ECO-NIWAS SAMHITA

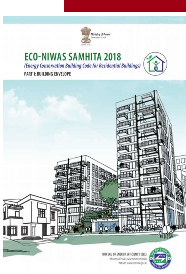
Part 2: Electro-Mechanical and Renewable Energy Systems
(Energy Conservation Building Code for Residential Buildings)

CONSULTATION WORKSHOP

Session 1: Code Scope and Content of ENS Part 2

Two Parts of ENS: Envelope & Active Measures

ENS Part 1:
Building Envelope



Already developed, and is now **getting implemented**

Draft ENS: Part 2
Electro-Mechanical and Renewable System

Currently under development
→ **Primary and Secondary study and stakeholder consultations**

ECO Niwas Samhita (ENS) 2018

ECO Niwas Samhita was launched on 14 December 2018 on the occasion of National Energy Conservation Day 2018

- For **"Residential buildings"with plot area ≥ 500m^2** and **"Residential part of Mixed-land use building projects" with plot area ≥ 500m^2**
- Minimum performance standards for residential building envelope to limit heat gains and heat loss
- Provisions include
  - Maximum **residential envelope transmittance value (RETV)** for building envelope except roof for all climate
  - Maximum **thermal transmittance value (U_{cold})** for building envelope except roof for cold climate
  - Maximum **thermal transmittance value (U_{roof})** for building envelope for all climate
  - Minimum **openable window-to-floor area ratio (WFR_{op})**
  - Minimum **visible light transmittance (VLT)** for non-opaque building envelope components

Proposed Content of the ENS Part 2

Scope of the code

- Chapter 1: Building services
- Chapter 2: Indoor electrical end use
- Chapter 3: Renewable energy integration
- Chapter 4: Compliance and implementation framework

- Appendix A: Annualized Embodied Energy
- Appendix B: Better Construction Practices
- Appendix C: Retrofitting of Residential Buildings
- Appendix D: Improved air cooling

Scope of the code

Description:

Scope of the code can be defined based on the following criteria:

1. **Definition of criteria based on the built-up area and/or plot area**
2. **Based on the type of building**
3. **Addition, alteration and repair of existing building**
4. **The code does not apply to ancillary facilities and spaces used for non-residential purposes**

Scope of the code

1. **Definition of criteria based on the built-up area and/or plot area**

→ **Suggestion**

Like ECBC-R: Part 1, it may be useful to harmonize the scope of ECBC-R: Part 2 with the scope mentioned in the Real Estate (Regulation and Development) Act, 2016.

This will be useful to bring clarity among the stakeholders (building owner, Third Party Assessors, ULBs etc.) to be involved in code compliance

The following projects **do not** require to be registered under the Act:

Area of land does not exceed 500 m²
No. of apartments does not exceed 8
In case of Renovation/Repair/Re-development

Scope of the Code

2. Based on the type of building

→ **Suggestion**

Building types in terms of detached housing, low rise and high rise have different requirements for building services (water pumping, outdoor lighting, vertical transportation, power back-up options) and renewable energy potential (lower solar fraction/DU on taller buildings).

It will important for the code to distinguish the provisions based on the building types.

- Multi-storey residential buildings
- Low rise apartments
- Farm house and villas
- EWS apartments with residential complexes
- Affordable housing

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Scope of the code

2. **Based on the type of building**

→ **Codes & Standards (international)**

International Energy Conservation Code, USA (2015)

- *"Three storey or less in height and comprise of detached one- and two-family dwelling or multiple single-family dwellings"*

National Construction Code, Australia (2016)

- *This code covers all new residential buildings which are –*
- *single dwelling being a detached house; or one of a group of two or more attached dwellings, each being a building, separated by a fire-resisting wall, including a row house, terrace house, town house or villa unit;*
- *a building containing two or more sole-occupancy units each being a separate dwelling.*

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Scope of the code

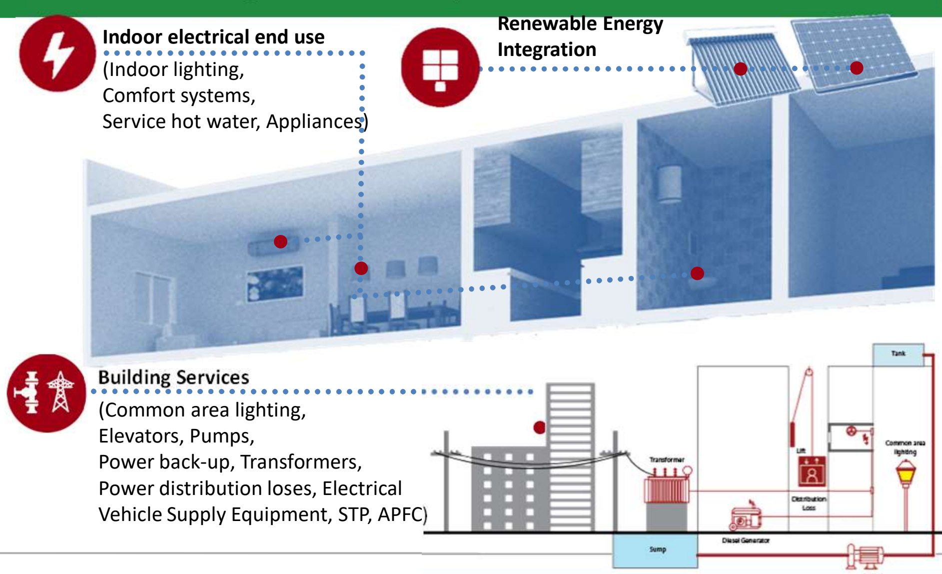
3. **Addition, alteration and repair of existing building**
   → **Codes & Standards (national, international)**
   - ***Environmental Sustainability of Buildings, Singapore (2013)***
   - *increasing the gross floor area of the existing buildings by 2,000 m² or more..*

4. **The code does not apply to <u>ancillary facilities and spaces used for non-residential purposes.</u>**
   → **Suggestion**

The function and the energy consumption pattern of the ancillary facilities like community hall, club house, departmental store, vegetable market etc. will be very different from the residential part of projects and their configuration will also highly differ among residential complexes.

