

Development of Environmental Building Regulations and Guidelines

to Achieve Energy Efficiency in Bangalore City

Booklet on energy efficiency guidelines for new and existing buildings





ABBREVIATIONS

AC Air conditioner

AHRI Air Conditioning, Heating and Refrigeration Institute

AHU Air handling unit

ARI American Refrigerant Institute

ASHRAE American Society of Heating, Refrigerating and Air-Conditioning Engineers

BEE Bureau of Energy Efficiency
BIS Bureau of Indian Standards
CFL Compact fluorescent lamp
COP Coefficient of performance
CRI Colour rendering index
DBT Dry bulb temperature
DG Diesel generator

ECBC Energy Conservation Building Code

EER Energy efficiency ratio
EPI Energy performance index
ERV Energy recover ventilato r
ETC Evacuated tube collectors
FPC Flat plate collectors
GPM Gallons per minute
HSA Horizontal solar angle

HVAC Heating, ventilation and air conditioning

IAQ Indoor air quality

IPLV Integrated part load value
LCCA Life cycle cost analysis
LED Light emitting diode
LPD Lighting power density
NBC National Building Code

PF Power factor RH Relative humidity

SEGR Specific energy generation ratio
SHGC Solar heat gain coefficient
SPV Solar photovoltaic

SRI Solar reflective index
TFL Tubular fluorescent lamp

TV Television

TR Tonnes of refrigeration U-factor Heat transfer coefficient VAV Variable air volume **VFD** Variable frequency drive VLT Visible light transmittance VSA Vertical solar angle WBT Wet bulb temperature WWR Window wall ratio

Bangalore, the capital of Karnataka state, is the fifth largest metropolitan city of India. The city is well known, nationally and internationally, as a destination of choice for high-technology industries. Bangalore has seen enormous growth in recent times, and along with it, challenges that are associated with unpredicted growth. Traffic congestion, urban sprawl, scarcity of water and electricity, and many more are the challenges faced by the city. The Bangalore Metropolitan Region (BMR) covers an area of 8005 square km and will be housing a population of approximately 8.8 million by 2011.

In line with the approach to make Bangalore into an international metropolis, the city needs to adopt stringent regulations and guidelines to achieve sustainability. Buildings alone are major contributors to energy resource consumption and, therefore, efficient buildings provide huge opportunities for conservation of energy resource.

The objective of this project under the support of the Renewable Energy & Energy Efficiency Partnership (REEEP) is to achieve energy efficiency and integrate renewable energy in buildings to attain energy security in Bangalore city. REEEP is an international multi-stakeholder partnership that promotes the uptake of renewable energy and energy efficiency.

About the project

Development of environmental building guidelines and regulations to achieve energy efficiency in Bangalore city—the project under support of REEEP was started in August 2009 with the objective to develop regulations and guidelines to achieve energy efficiency and promote renewable energy in both existing and new buildings in Bangalore.

The project is being carried out by TERI University, in partnership with Bhurat Bengaluru Mahanagara Palike (BBMP) and Bangalore Development Authority (BDA). Other associated organizations in the implementation of the project are Bangalore Electricity Supply Company (BESCOM) and Karnataka Renewable Energy Development Ltd (KREDL).

The current building regulations of Bangalore city do not cover all aspects of energy efficiency that should be integrated in the built environment of Bangalore to convert it into an energy-efficient city. It is, therefore, essential to develop a framework of guidelines and integrate certain basic energy-efficiency regulations with the existing building bye-laws of Bangalore city.

List of energy-efficiency guidelines formulated under the project:

- 1. Solar passive design integration in new buildings
- 2. Provision of roof treatment to cut heat gain
- 3. Window design for day lighting, ventilation, and to reduce solar heat gain
- 4. Energy-efficient artificial lighting design
- 5. Energy-efficient air-conditioning design for buildings
- Use of BEE-labelled equipment and appliances to achieve energy efficiency in new and existing buildings
- 7. Solar water heating systems for residential and commercial buildings
- 8. Energy-efficient electrical systems for buildings
- Mandatory energy audit for existing commercial buildings with connected load in cases of 500 kW or 600 kVA and reduction of energy consumption by 20% over previous year

Scope of booklet

This booklet is a compilation of one-page educational leaflets formulated for each guideline. These leaflets are a ready reference for building industry stakeholders, as well as for the layperson.

Kindly visit the website of BBMP and BDA for further detailed information on any of the guidelines.

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GUIDELINE: SOLAR PASSIVE DESIGN FOR NEW BUILDINGS

Achieve thermal and visual comfort inside the building by using natural energy sources such that there is significant reduction in energy consumption.

Solar passive design

Designers can achieve solar passive building design by following the steps mentioned below.

- Modulating the micro-climate of the site through landscaping
- · Optimization of orientation and building form
- Optimization of building envelope and window design to reduce cooling demand
- Daylight integration to reduce artificial lighting demand.
- · Low-energy passive cooling strategies

Landscaping

- Natural cooling without air-conditioning can be achieved in semi-open spaces by locating trees to channel cool breeze.
- Deciduous trees should be planted on the west and south-west to provide shade in summer and sunlight in winter.
- Water bodies should be created around the building for cooling the air.

