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Best Practices Guide for High- Performance Indian Office Buildings

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Environmental Energy Technologies Division

April 2013



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BEST PRACTICES GUIDE FOR HIGH-PERFORMANCE INDIAN OFFICE BUILDINGS

Reshma Singh, Dale Sartor, Girish Ghatikar



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LBNL -xxxx

Building Technologies and Urban Systems Department
Environmental and Energy Technologies Division



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Executive Summary

This document provides best practice guidance and energy-efficiency recommendations for the design, construction, and operation of high-performance office buildings in India. Through a discussion of learnings from exemplary projects and inputs from experts, it provides recommendations that can potentially help achieve (1) enhanced working environments, (2) economic construction/faster payback, (3) reduced operating costs, and (4) reduced greenhouse gas (GHG) emissions. It also provides ambitious (but achievable) energy performance benchmarks, both as adopted targets during building modeling (design phase) and during measurement and verification (operations phase). These benchmarks have been derived from a set of representative best-in-class office buildings in India. The best practices strategies presented in this guide would ideally help in delivering high-performance in terms of a triad—of energy efficiency, cost efficiency, and occupant comfort and well-being. These best practices strategies and metrics should be normalized—that is, corrected to account for building characteristics, diversity of operations, weather, and materials and construction methods.

Best practices should start by using early design principles at the whole building level. Optimal energy efficiency can be achieved through an integrated design process (IDP), with stakeholder buy-in from the beginning at the conceptual design phase. Early in the project, the focus of the stakeholder group should be on maximizing energy efficiency of the building as a whole, and not just on the efficiency of an individual building component or system. Through multi-disciplinary interactions, the design team should explore synergies between systems such as mutually resonating strategies; or sweet spots between inharmonious strategies. Buildings are the most energy efficient when designers and operators ensure that systems throughout the building are both efficient themselves, and work efficiently together. Systems integration and operational monitoring at the whole building level can help push the envelope for building energy efficiency and performance to unprecedented levels.

Whole-building systems integration throughout the building's design, construction, and operation can assure high performance, both in terms of ensures the energy efficiency and comfort/service levels. A Life cycle

Performance Assurance Framework emphasizes the critical integration between the buildings' physical systems and the building information technologies. The building physical systems include envelope, HVAC, plugs, lighting and comfort technology systems. Whereas, building information technologies provide information on the design and functioning of the building physical systems. This can be done- first, by performing building energy simulation and modeling at the design phase one can estimate the building's energy performance and code compliance; second, by integrating controls and sensors for communications, one can track real-time performance at the building phase, relative to the original design intent; and third, by conducting monitoring-based commissioning and benchmarking during operations, one can ascertain building performance compared to peers and provide feedback loops.

The next step should be assessing best practices at the systems and components level along four intersecting building physical systems- Mechanical Systems for Heating, Ventilation and Air Conditioning (HVAC), Plug Loads, Lighting and Envelope/Passive systems.

HVAC represents approximately 40%–60% of the electricity consumed in Indian office buildings. Best practices presented in this guide for HVAC loads and systems optimization include-

- Separating the spaces that could be naturally ventilated and exploring mixed-mode ventilation
- Right-sizing the equipment, and building in modularity
- Considering low-energy cooling options- such as mixed-mode cooling, displacement ventilation, under-floor air distribution (UFAD) and radiant cooling
- Managing loads by decoupling ventilation and cooling
- Providing thermal storage options
- Adopting a flexible setpoint and lifestyle changes
- Implementing component-level strategies

Plug loads represent approximately 20%–40% of all electricity consumed in commercial office buildings. Strategies must be included to reduce plugs loads in an office that cater to office electronics such as computers, monitors, and printers, but may include task lights, personal or ceiling fans, vertical transport (elevators/escalators) and/or other process loads. Best

practices discussed in this guide for plug loads optimization include-

- Setting aggressive power management settings
- Providing a computing infrastructure
- Pursuing DC power-based improvements
- Installing appropriate hardware
- Encouraging responsible occupant behavior
- Having occupants use laptops
- Reducing the number of plug-in devices

Lighting represents approximately 10%–25% of all electricity consumed in office buildings. Lighting load is greater for a building with a deeper floor plate or one that operates for evening or night shift hours. Strategies presented in the guide for reducing lighting loads include-

- Optimizing daylighting design
- Implementing a highly efficient equipment and optimized lighting layout
- Providing lighting sensors and controls

Planning energy conservation measures (ECMs) for Envelope/ Passive systems at the beginning of the design process can also help in achieving large, relatively low-cost gains. Note that the envelope ECMs (wall, window, roof assembly and shading) show bigger savings for buildings with smaller floor plates, which are external load-dominant. This is due to the larger surface-to-volume ratio in these cases where the role of envelope is more significant, as compared to the larger floor plate scenario. Strategies discussed in this guide include-

- Optimizing massing, orientation, and envelope; and simulate building energy performance
- Decreasing envelope heat gain
- Maximizing daylight autonomy without glare
- Optimizing fenestration and window-to-wall ratios

Buildings waste tremendous amounts of energy due to operational inefficiencies. The majority of commercial buildings do not operate and perform at the levels of their design intent. However, it is possible for building owners and operators to improve efficiencies and reduce costs by identifying whole building as well as systems and components level inefficiencies. This can be done by integrating building information systems, and designing for meterability, i.e. planning for and installing sensors and meters that measure the energy consumption of prioritized

set of points- of equipment, zones, and other performance indicators. By analyzing the data through an Energy Information System (EIS) one can determine what consumes how much energy and at what time. This helps to identify the sources of energy waste and inefficient equipment operation. Finally, the loop should be completed by actions taken based on this data and analysis. Specific strategies for managing and optimizing energy-efficient operations of a building outlined in the guide include-

- Designing for meterability
- Promoting data-driven decision-making.
- Having vigilant building managers and facility operators
- Recommending a green lease

The qualitative best practices described in this guide offer opportunities for building designers, owners, and operators to improve energy efficiency in commercial office buildings. Although the practices are presented individually, they should not be thought of as an “a la carte” menu of options. Rather, building systems must be integrated to realize the maximum energy and cost benefits. Also, designers and engineers, and developers and tenants need to work together to capitalize on the synergies between systems.

Last but not the least, this guide provides tangible quantitative best performance metrics, ready to be adopted by buildings in India. These metrics are concrete targets for stakeholder groups to work together and enable, by providing localized and customized solutions for each building, class, and occupants. Having targets early on in the design process also translates to more-efficient design lead times. The potential benefits of adopting these metrics include efficient operations, first-cost and lifecycle cost efficiencies, and occupant comfort and well-being.

The best practice strategies, if used thoughtfully provide an approach towards enabling office buildings that would deliver throughout their entire life cycle, a flexible optimization of energy consumption, productivity, safety, comfort and healthfulness. The adoption of the qualitative and quantitative goals, would provide an impetus to scale-up and market transformation toward energy-efficient processes, resources, and products- in addition to generating positive outcomes on global warming and societal benefits.

Introduction

This document provides best practice guidance and energy-efficiency recommendations for the design, construction, and operation of high-performance office buildings in India. Through a discussion of learnings from exemplary projects and inputs from experts, it provides recommendations that can potentially help achieve (1) enhanced working environments, (2) economic construction/faster payback, (3) reduced operating costs, and (4) reduced greenhouse gas (GHG) emissions. It also provides ambitious (but achievable) energy performance benchmarks, both for building modeling (design phase) and measurement and verification (operations phase). These benchmarks have been derived from a set of representative best-in-class office buildings in India. The best practices strategies presented in this guide are to ideally deliver high-performance in terms of a triad—of energy efficiency, cost efficiency, and occupant comfort and well-being. Note that these best practices strategies and metrics should be normalized—that is, corrected to account for building characteristics, diversity of operations, weather, and materials and construction methods.

Goals

This guide's primary goal is to provide meaningful information on framing building systems performance and guiding important decisions from conceptual design of a building to its operations and maintenance (O&M). It focuses on resource and energy-efficient solutions for high-performance conditioned offices (one/two/three shift, public/private sector), with spillover benefits to a diversity of building types, such as retail, hospitality, hospitals, and multi-storied housing.

The secondary goal is to initiate a useful, structured

repository of design wisdom that can be continually refined and updated over the years in order to time-test the effectiveness of its recommendations and document them. The authors look forward to integrating more 'Data Points' and information from buildings in India especially as the bar for best-in-class high-performance buildings is being continually raised. We intend to refine the best practices and metrics, in newer and revised versions of this guide.

The potential beneficiaries of this guide include building owners, designers, energy modelers, users, building developers, building facility managers and operators, building product manufacturers, and other stakeholders.

Introduction

Challenges

The guide originates from the need to address inherent challenges in designing smart, energy-efficient offices in India. The accompanying objectives describe this guide's role in addressing each challenge:

1. Integrating systems that optimize energy performance and cost-effectiveness throughout the building lifecycle. Buildings are typically designed, built, and operated with piecemeal consideration of various building systems like heating, ventilating, and air conditioning (HVAC); lighting; plug-loads; and construction methods. This fragmented application of systems and components can also lead to high costs. Moreover, the knowledge, processes, and applications of integrated technologies are sparsely available and are therefore challenging to incorporate reliably.

Objective: Present a Lifecycle Performance Assurance process that supports building system integration throughout the building's design, construction, and operation—a departure from the conventional approach—by requiring whole-building integration of building physical and information technology (IT) systems.

2. Optimizing building designs focused on high-performance. A wide diversity of building costs, services, and comfort levels requires application-specific design for optimizing energy efficiency. A small portion of the office stock consists of unconditioned, lower-cost indigenous buildings; with arguably acceptable low-energy solutions for comfort levels adapted to regional and climatic considerations. The bulk of the existing stock consists of mass-produced business-as-usual (BAU) office buildings with a typically lower level of services (e.g., unconditioned spaces), or fitted with ad hoc air conditioning to provide ostensibly higher level of services. However, the BAU trend is toward the construction of new, air-conditioned, sophisticated buildings that provide international levels of service. With the exponential increase in the floorspace of this type of buildings, the projected growth in building cooling demand will be explosive. It will force India to invest in hundreds of gigawatts of new power plant capacity.

Objective: Illustrate best practices to enable superior levels of Energy Performance Index (EPI) levels (the metric for energy consumption per unit area) without compromising on the aspiration and delivery of spaces that can meet or exceed international levels of service and sophistication.



FIGURE 1: Normalization of technologies across various regions, climates, and needs.

3. Customizing building energy-efficiency technologies for regional needs. Several building physical systems have been adopted from western applications without accounting for the regional, climatic, cultural, and economic context. On the other hand, several region-specific systems already exist in indigenous buildings that are able to offer higher performance for minimal cost, but the methods used to design such buildings are rapidly disappearing, because of a lack of visible documentation and analysis of the techniques. India needs appropriate localization of energy-efficient technologies to meet the needs of various regions, with respect to weather, standards, materials, construction, and technological maturity (Figure 1).

Objective: Emphasize strategies and solutions that leapfrog transitional technologies. These include innovative cooling; daylight/lighting technologies; passive and envelope design.



FIGURE 2: Sears Holdings offices occupy three floors of a multi-tenanted Special Economic Zone (SEZ) in Pune. (Photo: Sears Holdings India Facilities Team)

Introduction

Context

Buildings in India were traditionally built with high thermal mass (brick, stone masonry) and used natural ventilation as their principal ventilation and cooling strategy. However, contemporary office buildings are energy-intensive, increasingly being designed as aluminum and glass mid- to high-rise towers (Figure 2). Their construction uses resource-intensive materials, and their processes and operations require a high level of fossil fuel use. A large share of existing and upcoming Indian office space caters to high-density of occupancy and multiple shift operations.

Whereas the average for U.S. government offices is 20 m²/occupant and for US private sector offices is 30 m²/occupant, Indian offices have a typical density of 5–10 m²/occupant. Business Processing Office (BPO) spaces have three-shift hot seats—a situation that while conserving space because of its multiple usage also leads to considerably higher EPI levels. (See Figure 3 for comparison of EPIs across various building types). Moreover, with the increased demand for commercial office spaces from multinationals and IT hubs, and the current privileges being accorded to Special Economic Zones (SEZs), the trend is toward larger buildings with international standards of conditioned spaces, dramatically increasing the energy footprint of Indian offices (Figure 4).