It is suggested to consider the applicability of the code only to residential part of the housing complex.

ENS Part 2 – Proposed Chapters



Types of code compliance options

- Prescriptive
- Trade-offs code
- Performance code
- Outcome based code

Part 1 is based on Prescriptive and Trade-offs code

So, EPI approach has been proposed considering its advantages

Annual Energy Performance

Energy Performance Index (EPI) [kWh/m^2.year] or
Annual energy consumption [kWh/Dwelling Unit]
can be considered as a **unified matrix to show compliance** to ENS: Part 2

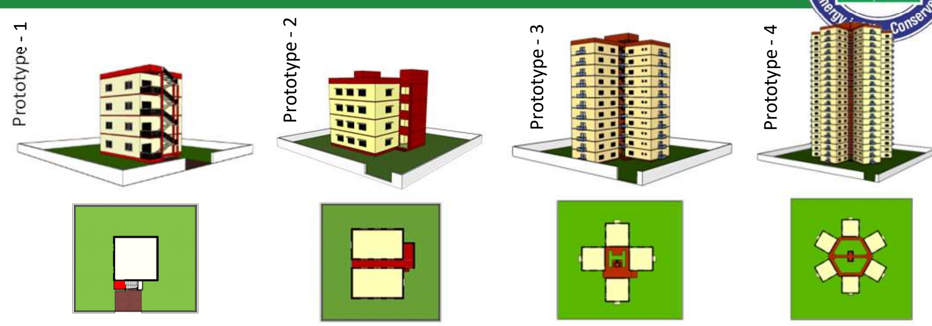
- To arrive at the EPI, each applicable component's specific energy consumption will be translated to annual net energy consumption and is normalized with dwelling super built-up area (m^2)
- Energy Performance Index (in kWh/m^2.year) is a widely accepted matrix used worldwide to measure and benchmark the energy performance of buildings. The matrix is especially useful for considering primary energy use where a mix of fuel supplies (like electricity, gas and renewable etc.) are part of the energy use in buildings.
- EPI can be translated to GHG emission matrix, which is used widely to measure the environmental performance of a ULB, state or the country.
- EPI can be considered both at the component level for electro-mechanical equipment and at the combined solution set/building level.

Consultation document: overall structure

For each building component, the consultation document discusses the following

- Description of the component and its energy use
- Energy efficient technologies and strategies
- Mapping of Indian initiatives, codes and standards
- Mapping and synthesis of International codes
- The formula for arriving at EPI

Prototypes considered for calculation of annual energy consumption



Features	Prototype-1	Prototype-2	Prototype-3	Prototype-4
Allowed Ground Coverage	21.0%	25.0%	18.2%	14.3%
Built-up area per dwelling (m²)	100	100	100	100
Corridor area per dwelling (m²)	5	30	20	16.67
Super built-up area per dwelling (m²)	105	130	120	116.67
No. of dwelling units per floor	1	2	4	6
No. of floors	4	4	11	21

Sample prototypes used for calculating annual energy consumption

	Units	G+3 (1 dwelling unit per floor)	G+3 (2 dwelling units per floor)	G+10 (4 dwelling units per floors)	G+20 (6 dwelling units per floor)
Allowed Ground Coverage	%	21.0%	25.0%	18.2%	14.3%
FAR		0.84	1	2	3
Plot area	m^2	500	1040	2640	4900
Built-up area per dwelling unit	m^2	100	100	100	100
Corridor area per dwelling unit	m^2	5	30	20	16.67
Super built-up area per dwelling unit	m^2	105	130	120	116.67
No. of dwelling units per floor	Nos	1	2	4	6
Super built-up area per floor	m^2	105	260	480	700
Corridor area per floor	m^2	5	60	80	100
No. of floors	Nos	4	4	11	21
Basement Parking Area	m^2	0	0	1920	7840
Total built-up area	m^2	420	1040	5280	14700
Total number of dwelling units in the building	Nos	4	8	44	126
Height per floor	m	3.5	3.5	3.5	3.5
Occupant per dwelling unit	Nos	4.5	4.5	4.5	4.5
Electrical Load per dwelling unit	kW	7	7	7	7
Tank height	m	5	5	5	5
Service water requirements per person	Litres per capita per day	135	135	135	135
Operating hours of pump	hours	1	1	1	1
Total number of occupants in the buildings	Nos.	18	36	198	567
Roof Area	m^2	105	260	480	700
Total service water requirement	litres/day	2430	4860	26730	76545

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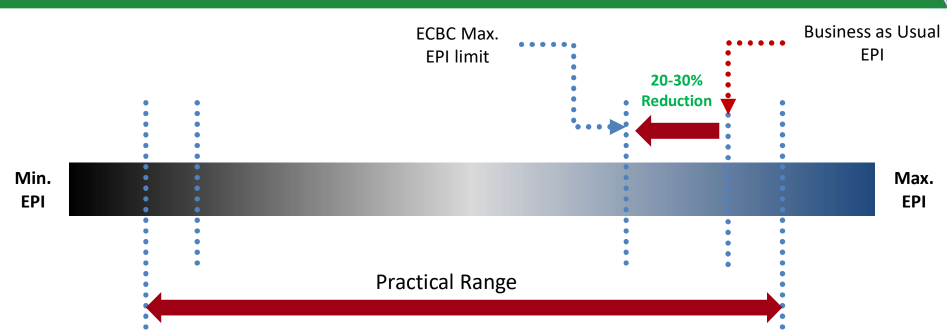
Approach for MEPS



