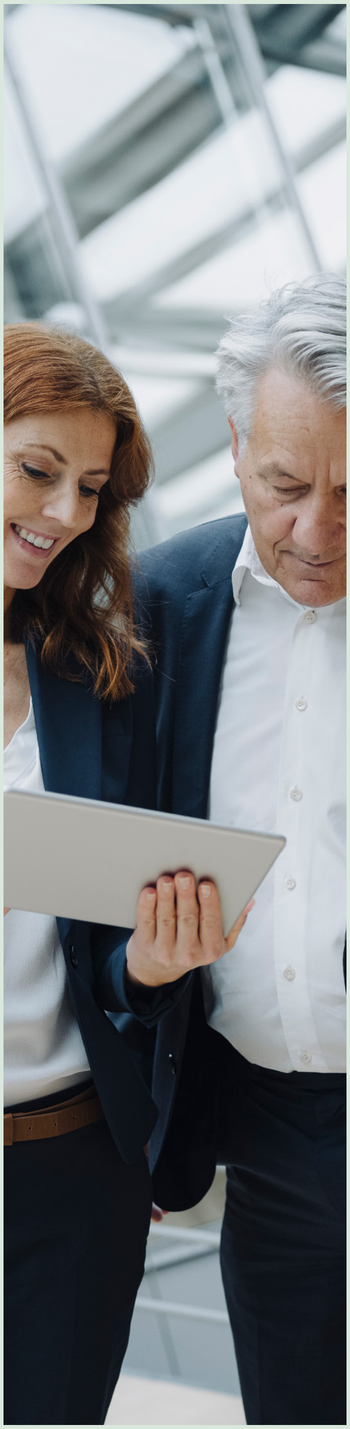
WHITE PAPER



GRID-INTERACTIVE SMART BUILDINGS(GSBs)

Infosys®
Navigate your next

Abstract

As the electricity demand continues to increase, integrating buildings, renewable sources, and the power grid is key in improving energy efficiency and reliability, reducing carbon emissions and energy costs. In this scenario, Grid-Interactive Smart building (GSB) can play a vital role by adjusting energy use dynamically in response to grid conditions, along with monitoring the asset capacity utilization, energy efficiency, and comfort and provide demand flexibility co-optimized to serve occupants and the grid.

Technological innovation, cost reduction, new business models, and enabling policies are accelerating the transformation of the traditional electricity grid into a decentralized grid with energy and information flowing both ways. The challenge is how to turn the potentially disruptive effects of multi-sources.

Significant challenges are: -

- leveraging the lowest-cost resources at a given moment, reducing operating costs, and optimally shaping demand
- utilizing intermittent renewables to its maximum capacity while automatically monitoring energy savings and emission reductions
- Selling surplus energy (or energy as a subscription service) favorably

All these require increasing energy monitoring, management and control, improving demand forecasting and predictive models, correlating operating parameters and energy prices, as well as developing services and tools to manage the integration of higher shares of renewable energy, balancing, and demand response services. All this while guaranteeing the security and stability of grid.

In the 21st century, GSB represents a paradigm shift in how they serve electricity utilities and builds.

This paper is a comprehensive study of the implementation approach and application of building-level control strategies for utilizing heating, ventilating, air conditioning and electrical systems to provide grid service. Various areas have been addressed, like power load shifting, power reduction, automating energy efficiency, occupant comfort, modeling utility pricing, grid integration, on-site energy resources, and combining different demand flexibility modes in control design. GSB will help to reduce carbon footprint by maximizing energy efficiency and integrating renewables, contributing significantly to climate change mitigation. This paper provides a high-level overview of GSB for decision-makers and stakeholders.

