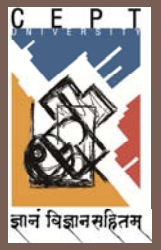
Energy Conservation Building Code (ECBC)

Building Envelope



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CEPT University, Ahmedabad

Implementation of Energy Conservation Building Code
Chandigarh, Dec 3-4, 2012

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Building physics TU Building ecology
TU VIENNA

ECO III

ENERGY IS LIFE
BEE
CONSERVE IT

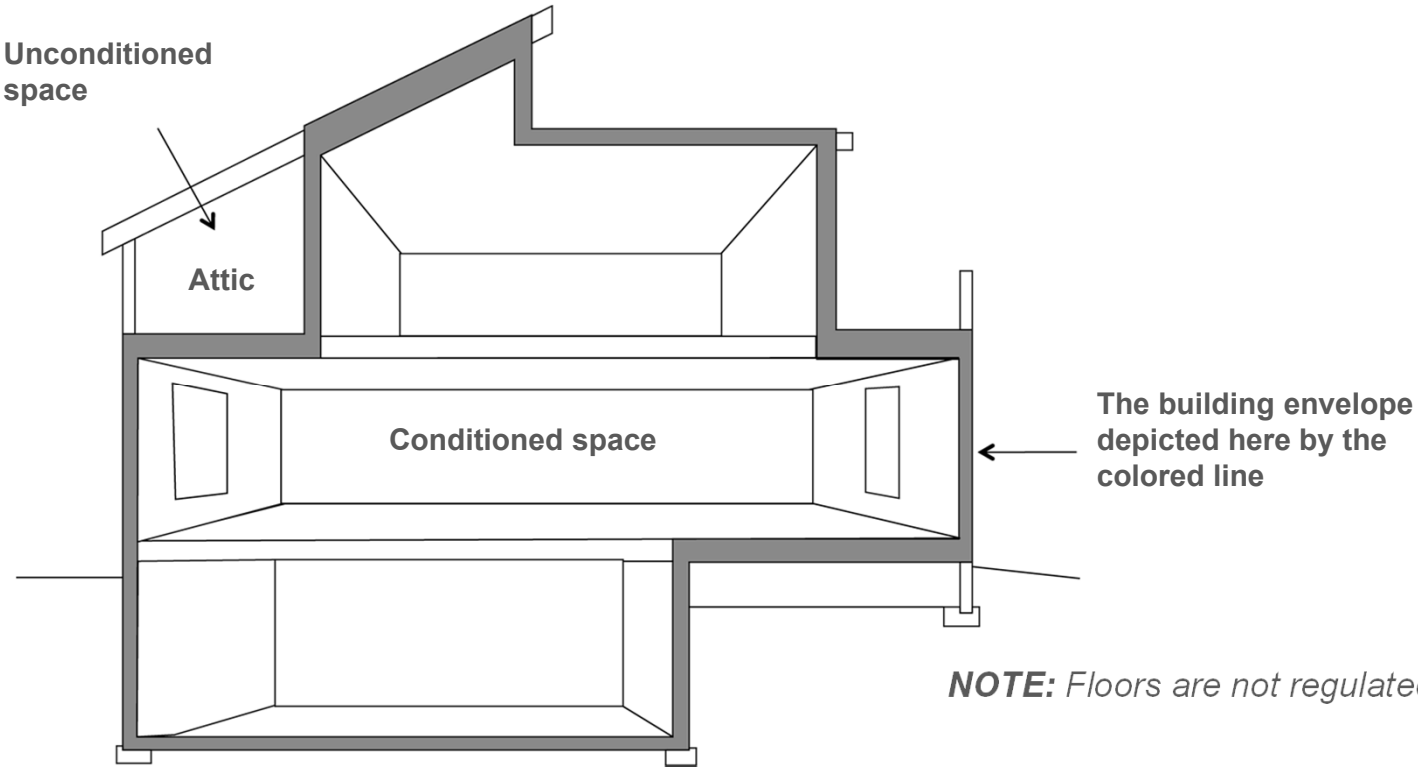
Building Envelope: Outline

- **Building Envelope**
- **Opaque Construction**
  - **Heat Transfer**
  - **ECBC Requirements**
- **Cool Roofs**
  - **ECBC Prescriptive Requirements**
- **Fenestration**
  - **Heat Transfer**
  - **ECBC Requirements**
- **Air Leakage**
  - **ECBC Mandatory Requirements**
- **ECBC Compliance Forms**

Building Envelope

Surface that separates external environment from the interior (occupied) space

- ***Opaque Construction:*** Roof, Walls and Floors
- ***Fenestration:*** Windows, Doors and Skylights



NOTE: *Floors are not regulated through the ECBC*

Building Envelope Design Considerations

- ***Climate & microclimate***
  - Temperature, humidity, solar radiation, wind speed/direction, landform, vegetation, water bodies, open spaces, etc.

