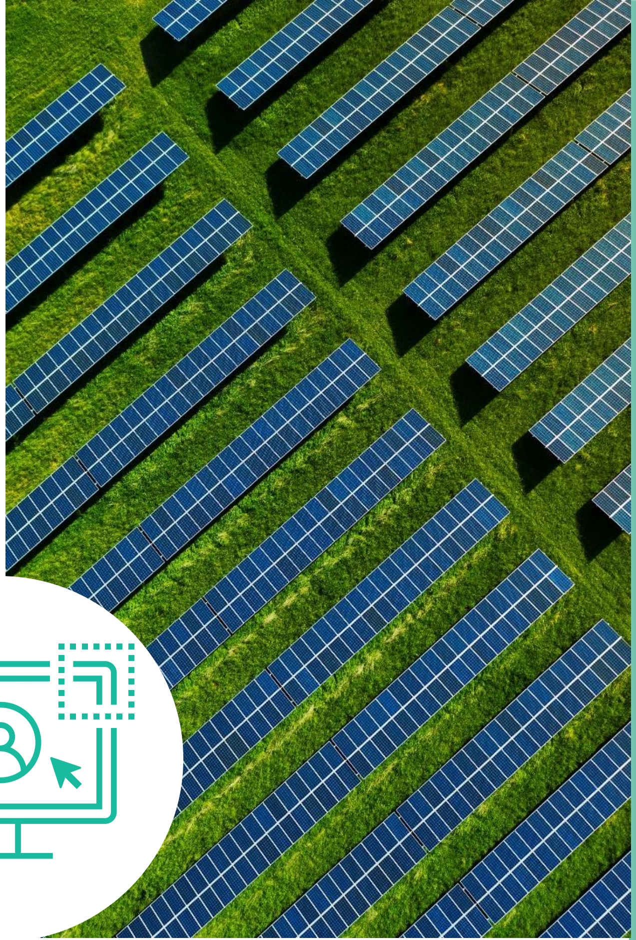
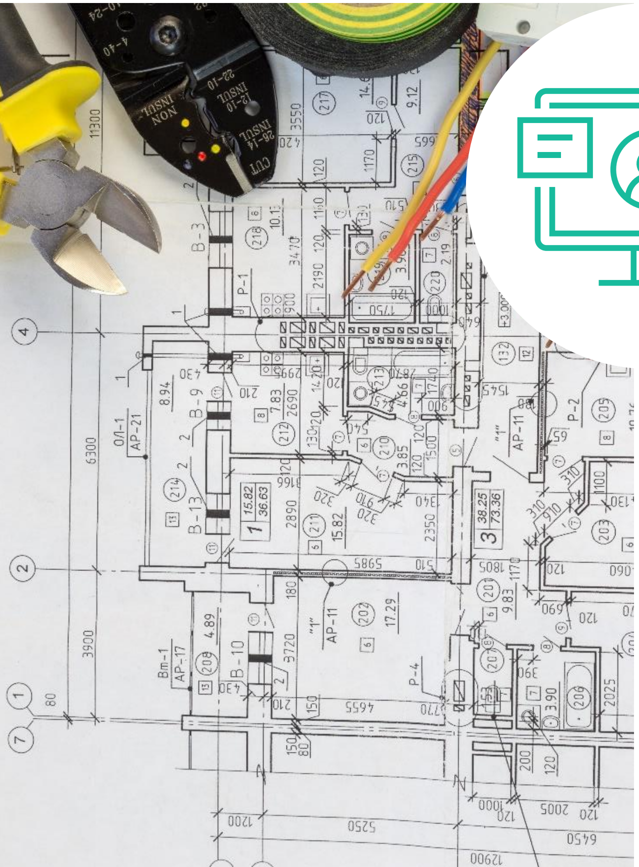
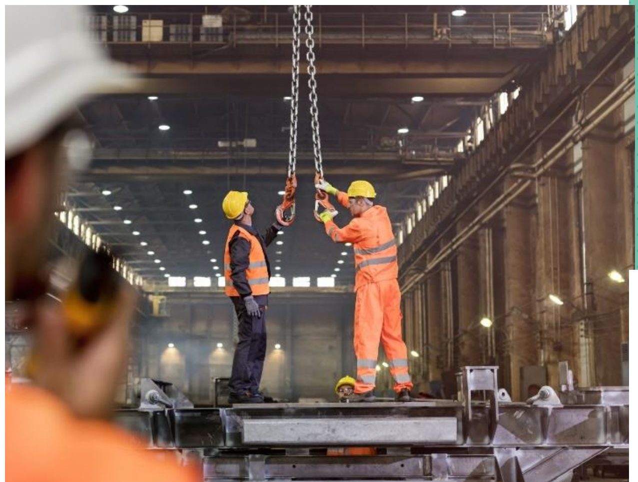






GGGI

ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy

2.6 Understanding the Basics of Energy Management

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 Classification of building types and energy use requirements

02 Energy benchmarks for different building types, including building star rating thresholds in India

03 Energy management approaches, systems and tools available for building facility managers

04 Building management and automation systems for energy optimization

05 Case examples

Image source: https://damiaglobalservices.com/building-energy-management-system/

BUILDINGS

Classification by type

Hospitality

- No Star
- Resorts
- Star Hotels

Healthcare

- Hospitals
- Out-patient Care

Assembly

- Theaters
- Transport Service Facilities
- Multiplexes

Business

- Small Offices: <10,000 sqm
- Medium Offices: 10,000–30,000 sqm
- Large Offices: >30,000 sqm

Education

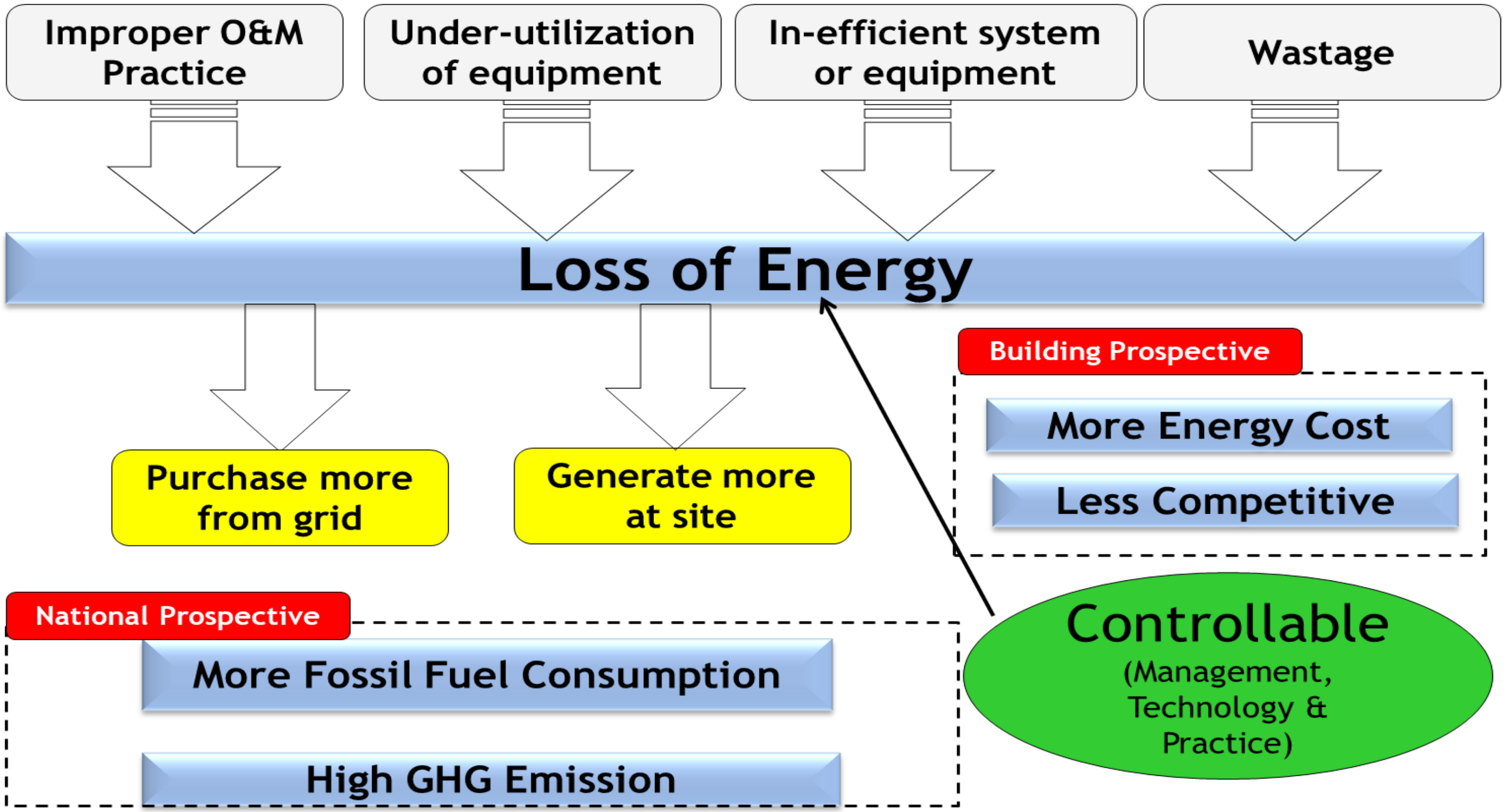
- Schools
- Colleges
- Universities
- Training Institutions

Retail

- Shopping Malls
- Stand-alone Retails
- Open Gallery Malls
- Supermarkets

ENERGY USAGE IN BUILDINGS

Issues and opportunities



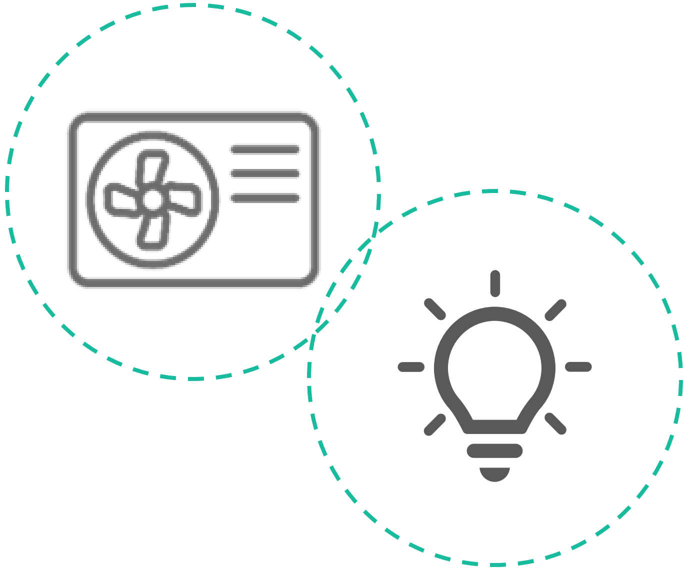
TYPICAL ENERGY SNAPSHOT

Example: Hotel building in Chiang Mai, Thailand

Location	:	Chaing Mai, Thailand
Building	:	5-Star, 5 Floors
Building Type Hotel Area Source of Supply	: :	Resort 12,825 m^2 22 KV from Authority Own Generation from DG Sets
Transformers	:	2 x 800 KVA
DG Sets	:	1 x 500 KVA
Major Electrical Loads	:	Lighting and Power, Air Conditioning, Water Pumping, Hot Water Generator
Estimated Connected Load	:	About 667 KW
Usage Hours	:	24 Hrs Operation
Air Conditioning System	:	Non-central AC
Annual Energy Consumption	:	344 Tons of Oil Equivalent
Annual Electricity Consumption Annual Energy Cost	: :	1.8 million kWh THB 11.4 million

