HARYANA ECO-NIWAS SAMHITA

(Draft for Notification)

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Chapter 1: INTRODUCTION

1.1. India's Intended Nationally Determined Contributions (INDCs) aim to reduce the emissions intensity of its gross domestic product (GDP) by 33 to 35 percent by 2030 from 2005 level[1]. Any effort to achieve this target is contingent upon the increase in efficiency of energy use across all sectors, especially in the building sector. The building sector in India consumes over 30% of the total electricity[2] consumed in the country annually and is second only to the industrial sector as the largest emitter of greenhouse gases (GHGs).

1.2. Out of the total electricity consumed in the building sector, about 75% is used in residential buildings. The gross electricity consumption in residential buildings has been rising sharply over the years. For instance, the consumption figure rose to about 260 TWh in 2016-17 from about 55 TWh in 1996-97[3]. That is an increase by more than four times in 20 years. Projections show it rising to anywhere between 630 and 940 TWh by 2032[4]. Among various reasons, increased use of decentralized room based air-conditioning units in homes for thermal comfort is an important reason contributing to this rapid increase in the electricity use in residential buildings. The demand for air-conditioning will continue its exponential growth with improvement in household incomes and will become the dominant contributor of GHG emissions nation-wide owing to increased electricity consumption. This situation calls for an immediate energy conservation action plan.

1.3. Energy codes for new buildings are an important regulatory measure for ushering energy efficiency in the building sector. They are particularly relevant for countries like India where the building stock is growing rapidly. The commercial sector among buildings has been addressed by the Energy Conservation Building Code (ECBC) for Commercial Buildings. Given the current and anticipated rapid growth in the residential building stock across India and the consequent opportunities as well as the necessity for energy conservation in this sector, the Energy Conservation Code for Residential Buildings is established by the Ministry of Power.

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[1] India's Intended Nationally Determined Contribution. Available at http://www4.unfccc.int/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf (accessed on 1 May 2018)

[2] Ministry of Statistics and Programme Implementation (MoSPI). 2018. Energy Statistics 2018. New Delhi: MoSPI, Government of India.

[3] Central Electricity Authority (CEA). 2017. Growth of Electricity Sector in India from 1947-2017. New Delhi: CEA, Government of India.

[4] NITI Aayog. India Energy Security Scenario, 2047. New Delhi: NITI Aayog, Government of India. Available at http://indiaenergy.gov.in/iess/default.php (accessed on 1 May 2018).

1.4. Building envelope consists of walls, roof, and fenestration (openings including windows, doors, vents, etc.). Design of building envelope influences heat gain/loss, natural ventilation, and daylighting[5], which, in turn, determines indoor temperatures, thermal comfort, and sensible cooling/heating demand.

1.5. Most parts of India have cooling-dominated climates.[6] Consideration of heat gain is often not given sufficient importance during residential building design. It is seen that current practices of residential building design and construction show a large variation in heat gains and hence in the sensible cooling demand. Depending on the envelope design and construction adopted for residential buildings located in a particular climate zone, the minimum and maximum sensible cooling demand can vary by as much as 1:3.[7]

1.6. Energy Conservation Building Code – Residential (ECBC-R) has been prepared to set minimum building envelope performance standards to limit heat gains (for cooling dominated climates) and to limit heat loss (for heating dominated climates[8]), as well as for ensuring adequate natural ventilation and daylighting potential. The code provides design flexibility to innovate and vary important envelope components such as wall type, window size, type of glazing, and external shading to windows to meet the compliance.

1.7. The code also specifies compliance approaches and minimum energy performance requirements for building services, indoor electrical end-use and renewable energy system.

1.8. The code is applicable to all residential buildings and residential parts of 'mixed land-use projects', both built on a plot area of ≥ 500 m^2. However, states and municipal bodies may reduce the plot area based on the prevalence in their area of jurisdiction. This provision is kept to take into account the prevalent plot sizes and housing types in different states, enabling the inclusion of a greater percentage of new multi-dwelling unit residential buildings within the scope of this code. (Please refer paragraph 2.4.)

1.9. Building envelope has the highest impact on thermal comfort, and consequently on the energy use in residential buildings. The envelope is also a permanent component of the building

[5] Bureau of Indian Standards (BIS). 1987 and 2016. Handbook on Functional Requirements of Buildings (Other than Industrial Buildings) SP: 41 (S & T) - 1987, and National Building Code (NBC) of India 2016. New Delhi: BIS.

[6] These are climates where the ambient temperatures are high during major part of the year and mechanical space cooling is required for thermal comfort.

[7] Bureau of Energy Efficiency (BEE). 2014. Design Guidelines for Energy-Efficient Multi-Storey Residential Buildings (Warm-Humid Climate). New Delhi: BEE.

[8] These are climates where the ambient temperatures are low during major part of the year and mechanical space heating is required for thermal comfort.

with the longest life cycle. An early introduction of this code would improve the design and construction of new residential building stock being built currently and in the near future, thus significantly curtailing the anticipated energy demand for comfort cooling in times to come. This critical investment in envelope design and construction made today will reap benefits of reduced GHG emissions for the lifetime of the buildings.

1.10. The code is designed in a simple-to-apply format, requiring only simple calculations based on inputs from the architectural design drawings of buildings. This can be used by architects and engineers and will not require any simulation software. This also enables the code to be readily adopted in the building bye-laws. A compliance tool is also available on BEE website to aid in the calculations and compliance check.

1.11. The code also provides following five appendices which are recommendatory in nature and envisaged to be added in future revision of the code.

Annex A: Annualized embodied energy
Annex B: Better construction practices
Annex C: Retrofitting of residential buildings
Annex D: Improved air cooling
Annex E: Smart Home

Chapter 2: SCOPE

2.1. The code sets minimum performance standards for building envelope to limit heat loss (as the state falls under composite climate) through it. The code gives the following provisions to this effect:

- Building Envelope (except roof): Maximum value of residential envelope transmittance value (RETV) for building envelope (except roof) applicable for composite climate[9].
- Roof: Maximum value of thermal transmittance of roof (U_{roof}) for composite climate.

2.2. The code sets minimum building envelope performance standard for adequate natural ventilation potential by specifying minimum openable window-to-floor area ratio (WFR_{op}).

2.3. The code sets minimum building envelope performance standard for adequate daylight potential by specifying minimum visible light transmittance (VLT) for the non-opaque building envelope components.

2.4. The code applies to –

2.4.1. 'Residential buildings' built on a plot area[10] ≥ 500 m^2

2.4.2. Residential part of 'Mixed land-use building projects',[11] built on a plot area[12] ≥ 500 m^2.

'Residential building' includes any building in which sleeping accommodation is provided for normal residential purposes with or without cooking or dining or both facilities. This definition includes:

One or two family private dwellings: These shall include any private dwelling, which is occupied by members of one or two families and has a total sleeping accommodation for not more than 20 persons.

Apartment houses: These shall include any building or structure in which living quarters are provided for three or more families, living independently of each other and with independent cooking facilities. This also includes 'Group Housing'.

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[9] For climate classification, see Annexure 2.

[10] States and municipal bodies may change the plot area based on the prevalence in their area of jurisdiction.

[11] However, residential accommodation in a building, where the carpet area of the residential part is not more than 30 m^2 for caretakers or persons employed in connection with the building, is exempted.

[12] States and municipal bodies may reduce the plot area based on the prevalence in their area of jurisdiction.

The following are excluded from the definition of 'residential building' for the purpose of this code.

Lodging and rooming houses: These shall include any building or group of buildings under the same management in which separate sleeping accommodation on transient or permanent basis, with or without dining facilities but without cooking facilities for individuals, is provided. This includes inns, clubs, motels, and guest houses.

Dormitories: These shall include any building in which group sleeping accommodation is provided, with or without dining facilities for persons who are not members of the same family, in one room or a series of closely associated rooms under joint occupancy and single management. For example, school and college dormitories, students, and other hostels and military barracks.

Hotels: These shall include any building or group of buildings under single management, in which sleeping accommodation is provided, with or without dining facilities.

2.5. The code is also applicable for all additions made to existing residential buildings where the existing building exceeds the threshold defined in section 2.4. For this purpose, the addition together with the existing residential building is required to show compliance with this code with the authority having jurisdiction.

2.6. The code is also applicable for all alterations made to existing residential buildings where the existing building exceeds the threshold defined in section 2.4 of the code and the alteration, part of the building or its system, is been done for an area more than 1000 square feet. For this purpose, the part of the building or its systems that are being altered is required to show compliance with this code with the authority having jurisdiction.

2.7. The code sets minimum requirements for electro-mechanical systems used in building services (i.e. common area and exterior lighting, elevators, pumps, basement ventilation, transformers, power distribution losses, power factor correction, electrical vehicle supply equipment etc.) and indoor electrical end-use (i.e. indoor lighting, comfort systems, service hot water etc.).

2.8. The code sets minimum requirements for renewable energy systems (Solar hot water requirements and Solar Photovoltaic) integration.

2.9. If a building project has more than one building block in multiple orientations, then compliance must be sought by showing that building block meet the performance requirements in each of the four-cardinal orientation (north, south, east, west). However, for identical building blocks with the same orientation, the compliance must be shown for one building block.

2.10. The following codes, programs, and policies will take precedence over the code in case of conflict:

2.10.1. Any policy notified as taking precedence over this Code, or any other rules on safety, security, health, or environment by Central, State, or Local Government.

2.10.2. BEE's Standards and Labelling for appliances and Star Rating Program for buildings, or any reference standard prescribed by the Code, provided both or either are more stringent than the requirements of this Code.

Chapter 3: CODE PROVISION

3.1 Openable Window-to-Floor Area Ratio (WFR_{op})

3.1.1 Openable window-to-floor area ratio (WFR_{op}) indicates the potential of using external air for ventilation. Ensuring minimum WFR_{op} helps in ventilation, improvement in thermal comfort, and reduction in cooling energy.

3.1.2 The openable window-to-floor area ratio (WFR_{op}) is the ratio of openable area to the carpet area of dwelling units.

$$WFR_{op} = \frac{A_{openable}}{A_{carpet}} \tag{1}$$

Where,

WFR_{op} : openable window-to-floor area ratio

$A_{openable}$: openable area (m^2); it includes the openable area of all windows and ventilators, opening directly to the external air, an open balcony, 'verandah', corridor or shaft; and the openable area of the doors opening directly into an open balcony. *Exclusions:* All doors opening into corridors. External doors on ground floor, for example, ground-floor entrance doors or back-yard doors.

A_{carpet} : carpet area of dwelling units (m^2); it is the net usable floor area of a dwelling unit, excluding the area covered by the external walls, areas under services shafts, exclusive balcony or verandah area and exclusive open terrace area, but includes the area covered by the internal partition walls of the dwelling unit.[13]

3.1.3 The openable window-to-floor area ratio (WFR_{op}) shall not be less than the values[14] given in Table 1.

Table 1: Minimum requirement of window-to-floor area ratio (WFR_{op})

Climatic zone	Minimum WFR_{op} (%)
Composite	12.50

Source: Adapted from Bureau of Indian Standards (BIS). 2016. National Building Code of India 2016. New Delhi: BIS.

[13] The Real Estate (Regulation and Development) Bill, 2016 (as passed by the Rajya Sabha on the 10 March 2016). Available at http://164.100.47.4/BillsTexts/RSBillTexts/PassedRajyaSabha/realest-238-RSP-E.pdf (accessed on 1 May 2018)

[14] To comply with the Code, WFRop (%) values shall be rounded off to two decimal places in accordance with IS 2: 1960 'Rules for rounding off numerical values'

3.2 Visible Light Transmittance (VLT)

3.2.1 Visible light transmittance (VLT) of non-opaque building envelope components (transparent/translucent panels in windows, doors, ventilators, etc.), indicates the potential of using daylight. Ensuring minimum VLT helps in improving daylighting, thereby reducing the energy required for artificial lighting.

3.2.2 The glass used in non-opaque building envelope components (transparent/translucent panels in windows, doors, etc.) shall comply with the requirements given in Table 2. The VLT requirement is applicable as per the window-to-wall ratio (WWR) of the building. WWR is the ratio of the area of non-opaque building envelope components of dwelling units to the envelope area (excluding roof) of dwelling units.

$$WWR = \frac{A_{non-opaque}}{A_{envelope}} \quad (2)$$

Table 2: Minimum visible light transmittance (VLT) requirement[15]

Window-to-wall ratio (WW R)[16]	Minimum VLT[17]
0–0.30	0.27
0.31–0.40	0.20
0.41–0.50	0.16
0.51–0.60	0.13
0.61–0.70	0.11

Source: Bureau of Indian Standards (BIS). 2016. National Building Code of India 2016. New Delhi: BIS.

3.3 Thermal Transmittance of Roof (U_{roof})

3.3.1 Thermal transmittance (U_{roof}) characterizes the thermal performance of the roof of a building. Limiting the U_{roof} helps in reducing heat gains or losses from the roof, thereby improving the thermal comfort and reducing the energy required for cooling or heating.

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[15] It is advised that a) the WWR $\leq$ 0.15, minimum VLT should be 40% and b) the WWR in residential buildings may not exceed 0.40.

[16] To comply with the Code, VLT values shall be rounded off to two decimal places in accordance with IS 2: 1960 'Rules for rounding off numerical values'

[17] To comply with the Code, WWR values shall be rounded off to two decimal places in accordance with IS 2: 1960 'Rules for rounding off numerical values'

3.3.2 Thermal transmittance of roof shall comply with the maximum U_{roof} value of 1.2 W/m^2-K.

3.3.3 The calculation[18] shall be carried out, using Equation 3 as shown below.

$$U_{roof} = \frac{1}{A_{roof}} \left[\sum_{i=1}^{n} (U_i \times A_i) \right] \qquad (3)$$

where,

U_{roof} : thermal transmittance of roof (W/m^2-K)

A_{roof} : total area of the roof (m^2)

U_i : thermal transmittance values of different roof constructions (W/m^2-K)

A_i : areas of different roof constructions (m^2)

3.4 Residential envelope transmittance value (RETV) for building envelope (except roof) for Composite Climate

3.4.1 Residential envelope heat transmittance (RETV) is the net heat gain rate (over the cooling period) through the building envelope (excluding roof) of the dwelling units divided by the area of the building envelope (excluding roof) of the dwelling units. Its unit is W/m^2.

RETV characterizes the thermal performance of the building envelope (except roof). Limiting the RETV value helps in reducing heat gains from the building envelope, thereby improving the thermal comfort and reducing the electricity required for cooling.

RETV formula takes into account the following:

- Heat conduction through opaque building envelope components (wall, opaque panels in doors, windows, ventilators, etc.),
- Heat conduction through non-opaque building envelope components (transparent/translucent panels of windows, doors, ventilators, etc.),
- Solar radiation through non-opaque building envelope components (transparent/translucent panels of windows, doors, ventilators, etc.)

3.4.2 The RETV for the building envelope (except roof) for composite climate shall comply with the maximum RETV[19] of 15 W/m^2.

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[18] To comply with the Code, U value shall be rounded off to one decimal places in accordance with IS 2: 1960 'Rules for rounding off numerical values'

[19] BEE plans to improve the RETV norm to 12 W/m^2 in the near future and the building industry and regulating agencies are encouraged to aim for it.

3.4.3 The RETV calculation[20] of the building envelope (except roof) shall be carried out, using Equation 4 as shown below.

$$RETV = \frac{1}{A_{envelope}} \times \left[\begin{array}{l} \left\{ a \times \sum_{i=1}^{n} \left(A_{opaque_i} \times U_{opaque_i} \times \omega_i \right) \right\} \\ + \left\{ b \times \sum_{i=1}^{n} \left(A_{non-opaque_i} \times U_{non-opaque_i} \times \omega_i \right) \right\} \\ + \left\{ c \times \sum_{i=1}^{n} \left(A_{non-opaque_i} \times SHGC_{eq_i} \times \omega_i \right) \right\} \end{array} \right] \quad (4)$$

where,

$A_{envelope}$	: envelope area (excluding roof) of dwelling units (m^2). It is the gross external wall area (includes the area of the walls and the openings such as windows and doors).
$A_{opaquei}$	: areas of different opaque building envelope components (m^2)
$U_{opaquei}$	: thermal transmittance values of different opaque building envelope components (W/m^2-K)
$A_{non\text{-}opaquei}$	: areas of different non-opaque building envelope components (m^2)
$U_{non\text{-}opaquei}$	: thermal transmittance values of different non-opaque building envelope components (W/m^2-K)
$SHGC_{eqi}$	: equivalent solar heat gain coefficient values of different non-opaque building envelope components (refer to Annexure 7)
ω_i	: orientation factor of respective opaque and non-opaque building envelope components; it is a measure of the amount of direct and diffused solar radiation that is received on the vertical surface in a specific orientation (values are given in Annexure 6)

The coefficients of RETV formula, for composite climate are given in Table 3.

Table 3: Coefficients (a, b, and c) for RETV formula

Climate zone	a	b	c
Composite	6.06	1.85	68.99

[20] To comply with the Code, RETV value shall be rounded off to nearest integer value in accordance with IS 2: 1960 'Rules for rounding off numerical values'

Chapter 4: CODE COMPLIANCE

4.1 Mandatory Requirements for Building Envelope

4.1.1 The code is designed in a simple-to-apply format, requiring only simple calculations based on inputs from the architectural design drawings of residential buildings. This can be used by architects and engineers and will not require any simulation software.

4.1.2 If a building project has more than one building block, each building block is required to comply with the code. However, for identical building blocks with the same orientation,[21] the compliance has to be shown for one building block.

4.1.3 The steps for checking compliance for composite climate are as follows:

Step 1: Openable window-to-floor area ratio shall comply with the minimum WFR_{op} values as given in Table 1 of paragraph 3.1.3. For calculation of WFR_{op}, refer Annexure 3.

Step 2: Visible light transmittance (VLT) of non-opaque building envelope components shall comply with the minimum VLT values as given in Table 2 of paragraph 3.2.2.

a) For calculation of WWR, refer Annexure 4.

b) Refer product specifications to know the VLT of transparent/translucent panels in windows, doors, and ventilators.

Step 3: Thermal transmittance of roof shall comply with the maximum U_{roof} value of 1.2 $W/m^2.K$ (refer paragraph 3.3). To calculate the U values of roof, refer Annexure 5.

Step 4: Residential envelope transmittance value (RETV) for building envelope (except roof) shall comply with the maximum RETV of 15 W/m^2 (refer paragraph 3.4).

a) Equation 4 is to be used for the calculation of RETV, with coefficients selected from Table 3 as per the composite climate zone.

b) For calculation of WWR, refer Annexure 4.

c) For calculation of U values, refer Annexure 5.

d) For orientation factor, refer Annexure 6.

e) For calculation of Equivalent SHGC, refer Annexure 7.

An example of code compliance is given in Annexure 8 (Example 1).

[21] For details of orientation, refer Annexure 6.

4.2 Compliance Approaches

4.2.1 In order to demonstrate compliance with the code, the building shall comply with all of the mandatory requirements stated in Chapter 5 along with either of the two approaches:

a) Prescriptive approach as mentioned in Chapter 6

b) Points based system approach as mentioned in Chapter 7

4.2.2 Table 4 below gives the minimum ENS score required to be obtained as per eligible project category:

Table 4: Minimum ENS Score Requirement

Project Category	Minimum ENS Score
Low rise buildings	47
Affordable Housing	70
High rise buildings	100

4.2.3 Low Rise Buildings: A building equal or below 4 stories, and/or a building up to 15 meters in height (without stilt) and up to 17.5 meters (including stilt).

4.2.4 Affordable Housing Projects: Affordable houses are Dwelling Units (DUs) with Carpet Area less than 60 sq.m.. It also includes Economically Weaker Section (EWS) category and Lower Income Group (LIG) category (LIG-A: 28-40 sq. m. and LIG-B 41-60 sq. m.).

4.2.5 High Rise Buildings: A building above 4 stories, and/or a building exceeding 15 meters or more in height (without stilt) and 17.5 meters (including stilt).