- ***Building Orientation & Form***
  - Orientation of the building, surface-to-volume ratio and exposed surface area

COMPOSITE CLIMATE

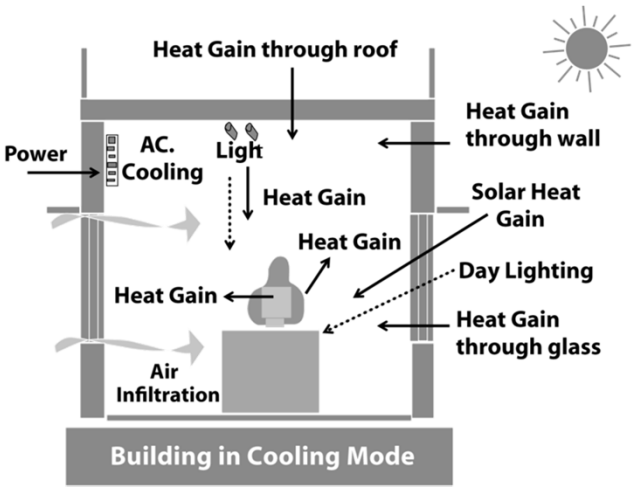
MODERATE CLIMATE

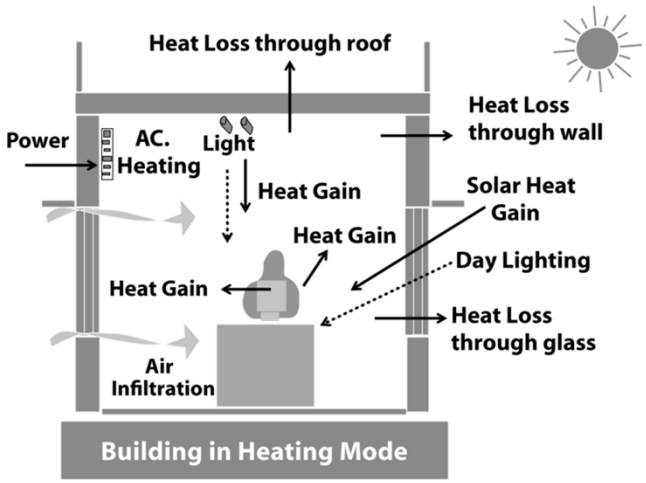
HOT-DRY CLIMATE

COLD CLIMATE

Building Envelope Design Considerations

- ***Building Envelope Component Design***
  - Area, orientation and tilt of the building envelope components
  - Roof form design, choice of shading devices, fenestration size, placement of windows, construction specifications etc.
- ***Building Material Specification***
  - Insulating Properties (U-values, SHGC), emissivity & color/texture





NOTE:

- *ECBC requirements affect envelope component design & material selection*
- *ECBC requirements impact heat transfer through buildings by regulating building insulation, area of fenestration and air leakage through buildings*

Opaque Construction

ECBC Building Envelope Requirements

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Chandigarh, Dec 3-4, 2012

Opaque Construction: Outline

- **Heat Transfer**
  - R-value (Insulation)
  - U-value
- **ECBC Requirements**
  - Mandatory Requirements
  - Prescriptive Requirements

Heat Transfer

Mode of Heat Transfer	Affected By	ECBC's role in regulating Heat Transfer
CONDUCTION	Thermal Properties of Materials & Effectiveness of Insulation	U-factors/ R-values of roofs & walls
CONVECTION	Air movement at the surface	Building Envelope Sealing Requirements
RADIATION	Indirect and direct solar radiation	• R-values of roofs & walls • Cool Roofs

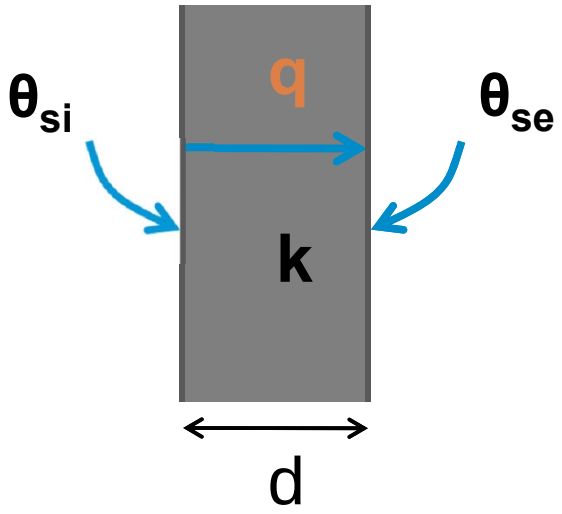
Heat Transfer

Thermal Property	Units	Effect of Thickness	Relationship
CONDUCTIVITY [k]	W/m·K	For unit thickness (m)	
RESISTIVITY [r]	m·K/W	For unit thickness (m)	1/k
RESISTANCE [R-value]	m^2·K/W	For thickness of construction (d)	d/k
CONDUCTANCE (Single Layer) [U-value]	W/m^2·K	For thickness of construction (d)	1/R-value
CONDUCTANCE (Multiple Layers) [U-factor]	W/m^2·K	For thickness of construction (d)	1/R-$value_{(Total)}$

