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GOVERNMENT OF PUNJAB

DEPARTMENT OF NEW & RENEWABLE ENERGY

(Approved vide Cabinet order No. 2167 dated 25.05.2016)

NOTIFICATION

The 24th June, 2016

No. 18/4/16-6ਨ1/1856.– In exercise of the powers conferred under Section 18 of The Energy Conservation Act-2001 (Act No. 52 of 2001), the Governor of Punjab is pleased to issue the following directions for the mandatory use of "Punjab Energy Conservation Building Code" for the energy efficiency and its conservation in the buildings or building complexes in the State of Punjab.

1. Purpose

The purpose of this code is to provide minimum requirements for the energy-efficient design and construction of buildings in the state of Punjab.

1.1. This code shall be called Punjab Energy Conservation Building Code (Punjab-ECBC).

2. Scope

The Punjab Energy Conservation Building Code (Punjab-ECBC) gives directives for the requirements for design or retrofit of buildings/ building complexes.

The code is applicable to buildings or building complexes that have connected load of 100 kW or greater or a contract demand of 120 kVA or greater or having conditioned area of 500 m² or more.

Punjab-ECBC pertains to all buildings / building complexes such as offices, hotels, shopping complexes, group housing complexes, hospitals and others that are not primarily for industrial i.e. manufacturing use.

2.1. Applicable Building systems

The provisions of Punjab-ECBC apply to:

a) Building envelopes, except for unconditioned storage spaces or warehouses;

b) Mechanical systems and equipment, including heating ventilating, and air conditioning;

c) Service hot water heating;

d) Interior and exterior lighting; and

e) Electrical power and motors.

2.2. Exemptions

The provisions of Punjab-ECBC do not apply to:

a) Buildings that do not use either electricity or fossil fuel; and

b) Equipment and portions of building systems that use energy primarily for manufacturing process

2.3. Safety, Health and Environmental Codes Take Precedence

Where this code is found to conflict with safety, health, or environmental codes, the safety, health, or environmental codes shall take precedence.

2.4. Reference Standards

The Energy Conservation Building Code 2007 and the National Building Code 2005 are the reference document/ standards for lighting levels, HVAC, comfort levels, natural ventilation, pump and motor efficiencies, transformer efficiencies and any other building materials and system performance criteria. In addition, a field survey was conducted with practicing architects and the common man to ascertain their requirements.

3. Administration and Enforcement

3.1 Compliance Requirements

3.1.1 Mandatory Requirements

a) Compliance with the requirements of Punjab-ECBC shall be mandatory for all applicable buildings discussed in clause 2.

b) All Government notifications related to energy conservation or mandatory use of any product/process or equipment shall be complied with.

c) In buildings specified in clause 2, preferably locally manufactured/ available material should be used.

3.1.2 New Buildings

New buildings shall comply with either the provisions of clause 4 through clause 8 of Punjab-ECBC or the whole building performance method of Appendix B clause 10.

In case, the project is to be built in phases, then Punjab-ECBC shall be applicable on the whole building load in total and not the individual buildings designed later on in phases.

3.1.3 Additions to Existing Buildings

Where the addition plus the existing building exceeds the conditioned floor area threshold of clause 2, additions shall comply with the provisions of clause 4 through clause 8. Compliance may be demonstrated in the following ways:

a) The addition alone shall comply with the applicable requirements, or

b) The addition, together with the entire existing building, shall comply with the requirements of this code that would apply to the entire building, as if it were a new building.

Exception to clause 3.1.3: When space conditioning is provided by existing systems and equipment, the existing systems and equipment need not comply with this code. However, any new equipment installed must comply with specific requirements applicable to that equipment.

3.1.4 Alterations to Existing buildings

Where the existing building exceeds the conditioned floor area threshold in clause 2, portions of a building and its systems that are being altered shall meet the provisions of clause 4 through clause 8. The specific requirements for alterations are described in the following subsections 3.1.4.1 to 3.1.4.6.

Exception to clause 3.1.4: When the entire building complies with all of the provisions of clause 4 through clause 8 as if it were a new building.

3.1.4.1 Building Envelope

Alterations to the building envelope shall comply with the requirements of clause 4 for fenestration, insulation, and air leakage applicable to the portions of the buildings and its systems being changed.

Exception to clause 3.1.4.1: The following alterations need not comply with these requirements provided such changes do not increase the energy usage of the building:

a) Replacement of glass in an existing sash and frame, provided the U-factor and SHGC of the replacement glazing are equal to or lower than the existing glazing

b) Modifications to roof/ceiling wall, or floor cavities which are insulated to full depth with insulation

c) Modifications to walls and floors without cavities and where no new cavities are created.

3.1.4.2 Heating, Ventilation and Air Conditioning

Alterations to building heating, ventilating, and air-conditioning, equipment or systems shall comply with the requirements of clause 5 applicable to the portions of the building and its systems being altered. Any new equipment or control devices installed in conjunction with the alteration shall comply with the specific requirements applicable to that equipment or control device.

3.1.4.3 Service Water Heating

Alterations to building service water heating equipment or systems shall comply with the requirements of clause

6 applicable to the portions of the building and its systems being altered. Any new equipment or control devices installed in conjunction with the alteration shall comply with the specific requirements applicable to that equipment or control device.

3.1.4.4 Lighting

Alterations to building lighting equipment or systems shall comply with the requirements of clause 7 applicable to the portions of the building and its systems being altered. New lighting systems, including controls, installed in an existing building and any change of building area type as listed in Table 7.1 shall be considered an alteration. Any new equipment or control devices installed in conjunction with the alteration shall comply with the specific requirements applicable to that equipment or control device.

Exception to clause 3.1.4.4: Alterations that replace less than 50% of the luminaries in a space need not comply with these requirements provided such alterations do not increase the connected lighting load.

3.1.4.5 Electric Power and Motors

Alterations to building electric power systems and motor shall comply with the requirements of clause 8 applicable to the portions of the building and its systems being altered. Any new equipment or control devices installed in conjunction with the alteration shall comply with the specific requirements applicable to that equipment or control device.

3.1.4.6 Star Labelling and Minimum Star Rating

All equipments and materials of type and specification coming under the purview of the star labeling program as notified by BEE shall have minimum three star rating or above or as notified by the State Government.

3.2 Compliance Approaches

The building shall comply with the mandatory provisions (clause 4.2, clause 5.2, clause 6.2, clause 7.2 and clause 8.2) and either of the following:

a) Prescriptive Method (clause 4.3, clause 5.3, clause 6.3)

   Exception to clause 3.2 (a): The envelope trade-off option of clause 4.4 may be used in place of the prescriptive criteria of clause 4.3

b) Whole Building Performance Method (Appendix B clause 10)

3.3 Administrative Requirements

Administrative requirements relating to permit requirements, enforcement, interpretations, claims of exemption, approved calculation methods, and rights of appeal are specified by the authority having jurisdiction.

3.3.1 Authority having Jurisdiction

For the administration and enforcement of the Punjab-ECBC, the State Designated Agency shall act as the "Authority having Jurisdiction" who shall be responsible for specifying permit requirements, code interpretations, approval calculation methods, worksheets and formats, compliance forms, manufacturing literature, rights of appeal and any other data to demonstrate compliance.

3.4 Compliance Documents

3.4.1 General

Plans and specifications shall show all pertinent data and features of the building, equipment, and systems in sufficient detail to permit the authority having jurisdiction to verify that the building complies with the requirements of Punjab-ECBC. Detail shall include, but are not limited to:

a) Building Envelope: Insulation materials and their R-values, fenestration U-factors, solar heat gain coefficients (SHGC), visible light transmittance (if the trade-off procedure is used), and air leakage; overhangs and sidefins, building envelope sealing details.

b) **Heating, Ventilation, and Air-Conditioning:** system and equipment types, sizes, efficiencies, and controls; economizers; variable speed drives; piping insulation; duct sealing insulation and location; requirement for balance report

c) **Service Hot Water and Pumping:** solar water heating system

d) **Lighting:** lighting schedule showing type, number, and wattage of lamps and ballasts; automatic lighting shutoff, occupancy sensors, and other lighting controls; lamp efficacy for exterior lamps

e) **Electrical Power:** Electric schedule showing transformer losses, motor efficiencies, and power factor correction devices, electric check metering and monitoring system.

3.4.2 Supplemental Information

The authority having jurisdiction may require supplemental information necessary to verify compliance with this code, such as calculations, worksheets, compliance forms, manufacturer's literature, or other data.

4. Envelope

4.1 General

The building envelope shall comply with the mandatory provisions of clause 4.2 and either the prescriptive criteria of clause 4.3 or the trade-off option of clause 4.4.

4.2 Mandatory Requirements

4.2.1 Fenestration

4.2.1.1 U-Factors

U-factors shall be determined for the overall fenestration product (including the sash and frame) in accordance with ISO-15099, as specified in Appendix C clause 11, by an accredited independent laboratory, and labeled and certified by the manufacturer or other responsible party. U-factors for sloped glazing and skylights shall be determined at a slope of 20 degrees above the horizontal. For unrated products, use the default table in Appendix C clause 11.

4.2.1.2 Solar Heat Gain Coefficient (SHGC)

SHGC shall be determined for the overall fenestration product (including the sash and frame) in accordance with ISO-15099, as specified in Appendix C clause 11, by an accredited independent laboratory, and labeled and certified by the manufacturer or other responsible party.

Exceptions to clause 4.2.1.2:

a) Shading coefficient (SC) of the centre glass alone multiplied by 0.86 is an acceptable alternate for compliance with the SHGC requirements for the overall fenestration area.

b) Solar heat gain coefficient (SHGC) of the glass alone is an acceptable alternate for compliance with the SHGC requirements for the overall fenestration product.

4.2.1.3 Air Leakage

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

4.2.2 Opaque Construction

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

4.2.3 Building Envelope Sealing

The following areas of the enclosed building envelope shall be sealed, caulked, gasketed, or weather-stripped to minimize air leakage:

a) Joints around fenestration and door frames;

b) Openings between walls and foundations and between walls and roof and wall panels;

c) Openings at penetrations of utility services through, roofs, walls, and floors;

d) Site-built fenestration and doors;

e) Building assemblies used as ducts or plenums; and

f) All other openings in the building envelope

4.3 Prescriptive Requirements

4.3.1 Roofs

Roofs shall comply with either the maximum assembly U-factor or the minimum insulation R-value in Table 4.1. R- Value is for the insulation alone and does not include building materials or air films. The roof insulation shall not be located on a suspended ceiling with removable ceiling panels.

Table 4.1: Roof assembly U-factor and Insulation R-value Requirements

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-ºC)	Minimum R-value of insulation alone (m^2-ºC/W)	Maximum U-factor of the overall assembly (W/ m^2-ºC)	Minimum R-Value of insulation alone (m^2-ºC/W)
Composite	U-0.261	R-3.5	U-0.409	R-2.1

Note: Punjab is covered by Composite climate zone only. For information on other climate zones, please refer relevant tables of ECBC-2007

4.3.1.1 Cool Roofs

Roofs with slops less than 20 degrees shall have an initial solar reflectance of no less than 0.70 and an initial emittance of no less than 0.75. Solar reflectance shall be determined in accordance with ASTM E903-96 and emittance shall be determined in accordance with ASTM E408-71 (RA 1996)

4.3.2 Opaque Walls

Opaque walls shall comply with either the maximum assembly U-factor or the minimum insulation R-value in Table 4.2. R-value is for the insulation alone and does not include building materials or air films.

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

Climate Zone	Hospitals, Hotels, Call Centres (24 Hour)		Other Building Types (Daytime)	
	Maximum U-factor of the overall assembly (W/ m^2-ºC)	Minimum R-value of insulation alone (m^2-ºC/W)	Maximum U-factor of the overall assembly (W/ m^2-ºC)	Minimum R-Value of insulation alone (m^2-ºC/W)
Composite	U-0.440	R-2.10	U-0.440	R-2.10

Note: Punjab is covered by Composite climate zone only. For information on other climate zones, please refer relevant tables of ECBC 2007

4.3.3 Vertical Fenestration

Vertical fenestration shall comply with the maximum area weighted U-factor and maximum area weighted SHGC requirements of Table 4.3. Vertical fenestration area is limited to a maximum of 60% of the gross wall area for the prescriptive requirement.

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
See Appendix C clause 11.2.1 for Default values of Unrated Fenestration			

Note: Punjab is covered by Composite climate zone only. For information on other climate zones, please refer relevant tables of ECBC 2007

Exception to clause 4.3.3: Overhangs and/or side fins may be applied in determining the SHGC for the proposed design. An adjusted SHGC, accounting for overhangs and/or sidefins, is calculated by multiplying the SHGC of the unshaded fenestration product times a multiplication (M) factor. If this exception is applied, a separate M Factor shall be determined for each orientation and unique shading condition by Equation 12-2 and the overhang and side fins coefficients are available in Table 12.6 clause 12.

Table 4.4: SHGC "M" Factor Adjustments for Overhangs and Fins

		Overhang "M" Factors for 4 Projection Factors				Vertical Fin "M" Factors for 4 Projection Factors				Overhang +Fin "M" Factors for 4 Projection Factors			
Project Location	Orientation	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	N	.88	.80	.76	.73	.74	.67	.58	.52	.64	.51	.39	.31
15° or greater	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°	N	.83	.74	.69	.66	.73	.65	.57	.50	.59	.44	.32	.23
North Latitude	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

Exception to SHGC Requirements in clause 4.3.3: Vertical fenestration areas located more than 2.2 m (7 ft) above the level of the floor are exempt from the SHGC requirement in Table 4.3 if the following conditions are complied with:

a) Total Effective Aperture: The total Effective Aperture for the elevation is less than 0.25, including all fenestration areas greater than 1.0m (3 ft) above the floor level; and,

b) An interior light shelf is provided at the bottom of this fenestration area, with an interior projection factor not less than:

   i. 1.0 for E-W, SE, SW, NE, and NW orientations

   ii. 0.5 for S orientation, and

   iii. 0.35 for N orientation when latitude is < 23 degrees.

4.3.3.1 Minimum Visible Transmission of glazing for vertical fenestration

Vertical fenestration product shall have the minimum Visual Light Transmittance (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

4.3.4 Skylights

Skylights shall comply with the maximum U-factor and maximum SHGC requirements of Table 4.6. Skylight area is limited to a maximum of 5% of the gross roof area for the prescriptive requirement.

Table 4.6: Skylight U-factor and SHGC Requirements (U-factor in W/ m^2-°C)

	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

SRR= Skylight roof ratio which is the ratio of the total skylight area of the roof, measured to the outside of the frame, to the gross exterior roof.

See clause 11.2.2 for typical complying skylight constructions.

4.4 Building envelope Trade Off Option

The building envelope complies with the code if the building envelope performance factor (EPF) of the proposed design is less than the standard design, where the standard design exactly complies with the criteria in clause 4.3. The envelope trade-off equation is found in Appendix D clause12.

5. Heating, Ventilation and Air Conditioning

5.1 General

a) All heating, ventilation and air conditioning equipments and systems shall comply with the mandatory provisions of clause 5.2 and the prescriptive criteria of clause 5.3.

b) The evaporative systems when used for cooling shall not use any potable water but their water requirement should be met from either the on site collected rainwater or the treated waste water.

Exception to clause 5.1(b): The evaporative cooling system using on site treated water or any other passive cooling systems such as Earth Air Tunnel (EAT) shall be used to pre cool the fresh air supplied to the building by at least 10ºC under peak summer temperature.

5.2 Mandatory Requirements

5.2.1 Natural ventilation

Natural ventilation shall comply with the design guidelines provided for natural verification in the National Building Code of India 2005 Part 8, Section 1, 5.4.3 and 5.7.1.

5.2.2 Minimum equipment Efficiencies

Cooling equipment shall meet or exceed the minimum efficiency requirements presented in Table 5.1. Heating and cooling equipment not listed here shall comply with ASHRAE 90.1-2004 clause 6.4.1. All cooling equipments shall comply with the provisions of clause 3.1.4.6.

Unitary Air Conditioner shall meet IS 1391 (Part 1), Split air conditioner shall meet IS 1391 (Part 2), Packaged air conditioner shall meet IS 8148 and Boilers shall meet IS 13980 with above 75% thermal efficiency.

Table 5.1: Chillers

Equipment class	**Minimum COP**	**Minimum IPLV**	**Test Standard**
Air Cooled Chiller <530 KW (<150 tons)	2.90	3.16	ARI 550/590-1998
Air Cooled Chiller ≥ 530 KW (≥150 tons)	3.05	3.32	ARI 550/590-1998
*Centrifugal water cooled Chiller <530 KW (<150 tons)	5.80	6.09	ARI 550/590-1998
*Centrifugal Water Cooled Chiller ≥530 and <1050 KW (≥150 and <300 tons)	5.80	6.17	ARI 550/590-1998
*Centrifugal Water Cooled Chiller ≥1050 KW (≥300 tons)	6.30	6.61	ARI 550/590-1998

Reciprocating Compressor, Water Cooled Chiller all sizes	4.20	5.05	ARI 550/590-1998
Rotary Screw and Scroll Compressor, Water Cooled Chiller <530KW (<150 tons)	4.70	5.49	ARI 550/590-1998
Rotary Screw and Scroll Compressor, Water Cooled Chiller ≥530KW and <1050 KW (≥150 and <300 tons)	5.40	6.17	ARI 550/590-1998
Rotary Screw and Scroll Compressor, Water Cooled Chiller ≥1050KW (≥300 tons)	5.75	6.43	ARI 550/590-1998
*These are aspirational values. For mandatory values refer to ASHRAE 90.1-2004			

5.2.3 Ceiling Fans Efficiencies

All fans including ceiling fans, wall mounted fans, pedestal fans and exhaust fans shall comply with the provisions of clause 3.1.4.6.

5.2.4 Controls

5.2.4.1 All mechanical cooling and heating systems shall be controlled by a time clock that:

a) Can start and stop the system under different schedules for three different day-types per week;

b) Is capable of retaining programming and time setting during loss of power for a period of at least 10 hours; and

c) Includes an accessible manual override that allows temporary operation of the system for up to 2 hours.

Exceptions to clause 5.2.4.1:

a) Cooling systems < 28 kW (8 tons)

b) Heating Systems < 7 kW (2 tons)

5.2.4.2

All heating and cooling equipment shall be temperature controlled. Where a unit provides both heating and cooling, controls shall be capable of providing a temperature dead band of 3ºC (5ºF) within which the supply of heating and cooling energy to the zone is shut off or reduced to a minimum. Where separate heating and cooling equipment serve the same temperature zone, thermostats shall be interlocked to prevent simultaneous heating and cooling.

5.2.4.3

All cooling towers and closed circuit fluid coolers shall have either two speed motors, pony motors, or variable speed drives controlling the fans.

5.2.4.4

The automatic door closure and door gaps sealing arrangement should be provided in all air conditioned rooms.

5.2.4.5

Each air conditioned space shall have a digital temperature indicator to indicate the operating temperature of the area.

5.2.4.6

Each air conditioned space shall be provided with ceiling fans/ wall mounted fans/air circulators so that effective cooling is maintained in the space.

5.2.4.7

Each room air conditioner shall be provided with at least one control device for display and regulation of temperature. The thermostat temperature of rooms/spaces can be preferably set at 24ºC when air conditioning is

used for comfort cooling.

5.2.4.8

Zone Control: The supply of cooling energy to each zone shall be controlled by individual thermostatic controls responding to temperature within the zone. Zone controls should be set no lower than indoor design conditions (24ºC). Temperature sensors shall be located in the zone or return air path.