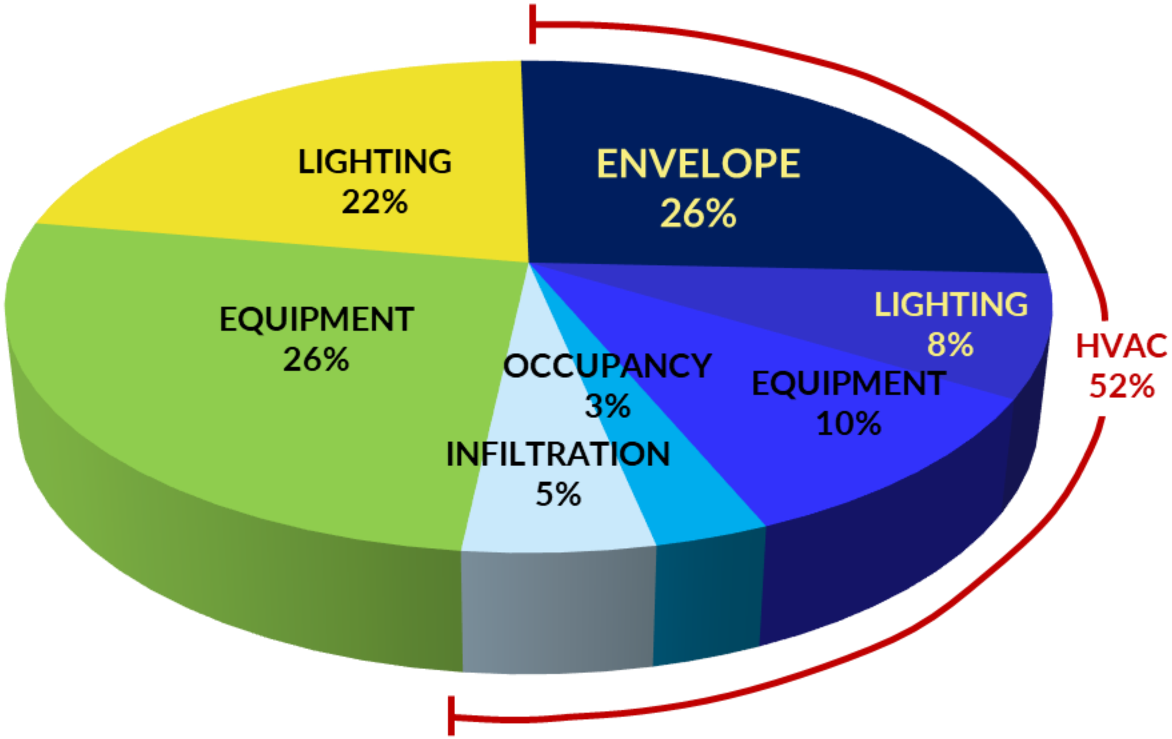
COMMERCIAL BUILDINGS

Typical energy consumption in commercial buildings



Air conditioning and lighting are the major focus area for energy management in buildings

Breakdown of energy consumption in a typical air-conditioned commercial building; note the contribution of heat load from various heat sources on the HVAC system; building envelope is usually the major contributor.



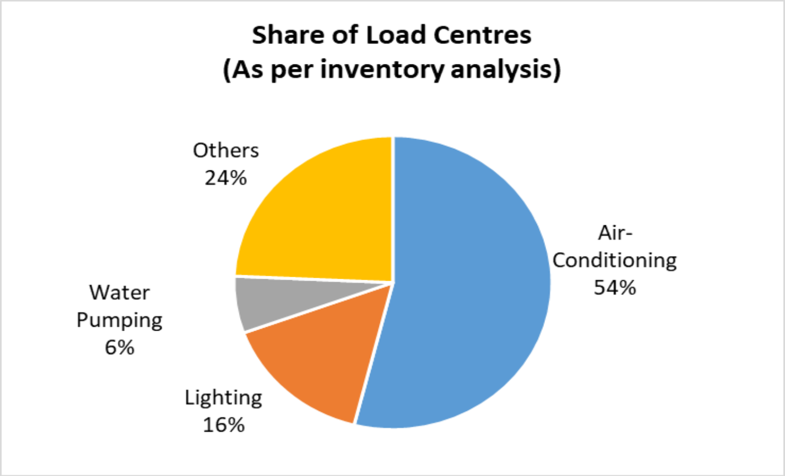
Source: Farheen Bano & Mohammad Arif Kamal. 2016. Examining the Role of Building Envelope for Energy Efficiency in Office Buildings in India. Architecture Research 2016.

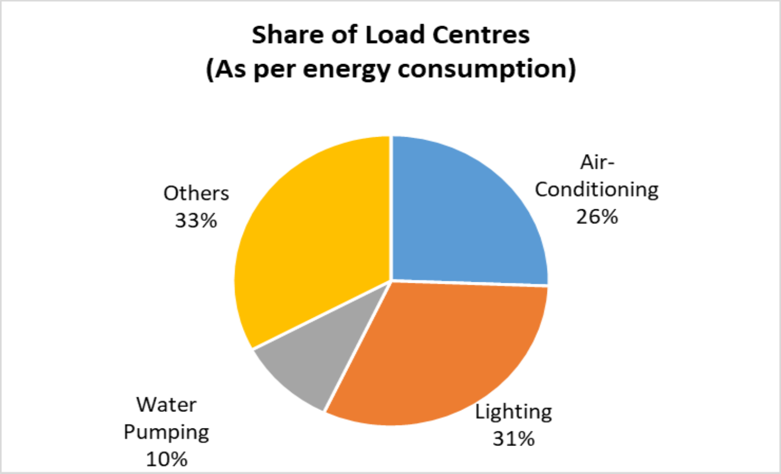
TYPICAL INVENTORY ANALYSIS

Example: Share of connected load and energy consumption in a commercial building

Load Centers	Connected Load kW	Annual Energy Consumption, kWh
Air Conditioning	360	460,800
Lighting	104	566,734
Water Pumping	42	182,953
Others	162	591,886
Total	667	1,802,372