R-value

- Thermal resistance : R-value

$$R = \frac{\text{Thickness of the material (d)}}{\text{Thermal conductivity of the material (k)}}$$



Thermal resistances of multi-layered components

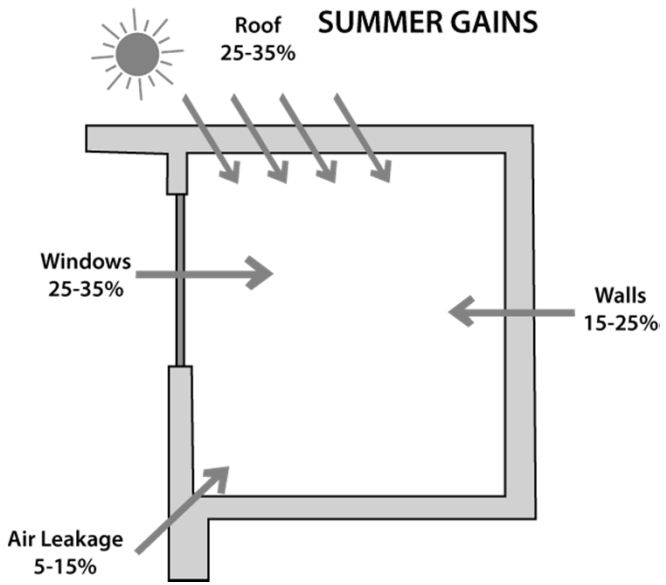
$$R_T = \frac{d_1}{k_1} + \frac{d_2}{k_2} + ... + \frac{d_n}{k_n} = \sum_n^1 \frac{d_n}{k_n}$$

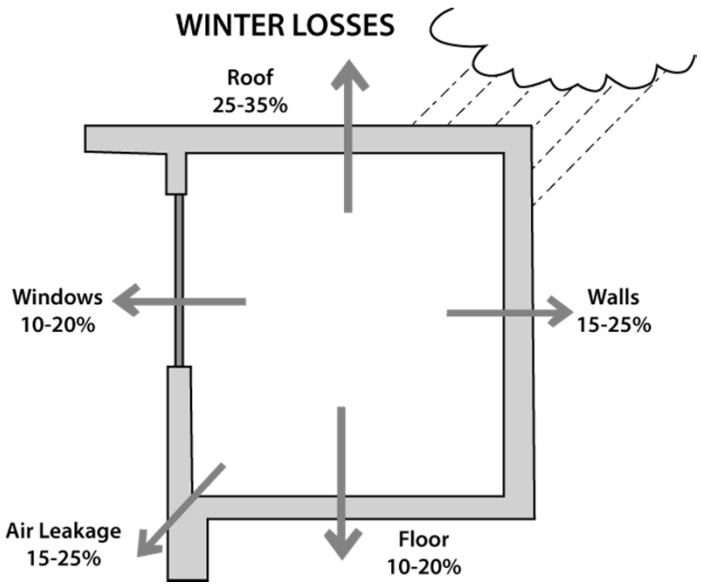
k : Conductivity
d : Thickness in m
θ_{si} : Indoor surface temperature
θ_{se} : Outdoor surface temperature

- Effectiveness of thermal insulation to retard the heat flow
- Higher R-value indicates higher insulating properties
  - (Units = $m^2 \cdot K/W$)

Building Insulation

- One of the ways to improve energy efficiency, especially in air conditioned buildings
- **Has high R-value**
- Increases thermal comfort in cooling & heating mode
- Helps in reducing heating and cooling costs





U-value

- Thermal Conductance (Heat Transfer Coefficient): U-value

$$U = \frac{1}{R}$$

- Measures heat transfer through the envelope due to a temperature difference between the indoors and outdoors (Unit = $W/m^2 \cdot K$)
- U-factor of composite wall/roof assembly as $1/R_T$
- Rate of the heat flow, therefore, lower numbers are better

ECBC Requirements: Mandatory

- U-factors shall be determined from the default tables in Appendix C §11 or determined from data or procedures contained in the ASHRAE Fundamentals, 2005.

Description	Density kg/m^3	Conductivity[b] (K), W/(m·K)	Conductance (C), W/(m^2·K)	Resistance[c] (R) 1/k, K·m^2/W	Resistance[c] (R) For Thickness Listed (1/C), K·m^2/W	Specific Heat kJ/(kg·K)
BUILDING BOARD						
Asbestos cement board.....	1900	0.58	—	1.73	—	1.00
Asbestos-cement board....3.2 mm	1900	—	187.4	—	0.05	—
Asbestos-cement board....6.4 mm	1900	—	93.7	—	0.011	—
Gypsum or plaster board. 9.5 mm	800	—	17.6	—	0.056	1.09

ECBC Requirements: Prescriptive

- For opaque construction, individual building envelope components must comply with:
  - **Maximum U-factor or Minimum R-value** (Exterior roofs , ceilings and opaque walls)
  - **Solar Reflectance & Emittance** (Cool Roofs)