Orientation

- Building layout should be based on solar radiation, wind pattern, and daylight.
- Longer facades of the building should have a northsouth orientation.
- West façade should be designed carefully to reduce heat gain in the afternoon.

Building envelope

- Building envelope components like walls, roofs, windows, floors, and surface finishes are the key determinants of the amount of heat gain or loss.
- Usage of green roof, high reflective materials and thermal insulation on roof reduce heat gain.
- The external finish of the wall should be smooth and light in color, to help in reflecting back heat from solar radiation.
- ECBC-recommended envelope for walls, roof, and glass should be used in air- conditioned spaces. This could save energy up to 12%.
- External shading of the roof, east and west wall and windows are recommended. These features could provide energy saving of up to 15%.







Optimum building orientation (Long façade N-S)

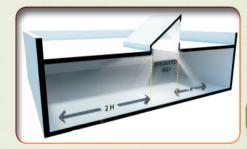
Daylight integration

 Adequate provision of daylight in buildings through proper window design is an important aspect of good building design. Daylight integration helps reduce dependence on artificial lighting and thus reduces electricity consumption of the building.

Low energy cooling strategies

The following low-energy cooling and design strategies could be adopted in Bangalore.

- Natural ventilation It is the exchange of air between the exterior and interior of a building, which can be attained through cross-ventilation and stack effect.
- Radiant cooling Heat loss from hotter surfaces will occur until equilibrium is achieved.
- Evaporative cooling In this type of cooling, sensible heat of air is used to evaporate the water, thereby releasing energy and cooling the air. Water bodies like ponds, lakes and fountains help reduce air temperature.



Use of skylight to integrate daylight

GUIDELINE: PROVIDE ROOF TREATMENT TO CUT HEAT GAINS

Provide roof treatment to cut down heat gain in airconditioned and naturally ventilated spaces to maximize thermal comfort.

Roof optimization

All exposed roof in air-conditioned and naturally ventilated spaces shall comply with the ECBC 2007 requirement as outlined below or shall be shaded.

Table 1 Ro 2007	oof assembly U-factor requ	irements as per ECBC
Climate zone	24-hour use buildings— hospitals, hotels, call centres, ad so on	Daytime use buildings Other building types
	Maximum U-factor of the overall assembly (W/m²K)	Maximum U-factor of the overall assembly(W/m²K)
Moderate	U-0.409	U-0.409

The roof insulation shall not be located on a suspended ceiling with removable ceiling panels.

Roof treatment: facts and benefits

- Treatment of roofs provides comfort levels and reduces cooling loads inside a building.
- Thermally insulating the roof reduces the U-value (thermal conductivity) for the roof section.
- A reflective roof absorbs less heat and reflects incident radiation. High-albedo (or solar reflectance, which is a measure of a material's ability to reflect sunlight) roof coatings or paints can be applied to roofs.
- An ideal exterior surface coating would have, on a scale 0 to 1, reflectance near 1 and absorptance near zero.
 White plaster very nearly achieves this.

Techniques to reduce solar heat gains through roofs

Green roof concept

· Green roofs should be used to improve the thermal



Green roof



Use of china mosaic tiles to reflect heat

performance of a roofing system through shading, insulation, evapo-transpiration and thermal mass, thus reducing a building's energy demand for space conditioning.

Use of high-reflective materials on rooftop

- Rooftop surface should be treated with light colored materials having high SRI factor of 50 % or more to prevent heat gain in the space below.
- · High reflective materials like broken china can be used.

Thermal insulation for roof

- Roof surfaces should be treated with ECBCrecommended materials in air-conditioned spaces to reduce heat gain.
- Insulation should be used on the external surface of the roof and adequate waterproofing should be given.

Insulation + cool roof

 As per the ECBC recommendation, cool roof, along with insulation, are recommended for air-conditioned spaces.

External shading of roof

 External roof should be shaded using design features like pergola and solar photovoltaic panels to help in reducing solar heat gain.



 Solar panels used in IIT Kanpur Research Centre to shade the roof and generate electricity

GUIDELINE: WINDOW DESIGN

Window design for air conditioned spaces

- The U-factor (overall heat transfer coefficient) for a fenestration product (including the sash and frame) should be determined as per ECBC 2007 requirements.
- The solar heat gain coefficient (SHGC) for a fenestration product (including the sash and frame) should be determined as per ECBC 2007 requirements.
- The U-factor and SHGC determined as per ECBC. It should conform to the ECBC 2007 requirement.

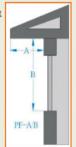
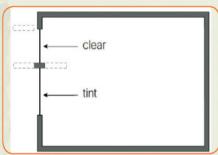


Table1 ECBC 2007 requirement for vertical fenestration								
Climate	Maximum U-factor (W/ m2-K)	Maximum SHGC for WWR ≤ 40%	Maximum SHGC for 40%< WWR ≤ 60%					
Moderate	6.9	0.4	0.3					

 The maximum permissible WWR on a facade should not exceed 60% as recommended in ECBC 2007

Window design for naturally ventilated occupied spaces

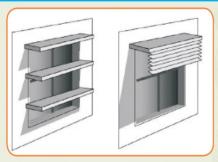
Window design should be optimized to maximize natural ventilation.