5.2.5 Piping and Ductwork

5.2.5.1

Piping for heating systems with a design operating temperature of 60ºC (140ºF) or greater shall at least R-0.70 (R-4) insulation. Piping for heating systems with a design operating temperature less than 60ºC (140ºF) but greater than 40ºC- (104ºF), piping for cooling systems with a design operating temperature less than 15ºC (59ºF), and refrigerant suction piping on split systems shall have at least R-0.35 (R-2) insulation exposed to weather shall be protected by aluminum sheet metal, painted canvas, or plastic cover. Cellular foam insulation shall be protected as above, or be painted with water retardant paint.

5.2.5.2

Ductwork shall be insulated in accordance with Table 5.2

Table 5.2: Ductwork Insulation (m^2 -ºC/W)

		Required Insulation (a)
Duct Location	**Supply Ducts**	**Return Ducts**
Exterior	R-1.4	R-0.6
Ventilated Attic	R-1.4	R-0.6
Unventilated Attic without Roof insulation	R-1.4	R-0.6
Unventilated Attic with Roof insulation	R-0.6	No Requirement
Unconditioned Space(b)	R-0.6	No Requirement
Indirectly Conditioned Space(c)	No Requirement	No Requirement
Buried	R-0.6	No Requirement

(a)Insulation R-Value is measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 24ºC (75ºF) at the installed thickness.

(b) Includes crawlspaces, both ventilated and non-ventilated

(c)Includes return air plenums with or without exposed roofs above.

5.2.6 System Balancing

5.2.6.1 General

Construction documents shall require that all HVAC systems be balanced in accordance with generally accepted engineering standards.

Construction documents shall require that a written balance report be provided to the owner or the designated representative of the building owner for HVAC systems serving zones with a total conditioned area exceeding 500m2(5,000ft2).

5.2.6.1.1 Air System Balancing

Air systems shall be balanced in a manner to first minimize throttling losses. Then, for fans with fan system power greater than 0.75 kW (1.0 hp), fan speed shall be adjusted to meet design flow conditions.

5.2.6.1.2 Hydronic System Balancing

Hydronic Systems shall be proportionately balanced in a manner to first minimize throttling losses, then the pump impeller shall be trimmed or pump speed be adjusted to meet design flow conditions.

Exceptions to Clause 5.2.6.1.2:

a) Impellers need not be trimmed nor pump speed adjusted for pumps with pump motors of 7.5 kW (10hp) or less;

b) Impellers need not be trimmed when throttling results in no greater than 5% of the name plate horsepower draw, or 2.2 kW (3 hp), whichever is greater.

5.2.7 Condensers

5.2.7.1 Condenser Locations

Care shall be exercised in locating the condensers in such a manner that heat sink is free of interference from heat discharge by devices located in adjoining spaces and also does not interfere with such other systems installed nearby.

The condensers (outdoor units) especially of single unit room air conditioners shall be located in shaded and well ventilated area closest to the evaporator (indoor unit). In case of unavailability of shaded area, the condensers shall be provided with artificial shading to prevent direct heating of the unit during day time by the sunlight. The unitary air conditioners shall also be installed in suitable locations to avoid direct sunlight and shading may be provided for improved performance. The piping system connecting the outdoor and indoor units shall be installed as per clause 5.2.5.1 and the length of such pipes shall not exceed the length as specified by the manufacturer.

5.2.7.2 Treated water for condensers

All high-rise buildings using centralized cooling water system shall use soft water for the condenser and chilled water system.

5.3 Prescriptive Requirements

Compliance shall be demonstrated with the requirements in clause 5.3.1 through clause 5.3.2 for each HVAC system that meets the following criteria:

a) Serves a single zone

b) Cooling (if any) is provided by a unitary packaged or split-system air conditioner or heat pump.

c) Heating (if any) is provided by a unitary packaged or split-system heat pump, fuel-fired furnace, electric resistance heater, or baseboards connected to a boiler.

d) Outside air quantity is less than 1,400 I/s (3,000 cfm) and less than 70% of supply air at design conditions.

Other HVAC systems shall comply with ASHRAE 90.1-2004, clause 6.5.

5.3.1 Economizers

5.3.1.1 Air Side Economizer

Each individual cooling fan system that has a design supply capacity over 1,200 I/s (2,500 cfm) and a total mechanical cooling capacity over 22 kW (6.3 tons) shall include either:

a) An air economizer capable of modulating outside-air and return-air dampers to supply 100 percent of the design supply air quantity as outside-air; or

b) A water economizer capable of providing 100% of the expected system cooling load at outside air temperatures of 10ºC (50ºF) dry-bulb/7.2ºC (45ºF) wet-bulb and below.

Exception to clause 5.3.1.1: Individual ceiling mounted fan systems <3,200 l/s (6,500 cfm) are exempt

5.3.1.2

Where required by clause 5.3.1.1 economizers shall be capable of providing partial cooling even when additional mechanical cooling is required to meet the cooling load.

5.3.1.3

Air-side economizers shall be tested in the field following the requirements in Appendix F clause 14 to ensure

proper operation.

Exception to clause 5.3.1.3: Air economizers installed by the HVAC system equipment manufacturer and certified to the building department as being factory calibrated and tested per the procedures in Appendix F clause 14.

5.3.2 Variable Flow Hydronic Systems

5.3.2.1

Chilled or hot-water systems shall be designed for variable fluid flow and shall be capable of reducing pump flow rates to no more than the larger of:

a) 50% of the design flow rate, or

b) The minimum flow required by the equipment manufacturer for proper operation of the chillers or boilers

5.3.2.2

Water cooled air-conditioning or heat pump units with a circulation pump motor greater than or equal to 3.7 kW (5 hp) shall have two-way automatic isolation valves on each water cooled air-conditioning or heat pump unit that are interlocked with the compressor to shutoff condenser water flow when the compressor is not operating.

5.3.2.3

Chilled water or condenser water systems that must comply with either clause 5.3.2.1 or clause 5.3.2.2 and that have pump motors greater than or equal to 3.7 kw (5hp) shall be controlled by variable speed drives.

6. Service Hot Water and Pumping

6.1 General

All service water heating equipment and systems shall comply with the mandatory provisions of clause 6.2.

6.2 Mandatory Requirements

6.2.1 Solar Water Heating

Residential facilities, hotels and hospitals with a centralized system shall have solar water heating for at least 1/5 of the design capacity.

Exception to clause 6.2.1: Systems that use heat recovery for at least 1/5 of the design capacity.

6.2.2 Equipment Efficiency

Service water heating equipment shall meet or exceed the performance and minimum efficiency requirements presented in available Indian Standards.

a) Solar water heater shall meet the performance/minimum efficiency level mentioned in IS 13129 Part (1&2)

b) Gas Instantaneous Water heaters shall meet the performance/minimum efficiency level mentioned in IS 15558 with above 80% thermal efficiency.

c) Electric water heater shall meet the performance/minimum efficiency level mentioned in IS 2082. All heating equipments shall comply with the provisions of clause 3.1.4.6.

6.2.3 Supplementary Water Heating System

Supplementary heating system shall be designed to maximize the energy efficiency of the system and shall incorporate the following design features in cascade:

a) Maximum heat recovery from hot discharge system like condensers of air conditioning units

b) Use of gas fired heaters wherever gas is available

c) Electric heater as last resort

6.2.4 Piping Insulation

Piping insulation shall comply with clause 5.2.4.1. The entire hot water system including the storage tanks, pipelines shall be insulated conforming to the relevant IS standards on material and applications.

6.2.5 Heat Traps

Vertical pipe risers serving storage water heaters and storage tanks not having integral heat traps and serving a non-recirculating system shall have heat traps on both the inlet and outlet piping as close as practical to the storage tank.

6.2.6 Swimming Pools

Heated pools shall be provided with a vapor retardant pool cover on or at the water surface. Pools heated to more than 32º C (90ºF) shall have a pool cover with a minimum insulation value of R-2.1 (R-12)

Exception to clause 6.2.6: Pools deriving over 60% of their energy from site-recovered energy or solar energy source.

6.2.7 Compliance Documentation

The application for approval shall furnish detailed calculation showing the design to ensure that at least 20% of the heating requirement shall be met from solar heat/heat recovery and not more than 80% of the heat shall be met from electrical heating. Wherever gas is available, not more than 20% of the heat shall be met from electrical heating.

7. Lighting

7.1 General

Lighting systems and equipment shall comply with the mandatory provisions of clause 7.2 and the prescriptive criteria of clause 7.3 and clause 7.3.4. The lighting requirements in this section shall apply to:

a) Interior spaces of buildings

b) Exterior building features, including facades, illuminated roofs, architectural features, entrances, exits, loading docks, and illuminated canopies.

c) Exterior building grounds lighting that is provided through the building's electrical service

Exceptions to clause 7.1:

a) Emergency lighting that is automatically off during normal building operation and is powered by battery, generator, or other alternate power source

b) Lighting in dwelling units

7.2 Mandatory Requirements

7.2.1 Lighting Control

7.2.1.1 Automatic Lighting Shutoff

Interior lighting systems in buildings larger than 500m^2 (5,000 ft^2) shall be equipped with an automatic control device. Within these buildings, all office areas less than 30 m^2(300ft^2) enclosed by walls or ceiling-height partitions, all meeting and conference rooms, all school classrooms, and all storage spaces shall be equipped with occupancy sensors. For other spaces, this automatic control device shall function on either:

a) A scheduled basis at specific programmed times. An independent program schedule shall be provided for areas of no more than 2500 m^2 (25000 ft^2) and not more than one floor; or,

b) Occupancy sensors that shall turn the lighting off within 10 minutes of an occupant leaving the space. Light fixtures controlled by occupancy sensors shall have a wall-mounted, manual switch capable of turning off lights when the space is occupied.

Exception to clause 7.2.1.1: Lighting systems designed for 24 hour use.

7.2.1.2 Space Control

Each space enclosed by ceiling-height partitions shall have at least one control device to independently control the general lighting within the space. Each control device shall be activated either manually by an occupant or

automatically by sensing an occupant. Each control device shall:

a) Control a maximum of 250m^2 (2,500 ft^2) for a space less than or equal to 1,000 m^2 (10,000 ft^2), and a maximum of 1,000 m^2 (10,000 ft^2) for a space greater than 1000 m^2 (10000 ft^2)

b) Be capable of overriding the shutoff control required in clause 7.2.1.1 for no more than 2 hours.

c) Be readily accessible and located so the occupant can see the control.

Exception to clause 7.2.1.2 (c): The required control device may be remotely installed if required for reasons of safety or security. A remotely located device shall have a pilot light indicator as part of or next to the control device and shall be clearly labeled to identify the controlled lighting.

7.2.1.3 Control in Day lighted areas

Luminaries in day lighted areas greater than 25m^2 (250 ft^2) shall be equipped with either a manual or automatic control device that:

a) Is capable of reducing the light output of the luminaries in the day lighted areas by at least 50%, and

b) Controls only the luminaries located entirely within the day lighted area.

7.2.1.4 Exterior Lighting Control

Lighting for all exterior applications not exempted in clause 7.3.4 shall be controlled by a photo sensor or astronomical time switch that is capable of automatically turning off the exterior lighting when daylight is available or the lighting is not required.

7.2.1.5 Additional control

The following lighting applications shall be equipped with a control device to control such lighting independently of general lighting:

a) Display/Accent Lighting: Display or accent lighting greater than 300m^2 (3,000 ft^2) area shall have a separate control device

b) Case Lighting: Lighting in cases used for display purposes greater than 300m^2 (3,000 ft^2) area shall be equipped with a separate control device.

c) Hotel and Motel Guest Room Lighting: Hotel and motel guest rooms and guest suites shall have a master control device at the main room entry that controls all permanently installed luminaries and switched receptacles.

d) Task Lighting: Supplemental task lighting including permanently installed under shelf or under cabinet lighting shall have a control device integral to the luminaries or be controlled by a wall-mounted control device provided the control device compiles with clause 7.2.1.2 (c)

e) Non-visual Lighting: Lighting for non-visual applications, such as plant growth and food-warming, shall be equipped with a separate control device.

f) Demonstration Lighting: Lighting equipment that is for sale or for demonstrations in lighting education shall be equipped with a separate control device accessible only to authorized personnel.

7.2.2 Signage/ Advertising Signage

Internally-illuminated exit signs shall not exceed 5W/ft2. The lighting power density in case of signage / advertisement signage should not exceed 5 W/ft^2 for internally illuminated signage and 2.5 W/ft^2 for externally illuminated signage. They all shall use LEDs

7.2.3 Exterior Building Grounds Lighting

Lighting for exterior building grounds luminaries which operate at greater than 100W shall contain lamps having a minimum efficacy of 60 lm/W, LED type unless the luminaries is controlled by a motion sensor or exempt under clause 7.1.

7.3 Perspective Requirements

7.3.1 Interior Lighting Power

The installed interior lighting power for a building separately metered or permitted portion of a building shall be calculated in accordance with clause 7.3.4 and shall not exceed the interior lighting power allowance determined in accordance with either clause 7.3.2 or clause 7.3.3. Tradeoffs of interior lighting power allowance among portions of the building for which a different method of calculation has been used are not permitted.

Exception to clause 7.3: The following lighting equipment and applications shall not be considered when determining the interior lighting power allowance, nor shall the wattage for such lighting be included in the installed interior lighting power. However, any such lighting shall not be exempt unless it is an addition to general lighting and is controlled by an independent control device.

a) Display or accent lighting that is an essential element for the function performed in galleries, museums, and monuments

b) Lighting that is integral to equipment or instrumentation and is installed by its manufacturer.

c) Lighting specifically designed for medical or dental procedures and lighting integral to medical equipment.

d) Lighting integral to food warming and food preparation equipment

e) Lighting for plant growth or maintenance

f) Lighting in spaces specifically designed for use by the visually impaired.

g) Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions

h) Lighting in interior spaces that have been specifically designated as a registered interior historic landmark.

i) Lighting that is an integral part of signage / advertising signage

j) Lighting that is for sale or lighting educational demonstration systems

k) Lighting for theatrical purposes, including performance, stage, and film or video production

l) Athletic playing areas with permanent facilities for television broadcasting.

7.3.2 Building Area Method

Determination of interior lighting power allowance (watts) by the building area method shall be in accordance with the following:

a) Determine the allowed lighting power density from Table 7.1 for each appropriate building area type.

b) Calculate the gross lighted floor area for each building area type.

c) The interior lighting power allowance is the sum of the products of the gross lighted floor area of each building area times the allowed lighting power density for that building area types.

Table 7.1: Interior Lighting Power-Building Area Method (LPD- Lighting Power Density)

Building Area Type	LPD (W/m^2)	Building Area Type	LPD (W/m^2)
Automotive facility	9.7	Multifamily Residential	7.5
Convention Centre	12.9	Museum	11.8
Dining: Bar Lounge/Leisure	14.0	Office	10.8
Dining: Cafeteria/Fast Food	15.1	Parking Garage	3.2
Dining: Family	17.2	Performing Arts Theater	17.2
Dormitory/Hostel	10.8	Police/Fire station	10.8
Gymnasium	11.8	Post Office/Town Hall	11.8

Healthcare-clinic	10.8	Religious Building	14.0
Hospital/Health Care	12.9	Retail/Mall	16.1
Hotel	10.8	School/University	14.0
Library	14.0	Sports Arena	11.8
Manufacturing facility	14.0	Transportation	10.8
Motel	10.8	Warehouse	8.6
Motion Picture Theater	12.9	Workshop	15.1
In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.			

7.3.3 Space Function Method

Determination of interior lighting power allowance (watts) by the space function method shall be in accordance with the following:

a) Determine the appropriate building type from Table 7.2 and the allowed lighting power density.

b) For each space enclosed by partitions 80% or greater than ceiling height, determine the gross interior floor area by measuring to the center of the partition wall. Include the floor area of balconies or other projections. Retail spaces do not have to comply with the 80% partition height requirements.

c) The interior lighting power allowance is the sum of the lighting power allowances for all spaces. The lighting power allowance for a space is the product of the gross lighted floor area of the space times the allowed lighting power density for that space.

Table 7.2: Interior Lighting Power-Space Function Method

Space Function	**LPD (W/m^2)**	**Space Function**	**LPD (W/m^2)**
Office-enclosed	11.8	• For Reading Area	12.9
Office-open plan	11.8	Hospital	
Conference/Meeting/Multipurpose	14.0	• For Emergency	29.1
Classroom/Lecture/Training	15.1	• For Recovery	8.6
Lobby*	14.0	• For Nurse Station	10.8
• For Hotel	11.8	• For Exam Treatment	16.1
• For Performing Arts Theater	35.5	• For Pharmacy	12.9
• For Motion Picture Theater	11.8	• For Patient Room	7.5
Audience/Seating Area*	9.7	• For Operating Room	23.7
• For Gymnasium	4.3	• For Nursery	6.5
• For Convention Center	7.5	• For Medical supply	15.1
• For Religious Buildings	18.3	• For Physical Therapy	9.7
• For sports Arena	4.3	• For Radiology	4.3
• For Performing Arts Theater	28.0	• For Laundry – Washing	6.5
• For Motion Picture Theatre	12.9	Automotive – Service Repair	7.5
• For Transportation	5.4	Manufacturing facility	
Attrium-first three floors	6.5	• For Low Bay(<8m ceiling)	12.9
Attrium-each additional floor	2.2	• For High Bay (>8m ceiling)	18.3
Lounge/Recreation	12.9	• For Detailed Manufacturing	22.6
• For Hospital	8.6	• For Equipment Room	12.9
• Dining Area*	9.7	• For Control Room	5.4
• For Hotel	14.0	• Hotel/Motel Guest rooms	11.8

• For Motel	12.9	• Dormitory – Living Quarters	11.8
• For Bar Lounge/Leisure Dining	15.1	Museum	
• For family dining	22.6	• For general exhibition	10.8
• Food Preparation	12.9	• For Restoration	18.3
• For Hotel	14.0	• Hotel/Motel Guest rooms	11.8
• For Motel	12.9	• Dormitory – Living Quarters	11.8
• For Bar Lounge/Leisure Dining	15.1	Museum	
• For family dining	22.6	• For general exhibition	10.8
• Food Preparation	12.9	• For Restoration	18.3
Laboratory	15.1	Bank Office-Banking Activity Area	16.1
Rest rooms	9.7	Retail	
Dressing/Locker/Fitting Room	6.5	• For Sales Area	18.3
• Corridor/Transition*	5.4	• For Mail Concourse	18.3
• For Hospital	10.8	Sports Arena	
• For Manufacturing Facility	5.4	• For Ring Sports Area	29.1
• Stairs-active	6.5	• For Court Sports Area	24.8
• Active Storage*	8.6	• For Indoor Field Area	15.1
• For Hospital	9.7	Warehouse	
Inactive Storage*	3.2	• For Fine Material Storage	15.1
• For Museum	8.6	• For Medium/ Bulky Material Storage	9.7
Electrical /Mechanical Facility	16.1	Parking Garage-Garage Area	2.2
Workshop	20.5	Transportation	
Convention Center-Exhibit Space	14.0	• For Airport-Concourse	6.5
Library		• For Air/Train/Bus-Baggage Area	10.8
• For Card File & Cataloging	11.8	• For Ticket Counter Terminal	16.1
• For Stacks	18.3		

*For all facilities except the following

7.3.4 Installed Interior Lighting Power

The installed interior lighting power calculated for compliance with 7.3 shall include all power used by the luminaires, including lamps, ballasts, current regulators, and control devices except as specifically exempted in clause 7.1.