- Compliance requirements vary according to:
  - The climate zone of the building location
  - Occupancy of the building (24 hour use or daytime use)

ECBC Requirements: Prescriptive (Opaque Walls)

- Maximum U-factor is prescribed for the complete wall assembly
- Minimum R-value is prescribed for insulation alone (excluding air films)

Table 4.2: Opaque Wall Assembly U-factor and Insulation R-value Requirements

Climate Zone	Hospitals, Hotels, Call Centers (24-Hour)		Other Building Types (Daytime)	
	Maximum U-factor of the overall assembly (W/m^2-°C)	Minimum R-value of insulation alone (m^2-°C/W)	Maximum U-factor of the overall assembly (W/m^2-°C)	Minimum R-value of insulation alone (m^2-°C/W)
Composite	U-0.440	R-2.10	U-0.440	R-2.10
Hot and Dry	U-0.440	R-2.10	U-0.440	R-2.10
Warm and Humid	U-0.440	R-2.10	U-0.440	R-2.10
Moderate	U-0.440	R-2.10	U-0.440	R-2.10
Cold	U-0.369	R-2.20	U-0.352	R-2.35

ECBC Requirements: Prescriptive (Roofs)

- Maximum U-factor is prescribed for the complete roof assembly
- Minimum R-value is prescribed for insulation alone (excluding air films)

Climate Zone	24-Hour use buildings Hospitals, Hotels, Call Centers etc.		Daytime use buildings Other Building Types	
	Maximum U-factor of the overall assembly (W/m^2-°C)	Minimum R-value of insulation alone (m^2-°C/W)	Maximum U-factor of the overall assembly (W/m^2-°C)	Minimum R-value of insulation alone (m^2-°C/W)
Composite	U-0.261	R-3.5	U-0.409	R-2.1
Hot and Dry	U-0.261	R-3.5	U-0.409	R-2.1
Warm and Humid	U-0.261	R-3.5	U-0.409	R-2.1
Moderate	U-0.409	R-2.1	U-0.409	R-2.1
Cold	U-0.261	R-3.5	U-0.409	R-2.1

- Recommendations made for proper placement, installation and protection of insulation

Cool Roofs

ECBC Building Envelope Requirements

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Chandigarh, Dec 3-4, 2012

ECBC Requirements: Prescriptive

For roofs with slope less than 20 degree

- Initial solar reflectance of no less than 0.70
- Initial emittance no less than 0.75

Initial reflectance/emittance may decrease over time, depending on the product, due to aging, dirt, and microbial accumulation.

Efficiency Recommendation for Cool Roofing Products (U.S. DOE)

Efficiency Recommendation[a]				
Roof slope	Recommended Solar Reflectance		Best Available Solar Reflectance [b]	
	Initial	3 Years after Installation	Initial	3 Years after Installation
Low-slope (<2:12)	65% or greater	50% or greater	87%	85%
High-slope[c] (<2:12)	25% or greater	15% or greater	77%	60%

a) Following this recommendation will provide the greatest benefit where cooling energy costs exceed heating costs
b) Roof products must be tested when new and after three years of exposure, according to ASTM E-903
c) For products that can be installed on both low- and high-slope roofs, "Low-slope" guidelines should be followed.

Fenestration

ECBC Building Envelope Requirements

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Chandigarh, Dec 3-4, 2012

Fenestration: Outline

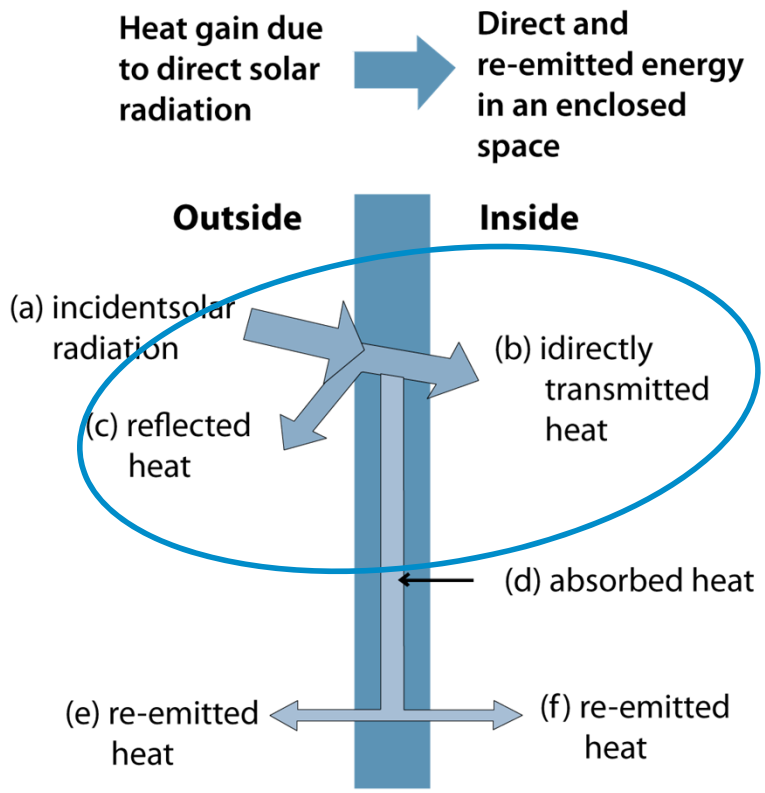
- **Heat Transfer**
  - Solar Heat Gain Coefficient (SHGC)
  - Shading Coefficient (SC) and SHGC
  - Visual Light Transmittance (VLT)
- **ECBC Requirements**
  - ECBC Mandatory Requirements
  - ECBC Prescriptive Requirements