4.2.6 Compliance for Mixed Mode Buildings

a) In a mixed-use building, having both commercial and residential building use, each category of a building use must be classified separately, and –

   i) If a part of the mixed-use building classification (residential or commercial) is less than 10% of the total above grade floor area, the mixed-use building part shall show compliance based on the building sub-classification having higher percentage of above grade floor area.

   ii) If a part of the mixed-use building has different classification (residential or commercial) and one or more sub-classification is more than 10% of the total above grade floor area, the compliance requirements for each sub-classification, having area more than 10% of above grade floor area of a mixed-use building, shall be determined by the requirements for the respective building classification.

iii) Basement and common area services, designed for a particular building use or documented with respective buildings for compliance with authority having jurisdiction, needs to show compliance with the clauses for the respective building requirement.

b) In a mixed mode building with different category of residential buildings in the same project and including one or more category listed in 4.2.2 (low rise building, affordable housing, and/ or High-rise building)

i) Compliance for site marked for affordable housing, as per the applicable bye law, shall be shown separately.

ii) The overall point to be achieved for ENS building for site marked for affordable housing is 70.

iii) If the site area with low rise buildings in the overall project is more than or equal to 20% of the total site area, the site marked for low rise building, as per the applicable bye law, shall be shown separately to other residential building type. The overall point to be achieved for ENS building for the site marked for this low-rise building is 47.

iv) If the site area with low rise buildings in the overall project is less than 20% of the total site area, the site marked for low rise building, as per the applicable bye laws, shall be shown together with other residential building category. The overall point to be achieved for ENS Compliance for the overall site is 100. In such projects:

1. Mandatory points – compliance to be shown only for the components which are provided in the project and is necessary as per the applicable building bye law.
2. Additional points –
    a. to claim the additional points of any component in building services and indoor area services mentioned in section 7.5 and 7.6, except for requirements for basement lighting, project needs to install the component for minimum 80% of the total above grade area (AGA) or for component designed for 80% of total AGA.
    b. to claim the additional points for requirements of basement lighting mentioned in section 7.5, ENS building to show compliance for total basement area designed in the project and as per applicable building by-law.

c. to claim the additional points of any component in building envelope mentioned in section 7.4, project needs to install the component as mention in section of the component for overall project.

4.2.7 Prescriptive Method

i. In order to demonstrate compliance with the code through the Prescriptive Method, the ENS building shall meet mandatory requirements specified under chapter 5 and all prescriptive requirements as per chapter 6, for compliance purpose.

4.2.8 Point System Method

i. In order to demonstrate compliance with the code through the Point System Method, the ENS building shall meet all applicable mandatory requirements specified in chapter 5 and obtain a minimum ENS Score as per section 7.1 in chapter 7, for this purpose:

- All Low-rise residential buildings must obtain minimum 47 points from 'Building Envelope' under section 7.4.
- All Affordable housing scheme must obtain minimum 70 points from 'Building Envelope', and 'Building Services' under section 7.4 and 7.5 respectively.
- All High-rise residential buildings must obtain minimum 100 points from 'Building Envelope' and 'Building Services', 'Indoor Electric End-Use' and 'Renewable Energy Systems' under section 7.4, 7.5, 7.6 and 7.7, respectively.
- The Table 5 below gives the component wise distribution of points for each building component to achieve minimum ENS Score.

Table 5: Component wise Distribution of ENS Score

Section	Components	Minimum points	Additional Points	Maximum Points
6.4	**Building Envelope**			
	Building Envelope	47	40	87
6.5	**Building Services**			
	Common area and exterior lighting	3	6	9
	Elevators	13	9	22
	Pumps	6	8	14
	Electrical Systems	1	5	6

6.6	**Indoor Electrical End-Use**			
	Indoor Lighting		12	12
	Comfort Systems		50	50
	ENS Score	**70**	**130**	**200**

ii. The code also provides additional 20 points for renewable energy as mentioned in Table 6 which can be availed after fulfilling the minimum points criteria as per Table 6.

Table 6: Score for Renewable Energy System Components

Section	Components	Minimum points	Additional Points	Maximum Points
6.4	**Renewable Energy Systems**			
	Solar Hot Water Systems		10	10
	Solar Photo Voltaic		10	10
Additional ENS Score			**20**	**20**

iii. In order to demonstrate compliance with the code using Point System Method, the ENS building must obtain the applicable minimum points as specified under section 7.1 and get remaining points by:

   a. meeting the requirements labelled as ‘additional points’ of building envelope under section 7.4; and/or

   b. meeting the requirements labelled as ‘additional’ of ‘Building Services’ & Indoor Electric End-Use under section 7.5 & 7.6; and/or

   c. meeting the requirements labelled as ‘additional’ of ‘Renewable Energy Systems’ under section 7.7.

iv. The mandatory points or additional points shall be assigned as per the least energy efficient specification of all the products installed under a category in the building, unless the trade off or weighted average is allowed for the particular category.

v. In a mixed mode building category, energy efficiency measure applied in the common services and installed at an overall site level shall meet the most stringent specification requirement among the mentioned requirements in different categories of building to claim the mandatory and additional points.

vi. To claim the points under the Renewable Energy Systems section, the renewable energy system can be installed collectively at the site level or installed collectively at one or more roofs as per the total renewable energy installation requirement.

4.3 Documentation

4.3.1 Construction drawings 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 this code.

4.3.2 Details shall include, but are not limited to:

i. Building envelope: opaque construction materials and their thermal properties including thermal conductivity, specific heat, density along with thickness; fenestration U-factors, solar heat gain coefficients (SHGC), visible light transmittance (VLT); overhangs and side fins and operable window area;

ii. Building services: Common area lighting (lamp efficacy for lamps and their controls); pump efficiencies; elevator technologies and their controls; transformer losses; power distribution losses; power factor correction devices; basement ventilation controls; efficiency of charging infrastructure and electric check metering and monitoring system;

iii. Indoor electrical end-use: Indoor lighting (type, number, and wattage of lamps and ballasts; automatic lighting shutoff, occupancy sensors, and other lighting controls); ceiling fans star labelling; service hot water type and their efficiency; air-conditioners (system and equipment types, sizes, efficiencies, and controls);

iv. Renewable energy systems: system peak generation capacity, solar water heating system; technical specifications, renewable energy zone area.

4.4 Compliance Tool

4.4.1 The compliance with the code can be demonstrated using the software/toolkit that has been approved by the BEE or authority having jurisdiction.

Chapter 5: MANDATORY REQUIREMENTS

5.1 Building Envelope

5.1.1 All requirements for building envelope under mandatory section as mentioned in Section 4.1 of Chapter 4.

5.2 Power Factor Correction

5.2.1 All 3 phase shall maintain the power factor of 0.97 at the point of connection.

5.3 Energy Monitoring

5.3.1 Residential buildings exceeding the threshold defined under section 2.4 of this code shall monitor the electrical energy use for each of the following separately:

i. Total electrical energy

ii. Electricity consumption of following applicable end-use:

a. Common area lighting (Outdoor lighting, corridor lighting, basement lighting)
b. Elevators
c. Water pumps
d. Basement car parking ventilation system
e. Electricity generated from power back-up
f. Electricity generated through renewable energy systems
g. Lift pressurization system

5.3.2 The electrical energy use shall be recorded at an interval of minimum of every 15 minutes and reported at least hourly, daily, monthly and annually. The monitoring equipment should be capable of transmitting the data to the digital control system/energy monitoring information system. The digital control system shall be capable of maintaining all data collected for a minimum of 36 months.

5.3.3 The metering shall 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 total current in case of transformers.

5.4 Electric Vehicle Charging System

5.4.1 If an Electric Vehicle Charging Infrastructure is installed in the premise, it shall be as per revised guidelines issued by Ministry of Power for Charging Infrastructure for Electric Vehicles on 1st October 2019, or any subsequent amendments.

5.5 Electrical Systems

5.5.1 The power cabling shall be sized so that the distribution losses shall not exceed 3% of the total power usage in the ENS building. Record of design calculation for the losses shall be maintained. Load calculation shall be calculated up to the panel level.

5.5.2 Voltage drop for feeders shall not exceed 2% at design load. Voltage drop for branch circuit shall not exceed 3% at design load.

Chapter 6: PRESCRIPTIVE REQUIREMENTS

6.1 Building Envelope

6.1.1 All requirements for building envelope including Openable Window-to-Floor area ratio, Visible Light Transmittance, as mentioned in section 4.1 of chapter 4.

6.1.2 The Residential Envelope Transmittance Value (RETV) for the building envelope (except roof) shall comply with the maximum RETV of 12 W/m^2.

6.1.3 Thermal transmittance of roof shall comply with the maximum U_{roof} value of 1.2 $W/m^2.K$.

6.2 Common Area and Exterior Lighting

6.2.1 The Lighting power density (LPD) and luminous efficacy (LE) of permanently installed lighting fixtures in common area of the ENS compliant building shall meet the requirements of either maximum LPD or minimum luminous efficacy given in Table 7.

Table 7: Common Area Lighting Requirements

Common Areas	Maximum LPD (W/m^2)	Minimum luminous efficacy (lm/W)
Corridor lighting & Stilt Parking	3.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 105 lumens per Watt
Basement Lighting	1.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 105 lumens per Watt

6.2.2 When the exterior lighting load is more than 100 W, the permanently installed lighting fixtures shall use lamps with an efficacy of at least 105 lumens per Watt or meet the maximum LPD requirements given in Table 8.

Table 8: Outdoor Lighting Requirement

Exterior Lighting Areas	Maximum LPD (W/m^2)
Driveways and parking (open/ external)	1.6
Pedestrian walkways	2.0
Stairways	10.0

Landscaping	0.5
Outdoor sales area	9.0

6.2.3 Lamps for all exterior applications apart from emergency lighting shall be controlled by 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.

6.3 Elevators, if applicable

6.3.1 The Elevators installed in the ENS compliant building shall meet the following requirements:

i. Install high efficacy lamps for lift car lighting having minimum luminous efficacy of 85 lm/W
ii. Install automatic switch-off controls for lighting and fan inside the lift car when are not occupied
iii. Install minimum class IE 4 high efficiency motors
iv. Installing the variable voltage and variable frequency drives
v. Installing regenerative drives.
vi. Group automatic operation of two or more elevators coordinated by supervisory control

6.4 Pumps, if applicable

6.4.1 Either hydro-pneumatic pumps having minimum mechanical efficiency of 70% or BEE 5 star rated Pumps shall be installed in the ENS building.

6.5 Electrical Systems, if applicable

6.5.1 Power transformers of the proper ratings and design must be selected to satisfy the minimum acceptable efficiency at 50% and full load rating. The permissible loss shall not exceed the values listed as per code in Table 9 for dry type transformers and BEE 5-star rating in Table 10 for oil type transformers.

Table 9: Permissible Limit for Dry Type Transformers

Rating kVA	Max. Losses at 50% loading W*	Max. Losses at 100% loading W*	Max. Losses at 50% loading W*	Max. Losses at 100% loading W*
	Up to 22 kV class		33 kV class	
100	940	2400	1120	2400
160	1290	3300	1420	3300
200	1500	3800	1750	4000
250	1700	4320	1970	4600
315	2000	5040	2400	5400
400	2380	6040	2900	6800
500	2800	7250	3300	7800
630	3340	8820	3950	9200
800	3880	10240	4650	11400
1000	4500	12000	5300	12800
1250	5190	13870	6250	14500
1600	6320	16800	7500	18000
2000	7500	20000	8880	21400
2500	9250	24750	10750	26500
***The values as per Indian Standard/BEE Standard & Labeling notification for dry type transformer corresponding to values in this table will supersede as and when the Indian standards/ BEE Standard & Labeling notification are published.**				

Table 10: Permissible Limit for Oil Type Transformers

Rating kVA	Impedance (%)	Max. Total Loss (W)					
		BEE 1 Star		BEE 3 Star		BEE 5 Star	
		50% loading	100% loading	50% loading	100% loading	50% loading	100% loading
16	4.5	135	440	108	364	87	301
25	4.5	190	635	158	541	128	448
63	4.5	340	1,140	270	956	219	791
100	4.5	475	1,650	392	1,365	317	1,130
160	4.5	670	1,950	513	1,547	416	1,281

200	4.5	780	2,300	603	1,911	488	1,582
250	4.5	980	2,930	864	2,488	761	2,113
315	4.5	1,025	3,100	890	2,440	772	1,920
400	4.5	1,225	3,450	1,080	3,214	951	2,994
500	4.5	1,510	4,300	1,354	3,909	1,215	3,554
630	4.5	1,860	5,300	1,637	4,438	1,441	3,717
1,000	5.0	2,790	7,700	2,460	6,364	2,170	5,259
1,250	5.0	3,300	9,200	3,142	7,670	2,991	6,394
1,600	6.25	4,200	11,800	3,753	10,821	3,353	9,924
2,000	6.25	5,050	15,000	4,543	13,254	4,088	11,711
2,500	6.25	6,150	18,500	5,660	16,554	5,209	14,813

Total loss values given in above table are applicable for thermal classes E, B and F and have component of load loss at reference temperature according to Clause 17 of IS 1180 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.

Permissible total loss values shall not exceed:

- **5% of the maximum total loss values mentioned in IS 1180 for oil type transformers in voltage class above 11 kV but not more than 22 kV**
- **7.5% of the maximum total loss values mentioned in above IS 1180 for oil type transformers in voltage class above 22 kV and up to and including 33 kV**

6.5.2 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.

Chapter 7: POINT SYSTEM METHOD

7.1 The Table 11 below gives the component wise distribution of points for each building component to achieve minimum ENS Score.

Table 11: Component wise Distribution of ENS Score

Components	Minimum points	Additional Points	Maximum Points
Building Envelope			
Building Envelope	47	40	87
Building Services			
Common area and exterior lighting	3	6	9
Elevators	13	9	22
Pumps	6	8	14
Electrical Systems	1	5	6
Indoor Electrical End-Use			
Indoor Lighting		12	12
Comfort Systems		50	50
ENS Score	**70**	**130**	**200**

i. **Minimum points:** are the set of points which are compulsory to achieve for each component to show compliance for ENS.

ii. **Additional Points:** are the set of points which are awarded for adopting additional or better energy efficiency measures in a respective component. These points are trade able with other components to achieve the total score mentioned in section 4.2.2 for ENS compliance.

iii. Maximum points are the total points available for each component.

7.2 The code also provides additional 20 points for renewable energy as mentioned in Table 12 which can be availed after fulfilling the minimum points criteria as per section 7.7.

Table 12: Score for Renewable Energy System Components

Renewable Energy Systems Components	Minimum points	Additional Points	Maximum Points
Solar Hot Water Systems		10	10

Solar Photo Voltaic		10	10
Additional ENS Score		**20**	**20**

7.3 In order to demonstrate compliance with the code using Point System Method, the ENS building must obtain the applicable minimum points as specified under section 7.1 and get remaining points by:

a. meeting the requirements labelled as 'additional points' of building envelope under section 7.4; and/or
b. meeting the requirements labelled as 'additional' of 'Building Services' & Indoor Electric End-Use under section 7.5 & 7.6; and/or
c. meeting the requirements labelled as 'additional' of 'Renewable Energy Systems' under section 7.7.

7.4 Building Envelope (Maximum 87 Points)

7.4.1 Thermal transmittance of roof (U_{roof})

Maximum Score	7 Points

Score breakup for the thermal transmittance of roof is as mentioned in the Table 13.

Table 13: Points for Thermal Transmittance of Roof (U_{roof})

Minimum, if opted: Thermal transmittance of roof shall comply with the maximum U_{roof} value of 1.2 W/m^2-K.	Up to 3 Points
Additional: 1 Point for every reduction of 0.23 W/m^2-K in thermal transmittance of roof from the Minimum requirement prescribed under §7.1(a).	Up to 4 Points

7.4.2 Residential Envelope Transmittance Value (RETV) for building envelope (except roof)

Maximum Score	80 Points

Score breakup for the Residential envelope transmittance value for building envelope (except roof) is as mentioned in the Table 14. Residential Envelope Transmittance Value

(RETV) for building envelope (except roof) for composite climate shall be calculated using Equation 4 as specified in chapter 3.

Table 14: Points for Residential Envelope Transmittance Value (RETV) for building envelope (except roof) for composite climate

The RETV for the building envelope (except roof) for Composite Climate shall comply with the maximum RETV of 15 W/m^2..	44 Points
For RETV less than 15 and up to 12 W/m^2, score will be calculated by following equation: $74 – 2 \times (RETV)$	Up to 50 Points
Additional: For RETV less than 12 and up to 6 W/m^2, score will be calculated by following equation: $110 – 5 \times (RETV)$	Up to 80 points
Additional: For RETV less than 6 W/m^2	80 Points

- If a proposed building development comprises two or more residential building blocks having different RETV. The weighted average RETV of the total residential project shall be computed using following equation –

$$RETV_{\text{Weighted average}} = \sum (RETV_{bldg.} \times EA_{bldg.})/EA_{total}$$

$$= \frac{(RETV_{bldg1} \times EA_{bldg1}) + (RETV_{bldg2} \times EA_{bldg2})/ + (RETV_{bldg3} \times EA_{bldg3})}{(EA_{total})} \quad (5)$$

Where,

$RETV_{\text{Weighted average}}$: is the combined RETV of the overall residential development project

$RETV_{bldg.\ i}$: is the individual RETV of each residential block

$EA_{bldg.\ i}$: is the total envelope area of the individual building or the total residential project

EA_{total}: is the total envelope area of the individual building or the total residential project

7.5 Building Services

7.5.1 Common Area and exterior Lighting

i. The Lighting power density (LPD) and Luminous efficacy (LE) of permanently installed lighting fixtures in common area of the ENS building shall meet the requirements of either maximum LPD or minimum LE given in Table 15.

Table 15: Common Area Lighting

Common Areas	Maximum LPD (W/m^2)	Minimum luminous efficacy (lm/W)
Corridor lighting & Stilt Parking	3.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 105 lumens per Watt
Basement Lighting	1.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 105 lumens per Watt

ii. When the exterior lighting load is more than 100 W, the permanently installed lighting fixtures shall use lamps with an efficacy of at least 85 lumens per Watt or meet the maximum LPD requirements given in Table 16.

Table 16: Outdoor Lighting Requirement

Exterior Lighting Areas	Maximum LPD (W/m^2)
Driveways and parking (open/external)	1.6
Pedestrian walkways	2.0
Stairways	10.0
Landscaping	0.5
Outdoor sales area	9.0

iii. Lamps for all exterior applications apart from emergency lighting shall be controlled by 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.

Maximum Score	9 Points

Score breakup for the Common Area and exterior Lighting is as mentioned in the Table 17.

Table 17: Score breakup for the Common Area and exterior Lighting

Minimum: The Lighting power density (LPD) and Luminous efficacy (LE) of permanently installed lighting fixtures in common area of the ENS building shall meet the requirements of either maximum LPD or minimum luminous efficacy given in Table 15, Table 16 and as	3 Points

<table>
<tr><td>mentioned in section 7.5.1 (ii) and 7.5.1 (iii) for all the areas/ zones applicable for the building for which compliance is sought.

If a particular area/ zone is not applicable to a building for which compliance is sought, the performance requirement of the respective zone/ area is not required.</td><td></td></tr>
<tr><td>Additional:
Installing all the permanently installed lighting fixtures with lamp luminous efficacy of 95 lm/W in areas mentioned below:
<table><tr><th>Area/ Zones</th><th>Points</th></tr><tr><td>Corridor lighting & Stilt Parking</td><td>1</td></tr><tr><td>Basement Lighting</td><td>1</td></tr><tr><td>Exterior Lighting Areas</td><td>1</td></tr></table></td><td>Up to 3 points</td></tr>
<tr><td>Additional:
Lamps for all exterior applications apart from emergency lighting shall be controlled by 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.
Installing all the permanently installed lighting fixtures in all corridor lighting, stilt parking, basement lighting and exterior lighting with lamp luminous efficacy of 105 lm/W.
<table><tr><th>Area/ Zones</th><th>Points</th></tr><tr><td>Corridor lighting & Stilt Parking</td><td>2</td></tr><tr><td>Basement Lighting</td><td>2</td></tr><tr><td>Exterior Lighting Areas</td><td>2</td></tr></table></td><td>Up to 6 points</td></tr>
</table>

7.5.2 Elevators

Maximum Score	22 Points

Score breakup for the elevators is as mentioned in the Table 18.

Table 18: Points for Elevators

<table>
<tr><td>Minimum:
Elevators installed in the ENS building shall meet all the following requirements:
i. Install high efficacy lamps for lift car lighting having minimum luminous efficacy of 85 lm/W
ii. Install automatic switch-off controls for lighting and fan inside the lift car when are not occupied
iii. Install minimum class IE 3 high efficiency motors</td><td>13 Points</td></tr>
</table>

iv. Group automatic operation of two or more elevators coordinated by supervisory control	
Additional: Additional points can be obtained by: i. Installing the variable voltage and variable frequency drives. (4 points) ii. Installing regenerative drives. (3 points) iii. Installing class IE4 motors. (2 points)	9 Points

7.5.3 Pumps

Maximum Score	14 Points

Score breakup for the thermal transmittance of roof is as mentioned in the Table 19.