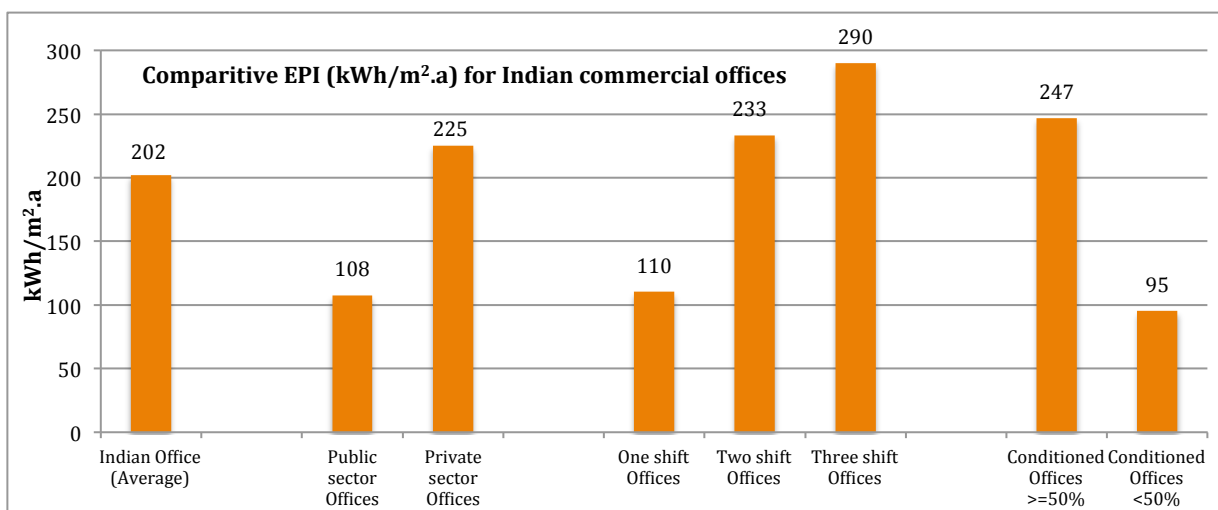
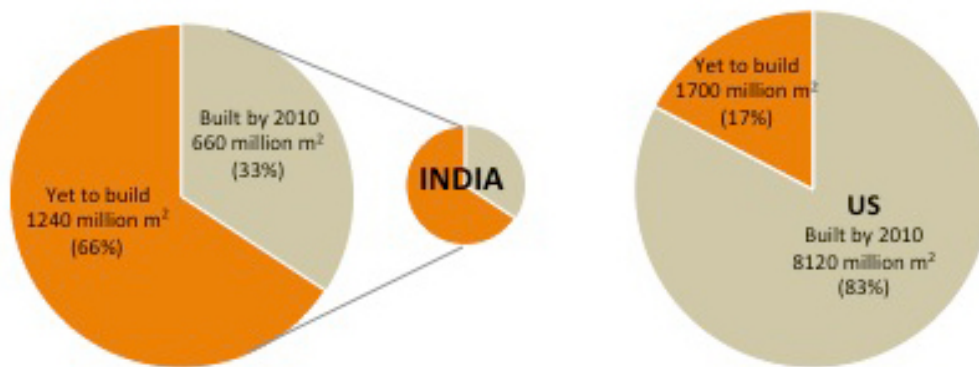


FIGURE 3: Energy Performance Index (EPI) using site energy data for various types of commercial facilities (kWh/m².a) in India. There is a strong correlation between the EPI and the ownership type, density/occupancy and amount of space conditioning. (Source: ECO-III India benchmark data, 2010¹)



FIGURE 4: (Left) Picture of a typical Business Processing Office (BPO) office space with dense occupancy, and ‘hot seats’ to accommodate multiple shifts at the same workstation. (Right) Despite the high density, levels of services are shifting to align with international practices and expectations. (Photos: Glassdoor²)

Introduction



India-

Total floor-space projection for 2030 is 1,900 million m².
Projected compounded growth rate from 2010-2030 is approximately 5.4% per annum.

United States-

Total floor-space projection for 2030 is 9,820 million m².
Projected compounded growth rate from 2010-2030 is approximately 1% per annum.

FIGURE 5: 2030 Floor-space forecast for the Commercial Buildings Sector: India 1,900 million m², and U.S. 10,340 million m². India is expected to triple its building stock by 2030, or in other words, two-thirds of the projected commercial building stock is yet to be built. (Sources: ECO-III benchmark data, 2010¹, 2010; Eia.gov³)

Building energy consumption in India has seen an increase from 14% of total energy consumption in the 1970s to nearly 33% in 2004-2005. The gross built-up area added to commercial and residential spaces was about 40.8 million square meters in 2004-05, which is about 1% of annual average constructed floor area around the world and the trends show a sustained growth of 10% over the coming years,⁴ highlighting the pace at which the energy demand in the building sector is expected to rise in India. In 2004-2005, the total commercial stock floor space was ~516 million m² and the average EPI across the entire commercial building stock was ~61 kWh/m²/year. Compare this to just five years later in 2010, when the total commercial stock floor space was ~660 million m² and the average EPI across the entire commercial building stock almost tripled to 202 kWh/m²/year (Figure 3). Energy use in the commercial sector is indeed exploding, not just due to the burgeoning of the Indian commercial sector- India is expected to triple its building stock by 2030 (Figure 5), but also through the increase in service-level requirements and intensity of energy use. Thus there are two intertwined effects: an increase in total building area and an increase in the EPI.

According to India's Bureau of Energy Efficiency (BEE), electricity consumption in the commercial sector is rising at double the rate (11%-12% annually) of the average electricity growth rate of 5%-6% in the economy. To deliver a sustained rate of 8% to 9% through 2031-32 and to meet life time energy needs of all citizens, India would need to increase its primary energy supply by 3 to 4 times and electricity generation capacity about 6 times.⁵ According to UNEP, approximately 80%-90% of the energy a building uses during its entire life cycle is consumed for heating, cooling, lighting, and other appliances. The remaining 10%-20% is consumed during the construction, material manufacturing, and demolition phases.⁶ To manage and conserve the nation's energy, it is imperative to aggressively manage building energy efficiency in each commercial building being designed and operated in India. By increasing energy efficiency in buildings and other sectors such as agriculture, transportation, and appliances, it is estimated that the total Indian power demand can be reduced by as much as 25% by 2030.⁷

To this end, the best practices outlined below identify processes and strategies to boost the energy efficiency in buildings, while also focusing on cost efficiency and occupant comfort.

Best Practices

The best practices detailed below contain tips for improving energy efficiency in commercial office buildings. The focus is also on cost efficiency and occupant comfort. These guidelines leave plenty of freedom for the design team, rather than limiting them with rigorous requirements or prescriptive measures.

Discussion

Just as no two buildings are identical, no two owners will undertake the same energy management program. It is also improbable to include all the listed best practices into one building, since some of them will conflict with each other. The practices are presented individually; however, they should not be thought of as an “a la carte” menu of options. Rather, designers and engineers, developers, and tenants need to work together to capitalize on the synergies between systems (e.g., a reduced lighting load can also reduce the building’s cooling load). From the

demand side, this means implementing a suite of measures that reduce internal loads (e.g., optimizing cooling levels, latent loads, lighting, and equipment loads) as well as external heat gains (e.g., optimizing envelope for insulation, reduced infiltration, and optimized glazing). Once the demand load is reduced, improve systems efficiency. Finally, improve plant design. This is illustrated through the Best Practice strategies and Data Points in this guide. The supply side can then add value by provision of renewables, waste heat sources, and other measures that are beyond this guide’s scope (Figure 6).

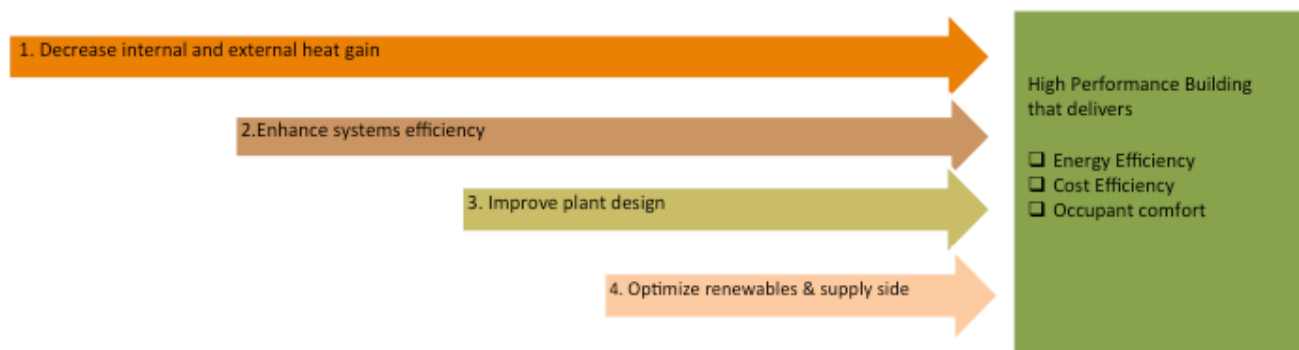


FIGURE 6: Sequence of approaches to create a set of integrated energy conservation measures (ECMs)

Best Practices

The guide illustrates innovative strategies and technologies across office buildings in India. It focuses on cross-cutting, whole-building strategies, as well as systematic measures for each load type (i.e., HVAC, plugs, lighting, and envelope heat gain). Tables of quantitative metrics allow for apples-to-apples comparisons, and provide hard targets. The “standard” data in the tables reference numbers from ECO III benchmarking or the National Building Code of India. This “standard” data is representative of the median or 50th percentile of commercial buildings in India. For “better” practice data, either the Energy Conservation Building Code (ECBC) or better performing buildings have been referenced, and are representative of the top quartile. For the “best” practice data (the highest level of efficiency that can be achieved in the building), the top 5th percentile, or best-in-class buildings have been referenced.

While referring to the tables provided in the guide, here are some things to keep in mind:

1. Some data are based on energy simulations of the proposed design (e.g., Greenspaces), some on utility level data after retrofits (e.g. Paharpur Business Center, Sears Holdings), and some on metered end-use data from new operational buildings (e.g., Infosys Pocharam). Although one cannot strictly compare modeled and metered data, the tables of metrics use both these types as a data backbone.
2. The representative buildings are in three of India’s five climate zones. Please refer to the buildings table in the appendix for more details on each. Please normalize the numbers based on your particular building’s location.
3. The metrics have a base assumption of an average 10-hour working day, 5 days a week. Please normalize based on the number of shifts and occupancy.
4. IT office spaces tend to have a higher EPI than non-IT operations buildings. Plug loads management is critical in IT buildings. Please normalize the metrics to account for this fact.
5. Commercially speculative buildings (i.e., leased buildings) tend to have higher energy consumption since the building is not “owner-occupied” or “built-to-suit” by type. However, if tenants and developers work together to harness the power of integrated ECMs from the beginning of the planning process, energy and cost efficiencies can benefit both stakeholders. Low first costs create direct benefits for the developer and low operating costs create direct benefits for the tenant.

Best Practices Use a Whole Building Approach

Early in the project, focus on maximizing energy efficiency of the building as a whole, not just on the efficiency of an individual building component or system. Buildings are the most energy efficient when designers and operators ensure that systems throughout the building are both efficient themselves, and work efficiently together. Optimal energy efficiency can be achieved through an integrated design process (IDP), with stakeholder buy-in from the beginning at the conceptual design phase.

Whole Building Lifecycle Performance Assurance Framework

A whole-building system integration (Figure 7) throughout the building’s **design, construction, and operation** can potentially assure high performance, both in terms of energy efficiency and comfort/service levels. We represent this as the Lifecycle Performance Assurance Framework. This Lifecycle Performance Assurance Framework was conceptualized by Lawrence Berkeley National Laboratory, USA (LBNL) and the Center for Environmental Planning and Technology, India (CEPT) through U.S. and Indian stakeholder engagements during the U.S.-India Joint Center for Building Energy Research and Development (CBERD) proposal to the U.S. Department of Energy and Government of India, 2011.

At each stage of the lifecycle, it is critical to ensure integration between the **buildings’ physical systems** and the **building information technologies**. The building physical systems include **Envelope, HVAC, Plugs, Lighting**

and **Comfort technology systems** (the last one being outside this guide’s scope). Whereas, building information technologies provide information on the design and functioning of the building physical systems. First, by performing **building energy simulation and modeling** at the design phase one can estimate the building’s energy performance and code compliance. This is especially relevant for certain energy conservation measures (ECMs) that may not be immediately attractive, but may become so through further analysis. Second, by building in **controls and sensors for communications**, one can track real-time performance at the building phase, relative to the original design intent. Third, by conducting **monitoring-based commissioning and benchmarking** during operations, one can ascertain building performance, compare to peer buildings and provide feedback loops. Thus the use of building IT creates metrics at all three stages of the lifecycle to help predict, commission, and measure the building performance and its systems and components. (See section on “Implement Metering, Monitoring and Controls” for more information).

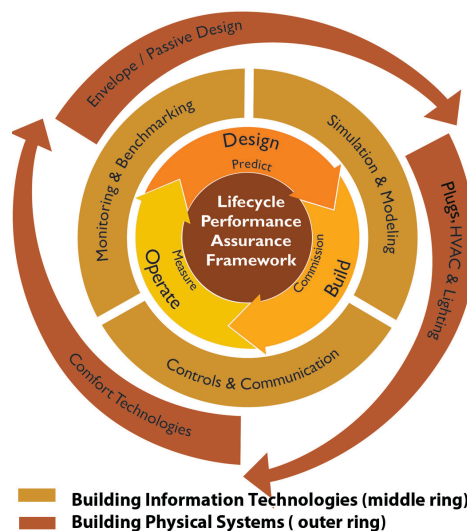


FIGURE 7: A Whole-Building approach (that is, strategically integrating all building systems) in a Lifecycle Performance Assurance Framework, that can potentially achieve large energy and cost benefits throughout the lifecycle of the building.

Best Practices Use a Whole Building Approach

To design and operate an energy-efficient building, focus on the energy performance based on modeled or monitored data, analyze what end uses are causing the largest consumption/waste, and apply a whole-building process to tackle the waste. For instance, peak demand in high-end commercial buildings is typically dominated by energy for air conditioning. However, for IT operations, the consumption pattern (and hence the “end-use pie”) is different. In the latter, cooling and equipment plug loads are almost equally dominant loads. The equipment plug load is mostly comprised of uninterrupted power supply (UPS) load from IT services and computers, and a smaller load is from raw power for elevators and miscellaneous equipment. Figure 8 shows typical energy consumption end-use pies (baseline data from Greenspaces Design team and monitored data from Infosys Green Initiatives team)—energy conservation measures need to specifically target these end uses. By doing so, one can tap into a huge potential for financial savings through strategic energy management. However, a utility bill does not provide enough information to mine this potential: metering and monitoring at an end-use level (at a minimum) is necessary to understand and interpret the data at the necessary level of granularity.

in the United States, a 30% reduction in energy consumption can lower operating costs by \$25,000 per year for every 5,000 square meters⁸ of office space. Another study of a national sample of US buildings has revealed that buildings with a “green rating” command on an average 3% higher rent and 16% higher selling price.⁹ Whether in the US or India, improvements to energy efficiency can often be attained through no-cost or low-cost ECMs that lower the first costs of construction and equipment. Optimizing building loads can lead to lower first costs and operating costs. By targeting low-hanging fruit through early-stage ECMs, the first costs saved through these can be applied toward more expensive technology solutions like high-quality glazing or sensors that can further the energy and cost benefits later in the building lifecycle. Hence, it is important to decide which measures to prioritize initially, and then what to cross-subsidize eventually. For example, if one is able to save costs by reducing the number of lighting fixtures and taking advantage of high daylight levels in a space, then those savings can be used to install daylight sensors. The latter can provide a large cost benefit with a relatively short payback time by driving down the operational hours for artificial lighting.

