



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



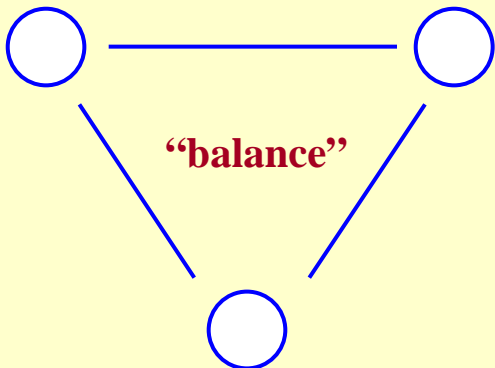
What is Green Design?

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



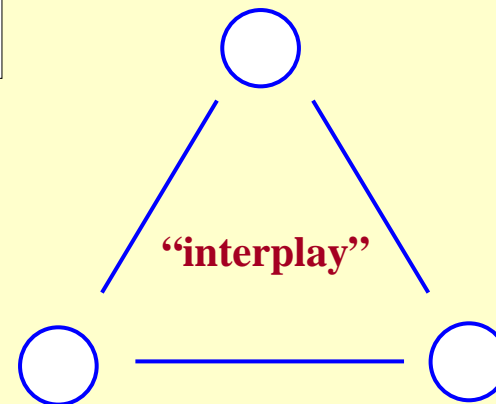
HEALTH

MACRO-VIEW

Durability

**Healthy
Building**

OCCUPANTS



“interplay”

ENVELOPE

SYSTEMS

MICRO-VIEW

Comfort

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



resilientdesign.org



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.

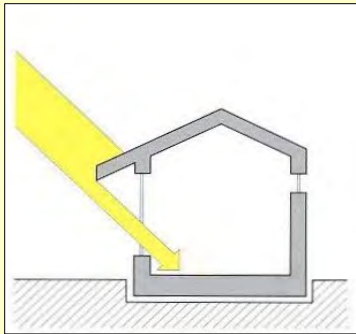
Resilient Design Principles

- **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.
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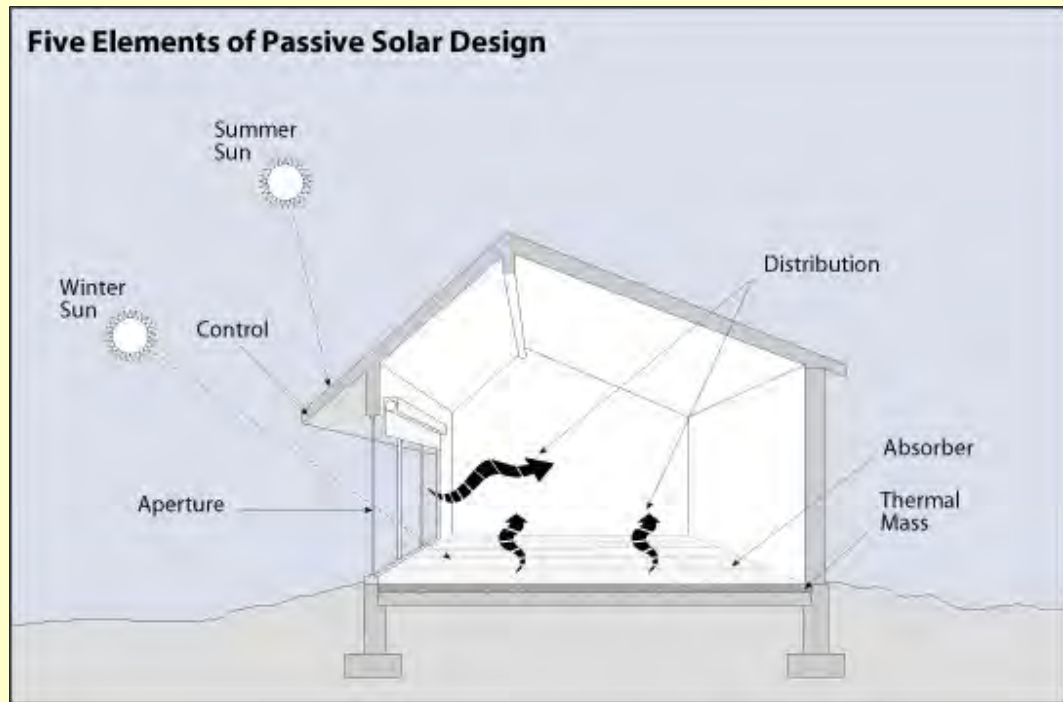
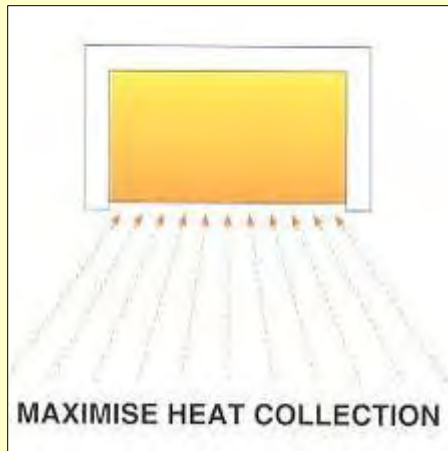
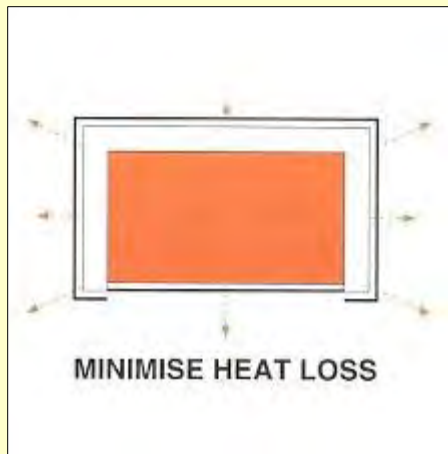
Orientation



Passive Solar

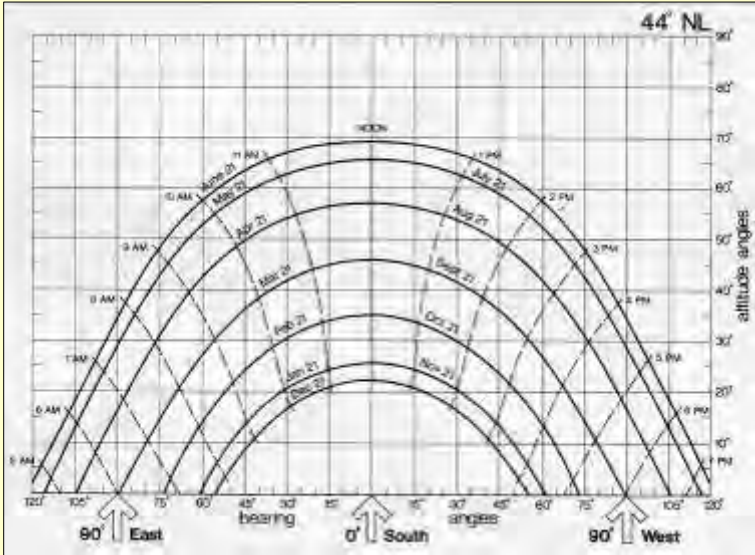
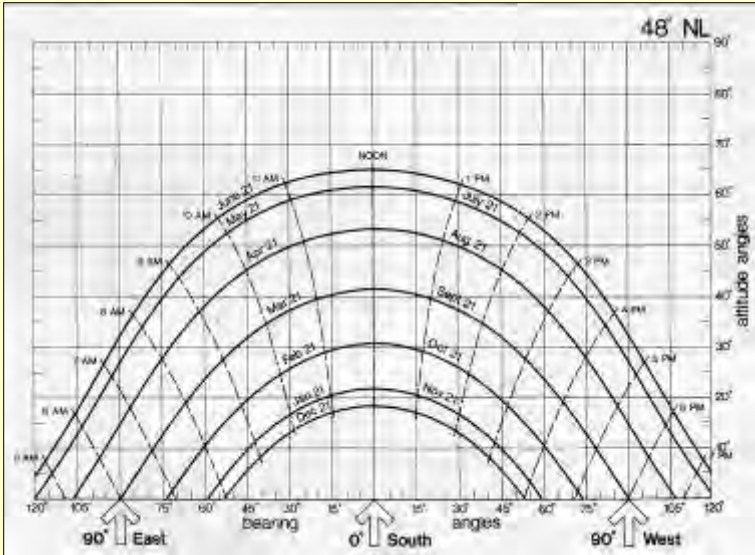
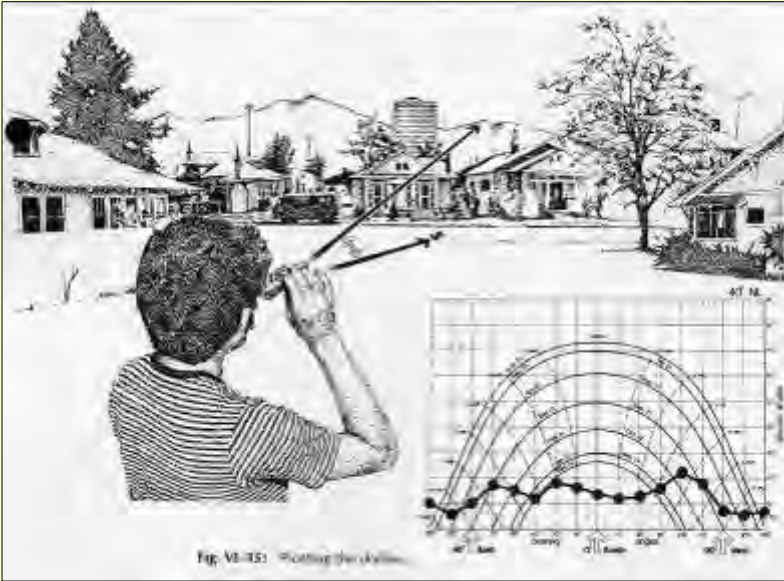


Passive Solar



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

Passive Solar - Sun Chart



- Source: [Passive-Solar-Mazria-Sun-Path-44.jpg](#)

Passive Solar

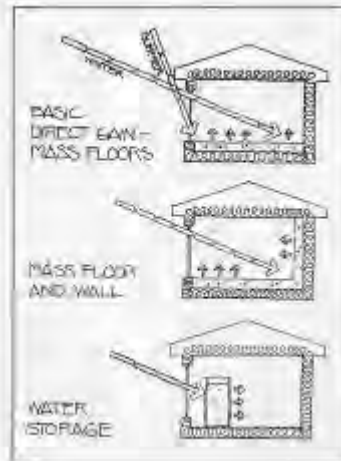
- Types

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. Movable shades can also be used as night insulation during winter and limit amount of solar heat gain during the summer.

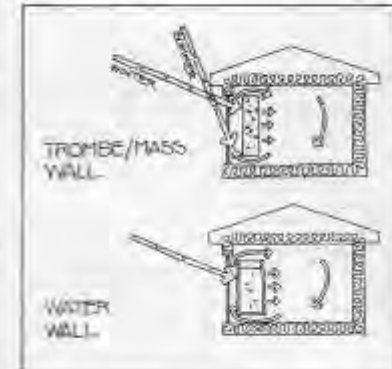
Also consider methods and materials which will prevent excessive glare. Some fabrics exposed to sunlight may fade, so use fabrics that resist fading or limit time fabrics are exposed to sunlight.



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.

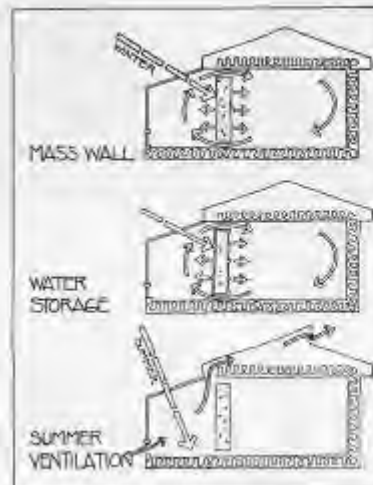
Two types of storage walls are used in direct-gain systems: mass storage walls or Trombe walls (pronounced *tromb*) and water storage walls. Both types of walls may or may not have vents. Vents help air circulate naturally between the glazing and the wall to the living area. Vents help warm room air move 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.

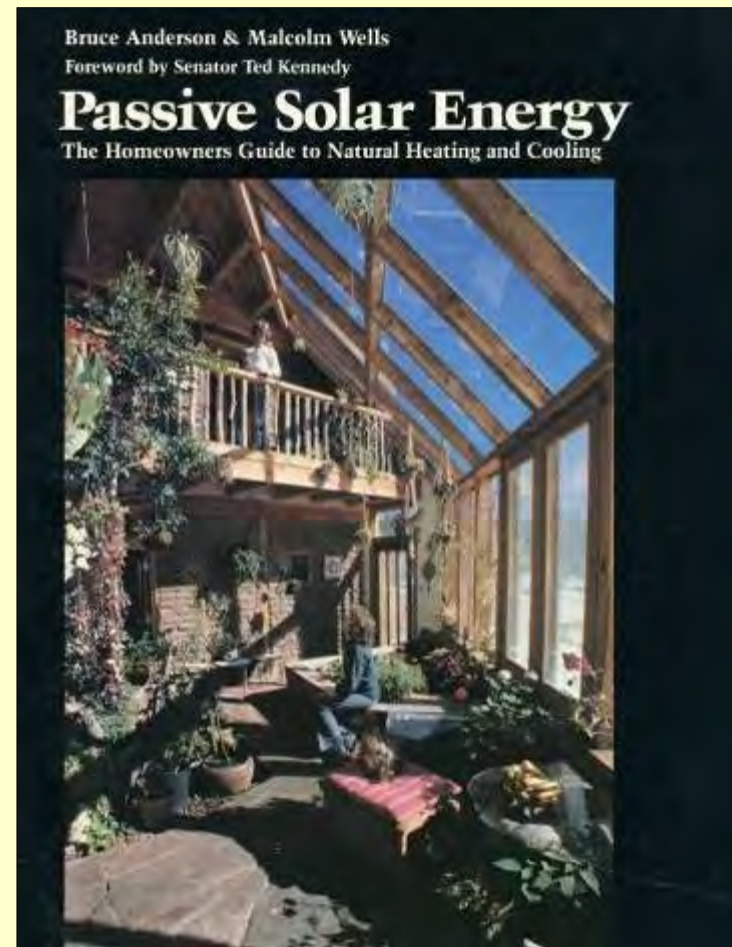
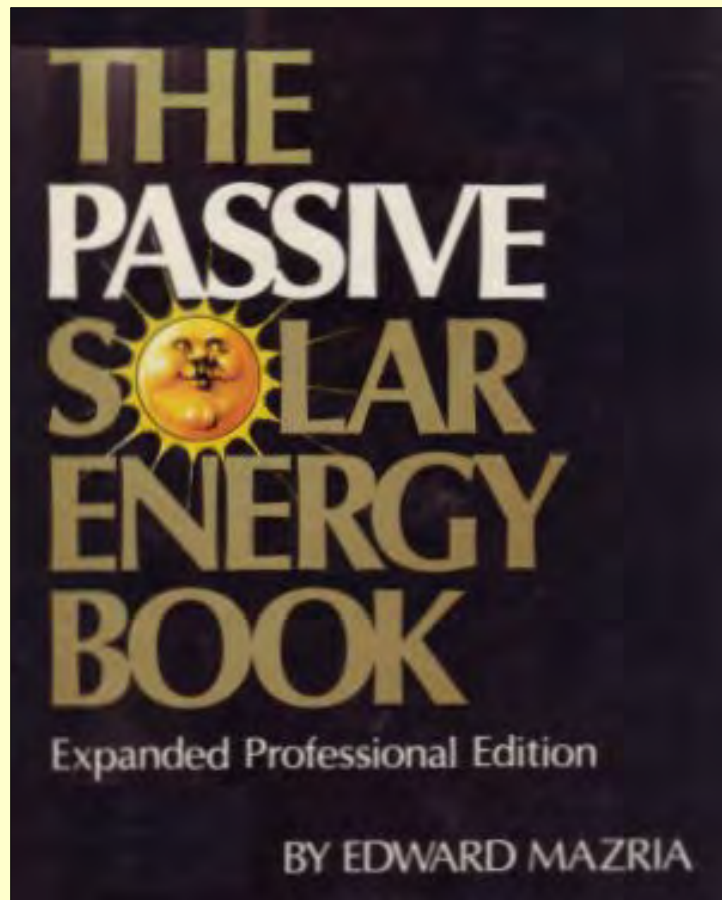
Carefully plan how to control heat flow between the collector and the living area so the right amount of heat is available at the right time.



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

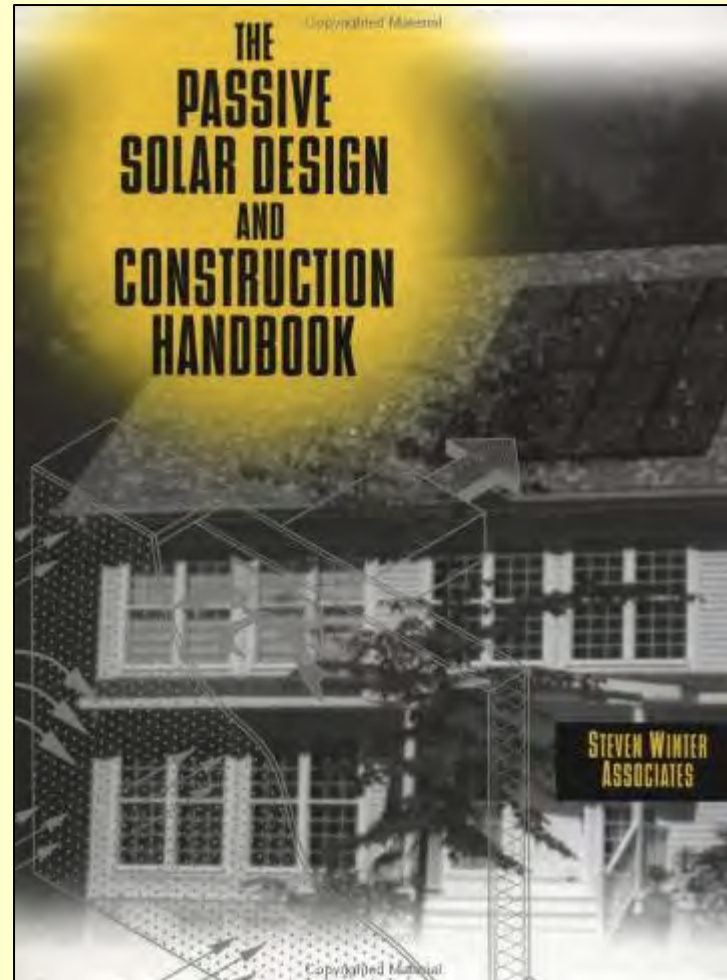
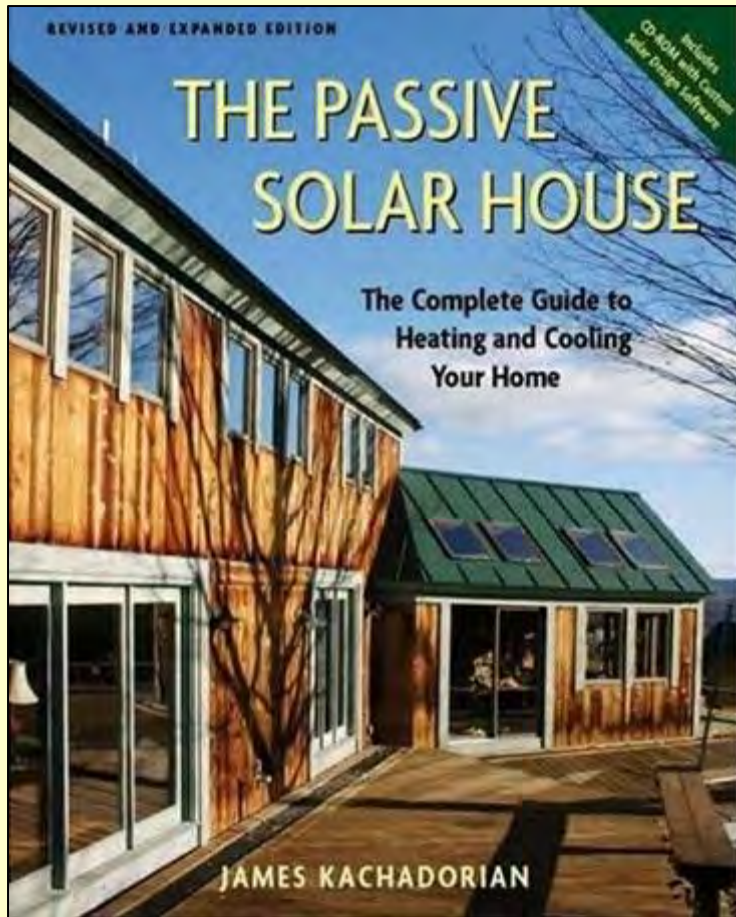
Passive Solar

- Resources



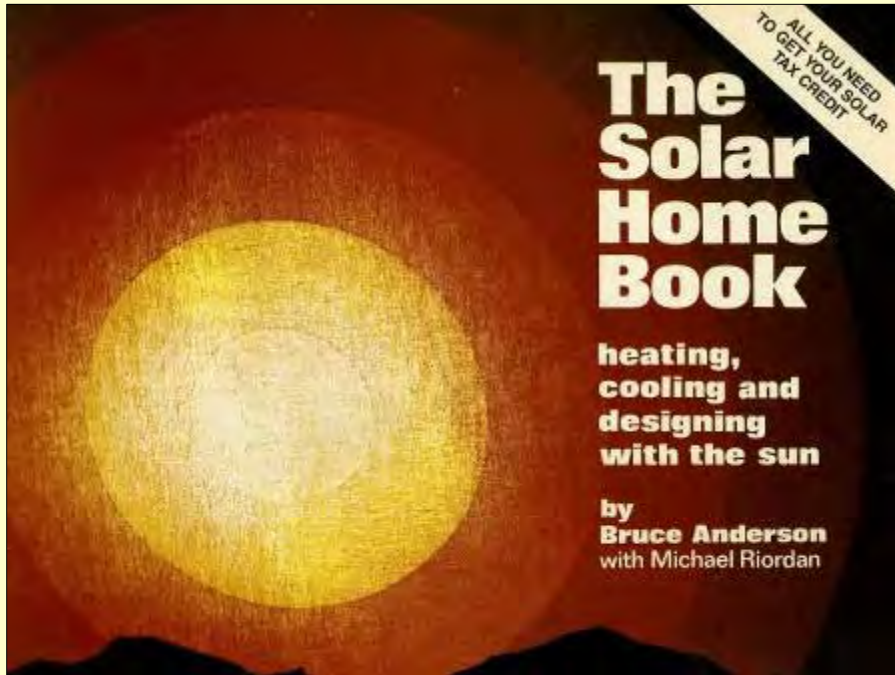
Passive Solar

- Resources

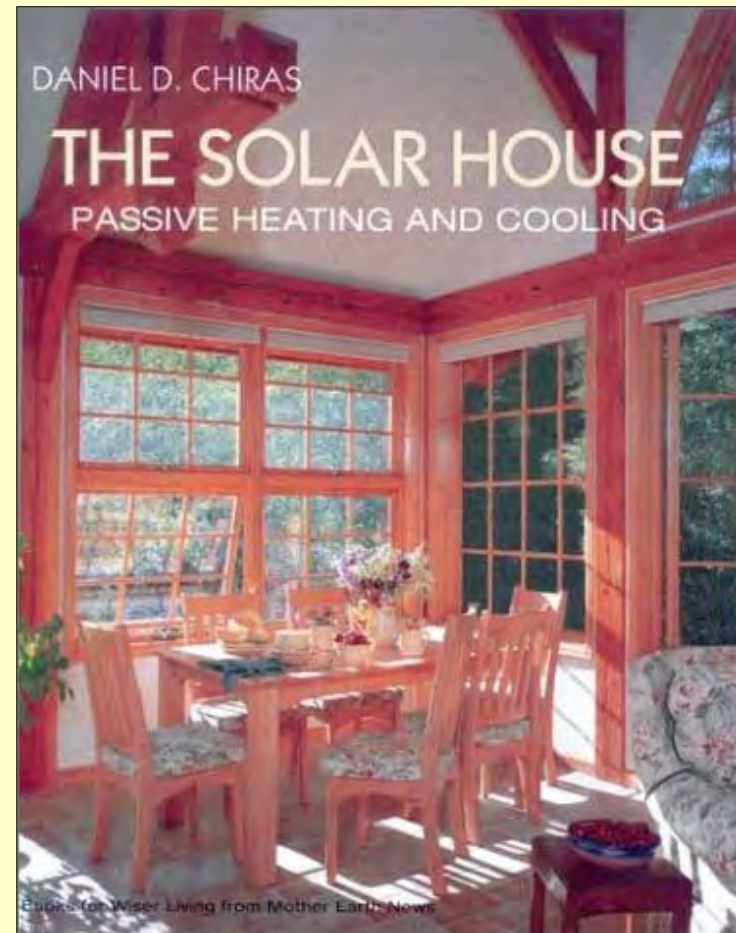


Passive Solar

- Resources



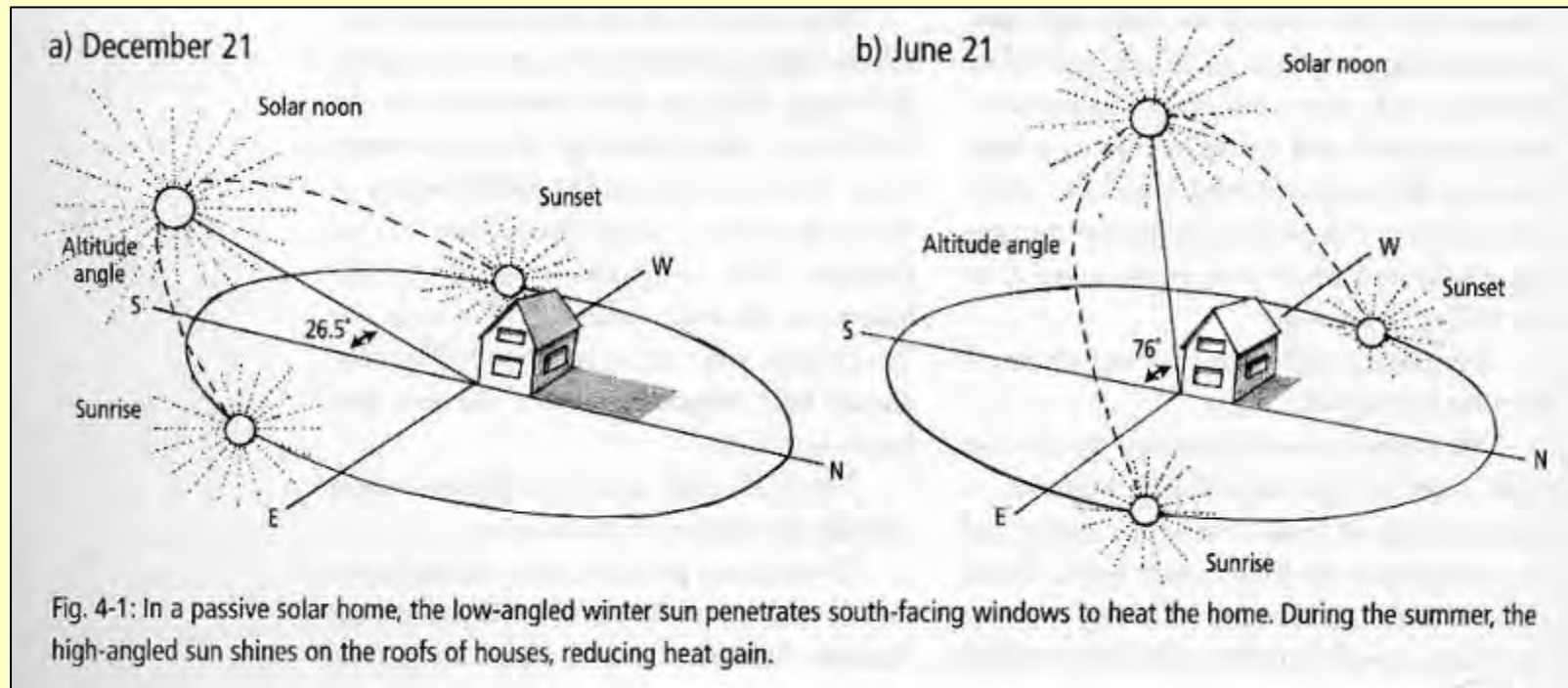
• Source: Solar-Home-Book-Anderson-cover-1.jpg



