GGGI

ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy

3.3 Understanding Operational Energy in Buildings

November 2024

Supported by:

Federal Ministry for Economic Affairs and Climate Action

IKI INTERNATIONAL CLIMATE INITIATIVE

on the basis of a decision by the German Bundestag

WHAT WILL YOU LEARN?

01 Operational energy and its end uses for different services

02 HVAC: Basics and commonly-used systems

03 Lighting: Basics and commonly-used systems

04 Commonly-used systems for other services

05 Operational energy indices

06 Energy star rating for buildings and key appliances

BUILDING OPERATIONAL ENERGY

The energy used for operating equipment in a building

Operational energy of buildings is the energy in the form of electricity and fuels for operating various equipment for providing comfortable room conditions for the occupants and operate various building equipment

HVAC equipment: Heating, ventilation and air-conditioning equipment to maintain comfortable indoor temperature and air quality

Electric lighting: Artificial lighting system to perform task when daylight is not sufficient or available

Hot water systems: Electric or fuel-fired equipment providing hot water for bathing, cooking, laundry, cleaning, etc.

Appliances: Refrigerators, deep freezers, computers, printers, projectors, television sets, etc.

Other services: Elevators, escalators, water pumps, kitchen and pantry appliances, etc.

OPERATIONAL CARBON

Emissions associated with operational energy use

$$Operational\ carbon\ (kgCO_2e) = Total\ Opertional\ energy\ usage\ (kWh)\ *\ Emission\ factor\ fuel\ used\ \left(\frac{kgCO_2}{kWh}\right)$$

- In most cases, the fuel used is grid electricity, thereby emission factor of grid electricity for the particular country is considered
- For other fuels, standard emission factors accepted globally are considered

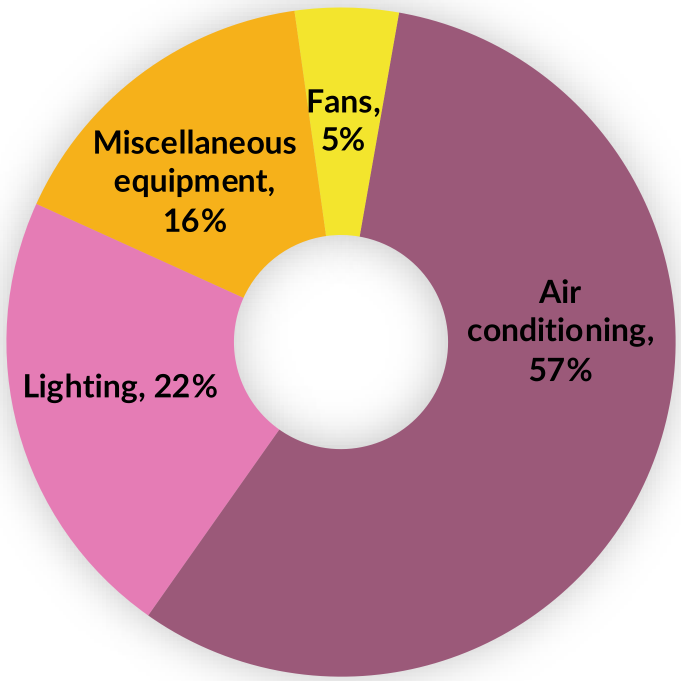
BUILDING OPERATIONAL ENERGY

End-use energy distribution in commercial buildings

Typically, in an air-conditioned commercial building, the energy consumption has four major components:

i. HVAC system (50%–70%)
ii. Lighting (5%–20%),
iii. Appliances (10%–20%)
iv. Ventilation and exhaust fans (1%–5%)

End-use energy distribution in a typical commercial building



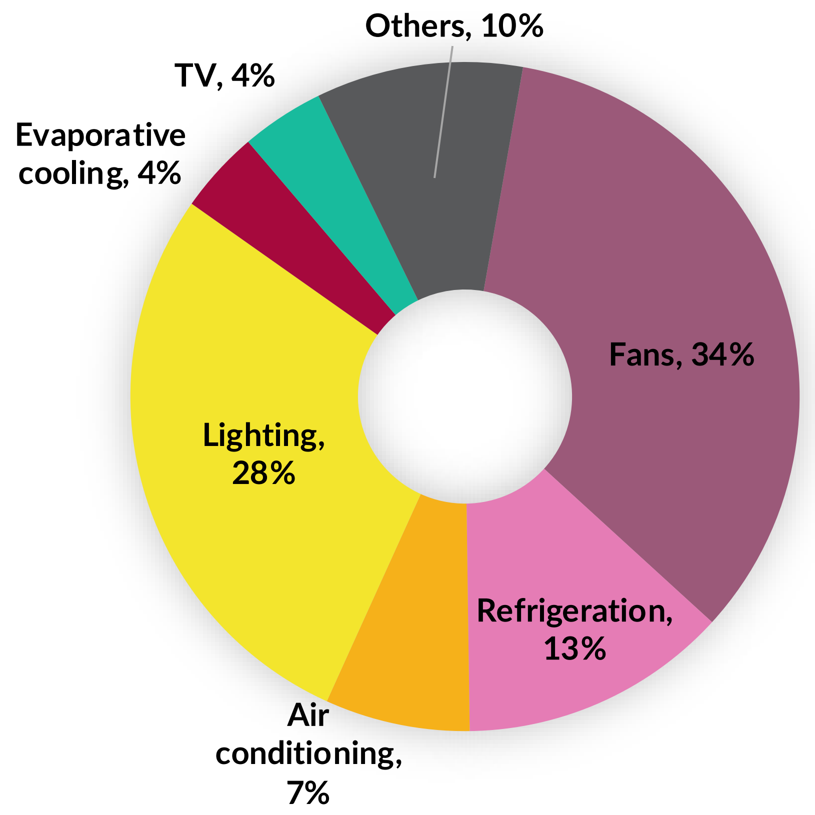
BUILDING OPERATIONAL ENERGY

End-use energy distribution in residential buildings

In India, studies of end uses in residential buildings show the following estimates:

- Energy for thermal comfort (air conditioning, evaporative coolers and fans) is about 45%
- Lighting is the second large end use accounting for about 28%
- Other appliances (including television sets, refrigerators, water heaters and various appliances) account for about 27%

End-use energy distribution in a typical residential building



Source: Bureau of Energy Efficiency, Government of India

HVAC

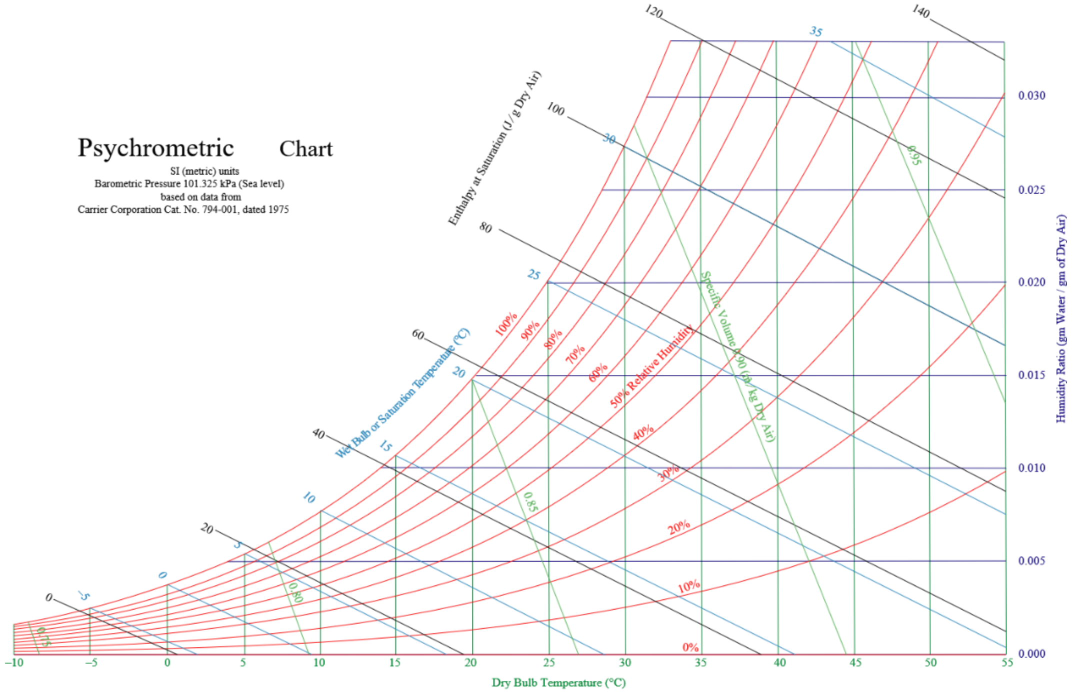
Basics and Commonly-used Systems

Image source: https://envigaurd.com/topics/what-is-hvac-

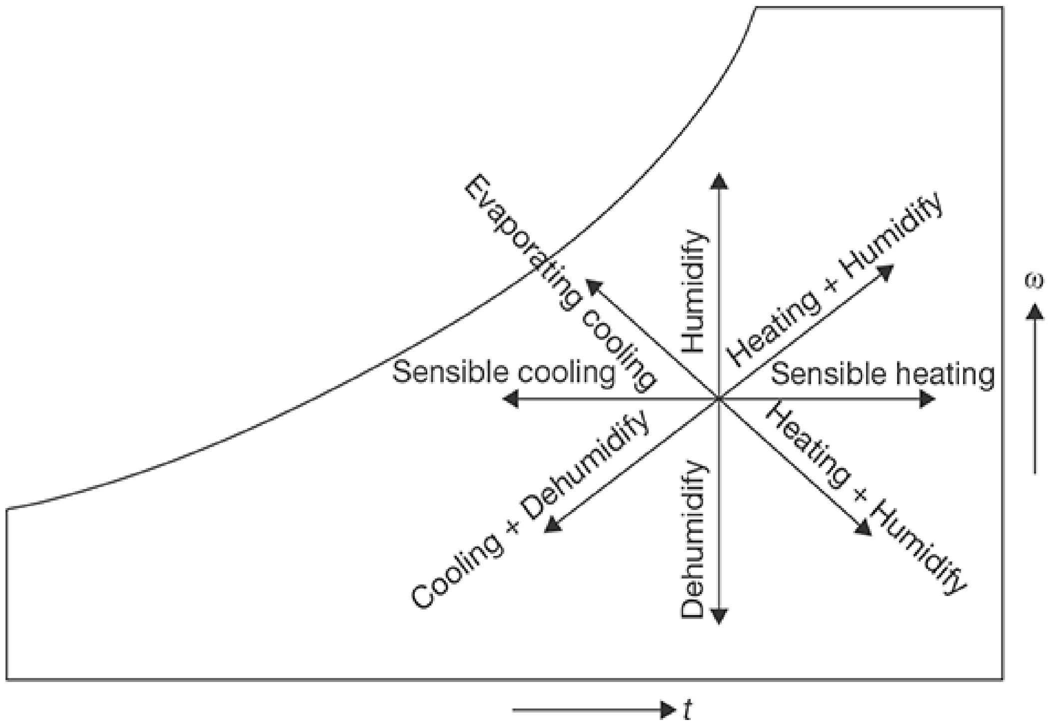
AIR PROPERTIES

Understanding condition of air on the psychrometric chart

A psychrometric chart is a family of graphs that shows the properties of air – dry bulb temperature, wet bulb temperature, relative humidity, dew point temperature, humidity ratio, total heat content (enthalpy) and specific volume at a specific barometric pressure