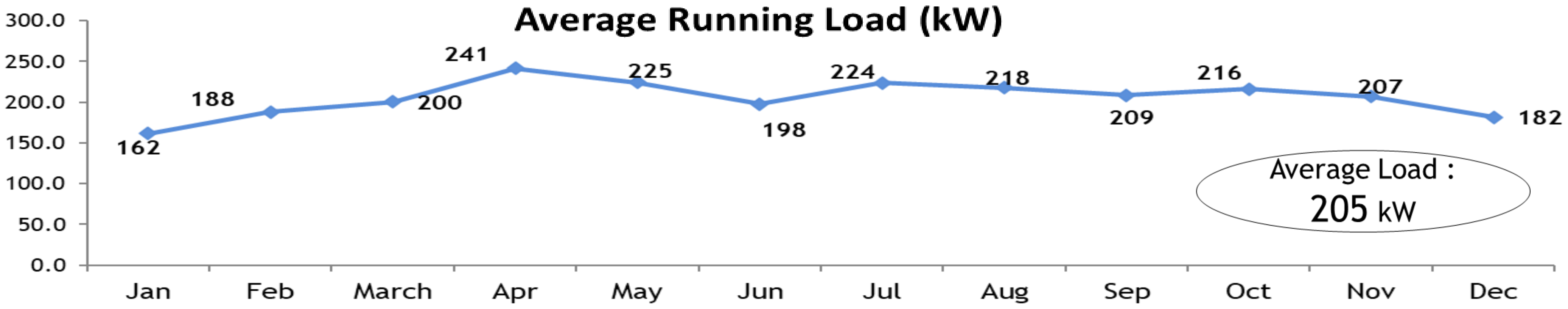
Connected Load
670 kW

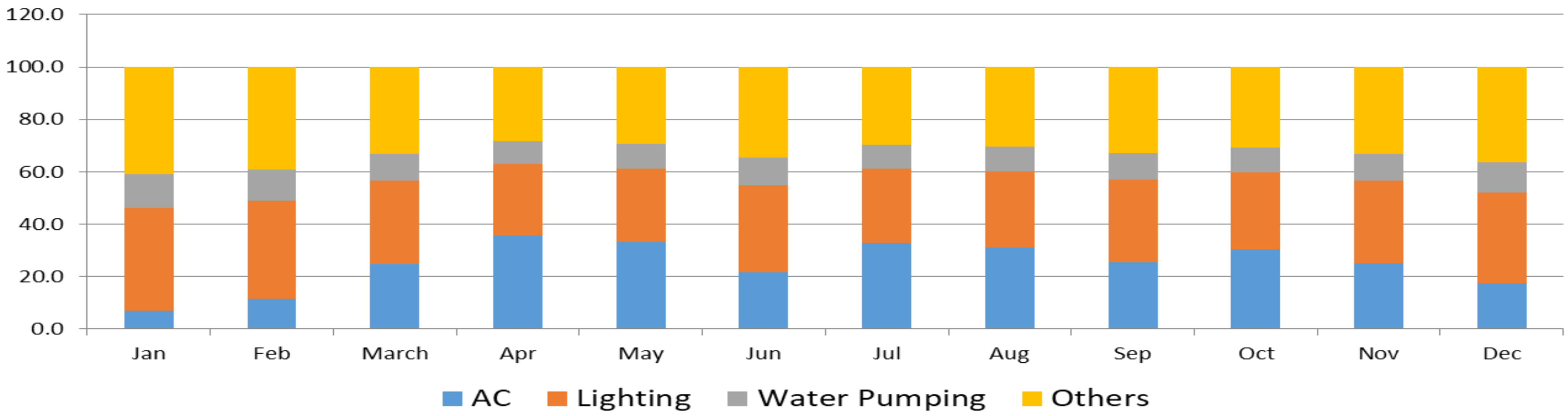




TYPICAL LOAD CURVE

Example: Monthly electrical energy usage pattern in commercial buildings

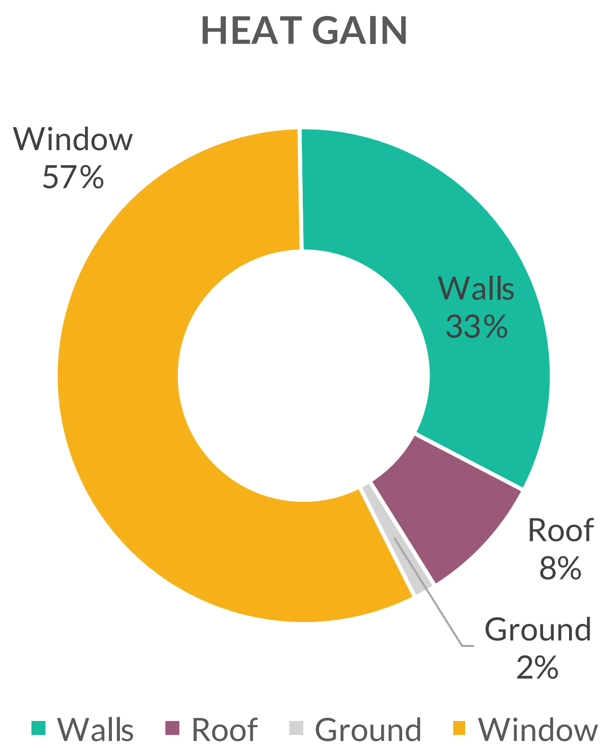




HVAC – EXAMPLE OF HEAT GAIN

Building envelope: Sources of heat load on HVAC in different climatic zones in India

Heat Gain through Building Envelope (Ground + 4 floors Office Building)								
Climate	Hot and Dry		Warm and Humid		Composite (Hot and Dry, Warm and Humid, Cold)		Composite (Hot and Dry, Warm and Humid, Cold)	
Building Component	Ahmedabad (223.037 MWh)		Mumbai (201.892 MWh)		Nagpur (198.756 MWh)		Pune (137.764 MWh)	
	Cooling Load (MWh)	Annual Cooling Load (%)	Cooling Load (MWh)	Annual Cooling Load (%)	Cooling Load (MWh)	Annual Cooling Load (%)	Cooling Load (MWh)	Annual Cooling Load (%)
Walls	81.141	36.4	66.532	33.0	71.151	35.8	36.487	26.5
Roof	18.996	8.5	15.148	7.5	17.845	9.0	12.288	8.9
Ground	4.957	2.2	4.557	2.3	3.000	1.5	0.129	0.1
Window (Conduction + Direct Solar)	117.941 (28.563 + 89.378)	52.9 (12.8 + 40.1)	115.654 (17.405 + 98.249	57.3 (8.6 + 48.7)	106.761 (19.608 + 87.153)	53.7 (9.9 + 43.8)	89.119 (6.180 + 82.939)	64.7 (4.5 + 60.2)



Source: Farheen Bano & Mohammad Arif Kamal. 2016. Examining the Role of Building Envelope for Energy Efficiency in Office Buildings in India. Architecture Research 2016.

HOTELS AND RESORTS

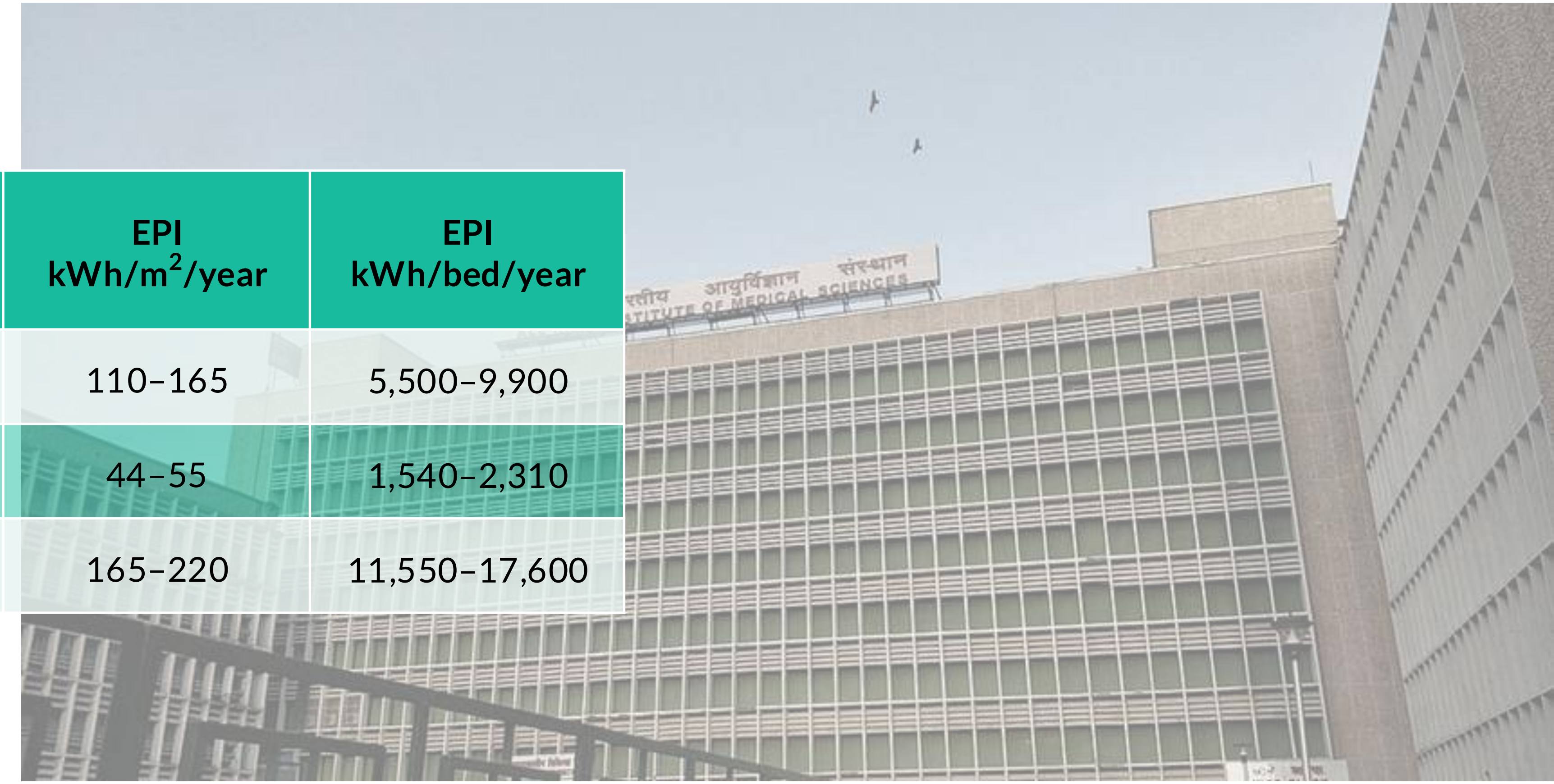
India: Estimated Energy Performance Index (EPI)

Category	Built-up Area m^2/room	EPI kWh/m^2/year	EPI kWh/room/year
1 Star	30–35	55–82.5	1,650–2,888
2 Star	35–40	110–137.5	3,850–5,500
3 Star	50–60	137.5–165	6,875–9,900
4 Star	60–70	165–192.5	9,900–13,475
5 Star	70–80	192.5–220	13,475–17,600
Heritage	80–90	220–247.5	17,600–22,275
Others	–	82.5–110	

Source: Kumar et al., 2017

HOSPITALS

India: Estimated Energy Performance Index (EPI)



Category	Built-up Area m^2/bed	EPI kWh/m^2/year	EPI kWh/bed/year
Government –Urban	50–60	110–165	5,500–9,900
Government – Rural	35–42	44–55	1,540–2,310
Private – All	70–80	165–220	11,550–17,600

Source: Kumar et al., 2017

Image source: Vishnoi

OFFICE BUILDINGS

India: Estimated Energy Performance Index (EPI)

Category	Built-up Area m^2/employee	EPI $kWh/m^2/year$	EPI kWh/employee/year
PRIVATE OFFICES			
Information Technology-enabled Services	9–11	82.5–110	743–1,210
Banking Services, Finance and Insurance	6–8	55–82.5	330–660
PUBLIC OFFICES			
Central Government	12–15	77–99	924–1,485
State Government	10–12	66–77	660–924
Quasi Government	8–10	77–88	616–880
Local Government	3–5	22–33	66–165

Source: Kumar et al., 2017

EDUCATION BUILDINGS

India: Estimated Energy Performance Index (EPI)

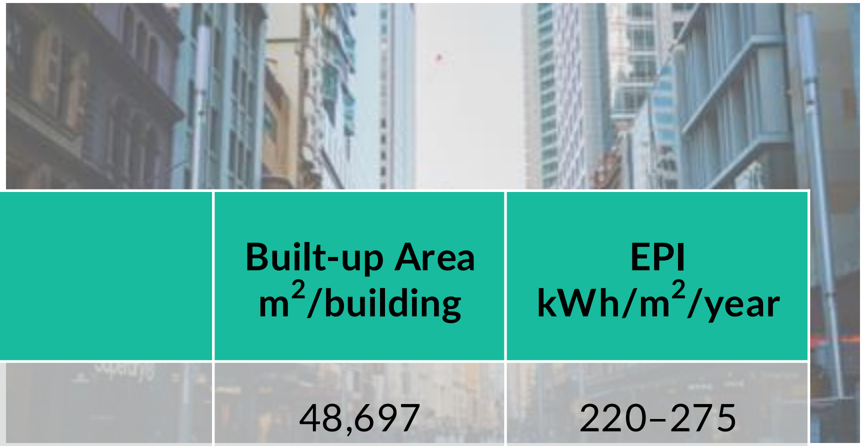
Category	Built-up Area m^2/building	EPI $kWh/m^2/year$
SCHOOLS		
Primary	150–160	20–25
Upper Primary	301–310	20–25
Secondary	554–560	30–40
Higher Secondary	1,313–1,320	30–40
UNIVERSITIES / COLLEGES		
Rural	1,500–2,000	22–27.5
Urban	2,000–2,500	33–44
Institutes of National Importance	20,000–25,000	44–55
Stand-alone Institutions	500–600	22–33