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

Passive Solar

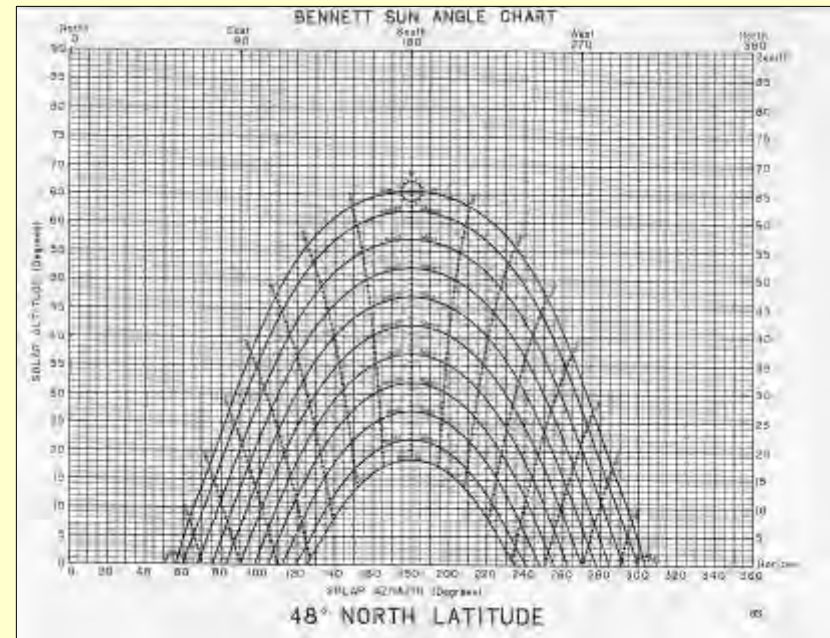
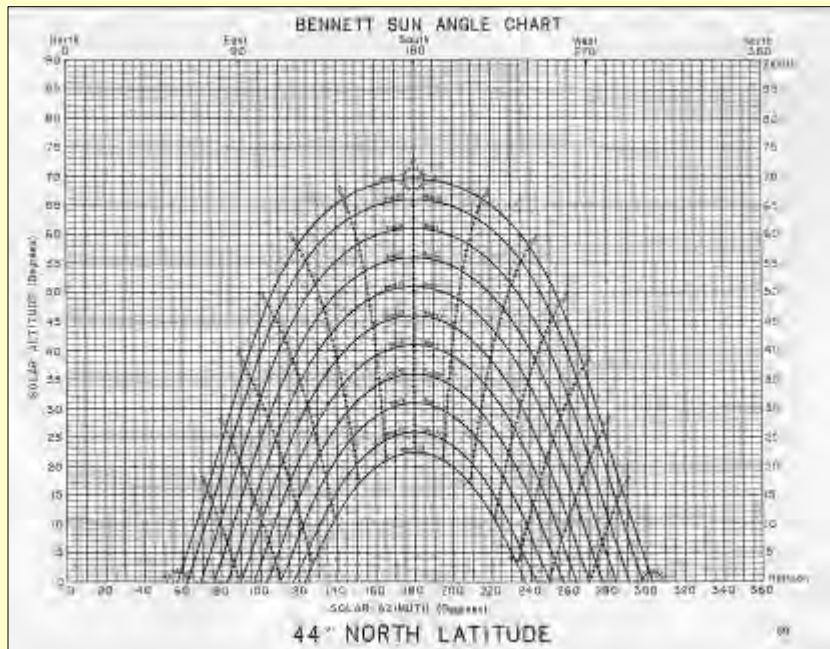
- Concepts



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

Passive Solar

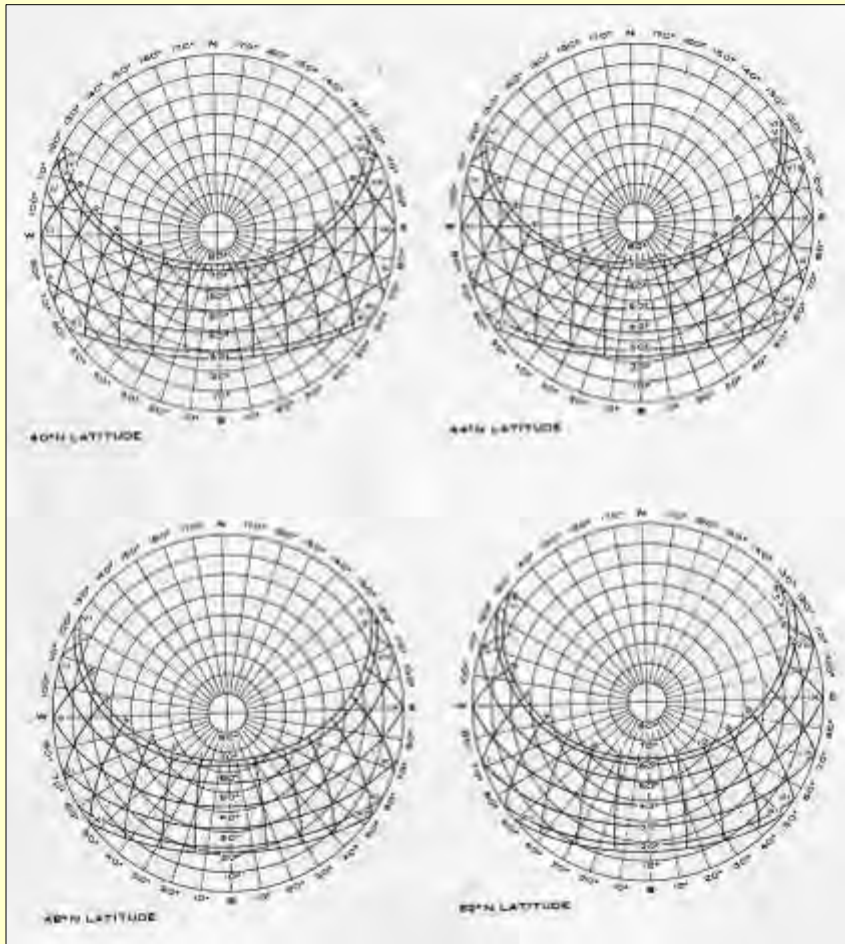
- Sun Chart



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

Passive Solar

- Solar Chart



Solar Radiation on South Walls on Sunny Days *

Date	Solar Time		Solar Radiation, Btus per hour per square foot					
	AM	PM	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*.

- 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

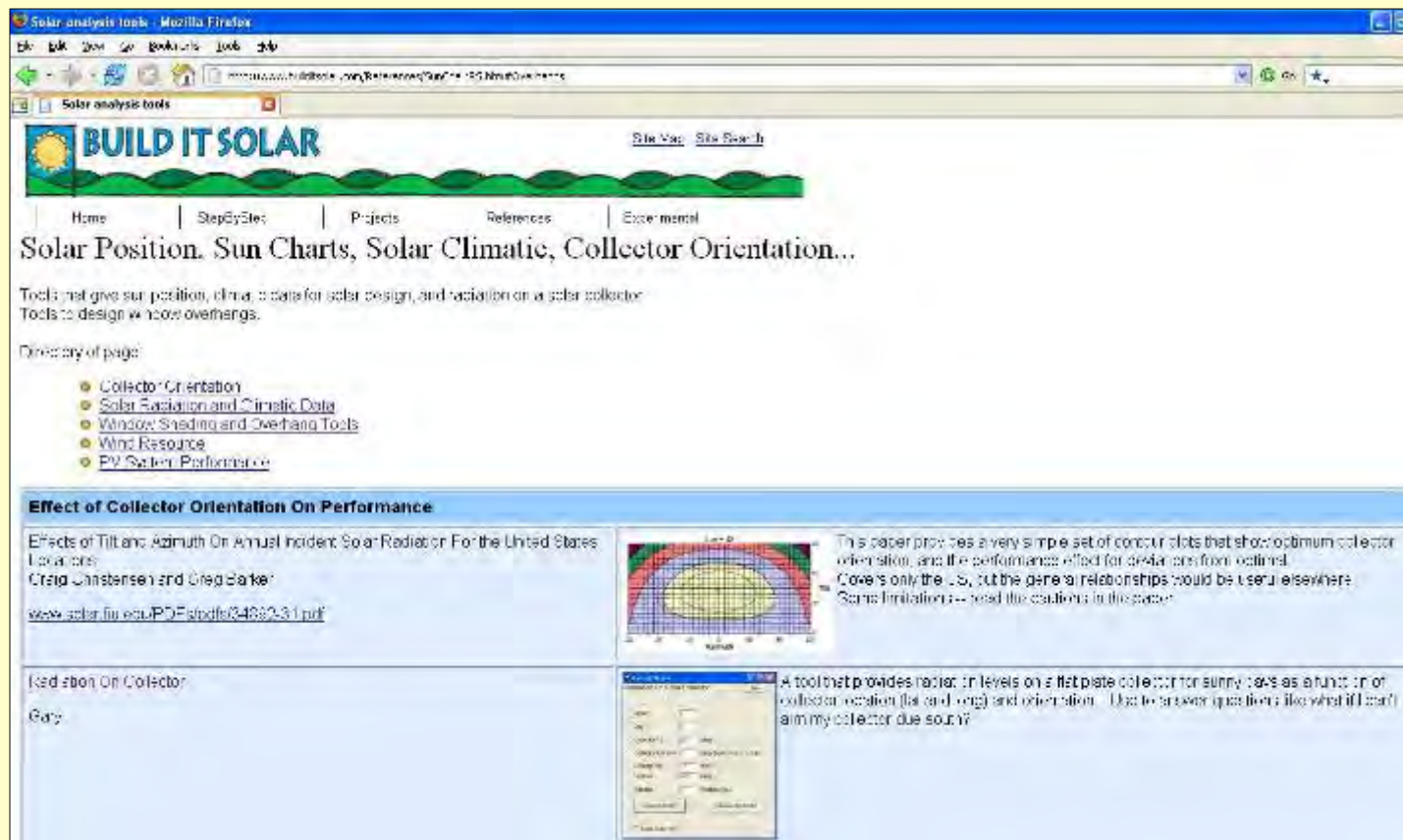
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
23.62	31.02	42.22	54.12	63.62	68.12	66.42	59.02	47.82	35.92	26.42	21.92

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

SunAngle

This tool calculates solar angle data based on date, time, and location. Please read the important [instructions](#), [notes](#), and [FAQ](#) pages before using this tool. Click on any input or output name for additional details.

INPUTS

longitude	80	West	time	12:01	PM
latitude	45	North	time zone	S (GMT-8:00)	
date	Dec	21	time basis	Clock time	
year	2007		daylight savings	NL	
elevation	300	meters	zero azimuth	South	

OUTPUTS

altitude angle	21.56	declination	-23.41
azimuth angle	-0.40	equation of time	0.00
clock time	12:00pm	time of sunrise	7:31am
solar time	12:01pm	time of sunset	4:24pm
hour angle	-0.48		

Support SunAngle!

The development and maintenance of SunAngle is supported 100% by voluntary user donations. If you found this program helpful, please consider making a small

QUICK DONATION

Commercial (\$25)

SunPosition

This tool calculates an array of solar angle data that can be copied into spreadsheets and other documents. Please read the important [instructions](#), [notes](#), and [FAQ](#) pages before using this tool. Click on any input label for additional details.

INPUTS

DATA TO CALCULATE

altitude azimuth declination

eq. of time hour angle day length

LOCATION

latitude degrees North South

DATA RESOLUTION

frequency start date

resolution time

OUTPUT FORMAT

delimiter date style

angle units time style

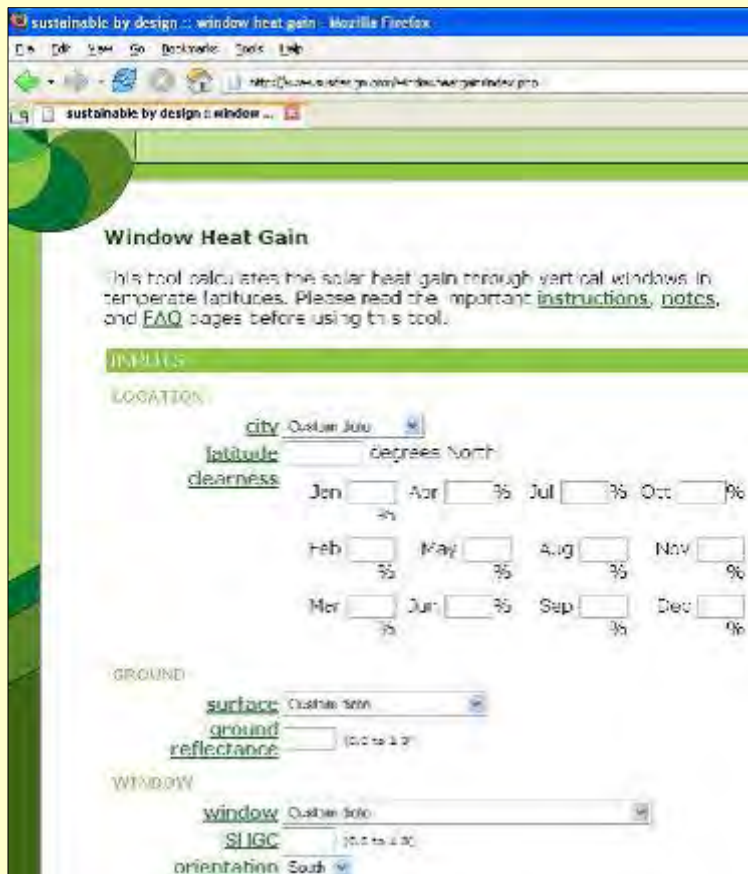
loop year include header

OUTPUTS

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

Passive Solar

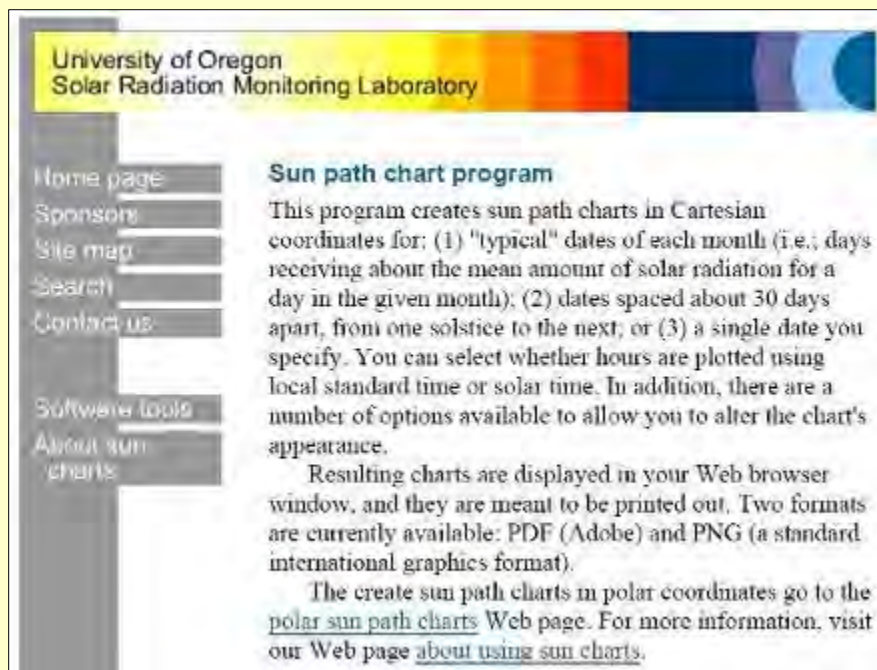
- Web Tools
- susdesign.com



- Source: [Sustainable-by-Design-website-Window-Heat-Gain-1.jpg](#)

Passive Solar

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



University of Oregon
Solar Radiation Monitoring Laboratory

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Software tools
About sun charts

Sun path chart program

This program creates sun path charts in Cartesian coordinates for: (1) "typical" dates of each month (i.e., days receiving about the mean amount of solar radiation for a day in the given month); (2) dates spaced about 30 days apart, from one solstice to the next; or (3) a single date you specify. You can select whether hours are plotted using local standard time or solar time. In addition, there are a number of options available to allow you to alter the chart's appearance.

Resulting charts are displayed in your Web browser window, and they are meant to be printed out. Two formats are currently available: PDF (Adobe) and PNG (a standard international graphics format).

The create sun path charts in polar coordinates go to the [polar sun path charts](#) Web page. For more information, visit our Web page [about using sun charts](#).



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Software tools

Solar position calculator

This calculator program returns solar zenith angle, declination, Julian day, equation of time, hour angle, instantaneous and daily extraterrestrial radiation values, and sunrise and sunset times. Equations were provided by the National Renewable Energy Laboratory.

Step 1—Specify date and time

Year	2002
Month	January
Day	1
Hour	12
Minute	0
Second	0

Step 2—Specify Location and time adjustments

Latitude (South negative)	45.00
Longitude (West negative)	-120.00
Time zone	GMT - 8 (PST)

Step 3—Specify other conditions

Pressure (mB)	1013.0
Temperature (C)	10.0
Aspect	180° (South)

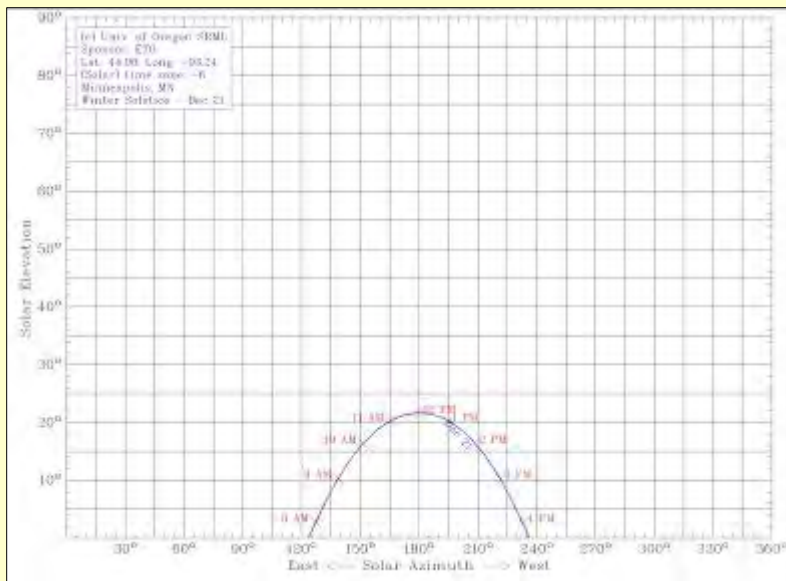
Step 4—Click the Calculate results button

• 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

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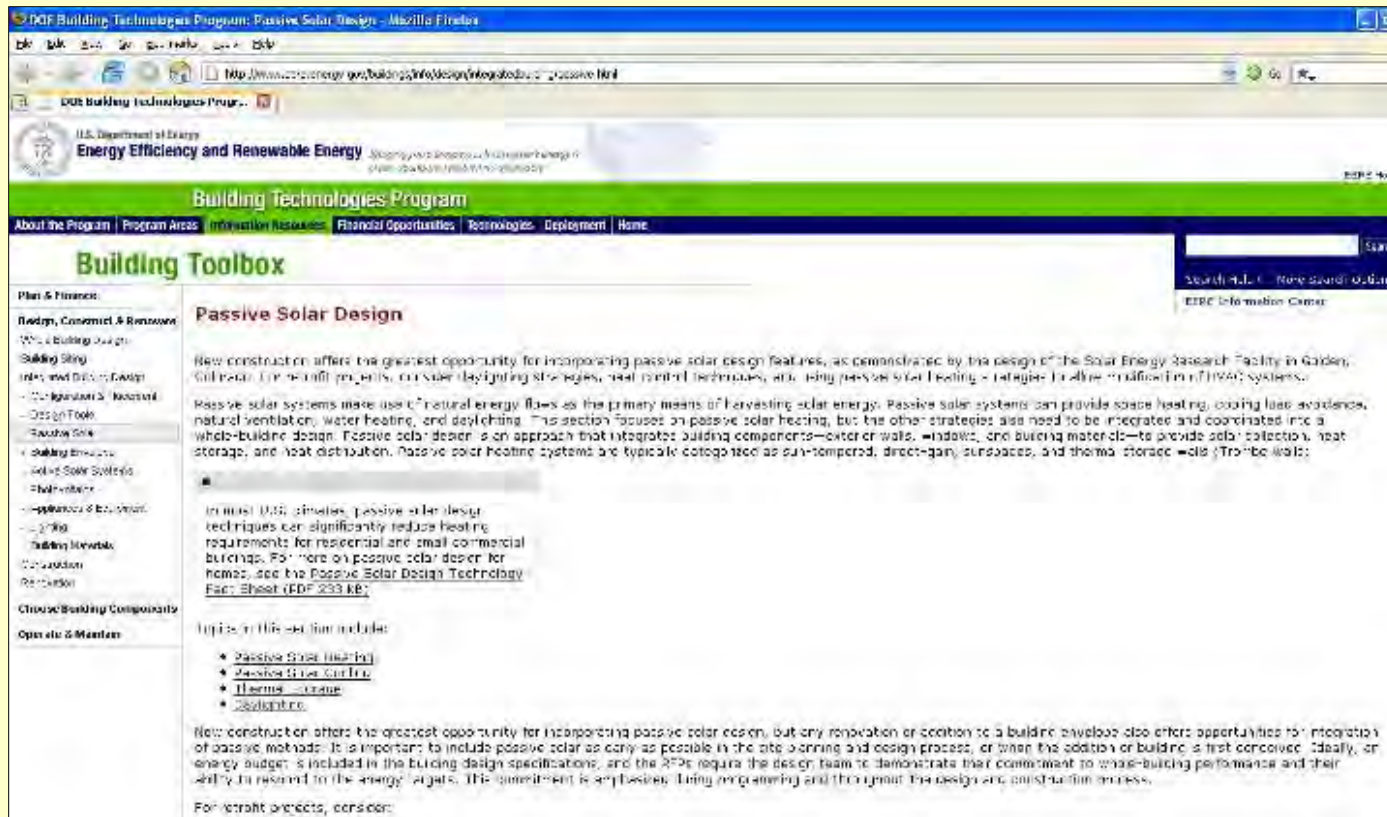
- Web Tools
- csbr.umn.edu.org
- msbg.umn.edu
- msdg.umn.edu



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

Passive Solar

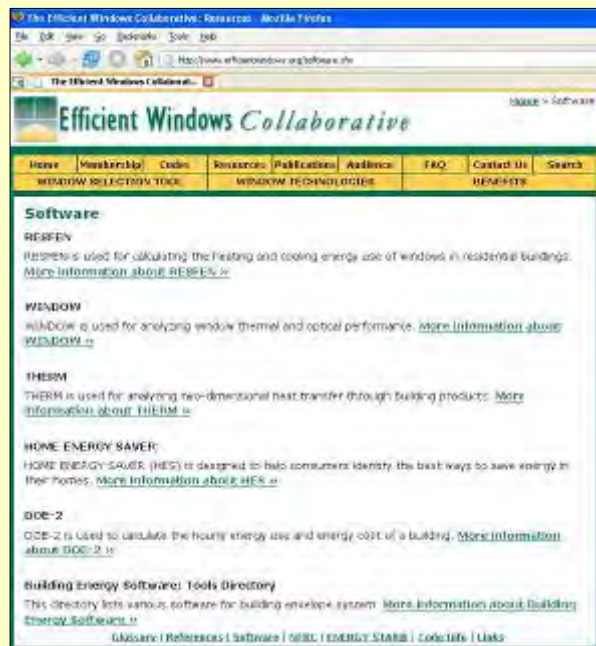
- Web Tools
- U.S. Dept. of Energy - Office of Energy Efficiency & Renewable Energy
- energy.gov/eere/energybasics/articles/passive-solar-building-design-basics



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

Passive Solar

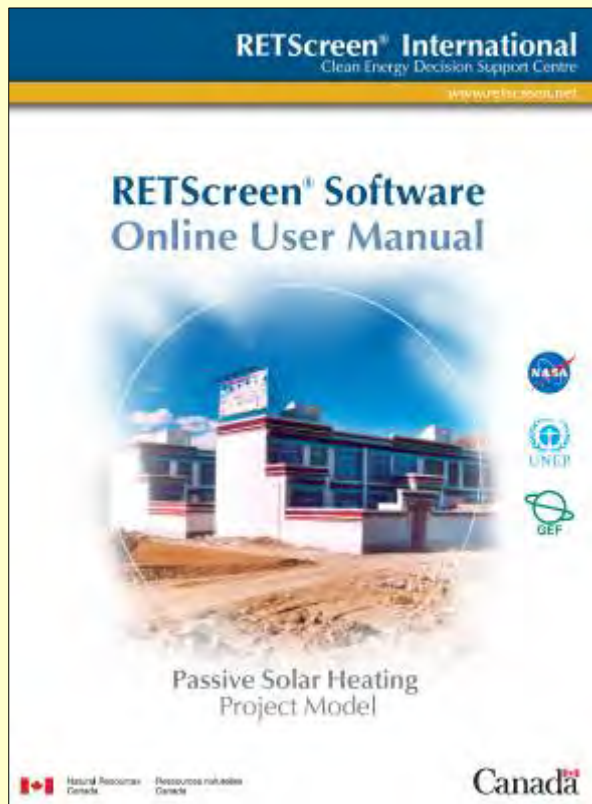
- Web tools
- efficientwindows.org



- Source: [EWC-Efficient-Windows-Collaborative-website.jpg](http://efficientwindows.org)

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

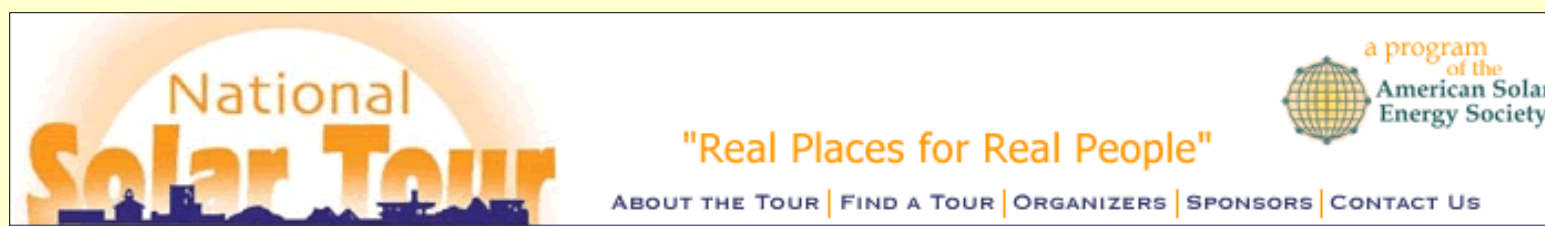


Solar Tour of Homes & Businesses

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
- research.umn.edu

Re-Arch: The Initiative for Renewable Energy in Architecture Fact Sheet



Technology: Passive Solar Design

Overview/Goal:
Passive solar design is especially useful in smaller buildings with irregular, non-rigid floor lines and fixed glass facades, an approach to larger, more cost-effective buildings. A hybrid approach, combining direct sun penetration in winter and full shading in summer, is the most common approach. A high level of interior thermal mass provides a period for heat storage, with the building responding slowly to temperature swings and dips.