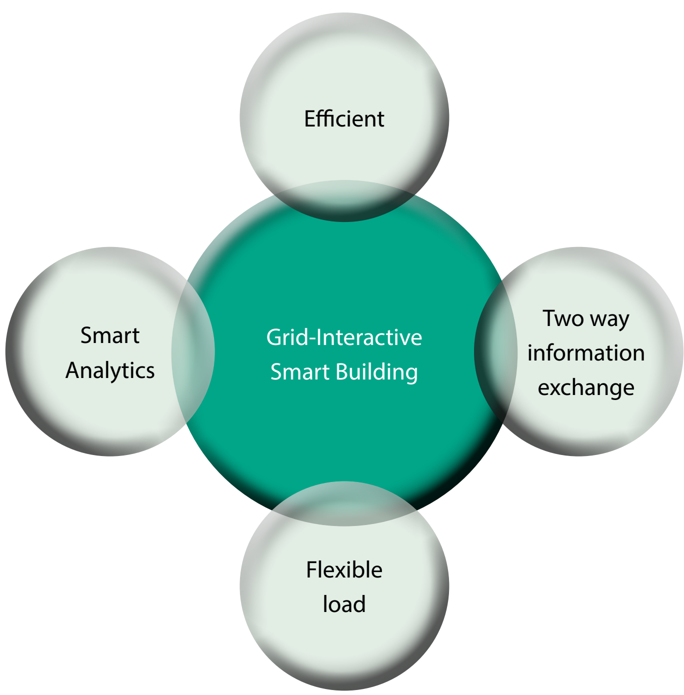


Figure 1: GSBs are efficient, connected, smart & flexible.

INTRODUCTION

The power grid faces multiple challenges due to the increased adoption of distributed renewable generation, increasing peak electricity demand and grid infrastructure constraints. Power grid energy distribution system must maintain grid stability, ensure desired power quality (PQ), deal with aging assets and reduce the operating costs. Most of the time, the gap between supply and demand creates challenges for Utility distribution. As most of the sectors depend on reliable grid electricity, CO_2 emissions in buildings account for 39% of today's global CO_2 emissions. Of this, around 3 Gt CO_2e are direct emissions; a further 9.8 Gt CO_2e are indirect emissions from electricity and heat consumption; and an additional 3.5 Gt CO_2e from materials used for construction.. The situation will worsen with a future increase in floor area, which is set to grow approximately 75% over 2020-2050, meaning CO_2 emissions will rise dramatically if no decarbonization efforts are made in the sector. Looking into supply and demand side challenges, finding the most cost-effective sustainable solutions is imperative. Demand side management (DMS) in buildings (commercial or residential) is vital in achieving grid stability, maximum renewable power plant capacity utilization, and improving energy efficiency. S*ome of the case studies can be referred to in the link provided in the reference section.*

The GSB solution is a software technology platform that can simulate utility cost (flat, ToD or dynamic), comfort, weather conditions, command and control with time-bound adjustment of parameters. It helps reduce peak demand, improve system reliability, support grid stability, maximize utilization of DSRs and BESS, and efficiently operation of HVAC & electrical equipment.