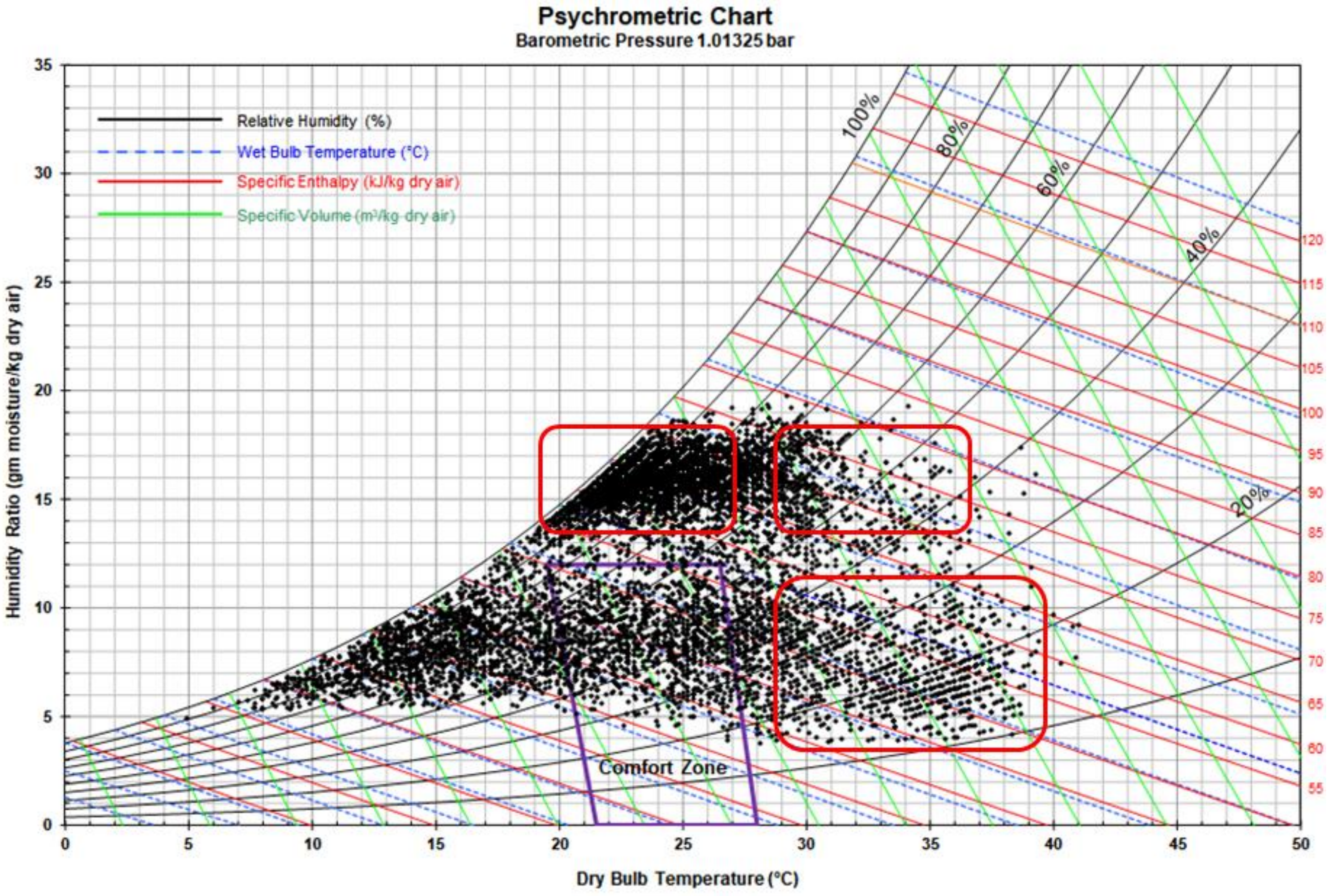
It is important to assess thermal comfort and understand the process of cooling, heating, dehumidification and humidification of air properties



THE NEED FOR HVAC

An example of Pune, India: Ambient conditions

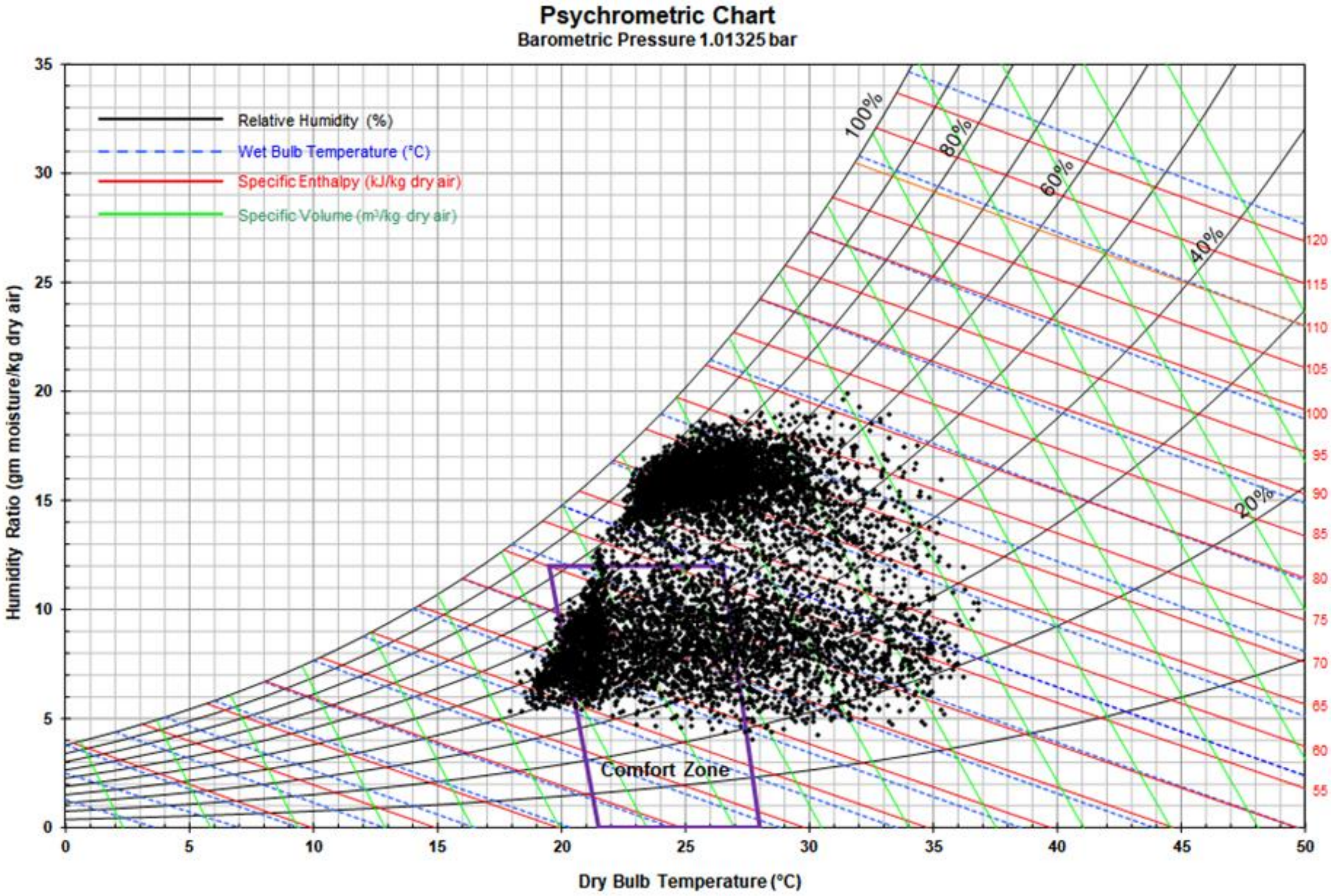
On an annual basis, the ambient conditions (indicated by black dots) are outside the human thermal comfort zone for a significant duration of the time



THE NEED FOR HVAC

Room conditions inside the building without HVAC

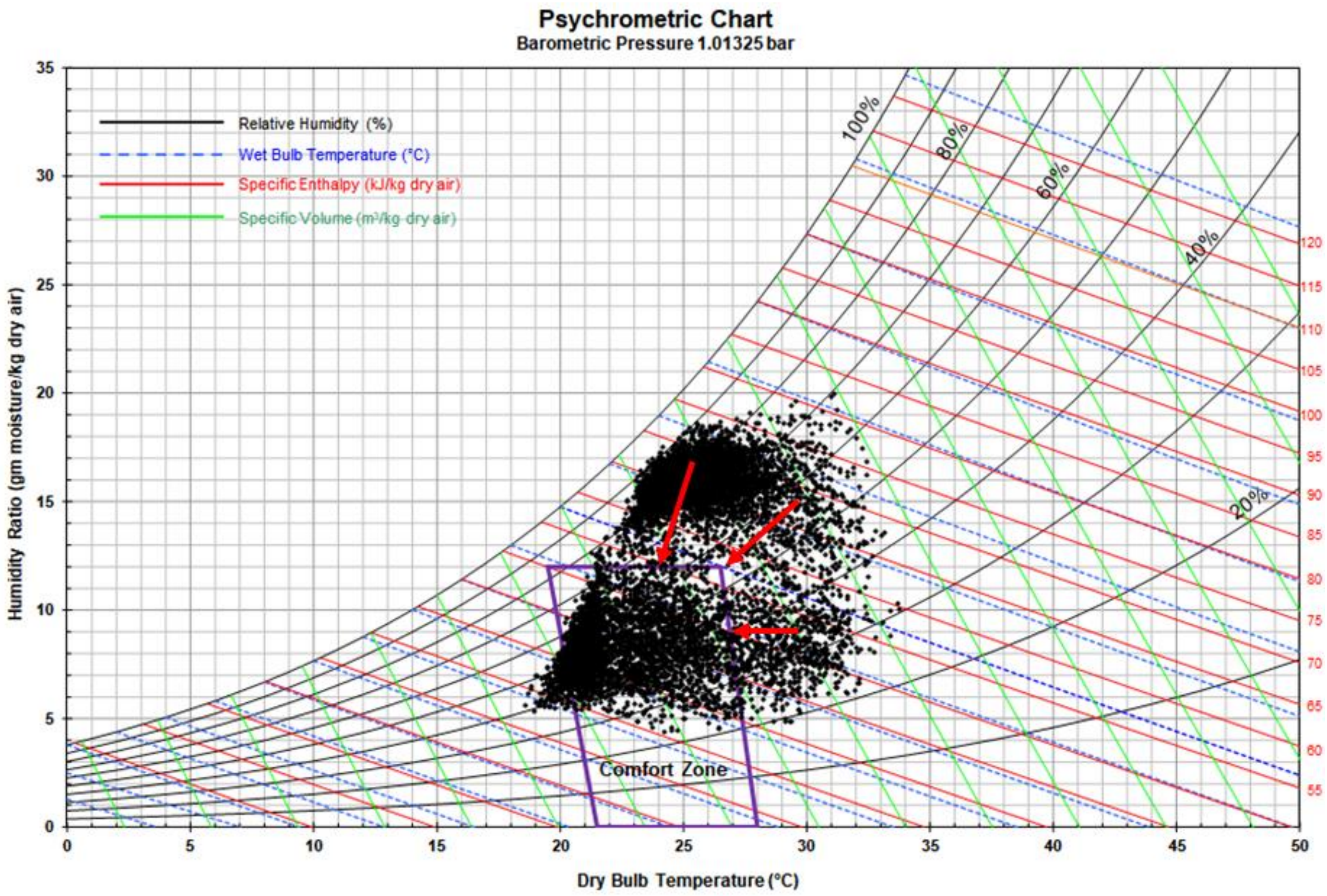
- Even with a business-as-usual building design, the conditions inside the building, compared to the ambient conditions, have less variations (observe the higher density of black dots in the comfort zone)
- However, for significant duration of time, the inside conditions fall outside the thermal comfort zone



