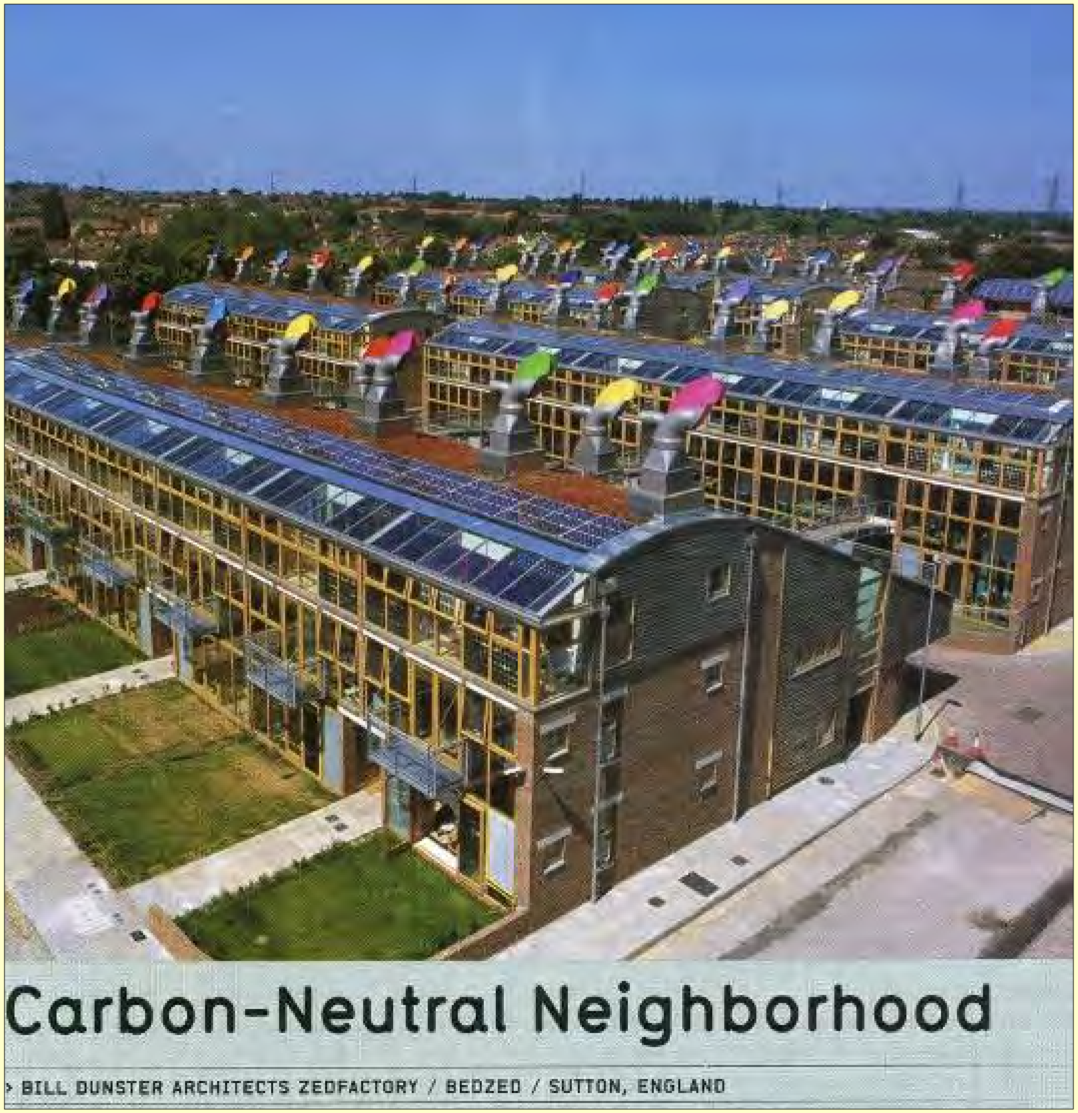


- Source: Window-System-High-Performance-Bldgs-Carmody-Selkowitz-BRE-Env-Bldg-UK-1.jpg

Passive Ventilation

- Example
- BedZED





- Source: Arch-Record-4-03-BedZed-UK-Dunster-Archs-1.jpg

Passive Ventilation

– Guidelines

General

- Natural ventilation can be induced or augmented by passive solar strategies and/or with mechanical-assisted ventilation to create a "mixed-mode" strategy. ASHRAE Standard 55 incorporates hybrid ventilation models.
- Double-skin facades work best with mixed-mode ventilation, utilizing passive solar chimney effect in the daytime to induce cross-ventilation, and nighttime venting to induce passive cooling.
- Single-side high-opening ventilated spaces are effective to a depth of 2x the room height.
- Single-side high and low-opening ventilated spaces are effective to a depth of 2.5 x the room height.
- Double-sided or cross-ventilated spaces are effective to a depth of 5x the room height.

- Source: gaia.lbl.gov/hpbf

Passive Ventilation

– Guidelines

Building Configuration

- Consider a narrow footprint perpendicular to prevailing breezes
- Take advantage of ceiling or building height to create “stack effect”
- Allow heat to rise and stratify, by careful placement of air returns
- Consider inducing stack effect with “solar chimney” elements
- Provide low inlet and high outlet venting
- Consider “double-skin” building shell at exterior walls
- Combine “ventilation” elements with “daylighting” elements
- Avoid high partitions to prevent obstruction of airflow

- Source: gaia.lbl.gov/hpbf

Passive Ventilation

– Guidelines

<u>Window Orientation & Configuration</u>

- Orient operable windows to prevailing winds
- Consider protruding elements, such as fins or wing walls, to catch and re-direct breezes
- Provide lower openings oriented to prevailing breezes and higher openings on the downwind or “lee” side of the building
- Choose window opening or hinging configurations to maximize airflow from different directions
- Consider center-hinged “butterfly” joining of multiple-ganged casement windows, to avoid self-blocking
- Consider high clerestories, in combination with low inlet openings

- Source: gaia.lbl.gov/hpbf

Passive Ventilation

– Guidelines

<u>Mechanically-assisted Ventilation</u>

- Supplement natural stack effect or cross-ventilation
- Whole-house-type fan units in remote locations to minimize noise
- Provide low openings to allow cooler make-up air to enter building

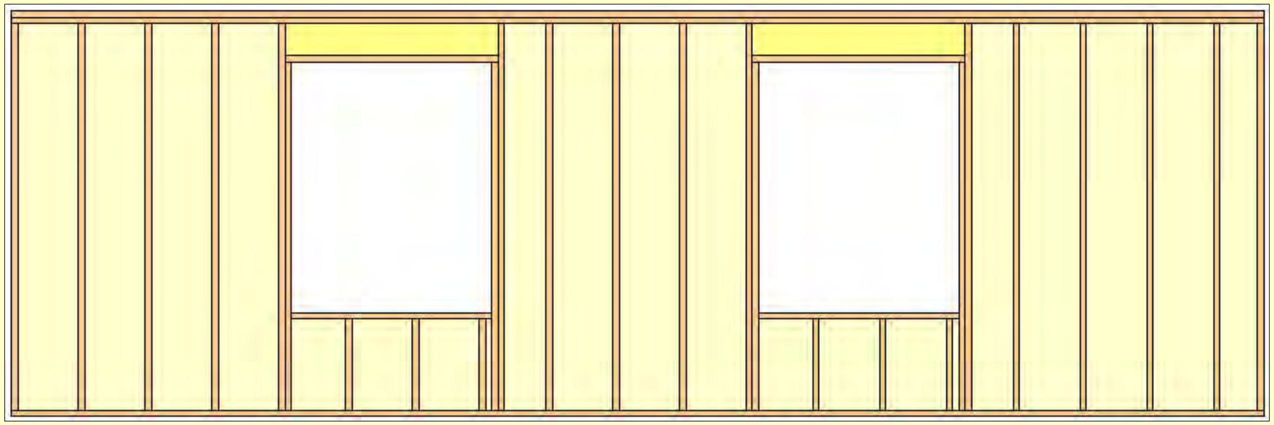
<u>Earth Cooling</u>

- Open-loop inlets
- Closed-loop ground-coupled heat-exchanger
- Provide adequate cross-section area to minimize airflow resistance
- Provide positive drainage and condensate removal to prevent mold growth or other air stream contamination

High Performance Building envelope

- Framing
- Insulation
- Air-tightness
- Bulk Moisture control
- Vapor control
- Construction details

Conventional wood-frame construction



Typical 2x wood framing

Building envelope

- Framing
- Insulation
- Air-tightness
- Bulk Moisture control
- Vapor control
- Construction details

Conventional Wood-Framing Issues:

- Solid Content of Framed Wall

- Box Sill @ Foundation/ First Floor Deck
- Box Sill @ Second Floor Deck

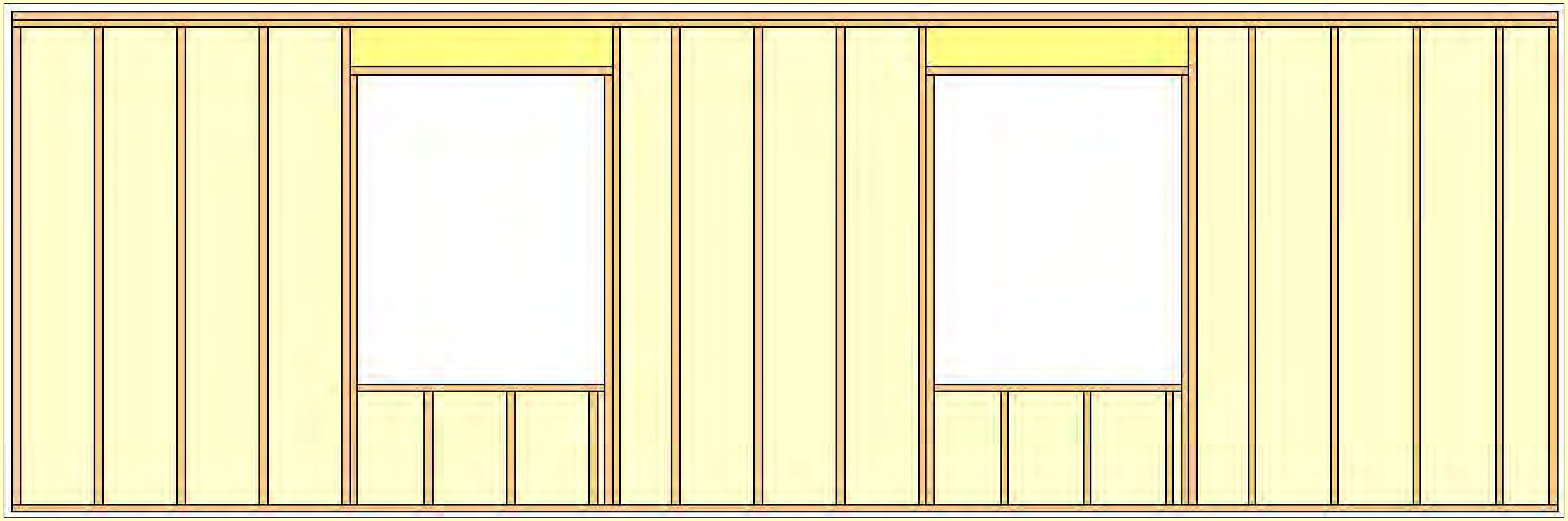
- Interior Partition Wall @ Ceiling/ Roof Framing
- Interior Partition Wall @ Exterior Wall

- Sloped Ceiling/ Roof Cavity

- Window & Door Rough Openings

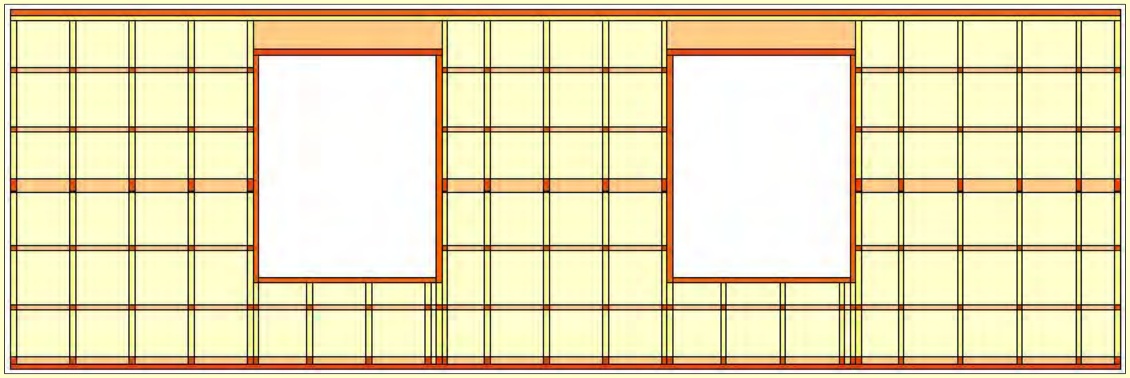
- Electrical Boxes @ Exterior Walls & Ceilings

2x6 Conventional Wall



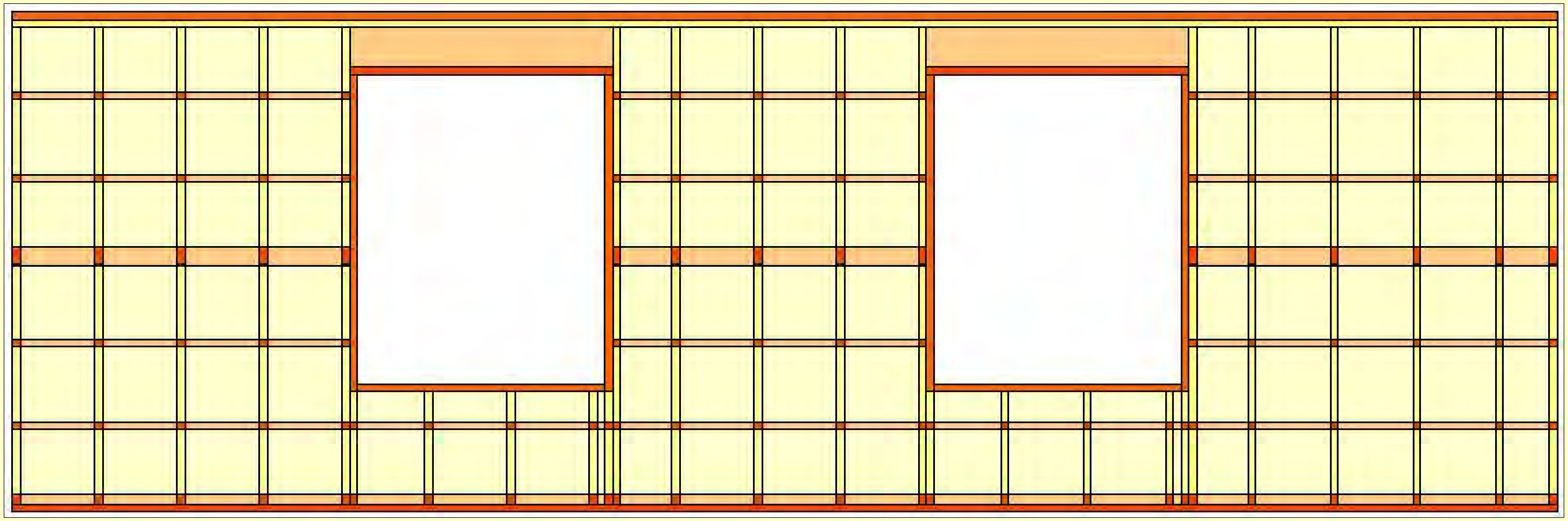
Conventionally-framed 2x6 Wall
(15-25% solid wood, thermally-conductive)