*Final EPI Range will be obtained based on following activities:

1. Site visits
2. Expert interviews
3. Consultation workshops
4. Primary data analysis

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Summary of all Equipment

EPI range for below given systems/equipment have been found using similar approach as shown in the previous slide for common area lighting:

Chapter 1: Building Services	Chapter 2: Indoor Appliances	Chapter 3: Renewable Energy Systems
Common area lighting	Indoor lighting	Solar hot water
Elevators	Ceiling fans	Solar PV
Pumps	Air conditioners	
UPS Losses	Refrigerators	
Distribution transformer	Television	
Power distribution losses	Service hot water	
Basement car parking		
Electric vehicle supply equipment		

Common Area Lighting

Description

- Lighting of common areas inside the building, such as corridors, staircases, and basements;
- lighting of outdoor areas, such as roads and parks.
- Lamps used for outdoor lighting are incandescent lamps, compact fluorescent lamps, halogen lamps and Light emitting diode (LED) lamps.

EE strategies

- Daylighting
- Optimization of height and distance
- Automatic controls

Lumen output table

Lumen Output	450	800	1,100	1,600
Incandescent	40 W	60 W	75 W	100 W
Halogen	29 W	43 W	53 W	72 W
CFL	10 W	13 W	16 W	20 W
LED	5 W	10 W	15 W	19 W

Common Area Lighting

Lighting Power Density (in W/m²) = Illuminance (in lm/m²) / {Lamp Efficacy (in lm/W) * Lamp Lumen maintenance Percentage * maintenance Factor * Coefficienct of Utilization (except outdoor)}

EPI (in kWh/m².year) = Lighting Power Density (in W/m²) * Area (in m²) * Annual Hours of operation / (1000 * Super Built-up Area (in m²))

Annual Energy Consumption = EPI x Super Built-up Area

- **Common Area Lighting: EPI Range in kWh/m².year**

0.46 — **16.06**

- **Common Area Lighting: Annual Energy Consumption Range per dwelling unit in kWh/year. dwelling unit**

48 — **2,088**

Common Area Lighting - Assumptions

- 20% floor reflectance, 80% ceiling reflectance and 50% wall reflectance
- Expert Advice has been taken to consider 10% energy consumption reduction for Photosensor
- Summer is considered for 4 months and outdoor lights will operate for 8 hours
- Spring, Autumn & Monsoon is considered for 4 months and outdoor lights will operate for 11 hours
- Winter is considered for 4 months and outdoor lights will operate for 12 hours
- Basement lighting is always switched on

Elevators

→ Description

- Traction elevators
  - geared traction elevator
  - gearless traction elevator
  - machine-room less traction elevator
- Hydraulic elevators

→ EE strategies

Component	Energy Conservation Measures
Hoist drive	Permanent magnet gearless
Car Elevator	PU-coated belts, multiple rope
Controls	Software-defined, e.g., destination dispatch
Lighting/HVAC	LEDs, efficient fans, occupancy sensors
Energy sources	Regeneration plus solar
Other considerations	Standby mode, variable door motors, power factor near 1, Machine-room less

Elevators-using NBC method

Motor Power Rating in kW = Assumed Weight per passenger (in kgs) * Acceleration due to gravity i.e. 9.81 m/s^2 * Assumed speed of Elevator (in m/s) * Capacity of Elevators * (1 – Counterweight Factor) * Motor efficiency * Mechanical efficiency

EPI (in kWh/m^2.year) = {[Motor Power Rating (in kW) * Hours of operation per year) * Motor efficiency* 365] + [Wattage of fan and luminaire (in kW) * Annual Hours of operation]} * No. of lifts / Super Built-up Area (in m^2)

Annual Energy Consumption = EPI x Super Built-up Area

ASSUMPTIONS:

- Lift parameters assumed to have been tested to fulfil the service requirement of Interval, 5 minute handling capacity, average waiting time and nominal travel time as provided in NBC
- Counterweight Factor assumed to be between 40% and 50%
- Mechanical efficiency assumed to be between 60% and 80%

Elevators-using VDI method

EPI (in kWh/m^2.year) = {[Specific Travel Energy (in mWh/m.kg) * Carrying Capacity (in kg) * Velocity of lift (in m/s) * Travel time (in seconds per day) / 1000000 + [Standby Power (in kW) * Standby time (in hours per day)]} * 365 * No. of lifts / Super Built-up Area (in m^2)

Annual Energy Consumption = EPI x Super Built-up Area

- **Elevators: EPI Range in kWh/m^2.year**

0.5 — **11.1**

- **Elevators : Annual Energy Consumption Range per dwelling unit in kWh/year.dwelling unit**

63 — **1,290**

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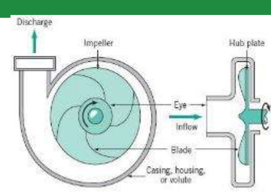
Pumps

→ **Description**

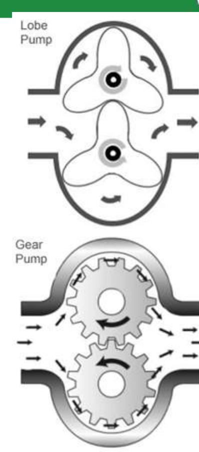
- Centrifugal pumps
- Positive displacement pumps
- Rotary-type positive displacement
- Reciprocating-type positive displacement
- Linear-type positive displacement