Key Considerations:
Orientation and building configuration are important to take advantage of passive solar design strategies. An optimized southeast axis is best, with the building set in clockwise shadow by clouds or vegetation in the south. A slight southeast orientation often provides an easier response to available solar energy and maximum shading from the winter sun.

Key Considerations:
Allocate 5% of the overall glazing to walls within 58 degrees of south. Provide 7-15% of the floor area in south-facing glazing. Limit west-to-east-facing glazing to less than 5% of the floor area. Lightweight structures exceeding 7% of the floor area in south-facing glazing should have additional thermal mass. Provide 2-4 in. R of thermal mass for each 1 sq ft of south-facing glazing (or double exposure to direct sunlight, more if double layer direct sunlight). Surface area of interior thermal mass is more important than thickness.

Design Considerations:
Maximize southern exposure while minimizing western exposure. Provide floor and ceiling for shading elements on the south and vertical shading elements on the west. Choose south-facing glazing with a higher Solar Heat Gain Coefficient (SHGC). Consider using heated interior mass materials, such as rock, stone, tile, masonry or concrete, to absorb thermal mass.

Design Goals:
There is minimal additional cost involved, since passive solar design involves a well-timed and comprehensive set of glazing by orientation, and reconfiguration of the building layout with an integrated west-west wall. The use of passive solar building materials may involve a cost premium, depending on what "right alternative" has been chosen.

Key Takeaways:
There are several books and reference guides that outline basic principles of passive solar design. Some of these publications are currently out of print but are readily available through libraries and online library tools. In addition, there are several web-based tools of particular use for determining costs, studies and design trends. Several home information programs to generate sustainable solar energy use building configurations.

Re-Arch: The Initiative for Renewable Energy in Architecture Fact Sheet



Technology: Integrated Whole-Building Design

Overview/Goal:
This is the most effective method to obtain maximum energy and performance from buildings and systems. Sustainable design and green building rating systems, such as LEED or Green Globes, advocate and in some cases require this approach, involving all stakeholders in a project at an early stage to develop and test a design against agreed upon criteria.

Key Considerations:
Sustainable strategies need to be addressed in the context of the overall building design. Maximizing energy benefits, using passive systems, requires careful attention to energy and resource efficiency, including lighting at all stages with a potential building design.

Design Considerations:
Integrated design often involves a synergy between different design elements and components in a building between integrated or sophisticated building envelope design, passive and active solar treatment and mechanical systems. In these systems, the incremental cost associated with building envelope improvements and lighting strategies can be offset by reducing heating and cooling of space conditioning and lighting systems.

Design Considerations:
The design team must take a holistic approach and coordinate all building elements to take advantage of passive solar or daylighting possibilities, within the constraints of the building site. Opportunities for daylighting and solar should be pursued in the overall design process. Team performance of coordination of the building envelope should be reflected in the appropriate design of the overall systems.

Design Goals:
Integrated design often results in higher performance at little or no additional cost. Energy savings of 30% or more for a typical building are readily achievable by following basic green building guidelines. Overall costs may actually be reduced, since the many issues are resolved early in the design process, resulting in fewer change orders during construction. The value of green building increases in probability over the useful life of a building can far exceed any initial capital cost premium for a high-performance design. Credit attention to reduction in construction energy impact may require higher design fees, which should be more than offset by operating savings. Any third-party certification program would have associated fees that would need to be included in project budget.

Key Takeaways:
There are several books and reference guides that outline basic principles of integrated design. In addition, there are several web-based tools of particular use. Many of these have downloadable spreadsheets and design tools.

Re-Arch: The Initiative for Renewable Energy in Architecture Fact Sheet



Technology: Daylighting

Overview/Goal:
Daylighting takes advantage of available sunlight to meet some or all of a building's illumination requirements during daylight hours. "Cool" daylighting refers to adding the sun side of the sun without introducing the heat associated with direct sunlight, to minimize cooling needs. To be effective, daylighting must be coordinated with a lighting control strategy for artificial lighting in the building.

Key Considerations:
Obtain the building architect's design objectives, with a focus on reducing the building's power system. "Natural" or "direct" daylighting for use-lighting. Design configurations include top-lighting or over-lighting, in addition to side-lighting. Research for shading techniques and how they also consider the relationship from adjacent buildings.

Key Considerations:
Because an added lighting as part of the overall daylighting strategy. Concentrate artificial lighting for work, exhibit cases, and other special areas. Consider top-lighting on south-facing glazing to reduce cooling loads and provide glare. Make indoor no deeper than 2 to 3.5 times the head height of the window for use-lighting. Consider a glazing area of 15 to 20% of the daylight area for use-lighting (or between 25 to 40% of the building wall area).

Design Considerations:
Because an added lighting as part of the overall daylighting strategy. Concentrate artificial lighting for work, exhibit cases, and other special areas. Consider top-lighting on south-facing glazing to reduce cooling loads and provide glare. Make indoor no deeper than 2 to 3.5 times the head height of the window for use-lighting. Consider a glazing area of 15 to 20% of the daylight area for use-lighting (or between 25 to 40% of the building wall area).

Design Goals:
There are several books and reference guides that outline basic principles of daylighting design. In addition, there are several web-based tools of particular use. Many of these have downloadable spreadsheets and design tools. Several web-based tools have detailed performance data for different occupancy types.

Re-Arch: The Initiative for Renewable Energy in Architecture Fact Sheet



Technology: Green Roofs

Overview/Goal:
The most important of glazing type dependent on a number of factors. These include climate or the passive solar gain is needed or not and whether the building is primarily of glass (greenhouse) or "interior" (domestic) climate studies and design trends. Green roofs need to be more "rain-dominated." Orientation should be a factor in choosing glazing materials.

Key Considerations:
The most important of glazing type dependent on a number of factors. These include climate or the passive solar gain is needed or not and whether the building is primarily of glass (greenhouse) or "interior" (domestic) climate studies and design trends. Green roofs need to be more "rain-dominated." Orientation should be a factor in choosing glazing materials.

Design Considerations:
High thermal mass materials of south-facing glazing are common in passive solar buildings. For "semi-attached" buildings, large areas of glazing are a major challenge to heat loss, so high mass walls, windows, edge spaces and thermal breaks are important. Glazing should be sized and located for a specific purpose. Wall and plant cover should be used.

Design Goals:
There are several books and reference guides that outline basic principles of green roofs and window design. In addition, there are several web-based tools of particular use. Many of these have downloadable spreadsheets and design tools. Several home information programs to generate sustainable solar energy use building configurations.

Re-Arch: The Initiative for Renewable Energy in Architecture Fact Sheet



Technology: Building Envelope Control

Overview/Goal:
Building envelope control is important to control the direct penetration of the sun's rays. These elements can be solar and can be used to handle different seasonal loads and can be used to reduce the building's energy consumption.

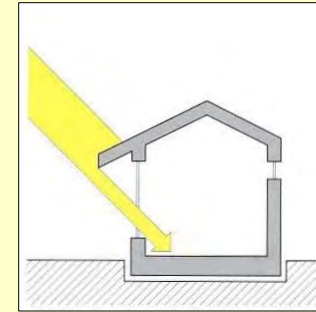
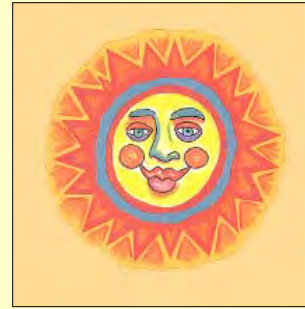
Key Considerations:
Emergent and circadian vegetation can provide natural shading in shading, especially on the west. Trees within the sun-facing "solar window" of a building should be deciduous, to maximize winter sunlight. Top-water and trees in the south-west and east in the south-west, with a few riparian trees in the north-west, allowing great solar penetration. The summer sun rises in the north-west and sets in the north-west, with a high northern sun angle in the afternoon good natural shading with overhangs. The sun is in the same position in spring and fall. In the long, hot, summer months, it is still overhead.

Design Considerations:
For southern exposures, a higher, deeper overhang provides better solar protection (and passive shading). Taller glazing requires a longer overhang to provide summer protection. Consider various sizes of smaller overhangs for local exposures of glazing. Overhang glazing will vary with latitude and can be determined by shading coefficient analysis and calculation for seasonal shading.

Design Goals:
There are several books and reference guides that outline basic principles of building and sun control. In addition, there are several web-based tools of particular use. Many of these have downloadable spreadsheets and design tools. Several home information programs to generate sustainable solar energy use building configurations.

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

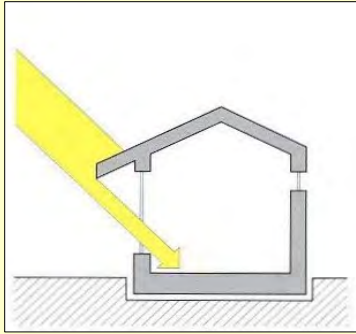
Building Shape

- 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

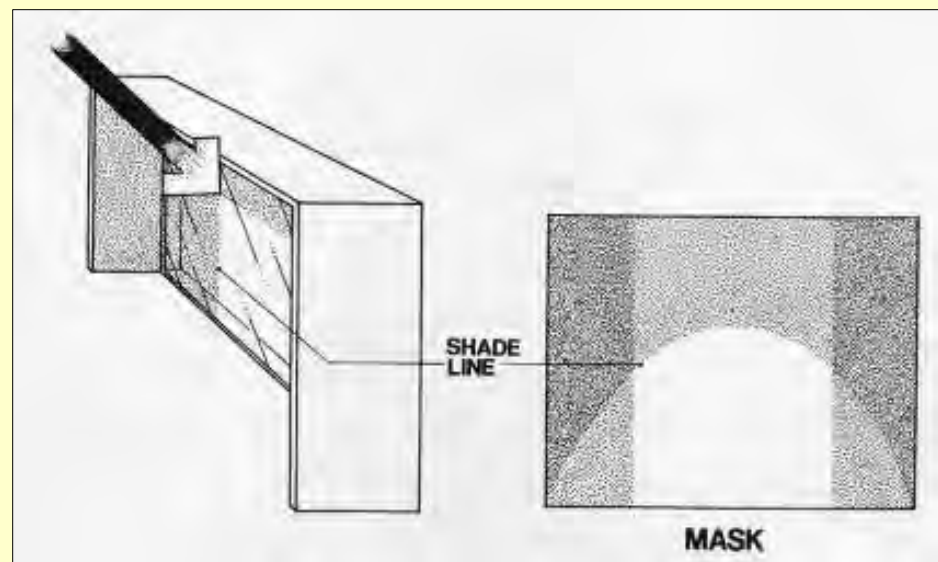
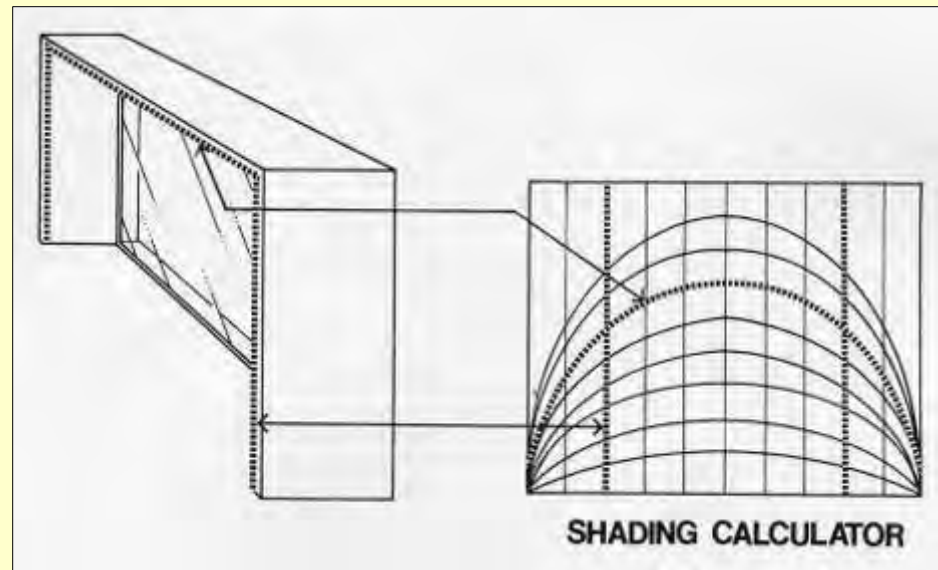
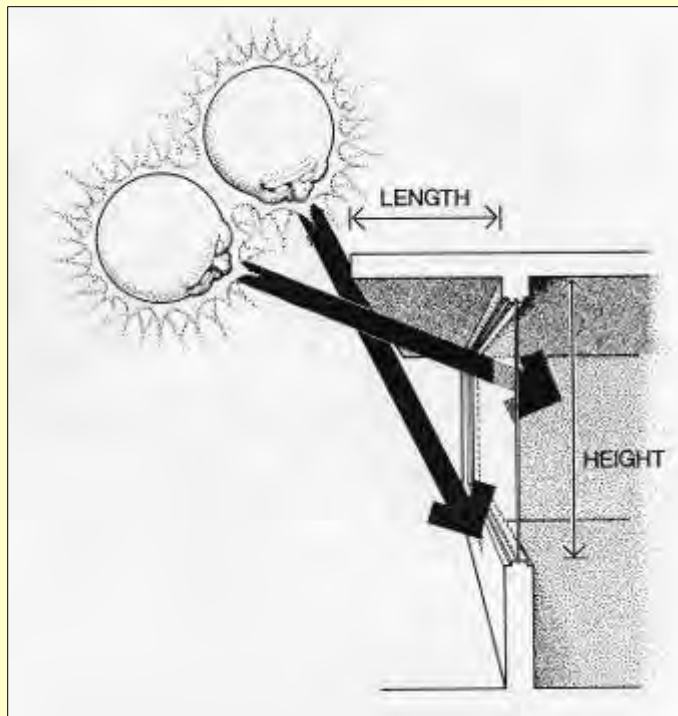
Shading



Passive Solar

Shading

- Overhang



- Source: [Passive-Solar-Mazria-Overhangs-1a.jpg](#)

Shading

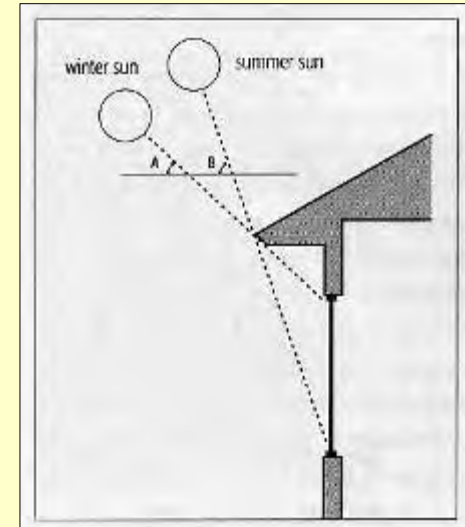
- Overhangs

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.



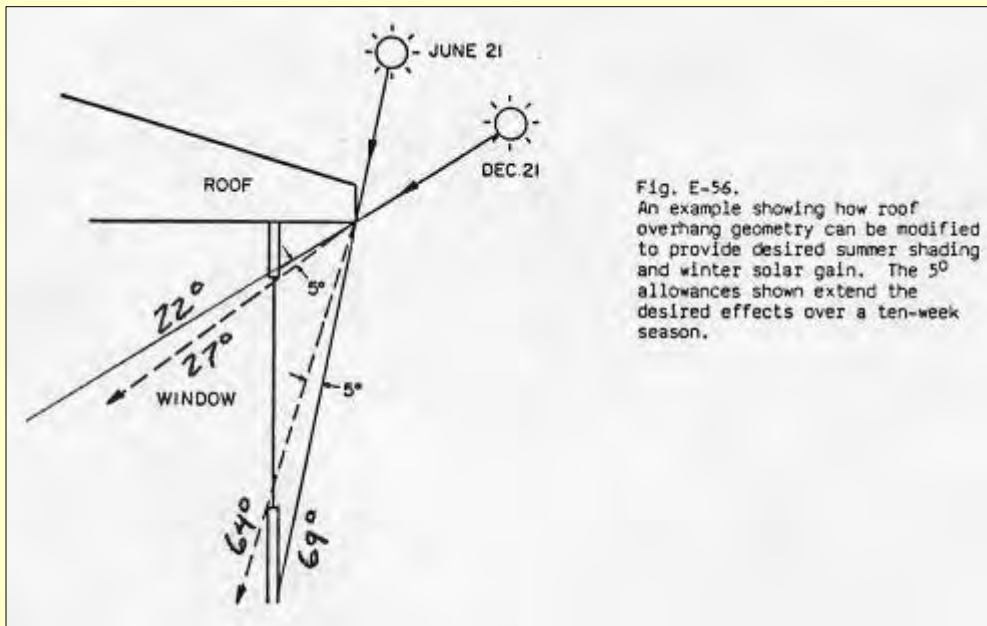
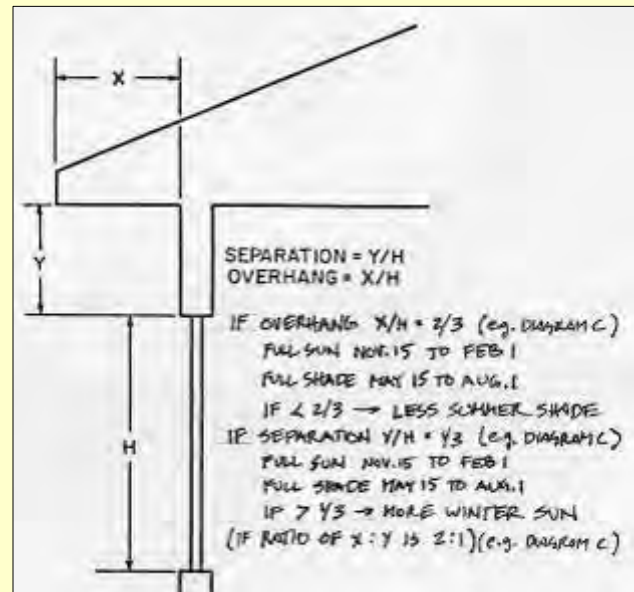
F Factor Used to Determine Length of Overhang Projection in All Passive Solar Designs

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

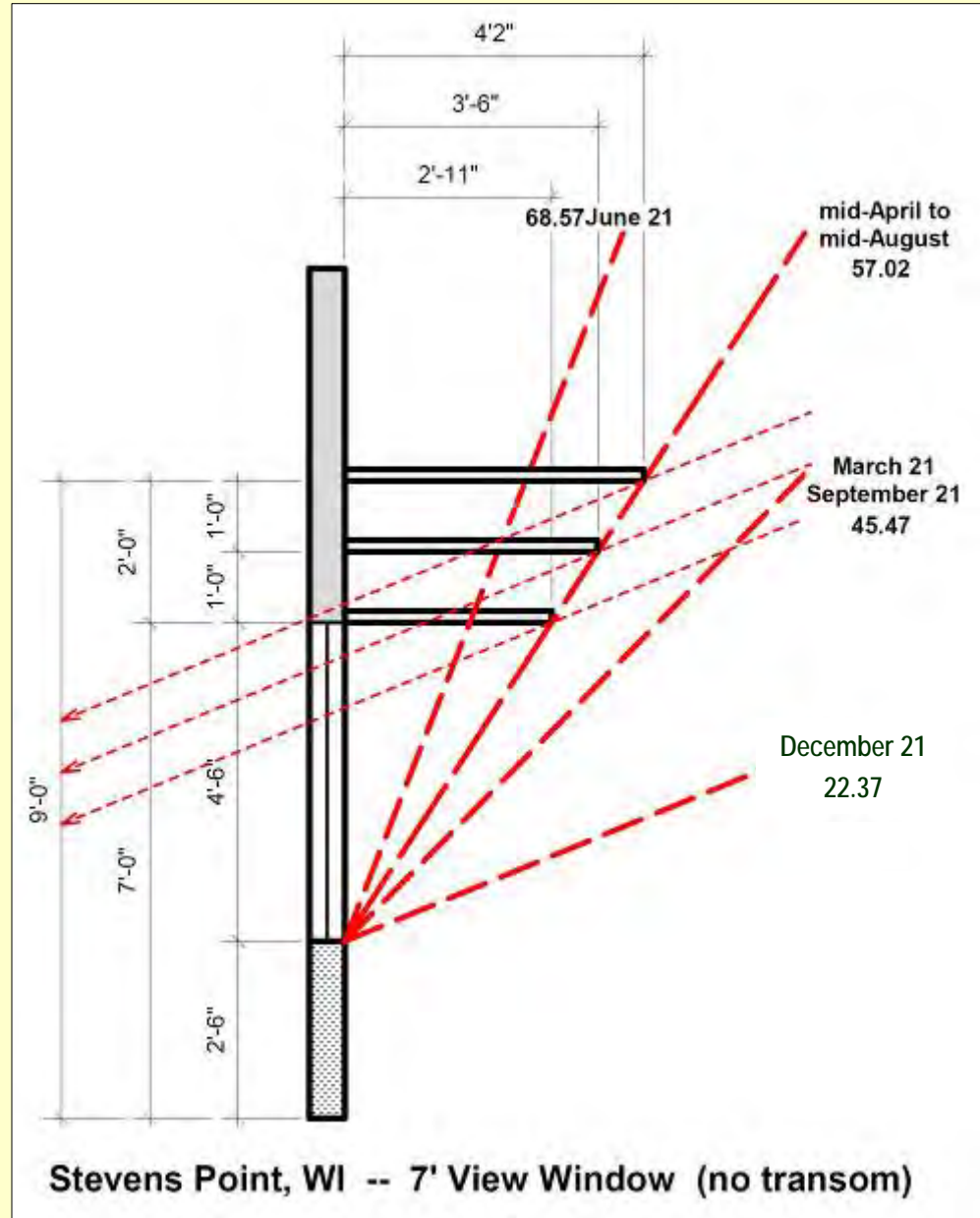


- Source: DOE-Passive-Handbook-vol-2-overhang-1.jpg

Shading

- Overhang Example

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



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.