Source: Kumar et al., 2017

Image sources: Deanndamon; AjZock

RETAIL

India: Estimated Energy Performance Index (EPI)



Category	Built-up Area m^2/building	EPI $kWh/m^2/year$
Modern Malls	48,697	220–275
Traditional Small Grocery Stores	14–18	33–38.5
Traditional Large Grocery Stores	42–55	55–66

Source: Kumar et al., 2017

INDIA: STAR RATING THRESHOLDS

Business process outsourcing (BPO) buildings

Climatic Zone		1 Star	2 Star	3 Star	4 Star	5 Star
Composite	Threshold EPI (y)	y = 0.21x + 28	y = 0.18x + 24	y = 0.15x + 20	y = 0.12x + 16	y = 0.09x + 12
	Calculated EPI Value	41.7	35.7	29.8	23.8	17.9
Hot and Dry	Threshold EPI (y)	y = 0.1x + 24	y = 0.08x + 20	y = 0.06x + 16	y = 0.04x + 12	y = 0.02x + 8
	Calculated EPI Value	30.5	25.2	19.9	14.6	9.3
Warm and Humid	Threshold EPI (y)	y = 0.17x + 36	y = 0.14x + 32	y = 0.11x + 28	y = 0.08x + 24	y = 0.05x + 20
	Calculated EPI Value	47.05	41.1	35.2	29.2	23.3
Temperate	Threshold EPI (y)	y = 0.13x + 31	y = 0.11x + 27	y = 0.09x + 23	y = 0.07x + 19	y = 0.05x + 15
	Calculated EPI Value	39.45	34.2	28.9	23.55	18.3

Notes: ‘x’ is air-conditioned floor area as a percentage of total floor area
‘y’ is threshold Energy Performance Index (EPI)
Sample EPI calculated values are provided for air-conditioned area @ 65% of total floor area
EPI values of buildings must be below the threshold value to qualify for star rating
Energy generated from onsite renewable energy sources is excluded from EPI calculation

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

INDIA: STAR RATING THRESHOLDS

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
	Calculated EPI Value	121.75	108.50	95.25	82.00	68.75
	Medium Office	y = 1.1x + 60	y = 1.05x + 50	y = 1.0x + 40	y = 0.95x + 30	y = 0.9x + 20
	Calculated EPI Value	131.50	118.25	105.00	91.75	78.50
	Small Office	y = 0.65x + 60	y = 0.6x + 50	y = 0.55x + 40	y = 0.5x + 30	y = 0.45x + 20
	Calculated EPI Value	102.25	89.00	75.75	62.50	49.25
Warm and Humid	Large Office	y = 0.9x + 65	y = 0.85x + 55	y = 0.8x + 45	y = 0.75x + 35	y = 0.7x + 25
	Calculated EPI Value	123.50	110.25	97.00	83.75	70.50
	Medium Office	y = 0.9x + 65	y = 0.85x + 55	y = 0.8x + 45	y = 0.75x + 35	y = 0.7x + 25
	Calculated EPI Value	123.50	110.25	97.00	83.75	70.50
	Small Office	y = 0.7x + 65	y = 0.65x + 55	y = 0.6x + 45	y = 0.55x + 35	y = 0.5x + 25
	Calculated EPI Value	110.50	97.25	84.00	70.75	57.50
Hot and Dry	Large Office	y = 1.1x + 55	y = 1.05x + 45	y = 1.0x + 35	y = 0.95x + 25	y = 0.9x + 15
	Calculated EPI Value	126.50	113.25	100.00	86.75	73.50
	Medium Office	y = 1.25x + 55	y = 1.2x + 45	y = 1.15x + 35	y = 1.1x + 25	y = 1.05x + 15
	Calculated EPI Value	136.25	123.00	109.75	96.50	83.25
	Small Office	y = 0.75x + 55	y = 0.7x + 45	y = 0.65x + 35	y = 0.6x + 25	y = 0.55x + 15
	Calculated EPI Value	103.75	90.50	77.25	64.00	50.75

Notes: 'x' is air-conditioned floor area as a percentage of total floor area
'y' is threshold Energy Performance Index (EPI)
Sample EPI calculated values are provided for air-conditioned area @ 75% of total floor area, 8–9 hours operation for 6 days/week
EPI values of buildings must be below the threshold value to qualify for star rating
Energy generated from onsite renewable energy sources is excluded from EPI calculation

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

INDIA: STAR RATING THRESHOLDS

Ranking for hospitals with more than 50% air-conditioned space

	5 Star	4 Star	3 Star	2 Star	1 Star	No Star
Performance Rank	<= 4	> 4 and <= 12	> 12 and <= 24	> 24 and <= 40	> 40 and <= 60	> 60 and <= 100

Note: Energy generated from onsite renewable energy sources is excluded from energy calculation

- The ranking methodology compares the energy consumption of a hospital with its benchmark value'
- The benchmark value represents the average energy consumption of hospitals with similar characteristics and is derived from sample data, using regression analysis
- The ratio of the actual energy consumption of a hospital to its benchmark value depicts the relative energy efficiency of the building
- A performance rank is derived by comparing this ratio to a distribution derived from the sample data set
- The performance rank lies in the range of 1–100. A rank of 1 implies performance among the top 1% hospital buildings in the nation, while a rank of 50 represents an average performance. The star rating is based on the rank

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

INDIA: STAR RATING THRESHOLDS

Shopping malls

Composite Climate	
EPI (kWh/m^2/year)	Star Label
350–300	1 Star
300–250	2 Star
250–200	3 Star
200–150	4 Star
Below 150	5 Star

Temperate Climate	
EPI (kWh/m^2/year)	Star Label
275–250	1 Star
250–225	2 Star
225–200	3 Star
200–175	4 Star
Below 175	5 Star

Hot and Dry Climate	
EPI (kWh/m^2/year)	Star Label
300–250	1 Star
250–200	2 Star
200–150	3 Star
150–100	4 Star
Below 100	5 Star

Warm and Humid Climate	
EPI (kWh/m^2/year)	Star Label
450–400	1 Star
400–350	2 Star
350–300	3 Star
300–250	4 Star
Below 250	5 Star

Note: Energy generated from onsite renewable energy sources is excluded from energy calculation

Source: Bureau of Energy Efficiency, Government of India, 2011

ENERGY MANAGEMENT

Genesis from the perspective of a building energy manger

- I should know my energy usage pattern
- I should know where I stand in comparison with other similar building(s)
- I should know the potential areas of energy saving
- My staff should manage energy in an efficient and sustainable manner
- I should be aware of the options for improving energy performance
- I should work toward continuous improvement of energy performance

Benchmarking

Data Monitoring

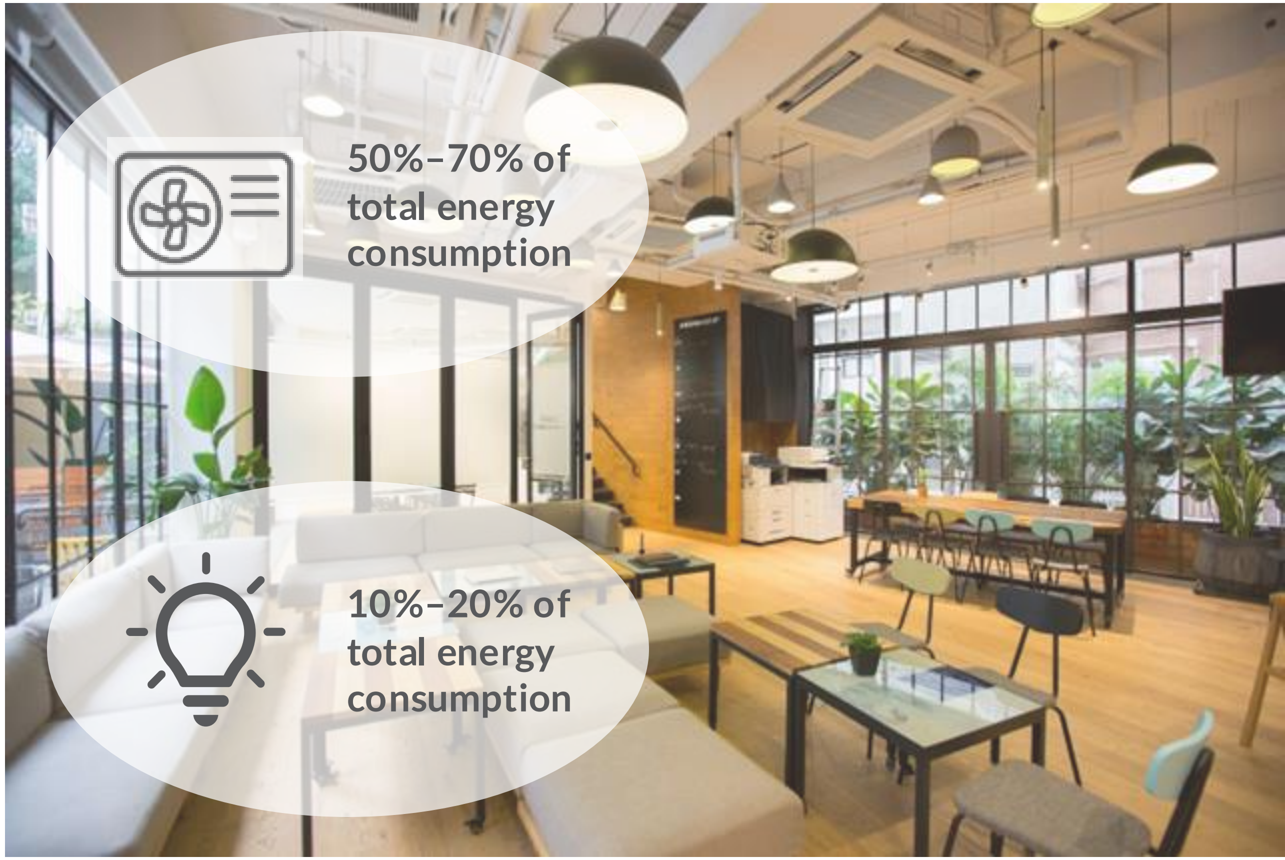
Energy Audit

Guidebook & Training

ENERGY MANAGEMENT

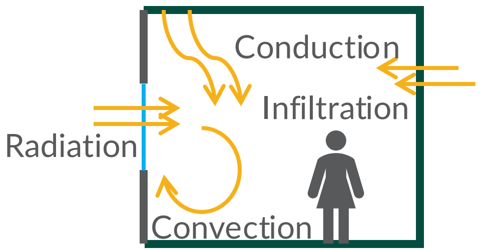
Understanding major loads in buildings

- In modern buildings, building cooling accounts for 50%–70% of total energy consumption, and lighting accounts for about 10%–20% of total energy consumption. The contribution to the HVAC heat load due to people and appliances vary significantly, depending on type of building i.e., office, hotel, hospital, BPO building, educational institution, etc.
- In naturally-ventilated buildings without air conditioning, ceiling fans may account for a significant portion of energy consumption
- The major energy saving potential is expected to be in building cooling and lighting. A holistic systems approach is recommended wherein opportunities for reduction in air conditioning and lighting load are addressed first, before focusing on equipment energy efficiencies