Centrifugal pump

→ **EE strategies**

- Avoiding the oversizing of motors and pumps
- Piping design to overcome losses
- Use of positive displacement pumps where head is low to moderate and constant flow is required
- Use of Variable Frequency Drive (VFD)s Careful design of pressure tanks, pumps and controls
- Solar water pumps



Positive displacement pump

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Pumps

Total head (in m) = Total Building Height + Tank Height

Discharge Rate (in m^3/s) = Water requirement (in LPD) / (Density of Water * Operating Hours i.e. 1 hour/day * 3600 seconds/hour)

Pump Power (Hydraulic) (in kW) = Density of Water * Discharge Rate (in m^3/s) * Acceleration due to gravity i.e. 9.81 m/s^2 * Total head (in m)

EPI (in kWh/m^2.year) = [Pump Power (Hydraulic) (in kW) / η] * Pumping System Energy Saving Potential * Annual Hours of Operation / Super Built-up Area (in m^2)

*Where η - Motor Efficiency x Mechanical Efficiency

Annual Energy Consumption = EPI x Super Built-up Area

EPI Range

- **Pumps: EPI Range in kWh/m^2.year**

0.08 — **1.24**

- **Pumps: Annual Energy Consumption Range per dwelling unit in kWh/year.dwelling unit**

10.6 — **144.5**

ASSUMPTIONS:

- Loss of power due to friction will be 30% for G+3, 50% for G+10 & 70% for G+20
- Hydro-pneumatic pumps can save 50% energy

Uninterruptible Power Supply

→ Description

- Emergency instantaneous power to critical devices e.g. emergency lighting, alarm system
- Protection against power surges, voltage drops, and frequency distortions.
- UPS with battery backup systems has been used in residential buildings as a power backup for operating the essential services like lighting, ventilation and low power rated appliances like TVs
- Technologies
  - on-line
  - line-interactive
  - standby

→ Assumptions

- It is assumed that UPS will run for 100 hours annually
- Battery Charging Losses vary from 40% to 50%

Uninterruptible Power Supply

Power required for charging UPS (in kW) = Electric discharge load per dwelling unit per hour (in kW) / (Efficiency of UPS * battery charging losses)

EPI (in kWh/m^2.year) = [Power required for charging UPS (in kW) + Electric discharge load per dwelling unit per hour (in kW)] * Annual hours of discharging operation / Super Built-up Area (in m^2)

- **UPS: EPI Range in kWh/m^2.year**

0.58 — **6.19**

- **UPS: Annual Energy Consumption Range per dwelling unit in kWh/year.dwelling unit**

76 — **650**

DG Set

→ **Description**

Diesel generator set convert some of the chemical energy, contained by the diesel fuel, to mechanical energy through combustion. This mechanical energy then rotates a crank to produce electricity. Single/three-phase diesel-generating (DG) sets consisting of an internal combustion (IC) engine driven by diesel as fuel, alternating current (AC) generator, associated control gear, switch gear, and auxiliary equipment.

The main parameter for design of DG sets is the specific fuel consumption (SFC), which determines the fuel efficiency of the diesel engine. The BEE Standards and Labelling for DG sets has defined the Star labels upto 19 kW based on this factor

DG Set

EPI (in kWh/m².year) (Energy Output) = [Generator Rating (in kVA) * Power Factor * Annual hours of operation] / [(specific fuel consumption / minimum specific fuel consumption of the DG Set) * Super Built-up Area (in m²)]

Annual Energy Consumption = EPI x Super Built-up Area

- **DG Set : EPI Range in kWh/m².year**

0.81 — **5.88**

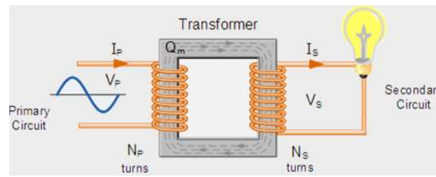
- **DG Set : Annual Energy Consumption Range per dwelling unit in kWh/year.dwelling unit**

105.3 — **617.4**

Transformers

→ Description

- Electrical device using **electromagnetic induction** to pass an alternating current (AC) signal from one electric circuit to another, often changing (or "transforming") the **voltage** and **electric current**



- During the step down or step up process transformers generate a lot of heat that must be dissipated to keep them running safely
- 2 types of transformers being used in the industry currently: Dry-type transformers and oil-cooled transformers

→ Differences:

- **Location**
- **Voltage Capabilities**
- **Efficiency**
- **Noise**
- **Maintenance**
- **Recyclability**

Oil cooled

→ Assumptions

- Transformers are sized to cater to 1.5 times or 2 times the total connected load

Transformer

For any given transformer, manufacturer provides No-Load Loss, $P_{No\text{-}Load}$ (in Watts) and Losses at full load, $P_{full\text{-}Load}$ (in Watts).
At any percent part load, losses, $P_{part\text{-}Load}$ (in Watts) can be calculated by,

$$P_{Part\text{-}Load} = P_{No\text{-}Load} + (\text{percent part load})^2 * (P_{full\text{-}Load} - P_{No\text{-}Load})$$

EPI (in kWh/m².year) = Calculated hourly power losses at part load (in kW) * percentage hourly loading on transformer * average monthly loading factor * Hours of operation/ Super Built-up Area (in m²)

Annual Energy Consumption = EPI x Super Built-up Area

- **Transformer: EPI Range in kWh/m².year**

0.41 — **1.09**

- **Transformer: Annual Energy Consumption Range per dwelling unit in kWh/year.dwelling unit**