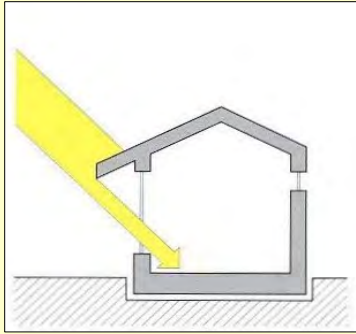
Shading

– Rules of Thumb

Building Construction

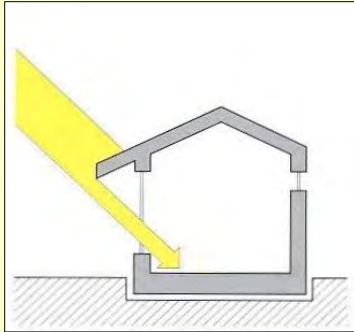
- Avoid standard truss or rafter framing, where exterior overhang soffits are tight to the top of the windows.
- Use raised-heel energy trusses, where the exterior soffit is at or near the interior ceiling height.
- For conventional stick-built framing, set rafters on a plate on top of ceiling joists,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

Glazing

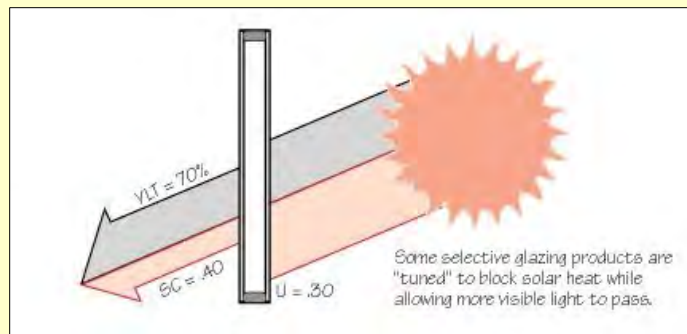
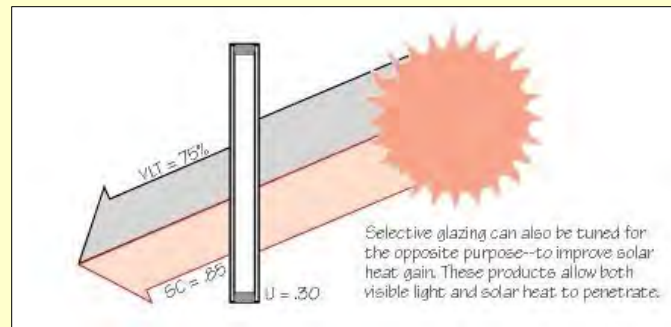
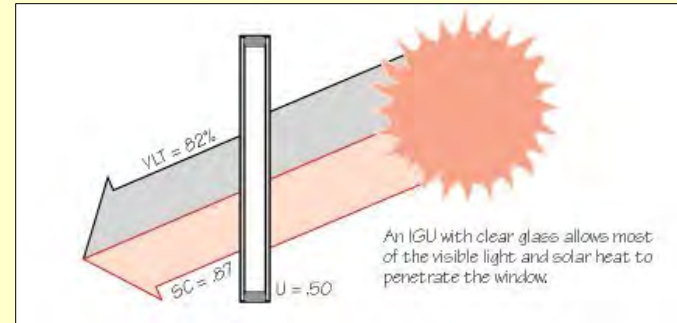


Passive Solar

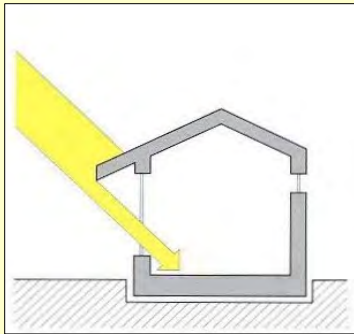
Glazing



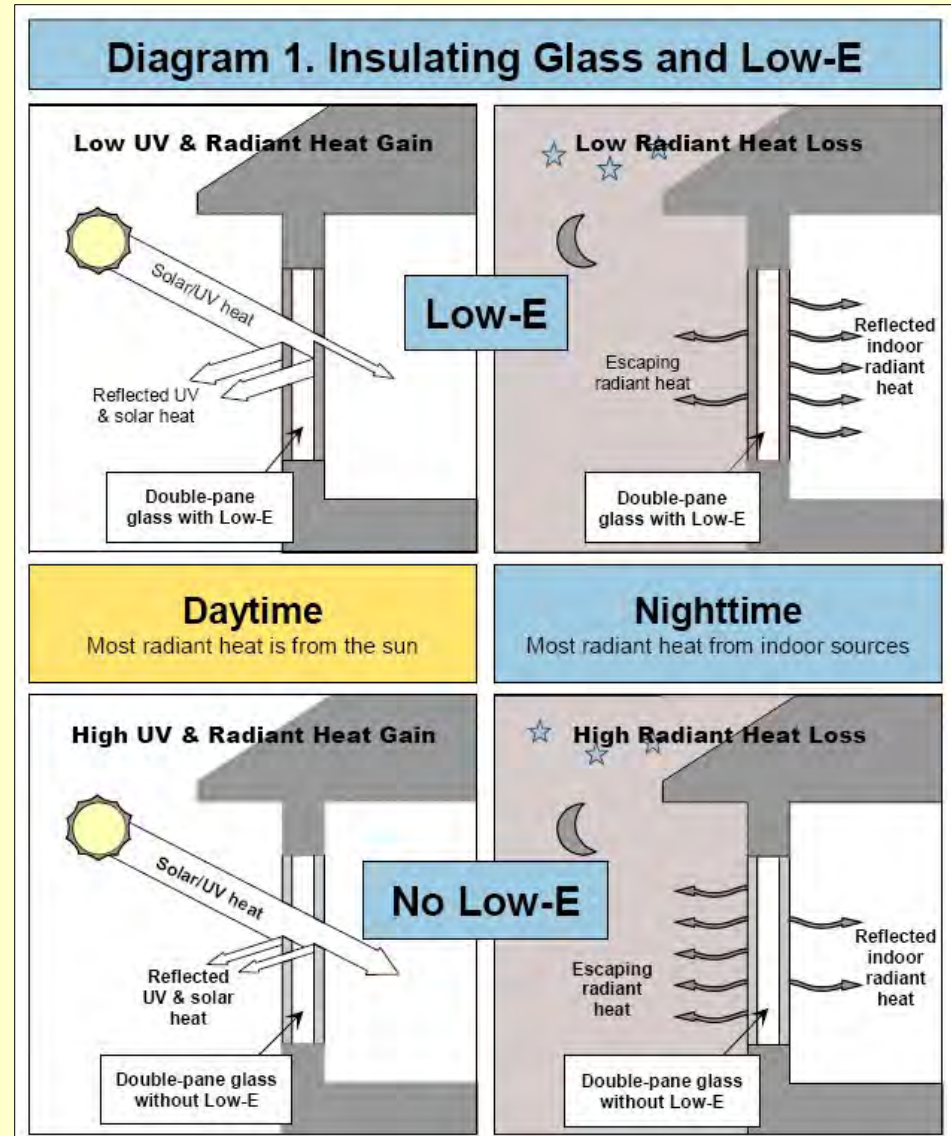
Passive Solar



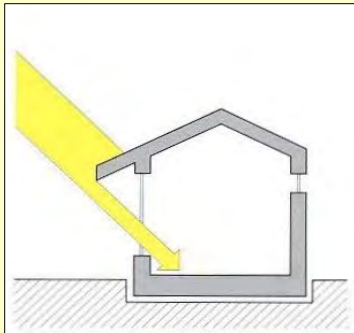
Glazing



Passive Solar



Glazing

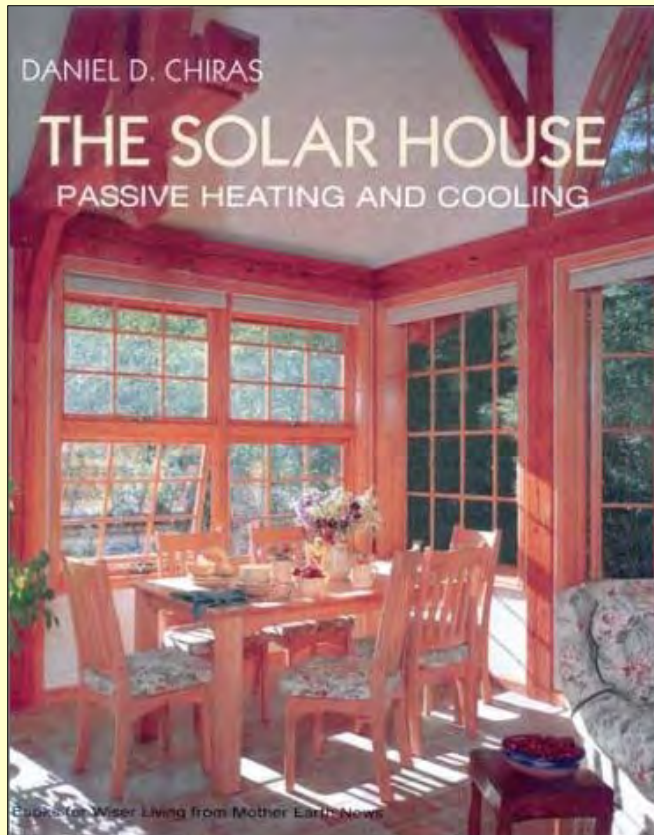


Passive Solar

 <p>National Fenestration Rating Council® CERTIFIED</p>	<p>World's Best Window Co.</p> <p>Millennium 2000+ Vinyl-Clad Wood Frame Double Glazing • Argon Fill • Low E Product Type: Vertical Slider</p>	
<p>ENERGY PERFORMANCE RATINGS</p>		
<p>U-Factor (U.S./I-P)</p> <p>0.35</p>	<p>Solar Heat Gain Coefficient</p> <p>0.32</p>	
<p>ADDITIONAL PERFORMANCE RATINGS</p>		
<p>Visible Transmittance</p> <p>0.51</p>	<p>Air Leakage (U.S./I-P)</p> <p>0.2</p>	
<p>Condensation Resistance</p> <p>51</p>	<p>—</p>	
<p><small>Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. NFRC does not recommend any product and does not warrant the suitability of any product for any specific use. Consult manufacturer's literature for other product performance information. www.nfrc.org</small></p>		

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

Glazing Type

- 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

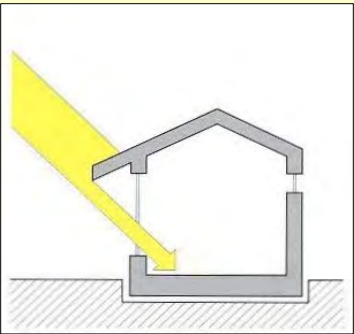
Glazing

– Rules of Thumb

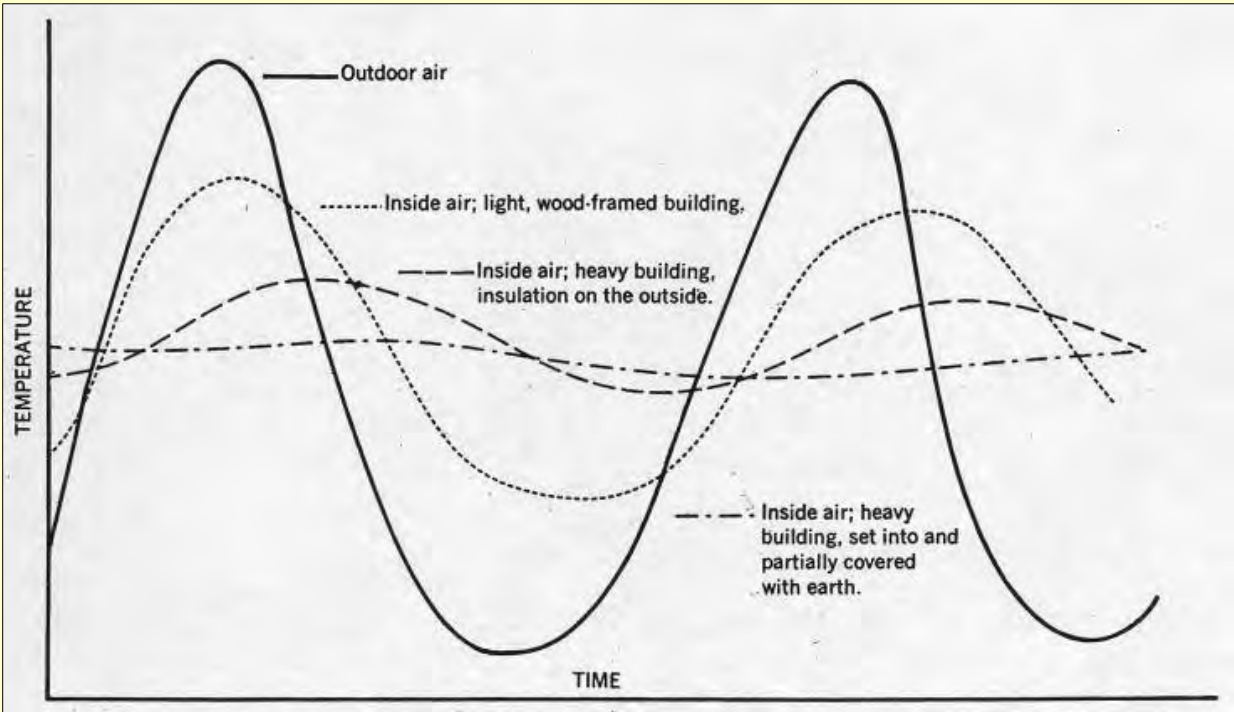
Glazing Area

- 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

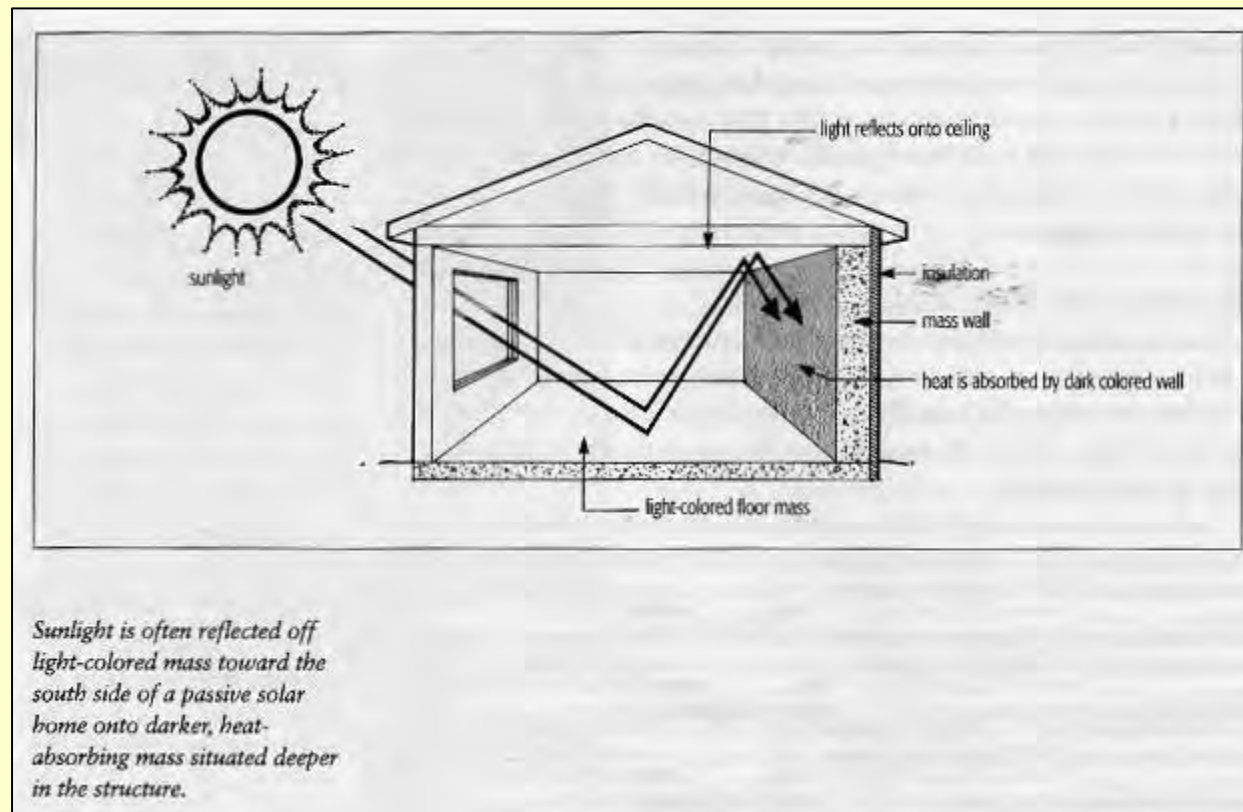


Passive Solar



Thermal Mass

– configuration



- 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

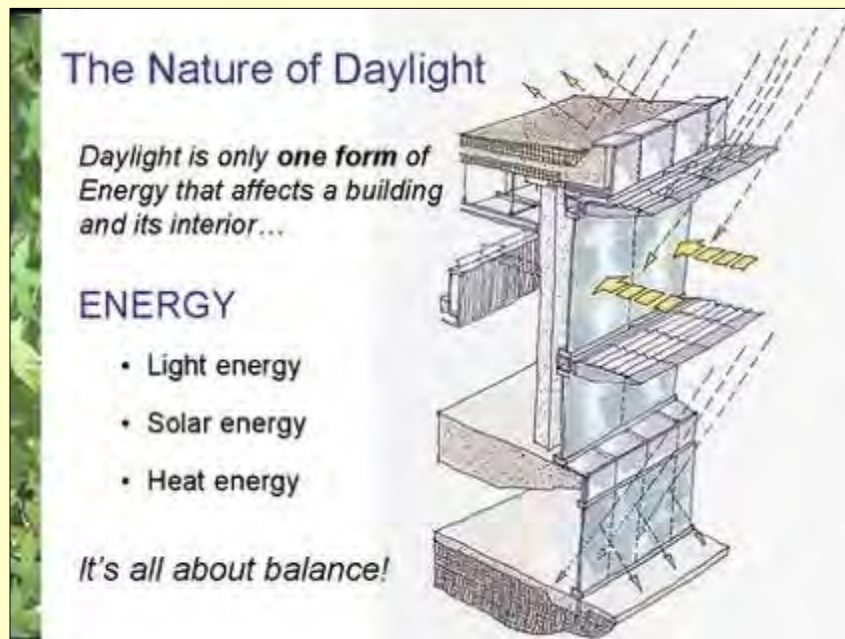
Side-lighting

Top-lighting

Core-lighting

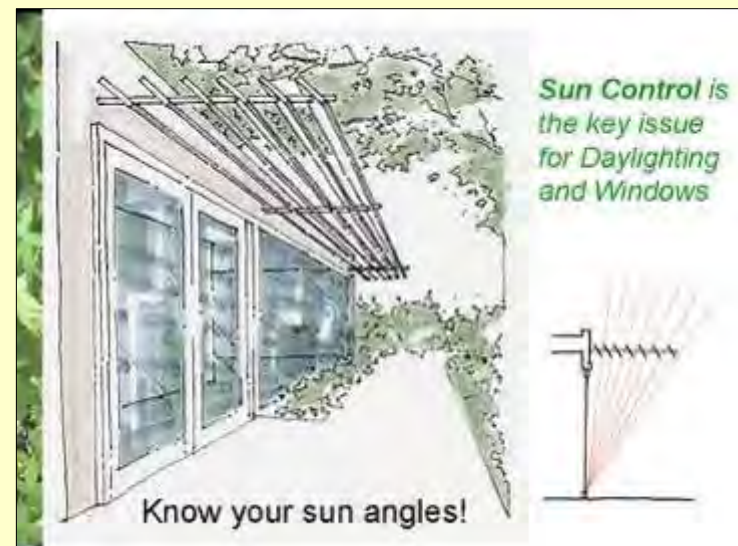
Daylighting

– Fundamentals



The three fundamental design issues in daylighting design are:

1. Glare Control
2. Sun Control
3. Variation Control



- Source: [BD+C-12-7-06-daylight-nature-1.jpg](#)

Daylighting

– Fundamentals

Elements of Integrated Daylighting

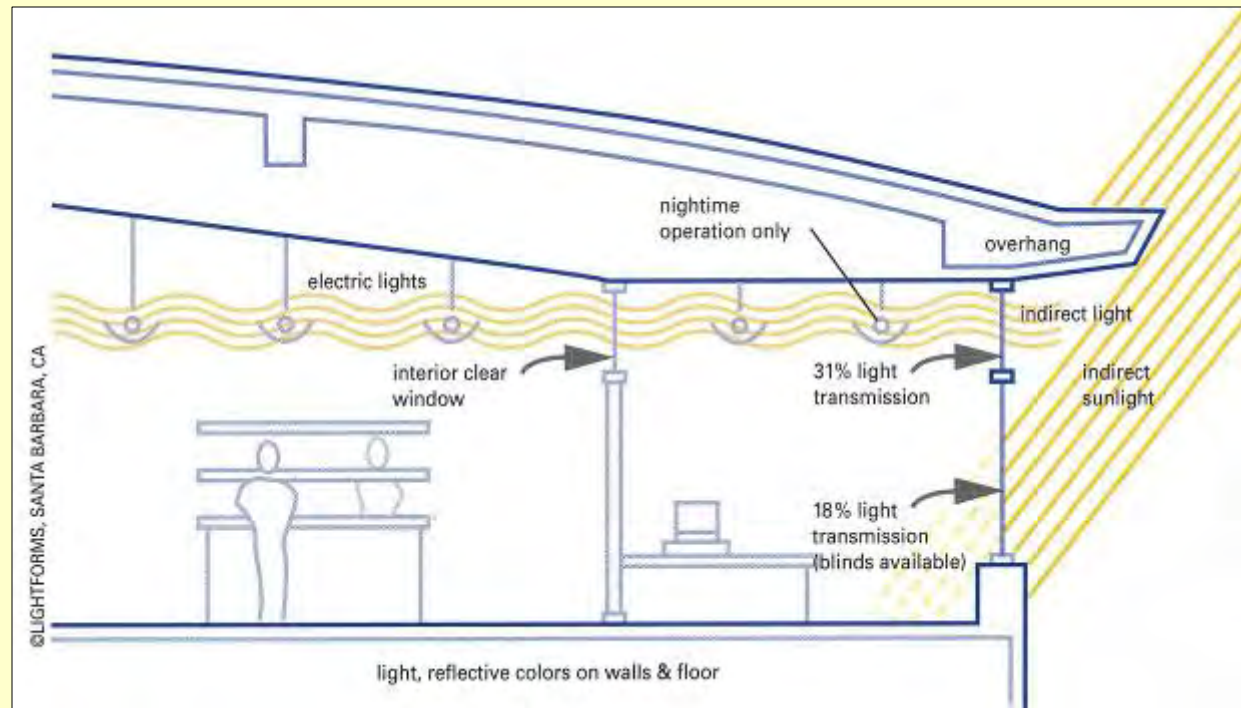
- Daylight Source
- Building Massing
- Building Orientation
- Window size & location
- Sun shading
- Glass types
- Space programming
- Interior surfaces
- Lighting design & control

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

The image shows a webpage titled "design brief DAYLIGHTING" from energydesignresources.org. The page is divided into two main columns. The left column contains a "Summary" section with a sub-heading "Summary" and a paragraph of text. Below the paragraph is a list of six bullet points. The right column contains a "CONTENTS" section with a table of contents listing various topics and their corresponding page numbers.

Summary

Daylighting provides the opportunity for both energy savings and improved visual comfort. Daylight may be introduced into a building using a variety of design concepts, including side lighting and/or toplighting strategies. The level of integration of daylighting into the design can have a profound influence on the architectural form of the building.

When developing a daylighting design, consider the fundamental components of the Daylighting Designer's Toolkit, which includes these six design principles:

- Treat the building as a luminous.
- Separate the view and daylight glazings.
- Position the daylighting apertures to create mood and visual focus.
- Address the requirements of the visual task.
- Integrate the daylighting system with the architecture.
- Integrate the daylighting system with the other building systems.

Care must be taken when developing a daylighting design to minimize direct solar penetration through careful placement of daylighting apertures and the incorporation of shading elements and/or light shelves. Glazing selection is a key consideration in the overall design. Integration with electric lighting, interior design, and mechanical systems also plays an important role in

CONTENTS

Introduction	1
So Important, Our Other Overlooked Daylighting Principles	1
Types of Daylighting Strategies	2
Three Levels of Design Integration in the Daylighting Designer's Toolkit	3
For More Information	46
Index	47

The image shows a webpage titled "Design Guidelines: Daylighting Guidelines" from energydesignresources.org. The page is displayed in a Mozilla Firefox browser window. The page content includes a "Resource Tools" section with links for "Mail", "Print", and "Save to My EDR". Below this is a paragraph of text about sustainable design and daylighting. Further down is a section titled "Daylighting Guidelines is comprised of the following documents:" followed by a list of document titles. At the bottom is a "Related Resources" section with a list of links.

Resource Tools

- [Mail](#)
- [Print](#)
- [Save to My EDR](#)

In a world newly concerned about carbon emissions, global warming, and sustainable design, the planned use of natural light in non-residential buildings has become an important strategy to improve energy efficiency by minimizing lighting, heating, and cooling loads. The introduction of innovative, advanced daylighting strategies and systems can considerably reduce a building's electricity consumption and also significantly improve the quality of light in an indoor environment.

Daylighting Guidelines is comprised of the following documents:

- [Cover/Table of Contents](#)
- [Introduction](#)
- [Daylight in Building Design](#)
- [Performance Parameters](#)
- [Daylighting Systems](#)
- [Daylight-Responsive Controls](#)
- [Design Tools](#)
- [Conclusions](#)

Related Resources

- [Design Guidelines: Skylighting Guidelines](#)
- [Design Briefs: Improving Mechanical System Energy Efficiency](#)
- [Design Briefs: Daylighting](#)
- [Design Briefs: Skylights with Suspended Ceilings](#)
- [Design Briefs: Lighting Controls](#)
- [Design Briefs: Glazing](#)
- [Design Briefs: Building Simulation](#)
- [Online Tools: EDR Charette](#)
- [Software: SkyCalc™](#)
- [Case Studies: Skylighting in Schools - A Healthy Advantage](#)

- Source: _EDR-website-daylighting.jpg

Daylighting

- Resources
- wbdg.org

WBDG - Whole Building Design Guide - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
http://www.wbdg.org/
WBDG - Whole Building Design G...