Benefits

Energy represents 30% of operating expenses in a typical office building; this is the single largest and most manageable operating expense in offices. As a data point,

The ECMs at the whole building level using systems integration can greatly benefit the EPI of a building. Table 1 shows whole building energy use metrics, using Standard (business-as-usual), Better (from ECBC/better-performing buildings), and Best Practices (from best-in-class Indian commercial buildings) at the whole building level.

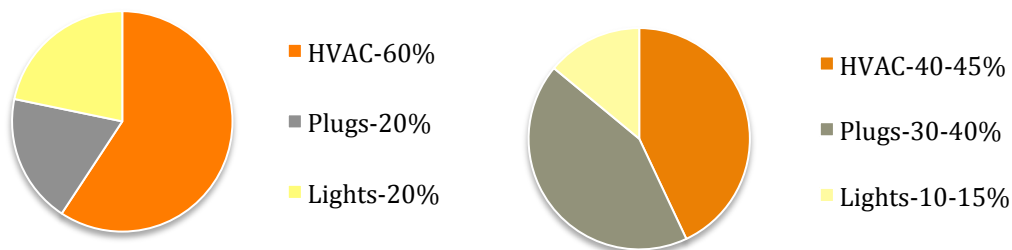


FIGURE 8: Electricity end-use consumption for (left) a typical commercial BAU building and (right) an IT office space in India. Absolute values would be different, but proportions would be similar in other commercial and IT office buildi

DATA POINT

At the Paharpur Business Center (PBC) in New Delhi, end-use loads were analyzed in order to retrofit the 100% conditioned 1990s building within the constraints of its government-specifications design. Some of the highest capital investments targeted the largest loads—upgrading HVAC and electrical systems and cooling towers- that have a payback period of 8–14 years. Other medium-sized capital investments included procuring Bureau of Energy Efficiency (BEE) five-star-rated air conditioners and replacing halogens with light-emitting diode (LED) lamps: these ECMs have a payback of 2–4 years. A mix of such well-strategized retrofits has led to a highly reduced energy consumption of 28 Wh/m²/hour.

Best Practices Use a Whole Building Approach

Figure 9 shows EPIs of selected offices in US, Germany and India. (Data from Infosys Green Initiatives Team; Sears Holdings Facilities Team; Paharpur Building Center (PBC); US CBECS 2003 data analyzed by New Buildings Institute¹⁰; REHAU and Technische Universitat Braunschweig¹¹)

Apart from providing energy benefits, ECMs can also **enhance the comfort and attractiveness of the environment**. Optimizing daylighting and lighting can

provide better views and improve the visual acuity of the occupants. Well-designed mechanical systems can improve indoor air quality while reducing initial equipment and operating energy costs. Workplace productivity can increase by providing individual controls, and with direct access to daylight. Given that the bulk of working time is spent indoors, a better indoor environment can boost worker performance and reduce sick leave that could equate to monetary benefits to businesses.

TABLE 1: Whole Building Energy Use Metrics

| Whole Building Metric | Units | Standard | Better | Best |
|----------------------------|------------------------|----------|--------|------|
| Annual energy use, EPI | kWh/ m ² .a | 250 | 150 | 60 |
| Peak Energy Use | W/ m ² | 90 | 40 | 20 |
| Annual energy use/occupant | kWh/a/person | 2250 | 1350 | 585 |

Table 1 Shows Standard (business-as-usual), Better (from ECBC/better-performing buildings), and Best Practices (from best-in-class Indian commercial buildings) at the whole building level.

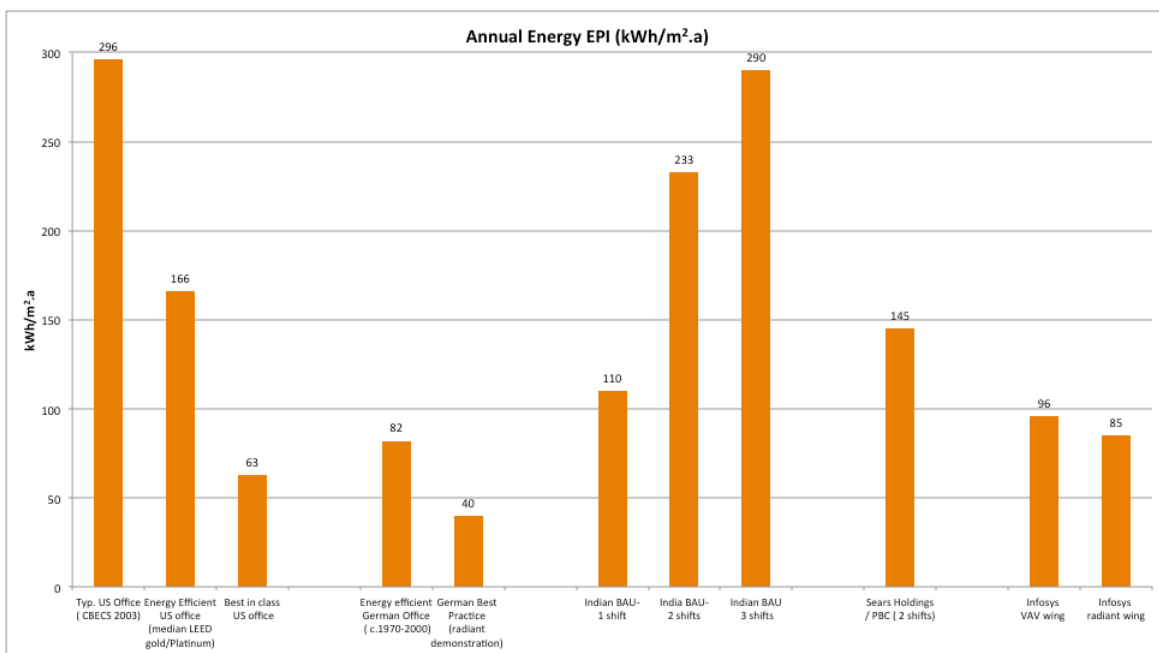


FIGURE 9: Comparative annual Energy Performance Index (EPI) (kWh/m².a) using site energy data of selected office buildings in the U.S., Germany and India. The number of shifts of operation has a strong bearing on the EPI. The EPI of a single-shift Indian office is comparable to that of an energy efficient U.S. office (median EPI is between 60-170 kWh/ m².a for the latter). Three- shift BAU Indian offices have an EPI comparable to a single-shift typical U.S. office. Compared to a best- in-class German demonstration office building, a best-in-class US office has 50% more EPI, and best-in-class Indian office has over twice the EPI.

Best Practices Optimize HVAC Systems

HVAC represents approximately 40%–60% of the electricity consumed in Indian office buildings. Outlined below are some best practices for HVAC loads and systems optimization.

1. Separate the spaces that could be naturally ventilated

This approach helps to decrease air-conditioning load and provide a variety of spaces, including semi-outdoor or naturally ventilated lounges, lobby spaces, corridors, active stairwells, Mechanical and Electrical (M&E) rooms, and others (Figure 10).

2. Right-size the equipment, and build in modularity

- Size the central plant to meet the peak building load, based on 'Most likely Maximum Loads'¹² rather than Peak Cooling Loads. Use a diversity of space types in the building to limit oversizing of mechanical plant and electrical services.
- Use a modular approach, adding capacity incrementally as loads actually materialize. Use unequal chiller sizes, and make sure the smallest size can efficiently accommodate the loads at initial occupancy.
- Consider providing mechanical and electrical space (plinth area) and design in the ability to meet much larger loads, especially in any one space, and connect to those loads only as they actually appear. For example, provide space for additional cooling towers

and pumps, "oversized" (relative to the initial load) process cooling water distribution piping with valves and blank-off plates in the plant to allow additional cooling equipment to be added as the load materializes.

- Right-size pumps and use bigger piping for low pressure drop design.

3. Consider low-energy cooling options

Options like variable refrigerant volume (VRV), displacement ventilation (DV), radiant cooling (RC), and underfloor air distribution (UFAD) generally have significant longer-term benefits, as discussed below.

Split air conditioning systems: Instead of designing a central cooling plant, consider the use of a Variable Refrigerant Volume (VRV) system—essentially a well-designed split air-conditioning system. This design is simpler and advantageous for smaller offices; more flexible (it can be controlled at an individual level and electricity metering and billing can be done at a zone level); and its operations are quieter.



FIGURE 10: (Left) The cafeteria at Infosys, Pocharam, utilizes natural ventilation (breezeway and ceiling fans) to provide a high-density yet comfortable dining and interaction space. (Right) Small terraces interspersed between office blocks serve as attractive breakroom spaces at Suzlon One Earth in Pune. (Photo: Synefra¹³)

Best Practices Optimize HVAC Systems

DATA POINT

The Sears Holdings Offices in Pune uses a VRV system with ceiling-hung cassette units rather than a central air conditioning plant. Every pod of workstations (four people to a pod) is provided with a cassette unit and an individual control for adjusting temperature and operation. This enables individually zoned comfort and energy benefits. The temperature setpoint is 24°C or higher, as compared to another leased office space on another floor of the same building where the setpoint is 23°C -this enables energy savings. The employees are encouraged, and the administrative staff and guards have a “key responsibility area” to conserve energy by turning off lights, computers, and air conditioning units in unoccupied areas (Figure 11).



FIGURE 11: Air conditioning controls at Sears Holdings, Pune, offices. Thermostats are set at 24°C. If occupants leave their office for a few hours, they reset their individual thermostats to 28°C in order to save energy. (Photo: Facilities Team, Sears Holdings India)

DATA POINT

At the Suzlon One Earth campus in Pune, energy-efficient air conditioning systems that use active, passive, and natural cooling techniques based on space use have been designed to reduce power consumption. Some occupied spaces such as informal meeting and break areas are designed as naturally ventilated, shaded pavilions. Circulation spaces, foyers, and atrium spaces use indirect evaporative cooling to maintain comfortable 25°C temperatures and eliminate the need for air conditioners. The primary HVAC system employs low-energy water-cooled VRVs and desert coolers to condition the main office areas. The system also utilizes strategies like pre-cooling of fresh air heat recovery/exchanger mechanisms to minimize energy consumption. The basement is designed with light wells and wind risers coupled with jet fans to create a stack effect that pushes out stale air to bring in fresh air, saving 50 percent of the energy that would be used to operate a ducted basement ventilation system. Overall, the campus has reduced its energy consumption by over 40% below the baseline. (Figure 12). (Source: Synefra¹³)



FIGURE 12: Suzlon One Earth building, Pune. (Left) Jet fans provide ventilation to the entire basement parking area, keeping this entrance area for employees comfortable. (Right) An energy-efficient water-cooled VRV system is used for the main office and conference areas. Mesh chairs improve the ventilation comfort for occupants. (Photos: Synefra¹³).

Best Practices Optimize HVAC Systems

Displacement ventilation (DV) delivers the air at low speeds using the principle of air stratification. Here, air is delivered at close to floor level for primarily conditioning the occupied volume (up to the first 2 m of room height) and extracted at the ceiling height rather than conditioning the unoccupied higher volume first. Well-designed DV systems provide better indoor air quality since the air in the occupied zone is generally fresher than that for mixing ventilation. There are no perceived air drafts. Any released pollutants rise rapidly to above the occupied zone. Large cooling energy savings are possible, as it uses a higher supply air temperature at 18°C, which also increases the efficiency of mechanical cooling equipment and lowers equipment requirements.

Underfloor Air Distribution (UFAD) technology uses the underfloor plenum beneath a raised floor to provide conditioned air through floor diffusers directly to the occupied zone. A thoughtful design can overcome the usually cited challenges of uneven floor surfaces, difficulty in providing added airflow to the perimeter of the building, and perceived control difficulty. The advantages of a well-designed UFAD system are: improved thermal comfort, occupant satisfaction, ventilation efficiency and indoor air quality, reduced energy use and the potential for reduced floor-to-floor height in new construction.

Radiant Cooling works on the principle that water can store 3,400 times more thermal energy per unit volume than air. It offers the potential to reduce cooling energy consumption and peak cooling loads when coupled with building thermal mass. Some radiant systems circulate cool water in dedicated panels; others cool the building structure (slab, walls, ceilings, and/or beams). Because radiant surfaces are often cooled only a few degrees below the desired indoor air temperature, there are many opportunities for innovative cooling energy sources, such as night cooling and ground-coupled hydronic loops. The heating and cooling supply water temperatures for radiant systems operate at higher set points compared to traditional systems. The radiant cooling system supply water temperature would typically operate at 15°C–18°C for cooling, whereas typical

supply water temperatures for a traditional forced air system are around 5.5°C–7.5°C. The central cooling equipment can operate more efficiently at these temperature set points.

