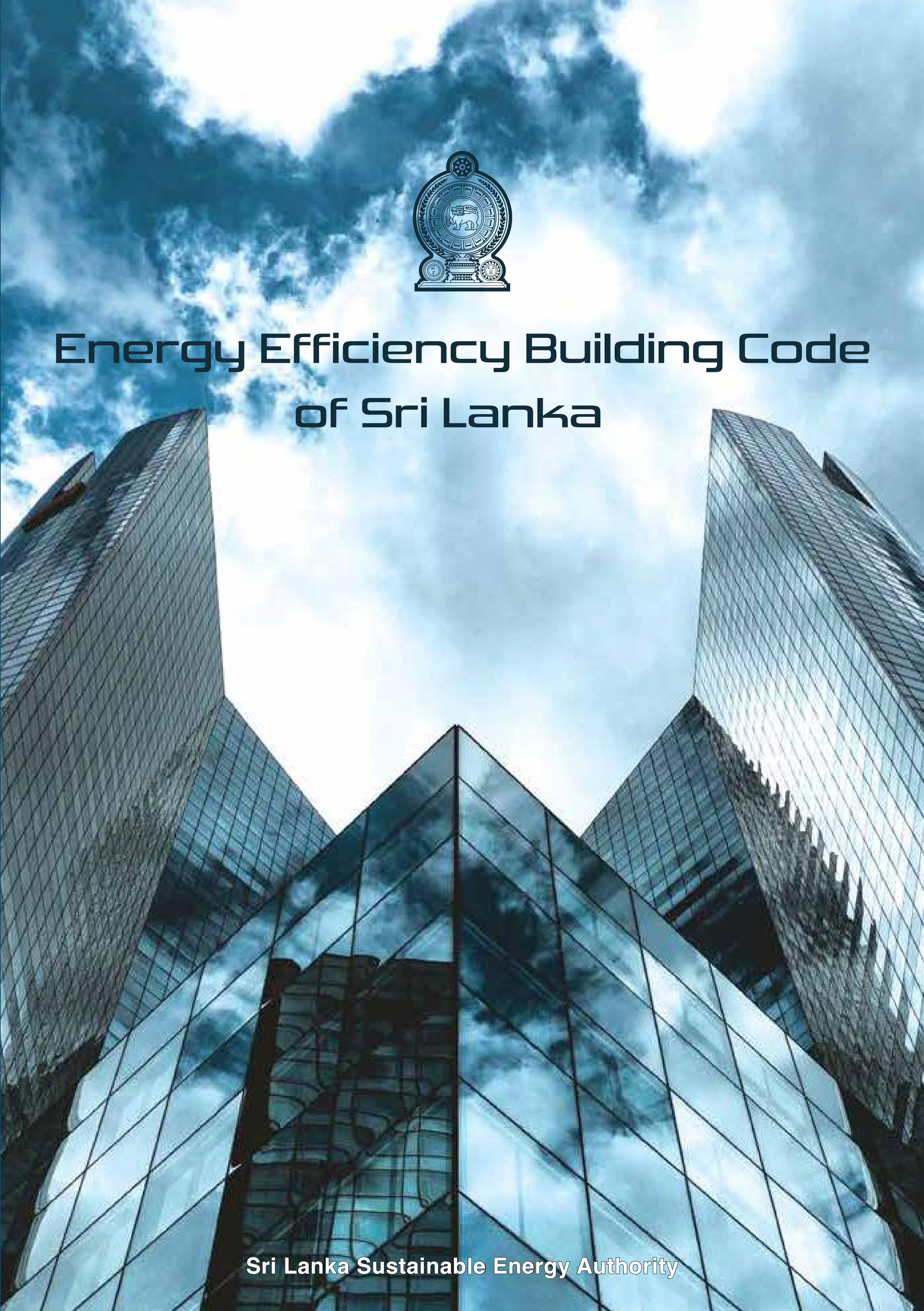

Energy Efficiency Building Code of Sri Lanka

Sri Lanka Sustainable Energy Authority

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Sri Lanka Sustainable Energy Authority
No. 72, Ananda Coomaraswamy Mawatha, Colombo 07, Sri Lanka.

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ISBN: 978-955-1476-27-4

First Printed in Sri Lanka 2021

Disclaimer

The main objective of publishing this Code is to guide the practitioners in the construction industry to reduce the energy use in buildings. Compilation of this was a complex task involving several branches of engineering expertise, sometimes with divergent views and with different objectives. Every attempt was made to satisfy those divergent views to realize a Code acceptable to all practitioners in the construction industry. This does not, however, preclude any errors and omissions, appearing in this Code. Whilst every attempt has been made to verify the data and information provided in this Code, neither the SLSEA nor the compliers of this code assume any responsibility for errors, omissions or inaccuracies. The SLSEA and the compliers of this Code shall in no event be held liable for any loss or other damages incurred from the use of this Code.

Foreword

Government of Sri Lanka recognises that improving the energy performance of buildings is an important part of the strategy in the sustainable energy development process in the country. Sri Lanka Sustainable Energy Authority (SEA) is empowered by Act No. 35 of 2007 to introduce a Code of practice for buildings on efficient energy utilisation, through its Section 36 (2) (f).

The ENERGY EFFICIENCY BUILDING CODE is published by SEA in line with the above regulatory provisions. The original compilation was made by a consultant Co-Energi (Pvt) Ltd which was subsequently developed into several modules by Sri Lanka Suatanable Energy Authority, supported by national experts in the relevant field.

Extensive stakeholder consultations have been made and most of their concerns have been considered in compiling this document.

Wide application of the Code will lead to reduced energy use and lower electricity demand and will contribute towards a cleaner environment through minimisation of energy waste and harmful emissions.

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1 Purpose

1.1

To encourage energy efficient design or retrofit of commercial buildings, industrial facilities excluding the process energy use and large scale housing developments, so that they may be designed, constructed, operated, and maintained in a manner that reduces the use of energy without constraining the building function, comfort, health, or productivity of the occupants and with appropriate regard for economic considerations.

1.2

To provide criteria and minimum standards for energy efficiency in the design of new facilities or retrofits of buildings, their equipment and systems within the purview of this Code and to provide methods for determining compliance with them.

1.3

To encourage energy efficient designs that exceed these criteria and minimum standards.

2 Scope

2.1

This Code sets forth the requirements for design of new facilities or retrofits of commercial buildings, industrial facilities and large scale housing developments and their equipment and systems as covered here.

2.2

This Code covers the following building elements:

a) Building envelope

b) Heating, ventilation and air conditioning

c) Service water heating

d) Electric power distribution

e) Lighting

f) Other equipment

2.3

All commercial buildings, industrial facilities and large scale housing developments meeting any of the following criteria must meet the requirements of this Code:

a) Floor area of 1,000 m^2 or greater

b) Electrical power demand of 500 kVA or greater

c) Air-conditioning cooling capacity above 350 kW_{th} or heating capacity above 250 kW_{th}.

2.4

This Code covers only the energy performance aspects of the building and does not cover other aspects such as health and safety. All other Codes and regulations pertaining to buildings will remain in effect.

3 Definitions, Abbreviations and Acronyms

3.1 Definitions

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

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

Area: see roof, wall, conditioned floor, day-lighting, façade, fenestration,

Authority: the agency or agent responsible for enforcing this standard, *i.e.* Sri Lanka Sustainable Energy Authority

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

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

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

Balancing (hydronic system): adjusting water flow rates through hydronic distribution system devices, such as pumps and coils, by manually adjusting the position valves or by using automatic control devices, such as automatic flow control valves.

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

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

Building: a structure completely or partially enclosed within exterior walls, or within exterior and partition walls, and a roof, affording shelter to persons, animals, or property

Existing building: a building or portion there-of that was previously occupied or approved for occupancy by any authority having jurisdiction

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

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

Exterior building envelope: the elements of a building that separate conditioned spaces from the exterior

Semi-exterior building envelope: the elements of a building that separate conditioned space from unconditioned space or that encloses semi-heated spaces through which thermal energy may be transferred to/from the exterior, or to/from unconditioned spaces, or to/from conditioned spaces

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

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

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

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

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

Control: to regulate the operation of equipment

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

Daylighting area: the daylight illuminated floor area under horizontal fenestration (skylight) or adjacent to vertical fenestration (window)

Demand: the highest amount of power (average kVA over a specific interval) recorded for a building or facility in a selected time frame

Demand Control Ventilation: a ventilation system capability that provides for the automatic reduction of outdoor air intake below design rates when the actual occupancy of spaces served by the system is less than design occupancy

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

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

Design System Efficiency (DSE): Energy efficiency of the building cooling or heating system in view of meeting human thermal comfort under designed operating conditions

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

Direct Digital Control : a type of control where controlled and monitored analog or binary data (e.g., temperature, contact closures) are converted to digital format for manipulation and calculations by a digital computer or microprocessor and then converted back to analog or binary form to control physical devices.

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

Efficiency: an indication of output given out when a unit of input is provided to an equipment, under specific conditions

Emittance: the ratio of the radiant heat flux emitted by a specimen to that emitted by a blackbody at the same temperature and under the same conditions

Energy: the capacity for doing work. It takes a number of forms that may be transformed from one into another such as thermal (heat), mechanical (work), electrical, and chemical. Unit of measurement is Joule (J)

Energy Factor (EF): a measure of overall efficiency used in water heating equipment

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

Equipment, existing: equipment previously installed in an existing building

Facility manager: a person responsible for the management and administration of a Facility

Fasçade: the front of a building, especially a large or attractive building

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

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

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

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

Integrated coefficient of performance ($ICOP_C$): a single-number figure of merit expressing cooling part-load COP efficiency for commercial unitary air-conditioning and heat pump equipment on the basis of weighted operation at various load capacities for the equipment (analogous to IEER, but for SI or other consistent units).

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

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

Kilo Watt (kW): the basic unit of measuring power, equal to 1,000 W

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

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

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

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

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

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

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

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

Manufacturer: the company engaged in the original production and assembly of products or equipment

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

Mechanical cooling: reducing the temperature of a gas or liquid by using vapour compression, absorption, desiccant dehumidification combined with evaporative cooling, or another energy-driven thermodynamic process

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

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

R-valuesa: the reciprocal of the time rate of heat flow through a unit area induced by a unit temperature difference between two defined surfaces of material or construction under steady-state conditions ($m^2 \cdot K/W$)

Seasonal coefficient of performance—cooling ($SCOP_c$): the total cooling output of an air conditioner during its normal annual usage period for cooling divided by the total electric energy input during the same period in consistent units (analogous to SEER but in SI or other consistent units).

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

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

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

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

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

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

Solar Heat Gain Coefficient (SHGC): the ratio of the solar heat entering the space through the fenestration area to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then re-radiated, conducted, or convected into the space

Solar Reflectance Index: a measure of the solar reflectance and emissivity of materials that can be used as an indicator of how hot they are likely to become when solar radiation is incident on their surface

Solar reflectance: a measure of the constructed surface's ability to reflect solar heat, as shown by a small temperature rise

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

Conditioned space: a cooled space, heated space, or indirectly conditioned space defined as follows:

a) **cooled space:** an enclosed space within a building that is cooled by a cooling system whose sensible output capacity is greater than or equal to 10 W/m^2 of floor area.

b) **heated space:** an enclosed space within a building that is heated by a heating system whose output capacity relative to the floor area is greater than or equal to 27 W/m^2 for 3A climatic zone and greater than or equal to 15 W/m^2 for other climatic zones.

c) **indirectly conditioned space:** an enclosed space within a building that is not a heated space or a cooled space, which is heated or cooled indirectly by being connected to adjacent spaces, provided.

1. the product of the U-factors and surface areas of the space adjacent to connected spaces exceeds the combined sum of the product of the U-factors and surface areas of the space adjoining the outdoors, unconditioned spaces, and to or from semi heated spaces (e.g., corridors) or

2. that air from heated or cooled spaces is intentionally transferred (naturally or mechanically) into the space at a rate exceeding 3 air changes per hour (e.g. atria)

d) **Semi-heated space:** An enclosed space within a building that is heated by a heating system whose output capacity is greater or equal to 10 W/m^2 of floor area but is not a conditioned space;

unconditioned space: An enclosed space within a building that is not conditioned space or a semi-heated space. Crawlspaces, attics, and parking garages with natural or mechanical ventilation are not considered enclosed spaces;

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

Thermal emittance: the surface capability to re emit the previously absorbed heat away from itself

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

Transformer: an electrical equipment used to convert electric power available in a circuit from one voltage to another voltage in another circuit

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

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

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

Verification Authority: Sri Lanka Sustainable Energy Authority or an accredited Energy Auditor/Energy Service Provider duly appointed by the Authority.

Wall: that portion of the building envelope, including opaque area and fenestration, that is vertical or tilted at an angle of 60° or more from horizontal.

Window-to-wall ratio: the fraction of the above grade wall area that is covered by fenestration, calculated as the ratio of the wall fenestration area to the gross above grade wall area

3.2 Abbreviations and Acronyms

ASHRAE	-	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	-	American Society for Testing and Materials
COP	-	Coefficient of Performance
DCV	-	Demand Control Ventilation
EF	-	Energy Factor
ETTV	-	Envelope Thermal Transfer Value
HC	-	Heat Capacity
HID	-	High Intensity Discharge (Lamps)
HVAC	-	Heating, Ventilation, and Air Conditioning
ICOP	-	Integrated Coefficient of Performance
IPLV	-	Integrated Part-Load Value
LE	-	Lighting Efficacy
Lin	-	Linear
LPD	-	Lighting Power Density
PF	-	Projection Factor
PMSM	-	Permanent Magnet Synchronous Motor
R	-	R-Value (Thermal Resistance)
RTTV	-	Roof Thermal Transfer Value
SC	-	Shading Coefficient
SCOP	-	Seasonal Coefficient of Performance
SHGC	-	Solar Heat Gain Coefficient
SL	-	Standby Loss
SRI	-	Solar Reflectance Index
TMY	-	Typical Meteorological Year
TR	-	Tons of Refrigerant
VAV	-	Variable Air Volume
VFD	-	Variable Frequency Drives
VSD	-	Variable Speed Drives
VLT	-	Visible Light Transmission
WWR	-	Window to Wall Ratio

3.3 Units

A	-	Ampere
C	-	Celsius
cm	-	centi meter
h	-	hour
K	-	Kelvin
kg	-	kilo gram
kVA	-	kilovolt-ampere
kW	-	kilo Watt
kWh	-	kilo Watt-hour
kW_{th}	-	kilo Watt (thermal)
lm	-	lumen
m	-	meter
mm	-	millimetre
TR	-	Tons of Refrigeration
V	-	Volt
W	-	Watt
Wh	-	Watthour

4 Administration and Enforcement

4.1 General

4.1.1 Scope

The following instances shall comply to the requirements of this Code.

a) New buildings;

b) Additions to existing buildings outside of the existing envelope that adds to the square foot area of the building;

c) Alterations or replacement of portions of existing buildings including envelope, HVAC system, service water heating system, electric power distribution system, lighting and other systems and equipment;

d) Whenever spaces considered to be unconditioned are converted into conditioned spaces;

4.1.2 Other laws and regulations

The provisions of this Code shall not be deemed sufficient to fulfil any provisions of local, sectorial or national laws and regulations. When there is a conflict between a requirement of this Code and such other law affecting construction of the building, precedence shall be determined by the Authority.

4.2 Compliance Paths

4.2.1 New buildings

New buildings shall comply with either the provisions of sections 5, 6, 7, 8, 9 and 10 or section 11 of this Code.

4.2.2 Additions to existing buildings

Additions to existing buildings shall comply with either the provisions of sections 5, 6, 7, 8, 9 and 10 or section 11 of this Code.

Exception to 4.2.2

When the addition by itself cannot meet the provisions of this Code, a trade-off will be allowed by modifying one or more of the existing components, provided that it can be demonstrated that the final energy consumption of the existing building and the addition does not exceed the energy consumption of the existing building and addition if the addition was in compliance.

4.2.3 Alterations or replacements of parts of the building

Alterations or replacements of parts of the buildings shall comply with either the provisions of sections 5, 6, 7, 8, 9 and 10 or section 11 of this Code, provided that such compliance does not result in exceeding the energy consumption of the existing building.

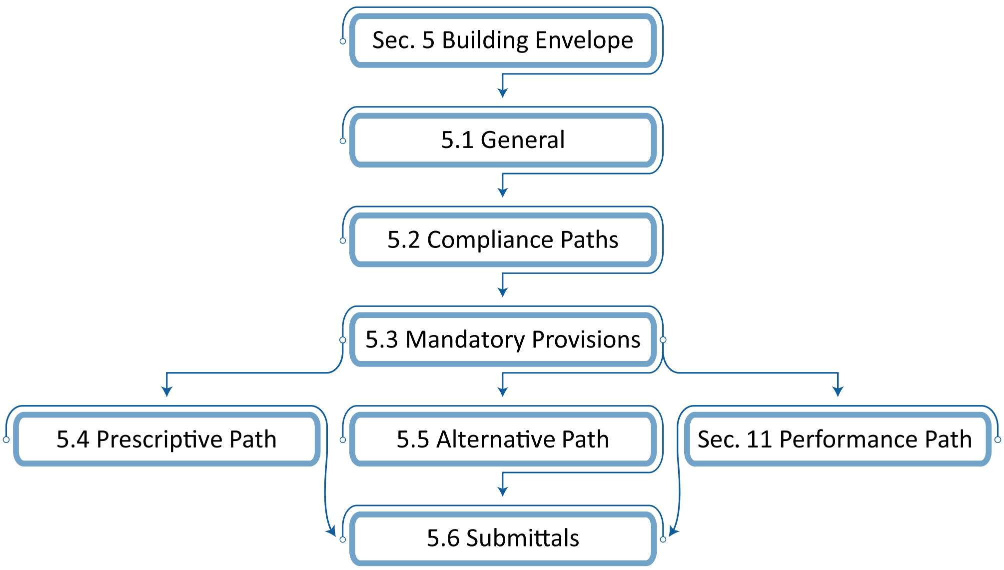
4.3 Compliance Documentation

Compliance documents shall show all the pertinent data and features of the building, equipment, and systems in sufficient detail to permit a determination of compliance with the requirements of this Code. Supplementary information necessary to verify compliance with this standard, such as calculations, worksheets, compliance forms, vendor literature, or other data, shall be made available when required by the Authority. Manuals, verification and commissioning reports shall be submitted as required by the Authority. Submissions shall be made by the facility manager.

5 Building Envelope

Building envelope creates a thermal boundary constituting of walls, roof and floor planes - between the outside environment and the interior of an occupied building space. The building envelope plays an important role with respect to the amount of energy necessary to maintain a thermally and visually comfortable indoor building environment and thus, governs the quantum of energy used - in its operative phase - throughout the entire life of the building.

Primary objective of the design of building envelopes is for the optimisation of thermal performance (cooling or heating, therefore reducing the need for mechanical systems) and daylight use (and therefore a reduced need for artificial lighting).



5.1 General

5.1.1 Scope

5.1.1.1 New buildings, additions and existing building retrofits

New buildings, addition of new sections to existing buildings and retrofits to existing building elements will need to adhere to the conditions stipulated in this section.

5.1.2 Space conditioning types

Separate envelope requirements are specified for each type of conditioned space in,

a) Conditioned buildings with enclosed actively cooled spaces;

b) Conditioned buildings with enclosed actively heated spaces and;

c) Buildings containing unconditioned spaces;

(Note- spaces for above a) and b) are assumed to be conditioned and shall comply with all regulations at the time of construction, regardless whether the equipment for conditioning is installed at that time or not.)

5.1.3 Climate zones

Climate zones shall be classified according to ASHRAE Standard 169-2013 and classifications based on Koppen climatic classification and both will be used as per requirements in this standard. Warm Dry Climates represent Am, Aw and As classified areas according to Koppen climatic classification while Warm Humid refers to the Af climate classified areas and highland refers to areas where Cfb climate can be found. Criteria for classifications are mentioned in Appendix 3. Based on each climate zone, the corresponding outdoor climatic parameters will vary. This will in turn dictate the thermo-physical properties of all building elements.

Table 5.1-1: District classification according to climate zones (populated places are considered)

	District	Climate zones (ASHRAE)	Climate zones
1	Colombo	0A	Warm Humid
2	Gampaha	0A	Warm Humid
3	Kalutara	0A, 1A	Warm Humid
4	Galle	0A, 1A	Warm Humid
5	Matara	0A, 1A	Warm Humid
6	Hambantota	0A	Warm Dry
7	Kandy	0A, 1A, 2A	Warm Humid, Warm Dry
8	Matale	0A, 1A, 2A	Warm Humid, Warm Dry
9	Nuwara-eliya	0A, 1A, 2A, 3A	Uplands, Warm Dry, Warm Humid
10	Badulla	0A, 1A, 2A, 3A	Uplands, Warm Dry, Warm Humid
11	Monaragala	0A	Warm Dry
12	Ratnapura	0A, 1A, 2A	Warm Humid, Warm Dry
13	Kegalle	0A, 1A	Warm Humid
14	Kurunegala	0A	Warm Humid, Warm Dry
15	Puttalam	0A	Warm Dry
16	Anuradhapura	0A	Warm Dry
17	Polonnaruwa	0A	Warm Dry
18	Trincomalee	0A	Warm Dry
19	Batticaloa	0A	Warm Dry
20	Ampara	0A	Warm Dry
21	Jaffna	0A	Warm Dry
22	Vavuniya	0A	Warm Dry
23	Mullaitivu	0A	Warm Dry
24	Mannar	0A	Warm Dry
25	Kilinochchi	0A	Warm Dry

5.1.4 Building typology

All buildings regardless of time of operation (day time /night time) shall comply with the requirements for building code.

5.2 Compliance Paths

5.2.1

For the appropriate climate, space-conditioning category, and building typology, the building envelope shall comply with Section 5.1, General; Section 5.3, Mandatory Provisions; Section 5.6, Submittals; and either

a) Section 5.4, Prescriptive compliance – Provided that;

   1. The window-to-wall ratio does not exceed 40% (WWR≤40%) for each space conditioning category, and;

   2. The skylight fenestration area does not exceed 3% of the gross roof area of each space conditioning category;

b) Section 5.5, Alternative Compliance - Envelope Thermal Transfer Value (ETTV)/ Roof Thermal Transfer Value (RTTV) Option.

5.2.2

Projects using the Performance Option (Section 11 in this Code) shall comply with section 5.3 mandatory provisions of this Code and Section 5.6, Submittals.

5.3 Mandatory Provisions

5.3.1 Air tightness and leakage

The design of the building envelope to prevent uncontrolled air leakage is focussed on minimising any infiltration of pollutants and hot & humid air from the outdoors.

Scope: Applicable to all building envelope elements bounding air conditioned spaces

The following areas of the building envelope shall be sealed, caulked, gasketed or weather- stripped to minimise air leakage for buildings whose occupancy areas are treated other than by natural or any mechanical means of ventilation:

a) Joints around fenestration and doors;

b) Junctions between walls and foundations, between walls and building corners, between walls and structural floors, roofs and between roof or wall panels;

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

d) Site built fenestrations and doors;

e) Building assemblies used as ducts or plenums;

f) Joints, seams and penetrations of vapour retarders;

g) All other openings in the building envelope;

Building or part of which required to be maintained in a positive pressure shall comply with the maximum air leakage levels of the 5% of the fresh air supply.

5.3.2 Visual light transmission (VLT)

Visual transmittance is the amount of light in the visible portion of the spectrum that passes through a glazing material. The mean Visual Light Transmittance (VLT) for all fenestrations shall be greater than 0.3 (VLT≥0.3).

5.3.3 Roof solar reflectance and thermal remittance

Roofs in Climate Zones 0 through 3 shall have one of the following:

a) A minimum three-year-aged solar reflectance of 0.55 and a minimum three-year-aged thermal emittance of 0.75 when tested in accordance with CRRC S100 or any other standard acceptable to the Authority;

b) Minimum Solar Reflectance Index of 64 when determined in accordance with the Solar Reflectance Index method in ASTM E1980 using a convection coefficient of 11.9 $W/m^2.K$ based on three-year-aged solar reflectance and three-year-aged thermal emittance tested in accordance with CRRC S100 or any other standard acceptable to the Authority;

This does not apply for roofs with vegetation, solar panels or insulation that can provide similar effect.

ENVELOPE

05

5.4 Prescriptive Building Envelope Option

Compliance to the Code is achieved by satisfying the prescriptive criteria of each building envelope sub-element discussed in this section. U-values for fasçades, fenestrations and roofs shall be determined from or material properties provided in Appendix 4 or specific data from material manufacturer. The maximum allowable value of window to wall ratio is 40% and Skylight coverage is 3%.

5.4.1 Envelope U value

The exterior building envelope U value shall comply with the requirements in tables 5.4-1 through 5.4-3 for the appropriate climate, conditioned status (Maximum allowable U values are given).

Table 5.4-1: Building envelope requirements for climate zone 'warm-humid'

	Conditioned cooled		Unconditioned	
Walls (maximum U Value) W/m²K	3.25		2.50	
Roofs (assembly maximum U Value) W/m²K	1.30		0.80	
	U-Value*	SHGC	U Value*	SHGC
Fenestration				
WWR Ratio (<40%)	2.84	0.23	2.84	0.23
Skylight				
Skylight Coverage <3% roof area	3.98	0.30	3.98	0.30

**incorporating the frame of the fenestration*
SHGC – Solar Heat Gain Co-efficient

Table 5.4-2: Building envelope requirements for climate zone 'warm-dry'

	Conditioned cooled		Unconditioned	
Walls (maximum U Value) W/m²K	3.25		2.50	
Roofs (assembly maximum U Value) W/m²K	1.30		0.80	
	U-Value*	SHGC	U Value*	SHGC
Fenestration				
WWR Ratio (<40%)	2.84	0.22	2.84	0.22
Skylight				
Skylight Coverage <3% roof area	3.98	0.30	3.98	0.30
**incorporating the frame of the fenestration* *SHGC – Solar Heat Gain Co-efficient*				

Table 5.4-3: Building envelope requirements for climate zone 'upland'

	Conditioned heated		Unconditioned	
Walls (maximum U Value) W/m²K	3.25		2.50	
Roofs (assembly maximum U Value) W/m²K	1.30		0.80	
	U-Value*	SHGC	U Value*	SHGC
Fenestration				
WWR Ratio (<40%)	2.39	0.25	2.39	0.25
Skylight				
Skylight Coverage <3% roof area	3.12	0.30	3.12	0.30
**incorporating the frame of the fenestration* *SHGC – Solar Heat Gain Co-efficient*				

5.4.2 SHGC of vertical fenestration

5.4.2.1 The SHGC for vertical fenestration that incorporates opaque, permanent projections, with a life span that equals that of the building envelope itself shall comply with values prescribed in table 5.4-1 to 5.4-3 for the appropriate climate and conditioned status. (Maximum allowable SHGC values are given)

5.4.2.2 For demonstrating compliance for south, east, or west-oriented vertical fenestration shaded by opaque permanent projections that will last as long as the building itself, the SHGC of the shaded vertical fenestration in the proposed design is permitted to be reduced by using the multipliers in Table 5.4-4.

