Intelligent Building Energy Management Systems

LANDMARK RESEARCH PROJECT

CABA AND THE FOLLOWING CABA MEMBERS FUNDED THIS RESEARCH PROJECT:

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Intelligent Building Energy Management Systems

This report was prepared for CABA by Harbor Research.

Harbor Research

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RESEARCH BACKGROUND & INTRODUCTION

The Continental Automated Buildings Association (CABA) commissioned Harbor Research to provide a comprehensive examination of the Intelligent Building Energy Management Systems (IBEMS) market. This report seeks to understand how use cases, customer environments, buying behaviors, and ecosystem interactions all impact and influence the development of the IBEMS market.

Harbor Research and the Steering Committee first convened via a webinar in Spring 2020 and established a regular schedule of discussion and collaboration for the duration of the project. The findings presented in this report showcase the results of primary and secondary research, including in-depth executive interviews and dual online stakeholder surveys.

The outcomes of this collaborative research project will provide a clear understanding of the trends and forces driving the evolution of IBEMS, as well as lay out potential paths and maneuvers for stakeholders looking to take advantage of the market opportunities that exist. Harbor Research and CABA would like to acknowledge and sincerely thank the following organizations for funding this research:

Figure ES1 Landmark Study Funders

SILVER

Automated Logic
BC Hydro
Cadillac Fairview
CanmetÉNERGIE VARENNES CanmetENERGY
Carrier
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Honeywell
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Energy
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RENESAS

Role of the Steering Committee

The Steering Committee represents a cross-section of solution providers in the Intelligent Buildings marketplace. Representatives from each organization joined Harbor Research and CABA on regular collaboration calls to ensure the research scope met the project objectives. The Steering Committee played a vital role in outlining the research product in terms of defining the required content as well in collaboration on the research approach including development of the interview scripts and surveys.

Each CABA Landmark Research project is directed by a Steering Committee made up of the Silver level project funders. The Steering Committee provides feedback and input throughout the course of the research to help define the scope, direction, and methodology. CABA and the project's Steering Committee commission a research firm to conduct the research, while CABA provides project management and leadership.

Figure ES2 Steering Committee Members

About CABA

The Continental Automated Buildings Association (CABA) is an international not-for-profit industry association, founded in 1988, composed of over 380+ major private and public technology organizations dedicated to the advancement of connected home and building technologies. These organizations include private firms involved in the design, manufacture, installation and retailing of products, as well as public utilities and governments responsible for regulations and incentives that affect home and building automation. CABA is a leader in developing collaborative research across building stakeholder types and encourages the development of standards that accelerate market development. More information is available at **CABA.org.**

About Harbor Research

Founded in 1984, Harbor Research Inc. has more than 30 years of experience in providing strategic consulting, design, and research services that enable our clients to understand and capitalize on emergent and disruptive opportunities driven by information and communications technology.

Harbor Research has been involved in the development of the smart systems and Internet of Things (IoT) market opportunity since 1998. The firm has established a unique competence in developing business models and strategy for the convergence of pervasive computing, global networking and smart systems. Harbor Research's extensive involvement in developing this market opportunity, through research and consulting, has allowed the firm to engage with clients in the technology supplier community—both large and emergent players—as well as a diverse spectrum of device OEMs and services providers as well as broad end customer interactions. Please visit **harborresearch.com** for more information.

Research Goals

The goal of this research is to examine various aspects of energy management systems as they relate to the Intelligent Building industry. In particular, the main goal is to define "Intelligent Building Energy Management Systems (IBEMS)" and explore the current state of the IBEMS market, technical barriers and opportunities related to its evolution, and key emerging use cases and technologies.

The outcomes of this collaborative research project will provide a clearer understanding of the IBEMS market and opportunities available to drive revenues. This study will assist organizations to make sound business decisions using reliable third-party qualitative and quantitative data. Harbor Research has examined the opportunities provided by IoT for Intelligent Building stakeholders, including: operators, integrators and architects, technology manufacturers, equipment manufacturers, and service providers—including utility companies, standards bodies, and property management firms.

To meet these goals, Harbor Research has conducted a detailed analysis about the current and future state of IBEMS, including key trends, buying behaviors, technology challenges, and opportunities. From this analysis, perspectives were developed on how IBEMS will evolve, the key pain points and barriers to its evolution, and how its advent will impact business models and operators.

Research Methods

The methodology for defining, identifying, and analyzing technical and business opportunities followed the procedures below:

- **Review Existing Intelligent Building and Energy Management Research:** Review and analyze existing CABA and industry research on the Intelligent Building market as it relates to design and implementation, cost structure and pricing models, impacts of BAS, technology, and market development roadmaps, and North America Intelligent Buildings market sizing.
- **Review Previous Harbor Research Analyses:** Review and analyze previous Harbor Research reports on Intelligent Buildings, energy and utilities, ecosystem development, IoT platforms, data management and analytics, network connectivity, and cybersecurity.
- **Conduct Interviews with Thought Leaders:** Identify and organize a list of key stakeholders and conduct interviews with industry thought leaders and Steering Committee members.

- **Define and Analyze the Evolution of IBEMS Hypotheses:** From the above blend of primary and secondary research, Harbor Research then created initial hypotheses about how IBEMS will evolve and the related business opportunities it will create.
- **Validate and Refine IBEMS Picture:** Once complete, Harbor will then conduct additional rounds of primary and secondary research focused on validating our hypotheses on how IBEMS will evolve and how it will affect each ecosystem participant.

Having identified and framed the opportunities via the process just described, Harbor Research performed this research by conducting primary research analysis along with supplementary market research and analysis. A consumer survey was developed and administered with more than 1,500 respondents, representing building operators and architects from the United States and Canada.

The results of this survey were utilized to identify the current state of the IBEMS market from an adoption and integration standpoint; uncover the most prevalent technical barriers, adoption challenges, and opportunities; reveal which IBEMS solution models are driving the most adoption today and in the near-future, and learn about Intelligent Building operator needs and pain points.

Harbor Research also conducted in-depth expert interviews with marketplace stakeholders to understand how technical requirements and user needs are shifting in the IBEMS market, along with how these stakeholders see product and service monetization models evolving in Intelligent Buildings.

In addition, Harbor Research leveraged previous work the firm has conducted, as well as CABA research, to identify key trends, players, IoT application evolution, and technical requirements for Intelligent Building stakeholders as IBEMS matures. From this analysis, a list of recommendations for each IBEMS ecosystem participant was developed.

Report Structure

The report begins by providing a base understanding of the trends and forces driving the development of IBEMS, and the adoption of smart devices in general across the Intelligent Building market. It also defines emerging business models and provides information that depicts the current state of IBEMS and the frustrations that have arisen from the perspective of operators and owners.

Needs, pain points, and adoption characteristics of architects and operators are the focus of the next section. After examining how architects and integrators consider energy management in the construction of buildings, the results are compared against the needs and pain points of operators. Then, a discussion of how much occupants and operators will pay for IBEMS-related solutions is provided.

The report goes on to examine the IBEMS market landscape and deployment models of IBEMS products. Then, it explores the emerging need for an IBEMS application overlay, and dives into how IBEMS solutions can integrate and interact with other key Intelligent Building systems. The third section concludes with an examination of recent innovations related to Intelligent Buildings safety standards, network communication, and power distribution.

The fourth section of the report is devoted to analyzing IBEMS in the broader context of North American power generation, distribution, and transmission. For the IBEMS market to mature, in-building energy management must account for and integrate with external utility infrastructures and onsite power generation. The section is devoted to exploring the emerging model of grid-interactivity, and how it can catalyze the evolution of energy management in Intelligent Buildings.

Finally, having analyzed the current and future state of IBEMS, the report provides a set of actionable short-, medium-, and long-term recommendations based on stakeholder type that are influenced by the combination of findings from primary and secondary research. After discussing the impact of COVID-19, the report concludes by recommending maneuvers and considerations by stakeholder type based on the outcomes that may affect the trajectory of how IBEMS is adopted.

SUMMARY OF FINDINGS

Introduction & Summary of Key Takeaways

According to the U.S. Department of Energy (DOE), the buildings sector consumes approximately 76 percent of the electricity consumed in America, but most of this energy is wasted—with some researchers suggesting that more than 20% of this energy consumption can be reduced with energy management practices and energy-efficient equipment.[1] However, since that DOE report was published in 2010, little has changed, and operators still pay for energy that they waste.

Emerging intelligent buildings provide a distributed control and information system that enables networks of intelligent devices to monitor and control the mechanical systems in a building while integrating data from existing building systems. These solutions are enabled by a new class of software tools and data frameworks that allow data to be aggregated from across the fractured vendor ecosystem. Advanced data management, analytics, AI and machine learning algorithms, when applied to integrated datasets, are identifying and capturing new efficiency gains from building systems. These innovative technologies and use cases are not only changing the way that buildings stakeholders operate, but also how they co-operate with each other.

Within the intelligent building market, two key applications have emerged to simplify building operation and control: "building management systems" (BMS) or "building automation systems" (BAS); and "intelligent building energy management systems" (IBEMS) or, more simply, "energy management systems" (EMS). These terms are often used interchangeably, but within this report, there are important distinctions, and these distinctions reflect the key changes impacting the intelligent building market.

In addition, for building owners and operators to satisfy the changing needs of their occupants, they must increasingly prioritize sustainability and procure technologies (including IBEMS) that allow for the generation, distribution, and storage of distributed energy resources (DERs).

The portrayal shown on the next page depicts the dire need for operators to adopt IBEMS solutions.

Figure ES3 Buildings Across Industries Need to Prioritize Energy Management

Intelligent Building Energy Management Systems

Integrated Energy Intelligence With Building Management, Automation & Control

Intelligent Buildings

Energy Management Systems

Building Automation & Control

Why Energy Management Strategies are Critical

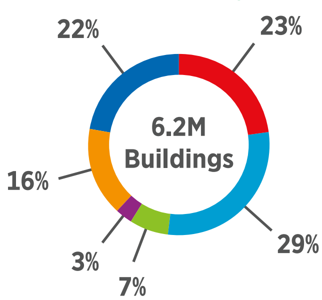
25-30%
of energy consumed in buildings is wasted

$100B
annual cost of emissions in the U.S.

30%
of total emissions from industrial sector

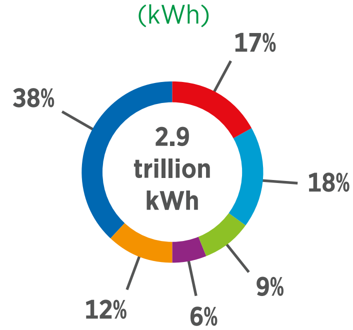
North America Building & Energy Demographics, 2020

Building Count by Type
(# of buildings)



- Commercial
- Retail & Hospitality
- Public Venues
- Medical
- Institutional
- Mission Critical

Energy Consumption by Type,
(kWh)



- Commercial
- Retail & Hospitality
- Public Venues
- Medical
- Institutional
- Mission Critical

Source: CABA Intelligent Building Energy Management Systems 2020 Report

Key Takeaways

The top insights gleaned from this report that outline the key considerations for stakeholders in the future smart home landscape include:

As Intelligent Building Technologies Evolve and Sustainability Becomes Prioritized, IBEMS Need to Evolve Beyond Simple Applications: Over the decade, the technological capabilities of IBEMS have grown exponentially and new ways of incorporating sustainable onsite power generation have emerged. However, most operators still struggle to gain value of their IBEMS products beyond simple scheduling and root-cause analysis functions.

Building Operators Struggle with Paying for and Prioritizing Technology Procurements: Operators lack the capital to invest in wholesale technology modernization efforts, so they are struggling to understand which investments to prioritize to generate value and improve occupant satisfaction. In addition, they often must rely on product installation guides to educate them about IBEMS.

While BACnet Adoption is Increasing, Further Protocol Consolidation and Data Labeling Standardization Need to Occur: Most suppliers now include BACnet compatibility in their products, as the protocol has overtaken Modbus and LonWorks, but electrical distribution systems are often only compatible with Modbus. In addition, buildings have trouble adopting a standard data labeling or naming convention, though organizations like Brick and Project Haystack seek to address this issue.

The IBEMS Market is Dominated by BAS/BMS Solutions from Large Suppliers: Large BAS/BMS suppliers, such as JCI, Trane, and Tridium, have a high adoption base of buildings who are locked-in to their brand of solutions. However, these suppliers are being challenged by digitally native, innovative solution provides who are positioning different technologies (e.g., digital twins, advanced analytics) to solve automation challenges in buildings. While no one solution has fully disrupted the market, incumbents and innovators need to continue to incorporate emerging technologies in buildings.

The Difficulty of Innovators to Displace IBEMS Incumbents Points to the Need for an IBEMS Application Overlay: While innovators are seeking to disrupt the IBEMS market by focusing on emerging technologies such as buildings analytics and digital twins, no solution has yet emerged. Buildings need an application overlay that can ingest data from existing BAS/BMS applications, while retaining the flexibility to integrate with DER systems and advanced metering infrastructure.

GEBs Can Help Operators Achieve Massive Cost and Energy Savings, but Utilities and Governments Must Support This Evolution: The emerging model of a grid-interactive efficient building (GEB) can automatically respond to utility price signals and allow for load flexibility. However, most buildings are not currently equipped for grid interactivity, so regulators and utilities need to work with these buildings to offer the right incentives to meet the technical requirements that GEBs demand.

The COVID-19 Pandemic Greatly Concerns Occupants and Operators, but its Ultimate Impact on IBEMS Remains Unclear: Across building types, occupants and operators are concerned with the potential for contracting COVID-19 in indoor spaces. While the pandemic will increase the overall costs to operate and construct buildings, as operators implement social distancing and expand sanitization, it still is unclear how the pandemic will ultimately affect energy management in buildings.

The Changing Consumer: Maximizing EMS Value to Architects and Operators

To truly understand the current state and future direction of IBEMS, one must drill down from a macro level into the day-to-day needs, issues, and decision-making that occur during the real-world use of these systems. To better understand this aspect of the IBEMS market, Harbor Research deployed two parallel surveys—one to buildings architects, constructors, integrators, and engineers; and the other to buildings owners, facilities managers, and occupant office managers—which help us explore how IBEMS are considered during building construction and operation. In addition, these surveys allow us to pinpoint key differences in how different demographics and regions view and prioritize energy.

More than half of building owners and operators indicated that their building(s) had energy management software (either standalone or as part of a BAS/BMS) in place. However, a significant number of buildings (28 percent) still manage energy consumption with a manual process, which is labor-intensive and expensive. In addition, adoption alone does not beget results, as many users still have difficulties maximizing the value of their IBEMS.

As buildings have embraced more complex technologies and systems, it has caused challenges in the design and integration process. Architects, who traditionally only focused on occupant convenience and structural integrity, now must consider energy efficiency, network communication, air quality monitoring, and other factors. In addition, system integrators are challenged with the need to promote seamless ease-of-use and data sharing between many devices from different manufacturers.

Today, energy costs are most expensive line item for most building operators after personnel/staff expenses, so it makes sense that constructors would prioritize energy efficiency in buildings, as they try to meet the needs of their clients. Slightly fewer respondents indicated that they prioritize sustainability, but most respondents still prioritize that need.

For IBEMS suppliers and building operators, these results provide guidance on how their products and best practices are implemented and considered during the building construction and design process. Clearly, building owners need to do a better job of educating architects and integrators as to the value and specificities of IBEMS implementation. In addition, suppliers play a key role in how IBEMS education is disseminated. By tailoring product installation guides to emerging IBEMS best practices and to individual building types, they can solve IBEMS issues before they manifest.

As shown in the below infographic, while IBEMS applications are well-adopted in buildings, operators and constructors do not glean much value out of these systems due to cost and complexity.

Figure ES4 Operators and Architects Struggle to Maximize the Value of IBEMS

The Changing Consumer

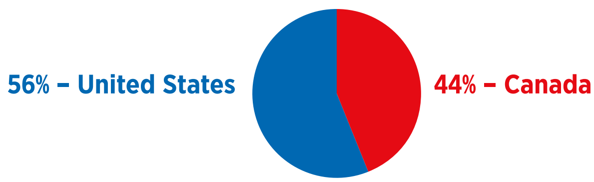
Respondent Demographics

2,209
Respondents

Operators & Occupants
Owners, Office Managers
1,401
Respondents

Constructors
Architects, Integrators, Engineers
808
Respondents

Geographic Distribution

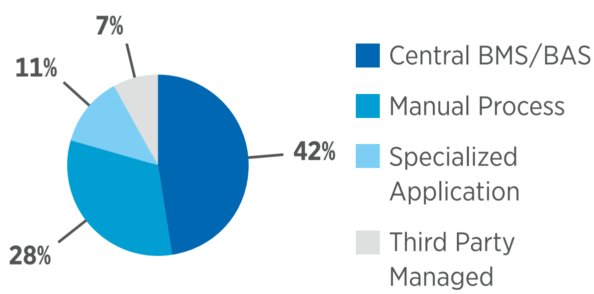


Operator Survey Deep Dive

Over 53%
building owners and operators have EMS software in place

47%
of building operators stated energy is well-managed and distributed efficiently in their building(s)

48%
of EMS in place are managed through central building management or automation systems

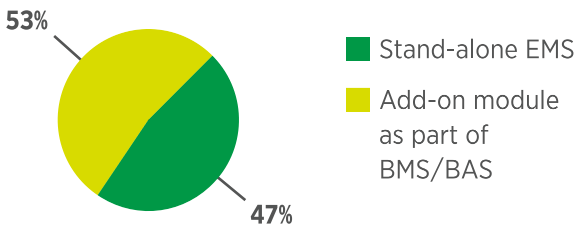


The Changing Consumer

Constructors Survey Deep Dive

53%

are add-on modules or part of broader building management and automation systems



81%

of constructors stated energy management & sustainability as a major factor the building architecture

38%

of constructors indicated the buildings they develop have cutting-edge automation and digital technologies

Top Challenges for Operators & Constructors

1. Lack of capital to purchase and implement the system
2. Lack of capital to maintain systems
3. Systems are too complex

Across both survey groups, roughly **45% of respondents indicated lack of capital to purchase & install energy management systems** as the biggest challenge in realizing value from an energy management strategy.

Source: CABA Intelligent Building Energy Management Systems 2020 Report

The Evolution of IBEMS in Relation to In-Building Technologies

IBEMS can be characterized as a suite of software and platform tools that leverage data from control and automation systems, metering infrastructure, distributed sensor networks, and external business intelligence and utility systems. The growing demand for greater visibility and control around energy usage and consumption, in conjunction with the increasing availability of emerging technologies, has led to a consistent cycle of innovation and progress around IBEMS.

IBEMS have evolved in parallel to building control and automation, providing a layer of power network applications designed to around three core objectives: reduce and manage building energy use, reduce cost while increasing occupant comfort and productivity, and improve environmental stewardship and ensure compliance with sustainability regulations. These objectives are often driven by the desire to drive down overhead costs and meet corporate-defined carbon emission goals.

Currently, most buildings have adopted one of two key models of IBEMS—either standalone EMS software applications for buildings, or energy management capabilities and features that exist as part of a larger BMS or BAS. While the energy management functions of each deployment model are relatively similar, each path presents distinct challenges and benefits.

However, as Intelligent Buildings mature, energy management practices and systems must inherently work closely with automation and controls systems, allowing for automated adjustments to appliances to better manage energy and leverage DERs. While this would seem to point to the model of EMS integrated on BAS/BMS systems, it needs a more wholesale change to systems architecture in buildings. Specifically, a new layer must emerge—the application/analytics overlay.

Currently, the IBEMS market landscape is fragmented, with many startups attempting to disrupt entrenched incumbents, whose systems are outdated, difficult to integrate, and do not incorporate emerging technologies. However, no single innovator has emerged as the market leader, and no business model has been adopted at scale to replace incumbents. The traditional buildings energy management value chain is transforming in the era of new intelligent buildings technologies. With the influx of new technologies, OEMs and service providers have new opportunities to provide value to customers through smart systems and services.

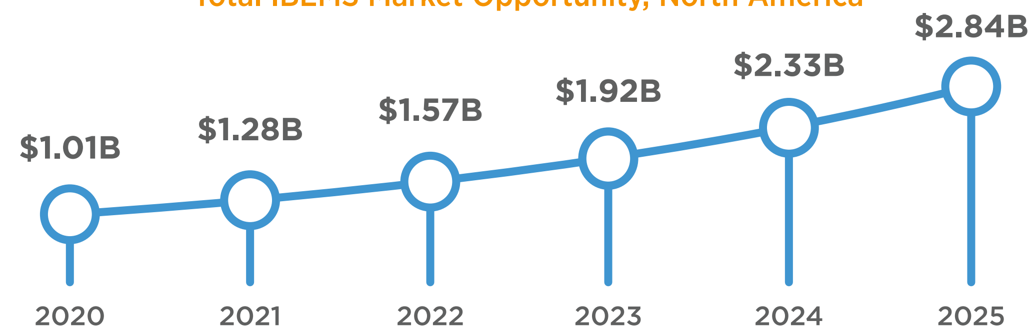
Technology suppliers are becoming a driving competitive force in this value chain, with growing influence on traditional suppliers and other buildings market participants. At the same time, building managers, owners and operators and utility providers across all building types are pressuring their suppliers to provide new products and support services, paired with more flexible, innovative payment methods. These forces are resulting in shifting competitive and ecosystem dynamics that require traditional equipment and service providers to take a new approach.

As depicted in the following infographic, players are taking different approaches to capture the robust, fast-growing IBEMS market opportunity.

Figure ES5 Players are Taking Different Approaches to Win the IBEMS Opportunity

The Evolution of the IBEMS Market

Total IBEMS Market Opportunity, North America



Large, Established BAS/BMS Incumbents

Large, established incumbents often sell EMS applications integrated into larger BMS or BAS applications, often as a separate module. While this removes the needs to separately integrate an EMS application with in-building devices and appliances, it promotes vendor lock-in and disincentivizes these players from innovating.

Utility Bill Tracking & Submetering Solutions

Utility bill tracking & submetering solution providers take a focused approach to energy management by simplifying the billing process and allowing for simple scheduling-based automation scripts. These solutions often do not involve automation or advanced analytics, but can help operators find and solve energy management “easy wins”.

Buildings Analytics Specialists

Buildings analytics specialists leverage data science expertise to interface their applications with building data storage systems to create predictive analytics to identify peak loads and automate controls. However, a lack of common building data naming standards inhibits these applications from providing value to all buildings.

Automated Supervisory Control Applications

Automated supervisory control applications create an additional layer on top of existing BAS/BMS products for cloud-based inferencing. Though these players add value over BAS/BMS applications, they often have difficulties convincing operators to switch from incumbent solutions.

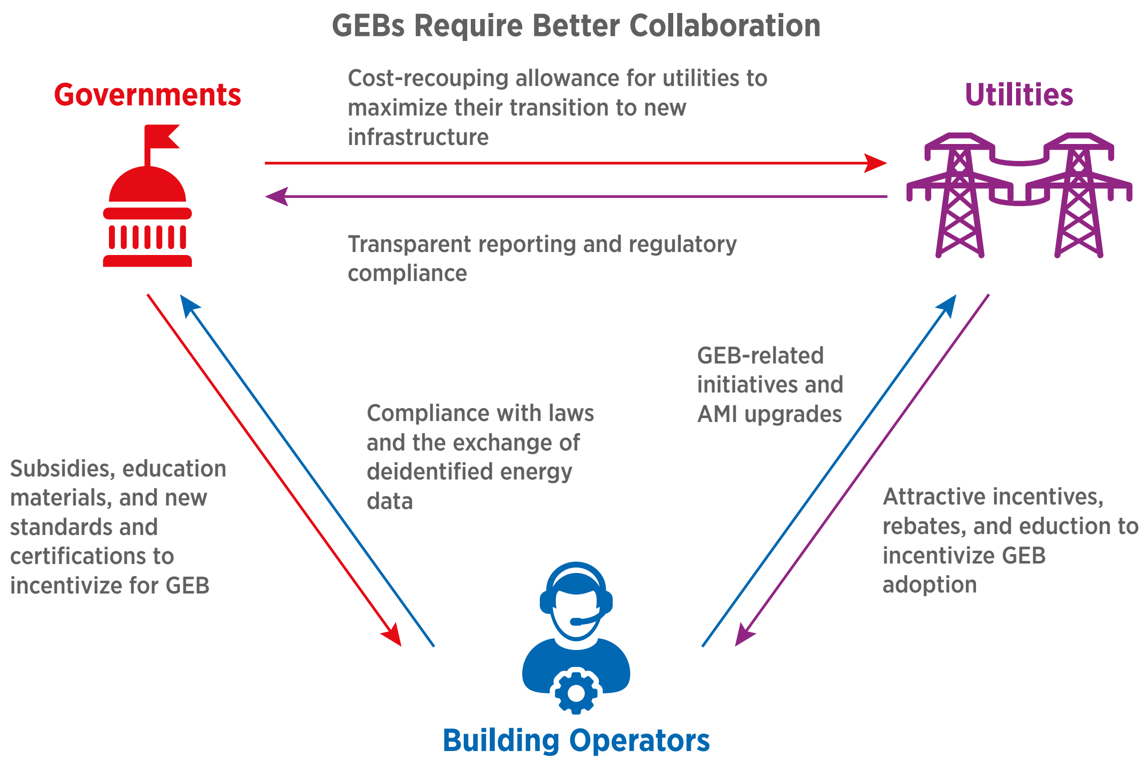
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Grid Interactivity: Building-to-Grid Interactions

Legacy transmission and distribution infrastructure—such as power lines, feeders, and substations—are not only expensive to build and maintain, but they are also inflexible, requiring expensive and time-consuming labor for configuration changes. The difficulty of maintaining this infrastructure is exacerbated as more North Americans consume more energy, and the inflexibility of these systems becomes more of an issue as consumers demand sustainability and governments mandate energy reduction.

These issues burden utilities, who are often owned, regulated, or controlled by Governments and therefore often lack the agility and profitability of private corporations—which can make it difficult for them to change business models and service offerings. However, solutions to these issues are arising, namely demand response, non-wire alternatives, and the emerging model of grid-interactive efficient buildings (GEBs). GEBs refer to the ability of buildings to predict their energy needs and communicate it external grid operators, allowing for better demand response. While federal organizations have recently accelerated the development of GEB-related research and associated policies, implementing these changes is an expensive undertaking that requires systematic changes. The portrayal below depicts collaboration interactions that need to occur for GEBs.

Figure ES6 Collaboration is Required to Enable GEBs



Source: CABA Intelligent Building Energy Management Systems 2020 Report

In-building energy generation and storage, and supply-side utilities strategies are converging to drive a new business model for IBEMS—the grid-interactive efficient building (GEB). Currently promoted by GSA, GEBs are defined by grid-interactivity—the ability of buildings to establish and use real-time two-way communication with utilities. The emphasis on time-value is key to GEBs, as it allows building to flexibly respond to changes in occupant energy demand and utility price signal fluctuations.

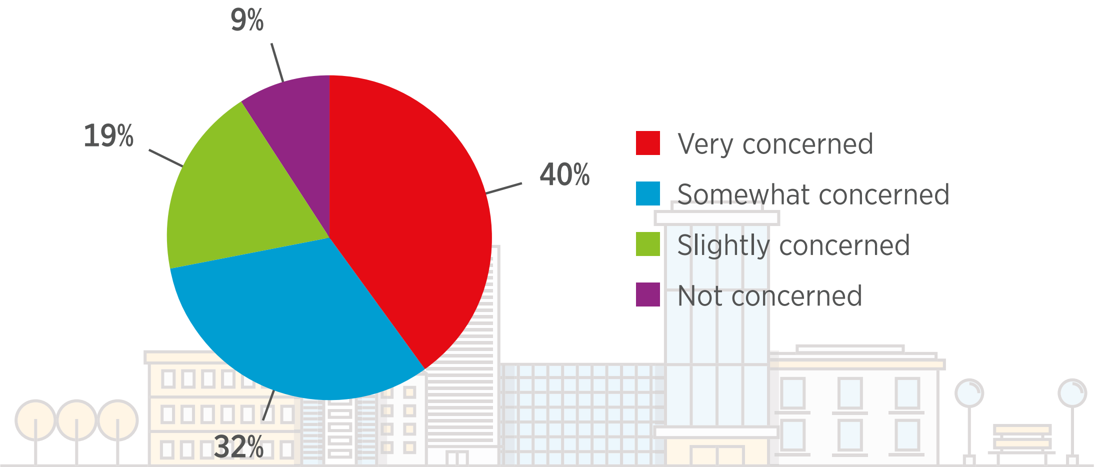
The Impact of COVID-19 and Conclusions & Recommendations

In Spring 2020, the COVID-19 pandemic struck North America, shuttering business, and buildings across the continent as governments enforced lockdowns and stay-at-home orders. Now, as occupants begin to return to work, they are re-entering buildings with new needs, concerns, and fears. Building operators, even those skeptical of modern technologies, are looking to follow public health recommendations and mitigate the spread of the virus by implementing new business practices and emerging technologies. However, the true effects of this change on IBEMS remains unclear. The portrayal shown on the next page demonstrates how technology can make key building functions safer and more efficient.

Figure ES7 The COVID-19 Pandemic Concerns Occupants

COVID-19 Concerns Building Occupants

How concerned are you with contracting COVID-19 in your building?



Technologies to Enable COVID-19 Response in Buildings

Working & Collaboration	Entry	Breaks & Socializing	Comfort & Cleanliness	Getting Around
Virtual Meetings	Keyless & Touchless Entry	Contactless Payment	Air Circulation & Monitoring	Touchless & On-Demand Elevators
E-Learning & Training	Facemask Detection	Digital Ordering	Ambient Temperature Control	Automated Room Access
Virtual Whiteboards	Fever Detection	Voice-Enabled Coffee Makers	UV & Disinfecting Robotics	People Counting & Spacing Analytics
	Contact Tracing	Contactless Vending Machines	Touchless Hand Sanitizer Stations	

Source: CABA Intelligent Building Energy Management Systems 2020 Report

New technologies in buildings can enable contactless functions and consistent air quality circulation and filtration. In addition, the combination of these technologies can enable healthier buildings while improving the efficiency of buildings functions. For example, an automatic temperature screening system with biometric access control capabilities can recognize an entrant, clear them of COVID-19 symptoms, and then automatically call an elevator to take them to the correct floor—all without having the entrant to touch any surface or have a face-to-face interaction with building staff/personnel.

EXECUTIVE SUMMARY

As the fragmented, value-inhibiting IBEMS market begins to consolidate and evolve, players across the intelligent building ecosystem will have the opportunity to emerge as key enablers of this market and unlock new, higher-margin energy streams from emerging services and analytics. IBEMS market participants need to improve the value of their IBEMS solutions while fostering a collaborative ecosystem aligned on IBEMS standards and best practices.

For **OEMs**, the value of building appliances and equipment will shift to the software and services that leverage the data that these systems produce. Although it might seem counter-intuitive in the near term, breaking up closed ecosystems and enabling "plug-and-play" based interoperability between devices and systems will help spur the overall IBEMS market and incentivize operators to purchase more complex, expensive systems over time. As this occurs, OEMs can embed their systems with energy usage monitoring and sensing. In the long-term, edge analytics and AI inferencing will allow OEMs to drive significantly higher margins from their products.

For **utility operators**, IBEMS is not just a new revenue opportunity—it is a necessity for survival. Disrupted by sustainability demands and aging, expensive infrastructure, utilities must significantly change their business models if they are to survive long into the future. To accomplish this, utilities need to integrate DERs and invest in demand-response programs. In addition, they should aggressively work with buildings and regulatory bodies to increase the adoption of DERs, onsite energy generation and storage, and grid interactivity analytics and communication capabilities.

IBEMS software providers today are hindered by market fragmentation and a lack of insight into real-world building operations and specifics. First, these providers should promote the adoption of a common IBEMS naming standard, which over time can position them to offer more advanced applications. Software providers need to either develop their systems as modules/add-on features to existing BAS/BMS applications, or they need to ensure easy interoperability between their applications and building controls systems. By continuing to develop applications in siloes, software providers will increasingly be pushed out the market in favor of large diversified OEMs and automation providers.

Lastly, **building owners and property managers** need to continue to prioritize energy management and sustainability at all stages of building construction and operation. They need to educate tenants and building staff as to the benefits of IBEMS and lay out clear strategies to meet energy and carbon emission goals established by the tenants or governments. Ultimately, building owners need to be creative about how they can upgrade their building's technology infrastructure and capabilities in a cost-effective manner. Therefore, governments and utility operators can help catalyze GEB adoption with incentives and rebates for buildings to adopt IBEMS and onsite generation dispatch controllers.

In conclusion, the IBEMS market is fragmented today, with operators struggling to choose between many products that require a significant amount of technical knowledge. Although IBEMS adoption is relatively high, both with standalone EMS software applications and integrated in larger BAS/BMS systems, operators are struggling to gain value from these systems.

Currently, IBEMS solutions frustrate operators due to their prohibitive costs, difficulty of use, lack of easy integration with buildings data, and their ultimate inability to articulate their value or provide an immediate, tangible return on investment (ROI). These issues all stem from a lack of visibility of the suppliers into real-world building operations, pain points, and specific data types. Greater two-way knowledge and collaboration can help these devices provide more value to buildings.

