ECBC Training Workshop

Introduction

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ACKNOWLEDGEMENT

This presentation was prepared by International Resources Group (IRG) for the Energy Conservation and Commercialization Project (ECO-III), and was made possible by the support of the American People through the United States Agency for International Development (USAID). The contents of this presentation are the sole responsibility of IRG and do not necessarily reflect the views of USAID or the United States Government. The ECO-III Project would like to acknowledge Ministry of Power and the Bureau of Energy Efficiency of Government of India for their support.

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ECBC Training Workshop Objectives

Energy Conservation Building Code (ECBC) Awareness

- Need for the ECBC : Energy Scenario Globally & in India
- ECBC Introduction
- ECBC & other building codes in India
- Impact of the ECBC

Provide Administrative Guidance

- ECBC Scope & Administration
- Compliance Approaches (Mandatory, Prescriptive, and Whole Building Performance)
- Compliance requirements

Provide Guidance for Code Compliance

- Technical examples/exercises, compliance forms etc.

ECBC Training Workshop Objectives

» **Provide Technical Guidance**
- Building thermal performance basics
- Energy efficiency tips
- Examples/Case Studies

» **Provide Useful List of Resources and Reference Materials**

» **ECBC knowledge Evaluation**
- Interactive Q & A sessions and quiz/test

ECBC Workshop Outline

MODULE 1: **ECBC Awareness**

MODULE 2: **ECBC Scope & Administration**

MODULE 3: **Building Envelope**

MODULE 4: **Heating, Lighting & Ventilation (HVAC)**

MODULE 5: **Service Hot Water & Pumping**

MODULE 6: **Lighting**

MODULE 7: **Electric Power**

MODULE 8: **Demonstrating Compliance**

MODULE 9: **Introduction to Building Physics**

ECBC Training Workshop

MODULE 1:
Energy Conservation Building Code (ECBC) Awareness

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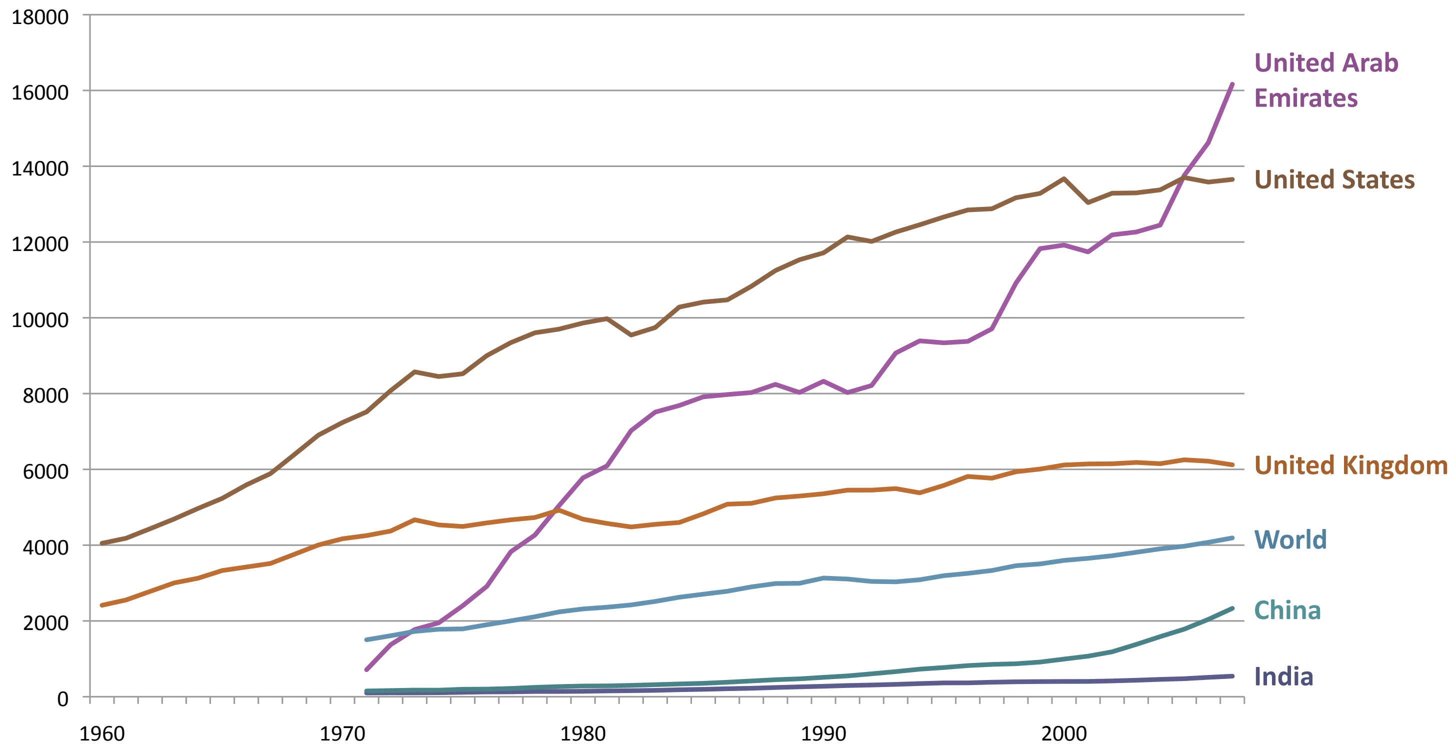
ECBC Awareness: Outline

- WORLD Energy Scenario
- Energy Scenario in INDIA
- About the ECO-III Project
- Introduction to ECBC
- Significance of ECBC

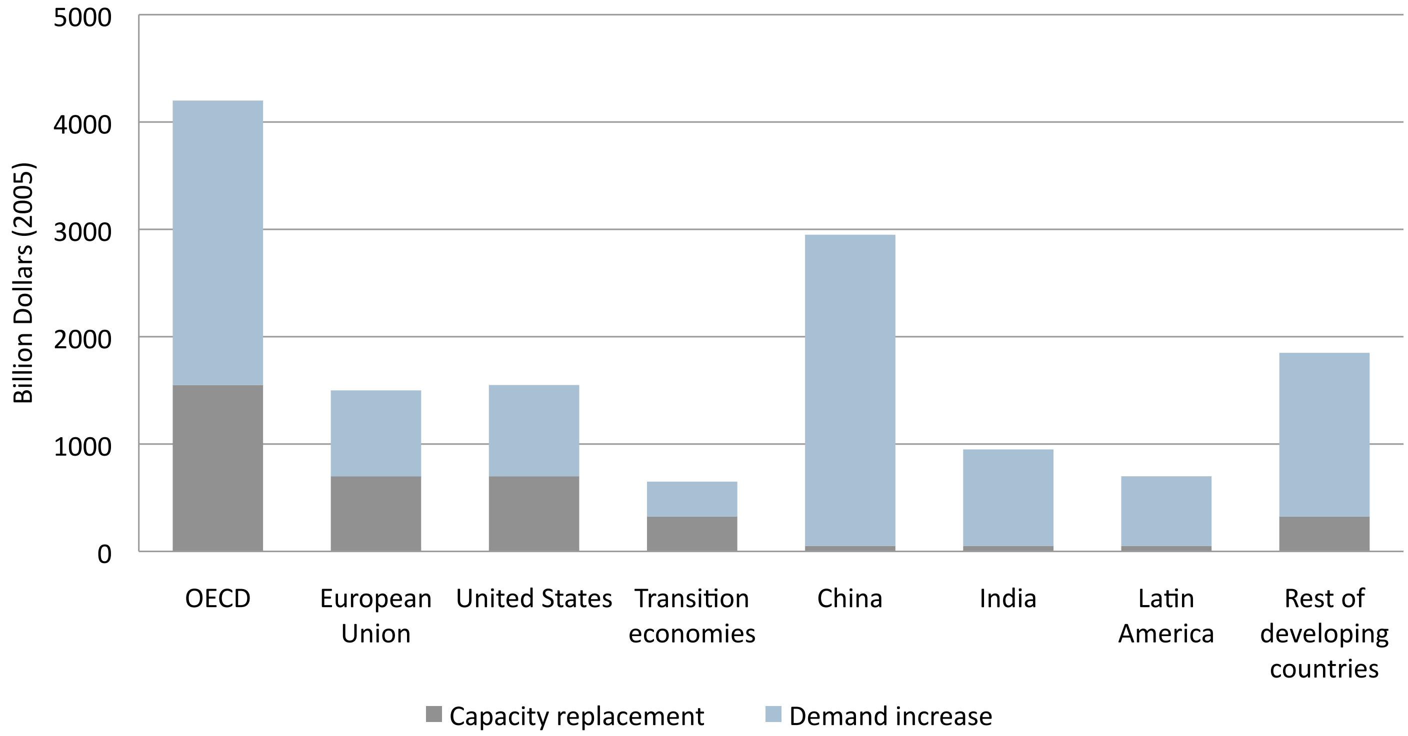
WORLD Energy Scenario



Electric Power Consumption (kWh Per Capita)

SOURCE: The World Bank. http://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC (International Energy Agency, Energy Statistics and Balances of Non-OECD Countries and Energy Statistics of OECD Countries)

WORLD Energy Scenario



Cumulative Power Sector Investment 2005-2030

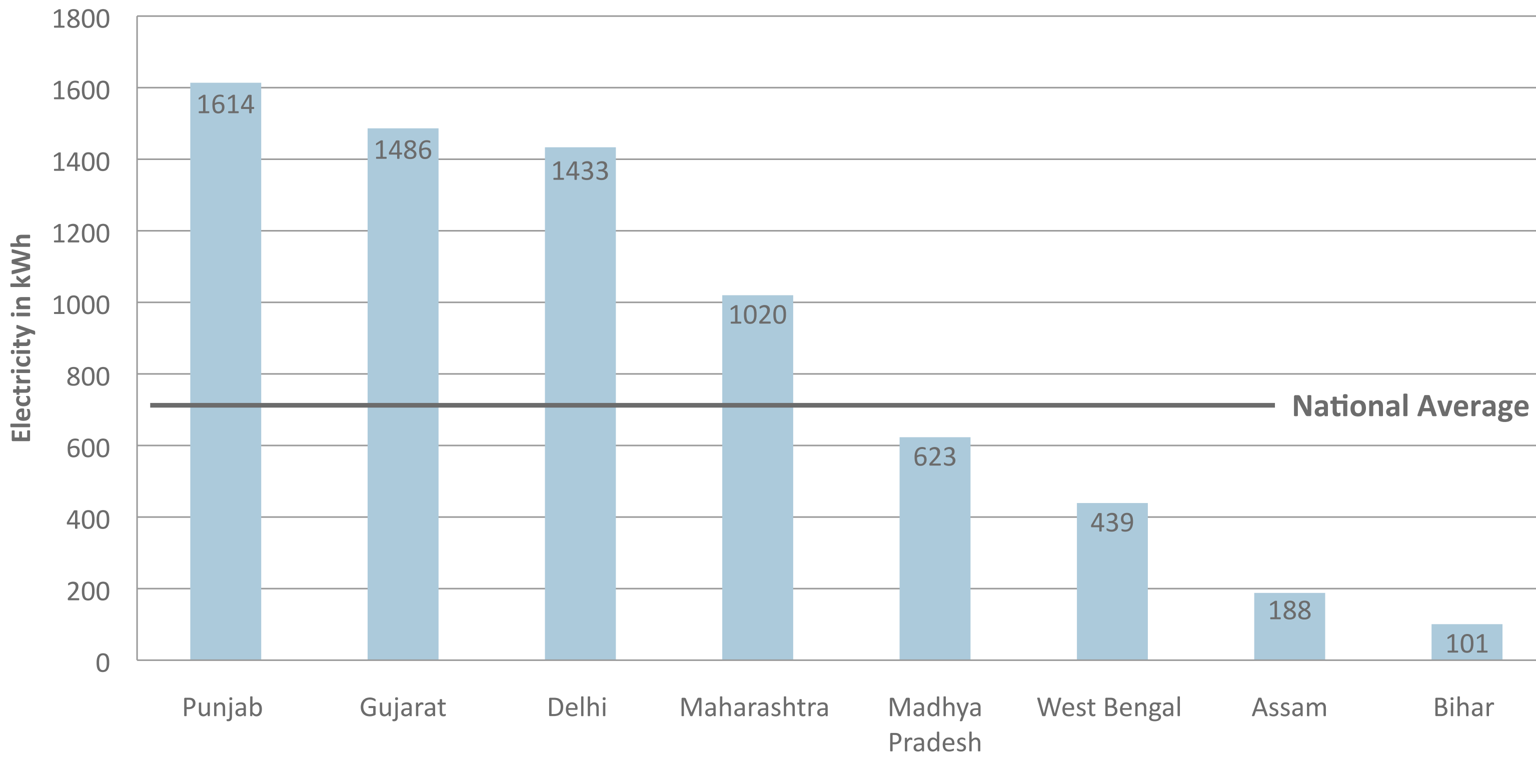
The largest investments are needed in developing countries, especially countries like China and India, mostly to meet surging demand

SOURCE: International Energy Agency, World Energy Outlook 2006

Energy Scenario in INDIA

- 16% of global population
- 4.5% Compound Annual Growth Rate (CAGR) in primary energy demand (1997-2007)
- Capital Investment needed on Supply Side - approx. $1 trillion
- Installed Capacity in India – approx. 160,000 MW
- Projected Capacity in 2030 – 800,000 MW
  - 600 MW capacity addition each week for the next 20 years
- Continued deficit supply in 2007-08 (MoP)
  - Peak power deficit of 16.6%
  - Energy Deficit of 9.9%
- Capacity Added by China in last two years – 180,000 MW
  - More than total installed capacity in India
- 66% of India's Commercial Buildings Stock in 2030 has not been built yet
- No other country in the history would have encountered the growth in the AC load that India is poised to experience

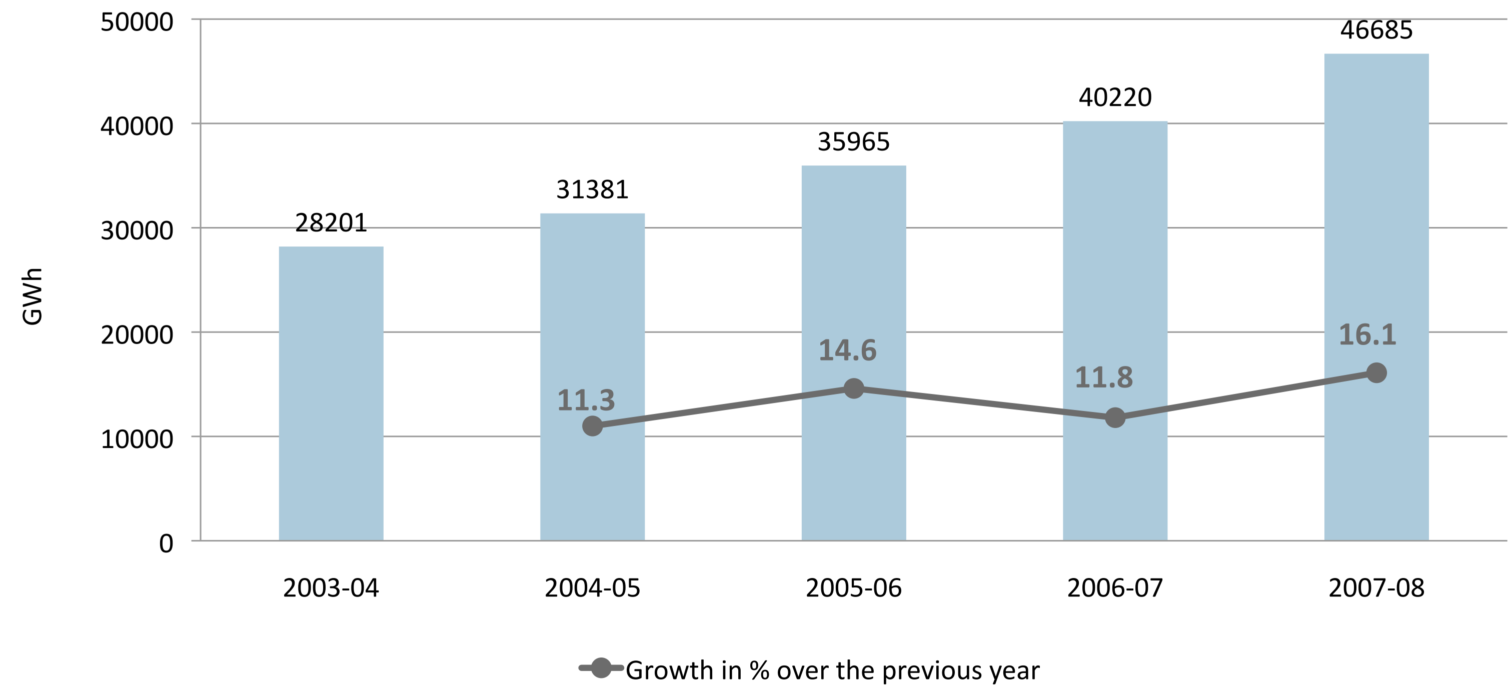
Energy Scenario in INDIA



State-wise Per Capita Electricity Consumption during 2007-08

SOURCE: Central Electricity Authority, Year End Review 2007-08

Energy Scenario in INDIA

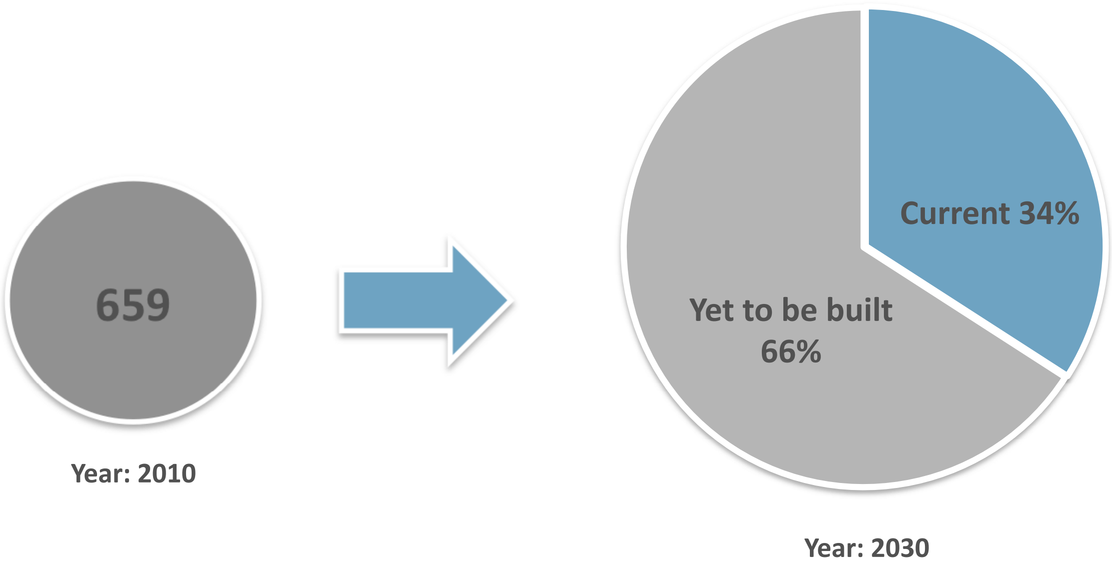


Growth of Electricity Consumption in Commercial Sector in India (2003-08)

SOURCE: Central Electricity Authority, General Review 2009

Commercial Buildings Growth Forecast

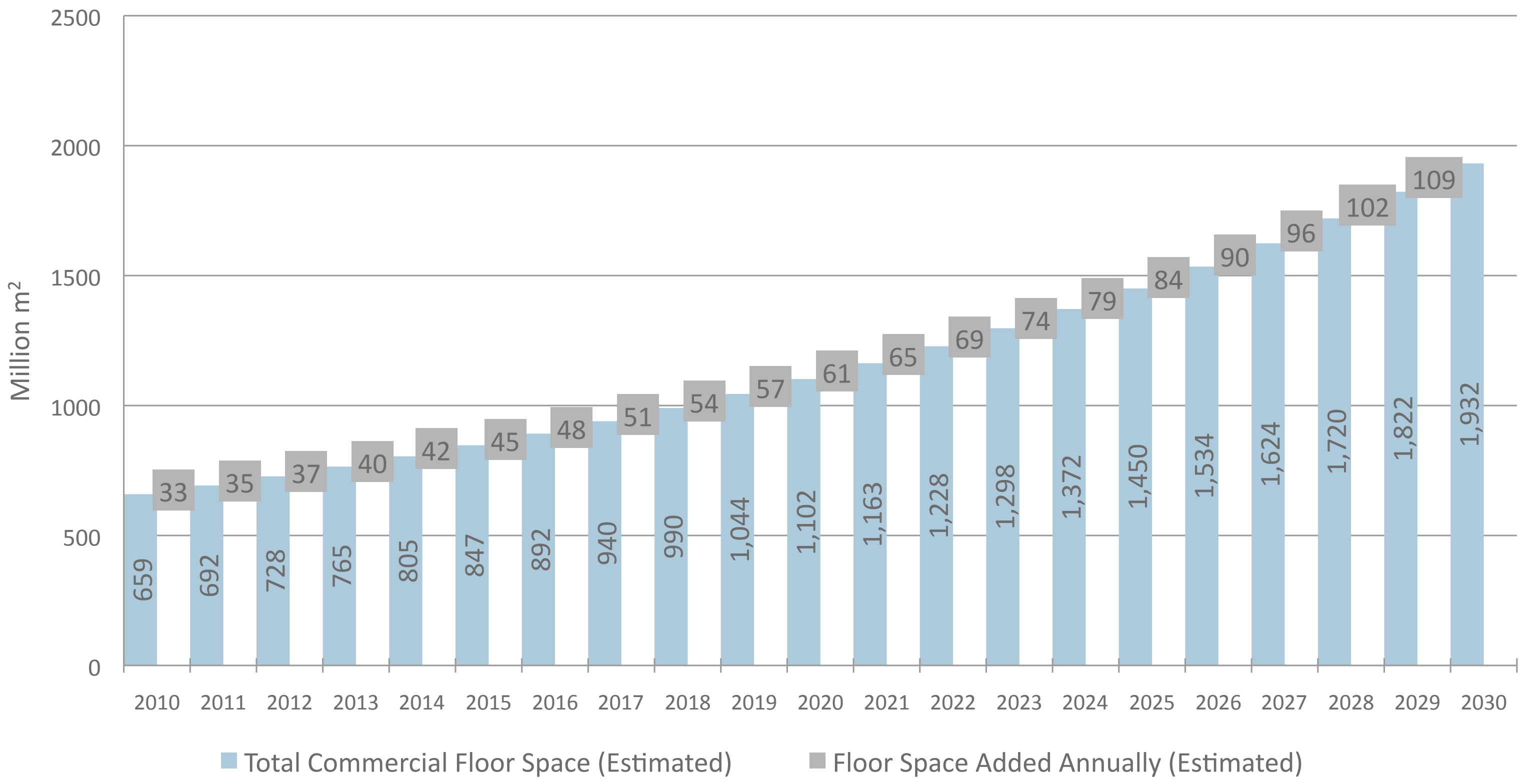
- Currently, ~ 659 million m^2 (USAID ECO-III Internal Estimate Using MOSPI, CEA and Benchmarked Energy Use data)
- In 2030,~ 1,900 million m^2 (estimated) *
  - 66% building stock is yet to be constructed



** Assuming 5-6% Annual Growth*

SOURCE: McKinsey & Company (2009), Environmental and Energy Sustainability: An Approach for India

Commercial Buildings Growth Forecast



Commercial Floor Space Projection for India *(Assuming 5-6% Annual growth)*

SOURCE: USAID ECO-III Project, New Delhi

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Changing Face of Indian Architecture

TRADITIONAL/VERNACULAR BUILDINGS

Selective use of HVAC |Climatic responsive architecture | Passive heating/cooling | Low Energy Use

MODERN BUILDINGS

Climate controlled | Hi-Tech | Energy Intensive | Emulates western modern architecture

Commercial Buildings in MUMBAI

Commercial Buildings in GURGAON

About the ECO-III PROJECT

- **Bilateral Project Between US and Govt. of India**
  - Implemented jointly with BEE
  - Phase III started in Nov. 2006
  - Implemented by IRG and its partners
- **Focused on BEE Thrust Areas**
  - Energy Conservation Action Plan for Designated State Agencies (SDAs)
  - Energy Efficiency in Buildings (new and existing)
  - Energy Efficiency in Municipalities (Water Pumping & Street Lighting)
  - Energy Efficiency in Small and Medium Enterprises (SME)
  - Curriculum Enhancement of Academic Institutes
- **Market transformation through innovative approaches**
  - Alliance for an Energy-Efficient Economy
  - Regional Energy Efficiency Centers
  - Capacity Building for Implementation of DSM Programs

ECBC Implementation: ECO-III Milestones

Technical Content Development and Capacity Building

- ECBC (version 2), ECBC User Guide, Tip Sheets, and Design Guides
- More than 20,000 hard copies of technical resources
- ECBC professional training module
- All technical documents posted on ECO-III and BEE web site

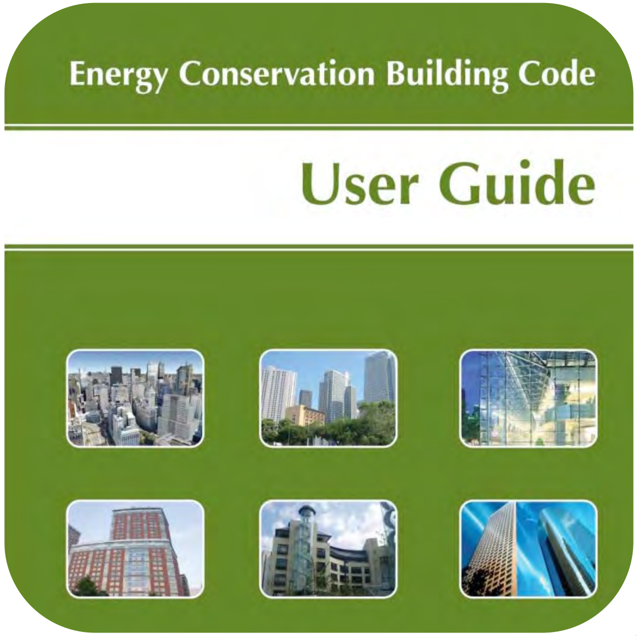
Awareness and Training Workshops on ECBC

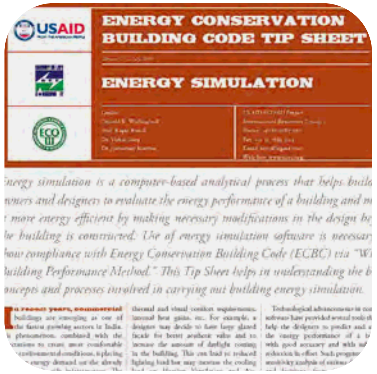
- Organized/Participated in 14 ECBC Training and Awareness workshops
- Launched a major capacity building effort in building energy simulation
- Linking ECBC to Architectural Curriculum

Next Steps

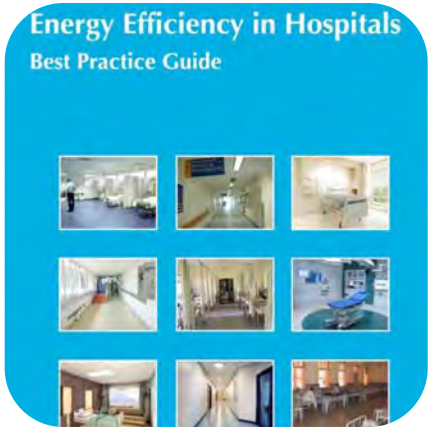
- ECBC Implementation Framework
- ECBC Compliance Check Tools
- Certified Building Energy Professional

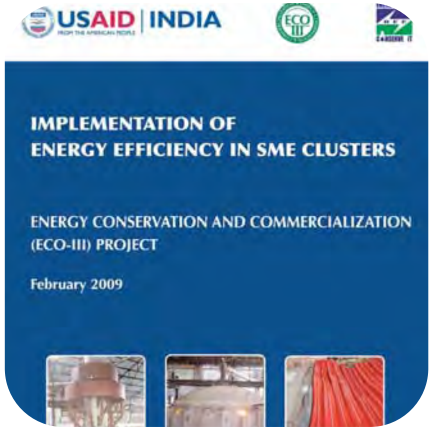
ECBC User Guide and Tip Sheets

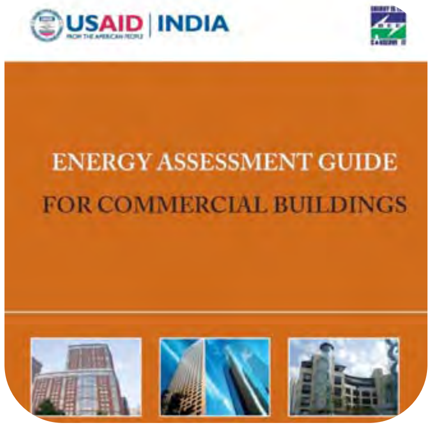




Building Energy Efficiency Guides







ECBC Introduction

- **ECBC sets minimum energy efficiency standards for design and construction of commercial buildings**
- **ECBC encourages energy efficient design or retrofit of buildings so that**
  - It does not constrain the building function, comfort, health, or the productivity of the occupants
  - It has appropriate regard for economic considerations
- **Addresses local design conditions and helps improve existing construction practices**
- **Emphasis on Integrated Building Design approach**
- **First generation code – ease of use and continuous improvement**

BACKGROUND: Energy Conservation Act 2001

» **Government of India - creation of Bureau of Energy Efficiency (BEE)**

» **Powers and Functions of BEE vis-à-vis ECBC**

- Prescribe ECBC for efficient use of energy
- Take suitable steps to prescribe guidelines for ECBC
- Link Energy Performance Index (from the EC Act) to the ECBC Prescriptive Compliance Approach in order to facilitate the implementation of the Code

[On Page 5, clause (j) of the EC Act, 2001 currently reads:
"energy conservation building codes" means the norms and standards of energy consumption expressed in terms of per square meter of the area wherein energy is used and includes the location of the building]