WBDG

WHOLE BUILDING DESIGN GUIDE

- Design Guidance
 - Building Types
 - Space Types
 - Design Disciplines
 - Design Objectives
 - Products & Systems
- Project Management
 - Delivery Teams
 - Planning & Development
 - Building Commissioning
 - Delivery & Controls
- Operations & Maintenance
- Mandates / References
 - Federal Mandates
 - Publications
 - Case Studies
 - Participating Agencies
 - Industry Organizations
 - Related Links
- Tools
- WBDG Services
 - CONSTRUCTION CRITERIA BASE
 - productguide
 - Visit WBDG Partners:
 - GreenerBuildings
 - US The Source for Critical Information and Insight™
 - SUSTAINABLE BUILDINGS INDUSTRY COUNCIL
 - National Institute of BUILDING SCIENCES

The Whole Building Design Guide

The Gateway to Up-To-Date Information on Integrated 'Whole Building' Design Techniques and Technologies

THE WHOLE BUILDING DESIGN APPROACH

The goal of 'Whole Building' Design is to create a successful high-performance building. To achieve that goal, we must apply the integrated design approach and the integrated team approach to the project during the planning and programming phases. [Read more](#)

FEMA Releases New Natural Hazards Protection Criteria

FEMA recently released two new criteria documents on natural hazard mitigation: *FEMA 454 Designing for Earthquakes: A Manual for Architects* and *FEMA 543 Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and Buildings*. These documents and more are referenced in the WBDG page [Resist Natural Hazards](#).

6th Annual TISP Congress

The TISP Congress, being held March 28-29, is an annual event that brings together leaders in the public and private sectors taking a proactive approach to improving the resilience of our nation's critical infrastructure and key assets. Now in its 6th year, the TISP Congress is affecting positive change through information sharing and collaboration. [Read more](#)

New Suite of Stormwater Management Guide Specifications Available for Comment

The Federal Green Construction Guide for Specifiers now includes new DRAFT sections covering:

- constructed wetlands,
- rainwater harvesting,
- stormwater management with compost, and
- green roofs (both vegetation and membranes).

WBDG Focus

Journal of Building Enclosures
The Building Enclosures Journal, published by The National Institute of Building Sciences, announces the content of the next issue. Publishing in the print and online formats, the journal focuses on the design of building enclosures—the premise of the building enclosure. [Read more](#)

WBDG Quick Links

Below are a selection of WBDG resources requested by users:

- [Construction Criteria Base \(CCB\)](#)
- [Construction Waste Management](#)
- [Building Envelope Design Guide](#)
- [Federal Green Construction Guide](#)
- [Unified Facilities Criteria](#)
- [Unified Facilities Guide Specifications](#)

New and Updated WBDG The Sustainable Design Objectives Guidance

To better reflect the interrelated nature of the Sustainable Design Objectives content and Resource Guidance and the Federal Green Construction Guide, the WBDG Sustainable Design Objectives Guidance has been updated to incorporate the Federal Green Construction Guide for Specifiers sections in approval.

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

Daylighting

- Resources
- eere.energy.gov

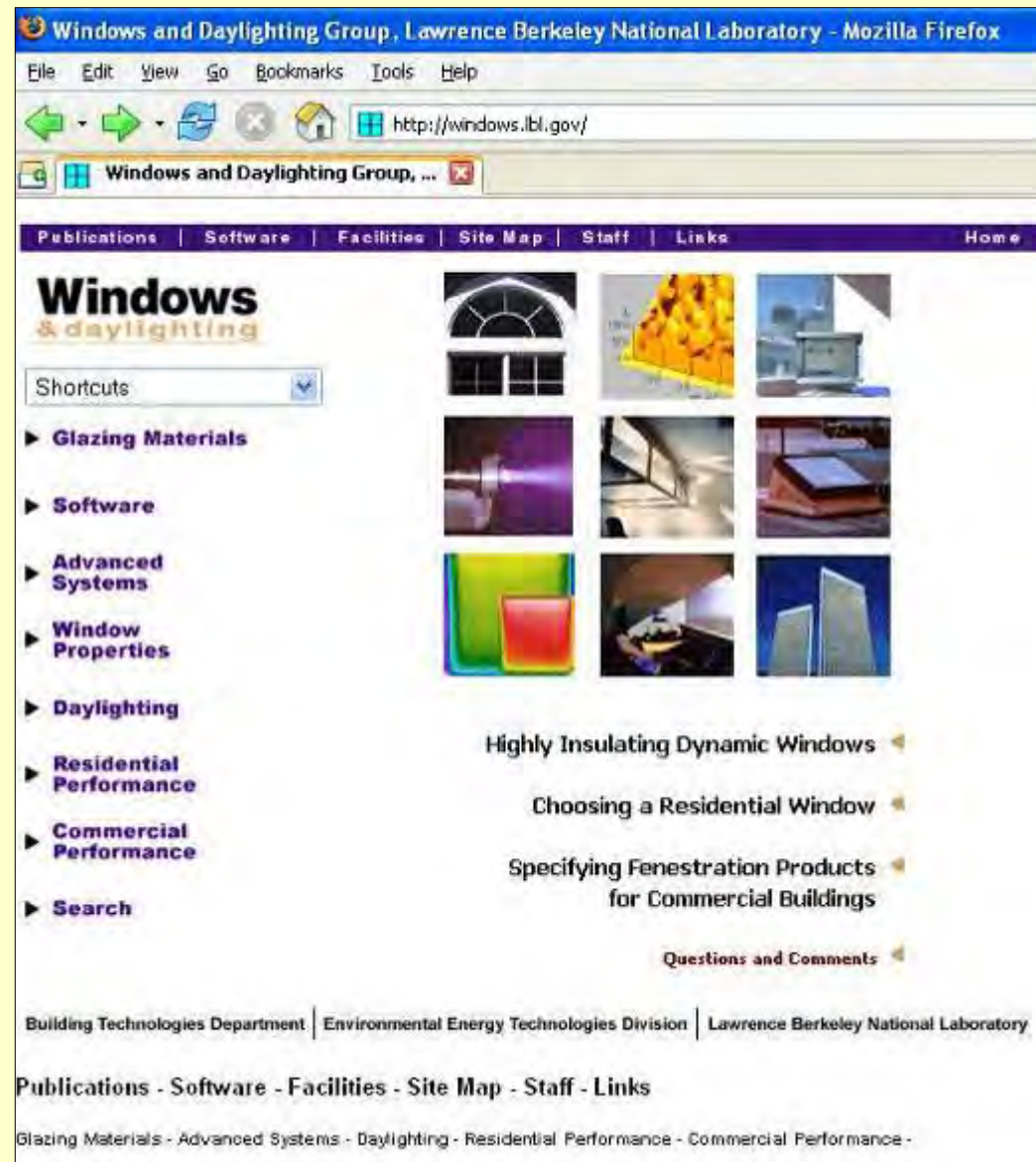


The screenshot shows a web browser window with the address bar displaying <http://www.eere.energy.gov/buildings/info/design/integratedbuilding/passivedaylighting.html>. The page header includes the U.S. Department of Energy logo and the text "Energy Efficiency and Renewable Energy" with the tagline "Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable". Below this is a green banner for the "Building Technologies Program" and a navigation menu with links: "About the Program", "Program Areas", "Information Resources", "Financial Opportunities", "Technologies", "Deployment", and "Home". The main content area is titled "Building Toolbox" and features a sidebar with categories: "Plan & Finance", "Design, Construct & Renovate", "Choose Building Components", and "Operate & Maintain". The "Design, Construct & Renovate" category is expanded to show sub-items: "Whole Building Design", "Building Siting", "Integrated Building Design", "Configuration & Placement", "Design Tools", "Passive Solar", "Building Envelope", "Active Solar Systems", "Photovoltaics", "Appliances & Equipment", "Lighting", and "Building Materials". The "Lighting" sub-item is further expanded to show "Construction" and "Renovation". The "Daylighting" section is highlighted in red and contains the following text: "When properly designed and effectively integrated with the electric lighting of the electric lighting load. A related benefit is the reduction in cooling ca to energy savings, daylighting generally improves occupant satisfaction an daylighted schools and offices. Windows also provide visual relief, a conta egress." Below this text is a list of links: "The Daylight Zone", "Window Design Considerations", "Effective Aperture", "Light Shelves", "Toplighting Strategies", "Daylighting Controls", "Design Coordination", and "Modeling Daylighting". The "The Daylight Zone" link is selected, and the text below it reads: "The Daylight Zone High daylight potential is found particularly in those spaces that are pred "seen" from the various potential window orientations. What proportion of sources? Is your building design going to shade a neighboring building or la

- Source: DOE-EERE-website.jpg

Daylighting

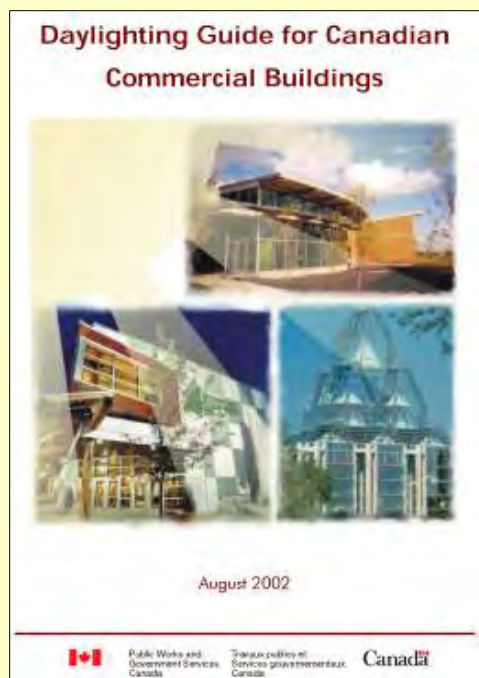
- Resources
- windows.lbl.gov



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

Daylighting

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



Advanced Building Technologies - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://www.advancedbuildings.org/

Advanced Building Technologies

90 technologies and practices that improve the energy and resource efficiency of commercial and multi-unit residential buildings

ADVANCED BUILDINGS Technologies & Practices

- Building Structure
- Finishes & Furnishings
- Heating & Cooling
- Plumbing & Water Heating
- Lighting & Daylighting
- Load Management
- Electricity Production
- Ventilation & Air Quality
- Site Services
- Motors & Equipment

CASE STUDIES **INFO SOURCES** **SEARCH** **CONTACT US**

A building professional's guide to more than 90 environmentally-appropriate technologies and practices. Architects, engineers and buildings managers can improve the energy and resource efficiency of commercial, industrial and multi-unit residential buildings through the use of the technologies and practices described in this web site. The following design and construction issues are covered:

- indoor air quality
- water conservation
- waste management
- electricity production
- non-toxic materials
- recycled materials
- daylighting
- energy efficiency

- 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

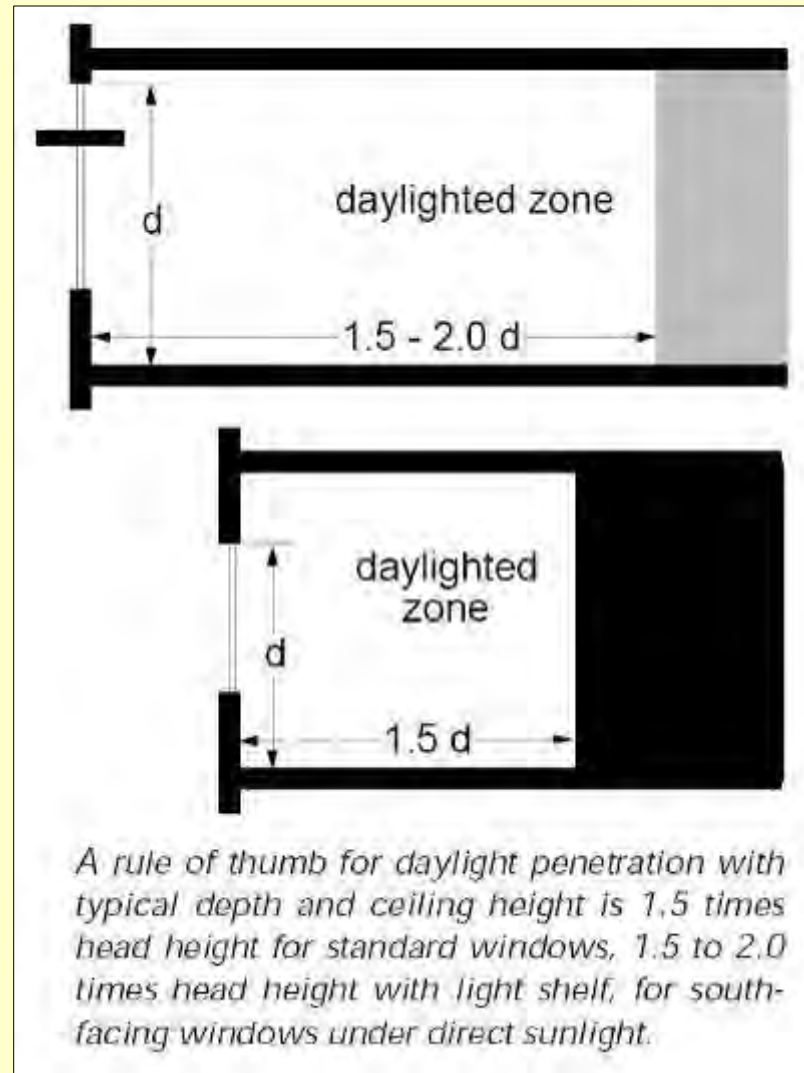
In addition to above:

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

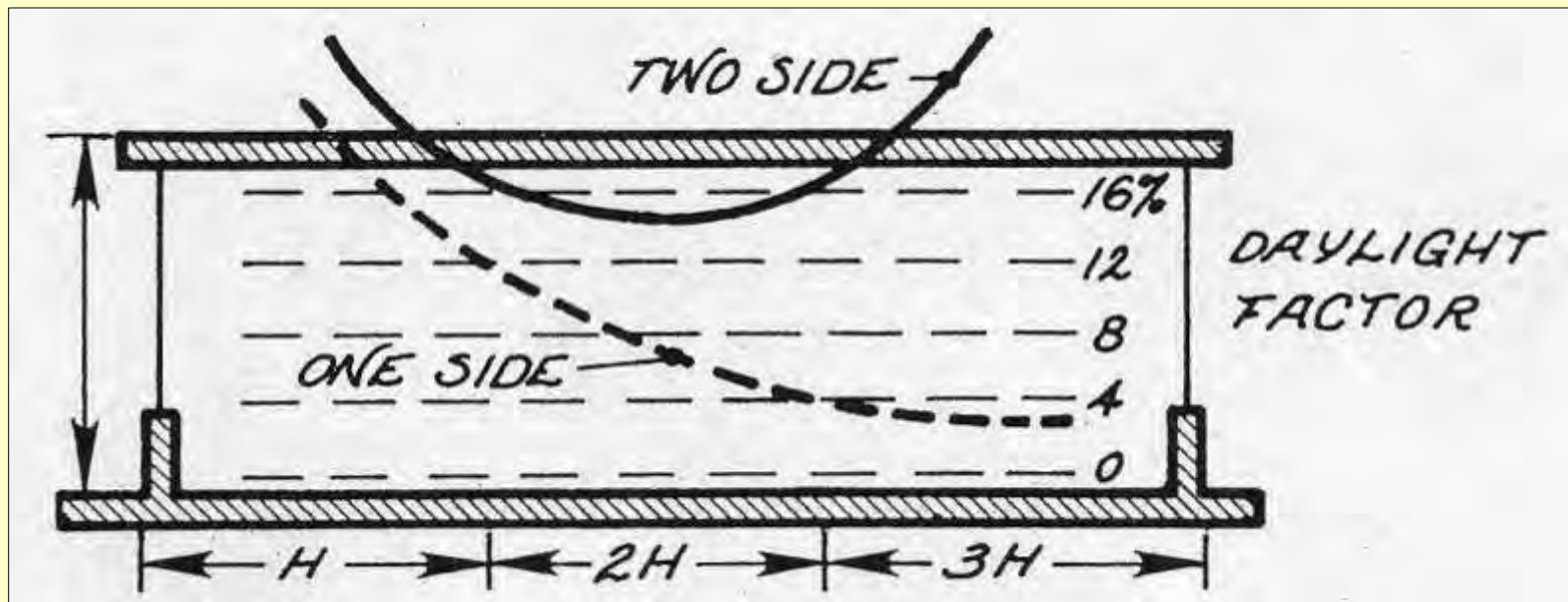
Daylighting

- Best Practices
- Side-lighting



Daylighting

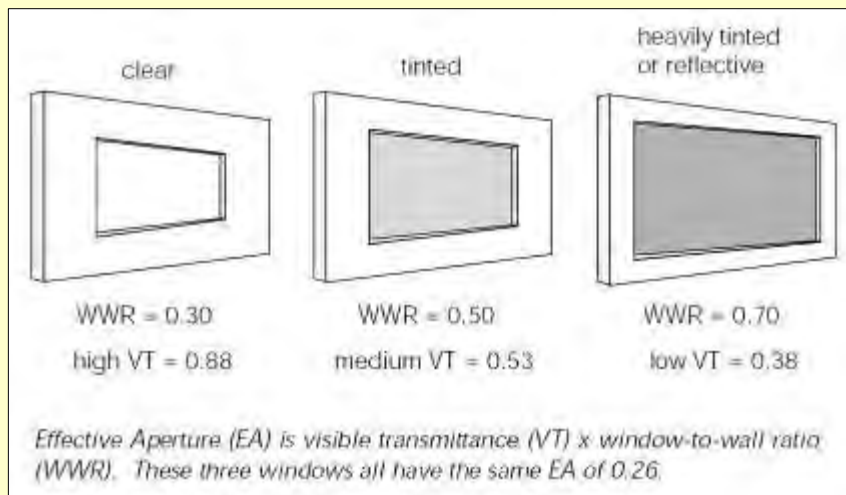
- Best Practices
- Side-lighting



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

Daylighting

- Best Practices
- Side-lighting



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

Daylighting

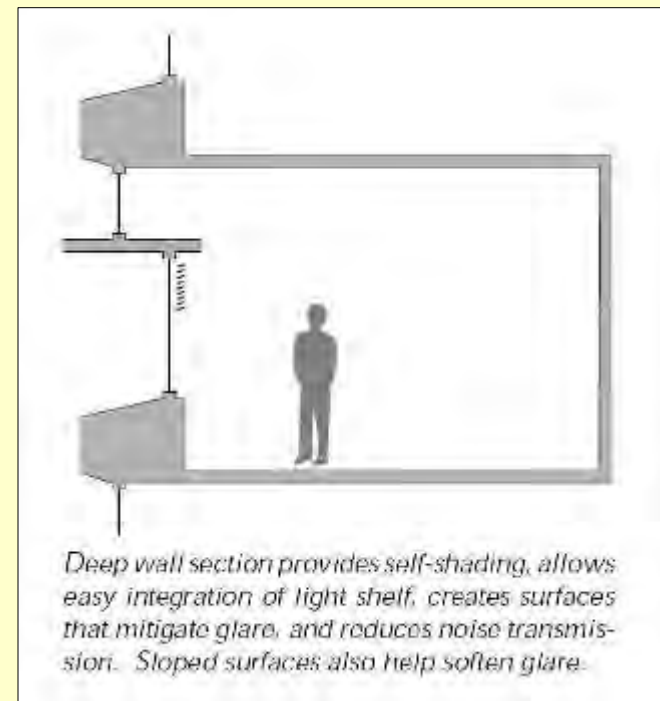
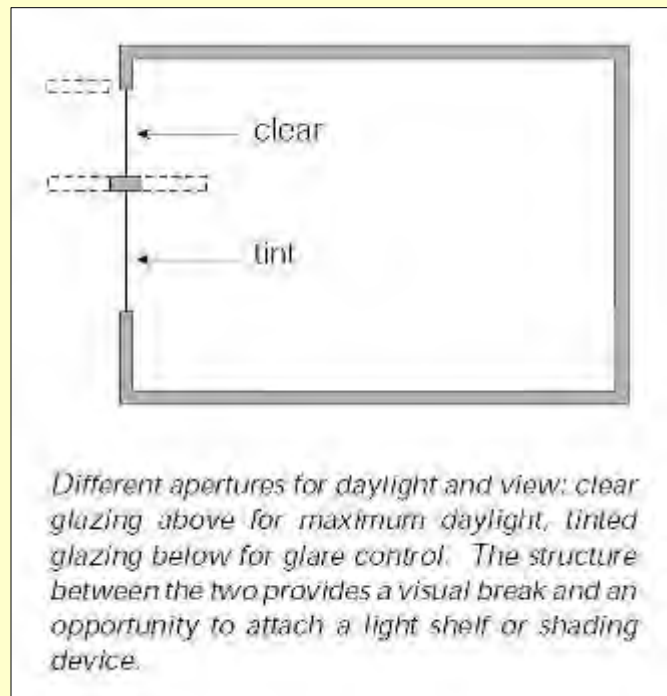
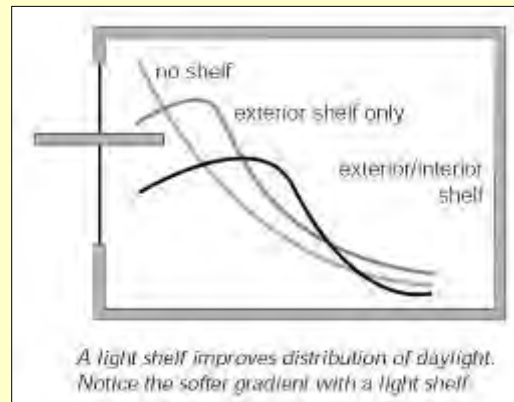
- Best Practices
- Side-lighting