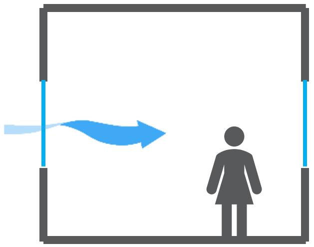


ENERGY MANAGEMENT

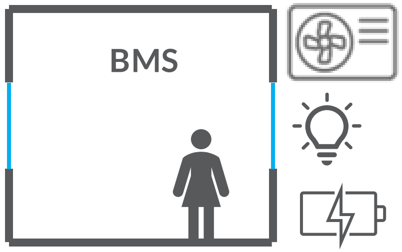
Holistic approach to energy savings in building cooling



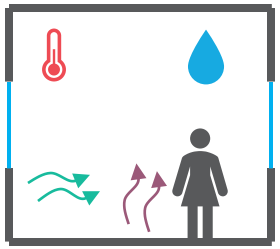
- Use principles of adaptive thermal comfort to vary HVAC temperature settings in relation to outside air temperatures and humidity



- Consider increasing convective air movement in rooms by providing low-speed fans to enable comfort at higher room temperature settings



- Consider increasing temperature settings of rooms without occupancy like unoccupied cabins, guest rooms, conference rooms, low occupancy foyers, document storage rooms, reprographics rooms, etc.
- Good control systems should be in place in the hydronic and air handling units (AHUs) or fan coil units (FCUs) to achieve higher temperature settings without the dripping of excessive water condensation, especially in FCUs
- A centralized building management system (BMS) with occupancy sensors is required for effective monitoring and control



- In most HVAC systems, the recirculating air quantity may be about 90% and the ventilation fresh air quantity about 10%
- Cooling has two components: (i) sensible heat removal by reduction of air temperature; and (ii) latent heat removal, which is heat removal due to condensation of moisture that helps in maintaining the room's relative humidity at a comfortable 50% to 60%
- Moisture is usually from two main sources: fresh air and gaseous bio-effluents from people (sweat, exhaled air, etc.)
- To ensure condensation of moisture, the air temperature has to be brought below dew point temperature of air

ENERGY MANAGEMENT

Holistic approach to energy savings in building cooling

- In conventional HVAC systems, the temperature of the entire recirculating and fresh air quantity is brought down to a low temperature, implying that along with moisture removal, the sensible cooling load also increases significantly, as the entire recirculating air quantity is brought down to a low temperature. Consider using a dedicated outside air system (DOAS) for removal of humidity from the fresh air at source with direct refrigerant cooled coil or desiccant wheel; this can enable temperature reset to higher temperature in the main air handling units, which are handling the large recirculating air quantity
- In the case of fixed speed chillers, monitoring of refrigeration load on chillers is essential to ensure that, to the extent possible, chillers are operating above 80% of the rated load to ensure operation close to the design COP
- In the case of variable speed chillers, operation at lower speeds increases the COP. In the case of fixed speed chillers, the improvement in COP may or may not be significant, depending on the capacity control method. There are no general rules, hence, the optimal trade-off between operating more chillers at lower load and additional auxiliary pumps should be established for each system and programmed into the operating control
- Operating COP of chillers should be established at normal loading. The performance should be correlated with chiller loading, logarithmic mean temperature differences (LMTD) in the evaporator and condenser, chilled water or cooling water flow rates in the chiller and condenser, water-side pressure drops across the evaporator and condenser, and refrigerant charge. Higher LMTDs may be an indication of fouling of evaporator and/or condenser; it may also be an indication of insufficient heat transfer area

ENERGY MANAGEMENT

Holistic approach to energy savings in building cooling (continued)

- Practical experience from energy audits indicates that the drop in efficiency of chillers are usually due to fixed speed compressors operating at partial loads or due to poor heat transfer in the evaporator and condenser; poor performance is rarely due to mechanical problem with the compressor
- Fouling of evaporators and condensers must be addressed through mechanical cleaning, retrofitting with in-line cleaning systems or resolving any chronic water quality issues
- In case the evaporator and condenser heat transfer areas are insufficient, replacement of these heat exchangers may be required to improve chiller efficiency
- The performance of chilled water pumps and cooling water pumps should be critically evaluated from the viewpoint of operating flow, pressure and operating efficiency; opportunities usually exist for optimization of flows, pressures and pump efficiencies. The operating head and flow should closely align with the pump's design head and flow within the optimal efficiency zone to ensure maximum pumping power
- Cooling tower performance impacts chiller operating efficiency. One of the critical parameters is ratio of water flow-to-air flow (L/G ratio). Insufficient heat transfer area, fouling of cooling tower and low air flow result in inefficient operation of chillers

ENERGY MANAGEMENT

Holistic approach to energy savings in building cooling (continued)

- Air flows in air-cooled condensers are difficult to measure under site conditions, but refrigerant condensing pressures and cooling air temperatures can provide guiding indicators for the performance and impact on chiller efficiency. Retrofitting evaporative coolers to reduce condensing pressure and temperature during high ambient dry bulb temperature (with low relative humidity) is an effective method to improve chiller efficiency
- Performance assessment of large AHU centrifugal fans needs critical review. Replacement of inefficient fans with energy efficient axial flow fans with permanent magnet and brushless direct current (BLDC) motors (the combination is popularly called EC fans in India) has energy saving potential in the range of 20%–30%, depending on the existing efficiencies of fans and motors
- All large AHUs should have variable speed drives to optimize air flow, while multi-speed motors are recommended for FCUs. For effective, trouble-free operation, each AHU or FCU should have proper controls for throttling and bypassing chilled water at lower air flows
- A good BMS is required wherein the cooling load of buildings and that of large areas are monitored by integration of chilled water temperatures and flows, and correlating them with energy consumption

ENERGY MANAGEMENT

Holistic approach to energy savings in lighting

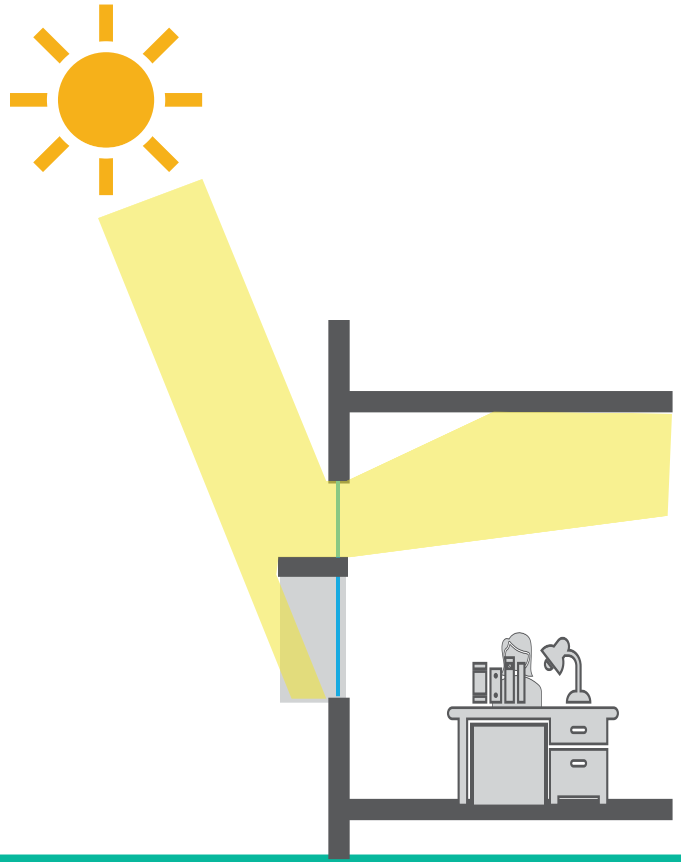
- In the past decade, the widespread availability and reduction in prices of energy efficient LED lamps have led to their widespread use across various applications, from bedside lamps to flood lighting in sports stadiums. Available in a range of wattages and offering numerous designs variations in lamps and luminaires, the primary driver has been aesthetics. As a result, there may be limited scope for energy optimization through the replacement of lamps and luminaires, as was the case with conventional gas discharge lamps and luminaires
- Due to the reduced energy consumption in lighting due to LED lamps, it is often difficult to justify investments in dedicated control systems only for lighting. However, it makes economic sense if it is part of a BMS that also controls HVAC

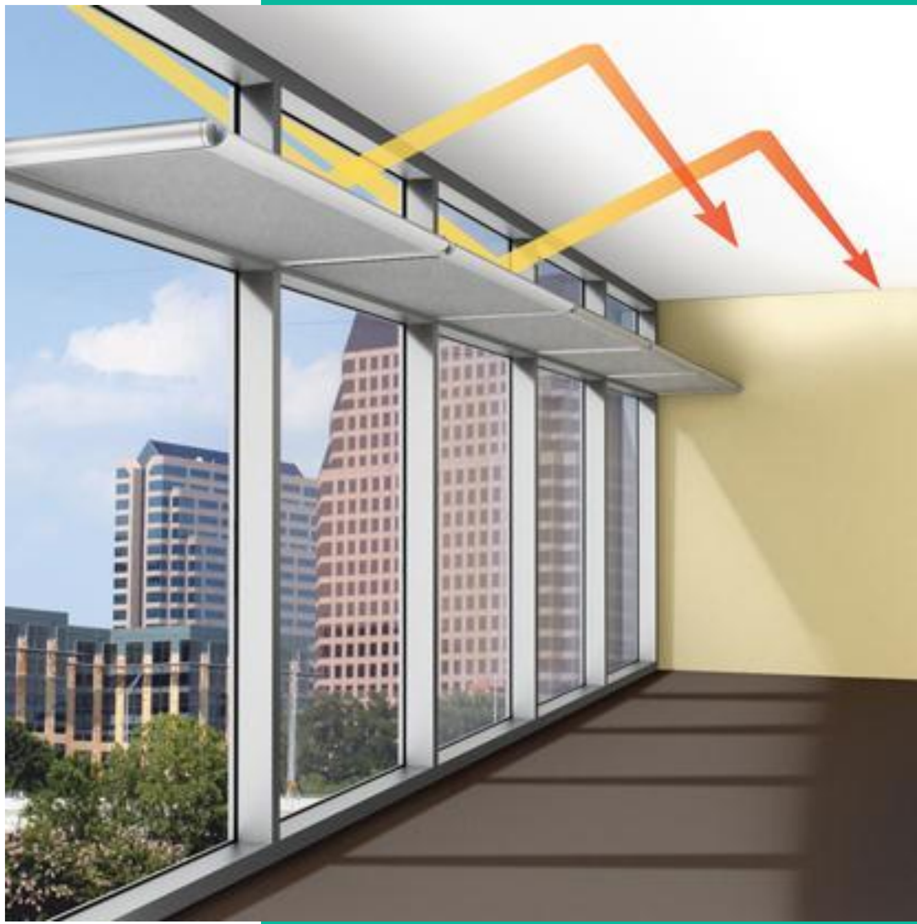
Image source: Wipro Lighting

ENERGY MANAGEMENT

Holistic approach to energy savings in lighting (continued)