For IBEMS applications to truly mature, they need to consider the context of the buildings with reference to external electrical power generation, distribution, and transmissions system in North America. In addition, they must evolve to incorporate onsite generation and energy storage, which will reduce energy consumption from the grid while providing a more resilient non-interruptible source of electricity. Massive energy savings and an effect integration of renewable energy generation and storage requires close collaboration and two-way data sharing between utilities and buildings. For this new business model to emerge—that of grid-interactive efficient buildings (GEBs)—utilities, governments, and building operators need to align on the proper incentives and develop a feasible roadmap.

Like almost every aspect of modern life, the IBEMS market evolution has been impacted by the COVID-19 global pandemic, as occupants fear for their health and operators clamor to adopt contactless technologies and better air quality filtration systems. While the true effect of COVID-19 on the prioritization of energy management and sustainability is still unclear, energy management will continue to be a huge part of buildings as more energy-intensive technologies are adopted.

For buildings, the path to energy efficiency exists, but it may not be clear how to achieve it. Therefore, all Intelligent Building ecosystem participants need to come together and collaborate on energy management best practices. The future of Smart Cities and the health of the environment depend on it.

Notes

1 U.S. Department of Energy. (2015, September). An Assessment of Energy Technologies and Research Opportunities, Chapter 5. *Quadrennial Technology Review*. https://www.energy.gov/sites/prod/files/2017/03/f34/qtr-2015-chapter5.pdf

1. INTRODUCTION: THE EVOLUTION OF INTELLIGENT BUILDINGS AND ENERGY MANAGEMENT

1.1 WHAT IS AN INTELLIGENT BUILDING?

Driven by continued urbanization and population growth, modern buildings with their increasingly complex sub-systems have become a vital part of everyday life in America. In earlier times, buildings and their relatively primitive conveniences (notably HVAC) were primarily a means of shelter. Today, occupants have come to expect that buildings will not only meet but also anticipate other needs, like safety and internet connectivity, in addition to comfort and convenience. To meet these expectations, building operators have installed increasingly complex technologies and appliances across the buildings they manage, including lighting systems, HVAC systems, surveillance cameras, elevators, and countless other "smart" interactive devices. As more people continue to spend a substantial portion of their lives in buildings, these devices will continue to proliferate and consume more energy.

However, the proliferation of devices causes two problems for building managers: these technologies are difficult to operate and maintain, and they are consuming a great deal of expensive energy. To address these challenges, the buildings industry has shifted towards a new business model: the intelligent building. As defined by the U.S. Intelligent Building Institute, an intelligent building is "...one that provides a productive and cost-effective environment through optimization of its four basic elements – structure, systems, services and management – and the interrelationships between them. Intelligent buildings help building owners, property managers and occupants realize their goals in cost, energy management, comfort, convenience, safety, long term flexibility and marketability."[1]

Emerging intelligent buildings provide a distributed control and information system that enables networks of intelligent devices to monitor and control the mechanical systems in a building while integrating data from existing building systems. These solutions are enabled by a new class of software tools and data frameworks that include advanced data management, analytics, AI and machine learning algorithms. These capabilities, when applied to integrated datasets, can identify and capturing energy efficiency gains (e.g., cost savings, emissions standards compliance) from building systems. These new technologies and use cases are not only changing the way that buildings stakeholders operate, but also how they co-operate with each other.

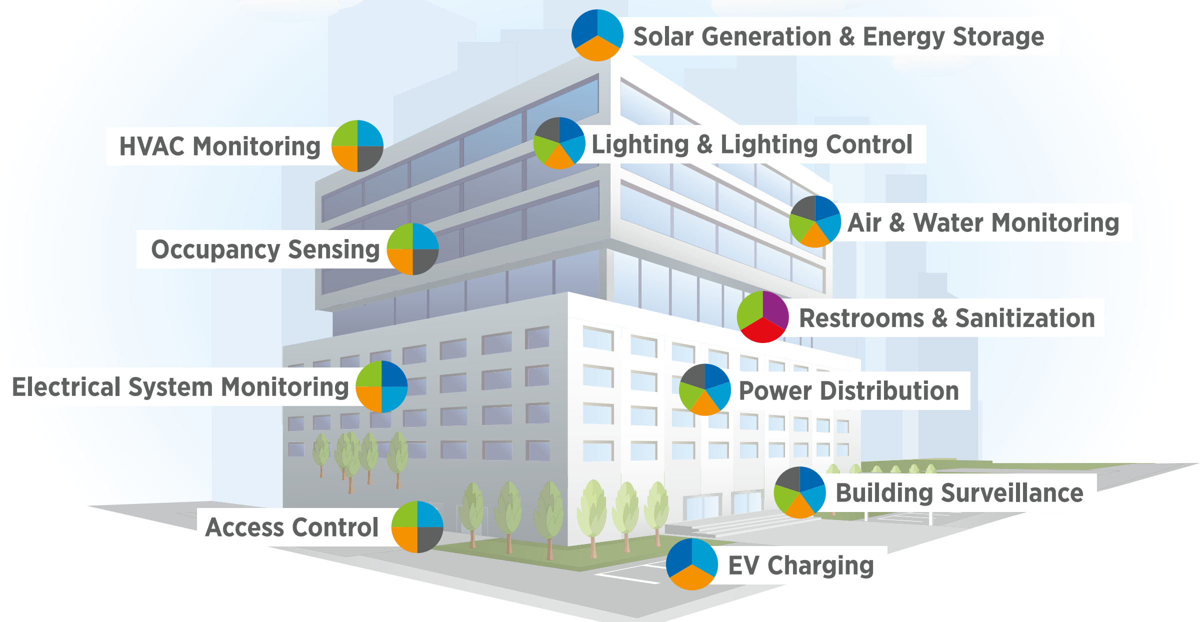
Within the intelligent buildings market, two key applications have emerged to simplify building operation and control: "building management systems" (BMS) or "building automation systems" (BAS); and "intelligent building energy management systems" (IBEMS) or, more simply, "energy management systems" (EMS). These terms are often used interchangeably, but within this report, there are important distinctions, and these distinctions reflect the key changes impacting the intelligent buildings market.

Traditionally, BAS offerings have focused on allowing operators to view and remotely configure device settings, while EMS systems provide simple scheduling capabilities to reducing energy consumption through HVAC and commercial lighting control. The expansion of "smart" sensors, actuators, meters and systems across buildings is challenging the ability of these systems to deliver the awareness, visibility, and control that users are increasingly demanding, especially as more complex systems emerge in buildings that require the careful coordination of devices and capabilities (Figure 1.1).

Figure 1.1 Intelligent Buildings Beget Complex, Overlapping Ecosystems

Evolving Market Status

IoT technologies have created the opportunity for new services and products to be deployed in intelligent buildings, but operators often fail to maximize the value of these technologies due to a deficiencies in available capital, technical expertise, and building network infrastructure.



Automation & Control

Applications that use wireless control or automation to increase comfort and ease of use, while reducing operation failure.

Related Devices/Appliances:
- BAS/BMS Software
- Gateways & Routers
- Wireless Access Points
- Screens & Monitors

Tenant Engagement & Comfort

Applications that use end user data to increase the value of offerings delivered by OEMs and service providers.

Related Devices/Appliances:
- Digital Signage
- Vending Machines
- Air Purifiers
- EV Charging Stations

User Safety & Security

Applications that enable remote monitoring of home and occupant safety and connect to third party security services.

Related Devices/Appliances:
- CCTV/IP Cameras
- Alarms
- Access Control
- Intercom Systems

Asset Mgmt. & Optimization

Applications that manage equipment & building usage to identify inefficient operations and reduce operating expenses.

Related Devices/Appliances:
- HVAC Systems
- Switchgear/Isolators
- Circuit Breakers
- Boilers & Chiller

Energy Management

Applications that monitor and analyze resource and energy usage data to support efficient use and reduce costs.

Related Devices/Appliances:
- EMS Software
- Smart Meters
- Plug Load Controls
- Power Supply Units

Source: CABA Intelligent Building Energy Management Systems 2020 Report

For EMS and BAS systems to successfully automate building control functions while optimizing energy consumption, they need to interact with and share data with many different buildings' devices and applications. Because of this need, some suppliers are integrating IBEMS applications within larger BAS/BMS systems, while others focus on interoperable, stand-alone software IBEMS software applications. These deployment models are further fragmenting the intelligent buildings market, while creating new integration challenges for operators and system integrators.

More broadly, the intelligent buildings market is host to a diverse mix of technology adopters with a varying set of primary needs. Building developers and real estate managers are focused on best serving property owners and operators, both of whom must focus on best serving tenants. However, occupant needs, and energy usage differ by building type, region, tenant demographics, and other factors.

Ultimately, the common denominator across the adopter base is the desire to maximize both end-user satisfaction and efficiency of building system operations and management. Building managers and tenants alike stand to benefit greatly from increased building system networking and have traditionally applied automated systems to HVAC, lighting, power devices, security and fire and life safety systems.

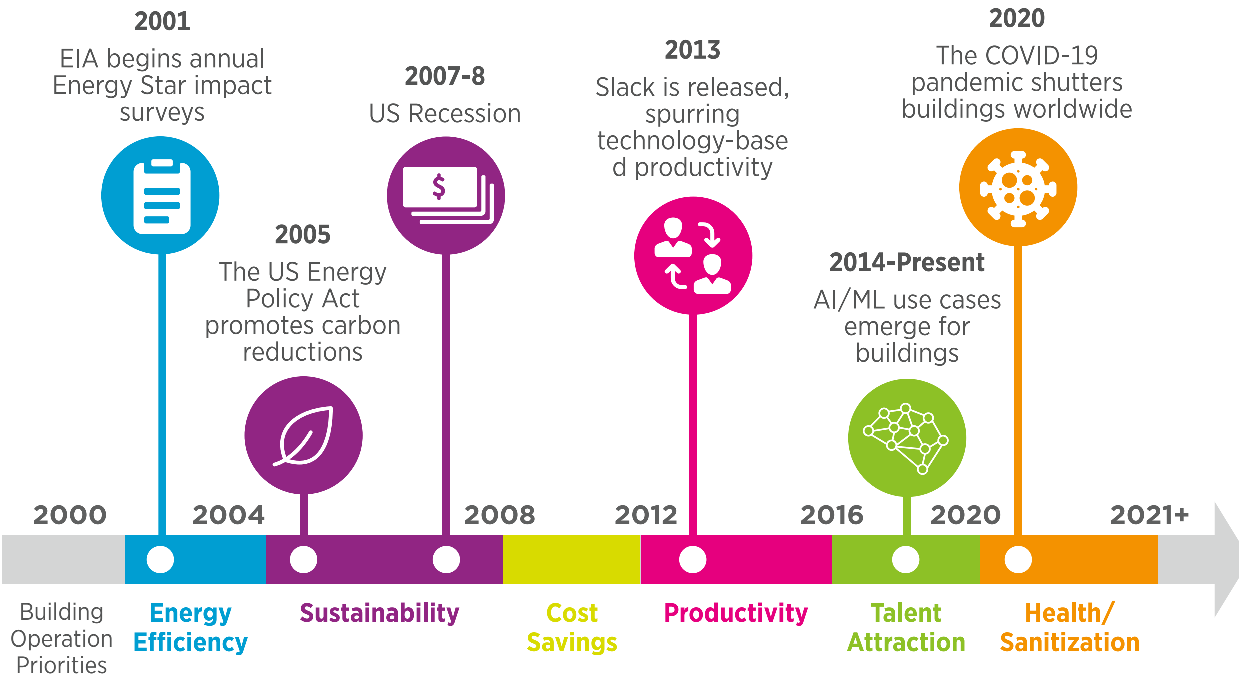
For operators to finally maximize the value of their IBEMS and BMS/BAS systems, suppliers need to converge around a common business model and agree on metadata, protocols, and other key standards. In addition, both operators and suppliers need a more granular understanding of each building's specific needs, data sources, and idiosyncrasies, for the intelligent buildings market to overcome its current fragmentation and mature to enable emerging energy management applications.

1.1.1 Intelligent Buildings Need to Address Key Energy Management Challenges

According to the U.S. Department of Energy (DOE), the buildings sector consumes approximately 76 percent of the electricity consumed in America, but most of this energy is wasted—with some researchers suggesting that more than 20% of this energy consumption can be reduced with energy management practices and energy-efficient equipment.[2] However, since that DOE report was published in 2010, little has changed, and operators still pay for energy that they waste and do not need.

One of the key reasons why energy waste has yet to be fully addressed in buildings is the changing priorities of building stakeholders over time. Throughout the past two decades, significant events in U.S. and Canada have impacted the needs, purchasing behaviors, and capital allocation priorities of building stakeholders. While all buildings value occupant satisfaction more than anything else, recent events (Figure 1.2) have shaped which technologies are adopted in North American buildings.

Figure 1.2 Building Technology Adoption Priorities are Mercurial



Source: CABA Intelligent Building Energy Management Systems 2020 Report

Building operators lack the capital to implement advanced technologies at scale across the buildings they manage, causing them to prioritize different applications based on their current needs. Because of this, energy efficiency and sustainability have faded in relevance in favor of other priorities, such as air quality monitoring in light of the COVID-19 pandemic. Today, while many buildings have EMS and BAS applications in place, they often de-prioritize their use and evolution in favor of other emerging technologies, leading to energy waste inefficiencies.

> "While none of these needs go away, building managers often ignore them in favor of the hot new technology or the priority of the day."
> -Co-Founder and Principal, Intelligent Buildings LLC

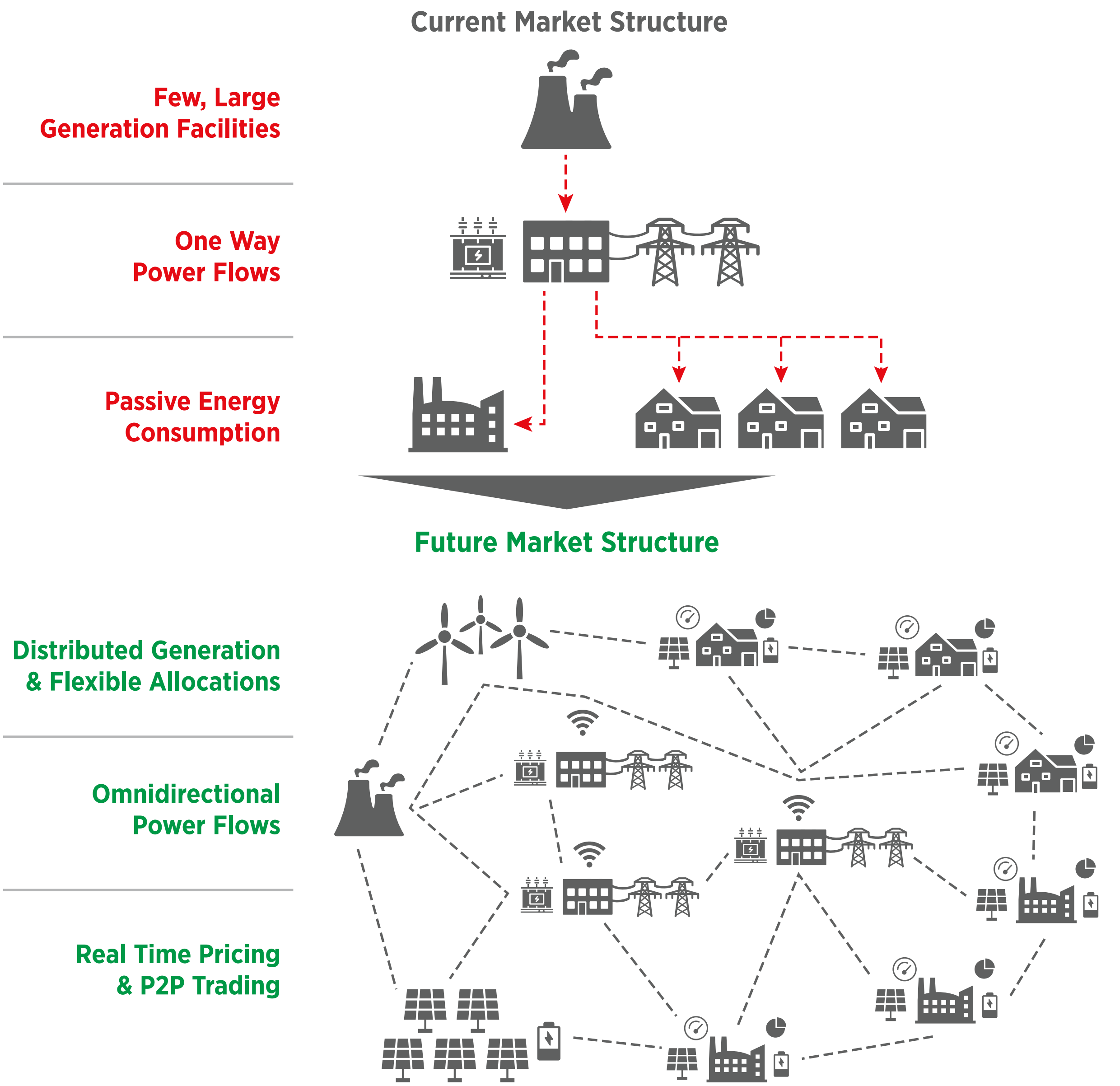
Some lease structures can also disincentivize landlords to invest in buildings technologies. For example, if the investment costs are paid by the landlord but the energy costs are paid by tenants, then it is difficult for landlords to recoup any value of their investments, as only the tenants will realize energy savings. This situation and its inverse paint the need for collaboration and sharing energy cost savings.

As technologies evolve in buildings, and more complex devices and applications are adopted at scale, the need for energy efficiency and management will increase. The U.S. Energy Information Administration forecasts that the world's energy consumption could grow by 28 percent by 2040.[3] If energy management and sustainability in buildings are not addressed today, operators and occupants alike will be increasingly burdened by costly wasted energy and high utility bills.

1.1.2 As Intelligent Buildings Evolve, External Power Utilities are Changing as Well

Traditionally, energy management systems in buildings have operated almost completely independently of external power distribution grids and transmission infrastructure. However, buildings are not alone in the adoption of technologies to improve energy management practices. Two key developments, the rise of distributed energy and the evolution of demand response, are changing the way that power is distributed (Figure 1.3) and allowing for new ways of interacting with grids.

Figure 1.3 Driven by Technology, a Distributed Energy Future has Nearly Arrived



Enabling Smart Systems Technologies

Artificial Intelligence will be applied for the purposes of predictive maintenance, energy optimization, and consumption insights

Blockchain allows for secure transactions of energy or data emitted from machines involved in distributed power

Real time operating systems and high performance networks enable low latency communications for effective event response

Data Integration and Management enables the aggregation of data and automatic provisioning of new systems

Source: CABA Intelligent Building Energy Management Systems 2020 Report

Today, power transmission and distribution infrastructure burdens utilities with aging, outdated equipment, passive energy consumption, and large centralized emissions-producing generation facilities. At the same time, Smart Cities and other related trends are demanding more control and localization over power transmission, leading to a decentralized energy production and storage system termed "Microgrids". This new business model features distributed power generation and allows for greater use of sustainable renewable energy. In addition, utilities are eager to switch to this model because of lower facility costs due to offsetting electricity consumption from the grid, as well as greater reliability of electricity supply for critical needs and corporate mandates to reduce carbon footprints.

While microgrids and distributed energy resources (DERs) will help solve today's pain points related to traditional power grids, on their own they will not address the biggest issue in energy management—buildings waste a significant amount of energy. Today, Smart Meters and better technological infrastructure in utilities have enabled utility operators to predict and respond to the variable energy needs of their consumers using a technique called demand response. The U.S. Federal Energy Regulatory Commission defines demand response as "changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized."[4]

Spurred by federal pressure and legislation, utilities have greatly increased their demand response capabilities since the turn of the century. The Peak Load Management Alliance (PLMA), an industry group that focuses on spurring the adoption of demand response, has organized the evolution of this technique into three distinct stages[5]:

- **Demand Response (DR) 1.0 (1990-2005):** The initial stages of demand response are typified by sensors (standalone or embedded) on key energy-consuming devices, such as HVAC systems, that monitor energy usage over time. Energy usage reporting to utilities typically lagged a day or more in this stage and was manual, and customer feedback was not considered. Most buildings in this stage of demand response use energy meters for more frequent readings. Utilities mainly used this energy usage data for capacity planning and for emergencies.
- **Demand Response (DR) 2.0 (2005-2015):** As more buildings adopted more powerful network infrastructure, near real-time demand response emerged. This allowed for automated energy usage reporting capabilities, where utilities and business owners could achieve a near real-time view of energy consumption in a building. This allows utilities to provide ancillary services such as load balancing, voltage support, and peak load shedding.
- **Demand Response (DR) 3.0 (2015+):** As demand response programs continue to advance, they have started to incorporate distributed energy resources (DER) to maximize building sustainability, not just energy savings. In addition, in-building devices can communicate their needs to utilities in near real-time, enabling grid interactivity.

The evolution of demand response in North America has been spurred by federal legislation that incentivizes utilities to implement energy savings programs. Increasingly, federal, state, and local governments have prioritized sustainable energy and usage-reduction goals into their policies, which have spurred demand response programs and adoption. But for these programs to continue to advance and evolve, suppliers can no longer wait to respond to new legislation to mandate their evolution. Instead, utilities should incentivize buildings with rebates and other programs to implement grid-interactive technologies, and all stakeholders need to prioritize energy efficiency and sustainability.

1.1.3 Sustainability Redefines the Goals of Energy Management in Buildings

Ultimately, technology adoption in intelligent buildings is tied to the changing demands of building occupants and tenants. As populations age and occupant demographics increasingly reflect a mix of more recent generations, energy management needs and expectations invariably shift. Most notably, younger generations are increasingly prioritizing sustainable energy use (Figure 1.4).

Figure 1.4 Younger Generations Prioritize Energy Sustainability

Q: Which of the following statements do you most agree with?	12-24	25-34	35-44	45-54	55-64	65+
Energy sustainability in my building is particularly important to me	75%	64%	68%	44%	57%	50%
Energy sustainability in my building is somewhat important to me	25%	27%	27%	56%	43%	50%
Energy sustainability in my building is not important to me	0%	9%	5%	0%	0%	0%

Source: CABA Intelligent Building Energy Management Systems 2020 Report

When asked to rate the importance of energy sustainability in buildings, younger building owners and occupants generally prioritized sustainable energy much more than older generations. This complicates the picture for building operators who seek to maximize tenant satisfaction—instead of merely optimizing energy consumption, they are now looking to maximize the use of sustainable energy. This causes them to invest in on-site power generation and distributed energy resources (DERs).

DERs are resources that produce electricity with controllable loads, in contrast to centralized energy resources, such as those provided by centralized power stations, and such as coal, hydro and nuclear plants. To date, most buildings with advanced DER systems primarily generate and consume energy from photovoltaic (solar) sources, but buildings are increasingly consuming energy from wind, gas, bioenergy, and hydroelectric sources.[6] Another common energy generation technology often found in large factories, university campuses, and hospitals is CHP (combined heat and power) systems, which typically operate in sync with the grid and other renewable generation sources.

For building owners and operators to satisfy the changing needs of their occupants, they must increasingly prioritize sustainability and procure technologies (including IBEMS) that allow for the generation, distribution, and storage of DERs. Balancing the often-competing needs of sustainable energy use and overall energy consumption reduction will change the way that IBEMS are developed, configured, and ultimately adopted in buildings. In addition, building operators need to be cognizant of any occupant concerns with third-party management over HVAC control settings that impact zone comfort.

1.1.4 Seven Core Enabling Technologies are Revolutionizing IBEMS

While building operators understand the need for energy management and sustainable energy, achieving these goals is difficult and expensive, which has hindered the maturity of IBEMS. However, as technology advances, operators have increasingly more options to improve energy management in their buildings. Specifically, seven core enabling technologies (Figure 1.5) are enabling new intelligent building applications in North America and much of the developed world.

Figure 1.5 Seven Core Technologies Enable IBEMS Maturity

High-Performance Networks & Infrastructure	Ethernet, WiFi, fixed wireless, and 5G are some of the new networking technologies that enable higher bandwidth and lower latency data transmission in buildings, which enables more complex applications
Sensors and Machine Data Fusion	Occupancy, thermal, density, audio, and other sensing technologies allow buildings to collect data at scale, setting the stage for advanced analytics applications and automated control
Device Data Integration and Management	Edge device inferencing allows building appliances to make complex decisions without relying on cloud infrastructure, such as a surveillance camera analyzing images to quickly detect false positives
Distributed Data and Information Architecture	Microservices architecture and integrated data platforms allow for higher-performance decision making at scale, and allow building operators to integrate data from across their held buildings
Application Development and Developer Tools	Simplified GUIs allow building operators to create simple scripts and controls without having to hire expensive data scientists
Artificial Intelligence and Machine Learning	AI and ML, when applied to building data, allow for true energy usage optimization and emerging use cases, such as blackout prediction
AR/VR, Content Delivery, UX & Interactions	AR/VR allow for digital twins of buildings, which can improve the construction process and allow for easier diagnostics pointing to maintenance needs

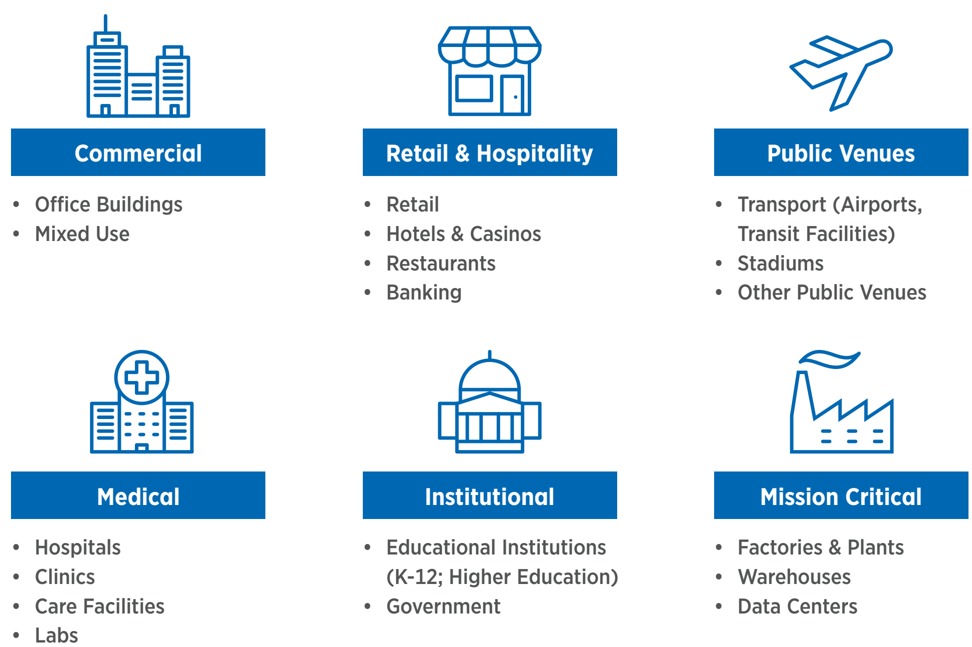
Source: CABA Intelligent Building Energy Management Systems 2020 Report

For IBEMS suppliers, understanding the technology infrastructure and maturity of each of their customers will help them configure systems and technologies to best meet their energy goals. However, these goals, and the ability of IBEMS to help achieve them, varies greatly between different types of buildings, as well as their location and occupant demographics.

1.2 ENERGY NEEDS OF BUILDINGS DIFFER GREATLY BY BUILDING TYPE, REGION, AND OTHER FACTORS

Across North America, there exist millions of buildings, each with a unique location, occupant mix, and ultimate purpose. Because of these differences, each building has its own idiosyncrasies related to energy management, consumption, and the possibilities for sustainable energy generation. For example, state regulations in California, when coupled with its climate, enable zero-net energy buildings, have allowed the adoption of zero-net energy buildings. Fully energy-independent buildings might not be currently possible to operate in regions with less favorable conditions. For this report, buildings are segmented as shown in Figure 1.6, by their high-level function.

Figure 1.6 Segmenting Buildings by Their Function



Source: CABA Intelligent Building Energy Management Systems 2020 Report

Each of the above macro buildings categories contain their own idiosyncrasies. Understanding these differences in relation to energy management will help to improve the value of IBEMS.

1.2.1 Residential Buildings and Multi-Dwelling Units (MDUs) Overview

The growth rate of cities naturally invites an increase in demand for residential housing. For a long time, residential buildings have provided an accepted solution to the scarcity of land and overpopulation of cities. By taking advantage of unused vertical space, residential building could pack hundreds to thousands of tenants within large-scale developments, thereby densifying areas within close proximity to business districts or commercial centers.

As a classification of housing, Multi-Dwelling Units (MDUs) lie at the intersection of residential buildings and single-family homes. Essentially, they are housing complexes that contain separate residential units which are adjacent vertically, horizontally, or a hybrid thereof. The recent explosion in MDU development across major cities has not gone unnoticed. These housing units are often modern and luxurious, catering to a mix of high-income young adults and families.

Both residential buildings and MDUs are increasing to satisfy a growing demand for housing units in prime city locations and they both espouse the use of universal design elements, such as common floor plans and appliance setups. That said, the most important thread of commonality underlying these complexes is that they are inhabited by cost-conscious occupants who have a relatively high-level of agency understanding over their energy usage, especially in comparison to mission-critical and medical buildings. In relation to energy management systems, this translates to a unique relationship wherein the occupant, and naturally the bill payer, can translate insights into deliberate daily actions or controls.

However, this agency is fragmented by differences between in-suite/in-home energy consumption and common area energy consumption. Because MDU units are typically smaller than single-family homes and often only have one exterior wall, energy costs may be lower relative to commercial buildings. The division of payment responsibilities between in-suite and common area expenses depends on how many costs are pushed down to the tenant/owner. This can be optimized by electrical or BTU sub-metering systems, but in many condos, the common area expenses are a proportionally quite high, and are allocated to the owners on a pro rata basis, eliminating occupant agency.

1.2.2 Commercial Buildings Overview

The “Commercial Buildings” grouping is a wider categorization of buildings that includes everything from restaurants to supermarkets, and from office buildings to gas stations. Week after week and month after month, these locations have a steady and predictable need for energy.

Studies by the U.S. Energy Information Administration (EIA) show that the largest proportion of electricity was used on the HVAC system, followed by lighting and refrigeration. As expected, large commercial buildings use up more energy than their smaller counterparts. However, this correlation is not a linear one. In fact, larger buildings need increasingly more energy with every extra square foot. This is due to the exponential increase in ventilation and cooling costs that arise from cooling a larger space. "In 2012, less than 1 percent of buildings were larger than 200,000 square feet, but these buildings accounted for about 26 percent of total commercial building energy consumption. About 11 percent of commercial buildings in 2012 were between 25,000 square feet and 200,000 square feet, and these buildings accounted for about 42 percent of total energy consumption in commercial buildings."[7]

Although most commercial buildings could benefit from energy management systems, the most prominent market is that of buildings over 25,000 square feet. These sites are required to maintain a reasonable level of comfort for customers and occupants. Nevertheless, understanding and optimizing cooling and ventilation costs can have a significant effect on operations. In some commercial buildings, such as those in highly concentrated areas, the available roof or parking lot space may limit energy production capacity through purely photovoltaic means, necessitating CHP or other generation or storage techniques to distribute peak loads.

1.2.3 Public Venues Overview

Although diverse in their end-use, public venues all share one key commonality; they must cater to sudden influxes of huge quantities of occupants. Airports, theaters, and stadiums are all examples of public venues that can hold masses of people. The immediate concern with regards to these influxes is the buildings ability to cool and ventilate. These systems will require much larger amounts of energy to deliver the needed results. However, the energy needed to produce those results is not a fixed amount, but rather depends on occupancy, among other location-specific variables.

Most public venues will operate their own microgrids and backup generators to maintain critical activities. For instance, air traffic operations offices at airports cannot lose access to power and will likely have their own generators. Another issue that certain public venues face is the energy costs associated with an act's light show. Quantifying and optimizing costs around these lights, or alternatively passing these costs onto the act's management, can bring a large amount of savings to the venue operators.

Ultimately, the enormity of logistical variables at play in these public venues stems directly from the immensity of their operations, even if they do occur only for a few hours at a time. It is for this reason that public venue managers should invest in energy management systems. Operators need actionable insights into the way that energy is used, generated, and prioritized.

1.2.4 Medical Buildings Overview

Though they seem like a consolidated group, medical buildings can range vastly in terms of their energy usage and efficiency. An internist's clinic that administers basic diagnoses requires much less energy than a hospital with a 15-bed ICU. The amount of energy a given property uses depends on many factors, including variable equipment operating efficiency, climate, and activities conducted.

According to EnergyStar, the median medical building is approximately 43,000 square feet. The difference in energy use intensity between the 5th and 95th percentiles is as much as six-fold. This is shown in the adjacent distribution. As can be seen, the distribution has a negative skew, which means that despite being fewer in number, certain buildings consume a disproportionally high amount of energy. These buildings likely operate critical equipment that must be on 24-7. In addition, they subscribe to a distributed energy architecture to decrease the risks associated with potential power outages.[8]

Although, these high energy-usage buildings are the most immediate target for EMS solutions, other medical building operators also benefit from these systems. Ventilation, strong lighting, and ongoing sanitization efforts are standard across the entire medical industry. Understanding and optimizing these expenditures can provide tangible return on investment.