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

Daylighting

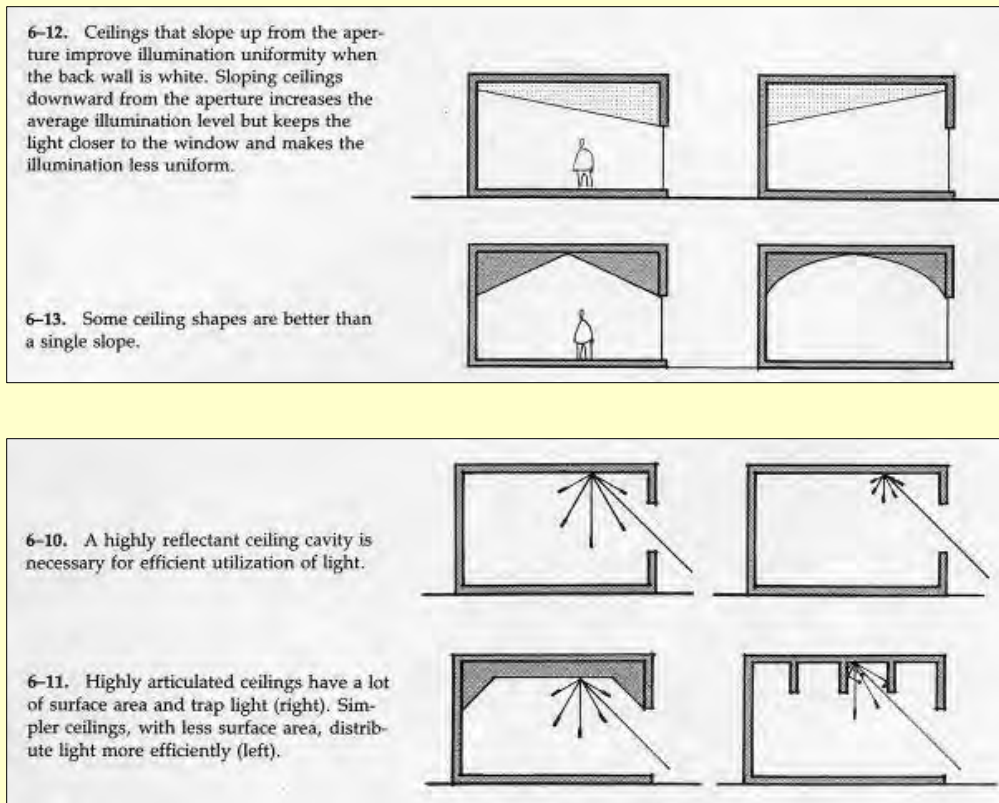
- Best Practices
- Side-lighting



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

Daylighting

- Best Practices
- Side-lighting



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

Daylighting

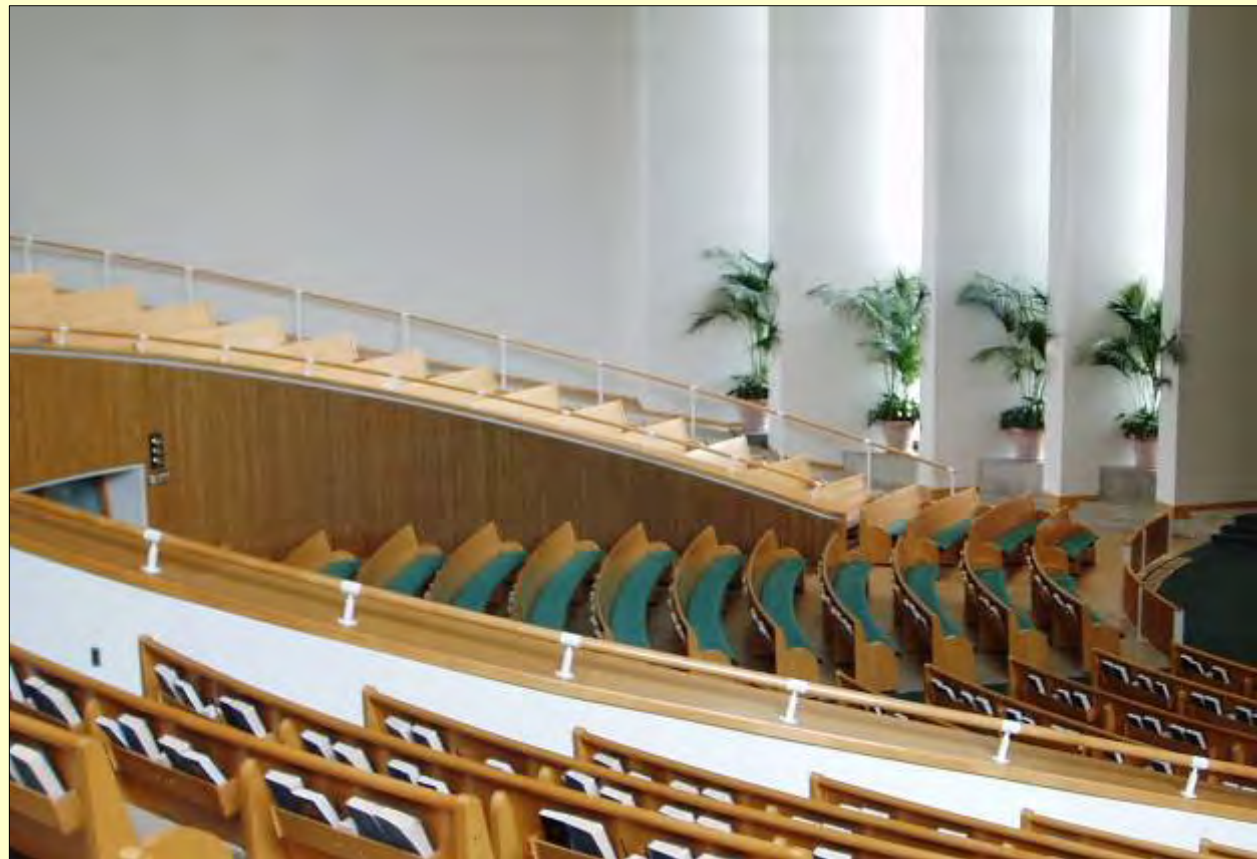
- Best Practices
- Side-lighting



- 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

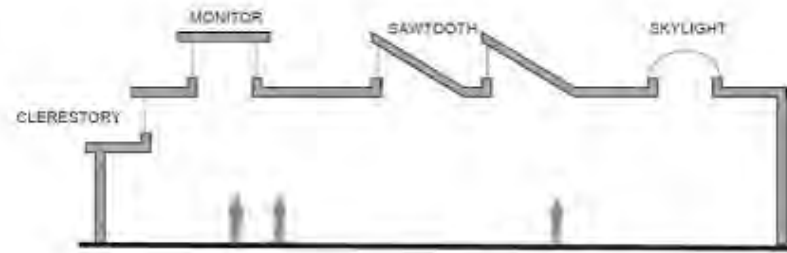


- Source: Columbus-IN-Cummins-Main-HQ-Office-5.JPG

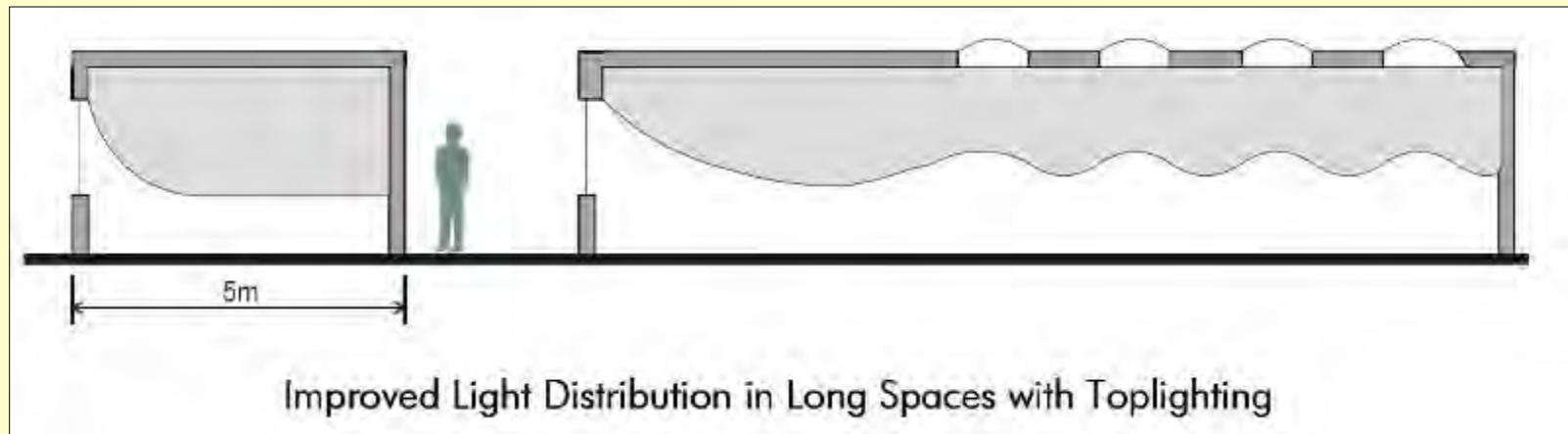
Daylighting

- Best Practices
- Top-lighting

There are several toplighting methods including skylights, monitors and clerestories. The following diagram illustrates the various toplighting possibilities. The sawtooth is a variation of a clerestory.



Example of Toplighting Strategies

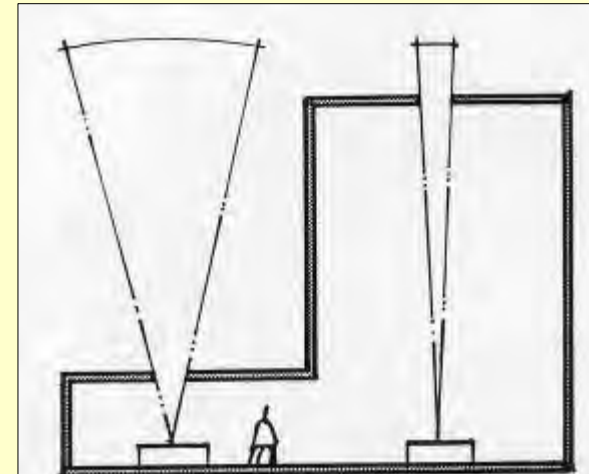


Improved Light Distribution in Long Spaces with Toplighting

- Source: [Canada-Daylighting-Guide-toplighting-1.jpg](#)

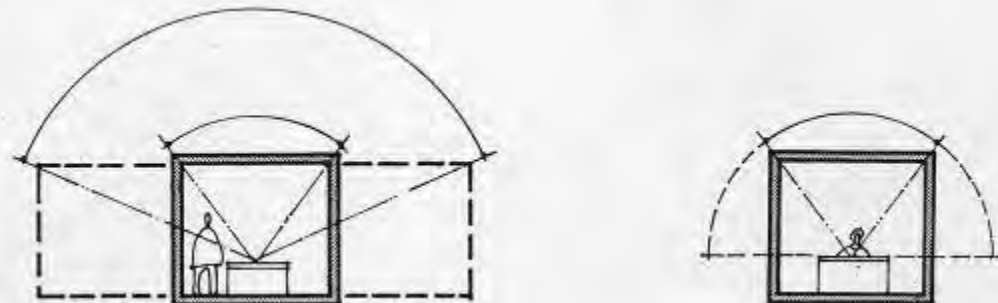
Daylighting

- 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' x 4' skylight is a point source; at a few feet, it is an area source.

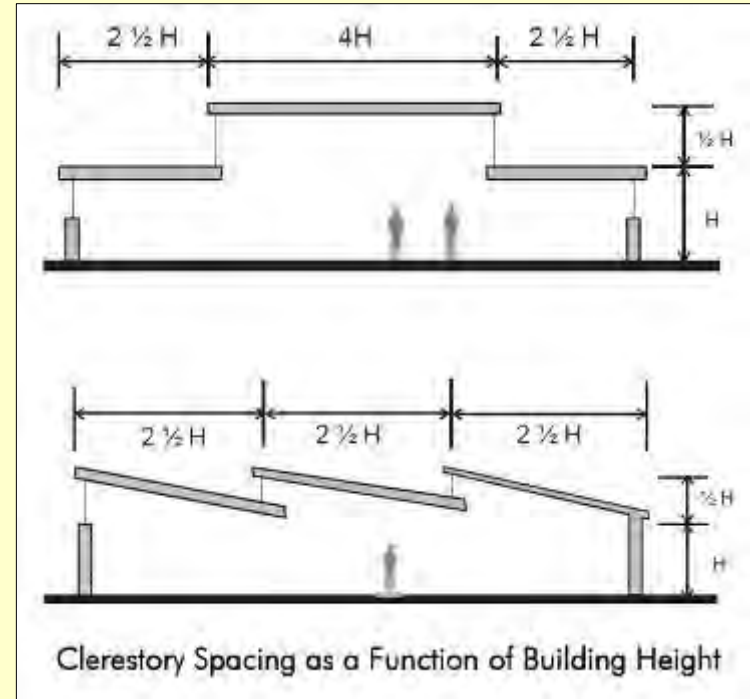
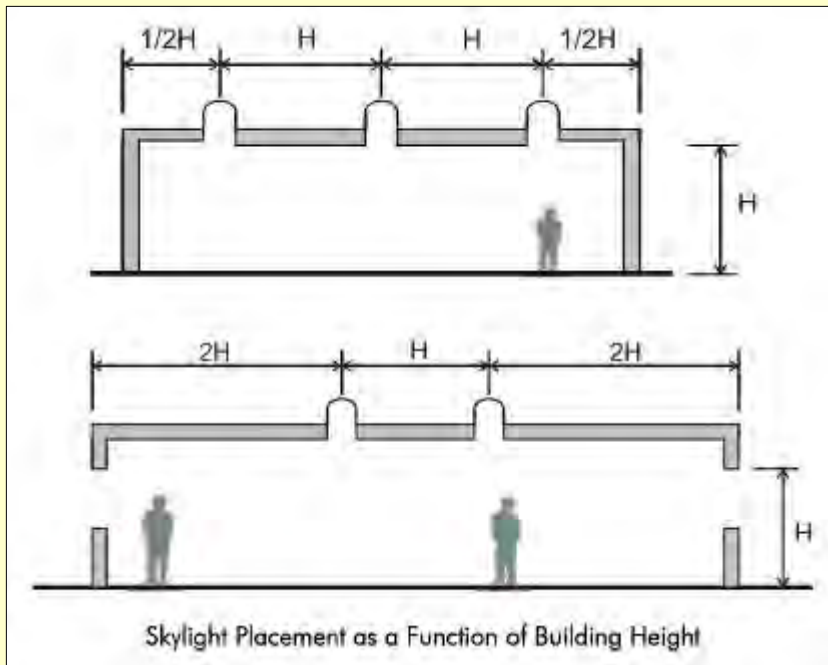
3-6. The ceiling of a small room must have a much higher luminance than that of a large room with wider proportions to produce equal illumination.



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

Daylighting

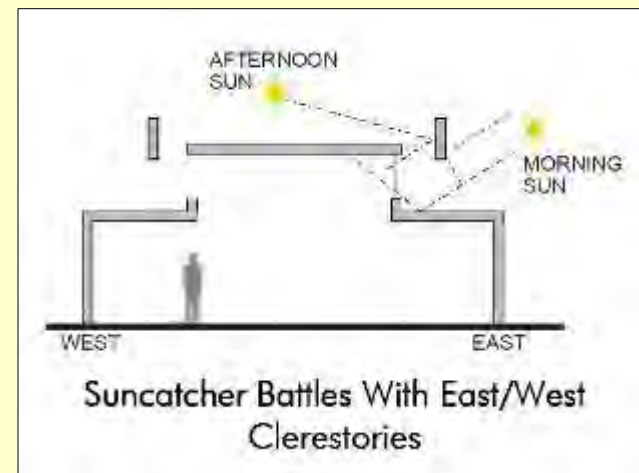
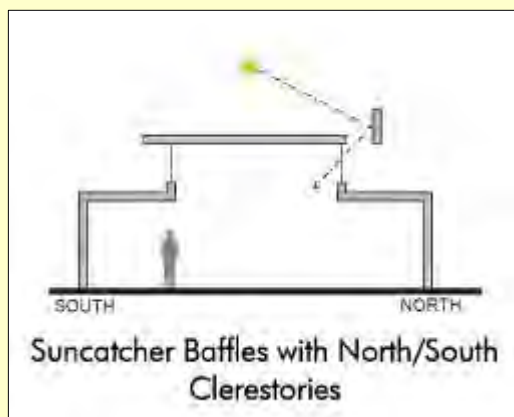
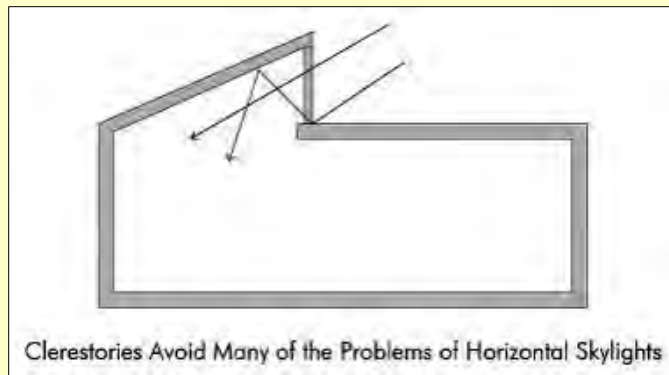
- Best Practices
- Top-lighting



- Source: [Canada-Daylighting-Guide-toplighting-3.jpg](#)

Daylighting

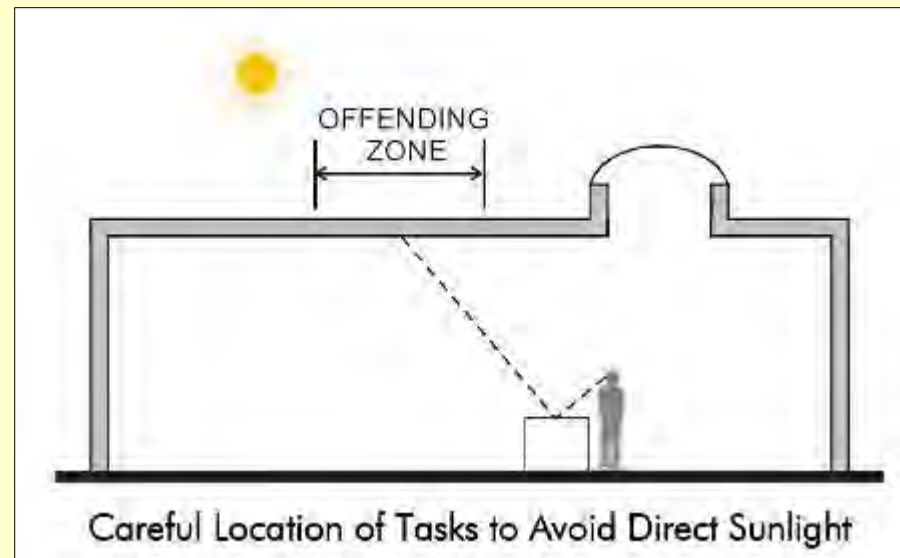
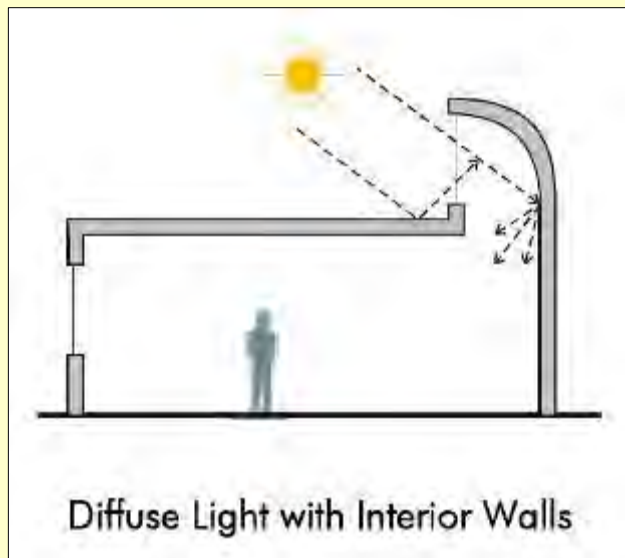
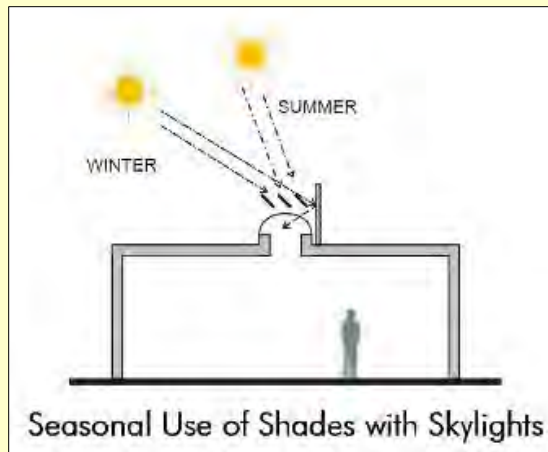
- Best Practices
- Top-lighting



• Source: [Canada-Daylighting-Guide-clerestories-2.jpg](#)

Daylighting

- Best Practices
- Top-lighting



- 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

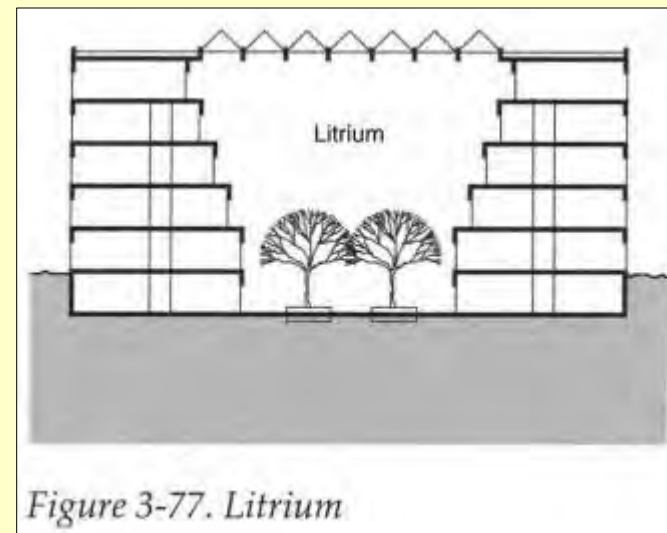
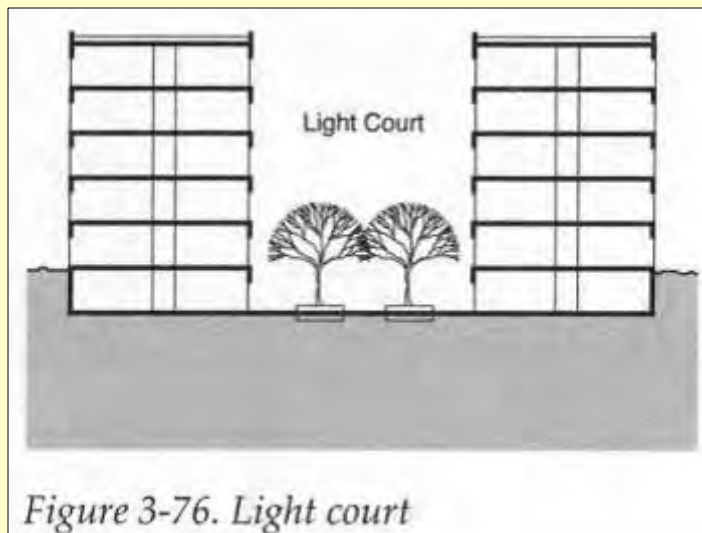
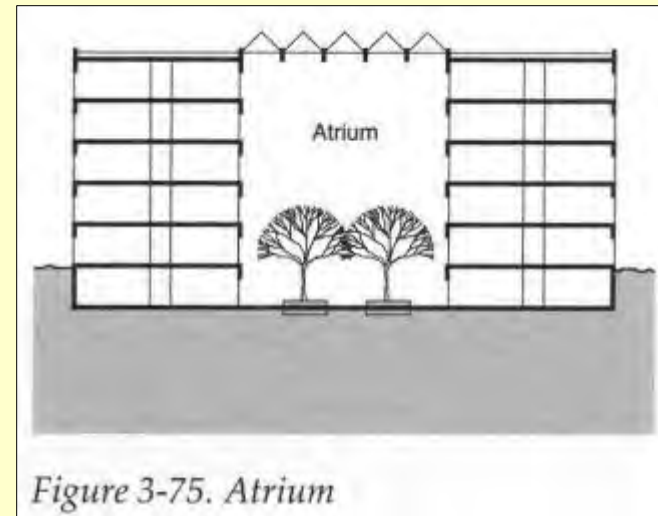
- Best Practices
- Top-lighting
- Side-lighting
- Clerestories
- Skylights w/diffusers



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

Daylighting

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



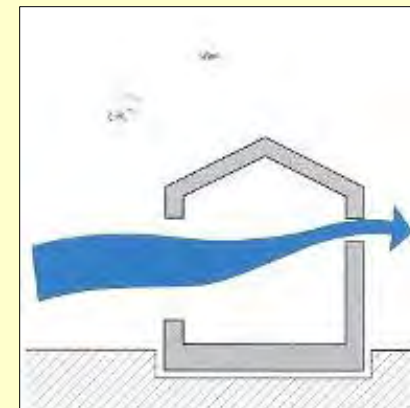
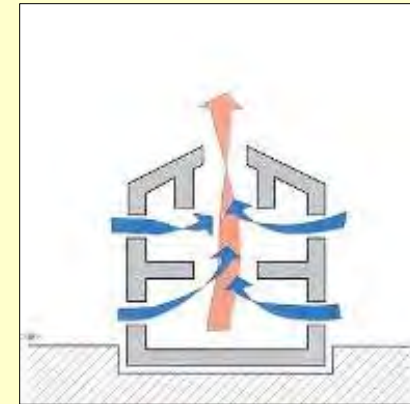
Ventilation and passive cooling



Stack Effect

Passive Ventilation

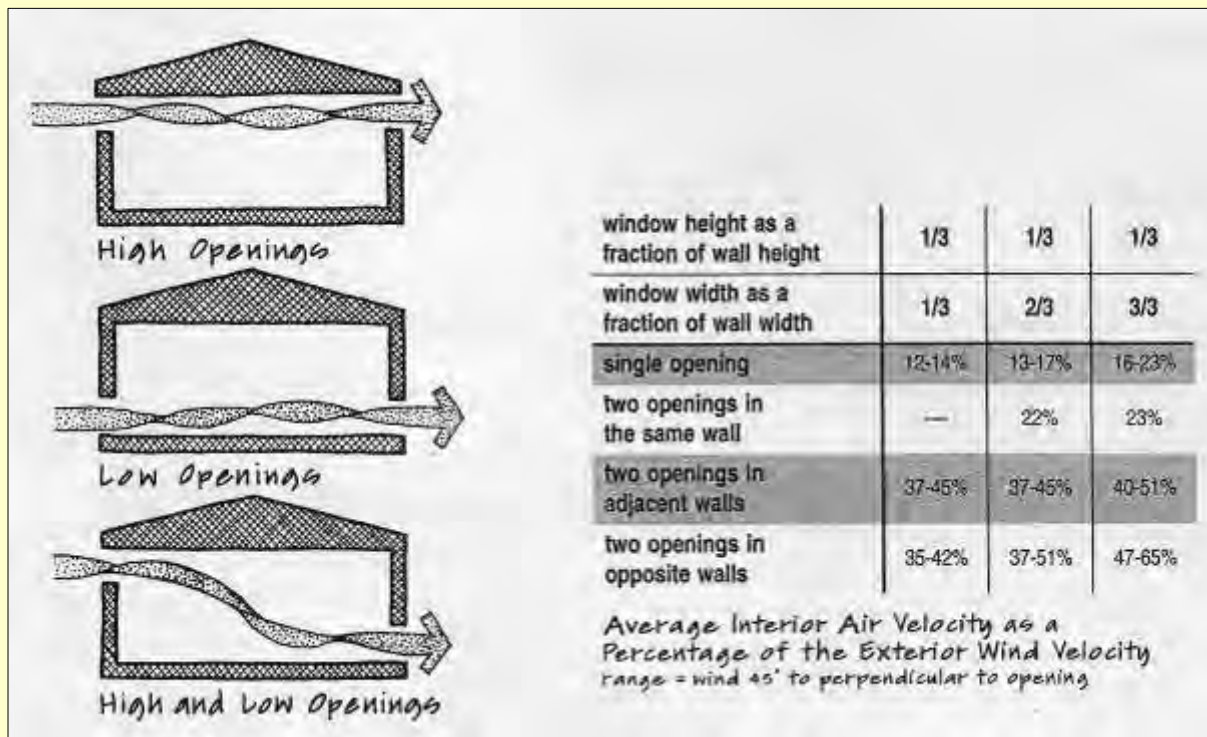
– Belvedere



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

Passive Ventilation

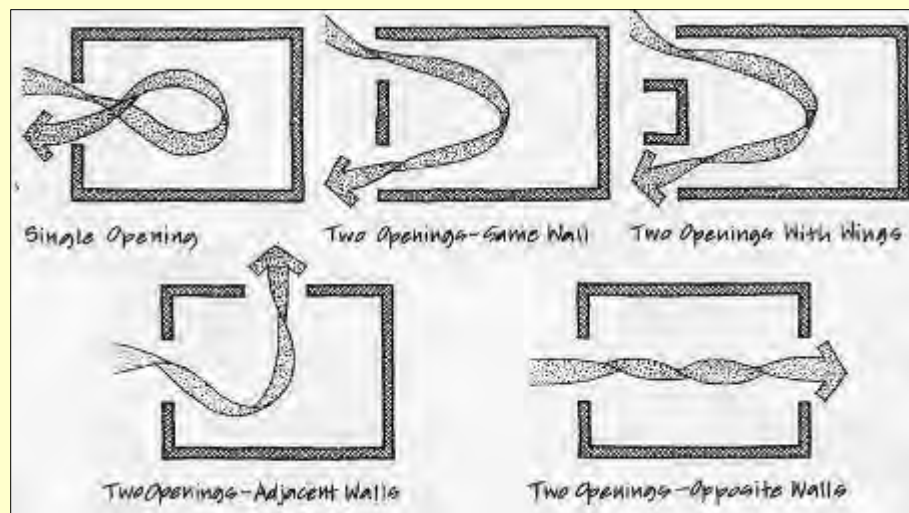
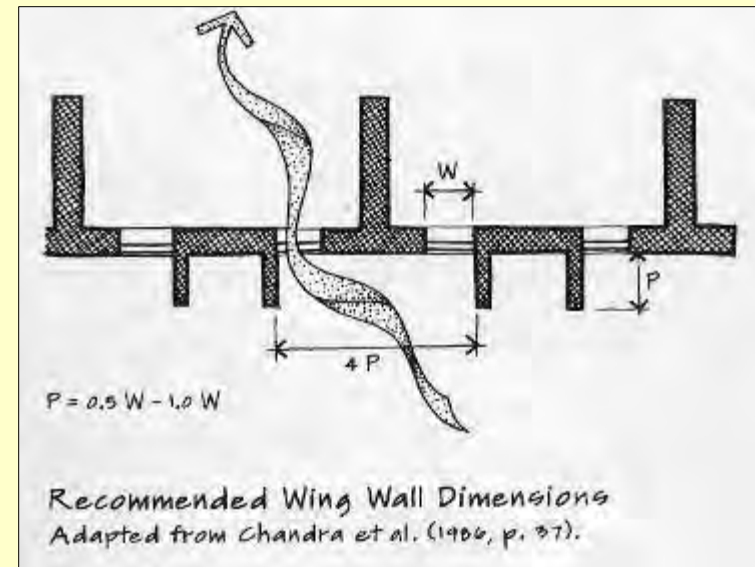
- Cross-ventilation
- Opening area