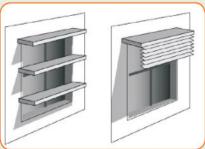


- Light shelf
- Windows should be fully shaded to reduce external solar heat gains.
- While designing windows, daylight integration to meet daylight levels as indicated in BIS should be met.

Design guidance

 While designing windows for air-conditioned spaces,
 U-factor of fenestration should be considered which can be achieved by low-e finish and gas fill.





Shading devices

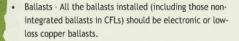
- Window frames made of fibreglass, wood and vinyl should be preferred to metals. A frame with thermal break or insulation performs better than normal ones.
- SHGC of the window should be maintained low by either selecting a high-performance glass or by designing external shading devices.
- Shading devices, both horizontal and vertical, should be designed to cut down direct incident solar radiation as per the orientation.
- In order to enhance daylighting, window design, size, placement and selection of glass with high visible light transmittance (VLT) is important.
- In order to maximize natural ventilation in non-airconditioned occupied spaces, the following guidelines should be maintained.
 - Design of windows must facilitate an easy operation, helping in regulating effective area for air flow.
 - Windows should be located opposite to each other on walls for cross-ventilation.
 - The inlet and outlet openings, when added up, should be in the range of 27%-56% of the floor area of that space and window wall ratio (WWR) in the range of 18%-36%, or whichever is critical.
 - Cross- and stack-ventilation should be used to achieve the required air change per hour in the space.

GUIDELINE: DESIGN ENERGY-EFFICIENT LIGHTING SCHEME FOR ALL NEW AND EXISTING BUILDINGS

Norms and standards to be followed

Interior lighting

- · The installed interior lighting power should not exceed the lighting power density (LPD) value as recommended by the ECBC 2007.
- Install lighting controls as recommended by ECBC
- Select lamps with highcolour rendering index (CRI).
- Lamps used for general lighting scheme should comply with the following.
 - o Point light source All the point light sources installed in the building for general lighting should be CFL or LED-based with minimum lamp efficacy of 50 lm/W.
 - o Linear light source All the linear light sources installed in the building for general
 - lighting should be T-5 or at least 4-star BEE-rated TFLs.



Efficiency in interior lighting

Efficiency in interior lighting design can be realized by the following measures.

- Interior lighting power density should conform to the ECBC-recommended values.
- The lighting scheme should utilize efficient lighting equipment, for example, lamps, luminaries and control
- Appropriate lighting controls should be provided as recommended by ECBC.
- · Daylight integration should be provided in order to minimize the usage of artificial lighting during daytime.

- · Effective maintenance plan should be in place for the lighting scheme in order to maintain its effectiveness and efficiency.
- · In addition to the above, the following parameters are also critical for achieving efficiency.
 - o Reflectance of various room surfaces
 - o Uniform light distribution

Some lighting design tips

- Lamps with high colour rendering index should be used.
- For offices, semi-direct luminaries are recommended.
- For corridors and staircases, direct type of luminaires with wide spread of light distribution are recommended.
- For residential buildings, bare fluorescent tubes are recommended.
- The National Building Code (NBC) recommends a range of illumination levels for an activity, as conditions might be different for the same activity in different interiors.
 - Higher value of the range should be used when unusually low reflectance or contrasts are present in the task, errors are costly to rectify, accuracy or high productivity is needed, and visual work is critical.
 - Lower value of the range may be used when the reflectance or contrast
 - is unusually high, speed and accuracy are not important, and the task is executed only
- · Lighting in common area for existing residential complexes/buildings should be retrofitted with efficient fixtures and lighting controls.
- · All the spaces should use efficient lighting equipment like lamps, luminaires, and control gears.
- · Lights should be dimmed or switched off when rooms are unoccupied or during daylight hours.

Benefits of efficient lighting

- · Improved visibility Energy-efficient lighting design enhances the quality and efficiency of lighting.
- · Energy saving By reducing the connected load of the lighting system, energy saving are maximized. Efficient lighting controls reduce energy consumption by avoiding wastage.
- · Retrofit Retrofit options can be used in buildings for saving electricity by replacing inefficient lamps, luminaires, and control gears with more efficient ones.

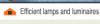


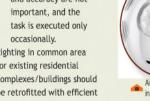
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GUIDELINE: DESIGN ENERGY-EFFICIENT AND RENEWABLE-ENERGY-BASED EXTERNAL LIGHTING IN ALL NEW AND EXISTING COMMERCIAL AND MULTI-STOREY RESIDENTIAL BUILDINGS

Norms and standards to be followed

- The installed exterior lighting power density for the respective applications should be in accordance with ECBC 2007
- Install lighting controls as recommended by ECBC 2007 for external lighting.
- Lamps external lighting sources should have luminous efficacies as per the table given below.