UNDERSTANDING THE NEED FOR HVAC

Room conditions with passive architectural measures

- Passive architectural measures help in partially moving inside conditions toward the thermal comfort zone
- Still, a significant portion of time duration will remain outside the thermal comfort zone
- **HVAC systems are needed to ensure that the entire time duration is within the comfort zone**



AIR CONDITIONING

Objectives

- Remove sensible heat from a confined place to maintain constant temperature inside the space
- Remove water (latent heat) from a confined space to maintain constant humidity inside the space
- Remove dust generated and contaminants in a confined space by air-sweeping
- Prevent dust and atmospheric contaminations from entering into a confined space
- Prevent microbial growth and cross-contamination between spaces

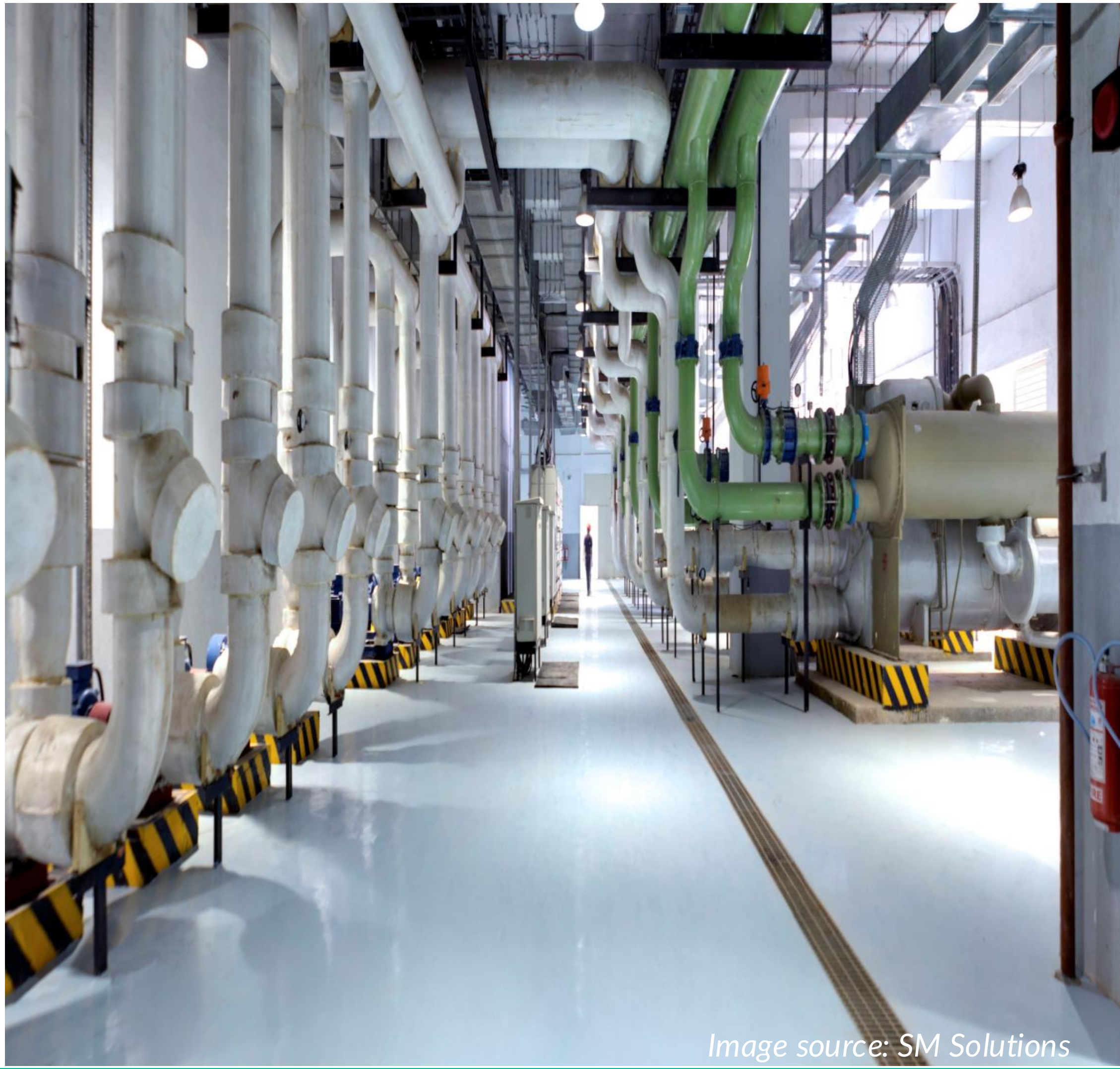
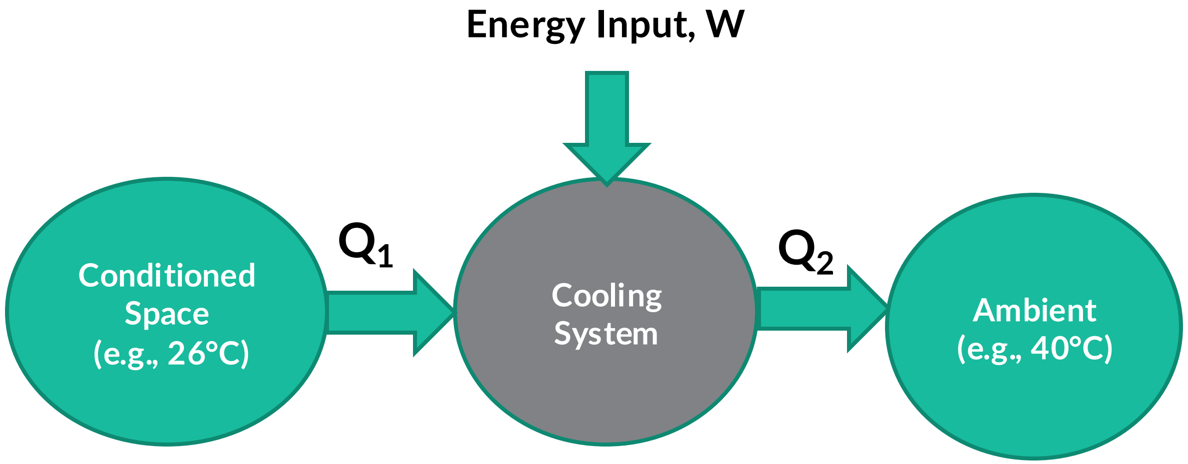


Image source: SM Solutions

TYPICAL COOLING AND HEATING SYSTEMS

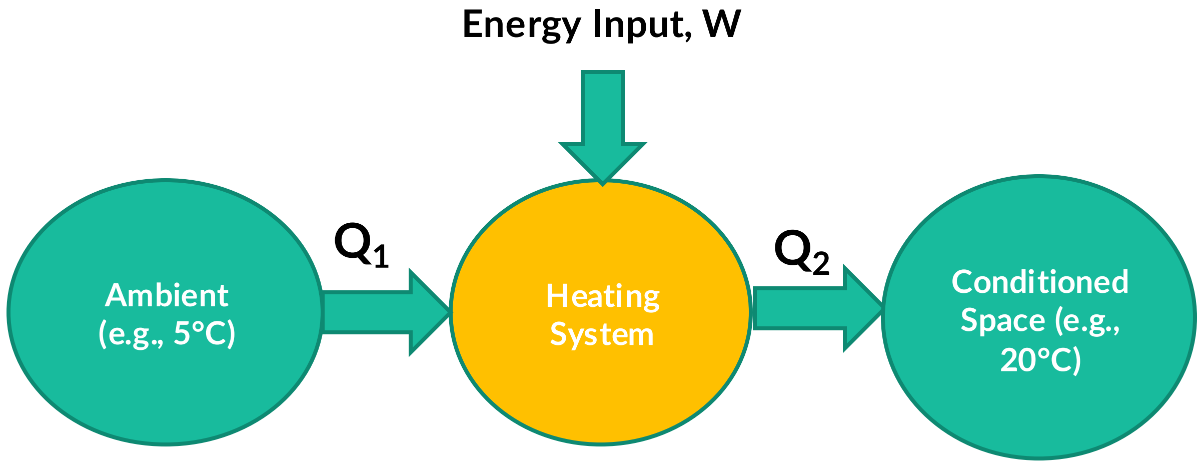
Basic heat balance and figure of merit

- Typical cooling uses some amount of energy (work) to move heat from low temperature to high temperature
- The figure of merit for assessing the efficiency is the coefficient of performance (COP)



$$Energy\ Balance,\ Q_1 + W = Q_2$$

$$Coefficient\ of\ Performance\ (COP) = \frac{Desired\ effect}{Required\ Input} = \frac{Q_1}{W}$$



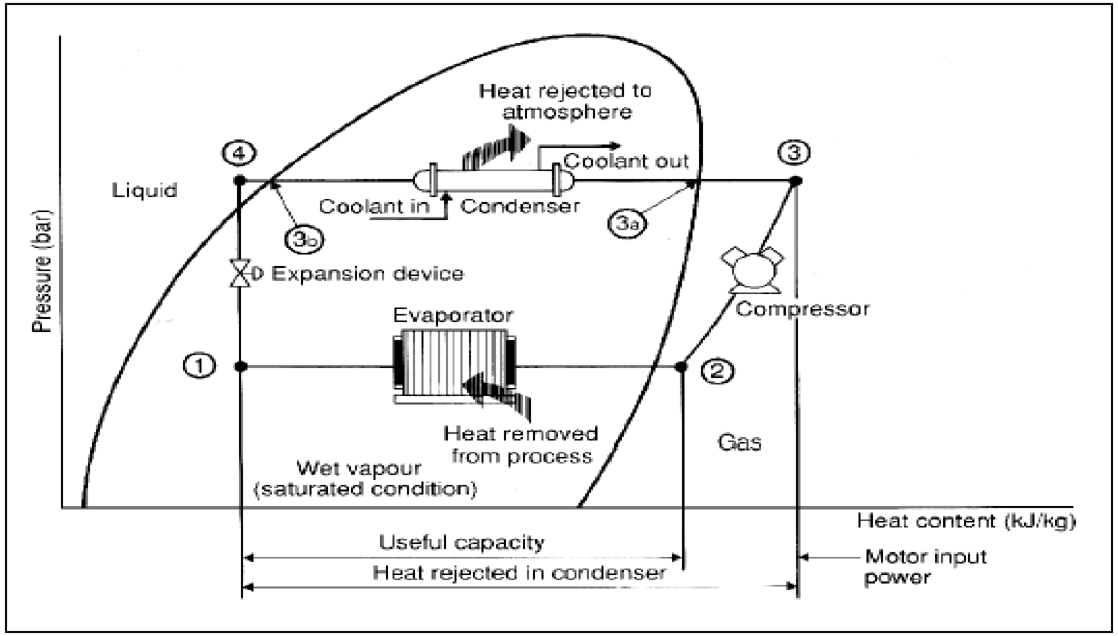
$$Energy\ Balance,\ Q_1 + W = Q_2$$

$$Coefficient\ of\ Performance\ (COP) = \frac{Desired\ effect}{Required\ Input} = \frac{Q_2}{W}$$

VAPOR COMPRESSION SYSTEM

Understanding the thermodynamics

- Heat naturally flows from higher to lower temperature. However, in refrigeration, heat must be transferred from a lower temperature to the ambient at a higher temperature. The second law of thermodynamics says that for transferring heat from a lower temperature to a higher temperature, work must be done
- In a vapor compression refrigeration system, this work is done by the condenser. The figure shows the vapor compression process on a pressure – enthalpy (or heat content) diagram:
  - Refrigerant evaporates in the evaporator at low temperature and pressure to chill water or air (1–2)
  - The vaporized refrigerant gas is compressed to raise its pressure and temperature above ambient temperature (2–3)
  - The heat is rejected to the atmosphere in water-cooled or air-cooled condenser, resulting in the condensation of the refrigerant gas into liquid at high pressure and low temperature (3–4)
  - The high pressure, low temperature liquid refrigerant from the condenser returns to the low pressure evaporator, resulting in evaporation of the refrigerant, providing cooling; the cycle repeats



