India: Opportunities in Buildings

As India is poised to become the fifth-largest economy in the world, building stock is being added at a healthy rate of 8% per year, and building energy use is increasing exponentially. While U.S. buildings use ~40%, or 38 quads of the nation's 97 quads of energy consumption (EIA 2018), Indian buildings already use 30% of the nation's 24 quads (IEA 2015) of energy consumption. India's power system needs to almost quadruple in size by 2040 to catch up and keep pace with electricity demand that—boosted by rising incomes and new connections to the grid—increases at almost 5% per year. Projections indicate that the Indian commercial sector footprint could triple to ~1.9 Billion m^2 (square meters) by 2030 over a baseline of 2010 (ECO III 2011). Although the buildings sector provides a challenge due to the extraordinary amount and pace of building construction, it also represents the most promising opportunities for fast and deep greenhouse gas emission mitigation.

With an active participation in the global economy, and influx of multi-national corporations, the Indian commercial building stock is becoming more international in form and function. Building energy use intensity is increasing at an unprecedented rate due to multiple factors, including the rapid addition of a large, new construction footprint, increasing urban temperatures, trends towards mechanical space cooling, highly glazed facades, enhanced computing and service levels, high occupant density levels, and multiple shift operations. The energy intensity in high-end Indian buildings has started to parallel and even exceed that of western, conditioned buildings. This is unsustainable given India's energy supply limitations, the additional burden on a constrained electric grid, reliance on fossil fuel imports, and the massive environmental implications. Indeed, the cost of new office buildings in India is rising, not only the economic cost of construction and operations, but also the environmental costs and associated productivity loss owing to unhealthy, polluted environments.

India has committed to an aggressive renewable energy target of 175 GW capacity by 2022 to provide equitable and clean energy access. This is coupled with recognition of energy efficiency as a primary resource, exemplified by the launch of the Energy Conservation Building Code (ECBC). India can continue its rapid buildings growth while taking advantage of regional opportunities such as passively cooled buildings with a wider occupant tolerance of heat, a ready supply of local, sustainable construction materials, inexpensive labor and craft costs, and a cultural ethos of careful resource use. Such approaches that have strong relevance, such as adaptive comfort and climate-suited construction, can also be suitable for transfer and transformation to other regions. These traditional opportunities, integrated with innovative building systems, information technology, and ecosystem processes, can enable a high-performance building stock.

Building Innovation: A Guide For High-Performance Energy-Efficient Buildings In India

This *Building Innovation Guide* provides technical recommendations for achieving high-performance Indian office buildings that are smart, green, and energy efficient. The best practices recommended in the *BIG* are particularly suited to the climatic, cultural, and construction context of India, thereby offering localized solutions.

Innovation occurs when new state-of-the-art is adopted into practice to create value. The key driver for building innovation in India is the emerging aspirations of a growing, young workforce. There exist innovative energy savings opportunities afforded by the intense growth in the buildings sector.

Inspired by cellphone technology that leapfrogged landlines for millions who gained unprecedented access to communications, the *BIG* consolidates knowledge about state-of-the-art transformed into best practices, in order to help leapfrog over transitional building methods, technologies and models. The transformative tools, technologies and approaches suggested in the *BIG* are poised at the edge of innovation. They have been validated through simulations and expert opinion, and demonstrated in exemplary buildings, and hence may be recommended for adoption.

The *Building Innovation Guide* is built on three core principles:

• *Develop a triple bottom-line framework for energy-efficiency decision making*. High-performance buildings can be achieved through consideration of (1) human capital—enhanced working environments for occupants, (2) financial capital—an attractive return on investments, and (3) environmental capital—mitigated environmental impact of buildings.

• *Adopt shared, aggressive but achievable energy performance targets across building stakeholders*. These benchmarks are localized to the climate zones of India, and are based on a triangulation of monitored data from exemplary projects (presented as "Data Points"), modeled data from building energy simulations (presented as "Simulation Results"), and experts' inputs. "Tables of Metrics", provide ambitious climate-specific targets. Best practice strategies from research and exemplary buildings are presented as proof-of-concept to show how real buildings are targeting and achieving high performance.

• *Focus on the entire building lifecycle i.e., design, construction, and operation*. The *BIG* provides recommendations about the "why and how" of strategies to be employed through the building lifecycle. The design phase is when building energy modeling may be performed; the build phase is when construction using energy-efficient materials and systems may be done; and the longest operations phase is when commissioning, monitoring, and controls may be incorporated. (Embodied and demolition-based energy uses are beyond the scope of the *BIG*).