Exception to clause 7.3.4: If two or more independently operation lighting systems in a space are controlled to prevent simultaneous user operation, the interior lighting power shall be based solely on the lighting system with the highest power.

7.3.4.1 Luminaire Wattage

Luminaire wattage incorporated into the installed interior lighting power shall be determined in accordance with the following:

a) The wattage of incandescent luminaries with medium base sockets and not containing permanently installed ballasts shall be the maximum labeled wattage of the luminaires

b) The wattage of luminaries containing permanently installed ballasts shall be the operating input wattage of the specified lamp/ballast combination based on values from manufacturers' catalogs or values from independent testing laboratory reports

c) The wattage of all other miscellaneous luminaire types not described in (a) or (b) shall be the specified wattage of the luminaires

d) The wattage of lighting track, plug-in bus way, and flexible-lighting systems that allow the addition

and/ or relocation of luminaires without altering the wiring of the system shall be the larger of the specified wattage of the luminaires included in the system or 135W/m(45W/ft).Systems with integral overload protection, such as fuses or circuit breakers, shall be rated at 100% of the maximum rated load of the limiting device

7.3.5 Exterior Lighting Power

For building exterior lighting applications specified in Table 7.3, the connected lighting power shall not exceed the specified lighting power limits specified for each of these applications. Trade-offs between applications is not permitted. Exterior lighting for all other applications (except those included in the Exceptions to 7.3.4) shall comply with the requirements of 7.2.3.

Table 7.3: Exterior Building lighting Power

Exterior Lighting Applications	Power Limits
Building entrance (with canopy)	13W/m² (1.3W/ft²) of canopied area
Building entrance (without canopy)	90W/m² (30 W/lin f) of the door width
Building exit	60W/m² (20 W/lin f) of the door width
Building facades	2 W/m² (0.2 W/ft²) of vertical façade area

Exception to clause 7.3.5: Lighting used for the following exterior application is exempt when equipped with an independent control device:

a) Specialized signal, directional, and marker lighting associated with transportation

b) Lighting used to highlight features of public monuments and registered historic landmark structures or buildings

c) Lighting that is specifically designated as required by a health or life safety statute, ordinance, or regulation

d) Lighting that is specifically designated as required by a health or life safety statute, ordinance, or regulation

7.3.6 Lighting Type and Efficiency

All fluorescent tube lights shall be of energy efficient or BEE star rated as specified in clause 3.1.4.6. No incandescent bulb shall be used for ordinary lighting applications.

8. Electrical Power

8.1 General

Electric equipment and systems shall comply with the mandatory requirements of clause 8.2.

8.2 Mandatory Requirements

8.2.1 Transformers

8.2.1.1 Maximum Allowable Power Transformer Losses

Power transformers of the proper ratings and design must be selected to satisfy the minimum acceptable efficiency at 50% and full load rating. In addition, the transformer must be selected such that it minimizes the total of its initial cost in addition to the present value of the cost of its total lost energy while serving its estimated loads during its respective life span. All distribution transformers shall comply with the provisions of clause 3.1.4.6.

Table 8.1: Dry Type Transformers- total losses for dry type transformers should conform as per the draft standard of Indian standard IS 2026: Part 11 2007

Rating KVA	Max. Losses at 50% loading KW*	Max. Losses at 100% loading KW*	Total losses at 50% loading KW*	Total losses at rated load KW*
	Up to 22 KV class		33KV class	
100	0.94	2.4	1.12	2.4
160	1.29	3.3	1.42	3.3
200	1.5	3.8	1.75	4

250	1.7	4.32	1.97	4.6
315	2	5.04	2.4	5.4
400	2.38	6.04	2.9	6.8
500	2.8	7.25	3.3	7.8
630	3.34	8.82	3.95	9.2
800	3.88	10.24	4.65	11.4
1000	4.5	12	5.3	12.8
1250	5.19	13.87	6.25	14.5
1600	6.32	16.8	7.5	18
2000	7.5	20	8.88	21.4
2500	9.25	24.75	10.75	26.5

Table 8.2: Oil Filled Transformers- total losses for oil filled transformers should conform as per the following table as specified in Central Electricity Authority norms

Rating VA	**Max. Losses at 50% loading W***	**Max. Losses at 100% loading W***	**Total losses at 50% loading W***	**Total losses at rated load W***
	Up to 11 KV class		**33KV class**	
100	520	1800	560	1820
160	770	2200	780	2580
200	890	2700	900	3000
250	1050	3320	-	-
315	1100	3630	1300	4300
400	1450	4630	1520	5100
500	1600	5500	1950	6450
630	2000	6640	2300	7600
1000	3000	9800	3450	11350
1250	3600	12000	4000	13250
1600	4500	15000	4850	16000
2000	5400	18400	5700	18500
2500	6500	22500	7050	23000

For Tables 8.1, 8.2:* Total loss values given in above table are applicable for thermal classes E,B&F and have component of the load loss at reference temperature according to clause 17 of IS 2026: Part 11, i.e., average winding temperature rise as given in column 2 of Table 8.2 plus 300C. An increase of 7% on total for thermal class H is allowed.

8.1.1.2 Measurement and Reporting of Transformer Losses

All measurement of losses shall be carried out by using calibrated digital meters of class 0.5 or better accuracy and certified by the manufacturer. All transformers of capacity of 500 kVA and above would be equipped with additional metering class current transformers (CTs) and potential transformers (PTs) additional to requirements of utilities so that periodic loss monitoring study may be carried out.

8.2.2 Energy Efficient Motors

Motors shall comply with the following:

a) All permanently wired motors of 0.375 kW or more serving the building and -expected to operate more than 1,500 hours per year and all permanently wired polyphase motors of 50 kW or more serving the building and expected to operate more than 500 hours per year shall have a minimum acceptable nominal full load motor efficiency not less than IS 12615 for energy efficient motors;

b) Motors of horsepower differing from those listed in the table shall have efficiency greater than that of the next listed kW motor;

c) Motor horsepower ratings shall not exceed 20% of the calculated maximum load being served;

d) Motor nameplates shall list the nominal full- load motor efficiencies and the full- load power factor;

e) Motor users should insist on proper rewinding practices for any rewound motors. If the proper rewinding practices cannot be assured, the damaged motor should be replaced with a new, efficient one rather than suffer the significant efficiency penalty associated with typical rewind practices;

f) Certificates shall be obtained and kept on record indicating the motor efficiency. Whenever a motor is rewound, appropriate measures shall be taken so that the core characteristics of the motor is not lost due to thermal and mechanical stress during removal of damaged parts. After rewinding, a new efficiency test shall be performed and a similar record shall be maintained;

g) All motors and pump sets shall comply with the provisions of clause 3.1.4.6.

8.2.3 Power Factor Correction

All electricity supplies exceeding 100 A, 3 phases shall maintain their power factor between 0.95 lag and unity at the point of connection.

8.2.4 Check – Metering and Monitoring

a) Services exceeding 120 kVA shall have permanently installed electrical metering to record demand (kVA), energy (kWh), and total power factor. The metering shall also display current (in each phase and the neutral), voltage (between phases and between each phase and neutral), and total harmonic distortion (THD) as a percentage of the current

b) Service not exceeding 120 kVA but over 65 kVA shall have permanently installed electric metering to record demand (kW), energy (kWh), and total power factor (or kVARh)

c) Services not exceeding 65 kVA shall have permanently installed electrical metering to record energy (kWh)

8.2.5 Power Distribution Systems

8.2.5.1 Power Distribution System Losses

The power cabling shall be adequately sized as to maintain the distribution losses not to exceed 1% of the total power usage. Record of design calculation for the losses shall be maintained.

Compliance

1. It will also be mandatory to implement the Punjab Energy Conservation Building Code (Punjab ECBC) in Govt. Buildings / Building Complexes including buildings / building complexes of Municipalities / Local Bodies, Boards, Corporations, Govt. Aided Institutions and Other Autonomous Bodies of the Govt. of Punjab.
2. The provisions of Punjab ECBC shall be integrated for effective implementation in the Building Bye-laws, specifications, relevant manuals by the concerned authorities / agencies and local bodies. Accordingly, Building Plan sanctions by Govt. Departments / Agencies / Municipal Corporations / Councils / Committees / Nagar Panchayats / Punjab Urban Development Authority / other Urban Development Authorities without Punjab ECBC implementation shall not be allowed.
3. All the line departments; Housing and Urban Development, Local Govt., Town and Country Planning, PWD (B&R), Water Supply & Sanitation, Architecture, Punjab Urban Development Authority and other Urban Development Authorities will amend their rules / bye-laws within a period of six months from the date of issue of this order to ensure the implementation of the Punjab ECBC.

4. These departments / authorities will also designate Nodal Officer to monitor and report the progress of enforcement of the State Government Decisions to the Department of New & Renewable Energy, Govt. of Punjab on quarterly basis.

Powers

Govt. of Punjab, Department of New & Renewable Energy can amend / relax / make addition / interpret / provisions under this "Punjab ECBC" with due approval of Chief Minister.
It shall come into force from the date of its publication in the Official Gazette.

Sd/-
(ANIRUDH TEWARI) IAS
Principal Secretary to Government of Punjab,
Department of New & Renewable Energy.

Chandigarh
The 21st June, 2016

9. Appendix A: Definitions, Abbreviations and Acronyms

9.1 General

Certain terms, abbreviations, and acronyms are defined in this section for the purposes of this code. These definitions are applicable to all sections of this code. Terms that are not defined shall have their ordinarily accepted meanings within the context in which they are used. Webster's Third New International Dictionary of the English Language, Unabridged, copyright 1986, shall be considered as providing ordinarily accepted meanings.

9.2 Definitions

Addition: an extension or increase in floor area or height of a building outside of the existing building envelope

Alteration: any change, rearrangement, replacement, or addition to a building or its systems and equipment; any modification in construction or building equipment

Annual fuel utilization efficiency (AFUE): an efficiency description of the ratio of annual output energy to annual input energy as developed in accordance with requirements of U.S.Department of Energy (DOE) 10CFR Part 430

Area: see roof and wall, conditioned floor, day lighted, façade, fenestration, lighted floor

Astronomical time switch: an automatic time switch that makes an adjustment for the length of the day as it varies over the year

Authority having jurisdiction: the agency or agent responsible for enforcing this standard

Automatic: self-acting, operating by its own mechanism when actuated by some non-manual influence, such as a change in current strength, pressure, temperature, or mechanical configuration.

Automatic control device: a device capable of automatically turning loads off and on without manual intervention

Balancing, air system: adjusting airflow rates through air distribution system devices, such as fans and diffusers, by manually adjusting the position of dampers, splitters vanes, extractors, etc., or by using automatic control devices, such as constant air volume or variable air volume boxes

Ballast: a device used in conjunction with an electric-discharge lamp to cause the lamp to start and operate under proper circuit conations of voltage, current, waveform, electrode heat, etc.

Boiler: a self- contained low-pressure appliance for supplying steam or hot water

Boiler, packaged: a boiler that is shipped complete with heating equipment mechanical draft equipment, and automatic controls; usually shipped in one or more sections. A packaged boiler includes factory-built boilers manufactured as a unit or system, disassembled for shipment, and reassembled at the site.

Building: a structure wholly or partially enclosed within exterior walls, or within exterior and party walls, and a roof, affording shelter to persons, animals, or property.

Building, existing: a building or portion thereof that was previously occupied or approved for occupancy by the authority having jurisdiction

Building complex: a group of buildings in a contiguous area under single ownership

Building entrance: any doorway set of doors, turnstiles, or other form of portal that is ordinarily used to gain access to the building by its users and occupants

Building envelope: the exterior plus the semi-exterior portions of a building. For the purposes of determining building envelope requirements, the classifications are defined as follows:

(a) **Building envelope, exterior:** the elements of a building that separate conditioned spaces from the exterior

(b) **Building envelope, semi-exterior:** the elements of a building that separate conditioned space from unconditioned space or that enclose semi-heated spaces through which thermal energy may be transferred to or from the exterior, or to or form unconditioned spaces, or to or form conditioned spaces

Building exit: any doorway, set of doors, or other form of portal that is ordinarily used only for emergency egress or convenience exit

Building grounds lighting: lighting provided through a building's electrical service for parking lot, site, roadway, pedestrian pathway, loading dock, and security applications

Building material: any element of the building envelope through which heat flows and that heat is included in the component U-factor calculations other than air films and insulation

Circuit breaker: a device designed to open and close a circuit by non-automatic means and to open the circuit automatically at a predetermined over-current without damage to itself when properly applied with its rating

Class of construction: for the building envelope, a subcategory of roof, wall, floor, slab-on-grade floor, opaque door, vertical fenestration, or skylight

Coefficient of performance (COP)-cooling: the ratio of the rate of heat removal to the rate of energy input, in consistent units, for a complete refrigerating system or some specific portion of that system under designated operating conditions

Coefficient of performance (COP)-heating: the ratio of the rate of heat delivered to the rate of energy input, in consistent units, for a complete heat pump system. Including the compressor and, if applicable, auxiliary heat, under designated operating conditions

Commercial building: all building except for multi-family buildings of three stories or fewer above grade and single-family buildings

Construction documents: drawings and specifications used to construct a building, building systems, or portions thereof

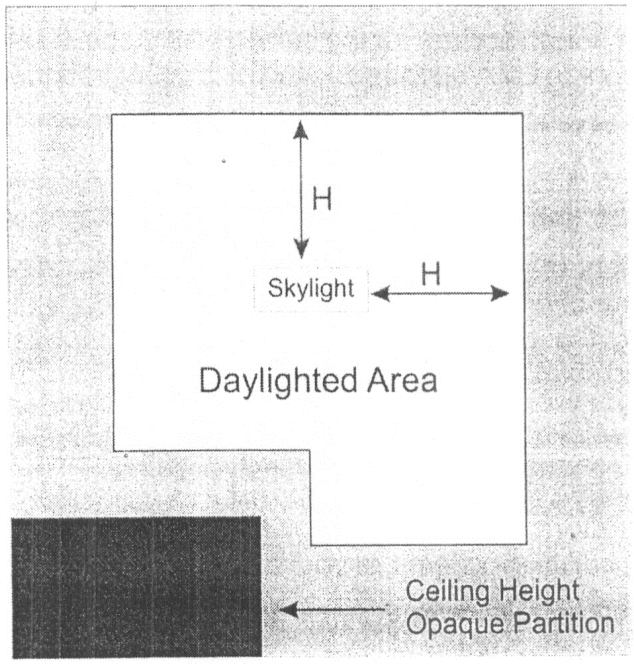
Control: to regulate the operation of equipment

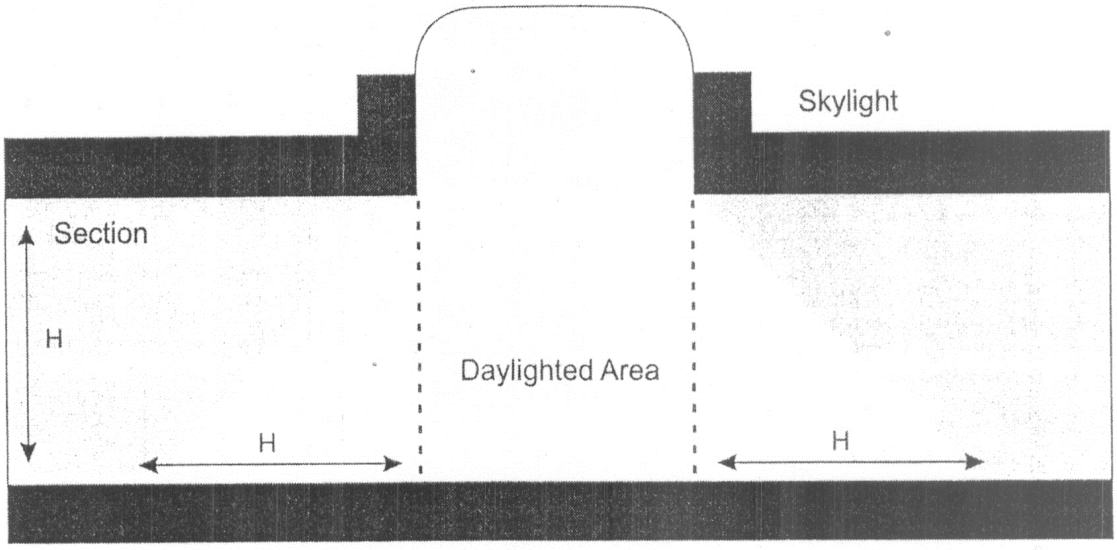
Control device: a specialized device used to regulate the operation of equipment

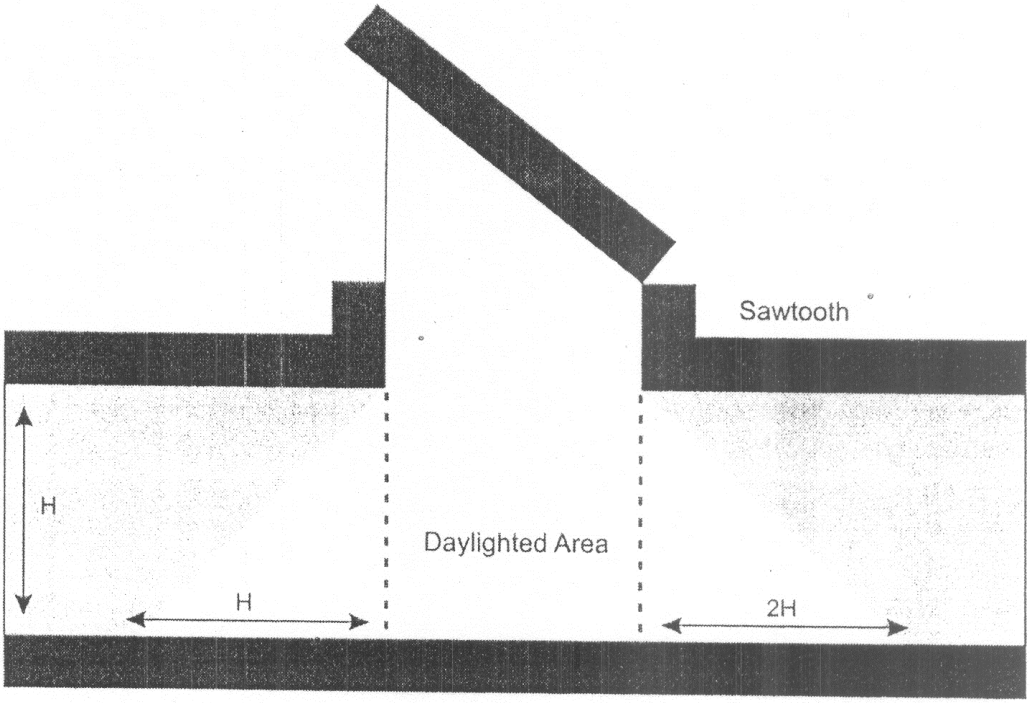
Cool roof: a property of a surface that describes its ability to reflect and reject heat. Cool roof surfaces have both a light color (high solar reflectance) and a high emittance (can reject heat back to the environment)