- However, energy saving opportunities still exist for optimizing the use of electric lights during daytime. Although excessive glass is used in modern buildings for aesthetics, most buildings still use electric lighting during daytime
- In most buildings, due to glare or excessive light and solar radiation, occupants usually prefer to draw the blinds and use electric lights
- The absence of light shelves to allow natural light without glare in building architectural design augments the problem. However, possibilities exist to innovatively and aesthetically retrofit light shelves in existing buildings to reduce daytime use of electric lighting





Retrofitting light shelves

Image source: https://www.designingbuildings.co.uk/wiki/Light_shelf

ENERGY MANAGEMENT

Integration of renewable energy

- The goal of net zero buildings cannot be achieved by energy efficiency measures alone. Integration of renewable energy with grid energy systems is required
- The simplest way forward is to source renewable electrical power from solar power plants or wind farms through offsite generation, although it may be more expensive if it is sourced from independent power producers
- Sizing of onsite solar power systems depends on space availability and matching electrical load availability during sunshine hours
- Onsite generation of solar power may give greater operational energy savings but will involve high initial capital cost
- Ideally, the solar power system should be sized to meet the building's entire energy demand, as the greatest cost savings are likely achieved when expensive grid electricity is offset. Exporting solar power typically reduces the return on capital investment, as the revenue from exported power is usually much lower than the cost of imported grid electricity

ENERGY MANAGEMENT

Integration of renewable energy (continued)

- Technical issues related to the electrical power system require attention, especially the point of connection to the power system. It is desirable for the solar power system to be connected on the upstream side of the main automatic power factor controller (APFC) to avoid malfunction in power factor control if the power is not fully absorbed in the building and power is exported. Most passive power factor controllers are designed to operate in power export mode
- Fixed charges of grid power should be factored in the calculations of economics of solar power systems, as higher contracted grid power is required for overcast days and nights. Operation with low margins of contracted power may demand automated electrical power management systems with non-critical load shedding capability
- The integration of wind power is usually from offsite wind farms. This is because the power capacities of onsite wind turbines are generally too small and dependent on highly unpredictable wind velocities, and hence, not popular
- The integration of thermal renewable energy in the form of solar hot water systems or biomass fired systems can be easily integrated and do not have the complications associated with electrical power integration

OFFICE BUILDING

Case example: Large office building in the IT/ITES sector

- Capgemini's EPIP Campus in Bengaluru, India, is the first information technology (IT) and information technology-enabled services campus in India to achieve the Net Zero Energy – Platinum (Operation) certification from IGBC

- The project team worked for almost three years to explore new and innovative measures for energy efficiency and retrofit old equipment to industry-benchmarked high performing equipment and systems. They included water-cooled chillers, inline primary pumps integrated with VFD, AHUs fitted with EC motors and ESP filters along with UVGI lamps, LED lighting fixtures, and integrated solar lighting fixtures for exterior illumination and street lighting

- Additionally, the project produces onsite renewable energy (over 20%) and imports green power to offset 100% grid energy use by renewables

Capgemini's EPIP Campus in Bengaluru, India

Source: Confederation of Indian Industry and Shakti Sustainable Energy Foundation, 2022

OFFICE BUILDING

Case example: Large office building in the IT/ITES sector (continued)

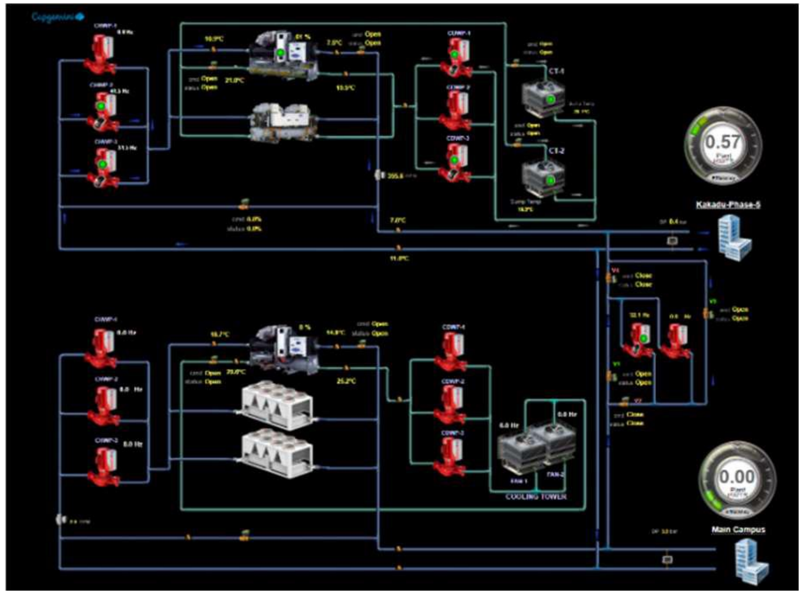
The integration of renewable energy:

- Significant increase in onsite renewable energy generation (1.35 MWp)
- Source about 78%–80% green power through purchase power agreement
- Installation of 100% solar-based street lighting
- Use of solar-powered chiller for maximum reduction in energy demand

Other measure include:

- Reduction in data center energy consumption by retro-commissioning, retrofitting, and managing hot and cold aisle containment and sophisticated control of cool air
- Rigorous metering and monitoring of energy at end use. It includes the monitoring of each equipment on real-time basis (at 15-minute intervals) and diagnose performance with respect to rated capacity and energy consumption
- Inferred decisions from online management system. It includes a central command center to map out energy usage and create alarms when performance deviates from design goals

These implementations reduced energy use of the facility by 16%. The Energy Performance Index ratio of the campus is 0.73



Source: Confederation of Indian Industry and Shakti Sustainable Energy Foundation, 2022

HOSPITAL BUILDING

Case example: Design interventions to improve EPI

A 350-bed multi-specialty hospital building in warm-humid climate (Pune, India) implemented measures for improving the Energy Performance Index (EPI) at the design stage; the main focus being on HVAC

The built-up area is 26,580 m^2 (excluding parking and service floor: ~9,500 m^2), with 3 underground floors and 9 overground floors + 1 service floor. The types of spaces include technical areas like MRI, ICUs, Cath lab, OTs; patient indoor rooms and recovery rooms; restaurants, emergency rooms, etc.

The measures implemented for the building envelope were:

- Roof insulation: 150mm of RCC roof slab was insulated with 100mm extruded polystyrene (XPS) which gives a U-value of 0.31 W/m^2.K
- External wall: External walls were made of 150mm AAC block with plaster on both sides, resulting in a U-value of 0.9 W/m2.K
- Glazing: The project team emphasized the importance of daylight in faster recovery of patients and clear glass was selected. Double glazed units were selected for a lower U-value of 2.8 W/m^2.K

A multi-speciality hospital in Pune, India

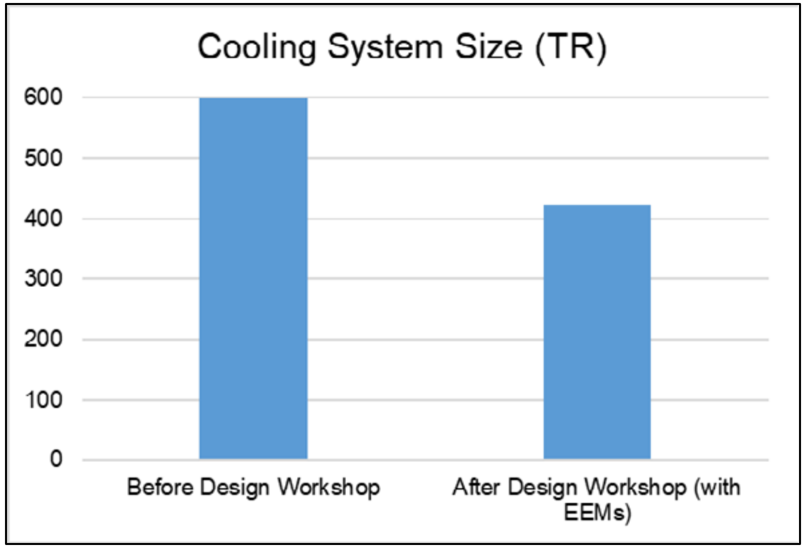
Source: Bhanware et al., 2020

HOSPITAL BUILDING

Case example: Design interventions to improve EPI (continued)

The measures implemented for the HVAC system were:

- Use of dynamic energy simulation software for chiller plant sizing instead of simplified calculation based on static design conditions. Installed chiller capacity is 560 TR (280 x 3 [2 working + 1 standby])
- Selection of a high efficiency chiller with a COP of 5.92 and very good part load performance (NPLV: 0.367)
- Integration of enthalpy recovery wheels in fresh air AHUs with 75% effectiveness for both latent and sensible heat recovery
- Use of condenser water for reheating the air in AHUs to maintain relative humidity. Backup hot water is provided by a heat pump system with a COP of 2.81
- Provisions for free cooling on patient floors, which means if the outside air is suitable for space cooling, it can directly be supplied without passing through the cooling coil



