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ECO III

ENERGY CONSERVATION BUILDING CODE TIP SHEET

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BUILDING ENVELOPE

Credit:
E Source Technology Atlas
Window Systems for High-Performance Buildings
90.1 User's Manual
LBNL Tips for Daylighting Guide
Alliance to Save Energy

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A well-designed building envelope not only helps in complying with the Energy Conservation Building Code (ECBC) but can also result in first cost savings by taking advantage of daylighting and correct HVAC system sizing. This document acts as a primer on better envelope design practices and steps needed to comply with ECBC.

The building envelope refers to the exterior facade, and is comprised of walls, windows, roof, skylights, doors, and other openings. The envelope protects the building's interior and occupants from the weather conditions and other external elements. The design features of the envelope strongly affect the visual and thermal comfort of the occupants, as well as energy consumption in the building.

Envelope Design Basics

From an energy efficiency point of view, the envelope design must take into consideration both the external and internal heat loads, as well as daylighting benefits. External loads include mainly solar heat gains through windows, heat losses across the envelope surfaces, and unwanted air infiltration in the building; internal loads include heat released by the electric lighting systems, equipment, and people working in the building space. (Fig. 1)

One of the goals of the envelope design should be to introduce daylighting into the interior space of the building through windows and skylights, thereby reducing the need for electric lighting. Thus, giving proper orientation to the building and due consideration to the size and placement of windows at the design stage can provide the advantage of daylighting.

Secondly, to maintain thermal comfort and minimize internal cooling/heating loads, the building envelope needs to regulate and optimize heat transfer through roof, walls, windows, doors, and other openings. Effective insulation of roof and walls, appropriate selection of glazing and framing for windows, and suitable shading strategy are important in designing energy-efficient buildings.

An integrated building design considers the Envelope, the Heating, Ventilation and Cooling (HVAC) system, and the Lighting system as a whole, rather than dealing with these independently. Changing the specifications of one system can affect the performance of the other two significantly. For instance, investments in good insulation of the roof, energy-efficient windows, or increased envelope airtightness can result in a smaller HVAC system, thereby reducing

Passive Solar Design Strategy

Architects should pay attention to the following basic design elements in an effort to reduce the energy consumption in small commercial building that can be operated without Central HVAC System.

Siting and Orientation: Longer axis of the building should be in east-west direction with maximum opening on north side; also position the building on site to facilitate breeze access.

Shade: Use different shading strategies to minimize solar heat gain and reduce glare inside buildings. Provide vertical louvers on east and west side and horizontal shading devices on south side.

Cross-Ventilation: Building envelope should allow the movement of breeze through out the building.

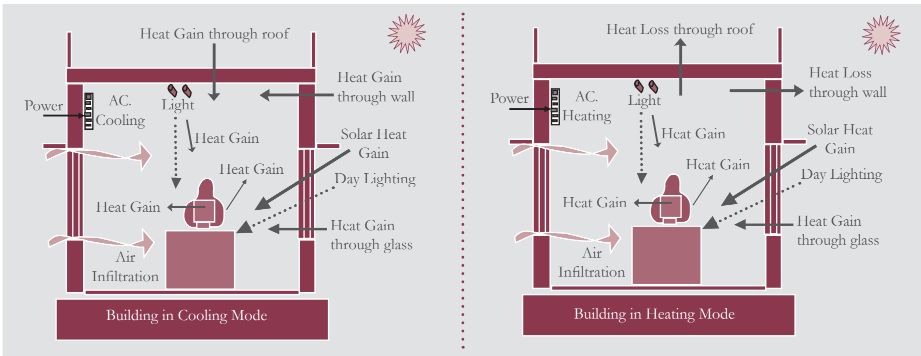


Fig. 1: External and Internal Heat loads

Key Technical Terms

Building Envelope: Exterior and the semi-exterior portions of a building. For the purposes of determining envelope requirements for the ECBC, these are:

a. Elements that separate the conditioned spaces from the weather conditions, or
b. Elements of a building that separate the conditioned spaces of the building from the unconditioned spaces, i.e. office space from unconditioned storage.

Cool Roof: Property of roof that describes its ability to reflect and reject heat. Cool roof surfaces have both high solar reflectance and a high emittance (rejecting heat back to the environment).

Effective Aperture: Visible Light Transmittance × Window-Wall Ratio (EA= VLT × WWR).

Envelope Performance Factor: Trade-off value for the building envelope performance compliance option, calculated using the procedures specified in Appendix D of the ECBC.

Fenestration: All openings (including the frames) in the building envelope that let in light (e.g. windows, plastic panels, skylights, glass doors) that are more than one-half glass, and glass block walls.

Skylight: A fenestration surface having a slope of less than 60 degrees from the horizontal plane.

Fenestration Area: Total area of the fenestration measured using the rough opening (including glazing, sash, and frame). For glass doors where glazed vision area is less than 50% of the door area, the fenestration area is the glazed vision area otherwise it is the door area.

Opaque Wall: All areas in the building envelope, except fenestration and building service openings such as vents and grills.