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

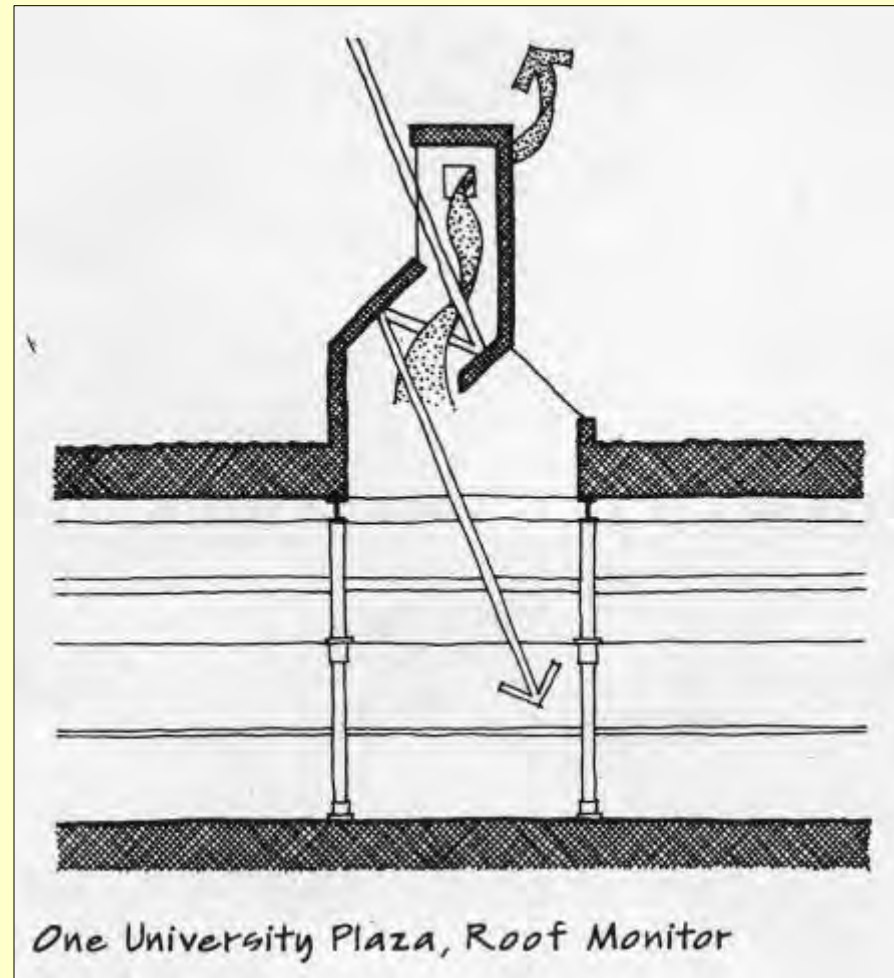
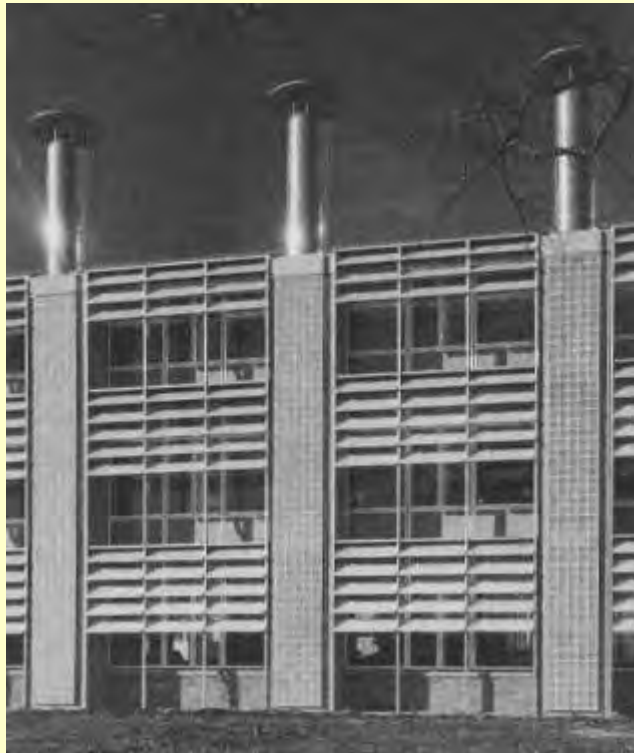
Passive Ventilation

- Cross-ventilation
- Configurations
- Wing Wall Deflection



Passive Ventilation

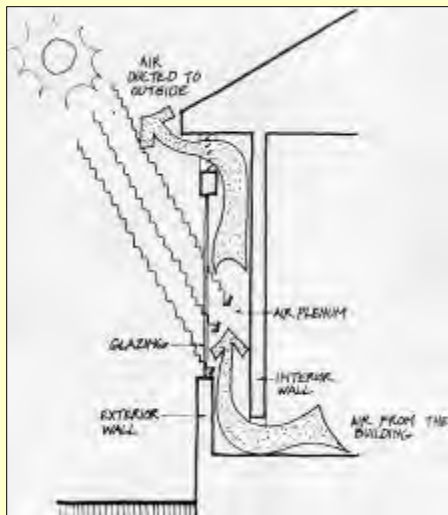
- Solar Chimney
- Stack Effect
- Exterior Sunshades



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

Passive Ventilation

- Example
- BedZED



Carbon-Neutral Neighborhood

> BILL DUNSTER ARCHITECTS ZEDFACTORY / BEDZED / SUTTON, ENGLAND

- 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

Passive Ventilation

– Guidelines

Window Orientation & Configuration

- 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

Passive Ventilation

– Guidelines

Mechanically-assisted Ventilation

- 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

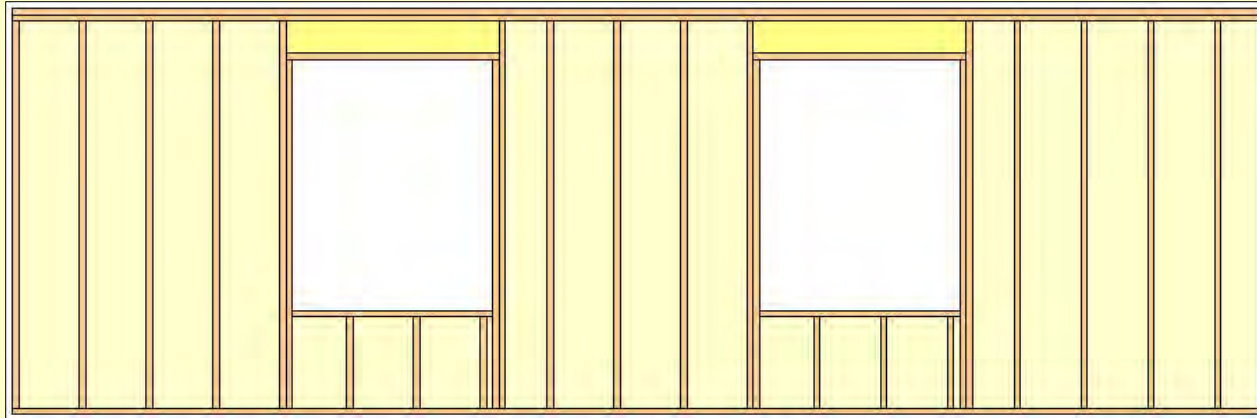
Earth Cooling

- 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

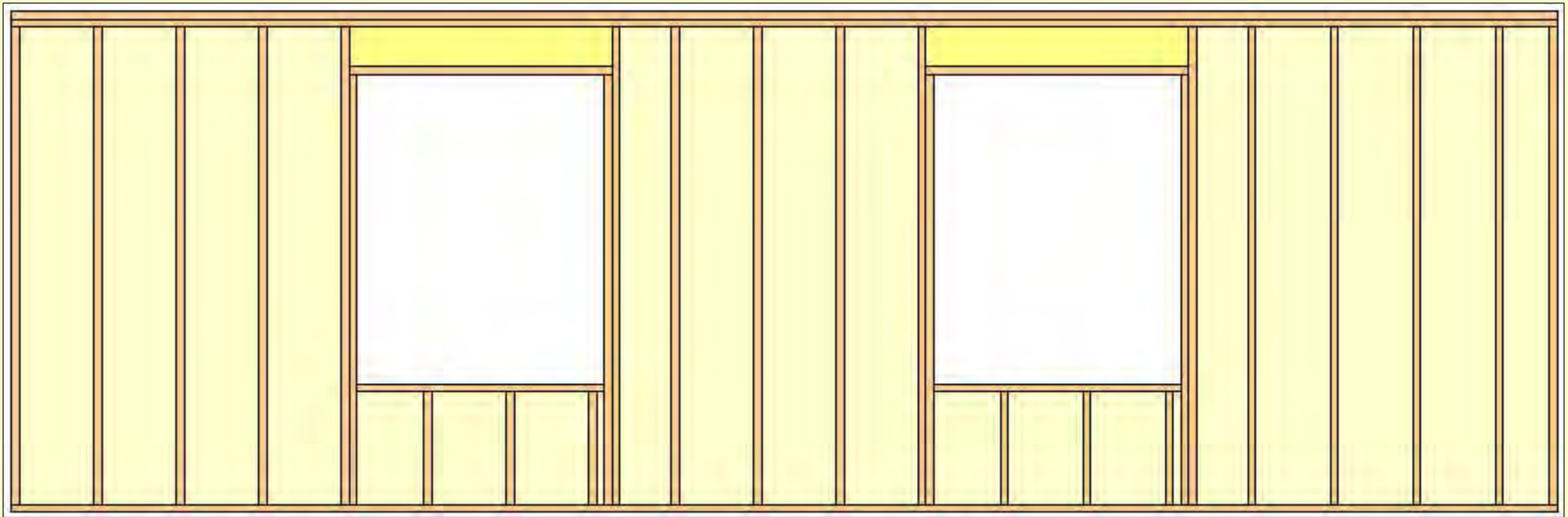
Building envelope

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

Conventional Wood-Framing Issues:

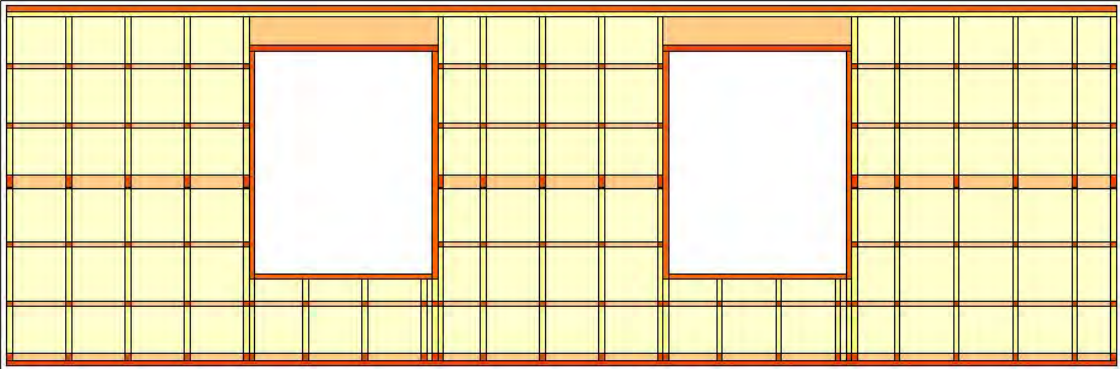
- Solid Content of Framed Wall
- Box Sill @ Foundation/ First Floor Deck
- Box Sill @ Second Floor Deck
- Interior Partition Wall @ Ceiling/ Roof Framing
- Interior Partition Wall @ Exterior Wall
- Sloped Ceiling/ Roof Cavity
- Window & Door Rough Openings
- Electrical Boxes @ Exterior Walls & Ceilings

2x6 Conventional Wall



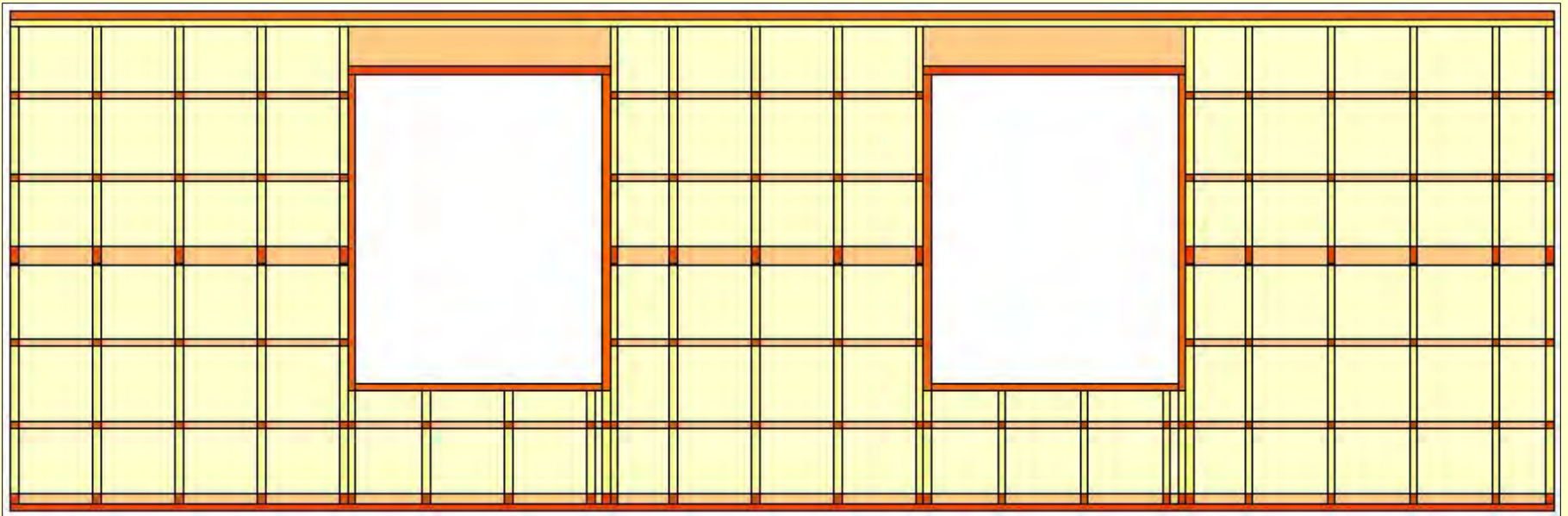
Conventionally-framed 2x6 Wall
(15-25% solid wood, thermally-conductive)

Modified wood-frame construction

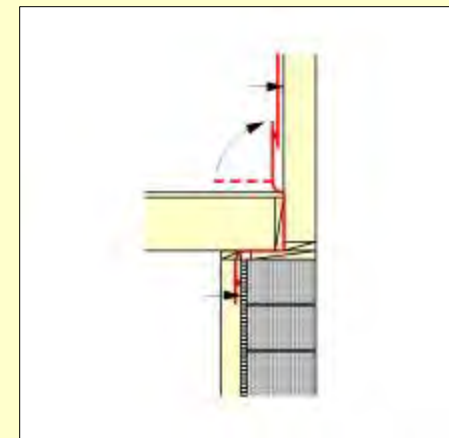
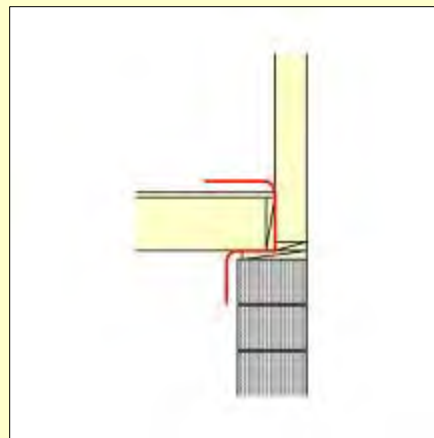
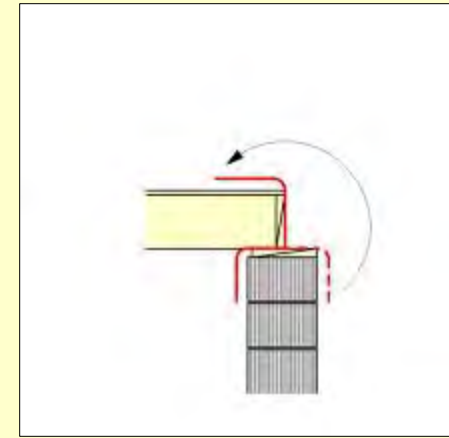
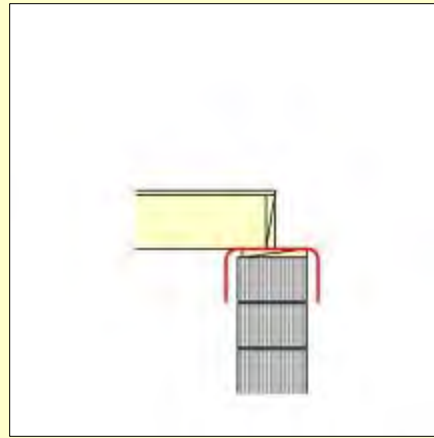
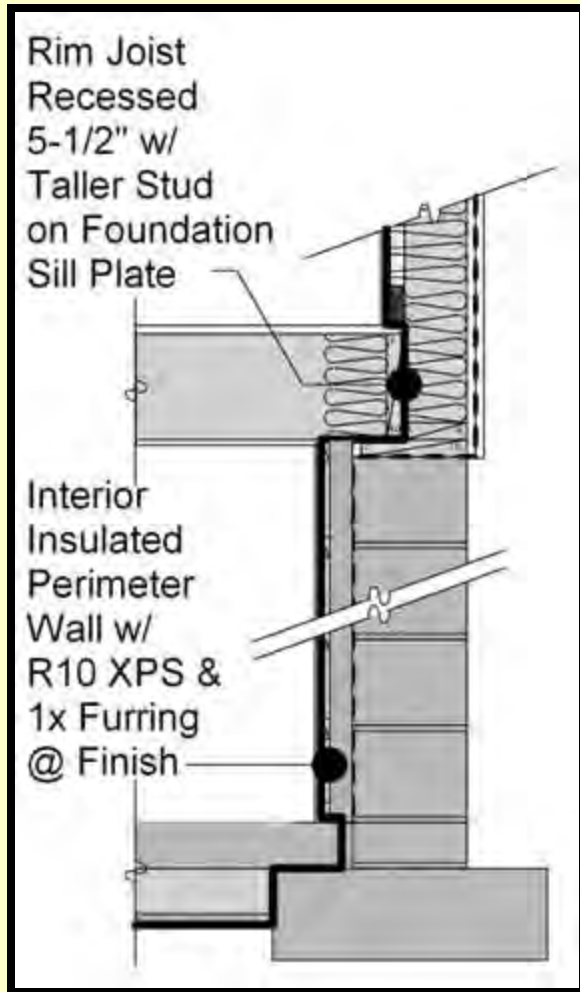


Interior-strapped 2x wood framing

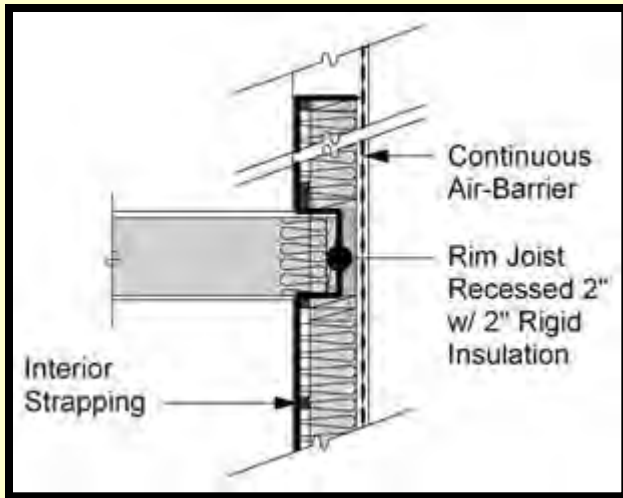
2x6 Interior Strapped-Wall



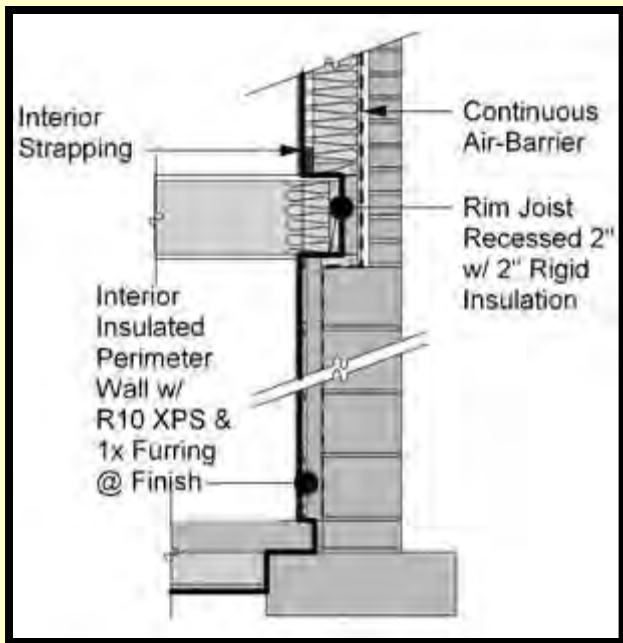
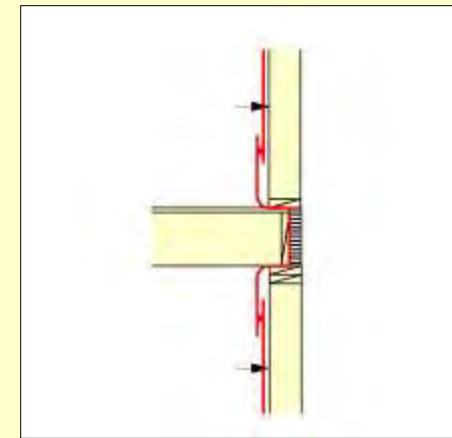
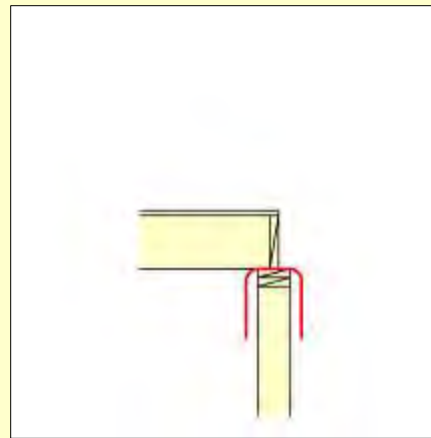
Interior Horizontal Strapped 2x6 Wall
(6-12% solid wood, thermally-broken)



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

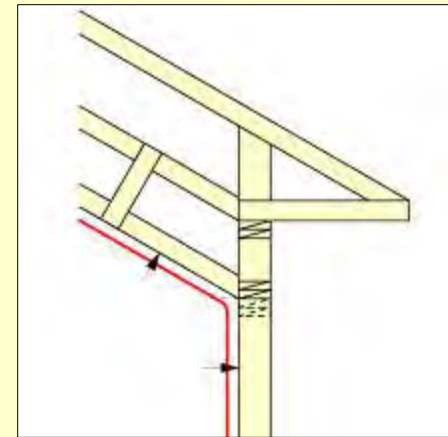
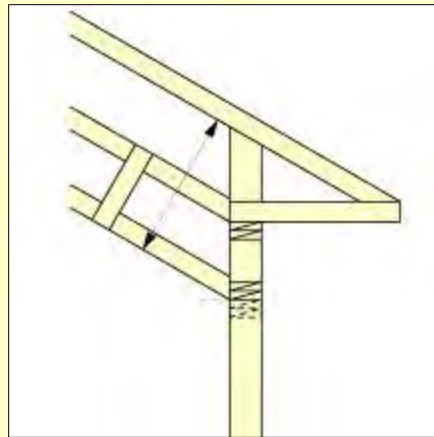
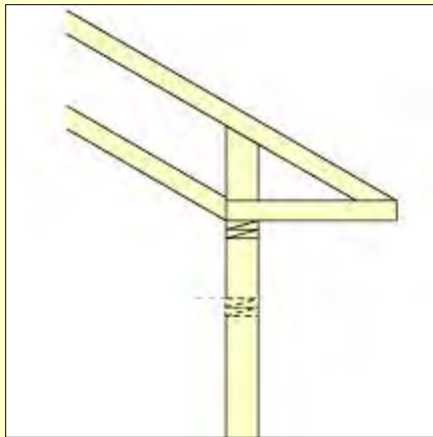
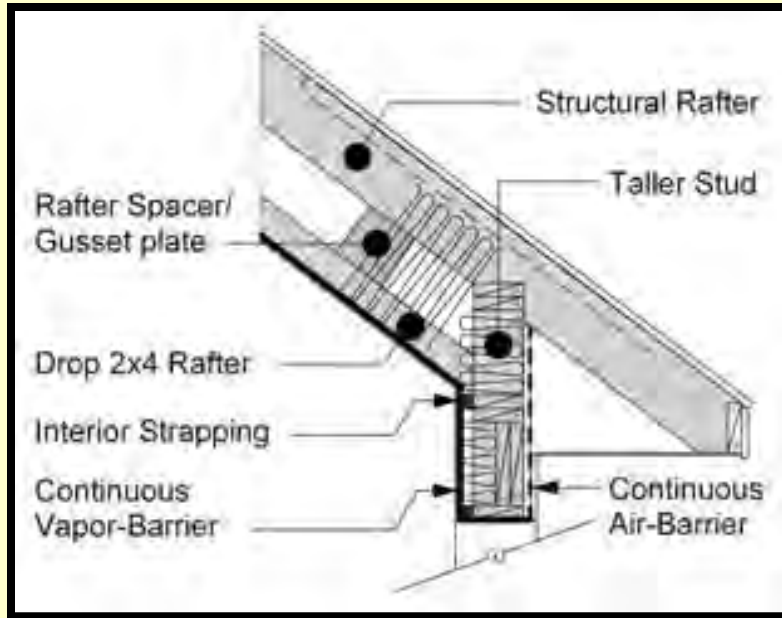