» **Power of State Government:**

The State Govt., in consultation with BEE, may

- amend ECBC to suit the regional and local climatic conditions with respect to use of energy in the buildings
- direct the owner or occupier of a building (if notified as a Designated Consumer) to comply with the provisions of ECBC

ECBC and NAPCC

Prime Minister's National Action Plan on Climate Change (NAPCC)

- National Solar Mission
- National Mission for Enhanced Energy Efficiency
- **National Mission on Sustainable Habitat**
- National Water Mission
- National Mission for Sustaining the Himalayan Ecosystem
- National Mission for a Green India
- National Mission for Sustainable Agriculture
- National Mission on Strategic Knowledge for Climate Change

» **Promoting Energy Efficiency in the Residential and Commercial Sector**

- **The Energy Conservation Building Code, which addresses the design of new and large commercial buildings to optimize their energy demand, will be extended in its application and incentives provided for retooling existing building stock.**

» Management of Municipal Solid Waste

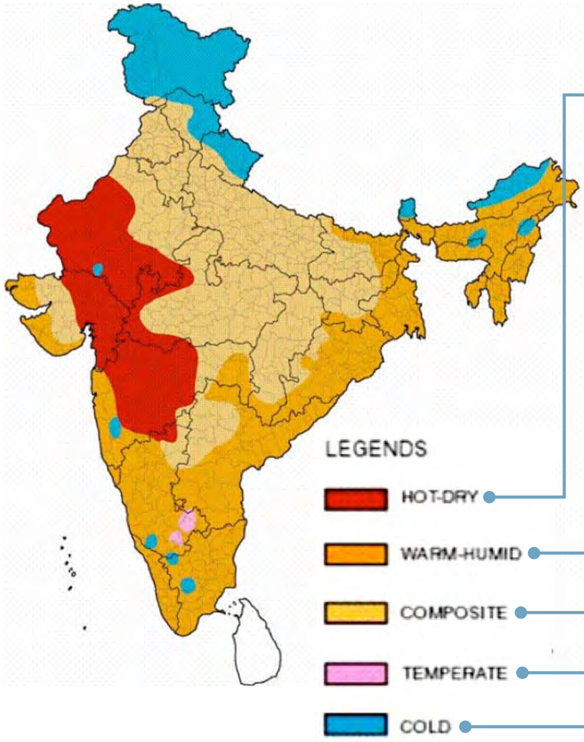
» Promotion of Urban Public Transport

SOURCE: Prime Minister's Council on Climate Change (2008), National Action Plan on Climate Change, Government of India, New Delhi

Development of ECBC

- **Broad Stakeholder participation**
  - Building Industry, Manufacturers, Professionals, Govt. Agencies etc.
- **ECO-II facilitated the development of ECBC**
  - ECBC committee of experts
- **An extensive data collection was carried out for construction types and materials, glass types, insulation materials, lighting and HVAC equipment**
- **Base case simulation models were developed**
- **The stringency analysis was done through detailed energy and life cycle cost analysis**
- **A stringency level for each code component was established**

Climate Zones in India



- **Hot-Dry:** High temperature • Low humidity and rainfall • Intense solar radiation and a generally clear sky • Hot winds during the day and cool winds at night
- **Warm-Humid:** Temperature is moderately high during day and night • Very high humidity and rainfall • Diffused solar radiation if cloud cover is high and intense if sky is clear • Calm to very high winds from prevailing wind directions
- **Composite:** This applies when 6 months or more do not fall within any of the other categories • High temperature in summer and cold in winter • Low humidity in summer and high in monsoons • High direct solar radiation in all seasons except monsoons high diffused radiation • Occasional hazy sky Hot winds in summer, cold winds in winter and strong wind in monsoons
- **Temperate:** Moderate temperature • Moderate humidity and rainfall • Solar radiation same throughout the year and sky is generally clear • High winds during summer depending on topography
- **Cold:** Moderate summer temperatures and very low in winter • Low humidity in cold/ sunny and high humidity in cold/cloudy • Low precipitation in cold/sunny and high in cold/cloudy • High solar radiation in cold/sunny and low in cold/cloudy • Cold winds in winter

SOURCE: Bureau of Indian Standards, National Building Code of India 2005, Part 8 Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation; Bansal, N. K. & G. Minke (1990), Climatic Zones and Rural Housing in India; Krishan, A., N. Y. Baker & S. V. Szokolay (2001), Climate Responsive Architecture: A Design Handbook for Energy Efficient Buildings, Tata McGraw Hill

ECBC and Other Programs

Program	Organization	Compliance Required	Building Type	Building With	Scope	Linkage to ECBC
ECBC	Ministry of Power/ BEE	Voluntary	Commercial	Connected Load > 100kW Contract Demand > 120kVA	Energy Efficiency	NA
LEED-India	CII-Green Business Center	Voluntary	Commercial/ Institutional	-	Sustainable design/green building	Refers to ECBC for energy efficiency credits
GRIHA	MNRE	Voluntary	Residential/ Commercial/ Institutional	-	Sustainable design/green building	Refers to ECBC for energy efficiency credits
Environmental Impact Assessment (EIA)	Ministry of Environment and Forests	Mandatory	Commercial/ Residential	Applicable to Large Projects	Environmental Impact	ECBC and Environmental Clearance requirements are related

Significance of ECBC

» **Regulates building thermal performance & energy use according to climate zone**
- Encourages climatic responsive building design

» **Encourages use of daylighting, shading, natural ventilation, solar energy etc.**
- Energy efficiency strategies appropriate for India

» **Focuses on energy performance of buildings rather than green building design**
- Material properties, water use, building site etc. not regulated
- Green Building Design standards will refer to ECBC for energy performance

ECBC and Energy Savings

» **Average energy use for lighting and HVAC**

- A typical "Class A Office" building consumes 150 kWh/m²/year.

Number of Buildings	Building Type	Floor Area (m²)	Annual Energy Consumption (kWh)	Benchmarking Indices	
OFFICE BUILDINGS				**kWh/m2/year**	**kWh/m2/hour**
145	One shift Buildings	16,716	20,92,364	149	0.068
55	Three shifts Buildings	31,226	88,82,824	349	0.042
88	Public Sector Buildings	15,799	18,38,331	115	0.045
224	Private Sector Buildings	28,335	44,98,942	258	0.064
10	Green Buildings	8,382	15,89,508	141	-
HOSPITALS				**kWh/m²/year**	**kWh/bed/year**
128	Multi-specialty Hospitals	8721	24,53,060	378	13,890
22	Government Hospitals	19,859	13,65,066	88	2,009
HOTELS				**kWh/m²/year**	**kWh/room/year**
89	Luxury Hotels (4 and 5 Star)	19,136	48,65,711	279	24,110
SHOPPING MALLS				**kWh/m2/year**	**kWh/m2/hour**
101	Shopping Malls	10,516	23,40,939	252	0.05642

» Mandatory enforcement of ECBC shall reduce the energy use by **30-40%** to 120-160 kWh/m²/year

» Nationwide Mandatory enforcement of ECBC will yield energy saving of **1.975 billion kWh in the 1st Year itself**

SOURCE: Building Energy Benchmarking study undertaken by the USAID ECO-III Project, New Delhi

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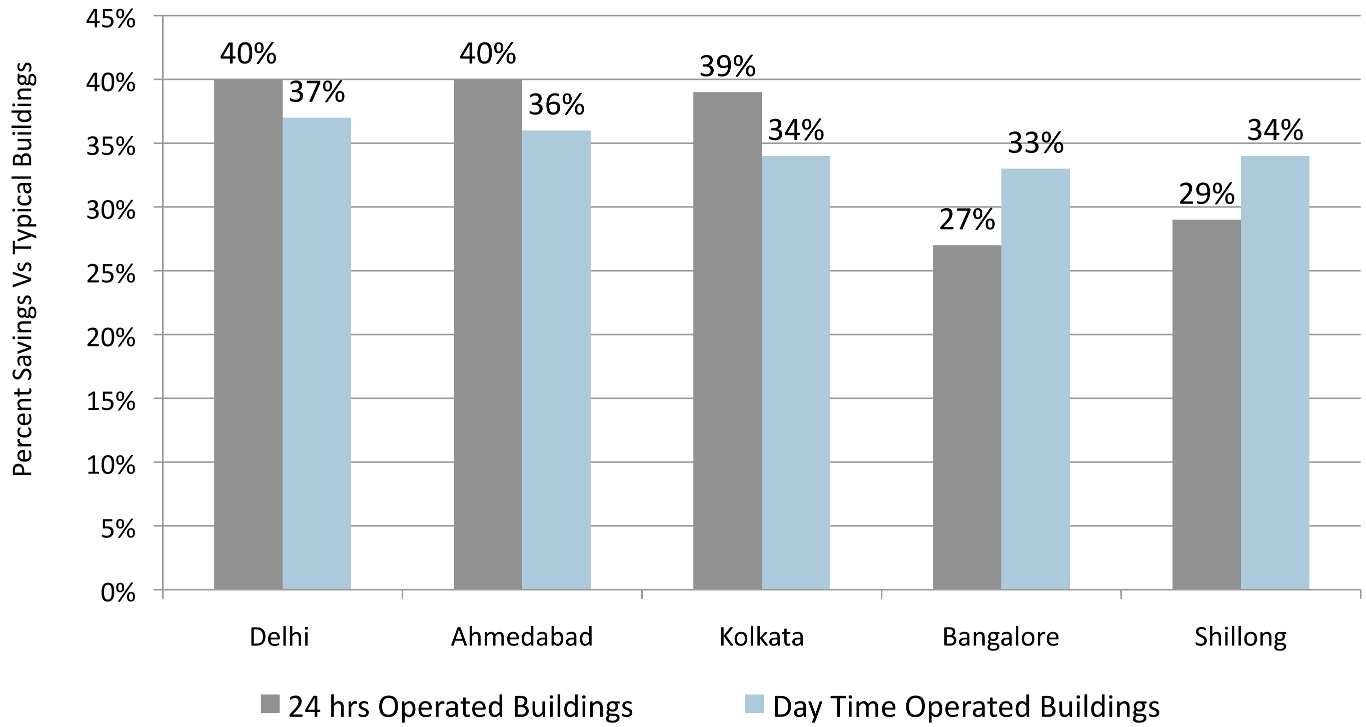
ECBC and Energy Savings



NATIONAL ENERGY SAVINGS = CODE STRINGENCY X LEVEL OF COMPLIANCE X ADOPTION RATE

SOURCE: ECBC Impact Analysis done by IECC under USAID ECO-III Project, New Delhi

Impact of ECBC Compliance

- **Market Development for EE products**
  - Building Insulation
  - Energy Efficient Windows (Glass and Frames)
  - High-Efficiency HVAC Equipment
- **Improved Design Practices**
  - Lighting and Daylighting
  - Natural Ventilation/Free-Cooling Systems
- **Improved Building Performance**
- **Lesser addition of Power Generation Capacity**
- **Lower HVAC Loads, reduced energy consumption and costs**

End of MODULE

- *WORLD Energy Scenario*
- *Energy Scenario in INDIA*
- *About the ECO-III Project*
- *Introduction to ECBC*
- *Significance of ECBC*

Project Guidance

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ECBC Training Workshop

MODULE 2:
ECBC Scope & Administration

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ATTRIBUTION

ECBC Scope & Administration: Outline

- ECBC Scope
- ECBC Compliance Process
- Administration and Enforcement
- ECBC User Guide

ECBC Scope

- **New Buildings with**
  - Connected load in excess of 100kW

    Or
  - Contract demand in excess of 120 kVA
- **Also applies to Additions and Major Renovation**
  - When addition + existing building area > 1000 m^2
  - Renovated portions and systems of a 1000 m^2 or larger building

ECBC Scope

Applicable building systems

- Building Envelope
- Mechanical systems and equipment, including HVAC
- Service hot water and pumping
- Interior and exterior lighting
- Electrical power and motors

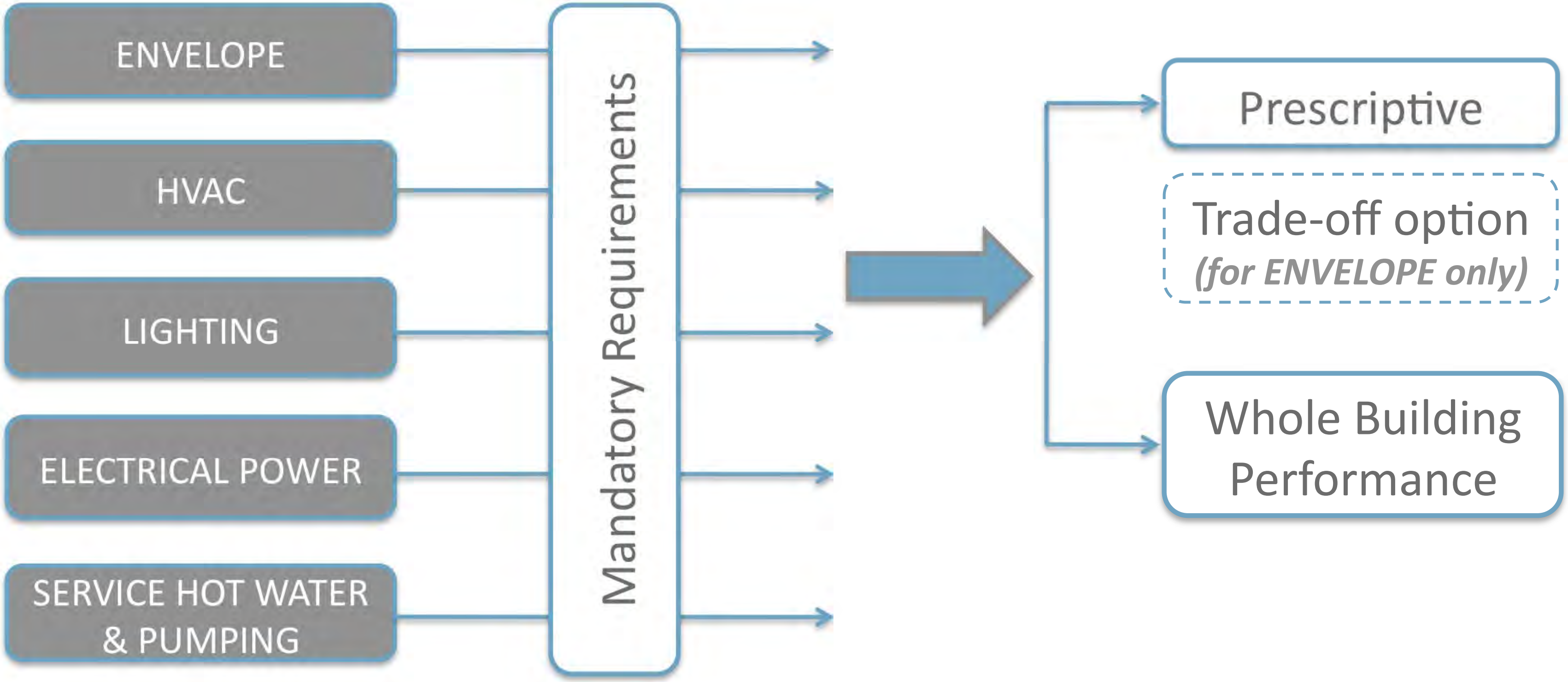
Exceptions

- Buildings that do not use either electricity or fossil fuels
- Equipment and portions of building systems that use energy primarily for manufacturing processes
- Safety, Health and Environmental codes take precedence

ECBC Compliance Process

Applicable BUILDING SYSTEMS

COMPLIANCE APPROACHES



Required for ALL Compliance Approaches

Compliance Approaches

PRESCRIPTIVE

- Each building/system component should have specific performance value
- Requires little energy expertise; provides minimum performance requirements; no flexibility

TRADE-OFF

- Applies to Building Envelope ONLY
- Component performance value can be less BUT Overall performance of the envelope complies with ECBC
- Allows some flexibility through the balance of some high efficiency components with other lower efficiency components

WHOLE BUILDING PERFORMANCE

Allows flexibility in meeting or exceeding energy efficiency requirements by optimizing system interactions

» **Component and Systems Modeling:** Envelope, Lighting, HVAC

» **Physical Processes:** Day lighting, Heat-flow, Airflow

Compliance Approaches

Approaches	Mandatory Provisions of ECBC	Flexibility	Expert Knowledge	Linear Approach	Use of Energy Simulation
PRESCRIPTIVE	Required	Low	Low	Yes	No
TRADE-OFF	Required	Medium	Medium	No	May be
WHOLE BUILDING PERFORMANCE	Required	High	High	No	Yes

Administration and Enforcement

	Programming (1)	Schematic Design	Design Development	Construction Documents (2)	Plans Check (3)	Bidding & Negotiation	Construction Management (4)	Commissioning	Field Inspection (5)	Acceptance
Design Team	X	X	X	X	X	X	X	X	X	X
General Contractor						X	X	X	X	X
Building Department					X				X	
Owner	X	X	X	X	X	X	X	X	X	X

1. Understand requirements of the ECBC and apply to building design
2. Construction documents submitted with the permit application contain ECBC compliance information that can be verified (Compliance Forms and Checklists)
3. Building officials verify through plans that building is ECBC compliant
4. Plans & specifications are followed to ensure ECBC compliance
5. Commissioning & Operations and Maintenance Guidelines provided to building operators

SOURCE: Adapted with suggested improvements from the ECBC User Guide, USAID ECO-III Project, New Delhi

Compliance Submittal

Checklists & compliance forms

- » Details about building envelope, HVAC, Service Hot Water & Pumping, Lighting and Electric Power
- » Prerequisite information for code compliance
- » Provide structure & order for necessary calculations
- » Allows for checking of drawings and specifications for compliance

Envelope Summary — **ENVELOPE Summary**

2005 India Energy Conservation Building Code Compliance Forms — Draft 1, 27 March 2005

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

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

Compliance Option: ☐ Prescriptive ☐ Envelope Trade-Off (Appendix D) ☐ Systems Analysis

○ Hospital, hotel, call center (24 hour) ○ Other building types (daytime)

	Total Vertical Fenestration Area (rough opening)	divided by	Gross Exterior Wall Area	times 100 equals	% Vertical Fenestration
Vertical Fenestration Area Calculation Note: Vertical fenestration area can not exceed 40% of the gross wall area for prescriptive option		▯		X 100 =	

	Total Skylight Area (rough opening)	divided by	Gross Exterior Wall Area	times 100 equals	% Skylight
Skylight Area Calculation Note: Skylight area can not exceed 5% of the gross roof area for prescriptive compliance.		▯		X 100 =	

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

ECBC User Guide

» **Follows the same structure as the Code**

Contents

ECBC User Guide

» Normal text in black
- Forms the core of the ECBC User Guide and provides overall guidance on how best to understand and apply ECBC

» Text shown in blue
- Direct excerpt from ECBC and serves as an anchor for most of the guidance text and examples given in the Guide

» Boxed text showing Tips, Frequently Asked Questions, Examples, etc.
- Provides guidance for better understanding of ECBC concepts and applicability in different situations

3.2 Compliance Approaches

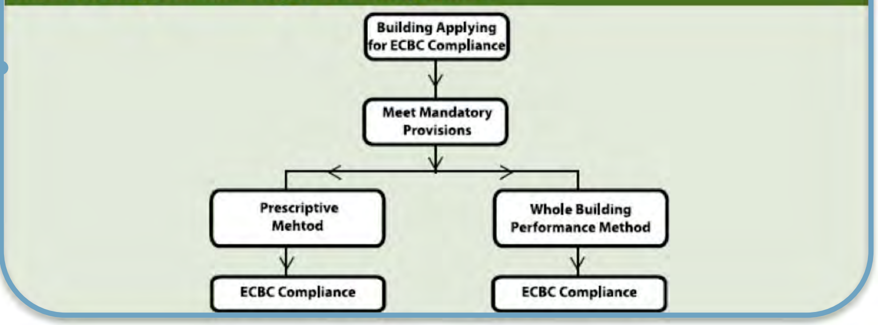
The Code requires that the building shall comply first with all the mandatory provisions discussed in Chapter 4 to 8 (of the Code). But every building project is different: each building has its own site that presents unique opportunities and challenges, each building owner or user has different requirements, and climate and microclimate conditions can vary significantly among projects. Architects and engineers need flexibility in order to design buildings that address these diverse requirements. The Code provides this flexibility in a number of ways. Building components and systems have multiple options to comply with the Code requirements. To use the building envelope section as an example, designers can choose the *Prescriptive Method* that requires roof insulation

Table 4.9: Minimum VLT Requirements (ECBC Table 4.5)

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

x 3-A provides an overview of the ECBC compliance process.

Box 3-A: Steps for meeting ECBC Compliance



ECBC: Referenced Standards

- ANSI/ASHRAE/IESNA Standard 90.1-2004, Energy Standard for Buildings Except Low-Rise Residential Buildings
- ASHRAE Handbook - Fundamentals 2005
- ISO 15099:2003, Thermal performance of windows, doors and shading devices - Detailed calculations
- ASTM E903 - 96, Standard Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres (Withdrawn 2005)
- ASTM E408 - 71(1996) e1, Standard Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques
- ASTM C518 - 10, Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus
- IS 1391: Part 1 (1992), Room Air Conditioners - Specification - Part 1: Unitary Air Conditioners
- IS 1391: Part 2 (1992), Room air conditioners: Part 2 Split air conditioners
- IS 8148 (2003), Packaged Air Conditioners – Specification
- IS 13980 (1995), Acceptance tests on industrial boilers - Code of practice
- IS 13129: Part 1 (1991), Solar heating - Domestic water heating system: Part 1 Performance rating procedure using indoor test methods
- IS 13129: Part 2 (1991), Solar heating - Domestic water heating systems: Part 2 Procedure for system performance characterization and yearly performance predication
- IS 15558 (2005), Mini domestic water heater for use with LPG – Specification
- IS 2082 (1993), Stationary storage type electric water heaters
- IS 2026: Part 2 (1977), Power transformers: Part 2 Temperature-rise
- IS 12615 (2004), Induction Motors - Energy Efficient, Three-phase, Squirrel Cage - Specification

End of MODULE

- *ECBC Scope*
- *ECBC Compliance Process*
- *Administration and Enforcement*
- *ECBC User Guide*

Project Guidance

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ECO III

ENERGY IS LIFE BEE CONSERVE IT

ECBC Training Workshop

MODULE 3:
Building Envelope

ACKNOWLEDGEMENT

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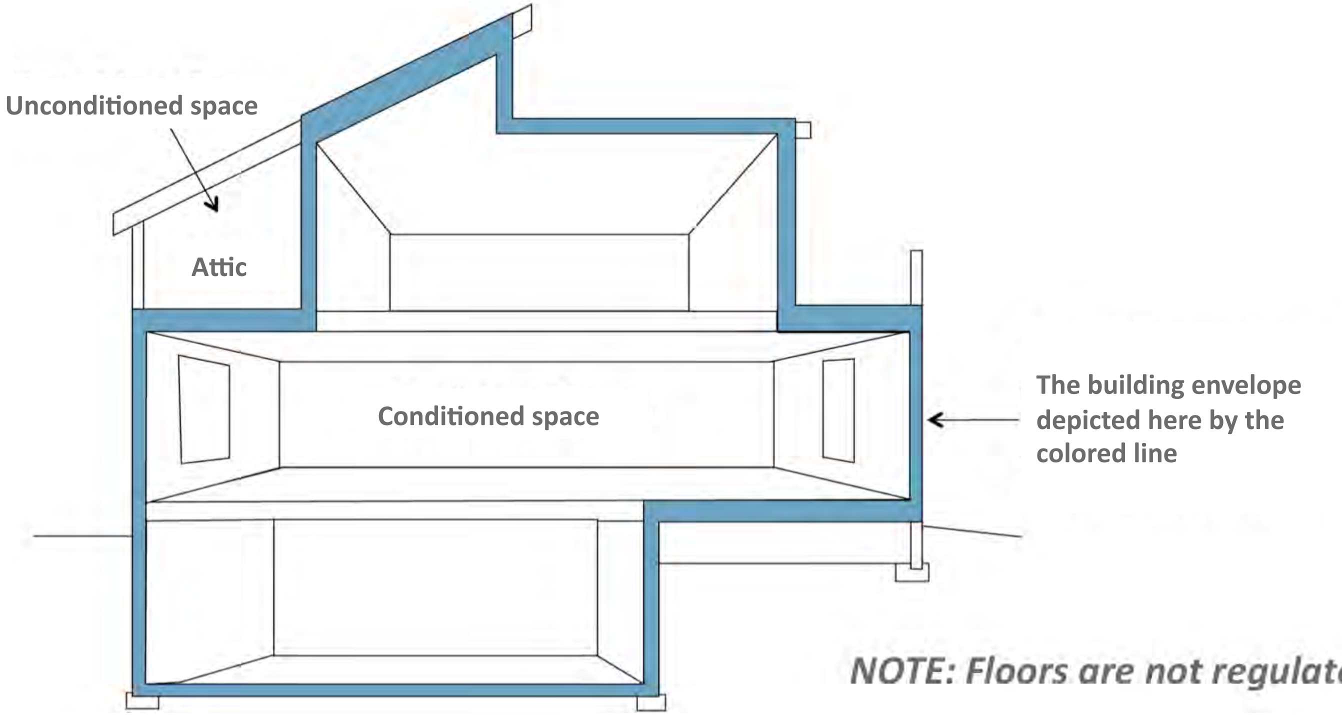
ATTRIBUTION

Building Envelope: Outline

- Building Envelope
- Opaque Construction
  - Heat Transfer
  - ECBC Requirements
  - Exercises
- Cool Roofs
  - Solar Radiation
  - Significance of Cool Roofs
  - ECBC Prescriptive Requirements
  - Selection Guidelines
- Fenestration
  - Fenestration Components
  - HeatTransfer
  - Optimization of Fenestration for Energy Performance
  - ECBC Requirements
- Moisture and Infiltration
  - Air leakage
  - Moisture Penetration
  - Air infiltration V.s Vapor diffusion
  - ECBC Mandatory Requirements
- ECBC Compliance Forms

Building Envelope

- Surface that separates external environment from the interior (occupied) space
- Opaque Construction: Roof, Walls and Floors
- Fenestration : Windows, Doors and Skylights



NOTE: Floors are not regulated through the ECBC

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

Building Envelope Design Considerations

Climate & microclimate

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

Building Orientation & Form

- Orientation of the building, surface-to-volume ratio and exposed surface area

COMPOSITE CLIMATE

MODERATE CLIMATE

HOT-DRY CLIMATE

COLD CLIMATE

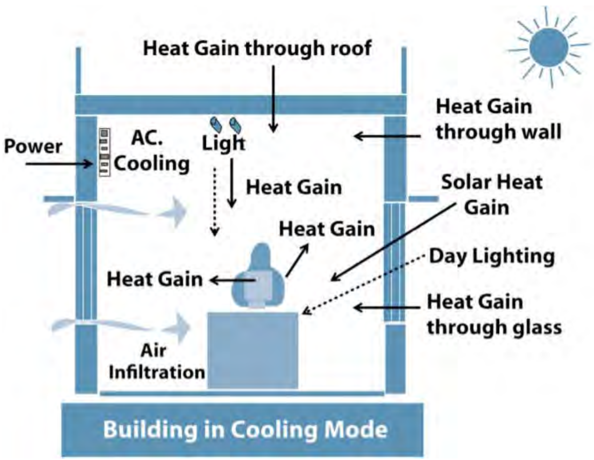
Building Envelope Design Considerations

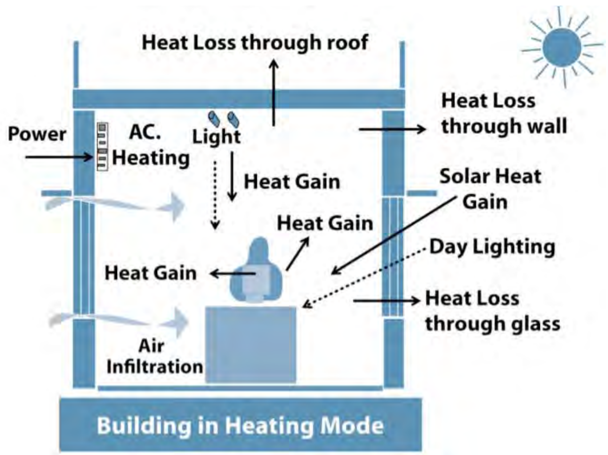
» Building Envelope Component Design

- Area, orientation and tilt of the building envelope components
- Roof form design, choice of shading devices, fenestration size, placement of windows, construction specifications etc.