Modified wood-frame construction

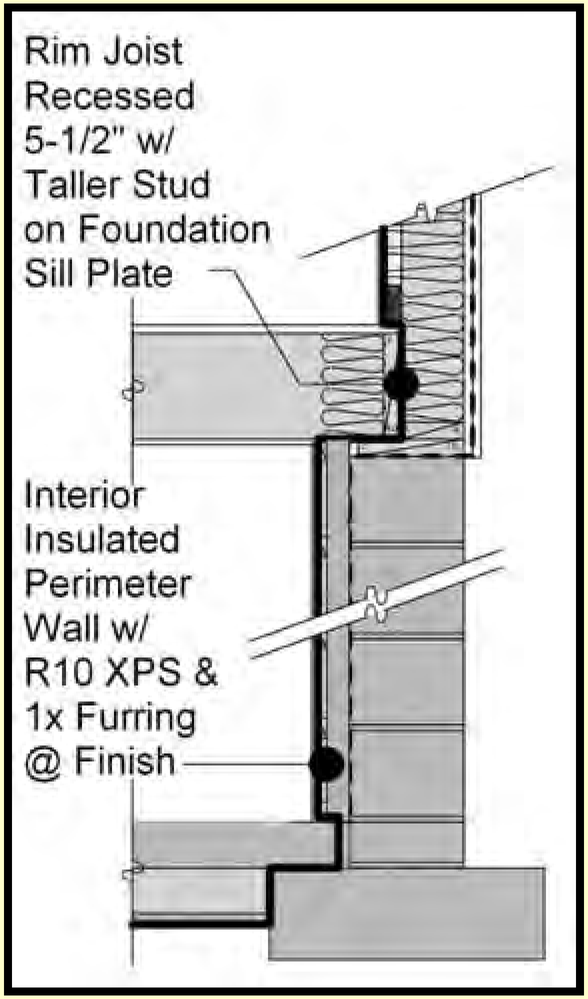


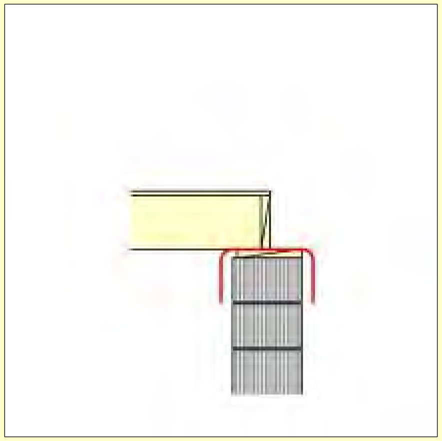
Interior-strapped 2x wood framing

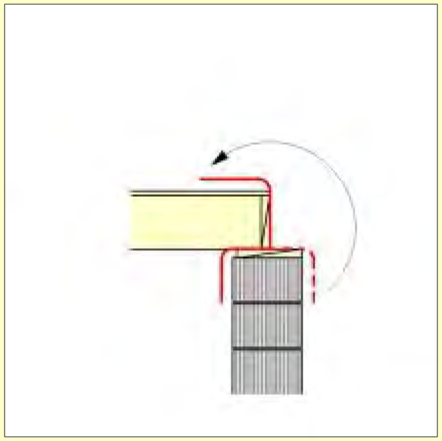
2x6 Interior Strapped-Wall

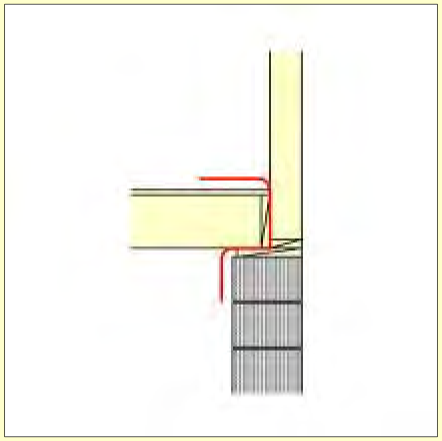


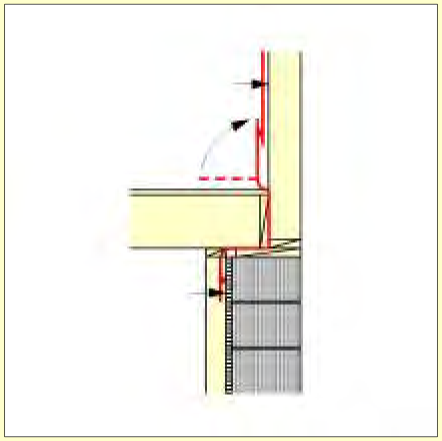
Interior Horizontal Strapped 2x6 Wall
(6-12% solid wood, thermally-broken)



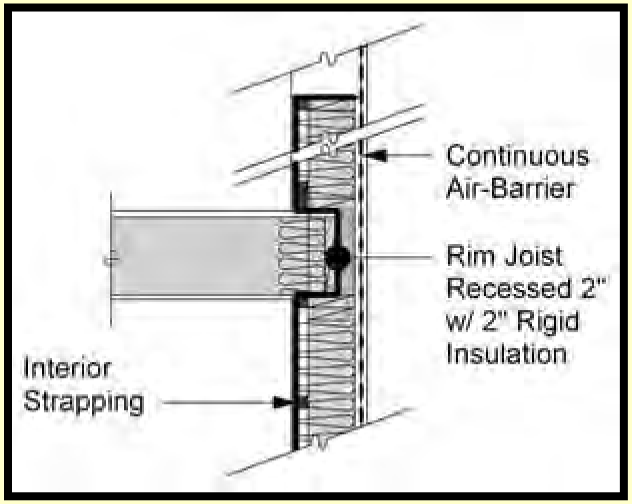




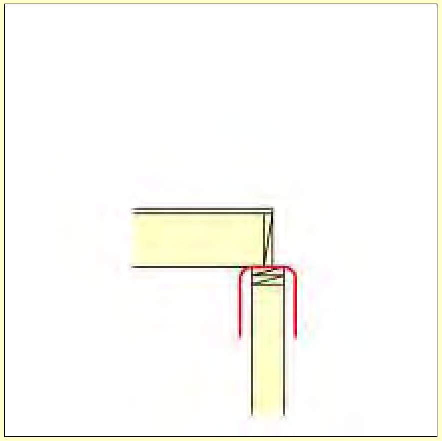


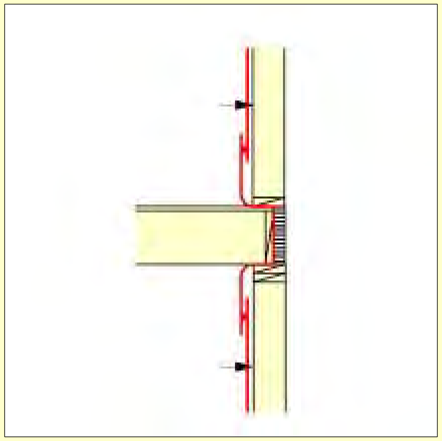


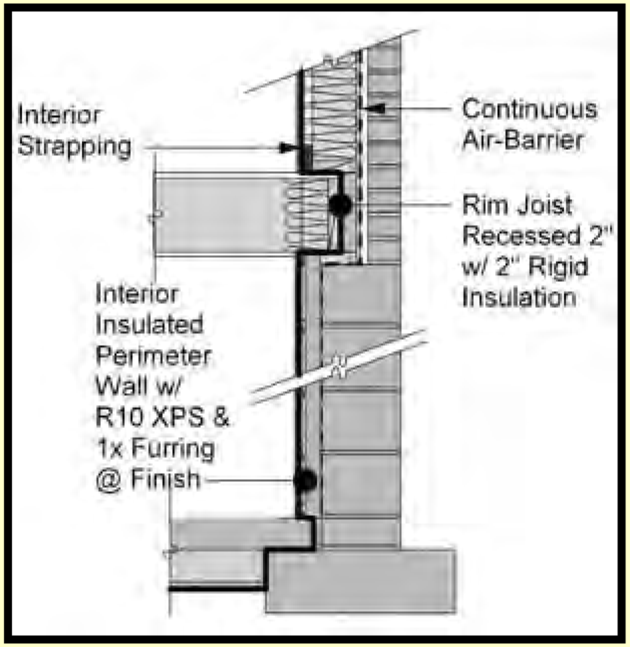
Recessed Floor Deck @ Masonry Foundation Wall w/ 5-1/2" Recessed Rim Joist & Siding



Recessed Floor Deck @ Wood-frame Bearing Wall w/ 2” Recessed Rim Joist & Masonry Veneer

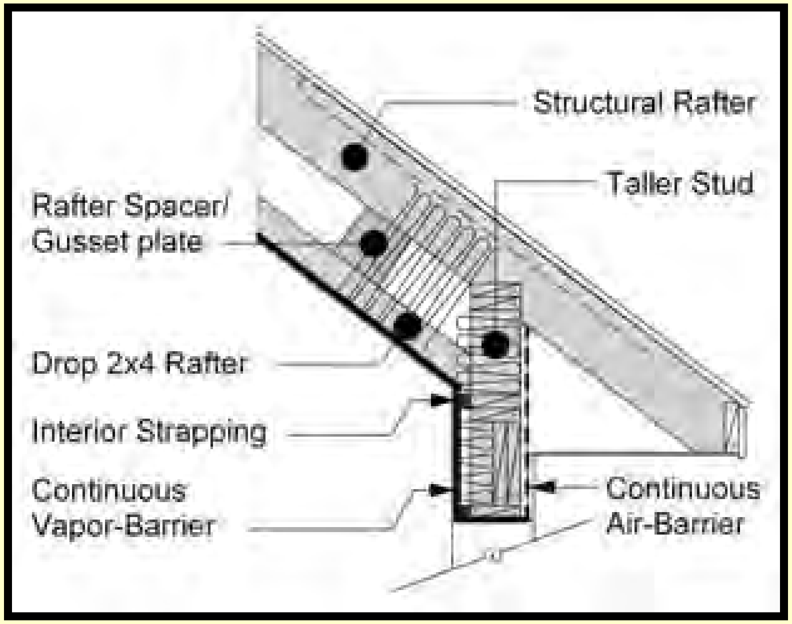


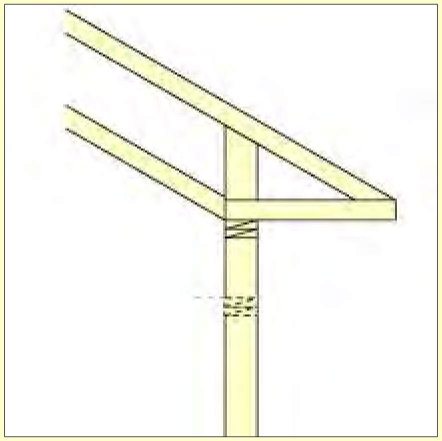


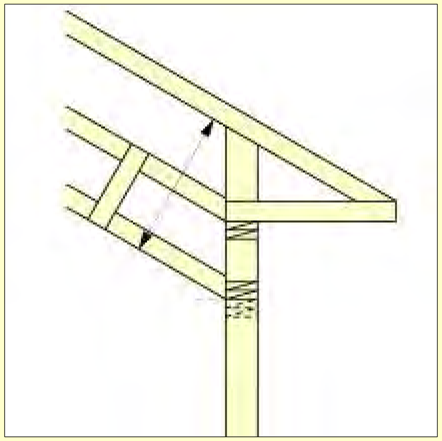


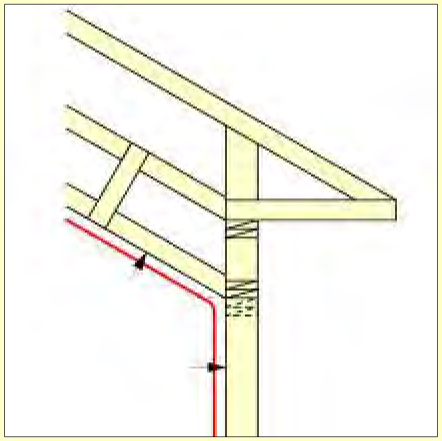
Recessed Floor Deck @ Masonry Foundation Wall w/ 2” Recessed Rim Joist & Masonry Veneer