Solar Reflectance: Ratio of the light reflected by a surface to the light incident upon it.

Solar Heat Gain Coefficient (SHGC): Regardless of outside temperature, heat can be gained through windows by direct or indirect solar radiation. The ability to control this heat gain through windows is characterized in terms of the SHGC of the window. SHGC is the ratio of solar heat gain that passes through fenestration to the total incident solar radiation that falls on the fenestration. Solar heat gains includes directly transmitted solar heat and absorbed solar heat, which is re- radiated, conducted, on convected into the interior space. (Fig.2)

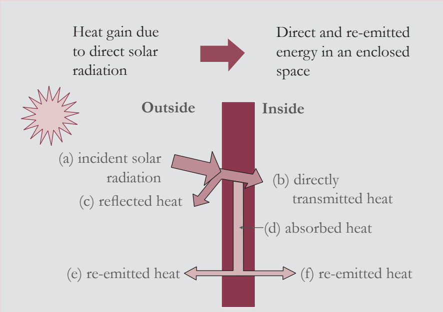


Fig. 2: Solar Heat Gain Coefficient

Sound Transmission: An important requirement in some projects. Many energy-efficient glazing deliver improved acoustic performance as a side benefit.

Spectral Selectivity: Refers to the ability of a glazing material to respond differently to different wavelengths of solar energy – in other words, to admit visible light while rejecting unwanted invisible infrared heat. Newer glazing products have achieved this characteristic, permitting much clearer glass than previously available for solar control glazing. A glazing with a relatively high VLT and a low SHGC indicates that a glazing is selective. Spectrally selective glazing use special absorbing tints or coatings, and are typically either clear or have a blue or blue/green appearance.

Thermal Emittance: Relative ability of a material to radiate the absorbed heat.

U-Factor ($W/m^2\cdot K$): When there is a temperature difference between inside and outside, heat is lost or gained through the window frame and glazing by the combined effects of conduction, convection, and long wave radiation. Fenestration U-factor is the rate of heat flow through one square meter of fenestration when there is 1°C temperature difference. U-factor dose not consider solar gains through the fenestration; this is addressed by SHGC. The lower the U-factor, the better it is. Center-of-glass U-factors are generally lower than whole-window U-factors, which account for the effect of the frame and mullions. This property is important for reducing heating load in cold climates and for reducing cooling load in hot climates.

Roof and opaque wall U-factor also refers to the amount of heat transferred (lost/gain), due to a temperature differential of 1°C between inside and outside, per square meter. Figure 3 illustrates the concept of U-factor. R-value is the resistance to heat flow (R=1/U), with higher values indicating better insulation.

Vertical Fenestration: All fenestration other than skylights.

Visible Light Transmittance (VLT): The ratio of light passing through the glazing to light passing through perfectly transmissive glazing. VLT is concerned only with the visible portion of the solar spectrum, as opposed to SHGC, which is the ratio of all solar radiation. VLT is an important parameter for daylighting of buildings.

Window-Wall Ratio (WWR): Ratio of vertical fenestration area to gross exterior wall area. Gross exterior wall area is measured horizontally from the exterior surface; it is measured vertically from the top of the floor to the bottom of the roof.

Weather stripping: Materials, such as a strip of fabric, plastic, rubber or metal, or a device used to seal the openings, gaps or cracks of venting window and door units to prevent water and air infiltration.

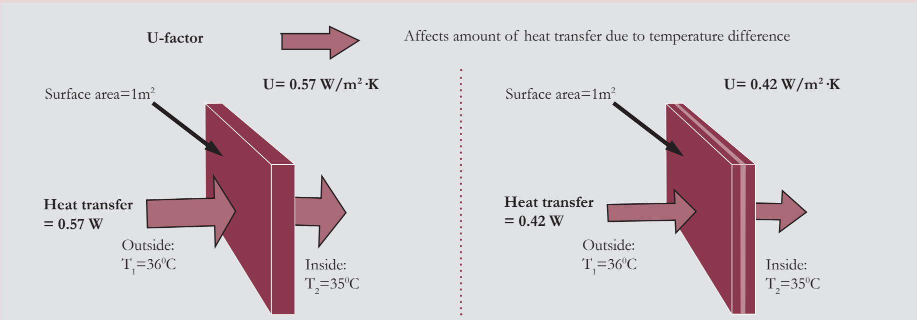


Fig. 3: Illustration of concept of U-factor

its first cost as well as recurring energy cost. Similarly, an inefficient lighting system not only increases lighting energy consumption but could also increases the cooling load on HVAC System, thereby increasing the energy consumption further.

When a building is in cooling mode, solar heat gains need to be minimized within the building space while optimizing daylight and intake of outside air. Outside air could be introduced particularly during evening/night hours, when the ambient temperature drops. This strategy cools the thermal mass in the building during night hours and reduces overall cooling load during the next day. On the other hand, if the building is in a heating mode, the envelope needs to be designed with appropriate glazing selection coupled with shading strategy, to enhance solar heat gains during daytime. Therefore in practice, the architects and building designers need to integrate and balance these varying requirements considerations while designing an energy-efficient building.