High-efficacy

Table 1 Efficacy of lamps	
Light source	Minimum permissible luminous efficacy (lm/W)
CFLs (compact fluorescent lamps)	50
LEDs (light emitting diodes)	50
Fluorescent lamps	75
Metal halide lamps	75
High-pressure sodium vapour lamps	90

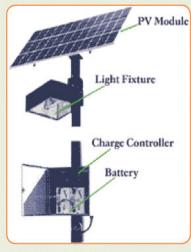
- Ballasts All the ballasts installed (including those nonintegrated ballasts in CFLs) should be electronic or lowloss copper ballasts.
- Integration with renewable energy sources 15% of the total external lighting load or load of 25% (in numbers) of the total external lighting fixtures, whichever is higher, should be met from renewable energy sources (solar, wind, biomass, fuel cells and so on).



Automatic controls in outdoor lighting

Efficient lighting

- Efficient lighting ensures visual comfort and utilizes energy optimally and efficiently.
- High-efficacy lamps as given in the above table shall be selected in the designed scheme.
- The switches used for outdoor lighting generally do not take seasonal variation into account, which results in wastage of energy. Therefore, a device or a timer should be used that is sensitive to seasonal variations and adjusts on the basis of actual length of day/night
- Microcontroller-based time switch has inputs like real time, date, month, year, as well as plus and minus offset.
 Due to its versatile concept of switching at sunset and sunrise timings throughout the year, it saves on electrical units, resulting in reduced electric bills.



- Solar PV-based outdoor light
- Solar energy and other sources of renewable energy can be used for outdoor lighting, which requires minimum maintenance and operation cost.

Criteria for choosing outdoor lighting

- The choice of source for external lighting is guided by the following considerations.
 - o Luminous flux
 - o Economy (determined by lumens/watt and life)
 - o Colour characteristics



GUIDELINE: DESIGN ENERGY-EFFICIENT SPACE CONDITIONING IN BUILDINGS

Achieve inside design condition in a conditioned space as recommended by the National Building Code with energy-efficient HVAC design by following mandatory requirements as recommended in the Energy Conservation Building Code (ECBC) of India.

Norms and standards to be followed

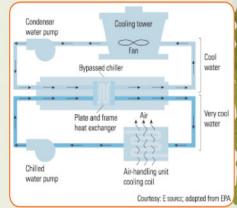
 The inside design conditions of a conditioned space should conform to the recommendations of the National Building Code 2005. Given below are examples of inside design conditions for different categories

Table 1	Table 1 Indoor design condition as per NBC 2005							
S. No.	Category	Inside Design Conditions						
(1)	Restaurants	DB 23 to 26 C	RH 55 to 60%					
(ii)	Office buildings	DB 23 to 26 C	RH 55 to 60%					
(iii)	Radio and television studios	DB 23 to 26 C	RH 45 to 55%					
(iv)	Departmental stores	DB 23 to 26 C	RH 50 to 60%					
(v)	Hotel guest rooms	DB 23 to 26 C	RH 50 to 60%					
(vi)	Class room	DB 23 to 26 C	RH 50 to 60%					
(vii)	Auditoriums	DB 23 to 26 C	RH 50 to 60%					
DB dry	DB dry bulb temperature							

- The outside design conditions shall be in accordance with the conditions specified in the National Building Code 2005 as given in table below.
- Efficiency of the equipment installed should comply with the ECBC requirement.

Towards energy-efficient HVAC systems

- · Optimization of cooling load
 - Inside design conditions should be selected as recommended by NBC for various categories of spaces as given in the above table.
 - Outdoor design conditions should selected as recommended by NBC for Bangalore climate.
 - Minimum ventilation rate in air-conditioned space should conform to ASHRAE Standard 62.1, 2007. For example, minimum ventilation rates for office space are shown below.



Schematic of a centralized AC system

Table 2 Outdoor design conditions for Bangalore

Cooling DB/MCWB					Cooling	Cooling WB/MCDB					
0.4% 1.0% 2.		2.0 %	2.0 %		0.4 %		1.0 %		2.0 %		
DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB
34.7	19.6	34	19.6	33.1	19.2	23.5	28.9	22.9	28.2	22.5	27.7

DB dry bulb temperature; MCWB mean coincidental wet bulb temperature; WB wet bulb temperature; MCDB mean coincidental dry bulb temperature

Table 3 Fresh air requirement for select space

Table 3 Tream on Tegenerical For Select Spaces									
Occupancy category	People outdoor air rate Rp		Area outdoor air rate Ra Note		Notes	Occupant density (see Note 4)	Combined outdoor air rate (see Note 5)		Air class
	CFM/person	L/s person	CFM/ft ²	L/sm²		#/1000 ft ² or #/100 m ²	CFM/ person	L/s person	
Office buildings									
Office space	5	2.5	0.06	0.3		5	17	8.5	1
Reception areas	5	2.5	0.06	0.3		30	7	3.5	1
Telephone/data entry	5	2.5	0.06	0.3		60	6	3.0	1
Main entry lobbies	5	2.5	0.06	0.3		10	11	5.5	1

CFM cubic feet/minute; L/s litre/sec

- o The fresh air should be pre cooled by energy recovery ventilators (ERVs).
- For different building types in Bangalore, the cooling demand should not exceed 500 square feet/TR
- The total connected electrical load of air-conditioning system shall not exceed 7 W/square feet
- · Energy efficiency in AHUs
 - Air system design should be equipped to operate in 100% outside fresh air mode.
 - Air side economizers should be designed in accordance with ASHRAE 90.1.2007.
 - AHUs should be equipped to vary the supply air quantities as per the cooling load.
 - Efficiency of AHU fans of size less than 6 bhp (break horse power) shall not be less than 65% and of size
 6 bhp and larger efficiency shall not be less than 80%.
 - Efficiency of the induction motors used in airconditioning should conform with Indian standard IS 12615: 2004 - energy efficiency induction motors.