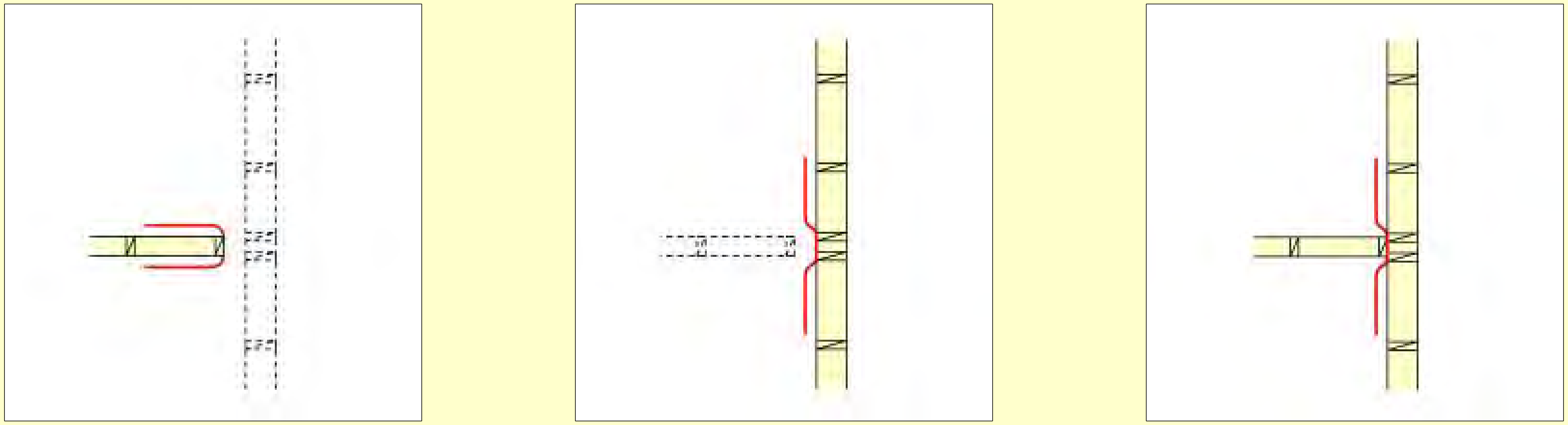
Sloped Ceiling
w/ Stick Framing & Drop Rafter