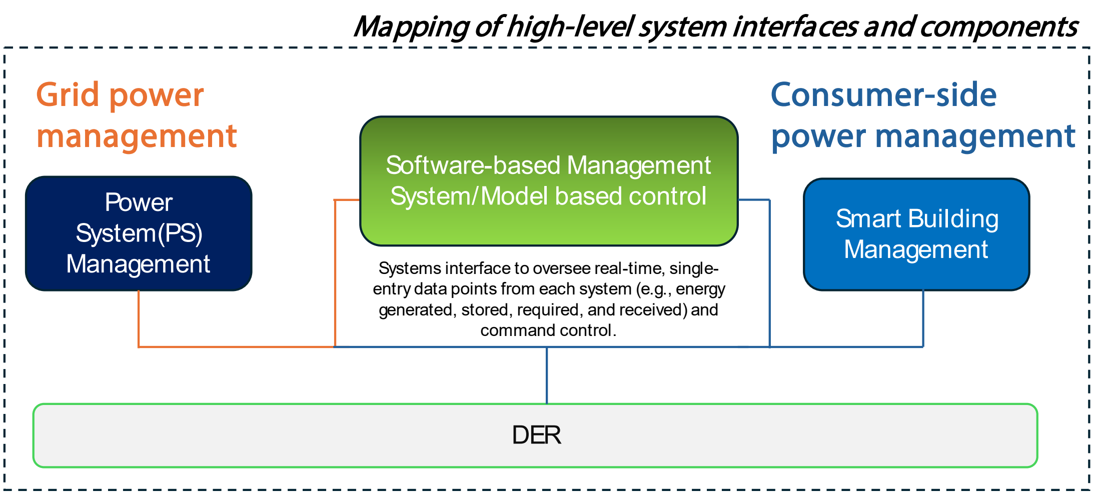


Figure 2: GSB System Interfaces and Interoperability

In 2019, the U.S. Department of Energy (US-DOE) released a series of reports about grid-interactive efficient buildings that use smart technologies and on-site demand-side resources (DSRs) to provide demand flexibility. s per the study carried out by Energy Efficiency & Renewable Energy (US-DOE) in, there is a potential savings of 30% with occupant-integrated smart control system applications. The US-DOE estimates that "Over the next two decades, grid-interactive buildings could deliver around \$100 - \$ 200 billion in savings to the U.S power system and cut CO2 emissions by 80 million tons per year by 2030. These positive impacts will drive further adoption of building-to-grid technologies and operational procedures. (Source: A national roadmap for grid-interactive efficient buildings).

Objectives

The goal of GSB is a resilient system focused on improved energy efficiency, reliability, and comfort with reduced carbon footprint and operational costs.

Drives a faster decarbonization of the energy system through demand-side flexibility, energy storage and renewable source	Recognizes, predicts & responds to users' need by meeting thermal comfort, safety, Energy Productivity and IAQ	Empower user with control over Energy flow, unified monitoring, data driven decison and improving productivity

To achieve the objectives, it is imperative to follow an integrated approach that adheres to established policies, regulations, and standards while engaging key stakeholders/sustainable digital partners with accountability, transparency, and privacy. A solution developed with this approach will reduce operating costs and improve energy efficiency with continuous measurement and verification. A successful program requires cooperation, dedication, and participation across levels and cannot succeed without all involved understanding the basic principles and supporting the cause. A novel approach towards successfully implementing grid-integrated smart building is shown in Figure 3- GSB *framework,* with areas to be covered to maximize the benefits of decreasing operating costs and carbon footprint.