A multi- speciality hospital in Pune, India

Source: Bhanware et al., 2020

HOSPITAL BUILDING

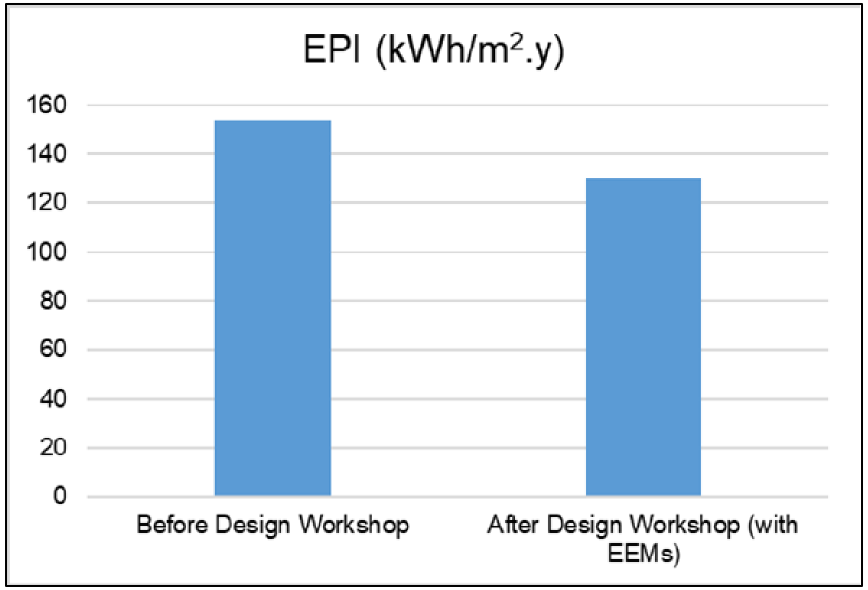
Case example: Design interventions to improve EPI (continued)

The system sizing calculation was done using HAP software and energy simulation of the building was conducted using DesignBuilder software to quantify the benefits of the integration of energy efficiency measures. The key results of the energy simulation were:

- Reduction in cooling system size – The cooling system size was reduced from 600 TR (before the design workshop) to 424 TR (after the integration), a 29% reduction in size
- Reduction in energy consumption – The Energy Performance Index (EPI) was reduced from 154 kWh/m^2.y to 130 kWh/m^2.y (16% reduction) after considering energy efficiency measures in energy simulation

The actual EPI achieved by the hospital was 136 kWh/m^2.y, which was very close to the predicted performance of 130 kWh/m^2.y. The hospital received a 4-star rating under BEE star rating for hospitals

Subsequently, operational improvements, namely, increasing chilled water generation temperature, reducing condenser water temperature, change in heat pump control, etc. were implemented, which resulted in approximately additional10% energy saving



A multi- speciality hospital in Pune, India

Source: Bhanware et al., 2020

EDUCATIONAL INSTITUTE

Case example: Hybrid air conditioning system

- Centre Point School is located at Nagpur, India
- It has been awarded the IGBC Green School Gold rating
- Air conditioning is provided by water-cooled variable speed screw chillers along with CTI-certified cooling towers
- For providing 50 CFM of fresh air per student in each classroom, on each floor, two 3,000 CFM treated fresh air (TFA) units per floor have been installed
- These TFAs are equipped with dual coils for cooling water (for lowering air temperature) and chilled water coils for dehumidification of air
- When the weather is favorable, cooling water is used (in conjunction with the humidity sensor coupled with control valve) for pre-cooling the air
- Indirect evaporative cooling system coils have been installed in TFA units to substitute chilled water-based air conditioning during dry weather

Source: Centre Point School, Nagpur, India

EDUCATIONAL INSTITUTE

Case example: Hybrid air conditioning system (continued)

- At locations with predominantly dry climate, hybrid cooling system can be cost effective, with cooling mode switching between conventional chillers and the evaporative cooling system, depending on the ambient temperature and humidity
- Evaporative cooling is effective only during dry weather
- During operation of the conventional chillers, the TFA unit ensures adequate moisture removal from fresh air, permitting operation of the air conditioning at higher temperature setting
- During cool and dry ambient weather, chillers can be switched off, and chilled water is substituted by ‘cold’ cooling water from the cooling tower, thus, almost achieving ‘free cooling’ with minimal cooling tower fan power
- The school has installed 60 kWp of roof top solar PV panels, which generate enough energy for all applications, other than chiller operations

Vapor compression screw chillers with VFD

Treated fresh air system with dual coil

Source: Centre Point School, Nagpur, India

EDUCATIONAL INSTITUTE

Case example: Hybrid air conditioning system (continued)

- All classrooms have three-speed FCUs with controls for room temperature and humidity
- Brushless direct current (BLDC) fans are used for room air circulation, for enhancement of thermal comfort, while operating chillers at higher chilled water temperatures

Source: Centre Point School, Nagpur, India

Ceiling fans retained in air-conditioned classrooms

BUILDING MANAGEMENT AND AUTOMATION

BMS and BAS for HVAC, lighting and other utilities

Building automation is the automatic centralized intelligent monitoring and control of a building's technical systems and services, such as heating, ventilation and air conditioning (HVAC), lighting and other systems through a building management system (BMS)

Controllers regulate the performance of various facilities within the building environment, which includes:

- Mechanical systems
- Plumbing systems
- HVAC systems
- Lighting
- Electrical system and meters
- Security system
- Surveillance system
- Fire alarm
- Lifts, elevators and escalators

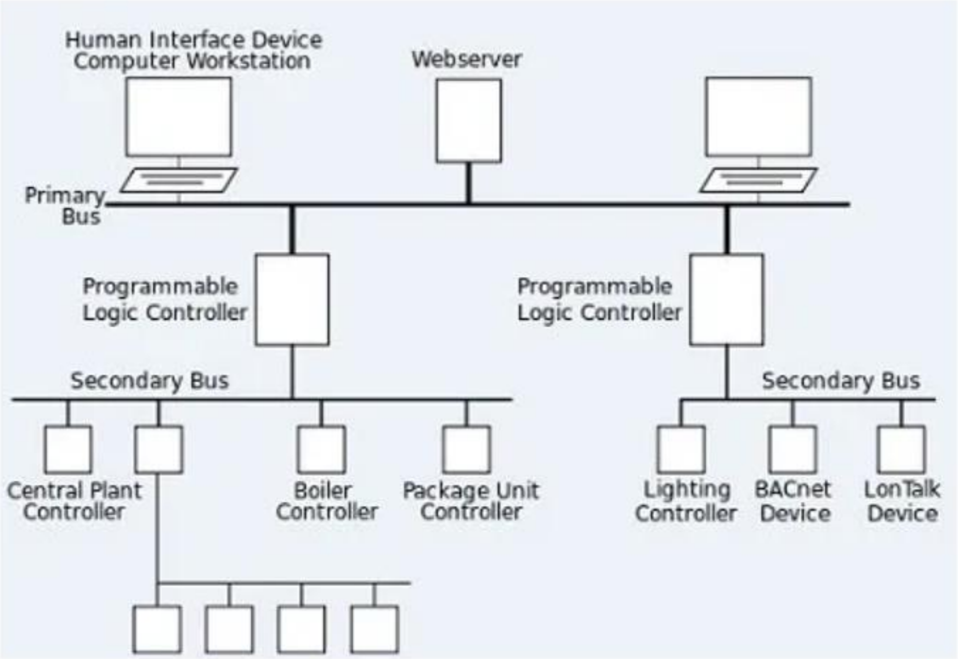
BAS applications in a commercial building

Source: Deorukhkar, 2017

BUILDING MANAGEMENT AND AUTOMATION

BMS and BAS for HVAC, lighting and other utilities (continued)

- The building automation system (BAS) plays a vital role in automating system operation and optimizing energy consumption of HVAC utility equipment. The BAS can help maintain the desired cooling conditions and modulate the system in relation to the load variations due to occupancy or seasonal changes
- Close monitoring and analysis of operations and energy consumption can improve control, reduce operating cost and even increase the life of equipment. Many green buildings have incorporated BAS to optimize ventilation air, energy and water consumption
- Most building automation networks consist of a primary and secondary bus that connects high-level controllers (generic system or network type, terminal unit type or PLC-based) with lower-level controllers, sensors, input-output devices and user interface (a computer workstation with graphical interface)
- For networking, various type of protocols are used, such as open protocols like ASHRAE's BACnet or LonWorks, or other protocols like SNMP, TCP/IP and Modbus



Typical three-tier system architecture for BAS

Source: Deorukhkar, 2017

BUILDING MANAGEMENT AND AUTOMATION

BMS and BAS for HVAC, lighting and other utilities (continued)

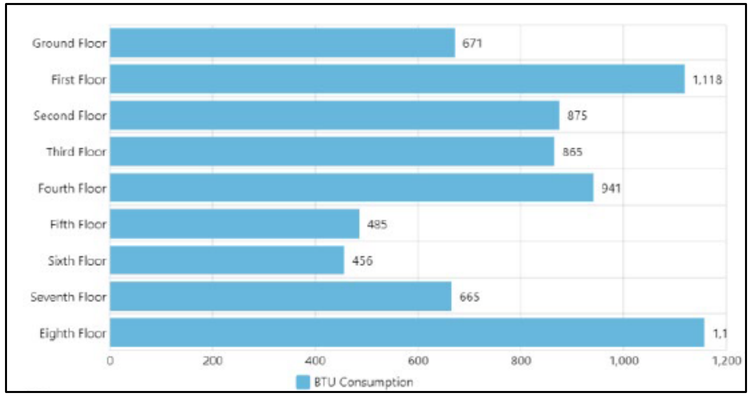
- Field devices and sensors for measuring various HVAC parameters like temperature, humidity, pressure, flow, speed, air quality, lighting intensity, etc. are connected by dedicated optical fiber, Ethernet, ARCNET, RS-232, RS-485 or a low-bandwidth special purpose wireless network
- The user interface involves a PC workstation having graphic interface with various dashboards, graphs or charts. BAS helps facility managers understand and analyze trends, enabling quick troubleshooting and real-time monitoring and control of building operation and performance
- BAS also eases the work of facility managers by providing reports on:
  - Operational data for an equipment or system (with available data points that are integrated with the system)
  - Historical trend (with graphs or charts) for various operational parameters
  - Alarms and/or alerts
  - Incident reports
  - Equipment energy consumption and operating time
- Smart buildings are transitioning from traditional BAS technology to cloud-based information systems, using web-based software