» Building Material Specification

- Insulating Properties (U-values, SHGC), emissivity & color/texture





NOTE:

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

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

ECBC Building Envelope Requirements

Opaque Construction

Opaque Construction: Outline

» Heat Transfer

- R-value (Insulation)
- U-value

» ECBC Requirements

- Mandatory Requirements
- Prescriptive Requirements

» Exercises

Heat Transfer

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

Heat Transfer

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

R-value

Thermal resistance : R-value

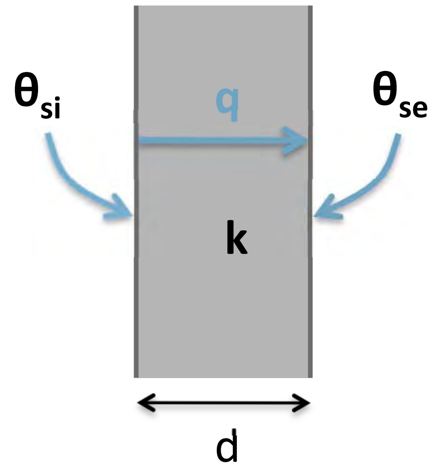
$$R = \frac{\text{Thickness of the material (d)}}{\text{Thermal conductivity of the material (k)}}$$

Thermal resistances of multi-layered components

$$R_T = \frac{d_1}{k_1} + \frac{d_2}{k_2} + \dots + \frac{d_n}{k_n} = \sum_{n}^{1} \frac{d_n}{k_n}$$

» Effectiveness of thermal insulation to retard the heat flow

» Higher R-value indicates higher insulating properties (Units = $m^2 \cdot K/W$)



k : **Conductivity**

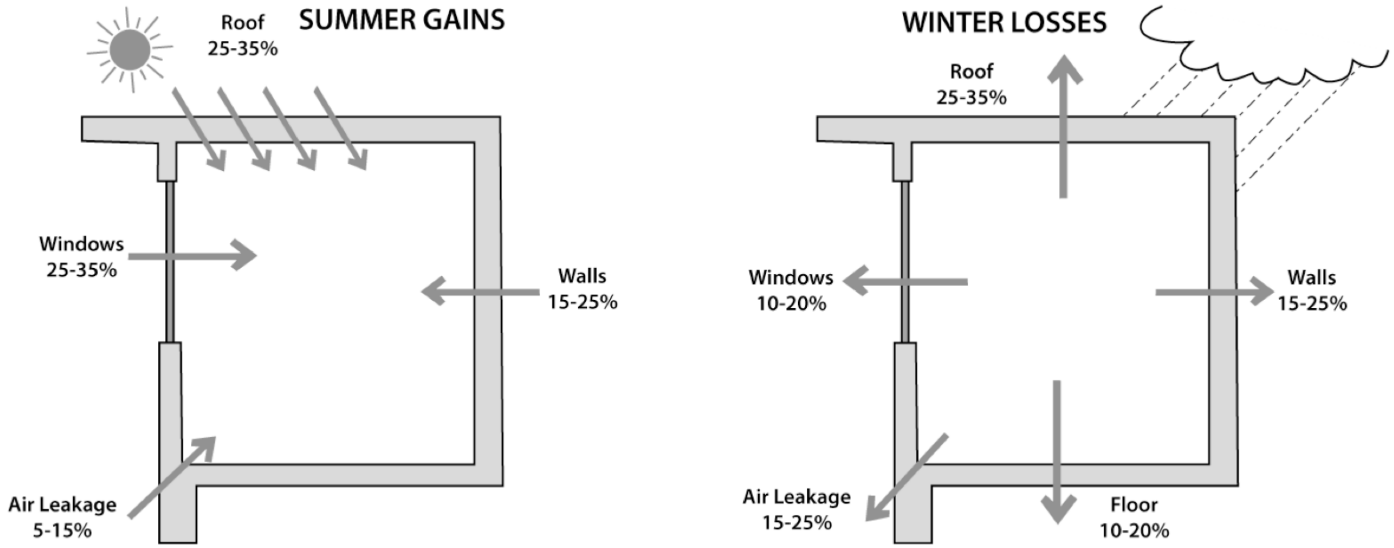
d : **Thickness in m**

θ_{si} : Indoor surface temperature

θ_{se} : Outdoor surface temperature

Building Insulation

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



Common Insulation Types

Type of Material	Density (kg/m^3)	Thermal Conductivity (W/m.K)	Specific Heat Capacity (kJ/kg.K)
Expanded polystyrene	16.0	0.038	1.34
Expanded polystyrene	24.0	0.035	1.34
Expanded polystyrene	34.0	0.035	1.34
Foam glass	127.0	0.056	0.75
Foam glass	160.0	0.055	0.75
Foam concrete	320.0	0.07	0.92
Foam concrete	400.0	0.084	0.92
Foam concrete	704.0	0.149	0.92
Cork slab	164.0	0.043	0.96
Cork slab	192.0	0.044	0.96
Cork slab	304.0	0.055	0.96
Rock wool (unbonded)	92.0	0.047	0.84
Rock wool (unbonded)	150.0	0.043	0.84
Mineral wool (unbonded)	73.5	0.03	0.92
Glass wool (unbonded)	69.0	0.043	0.92
Glass wool (unbonded)	189.0	0.04	0.92
Resin bonded mineral wool	48 .0	0.042	1.00
Resin bonded mineral wool	64.0	0.038	1.00
Resin bonded mineral wool	99.0	0.036	1.00
Resin bonded glass wool	16.0	0.04	1.00

SOURCE: Bureau of Indian Standards (1988), Handbook on Functional Requirements of Buildings (Other than Industrial Buildings) (SP : 41)

Insulation Installation Guidelines

» Proper installation is crucial
- Maintain R-value & thermal performance of insulation
- Provide a continuous barrier between the inside conditioned space and the outside

» Substantial Contact
- Permanent installation of insulation without gaps and voids
- Maintenance of contact with the inside surface of the construction assembly
- Air cavity on the outside surface

» Insulation Above Suspended Ceilings
- Roof insulation should not be located on a suspended ceiling with removable ceiling panels

» Insulation Protection
- Protection against sunlight, moisture, landscaping equipment, wind, and other physical damage
- Use of permanent waterproof membrane or exterior finish

U-value

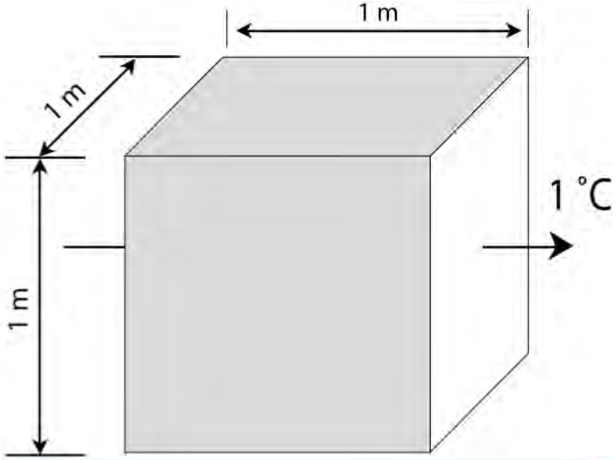
Thermal Conductance (Heat Transfer Coefficient): U-value

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

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

Sample Thermal Conductivity Values

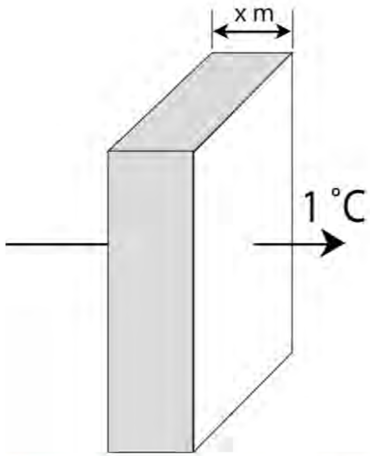
Effect of Thickness on Resistance & Conductance of Glass Fiber Insulation Board



Conductivity $k = 0.036\ \text{W/m·k}$

Resistivity $r = \frac{1}{k} = \frac{1}{0.036} = 27.78\ \text{m·k/W}$

1m Thick Board



Conductance $= \frac{k}{x} = \frac{0.036}{0.25} = 0.144\ \text{W/m}^2\text{·k}$

Resistance $R = \frac{x}{k} = \frac{0.25}{0.036} = 6.95\ \text{m}^2\text{·k/W}$

0.25 m (250 mm) Thick Board

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

ECBC Requirements: Mandatory

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

Description	Density kg/m³	Conductivity[b] (K), W/(m·K)	Conductance (C), W/(m²·K)	Resistance[c] (R) 1/k, K·m²/W	For Thickness Listed (1/C), K·m²/W	Specific Heat kJ/(kg·K)
BUILDING BOARD						
Asbestos cement board..............	1900	0.58	—	1.73	—	1.00
Asbestos-cement board....3.2 mm	1900	—	187.4	—	0.05	—
Asbestos-cement board....6.4 mm	1900	—	93.7	—	0.011	—
Gypsum or plaster board. 9.5 mm	800	—	17.6	—	0.056	1.09

ECBC Requirements: Prescriptive

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

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

ECBC Requirements: Prescriptive (Opaque Walls)

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

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

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

ECBC Requirements: Prescriptive (Roofs)

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

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

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

ECBC Appendix C:
Thermal Properties Of Common Building Materials

Density impacts thermal properties

Resistivity (r)

Description	Density kg/m³	Conductivity[b] (K), W/(m·K)	Conductance (C), W/(m²·K)	Resistance[c] (R) 1/k, K·m²/W	Resistance[c] (R) For Thickness Listed (1/C), K·m²/W	Specific Heat kJ/(kg·K)
		For unit thickness in meters	For thickness listed			
BUILDING BOARD						
Asbestos cement board...............	1900	0.58	—	1.73	—	1.00
Asbestos-cement board....3.2 mm	1900	—	187.4	—	0.05	—
Asbestos-cement board....6.4 mm	1900	—	93.7	—	0.011	—
Gypsum or plaster board. 9.5 mm	800	—	17.6	—	0.056	1.09
Gypsum or plaster board12.7 mm	800	—	12.6	—	0.079	—
Gypsum or plaster board15.9 mm	800	—	10.1	—	0.099	—

Exercise: R-value calculation

» Question

What is the thermal resistance (R-Value) for a 5.0 mm Asbestos cement board?

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

» Answer

0.086 K·m²/W

Calculated From: Thermal resistivity (1.73 * 0.05) OR

Thermal Conductivity (0.05 / 0.058)

Exercise: U-factor Calculation

STEP 1:
Estimate R-values for individual building material layers
ECBC Table 11.4

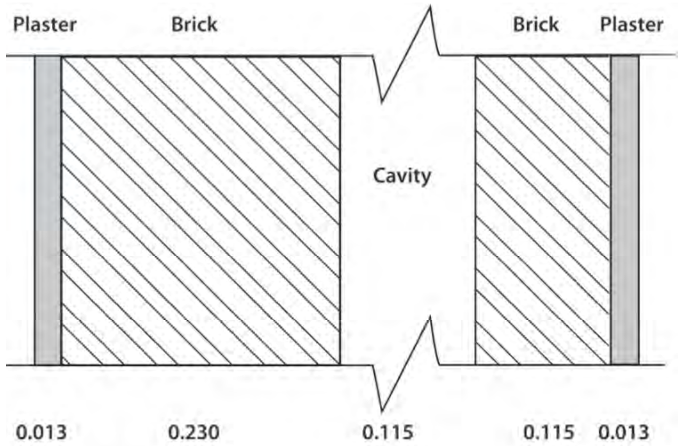


Figure 4.4: Typical Cavity Wall Construction

STEP 2:
Add individual R-values to obtain R-total

R1: Resistance for Layer 1 (13 mm Gypsum Plaster)	= 0.056 Km^2/W (from ECBC Table 11.4)
R2: Resistance of Layer 2 (230 mm brick wall, density=1920kg/m^3)	= d_2/k_2 = 0.230/0.81 =0.284 $K{\cdot}m^2/W$ (from ECBC Table 11.4)
R3: Resistance of Layer 3 (115 mm air gap)	=1.8 Km^2/W (from Table 4.1)
R4: Resistance of Layer 4 (115 mm brick wall, density=1920kg/m^3)	= d_4/k_4 = 0.115/0.81 =0.1426 $K{\cdot}m^2/W$ (from ECBC Table 11.4)
R_t: Minimum R-value for the composite wall	= R1+ R2+ R3 + R4 = 0.056+ 0.2840 + 0.18 + 0.1426 = 0.6626 $K{\cdot}m^2/W$
R_T: R_{si}+ R_t+R_{se}	= 0.1+ 0.6626 +0.04= 0.8026
Maximum U-factor for the composite wall: U_{min}	= $1/R_T$ = 1/0.8026 = 1.246 $W/m^2{\cdot}K$

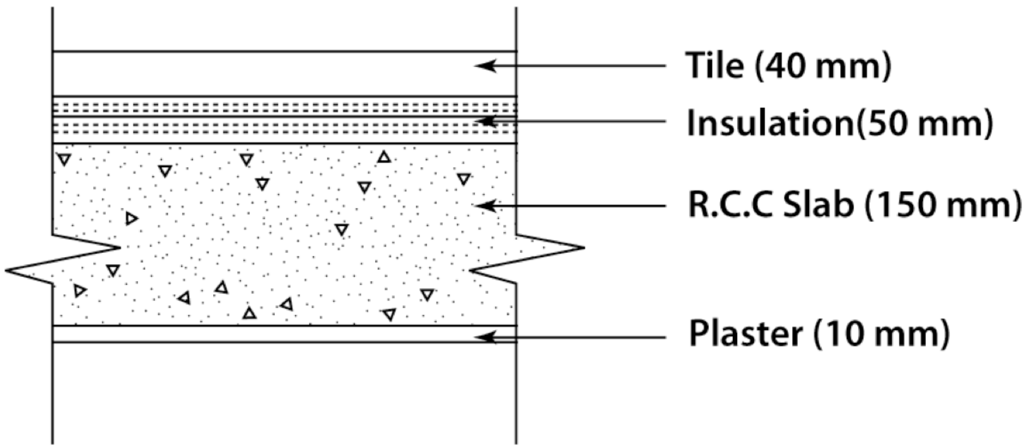
STEP 3:
Obtain U-factor by getting the reciprocal value for R-total

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

Exercise: U-factor Calculation

» **Question**

Calculate the U-factor for a roof assembly made up of a RCC roof slab insulated with 5.00 cm thick expanded polystyrene (density of 24 kg/m^3), and finished with 4.00 cm thick brick tiles (density of 1760 kg/m^3) on the top, and 1.00 cm thick cement plaster on the bottom.



NOTE: Refer to ECBC Appendix C for thermal properties of materials

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

Exercise: U-factor Calculation

From ECBC Appendix C

Layer 1: L_1= 0.04 m of brick tile

k_1= 0.79 W/m·K (Range 0.71-0.85)

$R_1 = L_1/k_1 = 0.04/ 0.79 = 0.051$ K·m²/W

MASONRY MATERIALS						
Masonry Units						
Brick, fired clay	2400	1.21-1.47	—	0.83-0.68	—	—
	2240	1.07-1.30	—	0.94-0.77	—	—

Energy Conservation Building Code 2007 C.9

Appendix C: Default Values for Typical Constructions

Description	Density kg/m³	Conductivity[b] (K), W/(m·K)	Conductance (C), W/(m²·K)	Resistance[c] (R) 1/k, K·m²/W	Resistance[c] (R) For Thickness Listed (1/C), K·m²/W	Specific Heat kJ/(kg·K)
	2080	0.92-1.12	—	1.08-0.89	—	—
	1920	0.81-0.98	—	1.24-1.02	—	0.79
	1760	0.71-0.85	—	1.42-1.18	—	—

Exercise: U-factor Calculation

Layer 2: L_2=0.05 m of insulation
k_2= 0.035 W/(m·K)
$R_2 = L_2/k_2$= 0.05/ 0.035 = 0.7 K·m²/W

Layer 3: L_3=0.15 m RCC slab (Cement/lime, mortar, and stucco)
k_3= 1.40 W/(m·K)
$R_3 = L_3/k_3$= 0.15/ 1.4 = 0.11 K·m²/W

Layer 4: L_4= 0.01 m plaster
k_4= 0.72 W/(m·K)
$R_4 = L_4/k_4$= 0.01/ 0.72 = 0.014 K·m²/W

$R_{roof} = R_{layer1} + R_{layer2} + R_{layer3} + R_{layer4}$
= 0.051 + 0.7 + 0.11 + 0.014 = 0.875 W/m²·K

$U_{roof} = 1/ R_{roof}$ = 1.14 W/m²·K

NOTE: This calculation does not take into consideration thermal resistance of air films for reasons of simplicity. Resistance of air film is critical for accurate U-value calculation. Please refer to ECBC User Guide, Building Envelope section, for sample calculations. SAME STEPS CAN BE USED FOR CALCULATING U-VALUE OF A WALL.

ECBC Building Envelope Requirements

Cool Roofs

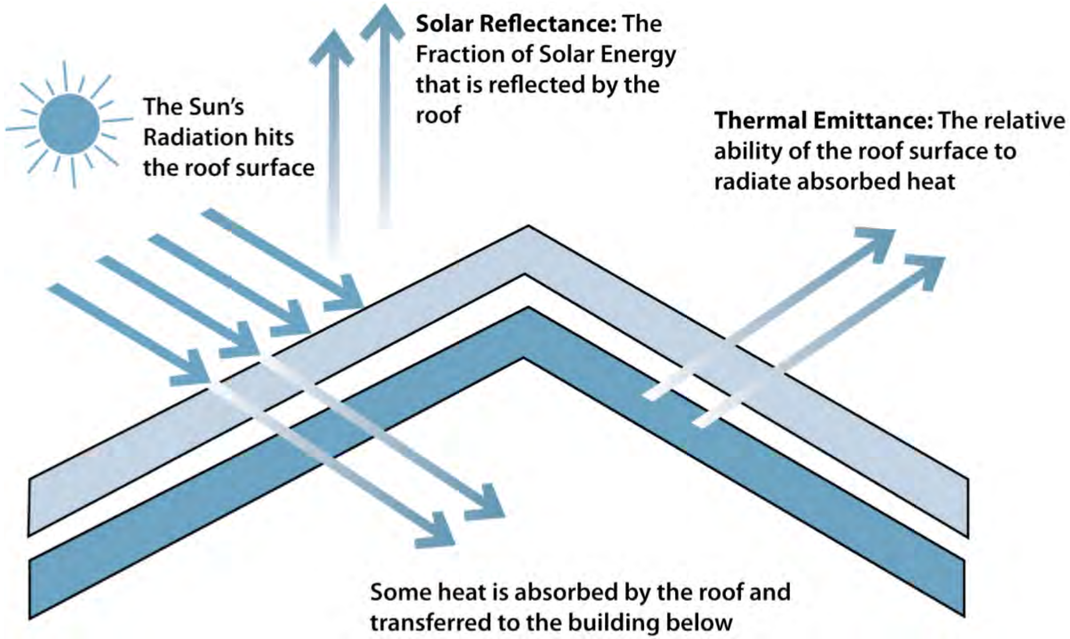
Cool Roofs: Outline

- Solar Radiation
- Significance of Cool Roofs
- ECBC Prescriptive Requirements
- Selection Guidelines

Solar Radiation

Components of Solar Radiation

- **Solar Reflectance** : Energy reflected back to the atmosphere
- **Solar Absorptance**: Energy absorbed by the roof and transferred to the building's interior
- **Solar Emittance**: Absorbed solar energy radiated back to the atmosphere



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

Significance of Cool Roofs

- "Cool roofs" are roofs covered with a reflective coating with a high emissivity property that is very effective in reflecting the sun's energy away from the roof surface.
  - Known to stay 10°C to 16°C cooler than a normal roof under a hot summer sun
  - Reduced Urban Heat Island Effect
- Ideal Exterior Surface in hot climates
  - Reflectance near 1 & Absorptance near zero to minimize solar gain
  - Emissivity near 1 to radiate absorbed heat back to the sky.

SOURCE: (Image) http://en.wikipedia.org/wiki/Santorini

Significance of Cool Roofs

Effect of Solar Reflective Roofs

Case study: Satyam Technology Center, Hyderabad, India

By International Institute of Information Technology (IIIT), Hyderabad, with Lawrence Berkeley National Lab, California

	Gray Roof	Cool Roof
Average daily maximum roof-surface temperature	52°C	32°C

- Measured daily electricity savings = 30 kWh (Building operation: 25 days/month, 12 month = 300 days)
- Estimated annual electricity savings = 9,000 kWh
- Annual savings per square meter = 13 kWh/m^2
- Monitory savings at Rs. 5 /kWh = Rs. 65 /m^2/year
- Incremental cost of cool roof = Rs. 700 /m^2
- Total discounted savings over the expected life of the roof = Rs. 430,000

Source: http://cbs.iiit.ac.in/Cool%20Roof/index.htm

Significance of Cool Roofs

Effect of Solar Reflective Roofs and Pavements in Cooling the Globe

	Δ Solar Reflectivity	CO_2 Offset by 100 m^2	CO_2 Offset Globally
White Roof	0.40	10 tons	
Average Roof	0.25	6.3 tons	24 Gt
Cool Pavement[1]	0.15	4 tons[2]	20 Gt
Total Potential			44 Gt
Value of 44 Gt CO_2 at $15/t ~ $660 Billion			

[1] White Roof will be "diluted" by cool colored roofs of lower reflectivity, and roofs that can not be changed, because they are long-lived tile, or perhaps they are already white.

[2] Compare 10 tons with a family car, which emits ~4 tons/year.

SOURCE: Akbari, Hashem, Surabi Menon & Arthur Rosenfeld (2009), Global Cooling: increasing world-wide urban albedos to offset CO2, Climatic Change 95 (May-June) http://www.energy.ca.gov/2008publications/CEC-999-2008-020/CEC-999-2008-020.PDF

Significance of Cool Roofs

» CO_2 Equivalency of Cool Roofs World-wide (Tropics + Temperate)
- Cool Roofs alone offset 24 Gt CO_2
- Worth > $600 Billion
- To Convert 24 Gt CO_2 one time into a rate
- Assume 20 Year Program, thus
- 1.2 Gt CO_2/year

» Average World Car Emits 4 t CO_2/year, equivalent to 300 Million Cars off the Road for 20 years.

100 m^2 of a white roof, replacing a dark roof, offset the emission of 10 tons of CO_2

SOURCE: Akbari, Hashem, Surabi Menon & Arthur Rosenfeld (2009), Global Cooling: increasing world-wide urban albedos to offset CO2, Climatic Change 95 (May-June) http://www.energy.ca.gov/2008publications/CEC-999-2008-020/CEC-999-2008-020.PDF

ECBC Requirements: Prescriptive

For roofs with slope less than 20 degree

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

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

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

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

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

Selection Guidelines

Low Slope Roofs

- White colored roofing materials
- Coatings
- Applied using rollers, sprays, or brushes
- Single Ply Materials
- Mechanically fastened over the existing roof and sealed at the seams

High Slope Roofs or roofs visible from ground

- Non-White, high reflectance materials (Glare control)
- Concrete Tile
- Clay Tiles

Common Indian Cool Roofing Products

- Lime coats
- White tiles grouted with white cement
- Special paints

ECBC Building Envelope Requirements

Fenestration

Fenestration: Outline

- **Fenestration Components**
- **Heat/Light Transfer**
  - Solar Heat Gain Coefficient (SHGC)
  - Shading Coefficient (SC) and SHGC
  - Visual Light Transmittance (VLT)
- **Optimization of Fenestration for Energy Performance**
- **ECBC Requirements**
  - ECBC Mandatory Requirements
  - ECBC Prescriptive Requirements

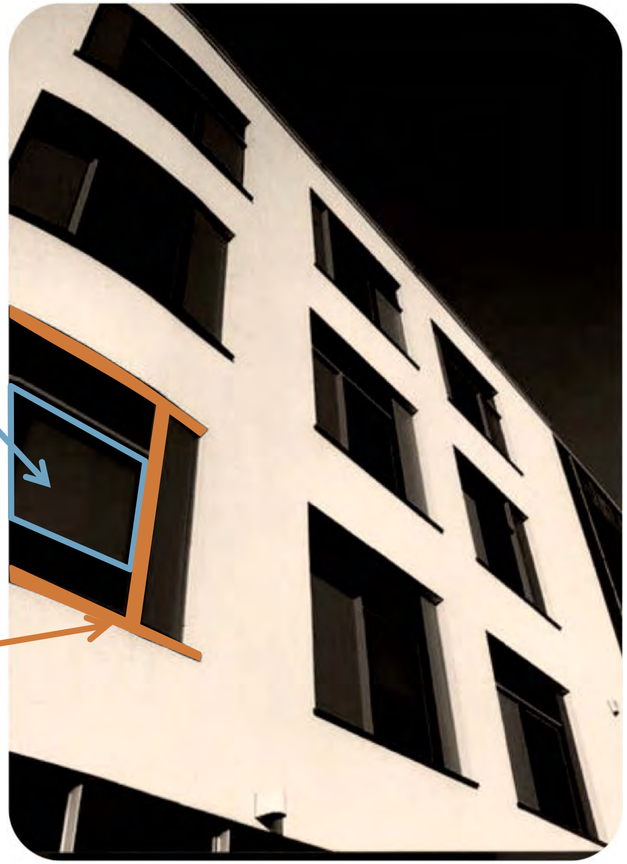
Fenestration Components

Glazing Area

80-90% of the total area and therefore the most important part to address for achieving energy efficiency

Frame

Important to optimize the overall energy efficiency of the window

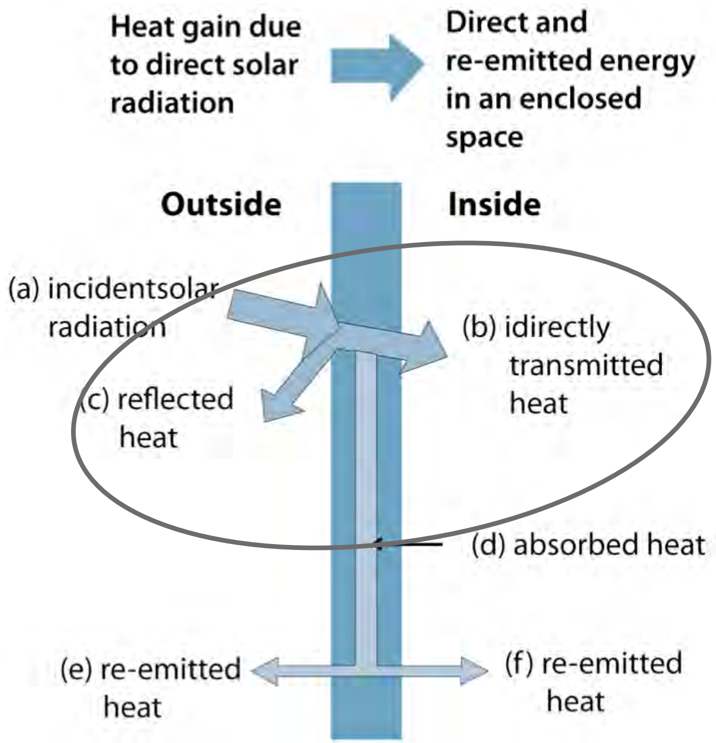


Heat Transfer

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

Solar Heat Gain Coefficient (SHGC)

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



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

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

Shading Coefficient (SC) & SHGC

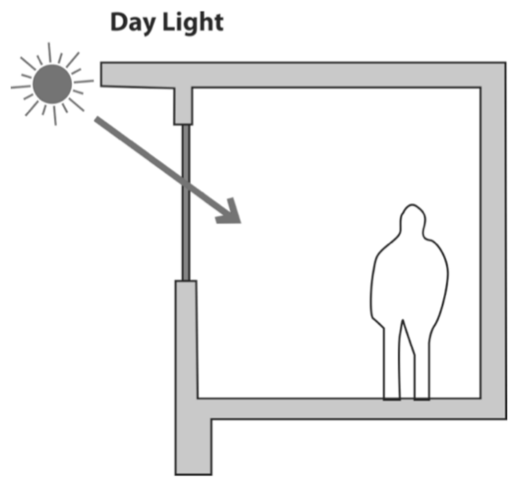
- The solar heat gain coefficient (SHGC) has replaced the shading coefficient (SC) as the standard indicator of a window's shading ability.