The best practice recommendations are classified into three categories:

Whole-building Design, Building Physical Systems, and Building Information Systems, as follows:

Best Practices for Whole-building Design

The BIG recommends that best practice strategies should be applied early at the whole-building design level. Optimum energy efficiency can be achieved through integrated stakeholder strategies that can be cost-effectively woven in as a "must-have" at the conceptual design phase, so they are not value-engineered out due to a 'much-too-late' incorporation into the design process. The stakeholders can also focus on maximizing energy efficiency of the building as a whole, and not just on the efficiency of an individual building component or system. The multi-disciplinary interactions can explore synergies between otherwise inharmonious design strategies. For instance, increased glazing to enable daylighting needs to be balanced with the objectives of thermal comfort and glare-free visual comfort. Systems integration during design, and monitoring during operations, can help achieve verifiable, deeper levels of building energy efficiency and higher levels of performance. This requires critical integration between the building's physical systems and its information systems, as described next.

Best Practices for Physical Building Systems

Best practices are explored for the four intersecting physical building systems: envelope/passive systems, electrical equipment (plug loads), lighting, and mechanical systems for heating, ventilation, and air conditioning (HVAC).

1. Envelope and Passive Systems:

Planning best practice strategies for passive envelope systems at the beginning of the design process can help achieve large gains at relatively lower-cost. Envelope strategies constitute wall, windows, roof assemblies and shading to avoid exposures to solar heat gain and glare, and to support natural ventilation where possible. These strategies demonstrate even bigger savings for buildings with smaller floor plates that exhibit external load-dominance due to the larger surface-to-volume ratio. Strategies discussed in the *BIG* include the following:

- Optimizing massing and orientation using building energy simulation

- Decreasing envelope heat gain through appropriate construction assemblies, passive construction, insulation, phase change materials, shading, and reflective ‘cool’ surfaces

- Optimizing fenestration and window-to-wall ratios
- Maximizing daylight autonomy without glare

2. Electrical Systems:

Plug loads represent a significant 20%–40% of the electricity consumed in Indian office buildings. Strategies must cater to office electronics such as computers, monitors, and printers, and also include task lights, personal or ceiling fans, vertical transport (elevators/escalators), and other process loads. Best practices discussed in this *Guide* for plug loads optimization include:

- Setting aggressive power management settings at the building and device level
- Providing an energy-efficient computing infrastructure
- Pursuing direct current power-based improvements
- Installing appropriate energy monitoring and control hardware
- Encouraging responsible occupant behavior
- Reducing the number, and increasing the efficiency of plug-in devices

3. Lighting Systems:

Lighting represents approximately 10%–25% of the electricity consumed in Indian office buildings. Lighting load is greater for buildings with deeper floor plans or with operations that include evening or night shift hours. Strategies presented in the *Guide* for reducing lighting loads include:

- Optimizing daylighting design
- Implementing highly efficient lighting equipment, luminaires, ballasts, and optimized lighting layouts
- Using lighting sensors and controls

4. Heating Ventilation and Air Conditioning Systems (HVAC):

HVAC represents approximately 40%–60% of the electricity consumed in Indian office buildings and provides some of the largest opportunities for energy savings. Best practices detailed in this *Guide* for HVAC energy optimization include:

- Separating the spaces that could be naturally ventilated and developing mixed-mode opportunities, rather than fully air conditioning all built spaces at all times
- Right-sizing equipment, and building-in modularity
- Leveraging opportunities such as district cooling to harness diversity and density of cooling loads
- Using non-compressor cooling or equipment with low greenhouse warming potential (low-GWP) refrigerants
- Considering low-energy cooling options such as night flush, displacement ventilation, under-floor air distribution (UFAD), radiant cooling and evaporative cooling
- Managing loads by decoupling ventilation and cooling
- Providing thermal storage options, such as passive thermal mass and active ice storage solutions
- Considering progressive or hybrid mechanical systems
- Adopting flexible temperature setpoints, and ceiling fans for adaptive comfort delivery

Best Practices for Building Information Systems Building information systems are critical to the "smartness" of buildings—they provide vital data in the form of actionable information to integrate the design and functioning of the building's four physical systems as follows:

- First, by performing building energy simulation and modeling at the design phase, one can predict the building's energy performance and simulated code compliance.
- Second, by integrating building controls and sensors for communications at the build phase, one can manage real- time performance relative to the original design intent.

• Third, by conducting monitoring-based commissioning and benchmarking during the longest, operations phase, one can track building performance and provide feedback loops for better operations, as well as insights for the design for the next generation of buildings.

In average buildings, 30% of the energy consumed is actually wasted because of operational inefficiencies (Energy Star 2010). Most commercial buildings do not operate and perform at levels intended during design. Fortunately, it is possible to improve efficiencies and reduce costs by identifying whole-building, system-level, and component-level inefficiencies. This can done by installing sensors and meters that measure the energy consumption at the level of whole-building, end- uses, equipment, zones, or any other important points of energy use. The collection and analysis of building energy use data through an energy management and information system (EMIS) can predict what end-uses or spaces consume how much energy and at what time. This also helps to identify excursions from predicted baselines, sources of energy waste, and inefficient equipment operations. Specific strategies for managing and optimizing energy-efficient operations of a building outlined in the *Guide* include:

- Implementing component-level control strategies
- Implementing HVAC and lighting sensors, monitoring, and controls strategies.
- Designing for meterability and installing smart energy meters and system sub-meters
- Promoting energy data-driven decision-making across the building ecosystem, from the facilities staff to the corporate boardroom
- Promoting sequential energy-saving actions (i.e., schedule, control, repair, audit, and retrofit)
- Training vigilant building managers and facility operators
- Implementing performance-based contracting
- Developing green leasing mechanisms.