1.2.5 Institutional Buildings Overview

According to the NGO Environment America, campus buildings make up 80 percent of total university energy spend. In addition, improved energy efficiency can save up to 60 percent of those costs. With the correct tools, this level of waste is easily avoidable.[9]

College campuses, local municipal offices, and other institutional buildings are well-equipped to reap the benefits of an energy management system. The reason for this is that certain universities and government entities believe that it is their responsibility to introduce environmental awareness and educate the community on energy awareness. That said, environmental consciousness and the degree to which institutional buildings are designed to minimize energy usage vary greatly. Some institutions take these goals so seriously that they set up innovation hubs and fund related start-ups.

University campuses are already one of the most prolific customer segments for EMS providers. The combination of highly structured, centrally controlled, and environmentally conscious campuses is fertile ground for optimizing energy usage.

1.2.6 Mission-Critical Buildings Overview

Broadly defined, mission-critical buildings contain at least one operation that, if disrupted, would cause significant harm. This harm could range from nonconformity with legal standards to loss of human life. Examples of these mission-critical buildings include data centers, power plants, utilities, and public safety buildings. The main point to keep in mind with mission-critical buildings is that they need consistently uninterrupted energy around the clock.

To maintain uninterrupted operation through difficult conditions, mission-critical buildings include a built-in level of redundancy for power and cooling needs. Naturally, these redundant systems may create energy inefficiencies. Operators must decide which of these system paths to use for varying purposes. This can be a time-consuming and arduous project without a comprehensive EMS.

1.3 THE STATE OF MONETIZATION AND BUSINESS MODELS OF INTELLIGENT BUILDINGS

New entrants to the building value chain have heavily disrupted the industry's operations. Increased competition from technology players matched with growing demand for high-tech building amenities is influencing major changes in the types of solutions and services offered, the creativity of new business models, and the flexibility of revenue models that cater to different occupants and operators.

1.3.1 Intelligent Building Ecosystem Overview

The traditional buildings value chain is transforming in the era of new intelligent buildings technologies. With the influx of new technologies, service providers have new opportunities to provide value to customers through smart systems and services. Technology players are increasingly invading this space by delivering novel solutions and services. Notably, these companies have access to information that traditional value chain participants never did. These shifting competitive structures are forcing traditional equipment and service providers to rethink their business models.

Figure 1.7 Ecosystem overview highlighting the complexity of interacting forces in the smart building market landscape.

Figure 1.7 The Intelligent Building Ecosystem Overview

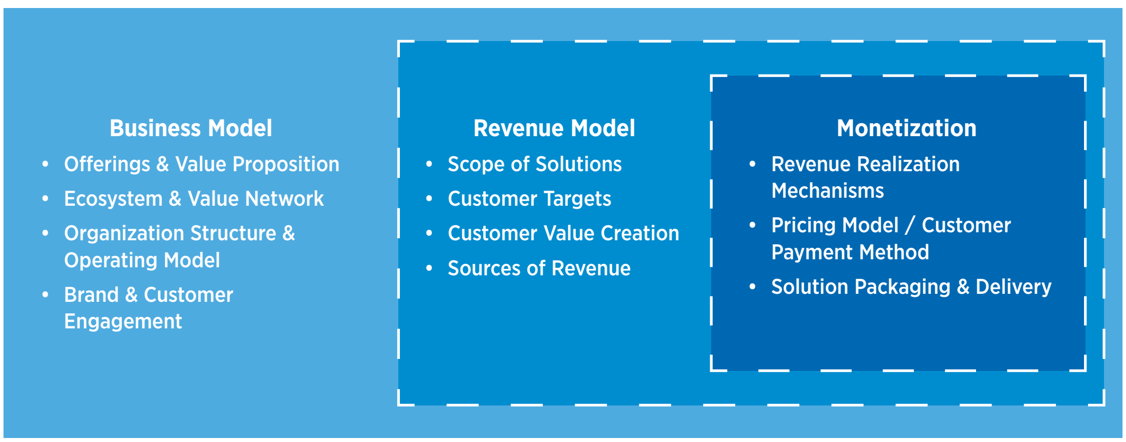
Source: CABA Intelligent Building Energy Management Systems 2020 Report

1.3.2 Intelligent Buildings Monetization and Performance Models Overview

Simply defined, monetization refers to the combination of systems and regulations set in place for a business to generate revenue. In the context of smart buildings, monetization can be regarded as a confluence of pricing inputs, revenue collection models, and overarching business model considerations (Figure 1.8). For added clarity, consider the example of an office building that charges tenants a fixed price for rent, including utilities. The operator collects rent monthly using automated bank account wire transfers. Now imagine that this building installs solar panels to mitigate energy costs but keeps all these savings as additional revenue. In this case, the building's monetization strategy is to amass rent and sell utilities by collecting a fixed monthly fee through wire transfers.

As innovative smart home and smart building technologies flood the market, building operators will need to develop novel revenue models and monetization approaches. The proportion of revenue per occupant attributed to ongoing service-based revenue models is slated to increase with improved monitoring and control capabilities. This can be achieved either by increasing the scope of software and services tailored to occupant usage or by unearthing new modes of revenue generation such as data monetization.

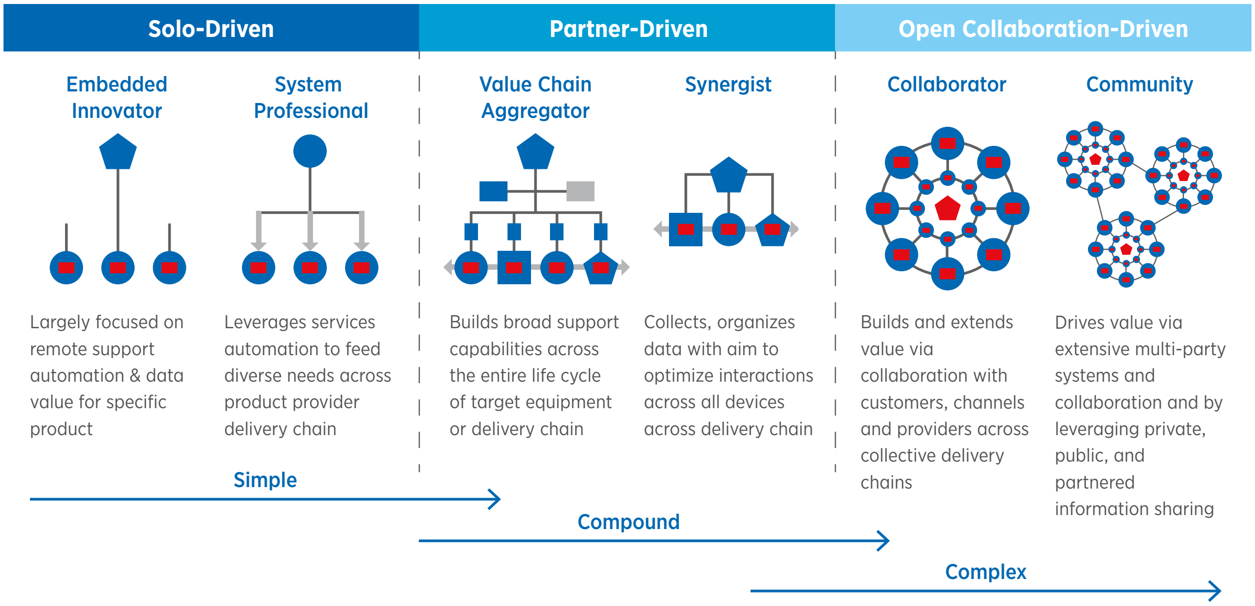
Figure 1.8 Overview of Intelligent Building Business Models



Source: CABA Intelligent Building Energy Management Systems 2020 Report

As shown in Figure 1.9, the overarching business models that inform new solutions in the intelligent buildings arena can be classified into three broad categories; Solo-Driven business models, Partner-Driven business models, and Collaboration-Driven business models.

Figure 1.9 A Business Model Framework for Intelligent Buildings



Source: CABA Intelligent Building Energy Management Systems 2020 Report

In a solo opportunity, a single product represents the opportunity. The two business models within the solo-opportunity category are differentiated by the scope of activities which make up the economic value of the overall opportunity. Where the scope is low, we call the company an "embedded innovator" and, where it is high, the company is a "systems professional."

For example, **Hewlett Packard (HP)** recently launched a subscription service targeted at residential and small office clients providing automatic printer ink order refilling. Instead of selling printers and then subsequently marketing the ink, HP can solve a customer pain point by leveraging information from its product. By providing this service, HP derives more value from customers than it ever could previously.

The two partner-driven models are those in which the opportunity cannot be tapped by a single device and a single vendor. There are situations in which a device may collect valuable data, but not valuable enough in and of itself to create the opportunity. Instead, several disparate devices work within an environment, and only by connecting all or most of them is a body of data created that is of high value.

For example, **Energy Management Systems** are a great example of partner-driven business models. For an EMS to be effective, it needs to connect to several systems and provide useful decision- making data. The most important of these systems are HVAC and lighting, the former because of its energy intensity and the latter due to ease of optimization. In addition, an EMS can connect to elevators, security cameras, air quality monitors, and many other smart building technologies. On their own, these systems provide low-value data, but together they introduce a combinatorial value for operators and occupants alike.

Collaboration-driven opportunities take the previous four models one step further to applications that drive interactions between and among devices, sub-systems, people and business processes across enterprises and multiple business entities (including public sector systems).

For example, **California** recently announced that beginning in 2030, all new commercial buildings and major renovations of existing buildings need to achieve zero net energy (ZNE) performance and support grid optimization. A ZNE building usually refers to one that only consumes energy that is produced onsite. In order for the state of California to oversee compliance, it will need access to information from EMS systems across every building in the entire state. The success of this regulation depends on development of an open energy management network across the state.[10]

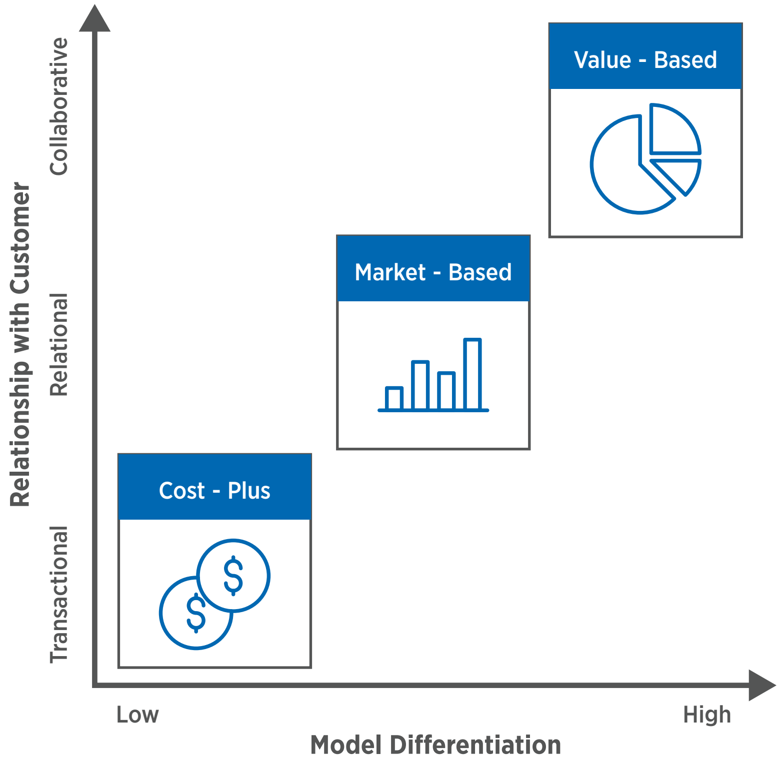
1.3.3 Intelligent Buildings Pricing Considerations and Incentive Programs

There are three fundamental types of pricing that are actively used in the market: cost-plus pricing, market-based pricing, and value-based pricing. Prices are set in these models based on two primary factors: competitive pressures and perceived customer value from the offering or solution set.

- **Cost-Plus Pricing:** Cost-plus pricing requires the business owner or strategist to calculate all the variable costs that went into the production of a product and then add a reasonable margin that covers profit and overhead.
- **Market-Based Pricing:** Without differentiation, commoditized product or solution suppliers are price-takers; they must accept the going-rate.
- **Value-Based Pricing:** Value-based pricing allows businesses to price products depending on the value they produce for customers. This requires an acute understanding of how much IBEMS benefit customers in terms of energy efficiency and cost savings.

As shown in Figure 1.10, value-based pricing is a much more collaborative endeavour that produces many more touchpoints between solution providers and end-customers. Many examples of creative business models have popped up in recent years. Covering every unique business model is out of scope for this paper, but a couple of examples should help communicate value-based pricing models.

Figure 1.10 Intelligent Buildings Pricing Models



Source: CABA Intelligent Building Energy Management Systems 2020 Report

Pay-Per-Period/Per-Usage Model: When each use of a product is of considerable value to the customer, the use of the product itself can be sold as a service, with charges being made per instance of use or per time period. The Italian laundry machine manufacturer **Merloni**, for instance, has Internet-enabled washing machines on the market right now, which they place in homes for free with "washer service" priced at about 50 cents per load; both usage-tracking and the financial transaction are accomplished remotely and automatically.

Product Life-Cycle Model: In this model, a single solution provider services all downstream value chain operations. For instance, **GE Healthcare** could supply customers with an MRI diagnostic machine, finance the transaction, and service it all under the same contract. The completeness of the GE solution makes it easy to buy. And as the device is networked, GE can begin to track maintenance and parts inventory, services, and replenishment, thereby further optimizing the process and increasing profitability on every dollar of the increased revenue.

While these pricing models can help suppliers drive revenues, they are ineffective if they do not meet the price considerations and needs of building owners and operators. Therefore, companies need to understand how energy management and sustainability are considered and prioritized in constructing and operating buildings. With this understanding, companies can tailor their solutions to meet the goals of their users in a cost-effective manner.

Product "As-a-Service": Across industries, companies have recently shifted business models to deliver products and services with a recurring subscription. In buildings, this model is being promoted for a variety of buildings functions, such as security, lighting controls, and energy management. For example, environmental organization **Carbon Lighthouse** offers energy management-as-service for buildings, in which they provide access to an IBEMS software application and will monitor and configure energy settings on an ongoing basis, in return for a continuous subscription fee.

While "as-a-service" pricing models can provide more flexibility to both the consumer and the supplier, they require a shift in the relationship between consumers and their products. While many consumers today simply want to procure a product and have it function unattended, "as-a-service" pricing models mandate that the consumer understands and pays for the services a product provides, rather than the physical product itself. For this to happen, developers need to create applications that provide continuous value, incentivizing consumers to pay for the service that a product delivers.

Notes:

1 Iwayemi, A., Wan, W., & Zhou, C. (2011, August 01). *Energy Management for Intelligent Buildings*. IntechOpen. https://www.intechopen.com/books/energy-managementsystems/energy-management-for-intelligent-buildings

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3 Verma, U. (2018, August 08). *How to use AI and ML to create a smart building*. In-Building Tech. https://inbuildingtech.com/ai-ml/ai-ml-smart-building/

4 Murthy Balijepalli, V. S. K., Pradhan, V., Khaparde, S. A., and Shereef, R. M. (2012, February). Review of demand response under smart grid paradigm. *IEEE PES International Conference on Innovative Smart Grid Technologies-India, ISGT India* 2011, 236–243. IEEE. https://ieeexplore.ieee.org/document/6145388

5 Peak Load Management Alliance (PLMA). (2017, May 25). *Evolution of Demand Response in the United States Electricity Industry*. https://www.peakload.org/assets/drdialogue/Evolution-of-DR-White-Paper.pdf

6 Source: Independent Electricity System Operator (IESO). (n.d.). *Ontario's Power System*. http://www.ieso.ca/en/Learn/Ontario-Power-System/A-Smarter-Grid/Distributed-Energy-Resources

7 U.S. Energy Information Administration (EIA). (n.d.). *Use of energy explained*. https://www.eia.gov/energyexplained/use-of-energy/commercial-buildings-in-depth.php

8 Source: ENERGY STAR®. (2015, January). *Energy Use in Medical Offices*. https://www.energystar.gov/sites/default/files/tools/DataTrends_MOB_20150129.pdf

9 Environment America. (n.d.). Energy efficiency in campus buildings. Environment America. https://environmentamerica.org/energy-101/energy-efficiency-campus-buildings

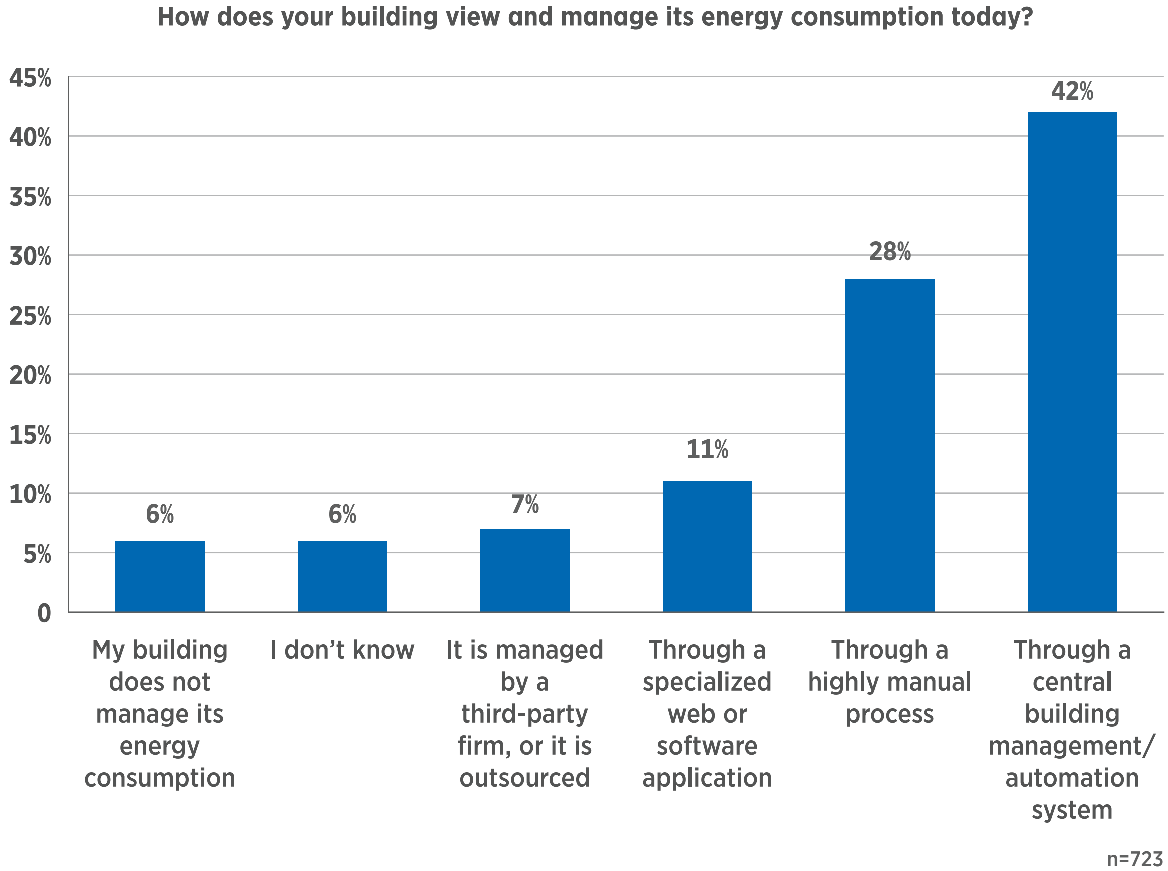
10 California Public Utilities Commission (2018, April). *Commercial Zero Net Energy Action Plan*. California Public Utilities Commission. https://docs.wixstatic.com/ugd/cc790b_ecb5c5e9cf004f2883e06fc765a12d8a.pdf

2. THE CHANGING CONSUMER: MAXIMIZING EMS VALUE TO ARCHITECTS AND OPERATORS

Commercial buildings and building systems have many different stakeholders, and many decision-makers affect how a building is designed, constructed, used, and managed. As a result, energy usage, management and sustainability are affected by multiple constituents. Understanding the current state and future direction of IBEMS needs connecting macro market trends and developments to the day-to-day needs, issues, and decision-making that occur during the real-world use of building and energy systems. To better understand this aspect of the IBEMS market, Harbor Research deployed two parallel surveys—one to buildings architects, constructors, integrators, and engineers; and the other to buildings owners, facilities managers, and occupant office managers—which make it possible to explore how IBEMS are considered during building construction and operation. In addition, the survey results reveal key differences in how different demographics and regions view and prioritize energy.

As shown in Figure 2.1, more than half of building owners and operators indicated that their building(s) had energy management software (either standalone or as part of a BAS/BMS) in place. However, a significant number of buildings (28 percent) still manage energy consumption with a manual process, which is labor-intensive and expensive. In addition, adoption of energy management software alone does not beget results, as many users still have difficulties maximizing the value of their IBEMS.

Figure 2.1 IBEMS Adoption in Buildings



Source: CABA Intelligent Building Energy Management Systems 2020 Report

Digging deeper into how energy management systems affect architects, operators, and occupants can provide IBEMS suppliers with insight into the procurement, installation, and operation of these systems so that they can better tailor their offerings to real-world user needs.

2.1 ARCHITECT NEEDS ILLUMINATE HOW IBEMS SOLUTIONS ARE IMPLEMENTED

As buildings have embraced complex technologies, it has caused challenges in the construction process. Architects, constructors, and engineers (ACE), who traditionally only focused on occupant convenience and structural integrity, now must consider energy efficiency, network communication, air quality monitoring, and other factors. In addition, system integrators are challenged with the need to promote seamless ease-of-use and data sharing between many devices from different manufacturers.

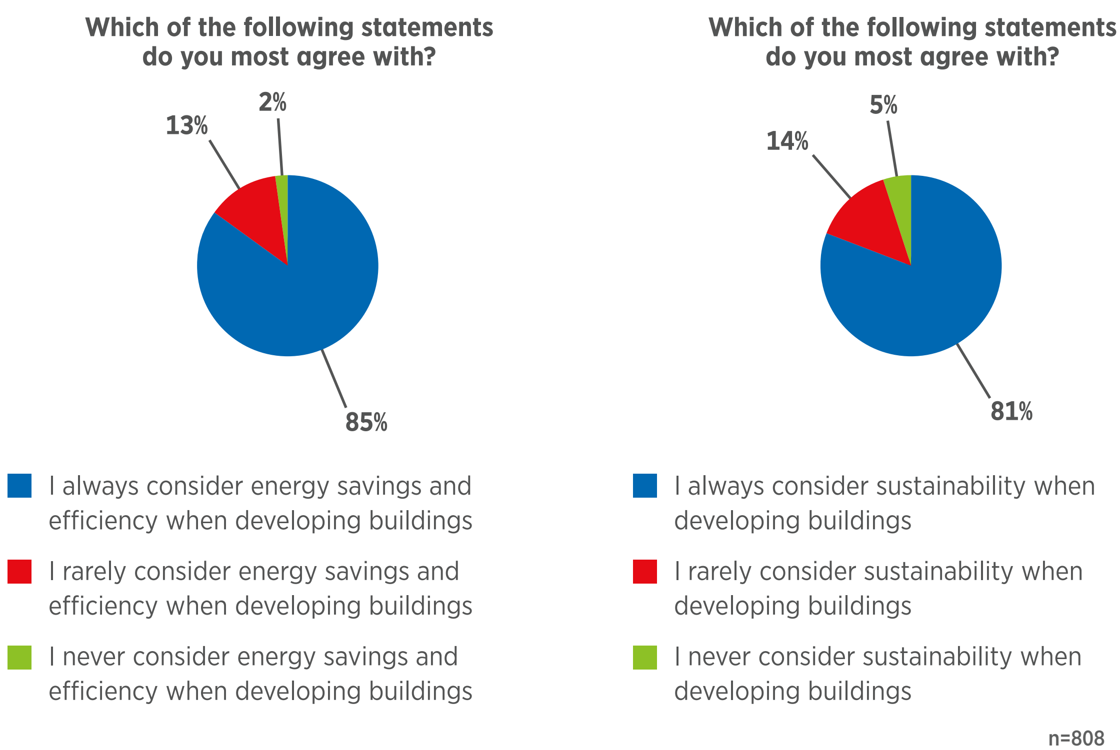
> "EMS systems are often specified in Division 26 (Electrical), while BMS systems often fall under Division 23 (HVAC). Often, different construction firms handle each system. There has been a push for greater use of Division 25 (Integrated Automation), but this division has been largely unused to date."
> -City Commissioner, City of Pittsboro, North Carolina

Often, a lack of coordination, forethought, and technical knowledge limits the ability of constructors to implement an IBEMS that operates efficiently, leaving the facility manager or operator to implement energy management techniques (such as implementing LED lighting automation in response to occupancy sensing) after construction is finished. Better education and construction standardization can help architects and integrators construct more energy-efficient and sustainable buildings, reducing the need for the operator to undertake expensive retrofitting efforts.

2.1.1 Energy Management is a Key Consideration During Building Construction

As depicted in Figure 2.2, the vast majority of architects and integrators consider both energy efficiency and sustainability during the development of buildings.

Figure 2.2 Energy Considerations During Building Construction



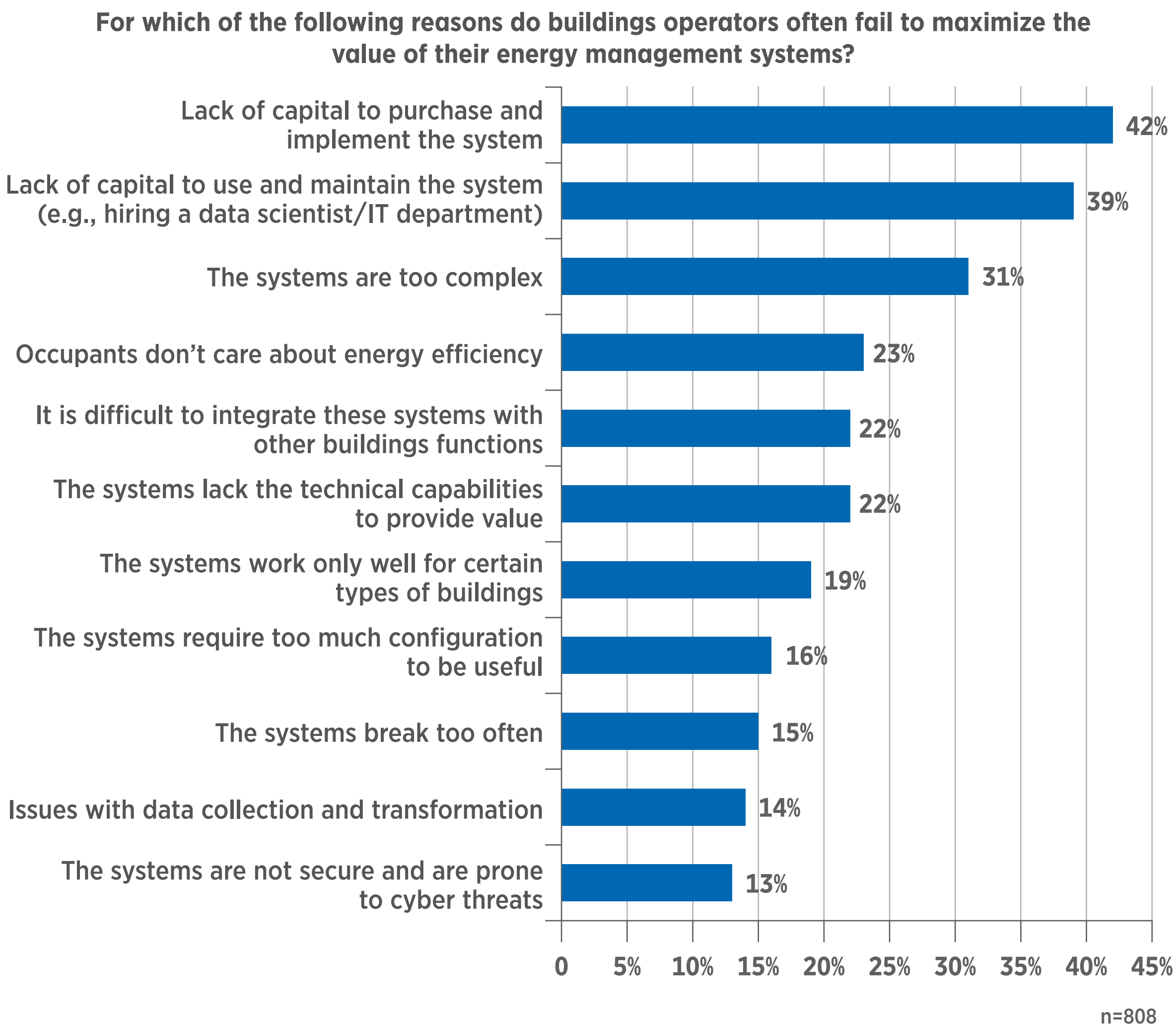
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Today, energy costs can be the most expensive line item for most building operators after personnel/staff expenses, so it makes sense that constructors would prioritize energy efficiency and DERs in buildings, as they try to meet the needs of clients and future occupants.

2.1.2 Cost is a Major Constraint for IBEMS Operation and Integration

In addition to a relative consensus opinion on the importance of energy efficiency and sustainability, architects and integrators were also aligned on what they view as the biggest issues with energy management systems to be.[1] When asked to select reasons why operators fail to maximize the value of their EMS, respondents most often selected reasons associated with cost and complexity (Figure 2.3).

Figure 2.3 Cost, Complexity Inhibit the Ability of IBEMS to Provide Value



Source: CABA Intelligent Building Energy Management Systems 2020 Report

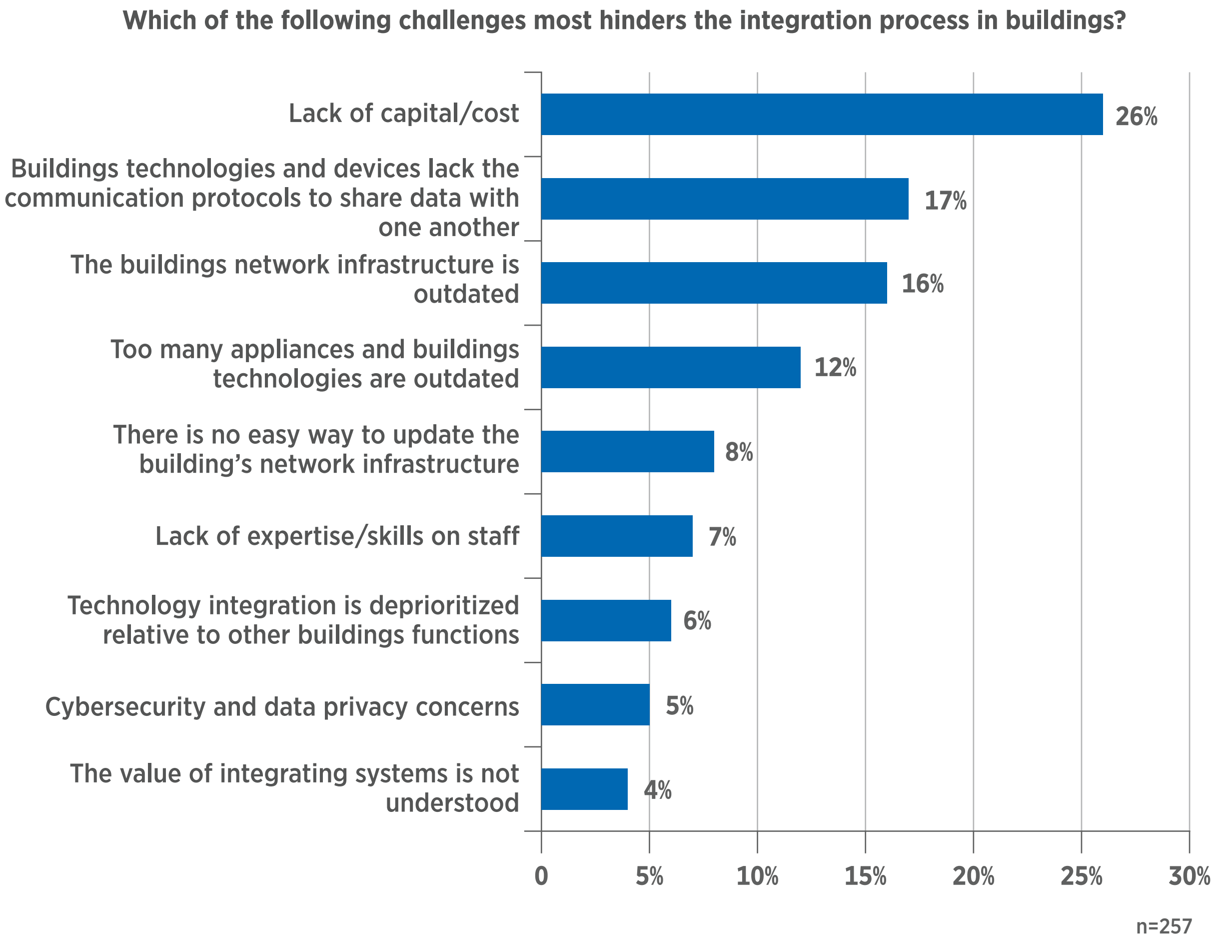
Respondents selected technical reasons (those related to data collection, systems integration, maintenance, and cybersecurity) far less often than business-related ones (capital, complexity, and occupant desire). This could indicate that architects lack the technical expertise to diagnose IBEMS issues, or that the technical capabilities of these systems outpace their usability and cost efficiency. Suppliers need to balance technology-based solutions with the actual budgets of their purchasers and users to ensure that their solutions can deliver the value promised.