- Relationship between SC and SHGC
  - SHGC is expressed as a number between 0 and 0.87
  - SC as a number between 0 and 1
  - $SHGC = SC \times 0.87$

- SHGC may be expressed in terms of the glass alone or may refer to the entire window assembly
  - SC is typically indicated for the glass alone, and does not take into consideration the effects of the frame

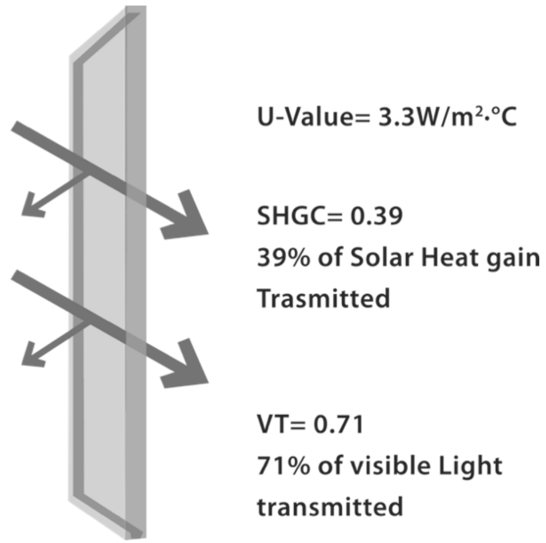
Visual Light Transmittance (VLT)

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



Optimization of Fenestration for Energy Performance

- Balance between window size and glazing selection
  - Use insulating glazing materials for larger windows. Dual pane or higher insulating glass instead of single pane glazing
  - Larger window area requires lower visible light transmittance; smaller windows requires high visible light transmittance
- Appropriate design of shading devices
  - to reduce SHGC ; vary according to orientation, climate (radiation)
- Vary glazing selection by facade, if possible
  - A lower SHGC & U-value on the south, east, and especially west windows reduces the cooling load.
- For optimum energy performance balance, Wall window ratio(WWR), SHGC (glazing and shading), U-Value and VLT need to be balanced



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

ECBC Requirements: Overview

ECBC regulates heat gain through fenestration through

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

ECBC Requirements: Mandatory

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

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

		Clear Glass			Tinted Glass		
Frame Type	**Glazing Type**	**U-Factor (W/m²-°C)**	**SHGC**	**VLT**	**U-Factor (W/m²-°C)**	**SHGC**	**VLT**
All frame types	Single Glazing	7.1	0.82	0.76	7.1	0.70	0.58
Wood, vinyl, or fiberglass frame	Double Glazing	3.3	0.59	0.64	3.4	0.42	0.39
Metal and other frame type	Double Glazing	5.1	0.68	0.66	5.1	0.50	0.40

ECBC Requirements: Prescriptive (Vertical Fenestration)

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

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

		WWR≤40%	40% <WWR≤60%
Climate	**Maximum U-factor**	**Maximum SHGC**	**Maximum SHGC**
Composite	3.30	0.25	0.20
Hot and Dry	3.30	0.25	0.20
Warm and Humid	3.30	0.25	0.20
Moderate	6.90	0.40	0.30
Cold	3.30	0.51	0.51
See Appendix C §11.2.1 for Defaults values of Unrated Fenestration			

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

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

ECBC Requirements: Prescriptive (Vertical Fenestration)

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

Table 4.5: Minimum VLT Requirements

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

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

Effective Aperture

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

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

ECBC Requirements: Prescriptive (Vertical Fenestration)

ECBC Exception To Vertical Fenestration Requirements

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

ECBC Exception To SHGC Requirements

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

M-factor (ECBC Table 4.4)

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

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

Projection Factors (PF) need to be calculated

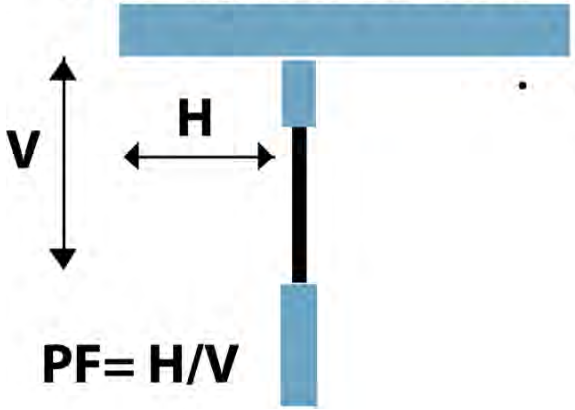
Project Location	Orientation	Overhang "M" Factors for 4 Projection Factors				Vertical Fin "M" Factors for 4 Projection Factors				Overhang+Fin "M" Factors for 4 Projection Factors			
		0.25-0.49	0.50-0.74	0.75 - 0.99	1.00 +	0.25-0.49	0.50-0.74	0.75-0.99	1.00 +	0.25-0.49	0.50-0.74	0.75 - 0.99	1.00 +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

Projection Factor (PF) Calculation

PF is needed to determine M-factor

PF = H (Horizontal) / V (vertical)

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

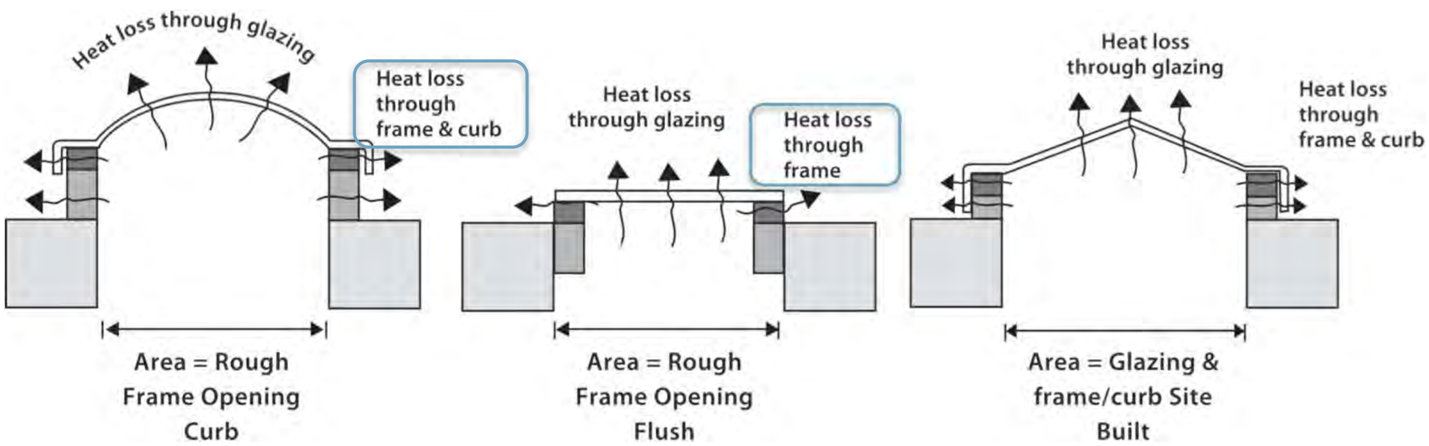


- **Solar heat gain Coffecient**
  - **Requirements dependent on:**
    - **Overhang projection factor**
    - **M- Factor from Table 4.3.3-2**
    - **Orientation**
    - **And Climate Zone**
  - **Without Overhang: SHGC range 0.25-0.51 based on climate zone.**

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

ECBC Requirements: Prescriptive (Skylights)

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



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

ECBC Requirements: Prescriptive (Skylights)

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

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

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

ECBC Building Envelope Requirements

Moisture and Infiltration

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Moisture and Infiltration: Outline

- Air Leakage
- Moisture Penetration
- Air infiltration Vs. Vapor diffusion
- ECBC Requirements

Air Leakage

Amount of air leakage through a building depends on:

- » Air Leakage through gaps in the building envelope
  - Between different building materials, fenestrations, and openings for piping, wiring ducts etc.
- » Air leakage due to pressure difference between a building's interior and exterior
  - Caused by wind, indoor and outdoor temperature differences, ventilation fans, exhaust fans etc.

NOTE: ECBC regulates air leakage through the building envelope only

Air Leakage

- Passage of air through the building envelope
  - Infiltration: Leakage to the interior
  - Ex-filtration: Leakage to the exterior
- Measured as the volumetric flow rate of outside air into a building - Cubic Feet per Minute (CFM) or Liters per second (LPS)
- Air Exchange Rate = Air Changes per hour (ACH= CFM* 60/Volume)
- Common places of air leakage
  - Windows and Doors
  - Openings of roofs, walls, and floors
  - Ducts or plenums
  - Other joints and seams

Air Leakage

Consequences

- Infiltrating air may contain pollutants, allergens, bacteria etc., as it is untreated
- Accompanying changes in air pressure may disrupt delicate pressure relationships between HVAC zones, esp. in critical facilities such as hospitals and labs, leading to IAQ problems
- Condensation of moisture from ex-filtrating air in cold climates and from infiltrating air in hot-humid climates may cause health problems and deterioration of building components
- Unnecessary energy consumption due to added heating and cooling loads and additional humidification/dehumidification needed

SOURCE: Whole Building Design Guide, http://www.wbdg.org/resources/airbarriers.php#

Air Barrier System

- Combination of interconnected materials, flexible sealed joints and components of the building envelope
  - Air-tightness of the building enclosure
  - Separation between conditioned and unconditioned spaces
- Features of an Air barrier system
  - Continuity
  - Structural support
  - **Air permeability**
  - Durability

SOURCE: Whole Building Design Guide, http://www.wbdg.org/resources/airbarriers.php#

Air Barrier System

Location

» Can be located anywhere in the envelope assembly (unlike the vapor retarder)

- If placed on the predominantly warm, humid side (high vapor pressure side) , can work as an ‘air and vapor barrier’
- If placed on the predominantly cool, drier side (low vapor pressure side) of the wall, it should be vapor permeable

SOURCE: Whole Building Design Guide, http://www.wbdg.org/resources/airbarriers.php#

Air Sealing Advantages

- Improved thermal integrity of envelope & improved thermal comfort
  - Improved performance of insulation
  - Minimized temperature differences between rooms
  - Reduction in unconditioned air, drafts, noise, and moisture
- Reduction of unwanted condensation
  - Reduction of insulation R-value, degradation of building materials
- Improved indoor air quality
  - Reduced pollution, dust, mold and moisture
- Reduced energy loss and heating/cooling costs
  - Infiltration loads can add upto 20-40% heating/cooling loads

Moisture Penetration

» Causes
- Rainwater intrusion
- Infiltration of outside moisture-laden air (a primary problem in hot, humid climates)
- Internally generated moisture (from occupant activities and routine housekeeping)
- Vapor diffusion through the building envelope

» To avoid moisture related problems, building envelope should do the following:
- Adequately retard moisture or air movement into the building
- Allow accumulated moisture to either drain to the exterior or evaporate

SOURCE: Whole Building Design Guide, http://www.wbdg.org/resources/moisturemanagement.php#

Vapor retarder

» May not be required in all situations; envelope (without vapor retarder) may perform as an adequate barrier to vapor diffusion

» Under many conditions using an air barrier is more important than using a vapor retarder (as moisture contributed by air leakage is much more than through vapor diffusion)

» Properties of Vapor retarders:

- Permeance (measure of resistance to vapor flow)
- **Location**
- Use of multiple retarders

SOURCE: Whole Building Design Guide, http://www.wbdg.org/resources/moisturemanagement.php#

Air infiltration Vs. Vapor diffusion

- In **hot, humid climates**, air barrier or vapor retarder must have proper air resistance or moisture permeability and **must be installed at the correct location** within the walls.
- The point where cool surfaces meet warm, moist air is where condensation and excess moisture can occur. If moisture-laden outside air is retarded before it meets the first cool surface inside the building envelope then few problems will result. If this moisture is allowed to further enter a wall system, it will condense.
- **Thus, the building envelope plays a vital role in minimizing uncontrolled moisture and air movement into a building and in preventing moisture entrapment within the wall system.**
- Confusion still exists related to the integrity requirements of air, weather barriers and vapor retarders; the way they can be incorporated into one membrane; the location of these features within the building envelope; the effects of using multiple vapor retarders; and even the need for air barriers and vapor retarders in every facility.
- **Different climates present different problems, and buildings should be designed and operated accordingly.**

SOURCE: Whole Building Design Guide, http://www.wbdg.org/resources/moisturemanagement.php#

Air infiltration Vs. Vapor diffusion

- Envelope must be designed to prevent the entry of liquid water into the envelope assembly
- Building envelope components should be designed for air tightness – provision of air barrier (on both the inside and outside of the insulated portion of the wall)
- Building envelope assemblies will tend to dry out if water vapor transmission toward the cool dry side of the envelope is not impeded with a vapor retarder; water vapor will migrate from the assembly towards that environment.
    - In cold climates the envelope will dry toward the outside.
    - In hot humid climates the envelope will dry to the air conditioned interior.
    - In mixed climates the envelope will dry to the outside during the heating season and to the inside during the cooling season.
- **The dynamics of water vapor movement through envelope assemblies is complex, especially in parts of the country that have both a heating and cooling season.**

SOURCE: Whole Building Design Guide, http://www.wbdg.org/resources/env_iaq.php

ECBC Requirements: Mandatory

» Air Leakage through doors and fenestration

- for glazed swinging entrance doors and revolving doors shall not exceed 5.0 $l/s\text{-}m^2$.
- Other fenestration and doors shall not exceed 2.0 $l/s\text{-}m^2$.

» Building Envelope Sealing

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

- Joints around fenestration and door frames
- Openings between walls and foundations and between walls and roof and wall panels
- Openings at penetrations of utility services through, roofs, walls, and floors
- Site-built fenestration and doors
- Building assemblies used as ducts or plenums
- All other openings in the building envelope

ECBC Building Envelope Requirements: Overview

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

ECBC Compliance Forms

15.1 Envelope Summary

Envelope Summary

2007 Energy Conservation Building Code Compliance Forms

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

Project Description	☐ New	☐ Addition	☐ Alteration	☐ Change of Use
Compliance Option	☐ Prescriptive	☐ Envelope Trade-Off (Appendix D)	☐ Whole Building Performance	

	○ Hospital, hotel, call center (24 hour)		○ Other building types (daytime)		
Vertical Fenestration Area Calculation Note: Vertical fenestration area can not exceed 60% of the gross wall area for prescriptive compliance	Total Vertical Fenestration Area (rough opening)	divided by	Gross Exterior Wall Area	times 100 equals	% Vertical Fenestration
		÷		X 100 =	
Skylight Area Calculation Note: Skylight area can not exceed 5% of the gross roof area for prescriptive compliance.	Total Skylight Area (rough opening)	divided by	Gross Exterior Wall Area	times 100 equals	% Skylight
		÷		X 100 =	

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

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

Building Permit Plans Checklist **ENVELOPE Checklist**

2007 Energy Conservation Building Code Compliance Forms

Project Address | Date

The following information is necessary to check a building permit application for compliance with the building envelope requirements in the Energy Conservation Building Code 2007.

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

End of MODULE

- *Building Envelope*
- *Opaque Construction*
- *Cool Roofs*
- *Fenestration*
- *Moisture and Infiltration*
- *ECBC Compliance Forms*

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ECBC Training Workshop

MODULE 4:
Heating Ventilation and Air Conditioning

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ATTRIBUTION

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HVAC: Outline

- Introduction
- Whole Building Design Approach
- Non-refrigerative cooling
- Refrigerative cooling
- Building Commissioning & System Balancing
- ECBC Requirements
  - Mandatory
  - Prescriptive
- ECBC Compliance Forms

Introduction

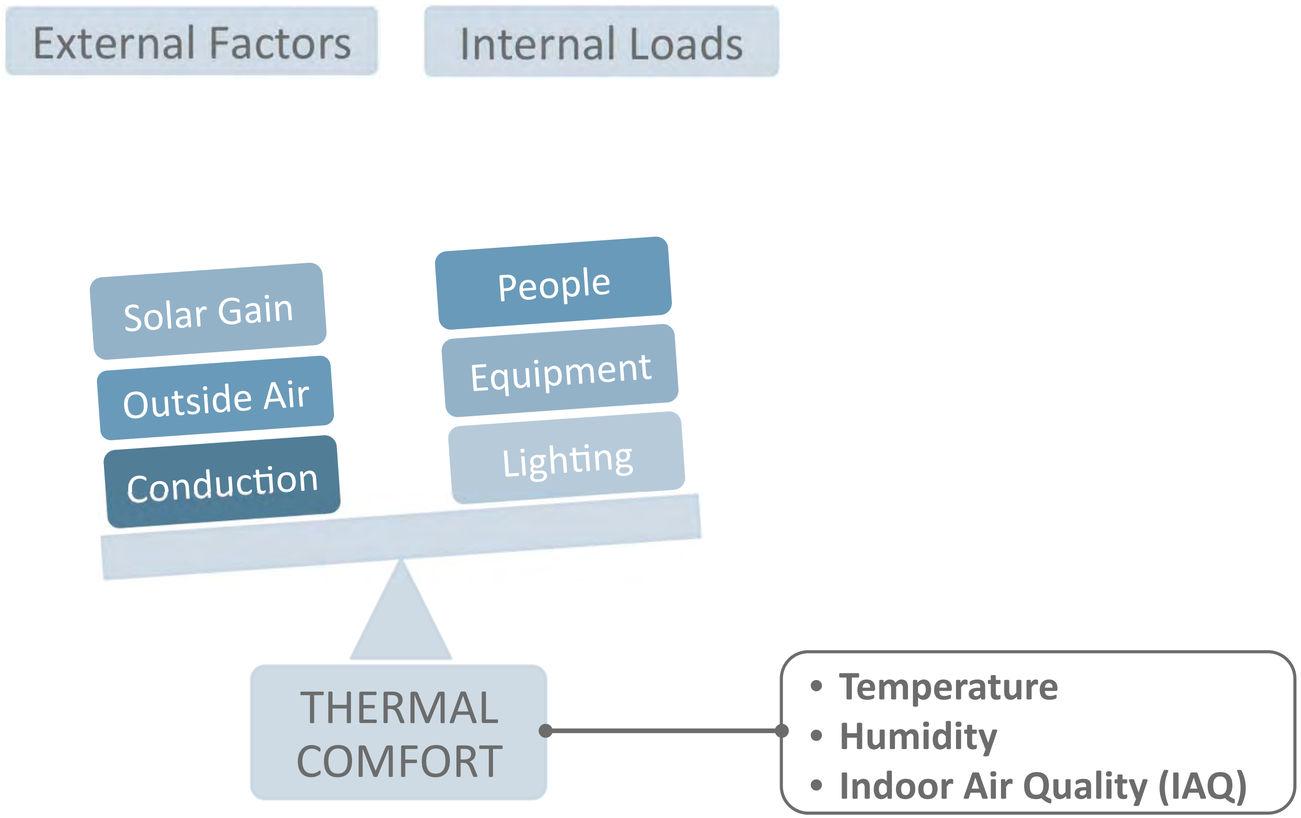
H V AC

Heating

Ventilating
- Natural Ventilation
- Mechanical Ventilation

Air Conditioning
- Cooling
- Dehumidification
- Humidification

Introduction



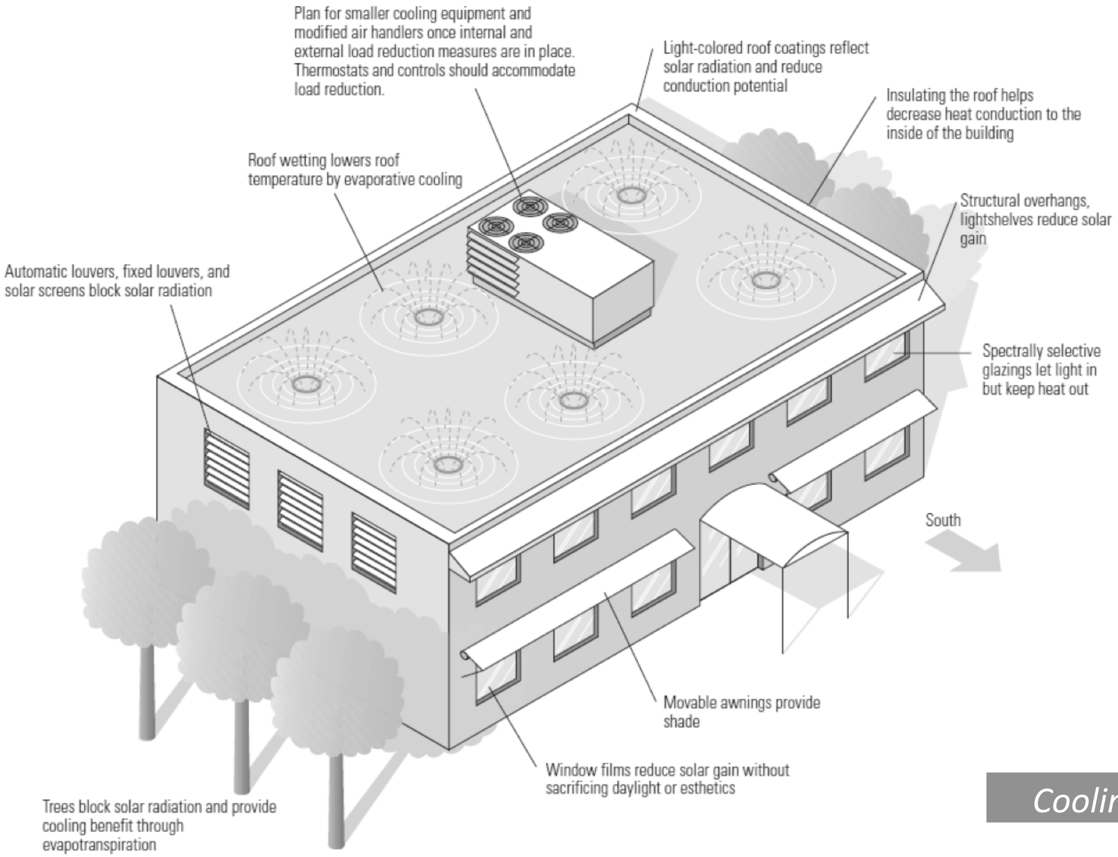
Whole Building Design Approach

1. **Reduce cooling loads by controlling unwanted heat gains**
2. **Expand the comfort envelope** (reduced latent heat load, air movement – ceiling fans, less insulated furniture, more casual dress codes)
3. **Optimize the delivery systems** (reducing velocity, pressure and friction in ducts and piping)
4. **Apply non-refrigerative cooling techniques**
5. **Serve the remaining load with high-efficiency refrigerative cooling**
6. **Improve controls** (sensors, signal delivery, user interface, simulators, etc.)

SOURCE: E Source Technology Atlas Series, Volume II Cooling (1997)

Whole Building Design Approach

1. Reduce cooling loads by controlling unwanted heat gains

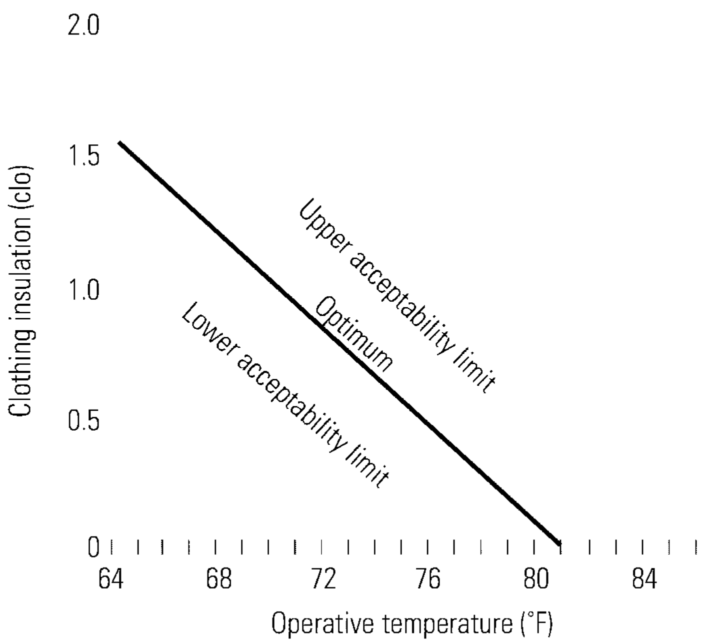


Cooling load reduction measures

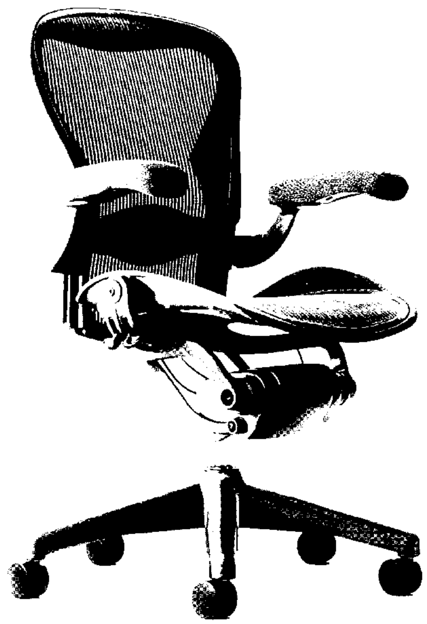
SOURCE: E Source Technology Atlas Series, Volume II Cooling (1997)

Whole Building Design Approach

2. Expand the comfort envelope (reduced latent heat load, air movement – ceiling fans, less insulated furniture, more casual dress codes)



Sensitivity of ASHRAE comfort conditions to clothing



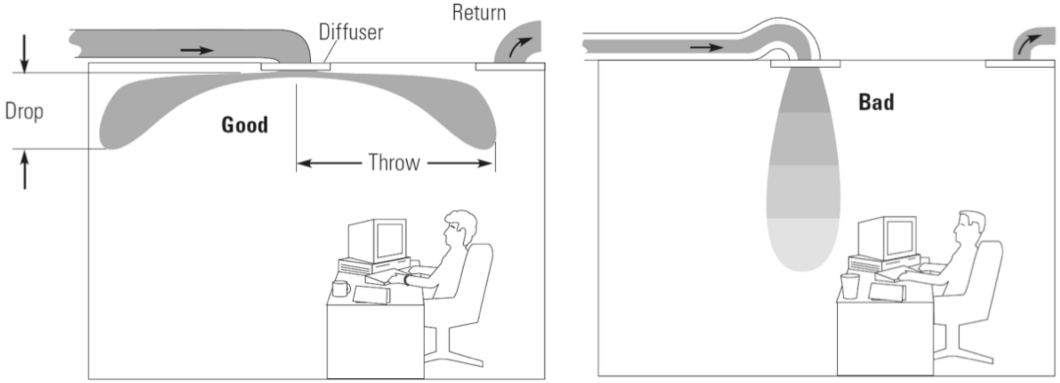
The Herman Miller Aeron Chair

The open mesh fabric in this chair keeps skin temperatures cooler than typical foam and fabric covered chairs

SOURCE: E Source Technology Atlas Series, Volume II Cooling (1997)

Whole Building Design Approach

3. Optimize the delivery systems (reducing velocity, pressure and friction in ducts and piping)



Diffuser operation and terminology

A properly operating diffuser spreads the supply air out along the ceiling nearly as far as the wall (or halfway to neighboring diffusers) before the air begins to drop into the space. At reduced flows, diffusers may "dump" their air in a narrow column, which creates poor air distribution and may chill occupants directly below the diffuser.

Round and rectangular ducts

Round ducts are more efficient, lighter, and quieter than rectangular ducts, which require at least 27 percent more metal per unit of air-handling capacity.

SOURCE: E Source Technology Atlas Series, Volume II Cooling (1997)

Whole Building Design Approach

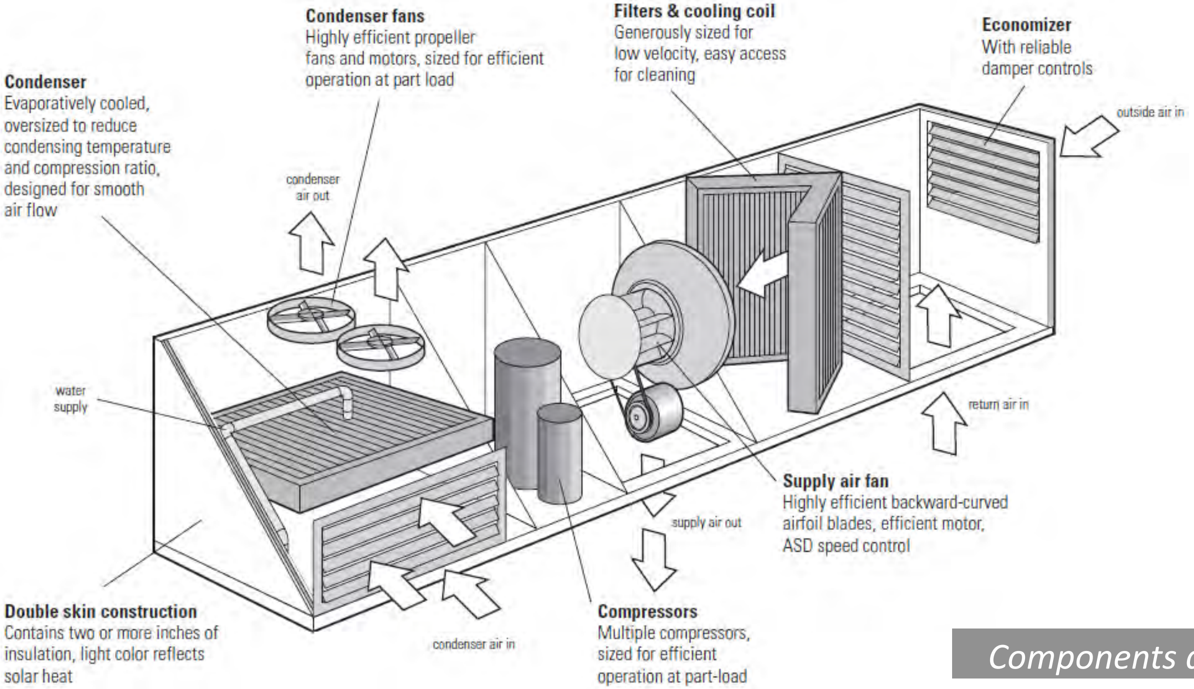
4. Apply non-refrigerative cooling techniques

- Ground-coupled cooling
- Night-sky radiation cooling
- Cooling with outdoor air
- Evaporative cooling
- Dessicant dehumidification and cooling
- Heat pipe cooling cycle enhancements
- Hydronic cooling

SOURCE: E Source Technology Atlas Series, Volume II Cooling (1997)

Whole Building Design Approach

5. Serve the remaining load with high-efficiency refrigerative cooling



Components and features of efficient design

6. Improve controls (sensors, signal delivery, user interface, simulators, etc.)

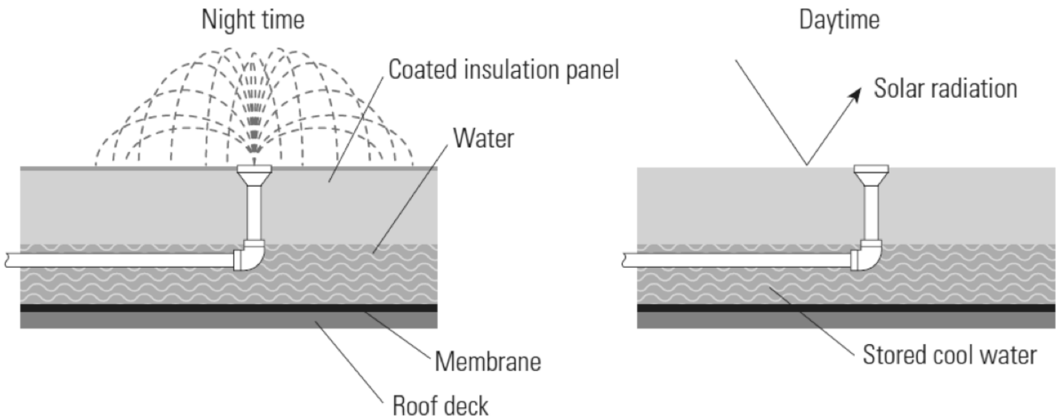
SOURCE: E Source Technology Atlas Series, Volume II Cooling (1997)

Non-refrigerative Cooling

1. Ground-coupled cooling

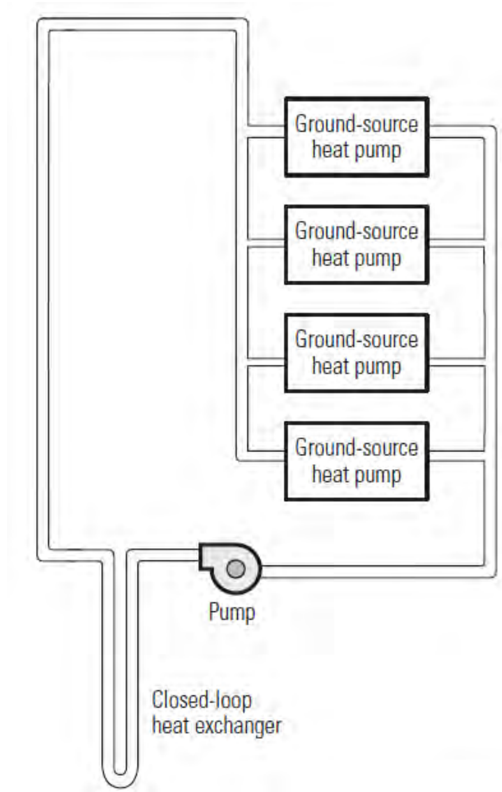
- Ground-source closed-loop heat pump system
- Ground-coupled water-loop heat pump systems

2. Night-sky radiation cooling



WhiteCap schematic

The original WhiteCap is limited to flat roofs. It sprays water at night over insulating panels, where it is cooled by radiation and evaporation and drains back under the panels, where it is stored for daytime cooling.