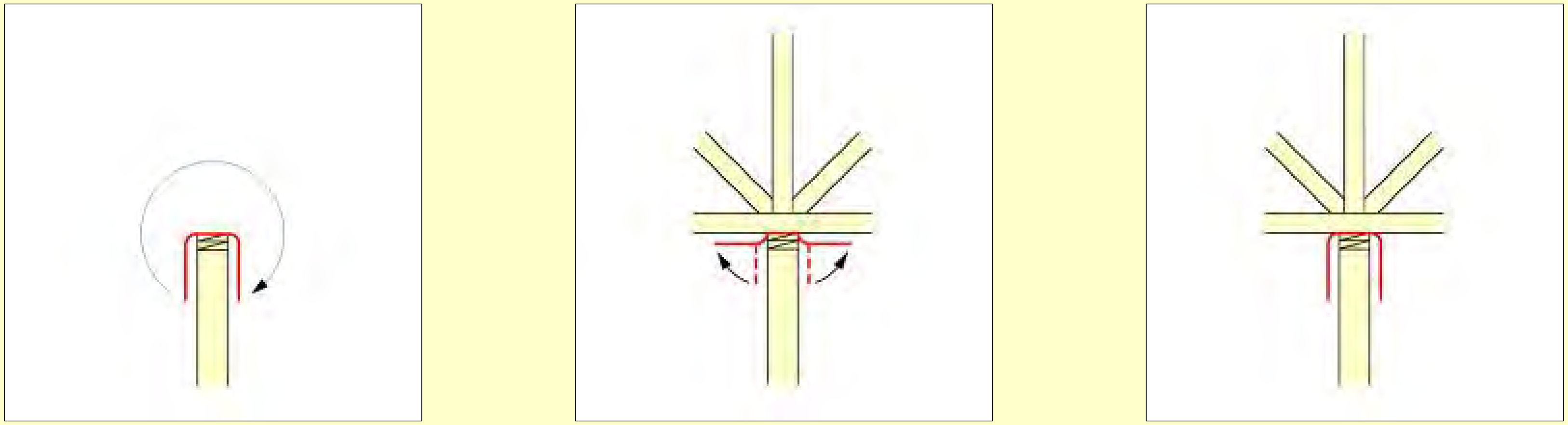




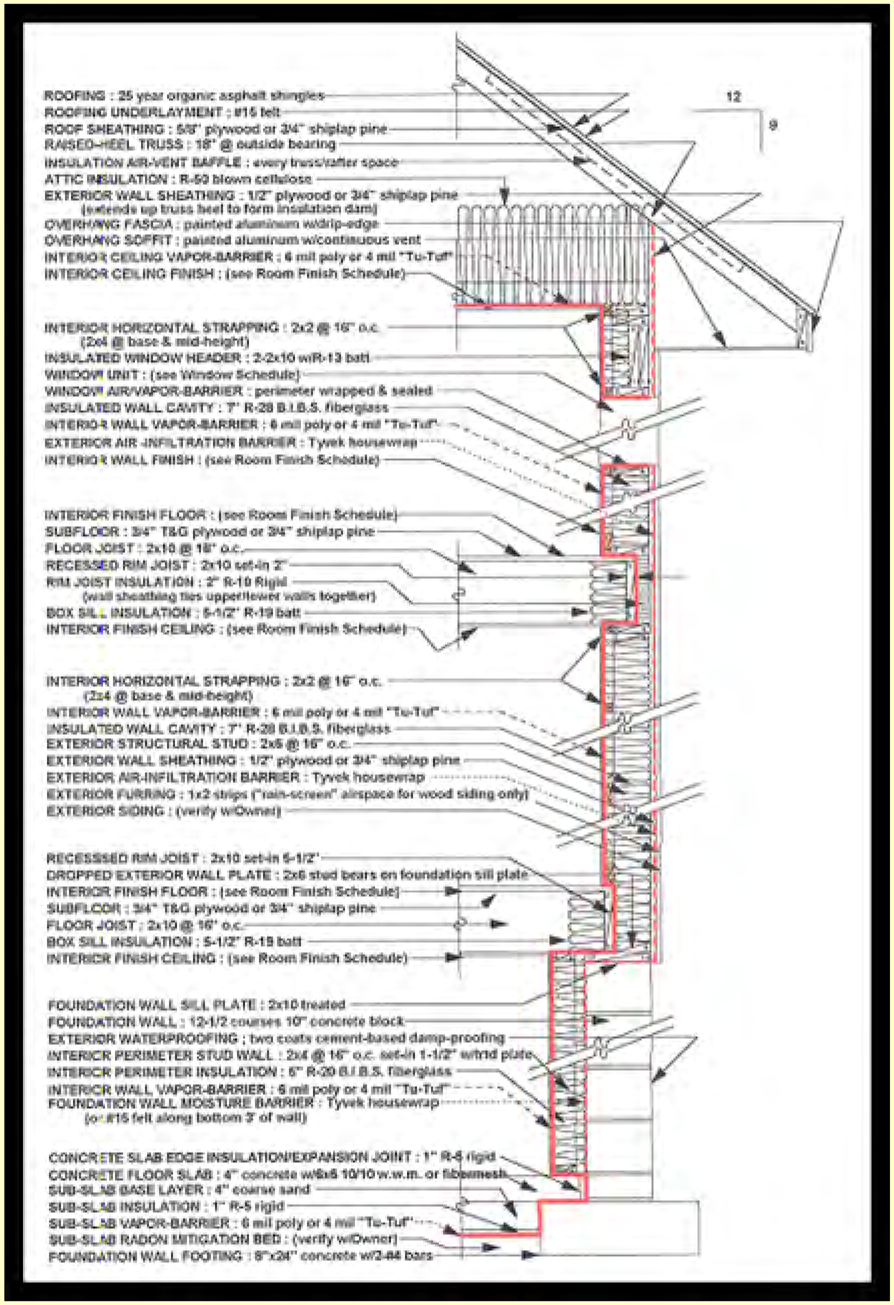




Interior Wall @ Exterior Wall



Interior Wall @ Roof Framing



Typical 2x6 Interior-Strapped Wall/Roof/ Foundation Section Detail

Rainscreen Exterior

- Bulk Moisture control
- Vapor control
- Construction details

Case Studies

- Residential
- Light Commercial

Residential Example

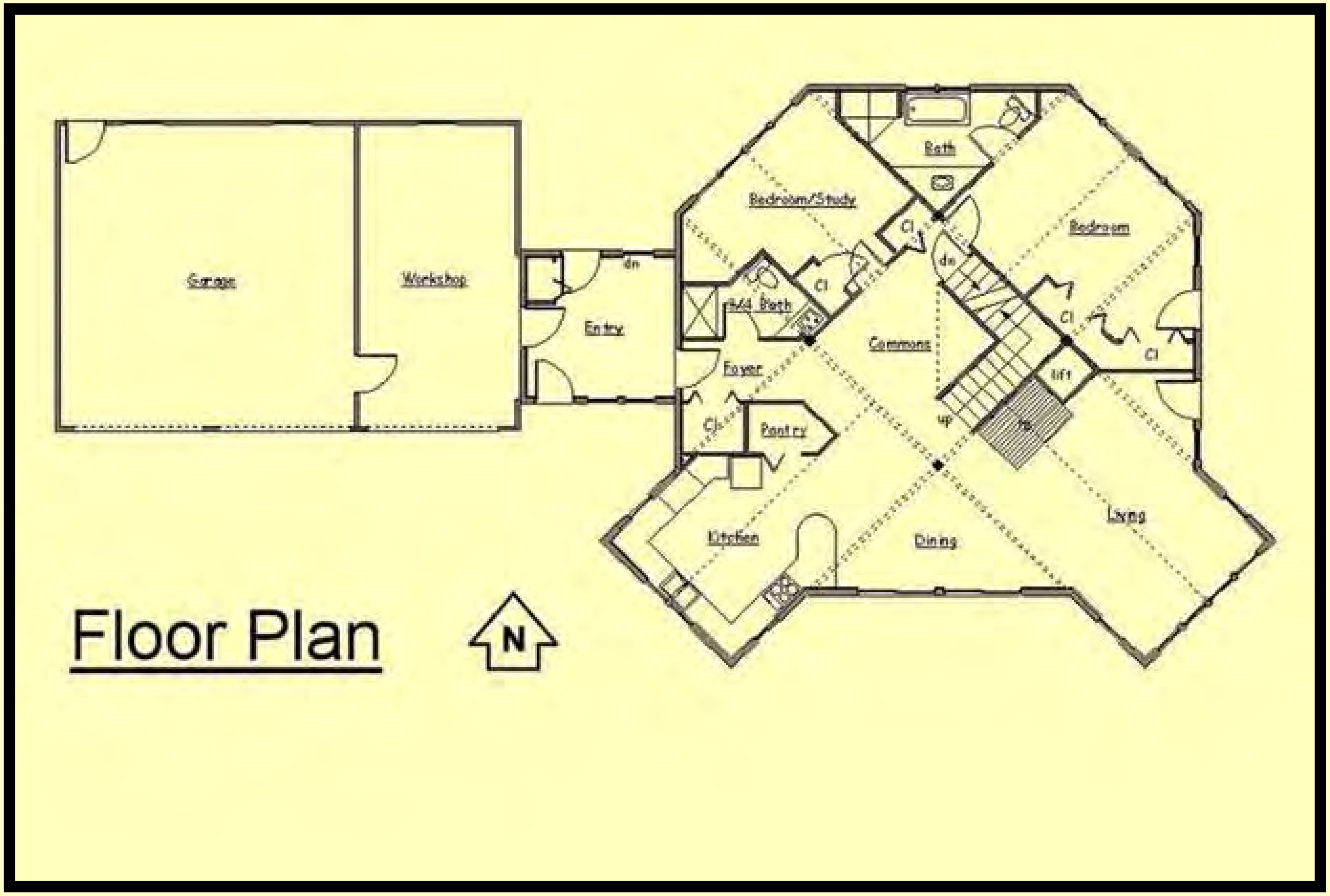
Sullivan Residence

Sullivan Residence

National Association of Home Builders Research Center

EnergyValue 2000 First Place Gold Award Winner

Sullivan Residence



2x6 Interior Strapped-Wall w/ Exterior Rain-screen

Heated Floor Area

- Main Floor Area = 1,596 sq.ft.
- Upper Loft Area = 196 sq.ft.
- Airlock Entry Area = 144 sq.ft.
- **Main Level Floor Area = 1,936 sq.ft.**
- Heated Garage Workshop Area = 296 sq.ft.
- Lower Level Floor Area = 1,596 sq.ft.

Total Heated Floor Area = 3,820 sq.ft.

Main Features:

- Airtight/Superinsulated Envelope
- Interior Strapped-Wall Detailing
- Exterior Rain-Screen Detailing
- Geothermal Hydronic-Radiant Heating
- Heat-Recovery Ventilation
- Passive-Solar Design Elements
- All-Electric Home

Glazing:

- South-Facing Glazing = 372 sq.ft.
  (10.5% of Total Floor Area)
- Other Glazing = 372 sq.ft.
  (10.5% of Total Floor Area)

Thermal Mass:

- Radiant Concrete Slab = 3,500 sq.ft.
  (875 cu.ft. = 65 Tons)
- Thin-coat Plaster over 5/8” Gypsum = 5,000 sq. ft.
  (approximately 10 Tons)
- Heat-Kit Central Masonry Heating Stove
  (backup heating system)

Construction Features:

- Foundation: 10” Concrete Block w/2x4 Interior Perimeter Stud Wall & 5” BIBS Insulation (R-22)
- Lower Level: 4” Hydronic-Radiant Slab w/2” Rigid Sub-Slab Insulation (R-10)
- Upper Walls: 2x6 Structural Studs @ 16” o.c. w/2x2 Interior Horizontal Strapping, 7” BIBS Insulation & 1x3 Exterior Rain-Screen Furring over Tyvek Housewrap (R-31)
- Main Level: 3” Hydronic-Radiant Slab over Wood Deck w/ Recessed Rim-Joist (R-22)
- Ceilings: 2x8 Structural Rafters w/2x4 Drop-Rafters & 18” Blown Cellulose Insulation (R-60)
- Roof: Site-Built Standing-Seam Galvanized Metal

Sullivan Residence

2x6 Interior Strapped-Wall w/ Exterior Rain-screen

Sullivan Residence

Airtight Electrical Box Enclosures

Heat-recovery Ventilation Unit

Recessed Rim Joist @ Main Level

2" Rigid Insulation @ Upper Rim Joist

Perimeter Stud Wall @ Foundation Wall & Walkout

Insulated Perimeter Stud Wall @ Foundation Wall & Walkout

Drop-Rafter & Ventilation Chute

Interior Strapping & Drop rafters

V.B. Box
& Interior
Strapping

V.B. Box
& Taped V.B.

Interior Horizontal Strapping

V.B. Detail
@ Partition/
Exterior
Wall Strapping

Sloped Ceiling/ Drop-Rafter

Loft/ Drop-Rafter/ Window V.B. Detail

Main Floor Hydronic-Radiant Slab Prep

Hydronic-Radiant Tubing Layout @ Living

Ground-Source Heat Pump Unit

Heat-recovery Ventilation Unit

Five 800’ Closed-Loops @ 8’ Depth

View from Southwest

Aerial View From Northwest

View from South/Southeast

View from Southeast/East

View from Entry to Loft Stair

View from Entry
to Loft Stair

View from Kitchen to Dining/ Living

View from Dining to Living

View from Living to Dining/ Kitchen

View from Dining to Kitchen

View from Dining to Kitchen

View of Bedroom

View of Bedroom

Site-built Standing Seam Metal Roofing

Documented Energy Usage

Sullivan Residence - Energy Usage Summary (11-year Average 1998-2008)