The fourth, fifth, and sixth most selected reasons place the blame on parties external to the building operator and architect/integrator. The answers "the systems lack the technical capabilities to provide value" and "the systems work only well for certain types of buildings" imply that suppliers develop EMS offerings that fail to account for operator needs and the specificities of each building. Therefore, suppliers need to do a better job of educating both operators and occupants as to the value and importance of EMS adoption.

2.1.3 Cost, Lack of Operator Support Challenges IBEMS Systems Integration

When a similar question was posed to integrator-related respondents only, they also indicated that cost is the top challenge for integrating IBEMS solutions. In this question, respondents were only allowed to select a single response, forcing them to choose among top integration challenges and making it possible to gauge the perceived importance of each one (Figure 2.4).

Figure 2.4 Cost is the Top Integration Challenge for IBEMS



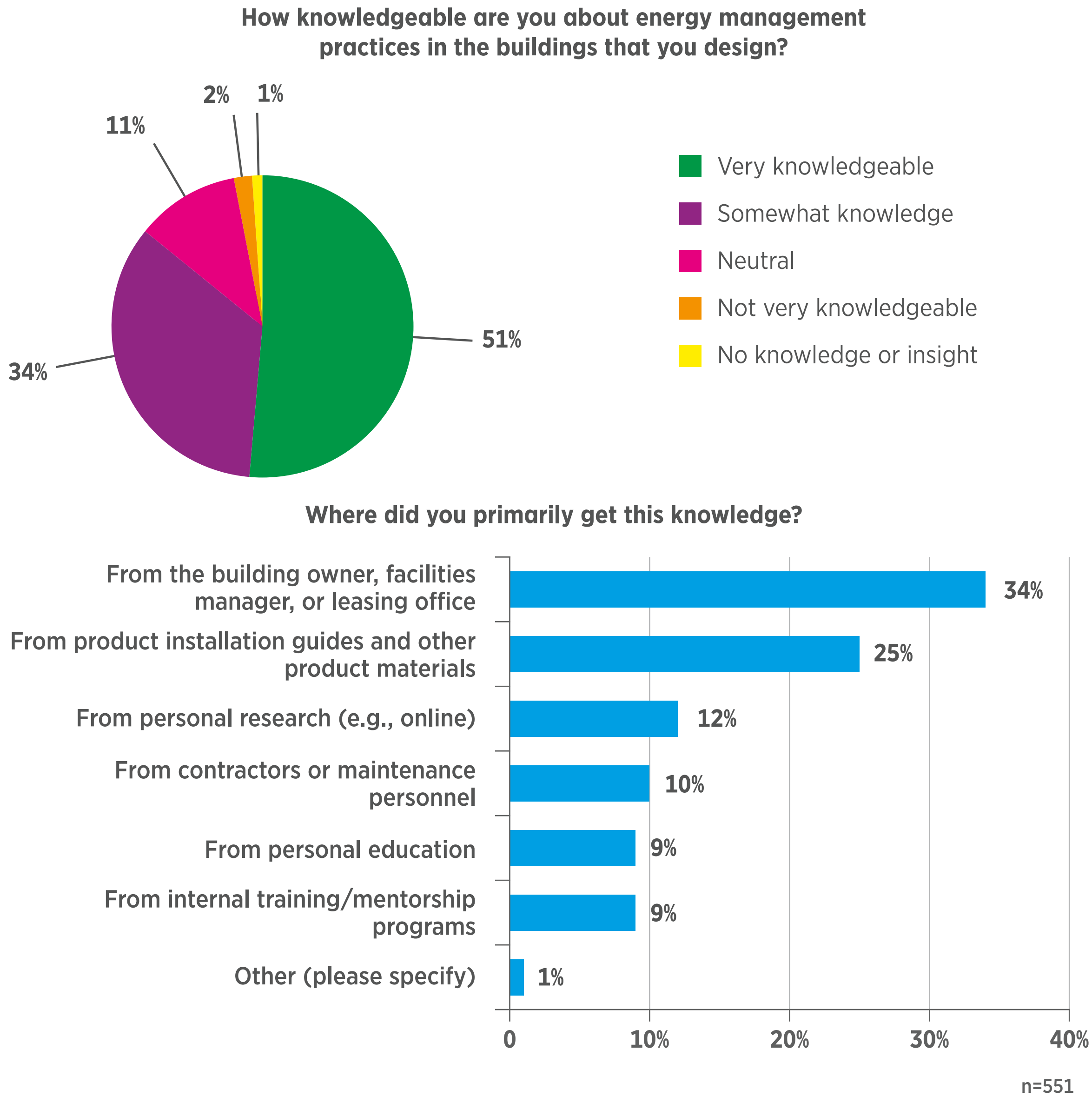
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Less than 5 percent of respondents indicated that the value of system integration was not understood, indicating that most building operators and construction managers prioritize and consider system integration when developing intelligent buildings. However, almost

50 percent of the difficulties with integration are related to cost and legacy infrastructure, which speaks more to a lack of capital with which to work rather than any gaps in understanding on the part of the integrator or operator.

To help illuminate these questions, architects and integrators were asked to rate their level of knowledge with IBEMS and identify the source of this knowledge. Architects indicated that they had better knowledge of IBEMS than integrators (Figure 2.5).

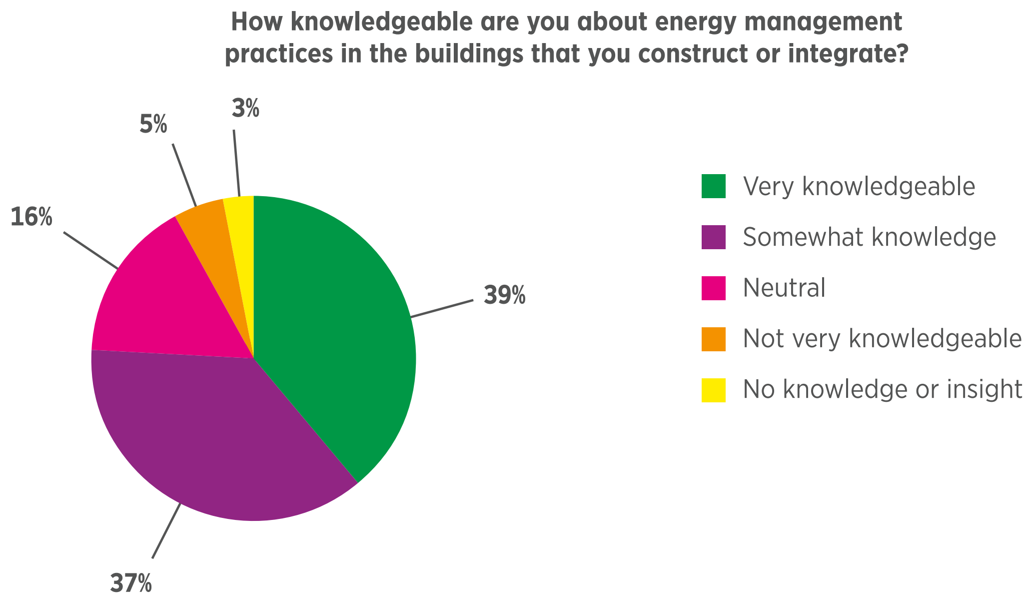
Figure 2.5 Architect IBEMS Knowledge and Education

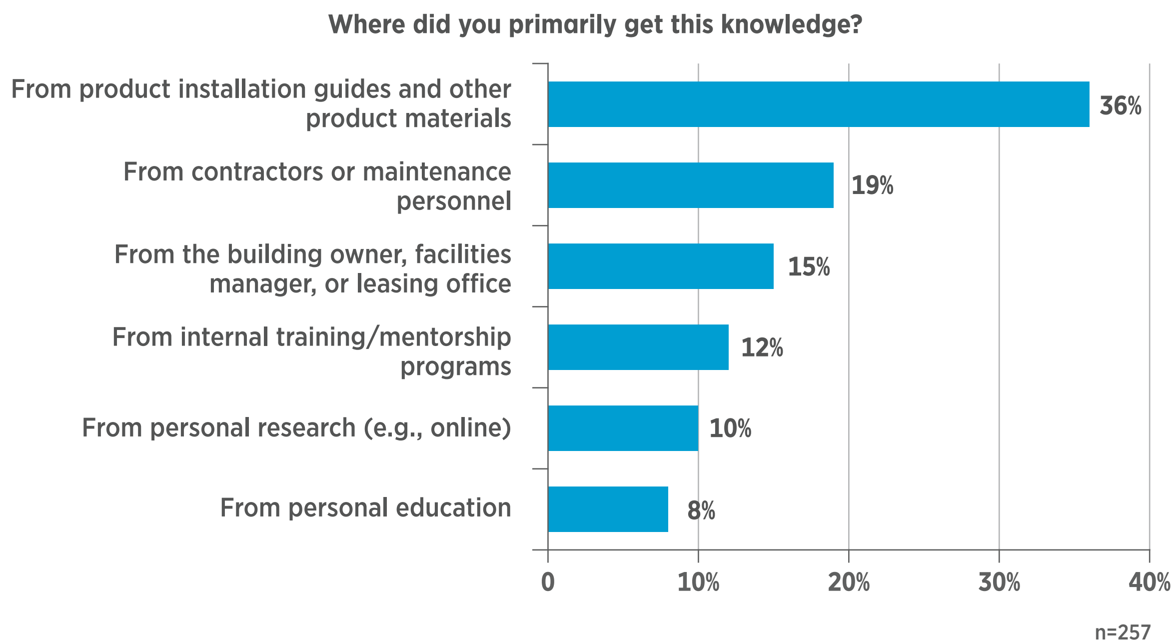


Source: CABA Intelligent Building Energy Management Systems 2020 Report

Most architects indicated some or a lot of knowledge of energy management practices, and they indicated that they gained this knowledge either from the building owner or product installation guides and related materials. However, system integrators indicated much less understanding of energy management practices than architects (Figure 2.6).

Figure 2.6 Integrator IBEMS Knowledge and Education





Source: CABA Intelligent Building Energy Management Systems 2020 Report

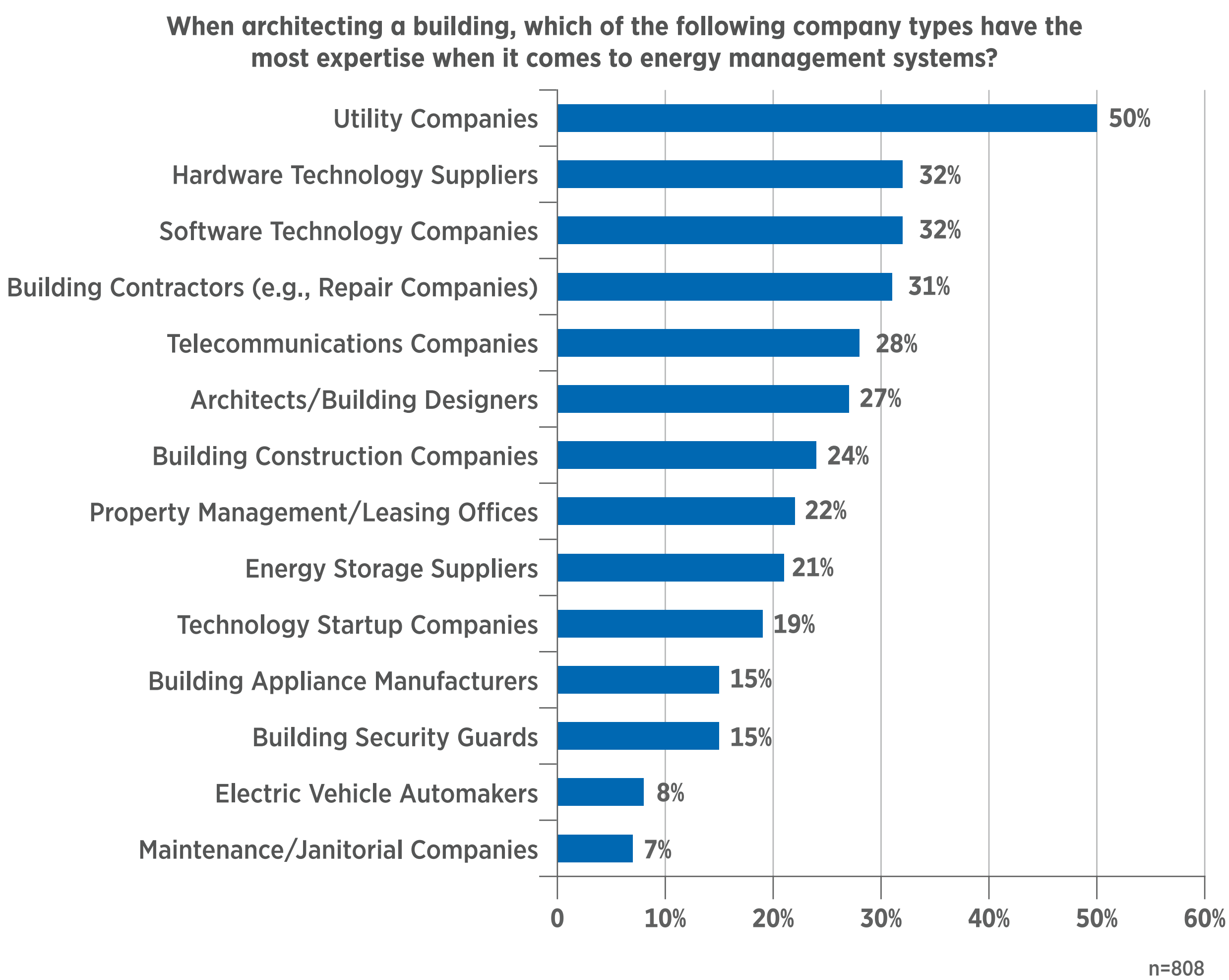
Unlike architects, integrators responded with less certainty of their knowledge of energy management practices in their buildings, with almost twice as many integrators rating their knowledge as "neutral". In addition, they more often selected "from product installation guides and other product materials" as their primary source of information, reflecting more of a do-it-yourself (DIY) learning style

For IBEMS suppliers and building operators, these results provide guidance on how their products and best practices are implemented and considered during the building construction and design process. Building owners can do a better job of educating architects and integrators as to the value and specificities of IBEMS implementation. In addition, suppliers play a key role in how IBEMS education is disseminated. By tailoring product installation guides to emerging IBEMS best practices and to individual building types, they can solve IBEMS issues before they manifest.

2.1.4 Utilities and Technology Suppliers Monopolize IBEMS Expertise

In addition to questions about pain points, integration challenges, and education, constructor respondents were asked to rate which company types have the most EMS expertise (Figure 2.7).[2]

Figure 2.7 Stakeholders with the Most IBEMS Expertise



Source: CABA Intelligent Building Energy Management Systems 2020 Report

Answers to this question could indicate that utility companies and technology software and hardware suppliers have the most knowledge of IBEMS. This could be due to the complexities of IBEMS interfaces and outputs—the intricacies of load data and kWh calculations can be difficult to understand without deep industry or technical expertise.

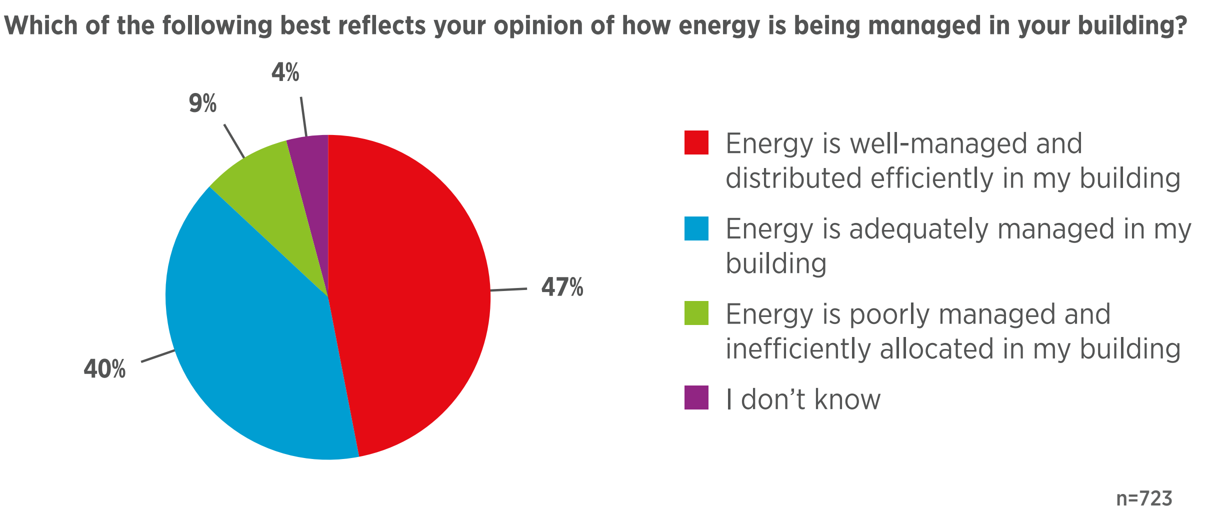
Technology start-up companies scored much lower than larger technology suppliers, with only 21 percent of respondents indicating that they have IBEMS expertise. Relative to large, established providers, new entrants face an uphill battle when it comes to penetrating the IBEMS market, due to ingrained business practices and the intensive subject matter expertise needed to displace existing solutions. Also, this data point could indicate a trend where large, incumbent BAS/BMS suppliers such as **Trane**, **Siemens**, **Honeywell**, **Carrier**, **Johnson Controls** and **Delta Controls** begin to consolidate the fragmented IBEMS market, offering holistic, integrated automation/management systems with EMS capabilities added on.

2.2 OPERATORS STRUGGLE TO MAXIMIZE IBEMS VALUE, ULTIMATELY HINDERING ADOPTION AT SCALE

While surveying ACE and systems integration firms provide insight into the upstream development and implementation of IBEMS, surveying users and stakeholders can illuminate issues in the purchase and use of IBEMS. The following sections provide an analysis of an IBEMS survey to operators—including building owners, facilities managers, and building energy managers—and office managers and associated tenant procurement professionals. These survey questions center on issues, needs, and benefits of using IBEMS in real buildings, as well as questions that focus on which features and needs most prioritize IBEMS procurement.

As shown in (Figure 2.8), most occupants and operators believe that energy is at least adequately managed in their buildings, which makes sense due to high rates of IBEMS adoption. However, more than half of the respondents indicated that there exists room for improvement in this area.

Figure 2.8 Operators Believe That Energy is Adequately Managed in Buildings Today

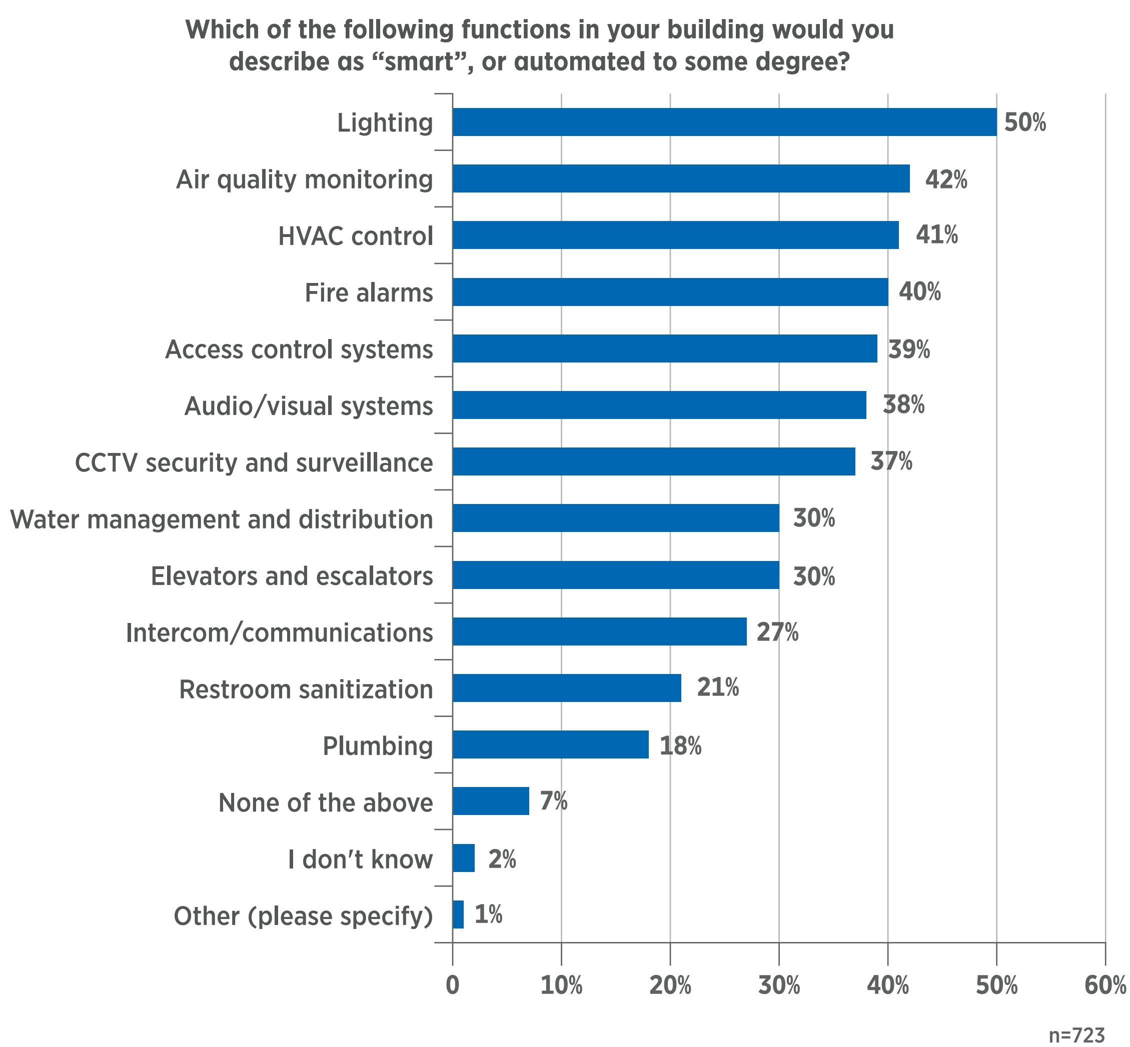


Source: CABA Intelligent Building Energy Management Systems 2020 Report

2.2.1 As Intelligent Buildings Evolve, So Must Their Energy Management Systems

It can be difficult for operators to procure the right IBEMS solution to meet their exact needs, due to differences in the function, region, data naming, and technical maturity of buildings. Understanding these differences is key to understanding the market more generally—as depicted in Figure 2.9, systems related to occupant comfort and convenience, such as lighting, air quality systems, and HVAC control systems, tend to be more automated in buildings than other systems.

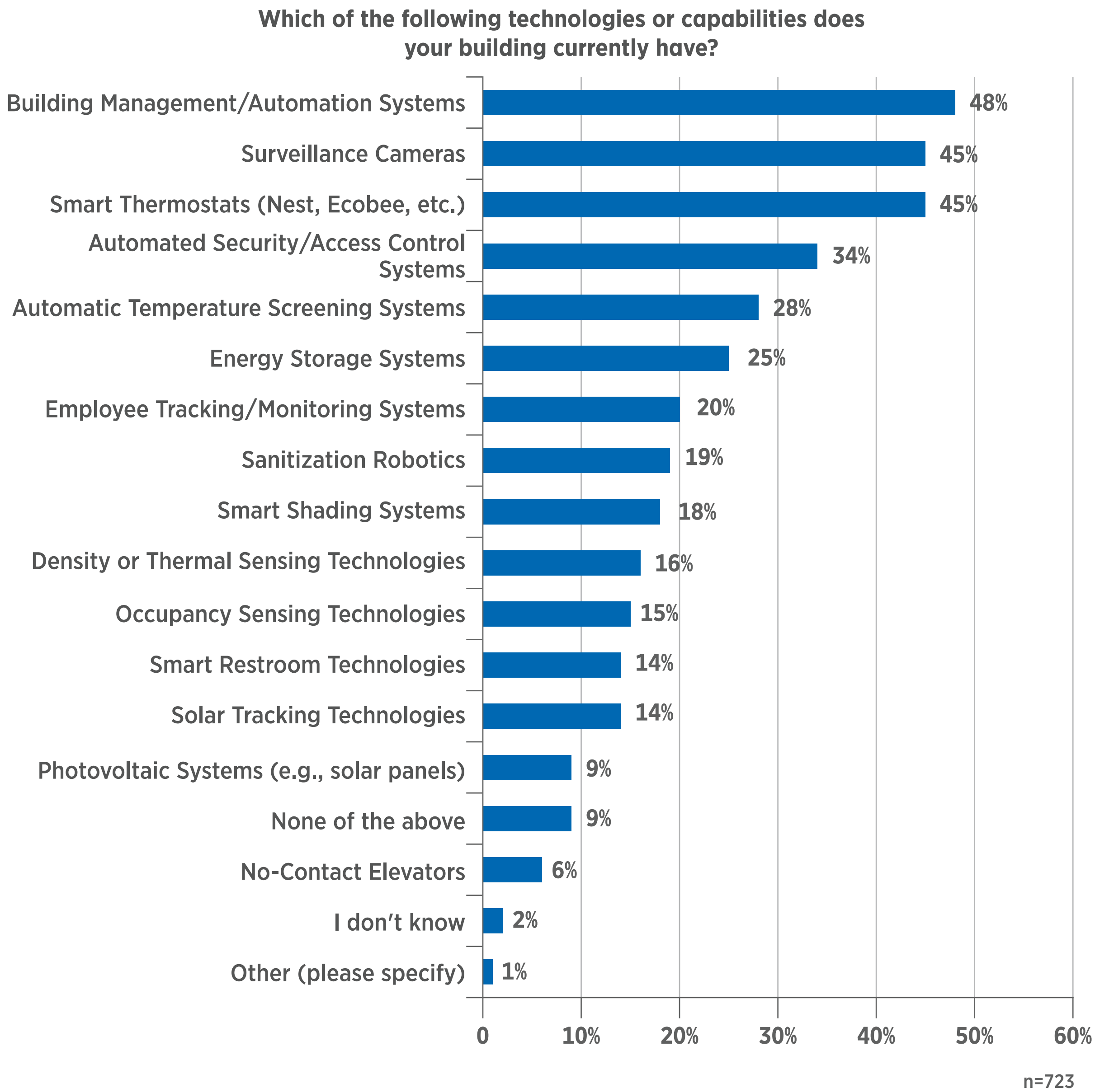
Figure 2.9 The Levels of Maturity of Automated Building Functions



Source: CABA Intelligent Building Energy Management Systems 2020 Report

However, this trend fails to hold up with the adoption of more complex technologies, as shown in Figure 2.10.

Figure 2.10 Emerging Technology Procurement Prioritizes Established, Existing Solutions



Source: CABA Intelligent Building Energy Management Systems 2020 Report

The above two images help depict the story of technology procurement decision-making in buildings. As seen in the first chart, automation tends to occur for more mission-critical buildings functions, as well as those related to occupant comfort. Water management, plumbing, and intercom communications tend to be less associated with occupant comfort, and as a result, they are often less automated.

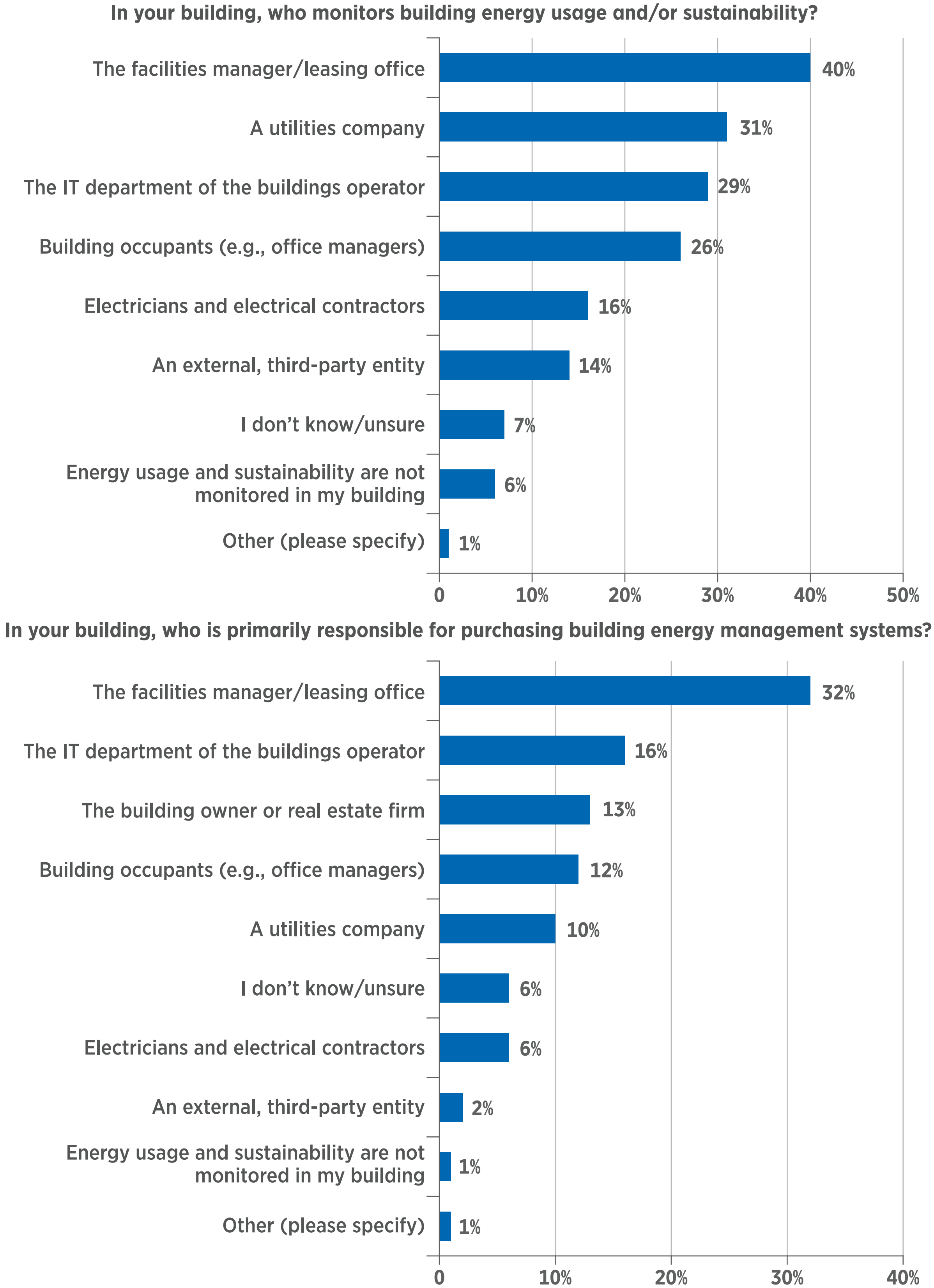
With connected, automated lighting, air quality, and HVAC systems, buildings can collect energy consumption data from these systems. This leads operators to invest in BAS/BMS systems that can use this data to drive energy efficiency insights and controls.

Further down the list, we can see relatively elevated levels of adoption for energy storage systems, smart shading systems, and smart thermostats, which can directly support advanced IBEMS applications. Interestingly, there seems to be little adoption for photovoltaic and solar tracking technologies, which could be due to regional variations and a lesser prioritization of sustainability in some regions.

2.2.2 While Facilities Managers are Primary IBEMS Users, Occupants Have Influence

The survey to occupants and operators features two related questions related to the exact stakeholders in the building who use and procure IBEMS applications. Most respondents indicated that facilities managers and leasing offices are both the primary user and purchaser of energy management systems in buildings (Figure 2.11).