Ground-source closed-loop heat pump system

Ground source closed-loop heat pump systems use a pump and ground-coupled heat exchanger to provide a heat source and heat sink for multiple ground-source heat pumps within the building.

SOURCE: E Source Technology Atlas Series, Volume II Cooling (1997)

Non-refrigerative Cooling

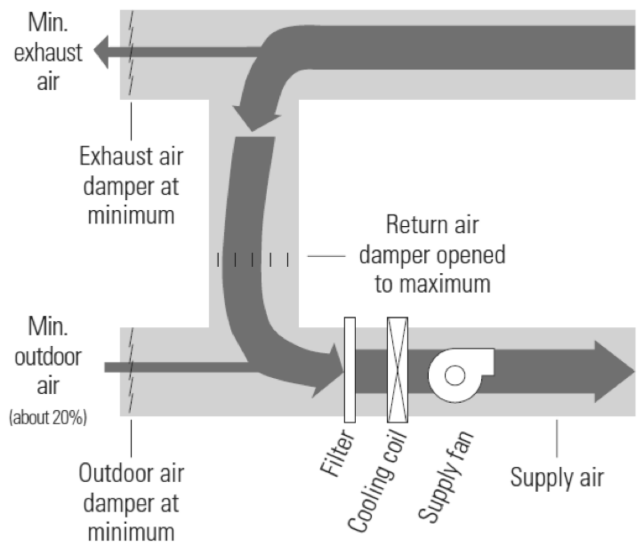
3. Cooling with outdoor air

- Natural ventilation
- Air-side economizer
- Night ventilation cooling

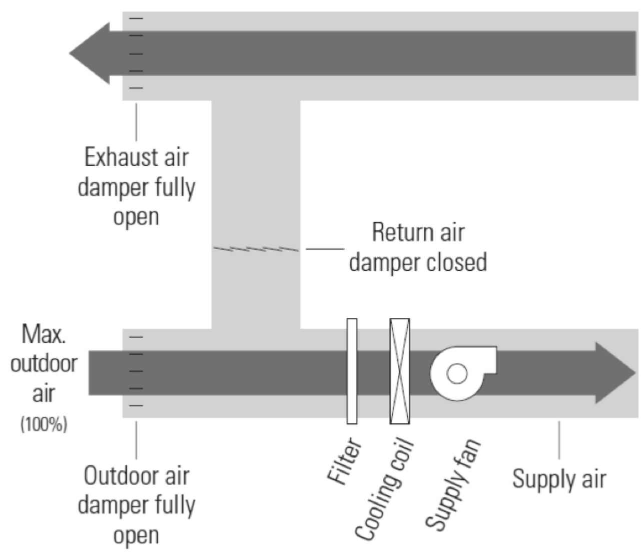
Damper positions with an air-side economizer

Damper positions can be adjusted to provide ventilation that ranges from about 20 percent to 100 percent outside air.

Damper positions when economizer controls call for minimum outdoor air



Damper positions when economizer controls call for 100% outdoor air

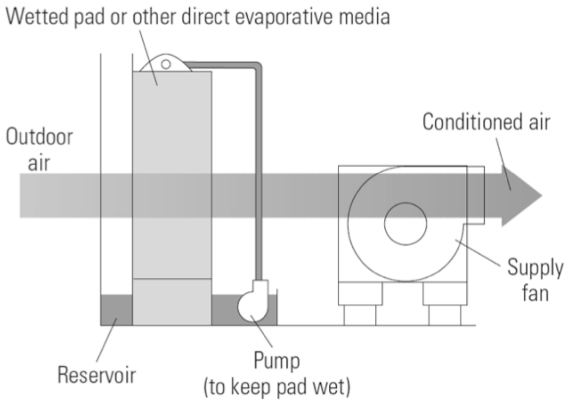


SOURCE: E Source Technology Atlas Series, Volume II Cooling (1997)

Non-refrigerative Cooling

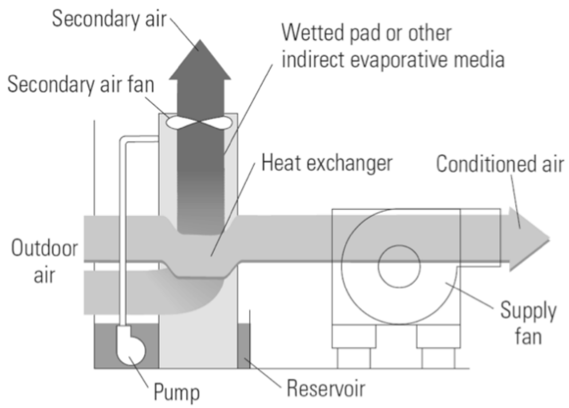
4. Evaporative cooling

- Direct
- Indirect – Water-side economizer
- Hybrid



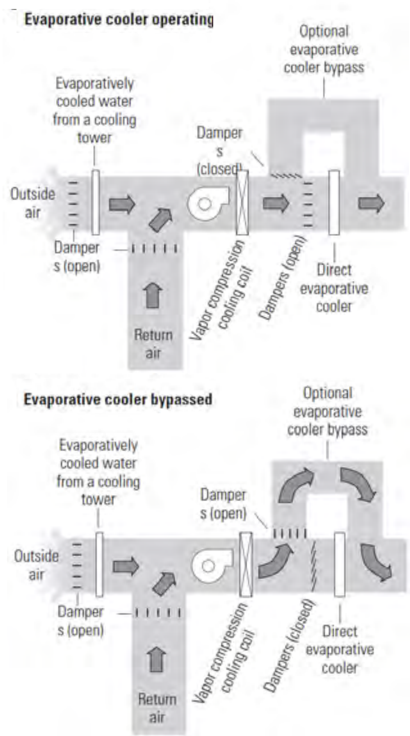
Direct evaporative cooler

Also known as swamp coolers, direct evaporative coolers simply blow air through a wetted-pad, thereby cooling it and increasing its humidity.



Air-to-air indirect evaporative cooler

Secondary air flows through a water spray and is cooled by evaporation. The building supply air flows through the other side of the heat exchanger where it is sensible cooled by the evaporatively cooled secondary air.



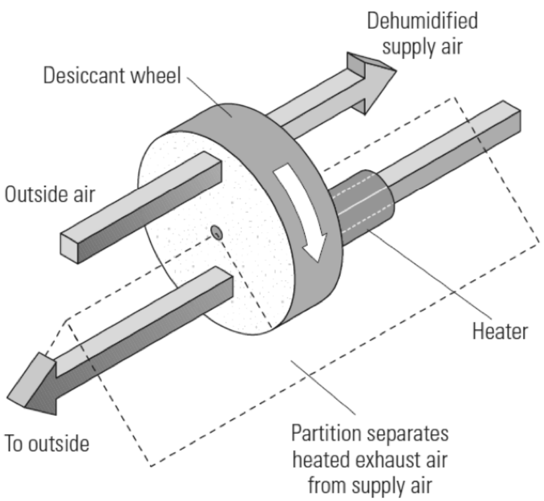
Integrated indirect and direct evaporative cooling with vapor compression cooling in an HVAC air-handling system

SOURCE: E Source Technology Atlas Series, Volume II Cooling (1997)

Non-refrigerative Cooling

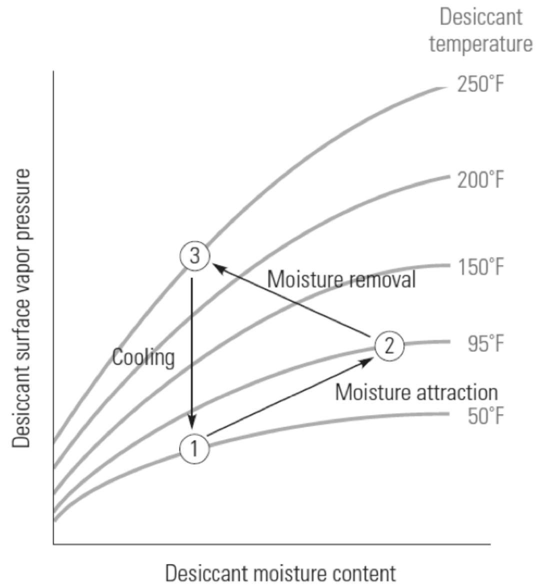
5. Dessicant dehumidification and cooling

- Helps in Air dehumidification - reduces cooling load
- Reduce/eliminate refrigerative air-conditioning



Solid desiccant wheels

The drawing shows how the desiccant wheel alternately passes through two separate air streams; one to be dehumidified and used in the building, and one to regenerate the desiccant with warm, dry exhaust air.



Desiccant cycle diagram

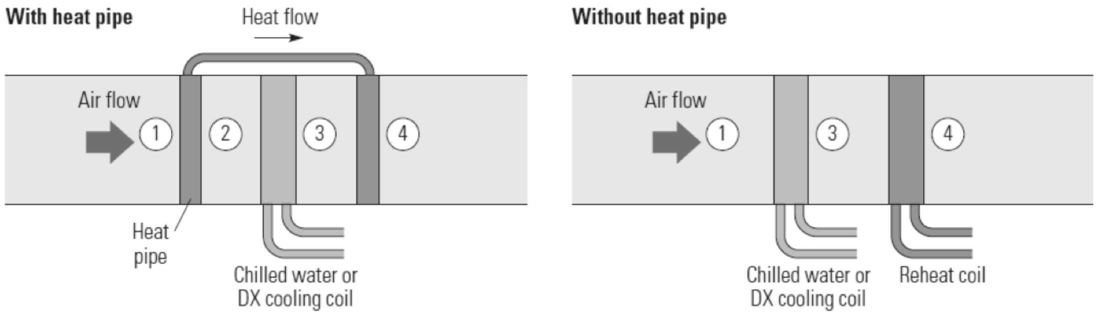
A cool dry desiccant (point 1) has a low surface vapor pressure so it attracts the moisture in air, which has a higher vapor pressure. After this moisture attraction (adsorption or absorption, see box on page 167), the desiccant is warm and moist, and its surface vapor pressure is higher (point 2). The desiccant must then be regenerated. It is placed in a different air stream (called scavenger air) and heated. Moisture moves from the surface of the desiccant to the scavenger air. The desiccant is now dry and hot, with a high vapor pressure (point 3). To restore its low pressure for another cycle of dehumidification, the desiccant is cooled, returning to the original state at point 1.

SOURCE: E Source Technology Atlas Series, Volume II Cooling (1997)

Non-refrigerative Cooling

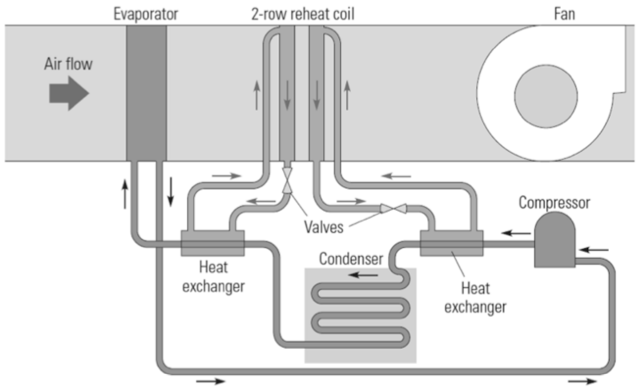
6. Heat-pipe cooling cycle enhancements

7. Hydronic cooling



Heat-pipe cooling coil bypass arrangement

This figure shows how cooling coils with heat pipes dehumidify with less energy that conventional reheat systems. The heat pipe precools the air (1-2), the cooling coil removes more heat (2-3), and the backend of the heat pipe reheats the air (3-4). The conventional system has to do more cooling at the coil (1-3), and then use additional energy for reheat (3-4).

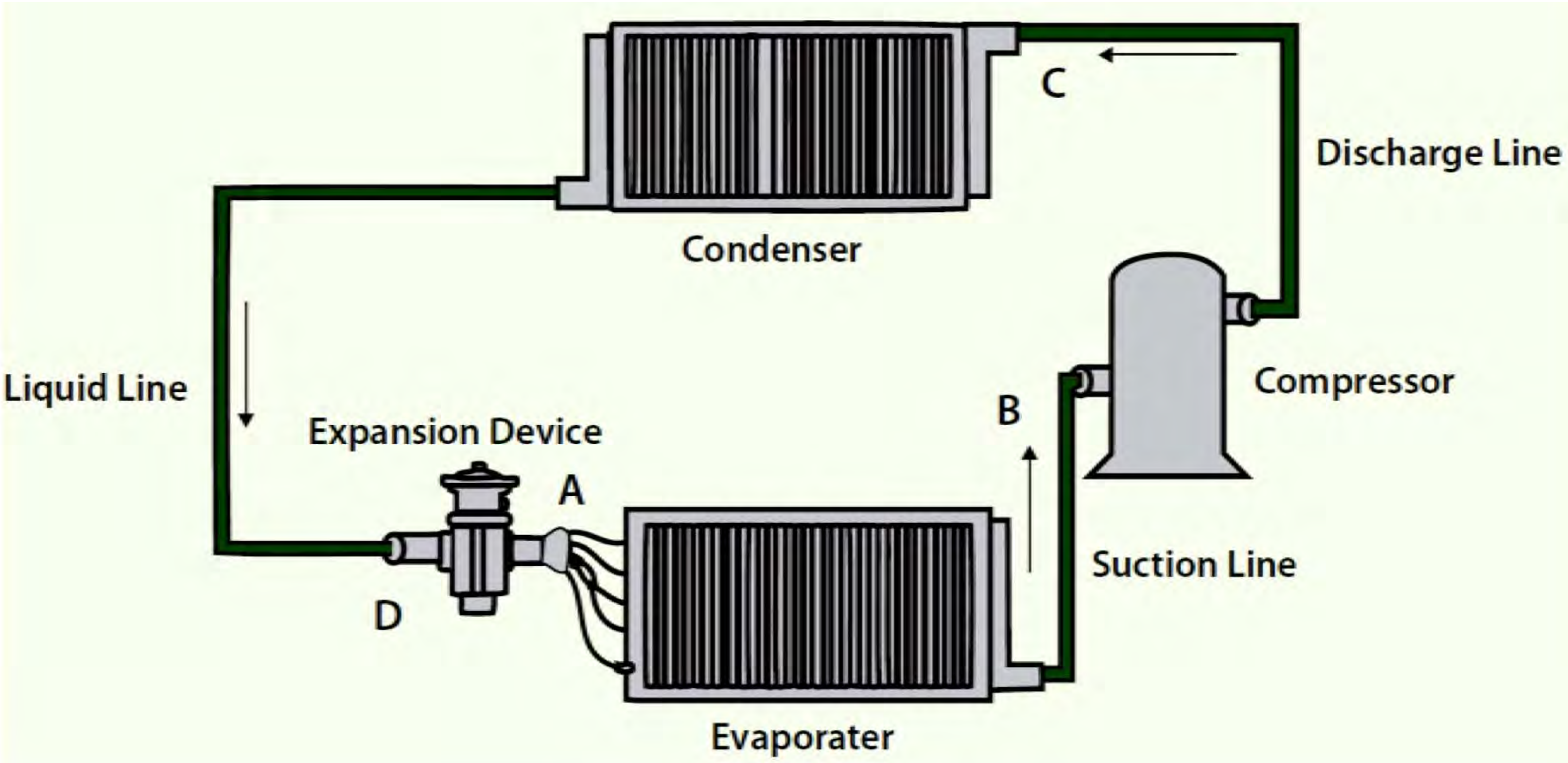


Heat pipe subcooling and desuperheating for DX systems

This system offers improved dehumidification with a single 2-row coil added to the airstream. The arrows show the flow of the refrigerant.

SOURCE: E Source Technology Atlas Series, Volume II Cooling (1997)

Refrigerative Cooling



Air-conditioning system basics

SOURCE: ECBC User Guide

HVAC System Components

- Furnace / Heating unit
- Filters
- Compressors
- Condensing units
- Evaporator (cooling coil)
- Control System (Thermostats, economizers, VAV's etc.)
- Distribution System (Supply/Return ducts, Piping, plenums etc)

HVAC System Types

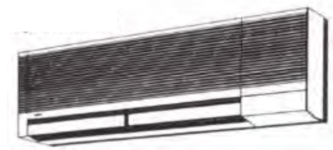
» Room Air Conditioners

- **Split systems** - separate indoor (evaporator) and outdoor (condenser + compressor)
- **Window systems** - all functions in one outdoor package

» Central Air Conditioners

Split system

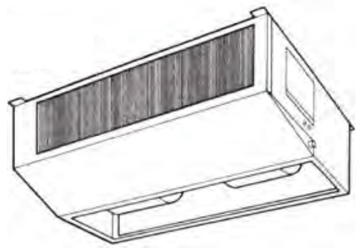
Single package



High wall fan coil

Ceiling suspended fan coil

Cassette fan coil



Satellite fan coil

SOURCE: E Source Technology Atlas Series, Volume II Cooling (1997)

Room Air Conditioners

Efficiency

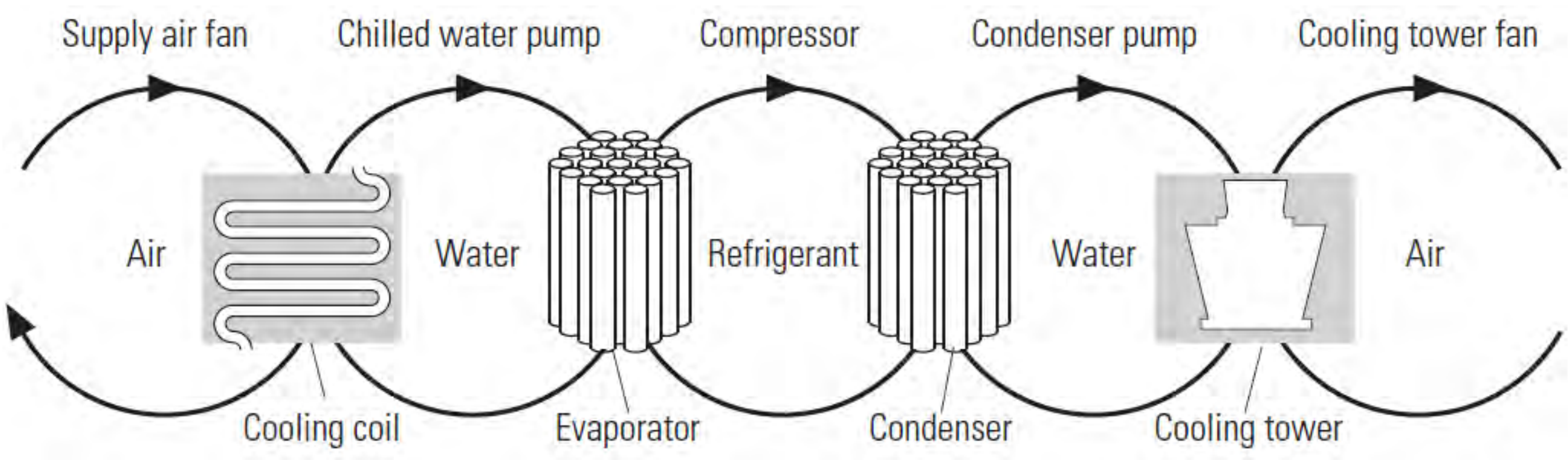
$$\textbf{EER}\text{ (Energy Efficiency Ratio)} = \frac{\textbf{Rate of cooling (or cooling output)}}{\textbf{Cooling input}}$$ *at full-load conditions*

Star Rating	Energy Efficiency Ratio (EER)	Cooling Capacity (Watts)	Input Power Watts	Units Consumption/ Day (kWh)	Per Unit Charge Rs. (Approx.)	Electricity Cost/ Month Rs.	Cost Saving Rs. Per Year (w.r.t. no star) (Approx.)
No Star	**2.20**	5200	2364	9.54	2.50	709	0
1	**2.30**	5200	2261	9.04	2.50	678	308
2	**2.50**	5200	2080	8.32	2.50	624	851
3	**2.70**	5200	1926	7.70	2.50	578	1313
4	**2.90**	5200	1793	7.17	2.50	538	1712
5	**3.10**	5200	1677	6.71	2.50	503	2059

Energy and Cost savings for 1.5 ton Window or Split Air Conditioners at different star ratings *(Assuming 8 hours operation per day for five months in a year)*

SOURCE: Bureau of Energy Efficiency

Central Air Conditioners



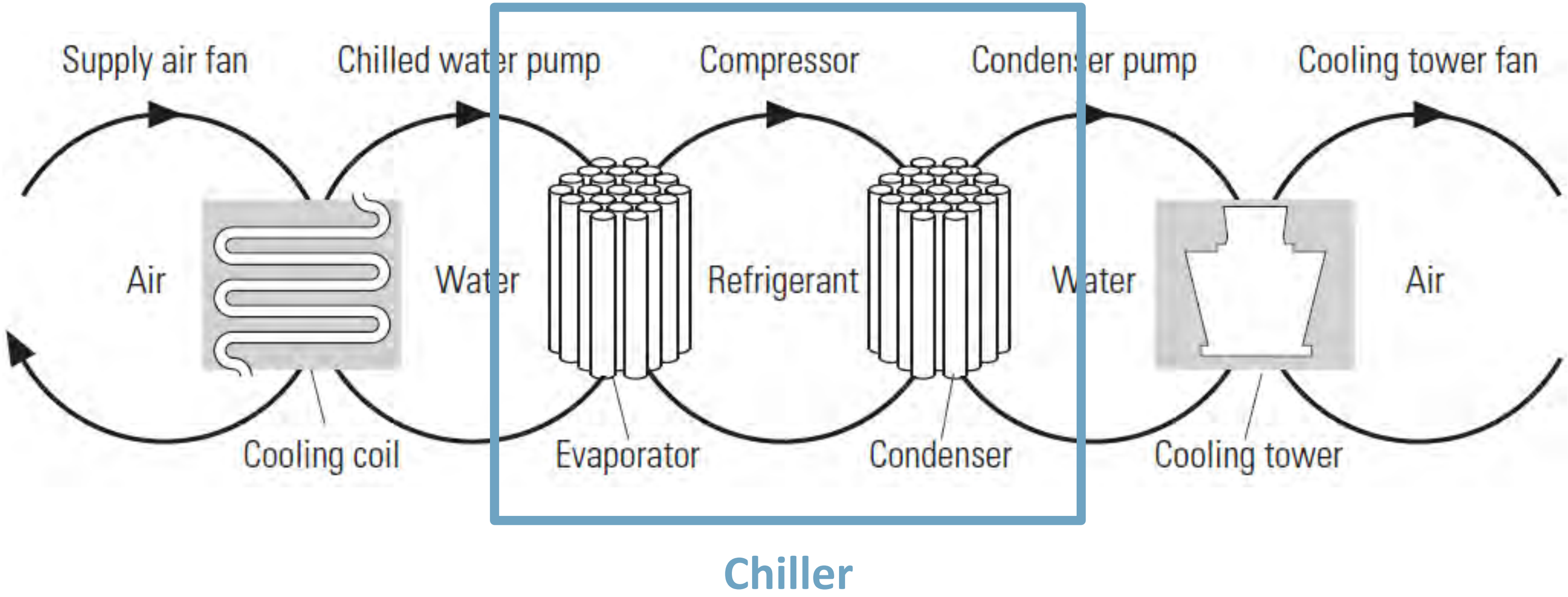
Conceptual view of a chilled-water air-conditioning system

In this figure, thermal energy moves from left to right as it is extracted from the space and expelled into the outdoors through the five loops of heat transfer:

- ***Indoor air loop**. In the leftmost loop, indoor air is driven by the supply air fan through a cooling coil, where it transfers its heat to chilled water. The cool air then cools the building space.*
- ***Chilled water loop**. Driven by the chilled water pump, water returns from the cooling coil to the chiller's evaporator to be re-cooled.*
- ***Refrigerant loop**. Using a phase-change refrigerant, the chiller's compressor pumps heat from the chilled water to the condenser water.*
- ***Condenser water loop**. Water absorbs heat from the chiller's condenser, and the condenser water pump sends it to the cooling tower.*
- ***Cooling tower loop**. The cooling tower's fan drives air across an open flow of the hot condenser water, transferring the heat to the outdoors.*

SOURCE: E Source Technology Atlas Series, Volume II Cooling (1997)

Central Air Conditioners



SOURCE: E Source Technology Atlas Series, Volume II Cooling (1997)

Central Air Conditioners

Chiller size & efficiency

» **Tons:** measure of the rate of cooling supplied (chiller size)

1 ton = 12,000 Btu/hr or 3.516 thermal kW

» **Efficiency ratings:**

- kW/ton rating - power input to compressor motor / tons of cooling produced
- COP rating - Coefficient of Performance: Btu output (cooling) / Btu input (electric power)
- EER rating - Energy Efficiency Ratio
- **kW/ton = 12/EER ; kW/ton = 3.516/COP**

» **Integrated part-load value (IPLV):** efficiency of the chiller, measured in kW/ton, averaged over a representative operative range

Building Commissioning & System Balancing

» Building Commissioning:

- *"Quality-oriented process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria*" – ASHRAE Guideline 0, The Commissioning Process.
- *"All inclusive process for all the planning, delivery, verification, and managing risks to critical functions performed in, or by, facilities."*

» Testing, Adjusting, and Balancing (TAB):

- *"TAB of all HVAC systems and equipment is needed to complete the installation and to make the system perform as the designer intended."*
- *"Intended to verify that all HVAC water- and air-flows and pressures meet the design intent and equipment manufacturer's operating requirements."*

» TAB is not Commissioning, although Commissioning includes TAB verification.

SOURCE: Whole Building Design Guide, http://www.wbdg.org/project/buildingcomm.php

COMMISSIONING: What is in it for Developers?

- Commissioning is required for green building rating programs (LEED and GRIHA)
- Commissioning assists in the delivery and overall quality assurance of a project including:
  - Planning delivery team member roles and responsibilities
  - Planning tasks for all project phases and activities, including
    - review and acceptance procedures,
    - documentation requirements,
    - development and approval of Commissioning Plans, Commissioning Schedules, and Testing and Inspection plans
- Cost of correcting deficiencies and contractor call-backs during warranty period often make up for the cost of commissioning

SOURCE: Whole Building Design Guide, http://www.wbdg.org/project/buildingcomm.php

ECBC Requirements: Overview

ECBC Mandatory Requirements

- Natural ventilation
- Equipment Efficiency
- Controls
- Piping and Ductwork
- System Balancing
- Condensers

ECBC Prescriptive Requirements

- Economizers
  - Reduce energy consumption by using cooler outdoor air to cool the building whenever possible
- Hydronic Systems
  - Variable fluid flow saves water and reduces energy use in water based systems

ECBC Requirements: Mandatory

Natural Ventilation

» As per National Building Code of India 2005

Select NBC Design Guidelines for Natural Ventilation	
Building Orientation	0-30 Deg. In the direction of Prevailing winds
	45Deg. In the direction of east and west winds
Inlet Openings	Located on the windward side
Outlet Openings	Located on the leeward side
Height of the Openings	Recommended sill height:
	For sitting on chair 0.75 m
	For sitting on bed 0.60 m
	For sitting on floor 0.40 m
Total Area (Inlet+ Outlet) of the Openings	For total area of openings between 20% to 30% of floor area, the average indoor wind velocity is around 30% of outdoor velocity

SOURCE: Bureau of Indian Standards, National Building Code of India 2005, Part 8 Building Services, Section 1 Lighting and Ventilation

ECBC Requirements: Mandatory

Minimum Equipment Efficiencies

» Cooling equipment shall meet or exceed the minimum efficiency requirements in ECBC Table 5.1. *Equipment not listed shall comply with ASHRAE 90.1-2004 §6.4.1*

Equipment Class	Minimum COP	Minimum IPLV	Test Standard
Air Cooled Chiller <530 kW (<150 tons)	2.90	3.16	ARI 550/590-1998
Air Cooled Chiller ≥530 kW (≥150 tons)	3.05	3.32	ARI 550/590-1998
*Centrifugal Water Cooled Chiller < 530 kW (<150 tons)	5.80	6.09	ARI 550/590-1998
*Centrifugal Water Cooled Chiller ≥530 and <1050 kW (≥150 and <300 tons)	5.80	6.17	ARI 550/590-1998
*Centrifugal Water Cooled Chiller ≥ 1050 kW (≥ 300 tons)	6.30	6.61	ARI 550/590-1998
Reciprocating Compressor, Water Cooled Chiller all sizes	4.20	5.05	ARI 550/590-1998

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

ECBC Requirements: Mandatory

Equipment Efficiencies at IPLV

- Efficiencies at Integrated Part Load Performance (IPLV) values can be calculated as follows:

  IPLV = 0.01 A + 0.42B + 0.45C + 0.12D

For COP and EER:

Where: A = COP or EER at 100%; B = COP or EER at 75%; C = COP or EER at 50%; D = COP or EER at 25%

For kW

$$\textbf{IPLV} = \frac{1}{\frac{0.01}{A} + \frac{0.42}{B} + \frac{0.45}{C} + \frac{0.12}{D}}$$

Where: A = kW/Ton at 100%; B = kW/Ton at 75%; C = kW/Ton at 50%; D = kW/Ton at 25%

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ECO III

ENERGY IS LIFE BEE CONSERVE IT

ECBC Requirements: Mandatory

Controls (Timeclock)

- Code specifies the mandatory use of time clocks to allow scheduling for 24-hour building.
- Allow scheduling for 24-hour building
  - Can start and stop the system under different schedules for three different day-types per week
- Take power outages into consideration
  - Is capable of retaining programming and time setting during loss of power for a period of at least 10 hours
- Allow custom scheduling
  - Includes an accessible manual override that allows temporary operation of the system for up to 2 hours

ECBC Requirements: Mandatory

Controls (Temperature)

» Ensure adequate dead band between cooling & heating set points to avoid conflicting thermostat control conditions

» For systems that provide simultaneous heating and cooling
- Controls shall be capable of providing a temperature dead band of 3°C (5°F) within which the supply of heating and cooling energy to the zone is shut off or reduced to a minimum.