Building envelope design must also consider the moisture management principles and the climate in which the building is to be located and the vapor permeability controls necessary to prevent condensation within the dry side of the exterior wall assembly. (Fig. 4)

ECBC Compliant Design Strategy for a Building

Many things can go wrong with the building envelope and well-intentioned attempts to make it energy-efficient. Critical missteps to watch out for, include:

- Providing good technical specifications for an energy-efficient building envelope but not ensuring its proper construction which can lead to poor energy performance.
- Adding a large window area to the facade for daylighting but ignoring the problems of solar heat gain and the need for shading to reduce glare.
- Designing a daylighting strategy but not enabling the lighting system to dim or turn off when there is sufficient daylight in the interior space.
- Designing/sizing the building's HVAC system on rules of thumb and not accounting for the reduction in heating and cooling loads created through efficient envelope and lighting design.

Climate Zones

ECBC defines five climate zones (Hot and Dry, Warm-Humid, Composite, Temperate, and Cold), which in turn dictates what ECBC requirements for the envelope, as well as other building components are going to be applicable to the building.

Compliance Approaches

After establishing the specific climate zone in which the building is located, determine which compliance approach is the best fit for envelope design. The ECBC allows the following approaches:

Prescriptive Approach prescribes the minimum performance requirements for each building component. It is quick and easy to use, but this approach is somewhat restrictive because requirements have to be met exactly as specified.

Envelope Trade-off Approach allows the designer to trade enhanced energy efficiency in one building component against decreased energy efficiency in another component, thereby offering flexibility. These trade-offs are applicable only within major building components i.e., roof, walls and fenestration.

Whole Building Performance Approach compares the proposed design with a standard design (same building meeting all the prescriptive requirements of ECBC) and demonstrates that the estimated annual energy use of proposed design is less then that of the standard design. This approach allows great flexibility but requires considerably more effort. Computer-based Energy Simulation Program can be helpful in this exercise.

Mandatory Requirements

Irrespective of the approach taken to show ECBC compliance, the mandatory requirements of ECBC must be met by all buildings.

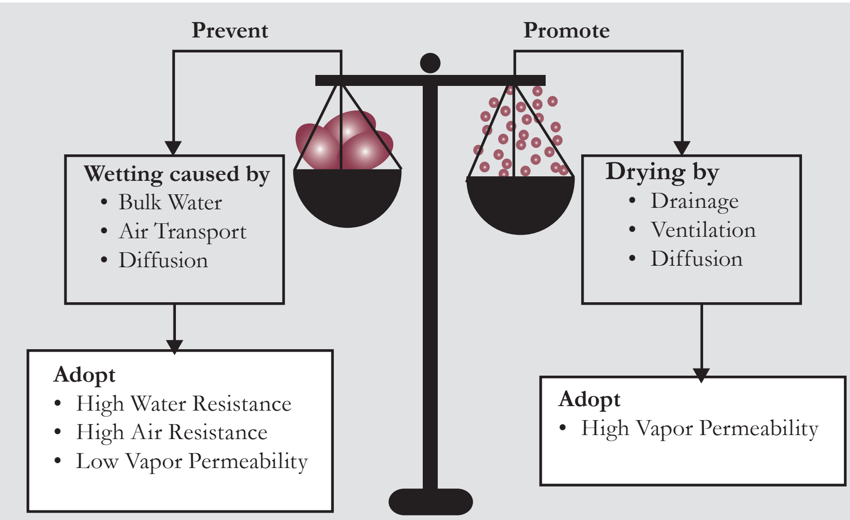
For the building envelope, ECBC requires U-factor and SHGC to be determined for the overall fenestration product (including sash and frame) and certified by the manufacturer or other responsible party [ECBC 4.2.1.1 and 4.2.1.2]. For unrated fenestration products, there are default values available in Appendix C of the code.

- A U-factor is also required to be determined for opaque constructions [ECBC 4.2.2].
- Maximum values for air leakage around all doors and windows must be met [ECBC 4.2.1.3]. Other openings in the building envelope (e.g. fenestration, doors, roofs, walls, ducts or plenums, etc.) are required to be sealed to minimize air leakage [ECBC 4.2.3].

Prescriptive Approach

The prescriptive requirements for walls, roof and fenestrations are climate-based and different for buildings used during the daytime, and those with 24-hours of use.

Roofs and opaque walls should meet maximum U-factors for assemblies or



Vapor Permeability

In hot, composite and humid climate zones, Vapor permeable materials which allow drying in both directions are preferable.

In cold and temperate climates or where the internal humidity and temperature is likely to be relatively higher than the outside, it must be ensured that materials that make up the envelope are progressively more Vapor permeable from the inside to the outside or are vented towards the outside, so that if the envelope components (such as insulation) get wet, they can dry themselves through Vapor diffusion.