Note that the chilled water supply temperature produced directly affects the chiller efficiency—chillers operate most efficiently when the temperature lift (the difference in temperature between the evaporator and the condenser) is minimized (Table 2). The rule of thumb¹⁴ is that for:

- Every 1°C increase in chilled water temp = 2.7% more efficiency, or
- Every 1°C decrease in condenser water temp = 2.7% more efficiency

If combined with a dedicated outdoor air system (DOAS), a well-designed radiant cooling system is adequate to provide for office-type loads, even in a hot-humid climate, without fear of condensation issues, as long as the building is well insulated and reasonably airtight. Studies have shown that the use of a tower side economizer coupled with radiant cooling and a DOAS can have significant reductions in cooling season energy costs when compared to traditional forced air VAV systems (see strategy below “Manage Loads by Decoupling Ventilation and Cooling Loads”). As a U.S. point of reference, this savings is estimated to be as high as 67% when applied in San Francisco, California.¹⁵

Other advantages of a well-designed radiant system are:

- No wall or floor space is required for diffusers, except small diffusers for ventilation air that can be located at one end of the space.
- No associated noise.
- Tolerates wide fluctuations in loads if coupled to high mass surfaces, such as floor slabs
- Tolerates a wide range of air temperatures
- Can extend the operating range of the water-side economizer.
- It has a gentle failure mode, as compared to a more drastic failure mode for standard variable air volume (VAV) systems. This means that the building can drift for a while without the occupants realizing the difference or feeling uncomfortable, even after the equipment is switched off.

TABLE 2: Chiller water supply temperature and efficiency

| Chilled Water Supply Temperature | Efficiency |
|----------------------------------|------------|
| 5.5°C (42°F) | 0.49 kW/TR |
| 15.5°C (60°F) | 0.31 kW/TR |

LBNL study based on manufacturers simulated data of the same chiller shows that the efficiency of the chiller increases with the increase in the temperature of chilled water. (Source: LBNL)¹⁶

Best Practices Optimize HVAC Systems

DATA POINT

At the Infosys, Pocharam campus, the SDB-1 building has been divided into two symmetric wings (Figure 13). One wing is conventionally cooled with an efficient VAV system, with variable-frequency drives on the air-handling units, chillers, pumps, and cooling tower. For the other wing, in-slab radiant cooling has been employed. Here, the sensible and latent (dehumidification) loads are decoupled, and two levels of cooling and chiller coil temperatures are provided. The radiant system caters to sensible cooling loads. The chilled water is delivered through a concrete floor core with embedded tubes. The slab temperatures are maintained at about 20°C by controlling the inflow of water through the floor. The chilled water is maintained at 15.5°C. This increase in temperature of supply water has considerable energy benefits (See Table 3). Further, the latent loads are served by a DOAS (See Figure 14).

TABLE 3: Efficiency in kW/TR at SDB-1 building at Infosys, Pocharam (Source: Infosys Green Initiatives Team)

| | VAV | Radiant Cooling |
|------------------------------------|------------|-----------------|
| Peak Design efficiency Plant kW/TR | 0.64 kW/TR | 0.57 kW/TR |
| Design Chilled water temp, °C | 8°C | 14°C |



FIGURE 13: The SDB-1 building at Infosys, Pocharam. A comparison between the two wings—one with a conventional VAV system and the other with a radiant cooling system—reveals the benefits of a radiant system. (Photo: Infosys Green Initiatives Team)



FIGURE 14: (Left) Air distribution from the DOAS through vents; (Right) A manifold at the perimeter workstations controls the tube water temperature. (Photo: Infosys Green Initiatives Team)

Best Practices Optimize HVAC Systems

4. Manage loads by decoupling ventilation and cooling

In a typical office space, the airflow required to cool and ventilate the space can be three to four times greater than that required to just ventilate the space. If the space cooling is decoupled from the ventilation, especially through a hydronic system, the central air handling system and associated distribution system can be downsized accordingly. A system called a Dedicated Outdoor Air System (DOAS) is typically used to serve the ventilation needs. A DOAS also allows for the effective use of energy recovery on the incoming outside air to further reduce the associated heating and cooling ventilation loads. Localized demand control ventilation (DCV) can also be implemented to turn off the ventilation air when the space is not occupied, which further reduces the total system energy. The efficiency gain of this demand-control ventilation strategy needs to be weighed against the

additional system complication, cost, and the additional fan energy necessary for the required air terminals. Also, the traditional air distribution system has air terminal devices to modulate the cooling capacity to each individual space. These air terminals add additional pressure drop and increase the associated fan energy. With a DOAS, the air terminals are not required for proper system operation. The space saved by using a DOAS can be used to install a low-static air-side distribution system to further reduce the associated fan energy.

Therefore, consider decoupling the cooling and ventilation. Separate the process load (equipment load) and the regulated sensible load (cooling, lighting, envelope heat gain) from the latent load (ventilation and dehumidification, people loads). Serve different types of loads by various levels of cooling relevant to the specific need.

DATA POINT

At the Infosys SDB-1 building in Pocharam, the DOAS is employed to supply fresh air to maintain indoor air quality and to cater to latent loads, i.e. indoor humidity levels. The DOAS needs to supply higher-than-minimum ventilation to keep the office air dry. Supply air is dehumidified and supplied at 15–20 cfm/person via a positively pressurized building, which delivers better air quality with occupant health benefits. Ventilation loads are also managed through DCV by constantly monitoring carbon dioxide (CO₂) levels in the zones. The air was originally dehumidified through a dedicated distributed-expansion (DX) unit to achieve a clear separation of energy consumption for conventional and radiant sides of the building. After about six months of operation, the DX unit and coil was replaced by a chilled water coil to improve the overall system efficiency further. The DOAS uses a runaround coil to transfer heat between the entering fresh air and the air leaving the chilled water coil. A total energy recovery wheel recovers energy from the exhaust air. Additionally, ceiling fans are used throughout the building to provide greater comfort and relief when the air conditioning is off or if it ever fails. These changes in cooling methods have also shown radical results in the building's energy consumption patterns, even when compared to the rest of the Infosys portfolio (Figures 16 and 17a). Apart from other advantages with respect to space utilization (Figure 15), and robustness in comfort benefits (Figure 17b) this leapfrog technology's cost is on par with the VAV system. *The costs have been calculated at Rs 3220 per m² for the VAV wing and Rs 3190 per m² for the radiant wing.*

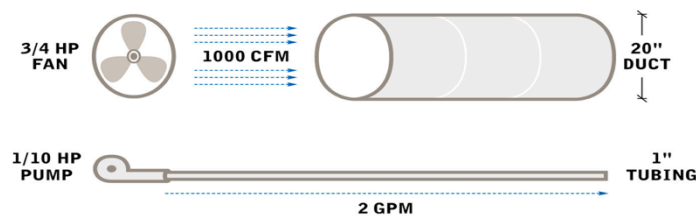


FIGURE 15: Advantages of small sizing of pipes in the radiant system (below), as compared to the size of VAV ducting (above). This implies more efficient utilization of space, the potential for more architectural flexibility, and first cost savings in materials. (Source: Integral Group, Oakland)

Best Practices Optimize HVAC Systems

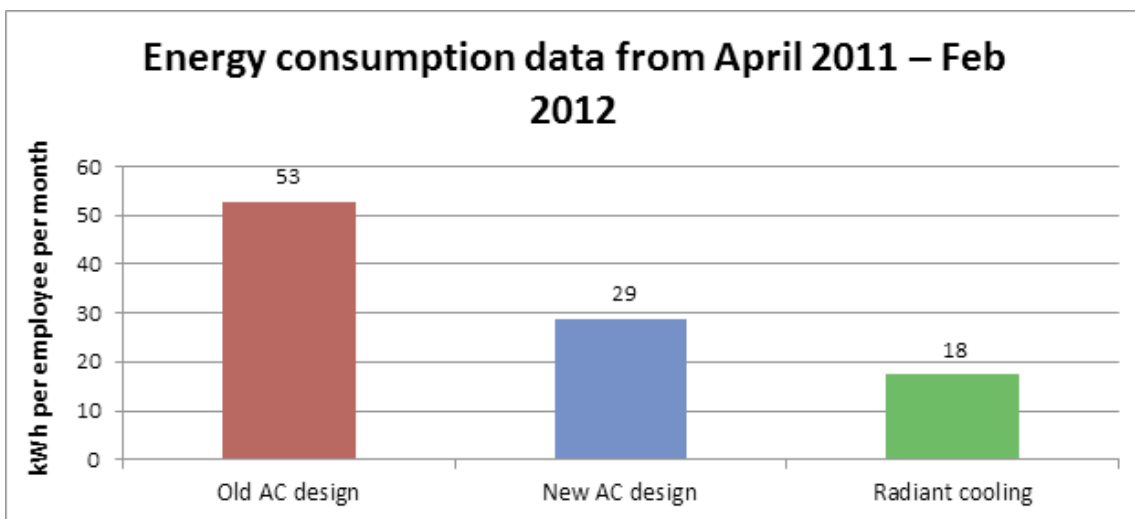


FIGURE 16: Comparative HVAC energy consumption data from Infosys Pocharam’s VAV and radiant wings. The radiant wing has provided a savings of 40% over the VAV wing (new AC design). The radiant wing also provides over 70% savings over the Infosys standard buildings at Gachibowli campus (old AC design) in the same city. (Source: Infosys Green Initiatives Team)

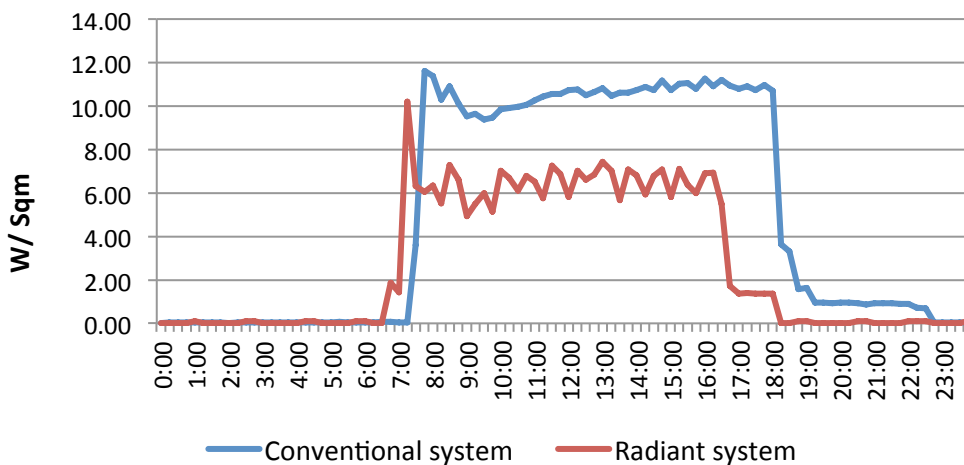


FIGURE 17a: Infosys, Pocharam SDB-1, HVAC demand profile graph for a typical day. The radiant equipment is switched on a couple of hours before occupancy in the morning for pre-cooling benefit. It is switched off a couple of hours before the end of business day. The building is allowed to drift on the coolness provided by the thermal mass of the slab without any perceptible change in occupant comfort. This schedule enables operational energy and cost savings. (Source: Infosys Green Initiatives Team)

Best Practices Optimize HVAC Systems

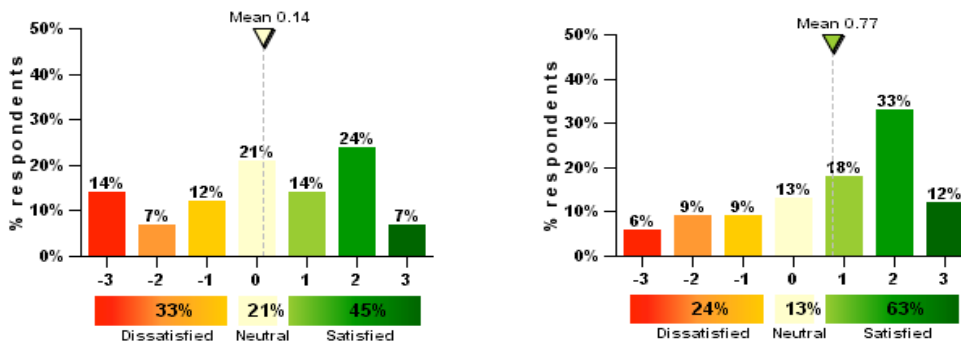


FIGURE 17b: Occupant comfort survey reveals greater comfort (63% satisfaction rate) in the radiant wing (right) as compared to the (45% satisfaction rate) in the VAV wing (left). (Source: Integral Group, Oakland)

5. Provide thermal storage options

Chilled water or ice thermal storage can be used to realize further reductions in the size of the chiller cooling capacity on hot days and shift cooling load to off-peak hours. The provision of such a storage tank helps in shaving the peak cooling load for the hottest day and provide flattened thermal and electric load profiles.

The benefits of thermal storage are; it can provide energy cost savings, provide capital cost benefit by helping decrease the size of the HVAC equipment, and have a dual-use for fire protection.¹⁷

6. Adopt a flexible setpoint and lifestyle changes

As controls in buildings are becoming more prevalent, it is technologically simple to adopt a flexible setpoint based on external environmental factors and occupant adaptations. According to a modeling study,¹⁸ one can realize a savings

of 5%–6% in EPI per 1°C increase in thermostat set-point temperature, and this savings is greatest for an internal load-dominant building. Separate setpoints should be adopted for summer and winter seasons.

7. Implement component-level strategies

Component-level strategies can also bring significant energy reductions. Some include:

- Design ducting and piping with minimum bends and turns; use 45-degree bends rather than 90 degree bends
- Provide variable-speed drives on all fans, pumps, and compressors

Table 4 provides HVAC metrics for standard, better, and best performing buildings with respect to operations of mechanical systems.