Organization of the Building Innovation Guide

The *BIG* has five main segments, relevant for the various stakeholders to work collaboratively to achieve high- performance, as follows: **I. Introduction** This segment discusses the challenges, opportunities, and goals for building energy efficiency in India. Context regarding U.S. and Indian commercial buildings is provided as background. **II. Best Practices** This segment is at the heart of the document, and presents best practice strategies for improving energy efficiency. It has three sections:

- Whole Building Approach,
- Building Physical Systems (Improve Envelope and Passive Design, Reduce Plugs and Process Loads, Optimize Lighting Design, Develop low-energy HVAC Strategies, Implement Climate Control Strategies),

- Building Information Systems (Install an Energy Information System). The over-arching frameworks provided in the section "Whole Building Approach" are relevant across the stakeholder groups– owner/developers, architects, engineers, operators, and building occupants– to define their whole building strategies and targets. The other sections provide detailed information for various building team members e.g. mechanical, electrical, architectural, and energy consultants, but as they relate back to a shared set of metrics at the whole building level. It is worth noting that each of these sections offers "Tables of Metrics" as benchmarks and targets, using a triangulation of modeled data, monitored operational data from exemplary buildings, and expert opinion. These are benchmarks relevant across the office building typology, but a similar method can be adapted for broader application across other building typologies. Further details about modeled data are provided in "Simulation Results", and about exemplary buildings are provided in "Data Points".

III. Conclusion

This segment provides a synthesizing framework for the localization and prioritization of best practice strategies for specific buildings. It also offers macro-level regulatory and policy implications of innovative building best practices.

IV. Appendix The **Glossary of Technical Terms** (Appendix 1) provides definitions of terms and abbreviations used in the *BIG*, in an effort to make technical information more accessible. A **List of Exemplary Buildings** and their locations is provided in Appendix 2. The **List of Technologies** (Appendix 3) provides information on potentially relevant technologies and services that can enable energy efficiency. The **List of Simulation Tools** (Appendix 4) provides information on software tools that may be helpful for various aspects of building design.

V. Climate Specific Modeling and Analysis (Annex) The Annex provides the methodology, assumptions, meta- analysis, and results of building energy simulations with results pertaining to building energy use and occupant thermal comfort. These simulations are conducted in the EnergyPlus building energy software tool, and may be a helpful deep-dive for architects, engineers and energy consultants, as they design their buildings.

Potential Benefits of the *Building Innovation Guide*

The *Building Innovation Guide* provides a *structured methodology* to enable building stakeholders to deliver high performance throughout the building life cycle. Although these best practices are presented individually, they should not be thought of as an "a la carte" menu of options but recommendations towards a strategy of synthesis. The *Guide* also provides *tangible, quantitative, adoption-ready best performance metrics* for various climate zones in India. The metrics are concrete targets for stakeholder groups to achieve, by capitalizing on the synergies between systems through an integrated design process. These synergies can impel localized and customized solutions for high-performance commercial offices.

The *Building Innovation Guide* offers a *shared set of values and metrics across the building stakeholder ecosystem*. The primary audiences of the *Guide* are building stakeholders, i.e., building owners, developers, energy modelers, architects, engineers, facility managers, operators, occupants, and auditors. These stakeholders may have questions such as: *How can I design, construct, and operate my building so that it is attractive and productive for the occupants while being economically and environmentally sustainable year after year?* Indirect audiences include building product industry experts with questions such as: "*What products will enable high performance and gain market share?*" and policy stakeholders with questions such as: "*How can we transform building stock to be high-performance?*"

The *Building Innovation Guide* provides a framework for prioritizations amongst best practice strategies that can empower building stakeholders to develop *lifecycle-based, triple-bottom-line-oriented decision-making processes*. Through adoption and validation of the qualitative and quantitative goals both at the building level, and across their office building portfolios, building stakeholders can also help influence regulations and policy towards a high-performance building stock. The set of best performance metrics can be an effective baseline in the absence of a formal benchmarking program. These metrics and strategies may also be relevant to other economies across the world with similar contexts.

India is at an inflection point. Energy-efficient processes, resources, and products across the building ecosystem can affect positive change and drive strong environmental and societal impact. We believe that this is a prime opportunity for building professionals to set ambitious building targets, and accelerate high-performance in a new generation of buildings. And propel India into the next frontier - of a decarbonized, digitized, and innovative future.