Metal roofs with under deck fibrous insulation present unique challenges in moisture management. Since the metal sheet prevents active drying of insulation to the outside, it is recommended that on the inner side, the insulation be faced with a Vapor- open air and water barrier, to allow incidental ingress of moisture to diffuse as Vapor. The exception to this would be in installations where the interior temperature and humidity are expected to be significantly higher that those on the outside.

Fig. 4: Moisture/Vapor Management Principles Source: DuPont

minimum R-values for the insulation only [ECBC 4.3.1 and 4.3.2].

Cool Roof should meet minimum solar reflectance of 0.7 and initial emittance levels of not less then 0.75, and determined in accordance with specified standards. [ECBC 4.3.1.1]

Vertical Fenestration area is limited to a maximum of 60% of the gross wall area and should meet maximum U-factor and SHGC based on climate and window-wall ratio, use modified SHGC limits when using overhangs or fins, and in the case of windows located over 2.2 meters from the floor [ECBC 4.3.3]. Based on the WWR, Vertical Fenestration should meet minimum levels of Visual Light Transmittance to facilitate use of daylighting [ECBC 4.3.3.1].

Skylights should meet maximum U-factor and SHGC with skylight area limited to a maximum of five percent of the gross roof area [ECBC 4.3.4].

Trade-Off Approach

Appendix D of ECBC provides guidance on the calculation of the Envelope Performance Factor (EPF). This is calculated for the proposed design and for the baseline design, for compliance. The proposed building's EPF must be equal to or better than that of the baseline design.

Whole Building Performance Approach

This approach (Appendix B of ECBC) requires computer-based energy simulation program to determine and compare the estimated annual energy use of the proposed design with that of a standard design.

Technical Tips for Building Orientation

In a predominantly hot climate, cooling load affects the total energy consumption in commercial buildings in a significant manner. Thus, controlling heat transfer through the roof, walls, and windows becomes of utmost importance and needs to be considered from the initial stages of design. Therefore, site planners and designers should properly orient buildings to minimize solar gains in the summer.

Plot lines and roads should be situated to minimize building exposure to the east and west. These orientations provide the highest solar heat gains. Subdivisions should be planned so that the longer sides of the buildings face north and south. With proper planning, there may be no added costs for good orientation.

Technical Tips for Roofs and Walls

The following factors need to be considered to optimize energy-efficient envelope design:

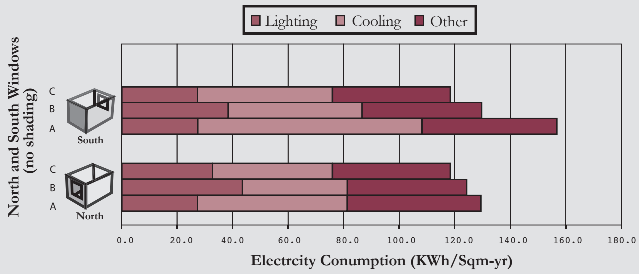
- ECBC requires various levels of roof insulation based on climate. Additional cost of insulation pays back in energy savings that result from correctly sizing the HVAC equipment to reduce cooling loads. Generally good insulation also extends the life of the roof system.
- Insulation of walls is also important for reducing conduction losses especially where significant difference exist between inside and outside temperature. Many insulation materials require an Air Barrier and Weather Resistive Barrier to prevent air and moisture movement into and out of the conditioned space, as well as for maintaining their installed R-value. (Fig. 7)
- Infiltration & exfiltration, the unwanted air movement through windows and envelope surfaces, is caused by a pressure difference (air moves from high pressure to a lower pressure- Fig. 8). Limiting air infiltration and exfiltration is key to

Role of Energy Simulation

Energy Simulation using a variety of computer software tools is not only the way a design professional or team can determine compliance with the ECBC, but it may be the best method for designing a building using an integrated approach. The Whole Building Performance Method yields the greatest flexibility of design for the design team, and may allow for a very cost-effective way to assure a successful design. However, this approach does require considerable knowledge of building simulation tools and very close communication between members of the design team.

In basic terms, this method makes a computer model, or Standard Design, of a building that is similar to the proposed design and which just meets the ECBC requirements (the "base case criteria" as described in detail in Appendix B of ECBC). The model compares the total predicted energy use of the Standard Design with that for the Proposed Design. A building complies with the whole building performance method when the estimated annual energy use of the Proposed Design is less than or equal to that of the Standard Design, even though it may not comply with all the prescriptive requirements specified in Section 4 through 8 of ECBC.

Fig. 5 shows the impact of different types of glazing for a 0.30 WWR within a five meter perimeter zone in a building located in a warm and humid climate (e.g. Mumbai or Chennai). Fig. 6 shows total energy use for different orientation (North and South- with and without shading) for the same glazing. Hourly simulation tools (e.g. Energy Plus and DOE2) are indispensable for conducting this type of energy simulation analysis that looks at the interactive effects of different building systems and are able to predict a more reliable energy performance of the building.