. **Table 19:** Points for Pumps

Minimum: Either hydro-pneumatic pumps having minimum mechanical efficiency of 60% or BEE 4 star rated Pumps shall be installed in the ENS building.	6 Points
Additional: Additional points can be obtained by: i. Installation of BEE 5 star rated pumps (5 Points) ii. Installation of hydro-pneumatic system for water pumping having minimum mechanical efficiency of 70% (3 Points)	8 Points

7.5.4 Electrical Systems

Maximum Score	6 Points

Score breakup for the electrical system is as mentioned in the Table 20.

Table 20: Points for Electrical System

Minimum: i. Power transformers of the proper ratings and design must be selected to satisfy the minimum acceptable efficiency at 50% and full load rating. The permissible loss shall not exceed the values listed in Table 8 for dry type transformers and BEE 4-star rating in Table 9 for oil type transformers.	13 Points
Additional: i. Additional points can be obtained by providing all oil type transformers with BEE 5 star rating.	5 Points

7.6 Indoor Electrical End-Use

The points mentioned under section 7.6 are not mandatory to show overall compliance.

7.6.1 Indoor lighting

Maximum Score	12 Points

Score breakup for the electrical system is as mentioned in the Table 21.

Table 21: Points for Indoor Lighting

Minimum: All the lighting fixtures shall have lamps with luminous efficacy of minimum 85 lm/W installed in all bedrooms, hall and kitchen.	4 Points
Additional: Additional points for indoor lighting by installing all lighting fixtures in all bedrooms, hall and kitchen shall have lamps luminous efficacy as per following: 95 lm/W (3 Points) 105 lm/W (8 Points)	Up to 8 Points

7.6.2 Comfort Systems

Maximum Score	50 Points

Score breakup for the comfort System for ceiling fans and Air Conditioners is as mentioned in the Table 22 and Table 23. If comfort system is applicable, in such case minimum marks for ceiling fans and air conditioners will be mandatory.

1. **Ceiling Fans:** Points for ceiling fans will be only applicable and could be achieved if all the bedrooms and hall in all the dwelling units are having ceiling fans and points could be gained, if installed as per Table 22.

Table 22: Points for Ceiling Fans

Minimum, if opted: All ceiling fans installed in all the bedrooms and hall in all the dwelling units shall have a service value as given below: For sweep size < 1200 mm: equal or greater than 4 m^3/minute-Watt For sweep size > 1200 mm: equal or greater than 5 m^3/minute-Watt BEE Standards and Labeling requirements for ceiling fans shall take precedence over the current minimum requirement, as and when it is notified as mandatory.	6 Points
Additional: Additional points for ceiling fans by installing in all the bedrooms and	1 Points

hall in all the dwelling units as per following: 4 Star 5 Star	3 Points

2. **Air Conditioners:** Points for air conditioners will be only applicable and could be achieved if all the bedrooms in all the dwelling units are having air conditioners (either unitary, split, VRF or centralized plant) and points could be gained, if installed as per Table 23. In case, air conditioners installed are of mixed type, in that case calculation of points will be based on following formula:

Table 23: Points for Air Conditioners

Minimum, if opted: Unitary Type: 5 Star Split AC: 3 Star VRF: 3.28 EER Chiller: Minimum ECBC Level values as mentioned in ECBC 2017	20 Points
Additional: Split AC: 4 Star VRF: Not Applicable as on date, however, whenever BEE Star labelling for VRF is launched, Star 4 will be applicable Chiller: Minimum ECBC+ Level values as mentioned in ECBC 2017	9 Points
Additional: Split AC: 5 Star VRF: Not Applicable as on date, however, whenever BEE Star labelling for VRF is launched, Star 5 will be applicable Chiller: Minimum SuperECBC Level values as mentioned in ECBC 2017	21 Points

7.7 Renewable Energy Systems

7.7.1 Solar Water Heating: Solar water heater shall meet the minimum efficiency level mentioned in IS 13129 Part (1&2) and for evacuated tube collector the storage tanks shall meet the IS 16542:2016, tubes shall meet IS 16543:2016 and IS 16544:2016 for the complete system.

Maximum Score	10 Points

Score breakup for the electrical system is as mentioned in the Table 24.

Table 24: Points for Solar Water Heating

Minimum, if opted:	

The ENS compliant building shall provide a solar water heating system (SWH) of minimum BEE 3 Star label and is capable of meeting 100% of the annual hot water demand of top 4 floors of the residential building. Or, 100% of the annual hot water demand of top 4 floors of the residential building is met by the system using heat recovery	5 Points
Additional: Additional points can be obtained by installing SWH system as per as per following: • 100% of the annual hot water demand of top 6 floors of the residential building (2 points) • 100% of the annual hot water demand of top 8 floors of the residential building (5 points)	Up to 5 Points

7.7.2 Solar Photo-Voltaic

Maximum Score	10 Points

Score breakup for the electrical system is as mentioned in the Table 25.

Table 25: Points for Solar Photo Voltaic

Minimum, if opted: The ENS compliant building shall provide a dedicated Renewable Energy Generation Zone (REGZ) – • Equivalent to a minimum of 2 kWh/m^2-year of electricity; or Equivalent to at least 20% of roof area. • The REGZ shall be free of any obstructions within its boundaries and from shadows cast by objects adjacent to the zone.	5 Points
Additional: Additional points can be obtained by installing solar photo voltaic as per following: • Equivalent to a minimum of 3 kWh/m^2-year of electricity or Equivalent to at least 30% of roof area (2 points) • Equivalent to a minimum of 4 kWh/m^2-year of electricity or Equivalent to at least 40% of roof area (5 points)	Up to 5 Points

ANNEXURES

ANNEXURE 1: Terminology and Definitions

Above Grade area: It is the carpet area plus the thickness of outer walls and the area covered by balcony, expressed in meters, and subtracting the basement area.

Addition: An extension or increase in the carpet area or height of a building or structure.

Affordable Housing Projects: Affordable houses are Dwelling Units (DUs) with Carpet Area less than 60 sqm. It also includes Economically Weaker Section (EWS) category and Lower Income Group (LIG) category (LIG-A: 28-40 sq. m. and LIG-B 41- 60 Sq.m.). Projects using at least 60 percent of the FAR/ FSI for dwelling units of Carpet Area not more than 60 sqm. will be considered as Affordable housing projects. This definition could be changed time to time by Ministry of Housing & Urban Affairs and respective states and latest definition for the respective state shall be considered.

Affordable housing scheme: The Pradhan Mantri Awas Yojana (PMAY), also known as, Affordable housing scheme, including any notification of change in name of the aforesaid scheme, is an initiative provided by the Government of India which aims at providing affordable housing to the urban poor.

Alteration: A change from one type of occupancy to another or the removal of part of a building, or any change to the structure, such as the construction of, cutting into or removal of any wall, partition, column, beam, joist, floor or other support, or a change to or closing of any required means of ingress or egress or a change to the fixtures or equipment.

Authority Having Jurisdiction: The Authority which has been created by a statute and which, for the purpose of administering the Code, may authorize a committee or an official or an agency to act on its behalf.

Building Envelope: The elements of a building that separate the habitable spaces of dwelling units from the exterior and are exposed to the ambient (i.e., exposed directly to external air and opening into balconies). It does not include walls facing open corridors and enclosed shafts, as well as walls of common services such as lifts and staircase. (See Figure 1. Dotted lines show the walls included in the definition of building envelope in this code.)

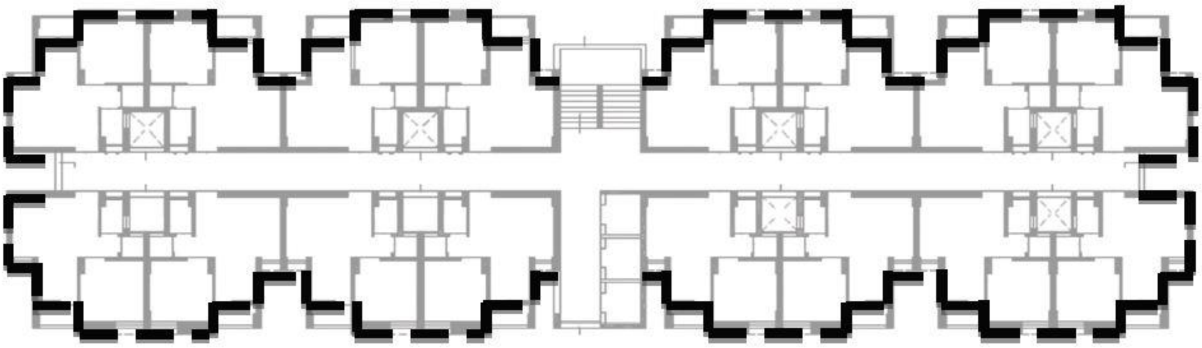


Figure 1: Walls included in the definition of building envelope

Building services: Basic MEP services such as firefighting systems, elevators and escalators, HVAC systems, gas supply systems, building management systems, power backup, water supply, water recycling etc. that are provided for the comfort and available to all dwelling units/apartments of the building or building complex.

Built-up area: It is the carpet area plus the thickness of outer walls and the area covered by balcony, expressed in meters.

Carpet Area[22]: Carpet area is the net usable floor area of a dwelling unit, excluding the area covered by the external walls, areas under services shafts, exclusive balcony or verandah area and exclusive open terrace area, but includes the area covered by the internal partition walls of the dwelling unit.

Common Area: Amenities such as corridors, hallways, lobby, staircases, lifts, pool, parking areas etc. provided for the comfort and available for use to all occupants, owners, tenants, or users of the building or building complex expressed in m^2.

Dwelling unit (DU): An Independent housing unit with separate facilities for Living, Cooking and sanitary requirement.

Envelope Area: Envelope area (excluding roof) of dwelling units is the overall area of the building envelope (see definition 'Building Envelope'). It is the gross external wall area (includes the area of the walls and the openings such as windows and doors), with measurement

[22] Source: The Real Estate (Regulation and Development) Bill, 2016 as passed by the Rajya Sabha on the 10 March 2016. Available at http://164.100.47.4/BillsTexts/RSBillTexts/PassedRajyaSabha/realest-238-RSP-E.pdf (accessed on 1 May 2018)

taken horizontally from outside surface to outside surface and measured vertically from the top of the floor to the top of the roof.

ENS building: Any building in which all covered spaces comply with the requirements of §4 of the ENS code.

ENS Score: It is the algebraic sum of the points that are obtained by meeting the requirements of ENS code.

Energy Efficiency Ratio (EER): the ratio of net cooling capacity in kW to total rate of electric input in watts under design operating conditions.

Floor area: the net enclosed area expressed in m^2 of a floor in the building including circulation spaces like lobby or corridors, service areas and semi-open spaces such as verandah or balcony.

High Rise Buildings: A building above 4 stories, and/or a building exceeding 15 meters or more in height (without stilt) and 17.5 meters (including stilt).

Integrated Energy Efficiency Ratio (IEER): is a single-number cooling part load efficiency figure of merit calculated as specified by the method described in ANSI/AHRI Standard 340/360/1230.

Indian Seasonal Energy Efficiency Ratio (ISEER): It is the ratio of the total annual amount of heat that the equipment can remove from the indoor air when operated for cooling in active mode to the total annual amount of energy consumed by the equipment during the same period.

Lighting Power Density (LPD): It is the total of the maximum power rating of the lamps (in Watts) in a space, other than those that are plugged into socket outlets for intermittent use such as floor standing lamps, desk lamps, divided by the area of the space (in meters).

Low Rise Buildings: A building equal or below 4 stories, and/or a building up to 15 meters in height (without stilt) and up to 17.5 meters (including stilt).

Low energy comfort systems: Space conditioning or ventilation systems that are less energy intensive then vapor compression-based systems.

Luminous Efficacy (LE): total luminous flux emitted from a luminaire upon input power, expressed in lumens per Watt.

Mechanical Efficiency: It is a dimensionless number that measures the effectiveness of a machine in transforming the power input to the device to power output.

Mixed land-use building projects: a single building or a group of buildings used for a combination of residential, commercial, business, educational, hospitality and assembly purposes.

Mixed-mode ventilated: building in which natural ventilation is employed as the primary mode of ventilating the building, and air conditioning is deployed as and when required.

Non-opaque Building Envelope Components: Non-opaque building envelope components include transparent/translucent panels in windows, doors, ventilators, etc.

Opaque Building Envelope Components: Opaque building envelope components include walls, opaque panels in doors, windows, ventilators, etc.

Openable Window-to-Floor Ratio (WFR_{op}): The openable window-to-floor ratio (WFR_{op}) is the ratio of the total openable area to the total carpet area of dwelling units. The total openable area of a dwelling unit is the addition of openable area of all windows and ventilators, opening directly to the external air, an open balcony, 'verandah', corridor or shaft; and the openable area of the doors opening directly into an open balcony.

Exclusions: Doors opening into corridors and external doors on ground floor (for e.g. ground floor entrance doors or back-yard doors).

Orientation Factor (ω): It is a measure of the amount of direct and diffused solar radiation that is received on the vertical surface in a specific orientation. This factor accounts for and gives weightage to the fact that the solar radiation falling on different orientations of walls is not same.

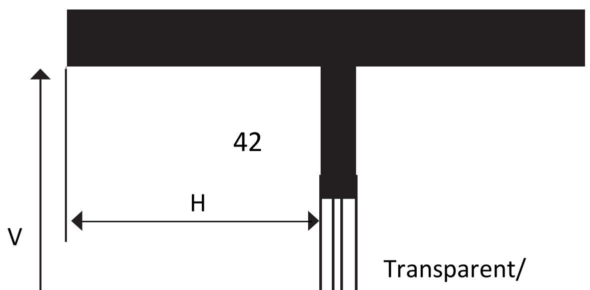


Figure 2: Projection factor, overhang

Plot Area: A parcel (piece) of land enclosed by definite boundaries expressed in m^2.

Projection Distance: It is the horizontal depth, expressed in meters, of the external shading projection.

Projection Factor, Overhang: Projection factor (overhang) is the ratio of the horizontal depth of the external shading projection to the sum of the height of a non-opaque component and the distance from the top of the same component to the bottom of the farthest point of the external shading projection, in consistent units (Figure 2).

Projection Factor, Side Fin: Project factor (side fin) is the ratio of the horizontal depth of the external shading projection to the distance from a non-opaque component to the farthest point of the external shading projection, in consistent units (Figure 3).

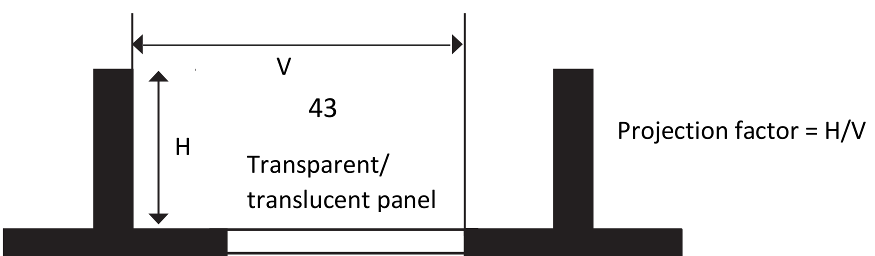


Figure 3: Projection factor, side fin

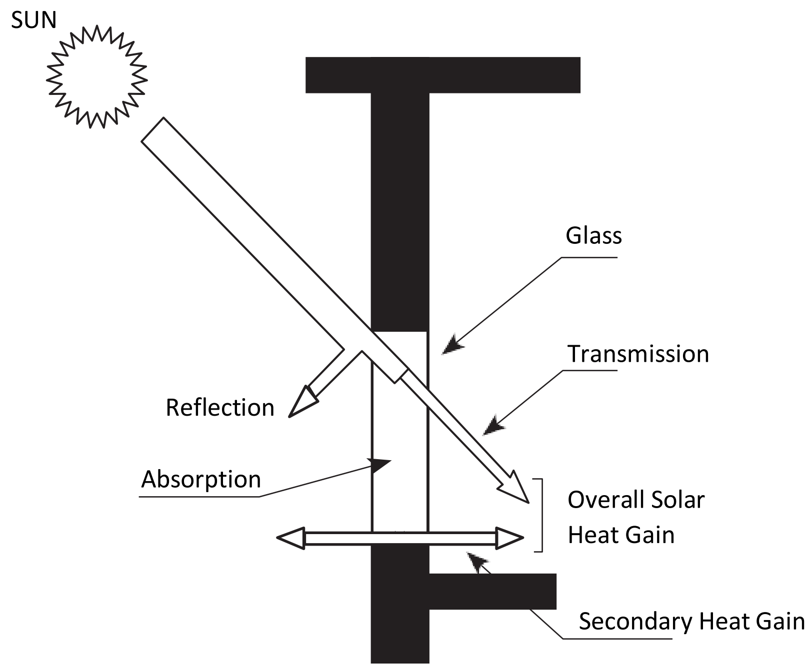


Figure 4: Solar heat gain through a non-opaque component

Renewable Energy Systems: Energy from renewable non-fossil energy sources, e.g. solar energy (thermal and photovoltaic), wind, hydropower, biomass, geothermal, wave, tidal, landfill gas, sewage treatment plant gas and biogases. A resource that is available naturally, harnessed, and can be replenished.

Residential Building(s)[23]: Residential building(s) (including affordable housing) include any building in which sleeping accommodation is provided for normal residential purposes with or without cooking or dining or both facilities. This includes:

i. One- or two-family private dwellings: These shall include any private dwelling, which is occupied by members of one or two families and has a total sleeping accommodation for not more than 20 persons.

ii. Apartment houses: These shall include any building or structure in which living quarters are provided for three or more families, living independently of each other and with independent cooking facilities. This also includes group housing.

However, following buildings are excluded for the purpose of this code.

- Lodging and rooming houses: these shall include any building or group of buildings under the same management in which separate sleeping accommodation on transient or permanent basis, with or without dining facilities but without cooking facilities for individuals, is provided. This includes inns, clubs, motels, and guest houses.
- Dormitories: these shall include any building in which group sleeping accommodation is provided, with or without dining facilities for persons who are not members of the same family, in one room or a series of closely associated rooms under joint occupancy and single management. For example, school and college dormitories, students, and other hostels and military barracks.
- Hotels: these shall include any building or group of buildings under single management, in which sleeping accommodation is provided, with or without dining facilities.

Residential Envelope Heat Transmittance (RETV): RETV is the net heat gain rate (over the cooling period) through the building envelope of dwelling units (excluding roof) divided by the area of the building envelope (excluding roof) of dwelling units. Its unit is W/m^2.

Retrofit: providing or adding something with a building component or feature not fitted when the building or building complex was first constructed.

R – Value: measurement of the thermal resistance of a material which is the effectiveness of the material to resist the flow of heat, i.e. the thermal resistance ($m^2 \cdot K/W$) of a component calculated by dividing its thickness by its thermal conductivity.

[23] Adapted from Bureau of Indian Standards (BIS). 2016. National Building Code of India 2016. New Delhi: BIS

Service Value: The Service value is the ratio of air delivery to power input.

Solar Heat Gain Coefficient (SHGC)[24]: SHGC is the fraction of incident solar radiation admitted through non-opaque components, both directly transmitted, and absorbed and subsequently released inward through conduction, convection, and radiation (Figure 4).

SHGC Equivalent[25]: SHGC Equivalent is the SHGC for a non-opaque component with a permanent external shading projection. It is calculated by multiplying the External Shading Factor (ESF) with the SHGC of unshaded non-opaque component.

Thermal Insulation: A material used to reduce heat loss or gain through thermal envelope component.

U Value: Thermal transmittance (U value) is the 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 either side. Unit of U value is W/m^2-K. The U value for a wall/roof/glazing indicates its ability to transfer heat through conduction.

Visible Light Transmittance (VLT): VLT is the ratio of the total transmitted light to the total incident light. It is a measure of the transmitted light in the visible portion of the spectrum through a material.

Window-to-Wall Ratio (WWR): WWR is the ratio of the non-opaque building envelope components area to the envelope area (excluding roof) of dwelling units.

[24] Bureau of Indian Standards (BIS). 2016. National Building Code of India 2016. New Delhi: BIS.
[25] Bureau of Energy Efficiency (BEE). 2017. Energy Conservation Building Code 2017. New Delhi: BEE.