DATA POINT

At the Paharpur Business Center (PBC) in New Delhi, lifestyle changes like implementing a climate-suitable dress code and mesh back chairs that aid ventilation, have also been adopted. The setpoint for offices is maintained at 24 +/- 1°C (75 +/- 2°F), with relative humidity not exceeding 60%. For this building, each 1°C increase in temperature provides a 5% savings in air conditioning costs. Additionally, volumes of fresh air are treated with the help of selected varieties of plants, then filtered and supplied through the mechanical system to the building. The treated fresh air is constantly monitored for volatile organic compounds and other contaminants, and has proven to be of high enough quality to enable adequate ventilation delivery at 11.8 cubic feet per minute (cfm)/person. This optimization between quality and quantity has provided a 10%–15% energy benefit. (Figure 18)

Best Practices Optimize HVAC Systems

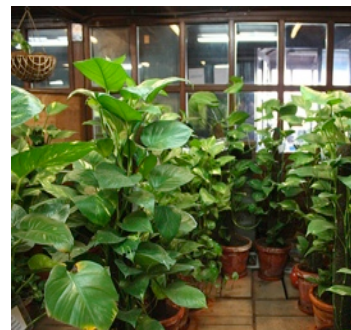
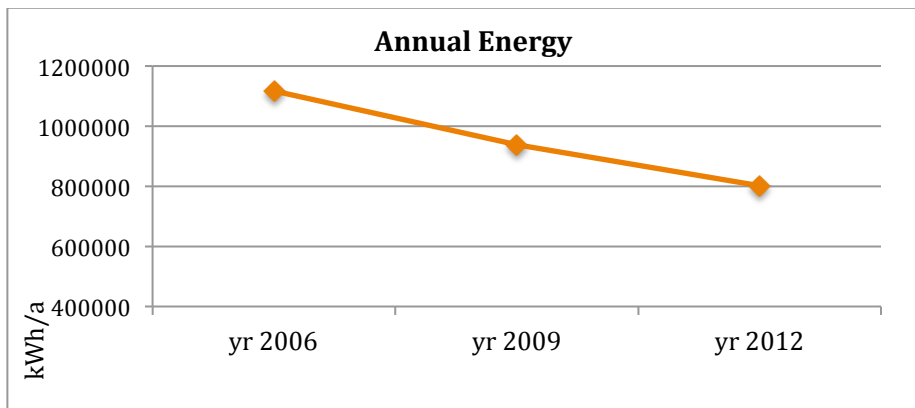
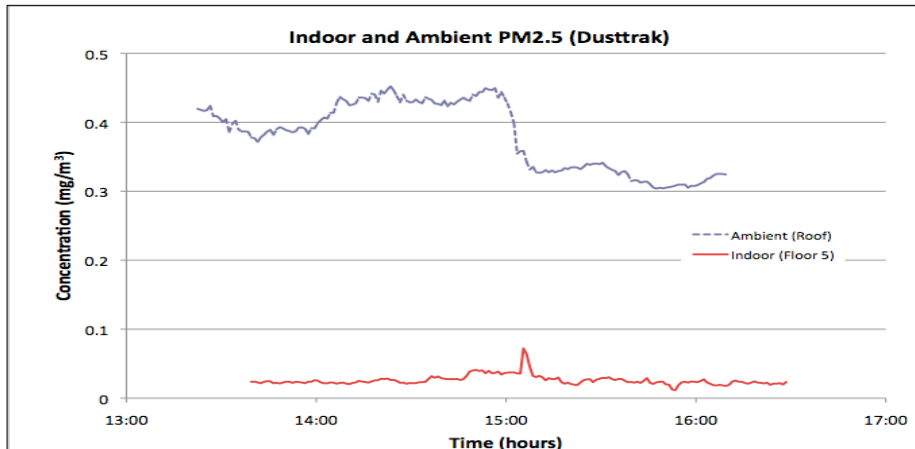


FIGURE 18: Data from Paharpur Business Center (PBC), Delhi. (Top left) Typical day real-time study of PM_{2.5} (2.5 micrometers particulate matter). The red line shows highly reduced indoor levels, as compared to the blue line that shows ambient (roof) levels. (Bottom left): Graph showing a 30% reduction of energy consumption from pre-retrofit level in 2006 at PBC owing to cross-cutting retrofits. (Right) Hundreds of indoor plants and hydroponic roof grown plants improve the indoor air quality. (Source: Paharpur Business Center)

TABLE 4: HVAC metrics table showing standard, better, and best metrics for mechanical design

| HVAC Metrics | Units | Standard | Better | Best |
|------------------------------------|-----------------------|----------|--------|------|
| HVAC Annual Energy Consumption | kWh/m ² .a | 110 | 80 | 25 |
| HVAC Peak | W/m ² | 65 | 25 | 15 |
| Chiller Plant Peak | kW/TR | 1.3 | 0.9 | 0.6 |
| Cooling Load (Building) Efficiency | m ² /TR | 20 | 40 | 60 |

Table 4 includes Standard (business-as-usual), Better (from ECBC/better-performing buildings), and Best practices (from best-in-class Indian commercial buildings) for HVAC systems.

Best Practices Reduce Plugs and Process Loads

Plug loads represent approximately 20%–40% of all electricity consumed in commercial office buildings. Outlined below are strategies to reduce plug loads in an office that cater to office electronics such as computers, monitors, and printers, but may include task lights, personal or ceiling fans, vertical transport (elevators/escalators) and other loads.

1. **Set aggressive power management settings** on all equipment or use power management software controlled by the IT departments.
2. **Provide a computing infrastructure** to tenants with thin clients (networked, secure monitor and terminals with access to a virtual machine infrastructure, separated from building electricity loads). The IT recommendations here need to be balanced with the computing needs for the business. (for e.g the above recommendation is good for a call center or bank; but may not be for an enterprise doing software development or engineering)¹⁹
3. **Pursue DC power-based improvements** in office equipment (no DC-to-AC power conversions at the UPS and back to DC conversion at the equipment). Consider providing DC for lighting, computers, and larger equipment. A simplified AC/DC hybrid coupled power network can provide the opportunity to use up to 30% less energy for 15% less capital cost while maintaining 200% of the reliability of an AC system.²⁰ This strategy is under consideration for some projects in India.
4. **Install hardware**, such as a solution of smart power strips that monitor and control the loads intelligently based on rules or optimized for occupant requirements, timers, and efficient office equipment (ENERGY STAR rated). This trend is now starting in India.
5. **Encourage responsible occupant behavior** by increasing awareness of efficiency settings and providing incentives programs to reduce plug loads (e.g., the tenant that practices the highest levels sustainability receives a 1% rebate on rent) and tenant guidelines for energy use.
6. **Have occupants use laptops** with peripherals like ergonomic keyboards and mice in lieu of desktops that consume more energy.
7. **Reduce the number of plug-in devices** by sharing printers, microwaves, refrigerators, coffee makers, and other appliances.

Table 5 provides plug load metrics for standard, better, and best performing buildings with respect to operations of electrical systems.

DATA POINT

At the Sears Holdings Offices in Pune, the equipment is shared--one projector and one printer is provided per floor, occupants use LCD screens for projection instead of having projectors in all meeting rooms, and staff uses laptops rather than desktops: all of these measures suffice for their operations (Figure 19). Other examples of frugal operations are--the average paper consumption is 35 sheets per month per employee. Most seats are shared “hot seats” used by different staff over multiple shifts, leading to efficient space utilization that aligns well to the type of operations required.

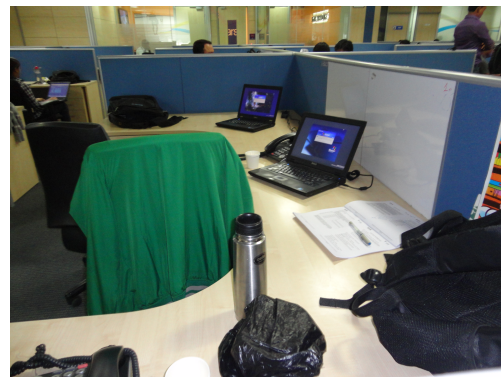


FIGURE 19: Sears Holdings, Pune office interiors showing use of laptops in occupant cubicles (Photos: Facilities Team, Sears Holdings India)

Best Practices Reduce Plugs and Process Loads

DATA POINT

At Infosys buildings, peaks for plug loads are 10–11W/m², based on 8 W/m² for computers and 2–3 W/m² for other equipment (Figure 20).

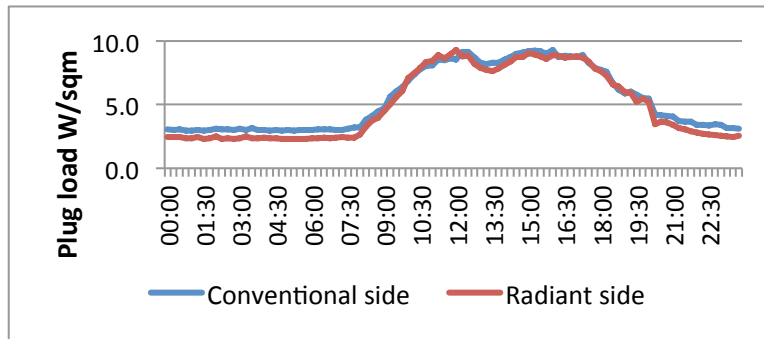


FIGURE 20: (Left) Plug Loads graph at Infosys Pocharam:

Nighttime computer plug loads are still substantial, which indicates that desktops are not turned off. (Source: Infosys Green Initiatives Team). This needs to be managed through behavioral and technology solutions. (Right) Banking shared office equipment on each floor helps minimize numbers of equipment and plug loads.

TABLE 5: Plug load metrics

| Plug Metrics (includes UPS and Raw Power) | Units | Standard | Better | Best |
|---|------------------------|----------|--------|------|
| Plug Annual Energy Consumption | kWh/ m ² .a | 100 | 55 | 30 |
| Plug Peak Load | W/ m ² | 20 | 15 | 7.5 |

Table 5 includes Standard (business-as-usual), Better (from ECBC/better- performing buildings) and Best practices (from best-in-class Indian commercial buildings) for plug loads, including UPS and Raw power.

Best Practices Optimize Lighting Design

Lighting represents approximately 10%–25% of all electricity consumed in office buildings. Lighting load is greater for a building with a deeper floor plate or one that operates for evening or night shift hours. The following section has strategies for reducing lighting loads.

1. Optimize daylighting design

Provide glare-free daylighting using optimized glazing and reflecting lightshelves, to remove the need for internal shading and artificial lighting during daytime (see Section “Envelope and Passive Design”).

2. Implement a highly efficient equipment and optimized lighting layout

- a. Consider designing for lower ambient lighting levels (e.g. 300 lux compared to 500 lux) in office spaces, and provide LED task lights for occupants who require higher levels of lighting. While reducing light levels, also design for light quality. Design lighting power to match the space requirements (see Table 6).
- b. Provide LED or T5 fluorescent luminaires. If not, then at the very least provide T-8 rather than T-12 lights.
- c. Provide electronic ballasts rather than magnetic ballasts: the former can save a minimum of 12% of energy consumed; even more if premium electronic ballasts are used.

3. Provide lighting sensors and controls

- a. Install photosensor controls that dim or shut off lights when adequate levels of natural light are detected.
- b. Install occupancy controls that shut off lights in unoccupied areas. These are high- resolution sensors that detect tiny movements and are

- c. applicable in occupied spaces like offices with sedentary workers or unoccupied storage spaces.
- c. Install motion sensors that detect walking movement, specifically for circulation spaces and restrooms.
- d. Install dimmers for the option for dimmable lighting, for example, in meeting rooms.
- e. Install sensors to continually monitor light levels in the space to ensure user comfort is maintained irrespective of conditions outside.
- f. Group the luminaires in layers, where the luminaires closest to the windows (the perimeter zone) are controlled separately than those in the center (the core zone).
- g. Use timers concurrently to switch off the lights once all users have left the space.
- h. The control system can be equipped with a timer for additional benefits. If the building reaches a high degree of daylight autonomy the daylight sensor and timer can be coupled together. It is only when the timer indicates that it is past daylight hours does the sensor get triggered to power itself on and start sensing for occupancy- this leads to enhanced energy savings.

Table 6 provides lighting power density for better (ECBC compliant) and best performing buildings with respect to various space types in an office building. Table 7 provides lighting metrics for standard, better, and best performing buildings with respect to operations of lighting systems.

TABLE 6: Lighting power density for various space types in office buildings, showing metrics from Energy Conservation Building Code (ECBC) and from best performing buildings.

| Space Type | ECBC (W/m ²) | Best Practice (W/m ²) |
|--------------------|--------------------------|-----------------------------------|
| Offices | 10.8 | 4.5 |
| Meeting room | 15 | 5 |
| Restroom | 5.4 | 3 |
| Common areas/lobby | 14 | 3 |
| Parking areas | 3.2 | 1 |

Best Practices Optimize Lighting Design

DATA POINT

At the ITC Green Center, Gurgaon building (Figure 21), T-5s and CFLs are used in mirror optic fixtures in the occupied spaces. In unoccupied spaces like the storage and M&E rooms, 36 W fluorescent lamps and magnetic ballasts are used. Lighting controls are used i.e., switch-off daylight sensors that turn off artificial lights when daylight is sufficient. Clerestory lighting in the atrium provides daylight. (Source: The Energy and Resources Institute, TERI²¹)



FIGURE 21: ITC Green Center building (Photo: TERI)²¹

DATA POINT

At the Sears Holdings offices in Pune, even with standard 12 W CFL and T-12, 8 W fluorescent fixtures, several operational measures keep the lighting power density (LPD) low. Alternate aisles of lights are switched off to conserve electricity while providing for adequate lighting levels at 450–500 lumens/m² (Figure 22). The cabins in the perimeter zones have glass partitions to maximize daylight penetration (Figure 32).