54 — **130**

Basement Ventilation Fans

Description

- When cars enter, exit and drive through enclosed parking garage, they release toxic and non-toxic gases. If car engines were perfect, the vehicles would release carbon dioxide (CO_2), water (H_2O) and Nitrogen (N). Unfortunately, car engines are not perfect, and they typically release unburned fuel and fuel particles, various nitrogen oxides (NOx), carbon monoxide (CO), carbon dioxide (CO_2) and water (H_2O).
- There are broadly two methods of complying with the Building Regulations regarding ventilation and these are by natural or mechanical ventilation

EE strategies

In normal day-to-day operation, the Jet fans are controlled by the CO system – in accordance with the concentration threshold setting. In this way, carbon monoxide-contaminated air is extracted from the car park

ASSUMPTIONS:

- Ducts would add 0.5 in wg (125 Pa) of pressure drop as per ASHRAE 90.1 which is elimminated by using Jet Fans
- Pressure drop across the fan is assumed to be 0.5 in wg (125 Pa)
- Fan effiiciency is assued to be 60%

Basement Ventilation Fans

Motor Power Rating (in kW) = Basement Volume (in m³) * Number of Air Changes per hour * Pressure Drop (in Pa) / (Motor efficiency * Mechanical efficiency * 3600)

If CO sensor is used and interlocked with VSD on fan,

EPI (in kWh/m².year) = {[Motor Power Rating (in kW) * 365 * (8.4 + 15.6 * Power at part load with VSD on fan)]/ Super Built-up Area (in m²)}

Else

EPI (in kWh/m².year) = Motor Power Rating (in kW) * 365 * 24/ Super Built-up Area (in m²)

Annual Energy Consumption = EPI x Super Built-up Area

- **Basement Ventilation Fans: EPI Range in kWh/m².year**

1.9 — **25.2**

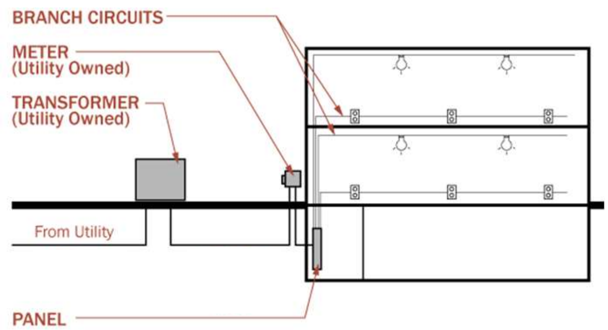
- **Basement Ventilation Fans : Annual Energy Consumption Range per dwelling unit in kWh/year.dwelling unit**

229 — **2,934**

Power distribution loses

→ Description

- The distribution system includes the 230 V lines, connections and supporting equipment, which carry electricity from the transformer to the consumer premises
- The extent of the system depends upon the capacity and position of the transformer and the location of the consumers
- Losses occur in this part of the system due to line resistance
- Primary reason for the technical losses: poor network configuration of the system and inappropriate network/equipment maintenance
  - Copper losses
  - Dielectric losses
  - Induction and radiation losses



Power distribution loses

The power distribution losses inside the residential building(s)/ complex shall be based on **restriction of voltage drop of 3% for the distance between the transformer and panel**

EPI (in kWh/m².year) =

System Voltage (in Volts) * 1.732 * Full Load Current (in Amps) * (Conductor Resistance (in ohm/km) * Power Factor + Conductor Reactance (in mho/km) * SinØ) * Length (in meters) * 100 * Full Load Current (in Amps) * Power Factor / (Line Voltage * No of Run * 1000 * 2 * Super Built-up Area (in m²))

- **Power Distribution Losses: EPI Range in kWh/m².year**

0.06 — **0.62**

- **Power Distribution Losses : Annual Energy Consumption Range per dwelling unit in kWh/year.dwelling unit**

6.8 — **72.0**

Electric Vehicle Supply Equipment (EVSE)

Description

An Electric Vehicle Supply Equipment (EVSE), is a component that provides electric energy for recharging electric vehicles.

For charging at home or work, a few EVs have installed converters that can connect to a standard electrical outlet or a high-limit apparatus outlet. Others either require or can utilize a charging station that gives electrical transformation, monitoring, or safety features. These stations are additionally required when travelling long distances, and many provide quicker charging at higher voltages and flows than that are accessible from private EVSEs. Open charging stations are given by electric service organizations

Energy Efficient Strategies for EVSE

Reduce the standby losses: Standby losses are due to No Vehicle Mode, Partial On Mode and Idle Mode

Electric Vehicle Supply Equipment (EVSE)

Charging Time for 0 to 100 State of Charge (SOC) (hours) =
Battery Capacity (in Ah) /(EVSE Output Current (in Amp) x Efficiency)

Energy loss per day assuming single 0 to 100 SOC charging per day (kWh) = Maximum Output Power (kW) * Charging Time (hours) * (1-EVSE efficiency) * No. of EVSE

Annual Energy Losses (in kWh/m^2.year) = Energy Loss per day (kWh) * 365

Annual Energy Losses per dwelling unit (in kWh/m^2.year) = Annual Energy Loss (kWh) * No. of dwelling units

EPI (in kWh/m^2.year) = Annual Energy Loss per dwelling unit (kWh) * No. of dwelling units

EPI Range & Q&A

- **Electric Vehicle Supply Equipment: EPI Range in kWh/m^2.year**

1.7 — 2.5

- **Electric Vehicle Supply Equipment: : Annual Energy Consumption Range per dwelling unit in kWh/year.dwelling unit**

208.2 — 290.8

Questions: Building Services

- Which BAU technology/ies are used?
- Which advanced energy efficiency technologies are available?
- Are there any challenges in adopting the energy efficient technologies?
- Are there good design strategies/practices for the component?
- What is the duration of operation of the component? (daily, monthly, yearly)
- What would be service life of the component?