ANNEXURE 2: Climatic zone and classification of cities

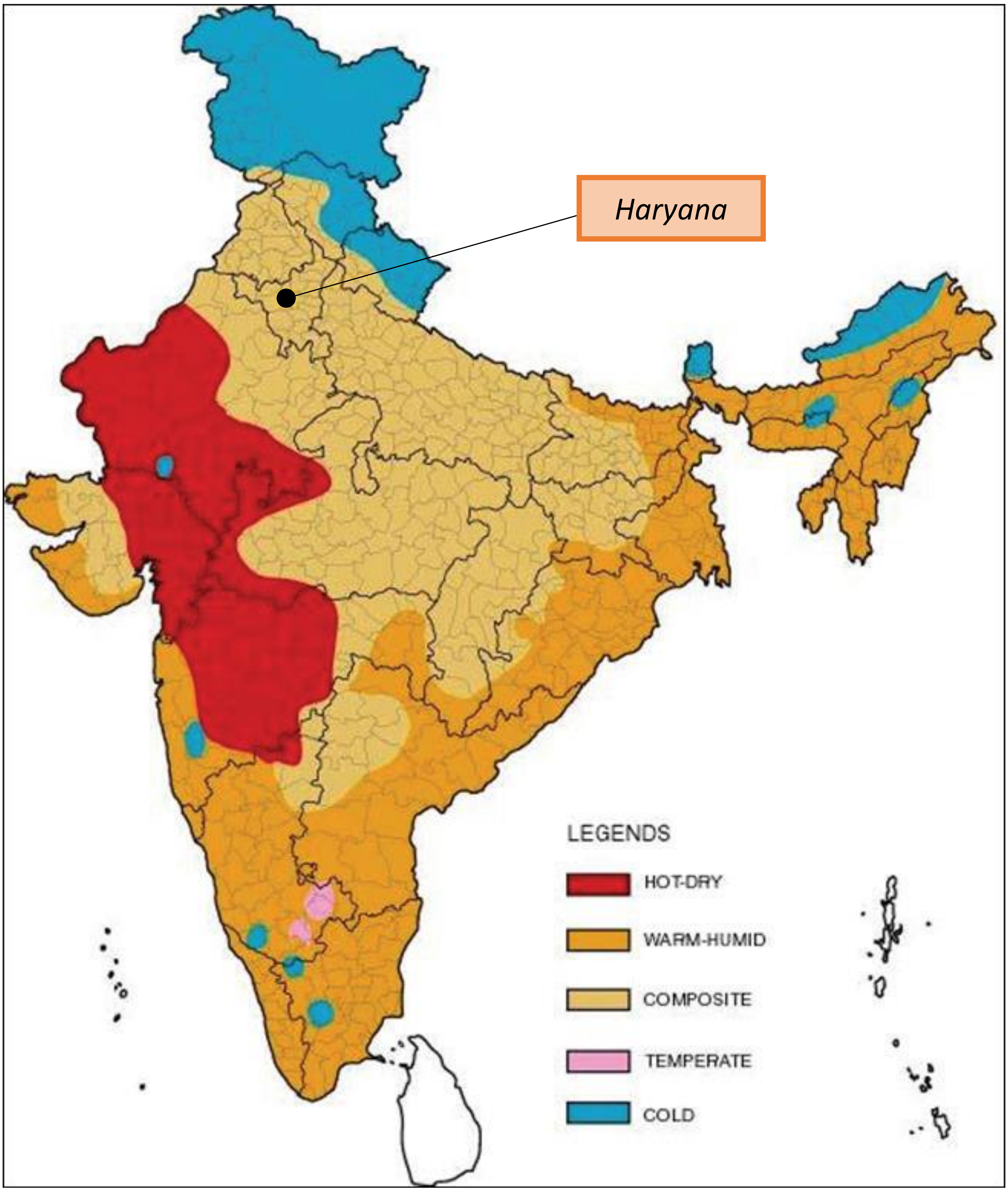


Figure 5: Climate zone map of India

ANNEXURE 3: Calculation of openable window-to-floor area ratio (WFR_{op})

a) Calculate the openable area of each dwelling unit (DU) by adding the openable area of all windows and ventilators, opening directly to the external air, an open balcony, 'verandah', corridor or shaft; and the openable area of the doors opening directly into an open balcony (doors opening into the corridors and ground-floor external doors are not included).

$$A_{openable_{DU}} = A_{openable_{window}} + A_{openable_{ventilator}} + A_{openable_{door}} \quad (6)$$

In case exact openable area is not known, the following default values can be used:

Table 26: Default openable area to opening area ratio

Type of window/door/ventilator Percentage	openable area
Casement	90%
Sliding (2 panes)	50%
Sliding (3 panes)	67%

Add openable areas of all dwelling units to get the total openable area.

$$A_{openable} = A_{openable_{DU1}} + A_{openable_{DU2}} + A_{openable_{DU3}} + \cdots \ldots \ldots \quad (7)$$

(b) Calculate the total carpet area by adding the carpet areas of all the dwelling units (DU). It excludes the areas covered by external walls, areas under services shafts, exclusive balcony or verandah area and exclusive open terrace area, but includes the areas covered by the internal partition walls of the dwelling unit.

$$A_{carpet} = A_{carpet_{DU1}} + A_{carpet_{DU2}} + A_{carpet_{DU3}} + \cdots \ldots \ldots \quad (8)$$

(c) Calculate the openable window-to-floor area ratio (WFR_{op}) by calculating the ratio of openable area to the carpet area.

$$WFR_{op} = \frac{A_{openable}}{A_{carpet}} \quad (9)$$

ANNEXURE 4: Calculation of window-to-wall ratio (WWR)

a) Calculate the total non-opaque (transparent/translucent panels of windows, doors, ventilators, etc.) area of the building envelope for each dwelling unit.

$$A_{non-opaque_{DU}} = A_{non-opaque_{window}} + A_{non-opaque_{door}} + A_{non-opaque_{other}} + \cdots \ldots \ldots \quad (10)$$

Add non-opaque areas of all dwelling units to get the total non-opaque area of the building block. Non-opaque components facing open corridors and enclosed shafts, as well as walls of common services such as lifts and staircase are to be excluded.

$$A_{non-opaque} = A_{non-opaque_{DU1}} + A_{non-opaque_{DU2}} + A_{non-opaque_{DU3}} + \cdots \ldots \ldots \quad (11)$$

b) Calculate the total envelope area (excluding roof) of dwelling units of the building block. For each wall of the building envelope, calculate the gross wall area (i.e., overall area of a wall including openings such as windows, ventilators, and doors, with measurement taken horizontally from outside surface to outside surface and measured vertically from the top of the floor to the top of the roof). Add the gross wall area of all walls to get the total envelope area (excluding roof) for the building. Walls facing open corridors and enclosed shafts, as well as walls of common services such as lifts and staircase are to be excluded.

$$A_{envelope} = A_{gross-wall_1} + A_{gross-wall_2} + A_{gross-wall_3} + \cdots \ldots \ldots \quad (12)$$

c) Calculate the window-to-wall ratio (WWR) by calculating the ratio of the total non-opaque area to the total envelope area.

$$WWR = \frac{A_{non-envelope}}{A_{envelope}} \quad (13)$$

ANNEXURE 5: Calculation of thermal transmittance (U value) of roof and wall

a) Calculate the thermal resistance of each uniform material layer, which constitutes the building component, as follows:

$$R_i = \frac{t_i}{k_i} \quad (14)$$

where,

R_i is the thermal resistance of material layer i, m^2-K/W

t_i is the thickness of material layer i, m

k_i is the thermal conductivity of material layer i, W/(m-K)

b) Find the total thermal resistance, R_T, as follows:

$$R_T = R_{si} + R_{se} + R_1 + R_2 + R_3 \dots \dots \dots \quad (15)$$

where,

R_T is the total thermal resistance, m^2-K/W

R_{si} is the interior surface film thermal resistance, m^2-K/W

R_{se} is the exterior surface film thermal resistance, m^2-K/W

R_1 is the thermal resistance of material layer 1, m^2-K/W

R_2 is the thermal resistance of material layer 2, m^2-K/W

R_3 is the thermal resistance of material layer 3, m^2-K/W

Use these default values for calculation,

Table 27: Values of surface film thermal resistance for U-value calculation for composite climate

	Wall	**Roof**
R_{si} (m^2-K/W)	0.13	0.17
R_{se} (m^2-K/W)	0.04	0.04

Source: Adapted from Bureau of Energy Efficiency (BEE), 2009. Energy Conservation Building Code User Guide, New Delhi

The thermal conductivity of commonly used building materials is given in Table 28, which can be used to calculate the thermal resistance (R value).

c) Calculate the thermal transmittance (or the overall heat transfer coefficient or U value) of a wall or roof assembly, as follows:

$$U = \frac{1}{R_T} \tag{16}$$

where,

U is the overall heat transfer coefficient, W/(m^2-K)

Table 28 gives typical thermal properties of commonly used building and insulating materials. This is not an all-inclusive list. In case, thermal conductivity values, measured using the appropriate IS codes, are available; those can also be used for calculations.

Table 28: Thermal properties of building and insulating materials

Sl no.	Type of material	Density (kg/m^3)	Thermal conductivity (W/m-K)	Specific heat capacity (kJ/kg-K)	Source
I. Building materials					
1.	Solid burnt clay brick	1920	0.980	0.80	(1)
2	Solid burnt clay brick	1760	0.850	NA	(1)
3	Solid burnt clay brick	1600	0.740	NA	(1)
4	Solid burnt clay brick	1440	0.620	NA	(1)
5	Resource efficient (hollow) brick	1520	0.631	0.65	(4)
6	Fly ash brick	1650	0.856	0.93	(2)
7	Solid concrete block 25/50	2427	1.396	0.20	(4)
8	Solid concrete block 30/60	2349	1.411	0.30	(4)
9	Aerated autoclaved concrete (AAC) block	642	0.184	1.24	(4)
10	Cement stabilized soil block (CSEB)	1700	1.026	1.03	(5)

SOURCES

a) American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 2009. 2009 ASHRAE Handbook (Fundamentals). Atlanta, United States: ASHRAE

b) Gourav K, et al. 2017. Studies into structural and thermal properties of building envelope materials. Energy Procedia 122: 104–108

c) Bureau of Indian Standards (BIS). 1987. Handbook on Functional Requirements of Buildings (Other than Industrial Buildings) SP: 41 (S & T) -1987. New Delhi: BIS.

d) Thermo-Physical-Optical Property Database of Construction Materials, U.S.- India Joint Center for Building Energy Research and Development (CBERD) and Ministry of New and Renewable Energy (MNRE). Available at http://www.carbse.org/wp-content/uploads/2017/10/Database-of-Construction-Materials_Oct17.pdf (accessed on 1 May 2018).
e) Balaji N C, et al. 2015. Influence of varying mix proportions on thermal performance of soil-cement blocks. Building Simulation Applications (BSA). 2nd IBPSA Italy Conference, Building Simulation Application - 2015 (BSA 2015). Available at http://www.ibpsa.org/proceedings/BSA2015/9788860460745_10.pdf (accessed on 1 May 2018).

In case, the construction has air layer, use values of thermal resistance of air layer given in Table 29 for U value calculation.

Table 29: Values of unventilated air layer thermal resistance for U-value calculation in composite climate

Thickness of Air Layer (mm)	Thermal resistance (m^2-K/W)	
	Wall	**Roof**
5	0.12	0.10
7	0.12	0.12
10	0.14	0.14
15	0.16	0.16
25	0.18	0.18
50	0.18	0.20
100	0.18	0.20
300	0.18	0.21

Source Adapted from Bureau of Energy Efficiency (BEE), 2009. Energy Conservation Building Code User Guide, New Delhi

ANNEXURE 6 Orientation Factor

The orientation factor (ω) is a measure of the amount of direct and diffused solar radiation that is received on the vertical surface in a specific orientation. This factor accounts for and gives weightage to the fact that the solar radiation falling on different orientations of walls is not same. It has been defined for the latitudes ≥ 23.5˚N and latitudes < 23.5˚N (Table 30). Table 30 should be read in conjunction with Figure 6.

Table 30: Orientation factor (ω) for different orientations

Orientation	Orientation factor (ω)	
	Latitudes ≥ 23.5˚N	Latitudes < 23.5˚N
North (337.6˚–22.5˚)	0.550	0.659
North-east (22.6˚–67.5˚)	0.829	0.906
East (67.6˚–112.5˚)	1.155	1.155
South-east (112.6˚–157.5˚)	1.211	1.125
South (157.6˚–202.5˚)	1.089	0.966
South-west (202.6˚–247.5˚)	1.202	1.124
West (247.6˚–292.5˚)	1.143	1.156
North-west (292.6˚–337.5˚)	0.821	0.908

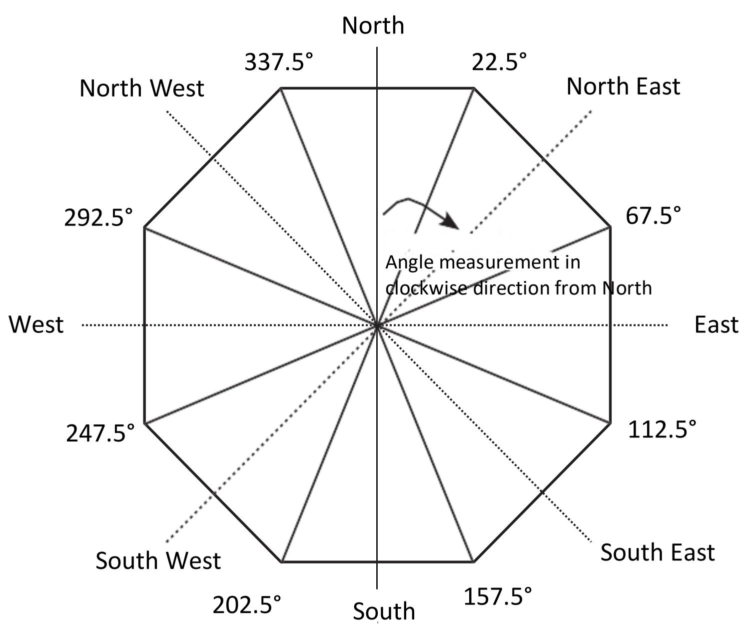


Figure 6: Primary orientations for determining the orientation factor ω

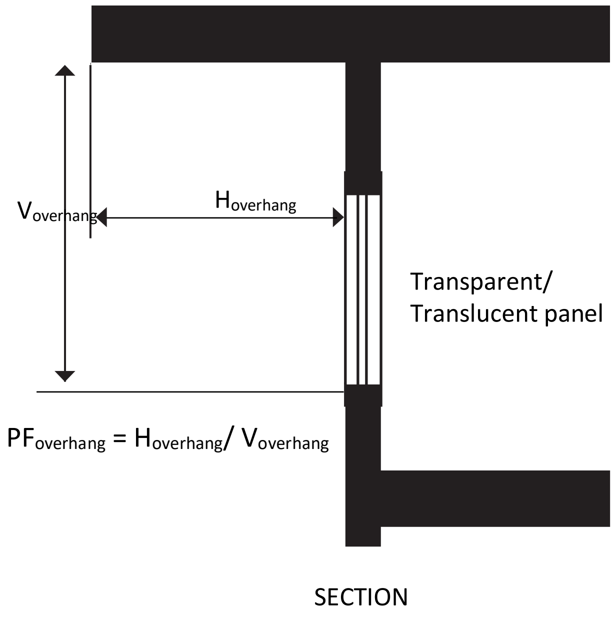
ANNEXURE 7 Calculation of Equivalent SHGC

SHGC Equivalent is the SHGC for a non-opaque component with a permanent external shading projection (overhang and side fins). It is calculated by multiplying the External Shading Factor (ESF) with the SHGC of unshaded non-opaque component. ESF values are defined based on the projection factor (PF). The procedure for calculation is given below:

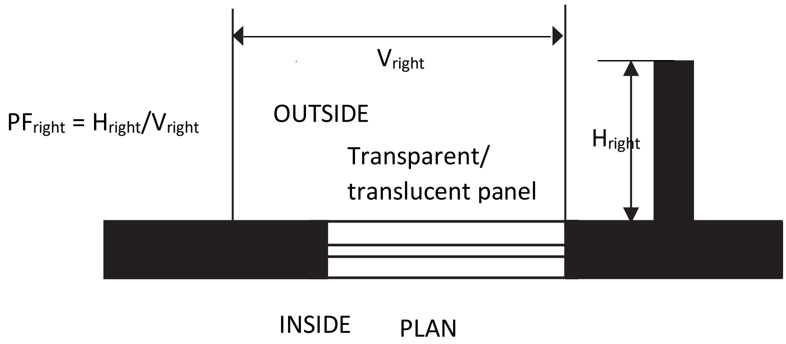
a) Calculate the projection factor (PF) for permanent external projection, including but not limited to overhangs, side fins, box frame, verandah, balcony, and fixed canopies, using the formula:

   i. *Projection factor, overhang:* the ratio of the horizontal depth of the external shading projection ($H_{overhang}$) to the sum of the height of a non-opaque component and the distance from the top of the same component to the bottom of the farthest point of the external shading projection ($V_{overhang}$), in consistent units.

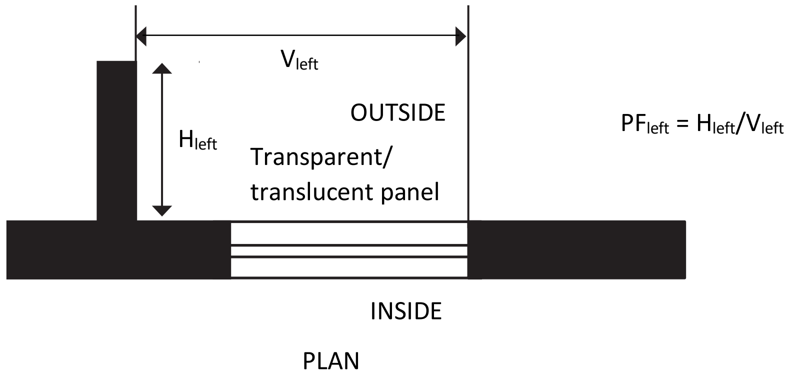
$$PF_{overhang} = \frac{H_{overhang}}{V_{overhang}} \tag{17}$$



   ii. *Projection factor, side/vertical fin:* the ratio of the horizontal depth of the external shading projection to the distance from a non-opaque component to the farthest point of the external shading projection, in consistent units. In case of single side/vertical fin, it could be on the 'Right' or 'Left' or there could be side/vertical fins on both the sides. A 'Right' side/vertical fin would be located on the right side of the window while looking out from the building and similarly, a 'Left' side/vertical fin would be located on the left side of the window while looking out from the building.



$$PF_{right} = \frac{H_{right}}{V_{right}} \tag{18}$$



$$PF_{left} = \frac{H_{left}}{V_{left}} \tag{19}$$

b) Select the ESF value for each shading element as:

i. Overhang ($ESF_{overhang}$): Refer Table 31 and Table 32

ii. Side fin-right (ESF_{right}): Refer Table 33 and Table 34

iii. Side fin-left (ESF_{left}): Refer Table 35 and Table 36

Table 31: External Shading Factor for Overhang ($ESF_{overhang}$) for LAT ≥ 23.5˚N

External Shading Factor for Overhang ($ESF_{overhang}$) for LAT ≥ 23.5˚N								
Orientation	**North**	**North-east**	**East**	**South-east**	**South**	**South-west**	**West**	**North-west**
$PF_{overhang}$	**(337.6˚–22.5˚)**	**(22.6˚–67.5˚)**	**(67.6˚–112.5˚)**	**(112.6˚–157.5˚)**	**(157.6˚–202.5˚)**	**(202.6˚–247.5˚)**	**(247.6˚–292.5˚)**	**(292.6˚–337.5˚)**
<0.10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.10-0.19	0.955	0.930	0.922	0.906	0.881	0.905	0.922	0.930
0.20-0.29	0.922	0.876	0.855	0.824	0.789	0.823	0.853	0.875
0.30-0.39	0.897	0.834	0.796	0.755	0.719	0.753	0.794	0.834
0.40-0.49	0.877	0.803	0.745	0.697	0.665	0.695	0.743	0.802
0.50-0.59	0.860	0.779	0.702	0.652	0.626	0.650	0.700	0.778
0.60-0.69	0.846	0.761	0.666	0.617	0.598	0.614	0.663	0.760
0.70-0.79	0.834	0.747	0.635	0.590	0.580	0.587	0.632	0.746
0.80-0.89	0.825	0.737	0.609	0.569	0.569	0.566	0.606	0.736
0.90-0.99	0.817	0.729	0.587	0.554	0.563	0.551	0.585	0.728
≥1	0.810	0.722	0.569	0.542	0.559	0.539	0.566	0.721

Table 32: External Shading Factor for Overhang ($ESF_{overhang}$) for LAT < 23.5˚N