Pressure – enthalpy (heat content) diagram

AIR-CONDITIONING (AC) SYSTEMS

Typical equipment and configurations

- Window air-conditioners
- Split ductable / non-ductable systems
- VRV ductable / non-ductable systems
- Centralized AC systems comprising of:
  - The chiller (chilled water generator)
  - Chilled water storage and pumping system
  - Air handling units (AHUs)
  - Ducting of air and its filtration

Window air conditioner

Split air conditioner

VRV AC system

Centralized AC system

SMALL COOLING SYSTEMS

Window and split air conditioners

Window air conditioner

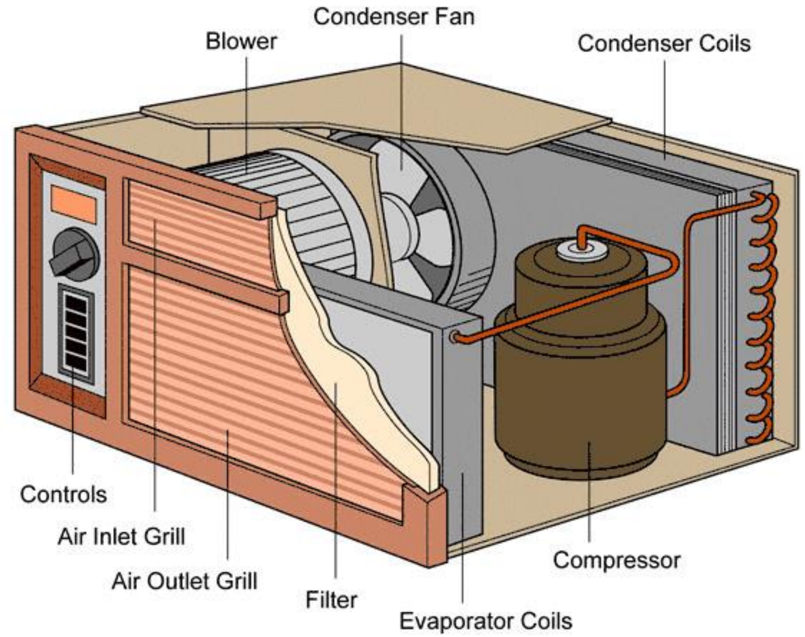


Image source: https://www.hometips.com/how-it-works/air-conditioners-room-window.html

Split air conditioner

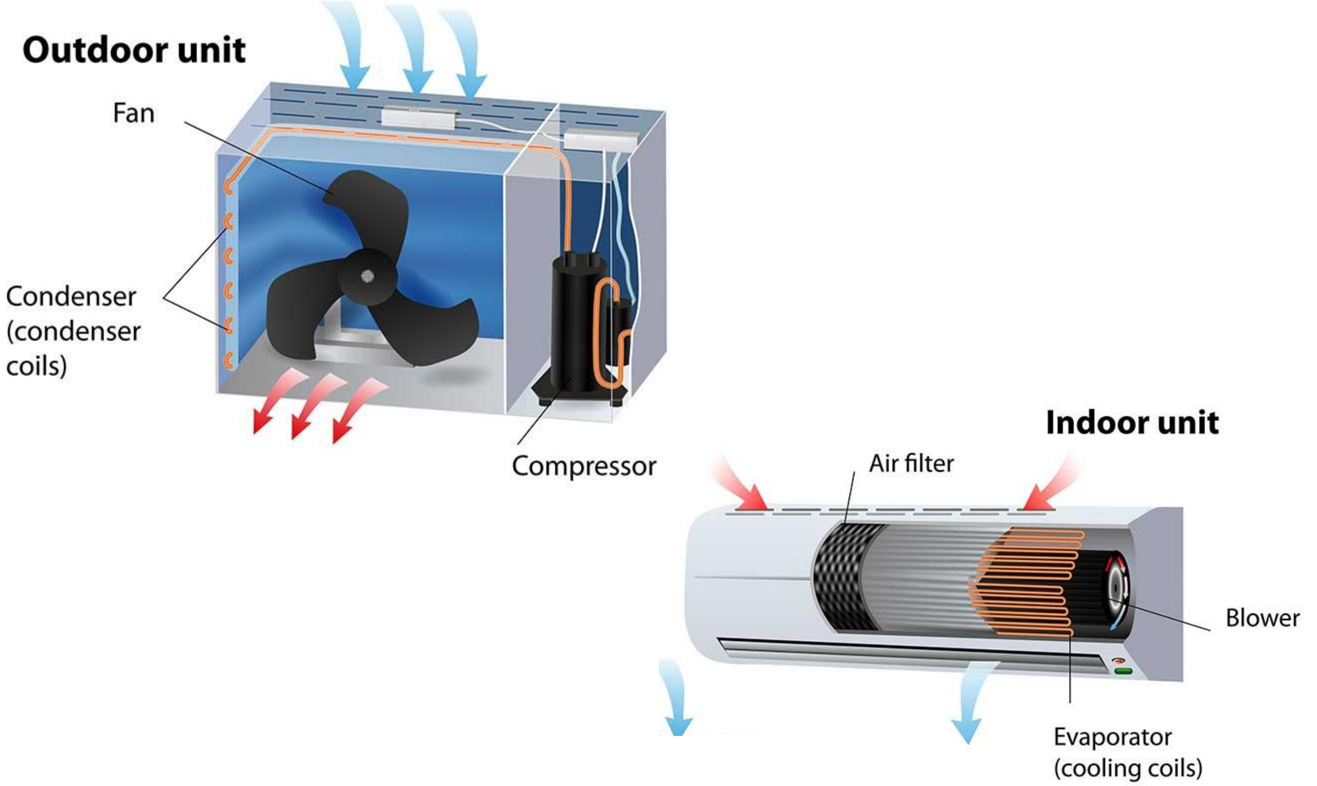


Image source: https://bprassets.s3.amazonaws.com/blogfiles/assets/images/post/Body%20Pics/05-03-12_images/split-system-indoor-and-outdoor-air-conditioning-units-diagram.jpg

VRF AIR CONDITIONERS

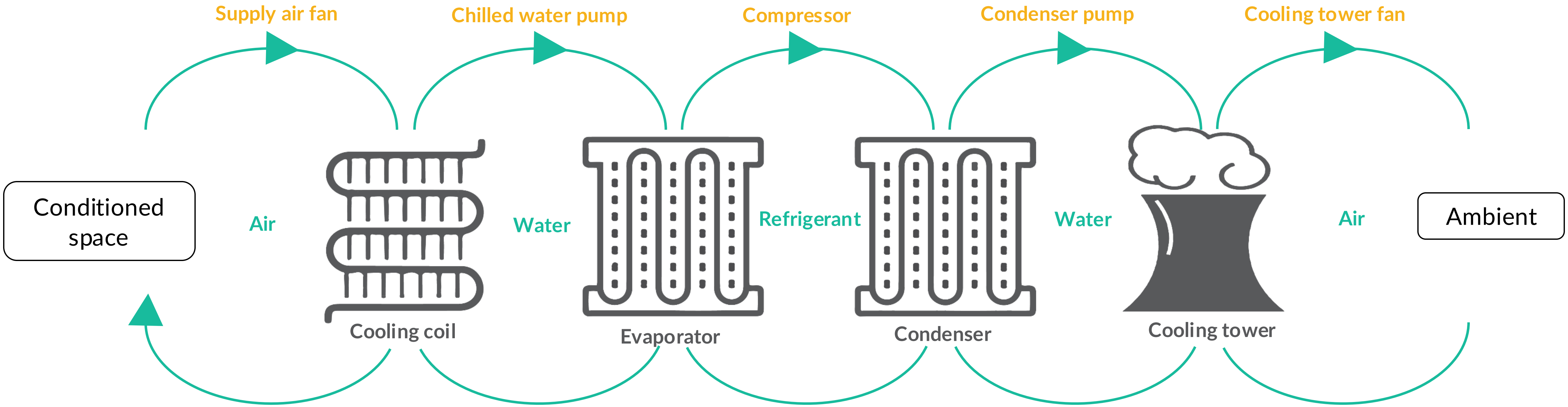
Variable refrigerant flow (VRF) for mid-sized applications

- For addressing variable loads, VRF type DX systems are gaining popularity
- It avoids installation of large ducts in user areas and avoids issues related to managing false ceiling heights
- In the user areas, cassette units or hi-wall units can be installed, depending on convenience of installation
- Even DX type AHUs can be designed to cater to special requirements of high static head and filtration levels

Image source: SM Solutions

CENTRAL COOLING SYSTEM

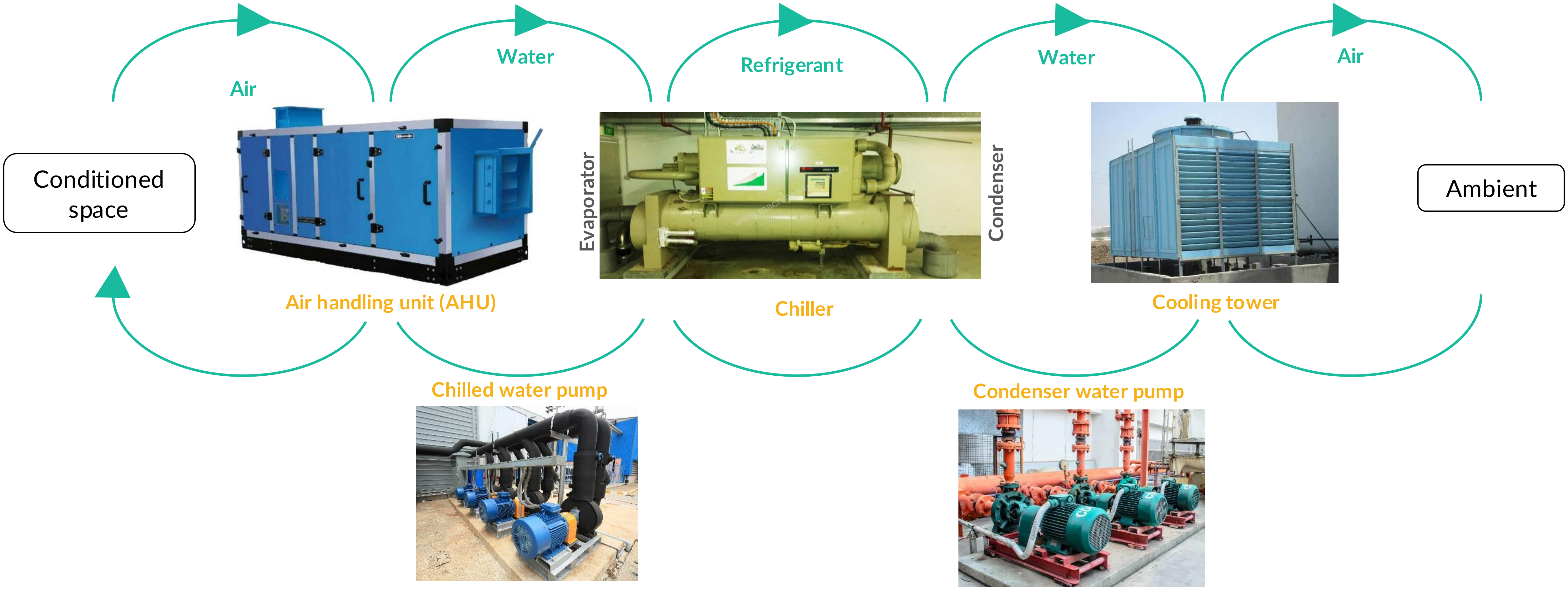
A conceptual overview



Thermodynamically, heat rejected at cooling tower is equal to summation of cooling effect delivered at evaporator and energy consumed by the chiller compressor