- Energy efficiency in chillers
 - Chiller efficiencies shall be as per ECBC recommendations as given in the table below.
 - o Chilled water supply temperatures for achieving comfort conditions shall not be lower than 440 $^{\circ}\text{F}.$
 - o Chilled water flow rate shall not exceed 2 GPM/TR.
 - o All unitary systems (split & window units) shall be BEE 5-star rated.
- Energy efficiency in cooling towers
 - Cooling towers in Bangalore should be designed for an approach temperature equal to or less than 50 °F.
- Improve control Through better algorithms, sensors, signal delivery, user interface, simulators, and other measures. Use of variable frequency drives in fans and pumps can save significant amount of energy.

Table 4 ECB-recommended chiller COPS							
S No	Equipment class	Minimum COP	Minimum IPLV	Test standard			
1	Air cooled chiller <530 kW (<150 tonnes)	2.9	3.16	ARI 550/590-1998			
2	Air cooled chiller ≥530 kW (≥150 tonnes)	3.05	3.32	ARI 550/590-1998			
3	Centrifugal water cooled chiller < 530 kW (<150 tonnes)	5.8	6.09	ARI 550/590-1998			
4	Centrifugal water cooled chiller ≥530 and <1050 kW (≥150 and <300 tonnes)	5.8	6.17	ARI 550/590-1998			
5	Centrifugal water cooled chiller ≥ 1050 kW (≥ 300 tonnes)	6.3	6.61	ARI 550/590-1998			
6	Reciprocating compressor, water cooled chiller all sizes	4.2	5.05	ARI 550/590-1998			
7	Rotary screw and scroll compressor, water cooled chiller <530 kW (<150 tonnes)	4.7	5.49	ARI 550/590-1998			
8	Rotary screw and scroll compressor, water cooled chiller ≥530 and <1050 kW (≥150 and <300 tonnes)	5.4	6.17	ARI 550/590-1998			
9	Rotary screw and scroll compressor, water cooled chiller ≥ 1050 kW (≥ 300 tonnes)	5.75	6.43	ARI 550/590-1998			
kW kilowatt; COP coefficient of performance; IPLV integrated part load value							

GUIDELINE: USE APPLIANCES RATED BY THE BUREAU OF ENERGY EFFICIENCY, GOVERNMENT OF INDIA

All new buildings should be equipped with the appliances labelled by Bureau of Energy Efficiency (BEE). BEE has labelled refrigerators, tube lights, distribution transformer, air conditioners and induction motors. Minimum 3-star-rated appliances should be used. Retrofit and replacement in existing premises shall be made only by at least 3-star-rated BEE labelled appliances.

Labelled appliance

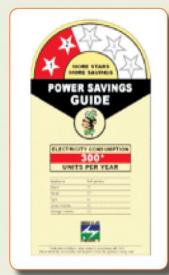
- Energy consumption of products manufactured by various manufacturers varies.
- Often, information on the energy consumption by a product is not easily available or is difficult to understand.
- Labelled appliances provide comprehensive understanding of energy consumption by respective products. They are reliable and recommended to be used.
- An appliance is rated based on its performance and energy consumption.

Advantages of using labelled products

- The energy rating label helps consumers compare energy efficiency of domestic appliances on a fair and equitable basis and make an informed decision.
- Manufacturers, in turn, vie with each other to improve their products.
- Labelled products perform better.
- Labelled products are generally energy efficient.
- Better performing and energy-efficient appliances with clean technology have minimal environmental impacts.
- High financial savings with savings in electricity bill and early payback period.

Star performance

- The rating of appliances in India is done by the BEE.
- Labelled appliances carry the symbol of stars.
- The higher the number of stars, the more efficient the product is. Star rating is currently used for room air conditioners, refrigerators, ceiling fans, electric geysers, colour televisions, tubular fluorescent lamps, distribution transformers, induction motors, agriculture pumpsets and LPG stoves.





- BEE star rating is currently mandatory for frost free refrigerators, room air conditioners, distribution transformers, and tubular fluorescent lamps.
- A BEE 3-star rated 1.5-tonne window air conditioner, EER 2.7 would consume 1500 units of electricity in a year compared to a 1-star rated (EER 2.3) of same size would consume 1750 units for same period.
- An efficient 3-star 1.5-tonne
 AC would cost about Rs 19500, while
 1-Star rated AC of the same size would cost Rs 18 000. The payback period is little over one year due to savings in the electricity bill.

Efficient installation and usage of room ACs

The following points should be kept in mind while using an AC.