External Shading Factor for Overhang ($ESF_{overhang}$) for LAT < 23.5˚N								
Orientation	**North**	**North-east**	**East**	**South-east**	**South**	**South-west**	**West**	**North-west**
$PF_{overhang}$	**(337.6˚–22.5˚)**	**(22.6˚–67.5˚)**	**(67.6˚–112.5˚)**	**(112.6˚–157.5˚)**	**(157.6˚–202.5˚)**	**(202.6˚–247.5˚)**	**(247.6˚–292.5˚)**	**(292.6˚–337.5˚)**
<0.10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.10-0.19	0.931	0.924	0.922	0.910	0.896	0.910	0.922	0.924
0.20-0.29	0.888	0.864	0.855	0.834	0.816	0.834	0.854	0.864
0.30-0.39	0.860	0.818	0.797	0.771	0.754	0.771	0.796	0.818
0.40-0.49	0.838	0.782	0.747	0.721	0.708	0.720	0.746	0.782
0.50-0.59	0.820	0.755	0.705	0.682	0.675	0.681	0.705	0.755
0.60-0.69	0.806	0.734	0.670	0.651	0.653	0.651	0.670	0.734
0.70-0.79	0.793	0.718	0.641	0.628	0.638	0.627	0.640	0.717
0.80-0.89	0.783	0.706	0.616	0.610	0.628	0.609	0.615	0.705
0.90-0.99	0.775	0.696	0.596	0.596	0.621	0.596	0.595 0.	0.695
≥1	0.768	0.688	0.579	0.585	0.616	0.585	0.578	0.688

Table 33: External Shading Factor for Side Fin-Right (ESF_{right}) for LAT ≥ 23.5˚N

External Shading Factor for side Fin-Right (ESF_{right}) for LAT ≥ 23.5˚N								
Orientation	**North**	**North-east**	**East**	**South-east**	**South**	**South-west**	**West**	**North-west**
PF_{right}	**(337.6˚–22.5˚)**	**(22.6˚–67.5˚)**	**(67.6˚–112.5˚)**	**(112.6˚–157.5˚)**	**(157.6˚–202.5˚)**	**(202.6˚–247.5˚)**	**(247.6˚–292.5˚)**	**(292.6˚–337.5˚)**
<0.10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.10-0.19	0.968	0.942	0.972	0.982	0.961	0.965	0.988	0.968
0.20-0.29	0.943	0.894	0.949	0.968	0.933	0.934	0.977	0.972
0.30-0.39	0.924	0.855	0.931	0.957	0.912	0.907	0.968	0.961
0.40-0.49	0.911	0.824	0.917	0.950	0.898	0.884	0.960	0.953
0.50-0.59	0.899	0.798	0.905	0.944	0.887	0.865	0.954	0.945
0.60-0.69	0.890	0.777	0.895	0.939	0.880	0.849	0.948	0.939
0.70-0.79	0.883	0.762	0.887	0.936	0.875	0.837	0.943	0.934
0.80-0.89	0.877	0.750	0.881	0.933	0.872	0.827	0.939	0.930
0.90-0.99	0.871	0.739	0.875	0.930	0.868	0.819	0.935	0.926
≥1	0.865	0.731	0.870	0.927	0.865	0.812	0.932	0.922

Table 34: External Shading Factor for Side Fin-Right (ESF_{right}) for < 23.5˚N

External Shading Factor for side Fin-Right (ESF_{right}) for LAT < 23.5˚N								
Orientation	**North**	**North-east**	**East**	**South-east**	**South**	**South-west**	**West**	**North-west**
PF_{right}	**(337.6˚–22.5˚)**	**(22.6˚–67.5˚)**	**(67.6˚–112.5˚)**	**(112.6˚–157.5˚)**	**(157.6˚–202.5˚)**	**(202.6˚–247.5˚)**	**(247.6˚–292.5˚)**	**(292.6˚–337.5˚)**
<0.10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.10-0.19	0.962	0.948	0.975	0.982	0.962	0.959	0.984	0.984
0.20-0.29	0.934	0.904	0.954	0.968	0.932	0.924	0.970	0.970
0.30-0.39	0.913	0.868	0.937	0.957	0.911	0.894	0.958	0.959
0.40-0.49	0.900	0.840	0.924	0.949	0.896	0.870	0.949	0.950
0.50-0.59	0.888	0.816	0.912	0.942	0.885	0.849	0.940	0.942
0.60-0.69	0.879	0.797	0.903	0.936	0.877	0.832	0.933	0.936
0.70-0.79	0.872	0.782	0.896	0.932	0.872	0.820	0.927	0.931
0.80-0.89	0.866	0.770	0.889	0.929	0.867	0.810	0.922	0.927
0.90-0.99	0.860	0.760	0.884	0.925	0.863	0.801	0.917	0.923
≥1	0.855	0.752	0.878	0.922	0.859	0.794	0.913	0.919

Table 35: External Shading Factor for Side Fin-Left (ESF_{left}) for LAT ≥ 23.5˚N

External Shading Factor for side Fin-Left (ESF_{left}) for LAT ≥ 23.5˚N								
Orientation	**North**	**North-east**	**East**	**South-east**	**South**	**South-west**	**West**	**North-west**
PF_{left}	**(337.6˚– 22.5˚)**	**(22.6˚– 67.5˚)**	**(67.6˚– 112.5˚)**	**(112.6˚– 157.5˚)**	**(157.6˚– 202.5˚)**	**(202.6˚– 247.5˚)**	**(247.6˚– 292.5˚)**	**(292.6˚– 337.5˚)**
<0.10	0.968	0.985	0.988	0.965	0.961	0.982	0.972	0.942
0.10-0.19	0.943	0.972	0.977	0.933	0.932	0.967	0.949	0.895
0.20-0.29	0.925	0.961	0.968	0.906	0.911	0.957	0.931	0.857
0.30-0.39	0.912	0.953	0.961	0.883	0.897	0.949	0.916	0.826
0.40-0.49	0.900	0.946	0.954	0.863	0.886	0.943	0.904	0.801
0.50-0.59	0.890	0.939	0.948	0.846	0.879	0.938	0.895	0.781
0.60-0.69	0.884	0.935	0.944	0.834	0.874	0.935	0.887	0.766
0.70-0.79	0.877	0.931	0.940	0.824	0.871	0.932	0.881	0.754
0.80-0.89	0.871	0.927	0.936	0.815	0.867	0.929	0.875	0.744
0.90-0.99	0.866	0.923	0.932	0.808	0.864	0.927	0.870	0.736
≥1	0.968	0.985	0.988	0.965	0.961	0.982	0.972	0.942

Table 36: External Shading Factor for Side Fin-Left (ESF_{left}) for < 23.5˚N

External Shading Factor for side Fin-Left (ESF_{left}) for LAT < 23.5˚N								
Orientation	**North**	**North-east**	**East**	**South-east**	**South**	**South-west**	**West**	**North-west**
PF_{left}	**(337.6˚– 22.5˚)**	**(22.6˚– 67.5˚)**	**(67.6˚– 112.5˚)**	**(112.6˚– 157.5˚)**	**(157.6˚– 202.5˚)**	**(202.6˚– 247.5˚)**	**(247.6˚– 292.5˚)**	**(292.6˚– 337.5˚)**
<0.10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.10-0.19	0.962	0.984	0.984	0.959	0.962	0.982	0.975	0.948
0.20-0.29	0.933	0.970	0.970	0.924	0.932	0.968	0.954	0.904
0.30-0.39	0.912	0.959	0.958	0.895	0.911	0.956	0.937	0.868
0.40-0.49	0.899	0.950	0.949	0.870	0.896	0.948	0.924	0.840
0.50-0.59	0.887	0.942	0.941	0.849	0.885	0.942	0.913	0.816
0.60-0.69	0.878	0.935	0.933	0.833	0.877	0.936	0.903	0.797
0.70-0.79	0.871	0.931	0.928	0.820	0.871	0.932	0.896	0.783
0.80-0.89	0.865	0.926	0.923	0.810	0.867	0.928	0.890	0.771
0.90-0.99	0.859	0.922	0.918	0.801	0.863	0.925	0.884	0.761
≥1	0.854	0.919	0.913	0.794	0.859	0.922	0.879	0.752

c) Calculate the total external shading factor (ESF_{total}) using the formula:

$$ESF_{total} = ESF_{overhang} \times ESF_{sidefin} \quad (20)$$

where,

$$ESF_{sidefin} = 1 - \left[\left(1 - ESF_{right}\right) + \left(1 + ESF_{left}\right)\right] \quad (21)$$

d) Calculate the equivalent SHGC of the fenestration ($SHGC_{eq}$) by multiplying the SHGC of the unshaded fenestration product ($SHGC_{Unshaded}$) with the total external shading factor (ESF_{total}), using the formula:

$$SHGC_{eq} = SHGC_{Unshaded} \times ESF_{total} \quad (22)$$

ANNEXURE 8 Examples of Code Compliance

Example 1: A 7-storey housing project in Hisar is trying to comply with the residential code. There are 11 identical residential towers in this project. The carpet area of each dwelling unit (DU) is 26.6 m^2.

There are three windows (W1, W2, W3) and one door (D) in each DU exposed to ambient. The windows are either fully glazed or partially glazed (glass and PVC panels) and are casement windows. The door is opaque with PVC panel. Each DU has two ventilators (V) in the bath and toilet, which face a ventilation shaft. The details of the exposed door, windows, and ventilators are given below.

Figure 7: Layout plan of the project (Example 1)

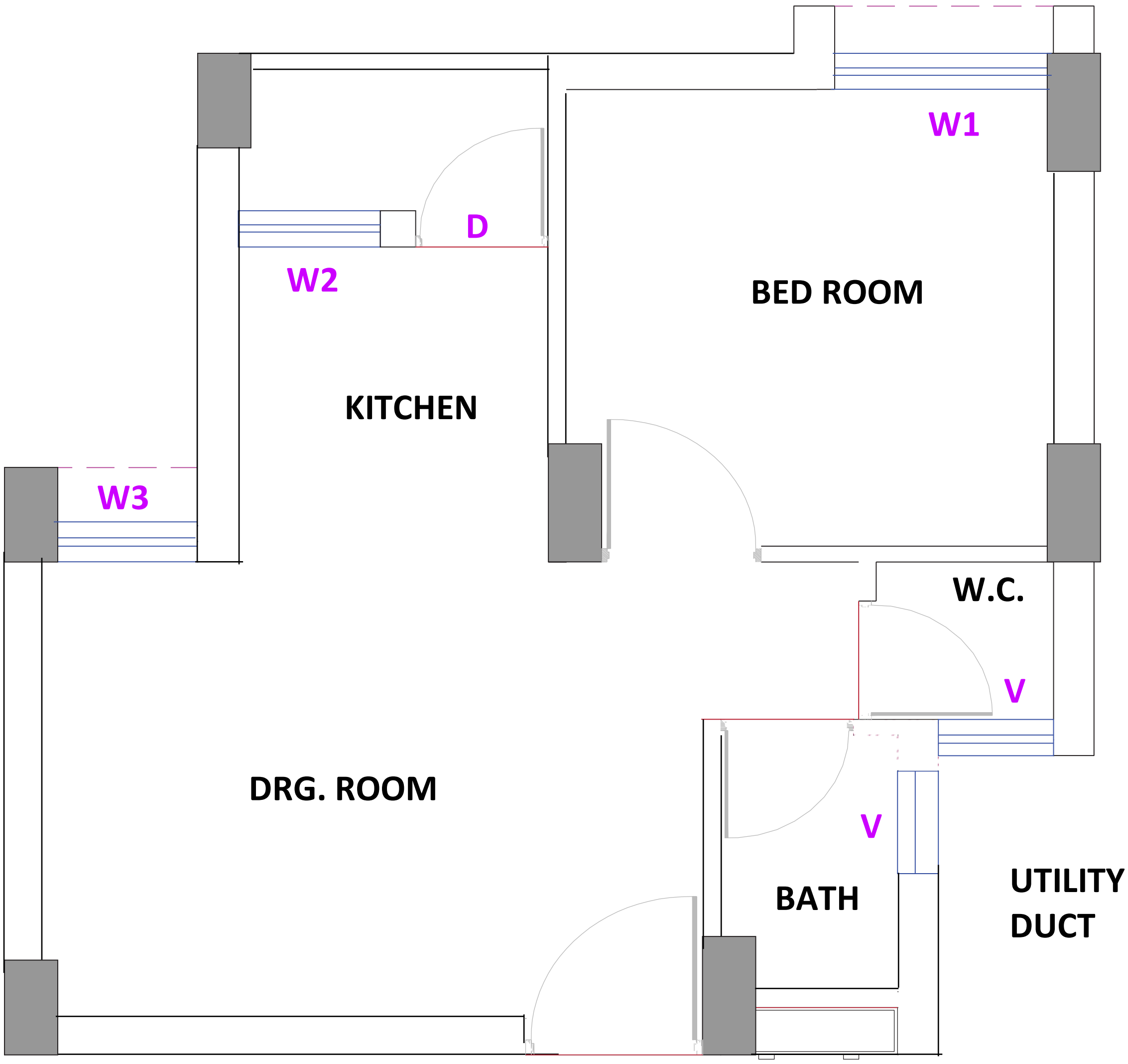


Figure 8: Plan of a typical DU (Example 1)

Table 37: Details of exposed doors, windows, and ventilators (Example 1)

Opening window/door/ ventilator	Opening width (m)	Opening height (m)	Opening area (m2)	Width of glass in Opening (m)	Height of glass in Opening (m)	Glass area in opening (m^2)	Opaque area (m^2)
W1	1.20	1.60	1.92	1.20	0.53	0.64	1.28
W2	0.80	1.30	1.04	0.80	0.43	0.35	0.69
W3	0.80	1.60	1.28	0.80	1.60	1.28	0.00
D	0.75	2.50	1.87	0.00	0.00	0.00	1.87
V (2 nos)	0.65	0.40	0.26	0.65	0.40	0.26	0.00

Material details are as follows:

Table 38: Details of construction material (Example 1)

Wall	200 mm AAC blocks with plaster on both sides. U-value 0.78 W/m^2-K
Roof	150 mm RCC with 40 mm polyurethane foam (PUF) insulation
Glass in windows	Single clear glass with SHGC 0.80, VLT 85%, and U-value 5.80 W/m^2-K
PVC panel	4 mm thick PVC panel used in doors and windows. U-value 5.23 W/m^2-K

Does this project comply with the code?

Compliance check:

Each of the 11 residential towers will need to comply with the code for the building project to be compliant. Though the towers are identical, their orientations differ.

The longer walls of Towers A-E face north-south, i.e., 0° and 180°. Towers F-I face 345° and 165°. Towers J and K face east-west, i.e., 90° and 270°. As per Table 8 in Annexure 6, Towers A-E and F-I can be considered having the same orientation. Thus, for this project, compliance may be shown for one of Towers A-I and one of Towers J and K.

In this example, compliance of Tower C, as marked in Figure 9, is being shown.

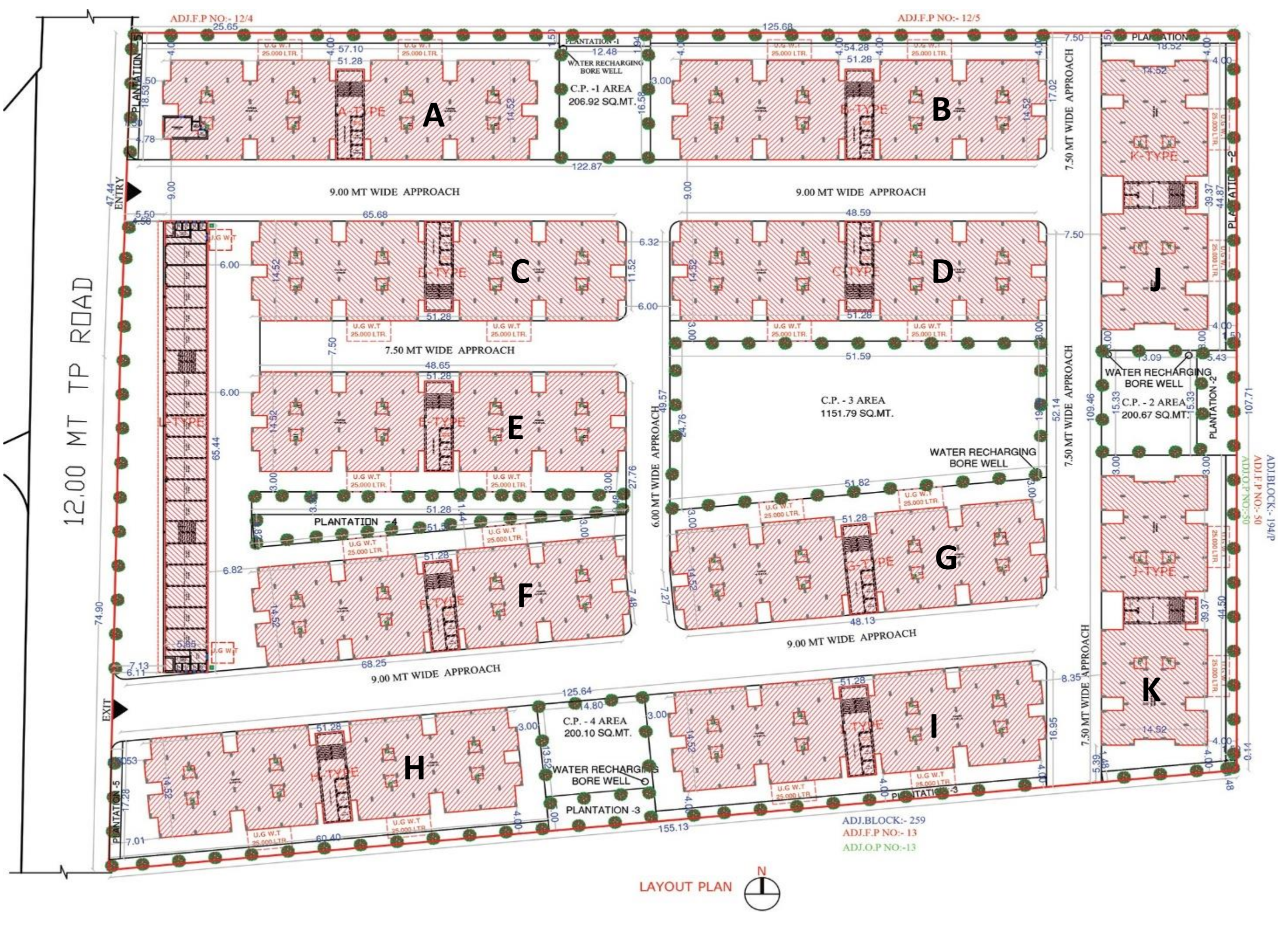


Figure 9: Building for compliance check on the layout of project (Example 1)

The longer sides of this tower face north-south. It has 112 dwelling units (DUs), 16 DUs on each floor. Half of the DUs face north and the rest face south.

Table 39: Envelope areas of the building (Example 1)

Orientation	Total wall length (m), exposed to ambient	Total wall height (m), exposed to ambient	Envelope area (m^2)
North	51.58	21.06	1086.27
South	51.58	21.06	1086.27
East	31.00	21.06	652.86
West	31.00	21.06	652.86
Envelope area (m^2), excluding roof			3478.26

Step 1: Openable window-to-floor area ratio (WFR_{op})

1.1: Calculation of total openable area ($A_{openable}$)

Each flat consists of three windows, one door opening to the balcony, and two ventilators. As all of them are casement openings, 90% of the opening area is considered openable.

Table 40: Openable area calculation (Example 1)

Opening name	Opening area (m^2)	Openable area (m^2)	Remarks
W1	1.92	1.73	90% openable (Table 5)
W2	1.04	0.94	
W3	1.28	1.15	
D (opening into balcony)	1.87	1.69	
V (2 nos)	0.52	0.47	
Openable area for each flat		5.97	
Openable area for 112 flats ($A_{openable}$)		668.81	

1.2: Calculation of total carpet area (A_{carpet})

$$A_{carpet} = no.of\ DUs\ \times carpet\ area\ of\ 1\ DU = 112 \times 26.6 = 2979.20\ m^2$$

1.3: Calculate the openable window-to-floor area ratio (WFR_{op})

$$WFR_{op} = \frac{A_{openable}}{A_{carpet}} = \frac{668.81}{2979.20} = 22.45\%$$

Hisar is in the composite climate. As per Table 1, the minimum WFR_{op} for this climate is 12.5%. Thus, this project complies with this requirement.