Table 5.4-4: SHGC Multipliers for Permanent Projections
(adapted from ASHRAE 90.1-2019)

Projection Factor	Projection Factor SHGC Multiplier (South, East, and West Orientations)
0 to 0.1	1.00
0.1 to 0.2	0.91
0.2 to 0.3	0.82
0.3 to 0.4	0.74
0.4 to 0.5	0.67
0.5 to 0.6	0.61
0.6 to 0.7	0.56
0.7 to 0.8	0.51
0.8 to 0.9	0.47
0.9 to 1.0	0.44

5.5 Alternative Path

The overall property of the building envelope is expressed by the indices – Envelope Thermal Transfer Value (ETTV) and Roof Thermal Transfer Value (RTTV) - allowing flexibility and variation in design of its constituent elements.

5.5.1 Envelope Thermal Transfer Value (ETTV)

Building envelope design with an Envelope Thermal Transfer Value (ETTV), computed based on the methodology and guidelines stipulated in this Code.

The ETTV takes into account the three basic components of heat exchange across the external walls and windows of a building. These are: heat conduction across opaque walls, heat conduction across glass windows, and solar radiation through glass windows. These three components of heat exchanges are averaged over the whole envelope area of the building to give an ETTV that represents the thermal performance of the whole envelope.

The maximum allowable ETTV would be 60 W/m^2. The calculation methodology for ETTV is provided in the Appendix 1.

5.5.2 Roof thermal transfer value (RTTV)

Building envelope design with a Roof Thermal Transfer Value (RTTV), computed based on the methodology and guidelines stipulated in this Code.

RTTV takes into consideration the three basic components of heat exchange across the opaque roof and skylights. These are; heat conduction across opaque roof, heat conduction across skylight, and solar radiation through skylight.

The maximum allowable RTTV would be 55W/m^2. The calculation methodology for RTTV is provided in the Appendix 2.

5.6 Submittals

The following documentation shall be submitted for verification of Code compliance.

5.6.1 All floor plans clearly identifying conditioned - cooled spaces, conditioned - heated spaces and unconditioned spaces

5.6.2 All detailed roof plans and sections indicating roof types and fenestration

5.6.3 All detailed sections and elevations indicating overall envelope, wall and fenestration types

5.6.4 Air tightness and leakage data -Test results provided by the professional according to the test methods stipulated in this standard

5.6.5 VLT data – VLT data for all fenestrations certified by an accredited laboratory, nationally recognized organisaion or manufacturer documentation as acceptable to the Authority

5.6.6 SRI data – SRI of roof sub-element certification by an accredited laboratory, nationally recognized organisaion or manufacturer documentation as acceptable to the Authority

5.6.7 For prescriptive building envelope – U value option, the following documentation shall be submitted.

5.6.7.1 Detailed construction of each envelope sub-element;

Detailed construction of each type of wall, and its U value; detailed construction of each type of roof, and its U value; U value and SHGC of each type of fenestration (including skylights) shall be submitted in a schedule.

5.6.7.2 For any item listed in the normative appendix 4, the U values stipulated therein can be used for Code compliance. If any material not in the list is considered, submission shall include proof by an accredited laboratory, nationally recognized organisaion or manufacturer documentation as acceptable to the authority.

5.6.8 For alternative building envelope - ETTV/RTTV option the following documentation shall be submitted.

5.6.8.1 ETTV calculation and RTTV calculation

5.6.8.2 Extracts of the construction specification or material schedules showing the material properties of the façade, fenestration, external walls and roofs. (Certified by an accredited laboratory, nationally recognised organisation or manufacturer documentation as acceptable to the authority)

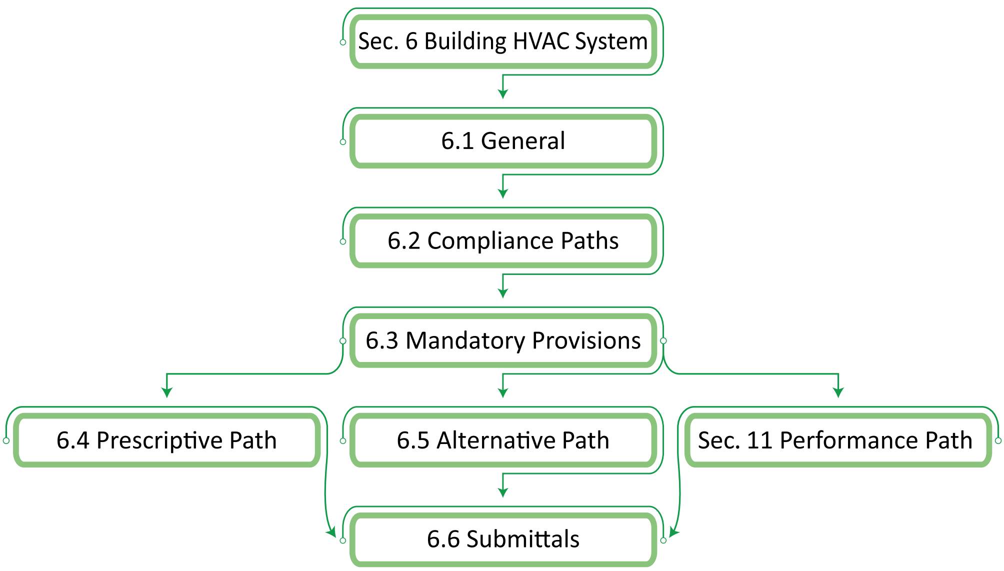
5.6.9 For performance option following documents shall be submitted

5.6.9.1 Extracts of the construction specification or material schedules showing the material properties of the façade, fenestration, external walls and roofs. (Certified by an accredited laboratory, nationally recognised organisation or manufacturer documentation as acceptable to the authority)

6 Heating Ventilation and Air-Conditioning System

Heating ventilation and air-conditioning (HVAC) systems intend to provide comfortable, healthy and safe indoor conditions to its occupants as per the predetermined indoor design parameters, irrespective of the solicitations to which the building is subjected to. The HVAC system of the building has to interact dynamically with the heat gains of the building in order to maintain the intended comfort and/or process conditions. Thus, the energy performance of the HVAC equipment and systems play a very significant role in the overall building energy intensity and also contributes quite much towards the efforts of establishing near net-zero energy buildings, where the energy share of the HVAC systems play a major role in the building's life cycle energy use.

Judicious selection of size and type of HVAC equipment and sub-systems based on the application, local climate zones and integration of proper controls are key aspects of this section.



6.1 General

6.1.1 Scope

6.1.1.1 New buildings

Mechanical equipment and systems serving needs related to heating, ventilation and air-conditioning of new buildings shall comply with the conditions stipulated in this section.

6.1.1.2 Addition to existing buildings

Mechanical equipment and systems serving the heating, ventilation and air-conditioning needs of additions to existing buildings shall comply with the conditions stipulated here.

Exception to 6.1.1.2

When HVAC to a building extension is provided by existing HVAC systems and equipment, such existing systems and equipment shall not be required to comply with this Code. However, any new systems or equipment installed must comply with specific requirements applicable to those systems and equipment.

6.1.1.3 Alterations to HVAC system in existing buildings

6.1.1.3.1 New HVAC equipment as a direct replacement of existing HVAC equipment shall comply with the following sections as applicable for the equipment being replaced:

a) 6.4.6 “Equipment efficiencies”;

b) 6.3.3.1, “Zone thermostatic controls”;

c) 6.3.3.2, “Off-hour controls” except for Section 6.3.3.2.1, 6.3.3.2.2 “Zone isolation”;

d) 6.3.3.3, “Ventilation system controls”;

e) 6.4.1.1 “Fan system power limitation”;

f) 6.4.2.2, “Chiller and boiler isolation”;

g) 6.4.3.1, “Fan speed control”;

6.1.1.3.2 New cooling *systems* installed to serve previously uncooled *spaces* shall comply with this section as described in Section 6.2.

6.1.1.3.3 New and replacement *ductwork* shall comply with Section 6.3.4

6.1.1.3.4 New and replacement *piping* shall comply with Section 6.3.4

Exceptions to 6.1.1.3

Compliance will not be required

1) For equipment that is being modified or repaired but not replaced, provided that such modifications and/or repairs will not result in an increase in the annual energy use of the equipment using the same energy type;
2) Where a replacement or alteration of equipment requires extensive revisions to other systems, equipment, or elements of a building, and such replaced or altered equipment is a like-to-like replacement;
3) For a refrigerant change of existing equipment;
4) For the relocation of existing equipment (if the increase of energy use is within 5% limit) ;
5) For ducts and piping where there is insufficient space or access to meet these requirements;

6.1.2 Space conditioning types

The following space conditioning types fall within the scope of this standard.

a) Enclosed actively cooled spaces;
b) Enclosed actively heated spaces;

6.1.3 Climate

Climate zones shall be determined in accordance with Section 5.1.3.

6.2 Compliance Paths

6.2.1 All facilities with HVAC systems shall comply with Section 6.1, General; Section 6.3, Mandatory Provisions; Section 6.6, Submittals; and either

a) 6.4, Prescriptive Path -Minimum equipment efficiencies option, or;

b) 6.5, Alternative Path -Design system efficiency (DSE) option;

6.2.2 Projects using the performance option (Section 11 of this Code) shall comply with section 6.3 Mandatory provisions of this Code and section 6.6 Submittals.

6.3 Mandatory Provisions

6.3.1 Product information verification & testing requirement

6.3.1.1 Product information (capacity, minimum equipment efficiency, etc.) pertaining to listed equipment in this section, under standard or non-standard conditions as per section 6.4.1.2 in ASHRAE 90.1-2019, shall be certified by a nationally recognized entity in the relevant technical field or nameplate, label or certification provided by the manufacturer certified by an accredited laboratory, as acceptable to the Authority

6.3.1.2 Product information pertaining to equipment not listed in this section shall be certified by an accredited laboratory or nameplate, label or certification provided by the manufacturer as acceptable to the Authority.

6.3.2 Load calculation

6.3.2.1 Calculation procedure

Cooling and heating system design loads for the purpose of sizing the relevant systems and equipment shall be determined in accordance with the procedures described in the latest edition of the ASHRAE Handbook or equivalent or by using computer simulation software, whereas for buildings whose conditioned floor area greater than 5,000 m^2, load calculations shall be done by computer simulation software acceptable to the Authority.

Following design conditions shall be considered for load calculation.

6.3.2.2 Indoor design condition

It is recommended to design the indoor thermal conditions of a conditioned space for a dry bulb temperature of 25 °C ± 1.5 °C and relative humidity of 55 % ± 10 % in case of actively cooled conditioned spaces and dry bulb temperature of 20 °C ± 1.5 °C and relative humidity of 55 % ± 10 % in case of actively heated conditioned spaces. The said conditions shall be considered differently and governed by the need for special applications such as hotels, medical care, sports-related spaces and laboratories, etc.. Indoor thermal conditions from perspectives other than human thermal comfort shall not be considered here. The combination of suitable high temperatures and humidity may be used within the comfort zone for energy saving purposes, provided that the conditions maintained herein are agreeable and acceptable to the occupants.

6.3.2.3 Outdoor design condition

These design values shall depend on the climate zone considered. The outdoor conditions (Dry and wet bulb temperatures) shall be decided by analysing hourly data for at least an year from the nearest weather stations data obtained form the Department of Meteorology of Sri Lanka . For computer software-simulated designs that require detailed climate data, data from Climatologic Tables from the Meteorological Department of Sri Lanka, SWERA, TMY2 or any equivalent acceptable to the Authority may be used.

6.3.2.4 Fresh air and exhaust

Fresh air rates supplied to each occupied space shall comply with those stipulated in ASHRAE 62.1-2007 Standard or latest as per the space category type, in view ensuring acceptable indoor air quality. The simplified table below shall be used as general guidance for office spaces in lieu of the ASHRAE 62.1-2007 standard.

Total fresh air volume = (per person rate x number of occupants) + (area rate x area)

Table 6.3-1: Fresh air rates for a typical office building (adapted from ASHRAE 62.1-2007)

Per person rate (m^3/h)	Area rate ($m^3/h/m^2$)
8.5	1.0

Use of Demand Control Ventilation (DCV) is recommended for high occupancy and/ or critical zones by means of using CO_2 sensors or any appropriate means. Special attention is needed for fresh air requirement when VAV systems are employed (zones exceeding 25 people per 100m^2) when the fraction of the cooling loads tends to get reduced at lighter climatic conditions for the same occupancy level. This may lead to a situation of insufficient fresh air for the occupants.

Exhaust air quantity shall also be estimated based on the fresh air supply considering the level of static pressure that must be maintained in the zone matching its intended application.

6.3.2.5 Equipment capacity selection

The equipment and systems serving needs related to ventilation and air-conditioning of the buildings shall be sized based on information and procedures for load estimation as per 6.3.2.1 above together with standard engineering practices and consistent with existing equipment sizes.

6.3.2.6 Equipment Type selection

Water cooled type chillers shall be used when cooling load is higher than 500TR. If there is any practical difficulty which prevents this, air cooled chiller can be used with a justification submitted to the Authority

6.3.3 Controls

6.3.3.1 Zone thermostatic controls

Cooling and heating energy requirement of each zone shall be individually controlled in response to the zone temperature.

Each thermostat in operation in turn will control the input of cooling energy, thereby resulting in effective economic control in response to the requirement of the zone.

Exception to 6.3.3.1

Independent perimeter zones designed to accommodate building envelop loads.

Temperature sensors shall be located in the zone or the return air path. The recommended interior temperature set by a thermostat provided for each zone shall be as per 6.3.2.2 of this section. However, temperatures higher than the designed indoor temperatures can be set by the zone thermostat, if necessary.

6.3.3.2 Off-hour control

HVAC systems shall be equipped with automatic controls capable of accomplishing a reduction of energy use through equipment shut down or increase in the temperature setpoint, during periods of non-use or alternative use of the spaces served by the system. In case of scheduled long-term shutdowns of equipment, arrangements must be made to isolate the power supply to the crankcase heaters.

Exceptions to 6.3.3.2

a) Systems serving areas that are expected to operate continuously;

b) Equipment with a connected load of 2 kW or less may be controlled by readily accessible manual off-hour controls;

6.3.3.2.1 Automatic operation

HVAC systems shall be equipped with one of the followings:

a) Controls that can start/stop equipment as per a pre-determined programmed time schedule(including fresh air purging);

b) Occupancy sensors;

c) Manually operated timer system;

d) Interlocked system coupled with the security system that will be activated when the security system is on;

Exception to 6.3.3.2.1

Residential systems

6.3.3.2.2 Zone Isolation

Systems that serve zones that can be expected to operate non-simultaneously for more than 300 hours per year shall include isolation devices and controls to shut off the supply of cooling to each zone independently. For central systems and plants, controls and devices shall be provided to allow stable system and equipment operation for any length of time while serving only the smallest isolation area served by the system or plant. Isolation is not required for zones that are expected to operate continuously.

Isolation areas may be pre-designed for buildings where occupancy patterns are not known at the time of the system design, such as in speculative buildings. Zones may be grouped into a single isolation area provided that the total conditioned floor area does not exceed 250 m^2 per group nor includes more than one floor.

6.3.3.2.3 Optimum start control

Cooling and heating systems with total design air supply flow rates greater than 17,000 m^3/hr supplied by a single fan shall have optimum start control that decides the amount of time period of system operation before the scheduled occupancy.

6.3.3.3 Ventilation system controls

Stair and elevator shafts shall be equipped with motorised dampers capable of being shut during normal operation but that shall come into operation in case of fire or smoke detection. This shall be used in compliance with relevant fire regulations in force.

All outdoor air supply and exhaust air related to vents and ventilation shall be equipped with motorised dampers that will automatically shut down when spaces served are not in use. If manual intervention could be ensured, manual switching off and/or modulating may be accommodated.

Exception to 6.3.3.3

Non-motorised systems and ventilation systems catering to unconditioned spaces

6.3.4 HVAC system construction and insulation

6.3.4.1 Duct and plenum insulation

All air handling ducts and plenum installed as a part of the HVAC air distribution system shall be thermally insulated in accordance with Minimum duct insulation R-values[a] given in the Table 6.3-3 below:

Table 6.3-2: Minimum duct insulation R-values[a] (adapted from ASHRAE 90.1-2019)

Climate zone	Duct location		
	Exterior [b]	Unconditioned space and burled ducts	Indirectly conditioned space [c,d]
Supply and return ducts for heating and cooling			
0 to 3	R-1.41	R-1.06	R-0.34
Supply and return ducts for heating only			
0 to 1	None	None	None
2 to 3	R-1.06	R-1.06	R-0.34
Supply and return ducts for cooling only			
0 to 3	R-1.41	R-1.06	R-0.34

a) *Insulation R-values, measured in* m²·K/W, *is for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapour transmission and possible surface condensation. Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 24°C at the installed thickness.*

b) *Includes attics above insulated ceilings, parking garages and crawl spaces.*

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

d) *Return ducts in this duct location do not require insulation.*

Exceptions to 6.3.4.1

Duct insulation is not required in any of the following cases:

a) Factory-installed plenums, casings or ductwork furnished as a part of HVAC equipment, provided that they are either insulated at the factory or installed in a conditioned space.

b) Exhaust air ducts;

c) Outdoor air ducts;

d) Return air ducts within conditioned space;

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6.3.4.2 Duct and plenum leakage levels

Ductwork and plenums shall be sealed in accordance with standard industry practice as defined in SMACNA 1995 (Sheet Metal and Air Conditioning Contractors' National Association, HVAC Duct Construction Standards - Metal & Flexible, 1995).

6.3.4.3 Piping insulation

All chilled water piping in an HVAC system shall be thermally insulated in accordance with Table 6.3-4 below. This provides not only to reduce heat gain from the outside, but also to avoid condensation on the surface of the installation. In this regard, the insulation shall be suitably protected from damage and reference is expected to be made to the insulation manufacturer's catalogue.

Table 6.3-3: Minimum piping insulation thickness in mm
(Adapted from ASHRAE 90.1-2019)

Fluid design	Insulation conductivity		Nominal pipe or tube size (mm)				
Operating temp. range (°C)	Conductivity (W/mK)	Mean rating temp. °C	<25	25 to <40	40 to <100	100 to <200	>200
Heating systems (steam, steam condensate, and hot water) related to HVAC system							
>177	0.046-0.049	121	162.5	193.0	193.0	259.0	259.0
122-177	0.042-0.046	93	96.5	162.55	193.0	193.0	193.0
94-121	0.039-0.043	66	96.5	96.5	129.5	129.5	129.5
61-93	0.036-0.042	52	63.5	63.5	63.5	96.5	96.5
41-60	0.032-0.040	38	33.0	33.0	63.5	63.5	63.5
Cooling systems (chilled water, brine, and refrigerant)							
16-4	0.032-0.040	38	33.0	33.0	63.5	63.5	63.5
<4	0.032-0.040	38	33.0	63.5	63.5	63.5	96.5

Exceptions to 6.3.4.3

Piping insulation shall not be required in any of the following areas:

a) Piping that conveys fluids that have a design temperature above 20° C.

Note that if the indoor designed conditions are exceeded, insulation may require a higher temperature piping to prevent condensation;

6.3.4.4 Water Treatment Systems

Chill water or water cool package type air conditioning plants equal or above 100 TR shall be installed with appropriate size water treatment systems to minimize scaling to achieve energy saving.

6.3.4.5 Hot water boilers used for space heating applications

Hot water boilers used for hot air generation HVAC shall comply with requirements in section 7 as applicable.

6.4 Prescriptive Path – Minimum Equipment Efficiencies Option

6.4.1 Air system design and control

Each HVAC systems having total fan system power exceeding 3.5 kW shall meet the provisions below:

6.4.1.1 Fan system power limitation

The fan system motor name plate power (kW) of each HVAC system at design conditions shall not exceed the values given in following Table 6.4-1.

Table 6.4-1: Fan power limitation (adapted from ASHRAE 90.1-2019)

	Limit	Constant volume	Variable volume
Fan system motor nameplate kW	Allowable nameplate motor kW	kW <Vx0.0017	kW <Vx0.0024

Where;

V = the maximum design supply airflow rate to conditioned spaces served by the system in litres per second

kW = the maximum combined motor nameplate in kW

6.4.1.2 VAV fan control

6.4.1.2.1 Part load fan power limit

Individual VAV fans with motors 10kW and above shall meet one of the following requirements

a) Fan shall be driven by a mechanical or electrical variable speed drive, but electrical drive is preferred;

b) Fan shall be of variable pitch blades;

6.4.1.2.2 Static pressure sensor location

Static pressure sensors used to control VAV fans shall be located such that the controller set pointis no greater than 3 cm of water. If this results in the sensor being located downstream of major duct splits, sensors shall be installed in each major branch to ensure that static pressure can be maintained in each branch.

6.4.1.2.3 Set point reset

For multiple-zone VAV systems with Direct Digital Control *(DDC)* of individual zones reporting to the central control panel, static pressure set point shall be reset,based on the zone requiring the maximum pressure; *i.e.*, the setpoint is reset lower until one zone damper is nearly wide open.

6.4.2 Hydronic system design and control

6.4.2.1 Hydronic variable flow systems

Chilled and hot-water distribution systems that include three or more control valves designed to modulate or step open and close as a function of load shall be designed for variable fluid flow and shall be capable of and configured to reduce pump flow rates to no more than the larger of 25% of the design flow rate or the minimum flow required by the heating/cooling equipment manufacturer for the proper operation of equipment.

Individual or parallel pumps serving variable-flow heating-water or chilled-water systems, where the nameplate horsepower of the motor or combined parallel motors is at least 7 kW shall have controls or devices that will result in pump motor demand of no more than 30% of design wattage at 50% of design water flow.

Controls and devices shall be controlled as a function of desired flow or to maintain minimum required differential pressure. Differential pressure shall be measured at the most remote/critical heat exchanger coil.

6.4.2.2 Chiller and boiler isolation

When a chilled water plant includes more than one chiller, provisions shall be made so that the flow in the chiller plant can be automatically reduced, correspondingly, when a chiller is shut down. Chillers referred to in this section, piped in series for the purpose of increased temperature differential, shall be considered as one chiller.

When a boiler plant includes more than one boiler, provisions shall be made so that the flow in the boiler plant can be automatically reduced, correspondingly, when a boiler is shut down.

6.4.2.3 Water temperature reset controls

Chilled and hot water systems with a design capacity exceeding 90kW thermal supplying chilled or heated water (or both) to comfort conditioning systems shall include controls that automatically reset supply water temperatures by representative building loads (including return water temperature) or by the outdoor air temperature.

Exceptions to 6.4.2.3

a) Variable flow systems;

b) when such rest control causes improper operation;

6.4.3 Heat rejection equipment

Heat rejection equipment employed in cooling systems such as air-cooled condensers, open cooling towers, closed-circuit cooling towers, and evaporative condensers are covered here.

Exception to 6.4.3:

Heat rejection devices whose energy usage is included in the equipment efficiency ratings presented in section 6.4.6 below:

6.4.3.1 Fan speed control

Each fan powered by a motor of 5.0 kW or larger shall have the capability to operate that fan at two-thirds of full speed or less and shall have controls that automatically change the fan speed to control the leaving fluid temperature or condensing temperature/pressure of the heat rejection device.

Exceptions to 6.4.3.1

a) Condenser fans serving multiple refrigerant circuits

b) Condenser fans serving flooded condensers

c) Open type cooling towers in warm-humid climate

6.4.4 Energy recovery

6.4.4.1 Exhaust energy recovery

Individual fan systems that have both a design supply air capacity of 8,500m^3/hr or greater and have a minimum outdoor air supply of 70% or greater of the design supply air quantity shall have an energy recovery system with at least 50% recovery effectiveness.

Exceptions to 6.4.4.1

a) Laboratory systems;

b) Hospitals and other related applications

c) Systems exhausting toxic material and commercial kitchens;

d) Systems requiring dehumidification with a series cooling coil;

e) Systems in which more than 50% of outdoor air heated by on-site solar energy;

6.4.4.2 Heat recovery for service water

Condenser heat recovery shall be installed for pre-heating service water for systems if all of the following requirements are satisfied.

a) The facility operates 24 hours a day;

b) The total installed heat-rejection capacity of the water-cooled systems exceeds 1,800 kW of heat rejection;

c) The design service water-heating load exceeds 273 kW;

6.4.5 Hot gas bypass

Cooling systems shall not use hot gas bypass or other evaporator pressure control systems unless the system is designed with multiple steps of unloading or continuous capacity modulation.

6.4.6 Equipment efficiencies

Equipment to be selected to meet not less than the minimum energy performance stipulated in Table 6.4-2 to Table 6.4-6.These tables indicate minimum performance requirements for equipment at specified rating conditions as per the stipulated standard in the table for Ceiling Fans, Unitary Air conditioners, VRF Systems, chillers, heat rejection equipment and heat pumps. The information are based on ASHRAE 90.1-2019, BEE-ECBC-2017 and Sri Lanka Standards.

Table 6.4-2: Electrically operated ceiling fans, unitary air conditioners and condensing units – Minimum efficiency requirements

Equipment type	Size category	Subcategory or rating condition	Minimum efficiency	Test procedure[a]
Ceiling Fans	Swept Dia:1400 mm	2 or more blades with regulator having minimum of 5 speed settings	At least 1 star	SLS 1600 :2011
Air Conditioners, air cooled	<19kW	Split system	2.75 COP[b]	AHRI 210/240 or as per latest
Air Conditioners, air cooled	≥19kW and<40kW	Split system and Single package	3.22 COP_C 3.76 $ICOP_C$	AHRI 340/360 or as per latest
	≥40kW &<70kW		3.17 COP_C 3.58 $ICOP_C$	
Air conditioners, air cooled (continued)	≥70kW and <223kW	Split system and single package	2.87 COP_C 3.34 $ICOP_C$	AHRI 340/360 or as per latest
	≥223kW		2.78 COP_C 3.22 $ICOP_C$	

Equipment type	Size category	Subcategory or rating condition	Minimum efficiency	Test procedure[a]
Air conditioners, water cooled	<19kW	Split system and single package	3.55 COP_C 3.60 $ICOP_C$	AHRI 210/240 or as per latest
	≥19kW and<40kW		3.49 COP_C 4.02 $ICOP_C$	AHRI 340/360 or as per latest
	≥40kW and<70kW		3.60 COP_C 4.02 $ICOP_C$	
	≥70kW and<223kW		3.58 COP_C 3.93 $ICOP_C$	
	≥223kW		3.52 COP_C 3.90 $ICOP_C$	
Air conditioners, evaporatively cooled	<19kW	Split system and single package	3.55 COP_C 3.60 $ICOP_C$	AHRI 210/240 or as per latest
	≥19kW and<40kW		3.49 COP_C 3.55 $ICOP_C$	AHRI 340/360 or as per latest
	≥40kW and<70kW		3.46 COP_C 3.52 $ICOP_C$	
	≥70kW and <223kW		3.43 COP_C 3.49 $ICOP_C$	
	≥223kW		3.37 COP_C 3.43 $ICOP_C$	
Condensing units, air cooled	≥40kW	-	3.08 COP_C 3.46 $ICOP_C$	AHRI 365 or as per latest
Condensing units, water cooled	≥40kW	-	3.96 COP_C 4.10 $ICOP_C$	AHRI 365 or as per latest
Condensing units, evaporatively cooled	≥40kW	-	3.96 COP_C 4.10 $ICOP_C$	AHRI 365 or as per latest

a) Section 12 in ASHRAE 90.1-2019 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure. Any other international test standard also can be used as accepatable to the Authority.

b) As per Energy Labelling Standard for Single Split Type Room Air Conditioners in Sri Lanka (SLS 1586 : 2018) The revised EER values as per Sri Lanka Standard for Single Split Type Room Air Conditioners corresponding to values in this table will supersede as and when the revised standards are published.