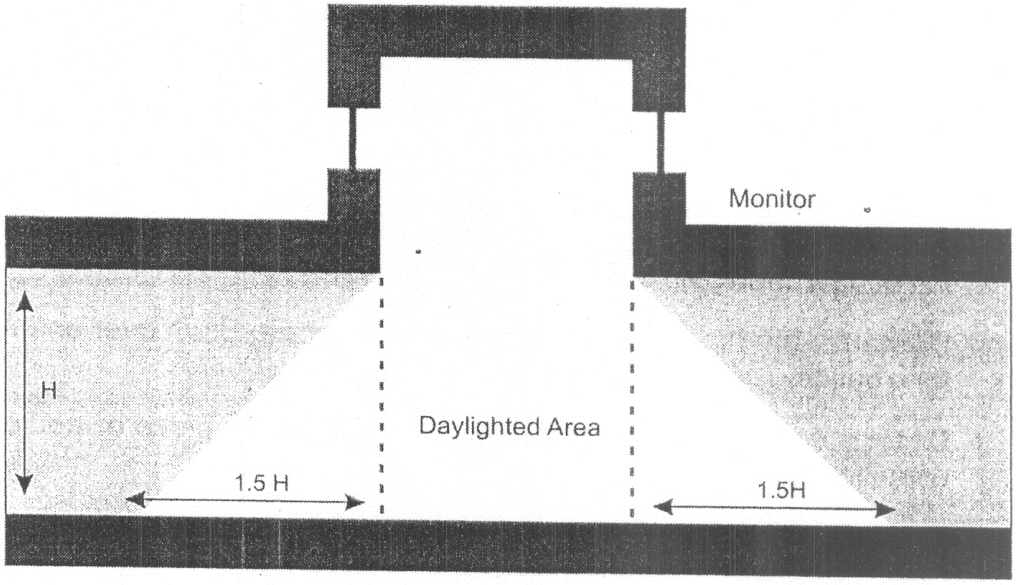
Day lighted area: the daylight illuminated floor area under horizontal fenestration (skylight) or adjacent to vertical fenestration (window), described as follows

(a) **Horizontal Fenestration:** the under a skylight, monitor, or saw tooth configuration with an effective aperture greater than 0.001 (0.1%). The day lighted area is calculated as the horizontal dimension in each direction equal to the top aperture dimension in that direction plus either the floor-to-ceiling height (H) for skylights, or 1.5 H for monitors, or H or 2H for the saw tooth configuration, or the distance to the nearest 1000mm (42 in) or higher opaque partition, or one-half the distance to an adjacent skylight or vertical glazing, whichever is least, as shown in the plan and section figures below:

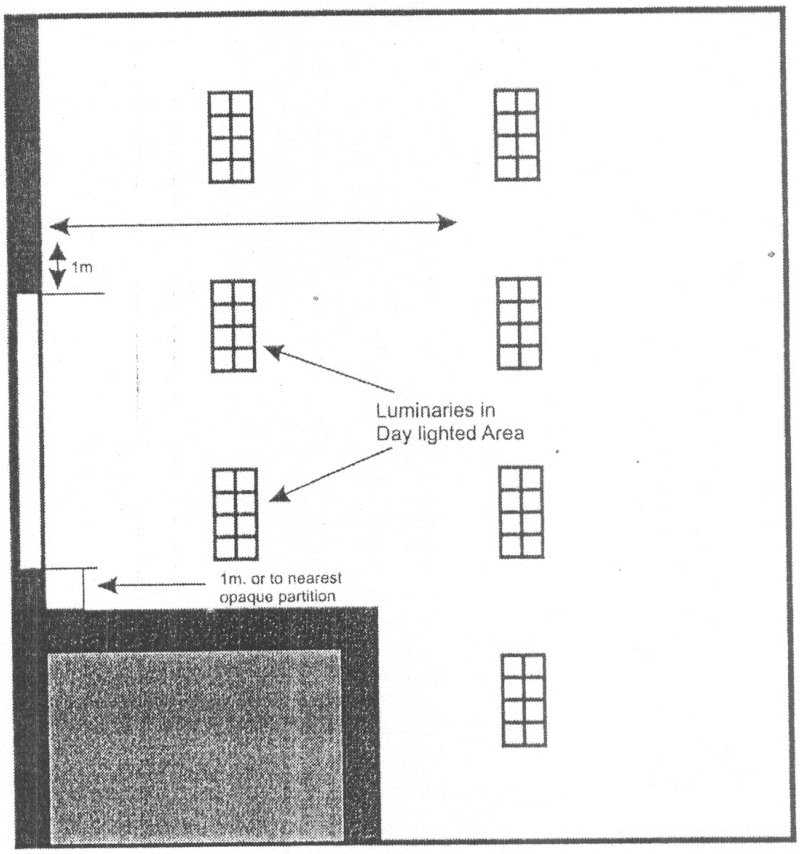

H
Skylight
H
Daylighted Area
Ceiling Height
Opaque Partition


Skylight
Section
H
Daylighted Area
H
H


Sawtooth
H
Daylighted Area
H
2H


Monitor
H
Daylighted Area
1.5 H
1.5H

(b) **Vertical Fenestration:** the floor area to adjacent to side apertures (vertical fenestration in walls) with an effective aperture greater than 0.06 (6%). The day lighted area extends into the space perpendicular to the side aperture a distance either two times the head height of the side aperture or to the nearest 1.35m (54 in) or higher opaque partition, whichever is less. In the direction parallel to the window, the day lighted area extends a horizontal dimension equal to the width of the window plus either 1 m (3.3 ft) on each side of the aperture, the distance to an opaque partition, or one-half the distance to an adjacent skylight or window, whichever is least.



Dead band: the range of values within which a sensed variable can vary without initiating a change in the controlled process

Demand: the highest amount of power (average Btu/h over an interval) recorded for a building or facility in a selected time frame.

Design capacity: output capacity of a system or piece of equipment at design conditions

Design conditions: specified environmental conditions, such as temperature and light intensity, required to be produced and maintained by a system and under which the system must operate.

Distribution system: a device or group of devices or other means by which the conductors of a circuit can be disconnected from their source of supply.

Door: all operable opening areas (which are not fenestration) in the building envelope, including swinging and roll-up doors, fire doors, and access hatches. Doors that are more than one- half glass are considered fenestration. For the purposes of determining building envelope requirements, the classifications are defined as follows:

(a) **Door, non-swinging:** roll-up sliding, and all other doors that are not swinging doors.

(b) **Door, swinging:** all operable opaque panels with hinges on one side and opaque revolving doors.

Door area: total area of the door measured using the rough opening and including the door slab and the frame.

Dwelling unit: a single unit providing complete independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, coking, and sanitation.

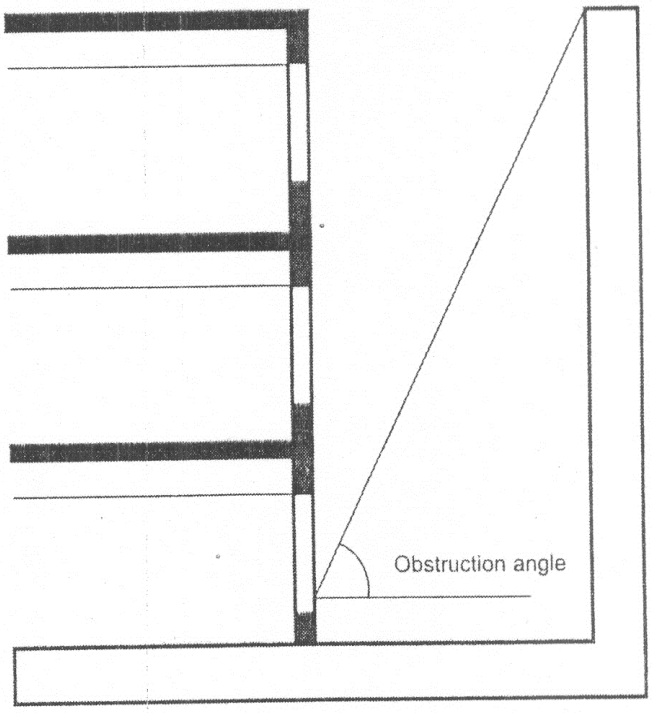
Economizer, air: a duct and damper arrangement and automatic control system that together allow a cooling system to supply outdoor air to reduce or eliminate the need for mechanical cooling during mild or cold weather.

Economizer, water: a system by which the supply air of a cooling system is cooled indirectly with water that is itself cooled by heat or mass transfer to the environment without the use of mechanical cooling

Effective aperture: visible light Transmittance x window-to-wall Ratio. (EA=VLT X WWR)

Effective aperture, horizontal fenestration: a measure of the amount of daylight that enters a space through horizontal fenestration (skylights). It is the ratio of the skylight area times the visible light transmission divided by the gross roof area above the day lighted area. See also day lighted area.

Effective aperture, vertical fenestration: a measure of the amount of daylight that enters a space through vertical fenestration. It is the ratio of the daylight window area times its visible light transmission plus half the vision glass area times its visible light transmission and the sum is divided by the gross wall area. Day lighted window area is located 202 m (7 ft) or more above the floor and vision window area is located above 1 m (3 ft) but below 2.2 m (7 ft). The window area, for the purposes of determining effective aperture shall not include windows located in light wells when the angle of obstruction (a) of objects obscuring the sky dome is greater than 70°, measured from the horizontal, nor shall it include window area located below a height of 1 m (3 ft). See also day lighted area.



Efficacy: the lumens produced by a lamp/ballast system divided by the total watts of input power (including the ballast), expressed in lumens per watt

Efficiency: performance at a specified rating condition

Remittance: the ratio of the radiant heat flux emitted by a specimen to that emitted by blackbody at the same temperature and under the same condition.

Enclosed building: a building that is totally enclosed by walls, floors, and openable devices such as doors and operable windows.

Energy: the capacity for doing work. It takes a number of forms that may be transformed form one into another such as thermal (heat), mechanical (work) electrical, and chemical. Customary measurements are watts (W)

Energy Efficiency Ratio (EER): the ratio of net cooling capacity in Btu/h to total rate of electric input in watts under designated operating conditions

Energy Factor (EF): a measure of water heater overall efficiency

Envelope performance factor: the trade-off value for the building envelope performance compliance option calculated using the procedures specified in Appendix D 12. For the purposes of determining building envelope requirements the classifications are defined as follows:

(a) **Base envelope performance factor:** the building envelope performance factor for the base design

(b) Proposed envelope performance factor: the building envelope performance factor for the proposed design

Equipment: devices for comfort conditioned, electric power, lighting, transportation, or service water heating including, but not limited to, furnaces, boilers, air conditioners, heat pumps, chillers, water heaters, lamps, luminaries, ballasts, elevators, escalators, or other devices or installations

Equipment, existing: equipment previously installed in an existing building

Façade area: area of the façade, including overhanging soffits, cornices, and protruding columns, measured in elevation in a vertical plane, parallel to the plane of the face of the building. Non-horizontal roof surfaces shall be included in the calculations of vertical façade area by measuring the area in a plane parallel to the surface.

Fan system power: the sum of the nominal power demand (nameplate W or HP) of motors of all fans that are required to operate at design conditions to supply air from the heating or cooling source to the conditioned space(s) and return it to the source of exhaust it to the outdoors.

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

a) **Skylight:** a fenestration surface having a slope of less than 60 degrees from the horizontal plane. Other fenestration, even if mounted on the roof of a building, is considered vertical fenestration.

b) **Vertical fenestration:** all fenestration other than skylights. Trombe wall assemblies, where glazing is installed within 300mm (12 in.) of a mass wall, are considered walls, not fenestration.

Fenestration area: total area of the fenestration measured using the rough opening and including the glazing, sash, and frame. For doors where the glazed vision area is less than 50% of the door area, the fenestration area is the glazed vision area. For all other doors, the fenestration area is the door area.

Floor area gross: the sum of the floor areas of the spaces within the building including basements, mezzanine and intermediate-floored tiers, and penthouses with headroom height of 2.5 m (7.5 ft) or greater. It is measured from the exterior faces of exterior walls or from the centerline of walls separating buildings, but excluding covered walkways, open roofed-over areas, porches and similar spaces, pipe trenches, exterior terraces or steps, chimneys, roof overhangs, and similar features.

(a) **Gross building envelope floor area:** the gross floor area of the building envelope, but excluding slab-on grade floors.

(b) **Gross conditioned floor area:** the gross floor area of conditioned spaces.

(c) **Gross lighted floor area:** the gross floor area of lighted spaces.

(d) **Gross semi heated floor area:** the gross floor area of semi heated spaces.

Flue damper: a device in the flue outlet or in the inlet of or upstream of the draft control device of an individual, automatically operated, fossil fuel-fired appliance that is designed to automatically open the flue outlet during appliance operation and to automatically close the flue outlet when then appliance is in standby condition.

Fossil fuel: fuel derived from a hydrocarbon deposit such as petroleum, coal, or natural gas derived from living matter of a previous geologic time.

Fuel: a material that may be used to produce heat or generate power by combustion.

Generally accepted engineer standard: a specification, rule, guide, or procedure in the field of engineering or related thereto, recognized and accepted as authoritative.

Grade: the finished ground level adjoining building at all exterior walls.

Guest room: any room or rooms used or intended to be used by a guest for sleeping purposes.

Heat capacity: the amount of heat necessary to raise the temperature of a given mass 1°C (1°F). Numerically, the heat capacity per unit area of surface (W/m²-°C [Btu/ft²-°F]) is the sum of the products of the mass per unit area of each individual material in the roof, wall, or floor surface multiplied by its individual specific heat.

Heating Seasonal Performance Factor (HSPF): the total heating output of a heat pump during its normal annual usage period for heating (in Btu) divided by the total electric energy input during the same period.

Historic: a building or space that has been specifically designed as historically significant.

HVAC system: the equipment, distribution systems, and terminals that provide, either collectively or individually, the processes of heating, ventilating, or air conditioned to a building or portion of a building.

Infiltration: the uncontrolled inward air leakage through cracks and crevices in any building element and around windows and doors of a building caused by pressure differences across these elements due to factors such as wind, inside and outside temperature differences (stack effect), and imbalance between supply and exhaust air systems.

Installed interior lighting power: the power in watts of all permanently installed general, task, and furniture lighting systems and luminaires.

Integrated part-load value (IPLV): a single number figure of merit based on part-load EER, COP, or kW/ton expressing part-load efficiency for air-conditioning and heat pump equipment on the basis of weighted operation at various load capacities for the equipment.

Kilovolt-ampere: where the term "kilovolt-ampere" (kVA) is used in this Code, it is the product of the line current (amperes) times the nominal system voltage (kilovolts) times 1.732 for three-phase currents. For single-phase applications, kVA is the product of the line current (amperes) times the nominal system voltage (kilovolts).

Kilowatt: the basic unit of electric power, equal to 1000 W.

Labeled: equipment or materials to which a symbol or other identifying mark has been attached by the manufacturer indicating compliance with specified standard or performance in a specified manner.

Lamp: a generic term for man-made light source often called bulb or tube.

Lighted floor area, gross: the gross floor area of lighted spaces.

Lighting, decorative: lighting that is purely ornamental and installed for aesthetic effect. Decorative lighting shall not include general lighting.

Lighting, emergency: lighting that provides illumination only when there is a general lighting failure.

Lighting, general: lighting that provides a substantially uniform level of illumination throughout an area. General lighting shall not include decorative lighting or lighting that provides a dissimilar level of illumination to serve a specialized application or feature within such area.

Lighting Efficacy (LE): the quotient of the total lumens emitted from a lamp or lamp/ballast combination divided by the watts of input power, expressed in lumens per watt.

Lighting system: a group of luminaires circuited or controlled to perform a specific function.

Lighting power allowance:

(a) **Interior lighting power allowance:** the maximum lighting power in watts allowed for the interior of a building

(b) **Exterior lighting power allowance:** the maximum lighting power in watts allowed for the exterior of a building.

Lighting Power Density (LPD): the maximum lighting power per unit of area of a building classification of space function.

Low-rise residential: single-family houses, multi-family structures of three stories or fewer above grade, manufactured houses (mobile homes), and manufactured houses (modular).

Luminaires: a complete lighting unit consisting of a lamp or lamps together with the housing designed to distribute the light, position and protect the lamps, and connect the lamps to the power supply.

Manual (non-automatic): requiring personal intervention for control. Non-automatic does not necessarily imply a manual controller, only that personal intervention is necessary.

Manufacturer: the company engaged in the original production and assembly of products or equipment or a company that purchases such products and equipment manufactured in accordance with company specifications.

Mean temperature: one-half the sum of the minimum daily temperature and maximum daily temperature.

Mechanical cooling: reducing the temperature of a gas or liquid by using vapor compression, absorption, and desiccant dehumidification combined with evaporative cooling, or another energy-driven thermodynamic cycle. Indirect of direct evaporative cooling alone is not considered mechanical cooling.

Metering: instruments that measure electric voltage, current, power, etc.

Multifamily high-rise: multifamily structures of four or more stories above grade

Multifamily low-rise: multifamily structures of three or less stories above grade

Multiplication factor: indicates the relative reduction in annual solar cooling load from overhangs and/or side fins with given projection factors, relative to the respective horizontal and vertical fenestration dimensions.

Non-automatic: See definition of "manual."

Occupancy sensor: a device that detects the presence or absence of people within an area and causes lighting, equipment, or appliances to be regulated accordingly.

Opaque: all areas in the building envelope, except fenestration and building service openings such as vents and grilles.'

Orientation: the direction an envelope element faces, i.e., the direction of a vector perpendicular to and pointing away from the surface outside of the element. For vertical fenestration, the two categories are north oriented and all other.

Outdoor (outside) air: air that is outside the building envelope or is taken from the outside the building that has not been previously circulated through the building.

Over current: any current in excess of the rated current of the equipment of the capacity of the conductor. It may result from overload, short circuit, or ground fault.

Packaged Terminal Air Conditioner (PTAC): a factory-selected wall sleeve and separate unencased combination of heating and cooling components, assemblies, or sections. It may include heating capability by hot water, steam, or electricity, and is intended for mounting through the wall to service a single room or zone.

Party wall: a firewall on an interior lot line used or adapted for joint service between two buildings.

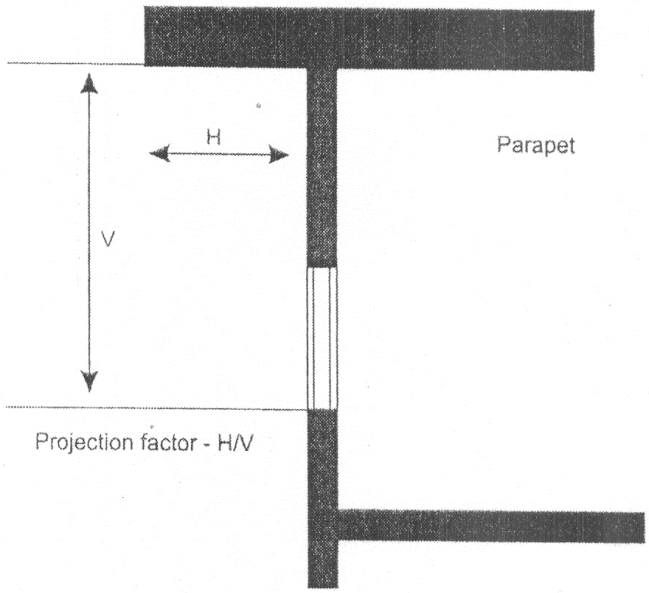
Permanently installed: equipment that is fixed in place and is not portable or movable.

Plenum: a compartment or chamber to which one or more ducts are connected, that forms a part of the air distribution system, and that is not used for occupancy or storage. A plenum often is formed in part or in total by portions for the building.