Figure 2.11 IBEMS Users and Procurement Influencers



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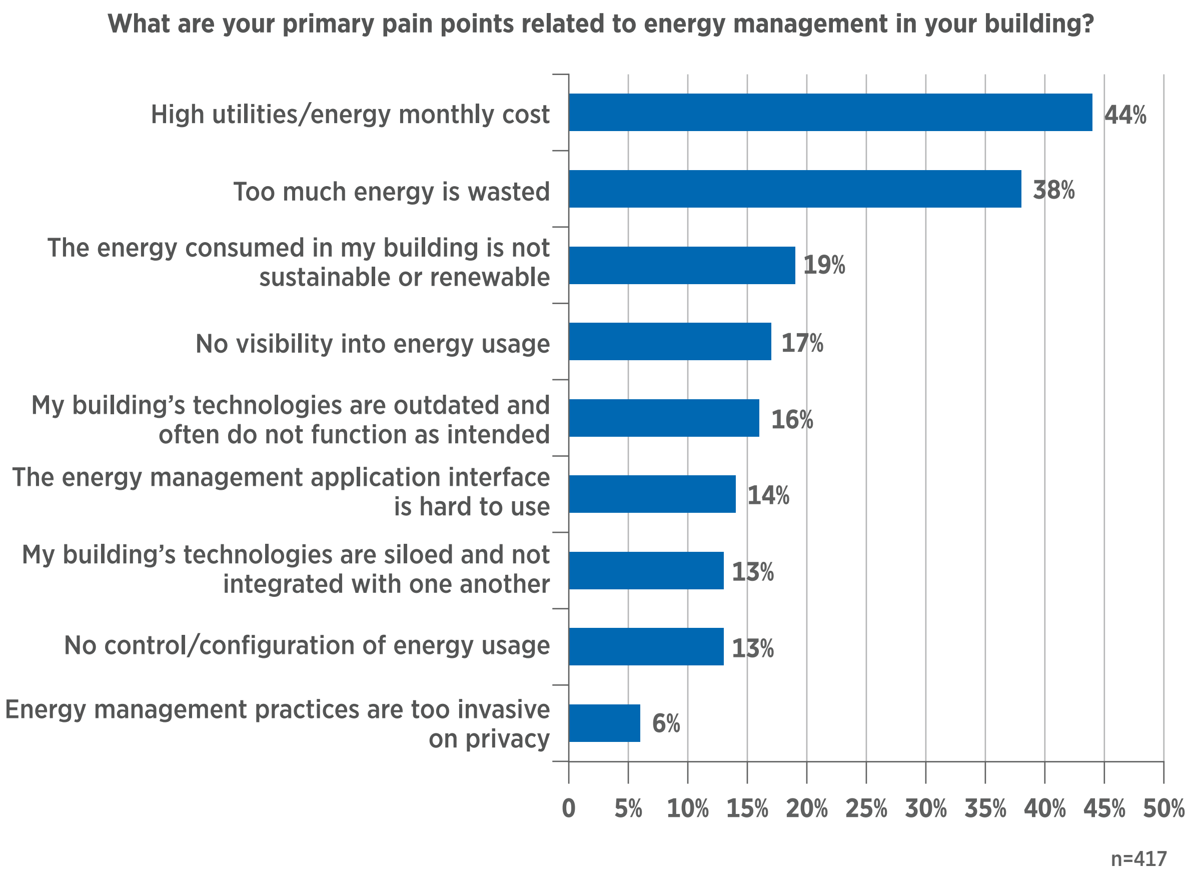
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Respondents also indicated that buildings occupants, such as office managers, have some level of visibility and procurement influence related to IBEMS. Contractors and third parties rarely interact or manage these systems remotely, which could be due to the expensive nature of that business model. In addition, respondents indicated that while utility companies do not influence the procurement of these systems, they do have some visibility into the data they provide. Suppliers should develop IBEMS applications with each key user and purchaser in mind, to help drive adoption of these systems and improve their usability.

2.2.3 IBEMS Systems are Well-Configured, but are Ultimately Inefficient

Operators, when asked to select their primary pain points related to energy management in their buildings, aligned behind two themes: cost and wasted energy (Figure 2.12).

Figure 2.12 Operator Energy Management Pain Points



Source: CABA Intelligent Building Energy Management Systems 2020 Report

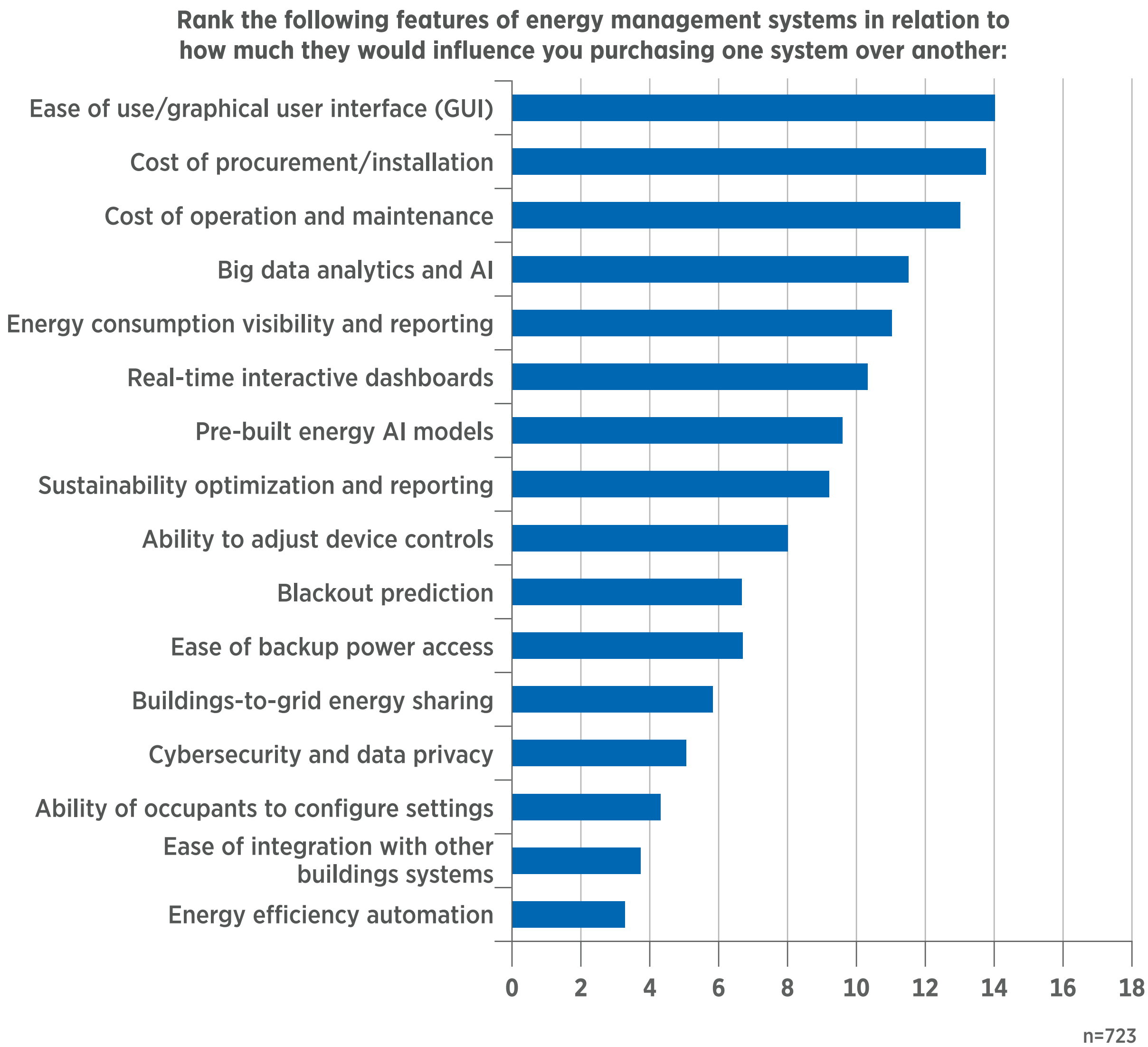
Once again, buildings stakeholders cite cost or lack of capital as a key barrier for intelligent buildings technology adoption and energy efficiency. This further highlights the need for suppliers and building operators to collaborate and develop more cost-effective solutions and financing models. For example, **EnTouch Controls** is an innovative EMS software provider that is exploring an "energy management as-a-service" type of offering, and they work directly with primarily retail clients to create customized packages that aim to deliver a positive, monetary ROI immediately after installation. In addition, they offer refunds if their solutions are not able to achieve energy consumption reduction.[3] While some organizations like **Wells Fargo** and **Clean Capital** are promoting new finance models to encourage onsite generation, this development is not enough to drive IBEMS adoption and evolution at scale.

Operators selected "too much energy is wasted" as the second biggest pain point related to energy management in buildings, behind only cost. This points to the need for more advanced energy management applications in buildings, which can leverage emerging technologies like AI/ML and emerging capabilities such as grid interactivity to further reduce wasted energy in buildings. By clearly understanding that more opportunities for energy savings exist in buildings, operators are expressing the need for IBEMS solution evolution.

2.2.4 Cost and Usability IBEMS Features are Top-of-Mind for Users

After respondents listed their pain points, they were asked how they prioritize different features of IBEMS, to drive a better understanding of where suppliers should focus their solution development efforts. In many software applications, key trends such as usability and automated data integration and reporting/export have driven the adoption of these systems in mission-critical and commercial environments. In addition, advanced analytics capabilities, such as unsupervised machine learning, have begun to allow software systems to run autonomously with little to no manual operation required. Building operators generally also desire capabilities related to these trends (Figure 2.13).

Figure 2.13 IBEMS Features That Influence Procurement



Source: CABA Intelligent Building Energy Management Systems 2020 Report

Usability was the top choice, reflecting a desire for IBEMS with simpler interfaces that can be used by more users, even those without deep technical knowledge. Data scientists are typically not staffed by facilities operators, so using a system that requires this knowledge demands an expensive hire or external contractor. The next top two features were both related to cost, and they reflect that up-front costs (capital expenditures) are more cumbersome than recurring costs (operating expenditures). This promotes the idea that energy management-as-a-service (EMaaS) subscription-based pricing models may be more attractive to building operators than up-front capital spending.

2.3 OCCUPANTS ARE WILLING TO PAY FOR BETTER, MORE EFFICIENT ENERGY MANAGEMENT

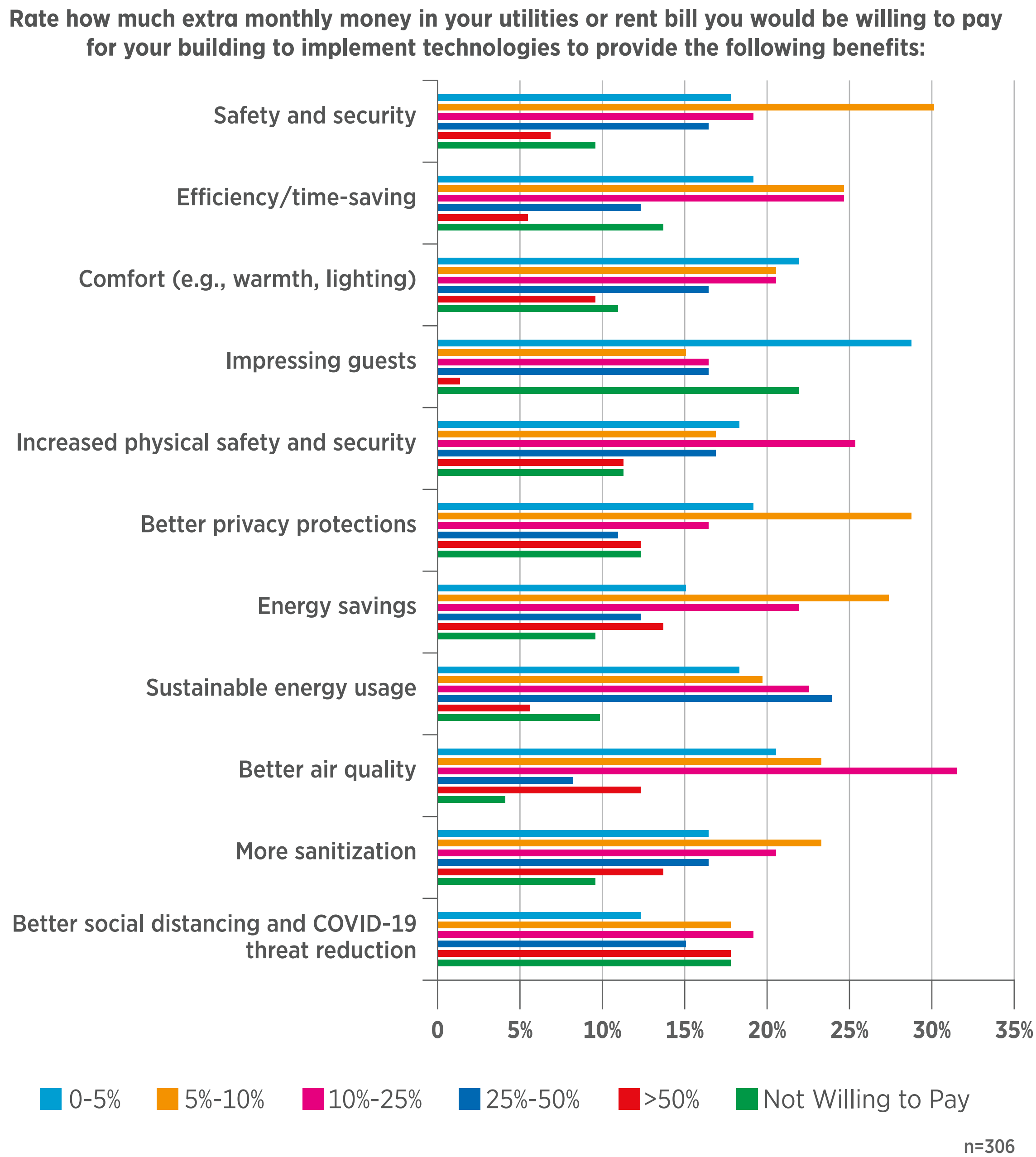
As a subset of the survey to operators, a separate survey branch was fielded for office managers and office procurement personnel who work in commercial building segments. Beyond establishing that these personnel value and prioritize energy management and sustainability in buildings, these questions also highlighted building needs and functions that respondents would be willing to pay for.

With a better understanding of what their tenants would be willing to pay for, operators can help alleviate some of their cost concerns and better improve occupant comfort and satisfaction. These results show that energy efficiency and sustainability are in-demand for occupants and should therefore drive operator procurement decision-making.

2.3.1 Occupants are Willing to Pay for Safety-Critical and Cost-Related Benefits

As seen in Figure 2.14, office managers and related personnel are most willing to pay an increased rent bill for solutions that provide better air quality, safety and security, and energy savings. By following the purple bar in the graph below, viewers can map each building benefit by how many respondents indicated that they would not be willing to pay for them. Items where the purple bars are higher, like social distancing, imply a stark difference in willingness to pay.

Figure 2.14 Occupants Will Pay for Safety-Critical and Cost-Related Benefits



Source: CABA Intelligent Building Energy Management Systems 2020 Report

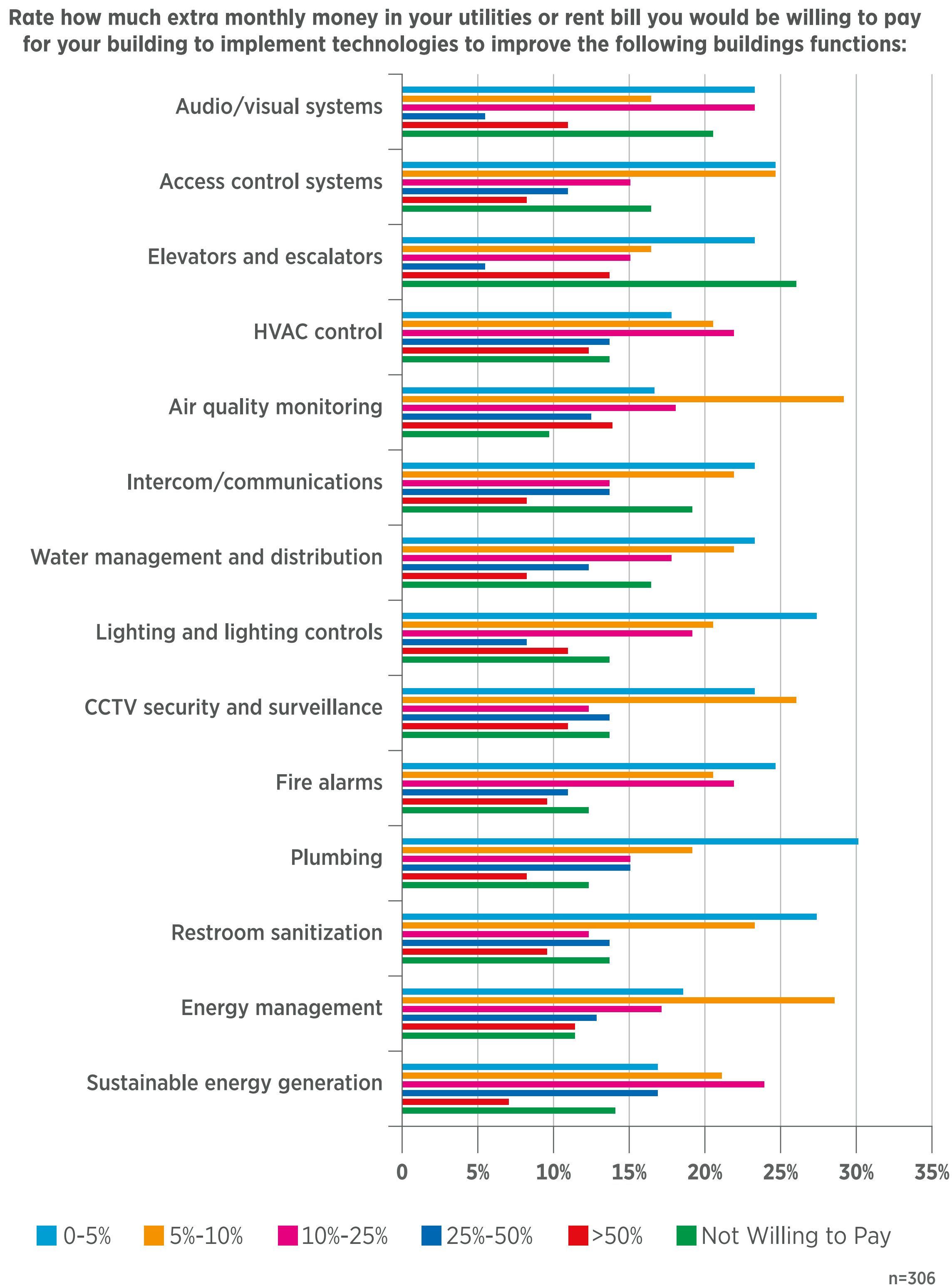
Perhaps due to concerns around returning to work amidst the COVID-19 pandemic, more than 95 percent of respondents indicated that they would be willing to pay for better air quality, even above safety and security, a key need that has driven the rise of integrated security services in residential homes and buildings. However, energy savings and sustainability were the third and fifth selections in terms of what occupants would be willing to pay for, but compared with the other selections, more respondents indicated that they would be willing to pay a smaller rent increase (0-10 percent) rather than larger (>10 percent) for these benefits.

Efficiency, impressing guests, privacy, and better social distancing were the features for which the fewest respondents indicated that they would be willing to pay. Discrepancies in the social distancing results may imply a discrepancy in belief of its effectiveness to drive safety, especially as more research implicates air particles as a higher cause of the disease's spread. Interestingly, respondents deprioritized their own comfort in relation to their safety, air quality, and energy efficiency.

2.3.2 Operator Willingness to Pay Correlates with the Perceived Value of IBEMS Solutions

When the same respondents were then asked to rate how much they would be willing to pay for technologies instead of the benefits they provide, similar trends manifested (Figure 2.15). Nearly 88 per cent of respondents indicated that they would be willing to pay increased rent or utility bills for better energy management technologies.

Figure 2.15 Occupants Will Pay for Energy Management Technologies



Source: CABA Intelligent Building Energy Management Systems 2020 Report

Fewer respondents would be willing to pay for sustainable energy generation, though more respondents would be willing to pay larger amounts (>10 percent) for this technology. Regional and age differences could affect this result, but it also may stem from a lack of education and best practices around sustainable energy generation in buildings. As buildings look to add sustainable power generation to offset technology and utilities costs and decrease emissions, operators must educate their occupants as to the importance of integration DERs, as well as how they can support energy management. In addition, technology advances, such as cheaper and more energy-efficient battery storage systems, might increase the willingness of occupants to pay for sustainable energy generation and storage.

With occupant, architect, and operator needs and pain points in mind, suppliers can better tailor their solutions to real-world users and buildings. Though IBEMS are well-adopted across buildings, the benefits they provide are often intangible and difficult to understand, and their adoption alone does little to end energy waste and cost issues. Each building owner and operator needs to continuously pulse their occupants/stakeholders to better procure and configure IBEMS to meet their needs.

2.3.3 Occupants Prioritize Living Cost and Indoor Air Conditions

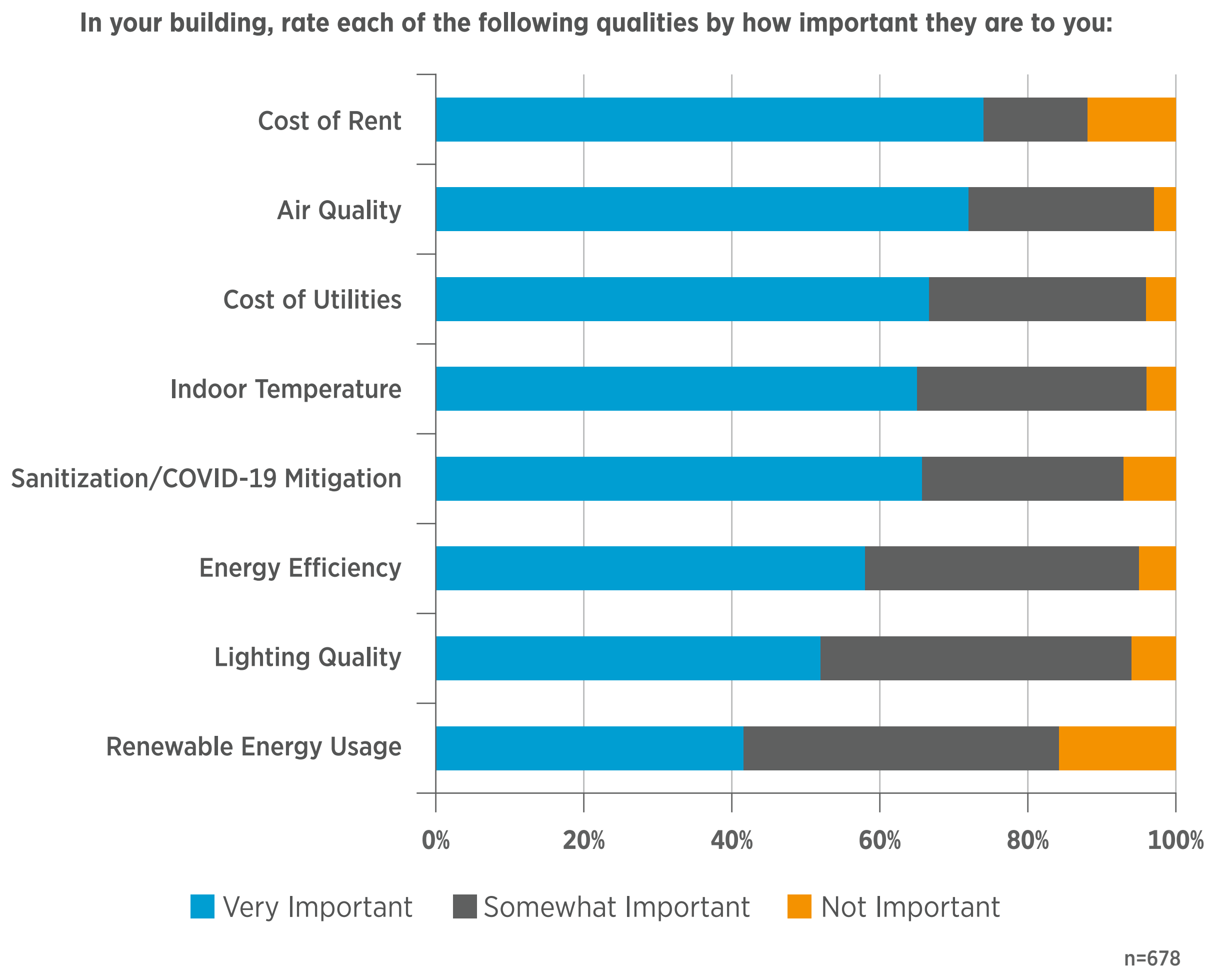
To augment the operator survey, which targeted office managers and related in-building operations personnel, we also deployed a survey to general buildings occupants to help pinpoint how occupants prioritize buildings functions and their willingness to sacrifice them in return for cost savings.

However, the satisfaction of building occupants is incredibly important to building owners, operators, and facilities managers. In fact, the performance of most facilities managers is measured using metrics such as tenant churn/turnover rate and occupant satisfaction, measured by the total number of occupant complaints. For IBEMS solutions to truly add value to their users, they need to meet the needs of their “end-users". Therefore, IBEMS applications that achieve energy efficiency while increasing occupant satisfaction can catalyze market adoption and accelerate its evolution.

> “The first goal [of HVAC installation and maintenance] is always occupant comfort. At a high-level, the entire point of HVAC is to enable more comfortable conditions for occupants. Services or products that fail to realize this will ultimately fail to provide value in buildings.”
>
> -HVAC Service Technician, Tolin Mechanical Systems

When specifying and configuring IBEMS, solution providers and users must ensure that their energy efficiency tactics do not interfere with occupant needs or preferences. As shown in Figure 2.16, building occupants are most concerned with in-building costs and air conditions.

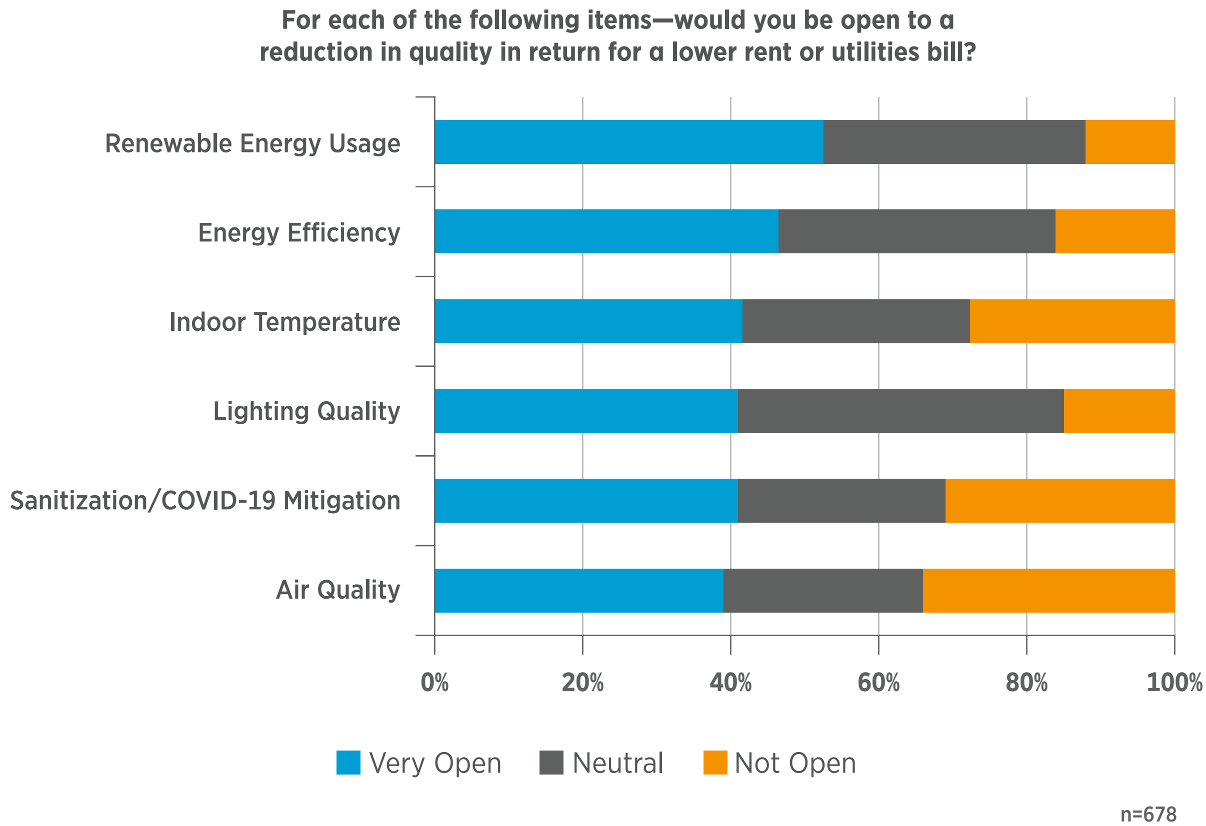
Figure 2.16 Occupants Prioritize Cost and Air Conditions



Source: CABA Intelligent Building Energy Management Systems 2020 Report

In addition, occupants are most willing to sacrifice energy efficiency and sustainability in favor of a lower rent or utility bill (Figure 2.17).

Figure 2.17 Occupants are Willing to Sacrifice Energy Efficiency and Sustainability



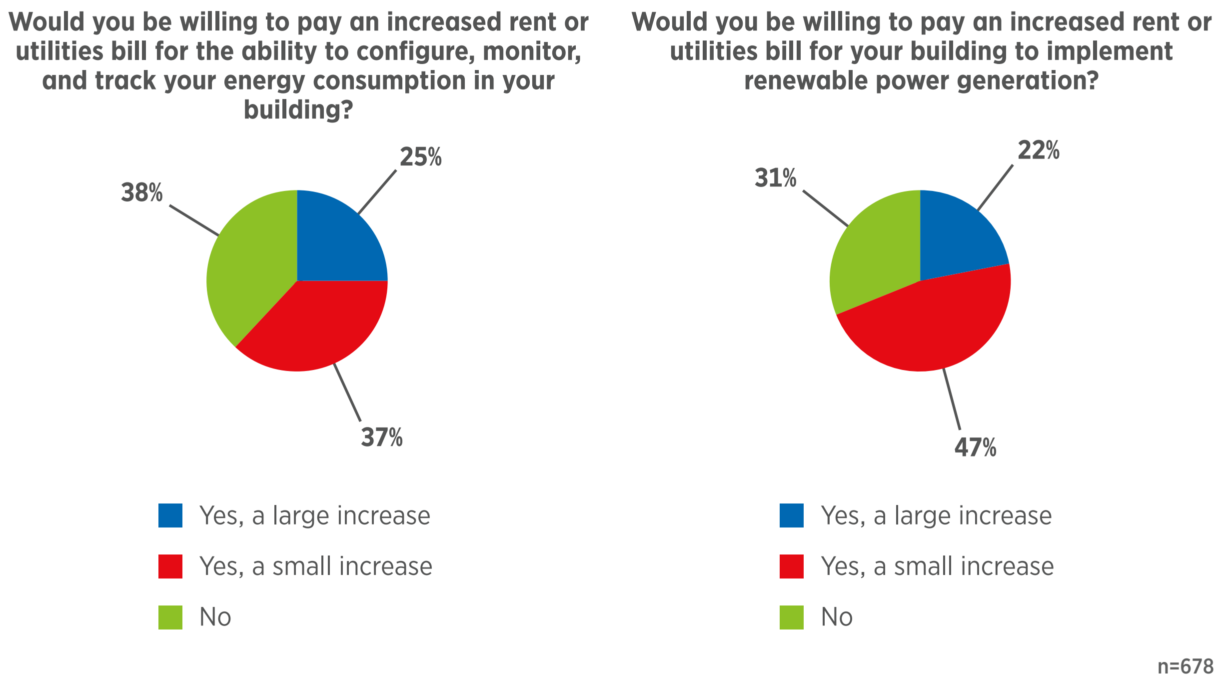
Source: CABA Intelligent Building Energy Management Systems 2020 Report

When implementing energy management solutions and best practices, operators need to be cognizant of their occupant's comfort at all times. Occupant surveys can help operators understood the specific needs and ideal conditions for their tenants, allowing them to tailor IBEMS configurations to achieve energy efficiency without sacrificing comfort. In addition, occupancy sensing technologies can help automatically schedule HVAC and lighting controls to drive energy efficiency during periods of vacancy. Analytics can further add value by predicting vacancy and peak load periods.

2.3.3 Occupants are Willing to Pay for Energy Control and Sustainability

Although occupants indicated their willingness to sacrifice energy efficiency and sustainability in favor of rent reduction, the inverse of this trend holds true as well—when asked whether they would be willing to pay for energy configuration and sustainability, the majority of occupants responded that they would be willing to pay (Figure 2.18).

Figure 2.18 Occupants are Willing to Pay for IBEMS-Related Functions



Source: CABA Intelligent Building Energy Management Systems 2020 Report

These contradictory survey results paint an interesting picture of how occupants view energy management and sustainability in buildings. While many would be more willing to sacrifice these functions in return for cost savings than other mission-critical functions like air and lighting quality, many would be willing to pay more for greater energy control and sustainability. By relinquishing some energy management control and influence on occupants, operators can at once improve occupant satisfaction while helping recoup the cost of technology investments.

Software suppliers have long ignored the needs of their users, which has led to the industry best practice of user-centered design (UCD). However, focusing purely on usability ignores the true value potential of developing solutions that meet the goals of users, namely improving occupant satisfaction and retention in buildings. If IBEMS providers want to improve the value of their applications, they should carefully consider how energy management strategies and adjustments affect occupants of buildings.