Step 2: Visible Light Transmittance (VLT)

2.1: Calculation of window-to-wall ratio (WWR)

There are three windows and one door in each DU exposed to ambient. The windows are either fully glazed or partially glazed (glass and PVC panels). The door is opaque with PVC panel.

Table 41: Calculation of window-to-wall ratio (Example 1)

Orientation	Opening name	Opening area (m^2)	Non-opaque (glass) area in opening (m^2)	No. of openings	Total opening area (m^2)	Total non-opaque (glass) area (m^2)
North	W1	1.92	0.64	56	107.52	35.62
North	W2	1.04	0.35	56	58.24	19.26
North	W3	1.28	1.28	56	71.68	71.68
North	D	1.88	0.00	56	105.00	0.00
South	W1	1.92	0.64	56	107.52	35.62
South	W2	1.04	0.35	56	58.24	19.26
South	W3	1.28	1.28	56	71.68	71.68
South	D	1.88	0.00	56	105.00	0.00
Total					684.88	253.16

$$WWR = \frac{A_{non-opaque}}{A_{envelope}} = \frac{253.12}{3478.26} = 0.073$$

As per Table 2, for WWR of 0.073 (range 0–0.30), the minimum required VLT is 27%. The glass used in this project has a VLT of 85% (as per certified specification for the product).

Thus, this project complies with this requirement. Also, it complies with the recommended value.

Step 3: Thermal transmittance of roof (Uroof)

3.1: Calculation of thermal transmittance of roof (U_{roof})

The roof of this building comprises the following material layers.

Table 42: Roof construction details (Example 1)

Material layer	Thickness, t (m)	Thermal conductivity, k (W/m.K)	Thermal resistance of material, R= t/k (m2.K/W)
China mosaic tile	0.007	1.500	0.005
Concrete (laid to slope)	0.050	1.740	0.029
Polyurethane foam (PUF)	0.040	0.023	1.739
Cement screed	0.020	0.720	0.028
RCC slab	0.150	1.580	0.095
Internal plaster	0.015	0.720	0.021
Sum of all material thermal resistance			1.917

Total thermal resistance,

$$R_T = R_{si} + R_{se} + R_1 + R_2 + R_3 \dots \dots \dots$$

$$= 0.17 + 0.04 + 1.917 = 2.127\ m^2 - K/W$$

Thermal transmittance of roof,

$$U_{roof} = \frac{1}{R_T} = 0.47\ W/(m^2 - K)$$

This is less than the maximum U_{roof} value of 1.2 W/m^2-K. Hence it complies with this requirement.

Step 4: RETV of the building envelope (except roof)

4.1: Calculation of envelope area, in every orientation

Table 43: Calculation of envelope area for each orientation (Example 1)

Orientation		Area (m^2)	U value (W/m^2-K)
North	Non-opaque (glass) area	126.56	5.80
	Opaque area 1 (AAC wall)	743.83	0.78
	Opaque area 2 (PVC panel in doors and windows)	215.88	5.23
South	Non-opaque (glass) area	126.56	5.80
	Opaque area 1 (AAC wall)	743.83	0.78
	Opaque area 2 (PVC panel in doors and windows)	215.88	5.23
East	Non-opaque (glass) area	0.00	
	Opaque area 1 (AAC wall)	652.86	0.78
	Opaque area 2 (PVC panel in doors and windows)	0.00	
West	Non-opaque (glass) area	0.00	
	Opaque area 1 (AAC wall)	652.86	0.78
	Opaque area 2 (PVC panel in doors and windows)	0.00	
Total Envelope Area, $A_{envelepe}$		3478.26	

(The U values of AAC block and PVC sheet are calculated the same way as that shown for the roof. The thermal conductivity of AAC block is 0.184 W/m-K and that of PVC is 0.19 W/m-K.)

4.3: Calculation of RETV

Rajkot is in the composite climate zone. Thus, the RETV equation, with applicable coefficients, is:

$$RETV = \frac{1}{A_{envelope}} \left[\begin{array}{c} \left\{ 6.06 \times \sum_{i=1}^{n} \left(A_{opaque_i} \times U_{opaque_i} \times \omega_i \right) \right\} \\ + \left\{ 1.85 \times \sum_{i=1}^{n} \left(A_{non-opaque_i} \times U_{non-opaque_i} \times \omega_i \right) \right\} \\ + \left\{ 68.99 \times \sum_{i=1}^{n} \left(A_{non-opaque_i} \times SHGC_{eq_i} \times \omega_i \right) \right\} \end{array} \right] \begin{array}{l} Term\ I \\ Term\ II \\ Term\ III \end{array}$$

Calculation for the 3 terms is shown in table below:

Table 44: Calculation of 3 terms of RETV formula

Calculation for Term-I					
Orientation	**Component**	**(a) Area (m^2)**	**(b) U value ($W/m^2.K$)**	**(c) Orientation factor*, ω**	**(a) x (b) x (c)**
North	Opaque area 1 (AAC wall)	743.83	382.34	0.659	382.34
North	North Opaque area 2 (PVC panel in doors and windows)	215.88	5.23	0.659	744.05
South	Opaque area 1 (AAC wall)	743.83	0.78	0.966	560.46
South	Opaque area 2 (PVC panel in doors and windows)	215.88	5.23	0.966	1090.66
East	Opaque area 1 (AAC wall)	652.86	0.78	1.155	588.16
West	Opaque area 1 (AAC wall)	652.86	0.78	1.156	588.67
					Term-I Total 3954.35

Calculation for Term-II					
Orientation	**Component**	**(a) Area (m^2)**	**(b) U value ($W/m^2.K$)**	**(c) Orientation factor*, ω**	**(a) x (b) x (c)**
North	Non-opaque (glass) area	126.56	5.80	0.659	483.74
South	Non-opaque (glass) area	126.56	5.80	0.966	709.09
					Term-II Total 1192.83

Calculation for Term-III					
Orientation	**Component**	**(a) Area (m^2)**	**(b) Equivalent SHGC#**	**(c) Orientation factor*, ω**	**(a) × (b) × (c)**
North	W1	35.62	0.523	0.659	12.28
North	W2-1	9.63	0.450	0.659	2.86
North	W2-2	9.63	0.450	0.659	2.86
North	W3-1	35.84	0.527	0.659	12.45
North	W3-2	35.84	0.527	0.659	12.45
South	W1	35.62	0.420	0.966	14.45
South	W2-1	9.63	0.363	0.966	3.38
South	W2-2	9.63	0.363	0.966	3.38
South	W3-1	35.84	0.486	0.966	16.83
South	W3-2	35.84	0.486	0.966	16.83
					Term-III Total 97.74

* Orientation factor is taken from Annexure 6; For Latitude < 23.5˚N and the specific orientation. e.g. for North orientation, it is 0.659
# Refer to step 4.2 for details.

Substitute the values of 3 terms and envelope area in the RETV formula:

$$RETV = \frac{1}{3478.26}[\{6.06 \times 3954.35\} + \{1.85 \times 1192.83\} + \{68.99 \times 97.74\}]$$
$$RETV = 9.46 W/m^2$$

This is less than the maximum RETV of 15 W/m^2. Hence it complies with this requirement.

The building complies with all four requirements and hence complies with the code.

ANNEXURE 9 Guidelines for Design for Natural Ventilation

This annexure provides a simple and illustrative interpretation of provisions for the location of windows in a room and its impact on natural ventilation. A detailed design guideline for natural ventilation is available in the NBC 2016[26] (Volume II, Part 8 Building Services, Section 1 Lighting and Natural Ventilation).

The code gives the following provision for minimum WFR_{op} values for natural ventilation (Table 1, Section 3.1):

Table 45: Minimum requirement of window-to-floor area ratio, WFR_{op}

Climatic zone	Minimum WFR_{op} (%)
Composite	12.50

Source: Bureau of Indian Standards (BIS). 2016. National Building Code of India 2016. New Delhi: BIS.

Openable window-to-floor area ratio (WFR_{op}) indicates the potential of using external air for ventilation. The openable area allows external air, when the ambient temperature is cooler than the inside air, into the internal spaces, which helps in ventilation, improvement in thermal comfort, and consequent reduction in cooling energy.

This openable area can be distributed on the external wall in a number of ways. Rooms may have openings on only one external wall or multiple external walls (usually two external walls). Some guidelines for design of these openings are given below. It is to be noted that internal doors cannot be relied for enhancing ventilation and are assumed to be closed.[27]

1. Distribution of the openable area on the external walls of a dwelling unit must be done to maximize cross-ventilation, i.e., the air inlet and outlet openings should be separate and positioned on different walls in a way that optimizes the air flow path through the space. This can be done by placing openings on adjacent walls or on opposite walls, where possible (Figure 10).

[26] Bureau of Indian Standards (BIS). 2016. National Building Code of India 2016. New Delhi: BIS.

[27] Heat exchange during night-time in hot/warm climates has greater value for thermal comfort. At this time, it is generally seen now that people keep the doors of their private rooms, i.e., the internal doors, closed.

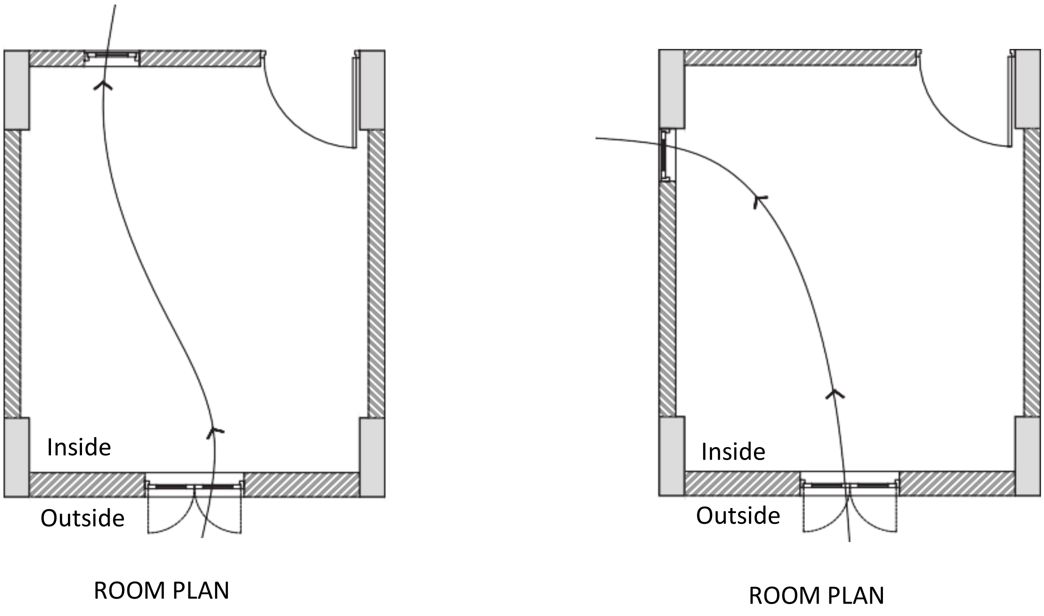


Figure 10: Openings on adjacent or opposite external walls for cross ventilation (Guideline)

2. In rooms that have openable area on only one external wall, cross ventilation can be achieved by having an opening at a higher level on one of the internal walls (Figure 11). This will enhance cross ventilation through the habitable space. This principle can be extended from room to room, for instance, from a bedroom into a living room which is cross-ventilated, thus enhancing cross ventilation through the entire dwelling unit.

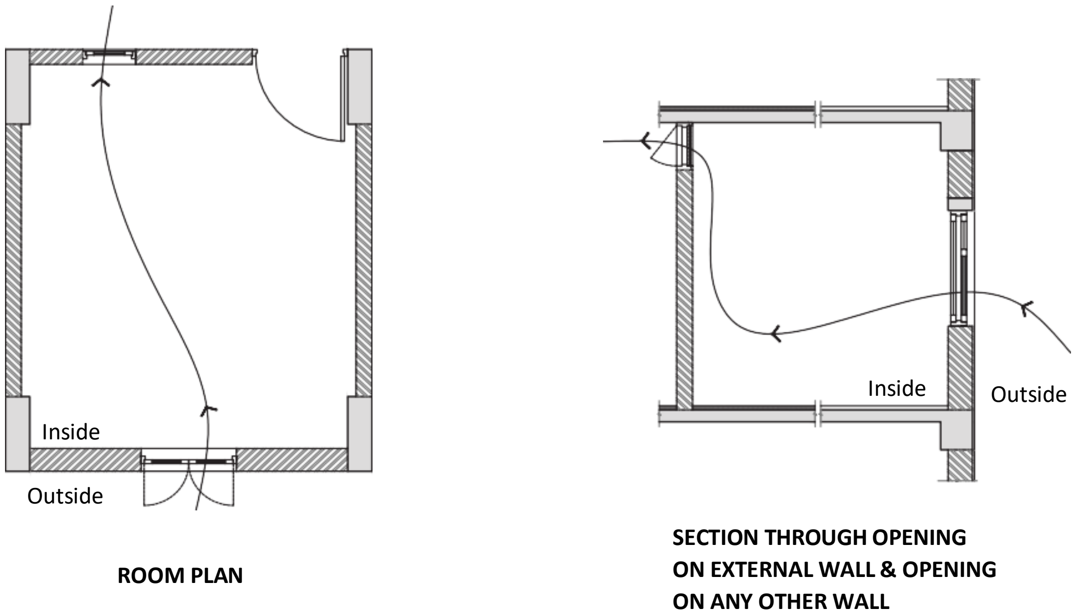


Figure 11: Openings on external wall and internal wall for cross ventilation (Guideline)

3. In rooms with only one external wall, and where cross ventilation is not possible (see point 2, above), provision of multiple windows on the external wall is preferred to that of a single window (Figure 12). The farther apart these windows are placed on the wall, the better is the effect of air movement across the room.

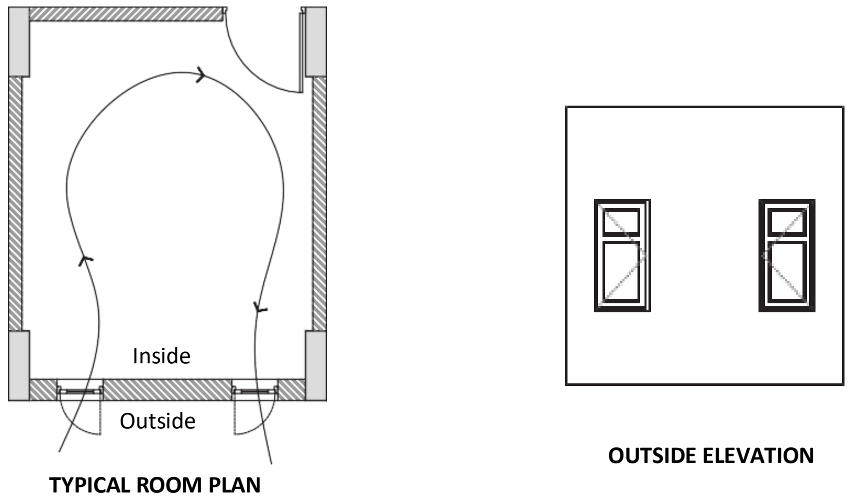


Figure 12: Two windows on single external wall (Guideline)

4. Adding a ventilator above the windows on the external wall helps increase the rate of convective heat exchange (Figure 13). This is especially helpful in cases where windows are available on only one external wall and there is no means of cross ventilation.

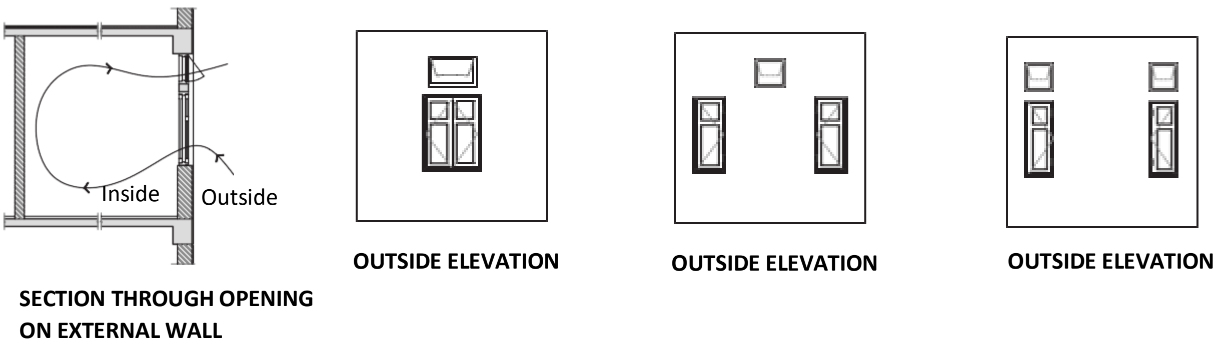
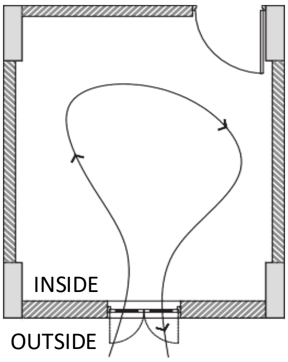


Figure 13: Adding ventilators above windows improves ventilation especially when only single external wall is available for openings (Guideline)

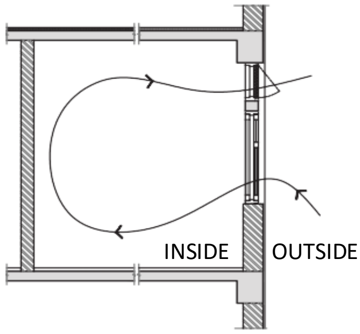
The following illustrative diagrams recommend good design strategies to help achieve better air exchange and increase the rate of heat loss through the buildings.

Single-sided ventilation

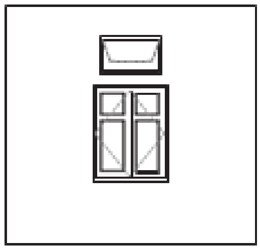
Case 1: Room with only one opening on the external wall



ROOM PLAN



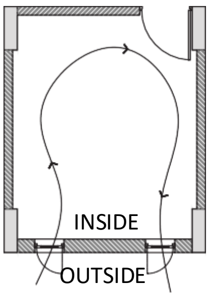
SECTION THROUGH OPENING ON EXTERNAL WALL



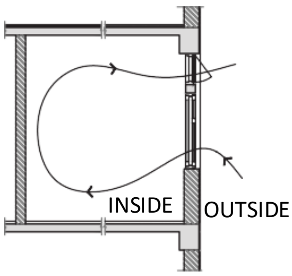
OUTSIDE ELEVATION

Addition of ventilator at an upper level increases the rate of convective heat exchange with the outside air.