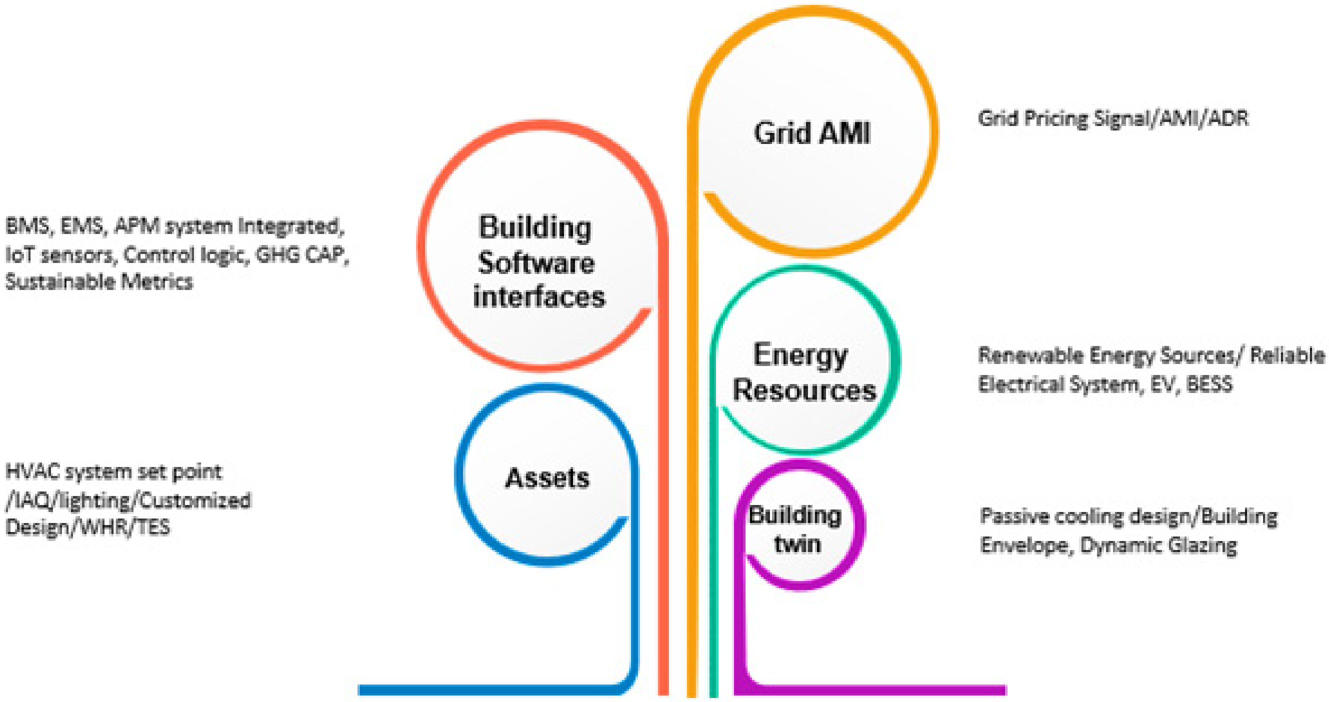


figure 3- GSB framework

CHALLENGES IN IMPLEMENTING GSB

To realize the benefits offered by GSB will require addressing various challenges, such as technical, including advancing sensors, smart meters, IoT device, control hardware and software, improving data management and analytics, model development and calibration, addressing standards and interoperability, and assuring cybersecurity and customer privacy. Some challenges have technical bases or aspects but are essential for informing and implementing policies, planning, regulation, and market operations, such as applying appropriate performance metrics, valuing demand flexibility-provided services, and integrating DER impacts into state and utility planning. Policies, regulation, administration, and market design are critical, including employing frameworks to align public policy goals with private benefits. Utilities and customers both must see value and benefits in implementing demand flexibility and GSB.

As mentioned earlier, the solution must focus on demand flexibility and carbon emission reduction and address the typical energy losses in building and system reliability.

Some of the rid side challenges in implementing GSB

1. **Lack of time differential pricing:** A time-varying pricing structure is considered an effective solution to provide passive flexibility by incentivizing time shift of loads.
2. **Regulations for demand or EVs as a resource** – A regulatory framework for defining demand-side resources is lacking. Furthermore, regulations don't identify EVs as a valuable storage resource.
3. **Aggregation of loads:** To attain the grid-wide benefits of DERs, aggregation of resources is critical to provide the required quantum of network-related services. To date, no regulatory definition is provided for aggregating demand-side resources.
4. **Lack of Measurement and Verification (M&V) standards:** M&V is an important step in incentivizing participant performance by verifying the value of services provided by a resource.

Some of the building side operational challenges in implementing GSB

1. There are operation silos and no real-time integrated monitoring of demand, energy consumption, carbon footprint, reliability, uptime and comfort.
2. Lack of holistic data modeling and CO_2 performance metrics.
3. Lack of demand forecasting and future thermal requirements.
4. Manual or semi-automatic system operation without energy management features.
5. Equipment control in bypassed/override/manual mode, faulty devices and controller error/higher standard deviation (e.g., leaky valves, sensors, controllers).
6. Lack of desired standards during functional tests and sequence of operation of the HVAC system. (e.g., ASHRAE Guideline 36-2021 – performance sequence of operations for HVAC system operation).
7. Mechanical, electrical and plumbing (MEP) and control providers lack scalable solutions to decarbonize medium and large commercial buildings.
8. Real-time condition monitoring and PdM (predictive maintenance) are inadequate, and there are no proper metrics to monitor operational failures.

OPPORTUNITY WITH GSB

Growing urbanization results in increased demand for grid electricity, reliable power supply and demand for renewable-based energy resources. At the same time, with an impressive rise in the use of smart devices to connect to the internet, life would be more comfortable with many IoT-based technologies. This implies the need for substantial electric energy or demand for low-power consumption solutions.