Annual Electricity and cooling Energy use Comparison by Orientation with no shading
Window A: single glazing, clear, U=1.25, SHGC = 0.72, VT = 0.7
Window B: double glazing, reflective coating, U=0.54, SHGC = 0.17, VT = 0.1
Window C: double glazing, spec. Selective low- E tint, U=0.46, SHGC = 0.27, VT = 0

Fig. 5: Annual Electricity Consumption by Orientation of Different Glazing

Total Energy Use for Different Orientation
Window B: double glazing, reflective coating, U=0.54, SHGC = 0.17, VT = 0.10

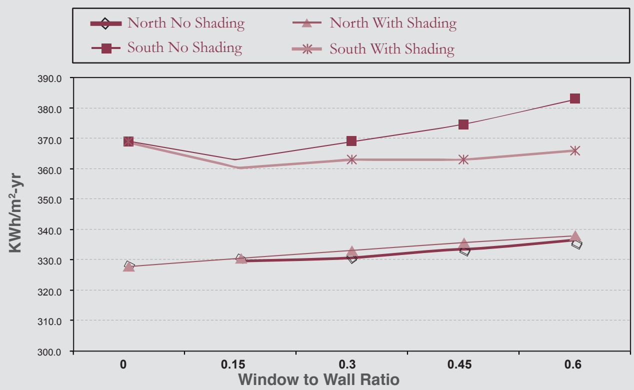
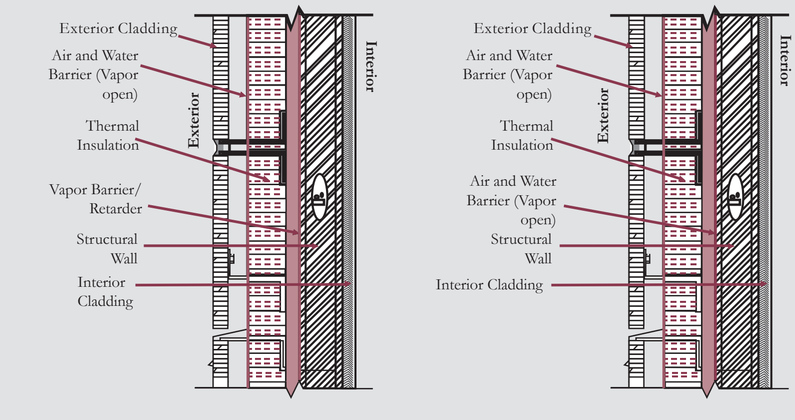


Fig. 6: Impact of Orientation and Shading on Annual Electricity Consumption



Assembly for Cold and Temperate climate zones

Assembly for Hot, Composite and Humid climate zones

Fig. 7: Schematic Showing the Correct Placement of Barriers.

Source: DuPont

Vapor retarders/barriers

Moisture management in envelope assemblies is a very critical design consideration and requires a fundamental understanding of the physics of moisture transport. There are three key moisture transport mechanisms: bulk water ingress, air transported water Vapor and water Vapor diffusion. The three mechanisms do not equally contribute to wetting. Bulk water has the largest contribution to wetting, followed by air transported moisture, with Vapor diffusion being the least important. Incidental moisture intrusion is nearly impossible to avoid: walls will sometimes get wet. However, moisture problems only occur when wetting exceeds drying; that is, when walls get wet and stay wet for extended periods of time. It is therefore critical to design forgiving walls which will allow drying of incidental moisture ingress. The key to avoiding moisture problems is to manage the balance between wetting and drying: protect against wetting and promote drying. As the diagram below shows, diffusion is minor wetting source; however, it is a very critical drying source. Vapor diffusion is the secondary line of defense that allows drying of incidental moisture intrusion.

improving energy efficiency; look for opportunities to include a continuous membrane or roll-applied continuous air barrier, which can also serve as the building's primary bulk moisture control layer.

Technical Tips for Glazing

Most large commercial buildings are dominated by cooling loads, so window selection for commercial buildings is usually an exercise in maximizing daylighting and keeping summer heat out. Today's best windows block heat transfer more than five times better than single-pane glass, the standard windows of just two decades ago. High-performance windows are not only a wise investment for new construction, but sometimes can be cost-effectively retrofitted, especially when timed with planned replacement and downsizing of HVAC equipment. Glazing products (windows, skylights, etc.) can be specified to reduce solar heat gain and control light levels and glare. As a rule of thumb, double glazing should always be preferred over single glazing since facades with double glazing not only offers superior thermal performance but can also help in significantly reducing unwanted external noise of traffic.

Windows are affected by many factors, which in turn affect the comfort and energy performance of buildings. Understanding these factors is critical to designing buildings that meet the needs of building owners and users. Once these factors are identified, a designer can then apply the appropriate technology to address them. The three components of the solar radiation are: Ultra-Violet (UV), Visible, and Near-Infrared (NIR)- Fig. 9. While half of this energy is invisible, either in the UV or NIR, it must still be considered in the selection of glazing. Standard, untreated glass is naturally transparent to 85 percent of the UV, Visible, and NIR rays, but selective glazing has the ability to distinguish visible from invisible energy in ways that decrease solar heat gain while maintaining daylight transmittance and vice-versa.