- While installing an AC, it should be ensured that the exterior, or back, is not exposed to direct sunlight and is
- away from heat sources like a chimney.
- Appliances such as TVs, computers or lamps should be kept away from the AC.
- The temperature (thermostat) of the AC should be set higher (25-27 degrees C) to reduce energy consumption.
- Regular maintenance of ACs improves their efficiency.

Efficient refrigerators

- The cost of running a refrigerator over the years is several times the initial purchase price. So, a more efficient model should be bought.
- Smaller models will obviously use less energy than larger models.
- On an average, models with top- or bottom-mounted freezers use 12% less energy than side-by-side designs.
- Features like through-the-door ice, chilled water or automatic ice-makers increase the energy consumption, purchase price, and energy use.
- A 5-star rated refrigerator does cost more initially compared to, say, a 2-star refrigerator, but its cost of operation over the years is less due to better design and insulation.

GUIDELINE: SOLAR WATER HEATING SYSTEMS FOR DOMESTIC AND COMMERCIAL BUILDINGS



Solar flat-plate collector

- Solar water heating systems should be provided for residential, commercial, and institutional buildings.
- · Insulation on pipelines should be provided as per norms.
- Water recycling pumps to reduce wastage should be provided in high- rise buildings.
- Existing buildings shall also be required to install solar water heating system. Pre-feasibility shall be carried out to determine applicability.

Solar water-heating system components

The main components of a solar water-heating system are solar collectors, insulated hot water tank, back-up system, plumbing, and control and instruments.

Types of solar water heating system

There are two types of solar water heating systems.

- Thermo siphon-type solar hot water system: for capacities of up to 2000 litres per day.
- Forced flow solar hot water system: for capacities higher than 2000 litres per day.

Guidelines for design, installation, and use of solar water heating systems

- A 3-4 m2 (per 100 lpd system) shadow-free area should be available on the terrace for installation.
- Solar collector should face true south for maximum solar radiation collection.
- The solar collector tilt equal to latitude +15° gives maximum energy collection in winter.
- Solar collector tilt equal to latitude -15° gives maximum energy collection in summer.
- Piping for a solar water heating system should be well insulated to minimize thermal losses.
- The load-carrying capacity of the roof before placing the solar water heating system should be checked.
- Proper anchoring of the system should be ensured, duly considering wind conditions.
- Solar collectors and tank must be easily accessible for cleaning and maintenance.
 - Gap between the nearest tall building and collector surface should be at least twice the building height for buildings in south and eastwest sides.
 - Water quality, including TDS /hardness should be less than 100 ppm. Consult expert if some minerals are more (refer ISI standard for water quality).
 - Hardness of water should be considered and water softener or heat exchanger type hot water system should be used.
 - Operating pressure of the cold water supply line should be considered for pressurized water circulation.



Evacuator tube collector

GUIDELINE: ENERGY EFFICIENT ELECTRICAL SYSTEMS FOR BUILDINGS

Design energy efficient and reliable electrical systems for buildings

Norms and standards to be followed

- The power factor of the building should be maintained above 0.95
- The transformer no load and full load losses should be in accordance with the conditions specified in ECBC 2007.

Electrical systems

Electrical system in a building comprises the infrastructure that supplies electricity. The main components are electrical substation, transformers, distribution systems, circuit breakers, electrical meters, and capacitors.

The objective of having an efficient electrical system in a building installation is to have energy-efficient delivery systems, thereby minimizing the losses in the electrical infrastructure. Also the installed electrical system should have suitable safety mechanism for providing reliable power supply.



Tranformer

Energy efficient electrical systems - facts and benefits

 Optimized building electrical load during the design will include peak load, load fluctuations under various operating conditions, nature of load, PF and its variation, calculated daily, monthly and annual load factor, and anticipated seasonal variation, effect of large motor starting



Energy-efficient motor

- For sanctioning of electrical load anticipation of the present demand over a period of time, peak load, maximum demand, diversity, load factors, as well as future demand forecasting and planning (building expansion plans) should be considered.
- Reduction in energy loss can be realized by selection of transformers conforming to the ECBC norms
- Energy-efficient motors can substantially reduce the annual energy consumption. Follow IS12615 for energyefficient motors.
- Improved efficiency in power distribution system by selection of suitable transmission cables
- · PF improvement can fetch the following benefits
 - o Reduced kVA (maximum demand) charges in utility bill
 - o Reduced distribution losses (kWh) within the plant
 - o Better voltage and improved performance of system
 - o A high power factor eliminates penalty charges imposed when operating with a low power factor
 - o Investment on system facilities such as transformers, cables, switch gears etc for delivering load is reduced
- Energy accounting through metering and monitoring should be followed to identify energy- saving opportunities and to conserve energy.

GUIDELINE: ENERGY AUDIT SHOULD BE CARRIED OUT IN ALL COMMERCIAL/INSTITUTIONAL BUILDINGS THAT HAVE A CONNECTED LOAD OF MORE THAN 500 kW OR 600 kVA

Energy performance indices should be derived for audited buildings and evaluated vis-à-vis the BEE star rating (note: presently the BEE does not have EPI for rating of office buildings in temperate zone; however, it is under development; BEE star rating band is available for BPO buildings only) Target should be set to achieve a minimum of 3-star rating by applying energy conservation measures (as and when developed).