CENTRAL COOLING SYSTEM

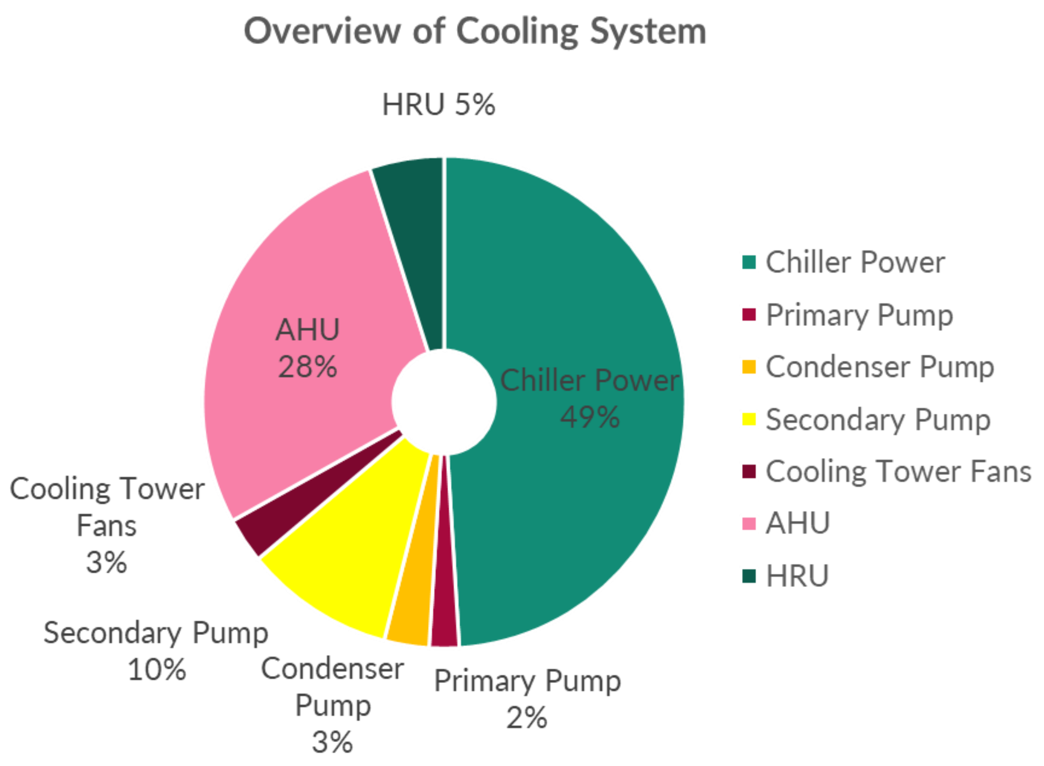
Main components



HVAC: ENERGY DISTRIBUTION

Water chillers are the major load

- In HVAC systems in commercial buildings, the water chillers account for almost 50% of load
- The other loads account for the following:
    - AHUs (28%)
    - Pumps (15%)
    - Heat recovery wheels (5%)
    - Cooling tower fans (3%)



QUANTIFYING COOLING EFFECT

Common terminologies and conversions

Definition of ‘ton of refrigeration (TR)’:

The amount of energy required to convert 1 ton of water at 0°C into ice within 24 hours

The relation between TR and its equivalent energy terms is as follows:

1 TR equals to:

- 3,024 kcal/h
- 3.51 kW
- 12,000 Btu/h

REFRIGERATION

Energy efficiency: Figures of merit

Quantification of Refrigeration Effect

1 Ton of Refrigeration (TR) = 3,023 kcal/h

= 3.51 $kW_{thermal}$

= 12,000 Btu/h

Coefficient of Performance (COP) = $\frac{\text{Refrigeration Effect}}{\text{Work Done}}$

Energy Efficiency Ratio (EER) = $\frac{\text{Refrigeration Effect (Btu/h)}}{\text{Work Done (Watts)}}$

Specific Power Consumption (SPC) = $\frac{\text{Power Consumption (kW)}}{\text{Refrigeration Effect (TR)}}$

Sample calculations

Refrigeration Load = 50 TR, say

= 175.5 $kW_{thermal}$

= 600,000 Btu/h

Compressor power consumption = 40 kW, say

COP = $\frac{175.5}{40}$ = 4.39

EER = $\frac{600,000}{(40 \times 1,000)}$ = 15

SEC = $\frac{40}{50}$ = 0.80 kW/TR

CHILLER EFFICIENCY

Figures of merit for water-cooled and air-cooled chillers

For water-cooled chillers:

SEC = 0.45 kW/TR – 0.65 kW/TR

COP = 5.4–7.8

EER = 18.5–26.7

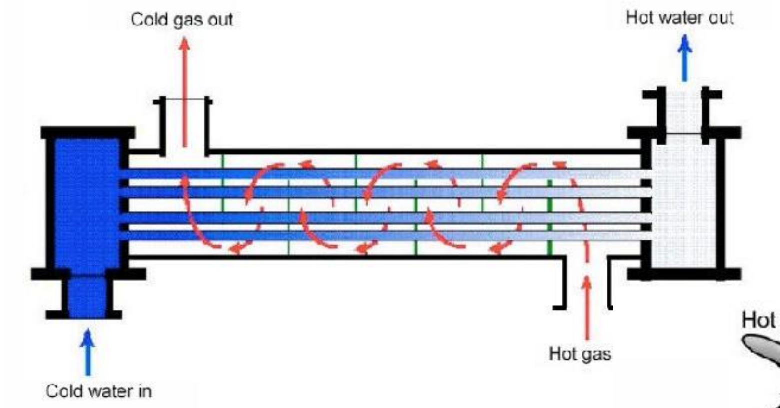
For air-cooled chillers:

SEC = 0.90 kW/TR – 1.20 kW/TR

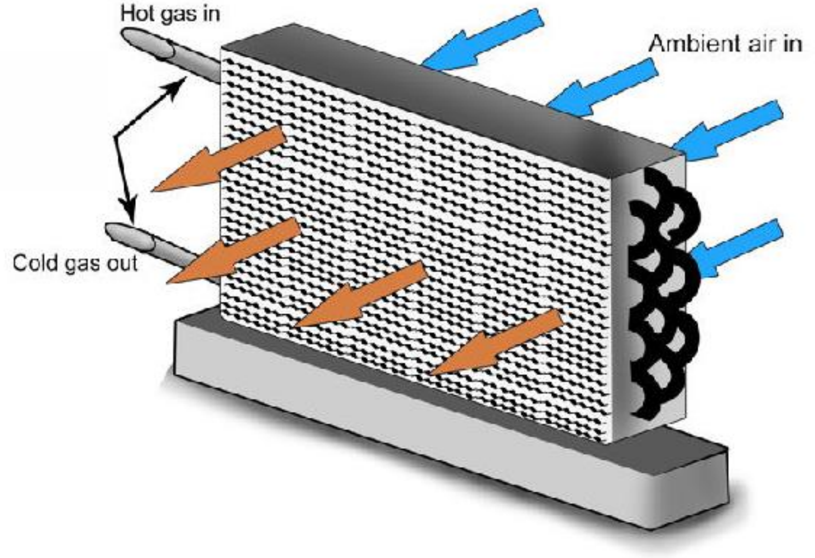
COP = 2.9–3.9

EER = 10–13.3

Higher COP / EER and lower SEC imply better system performance



Warer cooled type condenser



Air cooled type condenser

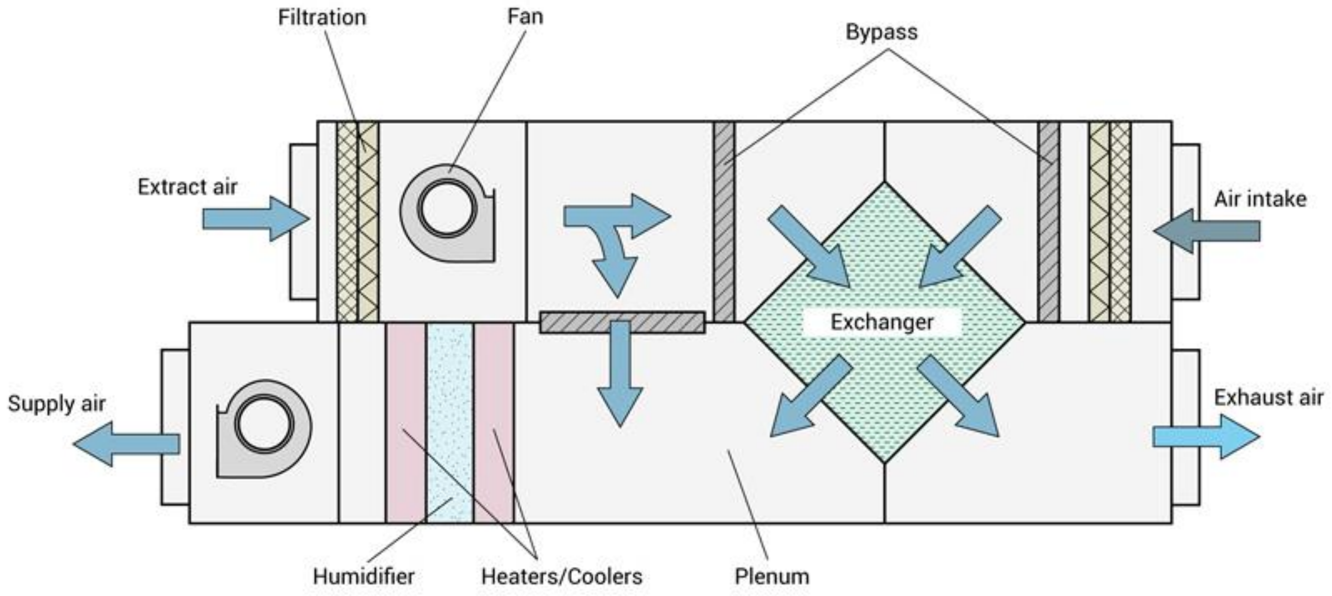
Image source: https://www.senho-chiller.com/technical-suport/difference-between-air-cooled-and-water-cooled-chiller.html

AIR HANDLING UNIT (AHU)

Components and energy consumption

- Key components
  - Supply fan
  - Return fan
  - Filters
  - Heating / cooling coils
  - Heat exchanger (optional)

- The energy consumption is determined by the air flow, pressure, and fan and motor efficiencies
- Operation at optimal air flows, determined by cooling load, optimal pressure (without excessive damper control), and use of appropriately-sized, high-efficiency fans and motors, preferably controlled by variable frequency drives, are desirable



Air handling unit

Image source: https://www.airtecnics.com/news/what-is-an-air-handling-unit-ahu

PUMPS IN HVAC SYSTEM

Components and energy consumption

- **Chilled water pumps** supply chilled water to AHU, which is cooled through the chiller. The connecting pipes are insulated to reduce heat loss
- **Condenser water pumps** circulate water to the cooling tower, removing heat from the condenser (heat rejection side) of the chiller. The connecting pipes are generally not insulated

The energy consumption is determined by the water flow, pressure, and pump and motor efficiencies

Operation at optimal water flows, determined by cooling load, optimal pressure (with excessive valve throttling), and use of appropriately-sized, high-efficiency pumps and motors, preferably controlled by variable frequency drives, are desirable