Electricity operated variable-refrigerant-flow minimum efficiency requirements

Table 6.4-3: Electrically operated variable – refrigerant – flow minimum efficiency requirements

Equipment type	**Size category**	**Subcategory or rating condition**	**Minimum efficiency**	**Test procedure**[a]
VRF air cooled (cooling mode)	<19kW	*VRF* multi split *system*	3.28 COP_C 4.36 $ICOP_C$	AHRI 1230 or as per latest
VRF air cooled (cooling mode)	≥19kW and <40kW	*VRF* multi split *system*	3.22 COP_C 4.28 $ICOP_C$	AHRI 1230 or as per latest
VRF air cooled (cooling mode)	≥19kW and <40kW	*VRF* multi split *system* with heat recovery	3.16 COP_C 4.22 $ICOP_C$	AHRI 1230 or as per latest
VRF air cooled (cooling mode)	≥40kW and <70kW	*VRF* multi split *system*	3.11 COP_C 4.07 $ICOP_C$	AHRI 1230 or as per latest
VRF air cooled (cooling mode)	≥40kW and <70kW	*VRF* multi split *system* with heat recovery	3.05 COP_C 4.01 $ICOP_C$	AHRI 1230 or as per latest
VRF air cooled (cooling mode)	≥70kW	*VRF* multi split *system*	2.78 COP_C 3.72 $ICOP_C$	AHRI 1230 or as per latest
VRF air cooled (cooling mode)	≥70kW	*VRF* multi split *system* with heat recovery	2.73 COP_C 3.66 $ICOP_C$	AHRI 1230 or as per latest
VRF water source (cooling mode)	≤19kW	*VRF* multi split *system* 30°C entering water	3.52 COP_C 4.69 $ICOP_C$	AHRI 1230or as per latest
VRF water source (cooling mode)	≤19kW	*VRF* multi split *system* with heat recovery 30°C entering water	3.46 COP_C 4.63 $ICOP_C$	AHRI 1230or as per latest
VRF water source (cooling mode)	≥19kW and <40kW	*VRF* multi split system 30°C entering water	3.52 COP_C 3.69 $ICOP_C$	AHRI 1230or as per latest
VRF water source (cooling mode)	≥19kW and <40kW	*VRF* multi split *system* with heat recovery 30°C entering water	3.46 COP_C 4.63 $ICOP_C$	AHRI 1230or as per latest

Equipment type	Size category	Subcategory or rating condition	Minimum efficiency	Test procedure[a]
VRFwater source (cooling mode)	≥40kW and <70kW	*VRF multi split system* 30^{0}C entering water	2.93 COP_C 4.10 $ICOP_C$	AHRI 1230or as per latest
		VRF multi split system with heat recovery 30^{0}C entering water	2.87 COP_C 3.52 $ICOP_C$	
	≥70kW	*VRF multi split system* 30^{0}C entering water	2.93 COP_C 3.52 $ICOP_C$	
		VRF multi split system with heat recovery 30^{0}C entering water	2.87 COP_C 3.46 $ICOP_C$	

a) Section 12 in ASHRAE 90.1-2019 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure. Any other international test standard also can be used as acceptable to the Authority.

b) This value is used as per Indian Energy Conservation Building Code-2017.

Water chilling packages–minimum efficiency requirements

Table 6.4-4: Water chilling packages – Minimum efficiency requirements

Equipment type	Size category	Units	Minimum efficiency	Test procedure[a]
Air cooled, electrically operated	<528kW	COP	2.98 FL 4.048 IPLV	AHRI 550/590 or as per latest
	>528kW		2.985 FL 4.137 IPLV	
Water cooled, electrically operated, positive displacement	<264kW	COP	4.694 FL 5.867 IPLV	AHRI 550/590 or as per latest
	264-528 kW		4.889 FL 6.286 IPLV	
	528-1,055 kW		5.334 FL 6.519 IPLV	

Equipment type	Size category	Units	Minimum efficiency	Test procedure[a]
Water cooled, electrically operated, positive displacement	1,055-2,110 kW		5.771 FL 6.770 IPLV	AHRI 550/590 or as per latest
	>2,110 kW		6.286 FL 7.041 IPLV	
Water cooled, electrically operated, centrifugal	<528 kW	COP	5.771 FL 6.401 IPLV	AHRI 550/590 or as per latest
	528-1,055 kW		5.771 FL 6.401 IPLV	
	1,055-1,407 kW		6.286 FL 6.770 IPLV	
	1,407-2,110 kW		6.286 FL 7.041 IPLV	
	>2,110 kW		6.286 FL 7.041 IPLV	
Air-cooled absorption single effect	All capacities	COP	0.6 FL	AHRI 560 or as per latest
Water-cooled absorption single effect	All capacities	COP	0.7 FL	AHRI 560 or as per latest
Absorption double effect, indirect-fired	All capacities	COP	1.0 FL 1.05 IPLV	AHRI 560 or as per latest
Absorption double effect, indirect-fired	All capacities	COP	1.0 FL 1.0 IPLV	AHRI 560 or as per latest

a) *The requirements for centrifugal chillers shall be adjusted for nonstandard rating conditions per Section 6.4.1.2.1 in ASHRAE 90.1-2019 and are only applicable for the range of conditions listed there. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure. Any other international test standard also can be used as accepatable to the Authority.*

b) *Both the full-load and IPLV.IP requirements must be met or exceeded to comply with this standard.*

c) *Section 12of ASHRAE 90.1-2019 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.*

d) *FL is the full-load performance requirements, and IPLV.IP is for the part-load performance requirements.*

Performance requirements for heat rejection equipment

Table 6.4-5 : Heat rejection equipment – Minimum efficiency requirement

Equipment type	Total system heat rejection capacity at rated conditions	Subcategory or rating condition	Performance required[a],[b]	Test procedure[c,d]
Propeller or axial fan cooling towers	All	35°C entering water 29°C leaving water 27°C wet bulb outdoor air	≥3.4 l/(s·kW)	CTI ATC-105 and CTI STD-201 or as per latest
Centrifugal fan cooling towers	All	35°C entering water 29°C leavingwater 27°C wet bulb outdoor air	≥1.7 l/(s·kW)	CTI ATC-105 and CTI STD-201 or as per latest
Air-cooled Condensers	All	52°C condensing temperature 88°C entering gas temperature 8°C sub-cooling 35°C entering dry bulb	≥69 COP_c (kW (thermal)/ kW(electrical))	AHRI 460or as per latest

a) *For purposes of this table, cooling tower performance is defined as the water flow rating of the tower at the thermal rating condition divided by the fan motor nameplate power.*

b) *For purposes of this table, air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the total fan motor nameplate power of the unit.*

c) *Section 12 of ASHRAE 2019 standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure. Any other international test standard also can be used as acceptable to the Authority.*

d) *The efficiencies and test procedures for cooling towers are not applicable to hybrid cooling towers that contain a combination ofseparate wet and dry heat exchange sections. The certification requirements do not apply to field-erected cooling towers.*

Heat pumps — Minimum efficiency requirements

Table 6.4-6: Heat pumps — Minimum efficiency requirements

Equipment type	Size category	Subcategory or rating condition	Minimum efficiency	Test procedure[a]
Air cooled (heating mode)	<19 kW (cooling capacity)	Split system	2.40 $SCOP_H$	AHRI 210/240-2017 or as per latest
		Single package	2.34 $SCOP_H$	
Space constrained, aircooled (heating mode)	≤9 kW (cooling capacity)	Split system	2.17 $SCOP_H$	
		Single package	2.17 $SCOP_H$	
Air cooled (heating mode)	≥19 kW and <40 kW	8.3°C dry bulb /6.1°C wet bulb outdoor air	3.30 $SCOP_H$	AHRI 340/ 360 or as per latest
		-8.3°C dry bulb /-9.4°C wet bulb outdoor air	2.25 $SCOP_H$	
	≥40 kW and <70 kW (cooling capacity)	8.3°C dry bulb/6.1°C wet bulb outdoor air	3.20 $SCOP_H$	
		-8.3°C dry bulb/-9.4°C wet bulb outdoor air	2.05 $SCOP_H$	
	≥40 kW (cooling capacity)	8.3°C dry bulb/6.1°C wet bulb outdoor air -8.3°C dry bulb/-9.4°C wet bulb outdoor air	3.20 $SCOP_H$ 2.05 $SCOP_H$	
VRF Water source (heating mode)	<19 kW (cooling capacity)	20°C entering water	4.3 $SCOP_H$	AHRI 1230 or as per latest
	≥19 kW and <40 kW		4.3 $SCOP_H$	
	≥ 40 kW and<70 kW (cooling capacity)		4.0 $SCOP_H$	
	≥70 kW (cooling capacity)		3.9 $SCOP_H$	

Equipment type	Size category	Subcategory or rating condition	Minimum efficiency	Test procedure[a]
VRF Groundwater source (heating mode)	<40 kW (cooling capacity)	10°C entering water	3.6 *COPH*	AHRI 1230or as per latest
	≥ 40 kW (cooling capacity)		3.3 $SCOP_H$	
VRF Ground source (heating mode)	<40 kW (cooling capacity)	0.0°C entering water	3.1 $SCOP_H$	
	≥ 40 kW		2.8 $SCOP_H$	

a) *Section 12 in ASHRAE 90.1-2019 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure. Any other international test standard also can be used as acceptable to the Authority.*

6.5 Alternative Path – Design System Efficiency Option

An alternative compliance path is provided in the standard based on Design System Efficiency (DSE) estimated based on the computed design load profile and each of the sub system performance.

For compliance, design must meet DSE (sections 6.5.1 or 6.5.2) minimum thresholds AND air handling system efficiency (6.5.3) minimum thresholds.

6.5.1 Water cooled system DSE

The design system efficiency (DSE) of the chilled water plant shall be established based on the computed operational design load profile together with the power inputs of various subsystem components at their respective operating load condition as described in the design, including the energy-related to chilled water circulation.

The following minimum design system efficiencies must be met:

Table 6.5-1: Water cooled system — Minimum design system efficiency (DSE)

Max building cooling load ≤ 500 TR	Max building cooling load > 500 TR
0.8 kW/TR	0.7 kW/TR

6.5.2 Air cooled system DSE

The design system efficiency (DSE) of the air-cooled plant shall be established based on the computed operational design load profile together with the power inputs of the relevant fan subsystem at their respective operating load condition as described in the design.

The following minimum design system efficiencies must be met:

Table 6.5-2: Air cooled system — Minimum design system efficiency (DSE)

Max building cooling load ≤ 500 TR	Max building cooling load > 500 TR
1.0 kW/TR	0.9 kW/TR

6.5.3 Air handling system efficiency

Fan system input power must be less than the prescribed values below:

Table 6.5-3: Allowable fan system input power (adapted from ASHRAE 90.1 -2019)

Air distribution system type	Allowable fan system input power	
	$kW/m^3/s$	$W/m^3/h$
AHUs ≥ 4kW(constant volume)	1.2	0.34
AHUs ≥ 4kW(variable volume)	1.7	0.47
FCUs < 4kW	0.4	0.11
Pressure drop adjustments can be considered based on ASHRAE 90.1-2007 Table 6.5.3.1 B or latest.		

6.6 Submittals

6.6.1 General

A submittal of compliance with this standard incorporating information as required by each of the subsections above shall be required by the Authority. The following requirements shall be needed as additional mandatory provisions that shall be satisfied for the compliance of the standard.

6.6.1.1 Description of load calculation

A description of load calculation as per section 6.3.2.1

6.6.1.2 Drawings

Record drawings shall include the information not less than the general configuration including piping and instrumentation, location, sub-system sizes and performance data.

6.6.1.3 Manuals

Incorporated to construction documents there shall be an operation and maintenance manual prepared according to standard industry practices and submitted to a person designated by the client and shall essentially include equipment that needs maintenance, details of service agency, controls information including those related to set points and calibration.

6.6.1.4 System balancing

Air system balancing shall be accomplished in a manner to minimise throttling losses and fan speeds shall be adjusted to meet designed flow conditions.

Hydronic system balancing shall be accomplished in a manner to minimise throttling losses and the pump impellers shall be trimmed or pump speeds shall be adjusted to meet designed flow conditions. HVAC control systems shall be tested to assure that control elements are calibrated and adjusted and that are in proper working condition.

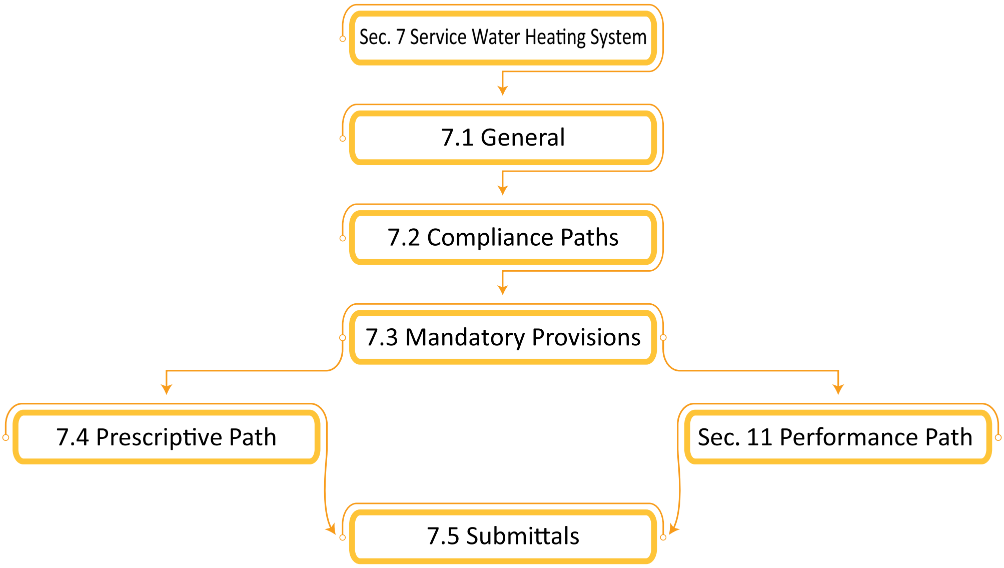
6.6.1.5 System commissioning

HVAC systems with cooling capacities greater than 25 TR shall go through a process of testing and commissioning as per the procedures defined by industry standards for their installation, controls & safety and relevant performance aspects. Systems larger than 350 kW_{th} of cooling shall be commissioned in accordance with the procedures in ASHRAE Guideline 1-1996 or latest, The HVAC Commissioning Process. Detailed instructions for commissioning HVAC systems shall be provided by the designer in plans and specifications.

7 Service Water Heating System

Service Water Heating (SWH) systems of buildings intend to provide hot water requirement of the facility and could include as an additional function, space heating as an integrated system and hence could be responsible for a significant share in the total energy use of the facility. Thus, the energy performance of the service water heating system plays a significant role in the overall building energy intensity.

Judicious selection of size and type of equipment and sub-systems and integration of proper controls are key aspects of this section.



7.1 General

7.1.1 Service water heating scope

7.1.1.1 New buildings

The service water heating systems and equipment of new buildings shall comply with the conditions stipulated in this section.

7.1.1.2 Addition to existing buildings

The service water heating systems and equipment of addition to the existing buildings shall comply with the conditions stipulated in this section.

Exception to 7.1.1.2

When the service water heating to an addition is provided by existing service water-heating systems and equipment, such systems and equipment shall not be required to comply with this standard.

7.1.1.3 Alterations to existing buildings

Direct replacement of equipment and systems related to service water heating related to existing buildings shall meet conditions stipulated here.

Exception to 7.1.1.3

Compliance shall not be required where there is insufficient space or access to meet these requirements.

7.2 Compliance paths

7.2.1 Project using prescriptive method shall comply with Section 7.1, General; Section 7.3, Mandatory Provisions; Section 7.4, Prescriptive Paths and Section 7.5, Submittals.

7.2.2 Projects using the performance option shall comply with section 7.3, Mandatory provisions in conjunction with section 11, Performance method and section 7.5, Submittals .

7.3 Mandatory Provisions

7.3.1 Product information verification & testing requirement

Product information (capacity, equipment efficiency, etc.) pertaining to selected equipment in this section, under standard or non-standard conditions, shall be certified by a nationally recognised entity in the relevant technical field, certified by an accredited laboratory or label or certification provided by the manufacturer as acceptable to the Authority.

7.3.2 Load calculation

Design loads for the purpose of sizing the relevant systems and equipment shall be determined in accordance with the procedures described in the latest edition of the ASHRAE Handbook or equivalent and/or as per the standard engineering practices as acceptable to the Authority.

7.3.3 Equipment efficiency selection

All water heating equipment, hot water supply boilers used solely for heating potable water, pool heaters and hot water storage tanks shall meet criteria given in Table 7.3-1. In addition to the given test procedures any other internationally accepted test procedures as acceptable to the authority can be adapted.

Table 7.3-1 Water heating equipment efficiency limits
(adapted from ASHRAE 90.1 -2019)

Equipment type	Size category (input)	Subcategory or rating condition	Performance required[a]	Test procedure
Electric table top water heaters	≤ 12 kW	<309.75 W/l ≥76 l and ≤450 l	See Footnote (d).	10 CFR 430 Appendix E
Electric storage water heaters	≤ 12 kW	<309.75 W/l ≥76 l and ≤208 l	See Footnote (d).	10 CFR 430 Appendix E
		<309.75 W/l ≥208 l and ≤450 l	See Footnote (d).	10 CFR 430 Appendix E
	>12 kW	<309.75 W/l	SL ≤0.3 + 27/*Vm*%/h	10 CFR 431.106

Equipment type	Size category (input)	Subcategory or rating condition	Performance required[a]	Test procedure
Electric instantaneous water heaters	≤ 12 kW	≥309.75 W/l <7.6 l	See Footnote (d).	10 CFR 430 Appendix E
	>12 kW and ≤ 58.6 kW	≥309.75 W/l <7.6 l ≤ 82 °C	Very Small DP: UEF = 0.80 Low DP:UEF = 0.80 Medium DP: UEF = 0.80 High DP: UEF = 0.80	10 CFR 430 Appendix E
Gas storage water heaters	≤ 22 kW	<309.75 W/l ≥76 l and ≤ 208 l	See Footnote (d).	10 CFR 430 Appendix E
		<309.75 W/l >208 l and ≤ 380 l	See Footnote (d).	10 CFR 430 Appendix E
	>22.kW and ≤ 31 kW [b]	<309.75 W/l ≤ 454 l ≤ 82.2°C	Very Small DP: UEF = 0.2674 – (0.0009 × *Vr*) Low DP: UEF = 0.5362 – (0.0012 × *Vr*) Medium DP: UEF = 0.6002 – (0.0011 × *Vr*) High DP: UEF = 0.6597 – (0.0009 × *Vr*)	10 CFR 430 Appendix E
	> 31 kW [b] (105,000 Btu/h)	<309.75 W/l	80% E_t SL≤(Q/800+ 0.0166√V), kW	10 CFR 431.106
Gas instantaneous water heaters	> 14.6 kW and ≤ 58.6 kW	≥ 309.75 W/l and < 7.6 l	See Footnote (d).	10 CFR 430 Appendix E
	≥ 58.6 kW	≥ 309.75 W/l and <38 l	80% E_t	10 CFR 431.106
	≥ 58.6 kW	≥ 309.75 W/l and ≥ 38 l	80% E_t SL (Q/800 + 16.6√V), kW	10 CFR 431.106

Equipment type	Size category (input)	Subcategory or rating condition	Performance required[a]	Test procedure
Oil storage water heaters	≤ 31 kW	< 309.75 W/l ≤189 l	See footnote (d).	10 CFR 430 Appendix E
	≥ 31 kW and ≤ 41 kW[c]	< 309.75 W/l < 454 l < 82 °C	Very Small DP: UEF =0.2932 – (0.0015 × Vr) Low DP: UEF = 0.5596 – (0.0018 × Vr) Medium DP: UEF =0.6194 – (0.0016 × Vr) High DP: UEF = 0.6740 – (0.0013 × Vr)	10 CFR 430 Appendix E
	> 41 kW[c]	< 309.75 W/l	80% E_t SL ≤ (Q/800 +0.166√V), kW	10 CFR 430 Appendix E
Oil instantaneous water heaters	≤ 61 kW	≥ 309.75 W/l <7.6 l	80% E_t EF≥ 0.59 - 0.0005×V	10 CFR 430 Appendix E
	> 61 kW	≥ 309.75 W/l and < 38 l	80% E_t	10 CFR 431.106
	> 61 kW	≥ 309.75 W/l and ≥ 38 l	78% E_t SL ≤Q/800 + 0.0166√V), kW	10 CFR 431.106
Hot Water supply boilers, oil and gas	≥ 88 kW and < 3663 kW	≥ 309.75 W/l and < 38 l	80% E_t	10 CFR 431.106
Hot water supply boilers, gas	≥ 88 kW and < 3663 kW	≥ 309.75 W/l and ≥ 38 l	80% E_t SL ≤(Q/800 + 0.166√V), kW	10 CFR 431.106
Hot water supply boilers, oil	≥ 88 kW and < 3663 kW	≥ 309.75 W/l and ≥ 38 l	78% E_t SL ≤ (Q/800 +0.0166√V), kW	10 CFR 431.106
Pool heaters oil and gas	All		82% E_t for commercial pool heaters	10 CFR 430 Appendix P
Unfired storage tanks	All		R-2.2	(none)

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a. *Thermal efficiency (Et) is a minimum requirement, while standby loss is a maximum requirement. In the standby loss equation, V is the rated volume in litres and Q is the nameplate input rate in w. Vm is the measured volume in the tank in litres. Standby loss for electric water heaters is in terms of %/h and denoted by the term 'S' and standby loss for gas and oil water heaters is in terms of w and denoted by the term 'SL'. Draw pattern (DP) refers to the water draw profile in the Uniform Energy Factor (UEF) test. UEF and Energy Factor (EF) are minimum requirements. In the UEF standard equations, Vr refers to the rated volume in liters..*

b. *Gas storage water heaters with input capacity >22 kW and ≤31 kW must comply with the requirements for the >31 kW if the water heater either (1) has a storage volume >454 l; (2) is designed to provide outlet hot water at temperatures greater than 82°C; or (3) uses three-phase power.*

c. *Oil storage water heaters with input capacity >31 kW and ≤41 kW must comply with the requirements for the >41 kW if the water heater either (1) has a storage volume >454 l (2) is designed to provide outlet hot water at temperatures greater than 82°C; or (3) uses three-phase power.*

d. *Comply to the requirements shown in Table 7.3-2.*

Table 7.3-2 Minimum Energy Efficiency Requirement for Water Heaters and Pool Heaters (Source: 10 CFR Part 430, Energy Conservation Program: Energy Conservation Standards for Water Heating Pumps Heaters)

Product Class	Rated Storage Volume And Input Rating (If applicable)	Draw Patten	Performance Unlform Energy Factor (UEF) or Thermal Efficiency (E_t) [a]	Test procedure
Gas-fired storage water heater	≥75.7 L and <208 L	Very Small	UEF = 0.3456 . (0.0005 x Vr)	10 CFR 430 Appendix E
Gas-fired storage water heater	≥75.7 L and <208 L	Low	UEF = 0.5982 . (0.0005 x Vr)	10 CFR 430 Appendix E
Gas-fired storage water heater	≥75.7 L and <208 L	Medium	UEF = 0.6483 . (0.0004 x Vr)	10 CFR 430 Appendix E
Gas-fired storage water heater	≥75.7 L and <208 L	High	UEF = 0.6920 . (0.0003 x Vr)	10 CFR 430 Appendix E
Gas-fired storage water heater	>208 L and ≤378 L	Very Small	UEF = 0.6470 . (0.0002 x Vr)	10 CFR 430 Appendix E
Gas-fired storage water heater	>208 L and ≤378 L	Low	UEF = 0.7689 . (0.0001 x Vr)	10 CFR 430 Appendix E
Gas-fired storage water heater	>208 L and ≤378 L	Medium	UEF = 0.7897 . (0.0001 x Vr)	10 CFR 430 Appendix E
Gas-fired storage water heater	>208 L and ≤378 L	High	UEF = 0.8072 . (0.0001 x Vr)	10 CFR 430 Appendix E
Oil- fired storage water heater	≤ 189 L	Very Small	UEF = 0.2509 . (0.0003 x Vr)	10 CFR 430 Appendix E
Oil- fired storage water heater	≤ 189 L	Low	UEF = 0.5330 . (0.0004 x Vr)	10 CFR 430 Appendix E
Oil- fired storage water heater	≤ 189 L	Medium	UEF = 0.6078 . (0.0004 x Vr)	10 CFR 430 Appendix E
Oil- fired storage water heater	≤ 189 L	High	UEF = 0.6815 . (0.0004 x Vr)	10 CFR 430 Appendix E

Product Class	Rated Storage Volume And Input Rating (If applicable)	Draw Patten	Performance Unlform Energy Factor (UEF) or Thermal Efficiency (E_t) [a]	Test procedure
Electric storage water heaters	≥75.7 L and ≤208 L	Very Small	UEF = 0.8808 . (0.0002 x Vr)	10 CFR 430 Appendix E
		Low	UEF = 0.9254 . (0.0001 x Vr)	
		Medium	UEF = 0.9307 . (0.0001 x Vr)	
		High	UEF = 0.9349 . (0.0003 x Vr)	
	>75.7 L and <454 L	Very Small	UEF = 1.9236 . (0.0042 x Vr)	10 CFR 430 Appendix E
		Low	UEF = 2.0440 . (10.0042 x Vr)	
		Medium	UEF = 2.1171 . (0.0042 x Vr)	
		High	UEF = 2.2418 . (0.0042 x Vr)	
Tabletop water heater	≥208 L and ≤454 L	Very Small	UEF = 0.6323 . (0.0015 x Vr)	10 CFR 430 Appendix E
		Low	UEF = 0.9188 . (0.0008 x Vr)	
		Medium	UEF = 0.9577 . (0.0006 x Vr)	
		High	UEF = 0.9884 . (0.0004 x Vr)	
Instantaneous gas-fired water heater Tabletop water heater	<7.57 L and >14.6 L	Very low	UEF = 0.80	10 CFR 430 Appendix E
		Low	UEF = 0.81	
		Medium	UEF = 0.81	
		High	UEF = 0.81	
Instantaneous electric water heater	<7.57 L	Very low	UEF = 0.91	10 CFR 430 Appendix E
		Low	UEF = 0.91	
		Medium	UEF = 0.91	
		High	UEF = 0.92	
Pool heater gas			82% Et	10 CFR 430 Appendix P

a. V_r is the rated storage volume in liters.

b. Standards for electric storage water heaters apply to both electric resistance water heaters and heat pump water heaters.