Notes:

1 Respondents were asked to select all answers that apply, and the graph shows what percentage of respondents selected each value. Percentage values will not total 100%.

2 Respondents were asked to select all answers that apply. The graph shows what percentage of respondents selected each value. Percentage values will not total 100 percent. This holds true for some subsequent graphs.

3 ENTOUCH Controls (2020, August). Capital Funding Solved. https://entouchcontrols.com/wp-content/uploads/2020/08/ENTOUCH-Capital-Solved-FINAL-08032020.pdf

3. THE EVOLUTION OF IBEMS AND HOW THEY COEXIST WITH IN-BUILDING TECHNOLOGIES

Technological advances are enabling the shift from basic building automation and management systems to integrated intelligent building systems. Chief among these are processing and data management innovations, which are accelerating development of distributed computing architectures. While standard communication protocols such as BACnet and LonWorks have gained significant traction, organizing around standardized data formats has been less successful and still is an obstacle to enabling complex applications without unduly burdening users with complicated device interactions. Innovators seek to address the challenges posed by the fragmented equipment supplier market with software advances across the technology stack, from networking and application deployment to device communications and application enablement.

3.1 IBEMS SOLUTIONS INTRODUCTION AND OVERVIEW

IBEMS can be characterized as a suite of software and platforms tools that leverage data from control and automation systems, metering infrastructure, distributed sensor networks, and external business intelligence and utility systems. The growing demand for greater visibility and control around energy usage and consumption, in conjunction with the increasing availability of emerging technologies, has led to a consistent cycle of innovation and progress around IBEMS.

IBEMS have evolved in parallel to building control and automation, providing a layer of power network applications designed for three core objectives: reduce and manage building energy use, reduce cost while increasing occupant comfort and productivity, and improve environmental stewardship and ensure compliance with sustainability regulations.

Currently, most buildings have adopted one of two key models of IBEMS—either standalone EMS software applications for buildings, or energy management capabilities and features that exist as part of a larger BMS or BAS. While the energy management functions of each deployment model are relatively similar, each path has distinct challenges and benefits over the other.

> "Both of those paths—standalone EMS systems and integrated BAS/BMS systems—are fairly robust. On one side, EMS-capable BAS systems, like [those from] Johnson Controls and Honeywell, feature more integration with buildings systems, while others feature a software application on top of those systems that does not require as much integration."
>
> -VP of Global Product Development, Johnson Controls

Each deployment model features unique strengths and weaknesses:

- **Standalone EMS Applications:** Energy management software applications independent of other buildings systems, that provide submetering, monitoring, and analytics functions.
  - **Strengths:** Ease of installation and integration, as the systems must only collect data from external systems and sensors without having to control them.
  - **Weaknesses:** Adds a layer of complexity, as operators must operate, maintain, and pay for two systems. Standalone EMS often require a cloud connection.
- **EMS Features Integrated in BAS/BMS:** Energy management features and functions as a module or feature set of BAS/BMS. This allows for additional uses like automated control.
  - **Strengths:** BAS/BMS allows for a central user interface (UI) and provides visibility into all systems, and it adds additional context/data beyond energy data.
  - **Weaknesses:** Systems are larger and difficult to continuously update. The BAS/BMS market also features frequent vendor-lock in and are often outdated.

However, as intelligent buildings mature, energy management practices and systems must inherently work closely with automation and controls systems, allowing for automated adjustments to appliances to better manage energy and leverage DERs. While this would seem to point to the model of EMS integrated on BAS/BMS systems, it actually needs a more holistic change to systems architecture in buildings. Specifically, a new layer must emerge—the application/analytics overlay.

3.1.1 Components and Capabilities of Available IBEMS Solutions

IBEMS solutions serve a diverse set of stakeholders and end-users, from building operators to utility providers. As such, they need to be designed to be configurable and flexible compared to the objectives of the user. IBEMS can be characterized in terms of three hierarchical levels of functionality—management, production, and field. Across each of these levels, IBEMS capabilities and requirements vary to ensure seamless integration and with building control and automation as well as external systems such as the electricity grid.

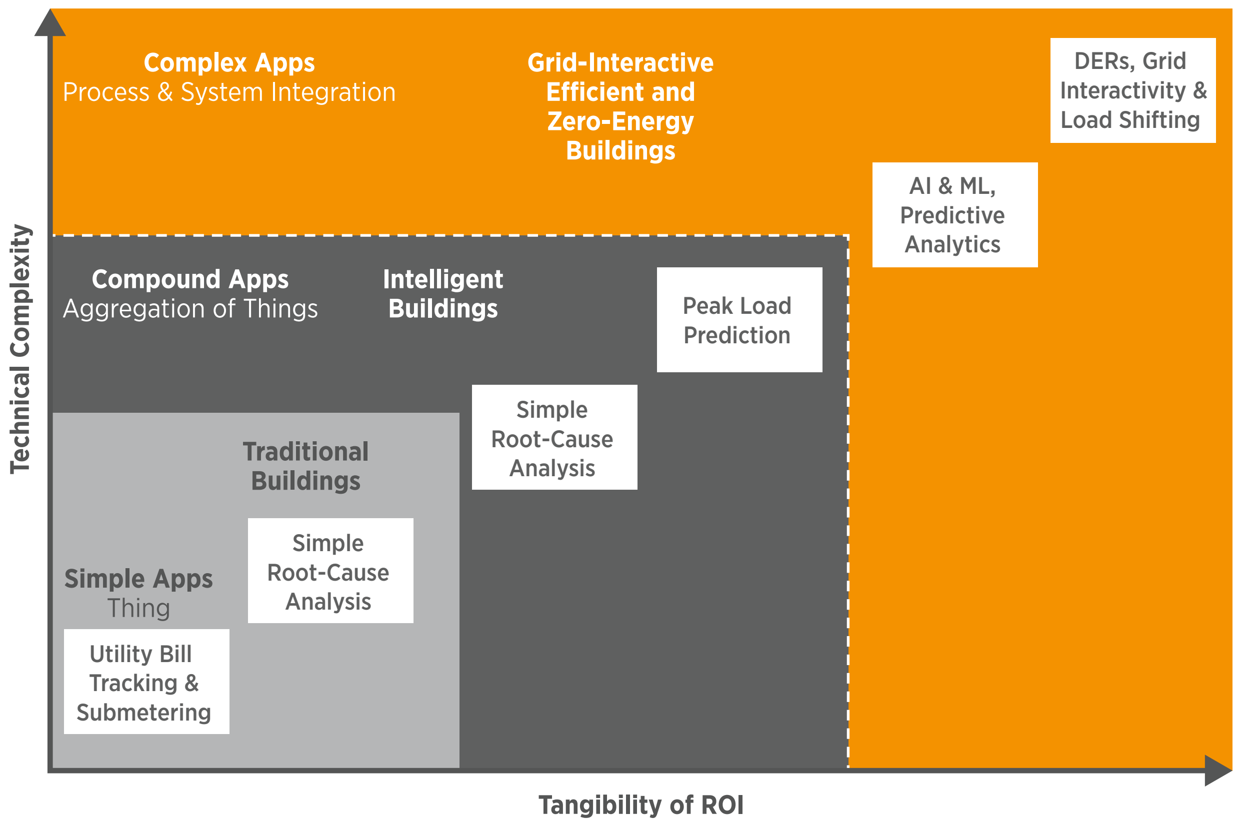
At the lowest level of functionality, IBEMS solutions are tied to data acquisition and control systems. These field-level systems are part of broader building control and automation systems, including HVAC, lighting, security, and other operational networks. Field level systems then feed production level interfaces, which aggregate, monitor, and process data to feed control logic to edge nodes or is sent to a central database or management system. The highest level of energy management systems is the management level, where company- or plant-wide analytics occurs to optimize energy consumption through value added applications including automated load balancing, predictive maintenance, and energy audits to optimize the energy profiles of buildings for relevant stakeholders. Although the above technological capabilities exist, very few buildings can use them.

> "While many of our clients have energy management systems in place, they are using them as little more than a glorified scheduling tool."
> -Energy General Manager, Dude Solutions

As shown in Figure 3.1, for operators to adopt and implement advanced energy management applications like predictive analytics, they need to invest in significantly upgrades to buildings infrastructure.

Figure 3.1 For More Advanced IBEMS Applications, Buildings Need to Evolve

The Evolution of Intelligent Building Energy Management Systems Applications



Requirements for Stage 2

- Smart meter integration
- Upgrades to network infrastructure
- Interoperable network protocols
- Device-based energy monitoring capabilities and sensing
- External data source integration (e.g., weather data)

Requirements for Stage 3

- Data lake and EMS application overlay
- 60 Hz utility (power line) frequency
- Occupancy sensing
- Attractive utility incentive programs
- Thermal and energy storage
- Advanced metering infrastructure

Source: CABA Intelligent Building Energy Management Systems 2020 Report

Today, most building operators use IBEMS for root-cause analysis in a reactionary manner in response to faults or occupant complaints. For example, an operator might open their EMS after an occupant calls to complain about a lack of heat on their floor during winter. That operator looks at the EMS to get a sense of the current operations of the HVAC system to determine is a problem exists.

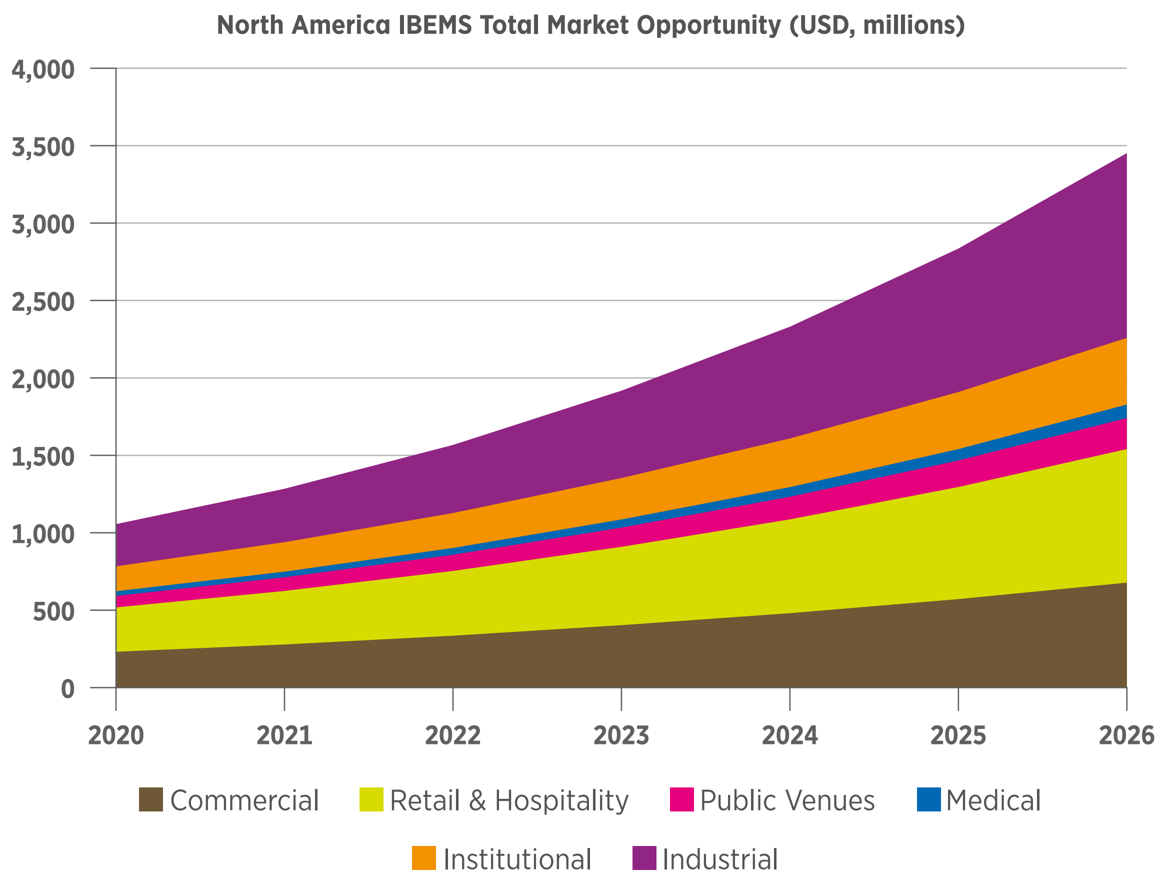
> "Energy savings are all about what I call the three Ss: sequences, subpoints, and schedules. While you can do all of them inside of a BAS, it's often difficult and expensive for operators."
>
> -Founder, Nexus Labs

This example is emblematic of how most IBEMS application are used today—to react to issues and determine their cause. Few operators have historical energy data capabilities or predictive capabilities in their IBEMS, instead only having a current-state view of energy data. For historical energy views and reports, operators need a data storage mechanism—simply uploading a spreadsheet to a business intelligence (BI) tool is not enough. With a database in place, operators can then make predictions on future energy data based on historical data patterns. However, operators lack these capabilities and instead pay for an expensive scheduling and root-cause analysis tool.

3.1.2 Supplier Landscape and the Evolution of the IBEMS Market

As shown in Figure 3.2, the IBEMS market is rapidly growing, both in terms of volume and revenue opportunities. Harbor Research forecasts this market as growing at a 22 percent CAGR to represent more than a $3B market opportunity by 2026.

Figure 3.2 The IBEMS Market Exceeds $1B, Growing at a 22% CAGR



Source: CABA Intelligent Building Energy Management Systems 2020 Report

Currently, the IBEMS market landscape is fragmented, with startups attempting to disrupt entrenched incumbents, whose systems are outdated, difficult to integrate, and do not incorporate emerging technologies. However, no single innovator has emerged as the market leader, and no business model has been adopted at scale to replace incumbents. Innovators are taking different approaches to the IBEMS space, with some focusing on digital twins and others on automation (Figure 3.3).[1]

Figure 3.3 Innovators are Approaching the IBEMS Market From Different Angles

Incumbents	Emerging Innovators			
Large, Established BAS/BMS Providers	**Utility Bill Tracking & Submetering**	**Building Analytics**	**Automated Supervisory Control**	**Digital Twins**
Johnson Controls	Dude Solutions	bep	BRAINBOX AI	PassiveLogic
SIEMENS	OnPoint	C3.ai	BuildingIQ	willow
TRANE	energyhippo	CORTEX	VERDIGRIS	ZYNKA BIM
Schneider Electric	goby	ENTOUCH	sensorsuite	SPACEWELL
McKinstry	GRIDPOINT	riptide	AXIOM CLOUD INC	LEAN fm
Automated Logic	SENSEI	SkySpark	SMART LOCUS	ThoughtWire
Honeywell	Wattics	ECOENERGY INSIGHTS	Hank	invicara

Source: CABA Intelligent Building Energy Management Systems 2020 Report

As depicted above, many different suppliers are attempting to capture the IBEMS market opportunity with different approaches. However, some players do not fit cleanly in any of the categories, especially as they seek to differentiate their solutions to influence adoption. While these business models have yet to define an industry standard, they could emerge. Some of these key innovators include:

- **SkyFoundry:** SkyFoundry's application **SkySpark** is widely used for building analytics, but SkyFoundry prefers to sell its solution through value-added resellers and system integrators. These partners—such as **ANKA Labs**, **Connexxion**, **EntroCIM**, and **Kodaru**—will configure and customize SkySpark for use in specific buildings and customer environments.
- **Brainbox AI:** Brainbox.ai tackles energy efficiency by focusing on the biggest energy consumer in buildings—HVAC systems. After studying buildings data, Brainbox.ai autonomously optimizes HVAC controls to optimize energy consumption, without human intervention.
- **75F:** 75F is an innovative company that focuses on improving occupant comfort in addition to optimizing energy consumption. It leverages IoT devices, sensors, and a cloud connection to continuously optimize indoor environmental conditions to conserve energy.

- **SensorSuite:** SensorSuite is a wireless HVAC control technology that has primarily focused on electrically heated buildings in the portfolios of large apartment REITs. More recently, they have been able to detect faults and improve performance in RTUs on large format retail buildings and are looking to leverage their hardware and software systems to provide demand response capabilities in the future.
- **ThoughtWire:** A digital twin platform that enhances the overall IBEMS in a building by connecting multiple management programs onto one digital command center for a property.

The traditional buildings energy management value chain is transforming in the era of new intelligent buildings technologies. With the influx of new technologies, OEMs and service providers have new opportunities to provide value to customers through smart systems and services. Technology suppliers are becoming a driving competitive force in this value chain, with growing influence on traditional suppliers and other buildings market participants. At the same time, building managers, owners and operators and utility providers across all building types are pressuring their suppliers to provide new products and support services, paired with more flexible, innovative payment methods. These forces are resulting in shifting competitive and ecosystem dynamics that need traditional equipment and service providers to take an innovative approach.

With a regulatory environment continuously establishing new precedents for sustainable operations, IBEMS solutions need to quickly prove ROI and catalyze energy management strategies. Significant savings can result within a building when combining IBEMS with DERs by continuously optimizing the energy generated and how it is used within the facility.

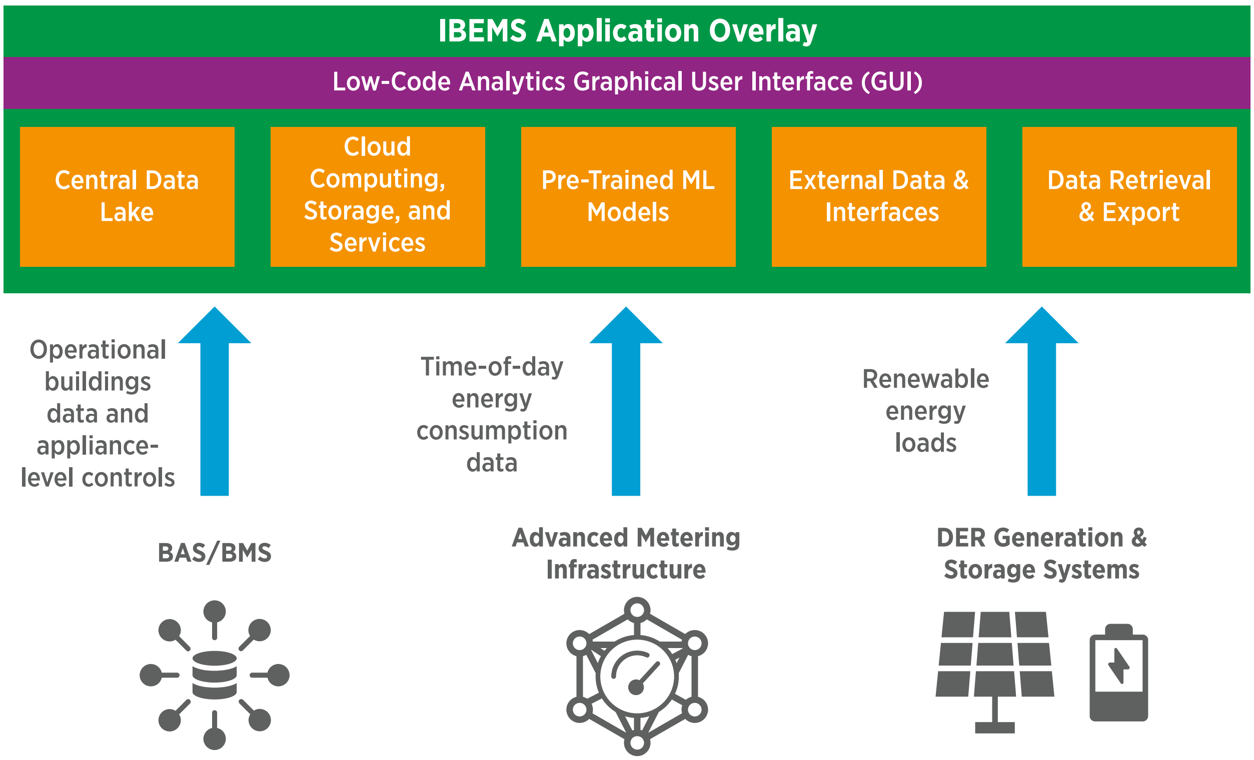
3.1.3 Issues with Building Automation & Control Point to the Need for an Overlay

Current IBEMS solutions, especially those from incumbents like **Trane** and **Johnson Controls International** (**JCI**) often only integrate with devices from certain brands or manufacturers. In addition, these manufacturers promote vendor lock-in by selling professional services, such as customer support and maintenance, exclusive to their product. In addition, the high amount of revenue that these professional service contracts bring to companies like **Trane** and **JCI** can create disincentives for these companies to offer remote support and automating work steps.

By leveraging brand awareness to sell products alongside multi-year service contracts, and by heavily promoting the adoption of added products and services from the same supplier, these incumbents are able to achieve vendor-lock in, where operators have little choice but to stay with the supplier because of the high costs and time needed to replace solutions and services. These companies then have little reason to invest in augmenting their products with value-added capabilities such as predictive analytics and automated energy optimization. This results in a high adoption density of outdated, expensive IBEMS applications that lack capabilities beyond simple root-cause analysis and scheduling.

Innovative solution providers have innovated given these constraints by creating applications that sit on top of BAS/BMS systems, rather than replace them. By creating a new application overlay that ingests data from BAS/BMS systems and the associated devices that they control, suppliers can add advanced technical capabilities, such as machine learning (ML) models, without having to reconfigure or replace BAS/BMS systems. In addition, this layer (Figure 3.4) can easily integrate new data and energy sources, such as DERs, without having to integrate them with the BAS/BMS.

Figure 3.4 IBEMS Evolution Requires Application Overlay Innovation



Source: CABA Intelligent Building Energy Management Systems 2020 Report

Within the IBMS overlay, five key functions are required to enable AI and predictive analytics:

- **Data Lakes/Central Data Storage:** For analytics to occur, buildings need the ability to store data from all systems and devices in a single, retrievable database or data lake. This storage system needs to be flexible and scalable, such as **Microsoft**'s Azure Data Lake.
- **Cloud Computing, Storage, and Services:** Currently, inferencing applications that require significant computing power are unable to occur at the edge, and therefore necessitate a cloud connection. Cloud computing also allows for disaster recovery, long term data storage, virtual instances/containers, and other services.
- **Pre-Trained, Out-of-the-Box (OOTB) Machine Learning (ML) Models:** Modern ML packaged applications usually come with pre-trained models, which allow users to quickly stand-up and run ML applications OOTB without data science expertise. These models can be pre-trained with data from other buildings and be tailored to a building's function, allowing them to quickly add value by identifying and optimizing energy inefficiencies.

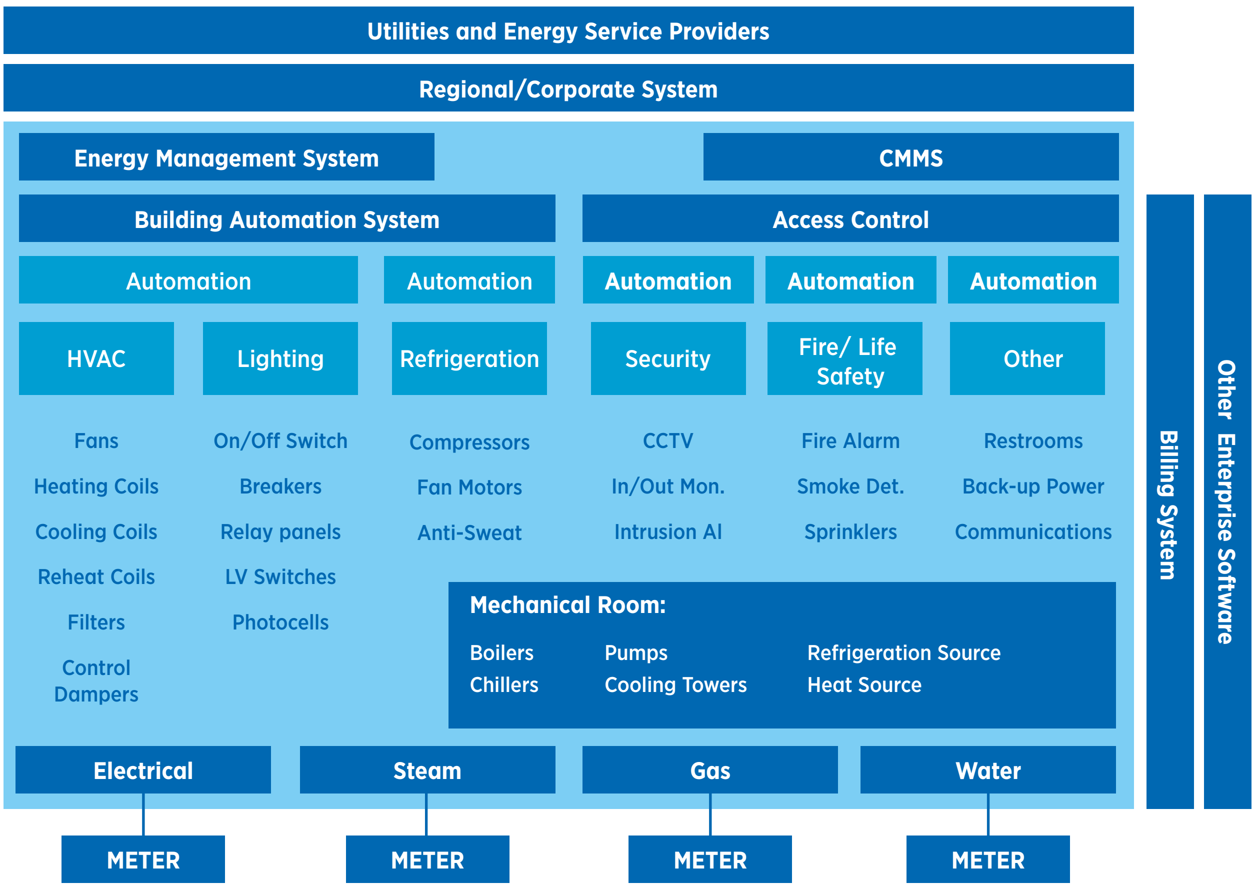
- **External Data Integration:** This application overlay should also integrate from external data sources, such as weather data, utilities data, and time-of-day energy consumption data from Smart Meters. This allows for greater data contextualization and more nuanced applications.
- **Data Retrieval and Export:** Lastly, this overlay should provide an intuitive, simple user graphical interface (GUI) that allow users to monitor and track energy usage in buildings. In addition, data export functions to XLS, CSV, and other formats allows for even easier root cause analysis, reporting/audit support, and analyzing key energy consumption trends.

For this overlay to arise and drive adoption in buildings, BAS/BMS suppliers need to embed their systems with open protocols and APIs to easily share and integrate their data and controls.

3.2 THE ROLE OF IBEMS IN THE INTELLIGENT BUILDINGS TECHNOLOGY LANDSCAPE

For IBEMS to provide value to buildings, they need to effectively interact with other systems within buildings. For operators, massive energy savings can be achieved by upgrading or retrofitting their systems with connectivity, configurability/control, and sensing capabilities. Figure 3.5 depicts a systems architecture example of IBEMS interacting with buildings systems.

Figure 3.5 IBEMS Must Consider Other In-Buildings Systems and Functions



Source: CABA Intelligent Building Energy Management Systems 2020 Report

For IBEMS suppliers to deliver more value to operators, and for operators to effectively optimize energy efficiency in their buildings without sacrificing occupant comfort, both parties must understand the specific energy needs and idiosyncrasies of major buildings systems and functions. In addition, IBEMS suppliers need to understand that energy efficiency cannot come at the cost of equipment reliability and safety—requiring these suppliers to understand the specifics of each device IBEMS interact with.

3.2.1 Occupant Comfort Systems (Lighting, Lighting Controls, and Shading Systems)

As shown in Figure 3.6, modernizing lighting systems can lead to massive energy and cost savings.

Figure 3.6 Case Study: Amatis Controls Lighting Modernization Leads to Massive Cost Savings

Vancouver Board of Trade Tower:
Achieving Energy Savings Through Lighting Controls Modernization

About five years ago, Golden Properties was facing significant issues with energy management and lighting controls in one of its buildings, the Vancouver Board of Trade Tower at 1177 West Hastings, Vancouver. However, since the building is constructed out of a large amount of concrete, rewiring the lighting systems in each floor was very expensive and difficult. In addition, the building's age (built in 1968) and the difficulty of making upgrades meant failure to comply with building standards and meet occupant needs.

In 2015, Golden Properties chose Amatis Controls to modernize its lighting systems

Amatis not only provided new lighting controls to the building, but they also developed new LED lighting fixtures without pulling a single wire, and they provided an easy-to-use smartphone application to easily manage lighting configurations. Amatis's solution was able to collect temperature, humidity, and daylight data from a single sensor, and integrated seamlessly with the building's BAS system.

BEFORE Amatis Lighting Controls
Non-compliant with buildings standards
Harsh fluorescent light quality
~60% of energy wasted
High operation and maintenance costs, difficult to rewire and upgrade
Difficult to view and configure lighting controls for individual floors

AFTER Amatis Lighting Controls
45,210 kWh annual savings per floor
$5,000 annual energy savings per floor
73-80% energy use reduction per floor
Seamless integration with Trane Ensemble BAS
Increased occupant satisfaction with in-building light quality

Source: CABA Intelligent Building Energy Management Systems 2020 Report

Modernizing lighting systems can lead to massive, quickly realized cost and energy savings with some simple tactics. For example, merely upgrading fluorescent or incandescent lighting fixtures to LED light can reduce lighting-related energy consumption by up to 75 percent.[2] In addition, LED lights emit less heat and last longer than fluorescent or incandescent light bulbs, lowering maintenance costs and lowering the interference with HVAC system heating processes.

However, upgraded lightings systems on their own do not represent a sustainable energy management strategy, because they must be integrated into IBEMS and feature automated controls to truly drive long-term energy efficiency. By using either BACnet protocols or gateways, operators can schedule lights to turn off in response to occupancy sensors and better integrate lighting systems with HVAC controls to monitor and reset zone temperatures automatically. In addition, lighting controls can collect energy load data related to lighting, which can be used for load shedding and utilities rebates.

For further lighting-related energy reductions, buildings need to integrate smart shading systems with their lighting controls systems. Currently, there is little understanding of how much window shading contributes to daylighting and room temperatures/heating. Shading systems include glazing and daylighting capabilities which can drastically affect room temperatures and lighting conditions. By enabling connectivity in windows shades through the implementation of sensors and actuators, these shades can automatically respond to changing outdoor conditions throughout the day.[3] This allows for coordination with HVAC and lighting controls systems to optimize room temperatures and lighting conditions with outdoor sunlight and heat insulation—minimizing the use of electrical power.

In a typical commercial office building, lighting accounts for 20-50 percent of all energy consumed.[4] Each of the above strategies (retrofitting lighting controls, implementing LED lighting fixtures, and adopting smart shading systems) seem relatively simple to implement, and can lead to massive cost and energy savings. However, operators still struggle to make these changes, due to difficulties with integrating lighting, controls, and shading systems in a holistic manner. Only by planning for and understanding how individual components of lighting systems can leverage synergies by working together to comprehensively optimize energy efficiency and sustainability can operators achieve value.

Recent theories highlights the importance of simulating natural, outside conditions in buildings design. Biophilic Design speaks to the value of building indoor spaces to reflect natural conditions in order to improve health, promote cost savings, and improve occupant comfort.[5] As biophilia emerges, integrated lighting and shading systems will be needed to effectively incorporate natural light and heat.

As described in Figure 3.7, a lack of buy-in and understanding prior to lighting system implementation is exactly what challenged the **U.S. Green Building Council (USGBC)**. However, with support from vendors like **Legrand** and with detailed planning for how lighting systems would integrate with shading and lighting controls, USBGC was able to solve this challenge and reduce lighting power by 34 percent.

Figure 3.7 Case Study: The USGBC Saves Energy Through Modernizing Lighting Controls

Digital Lighting Management: An Integration Success Story

U.S. Green Building Council's Headquarters

CHALLENGES

USGBC used a legacy lightings control system that had difficulties integrating with buildings systems from other manufacturers

USGBC's headquarters features multiple rooms with modular designs. Its lighting system was inflexible to changing layouts

In 2009, the U.S. Green Building Council (USGBC), the agency who developed the LEED rating system, unveiled a new headquarters building in Washington, DC.

In order to walk their talk, the facility sought LEED Platinum certification of their 2 floors in a larger Class-A commercial office in downtown D.C.

However, by 2015, the building's lighting control systems were outdated and incapable of meeting the building's advanced energy management needs.

SOLUTION

Flexibility: To allow for flexibility in reconfiguring office furniture, huddle rooms, and private offices, the USGBC opted for Legrand's digital lighting management (DLM) solution with high sensors density that ensured responsiveness of lights, no matter the configuration.

Integration: USGBC also installed architectural lighting fixtures, a smart shade system with rooftop sensors that measures daylight and works in conjunction with the DLM system, and a remote monitoring system to ensure the lighting operated as intended.

Eco Corridors: To improve occupant well-being, in addition to the lighting and shading system, USGBC implemented "Eco Corridors", which allowed sunlight to penetrate deeper into the space and reach more occupants.

BENEFITS

- **34% reduction** in lighting electricity
- **Higher** occupant comfort ratings
- **Easier** programming & configuration
- **New capabilities**, including circadian programming & smart time scheduling

"The DLM system offered the best opportunity to meet our energy efficiency and sustainability goals...It allows for flexibility with different tenants, offers reliability, lighting control efficiency, and interfaces with our HVAC system to lower electrical consumption and offer additional energy savings."