Pool: any structure, basin, or tank containing an artificial body of water for swimming, diving, or recreational bathing. The terms include, but are not limited to, swimming pool, whirlpool, spa, hot tub.

Process load: the load on a building resulting from the consumption or release of process energy.

Projection factor, overhang: the ratio of the horizontal depth of the external shading projection divided by the sum of the height of the fenestration and the distance from the top of the fenestration to the bottom of the farthest point of the external shading projection, in consistent units.



Projection factor, sidefin: the ratio of the horizontal depth of the external shading projection divided by the distance from the window jamb to the farthest point of the external shading projection, in consistent units.

R-value (thermal resistance): the reciprocal of the time rate of heat flow through a unit area induced by a unit temperature difference between two defined surfaces of material or construction under steady-state conditions. Units of R are m^2-°C/W (h-ft^2-°F/Btu). For the prescriptive building envelope option, R-value is for the insulation alone and does not include building materials or air films.

Readily accessible: capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc. In public facilities, accessibility may be limited to certified personnel through locking covers or by placing equipment in locked rooms.

Recirculating system: a domestic or service hot water distribution system that includes a close circulation circuit designed to maintain usage temperatures in hot water pipes near terminal devices (e.g., lavatory faucets, shower heads) in order to reduce the time required to obtain hot water when the terminal device valve is opened. The motive force for circulation is either natural (due to water density variations with temperature) or mechanical (recirculation pump).

Reflectance: the ratio of the light reflected by a surface to the light incident upon it

Resistance, electric: the property of an electric circuit or of any object used as part of an electric circuit that determines for a given circuit the rate at which electric energy is converted into heat or radiant energy and that has a value such that the product of the resistance and the square of the current gives the rate of conversion of energy

Reset: automatic adjustment of the controller set point to a higher or lower value

Residential: spaces in buildings used primarily for living and sleeping. Residential spaces include, but are not limited to, dwelling units, hotel/motel guest rooms, dormitories, nursing homes, patient rooms in hospitals, lodging houses, fraternity/sorority houses, hostels, prisons, and fire stations.

Roof: the upper portion of the building envelope, including opaque areas and fenestration, that is horizontal or tilted at an angle of less than 60° from horizontal

Roof area, gross: the area of the roof measured from the exterior faces of walls or from the centerline of party walls

Service: the equipment for delivering energy from the supply or distribution system to the premises served.

Service water heating: heating water for domestic or commercial purposes other than space heating and process requirements

Set point: point at which the desired temperature (°C) of the heated or cooled space is set

Shading Coefficient (SC): The ratio of solar heat gain at normal incidence through glazing to that occurring through 3 mm (1/8 in) thick clear, double-strength glass. Shading coefficient, as used herein, does not include interior, exterior, or integral shading devices

Simulation program: a computer program that is capable of simulating the energy performance of building systems

Single-zone system: an HVAC system serving a single HVAC zone

Site-recovered energy: waste energy recovered at the building site that is used to offset consumption of purchased fuel or electrical energy supplies

Skylight roof ratio (SRR): the ratio of the total skylight area of the roof, measured to the outside of the frame, to the gross exterior roof.

Slab-on-grade floor: that portion of a slab floor of the building envelope that is in contact with ground and that is either above grade or is less than or equal to 24 in below the final elevation of the nearest exterior grade

Solar energy source: source of thermal, chemical, or electrical energy derived from direction conversion of incident solar radiation at the building site.

Solar Heat Gain Coefficient (SHGC): the ratio of the solar heat gain entering the space through the fenestration area to the incident solar radiation, typically ranging from 0.9 to 0.1, where lower values indicate lower solar gain. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted, or convected into the space.

Space: an enclosed space within a building. The classifications of spaces are as follows for the purpose of determining building envelope requirements.

a) **Conditioned space:** a cooled space, heated space, or directly conditioned space.

b) **Semi-heated space:** an enclosed space within a building that is heated by a heating system whose output capacity is greater or equal to 10.7 W/m² (3.4 Btu/h-ft²) of floor area but is not a conditioned space.

c) **Enclosed Space:** space within a building that is not conditioned space or a semi-heated space. Crawlspaces, attics, and parking garages with natural or mechanical ventilation are not considered enclosed spaces.

Standard Design: a computer representation of a hypothetical design based on the actual *Proposed Design* as per Appendix B clause 10- Whole Building Performance Method

Storey: portion of a building that is between one finished floor level and the next higher finished floor level or the roof, provided, however, that a basement or cellar shall not be considered a story.

System: a combination of equipment and auxiliary devices (e.g., controls, accessories, interconnecting means, and terminal elements) by which energy is transformed so it performs a specific function such as HVAC, service water heating, or lighting.

System, existing: a system or systems previously installed in an existing building.

Terminal: a device by which energy form a system is finally delivered, e.g., registers, diffusers, lighting fixtures, faucets, etc.

Thermal block: a collection of one or more HVAC zones grouped together for simulation purposes. Spaces need not be contiguous to be combined within a single thermal block.

Thermal Zone: a term used in energy simulation to represent area catered to by one air conditioning unit. With the help of the "zoning" building plans are simplified to reduce the modeler's work. Normally, within one zone usage pattern, set point temperature and other conditions are identical. Building spaces that would experience similar heating and cooling loads are generally grouped under one zone.

Thermostat: an automatic control device used to maintain temperature at a fixed or adjustable set point.

Tinted: (as applied to fenestration) bronze, green, or grey coloring that is integral with the glazing material. Tinting does not include surface applied films such as reflective coatings, applied either in the field or during the manufacturing process.

Transformer: a piece of electrical equipment used to convert electric power from one voltage to another voltage.

U-factor (Thermal Transmittance): heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on each side. Units of U are W/m^2-°C (Btu/h-ft^2- °F).

Variable Air Volume (VAV) system: HVAC system that controls the dry-bulb temperature within a space by varying the volumetric flow of heated or cooled supply air to the space

Vent damper: a device intended for installation in the venting system or an individual, automatically operated, fossil fuel-fired appliance in the outlet or downstream of the appliance draft control device, which is designed to automatically open the venting system when the appliance is in operation and to automatically close off the venting system when the appliance is in standby or shutdown condition.

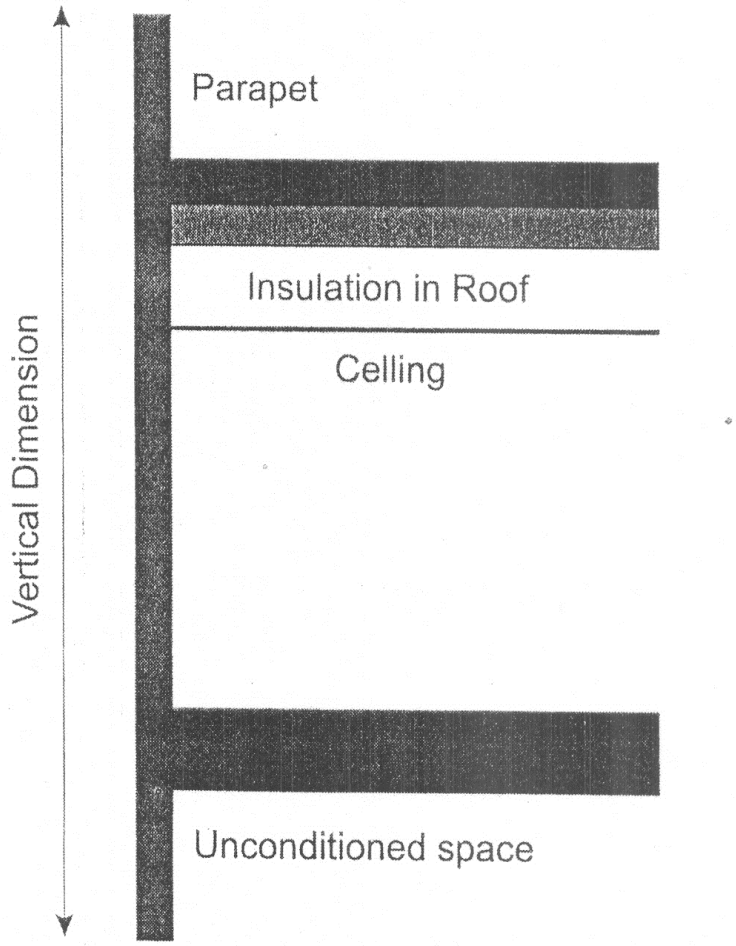
Ventilation: the process of supplying or removing air by natural or mechanical means to or from any space. Such air is not required to have been conditioned.

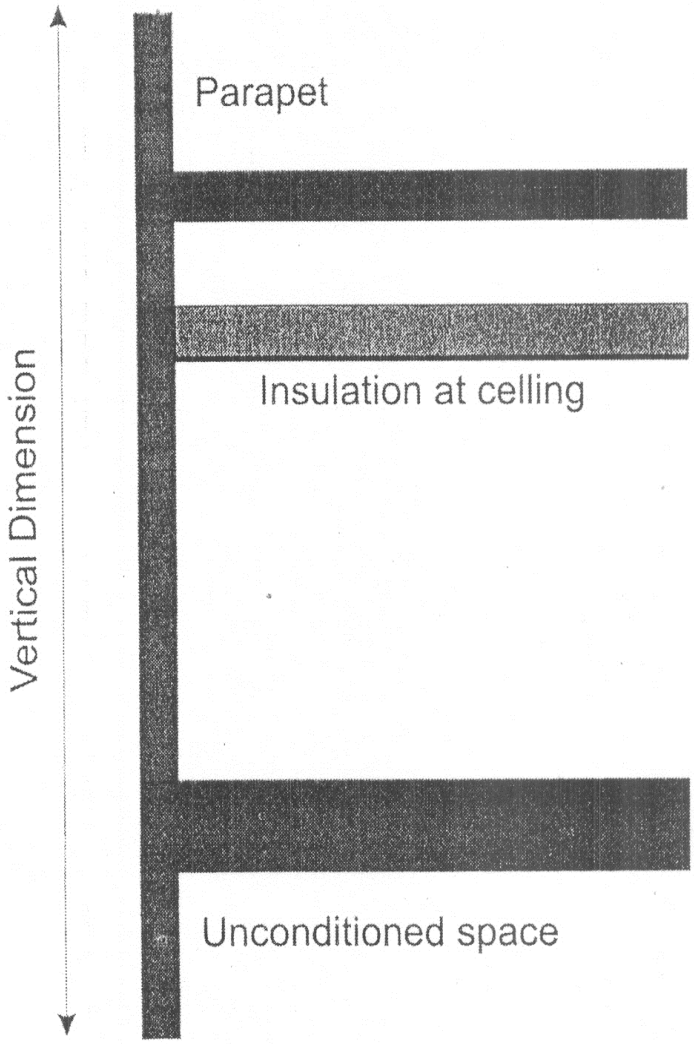
Wall: that portion of the building envelope, including opaque area and fenestration, that is vertical or tilted at an angle of 60° from horizontal or greater. This includes above and below-grade walls, between floor spandrels, peripheral edges of floors, and foundation walls.

a) **Wall, above grade:** a wall that is not below grade

b) **Wall, below grade:** that portion of a wall in the building envelope that is entirely below the finish grade and in contact with the ground

Wall area, gross: the overall area off a wall including openings such as windows and doors measured horizontally from outside surface to outside service and measured vertically from the top of the floor to the top of the roof. If roof insulation is installed at the ceiling level rather than the roof, then the vertical measurement is made to the top of the ceiling. (Note that clause 4.3.1 does not allow roof insulation to be located on a suspended ceiling with removable ceiling panels.) The gross wall area includes the area between the ceiling and the floor for multistory buildings.





Water heater: vessel in which water is heated and is withdrawn for use external to the system.

Window Wall Ratio (WWR): the 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.

Zone, HVAC: A space or group of spaces within a building with heating and cooling requirements that are sufficiently similar so that desired conditions (e.g., temperature) can be maintained throughout using a single sensor (e.g., thermostat or temperature sensor).

9.3 Abbreviations and Acronyms

AFUE	Annual fuel utilization efficiency
ANSI	American National Standards Institute
ARI	Air-Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
BIS	Bureau of Indian Standards
Btu	British thermal unit
Btu/h	British thermal units per hour
Btu/ft^2-°F	British thermal units per square foot per degree Fahrenheit
Btu/h-ft^2	British thermal units per hour per square foot
Btu/h-ft-°F	British thermal units per linear foot per degree Fahrenheit
Btu/h-ft^2-°F	British thermal units per hour per square foot per degree Fahrenheit
C	Celsius
cfm	Cubic feet per minute
cm	Centimeter
COP	Coefficient of Performance
DOE	Department of Energy, U.S.
EER	Energy Efficiency Ratio
EC Act 2001	Energy Conservation Act 2001
EF	Energy Factor
F	Fahrenheit
ft	Foot
h	Hour
HC	Heat capacity
h-ft^2-°F/Btu	Hour per square foot per degree Fahrenheit per British thermal unit
h-m^2-°C/W	Hour per square meter per degree Celsius per Watt
hp	Horsepower
HSPF	Heating seasonal performance factor
HVAC	Heating, Ventilation, and Air Conditioning
I-P	Inch-pound

in.	Inch
IPLV	Integrated part-load value
ISHRAE	Indian Society of Heating, Refrigeration and Air-conditioning Engineers
kVA	Kilovolt-ampere
kW	kilowatt
kWh	kilowatt-hour
LE	Lighting efficacy
lin	Linear
lin ft	Linear foot
lin m	Linear meter
lm	Lumen
LPD	Lighting Power Density
m	Meter
mm	Millimeter
NAECA	National Appliance Energy Conservation Act
PF	Projection factor
PTAC	Packaged terminal air conditioner
R	R-value (thermal resistance)
SC	Shading Coefficient
SHGC	Solar heat gain coefficient
SL	Standby loss
VAV	Variable air volume
VLT	Visible light transmission
W	Watt
W/ft^2	Watts per square feet
W/m^2	Watts per square meter
W/m^2-°C	Watts per square meter per degree Celsius
W/m^2	Watts per hour per square meter
W/m-°C	Watts per lineal meter per degree Celsius
W/m^2-°C	Watts per hour per square meter per degree Celsius
Wh	Watthour

10. APPENDIX B: Whole Building Performance Method

10.1 General

10.1.1 Scope

The whole building performance method is an alternative to the prescriptive requirements contain in clause 1 through clause 8 of this code. It applies for all building types covered by the code.

10.1.2 Compliance

A building compiles with the whole building performance method when the estimated annual energy use of the proposed design is less than the standard design, even though it may not comply with the specific requirements of the prescriptive requirements in clause1 through clause8 The mandatory requirements of clause 1 through clause 8 (clause 4.2, clause 5.2, clause 6.2, clause 7.2 and clause 8.2) shall be satisfied with the whole building performance method.

10.1.3 Annual Energy Use

Annual energy use for the purposes of the whole building performance method shall be calculated in kilowatt hours (kWh) of electricity use per year. Energy sources other than electricity which are used in the building shall be converted to kWh of electric energy at the rate of 0.75 kWh per mega Joule.

10.1.4 Trade-offs Limited to Building Permit

The whole building performance method may be used for building permit applications that include less than the whole building; however, any design parameters that are not part of the building permit application shall be identical for both the *Proposed Design* and the *Standard Design*. Future improvements to the building shall comply with both the mandatory and prescriptive requirements.

10.1.5 Documentation Requirements

Compliance shall be documented and submitted to the *Authority Having Jurisdiction*. The information submitted shall include the following:

a) The annual energy use for the *Proposed Design* and the *Standard Design*.

b) A list of the energy-related building features in the *Proposed Design* that is different from the *Standard Design*.

c) The input and output report (s) from the simulation program including a breakdown of energy usage by at least the following components: lights, internal equipment loads, service water heating equipment, space heating equipment, space cooling and heat rejection equipment, fans, and other HVAC equipment (such as pumps). The output reports shall also show the amount of time any loads are not met by the HVAC system for both the *Proposed Design* and *Standard Design*.2

d) An explanation of any error messages noted in the simulation program output.

10.2 Simulation General Requirements

10.2.1 Energy Simulation Program

The simulation program shall be a computer based program for the analysis of energy consumption in buildings and be approved by the authority having jurisdiction. The simulation program shall model the following:

a) Energy flows on an hourly basis for all 8,760 hours in the year.

b) Hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat set points, and HVAC system operation, defined separately for each day of the week and holidays,

c) Thermal mass effects,

d) Ten or more thermal zones,

e) Part load and temperature dependent performance of heating and cooling equipment,

f) Air side and water side economizers with integrated control, and

g) All of the standard design characteristics specified in this chapter.

10.2.2 Climatic Data

The simulation program shall use hourly values of climatic data, such as temperature and humidity from representative climatic data, for the city in which the proposed design is to be located. For cities or urban regions with several climatic data entries, and for locations where weather data are not available, the designer shall select available weather data that best represent the climate at the construction site.

10.2.3 Compliance Calculations

The proposed design and standard design shall be calculated using the following:

a) Same simulation program,

b) Same weather data,

c) Same building operation assumptions (thermostat set points, schedules, internal gains, occupant loads, etc.)

10.3 Calculating the Energy Consumption of the Proposed Design and the Standard Design

10.3.1 The simulation model for calculating the proposed design and the standard design shall be developed in accordance with the requirements in Table 10.1

10.3.2 HVAC Systems

The HVAC System type and related performance parameters for the standard design shall be determined from table 10.1 and the following rules:

a) Other Components: Components and parameters not listed in Table 10.2 or otherwise specifically addresses in this subsection shall be identical to those in the proposed design.(Exception to clause 10.3.2(a) where there are specific requirements in clause 5.2.2., the component efficiency in the standard design shall be adjusted to the lowest efficiency level allowed by the requirement for that component type).

b) All HVAC and service water heating equipment in the standard design shall be modeled at the minimum efficiency levels, both part load and full load, in accordance with clause 5.2.2.

c) Where efficiency ratings, such as EER and COP, include fan energy, the descriptor shall be broken down into its components so that supply fan energy can be modeled separately.

d) Minimum outdoor air ventilation rates shall be the same for both the standard and the proposed design.

e) The equipment capacities for the standard design shall be sized proportionally to the capacities in the proposed design based on sizing runs; i.e. the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be the same for both the proposed design and the standard design. Unmet load shall be the same for both the proposed design and standard design shall not differ from unmet load hours for the standard design by more than 50 hours. The maximum number of unmet hours shall not exceed 300 for either case.

Table 10.1 Modeling Requirements for Calculating Proposed and Standard Design

Case	Proposed Building	Standard Design
1. Design Model	A) The simulation model of the *Proposed Design* shall be consistent with the design documents, including proper accounting of fenestration and opaque envelope types and area; interior lighting power and controls; HVAC system types, sizes, and controls; and service water heating systems and controls. B) When the whole building performance method is applied to buildings in which energy related features have not yet been designed (e.g., a lighting system), those yet-to-be designed features shall be described in the *Proposed Design* so that they minimally comply with applicable mandatory and prescriptive requirements from clause4 through clause8.	The *Standard Designs* shall be developed by modifying the *Proposed Design* as described in this table. Except as specifically instructed in this table, all building systems and equipment shall be modeled identically in the *Standard Designs* and *Proposed Design*.
2. Space Use Classification	The building type or space type classifications shall be chosen in accordance with clause7.3.2 or clause7.3.3. More than one building type category may be used in a building if it is a mixed-use facility	Same as *Proposed Design*
3. Schedules	The schedules shall be typical of the proposed building type as determined by the designer and approved by the authority having jurisdiction.	Same as *Proposed Design*.
4. Building Envelope	All components of the building envelope in the proposed design shall be modeled as shown on architectural drawings or as installed for existing building envelopes. Exceptions: The following building elements are permitted to differ from architectural drawings. A) Any envelope assembly that covers less than 5% of the total area of that assembly type (e.g.,exterior walls) need not be separately described. If not separately described, the area of an envelope assembly must be added to the area of the adjacent assembly of that same type. B) Exterior surfaces whose azimuth orientation and tilt differ by no more than 45 degrees and are otherwise the same may be described as either a single surface or by using multipliers.	The standard design shall have identical conditioned floor area and identical exterior dimensions and orientations as the proposed design, except as noted in (a), (b), (c), and (d) below. A) Orientation. The baseline building performance shall be generated by simulating the building with its actual orientation and again after rotation the entire building 90, 180,270 degrees, then averaging the results. The building shall be modeled so that it does not shade itself.