Chiller water pump

Image source: https://www.durapump.co.uk/how-to-improve-chilled-cooled-water-system-efficiency/

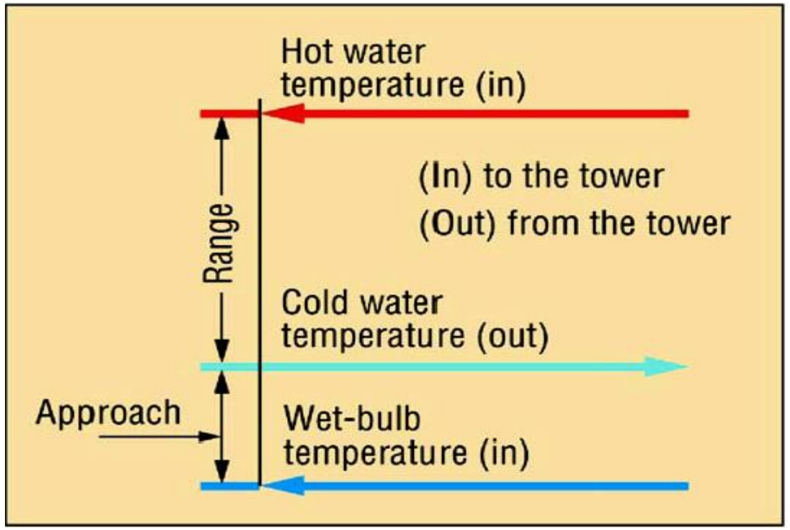
Condenser water pump

Image source: https://aircondlounge.com/how-to-calculate-chilled-water-pump-head/

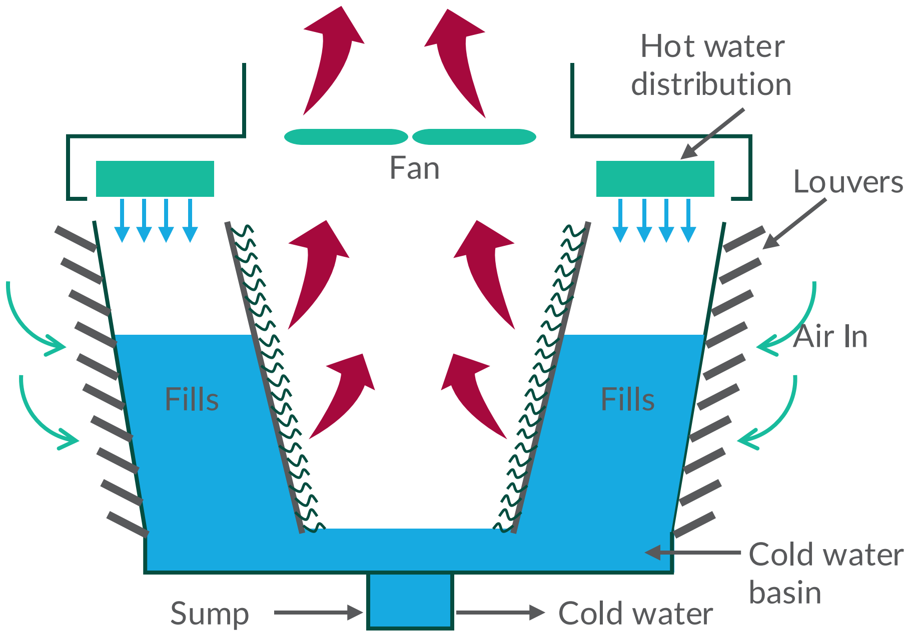
COOLING TOWER

Important parameters: Temperature range and temperature approach

Latent heat of condensation of the refrigerant vapor is transferred to the cooling water and rejected to the atmosphere by vaporization of water in the cooling tower, assisted by air flow



- **Range:** **Entering Water Temperature – Leaving Water Temperature**
- **Approach:** **Wet-bulb Temperature – Leaving Water Temperature**
- **Effectiveness:** **Range / (Range + Approach) {higher is better}**



Induced draft, double-flow crossflow tower

Source: Bureau of Energy Efficiency, Government of India, 2015

OVERALL SYSTEM EFFICIENCY

Including all components of the chilled water system.

- The combined central chilled water plant includes chillers, chilled water pumps, cooling water pumps and cooling tower fan (excluding air handling units)
- The figure of merit for assessing design system efficiency of central chilled water plant is defined as:

(total installed motor capacity, kW) per (refrigeration capacity, kW_r)

- In India, the Energy Conservation Building Code 2017 defines this threshold as 0.26 kW / kW_r

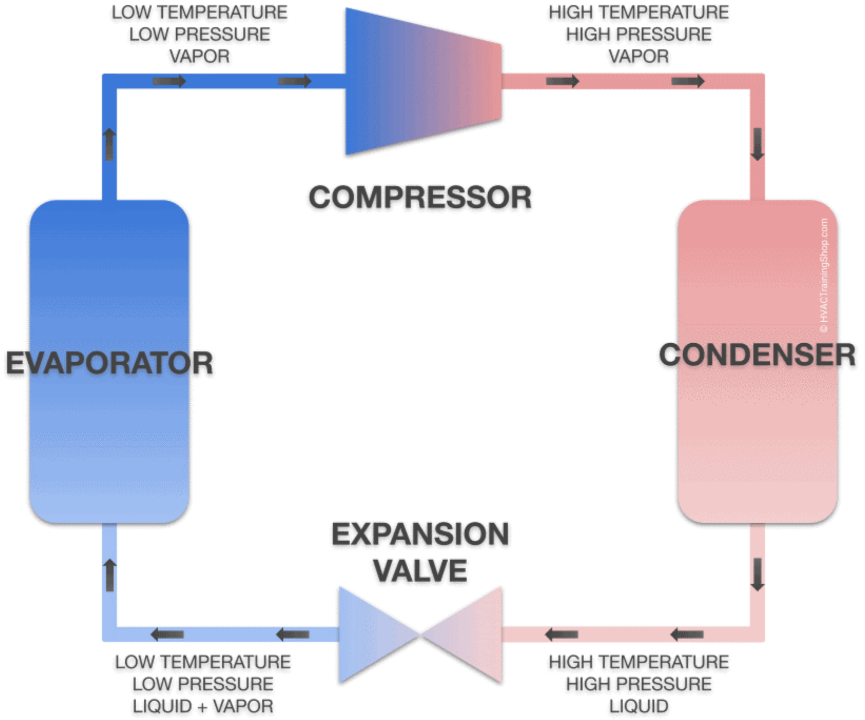


Image source: https://www.linkedin.com/pulse/how-chilled-water-system-works-muhammad-adnan-arshad/

LIGHTING

Basics and Commonly-used Systems

LIGHTING LUMINAIRES

Common indoor and outdoor luminaires

LIGHTING SYSTEMS

Performance parameters

- **Luminous flux** describes the quantity of light emitted by a light source. The most common measurement or unit of luminous flux is the **lumen (lm)**. The lumen rating of a lamp is a measure of the total light output of the lamp
- **Illuminance** is the quotient of the luminous flux incident on an element of the surface at a point of surface containing the point, by the area of that element. **Lux (lx)** is the metric unit of measure for illuminance of a surface
- **Luminous efficacy** is the ratio of luminous flux emitted by a lamp to the power consumed by the lamp. It is a reflection of efficiency of energy conversion from electricity to light form (**unit: lumens per lamp watt (lm/W)**)
- **Color Rendering Index (CRI)** is a measure of the effect of light on the perceived color of objects. It ranges from 0–100. A low CRI indicates that some colors may appear unnatural when illuminated by the lamp

$$E(Lux) = \frac{Lumens \times Design\ Factor}{Area}$$

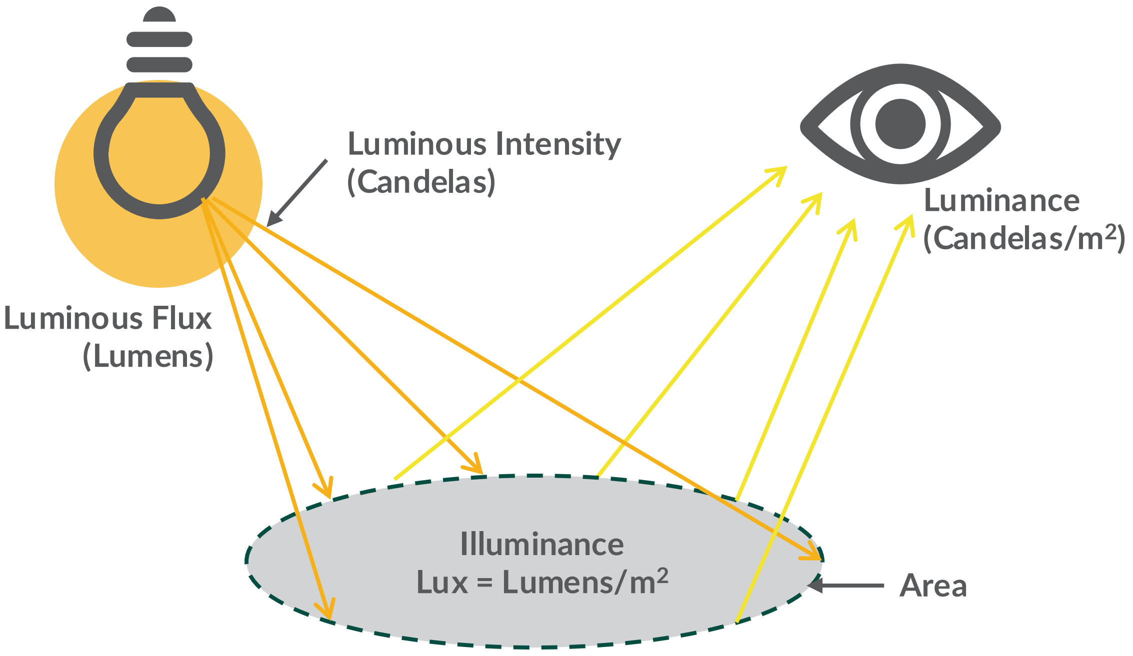


Image source: https://www.etaplighting.com/en/blog/lux-and-lumen-whats-difference

LIGHTING SYSTEMS

Commonly-used lamps

Conventional Lamps

Incandescent Lamp

Tubular Fluorescent Lamp

LED Lamps

Compact Fluorescent Lamp

LED Lamp

LED Tube Light

Lamps: Important Parameters

Type of Lamp	Life Span (in hours)	Lumens/ watt	Color Rendering Index (CRI)
Incandescent Lamp	1,000–2,000	8–18	100 (Excellent)
Compact Fluorescent Lamp (CFL)	12,000	40–70	85 (Very Good)
Tubular Fluorescent Lamp	25,000–40,000	46–60	67–77 (Good)
LED Tube Light/Bulb	50,000–100,000	50–130	80 (Very Good)

Source: Bureau of Energy Efficiency, Government of India, 2015

OTHER SERVICES

Commonly-used Equipment and Systems

Image source:

OTHER SERVICES

Efficiency metrics and minimum efficiency levels

- The system efficiency levels are prescribed at both international and national levels, and are updated at regular intervals
- Internationally, the minimum equipment efficiency values defined in **ASHRAE Standard 90.1** are well recognized and widely used. Meeting the prescriptions of the latest edition can ensure that selected systems will require lower operational energy
- At national levels, the local codes or standards will **supersede**; for example, in **India**, the **Energy Conservation Building Code (ECBC)** is applicable to both commercial and residential buildings. The minimum equipment efficiency values are prescribed with reference to the local conditions, available systems and future prescriptions on minimum performance levels
- The metrics for India's Star Labeling Program for appliances and equipment is referred to later in this module