FIGURE 22: (Left) Sears Holdings holding office interiors, Pune (Photo: Facilities Team, Sears Holdings India). (Right) Showing practice of switching on only alternate aisles of lights.

Best Practices Optimize Lighting Design

DATA POINT

At Infosys, Pocharam, direct/indirect suspended fluorescent T-5 lights and a few 8 W LED downlights have been used. Very few lights needed to be switched on during daytime working hours, due to adequate daylight. There are occupancy sensors in the restrooms and all external lights have LED lamps, with timers (Figure 23). A combination of lighting and daylighting ECMs have led to significant energy savings (Figures 24 and 25).



FIGURE 23: Infosys, Pocharam. (Top left) occupancy sensors in the restrooms; (Top right) T-5s and LED downlights are used. (Bottom Left and Right) The amount of daylighting in the office spaces and lobbies has minimized the requirement for artificial lighting substantially. (Photos: Infosys Green Initiatives Team)

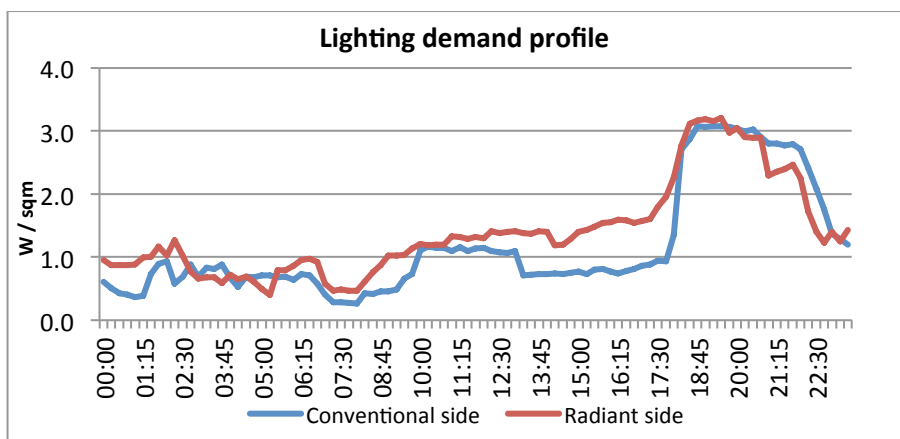


FIGURE 24: Infosys, Pocharam, Lighting Demand Profile. Artificial lighting is switched on only as needed after 6 p.m. (Source: Infosys Green Initiatives Team)

Best Practices Optimize Lighting Design

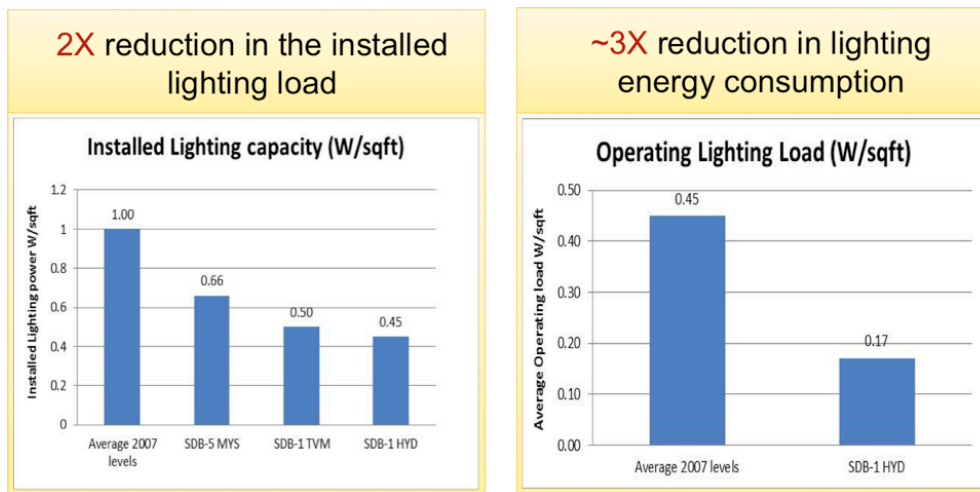


FIGURE 25: Infosys, Pocharam, use of Lighting and Daylighting ECMs have led to a two-thirds reduction in the operational lighting load (Source: Infosys Green Initiatives Team)

DATA POINT

At Suzlon One Earth’s Pune campus, the lighting system in the interiors incorporates dimmable ballasts, electronic ballasts, occupancy sensors, motion sensors, and daylight sensors. These ensure that lights get switched on only when required. The general lighting level from the ceiling luminaires is fixed at 350 lux. The artificial lights can be dimmed up and down from 0% to 100% depending on the adequacy of available daylight to meet the 350-lux requirement. The task lights in offices have a built-in occupancy sensor in conjunction with a continuous dimmer. Combined daylight and occupancy sensors control lighting of individual offices. Enhanced energy savings is also achieved due to an LED-based outdoor lighting system, which results in around 65% savings (in wattage) when compared with a conventional scheme. All the outdoor lights are controlled through the Integrated Building Management System (BMS). (Source: Synefra¹³)

TABLE 7: Lighting metrics

| Lighting Metrics | Units | Standard | Better | Best |
|------------------------------------|-----------------------|----------|--------|------|
| Lighting Annual Energy Consumption | kWh/m ² .a | 40 | 15 | 2 |
| Lighting Peak Energy Use | W/m ² | 15 | 10 | 5 |

Table 7 includes Standard (business-as-usual), Better (from ECBC/ better performing buildings), and Best practices (from best-in-class Indian commercial buildings) for lighting performance.

Best Practices Improve Envelope and Passive Design

Plan these energy conservation measures (ECMs) at the beginning of the design process, to achieve large, relatively low-cost gains. Note that the envelope ECMs (wall, window, roof assembly and shading) show bigger savings for buildings with smaller floor plates, which are external load-dominant. This is due to the larger surface-to-volume ratio in these cases where the role of envelope is more significant, as compared to the larger floor plate scenario.

1. Optimize massing, orientation, and envelope; and simulate building energy performance

Study through modeling the effects of shading elements, especially external and self-shading, to maximize views and minimize heat gain.

2. Decrease envelope heat gain

- a. Treat opaque surfaces as “cool” surfaces, by providing cool roofs and cool paints. Cool roofs reflect heat, and are most effective during the hottest part of the day and the hottest time of

year, coinciding with peak energy demand, and therefore help to reduce peak loads. Cool roofs can save up to around 25% of roofing energy loads, or roughly up to 5%–10% of air-conditioning loads at the top floor. However, care should be taken to have the right amount of albedo to avoid glare and heat reflection onto the neighboring buildings, and avoid increasing their energy consumption.

- b. Provide adequate wall and roof insulation to shield the building from external heat gain. This can be balanced with the provision of cool surfaces.

DATA POINT

“The color of green is white.” At the Paharpur Business Center in New Delhi, high albedo paint has been applied on the southwest façade and roof of the building to reduce the indirect heat gain into the building. The roof also houses a greenhouse that shades the roof and substantially reduces envelope heat gain (Figure 26).

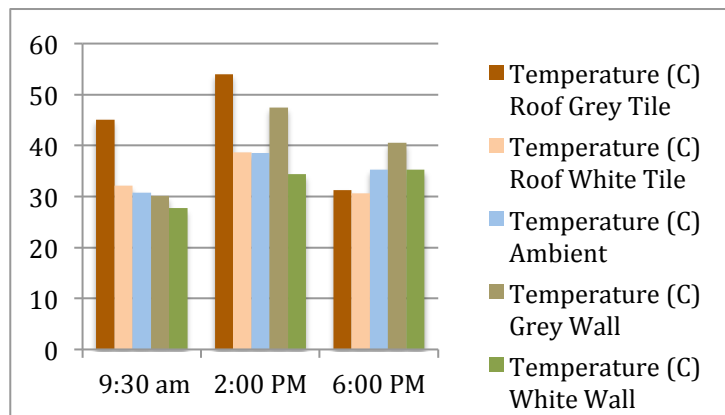


FIGURE 26: (Left) At the Paharpur Business Center (PBC), Delhi, light-colored tiles on the roof and cool wall paints are used to decrease envelope heat gain. (Right) Chart shows drop in surface temperatures using cool materials and paints (deg C) on a typical April day (Source: PBC)

Best Practices Improve Envelope and Passive Design

DATA POINT

At the ITC Green Center, Gurgaon (Figure 27), a low-rise (ground+3) structure with narrow floor plates has been designed to minimize external envelope heat gain, with the longer axis oriented northeast-north. The configuration and orientation of the L-shaped building ensures façade shading for the entrance areas and foyer. A high-albedo coating chosen for the roof has reduced the roof surface temperature by 30°C, and brought down the air conditioning loads in the top floor by 10%–15%. Low-E 6 mm double-glazing with 12 mm air gap (6-12-6) has been carefully selected such that the northern glazing has a higher level of visual transmittance (T-vis) without compromising on the uniformity of the visual esthetic. The window-to-wall ratio (WWR) is kept at 33% as compared to the ECBC standard 40%. Mutual shading and window shading is designed such that the shading coefficient is 0.26. The envelope heat gain has been reduced from the base case by about 65%. Additionally, roof and wall cross sections are designed for the assembly to have low U value; the wall assembly has a U value of 0.6 W/m².degK (Figure 28). (Sources: TERI ²¹, ITC²²)



FIGURE 27: ITC Green Center, Gurgaon, showing the daylighted atrium and façade with low-E windows. (Photos: ITC)²²

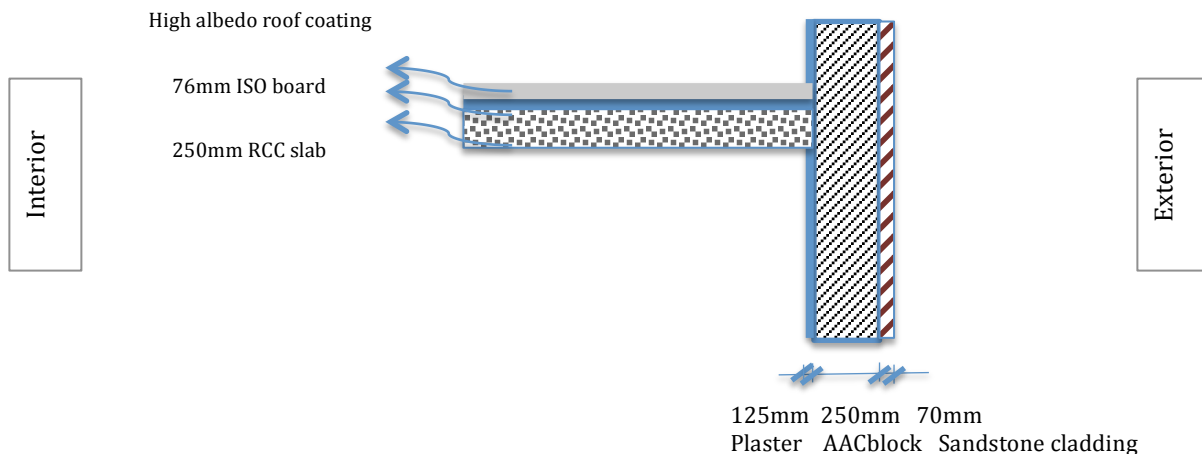


FIGURE 28: Wall and roof cross sections designed as low U-value assemblies at the ITC Green Center, Gurgaon.

Best Practices Improve Envelope and Passive Design

DATA POINT

At Infosys, Pocharam, an envelope with a second skin, i.e. cladding of aerated clay Weinerberger tiles have been used (Figures 29 and 30), with an air gap providing isolation of façade from structure. This creates a thermal break and a time lag to keep the heat absorbed by the skin away from the structure. The exterior wall also has R-10 insulation (extruded 2" polystyrene), with U-value of $0.4 \text{ W/m}^2 \cdot \text{degK}$ for the wall assembly.



FIGURE 29: Envelope with second skin/ cladding at Infosys Pocharam

3. Optimize Fenestration and Window-to-Wall ratio

- Maximize north and south exposures and fenestration; minimize east and west exposures.
- Limit the WWR to an optimum level.
- The glazing should have thermal breaks in the aluminum frame, and in any of the spacers.
- Carefully select the glazing and design window cross-section. Select the appropriate glazing to minimize solar heat gain and a reasonably high visible transmission level (T-vis) (See Table 8).

DATA POINT

At Infosys Pocharam, the massing and orientation has been designed to maximize the north-south orientation and minimize the east-west orientation. While there is virtually no fenestration on the east and west facades, the north and south WWR ratios are optimized to about 30%. Spectrally selective double-glazed low-E windows, with a Light to Solar Gain (LSG) ratio of 2.0 have been used. The window section includes a light shelf, a vision panel, and a daylight panel. The light shelf (Figure 30) is installed to distribute the light better and to reduce glare by bouncing the light off the ceiling. The windows (6-16-6) are double-pane filled with argon gas with a low U-value. The glazing has been selected such that the visual transmittance (T-vis) is higher for the daylight panel (above the lightshelf), and lower for the vision panel (below the lightshelf). This allows for brighter light to enter at higher wall levels and gain deeper penetration, without adding glare at the lower vision-level workplanes (Figures 30 and 31).