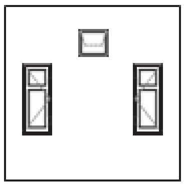
Case 2: Room with multiple openings on the external wall



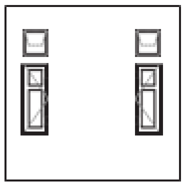
TYPICAL ROOM PLAN



SECTION THROUGH OPENING ON EXTERNAL WALL



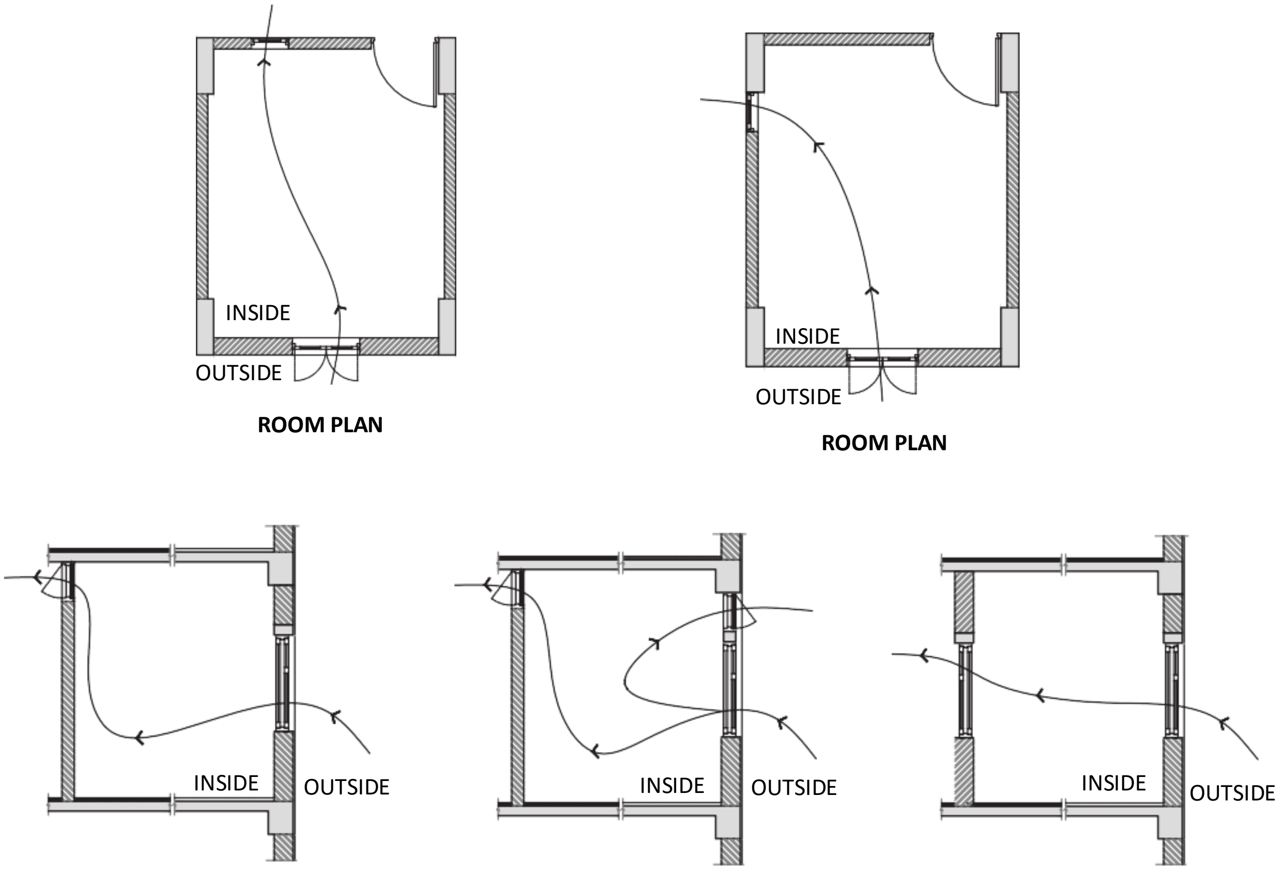
OUTSIDE ELEVATION



OUTSIDE ELEVATION

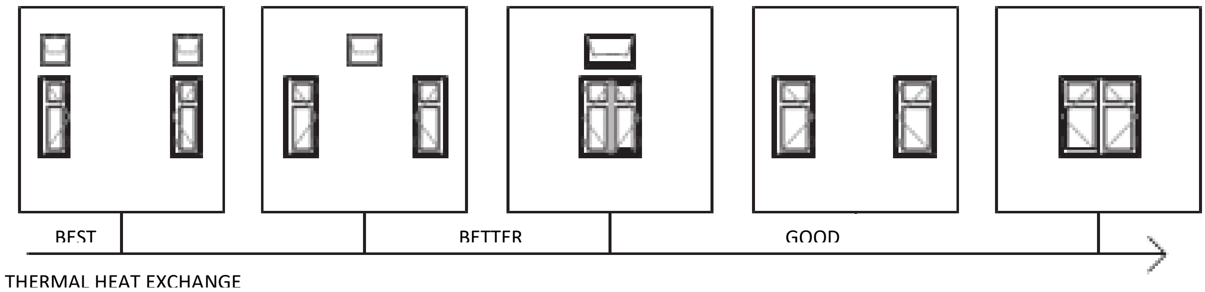
Cross ventilation

Case 1: Room with openings on both the external wall and another internal or external wall



SECTION THROUGH OPENING ON EXTERNAL WALL AND OPENING ON ANY OTHER WALL FOR GOOD CROSS VENTILATION

Comparison



For the same ratio of area of openings to floor area of a room, the thermal heat exchange increases as the number of openings increases on the wall.[28] It is thus recommended to have openable ventilators to aid better ventilation.

[28] This conclusion is generally valid for hot-dry, warm-humid climates. For cold regions, this may vary.

ANNEXURE 10 Cool Roof and Roof Gardens

A cool roof is one that reflects most of the incident solar radiation and efficiently emits some of the absorbed radiation back into the atmosphere, instead of conducting it to the building below.[29] The term specifically refers to the outer layer or exterior surface of the roof, which acts as the key reflective surface.[30] A cool roof minimizes the solar heat gain of a building by first reflecting a considerable amount of incoming radiation and then by quickly re-emitting the absorbed portion. Cool roof encompasses an extensive array of applications including roof coatings, colours, textures, finishes such as broken china mosaic, tiles, and even metals.

However, cool roofs are not to be seen as an alternative to the thermal transmittance requirement of the roof (U_{roof}) as given in this code. It is encouraged to have any cool roof application over a roof assembly complying with the maximum thermal transmittance value given in the code.

Defining a cool roof

The 'coolness' of a roof is influenced by its solar reflectance and thermal emittance.

- Solar reflectance: Solar reflectance is the ratio of solar radiation reflected by a surface to the solar radiation incident upon it. Solar reflectance is measured on a scale of 0 to 1. A reflectance value of 0 indicates that the surface absorbs all incident solar radiation, and a value of 1 denotes a surface that reflects all incident solar radiation. The term 'albedo' is often used inter-changeably with solar reflectance.
- Thermal emittance: Thermal emittance is the relative ability of a material to reradiate absorbed heat as invisible infrared radiation. Emittance, measured from 0 to 1, is defined as the ratio of the radiant flux emitted by a body to that emitted by a black body at the same temperature and under the same conditions.

According to ECBC 2017 cool roof requirement, roofs with slopes less than 20 degrees shall have an initial solar reflectance of at least 0.6 and an initial emittance of 0.9.

The Solar Reflectance Index (SRI) is a term that incorporates both solar reflectance and emittance in a single value and quantifies how hot a surface would get relative to standard black

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[29] Shakti Foundation. 2017. Cool Roofs for Cool Delhi: Design Manual. Available at http://shaktifoundation.in/wp-content/uploads/2017/06/cool-roofs-manual.pdf (accessed on 1 May 2018)

[30] ibid

and standard white surfaces. It is the ability of a material to reject solar radiation, as shown by a small temperature rise.[31] The SRIs of a standard black surface (having reflectance of 0.05 and emittance of 0.9) and a standard white surface (of reflectance 0.8 and emittance 0.9) are taken as 0 and 100, respectively.

IGBC Green Homes requires a minimum SRI value of 78 for roof slopes with gradient ≤ 1:6 and 29 for steeper roof.

For more detailed information on cool roof, please refer Cool Roofs for Cool Delhi: Design Manual.[32]

Roof Gardens

In the case of roofs with roof gardens on earth fill for plantation or lawn, the thermal resistance of the earth fill can be taken into the calculation of the thermal transmittance (U value) of the roof. Some of the heat absorbed by the earth fill is also released into the atmosphere due to evapotranspiration of irrigation water from the roof garden, thus giving additional benefit.

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[31] Bureau of India Standards (BIS). 2016. National Building Code 2016. Part 11. New Delhi: BIS

[32] Shakti Foundation. 2017. Cool Roofs for Cool Delhi: Design Manual. Available at http://shaktifoundation.in/wp-content/uploads/2017/06/cool-roofs-manual.pdf (accessed on 01 May 2018)

Annex A-Embodied Energy

Rationale

Embodied energy in construction in India (especially in "formal' residential buildings of the sort that are covered by the ENS code) can sometimes be of the order of magnitude of many decades of operating energy use[33] and therefore is very significant to consider when such a code is being developed.

However, this was true for non-air-conditioned housing stock, and it seems likely that, like in the developed economies, increasing consumption of operating energy (e.g., for appliances, common area services, air-conditioning etc.) may cause the embodied energy to become less significant compared to operating energy. Still, this is an important area to include in the code.

Embodied energy is also important because much of it is consumed in the form of primary energy (coal, oil, fuels) causing direct pollution and carbon emissions.

Embodied energy is the sum of all energy used in the construction process, i.e., in the product, transport and installation: from the extraction of raw materials, manufacture of materials and fabrication of products, to their transportation and installation in buildings. It is often measured in megajoules per square meter. But its units can also be kWh(th) (Thermal Kilowatt hours, with 1kWh(th) being equivalent of 3600 kJ) per sqm of built-up-area, making it more easily comparable with EPI of the ENS code.

Cement and steel are the major contributors of embodied energy in residential building construction in India. According to the study conducted by Jadavpur University[34], 98% of the embodied energy is attributed to the embodied energy of the materials used and 2% is the contribution of actual erection of the building. Unfortunately, embodied energy is often "hidden" in industry for the manufacture and transport of materials, and the transportation of workers.

Institutes of technological research need to be tasked with creating standards for embodied energy benchmarks based on average and best practice. If necessary, this research needs to attract funds from the building industry and foundations.

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[33] The Mud Village project, sponsored by HUDCO, entry by Studio Plus, 1987

[34] Embodied Energy Analysis of Multi-storied Residential Buildings in Urban India, S Bardhan - WIT Transactions on Ecology and the Environment, 2011

Embodied Energy measured in kWh(th)/sqm and Operating Energy measured in kWh(th)/sqm.year can be combined. In order to combine the (capital) embodied energy with the operating energy, it is necessary to merge the two to units equivalent of kWh(th)/sqm.year so that a single number can represent the energy performance of a project.

In a recent piece of research for Technology Information Forecasting and Assessment Council of India[35], it was found that the best way to translate from kWh(th)/sqm (Embodied Energy) to kWh(th)/sqm.year (equivalent Operating Energy) would be to set up a notional or actual discount/replacement rate of construction taking its nominal life, say, as:

- 50 years life leading to a 2% replacement rate of stock for mainstream buildings
- 20 years life leading to a 5% replacement rate of stock for temporary industrial materials (steel) buildings
- And so, on

According to a study by HUDCO[36], affordable housing uses 4257 MJ/sqm of embodied energy and so at a rated life of 50 years (or 2% replacement rate), this is equivalent of 85 MJ/sqm.year or 23.6 kWh(th)/sqm.year which is substantial for a building without air-conditioning but low for a building with various mechanical systems using up substantial operating energy.

This can be codified along with other benchmarks in the ENS code after suitable characterisation, study, analysis of best practices, and benchmarking.

Notes

Embodied energy is given less importance in the affluent regions of the world since their operating energy is high. There are two methods to evaluate this energy: by process or by input-output. Researchers in the Indian Institute of Science[37] identified process analysis as appropriate for embodied energy assessment in the Indian context.

One of the earliest researchers using process-based analysis of embodied energy, Dr. Mohan Rai, carried out studies at CBRI Roorkee in the early 1960s and made the first listing of embodied energy, sorted in descending order, as follows:

[35] Technology Vision 2035, Technology Information Forecasting and Assessment Council (TIFAC) 2014
[36] Accessed in December 2019 at https://www.slideshare.net/sslele456/embodied-energy-in-residential-cost-effective-units
[37] K.I. Praseeda, B.V. Venkatarama Reddy, Monto Mani, 2015. Embodied energy assessment of building materials in India using process and input–output analysis, Energy and Buildings, 86 (677-686), ISSN 0378-7788

Materials	Unit	kWh(th)	MJ
Sheet Glass	sqm	74.199	267.1
Linoleum	sqm	46.287	166.6
Aluminium	kg	39.891	143.6
PVC	kg	32.273	116.2
Sanitaryware	kg	9.071	32.7
Mild Steel	kg	7.327	26.4
L.D. Polyethylene	kg	6.048	21.8
Stoneware Pipes	kg	5.896	21.2
Cement	kg	2.245	8.1
Quick Lime	kg	1.756	6.3
Bloated Clay Aggregate	kg	1.477	5.3
Burnt Clay Roofing Tiles	each	1.233	4.4
Burnt Clay Bricks	each	1.187	4.3
Wood Particle Board	kg	0.861	3.1
Sand Lime Bricks	each	0.773	2.8
Clay Fly-Ash Bricks	each	0.643	2.3
Gypsum (Calcined)	kg	0.420	1.5
Brick Dust (Surkhi)	kg	0.384	1.4
Crushed Aggregate	kg	0.060	0.216

The table above shows (as is well-known) that the embodied energy of processed industrial materials like aluminium, steel and cement is much higher than relatively unprocessed and mined materials extracted from nature (like crushed aggregates). Natural and renewable materials such as timber may be deemed to have zero renewable energy. Therefore, all other things being equal, a concrete framed structure with cement and steel is worse than a load bearing structure with hardly any cement and steel and masonry (preferably non-fired) and funicular forms holding up the roof.

Annex B-Best Construction Practice

Energy can be consumed in bad practices that may be observed on building sites. This needs to be stopped but is currently outside the scope of the ENS code. Typical practices include excessive requirement of movement of fluids (like mixed concrete) or solids (like steel) on site due to bad layout, improper sizing of pipes to save initial costs but causing greater pumping power due to friction losses, an over- or under-reliance on assisted manual labour (which may be seen as a form of renewable energy), and industry having got used to fuel-based services or energy-on-tap (firm energy) and so unable to convert to renewable energy such as solar photovoltaic systems (due to their being infirm, not available on-tap). Often machinery is also often designed so as to have very high starting surge loads, thereby making it impractical to invest in capital-intensive technologies (renewable) instead of fuel-based technologies, causing emissions and/or pollution. These areas need to be improved and then can be codified.

Although according to the study conducted by Jadavpur University[38] 98% of the embodied energy is attributed to the embodied energy of the materials used and 2% is the contribution of actual erection of the building, it is important to look at this seemingly trivial 2% for the main reason that there can be a lot of energy wasted and emissions and pollution created by bad site practices, and also because better site practices lead to better buildings and saves cost for the builder, thereby (ultimately) resulting in more affordable construction.

To achieve this:

- Layout planning of sites should be made a course in civil engineering and project managers need to, by mandate, graduate in at least a one-semester course in this subject.
- Civil engineers need to be able to engage with concepts of renewable energy through manual labour and solar and wind energy systems and they, along with project managers, need to, by mandate, graduate in at least a one-semester course in this subject.
- Total energy losses due to waste and friction on site (per unit area of building being made) need to be analysed, benchmarked, and codified.
- All these point to research directions that need to be undertaken (again by Civil Engineering departments in our Engineering Institutes).

[38] Embodied Energy Analysis of Multi-storied Residential Buildings in Urban India, S Bardhan - WIT Transactions on Ecology and the Environment, 2011

- Best industry standards for ratios of running energy: starting surge, need to be analysed, benchmarked, and codified, so that infirm energy sources such as solar photovoltaics may be able to be considered to meet the demand of energy on site. It may be noted that infirm energy sources such as solar photovoltaics could be seen to be a form of production of energy, and if managed well and with sufficient open area, with a good rental market created for solar photovoltaics or wind turbines, sites can in the future become energy-neutral for construction of buildings.

Since research in this area is nascent, it has been kept out of the ENS code for now.

Annex C- Retrofitting of Residential Buildings

Retrofitting consists of additions and alterations to existing (and, in the context of the ENS code, residential) building stock and typically this is set into motion by building owners.

For reasons of poor research and difficult practice, this code is currently silent on retrofit provisions and this appendix is created because given the right conditions this situation may change. This code does not mention provisions for retrofit cases because of the principle that laws (and codes) should preferably not be applied retroactively (so we cannot declare a building not meeting standards before the standard was even made), but in doing so we lose out a large potential of building stock (say over 50% of the residential building stock in 2030 if we read the McKenzie report[39] that "nearly 70% of building stock that will be there in 2030 is yet to be built in India" and geometrically extrapolate it from 2010 when it was written to 2019 today).

The following market innovations need to be encouraged to cover a large part of India's existing residential building stock even when they are not being added to or being altered:

- For apartment dwellers, before enforcing this code, there need to be financial (low-interest loan) instruments available or created whereby collective retrofitting may take place through collective action, for example changing of window or wall specifications through RWA action to comply with provisions of the ENS so that capital cost of such retrofits may be kept low per month.
- For individual house owners, there need to be encouragement of vendors who can audit and retrofit because until that is done the implementation of ENS code shall be resisted or "loopholed" by homeowners.
- For rental stock, these audits and retrofit companies can undertake audit and retrofit to meet the ENS code provisions either through RWA or through apartment owners' associations (this is more difficult but can be eased by easy upgrade costs accompanied by strict compliance demands).

It would help a lot if the improvements effected by RWAs or contractors can be documented in a standardized way and the improvements in performance recorded numerically on a plaque or certificate for the owners to take pride in retrofitting their homes. This can be designed like the BEE star labels for various appliances.

[39] India's Urban Awakening: Building inclusive cities, sustaining economic growth (McKinsey Global Institute, April 2010)

It is anticipated that since the primary means of enforcing the ENS code is at the time of municipal approval and completion, this code could be immediately applied (subject to state-by-state acceptance into law) at the time of application for addition and alterations of buildings.

This would automatically exempt minor addition and alterations (such as raising internal walls, painting, etc.) For reference, these "minor" retrofits in existing buildings that do not need any permission according to Delhi Development Authority (DDA), similar to changes in buildings all over the country, are provided below:

Excerpt from DDA[40]

1. To convert existing barsati into room provided the wall is made of only 115 mm thick.
2. Grills and glazing in verandah with proper fixing arrangement.
3. Raising height of front and rear courtyard wall upto 7' height by putting up jali/fencing.
4. Providing door in courtyard wherever not provided.
5. Providing sunshades on doors and windows wherever not provided with proper fixing arrangements.
6. Closing the door.
7. If the bathroom or WC are not having roof, these may be treated as open urinals and allowed.
8. Raising the wall of balcony/terrace parapet with grill or glazing upto 5' height.
9. Construction of open staircase (cat ladder) where no staircase has been provided for approach to the terrace.
10. To put provide additional PVC water tank at ground floor area without disturbing the common passage.
11. To provide an additional PVC water tank in the scooter/car garage at the surface level.
12. To provide loft /shelf in the rooms without chase in the walls.
13. To change the flooring with water proofing treatment.
14. To remove half (41/2) brick wall.
15. To make a ramp at front gate without disturbing the common passage /storm water drain.
16. To provide sunshades or the outer windows upto 2'wide projection.
17. To provide false ceiling in rooms.
18. To make an opening of maximum size of 2'6" x1'9" for exhaust fan or air-conditioner in existing walls.

[40] http://www.dda.org.in/housing/pending_cases/permissible_alteration_housing.htm, accessed December 2019.

19. Fixing of door in back and front courtyard.
20. Converting of window into Almirah subject to availability of light and ventilation as per building byelaws provided that no structural elements are disturbed and there is no projection extending beyond the external wall.
21. Shifting of water storage tank/raising of parapet wall upto 5' height and putting additional water storage tank. Wherever the existing water storage tank capacity is less than 500 ltrs in a flat, a 500 ltrs tank can either replace the existing water storage tank or if possible, the additional tank can be added so as to make the total storage capacity upto 550 ltrs. However, such replacement/provision of additional tank will be done only on the locations specified for such tanks and the supporting beams will be required to be strengthened suitably. Parapet wall around terrace can be increased to a height of 5'.
22. To shift the front glazing, rooms/windows upto existing chajja.

Not implementing retrofit cases for, say, 5 years, it can then be suggested that the ENS code could be made applicable to all Addition and Alterations cases that come for approval to ULBs. This will cover at least some 5% of existing building stock (say 10% of 50%) and simultaneously measures (1) through (3) in the last page need to be actively pursued in the market to make alterations proactively possible for existing building stock, even when not undertaking additions and alterations.

Generally, alterations in themselves do not require municipal approval. The key changes that require getting municipal approval is increase of height / FAR / Ground Coverage, all of these are related to increasing the size of the home.

Studying codes from other countries[41], it can be seen that whenever a project comes up for municipal sanction, the codes require the renovated project to comply with the code provisions. This should be recommended in India also.

This will leave out only that part of the existing building stock that has a completion certificate from the ULB and remains unchanged. In time it shall be added to (requiring ULB approval) or demolished and rebuilt (requiring ULB approval). Therefore, by the later part of this century

[41] There are many references. See for instance, the Residential Compliance Manual for the 2019 Building Energy Efficiency Standards, California, at https://ww2.energy.ca.gov/2018publications/CEC-400-2018-017/CEC-400-2018-017-CMF.pdf, or https://www.buildwaikato.co.nz/building-projects/additions-alterations/ from the Waikato Building Consent Group (WBCG) in New Zealand, both accessed in December 2019.

definitely the entire residential building stock shall become ENS compliant, even if market forces do not already make it so.