7.3.4 Piping insulation

All following piping shall be insulated as per the conditions stipulated in the relevant sub section in Section 6, Table 6.3-3 of this standard.

a) Recirculating system piping, including the supply and return piping of a circulating tank type water heater;

b) The first 2m of outlet piping for a constant-temperature non-recirculating storage system;

c) The first 2m of branch piping connecting to recirculated, heat-traced, or impedance heated piping;

d) The inlet piping between the storage tank and a heat trap in a non-recirculating storage system;

e) Piping that is externally heated (such as heat trace or impedance heating);

7.3.5 Service water heating system controls

7.3.5.1 Temperature controls

Temperature controls shall be provided that allows storage control from 50°C or lower to a maximum temperature compatible with intended end use.

Exception to 7.3.5.1

When the manufacturers' installation instructions specify a higher minimum thermostat setting to minimise condensation and resulting corrosion

7.3.5.2 Temperature maintenance control

Systems designed to maintain usage temperatures in hot-water pipes, such as re-circulating hot-water systems or heat trace, shall be equipped with automatic time switches or other controls that can be set to switch off the usage temperature maintenance system during extended periods when hot water is not required.

7.3.5.3 Outlet temperature control

Temperature controls shall be provided to limit the maximum temperature of water delivered to the following applications as mentioned below (TMVA recommended code of procedure for safe water temperatures):

A. 44^0C for an unassisted bath fill;

B. 46^0C for an assisted bath fill;

C. 41^0C for shower applications;

D. 41^0C for washbasin applications;

E. 38^0C for bidet applications;

7.3.5.4 Circulating pump controls

Recirculating pumps shall be equipped with controls limiting operation to a period from the start of the heating cycle to a maximum of five minutes after the end of the heating cycle, when used to maintain storage tank water temperature.

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

7.4 Prescriptive Paths

7.4.1 Space heating and service water heating

The use of a gas-fired or oil-fired space-heating boiler system to provide the total space heating and service water heating for a building is allowed when one of the following conditions is met:

a) The single space-heating boiler, or the component of a modular or multiple boiler system that is heating the service water, has a standby loss in kW not exceeding ((3.7x10^6 x pmd) + 117)/n where pmd is the probable maximum demand in m^3/s determined in accordance with the procedures described in generally accepted Engineering standards and handbooks, and n is the fraction of the year when the outdoor daily mean temperature isgreater than 18°C. The standby loss is to be determined for a test period of 24 hours duration while maintaining a boiler water temperature of at least 32°C above ambient, with an ambient temperature between 16°C and 32°C. For a boiler with a modulating burner, this test shall be conducted at the lowest input;

b) It is demonstrated to the satisfaction of the Authority that the use of a single heat source will consume less energy than separate systems;

c) The energy input of the combined boiler and water heater system is less than 44 kW;

7.4.2 Service water heating equipment

Service water-heating equipment used to provide the additional function of space heating aspart of a combination (integrated) system shall satisfy all stated requirements for the service water-heating equipment.

7.4.3 Building with high capacity gas service water heating

New buildings with gas service water-heating systems with a total installed gas water-heating input capacity of 293 kW or greater, shall have gas service water-heating equipment with a minimum thermal efficiency (E_t) of 90%. Multiple units of gas water-heating equipment are allowed to meet this requirement if the water-heating input provided by equipment with thermal efficiency (E_t) above and below 90% provides an input capacity weighted average thermal efficiency of at least 90%.

Exception to 7.4.3

1) Where 25% of the annual service water-heating requirement is provided by site-solar Energy or site-recovered energy;
2) Water heaters installed in individual dwelling units;
3) Individual gas water heaters with input capacity not greater than 30 kW;

7.5 Submittals

7.5.1 General

A submittal of compliance with this standard incorporating information as required by each of the sub sections above shall be required by the SEA. The following requirements shall be fulfilled as additional mandatory provisions that shall be satisfied for the compliance of the standard.

7.5.1.1 Drawings

Record drawings shall include the information not less than the general configuration including piping and instrumentation, location, sub-system sizes and performance data.

7.5.1.2 Manuals

Incorporated to construction documents there shall be an operation and maintenance manual prepared according to standard industry practices and submitted to a person designated by the client within 90 days after the date of system acceptance and shall essentially include equipment that needs maintenance, details of service agency, controls information including those related to set points and calibration.

7.5.1.3 System commissioning

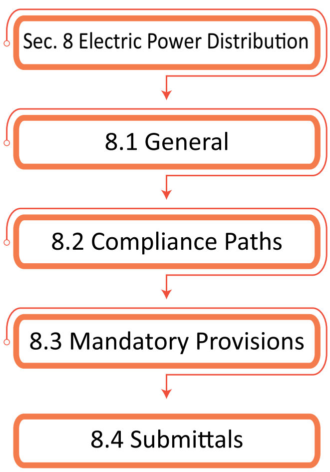
Service water heating systems with capacities greater than 15 kW_{th} shall go through a process of testing and commissioning as per the procedures defined by industry standards for their installation, controls & safety and relevant performance aspects.

8 Electric Power Distribution

The approach to energy efficiency is through both design and monitoring. The approach to design aims to select energy efficient components to be integrated into the electrical installation, and the approach to monitoring aims to provide required information for better energy utilisation and management.

Requirements for energy efficient design of electrical installations are for the purposes of minimising losses such as iron losses, copper losses, losses due to phase current imbalance and harmonics, indirect losses due to rise of temperature in the power distribution system and reducing losses and energy wastage in the utilisation of electrical power.

The requirements for energy efficient monitoring facilities of the electrical installations are for the purposes of getting required energy consumption data for better energy utilisation and management; identifying possible power quality problems so that appropriate solution can be devised to reduce the losses and facilitating energy audits



8.1 General

8.1.1 Scope

This section applies to all building power distribution systems. For existing buildings at the stage of expansion, rerouting and rewiring, all criteria under following sections shall apply.

8.2 Compliance Paths

Power distribution systems in all projects shall comply with the requirements of Section 8.1 General; Section 8.3 Mandatory Provisions; and Section 8.4 Submittals.

8.3 Mandatory Provisions

In order to reduce the capacities of incoming power and the current carrying capacities of cables, the Maximum demand shall be determined by analyzing the precious loads, diversity and operation sequence of electrical equipment. For approaching precious calculation of Maximum demand, accurate and appropriate loads of building services shall be taken into account. Besides that, the operation of plants shall be programmed to draw least maximum demand from the power distribution system. If the maximum demand is inclusive of future expansion, such expansion shall be subjected to implement within 2 years.

8.3.1 Voltage drop

8.3.1.1 Feeder and branch circuit conductors shall be sized for a maximum voltage drop as given in Table 8.3-1.

Table 8.3-1: Maximum voltage-drop between the origin of an installation and any load point (adapted from BS 7671 Table 4Ab)

Type of installations	Allowable maximum voltage-drop	
	Lighting Circuits	Other Circuits
Low voltage installations supplied directly from a public low voltage distribution system	3%	5%
Low voltage installation supplied from private LV supply	6%	8%

8.3.2 Power distribution loss

8.3.2.1 Distribution transformer

A distribution transformer other than that owned by the electricity supplier should have a minimum efficiency given in Table 8.3-2. based on test in accordance with IEC Standard 60076-1 Ed. 2.1, at the test condition of full load, free of harmonics and at unity displacement power factor.

Table 8.3 2: Minimum transformer efficiency

Transformer capacity	Efficiency
<1,000 kVA	98%
≥1,000 kVA	99%

The average loading of transformers and generators shall be at least 2/3rd of their capacities

8.3.3 Feeder circuit

The maximum copper loss in a feeder circuit, single or three phase, should not exceed 5% of the total active power transmitted along the circuit conductors at designed circuit current. This requirement is not applicable to circuits solely used for correction of reactive and distorted power.

8.3.4 Power factor correction

Electricity supplies exceeding 30A, three phase industrial category (tariff category I1 and I2) and all electricity supplies exceeding 60A, 3 phase shall maintain their power factor between 0.98 lag and unity at the point of connection. Loads should have power factor correction at the point of use (capacitors on motors and lighting fixtures with ballasts; harmonic filters on non-linear loads); if necessary, further correction equipment at the main switchboard should be provided to meet the overall requirement.

8.3.5 Balancing of single-phase loads

For three-phase 4-wire circuits at or above 160A (based on circuit protective device rating) with single-phase loads, the maximum current imbalance (unbalanced single-phase loads distribution) at designed circuit current should not exceed 10%.

8.3.6 Metering and monitoring facilities

8.3.6.1 All main incoming circuits at or above 250A current rating, single or three phase, (based on circuit protective device rating) should be incorporated with metering devices for measuring voltages (all phase-to-phase and phase-to-neutral), currents (three phases and neutral), total power factor, total energy use (kWh), maximum demand (kVA) and total harmonic distortion.

8.3.6.2 All feeder or sub-main circuits exceeding 160A and below 250A current rating, single or three phase, (based on circuit protective device), except for correction of reactive or distortion power purpose, should be incorporated with metering devices, for measuring currents (three phases and neutral) and total energy use (kWh).

8.3.6.3 All feeder or sub-main circuits at or above 250A current rating, single or three phase, (based on circuit protective device rating), except for correction of reactive and distortion power purpose, should be incorporated with metering devices for measuring voltages (all phase-to-phase and phase-to-neutral), currents (three phases and neutral), total power factor, total energy use (kWh), maximum demand (kVA) and total harmonic distortion.

8.3.6.4 Circuit serving each of the following installation should be incorporated with metering devices separately,

a) Entire chiller plant;

b) Entire heat pump plant;

c) All lifts, and;

d) All escalators or passenger conveyors;

In addition to above,approprite submetering as acceptable to Authority should be available;

8.4 Submittals

Basic data relating to the design, operation and maintenance of the electrical distribution system of the building shall be submitted to the Authority. This shall include:

a) A single-line diagram of the building electrical distribution system;
b) Floor plans indicating location and area served for all distribution;
c) Schematic and single-line diagram of electrical control systems used for power saving (if any);
d) Voltage drop calculations for feeder conductors and branch circuit conductors;
e) Manufacturers' data sheets confirming the maximum losses, allowed for transformers (applicable only for consumer owned transformers);
f) Electrical system commissioning report
g) Maximum demand calculation

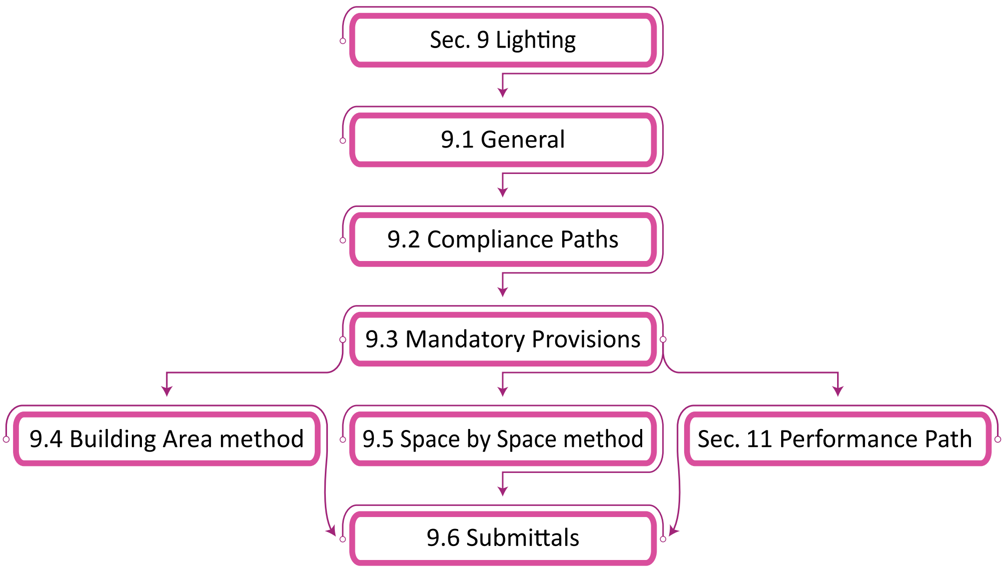
In addition any other submittal of compliance with this standard incorporating information as required by each of the subsections above shall be required by the Authority

9 Lighting

9.1 General

Lighting is a significant energy user in buildings. This Code will set the maximum allowable loads for building lighting systems as well as minimum limits for the acceptable efficiencies for commonly used lighting sources and components. The lighting designer therefore will face the challenge of using this Code as a minimum energy performance standard to develop lighting systems that balances the visual performance with energy use.

Lighting technology development and their application are on high growth, resulting in increasing opportunities for energy saving in building related applications. Working in proper illuminance level is also an important aspect. Therefore, guiding building designers and their owners to employ the most effective lighting system is the objective of this section.



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9.1.1 Scope

This section shall apply to the following:

a) Interior: Interior spaces of buildings;

b) Exterior: exterior spaces of buildings including roads, grounds and other areas powered by the building electrical system excluding building surfaces;

c) Façade: exterior building surfaces includes fasçades, illuminated roofs, entrances exits, loading docks, illuminated canopies and architectural features;

Exceptions to 9.1.1

a) Displays, backlit posters and architectural lighting that is an essential item on galleries, museums, historic landmarks and monuments;

b) Lighting built-in to equipment and machines installed by manufacturer for task lighting applications;

c) Lighting specifically designed for medical and dental tasks, research laboratories, etc.;

d) Lighting which is integral part of advertising boards, direction signage;

e) Lights used for exit signs and emergency lighting;

f) High-risk security areas identified by local laws or regulations or by security or safety personnel;

9.1.2 Lighting alterations

Alterations to any building space covered by the scope shall comply with the Code requirements.

Exception to 9.1.2

Need not comply for maintenance work or alterations leading to less than 10% lighting load addition.

9.1.3 Installed lighting power

Luminaire power shall include all related accessories power such as lamps, ballasts, drivers, igniters, capacitors, transformers and control devices.

Exception to 9.1.3

If two or more independently operating lighting systems can be operated preventing simultaneous operation, system with highest power should be considered for installed lighting power.

9.2 Compliance Paths

9.2.1 All buildings shall comply with Section 9.1, General; Section 9.3, Mandatory Provisions; Section 9.6, Submittals; and either;

a) 9.4, Prescriptive Path – Building area method, or;

b) 9.5, Alternative Path, Space-by-space method;

9.2.2 Projects using the performance option shall comply with section 9.3 Mandatory provisions in conjunction with section 11 of this Code and section 9.6, Submittals.

9.3 Mandatory Provisions

9.3.1 Illuminance levels

All spaces shall meet the required illuminance level that is listed in Appendix 6.

9.3.2 Automatic lighting shutoff

Interior lighting of the buildings larger than 500 m^2 shall be controlled by an automatic control device with manual override to shut off lighting in all spaces based on either;

a) A time-of-day operated control device that automatically turns the lighting off at specific programmed times;

b) A signal from another automatic control device or alarm/security system;

Exceptions to 9.3.2

Continuously illuminated areas within a building, areas need to be lit for reasons of security or emergency exit, are exempted from the switching requirements.

9.3.3 Space control

9.3.3.1 Each space having ceiling height partitions, and an area less than 30 m^2 shall have at least one control device to independently control space lighting.

9.3.3.2 Spaces larger than 1,000 m^2, should be able to control lighting to operate in between 30-60% of full lighting power.

9.3.3.3 Spaces excluded automatic controls, shall have manual lighting controls that are readily accessible to occupants.

9.3.3.4 Occupancy or a timer control shall be installed to shutoff lights within 15 minutes after all occupants leaving the space in classrooms, lecture rooms, conference rooms, meeting rooms, training rooms, lunch rooms, rest rooms and storage areas less than 100 m^2.

9.3.3.5 Spaces not covered by occupancy control given in above requirements shall be installed with manual or automatic controls. Each control device shall control a maximum of 250 m^2 of area for spaces 1,000 m^2 or less, and covering a maximum of 500 m^2 area for spaces greater than 1,000 m^2. They shall also be capable of overriding any time-of-day scheduled shutoff control for no more than four hours.

9.3.4 Automatic daylighting control – side lighting and top lighting

9.3.4.1 Lighting spaces within 6 m from the wall surface with at least 20% opening ratio (fenestration area) shall be controlled with a daylight controller.

9.3.4.2 Daylighting areas with top lighted spaces larger than 500 m^2 shall consist of at least three stage lighting control of 100%, 50-70% and less than 40% of total lighting power excluding total shutoff.

9.3.4.3 Daylighting areas with top lighted spaces smaller than 500 m^2 shall consist of at least two stage lighting control of 100%, 40-60% of total lighting power excluding total shutoff.

9.3.4.4 Spaces smaller than 1,000 m^2: possibility to switch off lighting after reaching 200% of required luminance level.

9.3.5 Exterior lighting control

9.3.5.1 Exterior lighting shall be controlled by an automatic lighting controller based on timer or daylight sensor.

9.3.5.2 All lamps used in exterior lighting greater than 70W of power shall have a minimum of 80 lm/W efficacy.

9.3.5.3 All building façade lighting shall have a facility to automatically/manually switched off after midnight or end of business close.

9.3.5.4 Name boards and advertising signage boards shall have a facility to automatically/manually reduce to less than 50% output after midnight or end of business close.

Exceptions for lighting controls to 9.3.3, 9.3.4 and 9.3.5:

a) Spaces which will endanger the safety with required mandatory requirements;
b) Spaces which consists of only one luminaire with less than 1,000 lm output;
c) Spaces with lighting power allowance less than 4 W/m^2;
d) Interior spaces lit up with HID lamps;
e) Lighting can be exempted from daylighting control in spaces where daylighting is constrained by shadowing;

All above (a to e) exempted lighting control areas shall consist of at least one manual control for maximum of 30 m^2 space.

9.3.6 Exterior building lighting power

Exterior building spaces shall comply with the requirements mentioned in table 9.3-1.

Table 9.3-1: Allowable exterior building lighting power
(adapted from BEE ECBC-2017)

Exterior space	Lighting power
Building entrance (with canopy)	10 W/m^2 of canopied area
Building entrance (w/o canopy)	90 W/ linear m of door width
Building exit	60 W/linear m of door width
Building façade	5.0 W/m^2 of vertical façade area
Emergency signs, ATM kiosks, Security areas façade	1.0 W/m^2
Driveways and parking (open/ external)	1.6 W/m^2
Pedestrian walkways	2.0 W/m
Stairways	10.0 W/m^2
Landscaping	0.5 W/m^2
Outdoor sales area	9.0 W/m^2

Lamps for general lighting shall comply with minimum energy performance specifed in the standards published by Sri Lanka Standards Institute (SLSI) updated from time to time.

9.4 Prescriptive Path - Building Area Method

Building Area method of calculating interior lighting power allowance is shown in below steps.

a) Determine the appropriate building area type from table 9.4-1 and the corresponding LPD allowance. For building area types not listed, selection of a reasonably equivalent type shall be permitted;

b) Determine the gross lighted floor area in m^2 of the building area type;

c) Multiply the gross lighted floor areas of the building area types by the LPD;

d) The interior lighting power allowance for the building is the sum of the lighting power allowance of all building area types. Trade-offs among building area types are permitted, provided that the total installed interior lighting power does not exceed the interior lighting power allowance;

Table 9.4-1: Lighting power densities using the building area method

Building area types	LPD (W/m²)	Building area types	LPD (W/m²)
Automotive facility	8.1	Multi-family	4.8
Convention center	6.9	Museum	5.9
Court house	8.5	Office	6.9
Dining: Bar lounge/leisure	8.6	Parking garage	1.9
Dining: Cafeteria/fast food	8.2	Penitentiary	7.4
Dining: Family	7.6	Performing arts theater	9.0
Dormitory	5.7	Police/Fire station	7.1
Exercise center	7.8	Post office	7.0
Gymnasium	8.2	Religious building	7.2
Health care-clinic	8.7	Retail	9.0
Hospital	10.3	School/University	7.8
Hotel	6.0	Sports arena	8.2
Library	8.9	Town hall	7.4
Manufacturing facility	8.8	Transportation	5.4
Motel	6.0	Warehouse	4.8
Motion picture theater	*4.7*	Workshop	9.8

In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

Note: Certain values were taken from ANSI/ASHRAE/IES Standard 90.1 – 2019

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9.5 Alternative Path - Space By Space Method

Space-by-space method of calculating interior lighting power allowance

a) Determine the appropriate space type and the corresponding LPD allowance from table 9.5-1. If a space has multiple functions, where more than one space type is applicable, that space shall be broken up into smaller subspaces, each using its own space type from table 9.5-1;

b) Based on the space type selected for each space or subspace, determine the lighting power allowance of each space or subspace by multiplying the calculated area of the space or subspace by the appropriate LPD allowance given in table 9.5-1. For space types not listed, selection of a reasonably equivalent type shall be permitted;

c) The interior lighting power allowance is the sum of the lighting power allowances of all spaces and subspaces. Trade-offs among spaces and subspaces are permitted, provided that the total installed interior lighting power does not exceed the interior lighting power allowance;

Table 9.5-1: Lighting power densities using the space-by-space method

Common space types	LPD (W/m^2)
Office-enclosed	8.0
Office-open plan	6.6
Conference/meeting/ multipurpose	10.4
Classroom/lecture/training	
Penitentiary	9.6
All other classroom/lecture/ training	7.6
Lobby	
Hotel	5.5
Performing arts theatre	13.5
Motion picture theatre	2.5
All other lobbies	9.0

Building specific space types	LPD (W/m^2)
Gymnasium/Exercise center	
Playing area	9.1
Exercise area	9.7
Courthouse/Police station/penitentiary	
Courtroom	12.9
Confinement cells	6.8
Judges' chambers	9.8
Fire stations	
Fire station engine room	6.0
Sleeping quarters	2.5
Post office—sorting area	8.2
Convention center—exhibit space	6.6

Common space types	LPD (W/m²)
Audience/seating area	
Gymnasium	2.5
Exercise center	2.3
Convention center	5.3
Penitentiary	*5.3*
Religious buildings	7.8
Sports arena	3.0
Performing arts theatre	12.5
Motion picture theatre	2.9
Transportation	3.8
All other audience/seating area	2.5
Atrium—first three floors	4.2
Atrium—each additional floor	5.2
Lounge/recreation	
Hospital	4.5
All other lounge/recreation	6.4
Dining area	
Penitentiary	4.5
Hotel	9.8
Motel	9.0
Bar lounge/leisure dining	9.3
Family dining	6.5
All other dining area	4.6
Food preparation	11.7

Building specific space types	LPD (W/m²)
Library	
Card file and cataloguing	8.3
Stacks	12.7
Reading area	10.3
Hospital	
Emergency	20.3
Recovery	13.5
Nurse station	12.6
Examination/Treatment	15.1
Pharmacy	17.9
Patient room	7.3
Operating theatre	24.3
Nursery	9.9
Medical supply	6.7
Physiotherapy	9.8
Radiology	10.1
Laundry—washing	5.7
Automotive—service/repair	6.5
Manufacturing	
Low bay (<25 ft floor to ceiling height)	9.3
High bay (≥25 ft floor to ceiling height)	13.3
Detailed manufacturing	8.6
Equipment room	8.2
Control room	3.8
Hotel/Motel guest rooms	8.3
Dormitory—living quarters	5.4

Common space types	LPD (W/m^2)
Laboratory	14.3
Restrooms	6.8
Dressing/locker/fitting room	4.5
Corridor/transition	
Hospital	7.6
Manufacturing facility	3.8
All other corridor/transition	4.4
Stairs—active	4.5
Active storage	
Hospital	6.8
All other active storage	6.0
Inactive storage	
Museum	6.0
All other inactive storage	2.3
Electrical/Mechanical	4.6
Workshop	13.6

Building specific space types	LPD (W/m^2)
Museum	
General exhibition	3.3
Restoration	11.8
Bank/Office—banking activity area	6.6
Religious buildings	
Worship pulpit, choir	9.1
Fellowship hall	5.8
Retail	
Sales area	11.3
Mall concourse	8.8
Sports arena	
Ring sports area	20.3
Court sports area	17.3
Indoor playing field area	10.5
Warehouse	
Fine material storage	10.5
Medium/Bulky material storage	3.6
Parking garage—Garage area	1.6
Transportation	
Airport—Concourse	2.7
Air/Train/Bus—Baggage area	4.2
Terminal—Ticket counter	5.5

In cases where both a common space type and a building specific type are listed, the building specific space type shall apply.

Note: Certain values were taken from ANSI/ASHRAE/IES Standard 90.1 – 2019

9.6 Submittals

A complete set of plans, depicting lighting devices, also to be accompanied by the following information shall be submitted to the Authority.

a) The standard and design maintained illuminance for all the interior spaces;

b) The specifications and numbers of each type of lighting device;

c) The total power of each type of lighting device including nominal rating and control gear losses;

d) The installed lighting power for interior and exterior spaces;

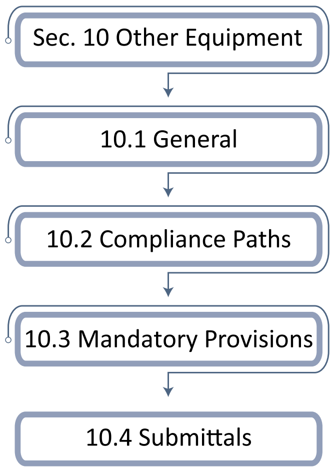
e) Control systems installed for the lighting system components including locations of sensors and controls;

In addition any other submittal of compliance with this standard incorporating information as required by each of the subsections above shall be required by the Authority.

10 Other Equipment

10.1 General

This section applies to motors, lifts and pumps installed in new buildings, addition to existing buildings and building alterations.



10.2 Compliance Requirements

All motors, pumps and lifts shall comply with the mandatory requirements described in section 10.3. and submittals 10.4

10.3 Mandatory requirements

10.3.1 Motors

10.3.1.1 Motor efficiency

All three-phase totally enclosed induction motors should have a nominal full-load motor efficiency fulfilling the corresponding value given in Table 10.3 1, except for a motor integrated into a machine such that it cannot be tested separately from the machine, or a motor specifically designed to operate at ambient air temperature exceeding 40^{0}C.

Table 10.3-1: Minimum Nominal Full-Load Motor Efficiency

for Single-Speed Three-phase Totally Enclosed Motor

Motor rated output (P, in kW)	Minimum rated efficiency (%)	
	2-pole	4-pole
0.75 kW ≤ P < 1.1 kW	77.40%	79.60%
1.1 kW ≤ P < 1.5 kW	79.60%	81.40%
1.5 kW ≤ P < 2.2 kW	81.30%	82.80%
2.2 kW ≤ P < 3 kW	83.20%	84.30%
3 kW ≤ P < 4 kW	84.60%	85.50%
4 kW ≤ P < 5.5 kW	85.80%	86.60%
5.5 kW ≤ P < 7.5 kW	87.00%	87.70%
7.5 kW ≤ P < 11 kW	90.10%	90.40%
11 kW ≤ P < 15 kW	91.20%	91.40%
15 kW ≤ P < 18.5 kW	91.90%	92.10%
18.5 kW ≤ P < 22 kW	92.40%	92.60%
22 kW ≤ P < 30 kW	92.70%	93.00%
30 kW ≤ P < 37 kW	93.30%	93.60%
37 kW ≤ P < 45 kW	93.70%	93.90%
45 kW ≤ P < 55 kW	94.00%	94.20%
55 kW ≤ P < 75 kW	94.30%	94.60%
75 kW ≤ P < 90 kW	94.70%	95.00%
90 kW ≤ P < 110 kW	95.00%	95.20%
110 kW ≤ P < 132 kW	95.20%	95.40%
132 kW ≤ P < 160 kW	95.40%	95.60%
160 kW ≤P < 200 kW	95.60%	95.80%
P ≥ 200 kW	95.80%	96.00%

Remarks:
Compliance to above should be based on testing to relevant international standards such as IEEE 112-B:2004.