-Melanie Mayo-Rodgers, USGBC Facility Manager

Source: CABA Intelligent Building Energy Management Systems 2020 Report

3.2.2 Uninterruptible Power Supply (UPS) Systems, and Failover/Disaster Recovery

At a high level, uninterruptable power supply (UPS) systems provide immediate emergency power loads in response to failure. In addition to allowing for continuity of operations and consistent occupant comfort, UPS systems also improve safety by solving for voltage spikes, sags, distortion, or other events, and ensure the safety of critical, expensive devices like servers.

Traditionally, UPS systems have been a critical part of data centers and other IT-focused facilities, given the high value of data center equipment and its continuous, intensive power demands. In commercial, institutional, and retail buildings, operators often lack this equipment and instead opt for cloud processing, servers, and instances rather than investing in on-premise servers. However, a cloud-only computing model is unsustainable due to latency and privacy requirements of emerging applications. Specifically, time-sensitive applications need on-premise computing and inferencing.

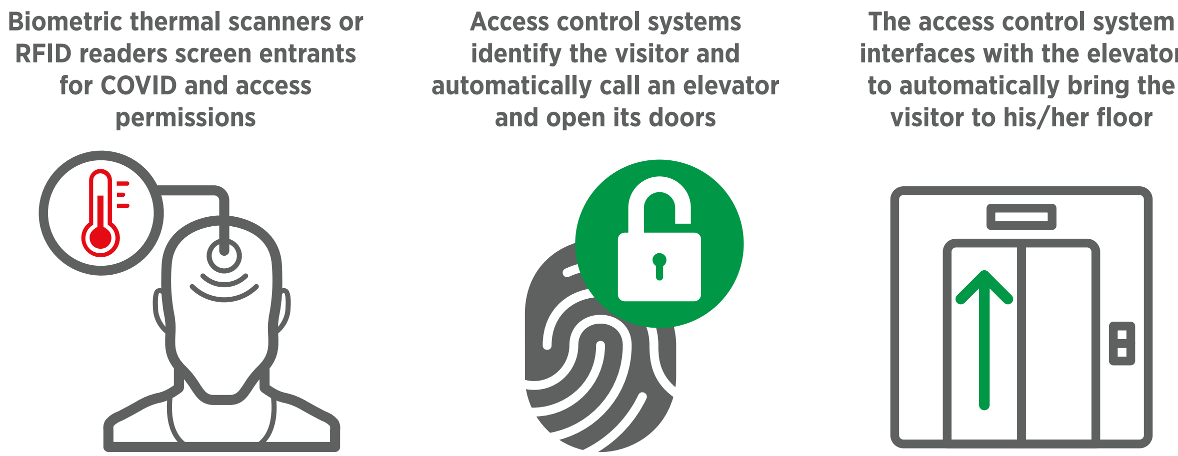
Therefore, a hybrid cloud-to-edge model is emerging to meet the technology needs of buildings. As buildings increasingly adopt more energy-intensive technologies, the importance of UPS systems will increase as well. As these systems are adopted, building operators should procure ENERGY STAR certified UPS systems, which can cut energy losses by 30-55 percent compared to standard UPS systems.[20]

However, DERs and Microgrids can replace of standard UPS systems. The primary difference between a UPS and a Microgrid is that the Microgrid will generate electricity from solar or a generator, and at the same time provide an uninterruptable supply of electricity for the critical load. Furthermore, these Microgrids can be used to provide power for not only the critical load, but the entire facility. As more buildings become capable of energy generation and storage, the role of UPS will decrease—but until that transition occurs, these systems will persist given the importance of continuous energy supply.

3.2.3 Access Control and People Moving Systems

One of the effects of the COVID-19 pandemic is an acceleration of demand for contactless solutions. Buildings, especially large commercial ones, feature many touch-based interactions, especially in functions related to access and entry (e.g., doors, elevators). To reduce these interactions and thereby creating a healthier, more efficient building environment, operators can invest in technologies to integrate secure access control with people moving systems (Figure 3.8).

Figure 3.8 Access Control & People Moving System Integration Reduces Contact Events



Source: CABA Intelligent Building Energy Management Systems 2020 Report

Integrating access control systems with biometric or RFID readers can allow buildings to automatically verify each occupant's access permissions in real-time. In buildings with frequent elevator usage like hotels, automatically restricting elevators from allowing guests to access floors on which they are not residing can both improve occupant safety and enforce social distancing. Other applications like this can arise, in addition to new security software and services—but only if access control and people moving systems are effectively integrated with other building functions.

3.2.4 Air Quality Monitoring and Chilling/Dehumidifying Systems

Air quality monitoring systems and energy management systems are intrinsically linked, since air temperature, CO_2 levels, relative humidity, and odor data can be collected and analyzed over time and in rooms, like energy usage and electricity consumption. Indoor air quality is one of the biggest factors that influence occupant health and comfort, so operators should invest in ensuring that buildings systems are in place that monitor and ensure high quality air circulation.

> "A big concern with COVID-19 is indoor air quality, because let us say you have someone in your building that has tested positive for COVID-19. Basically, you want to continuously circulate air in your building and replace it with fresh air. Therefore, commercial buildings normally have standards [that mandate] replacing the air with fresh air every hour or two—it is called air change level or rate."
>
> -HVAC Service Technician, Tolin Mechanical Systems

Currently, many cities across North America have mandate that retail outlets and restaurants maximize the use of outdoor space for uses like outdoor dining, in response to COVID-19. These mandates stem from the difficulty of ensuring consistent air quality in indoor spaces, especially with regards to mitigating the spread of respiratory diseases. For indoor quality to match or even exceed the safety and consistency of outdoor air quality, monitoring technologies must advance and be adopted at scale.

For example, occupancy sensors can be used in tandem with air quality monitoring systems to provide alerts and notifications to occupants based on air quality conditions, such as CO_2 levels. These sensors can also integrate with access control systems to switch off air quality monitoring or efficiently lower air change rates in response to occupancy or vacancy conditions, saving operation and energy costs. These systems are often a target for demand response programs.

In large commercial, industrial, and institutional facilities, water-cooled chillers are used over air-cooled chillers due to sustainability concerns. Chillers are often huge consumers of energy, especially in warmer climates where it is more difficult to cool and dehumidify outside air. However, as adoption of these systems has increased, new techniques have emerged to manage the energy consumption of chillers more efficiently. Specifically, variable speed or frequency drives allow operators to automatically sync chiller speed with load levels, which can reduce chiller consumption by up to 30 percent.

As seen in Figure 3.9, implementing higher-efficiency chillers, in combination with other IBEMS best practices, can help operators achieve significant energy savings without sacrificing occupant comfort.

Figure 3.9 Case Study: Combining BAS and Chiller Modernization Increases Energy Savings

Saving Energy Without Sacrificing Comfort: Rhode Island Department of Administration (DOA) Case Study

Within the Rhode Island DOA, the Office of Energy Resources (OER) works with State agencies to optimize energy consumption and sustainability across Rhode Island's public sector.

Rhode Island is committed to increasing energy efficiency and clean energy projects, and the OER wanted to better understand how the DOA building operates in order to optimize energy use without sacrificing occupant comfort.

To accomplish this goal, OER worked with **Siemens** to evaluate and implement energy management best best practices in the DOA building. After a detailed current state assessment, Siemens realized that energy was being wasted due to a lack of building-wide visibility and an aging building automation system.

In partnership with Siemens, the State of Rhode Island upgraded its previous building automation system to Desigo® CC and implemented energy conservation measures including water temperature reset strategies and a high-efficiency chiller with variable frequency drives.

After implementing these changes, DOA saves a weighted average of $15,000 a month due to energy savings, and was nominated for Rhode Island's "Lead by Example" award.

IBEMS Best Practices Used

- Sensor and actuator upgrades
- Desigo® CC BAS installation
- Water temperature reset strategies
- Air-side economizer implementation
- High-efficiency chiller with variable frequency drives

Near-Immediate ROI

- **$15,000** monthly energy savings on average
- Fewer occupant complaints
- Improved air circulation
- DOA building nominated for Rhode Island's "Lead by Example" award

"The project with Siemens gave us a much better understanding of the significant role building automation systems can play in energy efficiency and management, as well as building comfort."

George Sfinarolakis
Administrator of Energy Programs, State of Rhode Island

For more information, see: ***usa.siemens.com/rhodeisland***

Source: CABA Intelligent Building Energy Management Systems 2020 Report

As the Rhode Island case study illustrates, chiller modernization, when combined and integrated with BAS applications, can increase energy consumption visibility in buildings and lead to significant monthly cost savings. Operators should look for similar opportunities for synergistic upgrades.

3.2.5 Restroom and Sanitization Technologies

Often overlooked in studies and depictions of intelligent buildings, restrooms are nevertheless a key and necessary part of buildings. The U.S. Occupational Safety and Health Administration (OSHA) mandates the addition of a restroom in every worksite for roughly every 40 employees.[7] For a building with 400 occupants to comply with OSHA regulations, a minimum of 13 restrooms would be needed.

Restroom quality is highly correlated with occupant satisfaction, and the COVID-19 pandemic has furthered the need for proper sanitization.[8] As shown in Figure 3.10, implementing sensing and enabling connectivity in restroom dispensers can increase sanitization and reduce maintenance costs.

Figure 3.10 Case Study: Restroom Modernization Improves Tenant Satisfaction

Source: CABA Intelligent Building Energy Management Systems 2020 Report

Capacitive or fill-level sensors embedded in paper, towel, toilet paper, and other dispensers of consumable products can provide a real-time view of fill levels, helping to simplify the maintenance and reduce the purchase of unneeded suppliers. With cost savings from restroom modernization, operators can improve sanitization while achieving energy and cost savings.

3.2.6 HVAC Controls and Sustainability

As discussed in Section 3.2.4, chillers have evolved over time to enable a more energy-efficient way of cooling air in buildings. However, operators and owners can further achieve energy savings by implementing controls and enabling connectivity in every component of HVAC system—including fans, motors, and vents. In buildings, HVAC systems are by the biggest energy consumer, and typically account for 40 percent of a total building's energy consumption.[9]

HVAC-related energy savings can be achieved in a variety of manners, with most solutions involving implementing controls to adjust and optimize the flow of air through buildings. Traditionally, HVAC systems have relied on a system of pneumatic controls, which open and close valves in response to air pressure or temperature changes. However, these pneumatic controls cannot collect real-time data beyond pressure for analytics, as they require the installation of additional sensors to do so.

Over time, pneumatic controls have slowly been cannibalized by installations of digital HVAC controls. While many analog controls exist in buildings, they need to be individually networked to a BAS/BMS to allow operators to integrate data from each control together. To remedy this issue, the direct digital control model has arisen, in which a central controller networked to each individual analog or digital control aggregates, collects, and stores data from sensors embedded on controls or components (e.g., vents). This model allows for the collection of more air data types, such as temperature, humidity, and air quality, than pneumatic controls, which generally only collect air pressure data. Digital controls also improve expensive HVAC maintenance costs by identifying and reporting issues.

Many research organizations, facilities management companies, and suppliers are exploring the evolution of HVAC systems to drive greater levels of energy optimization and load reduction.[10] However, HVAC energy management evolution requires two major innovations:

- **Further Sensing and Automation**: By integrating HVAC controls with occupancy sensors and access control systems, rooms can automatically reduce loads in response to vacancy.
- **DER Integration**: Leveraging DER generation and storage capabilities, buildings can enable energy-efficient applications such a solar cooling, geothermal heating, and energy-efficient recirculation and reheating, by shifting DER loads to HVAC systems.

Further integrating HVAC systems with lighting and air quality monitoring systems allows data collected in one system to be labeled, stored, and available to be used for the next. For example, shading systems can monitor outside air temperature data and share it with lighting and HVAC systems, allowing both to adjust in lockstep to outside conditions to ensure that inside conditions are optimized.

3.2.7 Smart Meters: Advanced Metering Infrastructure

For most energy management applications in buildings, Smart Meters are critical. Electrical meters are key devices that provide readings of energy consumption, current, and voltage data. Without Smart Meters, it is difficult for operators to effectively integrate DERs and have real-time visibility into the energy consumption tendencies of individual buildings devices and systems.

> "In order for a building to use DERs, they need to have the right metering infrastructure in place, so that they can understand where the sustainable loads are going. With meters, you can understand how much solar or wind energy you would need throughout the day, so that you can configure assets accordingly."
>
> -Director of Utility Services, POWERHOME Solar

For more advanced applications, buildings need to adopt advanced metering infrastructure (AMI), which refers to a group of integrated smart electrical meters that communicate over a wired or wireless network and store data in a central location. AMI is defined by its ability to enable two-way communication between buildings and utility grids, which allows utilities to send price signals to buildings and implement demand response programs. This idea of buildings interacting and communicating with utilities is further examined in Section 4.

3.2.8 Combined Heat and Power (CHP) and On-Site Energy

Combined heat and power (CHP) is a rapidly emerging cogeneration method that allows buildings to simultaneously produce heat and electrical power from the same source—often a thermal generation system like a boiler or steam turbine. So far, CHP has mostly been adopted in large industrial or commercial buildings due to greater overall heating needs, which justifies the expense of advanced heating systems. However, other building operators are exploring these systems due to their massive potential benefits—the DOE estimates that CHP can achieve energy efficiencies of up to 42 percent.[11]

Although heating systems are more applicable for CHP, chillers can be used in concert with them to provide thermal energy storage, helping CHP to shift thermal loads to peak energy windows, smoothing the ultimate load profile of a building. Augmenting traditional HVAC systems with energy production capabilities can be an easier path to energy efficiency than net-new installations of solar and wind generation, but all methods will be needed for buildings to achieve net-zero energy consumption.

3.2.9 The Rapid Rise of EV Charging Complicates IBEMS

Harbor Research estimates that over the next five years, the number of electric vehicles (EVs) worldwide will increase at an approximately 30 percent CAGR. EVs, specifically battery electric (BEVs), will consume a significant amount of electrical power, which may complicate energy efficiency efforts in buildings. However, unlike with traditional vehicle fueling using gasoline, EV charging allows EVs to be fueled overnight or slowly throughout the day, in off-peak times.

Some utilities may be fearful of EV charging exponentially increasing peak loads, which would require expensive upgrades to power distribution infrastructure (e.g., transformers, natural gas pipelines) to meet these demands without causing blackouts. However, as the majority of EVs will charged in residential settings (~88 percent according to Harbor Research), most charging will likely occur in off-peak windows. In addition, Level 3 Direct Current Fast Charging (DC/FC) stations will most likely be adopted in gas stations rather than commercial buildings, due to the expense.

3.3 FOR IBEMS TO DELIVER VALUE, STANDARDS AND NETWORK COMMUNICATION MUST EVOLVE

Unlike the Smart Home market that is predominated by WiFi connectivity and personal freedom/privacy, intelligent buildings feature a variety of network types and are strictly regulated by buildings codes. In addition, intelligent buildings have coalesced around the BACnet protocol, while no single master protocol has emerged in the Smart Home market.

However, for the fragmented intelligent buildings market to evolve, further protocol standardization and buildings codes evolution need to occur. Buildings regulatory agencies and legislative bodies need to account for the accelerating adoption of technologies in buildings, by standardizing best practices for BAS/BMS use and integration without sacrificing occupant comfort, privacy, and security.

3.3.1 Buildings Codes Related to Safety and Energy Efficiency

In the U.S. and some other countries, building safety standards are specified in the International Building Code (IBC). In Canada, the federal government has specified the National Building Code of Canada, but it functions more as a model code that is implemented differently across the provinces.

While both sets of buildings codes have existed since the early twentieth century, they mostly focus on occupational safety and fire protection and prevention. Further updates need to include more codes related to BAS/BMS operation and integration, cybersecurity, and technologies to enable energy efficiency and sustainability. Regulators cannot rely on building operators to implement these strategies alone—instead, they must support buildings with clear roadmaps, regulations, and information.

In the U.S., energy efficiency codes are standardized by the DOE's Building Energy Codes Program (BECP), which collaborates closely with the **American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)** and the **International Codes Council (ICC)**. Together, these bodies have helped evolve the IBEMS market with detailed energy efficiency standards and performance measures through key performance indicators (KPIs) like the HVAC Total System Performance Ratio (TSPR).[12]

In addition, specific regulations from government bodies can catalyze IBEMS adoption. For example, California's Title 24 stipulates many energy-efficiency requirements for both residential and commercial buildings, which has helped to increase the adoption of IoT devices in California buildings. This measure and similar State regulations are more tailored to a building's specific climate and demographics, helping provide value over more generalized certifications, such as the LEED program.

If the BECP and IBC collaborate more closely, buildings codes and standards can help buildings achieve energy efficiency without sacrificing occupant safety. In addition, BECP should incorporate similar groups to **ASHRAE** that focus on energy-consuming appliances beyond the HVAC system, and work with non-profits to promote best practices to enable sustainable energy generation in buildings. Unfortunately, the COVID-19 pandemic has postponed the 2020 National Energy Codes Conference.[13]

3.3.2 The Evolution of Buildings Communication Protocols and Network Infrastructure

While BACnet compatibility is now the protocol of choice for most intelligent buildings devices and applications, electrical distribution equipment still predominately uses Modbus. In addition, industrial facilities and other buildings with mission-critical equipment that requires constantly availability often opt for the reliability of wired, Ethernet-based network solutions.

> "While electrical gear and equipment still use Modbus, most mechanical gear use BACnet. If electrical contractors and suppliers work together with mechanical engineers to specific BACnet for electrical distribution equipment, it would simplify engineering coordination and ease integration into BAS systems."
>
> -City Commissioner, City of Pittsboro, North Carolina

Emerging Ethernet innovations, such as time-sensitive-networking (TSN), will further promote the use of Ethernet for mission-critical industrial facilities by allowing for deterministic networking, which eliminates packet loss by prioritizing and scheduling data streams. As OPC UA emerges as the best protocol for specifying TSN, it will be important to map OPC UA objects and data structures[14] to BACnet to allow mission-critical facilitates to effectively integrate BAS/BMS applications.

For other local area network (LAN) communications, the Zigbee protocol is used to replace the need for WiFi-based device-to-device communication by enabling mesh networks. However, Zigbee still requires a central hub, which results in a fractured ecosystem as many devices have different variations on the protocol, which precludes them from interacting with each other. However, Zigbee is commonly used today for communication between IBEMS and Smart Meters.

As commercial building tenants adopt advanced internet connectivity and broadband solutions like fiber and fixed wireless access (FWA), operators and owners can leverage these advances to expand network connectivity beyond a single building. By implementing a small cell 5G wireless access point to provide connectivity to multiple buildings, operators can leverage this connectivity to gain a real-time view of energy management practices across a portfolio of buildings. This wider view exponentially increases the data available for model training and performance benchmarking.

3.4.3 Power-Over-Ethernet Simplifies Cable Installation and Maintenance

Though wireless network communication technologies are rapidly displacing wired solutions across industries, there is still a need for wired networking to meet the latency and availability demands of expensive, mission-critical equipment and applications. However, wired solutions feature the difficulty and expense of procuring, installing, and maintaining wires and cables. In addition, physical wires can be an eyesore to occupants, and they present safety and fire-related hazards in buildings.

To meet these challenges, the **Institute of Electrical and Electronics Engineers (IEEE)** has specified the IEEE 2.03 standard, which contextualizes Ethernet connectivity in terms of power distribution and energy efficiency. This standard has evolved to promote new power distribution models in buildings:

- **Power over Ethernet (802.3af, 802.3at, 802.3au, 802.3bt, 802.3bu, 802.3cq):** Power over Ethernet (PoE) and its set of standards define dual-purpose Ethernet cables that can transmit both internet connectivity and electrical power. PoE is aimed at applications that require both a constant internet connection and power supply, such as IP cameras and RFID readers.[15]
- **Energy-Efficient Ethernet (802.3az):** Energy-efficient Ethernet (EEE) standards promote energy savings in Ethernet controllers and wires with techniques such as automatically powering down when no data is being transmitted. This standard can reduce Ethernet power consumption by up to 50 percent, while extending battery life and promoting sustainability.[16]

As technologists innovate new strategies to optimize energy efficiency and enabled emerging applications, operators must stay abreast of these advancements to cost-effectively implement energy management systems and strategies. For this to happen, all stakeholders must align on common best practices and implementation strategies to reduce the burden of buildings owners and operators.

3.4.4 Cloud Storage and Processing Catalyzes New Applications

Many energy-consuming buildings functions such as HVAC and lighting must be constantly available. This constraint can deter some building operators from investing in energy efficiency, as they fear that any energy reductions to mission-critical systems will compromise their availability. However, advances in cloud computing, processing, and storage allow buildings to manage or configure buildings functions remotely, increasing redundancy enabling continuity of operations.

Though cloud computing and storage can help buildings quickly execute large AI inferencing workloads, they are unable to meet the latency demands of some applications, like building security. Therefore, each building must understand their specific applications and needs, and then accordingly craft a solution that includes both cloud-based and edge-based processing. Each building will eventually adopt a hybrid cloud architecture, in which different applications occur on-premise or in the cloud.

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4. DEVICE-TO-GRID INTERACTIONS AND THE CONVERGENCE OF IBEMS WITH EXTERNAL POWER

As described in Section 1.1.2, the business model of electrical power generation, transmission, and distribution is rapidly changing across North America. Legacy transmission and distribution (T&D) infrastructure—such as power lines, feeders, and substations—are not only expensive to build and maintain, but they are also inflexible, requiring expensive and time-consuming labor for configuration changes. The difficulty of maintaining this infrastructure is exacerbated as more North Americans consume more energy while demanding sustainability, and the inflexibility of these systems becomes more of an issue as consumers demand sustainability and Governments mandate energy reduction.

These issues burden North American utilities, who are often owned, regulated, or controlled by Governments and therefore may lack the agility and profitability of private corporations—hindering their ability to innovate. However, solutions to these issues are arising, namely demand response, non-wire alternatives, and the emerging model of grid-interactive efficient buildings (GEBs). While federal organizations have recently accelerated the development of GEB-related research and associated policies, implementing these changes is a momentous undertaking that requires systematic changes.

4.1 UTILITIES FACE CHALLENGES BUT ARE ALLEVIATING THEM THROUGH TECHNOLOGY

For grid interactivity to occur, utilities must not be burdened with the sole responsibility of defining and implementing a new power transmission and distribution model. Instead, governments and buildings owners and operators must prioritize and support the evolution to grid interactivity:

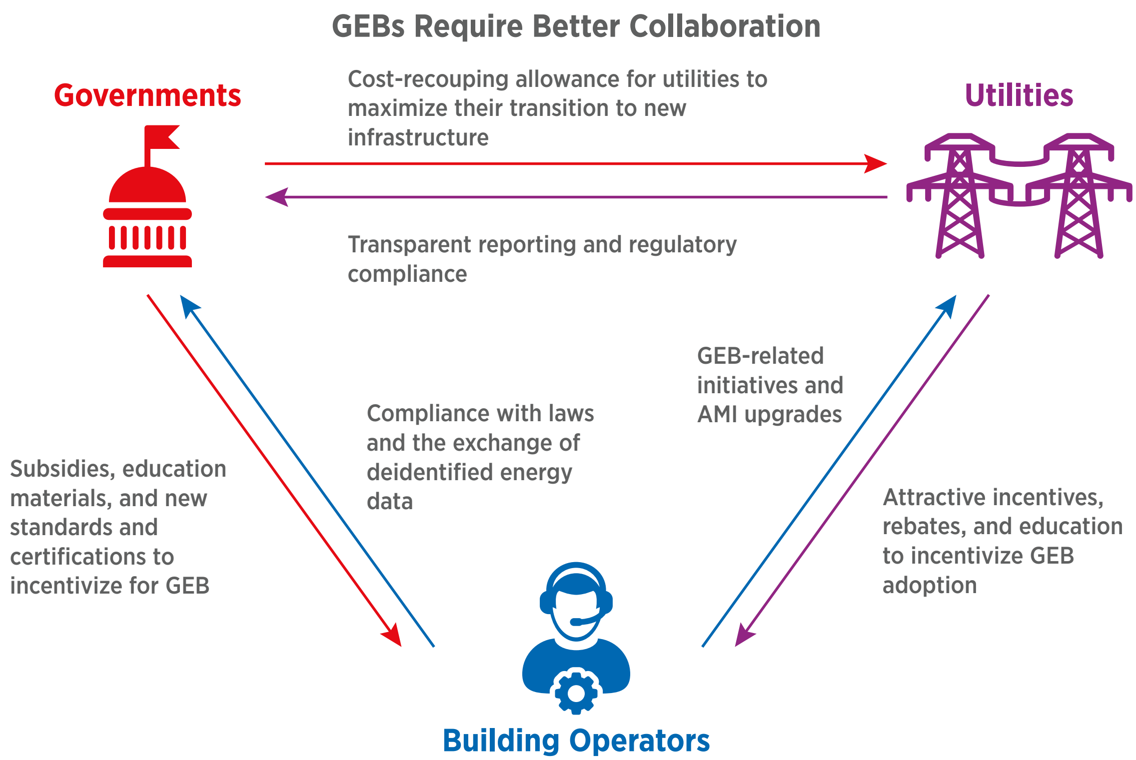
- **Governments:** Federal, state, and local governments across North America are increasingly mandating the conservation of energy and the use of distributed energy resources (DERs). Governments need to ensure that these mandates are achievable by providing the right investment support and infrastructure. They also need to incentivize buildings to enable grid-interactivity, perhaps by adding a new LEED certification. Governments should also allow utilities to recoup the costs of technology modernization through monetizing energy savings.
- **Utilities:** Utilities need to understand the specifics of both their regions and their

customers to effectively offer the right incentives (e.g., rebates and services) for buildings to implement grid-interactivity devices and technologies. In addition, utilities require a precise, real-time understanding of energy consumption peaks and valleys, and the ability to better predict outages and autonomously adjust. These capabilities not only require analytics tools and control systems, but they also need expertise and an understanding of the data's context.

- **Building Owners/Operators:** Building owners and operators need to be educated about what grid-interactivity is, and the specific benefits that are required to achieve it. Since owners are often reluctant to allocate a significant amount of up-front capital to modernization initiatives, they need to closely collaborate with governments, utility companies, and private companies to develop the right financing and return-on-investment structures.

As depicted in Figure 4.1, each of these stakeholder types cannot enable GEBs by operating in silos.

Figure 4.1 Stakeholder Collaboration is Needed for Grid-Interactivity



Source: CABA Intelligent Building Energy Management Systems 2020 Report

The demand for grid interactivity in buildings is rapidly increasing. When asked to indicate their interest in adopting grid interactivity, more than 85 percent of building operators surveyed were either very or somewhat interested. However, only 13 percent of these same respondents indicated that they had adopted grid-interactivity in their buildings. This wide delta of user demand illustrates the lack of understanding or available funding to equip buildings with grid interactivity.

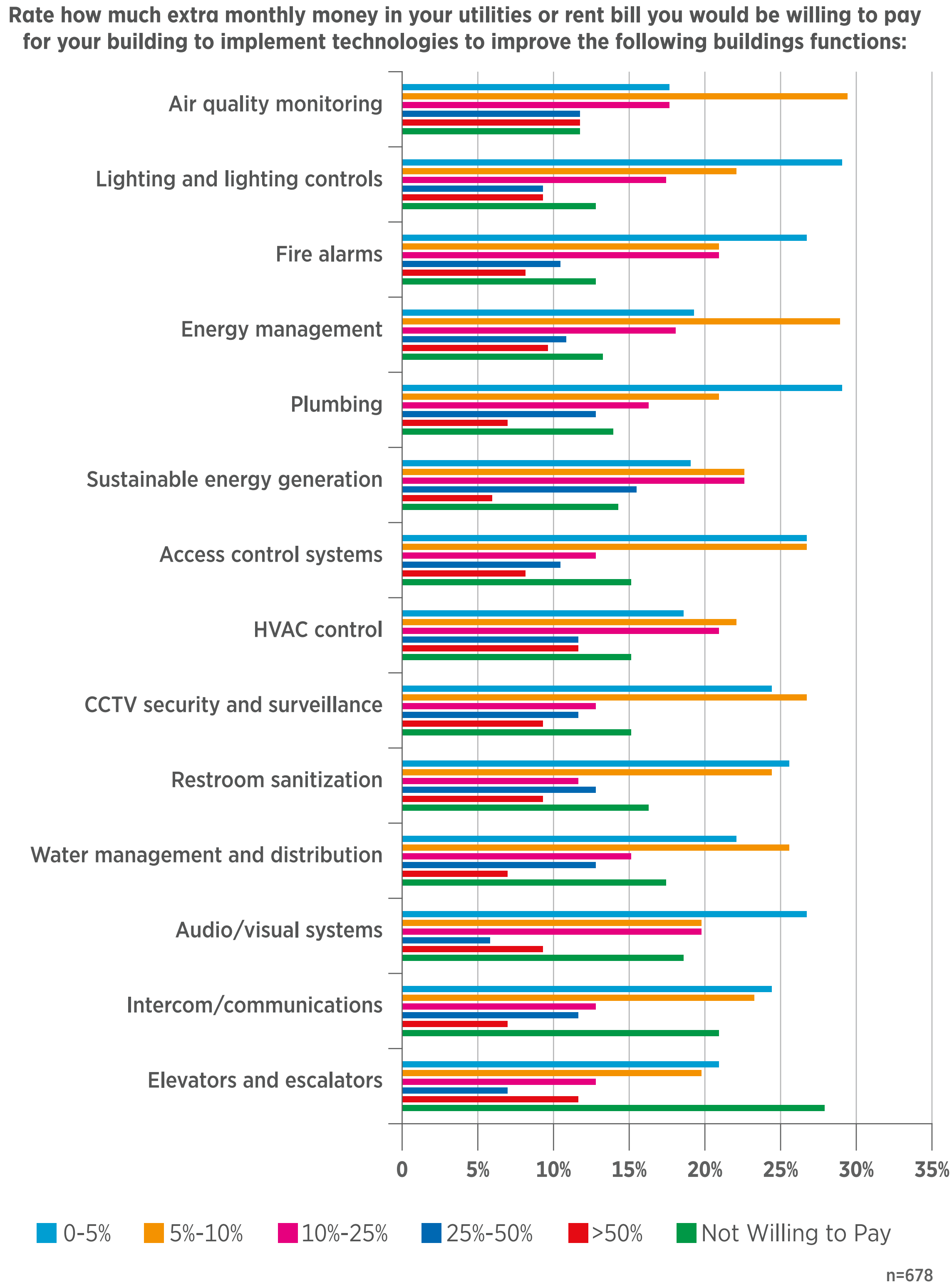
4.1.1 Distributed Energy Resources and Demand-Response Increase Utility Flexibility

As described in Section 1.1.3, consumers are increasingly demanding sustainable energy generation and usage in their buildings. For utilities, the increased emphasis on sustainable energy sources necessitates the development of new grid services that leverage distributed energy resources (DERs).

According to Advanced Energy Perspectives, DERs refer to "physical and virtual assets that are deployed across the distribution grid, typically close to load, and usually behind the meter, which can be used individually or in aggregate to provide value to the grid, individual customers, or both."[1] This definition does not require the resources to be sustainable or renewable—instead, it emphasizes flexibility and quick value-generation as attributes of DERs. A study by the **American Council for an Energy-Efficient Economy** (ACEEE) determined that demand response/energy efficiency is the cheapest DER, costing approximately 3.1 cents per kWh. This means that if utilities and buildings genuinely want to limit the use of carbon-producing energy, they should first tackle the low-hanging fruit of wasting less energy through better buildings-to-grid communications.

As shown in Figure 4.2, building occupants are willing to subsidize the cost of sustainable power generation in their building, with only 14 percent of respondents not willing to pay for this service.

Figure 4.2 Occupants are Willing to Pay for Air Quality, Energy Management, and Sustainability



Source: CABA Intelligent Building Energy Management Systems 2020 Report

To meet the demand for DERs, energy efficiency, and sustainability, utilities have responded by developing innovative techniques (Figure 4.3).