Annex D- Improved Air Cooling

Residential buildings sector accounts for 24% of the electricity consumption and is the second largest consumer after industries. Within the building sector, the residential electricity consumption amounts to 259 TWh. Within this sector, with increasing affluence in the Indian middle class, there is a tendency (in warm humid, hot dry, composite and even moderate climates which always have some hot days) to create comfort by installing an air-conditioner or two. Capital costs of air conditioning is low compared to capital costs of building (today, cheap – and inefficient – air-conditioning can be as low as 5% of the building cost). EMI-based loans make it easy for even a lower middle-class family to install split air-conditioners at less than the monthly energy costs of running the same.

Use of air-conditioning therefore is a major hurdle in creating energy efficient residential stock in India, since it cannot be denied that it creates superior comfort in all sorts of conditions: warm humid, hot dry, composite, and moderate.

Often the rationale for a lower middle-class family, who realize that the energy bills are not easy to manage, is that they will use it minimally, only in the night and only in extreme weather, or by setting the thermostat up to higher temperatures. However, air-conditioning, with its superior performance in terms of managing humidity, is addictive, and there is a tendency for its use to increase to the limit of the users' paying capacity, and even beyond it.

It is worse that in this economic class, the tendency is to procure cheap, lower rated inefficient equipment, and install it in poorly insulated houses, which uses even more electricity than it could.

This causes residential air-conditioning to become a major barrier in energy efficiency (USAID, 2014)[42]. This issue is a major guzzler of energy in houses and needs to be mitigated by codification. However, since the research on this is ongoing, this has not yet been included in the ENS code.

On November 15, 2019, the Rocky Mountain Institute (RMI) in collaboration with the Ministry of Housing and Urban Affairs (MoHUA) of the Government of India (GoI) announced the results of a Global Cooling Prize competition, for Incentivizing the development of a residential cooling solution that will have at least five times less climate impact than standard

[42] HVAC Market Assessment and Transformation Approach for India, PACE-D Technical Assistance Program, USAID, August 2014

residential/room air conditioners (RAC) units in the market today. This technology could prevent up to 100 gigatons (GT) of CO_2-equivalent emissions by 2050, and put the world on a pathway to mitigate up to 0.5˚C of global warming by 2100, all while enhancing living standards for people in developing countries around the globe[43].

Therefore, the following are urgently required to be researched and implemented for Indian residences to become comfortable while remaining energy efficient, at capital costs that are affordable or can be made affordable by fiscal incentives or financial instruments:

- Air-conditioning systems that can be used at higher set-point temperatures (say, up to 28 °C) in combination with ceiling fans. These require higher cfm of air to be pushed through (rather than the industry standard of 400 cfm per Ton) and a balance between refrigerant temperature, air flow, and set point since currently air-conditioning industry has optimised all systems for 22°C - 24°C. As the set point temperature is increased, the other parameters need to change. This kind of device will be ideal for bill-conscious lower middle classes even if they can progressively afford air-conditioning capex.
- Fiscal incentives or financial instruments to lower capex for improving house thermal performance to ENS code levels so that optimum (not too much) air-conditioning is installed. Unfortunately, at this point, the ENS code has been developed assuming that the cooling system is some form of air-conditioning.
- Rapid development and deployment of effective an acceptable intermediate technologies including adiabatic technologies, such as passive hybrid and active evaporative coolers, better natural ventilation, indirect evaporative coolers, or chilled coil indirect evaporative coolers, combined with fiscal incentives or financial instruments to lower capex for improving houses to a level so that sufficient passive cooling is managed and the number of days of usage of cooling or conditioning can be brought down.
- Alternative desiccant and evaporative systems for cooling (which are not yet well developed). This may require fundamental research and cannot be expected to be rapidly deployed.

Promotion of all these above alternatives through some cultural or social incentives (such as the BEE star rating system or TV promotions) so that they are not perceived as inferior to “complete” air-conditioning. This requires a major social change in attitude from progress seen

[43] https://globalcoolingprize.org/ accessed in December 2019

as consumption only to progress seen as sufficiency, but is probably the most effective instrument for meeting and even bettering the EPI targets of the ENS code.

Natural and SENS Score Ventilation

If buildings can achieve comfort by natural or sENS Score ventilation, this would entirely avoid the use of energy for mechanical cooling, and needs to be highly encouraged.
Natural ventilation fulfils two primary needs: first, it gives fresh air for satisfactory indoor quality; and, second when the outdoor temperature is comfortable (during night and transition seasons), it expels heat from inside the structure and facilitates cooling.
Natural ventilation is of course not useful for cooling when the outdoor air is at a temperature higher than the set-point or desired indoor temperatures. This leads us to another very important concept of ventilation, sENS Score ventilation, opening the building very much to the outdoor air whenever the temperature outside is more comfortable than the inside, namely summer nights and winter days.

The National Building Code 2016 (Part 8; 1; 5. Ventilation) or ASHRAE 62.1–2016 provide standard ventilation rates for acceptable indoor quality.

To aid cooling a larger volume of airflow is required than the standard ventilation rates.
The rate of ventilation by natural means through windows or other openings depends on,

a. direction and velocity of wind outside and sizes and disposition of openings (wind action); and
b. convection effects arising from temperature of vapour pressure difference (or both) between inside and outside the room and the difference of height between the outlet and inlet openings (stack effect).

One of the parameters to quantify the adequacy of natural ventilation is hourly air change rate (ACH), which is a proportion of how frequently the air volume inside a room is supplanted by outside air in 60 minutes. The larger the number, the better is the cooling potential through common ventilation. As a rule, 5 to 20 ACH gives good natural ventilation.

NBC 2016 discusses the design guidelines for natural ventilation in the 5.4.3 of Part 8: Building Services of the code.

Once the promotion of naturally ventilated buildings can be successfully undertaken, it should be possible to eliminate the use of air-conditioning or at least drastically reduce its use in all but the most affluent residences.

Ventilation in residential buildings can be provided by one of the following methods:

a) Natural supply and natural exhaust of air (natural ventilation)
b) Natural supply and mechanical exhaust of air (mechanical ventilation, see below)
c) Mechanical supply and natural exhaust of air (mechanical ventilation, see below)
d) Mechanical supply and mechanical exhaust of air (mechanical ventilation, see below).

Mechanical Ventilation

There are a range of circumstances in which natural ventilation may not be possible or sufficient to attain thermal comfort:

- The building is too deep to ventilate from the perimeter.
- Local air quality is poor, for example if a building is next to a busy road.
- Local noise levels mean that windows cannot be opened.
- The local urban structure is very dense and shelters the building from the wind.
- Privacy or security requirements prevent windows from being opened.
- Internal partitions block air paths.
- The density of occupation, equipment, lighting and so on creates very high heat loads or high levels of contaminants.

Some of these issues can be avoided or mitigated by careful design, and mixed mode or assisted ventilation might be possible, where natural ventilation is supplemented by mechanical systems. Naturally it is not desirable to go with mechanical ventilation where natural ventilation could achieve the similar results.

Where mechanical ventilation is necessary it can be:

- A circulation system such as a ceiling fan, which creates internal air movement, but does not introduce fresh air.
- A pressure system, in which fresh outside air is blown into the building by inlet fans, creating a higher internal pressure than the outside air.
- A vacuum system, in which stale internal air is extracted from the building by an exhaust fan, creating lower pressure inside the building than the outside air.

- A balanced system that uses both inlet and extract fans, maintaining the internal air pressure at a similar level to the outside air and so reducing air infiltration and draughts.
- A local exhaust system that extracts local sources of heat or contaminants at their source, such as cooker hoods, fume cupboards and so on.

Kitchen Ventilation

Kitchen is always the hottest space in a flat on account of the huge amount of heat produced due to cooking. The arrangement of a decent ventilation framework that can proficiently separate hot air from the kitchen before it blends with the encompassing air can help lessen the heat in the kitchen and adjoining spaces.

For powerful natural ventilation of the kitchen, notwithstanding the window, an extra louvre opening ought to be given to further aid the movement of air.

If the kitchen is ventilated utilizing a fume hood, the distance of the hood from the gas fire and the fume flow rate should be appropriately chosen for best ventilation of the kitchen.

Evaporative Cooling

Evaporative cooling is a process that uses the effect of evaporation of water as a natural heat sink. The amount of sensible heat absorbed depends on the amount of water that can be evaporated. Currently this is the most promising area of reducing energy for cooling, except that it is largely ineffective in warm and humid seasons or climates. Sensible heat from the air is absorbed to be used as latent heat necessary to evaporate water.

- Direct Evaporative cooling (DEC): In this system, commonly used in the form of a ‘desert’ cooler, the outdoor air is brought into direct contact with water, cooling the air by converting sensible heat to latent heat. DEC systems could be divided into: Active DECs which are electrically powered to operate and Passive DECs that are naturally operated systems with zero power consumption. In DEC, the water content of the cooled air increases because air is in contact with the evaporated water. This strategy is useful in dry and hot climates.
- Indirect Evaporative Cooling: Indirect evaporative coolers operate by decreasing air sensible heat without changing its humidity, which is a distinct advantage over DEC systems (the final temperature approached can be dew point instead of wet bulb temperatures). In indirect evaporative cooling, evaporation occurs inside a heat

exchanger and the absolute humidity of the cooled air remains unchanged. This strategy is even more effective in hot and dry climates that DEC and fairly effective for warm and humid climates, too.

EPI for Evaporative Cooler

The efficiency of the evaporative coolers is measured based on the evaporative efficiency which depends on the outside dry bulb temperature and relative humidity of the airstream.

The EPI shall be estimated for Evaporative Coolers as shown below:

EPI = [Total Wattage of fan(s) + Total wattage of pump(s)]
* Hours of operation/ (1000 * Built-up area)

Rationale for EPI calculation for evaporative cooler

Parameters influencing EPI for evaporative cooler are:

Design Parameters	Technology Parameter
• Location (Climate) • Air delivery rate • Pump water circulation rate • Fan and Pump efficiencies	• Direct evaporative cooling • Fan and pump motor types

Controls
Dew point based shut-off controller

The EPI ranges from

User inputs in calculating the EPI shall include:

- Power rating of the fan motor (From nameplate) in watts
- Power rating of the pump motor (From nameplate) in watts

If a residence uses DEC or IEC or any of the natural, ENS Score, or mechanical ventilation strategies for cooling and avoids Carnot cycle based air-conditioning altogether, then it is proposed that it should automatically be able to meet the ENS code without undergoing the rigorous process of showing complete EPI calculation processes. This part has not been codified but remains in this appendix as a proposal that may be considered.

District Cooling

District cooling systems, which typically require about 15% less capacity than conventional distributed cooling systems for the same cooling loads due to load diversity and flexibility in capacity design and installation. District cooling helps in greatly reducing the peak demands and provide new generation capacity to meet cooling demand. District cooling systems are appropriate for densely populated urban areas having mixed uses of buildings with high cooling requirement. It provides enhanced level of reliability and flexibility, as individual building's cooling demand can increase or decrease without the need to change the main plant's capacity.

District cooling indicates central manufacturing and distribution of cooling energy. Chilled water is generated at main plant and then by means of an underground insulated pipeline is provided to the buildings to cool down the interior within a neighbourhood/zone. Specifically, designed devices (HX & pumps, AHUs etc.) in each building utilize this chilled water to decrease the temperature level of air going through the building's cooling system.

Thermal Energy Storage

Thermal storage may be used for limiting maximum demand, by controlling peak electricity load through reduction of chiller capacity, and by taking advantage of high system efficiency during low ambient conditions. Thermal storage would also help in reducing operating cost by using differential time-of-the day power tariff, where applicable.

The storage media can be ice or water. Water needs stratified storage tanks and is mostly viable with large storage capacity and has an advantage of plant operation at higher efficiencies but requires larger storage volumes. In case of central plant, designed with thermal energy storage, its location shall be decided in consultation with the air conditioning engineer. For roof top installations, structural provision shall take into account load coming on the building/structure due to the same. For open area surface installation, horizontal or vertical system options shall be considered and approach ladders for manholes provided. Buried installation shall take into account loads due to movement of vehicles above the area.

Annex E-Smart Home

The concept of smart home is in existence for many decades; however, it has gained further importance in present scenario due to increase in demand for comfort and convenience (with growth of disposal income), increased dependence on appliances, increase in per capita electricity consumption and availability of rooftop solar PV and EV for potential onsite generation and storage respectively.

Alongside these drivers at consumer end; technology advancement in the form of availability of high speed computing devices (smart phones) and affordable internet data, reduction in size of IoT devices / sensors and by shifting sophisticated computing functions to cloud and development of complex algorithms to control systems as per user requirement and preference (using Artificial Intelligence) has provided fresh push to demand of smart home product and services.

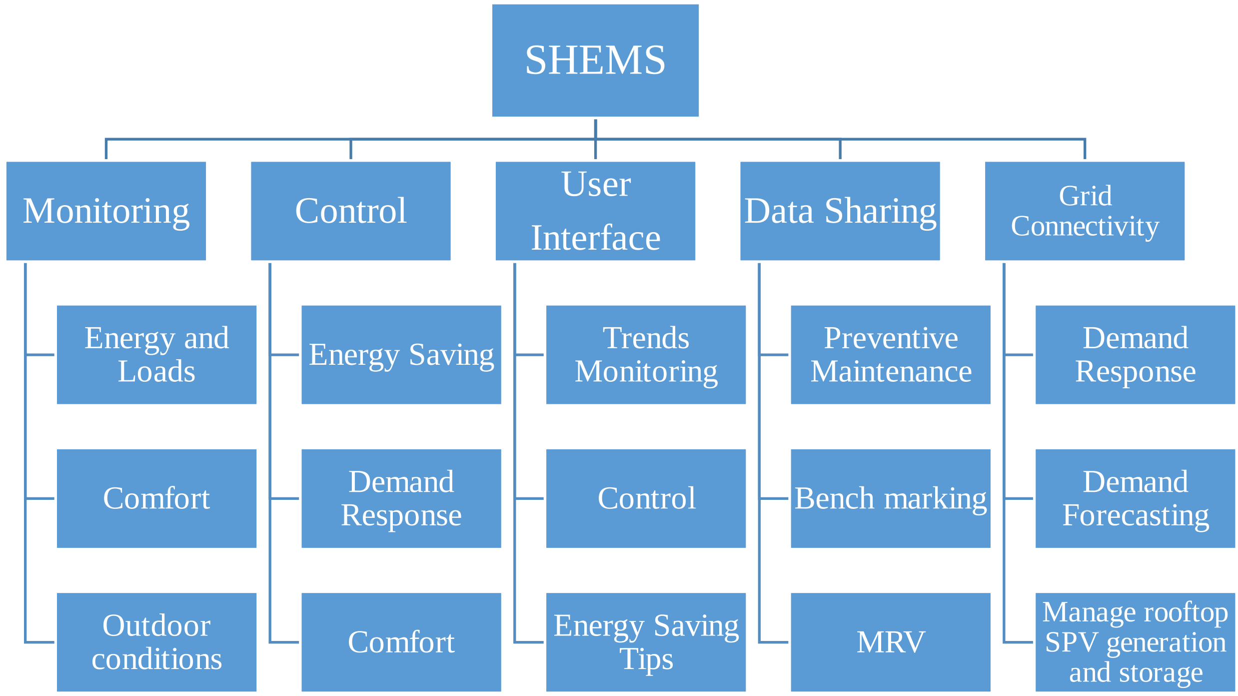
The need of utility-based demand response program to match the variable consumer demand (due to use of diverse appliances) with dynamic electricity supply (due to penetration of renewable energy in grid) is gradually making the smart home solutions a must have product/service in every home, to make it demand response ready.

To manage the energy use in a home in order to make optimum use of these opportunities and for minimizing the demand supply gap, there is need of Smart Home Energy Management System (SHEMS). SHEMS can be defined[44] as the combination of a service and devices that are designed to work together to deliver occupancy-based optimization of energy use. SHEMS[45] consist of hardware and software, which are linked and integrated to, monitor energy usage, provide feedback on energy consumption, enhance control and provide remote access and automation provisions over appliances and devices that use energy in the home. SHEMS can deliver a range of services and benefits to households, which includes:

- Energy management (energy efficiency)
- Demand response (contribute to regulating energy demand)
- Electricity generation, storage and delivery to the grid
- Comfort and convenience

[44] Source: ENERGY STAR® Program Requirements, Product Specification for Smart Home Energy Management Systems,
https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20SHEMS%20Version%201.0%20Program%20Requirements_0.pdf
[45] Source: Sustainable Now, https://sustainable-now.eu/guide-to-home-energy-management-systems/

The functionality of SHEMS can be broadly categorized in five areas that include monitoring, control, user interface, data sharing and grid connectivity. Schematics indicating the functionality of SHEMS and purpose of each functionality is given below:



The above-mentioned functionalities of SHEMS[46] can be operationalized with the support of:

- Physical sensors and devices
- Communication network for data transfer across smart devices, computation and data storage systems
- Data processing, decision making and relay commands as per defined logic or preference
- Smart appliances, devices and actuators to align the physical parameters to required level
- User interface to enable user to monitor, interact with smart home components and convey preferences
- Smart meter to monitor, record the energy consumption, load variation and to facilitate implementation of demand response program

In smart home, energy and cost savings is achieved by:

[46] Source: Based on the analysis conducted as part of BEE-GIZ study on Smart Home: Technology Assessment Study and Pilot Design through technical support of Deloitte Touche Tohmatsu India LLP and Prof. Vishal Garg (IIIT Hyderabad, India)

- Preventing idle running of energy consuming system
- Optimization of adjustable building envelope elements to minimize energy demand
- Optimization of operating parameters to match user preference
- Shifting the operation of non-essential energy consuming systems to off peak time
- Making use of renewable energy generation source, whenever available to meet the energy demand
- Optimization of charging and discharging of storage for cost saving

Smart home has significant potential for saving energy, however, the net energy savings depends on a range of factors, which include:

- The rationale behind automation (comfort or energy saving)
- Level and type of automation used (i.e. occupancy based on/off control or fine tuning of operating parameters based on user preference and weather conditions)
- User behaviour (whether the user just looks at energy monitoring information or uses this information to change settings or change behaviour)
- Power consumption by monitoring and control devices
- Additional power consumption by appliances in standby mode due to inclusion of smart communication features.

Several studies have been undertaken at international level by various public and private agencies, including manufacturer associations, to estimate the energy savings from smart home solutions (product and services). Based on one of them, conducted by the Connected Device Alliance (CDA)[47], energy savings potential in a dwelling enabled with smart home devices and services could be in the range of 20-30% of the present household energy use, subject to the factors mentioned above.

As technologies are optimised, developed and linked with the implementation of further energy efficiency opportunities in homes, the energy savings potential may increase. Smart Home requirement can be added to code along with other benchmarks in the ENS code after suitable characterisation, study, analysis of best practices, and benchmarking.

[47] A case study of barriers and solutions – Smart Home by Connected Device Alliance (CDA), which is a network of more than 350 government and industry participants that have come together to work on the energy efficiency opportunities provided by networked devices. Further information on the CDA is available at: https://cda.iea-4e.org

Notes

Minimum functionality requirement for smart home

To ensure availability of minimum capabilities (regarding monitoring, control, user-interface, data sharing and grid connectivity) and to successfully deliver basic smart home experience to user, a minimum set of smart home devices should to be installed in a home. Table indicating the minimum device/capability requirement for each functionality of SHEMS is provided below:

Functionality	Smart home device and/or solution
Monitoring	• Home level phase-wise energy and load monitoring • Two 15A outlets for energy use monitoring of two appliances • One temperature and humidity sensor • One occupancy sensor
Control*	• One AC Controller to control set point, mode of operations, ON/OFF with provision of receiving control signals • One Geyser Controller for ON/OFF, with provision of receiving control signals • One Controllable light with provision of receiving control signal
User interface	• Common user interface (app, voice or gesture based), to connect smart home devices over single software package for energy use monitoring and control
Grid connectivity	• Able to participate in utility demand response program
Data sharing	• Typical daily indoor conditions, and device-wise energy consumption, and hours of usage to be reported once a month in anonymous way

*All controllable devices to be able take control signals from hub/cloud

Data privacy, cyber security, interoperability, safety and energy efficiency - minimum requirement for smart home devices and components

- All components, devices or elements of smart home that connects "directly or indirectly" to the internet must be equipped with "reasonable" security features, designed to prevent unauthorized access, modification, or information disclosure.
- All components, devices or elements of smart home should follow common standards (for hardware and software), as prescribed by the concerned department for connected

devices, enabling them to discover and communicate with one another, regardless of manufacturer, operating system, chipset or physical transport.

- All components, devices or elements of smart home should have adequate level of fire, electricity and other user health related safety features to avoid potential accidents, hazards and discomfort.
- All components, devices or elements of smart home should be energy efficient and should meet the minimum energy efficiency criteria set by concerned government department.