10.3.2 Pumps

10.3.2.1 Pump Types

Under this code, rotodynamic pumps of following categories and nominal speeds of either 1,450 or 2,900 rpm are covered.

- End Suction Own Bearing Pumps (ESOB)
- End Suction Close Coupled Pumps (ESCC)
- In line End Suction Close Coupled Pumps (ESCCi)
- Vertical Multi Stage Pumps (MS-V)

10.3.2.2 Minimum Required Efficiency

All installed pumps should have Minimum efficiency Index (MEI) 0.4 or above (based on EN 16480). The MEI value can be calculated using the following formula based on manufacture declared values of flow rate, efficiency and specific speed at the best efficient point and referring the resultant C value from Table 10.3-2.

$$\eta_{BEP} = -11.48(\ln(n_s))^2 - 0.85(\ln(Q_{BEP}))^2 - 0.38\ln(n_s).\ln(Q_{BEP}) + 88.59\ln(n_s) + 13.46\ln(Q_{BEP}) - C$$

where; η_{BEP} in [%]

n_s in [min^{-1}]

Q_{BEP} in [m^3/h]

C constant in [%] depending on MEI

The range of validity of the formulae is,

$6\ min^{-1} \leq n_s \leq 120\ min^{-1}$

$2\ m^3/h \leq Q_{BEP} \leq 1000 m^3/h$

And the physical range of validity of the formulae is $\eta_{BEP} \leq 88\%$

$n_s = n_N \times (Q_{BEP})^{(1/2)} / H_{BEP}^{(3/4)}$

Q_{BEP} = Flow rate in m^3/s at Best Efficiency Point

H_{BEP} = Pump Total Head in m at Best Efficiency Point

n_N=Pump speed (min^{-1})

Note :- for multistage pumps , H_{BEP} is the head per stage which results from dividing the total pump head at the point of best efficiency by the number of stages.

Table 10.3-2: Minimum Efficiency Index (MEI) (adapted from EN 16480)

Pump type	**Minimum Efficiency Index**				
	0.3	**0.4**	**0.5**	**0.6**	**0.7**
C(ESOB 1450)	129.35	128.07	126.97	126.10	124.85
C(ESOB 2900)	131.61	130.27	129.18	128.12	127.06
C (ESCC 1450)	129.77	128.46	128.46	126.57	125.46
C (ESCC 2900)	132.23	130.77	130.77	128.80	127.75
C (ESCCi 1450)	133.44	132.30	132.30	130.32	128.98
C (ESCCi 2900)	134.91	133.69	133.69	131.34	129.83
C(MS-V 2900)	134.89	133.95	133.95	131.87	130.37

10.3.3 Elevators and Escalators

10.3.3.1 Planning Elevator systems for buildings

At the time of planning, the vertical transportation system shall be carefully designed to meet the acceptable performance, safe evacuation and less energy demand. The number of lifts, their capacities, speeds, locations and grouping shall be determined by following an acceptable methodology (e.g. CIBSE guide D).

10.3.3.2 Allowable technologies

Following technologies should be adopted according to the usage of lift. Lifts that make less than 300 trips per day are categorized as less intensive lifts.

Table 10.3-3: Allowable technologies

Usage	Method of driving	Electric motor type	Motor control method	Dynamic and regenerative braking
Cargo/heavy loads	Hydraulic or gear traction	Induction or PMSM[a]	A/C 2[b] or VSD[c]	Dynamic braking if VSD driven
Low rise with less intensive passenger traffic	Gear traction	Induction or PMSM	A/C 2 or VSD	Dynamic braking if VSD driven
Low rise to super high-rise lift for intensive passenger traffic	Gearless traction	PMSM	VSD	Dynamic braking or optional regenerative braking

a. *PMSM- permanent magnet synchronous motor*

b. *A/C 2 - two speed A/C control*

c. *VSD- Variable Speed Drives especially designed for traction lifts*

10.3.3.3 Building categorization

Table 10.3-4: Building categorization

Building category	Description
Low rise buildings	Not exceeding twelve (12) stories (floors) inclusive of basements and mezzanine floors.
High rise buildings	Not exceeding twenty (20) stories (floors) inclusive of basements, mezzanine floors.
Super high-rise buildings	Buildings exceeding twenty (20) stories (floors) inclusive of basements, mezzanine floors.

10.3.3.4 Energy Performance of Lifts

The following table shows the maximum allowable Specific energy demand and standby power for different usage categories.

Table 10.3-5: Maximum allowable Specific energy demand and Standby power

Usage category	Standby power (W)[a]	Specific energy demand for the reference running cycle (mWh/kg·m)[b]
Cargo/heavy loads carrying lifts	<400	<4.5
Low rise less intensive passenger lifts	<200	<2.5
Low rise intensive passenger lifts	<200	<2.2
High rise to Super high-rise intensive passenger lifts	<200	<2.0

a. *The standby power is the total active power measured at five minute after serving the last destination.*

b. *The reference running cycle is the reference running cycle specified in ISO 25745-2*

10.3.3.5 Energy Efficiency of Escalators and moving walks

The escalators and moving walks shall consist of variable speed drive and automatic passenger detection system except public places where intensive traffic is expected.

10.4 Submittals

10.4.1 Manufacturers' data sheets confirming the minimum rated efficiency for motors;

10.4.2 Manufacturerers data sheets confirming flow rate, efficiency and specific speed at the best efficient point for water pumps

10.4.3 Manufacturers data sheets confirming the standby power and specific energy demand of lifts

In addition any other submittal of compliance with this standard incorporating information as required by each of the subsections above shall be required by the Authority.

11 Performance Option

11.1 General

11.1.1 Scope

The performance option is a substitute to the prescriptive path and the alternative path of this Code. This gives the ability to trade-off between the minimum requirements stipulated in the prescriptive and alternative paths of this Code. It can be used to show compliance to the Code except in buildings without any mechanical cooling/heating systems.

11.1.2 Compliance

Compliance of Section 11 is achieved, if;

a) All mandatory requirements of sections 5.3, 6.3, 7.3, 8.3, 9.3 and 10.3 are met; and;

b) The design energy use within the boundaries of the overall facility shall not exceed ,the limits as prescribed, the baseline energy use as calculated by the simulation process described by section 11.2. Baseline energy use is that of the Baseline building that is identical in geometry to the building that is being proposed for compliance but with its elements having reference thermo-physical and performance data;

11.1.3 Documentation requirements

The information required is as follows:

a) Information documenting compliance to all mandatory requirements of this Code;

b) List of energy using features/processes and their properties;

c) Proposed design energy use and baseline energy use related to the overall facility as calculated by the simulation process;

d) Input output reports from the simulation programme with a breakdown of energy usage in components including lighting, space cooling, heat rejection, space heating, service water heating, internal loads and other energy using miscellaneous equipment;

e) Messages generated by the simulation tool employed, related to its inputs and outputs supporting the judgement of the compliance;

11.2 Simulation Requirements

11.2.1 Simulation programme

11.2.1.1 The simulation tool employed shall be tested according to ASHRAE Standard 140 and should be capable of modeling year round whole building energy use.

11.2.1.2 The simulation tool shall be approved by the Authority and shall, at a minimum, have the ability to explicitly model all of the following:

a) hour by hour performance over 8,760 hours per year, incorporating the site related weather data or that of an equivalent as approved;
b) hourly variations in occupancy, lighting power and miscellaneous equipment power, thermostat set points, and HVAC system operation, defined separately for each day of the week and holidays;
c) thermal mass effects of the envelop structure;
d) multi zone effects;
e) part-load performance of mechanical equipment;
f) capacity and correction curves for mechanical heating and cooling equipment;
g) design load calculation and equipment sizing;

11.2.1.3 The simulation program shall have the ability to either;

a) directly determine the proposed design building and baseline building energy use;
b) produce hourly reports of energy use by energy source suitable for determining the proposed design building and baseline building using a separate calculation;

11.2.2 Climate data

The simulation program shall perform the simulation using hourly values of climatic data, including temperature, humidity, solar radiation, and wind speed and direction from representative climate data, for the site in which the proposed design is to be located. For locations for which several climate data sources are available or where weather data are not available, the designer shall select available weather data that best represent the climate at the site. SWERA, TMY2 or any equivalent acceptable to the Authority may be used.

11.2.3 Modeling requirements for proposed design model and baseline model

Except as specifically instructed in the sub sections below, all the building systems and equipment shall be modelled identically in the baseline case and in the proposed design case. The design case is modelled as per the actual proposed design specifications and the baseline case is modelled geometrically identical to the proposed design subjected to specific instructions in the Code.

11.2.3.1 Additions and alterations

It is acceptable to demonstrate compliance using building models, without simulating the entire building, provided all of the following conditions are met:

a) Excluded parts of the building are served by HVAC systems that are entirely separate from those serving parts of the building that are included in the building model.

b) Design space temperature and HVAC system operating set points and schedules on either side of the boundary between included and excluded parts of the building are identical.

11.2.3.2 Space use classification

The user shall specify the space use classifications using either the building type or space type categories but shall not combine the two types of categories (as stipulated in Sec 9). More than one building type category may be used in a building if it is a mixed-use facility. If space type categories are used, the user may simplify the placement of the various space types within the building model, provided that building-total areas for each space type are accurate.

11.2.3.3 Schedules

Schedules including hourly variations in occupancy, lighting power, miscellaneous equipment power, temperature set points, and HVAC system operation, service hot water operation, except fresh air supply shall be identically modelled in both baseline and proposed design buildings. Schedules may be allowed to differ between proposed design and baseline building design when it is necessary to model specific energy efficiency measures (eg: when Demand Control Ventilation (DCV) is applicable) provided that the revised schedules have the approval of the Authority.

Table 11.2-1: Modelling requirements for proposed building design and baseline building design (adapted from ASHRAE 90.1-2019)

Proposed building design	Baseline building design
Building envelope	
All components of the building envelope in the proposed design shall be modelled as shown on architectural drawings or as built for existing building envelopes. Exceptions: The following building elements are permitted to differ from architectural drawings. 1. Any building envelope assembly that covers less than 5% of the total area of that assembly type (e.g., exterior walls) need not be separately described. If not separately described, the area of a building envelope assembly must be added to the area of the adjacent assembly of that same type; 2. Exterior surfaces whose azimuth orientation and tilt differ by less than 45 degrees and are otherwise the same shall be described as either a single surface or by using multipliers; 3. The exterior roof surface shall be modelled using the aged solar reflectance and thermal emittance determined in accordance with Section 5.3.3. Where aged test data are unavailable, the roof surface shall be modelled with a solar reflectance of 0.30 and a thermal emittance of 0.90; 4.Manually operated fenestration shading devices, such as blinds or shades, shall not be modelled. Permanent shading devices, such as fins, overhangs, and light shelves, shall be modelled;	The baseline building design shall have identical conditioned floor area and identical exterior dimensions and orientations as the proposed design, except as follows: a) Opaque assemblies, such as roof, floors, doors, and walls, shall be modelled as having the same heat capacity as the proposed design but with the minimum U-value required in Section 5.4.1 for new buildings, additions and alterations; b) The exterior roof surfaces shall be modelled with a solar reflectance and thermal emittance as required in Section 5.3.3; c) No shading projections are to be modelled; fenestration shall be assumed to be flush with the wall or roof; If the fenestration area for new buildings or addition exceeds the maximum allowed by Section 5.4, the area shall be reduced proportionally along each exposure until the limit set in Section 5.4 is met. d) Fenestration U-factor shall be equal to the criteria from Tables 5.4.1 through 5.4.3 for the appropriate climate, and the SHGC shall be equal to the criteria from Tables 5.4.1 through 5.4.3 for the appropriate climate. Where there is no SHGC requirement, the SHGC shall be equal to 0.40 for all vertical fenestration and 0.55 for skylights. The VLT for fenestration in the base line building envelope design shall be equal to 1.10 times the SHGC. e) Fenestration and doors shall be modelled with air leakage levels mentioned in section 5.3.1 if required by the modelling software;

Proposed building design	Baseline building design
Thermal blocks - HVAC zones designed	
Where HVAC zones are defined on HVAC design drawings, each HVAC zone shall be modeled as a separate thermal block. Exceptions: Different HVAC zones may be combined to create a single thermal block or identical thermal blocks to which multipliers are applied, provided that all of the following conditions are met: 1. The space-use classification is the same throughout the thermal block, or all of the zones have peak internal loads that differ by less than 32W/m^2 from the average; 2. All HVAC zones in the thermal block that are adjacent to glazed exterior walls and glazed semi-exterior walls face the same orientation or their orientations vary by less than 45 degrees; 3. All of the zones are served by the same HVAC system or by the same kind of HVAC system; 4. All of the zones have schedules that differ by 40 or less equivalent full-load hours per week	Same as proposed design.

Proposed building design	Baseline building
Thermal blocks - HVAC zones not designed	
Where the HVAC zones and systems have not yet been designed, thermal blocks shall be defined based on similar internal load densities, occupancy, lighting, thermal and space temperature schedules, and in combination with the following: a) Separate thermal blocks shall be assumed for interior and perimeter spaces. Interior spaces shall be those located more than 4.5 m from an exterior wall or semi exterior wall. Perimeter spaces shall be those located closer than 4.5 m from an exterior wall or semi exterior wall. A separate thermal zone does not need to be modeled for areas adjacent to semi-exterior walls that separate semi heated space from conditioned space; b) Separate thermal blocks shall be assumed for spaces adjacent to glazed exterior walls or glazed semi-exterior walls; a separate zone shall be provided for each orientation, except that orientations that differ by less than 45 degrees may be considered to be the same orientation. Each zone shall include all floor area that is 4.5 m or less from a glazed perimeter wall, except that floor area within 4.5 m of glazed perimeter walls having more than one orientation shall be divided proportionately between zones; c) Separate thermal blocks shall be assumed for spaces having floors that are in contact with the ground or exposed to ambient conditions from zones that do not share these features; d) Separate thermal blocks shall be assumed for spaces having exterior ceiling or roof assemblies from zones that do not share these features;	Same as proposed design.
Thermal blocks - multifamily residential buildings	
Residential spaces shall be modeled using at least one HVAC zone per dwelling unit except for those units with the same orientations, which may be combined into one thermal block. Corner units and units with roof or floor loads shall only be combined with units sharing these features.	Same as proposed design.

<table>
<tr><th>Proposed building design</th><th>Baseline building</th></tr>
<tr><td colspan="2">HVAC systems</td></tr>
<tr><td>The HVAC system type and all related performance parameters, such as equipment capacities and efficiencies, in the proposed design shall be determined as follows:

a) Where a complete HVAC system exists, the model shall reflect the actual system type using actual component capacities and efficiencies;

b) Where an HVAC system has been designed, the HVAC model shall be consistent with design documents. Mechanical equipment efficiencies shall be adjusted from actual design conditions to the standard rating conditions specified in Section 6.4.1.2 in ASHRAE 90.1-2019 if required by the simulation model. Where efficiency ratings include supply fan energy, the efficiency rating shall be adjusted to remove the supply fan energy from the efficiency rating in the baseline building design. The proposed design HVAC system shall be modelled using manufacturers' full and part-load data for the HVAC system without fan power;

c) Where no heating system exists or no heating system has been specified, the heating system shall be modelled as using fossil fuel.

The system characteristics shall be identical to the system modelled in the baseline building design.

d) Where no cooling system exists or no cooling system has been specified, the cooling system shall be modelled as an air-cooled single-zone system, one unit per thermal block. The system characteristics shall be identical to the system modelled in the baseline building design;</td><td>a) HVAC Systems for the base line building shall be selected based on the size of the conditioned floor area, number of floors and activity type. For distinctly different occupancy type within the same facility could use a different but appropriate base case HVAC system;

b) Reference HVAC systems for the Baseline building should be selected based on the peak building cooling Load (PBCL). Peak building cooling Load > 500RT, system will be centrifugal chiller. PBCL < 500 RT, screw chiller, PBCL < 500 RT and floor area < 5,000 m^2, system will be the same type as proposed. The efficiencies of the reference HVAC system equipment shall be as per section 6 of this Code, corresponding to the reference HVAC system capacities;</td></tr>
</table>

<table>
<tr><th>Proposed building design</th><th>Baseline building</th></tr>
<tr><td colspan="2">Lighting</td></tr>
<tr><td>Lighting power in the proposed design shall be determined as follows:

a) Where a complete lighting system exists, the actual lighting power for each thermal block shall be used in the model;

b) Where a complete lighting system has been designed, lighting power for each thermal block shall be determined in accordance with Sections 9.1.3;

c) Where no lighting exists or is specified, lighting power shall be determined in accordance with the Building Area Method for the appropriate building area type;

d) Lighting system power shall include all lighting system components shown or provided for on plans (including lamps, ballasts, task fixtures, and furniture-mounted fixtures). For hotel/motel guest rooms, and other spaces in which lighting systems consist of plug-in light fixtures that are not shown or provided for on design documents, assume identical lighting power for the proposed design and baseline building design in the simulations;

e) The lighting schedules in the proposed design shall reflect the mandatory automatic lighting control requirements in Section 9.3 (e.g. programmable controls or occupancy sensors).

f) Automatic daylighting controls included in the proposed design may be modelled directly in the building simulation or be modelled in the building simulation through schedule adjustments determined by a separate analysis approved by Authority. Modeling and schedule adjustments shall separately account for primary side lit areas, secondary side lit areas, and top lit areas.</td><td>a) Where a complete lighting system exists, lighting power in the baseline building design shall be the same as in the proposed design;

b) Where a lighting system has been designed, the interior lighting power allowance shall be determined using either the Building Area Method or Space-by-Space Method, and the space use classification shall be the same as the proposed design with lighting power set equal to the maximum allowed for the corresponding method and category in Section 9.3 and 9.4;

c) Where lighting neither exists nor is submitted with design documents, the lighting power in the baseline building design shall be the same as in the proposed design;

d) Power for fixtures not included in the lighting power calculation shall be modeled identically in the proposed design and budget building design;

e) Mandatory automatic lighting controls required by Section 9.3 shall be modeled the same as the proposed design;</td></tr>
</table>

Proposed building design	Baseline building
Service water-heating system	
The service water-heating system type and all related performance parameters, such as equipment capacities and efficiencies, in the proposed design shall be determined as follows: a) Where a complete service water-heating system exists, the model shall reflect the actual system type using actual component capacities and efficiencies; b) Where a service water-heating system has been designed and submitted with design documents, the service water-heating model shall be consistent with design documents; c) Where no service water-heating system exists or has been submitted with the design documents, no service water heating shall be modeled; Piping losses shall not be modeled.	The service water-heating system type in the Baseline Building shall be identical to the proposed design. The service water-heating system performance of the Baseline Building shall meet the requirements of Sections 7.3 and 7.4. Exceptions: 1. If the service water-heating system type is not listed in Table 7.3.1, it shall be determined based on Table G3.1.1-2 in ASHRAE 90.1- 2019; 2. Where Section 7.4 applies, the boiler shall be split into a separate space-heating boiler and hot-water heater with efficiency requirements set to the least efficient allowed; 3. For 24-hour facilities that meet the prescriptive criteria for use of condenser heat recovery systems described in Section 6.4.4.2, (HVAC) a system meeting the requirements of that section shall be included in the baseline building design. If a condenser heat recovery system meeting the requirements described in Section 6.4.4.2 cannot be modelled, the requirement for including such a system in the actual building shall be met as a prescriptive requirement in accordance with Section 6.4.4.2 and no heat recovery system shall be included in the proposed design or baseline building design; Service water-heating energy use shall be calculated explicitly based on the volume of service water heating required, the entering makeup water, and the leaving service water heating temperatures. Entering water temperatures shall be estimated based on the location. Leaving temperatures shall be based on the end-use requirements. Service water loads and use shall be the same for both the proposed design and baseline building design and typical of the proposed building type. Piping losses shall not be modelled.

Proposed building design	Baseline building
Miscellaneous loads	
Miscellaneous loads shall be modelled as identical to those in the proposed design including schedules of operation and control of the equipment. These sub-systems or components shall be modelled as having their efficiencies corresponding to the selection by the design and their power and energy rating or capacity of the equipment shall be identical between the baseline and the proposed design.	Same as proposed design.

11.2.3.4 Ventilation

Fresh air flow rates as per ASHRAE 62.1-2007 minimum ventilation rates as per the ventilation rate procedure except when Demand Control Ventilation (DCV) is compulsory for the proposed Building.

11.2.3.5 Modelling limitations

All energy using sub-systems shall be modelled as accommodated by the simulation tool employed. However, if any modelling limitations are encountered they shall be accommodated as per the decision by the Authority as exceptional modelling provided that such modelling is supported by a clear narration describing the salient steps.

11.2.4 Compliance calculations

The design energy use and the baseline energy use shall be calculated using the same simulation software and the same weather data. The proposed building annual energy use shall be less than the baseline building annual energy use estimated.

11.2.5 Exception calculations

When the simulation program cannot adequately model a design, material, or device, the Authority may approve an exceptional calculation method to be used to estimate the proposed building energy.

Appendix 1: Envelope Thermal Transfer Value - ETTV Formula

The ETTV formula is given as follows:

$ETTV = 12\ (1 - WWR)\ U_w + 3.4\ (WWR)\ U_f + 211\ (WWR)\ (CF)\ (SC)$

Where;

ETTV	Envelope thermal transfer value (W/m^2)
WWR	window-to-wall ratio (fenestration area/gross area of exterior wall)
Uw	Thermal transmittance of opaque wall (W/m^2K)
U*f*	Thermal transmittance of fenestration (W/m^2K)
CF	Correction factor for solar heat gain through fenestration
SC	Shading coefficients of fenestration

Where more than one type of material and/or fenestration is used, the respective term or terms shall be expanded into sub-elements as shown:

$$ETTV = \frac{12\ (A_{w1} \times U_{w1} + A_{w2} \times U_{w2} + \ldots + A_{wn} \times U_{wn})}{A_O} + \frac{3.4\ (A_{11} \times U_{11} + A_{12} \times U_{12} + \ldots + A_{fn} \times U_{fn})}{A_O} + \frac{211\ (A_{11} \times SC_{11} + A_{12} \times SC_{12} + \ldots A_{fn} \times SC_{fn})\ (CF)}{A_O}$$

Where;

A_{w1}, A_{w2}, A_{wn}	Areas of different opaque wall (m^2)
A_{f1}, A_{f2}, A_{fn}	areas of different fenestration (m^2)
A_o	Gross area of the exterior wall (m^2)
U_{w1}, U_{w2}, U_{wn}	Thermal transmittances of opaque walls (W/m^2K)
U_{f1}, U_{f2}, U_{fn}	Thermal transmittances of fenestrations (W/m^2K)
SC_{f1}, SC_{f2}, SC_{fn}	Shading coefficients of fenestrations
CF	Correction factor for solar heat gain through fenestration

As walls at different orientations receive different amounts of solar radiation, it is necessary in general to first compute the ETTVs of individual walls, then the ETTV of the whole building envelope is obtained by taking the weighted average of these values. To calculate the ETTV for the envelope of the whole building, the following formula shall be used:

$$ETTV = \frac{A_{01} \times ETTV_1 + A_{02} \times ETTV_2 + \ldots + A_{on} \times ETTV_n}{A_{01} + A_{02} + \ldots + A_{on}}$$

Where;

A_{o1}, A_{o2}, A_{on}: gross areas of the exterior wall for each orientation (m^2)

The solar correction factors for eight primary orientations of the walls have been determined for the climate conditions of Sri Lanka. They are given in Table A.1-1

Table A.1-1 Solar correction factors (CF) for walls (ETTV)

Pitch	Orientation							
Angle	N	NE	E	SE	S	SW	W	NW
70^0	1.17	1.33	1.47	1.35	1.21	1.41	1.56	1.38
75^0	1.07	1.23	1.37	1.25	1.11	1.32	1.47	1.28
80^0	0.98	1.14	1.30	1.16	1.01	1.23	1.39	1.20
85^0	0.89	1.05	1.21	1.07	0.92	1.14	1.31	1.11
90^0	0.80	0.97	1.13	0.98	0.83	1.06	1.23	1.03
95^0	0.73	0.90	1.05	0.91	0.76	0.99	1.15	0.96
100^0	0.67	0.83	0.97	0.84	0.70	0.92	1.08	0.89
105^0	0.62	0.77	0.90	0.78	0.65	0.86	1.01	0.83
110^0	0.59	0.72	0.83	0.72	0.61	0.80	0.94	0.78
115^0	0.57	0.67	0.77	0.67	0.58	0.75	0.87	0.73
120^0	0.55	0.63	0.72	0.63	0.56	0.71	0.81	0.69

Note:1. The correction factors for other orientations and other pitch angles may be obtained by interpolation.

If the wall is curved, the eight primary orientations are segmented as follows:

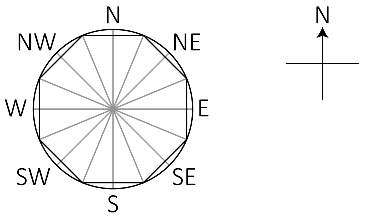


Figure A.1-1 : Eight primary orientations for a curved wall

Shading Coefficient

Shading coefficient of the fenestration system is defined as the ratio of solar heat gain through the fenestration system having combination of glazing and shading device to the solar heat gain through an unshaded 3mm clear glass. This ratio is a unique characteristic of each type of fenestration system and is represented by the equation:

$$SC = \frac{\text{Solar heat gain of any glass and shading combination Solar}}{\text{heat gain through a 3mm unshaded clear glass}}$$

In general, the shading coefficient of any fenestration system can be obtained by multiplying the shading coefficient of the glass (or effective shading coefficient of glass with solar control film where a solar control film is used on the glass) and the shading coefficient of the sun-shading devices as follows:

$SC = SC_1 \times SC_2$

where;

SC : shading coefficient of the fenestration system

SC_1 : shading coefficient of glass or effective shading coefficient of glass with solar control film where a solar control film is used on the glass

SC_2 : effective shading coefficient of external shading devices

The shading coefficient of the glass or effective shading coefficient of glass with solar control film should be based on the manufacturer's recommended value.

The effective shading coefficient of external shading devices as given in Tables A.1-2 to A.1-13 shall be used unless the type of shading device is not included in the tables. In that case, the effective shading coefficient shall be calculated from the basic solar data with the method specified Below.