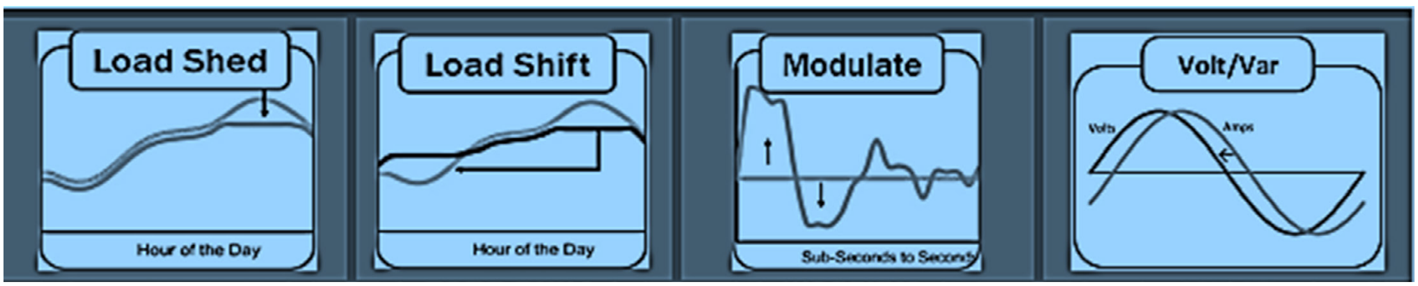
GSBs are designed to integrate buildings, renewable energy generation, V2G, and BESS into the grid and rely on data generation capabilities, digital metering (advanced metering infrastructure -AMI), controls, IoT sensors and communication protocols to process data for decision-making and automated controls. GSBs support grid-scale efficient operation by employing onsite distributed energy resources (DERs) and curtailable loads and require interoperability between the building management system, microgrid management system, and power management system for real-time grid interactivity.

Implementing comprehensive demand side management (DSM) solutions will take care of better grid flexibility and hence improve overall system reliability. Grid flexibility and resilience are the ability of the electric grid to cope with fluctuations in supply and demand, as well as disturbances and disruptions.

As more renewable energy sources, such as solar and wind, are integrated into the grid, the variability and uncertainty of generation increases. This poses challenges for balancing the grid and maintaining its frequency and voltage. On the other hand, demand can also vary depending on the time of day, season, and user behavior. The grid needs more flexibility and resilience to address these challenges, provided by smart building energy storage, with smart and energy efficient operations.

The four major categories of technology-driven demand flexibility or demand response features are illustrated below based on time duration.

Building Demand Flexibility Features



Reduction in peak demand to keep the grid from being overloaded	Mitigate Ramp and capture surplus renewables (time of use) ToU tariff	Frequency regulation	Fast DR to smooth net load and support frequency
e.g., Lighting systems, HVAC systems, temperature control	BESS, V2G, TES	Smart inverters	Volt/VAR optimization, CVR technique

(Ref: roadmap for consumer devices to participate in demand flexibility-EDNA)

Buildings' occupants are becoming "prosumers" (producers and consumers simultaneously), and their behavior during building operations is becoming vital in enhancing energy performance. The implementation of active demand initiatives and peak-saving strategies are expected to increase to help integrate these distributed resources and generation systems in the smart distribution grid.

In this context, implementing effective energy management strategies employing advanced control methods represents an attractive solution to reduce the operational energy demand of buildings and the mismatch between their energy demand and onsite generation, maximizing the exploitation of RES. Many investigations proved that more advanced control methods could ensure significant energy savings compared to traditional control methods.

However, HVAC control sequences are often targeted to "keep it simple" for the building operator to the extent that they are usually not in compliance with codes and standards such as ASHRAE 36-2021, Advanced Sequences of Operation for HVAC Systems-Phase II central plants and Hydronic Systems, ANSI/ASHRAE/IES Standard 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings, ANSI/ASHRAE Standard 62.1 and Ventilation for Acceptable Indoor Air Quality.

These oversimplified sequences are not always well programmed or debugged, resulting in subpar building performance. Guideline 36 was created to address these issues, including best-in-class control sequences optimized to minimize energy use and maximize comfort and IAQ. The sequences are intended to be preprogrammed and pre-debugged by control system manufacturers.