Best Practices Improve Envelope and Passive Design

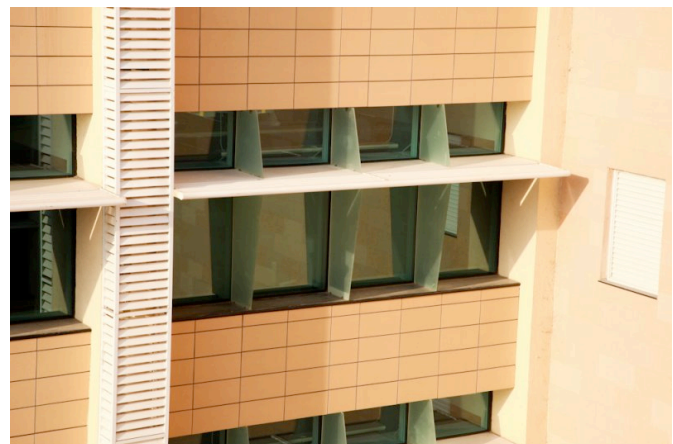
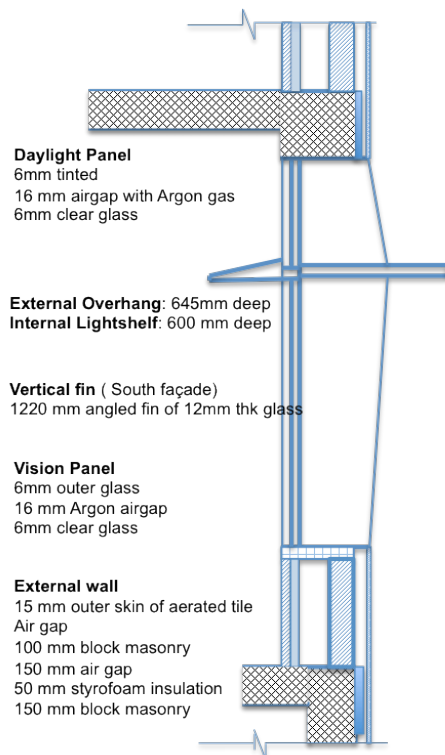
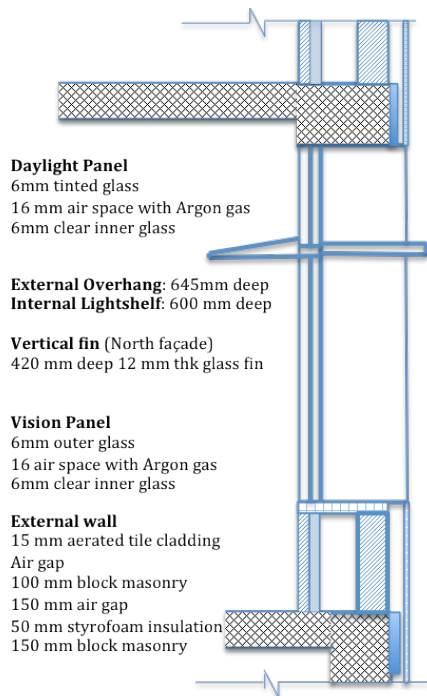


FIGURE 30: SDB-1 Infosys, Pocharam: (Top) North and (Bottom) South wall /window cross-sections. The south side has deeper, angled fins and overhangs as compared to the north side. The fin-overhang combination ensures that the window glazing is completely shaded, resulting in less glare and lesser solar heat gain. Additionally, the cross section also shows that the second skin is isolated from the structure of the building using an air gap. (Source: Infosys Green Initiatives Team)

Best Practices Improve Envelope and Passive Design

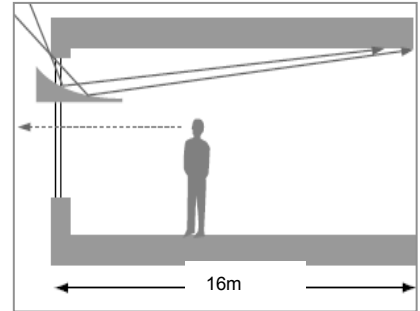


FIGURE 31: Infosys Pocharam office interiors. (Right): Schematic diagram showing that use of narrow floor plate, lightshelves, and specially selected glazing along the north-south facades of the building increases the penetration of glare-free daylight. (Source: Infosys Green Initiatives Team)

4. Maximize daylight autonomy without glare

Design a shallow floorplate, about 16 m–18 m for spaces with windows on both sides.

- a. Provide light shelves to increase the penetration of daylight and reduce glare. If light shelves are added into the space, daylight penetration can reach up to twice the height of the top of the light shelf into the space. That is, if the top of a light

shelf is four meters high, daylight can reach up to eight meters into space.

- b. To maximize the spread of daylight, plan intermittently occupied cabins and conference rooms in the core zones and open floorplan workstations in the perimeter zones. In terms of the interior space planning, provide low partitions and light colors to maximize daylighting (Figure 32).



FIGURE 32: (Left) Increase daylight autonomy by providing glass partitions at Sears Holdings, Pune (Photo: Facilities Team, Sears Holdings India); (Right) Providing open floor plan offices at perimeter zones and cabins in the core zones at the Infosys, Pocharam building.

Best Practices Improve Envelope and Passive and Design

DATA POINT

At the Suzlon One Earth campus in Pune, daylight is harnessed through curtain walls, but the massing is such that the curtain walls are shaded, either through self-shading or with extensive louvers. Some of the building blocks have narrow floorplates, about 17 m wide, which enhances the amount of daylighting. (Figure 33). (Source: Synefra¹³)

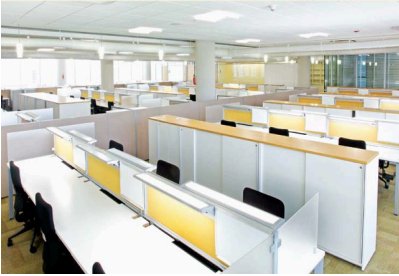


FIGURE 33: Use of louvers and the mass of the building's blocks to shade the large glazed areas at Suzlon One Earth, Pune. The glazing has low-E glass, there is extensive over-deck insulation provided, and the height of the buildings is kept deliberately low--all factors that substantially reduce the envelope heat gain. (Photos: Synefra¹³)

Best Practices Improve Envelope and Passive and Design

Table 8 provides best practices for passive design and envelope parameters.

TABLE 8: Best practices for passive design and envelope parameters

| Building Attribute | Best |
|---|---|
| Orientation | North-south maximized perimeter; locate services (like staircases, M&E rooms) on east-west perimeter |
| Massing/ Stories | Minimize surface area prone to envelope heat gain; increase self-shading potential |
| Floorplate depth | 9 m for single-sided window space, 18 m for double-sided window space (assuming interior lightshelves) |
| Shading Strategies | Overhangs for south façade windows; Small fins on north; Both fins and overhangs for east and west façade windows |
| Window Wall Ratio (WWR) | 25%–30% (ECBC code, WWR<40%)* |
| Vertical Fenestration | Meet or exceed ECBC values |
| Area serviced by daylight | 90% |
| U value (Insulation plus construction assemblies) | Meet or exceed ECBC values |

*It should be noted here that ECBC Prescriptive Compliance approach does not allow WWR to exceed 60%. Whereas, 80% WWR is the ratio that represents the full-glazed façade type of construction that has begun to dominate the commercial building design and practice in India.

Best Practices Implement Metering, Monitoring, Controls

Buildings waste 10%–30% of their energy due to operational inefficiencies.²³ However, building owners can improve efficiencies and reduce costs by identifying system- and component-level inefficiencies. This can be done by installing meters that measure the energy consumption of given equipment, zones, and other performance indicators.

From the data, determine what consumes how much energy and at what time. Then, identify the sources of energy waste and inefficient equipment operation. Finally, take action based on this data and analysis. Specific strategies are outlined below.

DATA POINT

At the Pocharam SDB-1 building, Infosys has installed meters and sub-meters at different levels to measure various building loads. These loads are segregated by floor. These data are analyzed and compared to historical averages. Energy reports assess the performance of the wings. The data from the system is constantly being analyzed by at least two dedicated personnel, to understand trends and identify anomalies. These data are further tied into a building management system (BMS), where the data are analyzed to identify potential areas of improvement.

- 1. Design for meterability.²⁴** Lay out the mechanical, electrical, and lighting systems so that these distinct end uses are separated at the panel level.
- 2. Promote data-driven decision-making.** Data must be made “actionable.” If energy data are available and actionable, operations and maintenance tasks can focus on proactively managing and maintaining energy performance rather than reactively responding to complaints. Understanding energy consumption allows building managers to identify and correct inefficient systems and components, and to reduce energy consumption 35%–50%.²⁵

A BMS builds intelligence into building operations in the form of energy saving algorithms. These help various building sub-systems communicate with one other and respond to the building’s changing needs. A BMS system

ensures that the system is living up to its energy potential. It provides valuable operational data on building energy consumption, energy demand, and comfort, which also helps verify design impact. This system is not only used to control the HVAC system, but is also used to gather electricity consumption data from the electric meters that monitor various loads.

- 3. Have vigilant building managers and facility operators** with a keen eye walk around the building and/or manage BMS systems regularly, to decipher building symptoms. (Figure 34)
- 4. Recommend a green lease,** which is primarily an environmental and energy savings agreement between the building owner and the tenants, in the case of tenanted operations. It encourages tenants to segregate their loads at the panel level.

Best Practices Implement Metering, Monitoring, Controls



FIGURE 34: Building facility technicians monitoring the BMS at the Suzlon One Earth, Pune campus. (Picture: Synefra¹³)

DATA POINT

Infosys uses the following factors to make data actionable: setting a baseline, data-driven engineering, performance-based contracts with design and product professionals, installing of field sensors, and continuous monitoring of the BMS (Figure 35). At the Pocharam campus, by trending the data from the BMS, it was discovered that the installed DX coil was staging on and off, leading to improper dehumidification, and therefore leading to the possibility of condensation in the buildings. It was replaced with a chilled water coil that increased efficiency. This issue would not have been identified without metering and monitoring through the BMS. The cost of the BMS was about Rs 515/m², or Rs 6.1 lakhs for a 12,000m² wing.

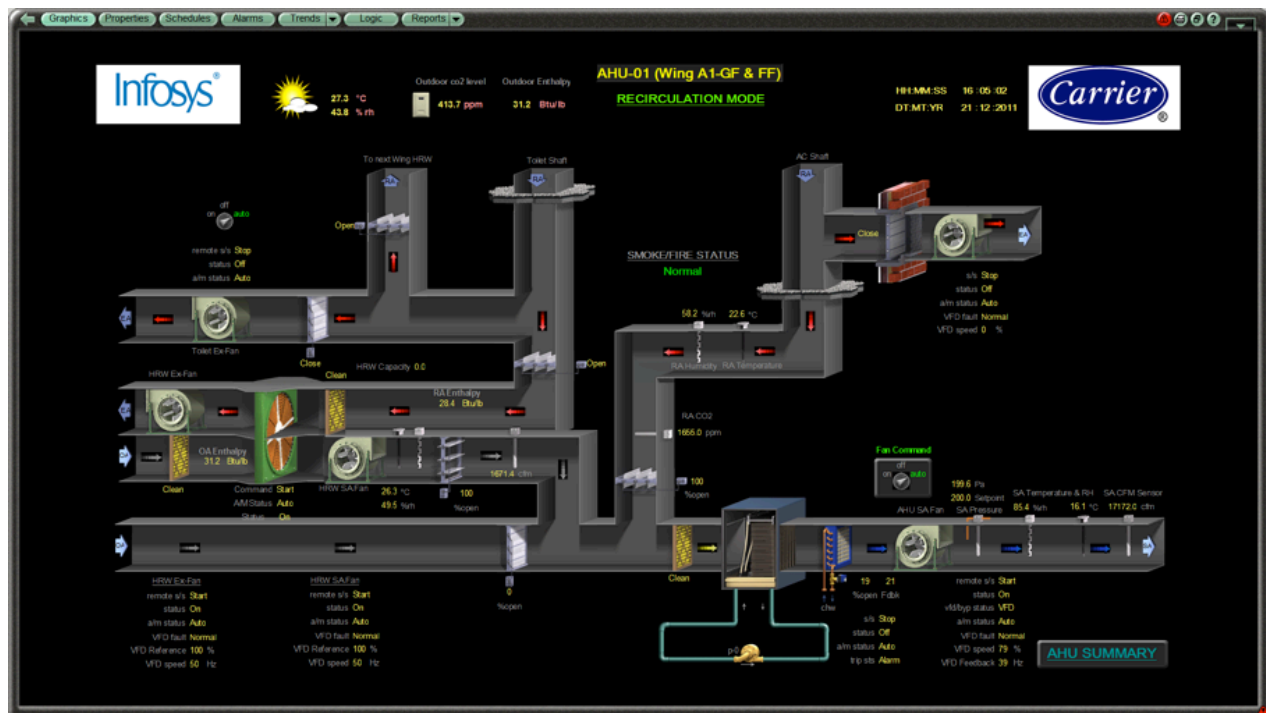


FIGURE 35: Screenshot from the Carrier Automated Logic Corporation BMS system installed at Infosys, Pocharam.

Best Practices Implement Metering, Monitoring, Controls

DATA POINT

At the Paharpur Business Center, the management understands that accurate measurement is at the core of any monitoring and reporting system, and hence over 50 calibrated meters have been installed during the retrofit. The BMS system logs and stores hourly energy consumption from these meters. The Engineering Department analyzes the energy consumption data from these meters and identifies area of improvement. The QA Department reviews measurement & Calibration methodology and it is checked and verified during internal audits, surveillance and third party audits under ISO-9001 and ISO-14001. The daily report of energy and water consumption is shared with the highly engaged CEO for inputs and major improvement decisions. Quarterly internal audits are carried out to analyze the efficiency of the energy management system and for continual improvements.