Heat Transfer

Mode of Heat Transfer	Affected By	ECBC's role in regulating Heat Transfer
CONDUCTION	Thermal properties of fenestration assembly	• U-factors& Solar Heat Gain Coefficient (SHGC) of glazing • Wall-Window Ratio (WWR) • Skylight Roof Ratio (SSR)
CONVECTION	Air movement at the surface	• Maximum Air Leakage
RADIATION	Indirect and direct solar radiation	• Solar Heat Gain Coefficient of Glazing and Skylights • Wall Window Ratio (WWR) • Skylight Roof Ratio (SSR)

Solar Heat Gain Coefficient (SHGC)

- Ratio of solar heat gain that passes through fenestration to the total incident solar radiation that falls on the fenestration
- Indicates how well fenestration insulates heat caused by direct solar rays
- Lower SHGC means lesser heat transfers into the building through the window
- Depends on properties of glazing material & Window Operation (Fixed or Operable)
- In hot climates, SHGC is more significant than U-factor



SHGC of 0.4 allows 40% solar radiation through and reflects 60% away

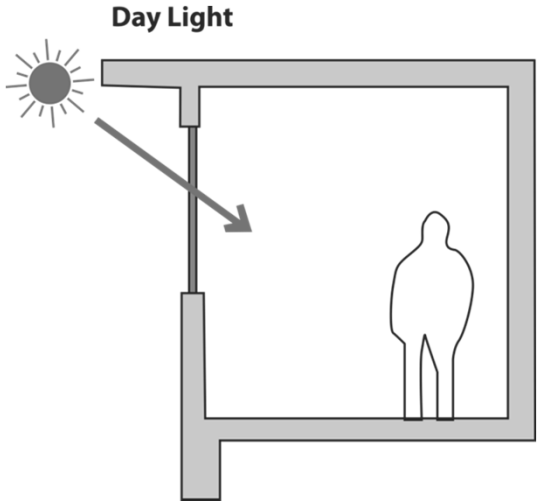
SOURCE: ECBC User Guide, USAID ECO-III Project, New Delhi

Shading Coefficient (SC) & SHGC

- The solar heat gain coefficient (SHGC) has replaced the shading coefficient (SC) as the standard indicator of a window's shading ability.
- Relationship between SC and SHGC
  - SHGC is expressed as a number between 0 and 0.87
  - SC as a number between 0 and 1
  - SHGC = SC × 0.87
- SHGC may be expressed in terms of the glass alone or may refer to the entire window assembly
  - SC is typically indicated for the glass alone, and does not take into consideration the effects of the frame

Visual Light Transmittance (VLT)

- Fraction of visible light transmitted through the glazing
  - Affects daylight and visibility
  - Varies between 0 & 1
- VLT is concerned with the visible portion of the solar spectrum as opposed to SHGC, which takes into account the entire solar radiation
- Typically, lower the SHGC, lower the VLT
  - Higher insulating property glass will reduce daylight
- Higher the VLT, more light is transmitted
  - Balance is needed between daylight requirements & heat gain through windows



ECBC Requirements: Overview

- ECBC regulates heat gain through fenestration through
- Size and Orientation
  - ECBC regulates maximum glazing area (Window-to-Wall Ratio)
- Shading Devices
  - ECBC takes into account reduction in heat gain through use of shading devices
- Glazing Properties
  - ECBC regulates Solar Heat Gain Factor (SHGC), U-value and Visual Light Transmittance (VLT)

ECBC Requirements: Mandatory

- U-factors AND SHGC (Appendix C of the ECBC)
- In accordance with ISO-15099 AND labeled and certified by the manufacturer
- U-Factors and SHGC must be certified by an accredited independent testing laboratory

Table 11.1: Defaults for Unrated Vertical Fenestration (Overall Assembly including the Sash and Frame)

		Clear Glass			Tinted Glass		
Frame Type	**Glazing Type**	**U-Factor (W/m^2-°C)**	**SHGC**	**VLT**	**U-Factor (W/m^2-°C)**	**SHGC**	**VLT**
All frame types	Single Glazing	7.1	0.82	0.76	7.1	0.70	0.58
Wood, vinyl, or fiberglass frame	Double Glazing	3.3	0.59	0.64	3.4	0.42	0.39
Metal and other frame type	Double Glazing	5.1	0.68	0.66	5.1	0.50	0.40