Method of calculating effective shading coefficient of external sun- shading device

When a window is partially shaded by an external shading device, it is assumed that the exposed portion receives the total radiation, I_T, and the shaded portion receives only the diffuse radiation, I_d.

The instantaneous heat gain due to solar radiation can then be expressed as follows:

$$Q = (A_e \times I_T) + (A_s \times I_d)$$

$$= (A_e \times I_D) + (A_e + A_s) \times I_d$$

where;
- Q : solar heat gain
- A_e : exposed area of window
- A_s : shaded area of window
- I_T : total radiation
- I_D : direct radiation
- I_d : diffused Radiation

Since

$$A = A_e + A_s$$

Therefore

$$Q = (A_e \times I_D) + (A \times I_d)$$

For an unshaded 3mm clear glass, the solar heat gain is given by $A \times I_T$. By definition, the hourly Shading Coefficient, SC, of a shading device can be expressed as:

$$SC = \frac{(A_e \times I_D) + (A \times I_d)}{A \times I_T}$$

$$= \frac{G \times I_D + I_d}{I_T}$$

where;

$$G = \frac{A_e}{A}$$

the fraction of area exposed to direct solar radiation

To calculate the shading coefficient (SC) of a shading device for the whole day, the hourly solar heat gain shall be computed and summed up for the 12 daylight hours. The total solar heat gain is then divided by the sum of the total radiation, IT, through an unshaded 3mm clear glass for the same hours of the day, to obtain the SC for the day. Mathematically, the computation can be expressed as follows:

$$SC_{day} = \frac{\sum_{h=1}^{h=12} (A_e \times I_D + I_d)_h}{\sum_{h=1}^{h=12} (A \times I_T)_h}$$

where subscript 'day' and 'h' refers to daily & hourly respectively.

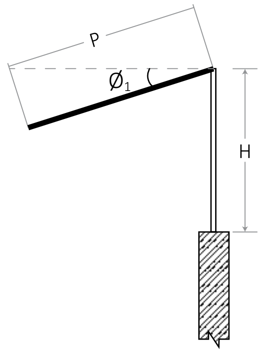
to determine the effective SC of a shading device, theoretically, the computation has to be carried out for each day of the year.

APPENDIX 1

Keys for Tables of Effective Shading Coefficient of External Shading Devices

Key 1 Horizontal Projections [Tables A.1-2 to A.1-5]

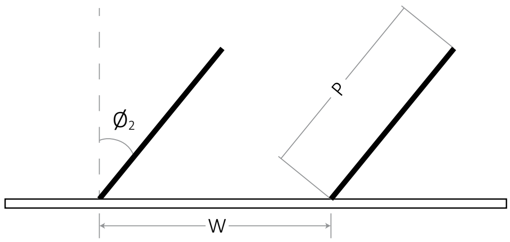
$$R_1 = \frac{P}{H}$$



$\varnothing_1$ = Angle of inclination

Key 2 Vertical Projections [Tables A.1-6 to A.1-9]

$$R_2 = \frac{P}{W}$$

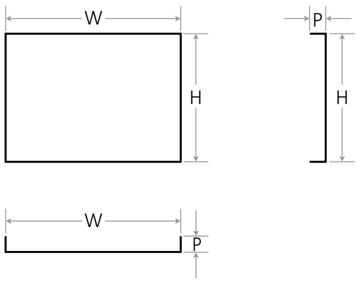


$\varnothing_2$ = Angle of inclination

Egg-crate Louvers [Tables A.1-10 to A.1-13]

$$R_1 = \frac{P}{H}$$

$$R_2 = \frac{P}{W}$$



Ø1 = Angle of inclination

Table A.1-2: Effective Shading Coefficients of Horizontal Projection at various Angles of Inclination

Orientation: North & South

R_1	0^0	10^0	20^0	30^0	40^0	50^0
0.1	0.9380	0.9330	0.9300	0.9291	0.9303	0.9336
0.2	0.8773	0.8674	0.8613	0.8595	0.8619	0.8685
0.3	0.8167	0.8017	0.7927	0.7899	0.7935	0.8033
0.4	0.7560	0.7392	0.7288	0.7245	0.7263	0.7382
0.5	0.7210	0.7080	0.7001	0.6950	0.6927	0.6938
0.6	0.7041	0.6921	0.6848	0.6804	0.6774	0.6760
0.7	0.6923	0.6842	0.6775	0.6723	0.6689	0.6672
0.8	0.6871	0.6779	0.6702	0.6661	0.6641	0.6626
0.9	0.6819	0.6718	0.6670	0.6643	0.6621	0.6604
1.0	0.6767	0.6690	0.6655	0.6625	0.6600	0.6583
1.1	0.6731	0.6678	0.6640	0.6607	0.6584	0.6577
1.2	0.6713	0.6667	0.6625	0.6589	0.6577	0.6577
1.3	0.6705	0.6656	0.6611	0.6582	0.6577	0.6577
1.4	0.6698	0.6644	0.6596	0.6577	0.6577	0.6577
1.5	0.6690	0.6633	0.6588	0.6577	0.6577	0.6577
1.6	0.6683	0.6622	0.6582	0.6577	0.6577	0.6577
1.7	0.6675	0.6610	0.6577	0.6577	0.6577	0.6577
1.8	0.6667	0.6599	0.6577	0.6577	0.6577	0.6577
1.9	0.6660	0.6594	0.6577	0.6577	0.6577	0.6577
2.0	0.6652	0.6589	0.6577	0.6577	0.6577	0.6577
2.1	0.6645	0.6585	0.6577	0.6577	0.6577	0.6577
2.2	0.6637	0.6581	0.6577	0.6577	0.6577	0.6577
2.3	0.6630	0.6577	0.6577	0.6577	0.6577	0.6577
2.4	0.6622	0.6577	0.6577	0.6577	0.6577	0.6577
2.5	0.6614	0.6577	0.6577	0.6577	0.6577	0.6577
2.6	0.6607	0.6577	0.6577	0.6577	0.6577	0.6577
2.7	0.6604	0.6577	0.6577	0.6577	0.6577	0.6577
2.8	0.6601	0.6577	0.6577	0.6577	0.6577	0.6577
2.9	0.6599	0.6577	0.6577	0.6577	0.6577	0.6577
3.0	0.6596	0.6577	0.6577	0.6577	0.6577	0.6577

Table A.1-3: Effective Shading Coefficients of Horizontal Projection at Various Angles of Inclination

Orientation: East & West

R_1	0^0	10^0	20^0	30^0	40^0	50^0
0.1	0.9363	0.9268	0.9195	0.9147	0.9124	0.9129
0.2	0.8752	0.8565	0.8416	0.8309	0.8257	0.8257
0.3	0.8228	0.7947	0.7723	0.7563	0.7470	0.7448
0.4	0.7703	0.7330	0.7036	0.6820	0.6693	0.6664
0.5	0.7248	0.6842	0.6550	0.6231	0.6045	0.5946
0.6	0.6911	0.6424	0.6013	0.5691	0.5467	0.5349
0.7	0.6574	0.6006	0.5559	0.5249	0.5012	0.4851
0.8	0.6237	0.5693	0.5273	0.4923	0.4651	0.4467
0.9	0.5998	0.5463	0.4991	0.4608	0.4389	0.4237
1.0	0.5827	0.5232	0.4727	0.4442	0.4222	0.4062
1.1	0.5656	0.5002	0.4587	0.4296	0.4075	0.4010
1.2	0.5485	0.4828	0.4468	0.4151	0.4036	0.3969
1.3	0.5314	0.4739	0.4349	0.4089	0.3999	0.3963
1.4	0.5156	0.4650	0.4230	0.4059	0.3969	0.3963
1.5	0.5051	0.4561	0.4147	0.4029	0.3963	0.3963
1.6	0.4995	0.4472	0.4123	0.3999	0.3963	0.3963
1.7	0.4939	0.4383	0.4101	0.3974	0.3963	0.3963
1.8	0.4882	0.4294	0.4079	0.3963	0.3963	0.3963
1.9	0.4826	0.4237	0.4057	0.3963	0.3963	0.3963
2.0	0.4770	0.4204	0.4035	0.3963	0.3963	0.3963
2.1	0.4713	0.4190	0.4013	0.3963	0.3963	0.3963
2.2	0.4657	0.4176	0.3991	0.3963	0.3963	0.3963
2.3	0.4601	0.4163	0.3978	0.3963	0.3963	0.3963
2.4	0.4544	0.4149	0.3968	0.3963	0.3963	0.3963
2.5	0.4488	0.4135	0.3963	0.3963	0.3963	0.3963
2.6	0.4432	0.4122	0.3963	0.3963	0.3963	0.3963
2.7	0.4400	0.4108	0.3963	0.3963	0.3963	0.3963
2.8	0.4369	0.4094	0.3963	0.3963	0.3963	0.3963
2.9	0.4339	0.4081	0.3963	0.3963	0.3963	0.3963
3.0	0.4333	0.4067	0.3963	0.3963	0.3963	0.3963

Table A.1-4: Effective Shading Coefficients of Horizontal Projection at Various Angles of Inclination

Orientation: North-East & North-West

R_1	0^0	10^0	20^0	30^0	40^0	50^0
0.1	0.9273	0.9193	0.9137	0.9106	0.9101	0.9122
0.2	0.8630	0.8471	0.8355	0.8285	0.8263	0.8291
0.3	0.8054	0.7820	0.7644	0.7533	0.7489	0.7515
0.4	0.7563	0.7278	0.7055	0.6895	0.6803	0.6799
0.5	0.7171	0.6824	0.6546	0.6345	0.6228	0.6198
0.6	0.6787	0.6443	0.6165	0.5946	0.5793	0.5710
0.7	0.6549	0.6166	0.5842	0.5587	0.5420	0.5320
0.8	0.6327	0.5889	0.5563	0.5360	0.5200	0.5088
0.9	0.6105	0.5681	0.5412	0.5184	0.5026	0.4919
1.0	0.5922	0.5560	0.5261	0.5051	0.4900	0.4826
1.1	0.5809	0.5440	0.5148	0.4939	0.4840	0.4790
1.2	0.5722	0.5321	0.5046	0.4877	0.4809	0.4759
1.3	0.5634	0.5243	0.4971	0.4850	0.4782	0.4759
1.4	0.5547	0.5165	0.4921	0.4825	0.4759	0.4759
1.5	0.5466	0.5086	0.4894	0.4802	0.4759	0.4759
1.6	0.5413	0.5037	0.4874	0.4780	0.4759	0.4759
1.7	0.5359	0.5001	0.4854	0.4759	0.4759	0.4759
1.8	0.5306	0.4965	0.4837	0.4759	0.4759	0.4759
1.9	0.5253	0.4949	0.4821	0.4759	0.4759	0.4759
2.0	0.5200	0.4936	0.4804	0.4759	0.4759	0.4759
2.1	0.5162	0.4923	0.4787	0.4759	0.4759	0.4759
2.2	0.5141	0.4909	0.4770	0.4759	0.4759	0.4759
2.3	0.5119	0.4897	0.4759	0.4759	0.4759	0.4759
2.4	0.5097	0.4886	0.4759	0.4759	0.4759	0.4759
2.5	0.5075	0.4876	0.4759	0.4759	0.4759	0.4759
2.6	0.5053	0.4865	0.4759	0.4759	0.4759	0.4759
2.7	0.5047	0.4855	0.4759	0.4759	0.4759	0.4759
2.8	0.5042	0.4844	0.4759	0.4759	0.4759	0.4759
2.9	0.5036	0.4834	0.4759	0.4759	0.4759	0.4759
3.0	0.5031	0.4823	0.4759	0.4759	0.4759	0.4759

Table A.1-5: Effective Shading Coefficients of Horizontal Projection at Various Angles of Inclination

Orientation: South-East & South-West

R_1	0^0	10^0	20^0	30^0	40^0	50^0
0.1	0.9253	0.9167	0.9107	0.9072	0.9065	0.9086
0.2	0.8574	0.8405	0.8280	0.8203	0.8177	0.8204
0.3	0.7964	0.7715	0.7527	0.7406	0.7355	0.7377
0.4	0.7413	0.7100	0.6862	0.6692	0.6601	0.6597
0.5	0.6981	0.6615	0.6321	0.6109	0.5985	0.5951
0.6	0.6578	0.6179	0.5890	0.5663	0.5503	0.5417
0.7	0.6289	0.5891	0.5555	0.5289	0.5107	0.5004
0.8	0.6059	0.5604	0.5251	0.5044	0.4880	0.4765
0.9	0.5828	0.5372	0.5096	0.4863	0.4702	0.4592
1.0	0.5619	0.5248	0.4942	0.4727	0.4573	0.4493
1.1	0.5502	0.5124	0.4826	0.4613	0.4507	0.4459
1.2	0.5413	0.5003	0.4722	0.4551	0.4477	0.4429
1.3	0.5323	0.4923	0.4646	0.4516	0.4451	0.4429
1.4	0.5234	0.4843	0.4596	0.4492	0.4429	0.4429
1.5	0.5150	0.4763	0.4558	0.4471	0.4429	0.4429
1.6	0.5096	0.4714	0.4538	0.4449	0.4429	0.4429
1.7	0.5042	0.4678	0.4521	0.4429	0.4429	0.4429
1.8	0.4988	0.4642	0.4505	0.4429	0.4429	0.4429
1.9	0.4933	0.4610	0.4489	0.4429	0.4429	0.4429
2.0	0.4879	0.4598	0.4472	0.4429	0.4429	0.4429
2.1	0.4841	0.4585	0.4456	0.4429	0.4429	0.4429
2.2	0.4820	0.4572	0.4440	0.4429	0.4429	0.4429
2.3	0.4798	0.4562	0.4429	0.4429	0.4429	0.4429
2.4	0.4777	0.4552	0.4429	0.4429	0.4429	0.4429
2.5	0.4755	0.4542	0.4429	0.4429	0.4429	0.4429
2.6	0.4734	0.4532	0.4429	0.4429	0.4429	0.4429
2.7	0.4712	0.4521	0.4429	0.4429	0.4429	0.4429
2.8	0.4699	0.4511	0.4429	0.4429	0.4429	0.4429
2.9	0.4694	0.4501	0.4429	0.4429	0.4429	0.4429
3.0	0.4688	0.4491	0.4429	0.4429	0.4429	0.4429

Table A.1-6: Effective Shading Coefficients of Vertical Projection at Various Angles of Inclination

Orientation: North & South

R_1	0^0	10^0	20^0	30^0	40^0	50^0
0.1	0.9526	0.9534	0.9549	0.9571	0.9606	0.9638
0.2	0.9066	0.9082	0.9110	0.9155	0.9225	0.9289
0.3	0.8605	0.8630	0.8672	0.8739	0.8844	0.8940
0.4	0.8144	0.8177	0.8236	0.8325	0.8463	0.8591
0.5	0.7752	0.7800	0.7892	0.8005	0.8159	0.8277
0.6	0.7540	0.7563	0.7632	0.7768	0.7950	0.8078
0.7	0.7379	0.7434	0.7464	0.7560	0.7771	0.7920
0.8	0.7290	0.7306	0.7348	0.7423	0.7637	0.7807
0.9	0.7202	0.7230	0.7269	0.7319	0.7507	0.7699
1.0	0.7114	0.7183	0.7190	0.7246	0.7388	0.7595
1.1	0.7060	0.7137	0.7144	0.7173	0.7308	0.7523
1.2	0.7022	0.7091	0.7098	0.7099	0.7251	0.7451
1.3	0.7000	0.7045	0.7053	0.7055	0.7206	0.7379
1.4	0.6977	0.6999	0.7007	0.7022	0.7173	0.7307
1.5	0.6954	0.6961	0.6981	0.7003	0.7141	0.7236
1.6	0.6932	0.6939	0.6960	0.6983	0.7109	0.7173
1.7	0.6909	0.6916	0.6940	0.6964	0.7077	0.7131
1.8	0.6886	0.6894	0.6919	0.6945	0.7044	0.7105
1.9	0.6864	0.6889	0.6899	0.6926	0.7012	0.7078
2.0	0.6841	0.6886	0.6878	0.6907	0.6980	0.7052
2.1	0.6818	0.6884	0.6858	0.6888	0.6948	0.7056
2.2	0.6796	0.6881	0.6853	0.6869	0.6915	0.7000
2.3	0.6773	0.6879	0.6849	0.6849	0.6910	0.6979
2.4	0.6750	0.6876	0.6845	0.6830	0.6909	0.6967
2.5	0.6728	0.6873	0.6841	0.6811	0.6908	0.6954
2.6	0.6705	0.6871	0.6837	0.6792	0.6908	0.6942
2.7	0.6695	0.6868	0.6833	0.6773	0.6907	0.6930
2.8	0.6686	0.6866	0.6829	0.6754	0.6906	0.6917
2.9	0.6677	0.6863	0.6826	0.6735	0.6905	0.6905
3.0	0.6668	0.6860	0.6822	0.6716	0.6904	0.6893

Table A.1-7: Effective Shading Coefficients of Vertical Projection at Various Angles of Inclination

Orientation: East & West

R_1	0^0	10^0	20^0	30^0	40^0	50^0
0.1	0.9805	0.9751	0.9704	0.9653	0.9584	0.9520
0.2	0.9607	0.9499	0.9406	0.9302	0.9166	0.9038
0.3	0.9409	0.9247	0.9108	0.8952	0.8747	0.8555
0.4	0.9223	0.9007	0.8821	0.8614	0.8338	0.8078
0.5	0.9047	0.8774	0.8537	0.8275	0.7931	0.7606
0.6	0.8870	0.8543	0.8259	0.7939	0.7523	0.7133
0.7	0.8694	0.8313	0.7980	0.7616	0.7129	0.6671
0.8	0.8518	0.8090	0.7728	0.7312	0.6753	0.6227
0.9	0.8348	0.7884	0.7476	0.7014	0.6406	0.5823
1.0	0.8193	0.7678	0.7233	0.6747	0.6098	0.5493
1.1	0.8057	0.7471	0.7015	0.6511	0.5850	0.5184
1.2	0.7921	0.7287	0.6810	0.6320	0.5605	0.4880
1.3	0.7785	0.7120	0.6631	0.6135	0.5361	0.4633
1.4	0.7654	0.6960	0.6482	0.5949	0.5120	0.4577
1.5	0.7541	0.6826	0.6334	0.5764	0.4899	0.4526
1.6	0.7441	0.6696	0.6187	0.5579	0.4820	0.4474
1.7	0.7349	0.6589	0.6042	0.5397	0.4790	0.4422
1.8	0.7257	0.6485	0.5906	0.5220	0.4760	0.4371
1.9	0.7185	0.6381	0.5770	0.5065	0.4730	0.4319
2.0	0.7122	0.6276	0.5634	0.4982	0.4700	0.4268
2.1	0.7070	0.6172	0.5497	0.4966	0.4670	0.4221
2.2	0.7036	0.6076	0.5362	0.4950	0.4641	0.4185
2.3	0.7019	0.5987	0.5232	0.4934	0.4611	0.4158
2.4	0.7007	0.5897	0.5101	0.4918	0.4581	0.4145
2.5	0.6999	0.5808	0.4971	0.4902	0.4551	0.4132
2.6	0.6990	0.5718	0.4849	0.4886	0.4521	0.4119
2.7	0.6982	0.5629	0.4747	0.4870	0.4491	0.4105
2.8	0.6974	0.5539	0.4668	0.4859	0.4461	0.4092
2.9	0.6965	0.5450	0.4616	0.4850	0.4431	0.4082
3.0	0.6957	0.5360	0.4591	0.4841	0.4401	0.4080

Table A.1-8: Effective Shading Coefficients of Vertical Projection at Various Angles of Inclination

Orientation: North-East & North-West

R_1	0^0	10^0	20^0	30^0	40^0	50^0
0.1	0.9517	0.9445	0.9389	0.9346	0.9317	0.9314
0.2	0.9074	0.8931	0.8819	0.8729	0.8670	0.8650
0.3	0.8646	0.8436	0.8268	0.8131	0.8036	0.8005
0.4	0.8262	0.7991	0.7770	0.7585	0.7449	0.7381
0.5	0.7912	0.7573	0.7297	0.7066	0.6895	0.6809
0.6	0.7562	0.7155	0.6824	0.6546	0.6342	0.6239
0.7	0.7230	0.6740	0.6356	0.6043	0.5832	0.5701
0.8	0.6899	0.6352	0.6038	0.5836	0.5643	0.5493
0.9	0.6575	0.6158	0.5921	0.5683	0.5465	0.5296
1.0	0.6359	0.6069	0.5806	0.5530	0.5288	0.5104
1.1	0.6300	0.5981	0.5691	0.5380	0.5125	0.5005
1.2	0.6240	0.5892	0.5576	0.5241	0.5038	0.4958
1.3	0.6181	0.5803	0.5461	0.5146	0.4984	0.4915
1.4	0.6121	0.5715	0.5348	0.5091	0.4946	0.4898
1.5	0.6061	0.5626	0.5257	0.5050	0.4908	0.4884
1.6	0.6002	0.5537	0.5201	0.5028	0.4881	0.4869
1.7	0.5942	0.5449	0.5161	0.5006	0.4874	0.4854
1.8	0.5883	0.5365	0.5120	0.4985	0.4867	0.4840
1.9	0.5823	0.5291	0.5094	0.4963	0.4860	0.4825
2.0	0.5763	0.5235	0.5079	0.4941	0.4853	0.4811
2.1	0.5704	0.5198	0.5064	0.4939	0.4846	0.4798
2.2	0.5644	0.5166	0.5050	0.4936	0.4839	0.4795
2.3	0.5590	0.5135	0.5035	0.4933	0.4831	0.4791
2.4	0.5541	0.5104	0.5020	0.4931	0.4824	0.4788
2.5	0.5494	0.5073	0.5005	0.4928	0.4817	0.4785
2.6	0.5452	0.5042	0.4991	0.4925	0.4810	0.4781
2.7	0.5410	0.5027	0.4976	0.4923	0.4803	0.4778
2.8	0.5376	0.5014	0.4961	0.4920	0.4796	0.4775
2.9	0.5349	0.5002	0.4946	0.4917	0.4788	0.4772
3.0	0.5323	0.4989	0.4941	0.4914	0.4781	0.4768

Table A.1-9: Effective Shading Coefficients of Vertical Projection at Various Angles of Inclination

Orientation: South-East & South-West

R_1	0^0	10^0	20^0	30^0	40^0	50^0
0.1	0.9528	0.9457	0.9396	0.9351	0.9317	0.9304
0.2	0.9081	0.8938	0.8815	0.8724	0.8654	0.8624
0.3	0.8650	0.8437	0.8253	0.8113	0.8005	0.7955
0.4	0.8257	0.7988	0.7746	0.7555	0.7395	0.7307
0.5	0.7907	0.7570	0.7269	0.7029	0.6829	0.6715
0.6	0.7561	0.7153	0.6791	0.6504	0.6264	0.6127
0.7	0.7229	0.6743	0.6313	0.5978	0.5698	0.5539
0.8	0.6897	0.6342	0.5861	0.5629	0.5412	0.5242
0.9	0.6565	0.5987	0.5700	0.5474	0.5235	0.5045
1.0	0.6233	0.5863	0.5584	0.5324	0.5059	0.4850
1.1	0.6056	0.5771	0.5470	0.5185	0.4894	0.4737
1.2	0.5983	0.5685	0.5357	0.5046	0.4792	0.4670
1.3	0.5915	0.5599	0.5244	0.4946	0.4717	0.4627
1.4	0.5853	0.5513	0.5130	0.4882	0.4677	0.4586
1.5	0.5791	0.5427	0.5037	0.4831	0.4642	0.4572
1.6	0.5730	0.5341	0.4966	0.4790	0.4612	0.4557
1.7	0.5668	0.5255	0.4915	0.4771	0.4583	0.4543
1.8	0.5606	0.5169	0.4876	0.4752	0.4577	0.4528
1.9	0.5547	0.5096	0.4836	0.4734	0.4571	0.4514
2.0	0.5499	0.5043	0.4796	0.4715	0.4565	0.4499
2.1	0.5451	0.4990	0.4772	0.4696	0.4558	0.4485
2.2	0.5403	0.4938	0.4757	0.4677	0.4552	0.4471
2.3	0.5355	0.4909	0.4741	0.4662	0.4546	0.4456
2.4	0.5307	0.4879	0.4726	0.4661	0.4540	0.4446
2.5	0.5258	0.4850	0.4711	0.4660	0.4534	0.4443
2.6	0.5210	0.4820	0.4695	0.4659	0.4528	0.4439
2.7	0.5168	0.4790	0.4680	0.4658	0.4522	0.4435
2.8	0.5135	0.4761	0.4665	0.4657	0.4516	0.4432
2.9	0.5110	0.4735	0.4649	0.4656	0.4510	0.4429
3.0	0.5084	0.4715	0.4634	0.4655	0.4504	0.4429

Table A.1-10: Effective Shading Coefficients of Egg-Crate Louvers with Inclined Horizontal Fins

Orientation: North & South

R_1	R_2	0^0	10^0	20^0	30^0	40^0
0.2	0.2	0.8482	0.8306	0.8165	0.8064	0.8013
0.2	0.4	0.8212	0.8047	0.7914	0.7818	0.7769
0.2	0.6	0.7942	0.7788	0.7663	0.7572	0.7525
0.2	0.8	0.7672	0.7529	0.7412	0.7327	0.7282
0.2	1.0	0.7417	0.7284	0.7175	0.7095	0.7052
0.2	1.2	0.7190	0.7066	0.6965	0.6890	0.6850
0.2	1.4	0.6968	0.6852	0.6758	0.6688	0.6652
0.2	1.6	0.6786	0.6677	0.6589	0.6524	0.6490
0.2	1.8	0.6626	0.6523	0.6440	0.6379	0.6348
0.4	0.2	0.7513	0.7162	0.6883	0.6678	0.6556
0.4	0.4	0.7323	0.6993	0.6730	0.6535	0.6418
0.4	0.6	0.7133	0.6825	0.6577	0.6393	0.6280
0.4	0.8	0.6943	0.6656	0.6424	0.6251	0.6143
0.4	1.0	0.6754	0.6488	0.6271	0.6108	0.6006
0.4	1.2	0.6570	0.6322	0.6118	0.5967	0.5871
0.4	1.4	0.6389	0.6158	0.5968	0.5827	0.5738
0.4	1.6	0.6235	0.6017	0.5840	0.5708	0.5625
0.4	1.8	0.6096	0.5890	0.5723	0.5599	0.5523
0.6	0.2	0.6768	0.6307	0.5917	0.5611	0.5398
0.6	0.4	0.6626	0.6190	0.5822	0.5532	0.5329
0.6	0.6	0.6483	0.6073	0.5726	0.5452	0.5260
0.6	0.8	0.6341	0.5956	0.5630	0.5372	0.5191
0.6	1.0	0.6198	0.5840	0.5535	0.5293	0.5121
0.6	1.2	0.6056	0.5723	0.5439	0.5213	0.5052
0.6	1.4	0.5915	0.5607	0.5344	0.5134	0.4984
0.6	1.6	0.5788	0.5500	0.5254	0.5058	0.4917
0.6	1.8	0.5668	0.5398	0.5167	0.4983	0.4852