Benefits of energy audit

- It indicates the ways in which different forms of energy are being used and quantify energy use according to discrete functions.
- It seeks to prioritize energy usage according to the most to least cost-effective opportunities for energy savings.
- It helps in achieving reduction in the energy costs by proper utilization of the existing equipment and systems.
- It helps in evaluating the present energy scenario in comparison with the standard specific consumption norms, for example, with that set up by the BEE.
- It leads to reduced adverse environmental impacts, as there will be reduction in the emission of greenhouse gases, increased comfort of building occupants and improved awareness.

Auditing energy consumption in a building Energy demand and consumption in a building can be identified using following steps.

- Data collection On annual energy bills, fuel bills, total built up area (m2), and air-conditioned area (m2)
- Analysis Of establishing energy performance index (kWh/m2-year), which is a measuring tool to evaluate the performance of the building in terms of the total energy consumption (kWh) and the total built-up area (m2) and the specific energy generation ratio (SEGR), which is a measuring tool to evaluate the performance of diesel generators.
- Observations and recommendations On comments on the energy performance of the building, on diesel generator performance, and tariff rate
- Energy conservation measures Improving SEGR of diesel generators, analysing the scope of reducing the existing operating consumption (kWh) of the building by installing energy-efficient systems.

Auditing electrical system

- Data collection On the main source of electricity for the building and its single line diagram
- Measurement Of building load for two days and operating load of LT motors

- Analysis Of motor loading (%), voltage, and power factor at transformer
- Observation and recommendation On the power factor, motor loading percentage, transformer losses, and voltage imbalance among the three phases
- Energy conservation measures Maintaining power factor by installing capacitor banks, identifying motors on the basis of their loading rates and balancing loads

Auditing lighting system

- · Data collection On lighting source
- · Measurement Of illumination level and lighting load (kW)
- Analysis Of lighting consumption (kWh) and lighting power density (W/m²)
- Observation and recommendation On maintained visual comfort and measured lighting power density (W/m²)
- Energy conservation measures Selecting proper fixture and integrating daylighting with artificial lighting and using automatic lighting control devices

Auditing HVAC system

- Data collection Detail layout of HVAC plant along with the design parameters of all HVAC equipment
- Measurement Of chiller performance, pump performance, AHU and cooling tower
- Analysis Of HVAC consumption (kWh), performance evaluation of chillers, pumps, AHUs, cooling tower and thermal comfort experienced by building occupants
- Observation and recommendation On maintained thermal comfort and measured chilled water, condenser water efficiency, cooling tower efficiency
- Energy conservation measures Replacing inefficient pumps and other equipment by efficient pumps and efficient equipment, selection of appropriate insulation to minimize heat gains, ensure adequate flow of chilled water and cooling water flows, adopt VFD for varying process loads.

GLOSSARY

Air change rate:

It is a measure of how quickly the air in an interior space is replaced by outside (or conditioned) air by ventilation and infiltration. Air change rate is measured in appropriate units such as cubic metres per hour divided by the volume of air in the room.

British thermal unit:

Any of several units of energy (heat) in the HVAC industry, each slightly more than 1 kJ. One BTU (British thermal unit) is the energy required to raise the temperature of one pound of water by 1° Fahrenheit, but the many different types of BTU are based on different interpretations of this definition. In the United States the power of HVAC systems (the rate of cooling and dehumidifying or heating) is sometimes expressed in BTU/hour instead of watts.

Chiller:

A device that removes heat from a liquid via a vapor-compression or absorption refrigeration cycle. This cooled liquid flows through pipes in a building and passes through coils in air handlers, fan-coil units or other systems, cooling and usually dehumidifying the air in the building. Chillers are of two types—air cooled or water cooled. Air-cooled chillers are usually outside and consist of condenser coils cooled by fan-driven air. Water-cooled chillers are usually inside a building and heat from these chillers is carried by re-circulating water to outdoor cooling towers.

Coil:

Equipment that performs heat transfer when mounted inside an air-handling unit or ductwork. It is heated or cooled by electrical means or by circulating liquid or steam within it. Air flowing across it is heated or cooled.

Condenser:

A component in the basic refrigeration cycle that ejects or removes heat from the system. The condenser is the hot side of an air conditioner or heat pump. Condensers are heat exchangers and can transfer heat to air or to an intermediate fluid (such as water or an aqueous solution of ethylene glycol) to carry heat to a distant sink such as ground (earth sink), a body of water, or air (as with cooling towers).

Constant air volume:

A system designed to provide a constant air volume (CAV) per unit time. This term is applied to HVAC systems that have variable supply-air temperature but constant air flow rates. Most residential forced air systems are small CAV systems with on/off control.

Controller:

A device that controls the operation of part or all of a system. It may simply turn a device on and off or it may more subtly modulate burners, compressors, pumps, valves, fans, dampers, and the like. Most controllers are automatic but have user inputs such as temperature set points, for example a thermostat. Controls may be analog, or digital, or pneumatic or a combination of these.

Daylight factor: The ratio of interior illuminance at a given point on a given plane (usually

the work plane) to the exterior illuminance (reference) under the same sky

conditions.