ECBC Requirements: Prescriptive (Vertical Fenestration)

- Fenestration area is limited to a maximum of 60% of the gross wall area for the prescriptive requirement.
- Maximum area weighted U-factor and maximum area weighted SHGC requirements

Table 4.3: Vertical Fenestration U-factor and SHGC Requirements (U-factor in W/m2-°C)

		WWR≤40%	40% <WWR≤60%
Climate	**Maximum U-factor**	**Maximum SHGC**	**Maximum SHGC**
Composite	3.30	0.25	0.20
Hot and Dry	3.30	0.25	0.20
Warm and Humid	3.30	0.25	0.20
Moderate	6.90	0.40	0.30
Cold	3.30	0.51	0.51

See Appendix C §11.2.1 for Defaults values of Unrated Fenestration

Reduced SHGC to compensate for increase in heat gain through a larger window to wall (WWR) ratio

Less stringent requirements for moderate Climates. Higher U-Factors and SHGC

ECBC Requirements: Prescriptive (Vertical Fenestration)

- Minimum VLT defined as function of Window Wall Ratio (WWR), where Effective Aperture > 0.1, equal to or greater than the Minimum VLT requirements of Table 4.5.

Table 4.5: Minimum VLT Requirements

Window Wall Ratio	Minimum VLT
0 - 0.3	0.27
0.31-0.4	0.20
0.41-0.5	0.16
0.51-0.6	0.13

Lower VLT requirements to offset the increased heat transfer through higher WWR

Effective Aperture

- *Light admitting potential of vertical fenestration*
- *Depends on glazing property and size of opening*

Effective Aperture = Visual Light Transmittance (VLT) * Window to Wall Ratio (WWR)

ECBC Requirements: Prescriptive (Vertical Fenestration)

ECBC Exception To Vertical Fenestration Requirements

- Applies to fenestration with shading devices (Overhangs/Fins)
- Adjustment to window SHGC through a multiplication (M) factor to account for reduced solar heat gain from windows that are well shaded
- "M Factor" shall be determined for each orientation, latitude of the building site and unique shading condition

ECBC Exception To SHGC Requirements

- Vertical Fenestration areas located more than 2.2 m (7 ft) above the floor level are exempt from the SHGC requirement in Table 4.3 if
  - The total Effective Aperture for the elevation is less than 0.25, including all fenestration areas greater than 1.0 m (3 ft) above the floor level
- An interior light shelf is provided at the bottom of this fenestration area, with an interior projection factor not less than:
  - 1.0 for E-W, SE, SW, NE, and NW orientations
  - 0.5 for S orientation, and
  - 0.35 for N orientation when latitude is < 23 degrees.

M-factor (ECBC Table 4.4)

- M-factor captures the effectiveness of shading devices to provide solar protection
- Varies according to latitude of site, choice of shading option and projection factor

FOR EXAMPLE:
Combination of Overhang + Fins provides maximum solar protection. Thus, M-Factors are the lowest

Projection Factors (PF) need to be calculated

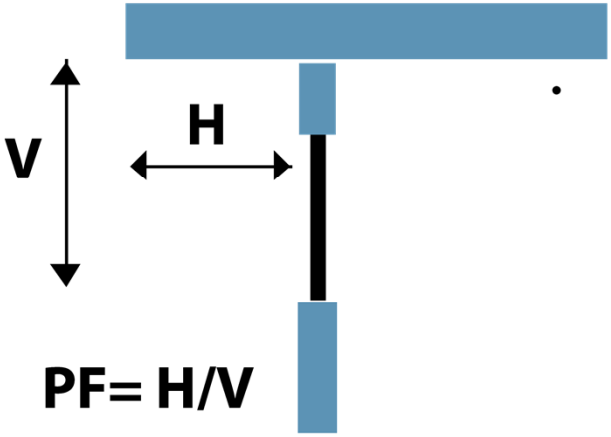
Project Location	Orientation	Overhang "M" Factors for 4 Projection Factors				Vertical Fin "M" Factors for 4 Projection Factors				Overhang+Fin "M" Factors for 4 Projection Factors			
		0.25-0.49	0.50-0.74	0.75 - 0.99	1.00 +	0.25-0.49	0.50-0.74	0.75-0.99	1.00 +	0.25-0.49	0.50-0.74	0.75 - 0.99	1.00 +
North latitude 15° or greater	N	.88	.80	.76	.73	.74	.67	.58	.52	.64	.51	.39	.31
	E/W	.79	.65	.56	.50	.80	.72	.65	.60	.60	.39	.24	.16
	S	.79	.64	.52	.43	.79	.69	.60	.56	.60	.33	.10	.02
Less than 15° North latitude	N	.83	.74	.69	.66	.73	.65	.57	.50	.59	.44	.32	.23
	E/W	.80	.67	.59	.53	.80	.72	.63	.58	.61	.41	.26	.16
	S	.78	.62	.55	.50	.74	.65	.57	.50	.53	.30	.12	.04