GRID INTEGRATED SMART SOLUTION ARCHITECTURE

Digital and physical enablement technology can significantly transform the employee experience, realize operational efficiencies, and reduce carbon emissions. However, it calls for an interlaced strategy combining digital and physical environments such as power grid, smart metering, smart buildings and campuses to create smart space. IoT leadership, design thinking, predictive analytics, cloud computing, open standard architecture, building management, and other technology systems involving cross-functional teams can significantly help.

A design thinking integrated approach to develop a unified platform is listed below.

- Identify the salient problems related to power suppliers, customers, businesses and employees through a proven and agile rapid learning and enablement process.
- Develop a blueprint with desirable occupant experience solutions by harnessing technical expertise and human-centric design methodology.
- Drive user adoption of solutions through change management frameworks that enable organization-wide governance.
- Measure and track value, thereby ensuring that innovation is meaningful to all stakeholders
- A digital thread needs to be established with a communication framework to help facilitate an integrated and connected data flow of the product's data throughout its lifecycle.

A unified system will benefit from connecting with the correct data and communication modules in a single repository.

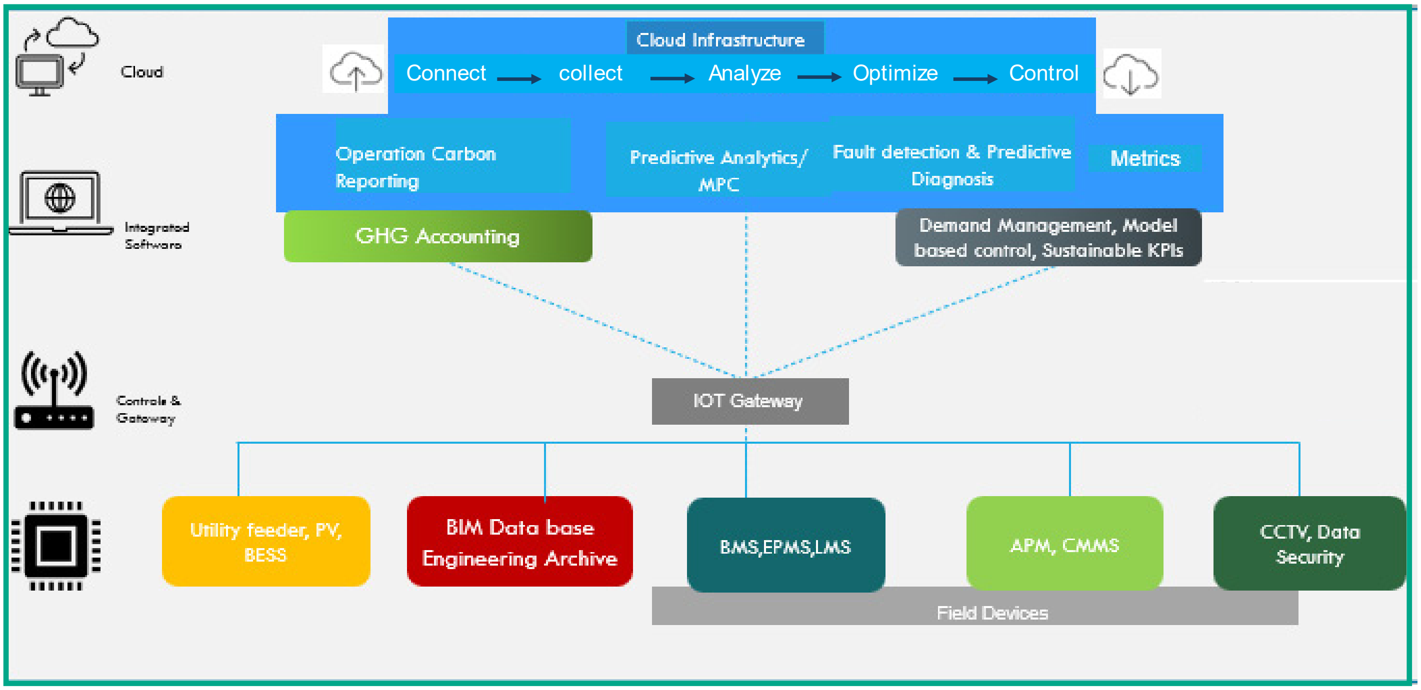


Figure 4: Proposed GSB System Architecture

The repository can be a local or cloud database, represented by the "Layout of GSB System," as shown in Figure 4. Data sharing between the siloed systems is essential to carry out GSB applications and critical in several areas of operation, such as power synchronization between them. Figure 4 depicts a unified system operation where the automation system can represent a building BMS connected to a microgrid or any form of DER. The same goes for the utility management system and associated grid-scale DER connections. While each system is necessary to oversee monitoring, controls, maintenance, and core functionality within itself, a GSB will benefit from a systems interface to manage real-time, single-entry data points from each system (e.g., energy generated, stored, required, and received).

Target Market and Audience

Unlike conventional energy sources, renewable generations are highly intermittent and of variable type. Large-scale integration of renewable generation requires a special balancing mechanism to deal with uncertainty and variability and maintain grid stability and security. Micro-grid development also needs attention to supplement capacity addition and electrification in remote areas. Successful integration of such large scale RE integration would require active participation of all players. The key players include:

Building owners and facility managers: This group is directly responsible for building operations and maintenance costs. They will be interested in the whitepaper's discussion on potential cost savings, improved energy efficiency, and potential return on investment (ROI) associated with a grid-interactive smart building platform. Others could be:

- Engagement of startups and major control companies
- Proposal to EESL to explore opportunities through the ESCO model
- Financial institutions for green financing