Table A.1-10: Effective Shading Coefficients of Egg-Crate Louvers with Inclined Horizontal Fins (Continue)

Orientation: North & South

R_1	R_2	0^0	10^0	20^0	30^0	40^0
0.8	0.2	0.6740	0.6688	0.6645	0.6622	0.6612
0.8	0.4	0.6609	0.6598	0.6589	0.6584	0.6583
0.8	0.6	0.6577	0.6577	0.6577	0.6577	0.6577
0.8	0.8	0.6577	0.6577	0.6577	0.6577	0.6577
0.8	1.0	0.6577	0.6577	0.6577	0.6577	0.6577
0.8	1.2	0.6577	0.6577	0.6577	0.6577	0.6577
0.8	1.4	0.6577	0.6577	0.6577	0.6577	0.6577
0.8	1.6	0.6577	0.6577	0.6577	0.6577	0.6577
0.8	1.8	0.6577	0.6577	0.6577	0.6577	0.6577
1.0	0.2	0.6681	0.6638	0.6619	0.6603	0.6590
1.0	0.4	0.6595	0.6586	0.6584	0.6581	0.6579
1.0	0.6	0.6577	0.6577	0.6577	0.6577	0.6577
1.0	0.8	0.6577	0.6577	0.6577	0.6577	0.6577
1.0	1.0	0.6577	0.6577	0.6577	0.6577	0.6577
1.0	1.2	0.6577	0.6577	0.6577	0.6577	0.6577
1.0	1.4	0.6577	0.6577	0.6577	0.6577	0.6577
1.0	1.6	0.6577	0.6577	0.6577	0.6577	0.6577
1.0	1.8	0.6577	0.6577	0.6577	0.6577	0.6577
1.2	0.2	0.6651	0.6626	0.6603	0.6584	0.6577
1.2	0.4	0.6588	0.6585	0.6581	0.6578	0.6577
1.2	0.6	0.6577	0.6577	0.6577	0.6577	0.6577
1.2	0.8	0.6577	0.6577	0.6577	0.6577	0.6577
1.2	1.0	0.6577	0.6577	0.6577	0.6577	0.6577
1.2	1.2	0.6577	0.6577	0.6577	0.6577	0.6577
1.2	1.4	0.6577	0.6577	0.6577	0.6577	0.6577
1.2	1.6	0.6577	0.6577	0.6577	0.6577	0.6577
1.2	1.8	0.6577	0.6577	0.6577	0.6577	0.6577

Table A.1-10: Effective Shading Coefficients of Egg-Crate Louvers with Inclined Horizontal Fins (Continue)

Orientation: North & South

R_1	R_2	0^0	10^0	20^0	30^0	40^0
1.4	0.2	0.6642	0.6613	0.6587	0.6577	0.6577
1.4	0.4	0.6587	0.6583	0.6579	0.6577	0.6577
1.4	0.6	0.6577	0.6577	0.6577	0.6577	0.6577
1.4	0.8	0.6577	0.6577	0.6577	0.6577	0.6577
1.4	1.0	0.6577	0.6577	0.6577	0.6577	0.6577
1.4	1.2	0.6577	0.6577	0.6577	0.6577	0.6577
1.4	1.4	0.6577	0.6577	0.6577	0.6577	0.6577
1.4	1.6	0.6577	0.6577	0.6577	0.6577	0.6577
1.4	1.8	0.6577	0.6577	0.6577	0.6577	0.6577
1.6	0.2	0.6634	0.6601	0.6580	0.6577	0.6577
1.6	0.4	0.6586	0.6581	0.6578	0.6577	0.6577
1.6	0.6	0.6577	0.6577	0.6577	0.6577	0.6577
1.6	0.8	0.6577	0.6577	0.6577	0.6577	0.6577
1.6	1.0	0.6577	0.6577	0.6577	0.6577	0.6577
1.6	1.2	0.6577	0.6577	0.6577	0.6577	0.6577
1.6	1.4	0.6577	0.6577	0.6577	0.6577	0.6577
1.6	1.6	0.6577	0.6577	0.6577	0.6577	0.6577
1.6	1.8	0.6577	0.6577	0.6577	0.6577	0.6577
1.8	0.2	0.6626	0.6589	0.6577	0.6577	0.6577
1.8	0.4	0.6584	0.6579	0.6577	0.6577	0.6577
1.8	0.6	0.6577	0.6577	0.6577	0.6577	0.6577
1.8	0.8	0.6577	0.6577	0.6577	0.6577	0.6577
1.8	1.0	0.6577	0.6577	0.6577	0.6577	0.6577
1.8	1.2	0.6577	0.6577	0.6577	0.6577	0.6577
1.8	1.4	0.6577	0.6577	0.6577	0.6577	0.6577
1.8	1.6	0.6577	0.6577	0.6577	0.6577	0.6577
1.8	1.8	0.6577	0.6577	0.6577	0.6577	0.6577

Table A.1-11: Effective Shading Coefficients of Egg-Crate Louvers with Inclined Horizontal Fins

Orientation: East & West

R_1	R_2	0^0	10^0	20^0	30^0	40^0
0.2	0.2	0.8482	0.8306	0.8165	0.8064	0.8013
0.2	0.4	0.8212	0.8047	0.7914	0.7818	0.7769
0.2	0.6	0.7942	0.7788	0.7663	0.7572	0.7525
0.2	0.8	0.7672	0.7529	0.7412	0.7327	0.7282
0.2	1.0	0.7417	0.7284	0.7175	0.7095	0.7052
0.2	1.2	0.7190	0.7066	0.6965	0.6890	0.6850
0.2	1.4	0.6968	0.6852	0.6758	0.6688	0.6652
0.2	1.6	0.6786	0.6677	0.6589	0.6524	0.6490
0.2	1.8	0.6626	0.6523	0.6440	0.6379	0.6348
0.4	0.2	0.7513	0.7162	0.6883	0.6678	0.6556
0.4	0.4	0.7323	0.6993	0.6730	0.6535	0.6418
0.4	0.6	0.7133	0.6825	0.6577	0.6393	0.6280
0.4	0.8	0.6943	0.6656	0.6424	0.6251	0.6143
0.4	1.0	0.6754	0.6488	0.6271	0.6108	0.6006
0.4	1.2	0.6570	0.6322	0.6118	0.5967	0.5871
0.4	1.4	0.6389	0.6158	0.5968	0.5827	0.5738
0.4	1.6	0.6235	0.6017	0.5840	0.5708	0.5625
0.4	1.8	0.6096	0.5890	0.5723	0.5599	0.5523
0.6	0.2	0.6768	0.6307	0.5917	0.5611	0.5398
0.6	0.4	0.6626	0.6190	0.5822	0.5532	0.5329
0.6	0.6	0.6483	0.6073	0.5726	0.5452	0.5260
0.6	0.8	0.6341	0.5956	0.5630	0.5372	0.5191
0.6	1.0	0.6198	0.5840	0.5535	0.5293	0.5121
0.6	1.2	0.6056	0.5723	0.5439	0.5213	0.5052
0.6	1.4	0.5915	0.5607	0.5344	0.5134	0.4984
0.6	1.6	0.5788	0.5500	0.5254	0.5058	0.4917
0.6	1.8	0.5668	0.5398	0.5167	0.4983	0.4852

Table A.1-11: Effective Shading Coefficients of Egg-Crate Louvers with Inclined Horizontal Fins (Continue)

Orientation: East & West

R_1	R_2	0^0	10^0	20^0	30^0	40^0
0.8	0.2	0.6135	0.5615	0.5215	0.4881	0.4622
0.8	0.4	0.6033	0.5537	0.5157	0.4839	0.4593
0.8	0.6	0.5931	0.5459	0.5099	0.4798	0.4564
0.8	0.8	0.5829	0.5381	0.5041	0.4756	0.4534
0.8	1.0	0.5727	0.5304	0.4983	0.4714	0.4505
0.8	1.2	0.5625	0.5226	0.4925	0.4673	0.4476
0.8	1.4	0.5523	0.5148	0.4867	0.4631	0.4447
0.8	1.6	0.5421	0.5070	0.4809	0.4589	0.4418
0.8	1.8	0.5320	0.4992	0.4751	0.4548	0.4389
1.0	0.2	0.5744	0.5178	0.4695	0.4422	0.4212
1.0	0.4	0.5661	0.5123	0.4663	0.4401	0.4201
1.0	0.6	0.5578	0.5068	0.4631	0.4381	0.4191
1.0	0.8	0.5495	0.5014	0.4599	0.4361	0.4180
1.0	1.0	0.5412	0.4959	0.4567	0.4341	0.4170
1.0	1.2	0.5329	0.4904	0.4535	0.4321	0.4159
1.0	1.4	0.5246	0.4849	0.4503	0.4301	0.4149
1.0	1.6	0.5163	0.4795	0.4471	0.4280	0.4138
1.0	1.8	0.5080	0.4740	0.4439	0.4260	0.4128
1.2	0.2	0.5420	0.4791	0.4447	0.4144	0.4033
1.2	0.4	0.5354	0.4754	0.4426	0.4137	0.4030
1.2	0.6	0.5289	0.4717	0.4405	0.4130	0.4027
1.2	0.8	0.5223	0.4680	0.4384	0.4123	0.4024
1.2	1.0	0.5158	0.4643	0.4363	0.4117	0.4021
1.2	1.2	0.5092	0.4606	0.4342	0.4110	0.4018
1.2	1.4	0.5027	0.4569	0.4321	0.4103	0.4015
1.2	1.6	0.4961	0.4532	0.4300	0.4096	0.4012
1.2	1.8	0.4896	0.4495	0.4279	0.4089	0.4009

Table A.1-11: Effective Shading Coefficients of Egg-Crate Louvers with Inclined Horizontal Fins (Continue)

Orientation: East & West

R_1	R_2	0^0	10^0	20^0	30^0	40^0
1.4	0.2	0.5107	0.4621	0.4220	0.4055	0.3969
1.4	0.4	0.5058	0.4592	0.4210	0.4051	0.3969
1.4	0.6	0.5008	0.4563	0.4200	0.4047	0.3969
1.4	0.8	0.4959	0.4535	0.4190	0.4043	0.3969
1.4	1.0	0.4910	0.4506	0.4180	0.4039	0.3969
1.4	1.2	0.4860	0.4477	0.4170	0.4035	0.3969
1.4	1.4	0.4811	0.4449	0.4160	0.4031	0.3969
1.4	1.6	0.4762	0.4420	0.4150	0.4028	0.3969
1.4	1.8	0.4712	0.4391	0.4140	0.4024	0.3969
1.6	0.2	0.4951	0.4451	0.4117	0.3998	0.3963
1.6	0.4	0.4907	0.4431	0.4110	0.3997	0.3963
1.6	0.6	0.4863	0.4410	0.4103	0.3996	0.3963
1.6	0.8	0.4820	0.4390	0.4096	0.3995	0.3963
1.6	1.0	0.4776	0.4369	0.4089	0.3994	0.3963
1.6	1.2	0.4732	0.4349	0.4083	0.3993	0.3963
1.6	1.4	0.4688	0.4329	0.4076	0.3992	0.3963
1.6	1.6	0.4644	0.4308	0.4069	0.3991	0.3963
1.6	1.8	0.4600	0.4288	0.4062	0.3990	0.3963
1.8	0.2	0.4844	0.4281	0.4075	0.3963	0.3963
1.8	0.4	0.4805	0.4269	0.4070	0.3963	0.3963
1.8	0.6	0.4767	0.4257	0.4065	0.3963	0.3963
1.8	0.8	0.4728	0.4245	0.4061	0.3963	0.3963
1.8	1.0	0.4690	0.4233	0.4056	0.3963	0.3963
1.8	1.2	0.4651	0.4221	0.4051	0.3963	0.3963
1.8	1.4	0.4613	0.4208	0.4047	0.3963	0.3963
1.8	1.6	0.4574	0.4196	0.4042	0.3963	0.3963
1.8	1.8	0.4536	0.4184	0.4037	0.3963	0.3963

Table A.1-12: Effective Shading Coefficients of Egg-Crate Louvers with Inclined Horizontal Fins

Orientation: North-East & North-West

R_1	R_2	0^0	10^0	20^0	30^0	40^0
0.2	0.2	0.8019	0.7886	0.7788	0.7727	0.7705
0.2	0.4	0.7439	0.7331	0.7250	0.7198	0.7178
0.2	0.6	0.6944	0.6857	0.6790	0.6746	0.6727
0.2	0.8	0.6452	0.6384	0.6332	0.6298	0.6281
0.2	1.0	0.6024	0.5973	0.5935	0.5909	0.5897
0.2	1.2	0.5926	0.5880	0.5844	0.5820	0.5809
0.2	1.4	0.5829	0.5786	0.5754	0.5732	0.5722
0.2	1.6	0.5732	0.5693	0.5663	0.5644	0.5635
0.2	1.8	0.5634	0.5599	0.5573	0.5555	0.5548
0.4	0.2	0.7138	0.6898	0.6709	0.6573	0.6494
0.4	0.4	0.6724	0.6527	0.6371	0.6258	0.6192
0.4	0.6	0.6369	0.6207	0.6079	0.5986	0.5933
0.4	0.8	0.6013	0.5887	0.5787	0.5715	0.5673
0.4	1.0	0.5688	0.5593	0.5519	0.5466	0.5436
0.4	1.2	0.5613	0.5524	0.5455	0.5407	0.5380
0.4	1.4	0.5537	0.5456	0.5392	0.5348	0.5325
0.4	1.6	0.5462	0.5387	0.5329	0.5290	0.5270
0.4	1.8	0.5386	0.5318	0.5266	0.5231	0.5214
0.6	0.2	0.6479	0.6186	0.5951	0.5766	0.5636
0.6	0.4	0.6178	0.5934	0.5741	0.5588	0.5481
0.6	0.6	0.5920	0.5718	0.5560	0.5435	0.5348
0.6	0.8	0.5663	0.5502	0.5379	0.5282	0.5214
0.6	1.0	0.5416	0.5294	0.5204	0.5134	0.5085
0.6	1.2	0.5353	0.5240	0.5159	0.5095	0.5051
0.6	1.4	0.5289	0.5186	0.5113	0.5056	0.5018
0.6	1.6	0.5225	0.5132	0.5067	0.5017	0.4984
0.6	1.8	0.5161	0.5078	0.5022	0.4978	0.4950

Table A.1-12: Effective Shading Coefficients of Egg-Crate Louvers with Inclined Horizontal Fins (Continue)

North-East & North-West

R_1	R_2	0^0	10^0	20^0	30^0	40^0
0.8	0.2	0.6089	0.5719	0.5445	0.5270	0.5133
0.8	0.4	0.5855	0.5551	0.5328	0.5182	0.5067
0.8	0.6	0.5652	0.5403	0.5225	0.5104	0.5010
0.8	0.8	0.5449	0.5255	0.5122	0.5027	0.4952
0.8	1.0	0.5252	0.5109	0.5019	0.4949	0.4895
0.8	1.2	0.5199	0.5070	0.4989	0.4927	0.4879
0.8	1.4	0.5147	0.5030	0.4960	0.4905	0.4863
0.8	1.6	0.5095	0.4991	0.4930	0.4883	0.4847
0.8	1.8	0.5042	0.4952	0.4900	0.4861	0.4831
1.0	0.2	0.5750	0.5440	0.5183	0.5005	0.4878
1.0	0.4	0.5579	0.5321	0.5105	0.4960	0.4856
1.0	0.6	0.5429	0.5218	0.5039	0.4922	0.4839
1.0	0.8	0.5279	0.5114	0.4972	0.4884	0.4822
1.0	1.0	0.5129	0.5010	0.4905	0.4847	0.4805
1.0	1.2	0.5087	0.4981	0.4888	0.4836	0.4799
1.0	1.4	0.5045	0.4952	0.4870	0.4825	0.4793
1.0	1.6	0.5002	0.4922	0.4852	0.4814	0.4787
1.0	1.8	0.4960	0.4893	0.4834	0.4803	0.4781
1.2	0.2	0.5577	0.5232	0.5002	0.4857	0.4802
1.2	0.4	0.5434	0.5144	0.4958	0.4838	0.4795
1.2	0.6	0.5309	0.5069	0.4922	0.4822	0.4787
1.2	0.8	0.5185	0.4994	0.4886	0.4806	0.4780
1.2	1.0	0.5060	0.4919	0.4850	0.4789	0.4773
1.2	1.2	0.5025	0.4900	0.4839	0.4785	0.4771
1.2	1.4	0.4990	0.4880	0.4827	0.4781	0.4769
1.2	1.6	0.4955	0.4860	0.4816	0.4777	0.4767
1.2	1.8	0.4919	0.4840	0.4804	0.4773	0.4765

Table A.1-12: Effective Shading Coefficients of Egg-Crate Louvers with Inclined Horizontal Fins (Continue)

Orientation: North-East & North-West

R_1	R_2	0^0	10^0	20^0	30^0	40^0
1.4	0.2	0.5424	0.5101	0.4894	0.4815	0.4759
1.4	0.4	0.5303	0.5039	0.4868	0.4805	0.4759
1.4	0.6	0.5199	0.4987	0.4846	0.4796	0.4759
1.4	0.8	0.5095	0.4936	0.4825	0.4786	0.4759
1.4	1.0	0.4991	0.4884	0.4803	0.4777	0.4759
1.4	1.2	0.4963	0.4868	0.4797	0.4774	0.4759
1.4	1.4	0.4935	0.4853	0.4791	0.4772	0.4759
1.4	1.6	0.4907	0.4837	0.4785	0.4770	0.4759
1.4	1.8	0.4879	0.4821	0.4779	0.4767	0.4759
1.6	0.2	0.5310	0.4994	0.4856	0.4777	0.4759
1.6	0.4	0.5208	0.4952	0.4838	0.4774	0.4759
1.6	0.6	0.5122	0.4917	0.4822	0.4771	0.4759
1.6	0.8	0.5036	0.4883	0.4806	0.4768	0.4759
1.6	1.0	0.4949	0.4848	0.4790	0.4765	0.4759
1.6	1.2	0.4926	0.4837	0.4785	0.4764	0.4759
1.6	1.4	0.4902	0.4825	0.4781	0.4763	0.4759
1.6	1.6	0.4879	0.4814	0.4777	0.4762	0.4759
1.6	1.8	0.4855	0.4803	0.4773	0.4761	0.4759
1.8	0.2	0.5221	0.4930	0.4826	0.4759	0.4759
1.8	0.4	0.5137	0.4897	0.4815	0.4759	0.4759
1.8	0.6	0.5067	0.4869	0.4803	0.4759	0.4759
1.8	0.8	0.4997	0.4841	0.4792	0.4759	0.4759
1.8	1.0	0.4926	0.4813	0.4780	0.4759	0.4759
1.8	1.2	0.4906	0.4806	0.4777	0.4759	0.4759
1.8	1.4	0.4885	0.4798	0.4775	0.4759	0.4759
1.8	1.6	0.4864	0.4791	0.4772	0.4759	0.4759
1.8	1.8	0.4843	0.4784	0.4769	0.4759	0.4759

Table A.1-13: Effective Shading Coefficients of Egg-Crate Louvers with Inclined Horizontal Fins

Orientation: South-East & South-West

R_1	R_2	0^0	10^0	20^0	30^0	40^0
0.2	0.2	0.7951	0.7808	0.7702	0.7634	0.7608
0.2	0.4	0.7351	0.7233	0.7144	0.7087	0.7064
0.2	0.6	0.6842	0.6745	0.6672	0.6623	0.6602
0.2	0.8	0.6340	0.6264	0.6205	0.6167	0.6149
0.2	1.0	0.5838	0.5782	0.5739	0.5710	0.5696
0.2	1.2	0.5669	0.5620	0.5581	0.5555	0.5542
0.2	1.4	0.5570	0.5525	0.5489	0.5465	0.5453
0.2	1.6	0.5471	0.5430	0.5397	0.5375	0.5364
0.2	1.8	0.5372	0.5334	0.5305	0.5285	0.5275
0.4	0.2	0.6979	0.6713	0.6510	0.6365	0.6285
0.4	0.4	0.6555	0.6334	0.6165	0.6044	0.5977
0.4	0.6	0.6193	0.6008	0.5868	0.5768	0.5713
0.4	0.8	0.5831	0.5683	0.5572	0.5492	0.5449
0.4	1.0	0.5469	0.5358	0.5275	0.5216	0.5185
0.4	1.2	0.5361	0.5263	0.5188	0.5135	0.5107
0.4	1.4	0.5286	0.5196	0.5127	0.5078	0.5053
0.4	1.6	0.5212	0.5129	0.5066	0.5022	0.4999
0.4	1.8	0.5137	0.5063	0.5005	0.4965	0.4944
0.6	0.2	0.6266	0.5923	0.5677	0.5483	0.5347
0.6	0.4	0.5959	0.5670	0.5466	0.5305	0.5192
0.6	0.6	0.5694	0.5452	0.5283	0.5150	0.5057
0.6	0.8	0.5430	0.5235	0.5101	0.4996	0.4923
0.6	1.0	0.5166	0.5018	0.4919	0.4842	0.4788
0.6	1.2	0.5091	0.4957	0.4868	0.4798	0.4751
0.6	1.4	0.5030	0.4905	0.4824	0.4761	0.4718
0.6	1.6	0.4969	0.4853	0.4780	0.4723	0.4685
0.6	1.8	0.4907	0.4801	0.4736	0.4685	0.4652

Table A.1-13: Effective Shading Coefficients of Egg-Crate Louvers with Inclined Horizontal Fins (Continue)

Orientation: South-East & South-West

R_1	R_2	0^0	10^0	20^0	30^0	40^0
0.8	0.2	0.5821	0.5434	0.5133	0.4954	0.4814
0.8	0.4	0.5586	0.5264	0.5016	0.4865	0.4747
0.8	0.6	0.5381	0.5114	0.4912	0.4787	0.4689
0.8	0.8	0.5176	0.4964	0.4808	0.4709	0.4631
0.8	1.0	0.4971	0.4815	0.4705	0.4630	0.4573
0.8	1.2	0.4914	0.4773	0.4675	0.4609	0.4557
0.8	1.4	0.4863	0.4734	0.4646	0.4587	0.4541
0.8	1.6	0.4812	0.4695	0.4616	0.4565	0.4525
0.8	1.8	0.4761	0.4656	0.4587	0.4543	0.4509
1.0	0.2	0.5448	0.5129	0.4864	0.4682	0.4552
1.0	0.4	0.5277	0.5009	0.4786	0.4637	0.4531
1.0	0.6	0.5125	0.4904	0.4719	0.4599	0.4514
1.0	0.8	0.4973	0.4800	0.4652	0.4561	0.4497
1.0	1.0	0.4822	0.4695	0.4585	0.4523	0.4480
1.0	1.2	0.4779	0.4666	0.4566	0.4512	0.4474
1.0	1.4	0.4738	0.4637	0.4548	0.4501	0.4468
1.0	1.6	0.4696	0.4608	0.4530	0.4490	0.4461
1.0	1.8	0.4654	0.4579	0.4512	0.4478	0.4455
1.2	0.2	0.5269	0.4915	0.4679	0.4532	0.4471
1.2	0.4	0.5125	0.4827	0.4636	0.4513	0.4464
1.2	0.6	0.5000	0.4751	0.4600	0.4497	0.4457
1.2	0.8	0.4874	0.4675	0.4564	0.4481	0.4450
1.2	1.0	0.4748	0.4600	0.4528	0.4465	0.4443
1.2	1.2	0.4713	0.4579	0.4516	0.4461	0.4441
1.2	1.4	0.4678	0.4559	0.4504	0.4456	0.4439
1.2	1.6	0.4643	0.4539	0.4493	0.4452	0.4438
1.2	1.8	0.4608	0.4519	0.4481	0.4447	0.4436

Table A.1-13: Effective Shading Coefficients of Egg-Crate Louvers with Inclined Horizontal Fins (Continue)

Orientation: South-East & South-West

R_1	R_2	0^0	10^0	20^0	30^0	40^0
1.4	0.2	0.5112	0.4781	0.4571	0.4483	0.4429
1.4	0.4	0.4991	0.4719	0.4545	0.4474	0.4429
1.4	0.6	0.4886	0.4668	0.4524	0.4465	0.4429
1.4	0.8	0.4781	0.4616	0.4502	0.4456	0.4429
1.4	1.0	0.4676	0.4564	0.4481	0.4447	0.4429
1.4	1.2	0.4647	0.4548	0.4474	0.4445	0.4429
1.4	1.4	0.4619	0.4532	0.4468	0.4442	0.4429
1.4	1.6	0.4590	0.4516	0.4462	0.4440	0.4429
1.4	1.8	0.4562	0.4500	0.4455	0.4438	0.4429
1.6	0.2	0.4995	0.4672	0.4522	0.4446	0.4429
1.6	0.4	0.4893	0.4631	0.4506	0.4443	0.4429
1.6	0.6	0.4806	0.4597	0.4491	0.4440	0.4429
1.6	0.8	0.4719	0.4563	0.4475	0.4437	0.4429
1.6	1.0	0.4633	0.4529	0.4460	0.4435	0.4429
1.6	1.2	0.4608	0.4517	0.4456	0.4434	0.4429
1.6	1.4	0.4584	0.4505	0.4452	0.4433	0.4429
1.6	1.6	0.4560	0.4493	0.4448	0.4432	0.4429
1.6	1.8	0.4536	0.4481	0.4444	0.4432	0.4429
1.8	0.2	0.4904	0.4609	0.4494	0.4429	0.4429
1.8	0.4	0.4821	0.4576	0.4483	0.4429	0.4429
1.8	0.6	0.4750	0.4549	0.4472	0.4429	0.4429
1.8	0.8	0.4680	0.4521	0.4461	0.4429	0.4429
1.8	1.0	0.4610	0.4493	0.4451	0.4429	0.4429
1.8	1.2	0.4588	0.4485	0.4448	0.4429	0.4429
1.8	1.4	0.4567	0.4477	0.4445	0.4429	0.4429
1.8	1.6	0.4545	0.4470	0.4442	0.4429	0.4429
1.8	1.8	0.4524	0.4462	0.4440	0.4429	0.4429

Appendix 2: Roof Thermal Transfer Value (RTTV) Formula

Conversion to Uniform Energy Units

The RTTV formula is given as follows:

$$RTTV = 12.5\ (1\text{-}SKR)U_r + 4.8\ (SKR)U_s + 485\ (SKR)\ (CF)\ (SC)$$

Where;

RTTV	Roof thermal transfer value (W/m^2)
SKR	Skylight ratio of roof (skylight area/gross area of roof)
U_r	Thermal transmittance of opaque roof (W/m^2K)
U_s	Thermal transmittance of skylight area (W/m^2K)
CF	Solar correction factor for roof
SC	Shading coefficient of skylight portion of the roof

Similarly, when more than one type of material and or skylight is used, the respective term or terms shall be expanded into sub-elements, such as;

$$RTTV = \frac{12.5\ (A_{r1} \times U_{r1} + A_{r2} \times U_{r2} + \ldots + A_{rn} \times U_{rn})}{A_O} +$$

$$\frac{4.8\ (A_{s1} \times U_{s1} + A_{s2} \times U_{s2} + \ldots + A_{sn} \times U_{sn})}{A_O} +$$

$$\frac{485\ (A_{s1} \times SC_{s1} + A_{s2} \times USC_{s2} + \ldots A_{sn} \times SC_{sn})}{A_O}$$

Where;

A_{r1}, A_{r2}, A_{rn}	Areas of different opaque roof (m^2)
A_{s1}, A_{s2}, A_{sn}	Areas of different skylight (m^2)
Ao	Gross area of roof (m^2)
U_{r1}, U_{r2}, U_{rn}	Thermal transmittances of opaque roofs (W/m^2K)
U_{s1}, U_{s2}, U_{sn}	Thermal transmittances of skylights (W/m^2K)
$SC_{s1}, SC_{s2}, SC_{sn}$	Shading coefficient of skylights

If a roof consists of different sections facing different orientations or pitched at different angles, the RTTV for the whole roof shall be calculated as follows:

$$RTTV = \frac{A_{01} \times RTTV_1 + A_{02} \times RTTV_2 + \dots + A_{on} \times RTTV_n}{A_{01} + A_{02} + \dots + A_{on}}$$

Where;

A_{o1}, A_{o2}, A_{on}	Gross areas of the roof for each section (m^2)

The solar correction factors for roof are given in Table A.2-1

Table A.2-1: Solar correction factors for roof

Pitch	Orientation							
Angle	N	NE	E	SE	S	SW	W	NW
0^0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5^0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10^0	0.99	0.99	1.00	1.00	1.00	0.99	0.99	0.99
15^0	0.98	0.98	0.99	0.99	0.99	0.98	0.98	0.98
20^0	0.96	0.97	0.98	0.98	0.97	0.97	0.97	0.96
25^0	0.93	0.95	0.96	0.96	0.95	0.95	0.95	0.94
30^0	0.91	0.92	0.94	0.94	0.93	0.93	0.93	0.91
35^0	0.88	0.90	0.92	0.91	0.90	0.90	0.90	0.89
40^0	0.84	0.87	0.89	0.88	0.87	0.87	0.87	0.85
45^0	0.80	0.83	0.86	0.85	0.83	0.84	0.84	0.82
50^0	0.76	0.80	0.83	0.82	0.79	0.80	0.81	0.78
55^0	0.72	0.76	0.80	0.78	0.75	0.76	0.78	0.75
60^0	0.67	0.72	0.76	0.74	0.70	0.73	0.74	0.71
65^0	0.63	0.68	0.73	0.70	0.66	0.69	0.71	0.67

*Appendix 2 information is based on Code on Envelope Thermal Thermal Performance for Buildings published by Building and Construction Authority of Singapore.