» For systems that provide separate heating and cooling
- Thermostats shall be interlocked to prevent simultaneous heating and cooling.

ECBC Requirements: Mandatory

Controls (Cooling Towers & Closed Circuit Fluid Coolers)

- To minimize energy consumption by reducing fan speed during lower ambient conditions
  - All cooling towers and closed circuit fluid coolers shall have either two speed motors, pony motors, or variable speed drives controlling the fans.

ECBC Requirements: Mandatory

Piping and Ductwork

» To minimize energy losses, ECBC requires that piping of heating and cooling systems, (including the storage tanks,) must be insulated

- ECBC specifies required R-values of insulation based on the operating temperature of the system

Heating System	
Designed Operating Temperature of Piping	Insulation with Minimum R-value ($m^2 \cdot K/W$)
60°C and above	0.74
Above 40°C and below 60°C	0.35
ECBC Insulation Specs. for Heating System	

Cooling System	
Designed Operating Temperature of Piping	Insulation with Minimum R-value (m2·K/W)
Below 15°C	0.35
Refrigerant Suction Piping	
Split System	0.35
ECBC Insulation Specs. for Cooling Systems	

» To maintain thermal integrity of the insulation

- Insulation exposed to weather shall be protected by aluminum sheet metal, painted canvas, or Plastic cover. Cellular foam insulation shall be protected as above, or be painted with water retardant paint.

ECBC Requirements: Mandatory

System Balancing

» Achieve energy efficiency by optimizing air/water distribution rates for all systems

» Balancing should be done prior to occupancy

» ECBC mandates system balancing be included in specifications in the construction documents

» Construction documents shall require
  - All HVAC systems be balanced in accordance with generally accepted engineering standards.
  - A written balance report including O&M guidelines be provided for HVAC systems serving zones with a total conditioned area exceeding 500 m^2 (5,000 ft^2).

ECBC Requirements: Mandatory

System Balancing (Air System Balancing)

- Air systems shall be balanced in a manner to minimize throttling losses. Then, for fans greater than 0.75 KW (1.0 HP), fans must then be adjusted to meet design flow conditions.

- *Air System Balancing refers to adjustment of airflow rates through air distribution system devices such as fans and diffusers.*
- *It is achieved through adjusting the position of dampers, splitter vanes, extractors, etc.*
- *Design options for improving air distribution efficiency include using*
  - *Variable-air-volume systems*
  - *VAV diffusers*
  - *Low-pressure-drop duct design*
  - *Low-face-velocity air handlers*
  - *Fan sizing and variable-frequency-drive motors*
  - *Displacement ventilation systems*

ECBC Requirements: Mandatory

System Balancing (Hydronic System Balancing)

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

- *Hydronic System Balancing refers to the adjustment of water flow rates through distribution system devices such as pumps and coils, by manually adjusting the position of valves, or by using automatic control devices, such as flow control valves.*
- *A balanced hydronic system is one that delivers even flow to all of the devices on that piping system.*
- *When a system is balanced, all of the pressure drops are correct for the devices which translates into reduced energy use & costs for pumping.*

ECBC Requirements: Mandatory

Condensers

ECBC regulates condenser locations to ensure:

- There is no restriction to the air flow around condenser coils
- No short circuiting of discharge air to the intake side
- Heat discharge of other adjacent equipment is not near the air intake of the condenser

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

ECBC regulates condenser water quality

- to eliminate mineral buildup in condensers and chilled water systems (Mineral deposits create poor heat transfer situations there by reducing the efficiency of the unit)

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

ECBC Requirements: Prescriptive

Prescriptive requirements apply if the HVAC system meets the following criteria:

- Serves a single zone
- Cooling (if any) is provided by a unitary packaged or split-system air conditioner or heat pump
- Heating (if any) is provided by a unitary packaged or split-system heat pump, fuel-fired furnace, electric resistance heater, or baseboards connected to a boiler
- Outside air quantity is less than 1,400 l/s (3,000 cfm) and less than 70% of supply air at design conditions

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

ECBC Requirements: Prescriptive

Air Side Economizer

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

- An air economizer capable of modulating outside-air and return-air dampers to supply 100% of the design supply air quantity as outside-air;

OR

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

ECBC Requirements: Prescriptive

Air Side Economizer

ECBC encourages use of ventilation fans in the economizer mode to pre-cool the building prior to daily occupancy in the cooling season.

» Economizers shall be capable of providing partial cooling even when additional mechanical cooling is required to meet the cooling load.

» Air-side economizers shall be tested in the field following the requirements in Appendix F (of the Code) to ensure proper operation.

ECBC Requirements: Prescriptive

Variable Flow Hydronic Systems

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

- 50% of the design flow rate, or
- The minimum flow required by the equipment manufacturer for proper operation of the chillers or boilers

» Automatic Isolation Valves

- Water cooled air-conditioning or heat pump units with a circulation pump motor greater than or equal to 3.7 kW (5 hp) shall have two-way automatic isolation valves on each water cooled air-conditioning

OR

- heat pump unit that are interlocked with the compressor to shut off condenser water flow when the compressor is not operating.

ECBC Requirements: Prescriptive

Variable Flow Hydronic Systems

» Variable Speed Drives

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

ECBC Compliance Forms

Mechanical Summary

2007 Energy Conservation Building Code Compliance Forms

Project Info

Project Address

Date

For Building Dept. Use

Applicant Name:

Applicant Address:

Applicant Phone:

Project Description

Briefly describe mechanical system type and features.

☐ Includes Plans

Compliance Option ☐ System ☐ Prescriptive ☐ Whole Building

Equipment Schedules

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

Cooling Equipment Schedule

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

Heating Equipment Schedule

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

Mechanical Permit Checklist — MECHANICAL Checklist

2007 Energy Conservation Building Code Compliance Forms

Project Address | Date

The following information is necessary to check a building permit application for compliance with the mechanical requirements in the Energy Conservation Building Code 2007

Applicability (yes, no, n.a.)	Code Section	Component	Information Required	Location on Plans	Building Department Notes
HEATING, VENTILATING, AND AIR CONDITIONING (Chapter 5)					
MANDATORY PROVISIONS (Section 5.2)					
	5.2.2	Equipment efficiency	Provide equipment schedule with type, capacity, efficiency		
	5.2.3	Controls			
	5.2.3.1	Time clocks	Indicate thermostat with night setback, 3 different day types, and 2-hour manual override		
	5.2.3.2	Temp. & dead band	Indicate temperature control with 3 degree C dead band minimum		
	5.2.3.3	Cooling tower, fluid cooler	Indicate two-speed motor, pony motor, or variable speed drive to control the fans		
	5.2.4.1	Piping & ductwork			
	5.2.4.1	Piping insulation	Indicate R-value of insulation		
	5.2.4.1	Ductwork insulation	Indicate R-value of insulation		
	5.2.4.1	Ductwork sealing	Specify sealing types and locations		
	5.2.5	System balancing	Specify system balancing		
PRESCRIPTIVE COMPLIANCE OPTION (Section 5.3)					
	5.3		Indicate whether project is complying with ECBC Prescriptive Option OR with ASHRAE Standard 90.1-2004		
	5.3.1	Economizer			
	5.3.1.1	Air economizer	Indicate 100% capability on schedule		
	5.3.1.2	Integrated operation	Indicate capability for partial cooling		
	5.3.1.3	Field testing	Specify tests		
	5.3.2	Variable flow hydronic			
	5.3.2.1	Pump flow rates	Indicate variable flow capacity on schedules		
	5.3.2.2	Isolation valves	Indicate two-way automatic isolation valves		
	5.3.2.3	Variable speed drive	Indicate variable speed drive		

End of MODULE

- *Introduction*
- *Whole Building Design Approach*
- *Non-refrigerative cooling*
- *Refrigerative cooling*
- *Building Commissioning & System Balancing*
- *ECBC Requirements*
  - *Mandatory*
  - *Prescriptive*
- *ECBC Compliance Forms*

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ECBC Training Workshop

MODULE 5:
Service Hot Water and Pumping

ACKNOWLEDGEMENT

This presentation was prepared by International Resources Group (IRG) for the Energy Conservation and Commercialization Project (ECO-III), and was made possible by the support of the American People through the United States Agency for International Development (USAID). The contents of this presentation are the sole responsibility of IRG and do not necessarily reflect the views of USAID or the United States Government. The ECO-III Project would like to acknowledge Ministry of Power and the Bureau of Energy Efficiency of Government of India for their support.

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Service Hot Water and Pumping: Outline

- Introduction
- Types of Water Heaters
- ECBC Requirements
  - Mandatory
- ECBC Compliance Forms

Introduction

Water heating is a thermodynamic process using an energy source to heat water above its initial temperature.

Hot Water Use

Domestic
- Cooking
- Cleaning
- Bathing
- Space heating

Commercial
- Hotels
  - Cooking
  - Laundry
  - Bathing
- Hospitals
  - Cleaning
  - Disinfection
  - Bathing

Industrial

SOURCE: http://en.wikipedia.org/wiki/Water_heating

Introduction

» Source Type

Conventional
- Electricity
- Natural Gas / LPG
- Oil
- Solid Fuels

Alternative
- Solar energy → Passive / Active
- Heat pumps
- Hot water recycling
- Geothermal heating

» System type

- **Storage**
- **Instantaneous**

SOURCE: http://en.wikipedia.org/wiki/Water_heating

Introduction

» Energy loss
- Inefficiency of heating equipment
- Heat loss from hot water storage tanks
- Heat loss from distribution network (piping)

» Opportunities for improvement
- Use hot water heating system that has a **Thermostat**
- **Reduce** Water Heating **Temperature**. For each 5.5°C (10°F) reduction in water temperature, can lead to 3-5% savings in energy costs
- **Insulate** the storage tanks, pipes and heat traps

Types of Water Heaters

- Storage Heaters (Gas or Electric)
  - Designed to heat and store water at less than 80°C
  - Water temperature is controlled with a thermostat
  - Storage electric water heaters have a manufacturer's specified capacity of at least two gallons.
- Storage Heat Pump
  - An electric water heater that uses a compressor to transfer thermal energy from one temperature level to a higher temperature level for the purpose of heating water
  - It includes all necessary auxiliary equipment such as fans, storage tanks, pumps or controls.
- Instantaneous (Gas or Electric)
  - Instantaneous water heaters provide hot water only as it is needed
    - Controlled manually or automatically by water flow activated control and/or thermostatic controls
  - Water heaters heat water directly without the use of a storage tank

Types of Water Heaters

» Indirect Gas

- A water heater consisting of a storage tank with no heating elements or combustion devices
- Connected via piping and recirculating pump to a heat source consisting of a gas or oil fired boiler, or instantaneous gas water heater

» Solar (Passive or Active)

- Systems which collect and store solar thermal energy for water heating applications
- Passive systems do not require electricity to recirculate water, whereas active systems require electricity to operate pumps or other components
- Passive systems are not readily available in the market and generally need to be designed for a particular usage

ECBC Requirements: Mandatory

ECBC through mandatory requirements seeks to minimize energy usage in water heating systems by:

- **Solar water heating**
- **Equipment efficiency**
- **Supplementary water heating system**
- **Piping insulation**
- **Heat traps**
- **Swimming pool (covers)**

ECBC Requirements: Mandatory

Solar Water Heating

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

- EXCEPTION: Systems that use heat recovery for at least 1/5 (20 percent) of the design capacity are exempted

ECBC Requirements: Mandatory

Equipment Efficiency

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

- IS 13129 (Part 1) provides information on the 'Performance Rating Procedure Using Indoor Test Methods'
- IS 13129 (Part 2) provides the information on the 'Procedure for System Performance Characterization and Yearly Performance Prediction'.
- These standards however, do not provide any performance/minimum efficiency levels

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

- As per this IS 15558 , thermal efficiency of the water heaters (under test conditions) shall not be less than:
- 84 percent for water heaters with a nominal heat input exceeding 10 kW
- 82 percent for water heaters with a nominal heat input not exceeding 10 kW

ECBC Requirements: Mandatory

Equipment Efficiency

» Electric water heater shall meet the performance / minimum efficiency level mentioned in IS 2082

- IS 2082 (Part 1) specifies the standing loss in the heaters

Rated Capacity in Liters	Loss in kWh/day for 45° Difference
6	0.792
10	0.99
15	1.138
25	1.386
35	1.584
50	1.832
70	2.079
100	2.376
140	2.673
200	2.97

SOURCE: Bureau of Indian Standards (1991), IS 2082 (Part 1): 1993 (Reaffirmed 2004) Edition 5.4 (2002-05) Stationary Storage Type Electric Water Heaters-Specification (Fourth Revision)

ECBC Requirements: Mandatory

Supplementary Water Heating System

» Supplemental Water Heating System shall be designed to maximize efficiency and shall incorporate and prioritize the following design features as shown:
- Maximum heat recovery from hot discharge system like condensers of air conditioning units
- Use of gas-fired heaters wherever gas is available
- Electric heater as last resort

ECBC Requirements: Mandatory

Piping Insulation

» The entire hot water system including the storage tanks, pipelines shall be insulated conforming to the relevant IS standards on materials and applications.

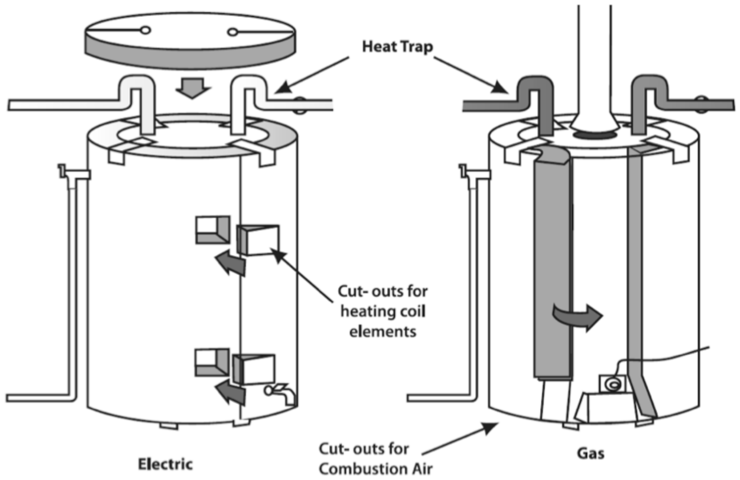
Heating System	
Designed Operating Temperature of Piping	**Insulation with Minimum R-value ($m^2 \cdot K/W$)**
60°C and above	0.74
Above 40°C and below 60°C	0.35

ECBC Requirements: Mandatory

Heat Traps

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

- *Heat traps are valves or loops of pipe that allow water to flow into the water heater tank but prevent unwanted hot-water flow out of the tank*
- *Heat traps can help save energy and cost on the water heating bill by preventing convective heat losses through the inlet and outlet pipes*



Heat trap elements

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

ECBC Requirements: Mandatory

Swimming Pools

- Heated pools shall be provided with a vapor retardant pool cover on or at the water surface. Pools heated to more than 32°C (90°F) shall have a pool cover with a minimum insulation value of R-2.1 (R-12).
  - EXCEPTION: Pools deriving over 60% of their energy from site-recovered energy or solar energy source.

ECBC Compliance Forms

Compliance submittals demonstrate the following:

- At least 20% of the heating requirement shall be met from solar heat/heat recovery
- Not more than 80% of the heat shall be met from electrical heating
- Wherever gas is available, not more than 20% of the heat shall be met from electrical heating
- ECBC Appendix G 15.4 Mechanical Checklist

SERVICE WATER HEATING AND PUMPING (Chapter 6)							
MANDATORY PROVISIONS (Section 6.2)							
			6.2.1	Solar water heating	Provide calculations to justify capacity to meet 20% threshold		
			6.2.2	Equipment efficiency	Provide equipment schedule with type, capacity, efficiency		
			6.2.4	Piping insulation	Indicate R-value of insulation		
			6.2.5	Heat traps	Indicate heat trap on drawings or provide manufacturers specifications to show that equipment has internal heat trap		
			6.2.6	Pool covers	Provide vapor retardant cover for pools		
			6.2.6	Pools over 32°C	Provide R-2.1 insulation		

End of MODULE

- *Introduction*
- *Types of Water Heaters*
- *ECBC Requirements*
  - *Mandatory*
- *ECBC Compliance Forms*

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MODULE 6:
Lighting

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Lighting: Outline

- Introduction
- Whole Building Design Approach
- ECBC Requirements
  - Mandatory
  - Prescriptive
- ECBC Compliance Forms

Introduction

- Lighting is a major energy consumer in commercial buildings
- Lighting accounts for 15% of total energy consumption in India
  - Commercial Buildings 20-40%
- In most commercial buildings, lighting is one of the largest sources of internal heat gain
  - Heat generated from electric lighting contributes significantly to the energy needed for cooling of buildings
  - Each kilowatt-hour (kWh) reduction in lighting energy approximately saves 0.4 kWh in cooling energy
- Lighting is one of the fastest developing energy-efficient technologies

Whole Building Design Approach

1. **Improve the space** (color of room surfaces and furnishings)

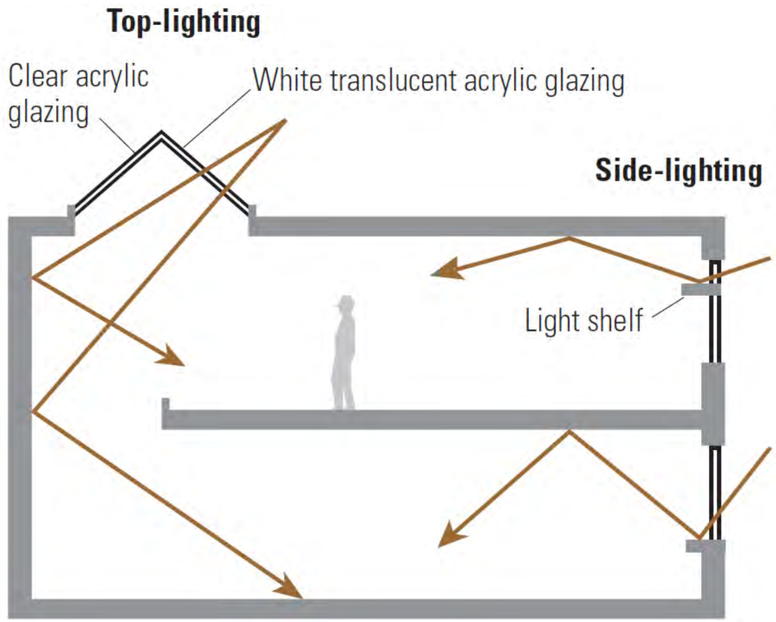
2. **Optimize light quality**
    - Reduction of Glare and veiling reflections
    - Proper Luminance Ratios
    - Mix of direct and indirect sources
    - Appropriate color temperature
    - Appropriate color rendering

SOURCE: E Source Technology Atlas Series, Volume I Lighting (2005)

Whole Building Design Approach

3. Capture Daylight

- Daylighting Design Approaches
  - Building form – U-shaped, stepped-back
  - Skylights, atria
  - Elements – light shelves, reflectors, louvers, blinds



Simple daylighting techniques

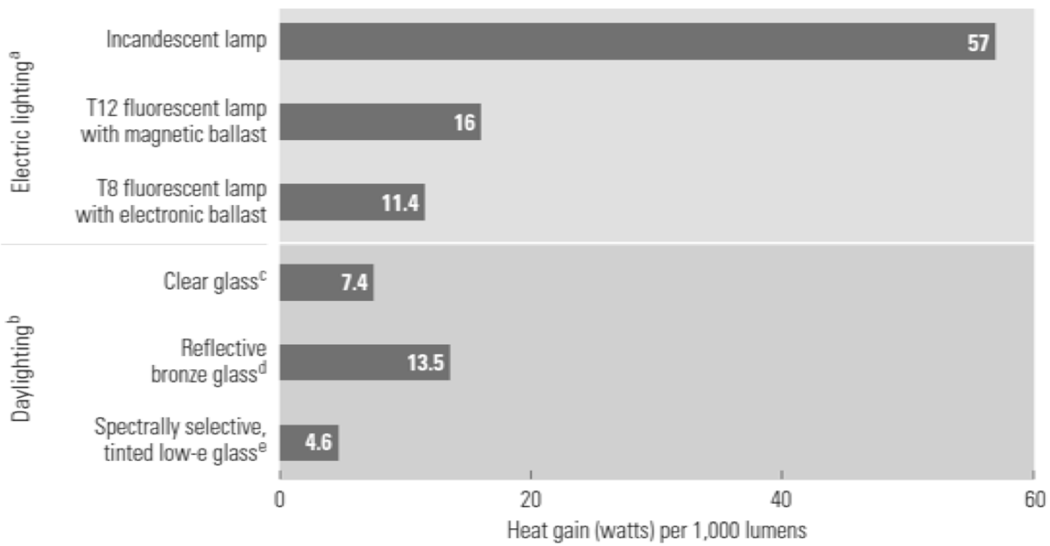
This schematic shows a mix of top-lighting and side-lighting, light shelves, high reflectance ceilings, and wall diffusion to provide fairly uniform deep-plan daylighting without the glare of direct sunlight.

SOURCE: E Source Technology Atlas Series, Volume I Lighting (2005)

Whole Building Design Approach

3. Capture Daylight

- Energy savings and demand reduction
  - Reducing need for electrical Lighting
  - Reducing cooling load (daylight contributes less heat to a space per given amount of light – *efficacy of daylight is significantly higher than most forms of electrical lighting*)



Building heat gain from different light sources

With proper glazing selection in a building, daylight will contribute far less heat per unit of light delivered to the interior than electric lights do.

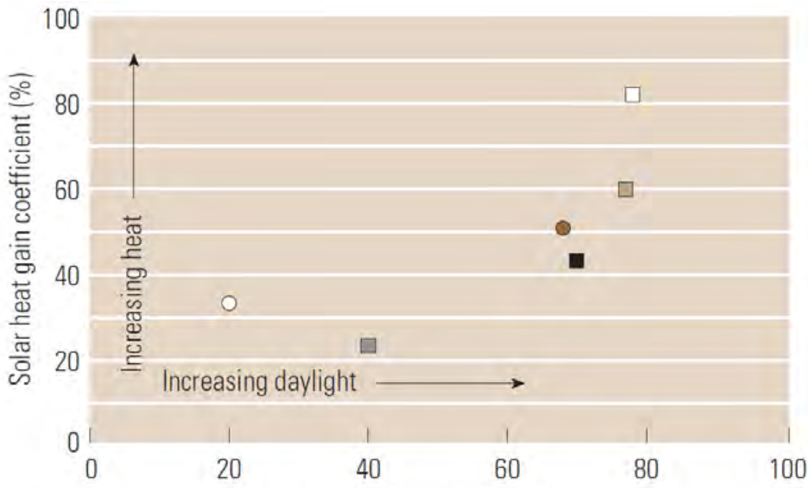
SOURCE: E Source Technology Atlas Series, Volume I Lighting (2005)

Whole Building Design Approach

3. Capture Daylight

- Glazing selection
  - Tinted
  - Reflective
  - Low-e
  - Spectrally selective

Glazing	Visible	SHGC
Clear	0.82	0.78
Low-e coating	0.77	0.60
Dark reflective bronze tint	0.20	0.33
Spectrally selective green tint	0.68	0.51
Spectrally selective low-e (clear)	0.70	0.43
Spectrally selective low-e with green tint	0.40	0.23



Total solar and visible light transmissions for selected glazing units

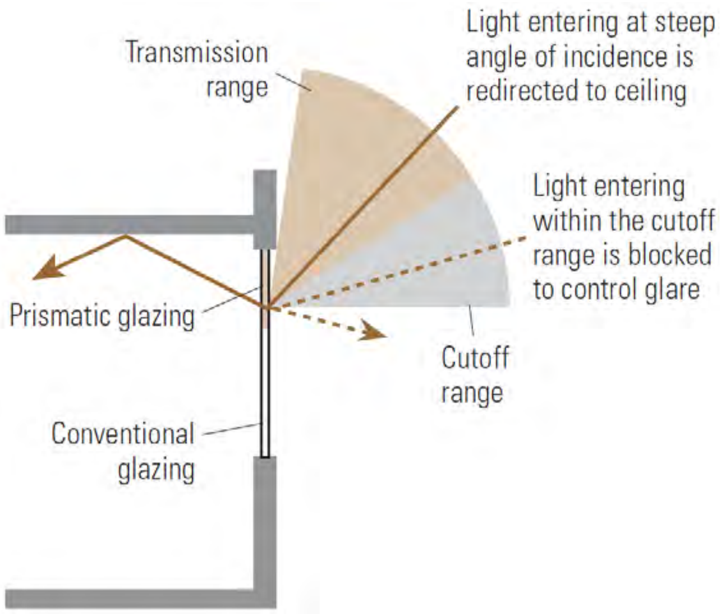
Glazing units with high visible light transmission and low solar heat gain coefficients (SHGC, the fraction of the incident solar energy transmitted through a window) are best for daylighting in buildings dominated by cooling loads.

SOURCE: E Source Technology Atlas Series, Volume I Lighting (2005)

Whole Building Design Approach

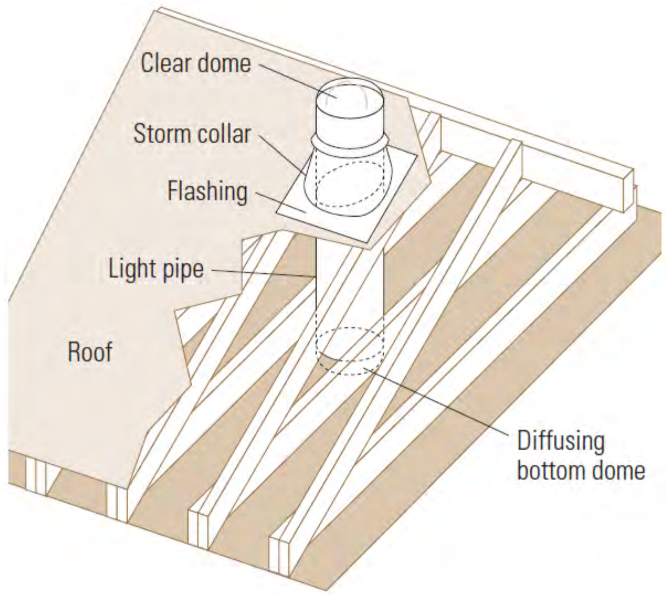
3. Capture Daylight

- Redirecting daylight (and light transport systems)



How light-bending panels can improve daylighting

Using refractive and reflective optics allows direct daylight to be distributed deeper into a building's core.



The Sun Pipe light pipe

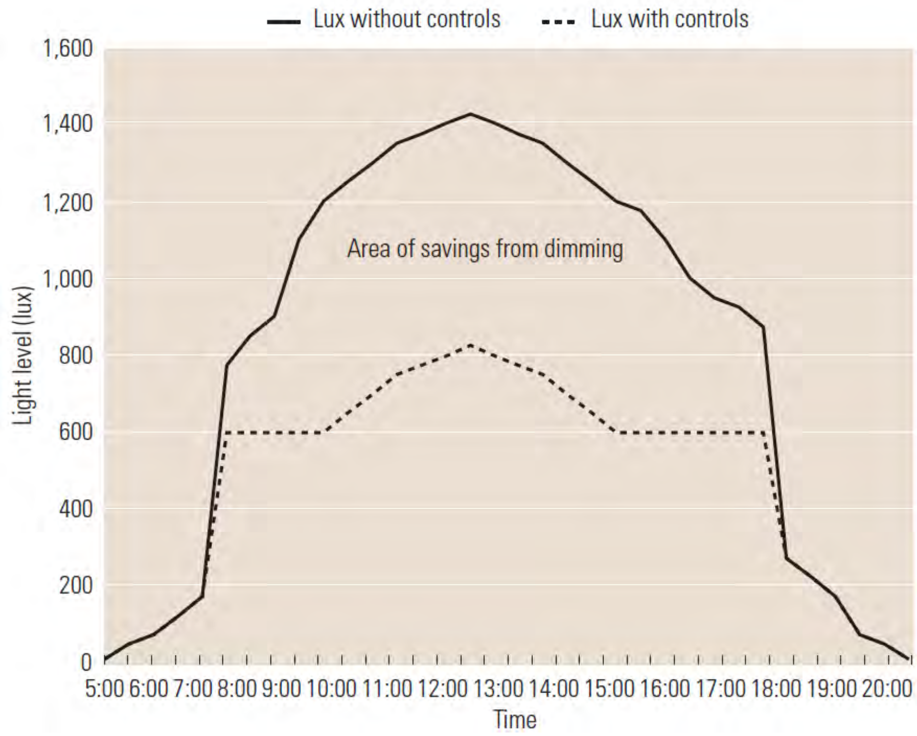
This simple daylighting product resembles a skylight in function, but it is easier to install and avoids direct glare.

SOURCE: E Source Technology Atlas Series, Volume I Lighting (2005)

Whole Building Design Approach

3. Capture Daylight

- Controls for daylight dimming



Light levels with and without dimming

These are typical light levels on a horizontal surface. In this example, electric lights supply 600 lux at night. Thus when the lights are turned on or off during the day, 600 lux is added or subtracted from the natural light. At midday, even with no lights, the illumination levels are greater than at nighttime levels.