- Policymakers, regulators
- Government building through MoP, MoUD, SDA/ULBs in India
- International clients (US & UK region)
- Architects, engineers and construction professionals
- Utility companies and grid operators
- Investors and financiers

Probable Risk and Mitigation

The GSB platform offers exciting possibilities for energy efficiency and grid stability. However, there are inherent risks that need to be considered. Here's a breakdown of some key risks and ways to mitigate them:

Cybersecurity Risks:

- **Hacking and data breaches:** Malicious actors could gain access to building systems, steal data or disrupt operations.
- **Denial-of-service** attacks could overwhelm the platform, preventing occupants from controlling building systems.

Mitigation:

- Implement robust cybersecurity measures like firewalls, intrusion detection systems and regular security audits.
- Encrypt sensitive data and enforce strong access controls.
- Regularly update software and firmware to patch vulnerabilities.

Operational Risks:

- **System outages:** Platform malfunctions could disrupt building operations and occupant comfort.
- **Integration issues:** Difficulty integrating the platform with existing building systems.

Mitigation:

- Engagement of all key stakeholders from the design and conception stage
- Design the platform with redundancy and fail-safe mechanisms to minimize downtime.
- Conduct thorough testing before deployment.
- Ensure compatibility with existing systems during the design phase.

Grid Management Risks:

- **Unintended impacts on the grid:** Building actions could destabilize the power grid if not correctly managed.
- **Unforeseen price fluctuations:** Volatile energy prices could make it challenging to optimize building operations.

Mitigation:

- Implement intelligent algorithms that optimize building energy use based on grid conditions.
- Adoption of interoperability standards for the overall system is a critical prerequisite. Seamless interoperability, robust information security, increased safety of new systems, compact set of protocols and communication exchange are some of the objectives that can be achieved with smart grid standardization efforts. Well-defined communication protocols for buildings to interact seamlessly with the grid operator are also essential.
- Use energy storage solutions to buffer fluctuations in energy prices.

Approach for change management

Transitioning to a GSB requires a well-defined change management approach. Here's a breakdown of key steps to ensure a smooth and successful implementation:

1. Define Goals and Benefits:

- Clearly articulate the goals of adopting a GSB platform. This could include energy cost reduction, improved sustainability, occupant comfort enhancement or grid stability support.
- Communicate the benefits to all stakeholders (building owners, occupants, facility managers, utility companies, regulating authority).

2. Assess Current State:

- Evaluate existing building systems, grid metering and network infrastructure, energy consumption patterns and occupant behavior.
- Identify potential challenges and areas requiring training or adjustment.

3. Develop a Change Management Plan:

- Outline the implementation timeline, including phases and milestones.
- Define roles and responsibilities for all stakeholders involved.
- Develop clear communication strategies for each stakeholder group.