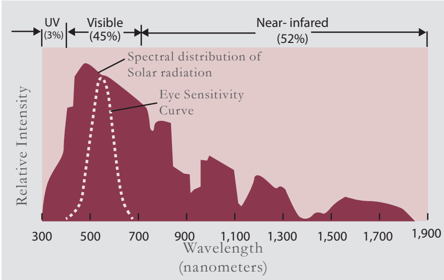
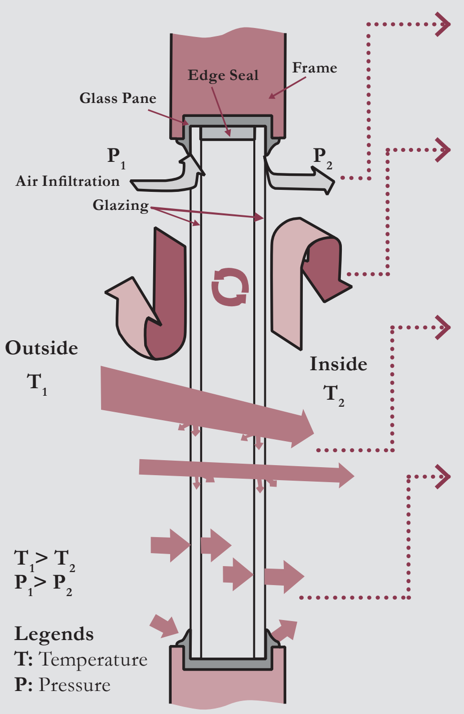


Fig. 9: Solar Spectrum

Source: E Source Lighting Atlas



Infiltration

Air leaks around the frame, around the sash, and through gaps in movable window parts. Infiltration is foiled by careful design and installation, weather stripping and caulking (type of sealing).

Convection

Convection takes place in gas. Pockets of high temperature, low-density gas rise setting up a circular movement pattern. Convection occurs within multiple-layer windows and on either side of window. Optimally spacing gas-filled gaps minimizes combined conduction and convention.

Radiation

Radiation is the energy that passes directly through air from a warmer surface to a cooler one. Radiation is controlled through low-emissivity films or coatings. SHGC determines the amount of radiation that can pass through glazing.

Conduction

Conduction occurs as adjacent molecules of gas or solids pass thermal energy between them. Conduction is minimized by adding layers to trap air spaces, and putting low conductivity (Argon or Krypton) gases in those spaces. Frame conductivity is reduced by using low-conductivity material such as vinyl or fiber-glass instead of aluminium. U-factor determines the amount of conduction heat transfer that can take place across glazing.

Fig. 8: Heat and Air Movement through Double Glazing Window System

Source: Adapted from E Source Technology Atlas

Clear glass, which is the most common type of glass used today, has no significant thermal resistance (R-value) from the pane itself. However, it has a value of R-0.9 to R-1.0 due to the thin films of air on the interior and exterior surfaces of the glass. Without any coatings, clear glass easily transmits UV, Visible, and NIR energy.

Technical Tips for Cool Roofs

Use of solar-reflective (cool) surfaces and the planting of urban trees are inexpensive measures that can reduce summer time temperatures. At the building scale, a dark roof is heated by the sun and thus directly raises the summer time cooling demand of

Glazing Selection Tips

- Choose between dual-pane and single-pane glazing. This is the critical first decision in glazing selection. Although higher in first cost, dual-pane insulating glass units (IGUs) typically improves comfort in perimeter zones, offers greater flexibility in product selection, improves acoustic performance, and reduces cooling or heating mechanical loads. Most new energy-efficient buildings should use insulating glazing.
- Choose a spectrally selective glazing. Select a moderate visible light transmittance for glare control (50-70% is a good starting point, depending on visual tasks, window size and glare sensitivity; the larger the windows or the more critical the glare control, the lower the desirable visible transmittance). Examine manufacturer literature for good glazing candidates. Find the product tables for IGUs and look for products with your desired visible light transmittance and the lowest possible solar heat gain coefficient.
- Balance the conflict between glare and useful light. A physical model studied outdoors is a good tool to qualitatively assess glare. If glare is an anticipated problem, and if an architectural solution to glare is not possible (moving windows out of the field of view, using deep reveals, shading systems, and other physical modifiers), then select a glazing visible light transmittance that is a compromise between glare and light.
- Window size and glazing selection can trade off with each other. Use the effective aperture approach when making these decisions: Larger window area requires lower visible light transmittance; smaller windows requires high visible light transmittance.
- Big windows require better glazing. The bigger the window, the lower the required solar heat gain coefficient and visible transmittance. The bigger the window, the greater the need for IGUs. Large areas of inefficient glazing bring major comfort and energy cost penalties, and may not be permitted by building codes.
- Do not assume that dark glass provides good solar heat control. Dark glazing can block more light than heat, and therefore only minimally reduce cooling load. Dark glass can produce a gloomy interior atmosphere and may affect productivity and absenteeism. Consult product brochures or manufacturer representatives to be sure you are aware of the range of product choices today. Dark glass not only reduces daylight, it also increases occupant discomfort on a sunny day. Today, solar heat control is available in much clearer glazing.
- Do not count on glazing alone to reduce heat gain and discomfort. If direct solar beam comes into the building, it still creates a mechanical cooling load and discomfort for occupants in their path. Exterior shading combined with a good glazing selection is the best window strategy. Interior shading options can also help control solar heat gain.
- Vary glazing selection by facade, if possible. A lower solar heat gain coefficient on the south, east, and especially west windows reduces the cooling load.
- ECBC restricts the WWR to a maximum of 60%. Often trade-offs are possible: more area is permitted if better glazing is specified.