Projection Factor (PF) Calculation

- PF is needed to determine M-factor

PF = H (Horizontal) / V (vertical)

- **PF= Ratio of overhang projection divided by height from window sill to bottom of overhang (must be permanent)**

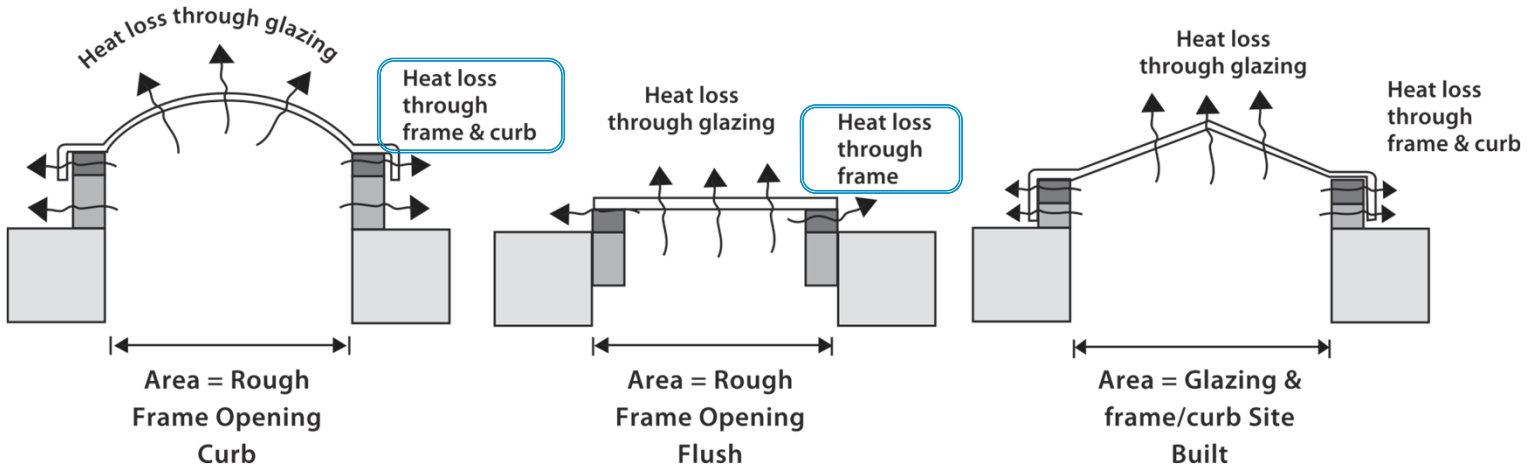


- **Solar heat gain Coffecient**
  - **Requirements dependent on:**
    - **Overhang projection factor**
    - **M- Factor from Table 4.3.3-2**
    - **Orientation**
    - **And Climate Zone**
  - **Without Overhang: SHGC range 0.25-0.51 based on climate zone.**

SOURCE: ECBC User Guide, USAID ECO-III Project, New Delhi

ECBC Requirements: Prescriptive (Skylights)

- ECBC regulates all fenestration (skylights) with slope of less than 60 Deg.
- U-Factor and SHGC requirements according to
  - Installation of skylight (Flush mounted/curb mounted)
  - Skylight Roof Ratio (SSR)



SOURCE: ECBC User Guide, USAID ECO-III Project, New Delhi

ECBC Requirements: Prescriptive (Skylights)

- Maximum U-factor and SHGC requirements of Table 4.6
  - Lower U-factors limit for flush mounted installation
- Skylight area is limited to a maximum of 5% of the gross roof area or Skylight Roof Ratio (SRR) =< 5%
  - Higher the SRR; lower the maximum SHGC required

	Maximum U-factor		Maximum SHGC	
Climate	**With Curb**	**w/o Curb**	**0-2% SRR**	**2.1-5% SRR**
Composite	11.24	7.71	0.40	0.25
Hot and Dry	11.24	7.71	0.40	0.25
Warm and Humid	11.24	7.71	0.40	0.25
Moderate	11.24	7.71	0.61	0.4
Cold	11.24	7.71	0.61	0.4

Higher SHGC limits for moderate and cold climate zones where heat gain through windows is less of a concern

Air Leakage

ECBC Building Envelope Requirements

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Implementation of Energy Conservation Building Code
Chandigarh, Dec 3-4, 2012

ECBC Requirements: Mandatory

- Air Leakage through doors and fenestration
  - for glazed swinging entrance doors and revolving doors shall not exceed 5.0 l/s-m^2.
  - Other fenestration and doors shall not exceed 2.0 l/s-m^2.