4. Consider lighting quantity ('less light properly delivered' Vs 'more light poorly delivered')

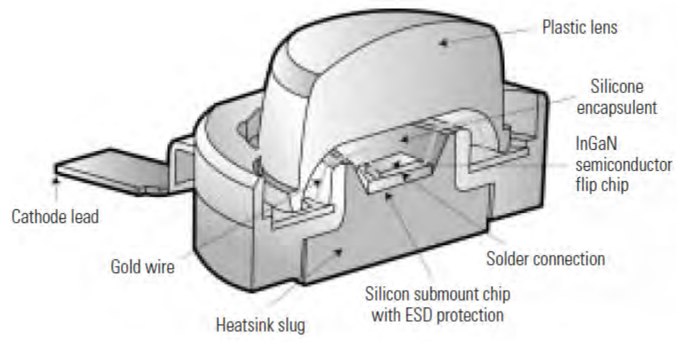
- Separate task and ambient lighting

SOURCE: E Source Technology Atlas Series, Volume I Lighting (2005)

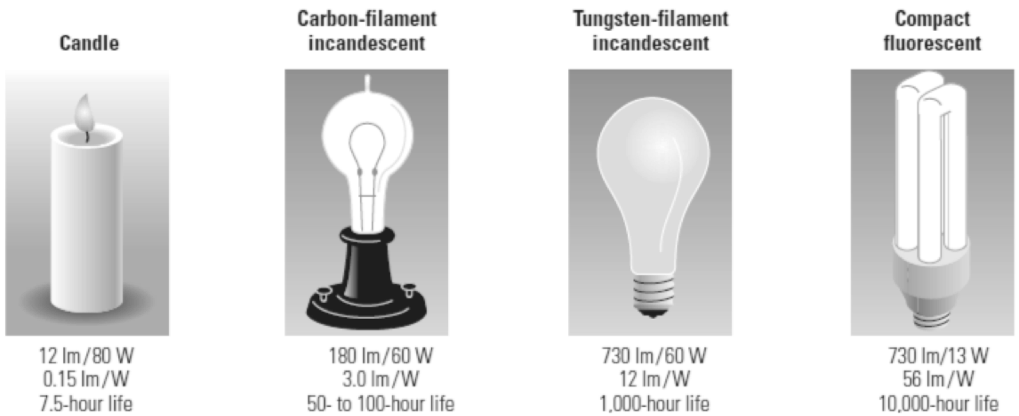
Whole Building Design Approach

5. **Energy-efficient electric lighting** based on

- Task
- Level of quality desired
- Amount of light required

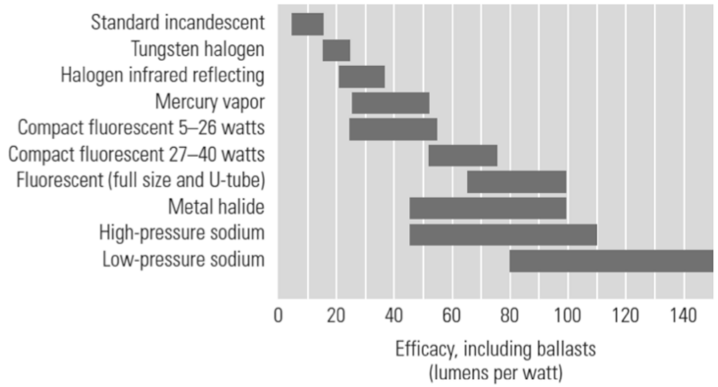


LED operation



A brief history of lighting

The compact fluorescent lamp has improved the product efficacy and lifetime 50-fold as compared with the tungsten-filament lamp and by half a million compared with the candle.



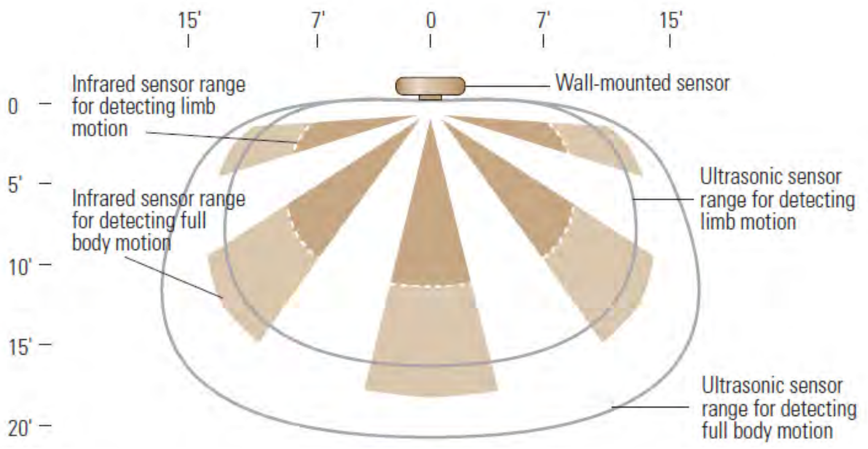
Lamp efficacy of major light sources

SOURCE: E Source Technology Atlas Series, Volume I Lighting (2005)

Whole Building Design Approach

6. Use of lighting controls

- On-off controls
  - Manual switches
  - Elapsed-time switches
  - Clock switches
  - EMS (Energy Management Systems) controls
  - Photocell controls
  - Occupancy controls
  - Switched power strips
- Dimming controls
  - Power reducers
  - Stepped-dimming controls
  - Continuous-dimming controls



Representative sensor coverage diagram

Ultrasonic sensors can detect motion at any point within the contour lines shown in the graph. Infrared sensors "see" only in the wedge-shaped zones and they generally don't see as far as ultrasonic units. Some sensors are further straight ahead than to the side. The ranges shown here are representative; some sensors may be more or less sensitive.

SOURCE: E Source Technology Atlas Series, Volume I Lighting (2005)

ECBC Requirements: Overview

ECBC Lighting Requirements apply to

- **Interior spaces** of buildings
- **Exterior building features,** including façades, illuminated roofs, architectural features, entrances, exits, loading docks, and illuminated canopies
- **Exterior building grounds** lighting that is provided through the building's electrical service

- The **mandatory requirements** for lighting mostly relate to **interior and exterior lighting controls**.
- The **prescriptive requirements** limit the **installed electric wattage** for interior building lighting.
  - Demonstrated through the Building Area Method or the Space Function Method

ECBC Requirements: Mandatory

Automatic Lighting Control

» Interior lighting systems in **buildings larger than 500 m²** (5,000 ft²) shall be equipped with an **automatic control device**.

- **All office areas less than 30 m²** (300 ft²) shall be equipped with **occupancy sensors**.
- For **other spaces, this automatic control device** shall function on either:
  - (a) **A scheduled basis at specific programmed times**. An independent program schedule shall be provided for areas of no more than 2,500 m² (25,000 ft²) and not more than one floor;

    OR

  - (b) **Occupancy sensors** that shall turn the lighting off within 30 minutes of an occupant leaving the space. Light fixtures controlled by occupancy sensors shall have a wall-mounted, manual switch capable of turning off lights when the space is occupied.

ECBC Requirements: Mandatory

Space Control

» Each space shall have **at least one control device** to independently control the general lighting

» Each control device shall be **activated either manually** by an occupant **or automatically** by sensing an occupant.

» Each control device shall:

- Control a maximum of 250 m^2 for a space less than or equal to 1,000 m^2, and a maximum of 1,000 m^2 for a space greater than 1,000 m^2
- Be capable of overriding the shutoff control required in Automatic Lighting Shutoff for no more than 2 hours
- Be readily accessible and located so the occupant can see the control

ECBC Requirements: Mandatory

Daylighting Control

If Daylighting strategy is used in the design, ECBC requires controls that can reduce the light output of luminaires in the daylit space.

» **Luminaire in daylighted areas** greater than 25 m^2 shall be equipped with either a **manual or automatic control** device that:
  - Is capable of reducing the light output of the luminaires in the daylighted areas by at least 50%
  - Controls only the luminaires located entirely within the daylighted area

There are also control requirements for exterior lighting (with photosensor or time switches) and specialty lighting applications (i.e. displays, hotel rooms, task lighting).

ECBC Requirements: Mandatory

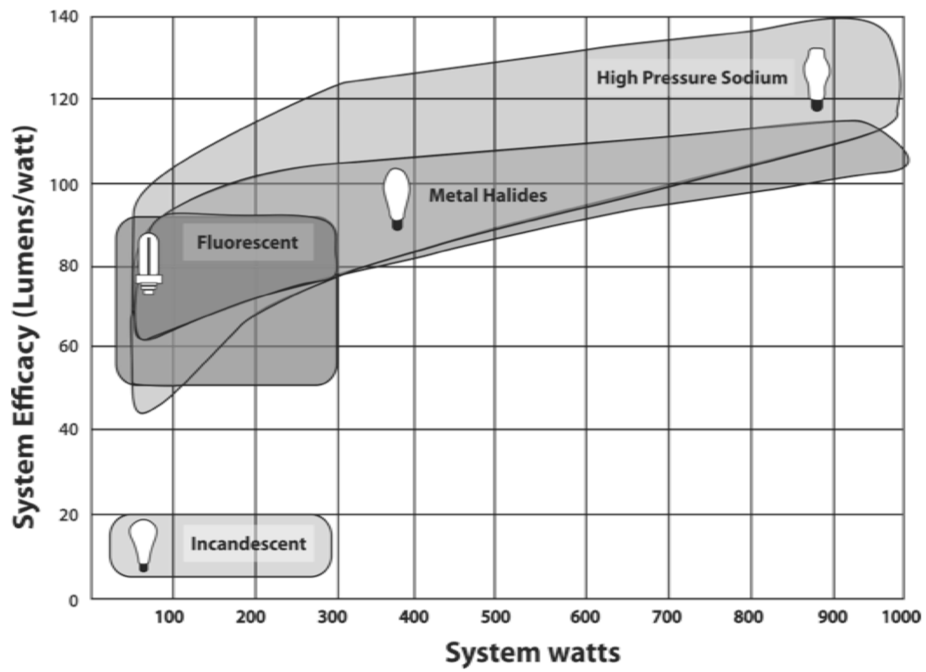
Exit Signs

- Internally-illuminated exit signs shall not exceed 5W per face.

Exterior Building Grounds Lighting

- Lighting for exterior building grounds luminaires which operate at greater than 100W shall contain lamps having a **minimum efficacy of 60 lm/W** unless the luminaire is controlled by a motion sensor.

***NOTE:** Luminaires meeting these requirements include fluorescent, mercury vapor and high pressure sodium*



Exterior Grounds Lighting and specific Technologies

SOURCE: (Image) Adapted from ASHRAE/IESNA Standard 90.1-1999

ECBC Requirements: Prescriptive

Interior Lighting Power

- Prescriptive lighting requirements limit the installed electric wattage for interior building lighting
- Trade-offs of interior lighting power allowance among portions of the building for which a different method of calculation has been used are NOT permitted
- Installed lighting power is calculated and compared using the maximum permissible interior lighting power densities
  - Specified for various building types (Building Area Method)

    OR
  - Building space functions (Space Function Method)

ECBC Requirements: Prescriptive

Building Area Method

1. Determine the allowed lighting power density (LPD) from Table 7.1 of ECBC for each appropriate building area type
2. Calculate the gross lighted floor area type
3. Multiply the allowed watts/sq.mt. Listed for each selected building type by the corresponding lighted floor areas to determine the allowed LPD
4. The sum of all the interior lighting power for various areas of the building cannot exceed the total watts to be in compliance

Table 7.1: Interior Lighting Power-Building Area Method

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

ECBC Requirements: Prescriptive

Space Function Method

1. Determine the appropriate building type and their allowed lighting power densities, which varies according to the function of the space
2. For each space enclosed by partitions 80% or greater than ceiling height, determine the gross interior floor area.
3. The lighting power allowance for a space is the product of the gross lighted floor area of the space times the allowed lighting power density for that space.
4. The interior lighting power allowance for the building is the sum of the lighting power allowances for all spaces.

Table 7.2: Interior Lighting Power – Space Function Method

Space Function	LPD (W/m^2)	Space Function	LPD (W/m^2)
Office-enclosed	11.8	• For Reading Area	12.9
Office-open plan	11.8	Hospital	
Conference/Meeting/Multipurpose	14.0	• For Emergency	29.1
Classroom/Lecture/Training	15.1	• For Recovery	8.6
Lobby*	14.0	• For Nurse Station	10.8
• For Hotel	11.8	• For Exam Treatment	16.1
• For Performing Arts Theater	35.5	• For Pharmacy	12.9

ECBC Requirements: Prescriptive

Exterior Lighting Power

- The connected exterior lighting power must not exceed the allowed limits by ECBC.
- Trade-offs between applications are not permitted.

Table 7.3: Exterior Building Lighting Power

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

ECBC Compliance Forms

15.5 Lighting Summary

Lighting Summary

2007 Energy Conservation Building Code Compliance Forms

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

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

Compliance Option	☐ Prescriptive	☐ Systems Analysis

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

Maximum Allowed Lighting Wattage (Interior, Section 7.3)

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

Proposed Lighting Wattage (Interior)

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

Maximum Allowed Lighting Wattage (Exterior, Section 7.4)

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

Proposed Lighting Wattage (Exterior)

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

15.6 Lighting Permit Checklist

Lighting Permit Checklist **LIGHTING Checklist**

2007 Energy Conservation Building Code Compliance Forms

Project Address | Date

The following information is necessary to check a building permit application for compliance with the lighting requirements in the Energy Conservation Building Code 2007

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

End of MODULE

- *Introduction*
- *Whole Building Design Approach*
- *ECBC Requirements*
    - *Mandatory*
    - *Prescriptive*
- *ECBC Compliance Forms*

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ECBC Training Workshop

MODULE 7:
Electrical Power

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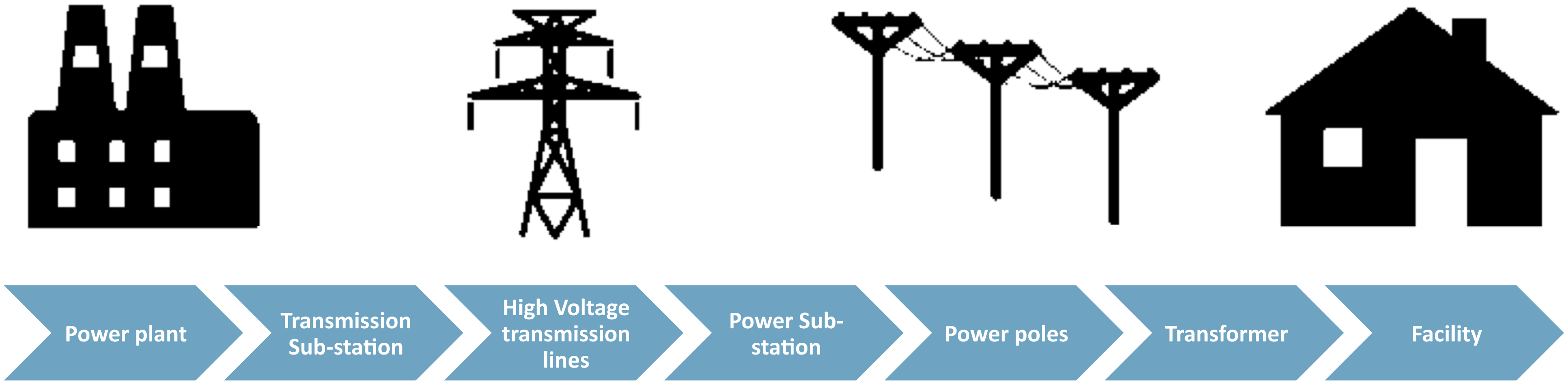
Electrical Power: Outline

- Introduction
- Transformers
- Electric Motors
- ECBC Requirements
  - Mandatory
- ECBC Compliance Forms

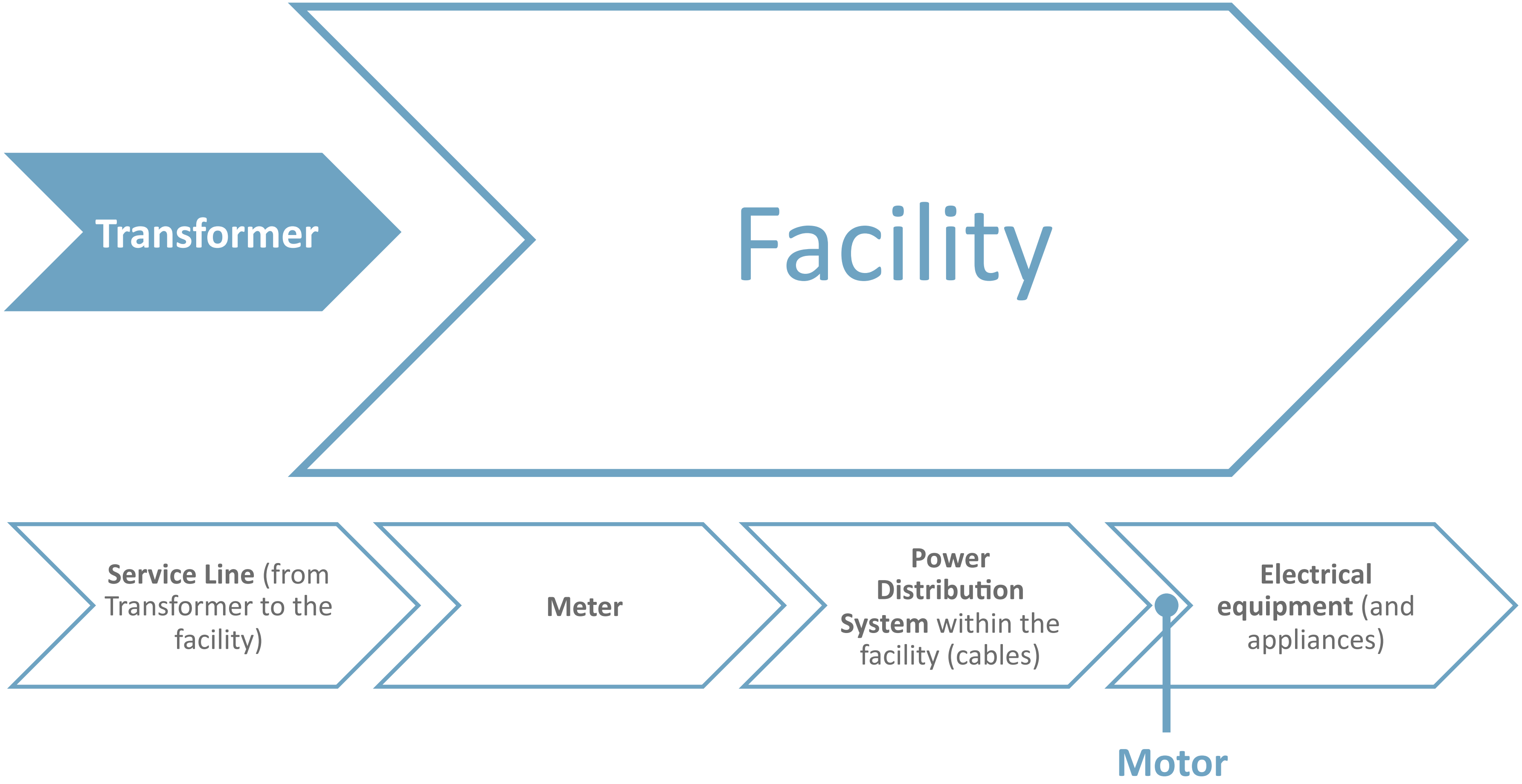
Introduction

ELECTRICAL POWER comprises of all physical components that make up the electric equipment and systems installed in a facility

Power Distribution System



Introduction



Transformers

Device to either increase (Step-up) or decrease (Step-down) the input supply voltage

Power plant → Transformer → User

High-tension voltage (400kV-33kV)
- *Reduced conductor size and investment on conductors*
- *Reduced transmission losses and voltage drop*

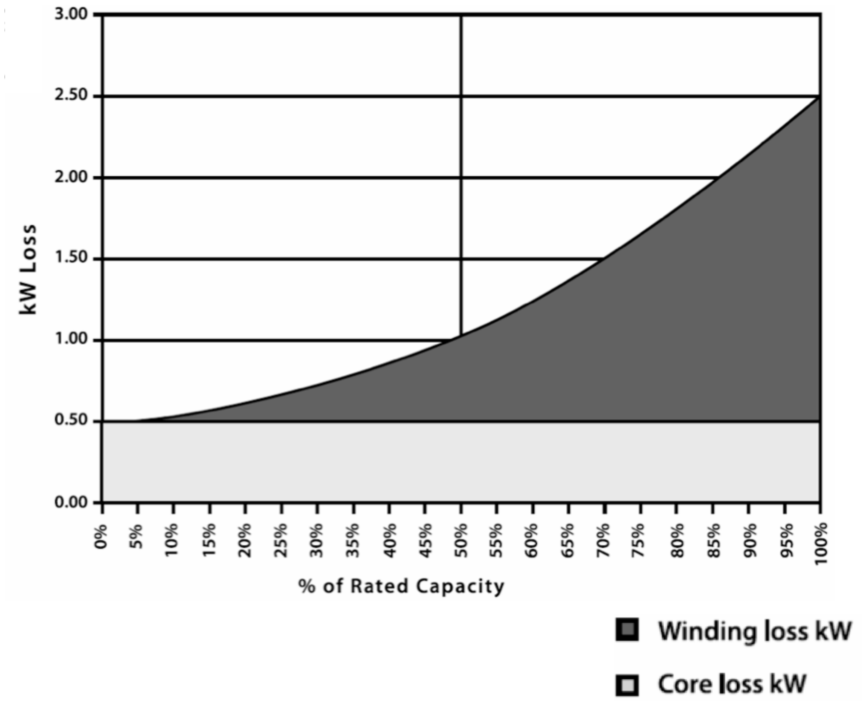
Voltage stepped-down (11kV-230V) for power supply distribution to various sections and equipment

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

Transformers

Efficiency

- varies anywhere between 96 to 99%.
- depends on the design and operating load
- Transformer losses consist of two parts:
  - No-load Loss: Occurs whenever the transformer is energized & it does not vary with load
  - Load Loss (Copper Loss): Associated with full-load current flow in the transformer windings & varies with the square of the load current ($P=I^2R$)



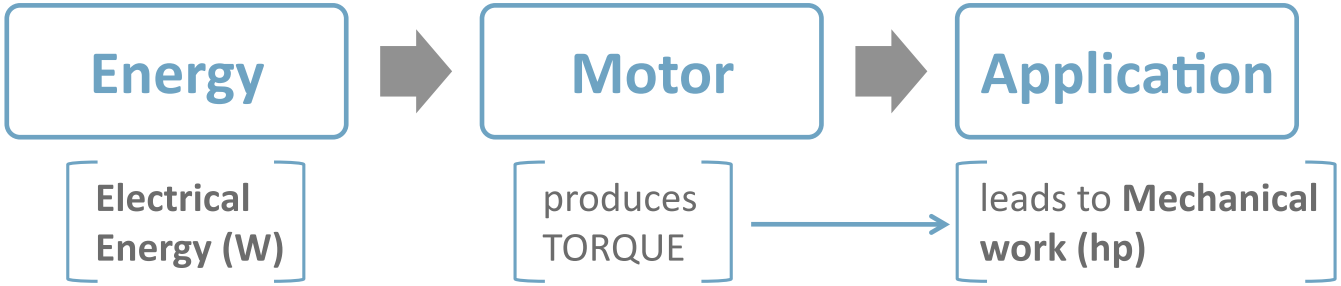
Transformer loss Vs % load

SOURCE: Energy Efficiency in Electrical Utilities, Bureau of Energy Efficiency, 2005

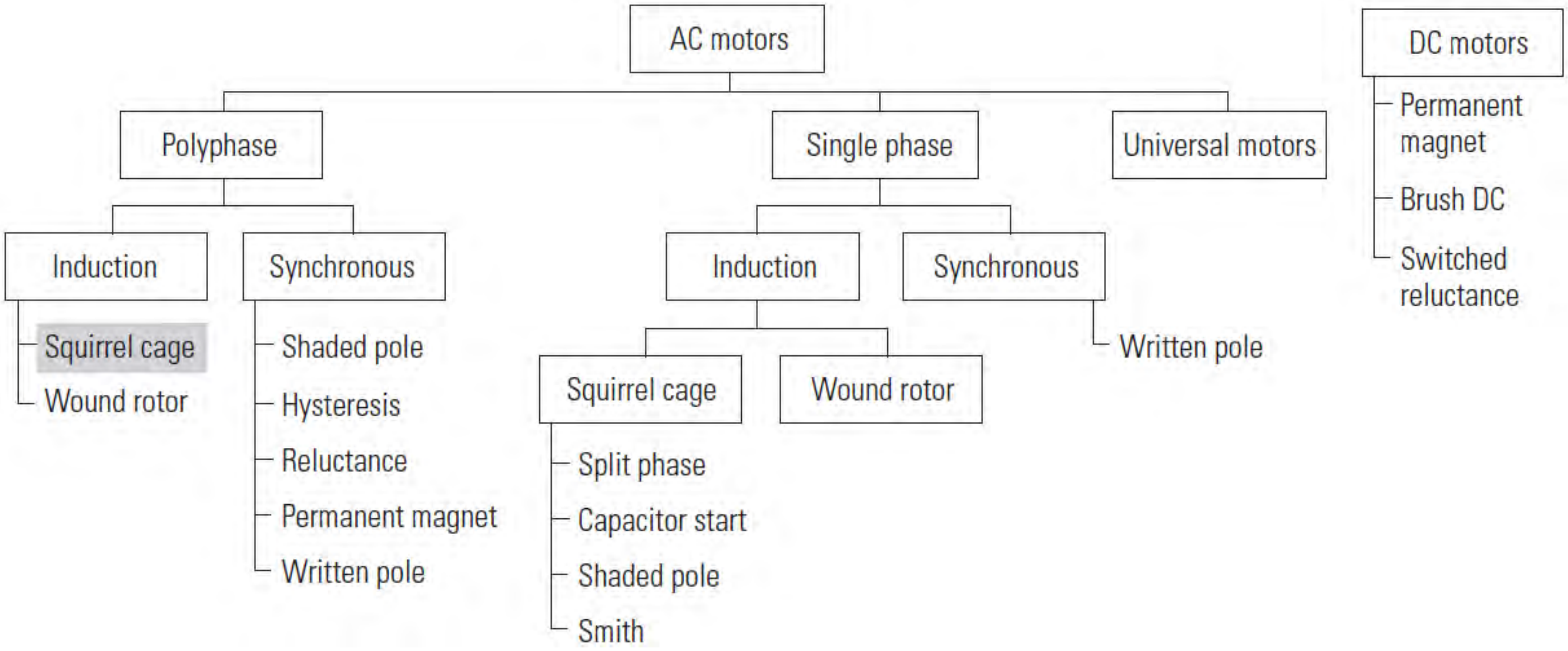
Electric Motors

Device to convert electrical energy into mechanical energy

- Drives equipment such as pumps, blowers and fans, compressors, conveyers and production lines



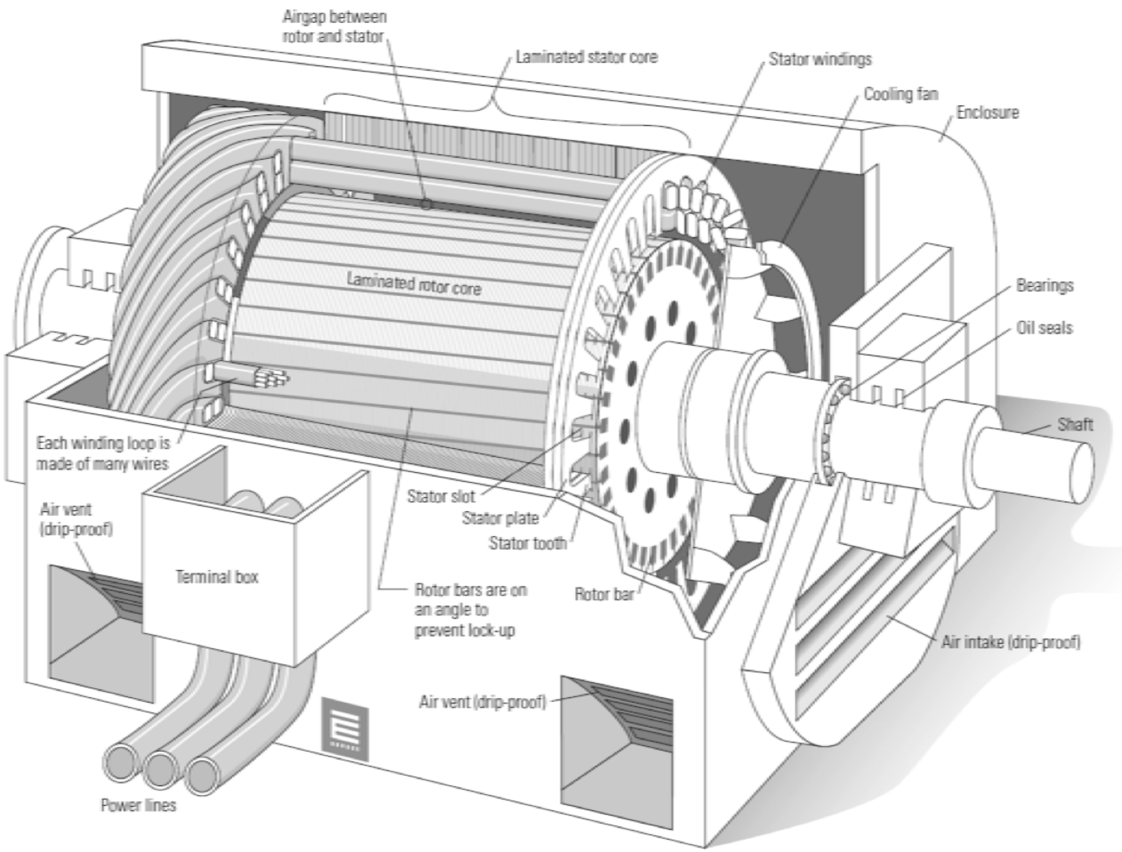
Electric Motors



Types of electric motors

SOURCE: E Source Technology Atlas Series, Volume II DrivePower (1999)

Electric Motors



Electric motor cutaway

SOURCE: E Source Technology Atlas Series, Volume II DrivePower (1999)

Electric Motors

Motor variables

Physical construction characteristics

- enclosure type
- winding pattern
- insulation system
- voltage
- physical dimensions and frame type

Performance characteristics

- single-speed, two-speed, and variable-speed
- startup and operating torque characteristics
- slip
- power factor
- efficiency
- overload capability

Environmental characteristics

- hazardous location
- temperature limit
- caustic and contaminant tolerance
- noise level

SOURCE: E Source Technology Atlas Series, Volume II DrivePower (1999)

Electric Motors

- **Winding:** number of turns of insulated wire, usually copper, wrapped around the core of steel laminations.
- **Rewinding:** a repair technique for induction motors where the old windings are removed and new windings are installed, either in the stator, rotor, or both.