DATA POINT

At the Sears Holdings offices in Pune, controls for HVAC and lighting are provided for each pod of four workstations. Also, each individual DX unit is controlled at the pod level; these are less efficient units, but that a higher level of control offsets inefficiency. Building guards have been empowered to check in every hour to make sure that lights and laptops are turned off when not being use and air conditioners are not unnecessarily functioning. These actions have resulted in substantial energy benefits.

Conclusions and Future Work

The best practices described in this guide offer opportunities for building designers, owners, and operators to improve energy efficiency in commercial office buildings. Although the practices are presented individually, they should not be thought of as an “a la carte” menu of options. Rather, building systems must be integrated to realize the maximum energy and cost benefits. Also, designers and engineers, and developers and tenants need to work together to capitalize on the synergies between systems.

This guide provides tangible best performance metrics, ready to be adopted by buildings in India. These metrics are concrete targets for stakeholder groups to work together, and enable providing localized and customized solutions for each building, class, and its occupants. Having targets early on in the design process could also translate to more-efficient design lead times. The potential benefits of adopting these metrics include efficient operations, first-cost and lifecycle cost efficiencies, occupant comfort, and well-being—in addition to positive outcomes on global warming and societal benefits. It is also anticipated that the performance metrics will provide an impetus to scale-up and market transformation toward energy-efficient processes, resources, and products.

There is a number of continued research and development areas and changes to practice needed to better support integrated building design. As future work, there is a need for:

- Researching more extensive systematic data points on commercial buildings at the granularity of end-use metrics from new construction and retrofits for India’s five different climate zones. (See Appendix: Exemplary Buildings) The outcomes will provide a set of more refined hard data that would be a critical baseline to develop a strategic framework to improve efficiency throughout the country.
- Developing updated fundamental principles of design and performance, given the improvements in

technology associated with energy use in buildings. For instance, it is critical to consolidate the best in traditional wisdom with new technologies like low-E glazing, lighting systems, use of LCD screens and laptop computers, chiller technology, and variable frequency drives for airflow controls.

- Conducting simulations to inform the actual building design process, rather than to just for compliance with a green rating system. Also, establishing methods to align modeled and monitored numbers and generate a refined set of metrics based on these alignments.
- Addressing parameters such as peak demand and time-of-use prices. As India moves from “self aware” buildings that account for best performance based on local conditions, to “grid-aware” buildings, which will be responding to the reliability of electric grid, this will maximize the benefit of operational and reliability benefits for buildings operators.
- Devising processes to break down barriers to high performance, including more work on cost-benefits, procurement processes, and increasing availability of resources in the Indian building ecosystem.

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Appendix

Appendix Glossary of Terms and Abbreviations

AC: Alternating Current, is the form in which electric power is delivered to businesses and residences

Albedo: It is the dimensionless reflection coefficient. The root is from albus "white", and indicates the reflecting power of a surface. It is defined as the ratio of reflected radiation from the surface to incident radiation upon it.

BAU: Business as Usual, the normal execution of operations within an organization

BEE: Bureau of Energy Efficiency

BMS: Building Management System; is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems.

BPO: Business process outsourcing services in India, catering mainly to Western operations of multinational corporations (MNCs).

CFL: Compact fluorescent lamp

Cfm: Cubic feet per minute, a unit of volumetric capacity

CO₂: Carbon dioxide

Daylight Autonomy: The amount of time that you can expect to reach a certain light level through the use of just daylight.

DC: Direct Current, unidirectional flow of electric charge. Direct current is produced by sources such as batteries, solar cells etc.

DCV: Demand Controlled Ventilation, is a combination of two technologies: CO₂ sensors that monitor CO₂ levels in the air inside a building, and an air-handling system that uses data from the sensors to regulate the amount of ventilation air admitted.

DOAS: Dedicated Outdoor Air System, is a type of HVAC system that consists of two parallel systems: a dedicated outdoor air ventilation system that handles latent (dehumidification) loads and a parallel system to handle sensible (cooling) loads.

DV: Displacement ventilation is a room air distribution strategy where conditioned outdoor air is supplied near the floor level and extracted above the occupied zone, usually at ceiling height.

DX: Direct-expansion unitary system, where the evaporator is in direct contact with the air stream, so the cooling coil of the airside loop is also the evaporator of the refrigeration loop. The term "direct" refers to the position of the evaporator with respect to the airside loop.

ECBC: Energy Conservation Building Code that was launched in India in May 2007 under the Energy Conservation Act, 2001. ECBC takes into account the five climatic zones present in India. This is a document that specifies the energy performance requirements for all commercial buildings those are to be constructed in India. Buildings with an electrical connected load of 500 kW or more are covered by the ECBC. BEE with the support of USAID ECO- III Project is promoting ECBC awareness and voluntary adoption through training and capacity building programs, pilot demonstration projects, and identifying steps for compliance check and monitoring of ECBC.

ECM: Energy Conservation Measure is any type of project conducted or technology implemented to reduce the consumption on energy in a building.

Appendix Glossary of Terms and Abbreviations

ECO-III: The third phase of the Energy Conservation and Commercialization (ECO) Bilateral Project Agreement ECO-III which started October 2006, is helping BEE implement the Energy Conservation Building Codes (ECBC) in Gujarat and Punjab, with an overall focus on improving energy efficiency in the building sector, developing capacity of states to implement energy efficiency programs, and establishing energy efficiency centers and institutions. As part of the ECO-III project, collection of building level energy use data has been done from more than 860 buildings (office, hotel, hospital, retail) along with a detailed analysis.

EPI: Energy Performance Index indicates the specific energy usage of a building. It is basically the ratio of total energy used to the total built-up area. This total energy used includes both purchased electricity as well as that generated on-site, but excludes renewable sources like solar photovoltaic etc. The total built-up area excludes basement and parking area. EPI is calculated after completion of one year of operation with full occupancy of the building and is measured in units of kWh/sq m/year.

Floor plate: Size of the floor space on a story of a building. Smaller floor plates with smaller core areas have a higher ratio of window walls to interior space. Large floor plates have a more limited ratio of window walls to interior space and are more suitable to open space plans with workstations.

FTE: Full Time Equivalent is a unit that indicates the workload of an employed person (or student) in a way that makes workloads comparable across various contexts. FTE is often used to measure a worker's involvement in a project, or to track cost reductions in an organization. An FTE of 1.0 means that the person is equivalent to a full-time worker (8 hour, 1 shift), while an FTE of 0.5 signals that the worker is only half-time (4 hours, ½ shift).

GHG: Greenhouse Gas is a gas in an atmosphere that absorbs and emits radiation within the thermal infrared range. This process is the fundamental cause of the greenhouse effect.

Green Lease: It is a lease of space in a green building that incorporates principles to ensure that the ongoing operation and maintenance of the building minimizes environmental impacts.

HVAC: Heating, Ventilation, and Air Conditioning, refers to technology of indoor and automotive environmental comfort.

ITC: Indian Tobacco Company is one of India's foremost private sector companies with a diversified portfolio.

LCD: A liquid crystal display is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals. LCDs are more energy efficient and offer safer disposal than CRTs. Its low electrical power consumption enables it to be used in battery-powered electronic equipment.

LED: A light-emitting diode is a semiconductor light source. LEDs present many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved robustness, smaller size, and faster switching. LEDs powerful enough for room lighting are relatively expensive and require more precise current and heat management than compact fluorescent lamp sources of comparable output.

Low-E: Low emissivity. Low-E coatings are microscopically thin, virtually invisible, metal or metallic oxide layers deposited on a window or skylight glazing surface primarily to reduce the U-factor by suppressing radiative heat flow. Windows with spectrally selective low-E glass have the ability to reduce solar heat gain while retaining high visible transmittance.

M&E room: Mechanical and Electrical room

PBC: Paharpur Business Center, Delhi

PM_{2.5} : Particulate Matter 2.5, is the group of air pollutants with a diameter of 2.5 micrometers or less, small enough to invade even the smallest airways. It is a standard measure of environmental air quality. Adverse health effects from

Appendix Glossary of Terms and Abbreviations

breathing air with a high PM_{2.5} concentration include: premature death, increased respiratory symptoms and disease, chronic bronchitis, and decreased lung function particularly for individuals with asthma.

QA: Quality Assurance refers to the planned and systematic activities implemented in a quality system so that quality requirements for a product or service will be fulfilled.

RC: Radiant Cooling system refers to a temperature-controlled surface that cools indoor temperatures by removing sensible heat and where more than half of heat transfer occurs through thermal radiation. Radiant cooling systems are usually hydronic, cooling using circulating water running in pipes in thermal contact with the surface. Typically the circulating water only needs to be 2-4°C below the desired indoor air temperature. Once having been absorbed by the actively cooled surface, heat is removed by water flowing through a hydronic circuit, replacing the warmed water with cooler water.

Rs: Rupees, the currency of India

SDB-1: Software Development Block, the generic name given to buildings at Infosys campuses across India.

SEZ: Special Economic Zone, a geographical region that has economic and other laws that are more free-market-oriented than a country's typical or national laws. Usually the goal of a structure is to increase foreign direct investment by foreign investors. India's SEZ was set up in 2005; currently there are 143 SEZs operating throughout India and over 500 more have been approved.

SHGC: Solar Heat Gain Coefficient, is the fraction of incident solar radiation admitted through a window, both directly transmitted and absorbed and subsequently released inward. SHGC is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits.

Site Energy: The amount of heat and electricity consumed by a building as reflected in utility bills.

TR: Tons of refrigeration. Commercial and industrial refrigeration systems are rated in **tons of refrigeration** (TR). Historically, one TR was defined as the energy removal rate that will freeze one short ton of water at 0 °C (32 °F) in one day.

T-vis: Visible transmittance is the fraction of visible light that comes through the product. This is influenced by glass selection, as well as the amount of opening taken up by non-transparent components such as the frame and sash. The greater the VT, the better the potential for daylighting. Normally, a reduction in SHGC comes with a reduction in VT.

U value: U-factor gives the rate of heat transfer through the window or wall (from inside to outside when it is cold, and from outside to inside when it is hot) per unit area and per unit temperature difference. The lower the U-factor, the more heat enters your space in the summer.

UFAD: Under floor Air Distribution, is an air distribution strategy for providing ventilation and space conditioning in buildings as part of the design of an HVAC system. UFAD systems use the underfloor plenum beneath a raised floor to provide conditioned air through floor diffusers directly to the occupied zone. Underfloor air distribution is frequently used in office buildings particularly highly reconfigurable and open plan offices where raised floors are desirable for cable management. UFAD is also common in command centers, IT data centers, and Server rooms that have large cooling loads from electronic equipment and requirements for routing power and data cables. The ASHRAE Underfloor Air Distribution Design Guide suggests that any building considering a raised floor for cable distribution should consider UFAD.

UNEP: United Nations Environmental Program

UPS: Uninterruptible or Universal Power Supply is an electrical apparatus that provides emergency power to a load when the input power source, typically mains power fails. While not limited to protecting any particular type of equipment, a UPS is typically used to protect computers, data centers, telecommunication equipment or other electrical equipment where an

Appendix Glossary of Terms and Abbreviations

unexpected power disruption could cause injuries, fatalities, serious business disruption or data loss. UPS units range in size from units designed to protect a single computer to large units powering entire data centers, buildings, or even cities.

VAV: Variable air volume is a type of HVAC system. The simplest VAV system incorporates one supply duct that, when in cooling mode, distributes approximately 55 °F (13 °C) supply air. Because the supply air temperature, in this simplest of VAV systems, is constant, the air flow rate must vary to meet the rising and falling heat gains or losses within the thermal zone served. There are two primary advantages to VAV systems. The fan capacity control, especially with modern electronic variable-speed drives, reduces the energy consumed by fans, which can be a substantial part of the total cooling energy requirements of a building. Dehumidification is greater with VAV systems than it is with constant-volume systems, which modulate the discharge air temperature to attain part load cooling capacity.

VFD: A variable-frequency drive is a system for controlling the rotational speed of an AC electric motor by controlling the frequency of the electrical power supplied to the motor. Variable-frequency drives are used in a wide number of applications to control pumps, fans in HVAC systems.

VRV: The variable refrigerant volume systems (VRV/VRF) is basically a large multiple split system. The system can comprise of several indoor fan coil units, matched to one or more outdoor condensing units.

WWR: A window to wall ratio is the measure of the percentage area of a building's exterior envelope that is made up of glazing, such as windows.

UNITS

kVA/VA: Kilo Volt Amperes/ Volt Amperes, is the unit used for the apparent power in an electrical circuit.

kW/TR: Kilo watt per ton refrigerated, a measure of chiller efficiency

kWh/m².a: Kilo watt hours per square meter per annum, a measure of the Energy Performance

W/m²: Watts per square meter, a unit for peak energy use

W/m²K: Watts per square meter per degree kelvin, a unit for measuring U value

Appendix Exemplary Buildings

List of Exemplary Buildings described in the Guide

| Building and Location | Climate Zone | Stage | Building Footprint (m ²) | Occupancy /# of shifts |
|---------------------------------|--------------|------------------------------|--------------------------------------|------------------------|
| Infosys, Hyderabad | Hot and Dry | New Construction, Operations | 20,000 | 1 shift |
| Suzlon One Earth, Pune | Warm humid | New Construction, Operations | 41,000 | 1 shift |
| Sears, Pune | Warm humid | Retrofit | 9,100 | 2 shifts |
| Paharpur Business Center, Delhi | Composite | Retrofit | 4,800 | 2 shifts |
| ITC Green Center, Gurgaon | Composite | New Construction, Operations | 17,000 | 1 shift |

Appendix Exemplary Buildings

Location of the Exemplary Buildings on Climate Zone Map of India