Daylighting Tips

Fenestration should be designed to facilitate daylighting and reduce the need for electric lighting. But bringing daylight to the interior of the building is complex. Effective daylighting strategy should include a combination of the following:

- ***Exterior shading:*** Overhangs and vertical fins block direct sun.
- ***Interior light distribution:*** Light shelves, diffusers, or reflective surfaces move the light further back into space.
- ***Daylighting controls:*** Automatic or manual controls dim or turn off electric lighting when there is sufficient daylight.

Tips that can be followed to maximize daylighting without compromising thermal performance are as follows:

- Know the true north orientation of the site and include it on all plan drawings. Lot property lines are typically given relative to true north.
- If the site allows, the first attempt at building placement should be with the long axis running east-west.
- Minimize apertures and large glazing surfaces on the east and the west. Low sun angles for these orientations make shading extremely difficult without blocking the entire window. Higher WWR requires careful handling.
- Study the potential for (a) an articulated form that yields a high percentage of perimeter space, (b) an envelope structure and cladding that can integrate shading, and (c) opportunities for the building to shade itself.
- Develop initial thoughts about shading strategy and glazing type.
- Determine whether the project budget allows consideration of a light shelf or exterior projecting shading elements.
- Begin window design with both interior considerations and exterior appearance concerns simultaneously. Place windows primarily to provide view and light. Size and place windows for best glare-free daylighting with minimal energy penalty. The designer should perform preliminary calculations at this point to help in window design and to determine the importance of glazing and shading decisions yet to come. If a light shelf or exterior shading are under consideration, include these elements in the calculations.
- Identify which occupant tasks best benefit from daylight before laying out task locations on floors. Put tasks requiring low, uniform light levels or with periodic occupancy in the building core. Keep interior finishes light-colored.
- Discuss daylighting concepts with lighting designer or consultant to ensure that electric lighting layout and controls address daylight needs at the start of lighting design process.
- Build a simple model and view it outdoors for lighting quality and glare.
- Check coordination issues with lighting, structural, and mechanical design. Keep ceiling as smooth and high as possible.

the building beneath it. A reflective roof is typically light in color and absorbs less solar radiation than does a conventional dark-colored roof. Thus, reflective roofs reduce air-conditioning energy use and increase occupant comfort level. The magnitude of energy savings depends upon building type, level of roof insulation, ventilation rate between roof and ceiling, HVAC system size and efficiency, and of course, solar reflectance of roof. Flat roofs can be covered with a highly reflective coating that has a high emissivity property (the characteristic of emitting infrared energy). Cool roof technologies include coatings, membranes, tiles, and shingles.

Installation of high-albedo roof coatings or paint is most cost-effective if done during new construction or when buildings are scheduled for re-roofing. Reflectance (albedo) is measured on a scale of 0 to 1, with 0 being a perfect absorber and 1 being a perfect reflector. The complement of reflectance is absorptance; whatever radiant energy incident on a surface that is not reflected gets absorbed. Absorptance is also rated from 0 to 1, and can be calculated from the relation: reflectance + absorptance = 1. An ideal exterior surface coating for a hot climate would have reflectance near 1.0, absorptance near zero, and infrared emissivity near 1.0 to radiate absorbed heat back to the environment. White plaster very nearly achieves this combination.

Table 1 summarizes Basic Measures for Energy-Efficient Envelope Design and Table 2 provides information on Different Types of Insulation for Roofs and Walls.

HVAC System Coordination Tips

Guide for Early Architectural Decisions

- Try to reduce cooling loads. Look for opportunities where architectural decisions can save operating costs, reduce mechanical first costs, and reduce mechanical space requirements.
- Calculate building energy use starting during schematic design phase, even if this requires many assumptions about unknown details, and refine the calculation as the building becomes more defined.
- Mechanical engineer should be an integral team player from the beginning. This is a departure from the traditional model of building design procedure, where the mechanical engineer enters the design process after major architectural decisions are already established.
- Assist in an optimal glazing selection. Stay up to date on glazing technologies-dark or reflective glazing are no longer the only choices for solar heat reduction. Consider carefully the radiant effect of windows on comfort when weighing the benefit of an improved U-factor or the disadvantages of a darkly tinted glazing.