Indoor electrical end use

Indoor lighting

→ EE strategies

- In order to reduce lighting energy use, it is pertinent that home designers and builders use windows and skylights to bring daylight into the home
- Designers should choose appropriate lighting fixtures, lamps that use energy more efficiently and install controls to reduce the number of time lights are on

Lamp	Efficiency (lumen/W)
15W	40
>15W-40W	50
>40W	60

Lighting Power Density (in W/m^2) = Illuminance (in lm/m^2) / {Lamp Efficacy (in lm/W) * Lamp Lumen Maintenance * maintenance Factor * Coefficienct of Utilization}

EPI (in kWh/m^2.year) = Lighting Power Density (in W/m^2) * Area (in m^2) * Annual Hours of operation / Super Built-up Area (in m^2)

Annual Energy Consumption = EPI x Super Built-up Area

EPI Range & Questions

- **Indoor Lighting: EPI Range in kWh/m^2.year**

2.78 — 21.51

- **Indoor Lighting: Annual Energy Consumption Range per dwelling unit in kWh/year.dwelling unit**

362 — 2,259

→ Questions

- What key factors do you keep in mind while designing the indoor lighting system for a dwelling unit?
- Do you provide a mix of lighting technologies? Or have any preferred choice?
- What would be the typical lighting power density of a dwelling unit?
- What is the typical illuminance/lux level which is kept in a dwelling unit?
- Do you follow any standards/guidelines while selecting the lighting system?

Fans

→ Description

- Attached to the ceiling using an electric motor to rotate blades or paddles in circular motion

→ EE strategies

- **Brushless DC (BLDC) Motor**:
  - permanent magnets (instead of electromagnets) for the Rotor → magnetic field → interacts with the magnetic field of the Stator to generate motion
- **Improved Blades**:
  - Improving fan blade design has been shown to have significant influence on fan efficiency, e.g.
    - Incorporation of aerodynamic attachments for conventional blades;
    - decrease in the angle of attack using twisted, tapered (TT) blades;
    - and use of TT blades with an air foil.
- **High Volume Low Speed (HVLS)**:
  - Optimised 3d-aerofoil blades, an active self-balancing system and electronically controlled high-efficiency DC motors use only a fractional 15-20% of the electricity consumed by conventional ceiling fans

Fans

The energy consumption and EPI of the ceiling/ table/ pedestal fans in the residential buildings can be directly estimated using the wattage of the fan(s)

EPI (in kWh/m².year) = Total Wattage of fan(s) * Annual Hours of operation/ 1000* Super Built-up Area (in m²)

(or)

The BEE star labelling uses the Service Value to determine the efficiency of the fan(s). The EPI shall be estimated from the Service Value:

EPI (in kWh/m².year) = [Air delivery rate in m³ per minute/Service Value of a fan] * No. of fans * Annual Hours of operation/ (1000*Super Built-up Area (in m²))

Service Value of a fan is the sum that we get after dividing the air delivery (in cubic meter/minute) by its power consumption. For example, if a fan gives air delivery of 220 CMM while consuming 50 Watts, its service value will be: 220/50 = 4.4

Annual Energy Consumption = EPI x Super Built-up Area

EPI Range & Questions

- **Fans: EPI Range in kWh/m².year**

1.76 — **9.19**

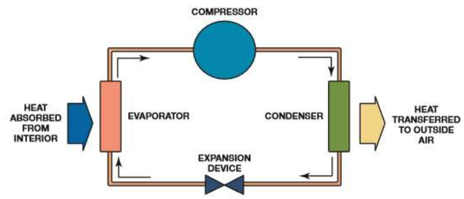
- **Fans: Annual Energy Consumption Range per dwelling unit in kWh/year.dwelling unit**

229 — **965**

Air-Conditioning

→ Description

- Works by collecting hot air from a given space, processing it within itself with the help of a refrigerant and a bunch of coils
- Releasing cool air into the same space where hot air had originally been collected



→ EE strategies

- Window and Split AC
  - EER represents the amount of cooling an air conditioner can provide per watt of electricity it consumes (BEE rates air conditioners based on EER)
- Inverter AC
  - Motor of the inverter compressor has a variable speed
- Variable refrigerant flow (VRF) System
  - Direct expansion (DX) multi-split system with variable speed compressor, capable of delivering capacity according to variable load requirement

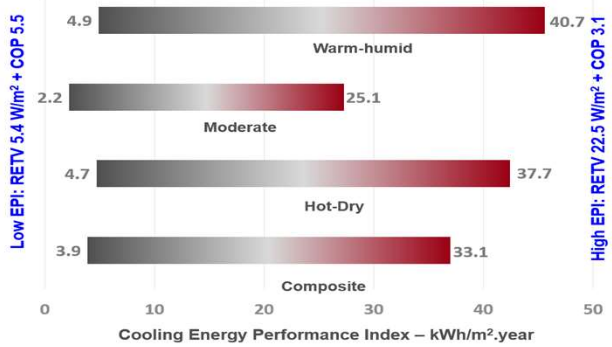
Air-Conditioning

- The EPI ranges for air-conditioner has been proposed based on the simulation study performed for the development of "Residential building energy labelling programme".
- Two models that are used to define EPI ranges are
  - RETV 22.5 W/m2 + COP 3.1
  - RETV of 5.4 W/m2 + COP 5.5