Utility Billing Dates	ON Peak $.10300 - .21422/kwh kwh	ON Peak $	OFF Peak $.02200 - .06182/kwh kwh	OFF Peak $	TOTAL (combined) kwh	TOTAL $	MMBTU 3,413 / kwh	HDD	BTU/HDD	BTU / HDD / SQ FT	Steady-State Heatloss BTUH @-20deg	Avg Normal Rate $0.08454 kwh	Avg Normal Rate $
Electric Rates: 12/97-12/98= $.02220 / $.10300 12/98-12/99 = $.02450 / $.11000 12/99-12/01 = $.02701 / $.11251									Main Floor = 1596 sq ft				
12/01-1/02 = $.03050 / $.12400 1/02-6/02 = $.03322 / $.14072 6/02-3/03 = $.03340 / $.14160 3/03-1/04 = $.03453 / $.14847									Loft = 196 sq ft			Normal Rate range	
1/04-1/05 = $.03843 / $.16179 1/05-2/06 = $.04165 / $.17700 2/06-2/07 = $.05150 / $.19000 2/07-2/08 = $.05365 / $.20260									Entry = 144 sq ft			($0.05470 - $0.11437)	
2/08-1/09 = $.05490 / $.20730 1/09-date = $.06182 / $.21422 Energy costs do not include customer meter charge of $7.50 < 12/00 > $8.00 per month - or - non-taxable Public Benefits charge of $1.48-$3.15 per month >10/00 - or - summer-season only sales ta									**Main Level = 1936 sq ft**				
mid-JAN - mid-FEB	182	25.97	2,515	91.66	2,697	117.63	9.21	1,333	Workshop = 296 sq ft			2,697	228.00
mid-FEB - mid-MAR	163	23.24	2,130	77.67	2,293	100.91	7.83	1,120	Lower Level = 1596 sq ft			2,293	193.85
mid-MAR - mid-APR	134	19.42	1,667	60.36	1,801	79.78	6.15	725	**Heated Area = 3820 sq ft**			1,801	152.28
(one year) mid-APR - mid-MAY	125	18.11	1,044	37.27	1,168	55.37	3.99	342	(transition month)			1,168	98.74
mid-MAY - mid-JUN	158	22.30	894	33.52	1,052	55.82	3.59	139				1,052	88.91
mid-JUN - mid-JUL	165	23.29	869	31.12	1,033	54.41	3.53	52	**4 month summer usage period**			1,033	87.36
mid-JUL - mid-AUG	164	23.29	777	27.61	941	50.90	3.21	11	**mid-May - mid-September**			941	79.55
mid-AUG - mid-SEP	163	23.07	875	31.48	1,039	54.55	3.54	79				1,039	87.80
summer subtotal	649	91.95	3,416	123.73	4,065	**215.68**	13.87	281	**summer subtotal**			4,065	**343.62**
% annual	**16.0%**	**42.6%**	**84.0%**	**57.4%**									159.3%
mid-SEP - mid-OCT	155	21.99	912	33.10	1,067	55.09	3.64	385	(transition month)			1,067	90.17
mid-OCT - mid-NOV	171	24.57	1,619	59.58	1,789	84.14	6.11	710				1,789	151.26
mid-NOV - mid-DEC	185	26.52	2,447	89.80	2,632	116.32	8.98	1,173				2,632	222.46
mid-DEC - mid-JAN	173	25.93	2,944	106.56	3,117	132.48	10.64	1,458	**6 month winter usage period**			3,117	263.51
mid-JAN - mid-FEB	172	26.07	2,573	101.56	2,745	127.63	9.37	1,375	**mid-October - mid-April**			2,745	232.01
mid-FEB - mid-MAR	153	23.24	2,161	85.73	2,314	108.97	7.90	1,149				2,314	195.63
mid-MAR - mid-APR	130	20.00	1,748	67.73	1,878	87.73	6.41	756				1,878	158.77
winter subtotal;	984	146.31	13,491	510.95	14,475	**657.26**	49.40	6,620	**winter subtotal**			14,475	**1223.64**
% annual	**6.8%**	**22.3%**	**93.2%**	**77.7%**									186.2%
mid-APR - mid-MAY	120	18.52	1,021	39.89	1,141	58.41	3.89	361	(transition month)			1,141	96.46
mid-MAY - mid-JUN	134	20.87	925	36.78	1,059	57.65	3.61	138				1,059	89.51
mid-JUN - mid-JUL	149	22.63	853	32.74	1,002	55.37	3.42	53	4 month summer usage period			1,002	84.67
mid-JUL - mid-AUG	150	22.92	768	29.57	917	52.49	3.13	11	mid-May - mid-September			917	77.54
mid-AUG - mid-SEP	146	22.33	847	33.02	992	55.36	3.39	87				992	83.87
summer subtotal	578	88.75	3,392	132.11	3,970	220.86	13.55	289	summer subtotal			3,970	335.60
% annual	14.6%	40.2%	85.4%	59.8%									
mid-SEP - mid-OCT	140	21.64	938	36.71	1,078	58.35	3.68	386	(transition month)			1,078	91.15
mid-OCT - mid-NOV	156	23.92	1,609	63.47	1,765	87.38	6.02	715				1,765	149.20
mid-NOV - mid-DEC	176	26.87	2,534	99.81	2,710	126.68	9.25	1,238				2,710	229.12
mid-DEC - mid-JAN	164	26.24	2,931	117.71	3,095	143.94	10.56	1,450				3,095	261.62
Annual Total									(based on **1936 sq ft** heated area)				
mid-April - mid-April	1,913	**$278.36**	18,862	**$705.04**	20,774	**$983.40**	70.90	7,628	9,295	4.80	34,857	20,774	**$1,756.16**
% annual	**9.2%**	**28.3%**	**90.8%**	**71.7%**					(includes ALL energy usage)				178.6%
Winter Total (6 months)	mid-October - mid-April				14,475	657.26	49.40	6,620	7,462	3.85	27,983	(total energy usage)	
Summer Total (4 months)	mid-May - mid-September				4,065	215.68	13.87	281					
Winter Total (heating only)	mid-October - mid-April				8,378	**333.75**	28.59	**6,199**	4,612	**2.38**	**17,297**	(summer avg deducted)	
Winter Average (monthly)	mid-October - mid-April				2,413	109.54	8.23	1,103	7,462	3.85	27,983	(total energy usage)	
Summer Average (monthly)	mid-May - mid-September				1,016	53.92	3.47	70					
Winter Avg (heating only)	mid-October - mid-April				1,396	**55.63**	4.77	**1,033**	4,612	**2.38**	**17,297**	(summer avg deducted)	
BTU/hr = (BTU/yr / HDD/yr) x (Design Temperature Difference / 24)							BTU/yr = (BTU/hr x 24hrs x HDD/yr) / Design Temperature Difference						

Sullivan Residence

Cumulative Energy Usage Summary

(1998 – 2008 11-year Average)

Annual Total Energy Usage = 20,774 kWH = $983.40

(mid-April - mid-April)   (1998 = 19,026/ $649.26   2008 = 21,050/ $1,352.56)

Summer Average Energy Usage = 1,016 kWH = $53.92

(mid-May - mid-September)   (1998 = 1,013/ $44.60   2008 = 1,091/ $77.61)

Winter Total Energy Usage = 14,475 kWH = $657.26

(mid-October - mid-April)   (1998 = 12,757/ $391.21   14,894/ $914.86)

Winter Heating Energy Usage = 8,378 kWH = $335.75

(Winter Total - Summer Average)   (1998 = 6,679/ $123.60   2008 = 8,347/ $449.20)

Sullivan Residence

Time-of-Day Energy Usage Summary

(1998 – 2008 11-year Average)

Total Annual Energy Usage: $983.40

(20,774 kWH)

Annual On-Peak Energy Usage: $278.36

(1,913 kWH = 9.2% usage @ $.10300-.20730/kWH = 28.3% cost)

Annual Off-Peak Energy Usage: $715.17

(18,862 kWH = 90.8% usage @ $.02220-.05490/kWH = 71.7% cost)

Estimated Normal-Rate Energy Usage: $1,756.16

(20,774 kWH @ $.05470-.11437/kWH)

Time-of-Use/Off-Peak Electricity Usage Savings: $772.76 (44.0%)

Sullivan Residence

Cumulative Energy Usage Summary

(@ 3,820 sq ft Total heated space)

Cumulative Energy Usage Summary Report

Description	Electric kWH	Electric BTU	Natural Gas Therms	Natural Gas BTU	Other Qty	Other BTU	Total BTU	Total MMBTU	Area Sq Ft	Area Sq M	HDD F	HDD C
Sullivan (Heated) (3,820 sq ft)	20,774	70,901,662	0	0	0	0	70,901,662	70.90	3820	354.88	7,628	4,238
Energy Use Index (EUI) =			18.56	kBTU/ Sq Ft/ Year		58.54	kWH/ M^2/ Year		1 =	0.0929	10,000	5,556
											9,500	5,278
Energy Intensity Index (EII) =			2.43	BTU/ Sq Ft/ HDD-F		0.014	kWH/ M^2/ HDD-C				9,000	5,000
											8,500	4,722
Steady State Heat Loss =			34,856	BTU/ Hr @ -20 F		74,786	mJ/ Hr @ - 28.9 C		1 kWh = 3.6 mJ		8,000	4,444
											7,500	4,167
EPA Target Finder Score =											7,000	3,889
EPA Portfolio Manager Score =									°F HDD to °C HDD = (5/9) x (°F HDD)			

2.4 BTU/sq. ft./HDD-F @ 3,820 sq. ft. = (.014 kWH/m2/HDD-C)
18.56 kBTU/sq. ft./yr = Energy Use Index (EUI) = (58.5 kWH/m2/yr)
34,856 BTU/hr @ -20 F Steady-state Heatloss Equivalent

Light Commercial Examples

Mead Wildlife Area
Education & Visitor Center

MREA Renew the Earth Institute
North training Building

Mead Wildlife Area
Education & Visitor Center

2x6 Interior Strapped-Wall w/ Exterior Rain-screen

Mead Wildlife Area
Education & Visitor Center

ENERGY STAR

Mead Wildlife Area Education & Visitor Center
S2148 Co Hwy S
Milladore, WI 54481

has earned the

ENERGY STAR

for

2009

The U.S. Environmental Protection Agency recognizes Mead Wildlife Area Education & Visitor Center for demonstrating superior energy performance.