4. Communication and Training:

- Create targeted communication materials to educate stakeholders about the GSB platform and its functionalities.
- Provide comprehensive training for occupants and facility managers on how to use the new system effectively.
- Address concerns proactively and foster a culture of open communication.

5. Implementation and Feedback:

- Deploy the GSB platform in a phased manner, allowing for adjustments and troubleshooting.
- Gather feedback from stakeholders throughout the process.
- Continuously monitor and refine the system for optimal performance.

GSB Capabilities and Benefits

Fortunately, new technologies offer prospects for orchestrating utility, customer and third-party energy resources to simultaneously meet grid and customer needs. Demand flexibility (DF), also called load flexibility, and its application in GSBs can:

- Improve system reliability and resilience and reduce emissions.
- Increase revenue for power aggregators and distribution companies and lower operating costs of end users.
- Reduce peak loads, moderate the demand ramping, and provide grid services by integrating distributed renewable energy resources.
- The combination of these flexible and distributed resources can support building performance and resilience and improve utility distribution systems (including as "non-wires solutions" or "non-wires alternatives" to traditional utility upgrades). When aggregated, it can serve as virtual power plants (VPPs), to achieve better prices on energy markets and more accurate planning of energy delivery, supplementing and, at times, supplanting conventional generation.
- Improve energy productivity and unified and advanced closed-loop control system operation at the user end.

Conclusion

Building owners/investors should adopt an integrated approach to implement disruptive control strategies and identifying technology gaps. For this, they must engage consultants, control system experts, data scientist, technology architects, utility companies, reliability professionals, and ESCO and explore using Advanced demand response logic control to maximize both occupants' comfort and energy savings while at the same time reducing users' complaints and energy bills.

Engaging in a business model with careful consideration of people, planet, and prosperity will ultimately lead to increased resilience and cost savings, decreased organization risk and unforeseen costs, and overall success for stakeholders.

Leadership commitment is essential for successfully implementing GSB by ensuring the right approach integrates environmental, social, and economic substantiality. Through triple bottom line theory, sustainability changemakers can strategically engage colleagues, leadership, vendors, and finance institutions with conducive policy support.

As a smart solution, a step-by-step approach must be devised to directly address the documented challenges through sustainable transformation, convergence of smart building system, grid and DER and efficient capacity utilization.

About the Authors

Sibaji Pattanaik

Principal Consultant IOT

Bikash Das Burma

Principal Consultant IOT

References

- Case Studies
  https://sftool.gov/Content/attachments/GSA%20GEB%20Case%20Study%20Report%20Mar%202021.pdf
- NASEO, 2019, Grid-interactive Efficient Buildings: State Briefing Paper
  https://naseo.org/data/sites/1/documents/publications/v3-Final-Updated-GEB-Doc-10-30.pdf
- State and Local Energy Efficiency Action Network, 2020, Grid-Interactive Efficient Buildings: An Introduction for State and Local Governments, https://www.naseo.org/Data/Sites/1/see-actiongebs-intro-report_april-2020.pdf
- U.S. Department of Energy, 2021, A National Roadmap for Grid-interactive Efficient Buildings, https://gebroadmap.lbl.gov/
- American Council for an Energy-Efficient Economy, 2019, State of the Market: Grid-Interactive Efficient Buildings Utility Programs, https://www.aceee.org/white-paper/gebs-103019
- U.S Department of Energy, Grid-interactive Efficient Buildings
  https://www.energy.gov/eere/buildings/grid-interactive-efficient-buildings
- https://www.linkedin.com/advice/1/how-can-smart-buildings-communicate-coordinate
- Smart Buildings: Using Smart Technology to Save Energy in Existing Buildings
  https://www.aceee.org/sites/default/files/publications/researchreports/a1701.pdf
- Various software tools used like Matlab, Pyomo, Modelicam CasADI, Jump
  https://web.casadi.org/
  https://in.mathworks.com/matlabcentral/answers/1720460-using-pyomo-module-in-matlab

For more information, contact askus@infosys.com

Infosys®
Navigate your next