SERVICE EQUIPMENT

With significant energy consumption: Ceiling fans and electric water heaters

PRESCRIBED PERFORMANCE PARAMETER

Service value is calculated as the ratio of air delivery (in cubic meters per minute) to power consumption (in watts)

PRESCRIBED PERFORMANCE PARAMETER

Standing loss is measured in kilowatt-hours per day (kWh/24 hours) for a temperature difference of 45°C. It indicates how much energy the water heater loses while maintaining the water temperature

SERVICE EQUIPMENT

With significant energy consumption: Pumps and elevators (lifts)

PRESCRIBED PERFORMANCE PARAMETER

Power consumption (kW) at specified head and flow

PRESCRIBED GUIDELINES

- **Compliance:** Guideline VDI 4707: Class 1–5 for energy efficiency of lifts
- **Type of motor:** Use of IE3 motor and above
- Use of variable voltage variable frequency drives and regenerative drives
- **Lumen efficacy of lamps in lifts: O**ver 85 lumen/W

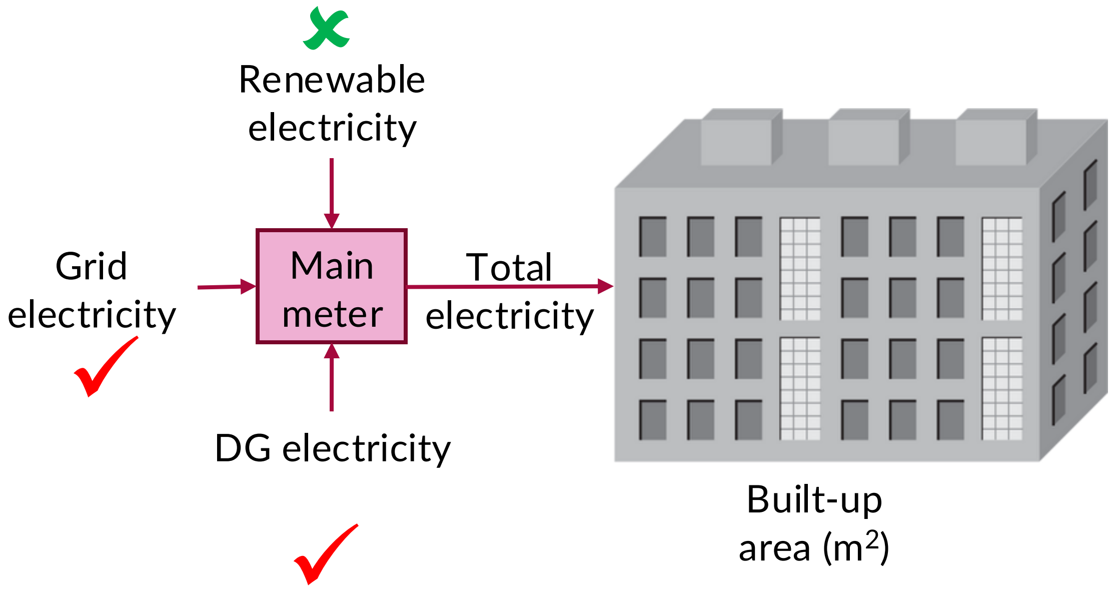
Operational Energy Indices

ENERGY PERFORMANCE INDEX (EPI)

Overall energy efficiency metric for buildings

- Definition: EPI is a metric used to measure the energy efficiency of a building or facility. It is typically defined as the total energy consumption per unit area, expressed in kWh/m² per year
- Purpose of EPI: EPI is crucial for assessing and comparing the energy efficiency of different buildings or urban areas. It helps identify opportunities for improvement and track energy conservation efforts over time
- EPI plays a key role in reducing operational costs, lowering carbon footprints, and contributing to sustainability goals. It is often used in compliance with energy efficiency regulations and certifications
- Formula:

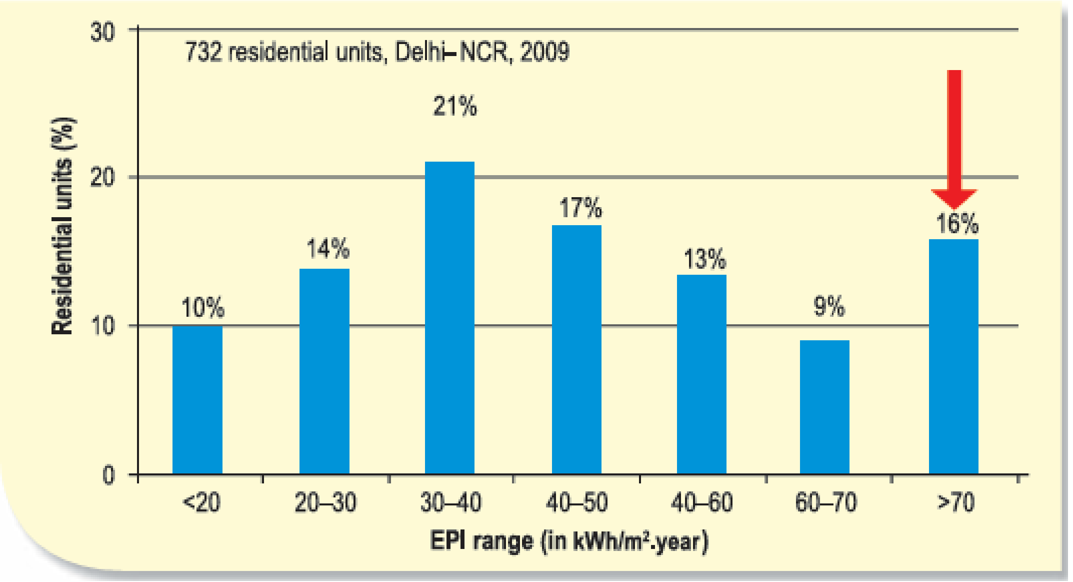
$$\text{EPI} = \frac{\text{Total Energy Consumption (kWh/year)}}{\text{Total Floor Area (m}^2\text{)}}$$



Sources: Bureau of Energy Efficiency, Government of India, 2022; Bureau of Energy Efficiency, Government of India, 2023b

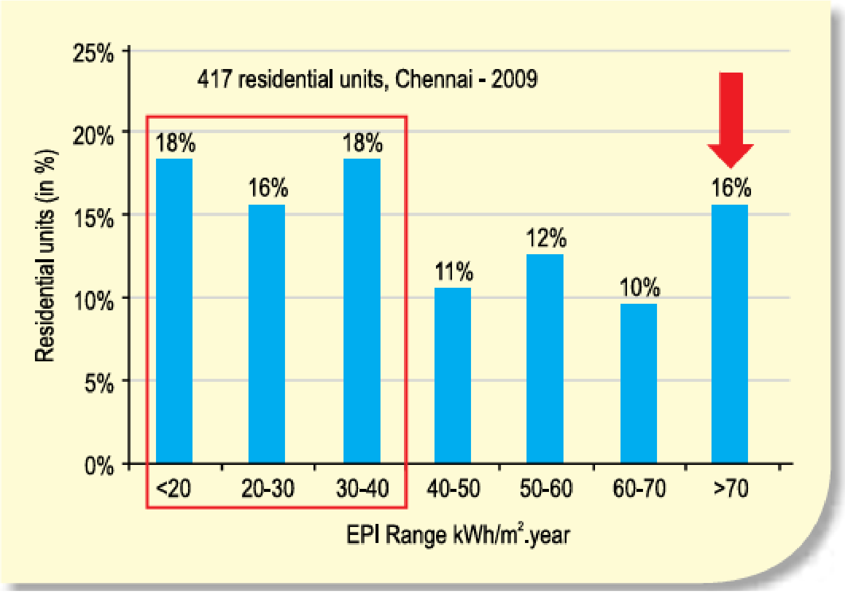
ENERGY PERFORMANCE INDEX (EPI)

For residential buildings



For **composite climate** in India, the average EPI, based on data collected from over 700 residential units for 2009 is **48 kWh/m^2.year**. The EPI does not include electricity consumption for common services

Over **16%** of the residential units have an EPI value **greater than 70 kWh/m^2.year**. Most of these residential units have three or more air-conditioners



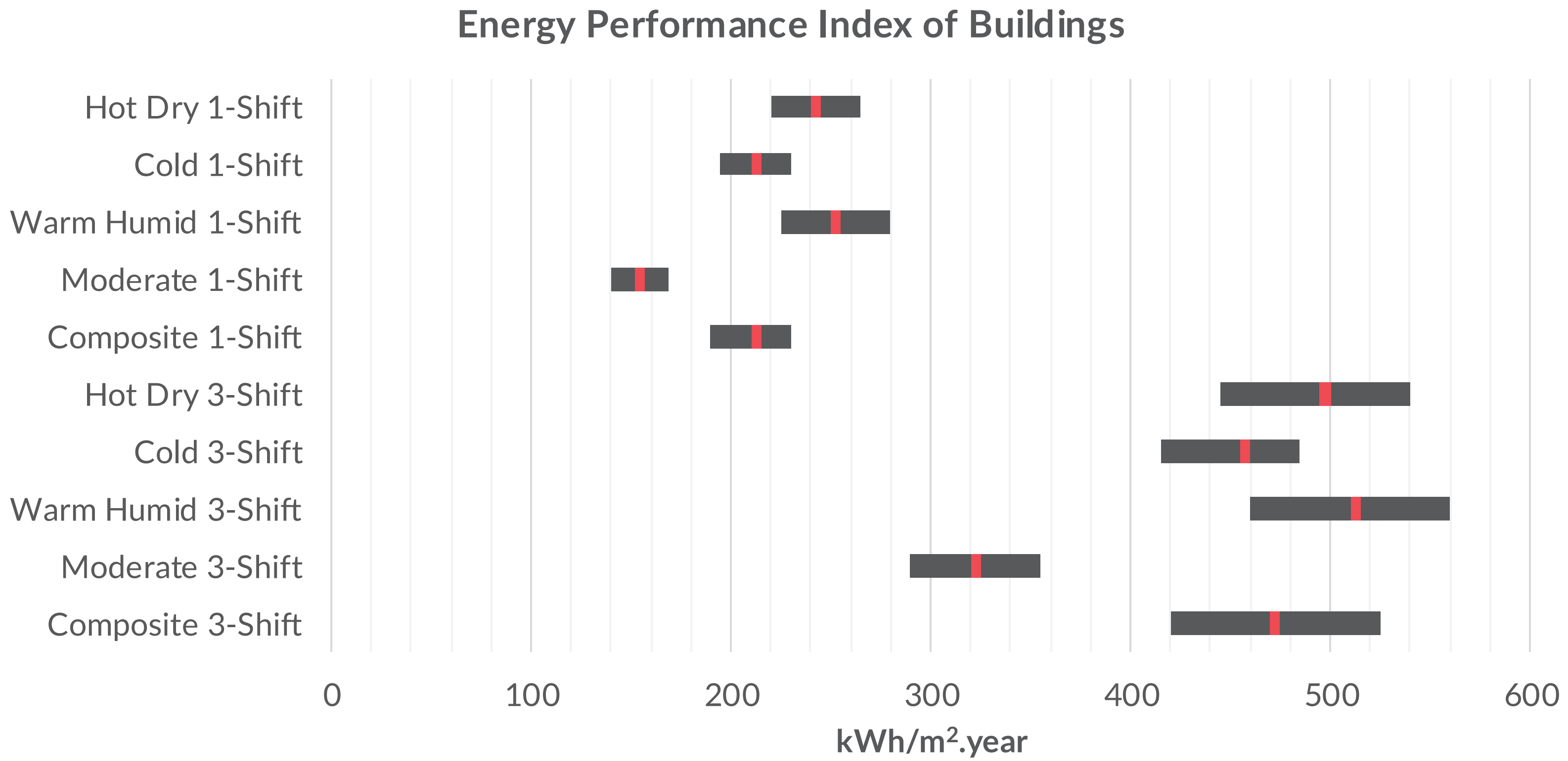
For **warm-humid climate** in India, the average EPI, based on data collected from over 400 residential units for 2009 is **44 kWh/m^2.year**. The EPI does not include electricity consumption for common services

ENERGY PERFORMANCE INDEX (EPI)

For buildings (1-shift and 3-shift operation)

A national survey for assessing the **EPI** of existing buildings in India was conducted in five climatic zones and two types of buildings:

- Daytime use
- 24 x 7 use



Source: CEPT University, Ahmedabad, & Shakti Foundation, New Delhi, "A stepped bundle approach to ECBC".