Case	Proposed Building	Standard Design
	C) For exterior roofs other than roofs with ventilated attics, the reflectance and emittance of the roof surface shall be modeled. The reflectance and emittance shall be tested in accordance with 4.3.1.1 D) Manually operated fenestration shading devices such as blinds or shades shall not be modeled. Permanent shading devices such as fins, overhangs, and light shelves shall be modeled.	B) Opaque assemblies such as, floors, doors, and walls shall be modeled as having the same heat capacity as the proposed design but with the minimum u-factor required in 4.3.1 and 4.3.2. C) Fenestration- fenestration areas shall equal that in the proposed design or 40% of gross above grade wall area, whichever is smaller, and shall be distributed uniformly in horizontal bands across the four orientations. No shading projections are to be modeled; fenestration shall be assumed to be flush with the exterior wall or roof. Manually operated fenestration shading devices such as blinds or shades shall not be modeled. Fenestration U-factor shall be the minimum required for the climate, and the solar heat gain coefficient shall be the maximum allowed for the climate and orientation. D) Roof albedo. All roof surfaces shall be modeled with a reflectivity of 0.30
5. Lighting	Lighting power in the *Proposed Design* shall be determined as follows: A) Where a complete lighting system exists, the actual lighting power shall be used in the model. B) Where a lighting system has been designed, the LPD should match the design which shall be determined in accordance with either clause7.3.2 or clause7.3.3. C) Where no lighting exists or is specified, lighting power shall be determined in accordance with the clause7.3.2 for the appropriate building type. D) Lighting system power shall include all lighting system components shown or provided for on plans (including lamps, ballasts, task fixtures, and furniture-mounted fixtures).	Lighting power in the *Standard Designs* shall be determined using the same categorization procedure (building area or space function) and categories as the *Proposed Design* with lighting power set equal to the maximum allowed for the corresponding method and category in either clause7.3.2 or clause7.3.3. Power for fixtures not included in the lighting power density calculation shall be modeled identically in the *Proposed* and *Standard Design*. Lighting controls shall be the minimum required.

Case	Proposed Building	Standard Design
6. HVAC Systems	The HVAC system type and all related performance parameters, such as equipment capacities and efficiencies, in the *Proposed Design* shall be determined as follows: A) Where a complete HVAC system exists, the model shall reflect the actual system type using actual component capacities and efficiencies. B) Where an HVAC system has been designed, the HVAC model shall be consistent with design documents. Mechanical equipment efficiencies shall be adjusted from actual design conditions to the standard rating conditions specified in clause5, if required by the simulation model. C) Where no heating system exists or no heating system has been specified, the heating system shall be modeled as electric resistance. The system characteristics shall be identical to the system modeled in the *Standard Designs*. D) Where no cooling system exists or no cooling system has been specified, the cooling system shall be modeled as an air-cooled single-zone system, one unit per thermal zone. The system characteristics shall be identical to the system modeled in the *Standard Designs*.	The HVAC system type and related performance parameters for the Standard Designs shall be determined from Table 10.2. Equipment performance shall meet the requirements of clause 5.
7. Service Hot Water	The service hot water system type and all related performance parameters, such as equipment capacities and efficiencies, in the *Proposed Design* shall be determined as follows: A) Where a complete service hot water system exists, the *Proposed Design* shall reflect the actual system type using actual component capacities and efficiencies. B) Where a service hot water system has been specified, the service hot water model shall be consistent with design documents. C) Where no service hot water system exists or has been specified but the building will have service hot water loads, a service hot water system shall be modeled.	The water heating system shall be of the same type of the *Proposed Design*. For residential facilities, hotels and hospitals the *Standard Designs* shall have a solar system capable of meeting 20% of the design load. Systems shall meet the efficiency requirements of clause6.2.2, the pipe insulation requirements of clause6.2.4 and incorporate heat traps in accordance with clause6.2.5.
8. Miscellaneous Loads	Receptacle, motor, and process loads shall be modeled and estimated based on the building type or space type category. These loads shall be included in simulations of the building and shall be included when calculating the standard design and proposed design.	Receptacle, motor and process loads shall be modeled the same as the *Proposed Design*. The water heating system shall be of the same type of the proposed design.

Case	Proposed Building	Standard Design
	All end-use load components within and associated with the building shall be modeled, unless specifically excluded, but not limited to, exhaust fans, parking garage ventilation fans, exterior building lighting, swimming pool heaters and pumps, elevators and escalators, refrigeration equipment, and cooking equipment.	
9. Modeling Limitations to the Simulation Program	If the simulation program cannot model a component or system included in the *Proposed Design*, one of the following methods shall be used with the approval of the *Authority Having Jurisdiction*: A) Ignore the component if the energy impact on the trade-offs being considered is not significant. B) Model the component substituting a thermodynamically similar component model. C) Model the HVAC system components or systems using the *Standard Designs*'s HVAC system in accordance with clause5. Whichever method is selected, the component shall be modeled identically for both the *Proposed Design* and *Standard Designs* models.	Same as proposed design.

Table 10.2: HVAC Systems Map

			Nonresidential	
	Residential More than 3 stories	Less than 3 floors or less than 7,500 m²	4 or 5 floors or less than 7,500 m² or less and 7,500- 15,000 m²	More than 5 floors or more than 15,000 m²
Code	PTAC	PSZ	RHFS	RHFS
System type	Packaged terminal air conditioner	Packaged rooftop air conditioner	Central cooling plant with constant volume AHU for each zone	Central cooling plant with variable air volume AHU for each zone
Fan control	Constant Volume	Constant Volume	Constant Volume air handler for each zone	Variable volume air handler
Cooling type	Direct expansion	Direct expansion	Chilled Water*	Chilled Water*
Heating type	Electric resistance	Electric resistance	Electric resistance	Electric resistance

- If the proposed building has an air cooled chiller/system then the budget building shall have air cooled chiller otherwise the budget case shall have water cooled centrifugal chillers. If the building has a mix of air and water cooled chillers then, the baseline building shall have the mix of air and water cooled chillers in the same proportion. Chiller Efficiencies shall be as per Table 5.1

11. APPENDIX C: Default Values for Typical Constructions

11.1 Procedure for Determining Fenestration Product U-Factor and Solar Heat Gain Coefficient

Clause 4.2.1.1 and clause 4.2.1.2 require that U-factors and solar heat gain coefficients (SHGC) be determined for the overall fenestration product (including the sash and frame) in accordance with ISO 15099. The building envelope trade-off option in clause4.4 requires the use of visible light transmittance (VLT).

In several cases, ISO 15099 suggests that individual national standards will need to be more specific and in other cases the ISO document gives users the choice of two options. This section clarifies these specific issues as they are to be implemented for this code:

a) Clause 4.1 of ISO 15099: For calculating the overall U-factor, ISO 15099 offers a choice between the linear thermal transmittance (4.1.2) and the area weighted method (4.1.3). The area weighted method (4.1.3) shall be used

b) Clause 4.2.2 of ISO 15099: Frame and divider SHGC's shall be calculated in accordance with clause4.2.2

c) Clause 6.4 of ISO 15099 refers the issue of material properties to national standards. Material conductivities and emissivities shall be determined in accordance with Indian standards

d) Clause 7 of ISO 15099 on shading systems is currently excluded

e) Clause 8.2 of ISO15099 addresses environmental conditions. The following are defined for India:

For U-factor calculations:

$T_{in} = 24°C$

$T_{out} = 32°C$

$V = 3.35\ m/s$

$T_{rm,out} = T_{out}$

$T_{rm,in} = T_{in}$

$I_s = 0\ W/m^2$

For SHGC calculations:

$T_{in} = 24°C$

$T_{out} = 32°C$

$V = 2.75\ m/s$

$T_{rm,out} = T_{out}$

$T_{rm,in} = T_{in}$

$I_s = 783\ W/m^2$

f) Clause 8.3 of ISO 15099 addresses convective film coefficients on the interior and exterior of the window product. In clause8.3.1 of ISO 15099, simulations shall use the heat transfer coefficient based on the center of glass temperature and the entire window height; this film coefficient shall be used on all indoor surfaces, including frame sections. In clause 8.3.2 of ISO 15099, the formula from this section shall be applied to all outdoor exposed surfaces

g) Clause 8.4.2 of ISO 15099 presents two possible approaches for incorporating the impacts of self-viewing surfaces on interior radiative heat transfer calculations. Products shall use the method in clause 8.4.2.1 of ISO 15099 (Two-Dimensional Element to Element View Factor Based Radiation Heat Transfer Calculation). The alternate approach in clause 8.4.3 of ISO 15099 shall not be used

11.2 Default U-factors and Solar Heat Gain Coefficients for Unrated Fenestration Products

All fenestration with U-factors, SHGC, or visible light transmittance determined, certified, and labeled in accordance ISO 15099 shall be assigned those values.

11.2.1 Unrated Vertical Fenestration

Unlabeled vertical fenestration, both operable and fixed, shall be assigned the U-

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 ($W/m^2 \cdot °C$)	SHGC	VLT	U-factor ($W/m^2 \cdot °C$)	SHGC	VLT
All frame types	Single Glazing	7.1	0.82	0.7	6 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

11.2.2 Unrated Sloped Glazing and Skylights

Unrated sloped glazing and skylights, both operable and fixed, shall be assigned the SHGCs and visible light transmittances in Table 11.1. To determine the default U-factor for unrated sloped glazing and skylights without a curb, multiply the values in Table 11.1 by 1.2. To determine the default U-factor for unrated skylights on a curb, multiply the values in Table 11.1 by 1.6.

11.3 Typical Roof Constructions

For calculating the overall U-factor of a typical roof construction, the U-factors from the typical wall construction type and effective U-factor for insulation shall be combined according to the following equation:

$$U_{Total\ Roof} = \frac{1}{\frac{1}{U_{Typical\ Roof}} + \frac{1}{U_{Typcical\ Insulation}}}$$

Where

$U_{Total\ Roof}$ Total U-factor of the roof with insulation

$U_{typical\ Roof}$ U-factor of the roof

$U_{Typical\ Insulation}$ U-factor of the effective insulation from Table 11.2

Table 11.2: Defaults for effective U-Factor for Exterior Insulation layers (under review)

Thickness	R-value	U-factor (W/m²·°K)
15 mm (0.5")	0.70 (4)	1.420
20 mm (0.75")	1.06 (6)	0.946
25 mm (1.0")	1.41 (8)	0.710
40 mm (1.5")	2.11 (12)	0.568
50 mm (2.0")	2.82 (16)	0.406
65 mm (2.5")	3.52 (20)	0.284
75 mm (3.0")	3.70 (21)	0.270

11.4 Typical Wall Constructions

For calculating the overall U-factor of a typical wall construction, the U-factors from the typical wall construction type and effective U-factor for insulation shall be combined according to the following equation:

$$U_{Total\ Wall} = \frac{1}{\frac{1}{U_{Typical\ Wall}} + \frac{1}{U_{Typcical\ Insulation}}}$$

Where

$U_{Total\ Wall}$	Total U-factor of the wall with insulation
$U_{Typical\ Wall}$	U-factor of the wall from
$U_{typical\ Insulation}$	U-factor of the effective insulation from Table 11.3 or Table 11.4

Table 11.3: Defaults for effective U-Factor for Exterior Insulation layers (under review)

Thickness	R-value	U-factor (W/m^2·K)
15 mm (0.5")	0.70 (4)	1.262
20 mm (0.75")	1.06 (6)	0.874
25 mm (1.0")	1.41 (8)	0.668
40 mm (1.5")	2.11 (12)	0.454
50 mm (2.0")	2.82 (16)	0.344
65 mm (2.5")	3.52 (20)	0.277
75 mm (3.0")	3.70 (21)	0.264

Table 11.4: Typical Thermal Properties of Common Building and Insulating Materials-Design Values (Source: ASHRAE Fundamentals Handbook, 2001)

Description	Density kg/m³	Conductivity[b] (k), W/(m.k)	Conductance (c) W/ (m². k)	Resistance[c] (R)		Specific heat kJ/(kg k)
				1/k, K.m² / w	For thickness listed (1/c), K.m²/W	
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
Gypsum or plaster board (12.7 mm)	800	—	12.6	—	0.079	—
Gypsum or plaster board (15.9 mm)	800	—	10.1	—	0.099	—
Plywood (Douglas fir)[d]...	540	0.12	—	8.66	—	1.21
Plywood or wood panels. (19.0 mm)	540	—	6.1	—	0.16	1.21
Vegetable fiber board						
Sheathing, regular density[e]....12.7 mm	290	—	4.3	—	0.23	1.30
.....19.0 mm	290	—	2.8	—	0.36	—
Sheathing intermediate density[e] ....12.7 mm	350	—	5.2	—	0.19	1.30
Nail-base sheathing[e]..12.7 mm	400	—	5.3	—	0.19	1.30
Shingle backer...9.5 mm	290	—	6.0	—	0.17	1.30

Description	Density kg/m³	Conductivity[b] (k), W/(m.k)	Conductance (c) W/ (m². k)	Resistance[c] (R)		Specific heat kJ/(kg k)
				1/k, K.m² / w	For thickness listed (1/c), K.m²/W	
Sound deadening board(12.7 mm)	240	—	4.2	—	0.24	1.26
Tile and lay –in panels, plain or acoustic....	290	0.058	—	17.	—	0.59
....12.7 mm	290	—	4.5	—	0.22	—
....19.0 mm	290	—	3.0	—	0.33	—
Laminated paperboard....	480	0.072	—	13.9	—	1.38
Homogeneous board from repulped paper ...	480	0.072	—	13.9	—	1.17
Hardboard[e]						
Medium density	800	0.105	—	9.50	—	1.30
High density, service-tempered grade and service grade ...	880	0.82	—	8.46	—	1.34
High density, standard-tempered grade...	1010	0.144	—	6.93	—	1.34
Particle Board[e]						
Low density..	590	0.102	—	9.77	—	1.30
Medium density..	800	0.135	—	7.35	—	1.30
High density	1000	0.170	—	5.90	—	1.30
Underlayment..(15.9 mm)	640	—	6.9	—	0.14	1.21
Waterboard...	590	0.01	—	11.0	—	—
Wood subfloor(19.0mm)	—	—	6.0	—	0.17	1.38

Description	Density kg/m³	Conductivity[b] (k), W/(m.k)	Conductance (c) W/ (m². k)	Resistance[c] (R)		Specific heat kJ/(kg k)
				1/k, K.m² / w	For thickness listed (1/c), K.m²/W	
BUILDING MEMBRANE						
Vapor-permeable felt…	—	—	94.9	—	0.011	—
Vapor-seal, 2 layers of mopped 0.73 kg/m frlt..	—	—	47.4	—	0.21	—
Vapor-seal, plastic film	—	—	—	—	Negl.	—
FINISH FLOORING MATERIAL						
Carpet and fibrous pad…	—	—	2.73	—	0.37	1.42
Carpet and rubber pad	—	—	4.60	—	0.22	1.38
Cork tile…3.2mm	—	—	20.4	—	0.049	2.01
Terrazzo…25 mm	—	—	71.0	—	0.014	0.80
Tile – asphalt, linoleum, vinyl, rubber,,,..	—	—	113.6	—	0.009	1.26
Cinyl asbestos…	—	—	—	—	—	1.01
Ceramic…..	—	—	—	—	—	0.80
Wood, hardwood finish…19 mm	—	—	8.35	—	0.12	—
INSULATING MATERIALS						
Blanket and Batt[f,g]						
Mineral fiber, fibrous form processed						
from roc, slag, or glass.						
Approx. 75-100mm…	6.4-3.2	—	0.52	—	1.94	—
Approx. 90mm	6.4-3.2	—	0.44	—	2.29	—
Approx. 90 mm..	19-26	—	0.38	—	2.63	—
Approx.140-165mm	6.4-3.2	—	0.30	—	3.32	—

Description	Density kg/m³	Conductivity[b] (k), W/(m.k)	Conductance (c) W/ (m². k)	Resistance[c] (R)		Specific heat kJ/(kg k)
				1/k, K.m² / w	For thickness listed (1/c), K.m²/W	
Approx. 140 mm	10-16	—	0.27	—	3.67	—
Approx. 150-190 mm	6.4-3.2	—	0.26	—	3.91	—
Approx. 210-250 mm..	6.4-32	—	0.19	—	5.34	—
Approx. 250- 330 mm..	6.4-32	—	0.15	—	6.77	—
Boards and slabs						
Cellular glass..	136	0.050	—	19.8	—	0.75
Cellular fiber, organic bonded..	64-140	0.036	—	27.7	—	0.96
Expanded perlite, organic bonded	16	0.052	—	19.3	—	1.26
Expanded rubber (rigid)	72	0.032	—	31.6	—	1.68
Expanded polystyrene, extruded (smooth skin surface) (CFC-12 exp.)	29-56	—	—	—	—	—
Expanded polystyrene, extruded (smooth skin surface) (HCFC-142 b exp.)[h]	29-56	0.029	—	34.7	—	1.21
Expanded polystyrene, molded beads..	16	0.037	—	26.7	—	—
	24	0.035	—	28.9	—	—
	28	0.035	—	28.9	—	—
	32	0.033	—	30.2	—	—
	20	0.036	—	27.7	—	—
Cellular polyurethane/ polyisocyanurate (CFC-11EXP.) (unfaced)	24	0.023-0.026	—	43.3-38.5	—	1.59

Description	Density kg/m³	Conductivity[b] (k), W/(m.k)	Conductance (c) W/ (m². k)	Resistance[c] (R)		Specific heat kJ/(kg k)
				1/k, K.m² / w	For thickness listed (1/c), K.m²/W	
(GAS – PERMEABLE FACERS)..Cellular polyisocyanurate (CFC-11 EXP.)	24-40	0.023-0.026	—	43.3-38.5	—	0.92
(GAS-IMPERMEABLE FACERS)	32	0.020	—	48.8	—	0.92
CELLULAR PHENOLIC (closed cell) (CFC-11. CFC-113 EXP.)[k]	32	0.017		56.8	—	—
Cellular phenolic (open cell)	29-35	0.033	—	30.5	—	—
Mineral fiber with resin binder..	240	0.042	—	23.9	—	0.71
Mineral fiberboard, wet felted Core or roof insulation	260-270	0.049	—	20.	—	—
Acoustical tile	290	0.050	—	19.8	—	0.80
Acoustical tile	340	0.053	—	18.7	—	—
Mineral fiberboard, wet molded Acoustical tile..	370	0.060	—	16.5	—	0.59
Wood or cane fiberboard Acoustical tile…12.7 mm	—	—	4.5	—	0.22	1.30
Acoustical tile…19.0 mm	—	—	3.0	—	0.33	—
Interior finish (plank, tile)	240	0.050	—	19.8	—	1.34
Cement fiber slabs (shredded wood with Portland cement binder)	400-430	0.072-0.076	—	13.9-13.1	—	—
Cement fiber slabs (shredded wood with magnesia oxysulfide binder)	350	0.082	—	12.1	—	1.30