Jean M. Lupinacci
Director, Commercial & Industrial Branch
ENERGY STAR

2006 Wisconsin
Governor’s Award
Excellence in Sustainable Design and Construction

2006 Wisconsin
Sustainability & Energy Efficiency (SE2)
Award of Excellence – Sustainable Design & Construction

SE2 is a joint award by the Wisconsin Green Building Alliance (WGBA), American Institute of Architects (AIA) – Wisconsin, American Society of Heating, Refrigeration & Air Conditioning Engineers (ASHRAE), Illuminating Engineering Society (IES) – Wisconsin, International Facilities Management Association (IFMA) – Wisconsin, Energy Center of Wisconsin (ECW) and Wisconsin Focus on Energy Program

2006 National Association of Conservation Engineers
Award of Honor

Green Features

Mead Wildlife Area
Education & Visitor Center
Milladore, Wisconsin

High Performance Building Envelope	R-30/R-60
Cool Daylighting & Advanced Lighting Controls	
Passive Solar Orientation & Layout	
Ground-source Geothermal Heating & Cooling	
10,000 watt Grid-intertied Wind Energy System	
2,300 watt Solar Photovoltaic Energy System	
3-panel Solar Domestic Hot Water System	
Wood Biomass Central Masonry Heater	
Environmentally-friendly Materials & Finishes	

Thomas Brown, Architect
tbjs@coredcs.com
Stevens Point, WI
www.tombrownarchitect.com

Sustainability Facts

Mead Wildlife Area
Education & Visitor Center
Milladore, Wisconsin

Projected Energy Use	- 86%
On-site Renewable Energy Generation	25%
Renewable Energy from Utility	100%
Projected Water Use	- 30%
Construction Waste Recycled	96%
Building Materials Recycled Content	11%
Building Materials Locally Produced	88%
Natural Daylighting & Access to Views	100%
Non-irrigated Native Vegetation	100%

Thomas Brown, Architect
tbjs@coredcs.com
Stevens Point, WI
www.tombrownarchitect.com

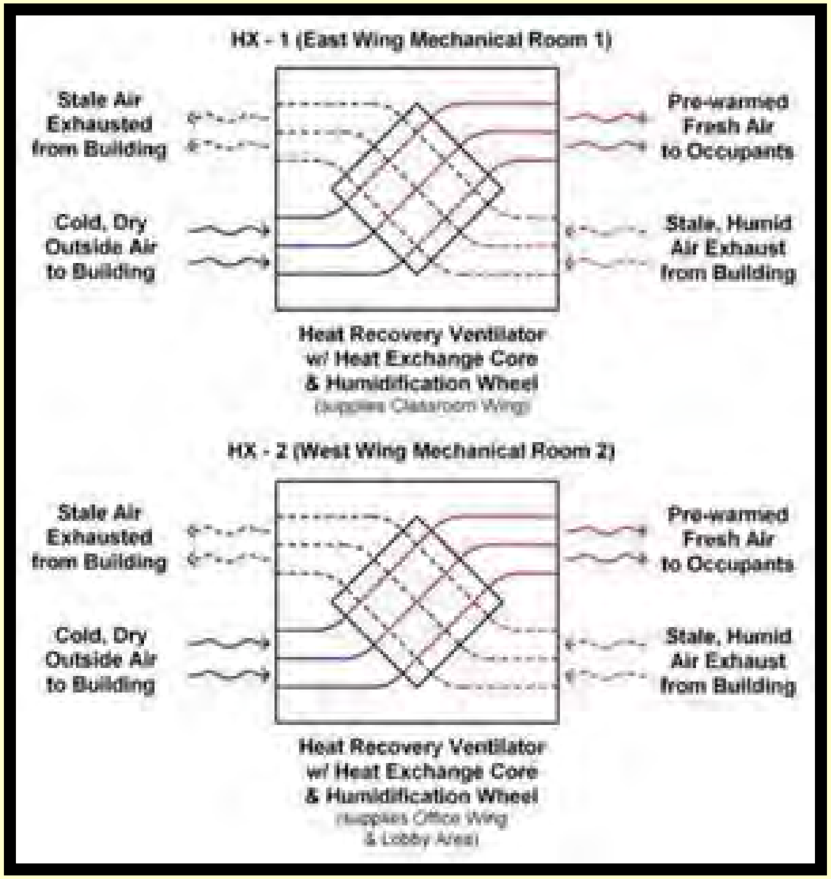

Staff Office Wing
2,232 sq ft
Reception/Lobby/Display Wing
1,670 sq ft
Education Wing
2,306 sq ft
N
Floor Plan

Mead Education & Visitor Center

Interior Strapped Wall
w/ Raised-heel Roof Truss

Airtight Electrical Box Enclosure

Electrical Box/ Airtight Enclosure/ Interior Strapping/ Spray-cellulose Insulation

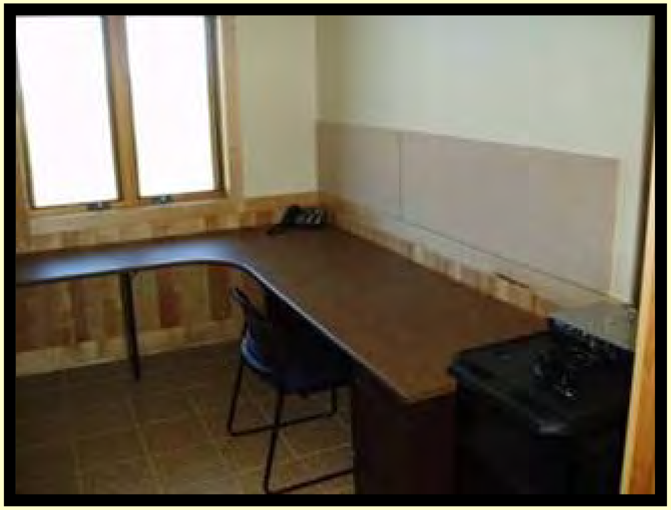


Commercially-sized
Heat Recovery Ventilation (HRV) Unit

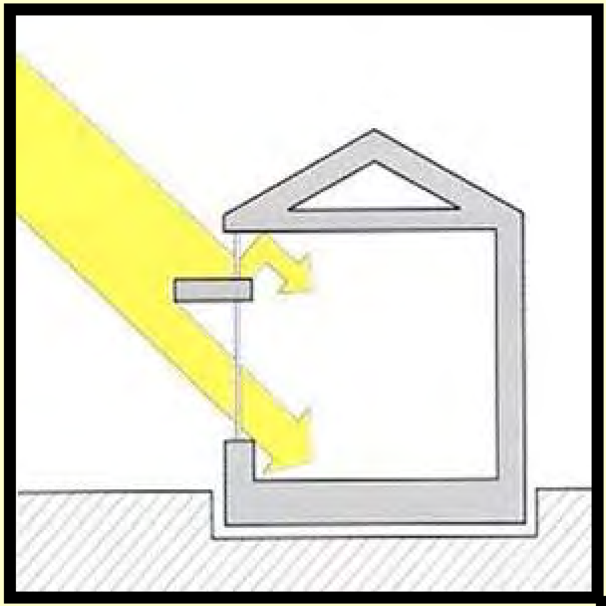
Depressed Floor Slab with Raised "walk-off" Paver Tiles

Locally-produced Recycled-Glass Floor Tiles

Recycled-content Ceiling & Floor Tiles Recycled Office Furniture

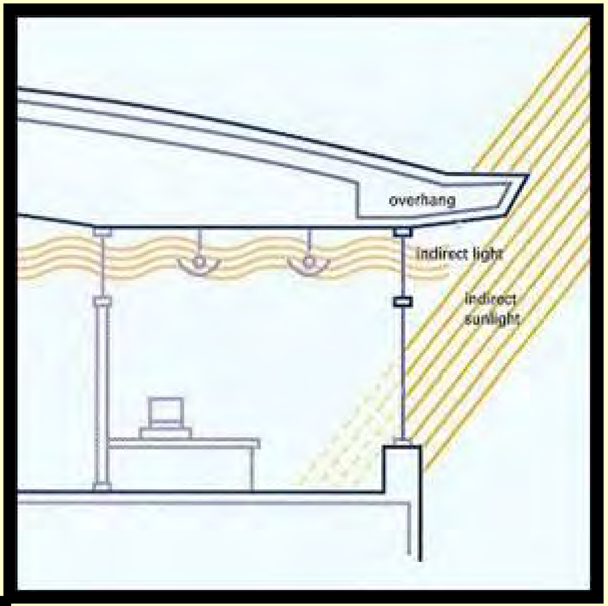


Sunflower Seed Agri-panel Desktops



Passive Solar Design

Compact Fluorescent Lighting Fixtures



Cool Daylighting & Advanced Lighting Controls

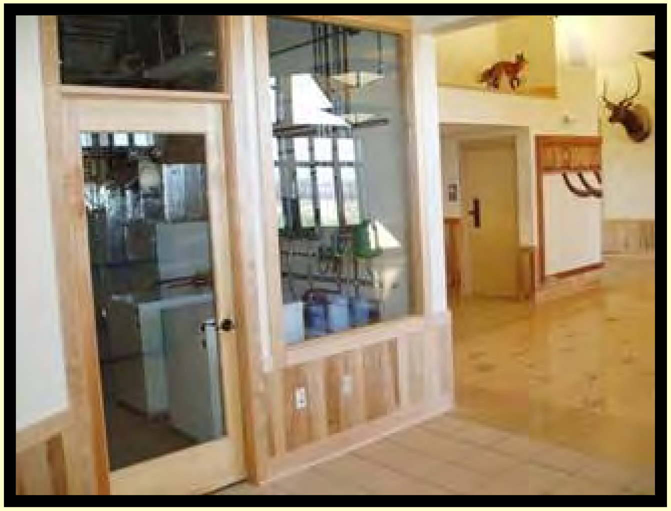
10 kW Grid-intertied Wind Turbine
on 120’ Freestanding Tower