Energy Star Rating for Buildings

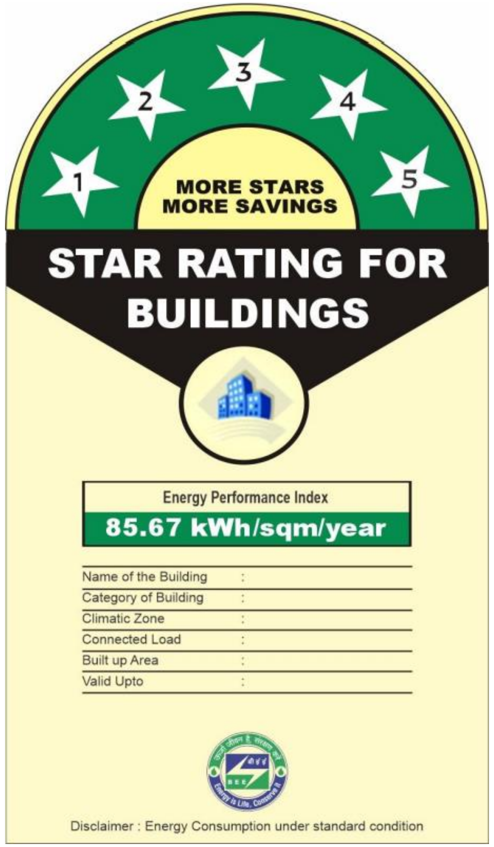
STAR RATING FOR BUILDINGS

For buildings (1-shift and 3-shift operation)

The star rating system is designed to evaluate and rate the energy efficiency of buildings on a scale, typically from 1 to 5 stars. It offers an easy-to-understand metric for homeowners, buyers and tenants to evaluate how energy efficient a property is.

Rating scale: A 1-star rating indicates poor energy performance, while a 5-star rating signifies excellent energy efficiency. Each additional star represents a higher level of energy efficiency:

- 1-Star: Basic compliance with local building codes; minimal insulation and little to no energy efficient systems
- 2-Star: Slight improvements over baseline requirements, with some energy efficient appliances and insulation
- 3-Star: Moderate energy efficiency with adequate insulation, and energy efficient HVAC and LED lighting
- 4-Star: Above-average energy efficiency, possibly including double-glazed windows, higher-quality insulation and efficient HVAC systems
- 5-Star: Top-tier energy efficiency with renewable energy sources, comprehensive insulation, advanced window glazing, smart home technology and low energy consumption throughout



Source: Bureau of Energy Efficiency, Government of India

RESIDENTIAL BUILDINGS

Star rating system

- The Star Rating System for Residential Buildings in India, established by the Bureau of Energy Efficiency (BEE), is a program that rates the energy efficiency of residential buildings on a **scale from 1 to 5 stars**
- **EPI calculation:**

  EPI for air-conditioned spaces (25% area) with 24°C as set point (E1) + EPI for other spaces (75% area) with natural ventilation (E2) set points defined by IMAC with air conditioner switched on
- EPI for other appliances: E3 (constant value)
- **Calculation of the EPI** is through a simulation-based tool to calculate the EPI of dwelling units. The user is required to feed-in information of the dwelling unit in the tool based on which the tool will automatically calculate the EPI

Residential Building Star Rating Plan				
Period: 14 December 2018 to 31 December 2024				
Star Rating	Energy Performance Index[1] (E1 + E2) of Dwelling Unit			
	Composite	Warm & Humid	Hot and Dry	Temperate
1-star	52 < EPI ≤ 60	58 < EPI ≤ 64	55 < EPI ≤ 67	28 < EPI ≤ 31
2-star	45 < EPI ≤ 52	49 < EPI ≤ 58	47 < EPI ≤ 55	24 < EPI ≤ 28
3-star	37 < EPI ≤ 45	39 < EPI ≤ 49	38 < EPI ≤ 47	21 < EPI ≤ 24
4-star	29 < EPI ≤ 37	30 < EPI ≤ 39	29 < EPI ≤ 38	17 < EPI ≤ 21
5-star	EPI ≤ 29	EPI ≤ 30	EPI ≤ 29	EPI ≤ 17

- **E1** and **E2** includes following systems: Building envelope characteristic; lighting system; and comfort system (AC)
- **E3** includes appliances such as: microwave oven, grinder, refrigerators, television, water pump, washing machine, etc.

Source: Bureau of Energy Efficiency, Government of India

OFFICE BUILDINGS

Star rating system

- The three building categories are based on built-up area (BUA) and in line with the categories in ECBC 2017
- The star rating band is formed by straight line equations in the form **y = (a*b) + c:**
  - 'y' denotes the EPI
  - 'a' denotes the coefficient in the table
  - 'b' denotes the percentage of AC area out of total built-up area

Star rating for office buildings

Climatic Zone	Building Category	1 Star	2 Star	3 Star	4 Star	5 Star
Composite	Large Office	y = 0.95x + 60	y = 0.9x + 50	y = 0.85x + 40	y = 0.8x + 30	y = 0.75x + 20
	Medium Office	y = 1.1x + 60	y = 1.05x + 50	y = x + 40	y = 0.95x + 30	y = 0.9x + 20
	Small Office	y = 0.65x + 60	y = 0.6x + 50	y = 0.55x + 40	y = 0.5x + 30	y = 0.45x + 20
Warm & Humid	Large Office	y = 0.9x + 65	y = 0.85x + 55	y = 0.8x + 45	y = 0.75x + 35	y = 0.7x + 25
	Medium Office	y = 0.9x + 65	y = 0.85x + 55	y = 0.8x + 45	y = 0.75x + 35	y = 0.7x + 25
	Small Office	y = 0.7x + 65	y = 0.65x + 55	y = 0.6x + 45	y = 0.55x + 35	y = 0.5x + 25
Hot & Dry	Large Office	y = 1.1x + 55	y = 1.05x + 45	y = x + 35	y = 0.95x + 25	y = 0.9x + 15
	Medium Office	y = 1.25x + 55	y = 1.2x + 45	y = 1.15x + 35	y = 1.1x + 25	y = 1.05x + 15
	Small Office	y= 0.75x + 55	y = 0.7x + 45	y = 0.65x + 35	y = 0.6x + 25	y = 0.55x + 15

Source: Bureau of Energy Efficiency, Government of India, 2023b

OFFICE BUILDINGS

Star rating system: Understanding the band for each star category

- **Star label bands**
  - Upper value of band: As per the equation given
  - Lower value of band: As per the equation of the next high rating (e.g., equation of the 2 star for a 1-star rating)

- **Example:** Any large office building in composite climatic zone, having 75% AC area (b=75)
  - For 1-star rating the upper value of band will be: 0.95*75 + 60 = **131.25 kWh/m²**
  - For 1-star rating the lower value of band will be: 0.9*75 + 50 = **117.5 kWh/m²**
  - For a building with 75% air-conditioned area, the **EPI band** for 1 star will be **117.5– 131.25 kWh/m²**

Star rating for office buildings

Climatic Zone	Building Category	1 Star	2 Star	3 Star	4 Star	5 Star
Composite	Large Office	y = 0.95x + 60	y = 0.9x + 50	y = 0.85x + 40	y = 0.8x + 30	y = 0.75x + 20
	Medium Office	y = 1.1x + 60	y = 1.05x + 50	y = x + 40	y = 0.95x + 30	y = 0.9x + 20
	Small Office	y = 0.65x + 60	y = 0.6x + 50	y = 0.55x + 40	y = 0.5x + 30	y = 0.45x + 20
Warm & Humid	Large Office	y = 0.9x + 65	y = 0.85x + 55	y = 0.8x + 45	y = 0.75x + 35	y = 0.7x + 25
	Medium Office	y = 0.9x + 65	y = 0.85x + 55	y = 0.8x + 45	y = 0.75x + 35	y = 0.7x + 25
	Small Office	y = 0.7x + 65	y = 0.65x + 55	y = 0.6x + 45	y = 0.55x + 35	y = 0.5x + 25
Hot & Dry	Large Office	y = 1.1x + 55	y = 1.05x + 45	y = x + 35	y = 0.95x + 25	y = 0.9x + 15
	Medium Office	y = 1.25x + 55	y = 1.2x + 45	y = 1.15x + 35	y = 1.1x + 25	y = 1.05x + 15
	Small Office	y= 0.75x + 55	y = 0.7x + 45	y = 0.65x + 35	y = 0.6x + 25	y = 0.55x + 15

Source: Bureau of Energy Efficiency, Government of India, 2023b

Standards and Labeling

For Appliances

Image source: https://www.paiinternational.in/blogs/understanding-the-bee-star-rating-in-electronics-

STANDARDS AND LABELING (S&L)

For appliances

- In India, the S&L system provides consumers with an easy way to compare the energy use and operating costs of different products, encouraging the purchase of energy efficient models
- Rating scale: Appliances are rated from 1 star (least efficient) to 5 stars (most efficient)
- Energy consumption labeling: Each appliance label includes information about the product's energy consumption and an efficiency rating
- Product testing and standards: Appliances are tested against standards set by the Bureau of Energy Efficiency, which periodically updates the criteria to reflect advancements in technology
- Commonly-rated appliances: Refrigerators, air conditioners, ceiling fans, televisions, washing machines, water heaters, LED bulbs and tube lights
- Star rating criteria
  - Energy efficiency ratio (EER): Indicates efficiency for appliances like air conditioners and refrigerators
  - Annual energy consumption: Specifies the estimated annual electricity consumption in kilowatt-hours (kWh) for typical usage

S&L

Appliances covered – mandatory and voluntary

S NO	MANDATORY
1	Frost Free Refrigerator
2	Direct Cool Refrigerator
3	Deep Freezer
4	Room AC (Variable Speed)
5	Room AC (Fixed Speed)
6	RAC (Cassette, Floor Standing Tower, Ceiling Corner AC)
7	Light Commercial AC (Fixed Speed)
8	Stationary Storage Type Electric Water Heater
9	Tubular Fluorescent Lamp
10	LED Lamp
11	Ultra High Definition Television
12	Colour Television
13	Distribution Transformer
14	Ceiling Fan
15	Chiller
16	Washing Machine

S NO	VOLUNTARY
1	General Purpose Industrial Motor
2	Submersible Pump Set
3	Domestic Gas Stove
4	Computer
5	Ballast
6	Office Automation Product
7	Diesel Engine Driven Monoset Pump for Agricultural Purposes
8	Solid State Inverter
9	Diesel Generator Set
10	Microwave Oven
11	Solar Water Heater
12	Air Compressor
13	High Energy Li-Battery
14	Tyre
15	Multi Door Refrigerator
16	Pedestal Fan, Table Fan, Wall Fan
17	Induction Hob
18	Solar Photovoltaic

Thank you!

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or scan the QR code below

IKI Independent Complaint Mechanism

Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/.

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