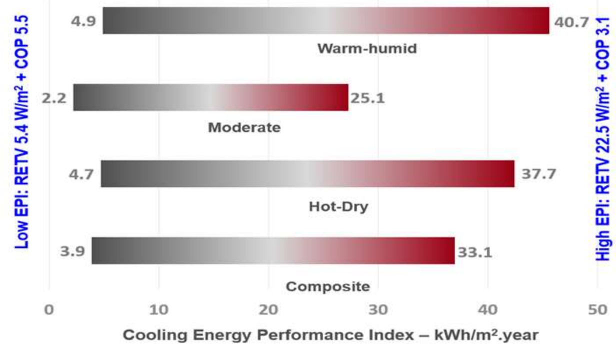
EPI (in kWh/m².year) = EPI for air conditioned spaces (20% area) with 24 °C as set point (E1) + EPI for other spaces (80% area) with natural ventilation (E2) set points defined by IMAC with Air conditioner switched ON* + EPI for other appliances: E3

EPI Range in kWh/m².year

- Air conditioners : EPI Range in kWh/m².year



- Air conditioners: Annual Energy Consumption Range per dwelling unit in kWh/year.dwelling unit



Air-Conditioning: Q&A

• What key factors do you keep in mind while selecting an air-conditioner for a room
• Which types of air conditioners are common in a dwelling unit
• Which star rating is widely used while used in residences? (5/4/3/2/1 star)
• How do you size/select the AC in a house? (eg.1 ton per 150 Sqft)
• Does dwelling unit floor area determines the type of air-conditioning unit?
• What is the cost implication of selecting an energy efficient technology like inverter AC's?

Service Hot Water

→ **Description**

- The typical electric water heater unit is wired to a 220-volt circuit.
- The current passes through electrical-resistance heating elements to heat the water
- Power is delivered to each element through a thermostat

→ **EE strategies**

- Increasing the amount of water drawn

→Increase in amount of energy delivered and ratio of useful energy (delivered hot water) to wasted energy (tank losses)

- Energy consumption is much greater in cases with colder mains temperature because more energy is required to bring the water up to a useful temperature
- Avoid unconditioned spaces so as to reduce the tank losses

EPI (in kWh/m^2.year) = [Total Wattage of water heater (s)] * Annual Hours of operation based on 35 degree temperature difference/ Super Built-up Area (in m^2)

EPI Range & Questions

- **Service Hot Water: EPI Range in kWh/m^2.year**

8.45 — **41.39**

- **Service Hot Water : Annual Energy Consumption Range per dwelling unit in kWh/year.dwelling unit**

1099 — **4346**

Appliances

Two Products considered

→ **Refrigerators**

- EE of refrigerators has improved considerably over the past two decades
- Room for improvements remains especially in developing countries
- Successful strategies for improving average EE of a country's refrigerator stock include MEPS and mandatory energy labels linked with financial incentives for consumers

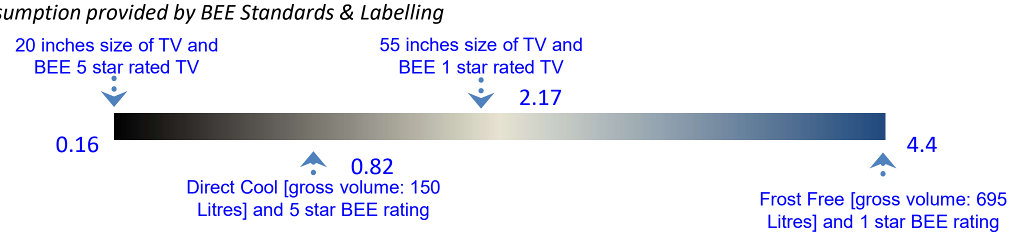
→ **Televisions**

- Product relies upon one of the following technologies: Cathode Ray Tube (CRT), Liquid Crystal Display (LCD) with Cold Cathode Fluorescent Lamp (CCFL) backlight, and Light Emitting Diode (LED) backlight and Plasma Display

EPI Range & Q&A

EPI (in kWh/m².year) = Average Annual Energy Consumption of the TV(s) or Refrigerator(s) (in kWh)/ Super Built-up Area (in m²)

The EPI (in kWh/m2.year) of the refrigerator or TV can be estimated by finding out the average annual energy consumption provided by BEE Standards & Labelling



Questions: Indoor Appliance

• Which BAU technology/star rating are used?
• What are the advanced energy efficiency technologies available?
• Which star rating can be considered as adoptable/affordable in the residential buildings?

Solar Water Heating

→ **Description**

- Requirement for hot water varies from 6 to 12 months in a year
- Average daily demand for hot water (at 40°C) per flat is around 300 litres
- two configurations:
  - smaller individual systems for each flat
  - larger community system, which supplies hot water through a common pipe network to a group of flats

→ **EE strategies**

- Flat Plate Collectors (FPC)
- Evacuated Tube Collectors (ETC)

Solar Hot Water

The EPI for the Solar Water Heating (SWH) systems can be evaluated as shown as below:

Average Daily Solar Heat Requirement (in kWh/day) = Total Hot water requirement per day (in LPD) * 1000 L/m^3 * Specific heat capacity of water i.e. 0.00116 kWh/kg °C [Outlet water temperature(in °C) - Inlet water temperature (in °C) / Density of Water i.e. 1000 kg/m^3

Average Daily Collector Yield (in kWh/m^2.day) = Average Daily Global Horizontal Irradiance (in kWh/m^2.day) * Solar Fraction * Hot Water distribution efficiency