SOURCE: E Source Technology Atlas Series, Volume II DrivePower (1999)

Electric Motors

- **Power Factor:** The ratio between the real power (in watts or kW) and apparent power (the product of the voltage times the current measured in volt-amperes or kVA).

- **Power Factor Correction:** The application of capacitors to compensate the lagging power factor caused by induction motors.

- *Power factor correction (PFC) may be applied either by an electrical power transmission utility to improve the stability and efficiency of the transmission network or, correction may be installed by individual electrical customers*

SOURCE: E Source Technology Atlas Series, Volume II DrivePower (1999)

Electric Motors

Motor input ≠ consumption

- **Motor efficiency**: ratio of the useful mechanical power output to the total electric power input to the motor.
    - ***Nameplate efficiency****: efficiency provided by a motor manufacturer and the nominal efficiency for that motor design. Actual motor efficiency can be above or below this value.*
- Electrical energy input is measured in watts (W), while output is given in horsepower (hp).
- 1 hp = 746 W

SOURCE: E Source Technology Atlas Series, Volume II DrivePower (1999)

Electric Motors

- **Oversizing:** process of system design and hardware selection that results in the selection of a motor (or other component) that is larger than necessary to perform the job.

- Oversized motors that operate at part load are disadvantageous:
  - Reduced efficiency,
  - Reduced slip (important if the load is a cube-law type)
  - Reduced power factor

- Efficiency drops precipitously below 50% load
  - Average 100-hp energy efficient motor losing over two points between 50 and 25% load
  - The average 100-hp standard efficiency induction motor dropping some 5.5 points over the same range

SOURCE: E Source Technology Atlas Series, Volume II DrivePower (1999)

ECBC Requirements: Overview

» ECBC has only **Mandatory requirements** for electric power systems installed in buildings

» The mandatory requirements of the Code, cover the following electrical equipment and systems of building:

- Transformers
- Energy-efficient Motors
- Power Factor Correction
- Electrical Metering and Monitoring
- Power Distribution Systems

ECBC Requirements: Mandatory

Transformers *(Maximum Allowable Power Transformer Losses)*

- Power transformers of the proper ratings and design must be selected to satisfy the **minimum acceptable efficiency at 50% and full load rating**.
- The transformer must be selected such that it **minimizes the total of its initial cost in addition to the present value of the cost of its total lost energy** while serving its estimated loads during its respective life span.

ECBC lists various transformer sizes of dry-type and oil-filled transformers and their associated losses at 50% and full load rating.

ECBC Requirements: Mandatory

Transformers *(Maximum Allowable Power Transformer Losses)*

DRY TYPE TRANSFORMER LOSSES

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

Rating KVA	Max. Losses at 50% loading kW*	Max. Losses at 100% loading kW*	Total losses at 50% loading kW*	Total losses at rated load kW*
	Up to 22 kV class		33 kV class	
100	0.94	2.4	1.12	2.4
160	1.29	3.3	1.42	3.3
200	1.5	3.8	1.75	4
250	1.7	4.32	1.97	4.6
315	2	5.04	2.4	5.4
400	2.38	6.04	2.9	6.8
500	2.8	7.25	3.3	7.8

ECBC Requirements: Mandatory

Transformers *(Maximum Allowable Power Transformer Losses)*

OIL FILLED TRANSFORMER LOSSES

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

Rating KVA	Max. Losses at 50% loading kW*	Max. Losses at 100% loading kW*	Total losses at 50% loading kW*	Total losses at rated load kW*
	Up to 11 kV class		33 kV class	
100	520	1800	560	1820
160	770	2200	780	2580
200	890	2700	900	3000
250	1050	3320	--	--
315	1100	3630	1300	4300
400	1450	4630	1520	5100
500	1600	5500	1950	6450
630	2000	6640	2300	7600

ECBC Requirements: Mandatory

Transformers *(Measurement and Reporting of Transformer Losses)*

- All measurement of losses shall be carried out by using **calibrated digital meters** of class 0.5 or better accuracy and certified by the manufacturer.

- All transformers of capacity of 500 kVA and above would be equipped with additional metering class **current transformers (CTs)** and **potential transformers (PTs)** additional to requirements of Utilities so that periodic loss monitoring study may be carried out.

ECBC Requirements: Mandatory

Energy Efficient Motors

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

- Motor **horsepower ratings shall not exceed 20% of the calculated maximum load** being served.

- Motor **nameplates shall list the nominal full-load motor efficiencies and the full-load power factor**.

ECBC Requirements: Mandatory

Energy Efficient Motors

- Motor users should insist on **proper rewinding practices** for any rewound motors, **Or**, the **damaged motor should be replaced with a new, efficient one**
- **Certificates** shall be obtained and kept on record indicating the **motor efficiency**. During rewinding of motors, the core characteristics of the motor should not be lost during removal of damaged parts. **After rewinding, a new efficiency test** shall be performed and a similar record shall be maintained.

ECBC Requirements: Mandatory

Power Factor Correction

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

» *Benefits of Power Factor Correction*

- *Reduced power consumption & electricity bills*
- *Improved electrical energy efficiency*
- *Extra kVA availability from the existing supply*
- *Reduced I2R losses from transformer and distribution equipment*
- *Minimized voltage drop in long cables*

» *Ways to correct the power factor*

- *Minimize operation of idling or lightly loaded motors*
- *Avoid operation of equipment above its rated voltage*
- *Replace standard motors as they burn out with energy-efficient motors*
- *Install capacitors in your AC circuit to decrease the magnitude of reactive power*

ECBC Requirements: Mandatory

Check-Metering and Monitoring

- **Services exceeding 1000 kVA** shall have permanently installed **electrical metering to record demand (kVA), energy (kWh), and total power factor.** The metering shall also display current (in each phase and the neutral), **voltage** (between phases and between each phase and neutral), and **Total Harmonic Distortion** (THD) as a percentage of total current

- Services not exceeding 1000 kVA but **over 65 kVA** shall have permanently installed electric **metering to record demand** (kW), **energy** (kWh), and **total power factor** (or kVARh)

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

ECBC Requirements: Mandatory

Power Distribution System Losses

» The power cabling shall be adequately sized as to **maintain the distribution losses not to exceed 1% of the total power usage**.

» **Record of design calculation for the losses** shall be maintained.

» *Advantages of optimally sized distribution system:*
- *Lower heat generation*
- *Increased flexibility of installation*
- *Reduced energy consumption and cost*

ECBC Compliance Forms

ELECTRICAL POWER (Chapter 8)							
MANDATORY PROVISIONS (Section 8.2)							
			8.2.1	Transformers	Provide schedule with transformer losses		
			8.2.2	Motor efficiency	Provide equipment schedule with motor capacity, efficiency		
			8.2.3	Power factor correction	Provide schedule with power factor correction		
			8.2.4	Check metering	Provide check metering and monitoring		

End of MODULE

- *Introduction*
- *Transformers*
- *Electric Motors*
- *ECBC Requirements*
  - *Mandatory*
- *ECBC Compliance Forms*

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MODULE 8:
ECBC Compliance

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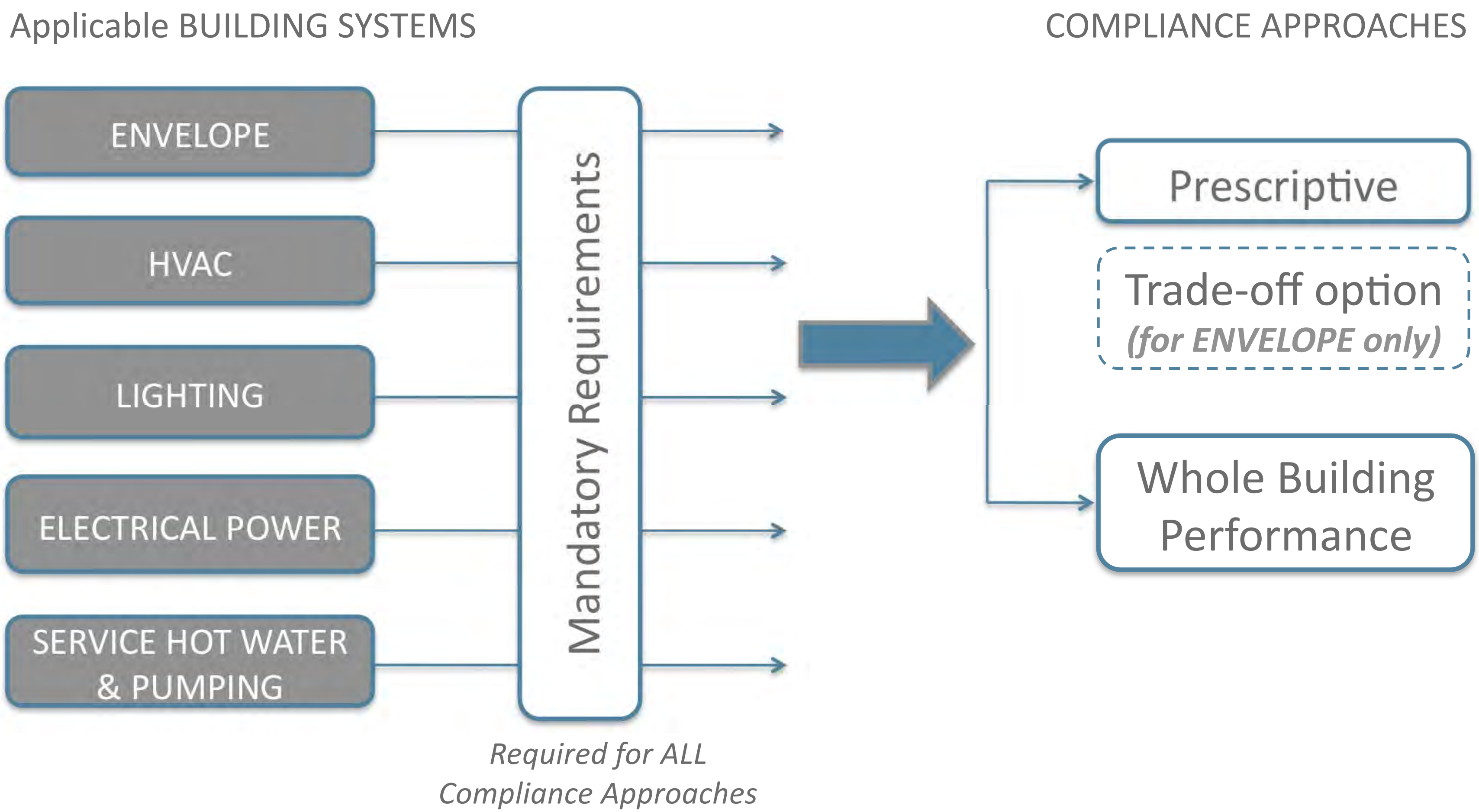
ECBC Compliance: Outline

- **ECBC Compliance Process**
  - Mandatory Requirements
  - Prescriptive Requirements
  - Trade-off Compliance
  - Demonstrating Compliance
  - Whole Building Performance (WBP) Compliance
- **Building Energy Simulation**
- **ECBC Conformance Check Tool**

ECBC Compliance Process



ECBC Compliance Process

Mandatory Requirements

- **Must be met by all buildings**

Prescriptive Requirements

- **Minimum performance criteria for all building systems are set by ECBC**
  Envelope performance varies according to climate zone and building occupancy type
- **Easy to follow method: Does not require expert knowledge**
  Building materials and systems chosen and specified according to ECBC requirements
- **Does not allow flexibility**
  All requirements must be met
- **Does not involve computer simulation**

ECBC Compliance Process

Mandatory Requirements

» Building Envelope

- Rating and determination of U-factor & SHGC using procedures and methods as per referenced standards
- Building sealing requirements

» Heating, Ventilation & Air Conditioning

System and equipment types, sizes, efficiencies, and controls, piping insulation; duct sealing, insulation and location & system balancing

Prescriptive Requirements

» Building Envelope

Prescribed values of U-factor, Solar Heat Gain Coefficient (SHGC), Visual Light Transmittance (VLT), Wall Window Ratio (WWR) & Skylight Roof Ratio (SRR)

» Heating, Ventilation & Air Conditioning

Economizers and Variable Speed Drives

ECBC Compliance Process

Mandatory Requirements

- **Service Hot Water & Pumping**
  Equipment Efficiencies, Solar Hot Water Heating, Heat Traps, Piping insulation & swimming pool covers
- **Lighting**
  Lighting controls, maximum wattage for exit lights, motion sensors for exterior lighting
- **Electric Power**
  Transformer losses, motor efficiencies, power factor correction and electric metering and monitoring

Prescriptive Requirements

- **Service Hot Water & Pumping**
  None
- **Lighting**
  Maximum wattage allowance for interior and exterior lighting systems
- **Electric Power**
  None

Trade-off Compliance

- **Applicable only to the Building Envelope. All other building systems need to follow the Prescriptive Compliance path.**
- **Offers a flexible alternative to the Prescriptive Compliance of the building envelope**
  - **Involves manual calculation of the Envelope Performance Factor**
  - Envelope Performance Factor (EPF) of proposed design should be less than that of standard design, even if individual components do not comply prescriptively
  - *For example, shading devices help achieve a lower EPF by reducing SHGC*
- **Cost effective alternative for Code compliance**

Envelope Performance Factor (EPF)

$$EPF_{Total} = EPF_{Roof} + EPF_{Wall} + EPF_{Fenest}$$

$$EPF_{Roof} = C_{Roof} \sum_{S=1}^{n} U_S A_S$$

$$EPF_{Wall} = C_{Wall,Mass} \sum_{S=1}^{n} U_S A_S + C_{Wall,Other} \sum_{S=1}^{n} U_S A_S$$

$$EPF_{Fenest} = C_{1Fenest,\,North} \sum_{W=1}^{n} SHGC_W M_W A_W + C_{2\,Fenest,\,North} \sum_{W=1}^{n} U_W A_W +$$
$$C_{1Fenest,\,NonNorth} \sum_{W=1}^{n} SHGC_W M_W A_W + C_{2\,Fenest,\,NonNorth} \sum_{W=1}^{n} U_W A_W +$$
$$C_{1Fenest,\,Skylight} \sum_{S=1}^{n} SHGC_S M_S A_S + C_{2\,Fenest,\,Skylight} \sum_{S=1}^{n} U_S A_S$$

where

EPF_{Roof}	:	Envelope performance factor for roofs. Other subscripts include walls and fenestration.
A_s, A_w	:	The area of a specific envelope component referenced by the subscript "s" or for windows the subscript "w".
$SHGC_w$	:	The solar heat gain coefficient for windows (w). SHGCs refers to skylights.
M_w	:	A multiplier for the window SHGC that depends on the projection factor of an overhang or sidefin.
U_s	:	The U-factor for the envelope component referenced by the subscript "s"
C_{Roof}	:	A coefficient for the "Roof" class of construction
C_{Wall}	:	A coefficient for the "Wall"
$C_{1\ Fenest}$	:	A coefficient for the "Fenestration 1"
$C_{2\ Fenest}$	:	A coefficient for the "Fenestration 2"

Values of "C" are taken from Table 12.1 through Table 12.5 for each class of construction.

Demonstrating Compliance

ECBC compliance is demonstrated on plans and specifications that show all pertinent data and features of the building, equipment, and systems in detail. Details shall include, but are not limited to:

» Building Envelope:

- Insulation materials and their R-values
- Fenestration U-factors, SHGC, visible light transmittance (if using the trade-off approach), and air leakage
- Overhang and side-fin details
- Envelope sealing details

» Heating, Ventilation & Air Conditioning (HVAC):

- Type of systems and equipment, including their sizes, efficiencies, and controls
- Economizer details
- Variable speed drives
- Piping insulation
- Duct sealing
- Insulation type and location
- Report on HVAC balancing

Demonstrating Compliance

» **Service Hot Water and Pumping:**

- Solar water heating system details

» **Lighting:**

- Schedules that show type, number, and wattage of lamps and ballasts
- Automatic lighting shutoff details
- Occupancy sensors and other lighting control details
- Lamp efficacy for exterior lamps

» **Electrical Power:**

- Schedules that show transformer losses, motor efficiencies, and power factor correction devices
- Electric check metering and monitoring system details

Whole Building Performance (WBP) Compliance

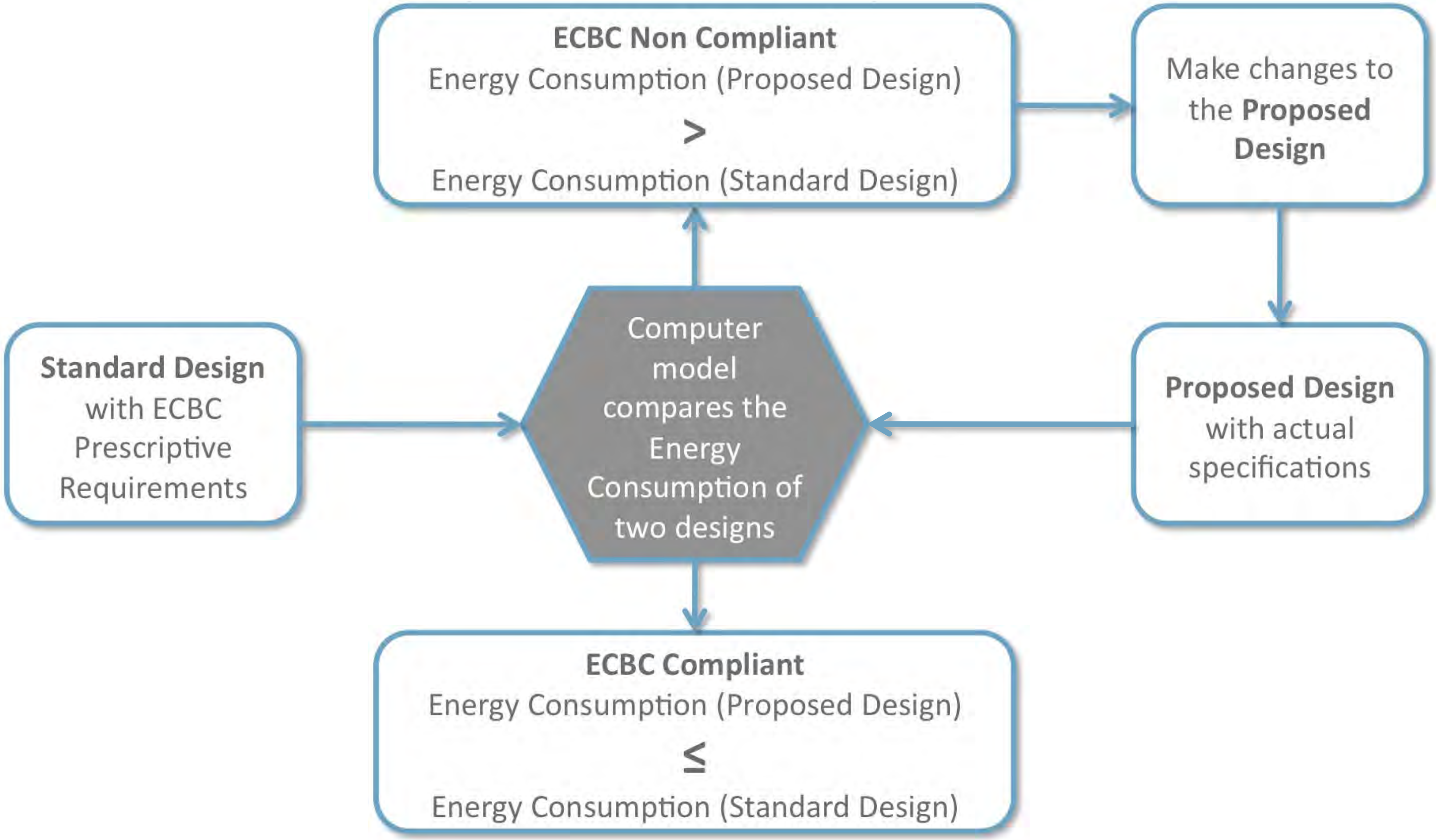
» **WBP should be followed:**
  - When the building doesn't comply via other methods
  - To allow design flexibility/ innovation
  - To evaluate viability of alternative Energy Conservation Measures (ECMs)

» **Use of building energy simulation is necessary to show compliance with ECBC via Whole Building Performance method**

» **For Code compliance**

Energy Use of Proposed Design < Energy Use of Standard Design

WBP Compliance Process



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

Demonstrating Compliance using WBP

Documentation requirements as per ECBC:

- The annual energy use for the *Proposed Design and the Standard Design.*
- A list of the energy-related building features in the *Proposed Design that is different from the Standard Design.*
- The input and output report (s) from the simulation program *[including a breakdown of energy usage by at least the following components: lights, internal equipment loads, service water heating equipment, space heating equipment, space cooling and heat rejection equipment, fans, and other HVAC equipment (such as pumps)].* The output reports shall also show the amount of time any loads are not met by the HVAC system for both the *Proposed Design and Standard Design.*
- An explanation of any error messages noted in the simulation program output.

Building Energy Simulation

"Energy simulation is a computer-based analytical process that allows building owners and designers to evaluate the energy performance of the building and make it more energy efficient by making necessary modifications in the design before the building is constructed. "

SOURCE: ECBC Tip Sheet: Energy Simulation, USAID ECO-III Project, New Delhi

Energy Simulation Considerations

Energy performance is predicted by taking into account:

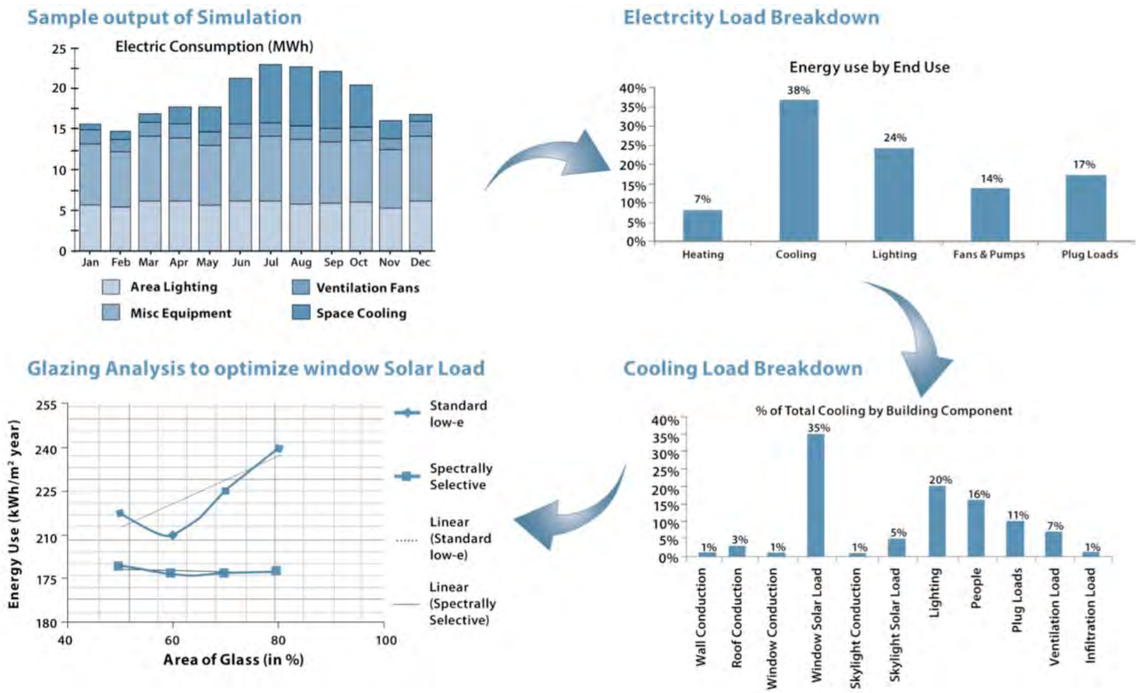
- Building geometry and orientation
- Building materials
- Building façade design
- Weather parameters
- Indoor environmental conditions
- Occupant activities and schedules
- Heating, Ventilation and Air Conditioning (HVAC)
- Lighting system

Integration of Computer Simulation & Architectural Design

Stage	Architectural Design	Energy Simulation
Concept Design/ Program	Climate, Indoor environmental conditions	Weather data
	Orientation and shape	Sun path diagram
	Building siting, usable floor space	Solar analysis
	Building massing	Mutual shading
	Operating schedule, ventilation rates	Proper zoning
Simple model geometry; Rule of thumb calculations, % opening (WWR)	Basic equipment options, peak and schematic	Monthly/annual simulation
Schematic Design/ Design Development	Geometry: *Walls/opening/projections/ volumes/ design elements, elevation*	Sensitivity analysis: Zoning the building by system types with surface information; Integration of loads, advanced fenestration calculations, full interior and exterior solar distribution
	Services: *Types and placement of systems (structural design, HVAC design/selection, electrical lighting, plumbing)*	
	Programming schedule: *Activity type/ occupancy, controls*	Hourly simulation
Construction	Tender drawings, system specifications, material selection, working drawings	Energy Conservation Measures (ECM)s and payback

SOURCE: ECBC Tip Sheet: Energy Simulation, USAID ECO-III Project, New Delhi

Simulation Program Outputs



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Area Lights	5.53	5.24	6.05	6.04	5.53	6.04	6.05	5.79	5.78	5.79	5.26	6.05	69.16
Misc. Equipment	7.58	7.04	7.99	7.87	7.58	7.87	7.99	7.79	7.67	7.79	7.27	7.99	92.43
Ventilation Fans	1.61	1.53	1.77	1.77	1.61	1.77	1.77	1.69	1.69	1.69	1.53	1.77	20.17
Space Cooling	0.62	0.96	1.16	2.22	3.13	5.72	7.23	7.37	6.96	5.1	2.32	0.86	43.66
Total	15.34	14.77	16.97	17.9	17.85	21.4	23.04	22.64	22.22	20.37	15.38	16.67	225.42

SOURCE: ECBC Tip Sheet: Energy Simulation, USAID ECO-III Project, New Delhi

Tips for Energy Simulation

How Accurate are Computer Simulations?

- Range of Simulation Capabilities
- Accuracy of Component Simulation
- Number of Calculation Intervals
- Weather Data
- Number of Zones
- Equipment Defects and Unpredictable Behavior
- Program Errors
- Input Errors and Misunderstandings

How to Catch Errors

- Read the Output in Detail
- Check Reasonableness of Capacity Calculations
- Use Sensitivity Analysis
- Analyze the Relative Performance of Dummy Configurations
- Compare to Measured Energy Consumption

SOURCE: ECBC Tip Sheet: Energy Simulation, USAID ECO-III Project, New Delhi

Simulation Tools: Challenges

- Availability of weather data
- Availability of thermo-physical properties
- Correct performance value of assembled building material
- Inputs can be voluminous and output reports can be complex to infer
- Many detailed tools are research-oriented
- Graphical user interfaces of many tools are yet to become mainstream
- The skill and experience required

ECBC Conformance Check Tool

ECBC Conformance Check Tool

Introduction

- assists the user in finding out if the building conforms to the requirements of ECBC, keeping in view five climatic zones in India as specified in ECBC
- assesses the overall conformance of building as well as its major building systems which include Building Envelope, HVAC, Lighting, Service Water Heating & Pumping and Electrical Power Systems
- has been developed as a web-based application to ensure that it reaches a wide spectrum of users across the country

ECBC Conformance Check Tool

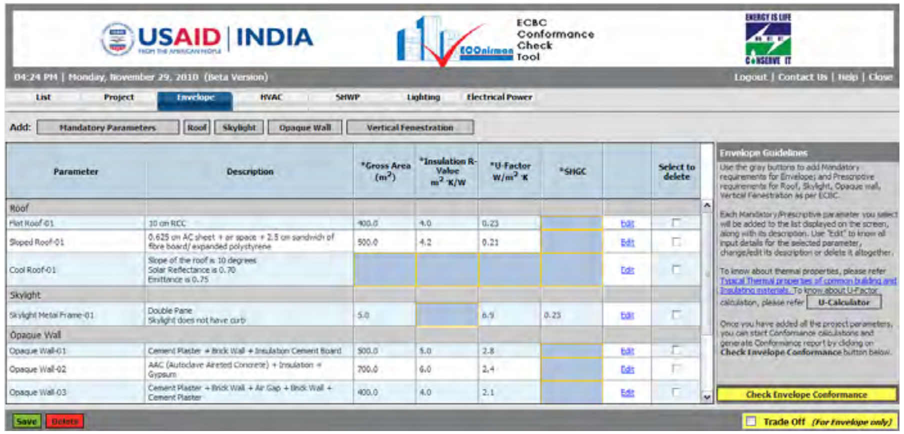
Salient features

- assesses the conformance of the building based on mandatory and prescriptive requirements
- offers the option of checking the conformance of building envelope through "Trade-off Method"
- generates Building's ECBC Conformance Report which compiles data fed by the user and also indicates which systems and sub-systems of the building are 'conforming' or 'not conforming' to ECBC
- has the option of including data on a number of building projects which can be saved under a single user profile
- stores information in a central database for future reference, review, editing and analysis by the user and can provide assistance in case of loss of authentication information
- is available in public domain for easy access to the users (www.buildingenergytools.in/econirman)

ECBC Conformance Check Tool

ECOnirman User Manual

ECO-III has also developed ECOnirman User Manual that provides assistance for on-line submission of data and generation of building conformance report. It can be downloaded from http://eco3.org/ECOnirman-User-Manual.pdf



Envelope Conformance Summary

Envelope Component	Conformant	Non-Conformant	Conformance Status
Walls	4	0	Yes
Roofs	3	0	Yes
Vertical Fenestration	2	0	Yes
Skylights	2	0	Yes

End of MODULE

- ***ECBC Compliance Process***
  - *Mandatory Requirements*
  - *Prescriptive Requirements*
  - *Trade-off Compliance*
  - *Demonstrating Compliance*
  - *Whole Building Performance (WBP) Compliance*
- ***Building Energy Simulation***
- ***ECBC Conformance Check Tool***

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