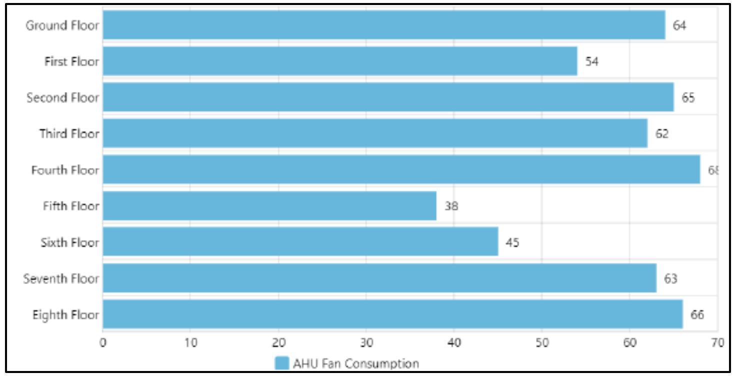
Source: Deorukhkar, 2017

BUILDING MANAGEMENT AND AUTOMATION

Case example: Large office complex of online retail company

- The campus of Flipkart, located at Bengaluru, India, comprises three blocks with an approximate total carpet area of 837,279 sq. ft. Space cooling is by a centralized air conditioning system with air-handling units (AHUs)
- One of the issues was **inconsistent cooling with cold and hot spots** across the office spaces. Additionally, in the absence of a building management system (BMS), the facility **lacked AHU scheduling**; all control was manual
- As a retrofit energy-saving project, a BMS with dynamic airflow and chilled water balancing and indoor air quality (IAQ) monitoring systems was incorporated. The system aims to eliminate thermal discomfort, deliver end-to-end automation, and provide customizable dashboards for energy management and IAQ and AHU-level monitoring
- The AI-backed data analysis tool provides a single-pane view of key metrics in real time to analyze critical factors, such as heat maps and occupancy trends for granular-level reporting. The insights and analysis offered in an intuitive graphical user interface empowers the facility team to control buildings with minimal intervention while increasing energy efficiency and maximizing comfort

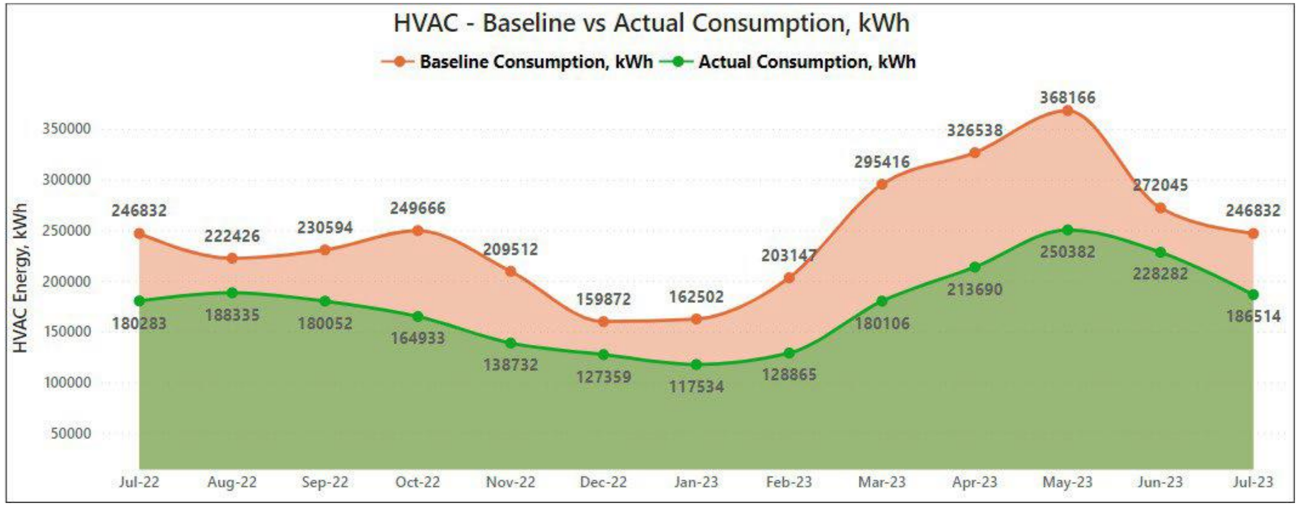


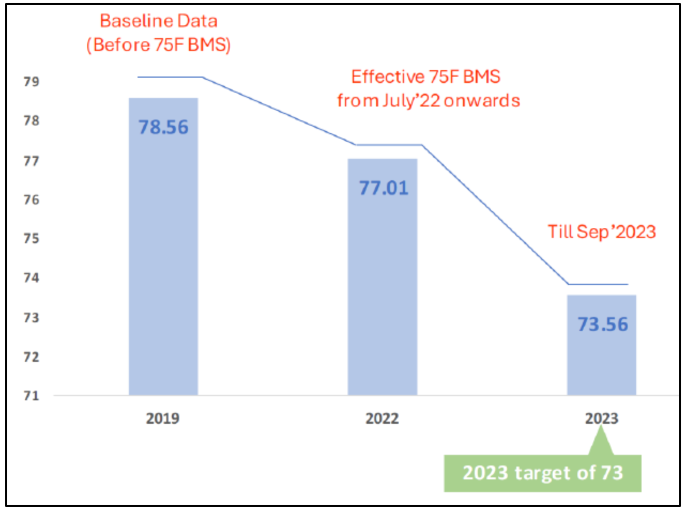


Source: Nawathe, 2023

BUILDING MANAGEMENT AND AUTOMATION

Case example: Large office complex of online retail company (continued)





- Within a short span of the project commissioning, the complaints related to hot and cold spots reduced by 60%
- Additionally, the improved air quality helped earn the prestigious UL Certification for IAQ Management
- The energy saving in comparison to the baseline was 27%, with estimated carbon emissions reduction of 711.4 metric tons

Source: Nawathe, 2023

BUILDING MANAGEMENT AND AUTOMATION

Case example: Small office space of a banking and financial services company

Mode	Manual	Auto	Savings (kWh)	Savings (%)
Total electrical unit (KWh)	183.2	74.2	109	59.4
Total heat load (KWh)	2627	1191	1436	54.6

- A banking and financial services company in Chennai, India, has a HVAC system with an AHU capacity of 9,000 CFM. All controls were manual with variable frequency drives operating at fixed frequency and no modulation of chilled water flow, resulting in uneven cooling across rooms
- Variable air volume sensor boxes were installed to optimize air flows depending on room occupancy. Deployment of an automated air conditioning system ensured that the centralized air conditioning equipment operates at variable speeds, thus optimizing power in relation to prevailing air conditioning loads
- The estimated reduction in cooling load and energy consumption were 54.6% and 59.4%, respectively

Source: ZEDBEE Technologies

ENERGY MANAGEMENT

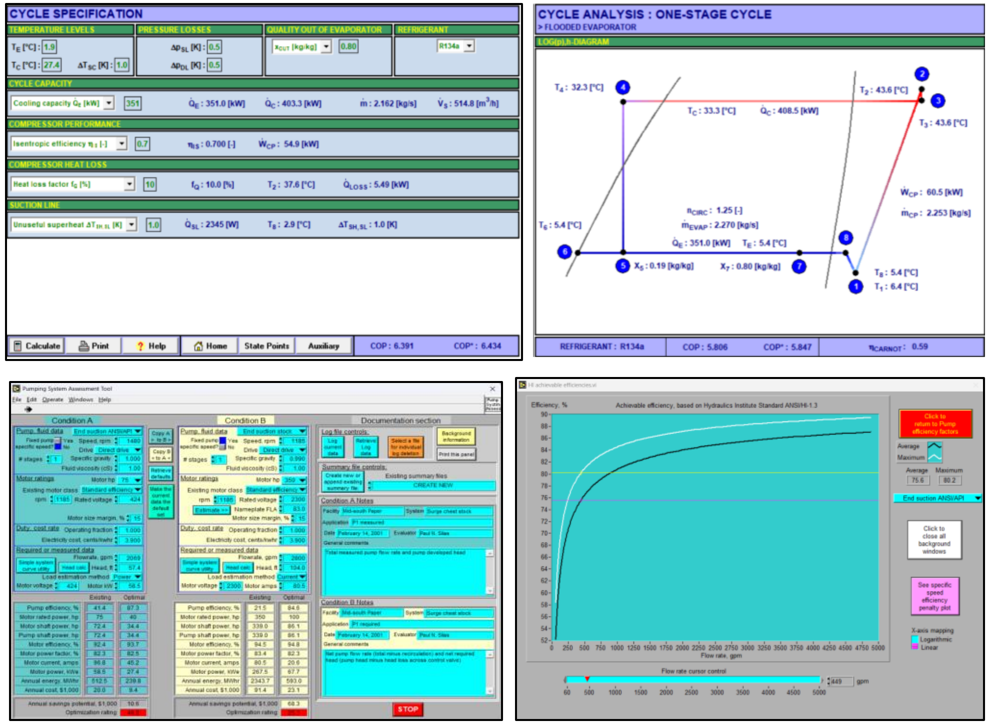
Effective monitoring and control by integrating BMS with EMS

- Many modern buildings still operate with manual controls, based on physical observation of operations or fixed switching at pre-decided clock time. While this strategy may be acceptable for small buildings, large air-conditioned buildings need more sophisticated control
- It is observed that building management system (BMS) in many buildings is used only for monitoring, while controls are manual; automation is necessary for energy optimization. Another common issue is that the BMS is not integrated with the energy management system (EMS), resulting in separate reports for HVAC and energy. The EMS should be an integral part of the BMS to enable creation of a dashboard that can report figures of merit like EPI, kW/TR, cooling kW/sqm, lighting power, etc. in real time
- Simulation studies indicate that BMS based on Internet of Things (IoT) can reduce energy consumption in building HVAC systems by 13%–15% across climatic zones
- Critical review of the trends of important parameters during different weather conditions and building occupancy levels can help identify practical and implementable opportunities for optimizing energy consumption in all areas, especially HVAC through automatic setting resets for temperatures, chilled water flows, HVAC air flows and switching of chillers and auxiliaries. It provides indicators for deterioration in equipment performance due to fouling of heat exchangers, malfunctioning or erratic operation of HVAC and lighting controls, etc.

EQUIPMENT EFFICIENCIES

Chillers, pumps and fans: Tools to understand achievable equipment efficiencies

- Building managers and engineers are often not sufficiently aware of the achievable energy efficiency levels for various energy-intensive equipment such as chillers, pumps and fans. Often, decisions are made based on rule of thumb or guidance from equipment vendors, which may not be optimal solutions
- Building engineers should be familiar with simple software tools that are relevant for chillers, pumps and fans to help understand achievable efficiencies for relevant operating parameters of equipment. Some of the free tools available are:
    - CoolPack for chillers (from the Technical University of Denmark)
    - PSAT for pumps (from the Department of Energy, USA)
    - FSAT for fans (from the Department of Energy, USA)
- These tools are discussed in module 3.2(b) on HVAC Systems: Performance Assessment



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