Dew point: The temperature at which a moist air sample at the same pressure would

reach water vapour saturation.

Dry bulb temperature: The temperature of air measured by a thermometer freely exposed to the air

but shielded from radiation and moisture.

Energy Performance Index: The ratio of total building energy consumption in a year to the total built-up

area.

Evaporator: A component in the basic refrigeration cycle that absorbs or adds heat to

the system. Evaporators can be used to absorb heat from air (by reducing temperature and by removing water) or from a liquid. The evaporator is the

cold side of an air conditioner or heat pump.

Fan coil unit: A small terminal unit that is often composed of only a blower and a

heating and/or cooling coil (heat exchanger), as is often used in hotels, condominiums, or apartments. One type of DCU (fan coil unit) is a unit

ventilator.

Fenestration: All areas (including the frames) in the building envelope that let in light,

including windows, plastic panels, clerestories, skylights, and glass doors that

are more than one-half glass, and glass block walls.

Heat load, heat loss or heat gain: Terms for the amount of heating (heat loss) or cooling (heat gain) needed to

maintain desired temperatures and humidity in controlled air. Regardless of how well-insulated and sealed a building is, buildings gain heat from warm air or sunlight or lose heat due to cold air and radiation. Engineers use a heat load calculation to determine the HVAC needs of the space being cooled or

heated.

Hottest average day: The day with the highest average temperature in the year.

Louvers: Blades, sometimes adjustable, placed in ducts or duct entries to control the

volume of air flow. The term may also refer to blades in a rectangular frame

placed in doors or walls to permit the movement of air.

Makeup air unit: An air handler that conditions 100% outside air. Makeup air units (MAUs)

are typically used in industrial or commercial settings, or in 'once-through' blower sections that only blow air one-way into the building), 'low flow' (air handling systems that blow air at a low flow rate) or 'primary-secondary' (air handling systems that have an air handler or rooftop unit connected to an

add-on makeup unit or hood) commercial HVAC systems.

Illuminance: Illuminance is the total luminous flux incident on a surface, per unit area.

Infiltration: The uncontrolled inward air leakage through cracks and crevices in any

building element and around windows and doors of a building caused by pressure differences across these elements due to factors such as wind, inside and outside temperature differences (stack effect), and imbalance between

supply and exhaust air systems.

Luminous intensity: Luminous intensity is a measure of the wavelength-weighted power emitted

by a light source in a particular direction per unit solid angle.

Mean radiant temperature: Mean radiant temperature (MRT) is simply the area weighted mean

temperature of all the objects surrounding the body.

Metabolic rate: The metabolic rate, expressed in met, is used as a measuring unit of human

heat production.

Orientation: It is the direction an envelope element faces, that is, the direction of a

vector perpendicular to and pointing away from the surface outside of the

element.

Packaged terminal air conditioner An air conditioner and heater combined into a single, electrically powered

unit, typically installed through a wall and often found in hotels.

Packaged unit or rooftop unit: An air-handling unit, defined as either 'recirculating' or 'once-through'

design, made specifically for outdoor installation. They most often include, internally, their own heating and cooling devices. Rooftop unit (RTUs) are very common in some regions, particularly in single-story commercial buildings.

Reflectance: The fraction of radiant energy that is reflected from a surface.

Solar heat gain coefficient: The fraction of external solar radiation that is admitted through a window or

skylight, both directly transmitted and absorbed and subsequently released

inward.

Transmittance: The fraction of radiant energy that passes through a surface.

U-factor: It measures the rate of heat transfer through a building element over a given

area, under standardized conditions. The usual standard is at a temperature

gradient of 24 $^{\circ}\text{C},$ at 50% humidity with no wind.

Wet bulb temperature: The temperature measured using a standard mercury-in-glass thermometer,

with the thermometer bulb wrapped in muslin, which is kept wet.

Window wall ratio: The fraction of the cumulative window area to the wall area (including

fenestration area) on the same facade.





The city of Bangalore, like any other city in India, faces an enormous challenge in meeting its ever increasing demand of energy and water.

Under these circumstances, TERI University initiated the project Development of Environmental Building Regulations and Guidelines to achieve Energy Efficiency in Bangalore city, in association with Bhurat Bengaluru Mahanagara Palike (BBMP) and Bangalore Development Authority (BDA) with the support of the Renewable Energy and Energy Efficiency Partnership (REEEP).

The project aims to mainstream design and operation of energy-efficient buildings. Under this project, the BBMP, BDA Bangalore Electricity Supply Company (BESCOM), and Karnataka Renewable Energy Development Limited (KREDL) have come together under the guidance of Dr Ravindra (Advisor to Chief Minister of Karnataka, Urban Affairs), along with TERI, to reframe the existing building bye-laws and add the energy efficiency clause in the existing building regulations of Bangalore city. Along with the regulations, detailed guidelines to achieve energy efficiency have also been formulated.

This educational booklet provides a summary of all guidelines formulated under this project to achieve energy efficiency in the built environment in Bangalore city.

The guidelines are formulated under nine different sub-sections, which include solar passive architecture, energy efficiency in electrical systems of buildings, and renewable energy integration in a building.