- Building Envelope Sealing
  - The following areas of the enclosed building envelope shall be sealed, caulked, gasketed, or weather-stripped to minimize air leakage:
    - Joints around fenestration and door frames
    - Openings between walls and foundations and between walls and roof and wall panels
    - Openings at penetrations of utility services through, roofs, walls, and floors
    - Site-built fenestration and doors
    - Building assemblies used as ducts or plenums
    - All other openings in the building envelope

ECBC Building Envelope Requirements: Overview

Building Component	Mandatory Requirements	Prescriptive Requirement
OPAQUE CONSTRUCTION (Roofs and Walls)	Building Envelope Sealing Requirements [ECBC 4.2.3]	Maximum U-factors & Minimum R-values of roofs & walls [ECBC 4.3.1 & 4.3.2) Cool Roof Specifications [ECBC 4.3.1.1]
FENESTRATION (Doors, Windows and Skylights)	Calculation of U-factors & Solar Heat Gain Coefficient (SHGC) of glazing [ECBC 4.2.1 & 4.2.1.2] Air Leakage Maximum Limits [ECBC 4.2.1.3]	Maximum U-factors & SHGC, Wall-Window Ratio (WWR), & Visible Transmission (VLT) of Glazing [ECBC 4.3.3] Skylight Roof Ratio (SSR); Maximum U-factors & SHGC of glazing [ECBC 4.3.4]

ECBC Compliance Forms

15.1 Envelope Summary

Envelope Summary

2007 Energy Conservation Building Code Compliance Forms

Project Info	Project Address	Date
		For Building Department Use
	Applicant Name:	
	Applicant Address:	
	Applicant Phone:	

Project Description	☐ New	☐ Addition	☐ Alteration	☐ Change of Use

Compliance Option	☐ Prescriptive	☐ Envelope Trade-Off (Appendix D)	☐ Whole Building Performance

	○ Hospital, hotel, call center (24 hour)		○ Other building types (daytime)	
Vertical Fenestration Area Calculation	Total Vertical Fenestration Area (rough opening)	divided by	Gross Exterior Wall Area	times 100 equals % Vertical Fenestration
Note: Vertical fenestration area can not exceed 50% of the gross wall area for prescriptive compliance		÷		X 100 =
Skylight Area Calculation	Total Skylight Area (rough opening)	divided by	Gross Exterior Wall Area	times 100 equals % Skylight
Note: Skylight area can not exceed 5% of the gross roof area for prescriptive compliance.		÷		X 100 =

Hospital, hotel, call center (24 hour)		
OPAQUE ASSEMBLY		
Roof	Minimum Insulation R-value	
Wall	Minimum Insulation R-value	
FENESTRATION		
Vertical		
	Maximum U-factor	
	Maximum SHGC	
Overhang (yes or no)		
	If yes, enter Projection Factor	
Side fins (yes or no)		
	If yes, enter Projection Factor	
Skylight		
	Maximum U-factor	
	Maximum SHGC	

Other building type (daytime)		
OPAQUE ASSEMBLY		
Roof	Minimum Insulation R-value	
Wall	Minimum Insulation R-value	
FENESTRATION		
Vertical		
	Maximum U-factor	
	Maximum SHGC	
Overhang (yes or no)		
	If yes, enter Projection Factor	
Side fins (yes or no)		
	If yes, enter Projection Factor	
Skylight		
	Maximum U-factor	
	Maximum SHGC	

Building Permit Plans Checklist — ENVELOPE Checklist

2007 Energy Conservation Building Code Compliance Forms

Project Address						Date	
The following information is necessary to check a building permit application for compliance with the building envelope requirements in the Energy Conservation Building Code 2007.							
Applicability (yes, no, n.a.)			Code Section	Component	Information Required	Location on Plans	Building Department Notes
MANDATORY PROVISIONS (Section 4.2)							
			4.2.1	Fenestration rating			
			4.2.1.1	U-factor	Specify whether per 4.2.1.1 or default in Appendix C		
			4.2.1.2	SHGC	Specify whether per 4.2.1.2 or default in Appendix C		
			4.2.1.3	Air leakage	Specify leakage rates		
			4.2.2	Opaque U-factors	Specify whether per default in Appendix C or ASHRAE		
			4.2.3	Bldg. env. sealing	Indicate sealing, caulking, gasketing, and weather stripping		
PRESCRIPTIVE COMPLIANCE OPTION (Section 4.3)							
			4.3.1	Roof	Indicate R-values on roof sections		
			4.3.1.1	Cool roof	Indicate minimum reflectance and emittance on plans		
			4.3.3	Opaque Walls	Indicate R-values on wall sections		
			4.3.3	Vertical fenestration	(1) Indicate U-factors on fenestration schedule. Indicate if values are rated or default. If values are default, then specify frame type, glazing layers, gap width, low-e. (2) Indicate SHGC or SC on fenestration schedule. Indicate if values are rated or default. (3) Indicate if overhangs or side fins are used for compliance purposes. If so, provide projection factor calculation.		
			4.3.4	Skylight	(1) Indicate U-factors on fenestration schedule. Indicate if values are rated or default. If values are default, then specify frame type, glazing layers, gap width, low-e. (2) Indicate SHGC or SC on fenestration schedule. Indicate if values are rated or default.		
BUILDING ENVELOPE TRADE-OFF OPTION (Section 4.4)							
					Provide calculations		

Contact Information

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