Collector Area Required to supply Average Daily Solar Heat Requirement (in m^2) = Average Daily Solar Heat Requirement (in kWh/day) / Average Daily Collector Yield (in kWh/m^2.day)

EPI (in kWh/m^2.year)(SWH) savings = Collector Area Required (in m^2) * Annual Energy consumption of electric geysers (in kWh/year) / (Available Roof Area (in m^2) * Super Built-up Area (in m^2))

where Collector Area Required ≤ Available Roof Area

EPI Range & Q&A

- **Solar Hot Water: EPI Range in kWh/m^2.year**

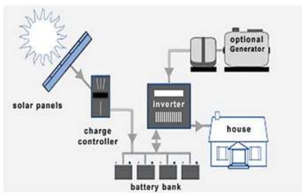
-8.5 **-41.4**

- **Solar Hot Water : Annual Energy Consumption Range per dwelling unit in kWh/year.dwelling unit**

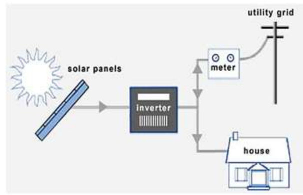
-1,099 **-4,346**

Solar Photovoltaic

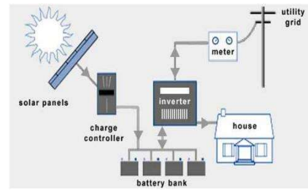
→ Description & EE Strategies



Stand-alone (off-grid) solar PV system with dedicated loads

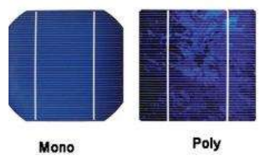


Grid-connected solar PV system with net metering

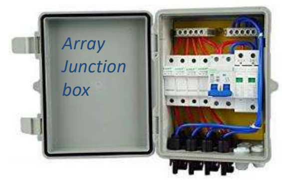


Hybrid system (system with grid back-up power)

Components
- Solar Photovoltaic Panels
- Inverters
- Batteries
- Charge Controller
- Array Junction box



Monocrystalline & Polycrystalline panels



Array Junction box

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Solar PV

The energy generation and EPI of the solar PV system in the residential buildings can be estimated using the following inputs:

- % of available roof area
- Average annual Solar irradiance
- Efficiency of Solar PV Cells
- Inverter Efficiency

EPI (in kWh/m^2.year) =
% of available roof area * Average annual Solar irradiance
* Efficiency of Solar PV Cells * Inverter Efficiency / Super Built-up Area (in m^2)

Annual Energy Generation = EPI x Super Built-up Area

- **Solar PV: EPI Range in kWh/m^2.year**

-2.82 → **-82.16**

- **Solar PV: Annual Energy Consumption Range per dwelling unit in kWh/year.dwelling unit**

-329 → **-10,681**

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Questions: Renewable Energy Integration

Solar Hot Water:

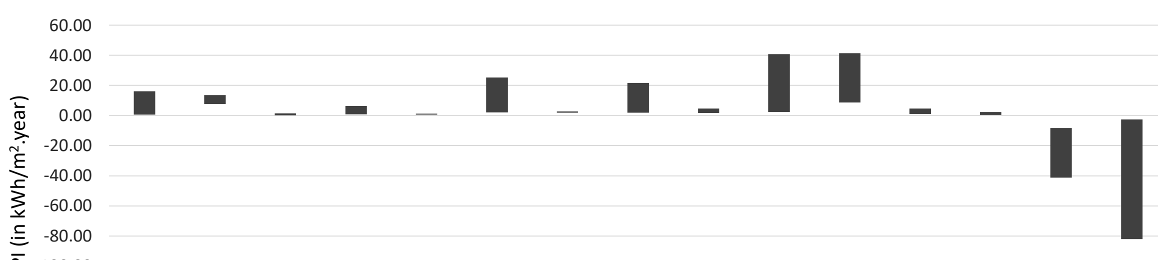
- What key factors do you keep in mind while designing solar water heater system for residential building?
- Which types of collectors for Solar water heaters are preferred for any system in a residential building? (Flat Plate, Evacuated tube etc.)
- Measures for insulating the storage tank for efficient storage of hot water?
- What is the service life of a typical solar water heater system?
- What is the cost of installing a solar water heater system of certain capacity?
- Do you follow any standards/guidelines while selecting the solar water system?

Solar Photovoltaics:

- What key factors do you keep in mind while designing the solar PV system for a building?
- Which types of PV module technologies are common in residential buildings? (e.g. Mono-Crystalline, Poly-Crystalline etc.)
- Which types of invertor are generally preferred in residential buildings?
- Which type of system is more often used, Grid connected or Stand alone?
- What is the service life of a typical SPV system?
- What is the cost of designing a solar PV system? How much extra cost it would take to buy an energy efficient technology cell as compared to the conventional cells?
- Do you follow any standards/guidelines while designing the SPV system?

EPI Range Summary

For each prototype define saving potential
- Based on energy saving potential and incremental cost define MEPS for individual components



	Common Area Lighting	Elevators	Pump	UPS Losses	Transformer	Car Parking Basement Fans	EVSE	Indoor lighting	Comfort System_ Fans	Comfort System_ AC	Service Hot Water	Appliance_Refrigerator	Appliance_TV	Solar Water Heating	Solar PV
High EPI case	16.06	13.50	1.24	6.19	1.09	25.15	2.5	21.51	4.59	40.70	41.39	4.40	2.17	-8.45	-2.82
Low EPI Case	0.46	7.49	0.08	0.58	0.41	1.91	1.7	1.69	1.58	2.20	8.45	0.82	0.16	-41.39	-82.16

Discussion

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Thank You

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