Description	Density kg/m³	Conductivity[b] (k), W/(m.k)	Conductance (c) W/ (m². k)	Resistance[c] (R)		Specific heat kJ/(kg k)
				1/k, K.m² / w	For thickness listed (1/c), K.m²/W	
Loose fill Cellulosic insulation (milled paper or wood pulp)	37-51	0.039-0.046	—	25.6-21.7	—	1.38
Perlite, expanded..	32-66	0.039-0.045	—	25.6-22.9	—	1.09
	66-120	0.045-0.052	—	22.9-19.4	—	—
	120-180	0.052-0.060	—	19.4-16.6		—
Mineral fiber(rock, slag, or glass) Approx. 95-130 mm..	9.6-3.2	—	—	—	1.94	0.71
Approx. 170-220 mm..	9.6-3.2	—	—	—	3.35	—
Approx. 190-250 mm..	9.6-3.2	—	—	—	3.87	—
Approx260-350 mm..\	9.6-3.2	—	—	—	5.28	—
Mineral fiber(rock, slag, or glass) Approx. 90 mm (closed sidewall application)	32-56	—	—	—	2.1-2.5	—
Vermiculite, exfoliated..	110-130	0.068	—	14.8	—	1.34
	64-96	0.063	—	15.7	—	—
Spray applied Ployurethane foam..	24-40	0.023-0.026	—	43.3-38.5	—	—
Urea formaldehyde foam.	11-26	0.032-0.040	—	31.5-24.7	—	—
Cellulosic fiber	56-96	0.042-0.049	—	23.9-20.4	—	—
Glass fiber	56-72	0.038-0.039	—	26.7-25.6	—	—
Reflective material (<0.5) in center of 20 mm cavity forms two 10 mm vertical air spaces[m]..	—	—	1.76	—	0.57	—
METALS (See chapter 38, table 3 of Ashare Fundamentals Handbook 2001)	—	—	—	—	—	—

Description	Density kg/m³	Conductivity[b] (k), W/(m.k)	Conductance (c) W/ (m². k)	Resistance[c] (R)		Specific heat kJ/(kg k)
				1/k, K.m² / w	For thickness listed (1/c), K.m²/W	
ROOFING						
Asbestos-cement shingles	1900	—	27.0	—	0.037	1.00
Asphalt roll roofing.	1100	—	36.9	—	0.026	1.51
Asphalt shingles.	1100	—	12.9	—	0.077	1.26
Built-up roofing.. 10 mm	1100	—	17.0	—	0.058	1.46
Slate..13 mm	—	—	114	—	0.009	1.26
Wood shingles, plain and plastic film faced..	—	—	6.0	—	0.166	1.30
PLASTERING MATERIALS Cement plaster, sand aggregate..	1860	0.72	—	1.39	—	0.84
Sand aggregate ..10 mm	—	—	75.5	—	0.013	0.84
Sand aggregate ..20 mm	—	—	37.8	—	0.026	0.84
Gypsum plaster: Lightweight aggregate..13 mm	720	—	17.7	—	0.056	—
Lightweight aggregate..16 mm	720	—	15.2	—	0.066	—
Lightweight aggregate on metal lath..19 mm	—	—	12.1	—	0.083	—
Perlite aggregate.,.	720	0.22	—	4.64	—	1.34
Sand aggregate...	1680	0.81	—	1.25	—	0.84
Sand aggregate...13 mm	1680	—	63.0	—	0.016	—
Sand aggregate...16 mm	—	—	51.7	—	0.019	—
Sand aggregate on metal lath ..19 mm	720	0.24	43.7	—	0.023	—

Description	Density kg/m³	Conductivity[b] (k), W/(m.k)	Conductance (c) W/ (m². k)	Resistance[c] (R)		Specific heat kJ/(kg k)
				1/k, K.m² / w	For thickness listed (1/c), K.m²/W	
Vermuculite aggregate..	2400	1.21-1.47	—	4.09	—	—
MASONRY MATERIALS Bricks, fired clay..	2240	1.07-1.30	—	0.83-068	—	—
			—	0.94-0.77	—	—
	2080	0.92-1.12	—	1.08-0.89	—	—
	1920	0.81-0.98	—	1.24-1.02	—	0.79
	1760	0.71-0.85	—	1.42-1.18	—	—
	1600	0.61-0.74	—	1.65-1.36	—	—
	1440	-0.52-0.62	—	1.93-1.61	—	—
	1280	0.43-0.53	—	2.31-1.87	—	—
	1120	0.36-0.45	—	2.77-2.23	—	—
Clay tile, hollow 1 cell deep..75 mm	—	—	7.10	—	0.14	0.88
1 cell deep..100 mm	—	—	5.11	—	0.20	—
2 cell deep..150 mm	—	—	3.75	—	0.27	—
2 cell deep..200 mm	—	—	3.07	—	0.33	—
2 cell deep..250 mm	—	—	2.56	—	0.39	—
3 cell deep..300 mm	—	—	2.27	—	0.4	—
Concrete blocks[b,c] Limestone aggregate 200 mm , 16.3 kg, 2210 kg/m concrete, 2 cores..	—	—	—	—	—	—
Same with perlite filled cores	—	—	2.73	—	0.37	—

Description	Density kg/m³	Conductivity[b] (k), W/(m.k)	Conductance (c) W/ (m². k)	Resistance[c] (R)		Specific heat kJ/(kg k)
				1/k, K.m² / w	For thickness listed (1/c), K.m²/W	
300 mm, 25 kg, 2210 kg/m cibcrete, 2 cores…	—	—	—	—	—	—
Same with perlite filled cores	—	—	1.53	—	0.65	—
Normal mass aggregate (sand and gravel) 200 mm	—	—	5.1-5.8	—	0.20-0.17	0.92
15-16 kg, 2020-2180 kg/m concrete, 2 or 3 cores..	—	—	2.84	—	0.35	—
Same with perlite filled cores	—	—	3.0-4.1	—	0.34-0.24	—
Same with vermiculite filled cores	—	—	4.60	—	0.217	0.92
300 mm, 22.7 kg, 2000 kg/m concrete, 2 cores..						
Medium mass aggregate (combinations of normal and low mass aggregate) 200 mm 12-13 kg, 1550-1790 kg/m concrete, 2 or 3 crores…	—	—	3.3-4.4	—	0.30-0.22	—
Same with perlite filled crores..	—	—	1.5-2.5	—	0.65-0.41	—
Same with vermiculite filled crores	—	—	1.70	—	0.58	—
Same with molded EPS (beads) filled crores..	—	—	1.82	—	0.56	—
Same with molded EPS inserts in crores..	—	—	2.10	—	0.47	—

Description	Density kg/m³	Conductivity[b] (k), W/(m.k)	Conductance (c) W/ (m². k)	Resistance[c] (R)		Specific heat kJ/(kg k)
				1/k, K.m² / w	For thickness listed (1/c), K.m²/W	
Low mass aggregate (expanded shale, clay, slate or slag, pumice) 150mm 7.3-7.7 kg, 1360-1390 kg/ m concrete, 2 or 3 crores..	—	—	3.0-3.5	—	0.34-0.29	—
Same with perlite filled crores..	—	—	1.36	—	0.74	—
Same with vermiculite filled crores..	—	—	1.87	—	0.53	—
200 mm , 8.6-10.0 mm, 1150.1380 kg/m concrete ..	—	—	1.8-3.1	—	0.56-0.33	0.88
Same with perlite filled crores..	—	—	0.9-1.3	—	1.20-0.77	—
Same with vermiculite filled crores..	—	—	1.1-1.5	—	0.93-0.69	—
Same with moldede EPS (beads) filled cores..	—	—	1.19	—	0.85	—
Same with UF foam filled cores.	—	—	1.25	—	0.79	—
Same with molded EPS inserts in cores	—	—	1.65	—	0.62	—
300 mm ,14.5-16.3 kg, 1280-1440 kg/m concrete, 2 or 3 cores..	—	—	2.2-2.5	—	0.46-0.40	—
Same with perlite filled crores..	—	—	0.6-0.9	—	1.6-1.1	—
Same with vermiculite filled crores..	—	—	0.97	—	1.0	—
Stone, lime or sand Quartzitic and sandstone..	2880	10.4	—	0.10	—	—
	2560	6.2	—	0.16	—	—
	2240	3.5	—	0.29	—	0.79

Description	Density kg/m³	Conductivity[b] (k), W/(m.k)	Conductance (c) W/ (m². k)	Resistance[c] (R)		Specific heat kJ/(kg k)
				1/k, K.m² / w	For thickness listed (1/c), K.m²/W	
	1920	1.9	—	0.53	—	
Calcitic, dolomitic, limestone, marble, and granite...	2880	4.3	—	0.23	—	—
	2240	2.3	—	0.43.	—	—
	1920	1.6	—	0.63	—	0.79
	1600	1.1	—	0.90	—	—
Gypsum partition tile 75 by 300 by 760 mm, solid..	—	—	4.50	—	0.222	0.79
75 by 300 by 760 mm, 4 cells..	—	—	4.20	—	0.238	—
100 by 300 by 760 mm, 3 cells..	—	—	3.40	—	0.294	—
Concretes[o] Sand and gravel or stone aggregate concretes (concretes with more than 50% quartz or quartzite sand have conductivities in the higher end of the range)...	2400	1.4-2.9	—	0.69-0.35	—	—
Limestone concretes...	2240	1.3-2.6	—	0.77-0.39	—	0.8-1.0
	2080	1.0-1.9	—	0.99-0.53	—	—
	2240	1.60	—	0.62	—	—
	1920	1.14	—	0.88	—	—
	1600	0.79	—	1.26	—	—
Gypsum-fiber concrete (87.5% gypsum, 12.5% wood chips)	816	0.24	—	4.18	—	0.88
Cement/lime, mortar, and stucco	1920	1.40	—	0.71	—	—

Description	Density kg/m³	Conductivity[b] (k), W/(m.k)	Conductance (c) W/ (m². k)	Resistance[c] (R)		Specific heat kJ/(kg k)
				1/k, K.m² / w	For thickness listed (1/c), K.m²/W	
	1600	0.97	—	1.04	—	—
	1280	0.65	—	1.54	—	—
Lightweight aggregate concretes Expanded shale, clay, or slate; expanded slags;	1920	0.9-1.3	—	1.08-0.76	—	—
Cinders; pumice (with density up to 1600 kg/m); And scoria (sanded concretes have conductivities in the higher end of the range)	1600	0.68-0.89	—	1.48-1.12	—	0.84
	1280	0.48-0.59	—	2.10-1.69	—	0.84
	960	.0.30-0.36		3.30-2.77	—	—
	640	0.18	—	5.40	—	—
Perlite, vermiculite, and polystyrene beads..	800	0.26-0.27	—	3.81-3.68	—	—
	640	0.20-0.22	—	4.92-4.65	—	0.63-0..96
	480	0.16	—	6.31	—	—
	320	0.12	—	8.67	—	—
Foam concretes..	1920	0.75	—	1.32	—	—
	1600	0.60	—	1.66	—	—
	1280	0.44	—	2.29	—	—
	1120	0.36	—	2.77	—	—
Foam concretes and cellular concretes..	960	0.30	—	3.33	—	—
	640	0.20	—	4.92	—	—
	320	0.12	—	8.67	—	—
SIDING MATERIALS (ON FLAT SURFAFCE) shingles Asbestos-cement	1900	—	27.0	—	0.037	—

Description	Density kg/m³	Conductivity[b] (k), W/(m.k)	Conductance (c) W/ (m². k)	Resistance[c] (R)		Specific heat kJ/(kg k)
				1/k, K.m² / w	For thickness listed (1/c), K.m²/W	
Wood,400mm, 190mm exposure..	—	—	6.53	—	0.15	1.30
Wood, dobule,400mm, 300 mm, exposure..	—	—	4.77	—	0.21	1.17
Wood, plus insul, backer board,...8mm siding	—	—	4.03	—	0.25	1.30
Asbestos-cement, 6.4mm, lapped	—	—	27.0	—	0.037	1.01
Asphalt roll siding..	—	—	36.9	—	0.026	1.47
Asphalt insulating siding (12.7 mm bed..)	—	—	3.92	—	0.26	1.47
Hardboard siding, 11mm..	—	—	8.46	—	0.12	1.17
Wood, drop, 20 by 200mm	—	—	7.21	—	0.14	1.17
Wood, bevel, 13 by 200 mm, lapped	—	—	6.98	—	0.14	1.17
Wood, bevel,19 by 250 mm, lapped..	—	—	5.40	—	0.18	1.17
Wood, plywood, 9.5 mm, lapped..	—	—	9.60	—	0.10	1.22
Aluminum, steel or vinyl[p,q] over sheathing Hollow –backed.. Insulating-board backed	—	—	9.31	—	0.11	1.22
9.5 mm nominal	—	—	3.12	—	0.32	1.34
9.5 mm nominal, foil backed	—	—	1.93	—	0.52	—
Architectural (soda –lime float) glass	—	—	56.8	—	0.018	0.84

Description	Density kg/m³	Conductivity[b] (k), W/(m.k)	Conductance (c) W/ (m². k)	Resistance[c] (R)		Specific heat kJ/(kg k)
				1/k, K.m² / w	For thickness listed (1/c), K.m²/W	
WOODS(12% moisture content)[e,r] Hardwoods Oak..	659-749	0.16-0.18	—	6.2-5.5	—	1.63
Birch..	682-726	0.167-0.176	—	6.0-5.7	—	—
Maple	637-704	0.157-0.171	—	6.4-5.8	—	—
Asg	614-670	0.153-0.164	—	6.5-6.1	—	—
Softwoods Southern pine	570-659	0.144-0.161	—	6.9-6.2	—	—
Douglas fir-Larch..	536-581	0.137-0.145	—	7.3-6.9	—	1.63
Southern cypress	502-514	0.130-0.132	—	7.7-7.6	—	—
Hem-fir, Spruce-Pine-fir	392-502	0.107-0.130	—	9.3-7.7	—	—
West coast woods,Cedars..	347-502	0.098-0.130	—	1.3-7.7	—	—
California redwood..	392-448	0.107-0.118	—	9.4-8.5	—	—

* For referencing a, b, c, etc. of the above table, refer to the notes on the next pages

***Notes of Table 11.4**

[a]Values are for a mean temperature of 24°C. Representative values for dry materials are intended as design (not specification) values for materials in normal use. Thermal values of insulating materials may differ from design values depending on their in-situ properties (e.g., density and moisture content, orientation etc.) and variability experienced during manufacture. For properties of a particular product, use the value supplied by the manufacturer or by unbiased tests.

[b]The symbol λ is also used to represent thermal conductivity.

[c]Resistance values are the reciprocals of C before rounding off C to two decimal places.

[d]Lewis (1967).

[e]U.S. Department of Agriculture (1974).

[f]Does not include paper backing and facing, if any. Where insulation forms a boundary (reflective or otherwise) of an airspace, see Tables 2 and 3 for the insulating value of an airspace with the appropriate effective emittance and temperature conditions of the space.

[g]Conductivity varies with fiber diameter. (See Chapter 23, Factors Affecting Thermal Performance.) Batt, blanket, and loose-fill mineral fiber insulations are manufactured to achieve specified R-values, the most common of which are listed in the table. Due to differences in manufacturing processes and materials, the product thicknesses, densities, and thermal conductivities vary over considerable ranges for a specified R-value.

[h]This material is relatively new and data are based on limited testing.

[i]For additional information, see Society of Plastics Engineers (SPI) *Bulletin* U108. Values are for aged, Unfaced board stock. For change in conductivity with age of expanded polyurethane/polyisocyanurate, see Chapter 23, Factors Affecting Thermal Performance.

[j]Values are aged products with gas-impermeable facers on the two major surfaces. An aluminum foil facer of 25 μm thickness or greater is generally considered impermeable to gases. For change in conductivity with age of expanded polyisocyanurate, see Chapter 23, Factors Affecting Thermal Performance, and SPI Bulletin U108.

[k]Cellular phenolic insulation may no longer be manufactured. The thermal conductivity and resistance values do not represent aged insulation, which may have a higher thermal conductivity and lower thermal resistance.

[l]Insulating values of acoustical tile vary, depending on density of the board and on type, size, and depth of perforations.

[m]Cavity is framed with 20 mm wood furring strips. Caution should be used in applying this value for other framing materials. The reported value was derived from tests and applies to the reflective path only. The effect of studs or furring strips must be included in determining the overall performance of the wall.

[n]Values for fully grouted block may be approximated using values for concrete with a similar unit density.

[o]Values for concrete block and concrete are at moisture contents representative of normal use.

[p]Values for metal or vinyl siding applied over flat surfaces vary widely, depending on amount of ventilation of airspace beneath the siding; whether airspace is reflective or non-reflective; and on thickness, type, and application of insulating backing-board used. Values are averages for use as design guides, and were obtained from several guarded hot box tests (ASTM C 236) or calibrated hot box (ASTM C 976) on hollow-backed types and types made using backing of wood fiber, foamed plastic, and glass fiber. Departure of 50%±from these values may occur.

[q]Vinyl specific heat = 1.0 kJ/(kg.K)

[r]See Adams (1971), MacLean (1941), and Wilkes (1979). The conductivity values listed are for heat transfer across the grain. The thermal conductivity of wood varies linearly with the density, and the density ranges listed are those normally found for the wood species given. If the density of the wood species is not known, use the mean conductivity value. For extrapolation to other moisture contents, the following empirical equation developed by Wilkes (1979) may be used:

$$k = 0.7494 + \frac{(4.895\times10-3+1.503\times10-4M)p}{1+0.01M}$$

where p is density of the moist wood in kg/m^3, and M is the moisture content in percent.

$$c_p = 0.1442\times\frac{(0.299+0.01M)}{(1+0.01M)} + \Delta c_p$$

where Δc_p accounts for the heat of absorption and is denoted by $\Delta c_p = M(0.008037 - 1.325\times10^{-4}M)$

where M is the moisture content in percent by mass.

Assuming parallel heat flow only, the calculated resistance is higher than that calculated on the assumption of isothermal planes. The actual resistance generally is some values between the two calculated values. In the absence of test values, examination of the construction usually reveals whether a value closer to the higher or lower calculated R- value should be used. Generally, if the construction contains a layer in which lateral conduction is high compared with transmittance through the construction, the calculation with isothermal planes should be used. If the construction has no layer of high lateral conductance, the parallel heat flow calculation should be used.

Hot box tests of insulated and uninsulated masonry walls constructed with block of conventional configuration show that thermal resistances calculated using the isothermal planes heat flow method agree well with measured values (Van Geem 1985, Valore 1980, Shu et al. 1979). Neglecting horizontal mortar joints in conventional block can result in thermal transmittance values up to 16% lower than actual, depending on the density and thermal properties of the masonry, and 1 to 6% lower, depending on the core insulation material (Val Geem 1985, McIntyre 1984). For aerated concrete block walls, other solid masonry, and multicore block walls with full mortar joints, neglecting mortar joints can cause errors in R-values up to 40% (Valore 1988). Horizontal mortar joints, usually found in concrete block wall construction are neglected in Example 2.