Wind Energy & Solar Photovoltaic
Electricity

2.3 kW Tracking Array Solar Photovoltaic
Grid-intertied System

View from Lobby to entry

View to Education Wing



Publicly-viewable Mechanical Room in Lobby

Classroom with Seating

Classroom Kitchen

Classroom Student Lab Stations

Classroom Student Lab Stations

Library & Small Meeting Room

DNR Staff Office Wing

DNR Staff Office Wing

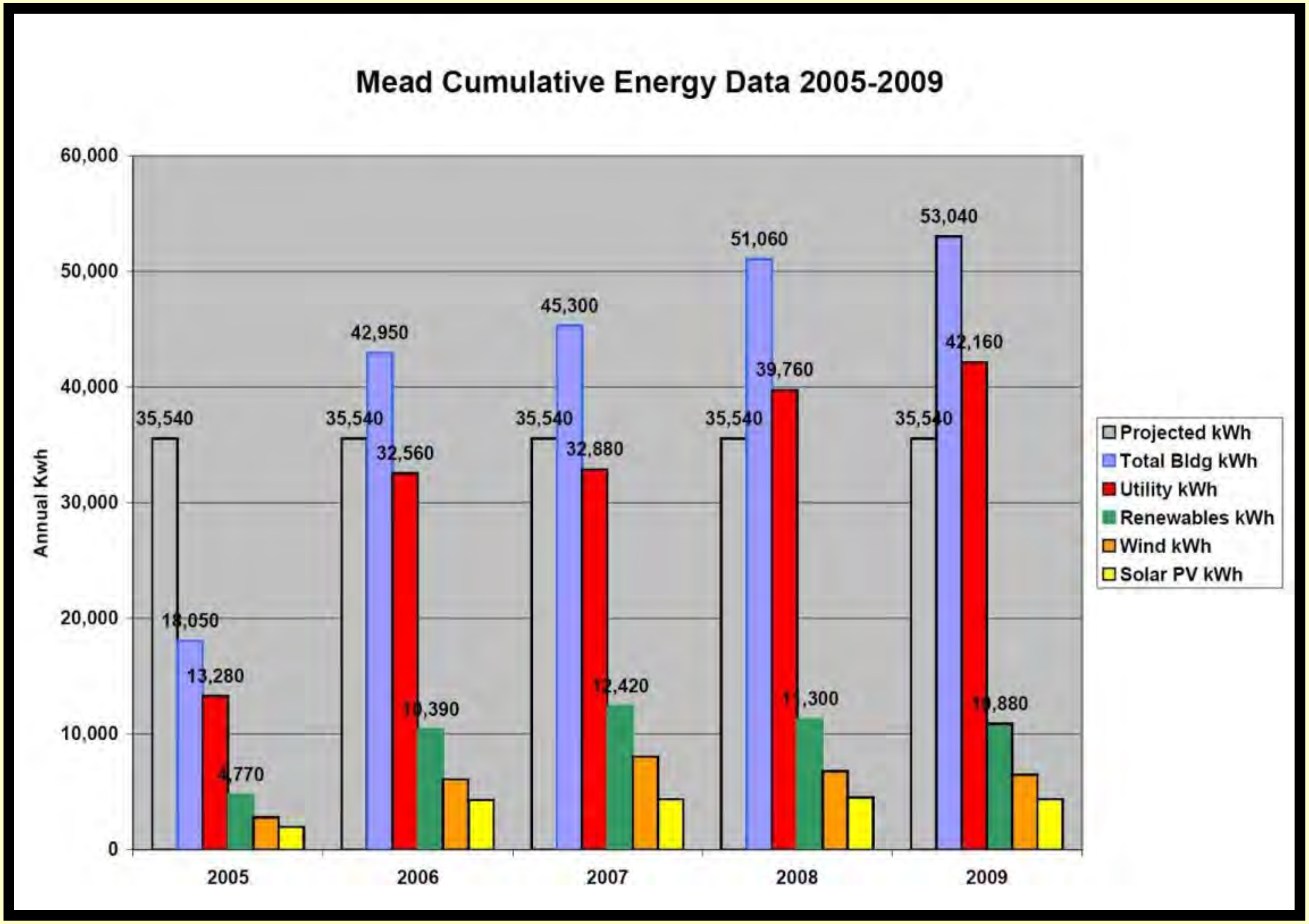
Documented Energy Usage

Mead Wildlife Area DNR Headquarters & Education Center

Cumulative Summary of Actual Energy Usage & Renewable Energy Generation

	Cumulative To Date					
	Months of Data =		54		12	
	7/15/05 - 1/18/10		Average / month		Average / year	
Description	kWh	$	kWh	$	kWh	$
Building Total	210,400	$21,320.90	3,896	$394.83	46,756	$4,737.98
%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
rate $/kWh		$0.101		$0.101		$0.101
Utility Total	160,640	$16,265.32	2,975	$301.21	35,698	$3,614.52
%	76.35%	76.29%	76.35%	76.29%	76.35%	76.29%
Photovoltaic	19,560	$2,011.73	362	$37.25	4,347	$447.05
%	9.30%	9.44%	9.30%	9.44%	9.30%	9.44%
Wind	30,200	$3,043.74	559	$56.37	6,711	$676.39
%	14.35%	14.28%	14.35%	14.28%	14.35%	14.28%
Renewables Total	49,760	$5,055.47	921	$93.62	11,058	$1,123.44
%	23.65%	23.71%	23.65%	23.71%	23.65%	23.71%
				Projected Energy Use	35,540	kWh / year
				Actual Energy Use	46,756	kWh / year
				Difference	11,216	kWh / year
				% Difference	31.56%	

Documented Energy Usage



Cumulative Energy Usage Summary

(@ 6,208 sq ft = 576.72 m^2)

Mead Cumulative Energy Usage Summary

	Electric		Natural Gas		Other		Total		Area		HDD	
Description	kWH	BTU	Therms	BTU	Qty	BTU	BTU	MMBTU	Sq Ft	Sq M	F	C
Mead (6,208 sq ft)	46,756	159,578,228	0	0	0	0	159,578,228	159.58	6208	576.72	7,500	4,167
		Energy Use Index (EUI) =	25.71	kBTU/ Sq Ft/ Year		81.07	kWH/ M^2/ Year		1 =	0.0929	10,000	5,556
											9,500	5,278
		Energy Intensity Index (EII) =	3.43	BTU/ Sq Ft/ HDD-F		0.019	kWH/ M^2/ HDD-C				9,000	5,000
											8,500	4,722
		Steady State Heat Loss =	79,789	BTU/ Hr @ -20 F		287,241	mJ/ Hr @ - 28.9 C		1 kWh = 3.6 mJ		8,000	4,444
											7,500	4,167
		EPA Energy Star Score =	85								7,000	3,889
									°F HDD to °C HDD = (5/9) x (°F HDD)			

3.43 BTU/sq. ft./HDD-F @ 6,208 sq. ft. = (.019 kWH/m2/HDD-C)
25.71 kBTU/sq. ft./yr = Energy Use Index (EUI) = (77.9 kWH/m2/yr)
79,789 BTU/hr @ -20 F Steady-state Heatloss Equivalent

Cumulative Energy Usage Summary (2005-2009)

(@ 6,208 sq ft = 576.72 m^2)

Mead Base Case Energy Model	**= 121,009 kWh/year**	**= 100%**
Mead Actual Energy Usage	**= 46,756 kWh/year**	**= 39%**
Actual Energy Savings	**= 74,253 kWh/year**	**= 61%**

Carbon Equivalents **= 67.9 tons CO^2/year**
= 11.8 vehicles removed
= 6,928 gallons of gasoline
= 143 barrels of oil
= 8 average home's electrical use
= 1,579 tree seedlings over 10 years
= 13.1 acres of pine forest
= 20.7 tons recycled waste diverted

Carbon Equivalencies: EPA National Average Electricity Emissions Data

Fossil Fuel: www.epa.gov/RDEE/energy-resources/calculator.html

Green Power: www.epa.gov/greenpower/pubs/calculator.htm

MREA Training Building

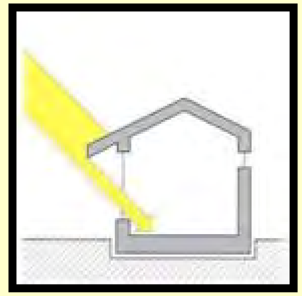
2x6 Exterior Strapped-Wall w/ Exterior Rain-screen

MREA Training Building

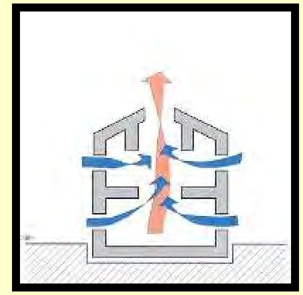
2x6 Exterior Strapped-Wall w/ Rain-screen Furring

Some final advice…

- Build it Tight
- Super-insulate it
- Orient it to the Sun
- Manage Sunlight
- Include Thermal Mass
- Incorporate Redundancy



Thank You



Thomas Brown

ARCHITECT

Environmentally-responsive design

1052 Main Street Stevens Point, WI 54481 715.341.9596

LEED ACCREDITED PROFESSIONAL

tbrownarch@gmail.com www.tombrownarchitect.com