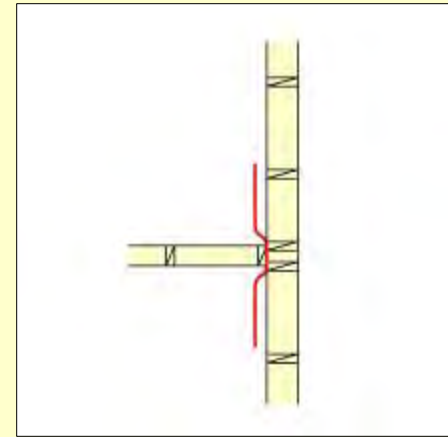
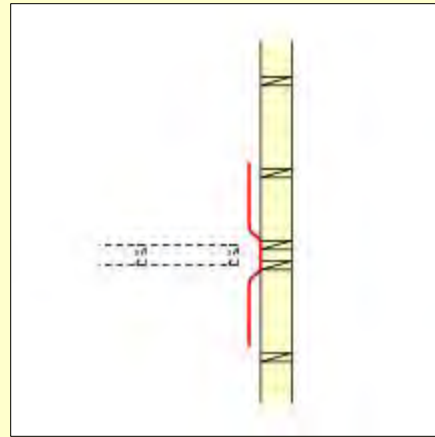
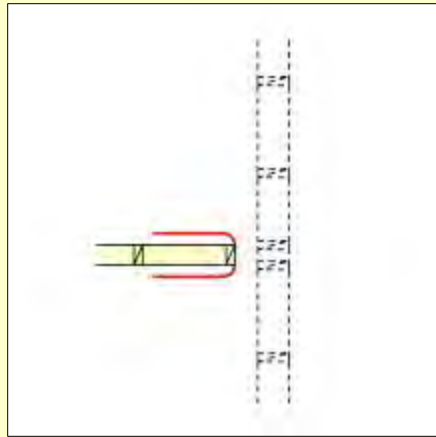
Recessed Floor Deck @ Wood-frame Bearing Wall w/ 2" Recessed Rim Joist & Masonry Veneer



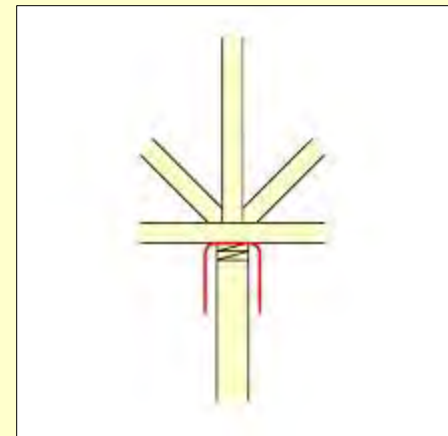
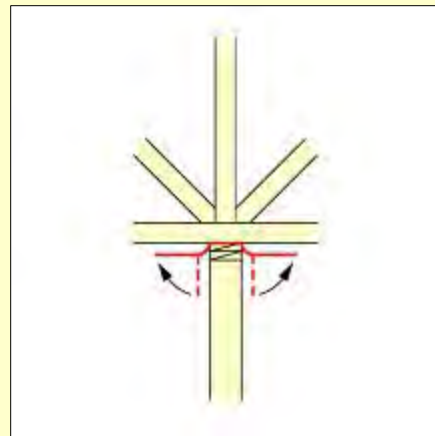
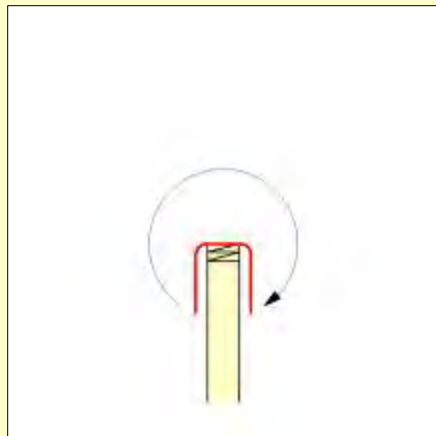
Recessed Floor Deck @ Masonry Foundation Wall w/ 2" Recessed Rim Joist & Masonry Veneer

Sloped Ceiling w/ Stick Framing & Drop Rafter

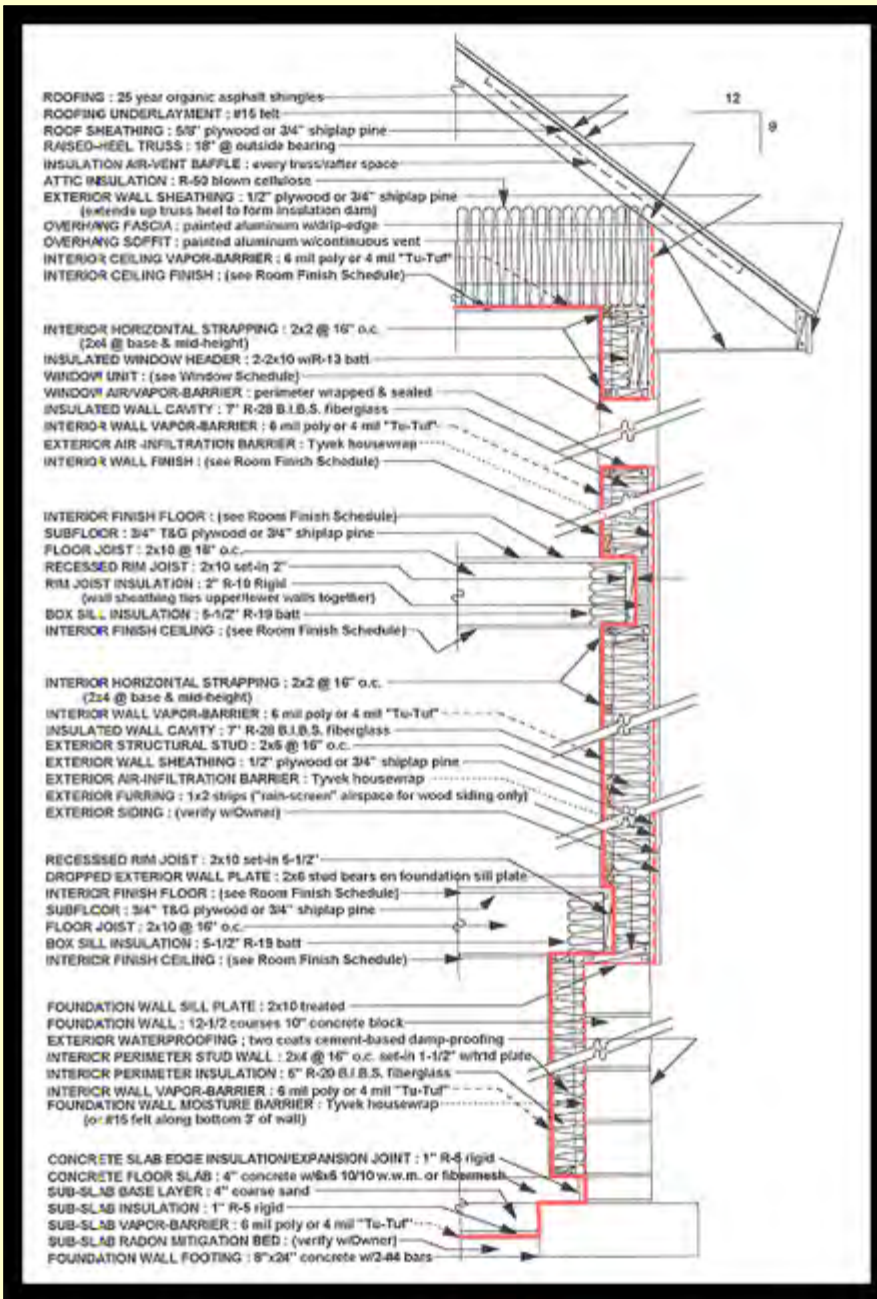




Interior Wall @ Exterior Wall



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

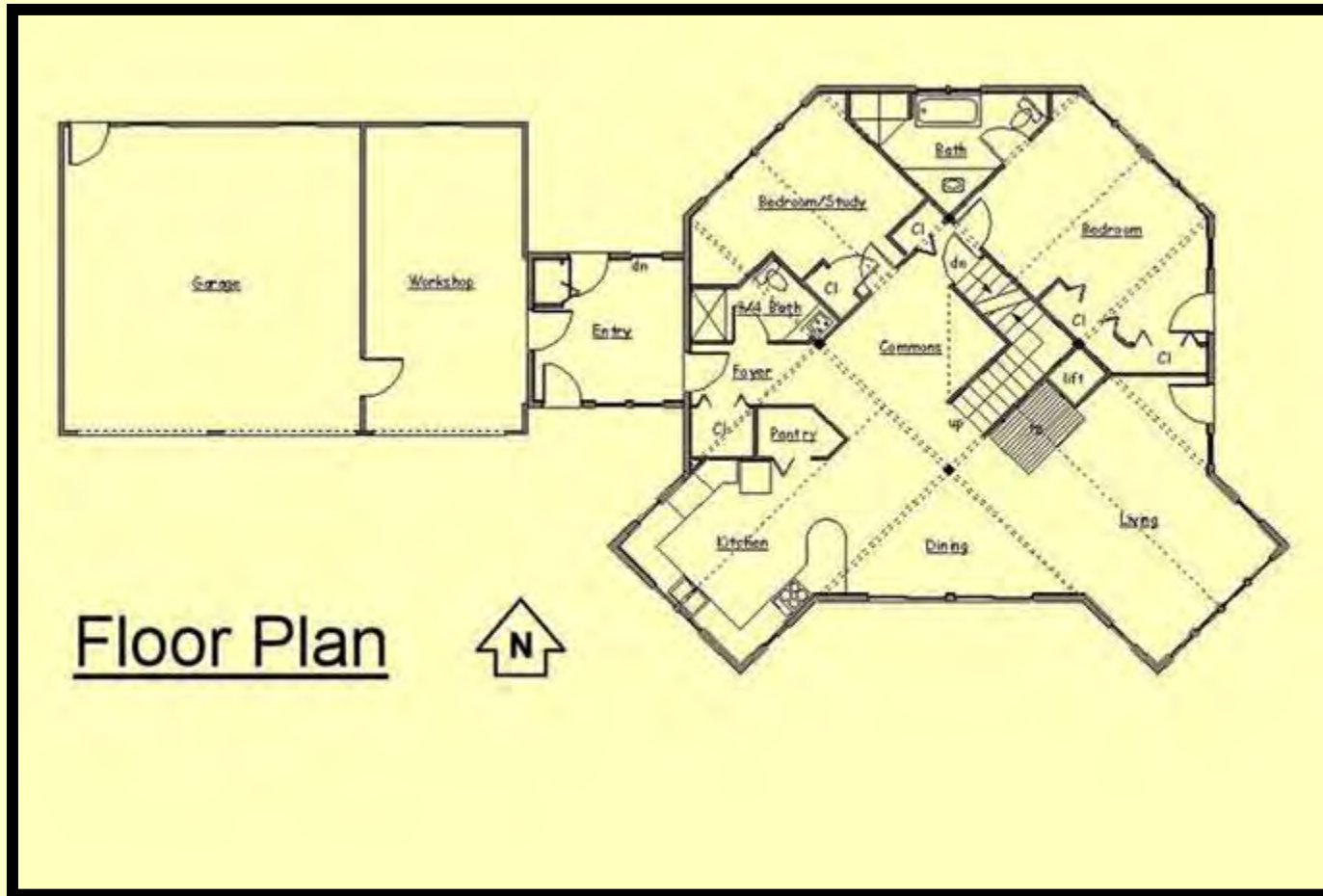
Sullivan Residence



**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		OFF Peak \$.02200 - .06182/kwh		TOTAL (combined)		MMBTU 3.413 / kwh	HDD	BTU/HDD	BTU / HDD / SQ FT	Steady-State Heatloss BTUH @-20deg	Avg Normal Rate \$.08454	
	kwh	\$	kwh	\$	kwh	\$						kwh	\$
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	
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	
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										Main Level = 1936 sq ft	
per month - or - non-taxable Public Benefits charge of \$1.48-\$3.15 per month > 10/00 - or - summer-season only sales tax												Workshop = 296 sq ft	
mid-JAN - mid-FEB	182	25.97	2,515	91.66	2,697	117.63	9.21	1,333			Lower Level = 1596 sq ft		
mid-FEB - mid-MAR	163	23.24	2,130	77.67	2,293	100.91	7.83	1,120			Normal Rate range (\$0.05470 - \$0.11437)		
mid-MAR - mid-APR	134	19.42	1,667	60.36	1,801	79.78	6.15	725			2,697 228.00		
mid-APR - mid-MAY	125	18.11	1,044	37.27	1,168	55.37	3.99	342			1,801 152.28		
mid-MAY - mid-JUN	158	22.30	894	33.52	1,052	55.82	3.59	139			1,168 98.74		
mid-JUN - mid-JUL	165	23.29	869	31.12	1,033	54.41	3.53	52	4 month summer usage period mid-May - mid-September		1,052 88.91		
mid-JUL - mid-AUG	164	23.29	777	27.61	941	50.90	3.21	11			1,033 87.36		
mid-AUG - mid-SEP	163	23.07	875	31.48	1,039	54.55	3.54	79			941 79.55		
summer subtotal	649	91.95	3,416	123.73	4,065	215.68	13.87	281			1,039 87.80		4,065 343.62
% annual	16.0%	42.6%	84.0%	57.4%							summer subtotal		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	6 month winter usage period mid-October - mid-April		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			3,117 263.51		
mid-JAN - mid-FEB	172	26.07	2,573	101.56	2,745	127.63	9.37	1,375			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			14,475 1223.64		
% annual	6.8%	22.3%	93.2%	77.7%							winter subtotal		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	4 month summer usage period mid-May - mid-September		1,059 89.51		
mid-JUN - mid-JUL	149	22.63	853	32.74	1,002	55.37	3.42	53			1,002 84.67		
mid-JUL - mid-AUG	150	22.92	768	29.57	917	52.49	3.13	11			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%							(transition month)		1,078 91.15
mid-SEP - mid-OCT	140	21.64	938	36.71	1,078	58.35	3.68	386			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													
mid-April - mid-April	1,913	\$278.36	18,862	\$705.04	20,774	\$983.40	70.90	7,628	(based on 1936 sq ft heated area)		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		Natural Gas		Other		Total		Area		HDD	
	kWH	BTU	Therms	BTU	Qty	BTU	BTU	MMBTU	Sq Ft	Sq M	F	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





**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%

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Mead Education & Visitor Center



**Interior Strapped Wall
w/ Raised-heel Roof Truss**



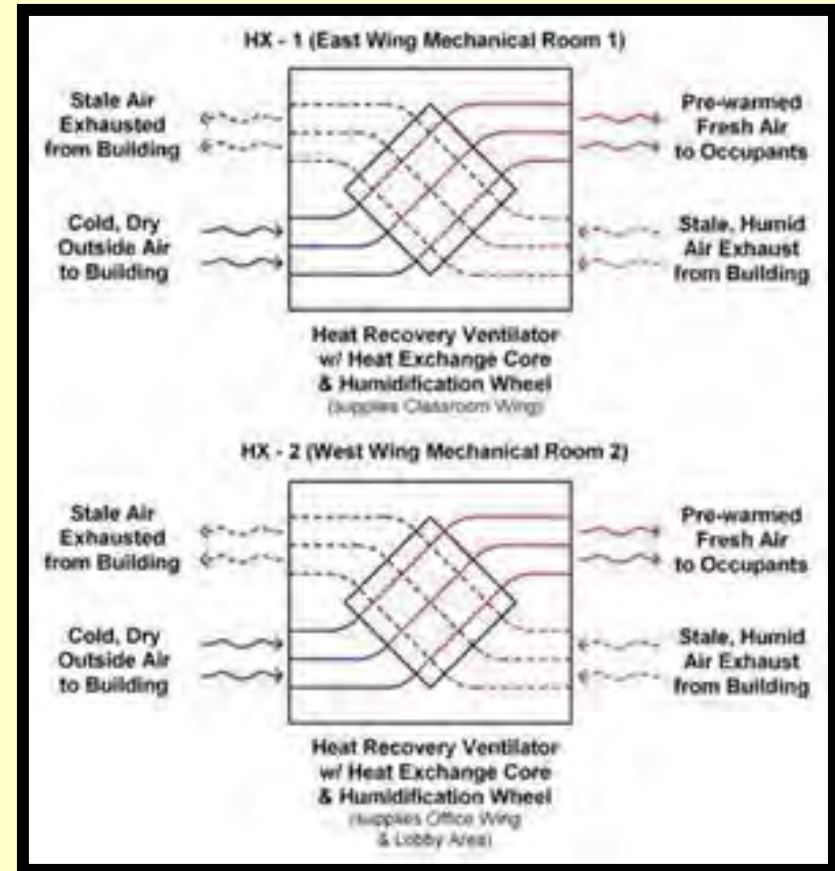
Airtight Electrical Box Enclosure



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**



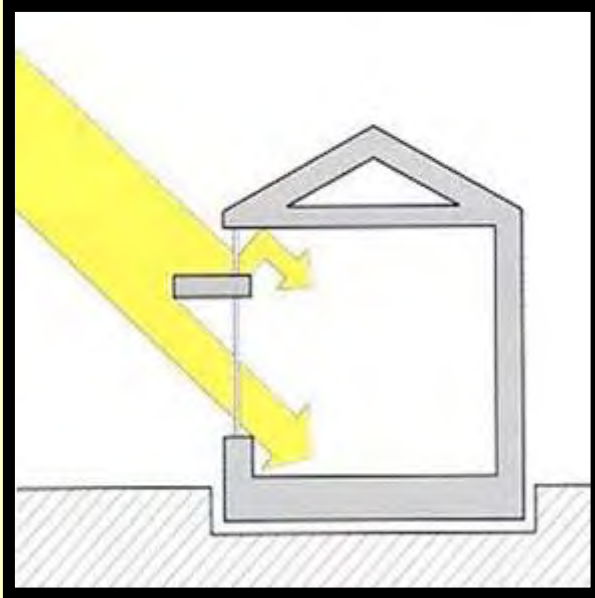
**Locally-produced
Recycled-Glass Floor Tiles**



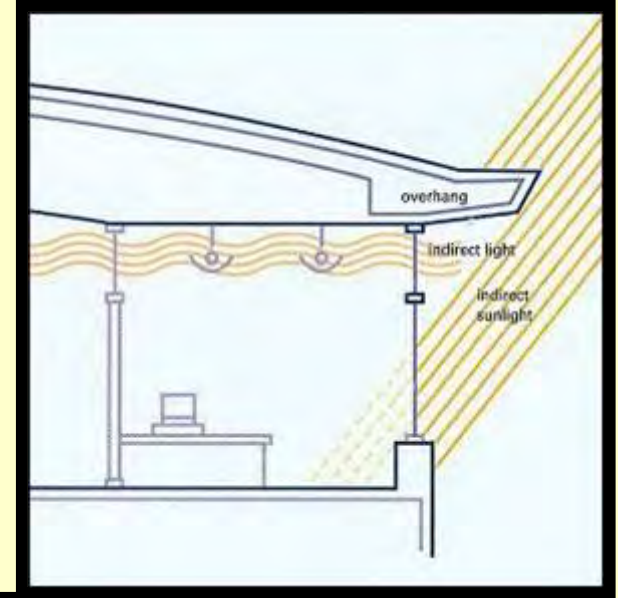
**Recycled-content Ceiling & Floor Tiles
Recycled Office Furniture**



**Sunflower Seed
Agri-panel Desktops**



Passive Solar Design



Cool Daylighting & Advanced Lighting Controls



Compact Fluorescent Lighting Fixtures



**Wind Energy & Solar Photovoltaic
Electricity**



**10 kW Grid-intertied Wind Turbine
on 120' Freestanding Tower**



**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

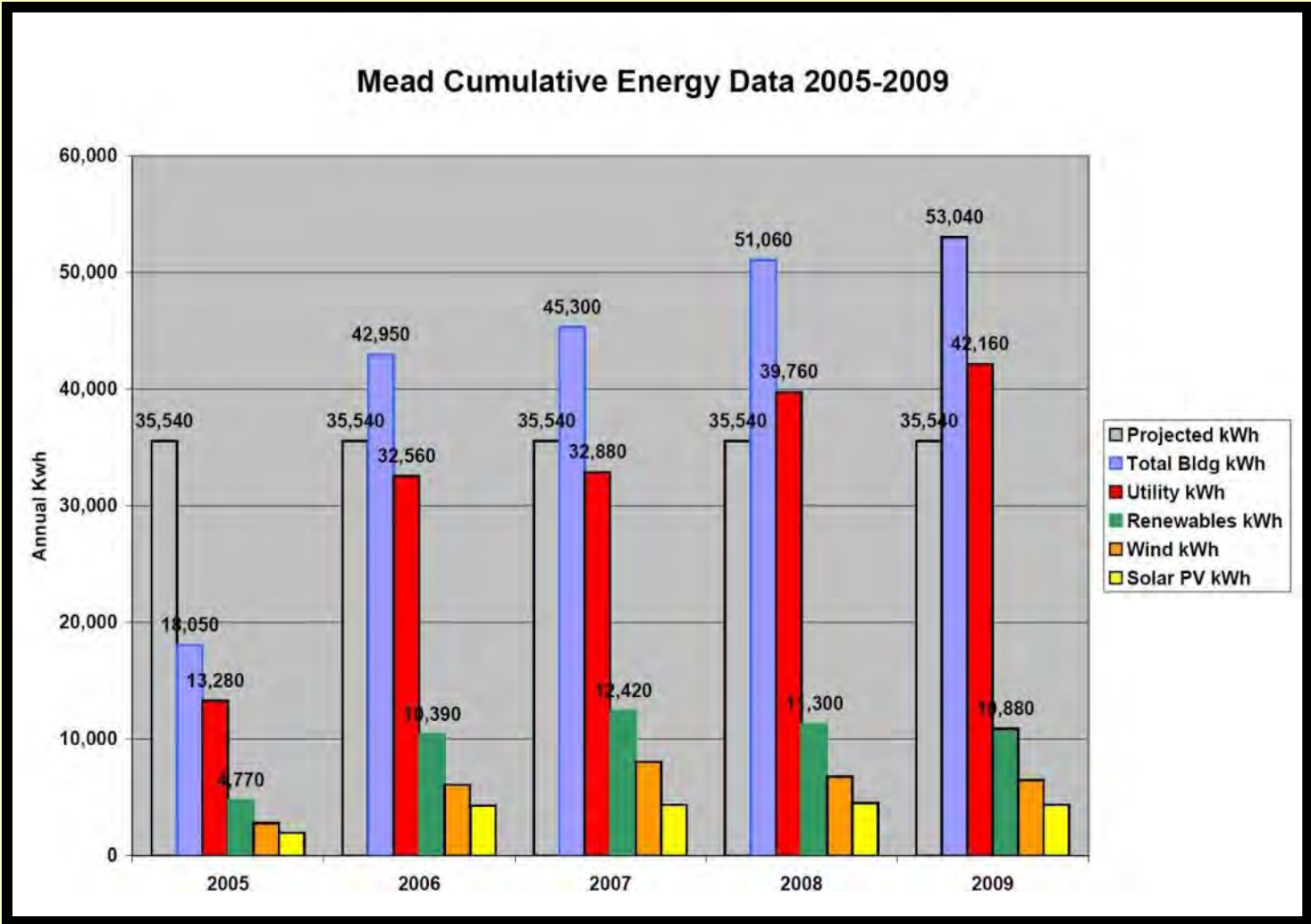


DNR Staff Office Wing

Documented Energy Usage

Mead Wildlife Area DNR Headquarters & Education Center						
Cumulative Summary of Actual Energy Usage & Renewable Energy Generation						
Description	Months of Data = 7/15/05 - 1/18/10		Cumulative To Date 54		12	
	kWh	\$	Average / month kWh	\$	Average / year 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 m²)

Mead Cumulative Energy Usage Summary												
Description	Electric		Natural Gas		Other		Total		Area		HDD	
	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
Energy Intensity Index (EII) =			3.43	BTU/ Sq Ft/ HDD-F		0.019	kWH/ M ² / HDD-C				9,500	5,278
Steady State Heat Loss =			79,789	BTU/ Hr @ -20 F		287,241	mJ/ Hr @ -28.9 C		1 kWh = 3.6 mJ		8,500	4,722
EPA Energy Star Score =			85								7,500	4,167
											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 m²)

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

Carbon Equivalents	= 67.9 tons CO²/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

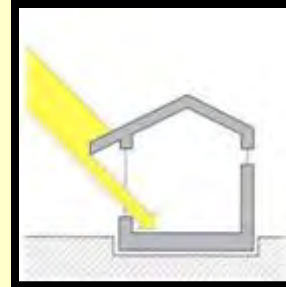
MREA Training Building



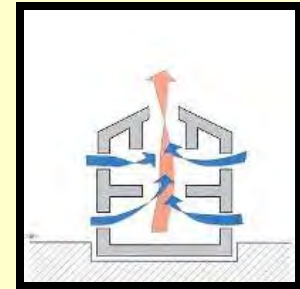
2x6 Exterior Strapped-Wall w/ Rain-screen Furring

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

A R C H I T E C T

Environmentally-responsive design

1052 Main Street Stevens Point, WI 54481 715.341.9596

LEED ACCREDITED PROFESSIONAL

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