Appendix 3 : Climate Zone Classification

ASHRAE standard method

Determine the thermal climate zone, 0–3, from Table A.3-1, using the heating andcooling degree-days (CDD/HDD) for the location.

Table A.3-1: Thermal climate zones

Thermal zone	Name	Range
0	Extremely hot	CDD 10 ^{0}C > 6,000
1	Very hot	5,000 > CDD 10 ^{0}C ≥ 6,000
2	Hot	3,500 > CDD 10 ^{0}C ≥ 5,000
3	Warm	CDD 10^{0}C < 3,500 and HDD18 ^{0}C ≤ 2,000

Dry (B) /Wet(A) Classification

a) If 70% or more of the precipitation, *P*, occurs during the high sun period, then thedry/humid threshold is

$P < 20.0 \times (T + 14)$ (SI)

b) If between 30% and 70% of the precipitation, *P*, occurs during the high sunperiod, then the dry/humid threshold is

$P < 20.0 \times (T + 7)$ (SI)

c) If 30% or less of the precipitation, *P*, occurs during the high sun period, then thedry/humid threshold is

$P < 20 \times T$ (SI)

where;

P -annual precipitation, in. (mm)

T - annual mean temperature, °C

Summer or high sun period = April through September in the northern hemisphere and October through March in the southern hemisphere

Winter or cold season = October through March in the northern hemisphere and April through September in the southern hemisphere

Climatic zone classification (Koppen)

Tropical climates (Af,Am,Aw/As)

This type of climate has every month of the year with an average temperature of 18 °C or higher, with significant precipitation.

Af = (Tropical Rainforest Climate)

average precipitation of at least 60 mm in every month.

Am = Tropical Monsoon Climate

Driest month with precipitation less than 60 mm (2.4 in), but at least

100 mm-(annual precipitation (mm)/25)

Aw or As = Tropical wet and dry or savannah climate; with the driest month having precipitation less than 60 mm and less than

100 mm-(annual precipitation (mm)/25)

Subtropical highland climate (Cfb)

Areas with this climate feature monthly averages below 22 °C but above −3 °C and at least one month's average temperature is below 18 °C with year around rainfall.

Appendix 4: U-Values for Commonly Used Building Materials

The Table A.4-1 lists U-value of typical building materials.

Table A.4-1: U-values of typical building materials

Envelope component	Construction type	U-value (W/m²K)
Wall	Single brick wall with textured plaster	3.39
	Single brick walls with 5mm air gap and textured plaster	1.95
	Single brick walls with 10mm air gap and textured plaster	1.84
	Single brick walls with 70 mm polystyrene insulation and textured plaster	0.40
	Double brick wall with textured plaster	2.47
	English bond brick wall with textured plaster	2.47
	Flemish bond brick wall with textured plaster	2.47
	Cement block wall (large solid blocks) with textured plaster	2.68
	Cement block walls (large solid blocks) with 10 mm air gap and textured plaster	1.43
	Cement block wall (small solid blocks) with textured plaster	3.22
	Cement block walls (small solid blocks) with 10 mm air gap and textured plaster	1.74
	Rubble wall	4.38
	RCC wall (wide)	3.84
	RCC wall (narrow)	4.75

Envelope component	Construction type	U-value (W/m²K)
Windows	Single glazing 6 mm clear glass (timber frame)	5.80
	Double glazing with 6mm clear glass and 12 mm air gap (timber frame)	2.70
	Double glazing with one Low e glass and 12 mm air gap (timber frame)	1.70
	Single glazing 6 mm clear glass (Aluminium frame)	6.09
	Double glazing with 6mm clear glass and 12 mm air gap (Aluminium frame)	3.46
	Double glazing with one Low e glass and 12 mm air gap (Aluminium frame)	2.17
Roof	Pitched tiled roof with horizontal ceiling and no insulation	1.30
	Pitched metal roof with horizontal ceiling and no insulation	1.33
	Pitched tiled roof with horizontal ceiling and 50 mm insulation on ceiling	0.57
	Pitched tiled roof with horizontal ceiling and 100 mm insulation on ceiling	0.30
	Pitched tiled roof with sloping flat ceiling and no insulation	2.03
	Pitched tiled roof with sloping ceiling and 100 mm insulation at rafter level	0.30
	Pitched metal roof with sloping ceiling and 50 mm insulation	0.51
	Concrete roof	0.88

Appendix 5 : Calculating Design System Efficiency (DSE)

Calculation of Design System Efficiency (DSE) of Water Cooled Central Chilled-Water Plant - Primary Variable Chilled-Water System

Background info

Office building air-conditioned floor area = 8800 m^2

Variable-speed drives are designed to control the speed of the chilled-water pumps and cooling tower fans

Building operating hours as specified: Monday to Friday: 9 a.m. to 5 p.m.

Step 1 – Determine the peak building cooling load and relevant baseline Simulation analysis of the building cooling load profile based on design day to be carried out to determine the peak building cooling load and the relevant baseline standard.

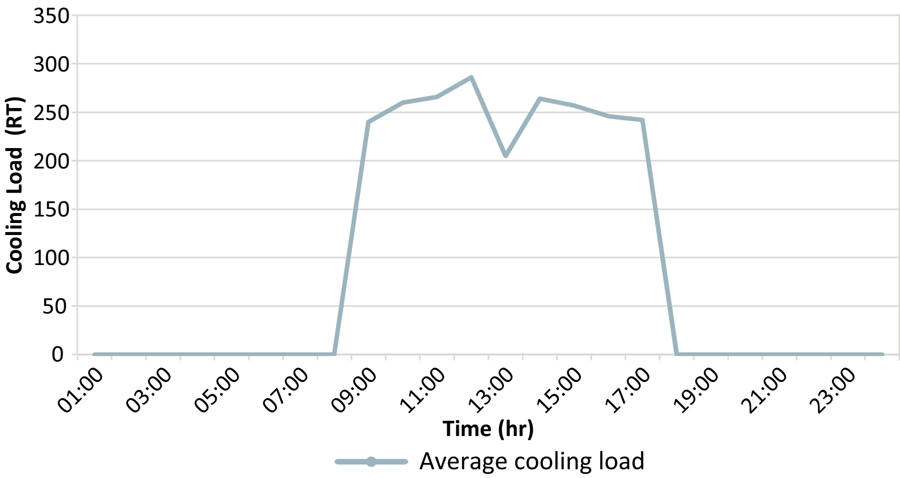


Figure A.5-1: Building cooling load profile

From the simulated building cooling load profile, the peak building cooling load is 286 RT (< 500 RT) and the minimum Design System Efficiency for water cooled chilled water plant is 0.75 kW/RT.

Step 2 – Generate the simulated total building cooling load profile based on the annual average load profile for the building operating hours specified.

Table A.5-1: Building Cooling Load

Time	Average Cooling Load (RT)
8:00	0
9:00	240
10:00	260
11:00	266
12:00	286
13:00	205
14:00	264
15:00	257
16:00	246
17:00	242
18:00	0
19:00	0

Step 3 – Propose air-conditioning plant configuration and derive the respective power input of various components

Proposed air-conditioning plant configuration for the building operating hours specified to be as follows:

Table A.5-2: Building Equipment Schedule

Chillers	3 Nos. x 150 RT	(2 in operation and 1 stand by)
Chilled Water Pumps	3 Nos. x 11 kW	(2 in operation and 1 stand-by)
Condenser Water Pumps	3 Nos. x 11 kW	(2 in operation and 1 stand-by)
Cooling Towers	3 Nos. x 200 RT	(2 in operation and 1 stand-by)

3(a) Screw water-cooled chiller (150 RT)

Based on the performance data of the selected chillers from manufacturer

Table A.5-3: Chiller Manufacturer Performance Data

% Load	Capacity (RT)	Chiller Input Power (kW)	Chiller Efficiency kW/RT	Evaporator		Condenser	
				CHWS T (°C)	CHWR T (°C)	CWST (°C)	CWRT (°C)
100	150	90.00	0.600	7	12	30	35
90	135	81.00	0.600	7	12	30	35
80	120	73.44	0.612	7	12	30	35
70	105	65.43	0.623	7	12	30	35
60	90	55.71	0.619	7	12	30	35
50	75	39.87	0.532	7	12	30	35

Installed capacity of the chillers (excluding standby) = 300 RT

Chillers configuration: 2 x 150 RT screw chillers (operating); 1 x 150 RT screw chiller (standby)

Based on simulated total building load profile, we have

Table A.5-4: Chiller Performance Results Based on Simulation

Time	Cooling load (RT)	No. of Chillers in Operation	Chiller Efficiency	Chiller Input Power
9:00	240	2 x 150RT @ 80%	0.612	146.9
10:00	260	2 x 150RT @ 88%	0.602	156.5
11:00	266	2 x 150RT @ 88%	0.602	160.1
12:00	286	2 x 150RT @ 95%	0.600	171.6
13:00	205	2 x 150RT @ 68%	0.622	127.5
14:00	264	2 x 150RT @ 88%	0.602	158.9
15:00	257	2 x 150RT @ 88%	0.602	154.7
16:00	246	2 x 150RT @ 80%	0.612	150.6
17:00	242	2 x 150RT @ 80%	0.612	148.1

3(b) Chilled-water pumps (primary only):

(i) 2 Nos x 11 kW primary chilled-water pump to be installed with Variable Speed Drive (VSD)

(ii) Water flow rate per pump at full load (Q) = 22.68 l/s

(iii) Operating static head (h) =32 m

(iv) Pump efficiency (η_p) = 89 %

(v) Motor efficiency (η_m) = 90 %

$$\text{Power requirement of chilled-water pump at full load (kW)} = \frac{(Q)(\rho)(g)(h)}{(10^6)(\eta_p)(\eta_m)}$$

Where; Q = water flow rate in L/s

ρ = density of water in kg/m^3

g = gravitational acceleration in m/s^2

h = static pressure head in m

η_p = pump efficiency

η_m = motor efficiency

$$\text{Power requirement of chilled-water pump at full load (kW)} = \frac{(22.68)(1{,}000)(9.81)(32)}{(10^6)(\eta_p)(\eta_m)}$$

$$= 8.89 \text{ kW}$$

For part-load operating condition,

$$\frac{\textit{Pump Power@ 80\%}}{\textit{Pump Power@ 100\%}} = \left[\frac{\textit{Pump Speed @ 80\%}}{\textit{Pump Speed @ 100\%}}\right]^3$$

Pump power at 80% part-load (kW) = 8.89 x $(0.8)^3$ = 4.55 kW

Total operating pump power (kW) = 4.55 kW x 2 = 9.10 kW

Similarly,

Pump power at 87% part-load (kW) = 8.89 x $(0.88)^3$ = 6.06 kW

Total operating pump power (kW) = 6.06 kW x 2 = 12.12 kW

Similarly,

Pump power at 95% part-load (kW) = 8.89 x $(0.95)^3$ = 7.62kW

Total operating pump power (kW) = 7.62 kW x 2 = 15.24 kW

Similarly,

Pump power at 68% part-load (kW) = 8.89 x $(0.68)^3$ = 2.8 kW

Total operating pump power (kW) = 2.8 kW x 2 = 5.6 kW

Table A.5-5: Chilled Water Pump Performance Results Based on Simulation

Cooling Load (RT)	No. of Chilled Water-Pumps in operation	Total Operation Pumps Power (kW)
240	2 x 11 kW @ 80%	9.10
260	2 x 11 kW @ 88%	12.12
266	2 x 11 kW @ 88%	12.12
286	2 x 11 kW @ 95%	15.24
205	2 x 11 kW @ 68%	5.60
264	2 x 11 kW @ 88%	12.12
257	2 x 11 kW @ 88%	12.12
246	2 x 11 kW @ 80%	9.10
242	2 x 11 kW @ 80%	9.10

3(c) Condenser water pumps:

(i) 2 Nos x 11 kW condenser water pumps to be installed with VSD

(ii) Water flow rate for the condenser water pump (Q) = 28.35 l/s

(iii) Operating static head (h) =20 m

(iv) Pump efficiency (η_p) = 80%

(v) Motor efficiency (η_m) = 90%

$$\text{Power requirement of chilled-water pump at full load (kW)} = \frac{(22.35)(1{,}000)(9.81)(20)}{(10^6)(0.8)(0.9)}$$

$$= 7.73 \text{ kW}$$

For part-load operating condition,

$$\frac{\textit{Pump Power@ 80\%}}{\textit{Pump Power@ 100\%}} = \left[\frac{\textit{Pump Speed @ 80\%}}{\textit{Pump Speed @ 100\%}}\right]^3$$

Pump power at 60% part-load (kW) = 7.73 x $(0.8)^3$ = 3.96 kW

Total operating pump power (kW) = 3.96 kW x 2 = 7.92 kW

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Similarly,

Pump power at 88% part-load (kW) = 7.73 x $(0.88)^3$ = 5.27kW

Total operating pump power (kW) = 5.27 kW x 2 = 10.54 kW

Similarly,

Pump power at 68% part-load (kW) = 7.73 x $(0.68)^3$ = 2.43 kW

Total operating pump power (kW) = 2.43 kW x 2 = 4.86 kW

Similarly,

Pump power at 95% part-load (kW) = 7.73 x $(0.95)^3$ = 6.63kW

Total operating pump power (kW) = 6.63 kW x 2 = 13.26 kW

Table A.5-6: Condenser Water Pump Performance Results Based on Simulation

Cooling Load (RT)	No. of Condenser Water-Pumps in operation	Total Operation Pumps Power (kW)
240	2 x 11 kW @ 80%	7.92
260	2 x 11 kW @ 88%	10.54
266	2 x 11 kW @ 88%	10.54
286	2 x 11 kW @ 95%	13.26
205	2 x 11 kW @ 68%	4.86
264	2 x 11 kW @ 88%	10.54
257	2 x 11 kW @ 88%	10.54
246	2 x 11 kW @ 80%	7.92
242	2 x 11 kW @ 80%	7.92

3(d) Cooling towers:

(i) 3 Nos. of cooling towers to be installed with VSD

(ii) Heat rejection capacity per cooling tower = 200 RT

(iii) Total heat rejection for 2 x cooling towers = 400 RT

(iv) Each cooling tower with 2 fan cells with fan motor = 4 kW

(v) Fan motor efficiency = 92%

(vi) Input power per cooling tower = (4 kW x 2 fans) x 92% = 7.36 kW

(vii) Total input power for 2 Nos. of cooling towers = 7.36 kW x 2 = 14.73 kW

In general,

Total heat rejection of chiller plant (kW) =Total Cooling load (kW) + Total electrical power input to chiller compressor (kW)

$$\frac{\text{Fan Power@ Part load \%}}{\text{Fan Power@ 100\%}} = \left[\frac{\text{Fan Speed @ Part load \%}}{\text{Fan Speed @ 100\%}}\right]^3$$

Table A.5-7: Cooling Tower Performance Results Based on Simulation

Cooling Load (a) (RT)	Chiller Input Power (b) (kW)	Required Heat Rejection (c) = (a) + (b) (RT)	Total heat rejection capacity for 2 nos of cooling tower (RT)	Percentage Loading required (%)	Total fan motor power at required part-load condition (kW)
240	146.88	281.7	400	70	5.05
260	156.52	304.5	400	76	6.49
266	160.13	311.5	400	78	6.95
286	171.60	334.8	400	84	8.63
205	127.51	241.2	400	60	3.23
264	158.93	309.2	400	77	6.80
257	154.72	300.9	400	75	6.27
246	150.55	288.8	400	72	5.54
242	148.11	284.1	400	71	5.27

Step 4 – Derive the Design System Efficiency (DSE)

Table A.5-8: Design System Efficiency

Time	Average Cooling Load (RT)	Chillers Power Input (kW)	CHW Pumps Power (kW)	CW Pumps Power (kW)	CT power (kW)	Total Power Input (kW)
9:00	240	146.88	9.10	7.92	7.71	171.61
10:00	260	156.52	12.12	10.54	9.74	188.92
11:00	266	160.13	12.12	10.54	10.43	193.22
12:00	286	171.60	15.24	13.26	12.94	213.04
13:00	205	127.51	5.60	4.86	4.84	142.81
14:00	264	158.93	12.12	10.54	10.19	191.78
15:00	257	154.72	12.12	10.54	9.40	186.78
16:00	246	150.55	9.10	7.92	8.31	175.88
17:00	242	148.11	9.10	7.92	7.91	173.03
Total (0900 to 1700)	∑ CLi= 2,266	1,374.94	96.62	84.04	81.48	∑ TPLi= 1,637.1
Efficiency kW/RT		0.61	0.043	0.037	0.024	0.72

Design Efficiency of the various components of the proposed building cooling system

Design System Efficiency (DSE) of the proposed building cooling system = Total Power Input/Total Cooling Load = $\sum TPL_i / \sum CL_i$	< 0.8 kW/RT Ok

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Calculation of Design System Efficiency for Unitary Air-Conditioners/ Condensing Units - VRF System

Background info

Air-conditioned areas = 2,400 m^2

Building operation hours are defined as: Monday to Friday

Step1 – Determine the peak building cooling load and relevant baseline

Simulation analysis of the building cooling load profile based on design day to be carried out to determine the peak building cooling load and the relevant baseline standard.

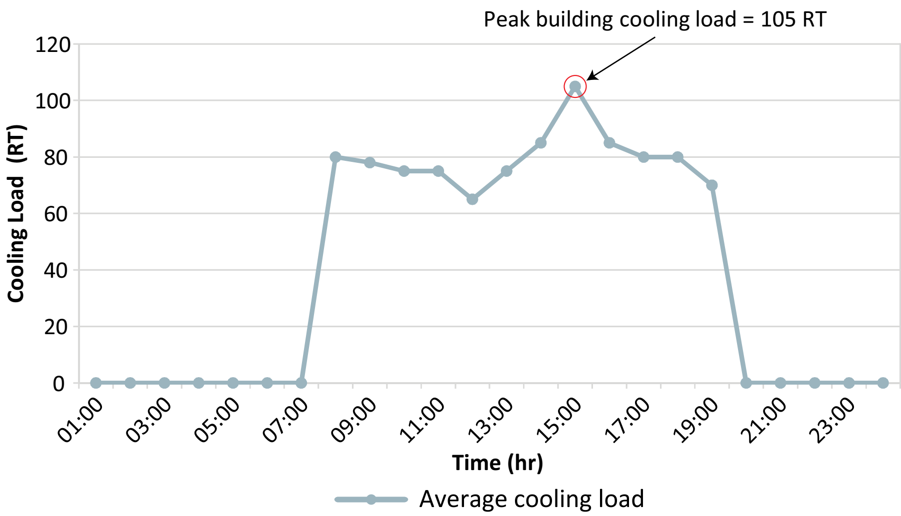

Figure A.5-2 Building cooling load profile

Method (A): Computation of the Design System Efficiency (DSE) based on full installed capacity

Step A-1 - Determine the required capacities of the VRF systems at full-load condition - Proposed VRF System Schedule

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Table A.5-9: VRF System Schedule

System No.	Floors served	Location Served	Specification of VRF Outdoor Condensing Unit		
			Total Cooling Capacity (kW) Full Installed Capacity	Power Input (kW) Full Installed Capacity	COP Full Installed Capacity
1	1	FCC Room Lift Lobby + Internal Corridor Reception	22.4	5.24	4.20
2	2 to 9	Office	44.8	10.50	4.27
		Lift Lobby			
		Lobby 2			

Note: Typical VRF Systems are designed for Floors 1 to 9

Specify conditions for overall system full load COPs $= \frac{(6.37 \times 4.2) + (102 \times 4.29)}{(102+6.37)}$

$= 4.27$

Step A-2 - Determine the Design System Efficiency (DSE) of the VRF system at full load condition

Full load efficiency

Table A.5-10: VRF Full Load Efficiency

System	Floor	Total Power Input (kW) @ Full Load	Total Required Cooling (kW) @ Full Load	Total Required Cooling (RT)
1	1	5.24	22.4	6.37
2	2 to 9	84.00	358.4	102.00
Total:		89.24	380.8	108.37

Design System Efficiency (DSE) for the VRF system= 89.24/108.37 at full load condition

= 0.82 kW/RT

0.82 kW/RT <1kW/RT Ok

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Appendix 6: Recommended Illuminance Levels

Standard maintained illuminance

Table A.6-1: Standard maintained illuminance

Standard maintained illuminance (lux)	Characteristics of activity/interior	Representative activities/interiors
50	Revalued interiors rarely with visual tasks confined to movement and casual seeing without perception of detail	Cable tunnels, indoor storage tanks, walkways
100	Interiors used occasionally with visual tasks confined to movement and casual seeing calling for only limited perception of detail	Corridors, changing rooms, bulk stores, auditoria
150	Interiors used occasionally or with visual tasks not requiring perception of detail but involving some risk to people, plant or product	Loading bays, medical stores, plant rooms
200	Interiors occupied for long periods, or for visual tasks requiring some perception of detail	Foyers and entrances, monitoring automatic processes, casting concrete, turbine halls, dining rooms
300†	Interiors occupied for longer periods, or when visual tasks are moderately easy, i.e. large details > 10 min arc and/ or high contrast	Libraries, sports and assembly halls, teaching spaces, lecture theaters, packing
500†	Moderately different visual tasks, i.e. details to be seen are of moderate size (95-10 min arc) and may be of low contrast; also colour judgment may be required	General offices, engine assembly, painting and spraying,kitchens, laboratories, retail shops

Standard maintained illuminance (lux)	Characteristics of activity/interior	Representative activities/interiors
750†	Difficult visual tasks, i.e. details to be seen are small (3-5 min arc) and of low contrast; also good colour judgment or the creation of a well-lit, inviting interior may be required	Drawing offices, ceramic decoration, meat inspection, chain stores
1,000†	Very difficult visual tasks, i.e. details to be seen are very small (2-3 min arc) and of low contrast; also accurate colour judgments or the creation of well lit, inviting interior may be required	General inspection, electronic assembly, gauge and tool rooms, retouching paintwork, cabinet making, supermarkets
1,500†	Extremely difficultvisual tasks,i.e. details to be seen extremely small (1-2 min arc) and of low contrast; optical aids and local lighting may be of advantage	Fine work and inspection, hand tailoring, precision assembly
2,000†	Exceptionally difficultvisual tasks, i.e. details to be seen exceptionally small (1 min arc) with very low contrast; optical aids and local lighting will be of advantage	Assembly of minute mechanisms, finished fabric inspection

† 1 minute of arc (min arc) is 1/60 of a degree. This is the angle of which the tangent is given by the dimension of the task detail to be seen divided by the viewing distance.

(Courtesy: CIBSE Code of Interior Lighting – 1994)

It is the responsibility of the Lighting Designer to select the illumination level required for any given task and these values are tabulated as ‘Standard Maintained Illuminance’ in Table A.6-1. These values shall be the starting point of any lighting design. However, for further details on ‘Standard Maintained Illuminance’ for specific tasks, the designer may refer “Code of Interior Lighting – 1994”, published by the Chartered Institution of Building Services Engineers (CIBSE), UK.

Design maintained illuminance

However, depending on the task size and contrast, task duration and the risk, serious consequences shall be taken into account in designing lighting systems for specific applications. The methodology that may be adopted for arriving at final illumination levels, which is known as “Design Maintained Illuminance” is given below:

Table A.6-2: Design maintained illuminance

(lux)	Task size and contrast				Task duration				Error risk		(lux)
Standard maintained illuminance	Are task details unusually difficult to see?		Are task details unusually easy to see?		Is task undertaken for ususually long time?		Is task undertaken for ususually short time?		Do errors have unusually serious consequences for people, plant or product?		Design maintained illuminance
200	Yes	200		200	Yes	200		200	Yes	200	200
		250		250	Yes	250		250	Yes	250	250
300	Yes	300	Yes	300	Yes	300	Yes	300	Yes	300	300
		400		400	Yes	400	Yes	400	Yes	400	400
500	Yes	500	Yes	500	Yes	500	Yes	500	Yes	500	500
		600		600	Yes	600	Yes	600	Yes	600	600
750	Yes	750	Yes	750	Yes	750	Yes	750	Yes	750	750
		900		900	Yes	900	Yes	900	Yes	900	900
	Yes	1,000		1,000	Yes	1,000	Yes	1,000	Yes	1,000	1,000
	Yes					1,300				1,300	1,300
	Yes					1,500				1,500	1,500

(Courtesy: CIBSE Code of Interior Lighting – 1994)

APPENDIX 6

Energy Efficiency Building Code of Sri Lanka

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ISBN 978-955-1476-27-4

Cover picture by Corentin-le-Leannec