Reduce First and Operating Costs

- Calculate peak cooling load and energy use with reduced perimeter electric lighting load and size mechanical system accordingly. Be sure to specify proven and reliable daylight controls that will dim or switch electric lighting during peak cooling conditions.
- Examine cooling system downsizing opportunities with various glazing and shading options. Work with architect in fine-tuning window sizing and location, shading strategy and glazing selection for a smaller and more efficient system.
- Calculate the annual energy saved with improved fenestration elements. Calculations will show some of the benefit of exterior over interior shading, lower solar heat gain coefficient glazing, and daylighting controls.
- Select an effective energy management system to optimize building operation and tie together all HVAC, lighting and automated shading controls.

Maintain Thermal Comfort

- Window and shading design are strongly linked to perimeter zone comfort, regardless of air temperature. Hot or cold glass behaves like a radiant panel and affects occupant comfort independent of air temperature.
- An airtight building envelope contributes to increased thermal comfort of building occupants.
- Consider the effect of the window's mean radiant temperature on thermal comfort. Poorly insulated windows (high U-factor) decrease the surface temperature in winter. Since the mechanical system controls the room's air temperature, occupants near the windows can be very uncomfortable.

Table 1: Basic Measures for Energy-Efficient Envelope Design

Measures	Wall	Roof	Window
Minimize Conduction Losses	Use insulation with low U-factor	Use insulation with low U-factor	Use material with low U-factor
Minimize Convection Losses	Reduce air leakage using a continuous air barrier system	Reduce air leakage using a continuous air barrier system	Use prefabricated windows and seal the joints between windows and wall
Minimize Moisture Penetration	Reduce water infiltration– use continuous drainage plane Reduce air transported moisture- use continuous air barrier Reduce moisture diffusion into the wall – use vapor barrier/retarder*	Watertight Airtight: continuous air barrier Use vapor barrier/ retarder*	Use prefabricated windows and seal the joints between windows and walls
Minimize Radiation Losses	Use light colored coating with high reflectance	Use light colored coating with high reflectance	Use glazing with low Solar Heat Gain Coefficient (SHGC); Use shading devices

* See the discussion about where to place a vapor barrier/retarder. (Fig. 7)

Table 2: Different Types of Insulation for Roofs and Walls

Form	Method of Installation	Where Applicable	Advantages
Blankets: Batts or Rolls, Fiberglass, Rock wool	• Fitted between studs, joists and beams. Insulation must be protected by an air barrier membrane in order to maintain the installed R-value (conductive loops & wind washing) • The air barrier can be installed over exterior and/ or interior sheathing and must be continuous	• Unfinished walls, floors and ceilings	• Easy installation, suited for standard stud and joist spacing, which is relatively free from obstructions
Loose-Fill: Spray-applied Rock wool, Fiberglass, Cellulose Polyurethane foam	• Blown into place or spray applied by special equipment Insulation must be protected by an air barrier membrane in order to maintain the installed R-value (conductive loops & wind washing) • The air barrier can be installed over exterior and/ or interior sheathing and must be continuous	• Enclosed existing wall cavities or open new wall cavities • Unfinished attic floors and hard to reach places	• Commonly used insulation for retrofits (adding insulation to existing finished areas) • Good for irregularly shaped areas and around obstructions
Rigid Insulation: Extruded polystyrene foam (XPS), Expanded polystyrene Foam (EPS or Beadboard), Polyurethane foam, Polyisocyanurate foam	• Interior applications: Must be covered with 1/2-inch gypsum board or other building-code approved material for fire safety • Exterior applications: Must be covered with weather-proof facing or continuous Air and Weather Resistive Barrier (WRB)	• Basement walls, Exterior walls under finishing (Some foam boards include a foil facing which will act as a vapor retarder. Additionally, some insulation materials- e.g. XPS and closed cells polyurethane foams– are vapor retarders. Please read the discussion about where to place, or not to place a vapor retarder) • Unvented low slope roofs	• High insulating value for relatively little thickness • Can block thermal short circuits when installed continuously over frames or joists
Reflective Systems: Foil-faced paper, Foil-faced polyethylene bubbles, Foil-faced plastic film, Foil-faced cardboard	• Foils, films, or papers: Fitted between wood-frame studs joists, and beams	• Unfinished ceilings, walls, and floors (for wall applications, must consider that most foil faced systems act as a vapor retarder)	• Easy installation: All suitable for framing at standard spacing • Bubble-form suitable if framing is irregular or if obstructions are present

Getting Started

In this new and emerging market for energy-efficient buildings and building components, it can be difficult at times to locate and secure the best products for use in construction. This may be because they are not available locally or are too expensive for the building owner's budget. It may also be a significant task to determine the energy efficiency properties (default values) of products that are used for typical construction and building assemblies used locally.

As the demand for products grows, there will likely be more competition and choice available to designers. In the meantime, it is important to note that construction technique– i.e. proper installation of an air insulation system and barrier, and correct use of shading devices for windows –has a significant impact on energy efficiency along with the energy efficiency of individual components.

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