Constructions Containing Metal

Curtain and metal stud-wall constructions often include metallic and other thermal bridges, which can significantly reduce the thermal resistance. However, the capacity of the adjacent facing materials to transmit heat transversely to the metal is limited, and some contact resistance between all materials in contact limits the reduction. Contact resistances in building structures are only 0.01 to 0.1 K.m^2/ W- too small to be of concern in many cases. However, the contact resistances of steel framing members may be important. Also, in many cases (as illustrated in Example3), the area of metal in contact with the facing greatly exceeds the thickness of the metal, which mitigates the contact resistance effects.

Thermal characteristics for panels of sandwich construction can computed by combing the thermal resistances of the various layer. R-values for the assembled sections should be determined on a representative sample by using a hot box method. If the sample is a wall section with air cavities on both sides of fibrous insulation, the sample must be of representative height since convective airflow can contribute significantly to eat flow through the test section. Computer modeling can also be useful, but all heat transfer mechanism must be considered. In Example 3, the metal member is only 0.5 mm thick, but it is in contact with adjacent facings over a 32 mm-wide area. The steel member is 90 mm deep, has a thermal resistance of approximately 0.0019 K.m^2/W, and is virtually isothermal. The calculation involves careful selection of the appropriate thickness for the steel member. If the member is assumed to be 0.5 mm thick, the fact that the flange transmits heat to the adjacent facing is ignored, and but the heat flow through the steel is underestimated. If the member is assumed to be 32 mm thick, the heat flow through the steel is overestimated. In Example 3, the steel member behaves in much the same way as a rectangular member 32 mm thick and 90 mm deep.

12. APPENDIX D: Building Envelope Tradeoff Method

12.1 The Envelope Performance Factor

12.1.1 The envelope performance factor shall be calculated using the following equations.

Equation 12 1: $EPF_{Total} = EPF_{Roof} + EPF_{wall} + EPF_{Fenest}$

where

$$EPF_{Roof} = c_{Roof} \sum_{s=1}^{n} U_s A_s$$

$$EPF_{Wall} = c_{Wall,Mass} \sum_{s=1}^{n} U_s A_s + c_{Wall,Other} \sum_{S=1}^{n} U_s A_s$$

$$EPF_{Fenest} = c_{1Fenest,North} \sum_{w=1}^{n} SHGC_w M_w A_w + c_{2Fenest,North} \sum_{w=1}^{n} U_w A_w +$$

$$c_{1Fenest,NonNorth} \sum_{w=1}^{n} SHGC_w M_w A_w + c_{2Fenest,NonNorth} \sum_{w=1}^{n} U_w A_w +$$

$$c_{1Fenest,Skylight} \sum_{s=1}^{n} SHGC_s A_s + c_{2Fenest,Skylight} \sum_{s=1}^{n} U_s A_s$$

Where

EPF_{Roof} : Envelope performance factor for roofs. Other subscripts include walls and fenestration.

A_s, A_w : The area of a specific envelope component referenced by the subscript “s” or for windows the subscript “w”.

$SHGC_w$: The solar heat gain coefficient for windows (w). $SHGC_s$ refers to skylights.

M_w : A multiplier for the window SHGC that depends on the projection factor of an overhang or sidefin.

U_s : The U-factor for the envelope component referenced by the subscript “s”

C_{roof} : A coefficient for the “Roof ” class of construction

C_{wall} : A coefficient for the "Wall"

$C_{1\ Fenest}$: A coefficient for the "Fenestration 1"

$C_{2\ Fenest}$: A coefficient for the "Fenestration 2"

Values of "c" are taken from Table 12.1

Table 12.1: Envelope Performance Factor Coefficients-Composite Climate (under review)

	Daytime Occupancy		24-Hour Occupancy	
	U-factor	SHGC	U-Factor	SHGC
Mass Walls	6.01	-	13.85	-
Curtain Walls, Other	15.72	-	20.48	-
Roofs	11.93	-	24.67	-
North Windows	-1.75	40.65	-4.56	58.15
Non-North Windows	-1.25	54.51	0.68	86.57
Skylights	-96.35	311.71	-294.66	918.77

Note: Punjab is covered by Composite climate zone only. For information on other climate zones, please refer relevant tables of ECBC 2007.

12.1.2 Overhang and Side Fin Coefficients

The "M" multiplication factor can also be calculated using Equation 12 2. If the equation is used, a separate calculation shall be made for each orientation and unique shading condition.

Equation 12 2: $M = a \cdot PF^2 + b \cdot PF + 1$

Table 12.2: Overhang and Side Fin Coefficients

Device	Coefficient	North	South	East/West
Overhangs	A	0.16	0.21	0.10
	B	-0.61	-0.83	-0.58
Side Fins	A	0.23	0.12	0.14
	B	-0.74	-0.59	-0.52

12.1.3 Baseline Building Definition

The following rules shall be used to define the Baseline Building for Envelope Tradeoff:

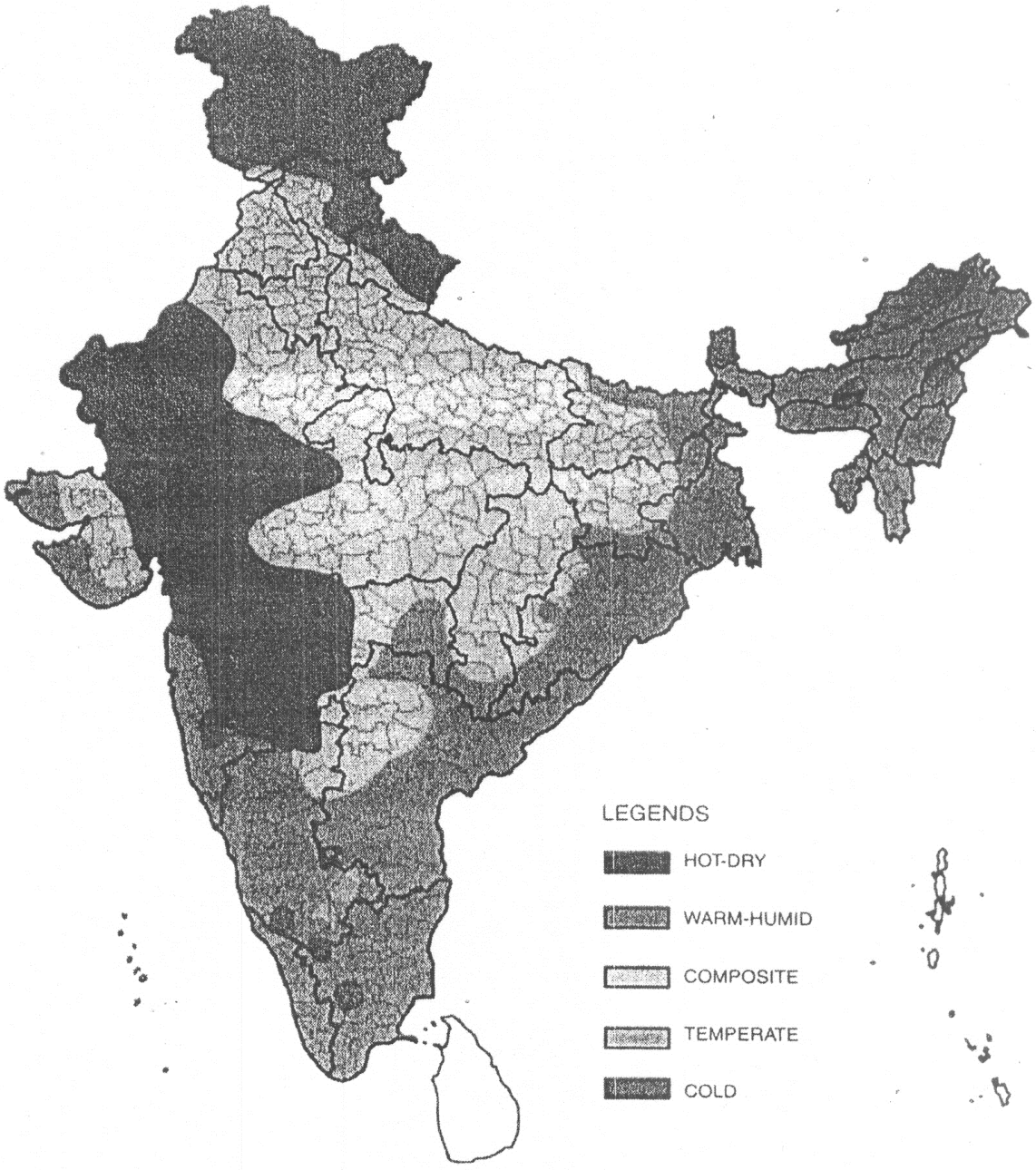
a. The Baseline Building shall have the same building floor area, gross wall area and gross roof area as the proposed design. If the building has both 24-hour and daytime occupancies, the distribution between these shall be the same as the proposed design

b. The U-factor of each envelope component shall be equal to the criteria from clause4.3 for each class of construction

c. The vertical fenestration area shall be equal to the proposed design or 40% of the gross exterior wall area, whichever is less. The skylight area shall be equal to the proposed design or 5% of the gross exterior roof area, whichever is less

d. The SHGC of each window or skylight component shall be equal to the criteria from clause4.3

13. APPENDIX E: Climate Zone Map of India



Source: National Building Code 2005, Part 8, Fig.2

14. APPENDIX F: Air-Side Economizer Acceptance Procedures Envelope Summary

14.1 Construction Inspection

Prior to Performance Testing, verify and document the following:

a) System controls are wired correctly to ensure economizer is fully integrated (i.e. economizer will operate when mechanical cooling is enabled)
b) Economizer lockout control sensor location is adequate (open to air but not exposed to direct sunlight nor in an enclosure; away from sources of building exhaust; at least 8 m [25 ft] away from cooling towers)
c) System is provided with barometric relief, relief fan or return fan to control building pressure

14.2 Equipment Testing

Step 1: Simulate a cooling load and enable the economizer by adjusting the lockout control setpoint. Verify and document the following:

a) Economizer damper modulates opens to 100% outside air
b) Return air damper modulates closed and is completely closed when economizer damper is 100% open
c) Economizer damper is 100% open before mechanical cooling is enabled Relief fan or return fan (if applicable) is operating or barometric relief dampers freely swing open

Step 2: Continue from Step 1 and disable the economizer by adjusting the lockout control setpoint. Verify and document the following:

a) Economizer damper closes to minimum ventilation position
b) Return air damper opens to at or near 100%
c) Relief fan (if applicable) shuts off or barometric relief dampers close. Return fan (if applicable) may still operate even when economizer is disabled

15. APPENDIX G: Punjab-ECBC Compliance Forms

15.1 Envelope Summary

Envelope Summary

The Punjab Energy Conservation Building Code Compliance Forms

Project Info	Project Address			Date For Building Department Use
	Applicant Name: Applicant Address: Applicant Phone:			
Project Description	☐ New Building	☐ 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 Note: Vertical fenestration area can not exceed 60%of the gross wall area for prescriptive option	Total Vertical Fenestration Area (rough opening)	divided by	Gross Exterior Wall Area	times 100 equals	**% Vertical Fenestration**
		÷		X 100 =	
Skylight Area Calculation Note: Skylight area can not exceed 5% of the gross roof area for prescriptive compliance.	Total Skylight Area (rough opening)	divided by	Gross Exterior Wall Area	times 100 equals	**% Vertical Fenestration**
		÷		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 (or SC)	
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 (or SC)	

Other Building type (daytime)

OPAQUE ASSEMBLY	
Roof	*Minimum Insulation R-value*
Wall	*Minimum Insulation R-value*
FENESTRATION	
Vertical	
	Maximum U-factor
	Maximum SHGC (or SC)
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 (or SC)

15.2 Building Permit Plans Checklist

Building Permit Plans Checklist — ENVELOPE Checklist

The Punjab 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 Punjab Energy Conservation Building Code.

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. envelope sealing	Indicate sealing, caulking, gasketing, and weather stripping		
PRESCRIPTIVE COMPLIANCE OPTION (Section 4.3)					
	4.3.1	Roof	Indicate R-values on roof sections		
	4.3.2	Cool roof	Indicate minimum reflectance and emittance on plans		
	4.3.3	Opaque walls	Indicate R-values on wall sections		
	4.3.4	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.		
	4.3.5	Skylights	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		

15.3 Mechanical Summary

Mechanical Summary

The Punjab Energy Conservation Building Code Compliance Forms

Project Info	Project Address	Date For Building Department Use
	Applicant Name: Applicant Address: Applicant Phone:	
Project Description Briefly describe mechanical system type and features. ☐ Includes Plans		

Compliance Option	☐ System	☐ Presciptive	☐ Whole Building

Equipment Schedules The following information is required to be incorporated with the mechanical equipment schedules on the plans. For projects without plans, fill in the required information below.

Cooling Equipment Schedule

Equip.ID	Brand Name	Model No.	Capaity kW	Total L/s	OSA CFM or Econo?	SEER or EER	IPLV	Location

Heating Equipment Schedule

Equip. ID	Brand Name	Model No	Capacity kW	Total L/s	OSA CFM or Econo?	Input kW	Output kW	Efficiency

Fan Equipment Schedule

Equip. ID	Brand Name	Model No.	Total L/s	SP	kW	Flow Control	Location of Service

15.4 Mechanical Permit Checklist

Mechanical Permit Checklist

MECHANICAL Checklist

The Punjab Energy Conservation Building Code Compliance Forms

Project Address:	Date:

The following information is necessary to check a building permit application for compliance with the mechanical requirements in the Punjab Energy Conservation Building Code.

Applicability (yes, no, n.a.)	Code Section	Component	Information Required	Location on Plans	Building Dept. Notes
HEATING, VENTILATING, AND AIR CONDITIONING (Chapter 5)					
MANDATORY PROVISIONS (Section 5.2)					
	5.2.2	Equipment efficiency	Provide equipment schedule with type, capacity, efficiency		
	5.2.4	Controls			
	5.2.4.1	Timeclocks	Indicate thermostat with night setback, 3 different day types, and 2-hour manual override		
	5.2.4.2	Temp. & dead band	Indicate temperature control with 3°C deadband minimum		
	5.2.4.3	Cooling tower, fluid cooler	Indicate two-speed motor, pony motor, or variable speed drive to control the fans		
	5.2.5.1	Piping & ductwork			
	5.2.5.1	Piping insulation	Indicate R-value of insulation		
	5.2.5.1	Ductwork insulation	Indicate R-value of insulation		
	5.2.5.1	Ductwork sealing	Specify sealing types and locations		
	5.2.6	System balancing	Specify system balancing		
PRESCRIPTIVE COMPLIANCE OPTION (Section 5.3)					
	5.3		Indicate whether project is complying with Punjab-ECBC Prescriptive Option OR with ASHRAE Standard 90.1-2004		
	5.3.1	Economizer			
	5.3.1.1	Air economizer	Indicate 100% capability on schedule		
	5.3.1.2	Integrated operation	Indicate capability for partial cooling		
	5.3.1.3	Field testing	Specify tests		
	5.3.2	Variable flow hydronic			
	5.3.2.1	Pump flow rates	Indicate variable flow capacity on schedules		
	5.3.2.2	Isolation valves	Indicate two-way automatic isolation valves		
	5.3.2.3	Variable speed drive	Indicate variable speed drive		
SERVICE WATER HEATING AND PUMPING (Chapter 6)					
MANDATORY PROVISIONS (Section 6.2)					
	6.2.1	Solar water heating	Provide calculations to justify capacity to meet 20% threshold		
	6.2.2	Equipment efficiency	Provide equipment schedule with type, capacity, efficiency		
	6.2.4	Piping insulation	Indicate R-value of insulation		
	6.2.5	Heat traps	Indicate heat trap on drawings or provide manufacturers specifications to show that equipment has internal heat trap		
	6.2.6	Pool covers	Provide vapor retardant cover for pools		
	6.2.6	Pools over 32 °C	Provide R-2.1 insulation		

15.5 Lighting Summary

Lighting Summary

The Punjab Energy Conservation Building Code Compliance Forms

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

Project Description	☐ New Building	☐ Addition	☐ Alteration	☐ Change of Use
Compliance Option	☐ Prescriptive	☐ System Analysis		

Alteration Exceptions (check box, if appropriate) ☐ Less than 50% of the fixtures are new and installed lighting wattage is not being increased

Maximum Allowed Lighting Wattage (Interior, Section 7.3)

Location (floor/room no.)	Occupancy Description	Allowed Watts per m² **	Area in m²	Allowed x Area
	** Document all exceptions		Total Allowed Watts	

Proposed Lighting Wattage (Interior)

Location (floor/room no.)	Fixture Description	Number of Fixtures	Watts/ Fixture	Watts Proposed
Total Proposed Watts may not exceed Total Allowed Watts for Interior			Total Proposed Watts	

Maximum Allowed Lighting Wattage (Exterior, Section 7.4)

Location	Description	Allowed Watts per m² or per lm	Area in m² (or lm for perimeter)	Allowed Watts x m² (or x lm)
			Total Allowed Watts	

Proposed Lighting Wattage (Exterior)

Location	Fixture Description	Number of Fixtures	Watts/ Fixture	Watts Proposed
Total Proposed Watts may not exceed Total Allowed Watts for Exterior			Total Proposed Watts	

15.6 Lighting Permit Checklist

Lighting Permit Checklist — Lighting Checklist

The Punjab Energy Conservation Building Code Compliance Forms

Project Address — Date:

The following information is necessary to check a building permit application for compliance with the lighting requirements in the Punjab Energy Conservation Building Code.

Applicability (yes, no, n.a.)	Code Section	Component	Information Required	Location on Plans	Building Dept. Notes
LIGHTING (Chapter 7)					
MANDATORY PROVISIONS (Section 7.2)					
	7.2.1	Lighting Controls			
	7.2.1.1	Automatic shutoff	Indicate automatic shutoff locations or occupancy sensors		
	7.2.1.2	Space control	Provide schedule with type, indicate locations		
	7.2.1.3	Daylight zones	Provide schedule with type and features, indicate locations		
	7.2.1.4	Ext. lighting control	Indicate photosensor or astronomical time switch		
	7.2.1.5	Additional control	Provide schedule with type, indicate locations		
	7.2.2	Signage/Advertising signage	Indicate 5 watts maximum		
	7.2.3	Exterior building grounds lighting	Indicate minimum efficacy of 60 lumens/Watt		
PRESCRIPTIVE INTERIOR LIGHTING POWER COMPLIANCE OPTION (Section 7.3)					
	7.3		Indicate whether project is complying with the Building Area Method (7.3.2) or the Space Function Method (7.3.3)		
	7.3.2	Building area method	Provide lighting schedule with wattage of lamp and ballast and number of fixtures. Document all exceptions.		
	7.3.3	Space function method	Provide lighting schedule with wattage of lamp and ballast and number of fixtures. Document all exceptions.		
	7.3.4.1	Luminaire wattage	Indicate on plans		
PRESCRIPTIVE EXTERIOR LIGHTING POWER COMPLIANCE OPTION (Section 7.3.5)					
	7.3.5	Exterior Lighting Power	Provide lighting schedule with wattage of lamp and ballast and number of fixtures. Document all exceptions.		
ELECTRICAL POWER (Chapter 8)					
MANDATORY PROVISIONS (Section 8.2)					
	8.2.1	Transformers	Provide schedule with transformer losses		
	8.2.2	Motor efficiency	Provide equipment schedule with motor capacity, efficiency		
	8.2.3	Power factor correction	Provide schedule with power factor correction		
	8.2.4	Check metering	Provide check metering and monitoring		

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