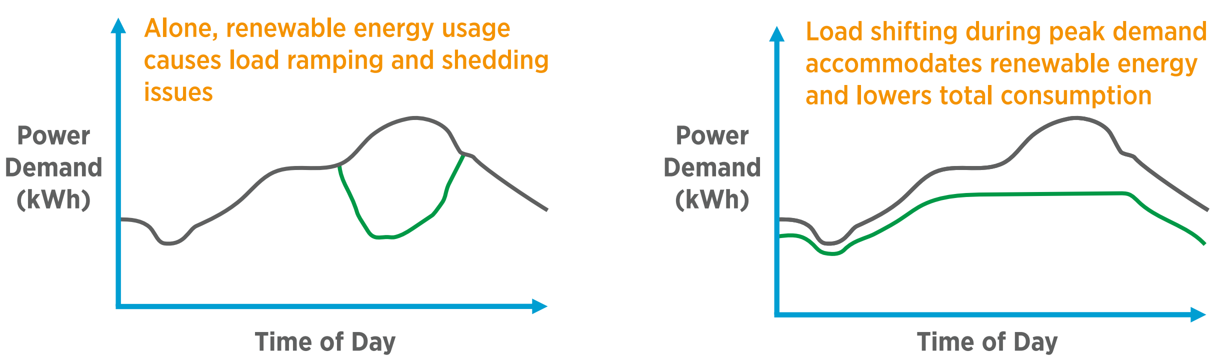
Figure 4.3 Supply-Side Strategies for Energy Efficiency Optimization

Supply-Side Strategy	Description
Demand Response/ Flexibility	Demand response refers to activating DERs to quickly adjust a building's load profile across different timescales
Load Shedding	A short-term load reduction in response to peak demand or generation shortfalls, typically to avoid excessive load
Load Modulation	Rapid, real-time load mapping to grid signals for precise energy efficiency and rapid ramping
Load Shifting	Shifting energy loads from peak periods avoids grid congestion and allows to maximize renewable energy consumption
Distributed Generation	On-site or distributed generation allows energy to be fed to the grid and quickly mobilized for demand response

Source: CABA Intelligent Building Energy Management Systems 2020 Report

These strategies can be deployed in tandem to optimize energy distribution and consumption in near-real time. For example, distributed generation can support load shifting by allowing grid operators to align peak periods with sustainable energy generation and storage, maximizing the use of sustainable energy and shifting non-sustainable resources to off-peak periods (Figure 4.4).

Figure 4.4 Load Shedding to Maximize Sustainable Energy



Source: CABA Intelligent Building Energy Management Systems 2020 Report

On its own, leveraging renewable energy sources during peak hours might reduce demand strains on the utility grid, but its value is offset by the difficulty of rapidly ramping and shedding loads, resulting in wasted energy. However, by combining the use of sustainable energy generation and storage with load shifting by rescheduling the peak load energy to off-peak hours, the entire load profile of the building is reduced, ultimately reducing wasted energy, lowering overall energy costs for the building operator, and reducing the burden on the external utility grid infrastructure and labor much more significantly.

These strategies can provide massive cost and energy savings for building operators and utility grid operators alike. However, many of the more advanced techniques, such as real-time load modulation, require significant investment in technology-based systems and infrastructure. For example, load modulation requires automated grid control signals to be shared in real-time between external power substations, peaker plants, and Smart Meters, which requires advanced metering infrastructure and low latency network communication infrastructure.

> "In Canada, I've only seen grid interactivity in some buildings in Ontario. Unlike BC or Alberta, Ontario utilities have more price variability, which incentivizes buildings to collect time-of-use pricing data for load shifting and charging batteries when energy prices are low."
> -Energy & Sustainability Manager, Colliers International

The ability of utilities to adjust loads and optimize energy distribution depends on the ability of buildings to support them. Buildings must understand the return on investment (ROI) of enabling grid interactivity, and the massive amount of flexibility that such capabilities provide to utility grid operators.

4.1.2 How Non-Wire Alternatives Alleviate Strained Distribution Mechanisms

Every year, U.S. utilities spend approximately $100B on maintaining and upgrading the physical grid transmission and distribution infrastructure.[2] This massive expense hinders the ability of utilities to innovate and leads to higher utility bills for building operators and occupants. Across other industries, innovative digital natives (e.g., **Charles Schwab**, **Netflix**, Bonobos) are disrupting industries that have been traditionally dominated by companies reliant on physical stores and infrastructure (e.g., **Bank of America**, **AMC**, **JC Penny**). For utilities to compete in the future and reduce costs to customers, they must reduce their reliance on physical power distribution infrastructure.

The difficulty of power distribution infrastructure maintenance has led to a new business model for utilities—the use of non-wire alternatives (NWA). According to **Navigant Research**, an NWA is "an electricity grid investment or project that uses non-traditional transmission and distribution solutions, such as distributed generation, energy storage, energy efficiency, demand response, and grid software."[3] Basically, NWAs refer to anything that is an alternative to power transmission and distribution that does not use physical infrastructure.

Governments across North America have embraced NWAs as they try to convince utilities to consider this approach above physical infrastructure-based solutions for new installations and upgrades. For example, the state of Maine signed the Smart Grid Policy Act Directive in 2016, which required regulators to consider and prioritize NWAs before approving T&D projects. NWAs can also help utilities avoid the permitting processes of power line upgrades and easily integrate with onsite generation.

Although NWAs are highly desirable to both regulators and utilities, there exist few examples of actual NWA deployments in North America. As of 2019, only 90 such deployments existed in the U.S., and those are heavily concentrated in the states of California and New York.[4] A lack of research and mutual understanding of NWAs causes these deployments to vary in scope, purpose, and complexity. As shown in Figure 4.5, creative deployments stem from regulatory bodies and utilities collaborating.

Figure 4.5 NWA Deployments are Nascent Across North America

NWA Deployment	Description
New York: Brooklyn-Queens Demand Management (BQDM) Program	Led by Con Edison, this project replaced designs for a $1B substation with $200M in NWAs, including distributed energy and a self-sustaining microgrid in Queens
Washington: Bonneville Power Administration (BPA)	BPA is completely replacing an 80-mile transmission line between Washington and Oregon with NWAs
Tennessee: Duke Energy's Mount Sterling Microgrid	Duke Energy replaced a 12.47 kV grid-connected distribution feeder with a NWA microgrid with 10 kW of solar generation and 95 kWh of storage capabilities
Arizona: Arizona Public Service (APS) Punkin Center	Rather than replace 17 miles of transmission line, APS installed battery storage to address load growth issues
Rhode Island: National Grid DemandLink Pilot Update	In response to legislation, National Grid invested in demand response to meet Rhode Island's energy needs without installing expensive new infrastructure
Maine: Central Maine Power (CMP) Transmission Upgrade	When CMP proposed a $1.5B upgrade to transmission substations and lines, GridSolar intervened and implemented battery and thermal storage solutions
New York: Central Hudson's Peak Perks Targeted Demand Program	This program implemented direct load control and demand response to defer upgrades for 10-15 years
California: Southern California Edison (SCE) Virtual Power Plant	In Southern California, SCE replaced a nuclear power plant with a "virtual power plant" consisting of solar generation and battery storage systems

Source: CABA Intelligent Building Energy Management Systems 2020 Report

Unfortunately, utilities are incentivized against NWAs. In North America (as well as Europe), utilities realize revenue from investing in, developing, and operating physical grid infrastructure, including transformers, power lines, and substations. For Governments to truly catalyze the use of NWAs, they need to offset the loss of these revenues with subsidies and rebates. Alternatively, they can finally allow utilities to explore new revenue streams such as utility data monetization and value-added software and services. For utilities to exist in the new distributed energy paradigm, their business models must shift to accommodate and incentivize NWA-based strategies, and allow for buildings to have some ownership of the energy they produce to sell it back to the grid.

4.1.3 Other Supply-Side Innovations Can Enable Grid Interactivity

The COVID-19 global pandemic has significantly affected energy management in buildings in a number of ways (further described in Section 5.1). With regards to utilities, the pandemic has raised calls for an emerging, contactless way of improving energy efficiency in buildings: the virtual energy audit.

At a high level, traditional energy audits feature on-site visits where the auditor examines a building's data, its controls system, and other factors to provide a list of actionable Energy Efficient Measures (EEMs), or actions to improve energy efficiency. This service, typically done by consultants, external contractors, or federal regulators, is key, as building operators often lack the ability to properly identify areas of improvement for energy efficiency.

> "I would estimate that less than 10% of building operators are knowledgeable enough to identify and solve energy efficiency issues in buildings. Often, buildings are owned by REITs, who tend to hire unskilled, inexpensive operators."
>
> -Project Development Specialist, McKenney's

In the age of COVID-19, operators are instead increasingly looking for virtual energy audits to identify key areas of energy management improvement. At a high level, these audits consist of the operator providing meter data to the auditor, and the auditor commissions a survey to the building operator. Then, this data is compiled and sometimes measured against baselines to identify and report on specific tactics for energy efficiency improvement.

If the operator can provide all the necessary data, photos, and information necessary for the auditor to conduct a comprehensive virtual energy audit, they can provide significant benefits over physical ones. Compared to physical audits, virtual energy audits are significantly cheaper, require less staff time, and are able to identify EEMs much faster.[5] In addition, virtual energy audits allow the auditor to easily integrate the audited building's data with external data sources, helping to quickly benchmark its energy consumption against other, similar buildings.

However, significant issues limit the effectiveness of virtual energy audits. Most building operators often do not know what data, irregularities, or photos to report, as they lack the understanding of how energy is managed in their buildings. For virtual energy audits to fully replace in-person ones, auditors need to proactively educate auditees on exactly what data to provide and key irregularities to identify.

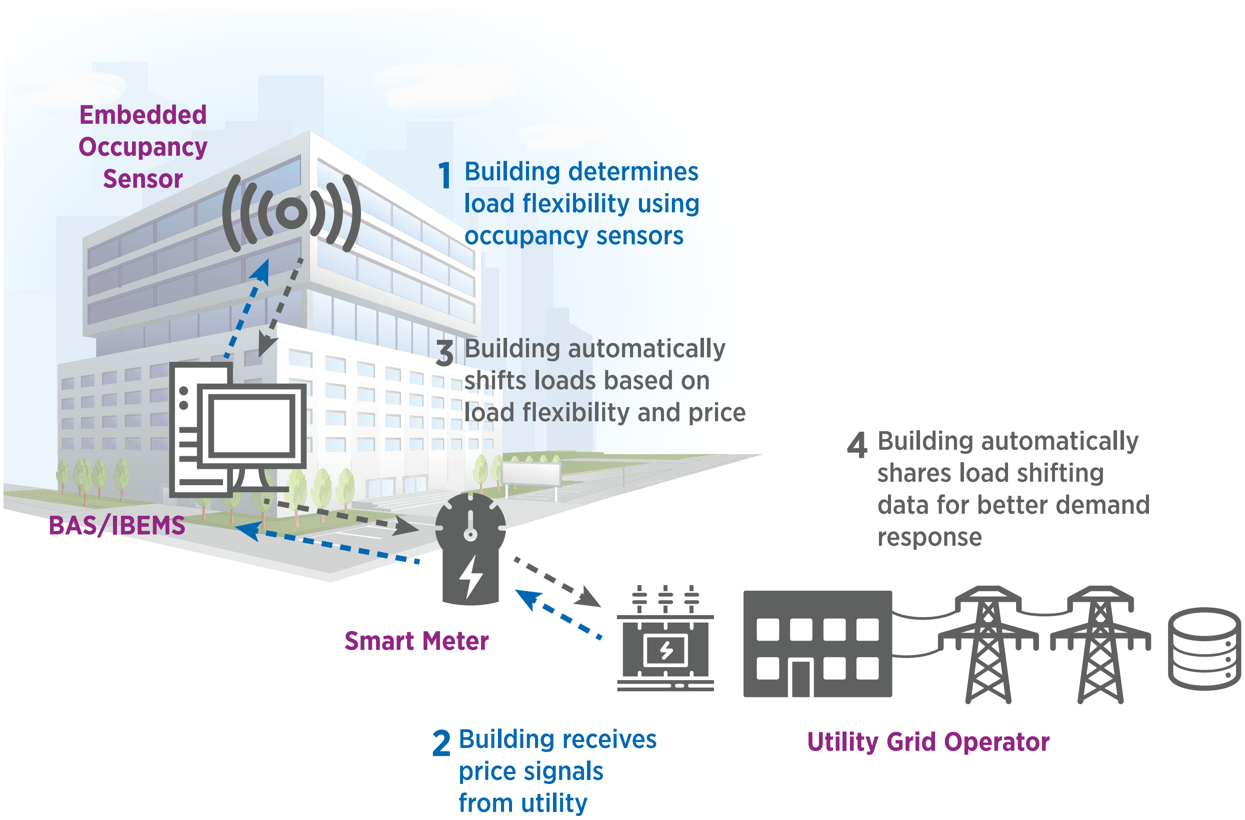
4.1.4 The Rise of Grid-Interactive Efficient Buildings (GEBs)

All of the aforementioned in-building energy management innovations and supply-side utilities strategies are converging to drive a new business model for IBEMS—the grid-interactive efficient building (GEB). Currently promoted by GSA, GEBs are defined by grid-interactivity—the ability of buildings to establish and use real-time two-way communication with utilities. As defined by GSA, GEBs can exceed current IBEMS capabilities by "focus[ing] on demand and the time value of energy via energy efficiency, renewable energy, storage, and load flexible technologies, thereby reducing grid constraints and enabling decarbonization."[6] The emphasis on time-value is a key trait of GEBs, as it allows a building to flexibly respond to changes in occupant energy demand and utility price signal fluctuations.

GEBs rely on emerging technologies and real-time data communication infrastructure and protocols to quickly share data with utilities and to continuously estimate energy demand needs. In addition, GEBs need a fully integrated building automation and control system to allow them to automatically shift a building's holistic load profile, by controlling which requires the ability to shift the load profiles of individual devices and loads (e.g., plug loads, HVAC). Further technologies, such as photovoltaic energy generation, efficient energy storage and machine learning (to predict demand and automatically schedule loads), allow for greater flexibility to shift loads and predict peak demand.

GEBs typically have multiple advanced energy management capabilities in place, such as the ability to generate power from localized energy sources and integrated building automation systems. However, no one model is necessary for GEB use cases—instead, GEBs merely require two-way communication between buildings and utilities, and the ability to use this communication for load shifting and demand response/demand flexibility. For example, Figure 4.6 depicts a GEB using a fully integrated BAS, embedded occupancy sensors, and a Smart Meter to shift loads in response to grid signals. Many inverters used in photovoltaic system are IEEE 2030.5 compatible, which is a simplified technology that allows utilities to control how much electricity is put back onto the grid from DERs.

Figure 4.6 An Example Use-Case of GEBs



Source: CABA Intelligent Building Energy Management Systems 2020 Report

However, GEB use cases are not solely limited to load shifting and demand flexibility. GEBs can also optimize the use of DERs and localized power generation, shifting them to peak load periods and even offload excess energy to utility grids. In addition, utilities can use peak load data collected from multiple buildings for capacity planning and surge prediction. As energy storage becomes competitive, DERs will have the capacity to dispatch power in response to utility signals. For example, bidirectional EV charging can supply electrical power from an EV's battery to the grid via a DC to AC conversion system, usually embedded in the EV charger.

4.2 IN-BUILDING CONTROL AND AGGREGATION SYSTEMS NEED TO EVOLVE TO ENABLE GEBS

Though GEBs promise tremendous cost savings (according to GSA, annual savings can range from $50,000 to $600,000 per building), they require technology retrofits to buildings or high-capital construction to realize a positive ROI. Without incentives from utilities or government subsidies, upgrading a building to support GEBs will take years for an operator to recoup the value. Therefore, operators need to work with utilities and suppliers to create an efficient, technology roadmap to becoming a GEB. The following technologies should be prioritized, as they can best enable GEB use cases.

4.2.1 Occupancy and Vacancy Sensing

Occupancy sensing technology does exactly what its name implies: it estimates the number of people in a room. Occupancy and vacancy sensing can be accomplished by collecting a variety of different approaches, such as motion detection, ultrasonic sensing, audio detection, passive infrared sensing (PIR), RFID/footfall tracking, and microwave sensors. Compared to more precise sensing applications, occupancy sensors can accurately measure a room's occupants through heat, radiation, light, noise, and pressure. Even simple applications of occupancy sensing, such as automatically turning off a light in a vacant room, can lead to massive energy savings, with an average energy savings of 24 percent.[7]

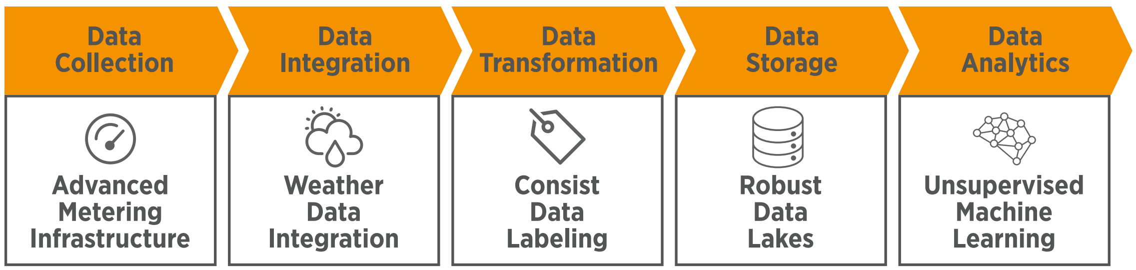
Some buildings opt for more direct occupancy sensing and people counting, especially to enforce strict social distancing and room occupant limits due to COVID-19. However, direct people-counting often involves cameras, which capture occupant images, creating identifiable data that infringes on privacy.

For GEBs and precise HVAC control, occupancy sensing is a necessary enabler. By collecting occupancy data over time and effectively communicating it to BAS or EMS systems, buildings can track occupancy over time and predict peak loads. In addition, occupancy sensors are relatively cheap, starting at roughly $20 per unit, and only need basic WLAN networks such as WiFi to communicate data.

4.2.2 Data Collection and Integration

A big issue preventing energy efficiency and sustainability in buildings is a lack of usable data. While some pin the blame on data collection challenges or a lack of standards for building data labeling/naming, there are issues across the data analytics pipeline. As shown in Figure 4.7, buildings need an end-to-end strategy of data collection, integration, and transformation before analytics can occur.

Figure 4.7 AI-Capable GEBs Require Upgrades Across the Data Pipeline



Source: CABA Intelligent Building Energy Management Systems 2020 Report

For GEBs to effectively collect, transform, and derive insights from buildings data in real-time, they need to upgrade their infrastructure during each state of the data pipeline:

- **Data Collection**: Advanced metering infrastructure is required for the collection of time-of-day energy consumption data, without which it is virtually impossible for accurate peak load predictions. Smart Meters produce 35,000 data points per year[8], which is organized over time, creating time-series data that is excellent for machine learning-based inferencing.
- **Data Integration**: The use of software application programming interfaces (APIs) is increasing, along with their availability in common software development kits (SDKs). Even common RESTful APIs can greatly ease the integration of buildings data with external data sources, such as local weather data, and utilities which is necessary for GEB applications.
- **Data Transformation**: Though many buildings systems (except for electrical distribution systems, which typically use Modbus) have switched to BACnet, similar standardization has not occurred for data labeling. Project Haystack and Brick are some of the efforts to standardize data labeling in buildings, but a common standard needs to be adopted to enable analytics.
- **Data Storage**: Once data is transformed and external data sources are integrated, it must be stored in a central, secure manner. Data lakes, such as those offered by **Microsoft** Azure, can effectively meet this need, and enable big data analytics, like machine learning.
- **Data Analytics**: Due to issues with each of the above stages, machine learning to enable predictive analytics is seldom used in buildings today. However, as more and more buildings data are collected, machine learning algorithms can be used for peak demand and blackout prediction. For automated GEB functions, unsupervised machine learning with automated feature engineering can remove the need for data scientists, who are very expensive, and put advanced analytics capabilities into the hands of facility managers and operators.

Implementing advanced data infrastructure required for big data analytics is very capital intensive and challenging. Suppliers can spur the evolution of this market by simplifying data collection and integration on their products and by adopting a common data standard. Even simple differences in data naming, such as room temperature vs. space temperature, can inhibit analytics or data collection.

4.2.3 Full-Controllable LED Fixtures and HVAC Systems

Upgrading LED fixtures to enable full control is common in existing buildings, especially compared to other GEB technologies. However, since lighting systems are critical to occupant comfort and energy efficiency, the ability to proactively dim and brighten lights across buildings in response to occupancy and energy price signals is required for GEBs. Fully controllable LED fixtures often refers to the ability to control lighting systems remotely or with a Smartphone, rather than with a panel or switch. Often, Bluetooth wire-mesh node systems are required to enable this control, which can be expensive to implement and requires retrofitting.

In addition to lighting controls, enabling similar automated control functionality on HVAC systems is critical to driving true load shedding and energy reduction, given how much energy HVAC systems consume. Luckily, operators and suppliers have recognized the value-potential of HVAC controls, so the cost to implement HVAC system controls is cheap and requires little to no hardware.

4.2.4 Solar Photovoltaics, Energy Storage and other Energy Generation Technologies

For GEB use cases related to sustainability, photovoltaic and energy storage systems are especially important. The ability for a building to produce its own energy helps reduce its reliance on traditional utility energy sources, which are often carbon-based. In addition, some utilities allow buildings to transmit excess energy to the grid, which can lead to even greater cost savings for operators. Combining energy generation and storage technologies such as photovoltaics and storage with IBEMS is necessary for buildings to achieve grid interactivity. In addition, IBEMS and the DER control systems need to be standardized so they can effectively communicate and make decisions around how energy in the building is used, stored, or dispatched to the grid.

Energy storage technologies in buildings allow buildings to intelligently shift loads to maximize the use of sustainable energy. Typically, buildings exercise a chemical storage technique using batteries as UPSs, but mission-critical buildings and data centers often invest heavily in cooling systems and chillers, which can help enable thermal energy storage.

Other emerging onsite energy generation technologies are making their way into buildings around the country, such as fuel cells, distributed wind energy, hydroelectric energy, and biogas generators. Each building region differs in the cost-effectiveness of renewable energy sources. For example, in British Columbia, hydroelectric sources provide 90 percent of the provinces electricity[9], while in California, climate trends and government policies have led to widespread adoption of solar. While the exact mix of DER loads will differ by building type and region, the importance of integrating these loads and storing them for off-peak load shifting will persist.

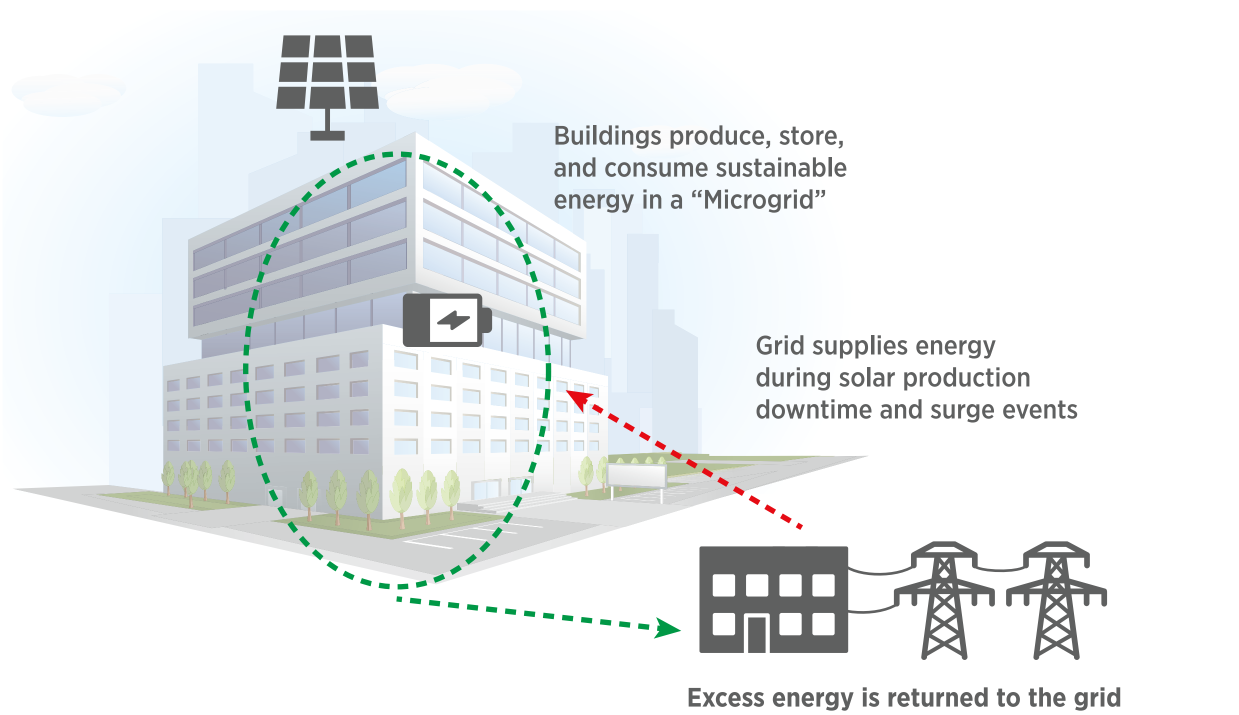
4.3 RECONCILING THE COMPETING TRENDS OF GRID INTERACTIVITY AND GRID INDEPENDENCE

As discussed, GEBs are defined by their close integration with external utility grid infrastructure. However, the other key IBEMS trend, zero net-energy buildings (see Section 3.5.4), refers to building that operate independently from utilities. At first glance, these trends might seem mutually exclusive. However, by carefully considering the rise of GEBs in the context of building energy self-sustinability, one can accurately determine how buildings will interact with energy distribution in the future.

4.3.1 Hybrid Energy Consuming and Producing Intelligent Buildings

Due to technical limitations with distributed renewable energy generation and the price variability of utilities, it is impossible for all buildings in all regions to function independently of external power grids in an efficient manner for the near future. This unfortunate fact makes grid interactivity more important for buildings with energy generation capabilities. With a real-time interface with external utilities, buildings can optimize their use of self-generated power (Figure 4.8).

Figure 4.8 Grid Interactivity Can Optimize In-Building Energy Production



Source: CABA Intelligent Building Energy Management Systems 2020 Report

Instead of replacing the grid or fully integrating into it, buildings and utilities must change the way that they interact with each other. With the proper two-way price incentives, both parties can collaborate to enable new levels of energy efficiency and sustainability—alone, each group faces issues. For example, in September 2020, the **Federal Energy Regulatory Commission (FERC)** approved Order 2222, which allow large buildings capable of producing excess energy to participate in the electricity wholesale market by offloading excess energy, allowing buildings to essentially act as power plants.

> "It is not realistic for all buildings to become self-sufficient and achieve net-zero on an annual basis. The more self-sufficient a building is, the more its energy consumption fluctuates, with places more strain on the grid. Solar-powered buildings have the same load profiles as existing utility grids, making the renewables problem worse, unless they utilize grid interactivity."
> -Regional Director, McKinstry

By collaborating closely, building operators and utilities can enable a hybrid future where buildings generate and store renewable energy, and utilities help them optimize its use. This model will enable buildings to operate more efficiently and meet the energy demands of new, emerging applications.

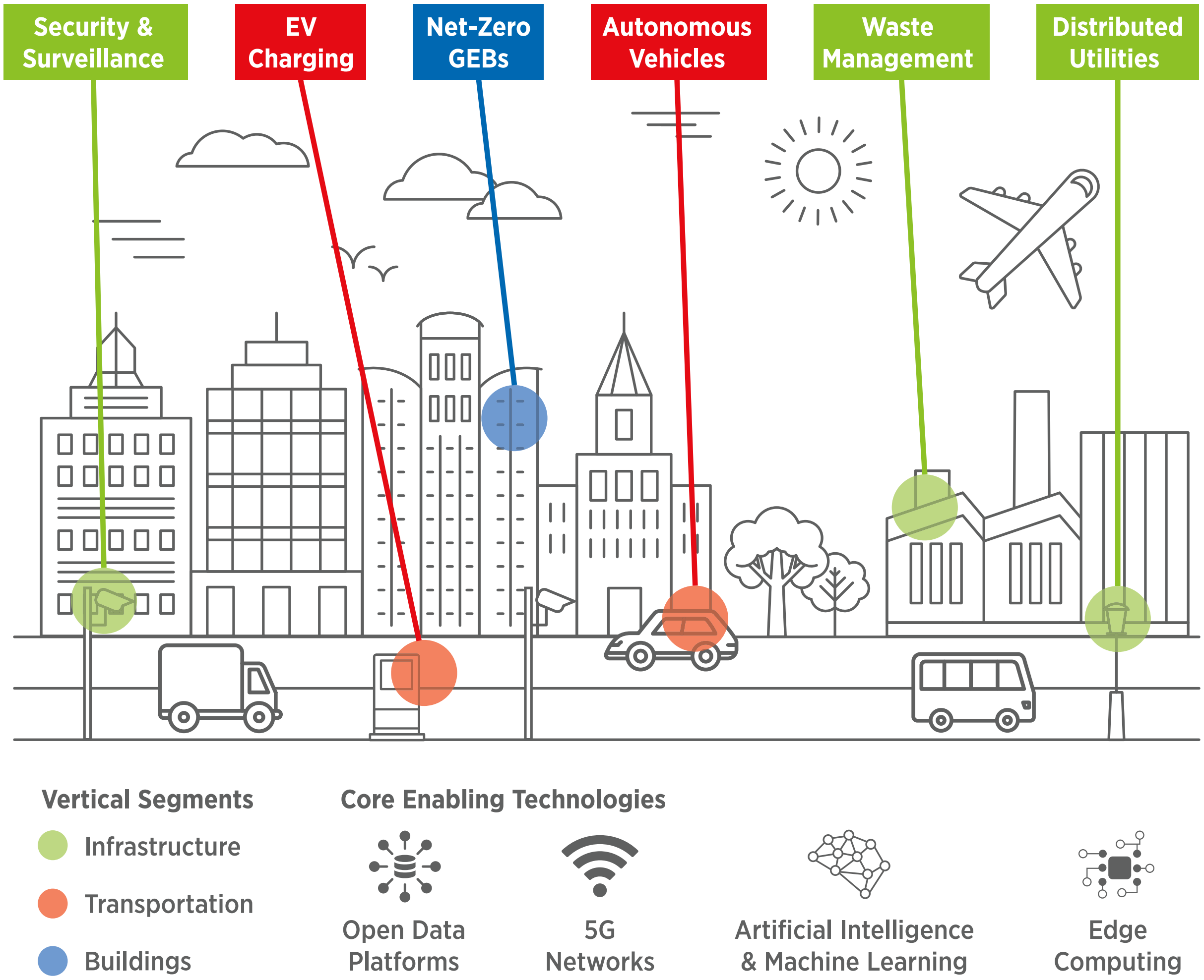
Building operators can consider the use of all these emerging technologies within their facilities with the use of optimization software, such as HOMER Grid and Der-Cam. These software programs take into consideration the use of various energy generation and storage technologies and then optimize their use based on economics to maximize the impact of the DER on the building's load profile.

4.3.2 Considerations for IBEMS in Smart Cities

Smart Cities promise to be the next evolution of urbanization, as cities increasingly adopt emerging technologies to automate and optimize municipal functions. Cities are diverse, broad, and encompass almost every sector of the North American economy. Harbor Research forecasts the Smart Cities opportunity to grow to approximately $367B by 2025, with buildings as a key component of this market.

As shown in Figure 4.9, Smart Cities will feature multiple emerging use cases based on applications of emerging technologies. Many of these use cases, like autonomous vehicles and holistic public safety surveillance programs, have intense energy demands that will require greater energy efficiency.

Figure 4.9 Building-to-Grid Communication Will Enable Sustainable Smart Cities



Source: CABA Intelligent Building Energy Management Systems 2020 Report

Like buildings and vehicles, cities are also mandating the use of electricity for power consumption and distribution instead of relying on fossil fuels and natural gas, in a trend broadly termed electrification. Like buildings, cities will adopt alternative distributed power generation sources to achieve electrification, which will have DER loads that require advanced analytics to effectively distribute. By first making use of these advancements and by adopting IBEMS to predict and schedule loads, buildings can lead the charge of electrification in Smart Cities and relieve stressed power distribution systems.

The ability of buildings to generate, store, and efficiently consume energy will greatly accelerate the adoption and maturity of Smart Cities. Without having to rely on expensive, aging nationwide power distribution transmission infrastructure, Smart Cities can sustain themselves with efficient microgrids, tailored the specific energy needs of each city's unique demographics and region.

4.3.3 Grid Interactivity Raises Security Challenges That Need to be Addressed

The rise of integrated building automation and building management has helped to simplify cybersecurity in buildings. Instead of having to implement individual security controls and firewalls for each connected device or appliance in buildings, building automation systems allow devices to be secured through a single gateway. However, integrating buildings with external utility grids will raise further security concerns, that buildings and utility operators must address.

Utility grids are some of the most security-sensitive assets in North America, and many worry about the potential of terrorist or cyber-attacks to cause massive outages and disruptions across the continent. Theoretically, vulnerabilities in a GEB's hardware or software systems would enable hackers to compromise the utility grid.[10] Therefore, buildings and utility operators need to pay extra attention to cybersecurity in GEBs. Some cybersecurity tactics and best practices for GEBs include:

- **Network-Layer Protocols:** In addition to firewalls and implementing access controls, buildings need to adopt secure network communication protocols on the network layer, such as Transport Level Security (TLS), which can be used to encrypt data as it is communicated between buildings and transformers/substations. The U.S. National Renewable Energy Laboratory (NREL) is currently working on common security standards for DERs[11], but efforts are still ongoing, and no common approach has been adopted. Recently, Sandia National Laboratories, a subsidiary of Honeywell International, published added recommendations for DER security that promotes solutions such as blockchain to solve this issue.[12] In addition, data diodes can improve network security, but they do limit two-way communications.
- **Arc Fault Detection Devices (AFDD):** Electric arcs refer to electrical power breakdowns of gas that produce an electrical discharge, which can cause fires. Traditional electrical circuit breakers are unequipped to detect and effectively respond to electric arcs. AFDD can detect electric arcs and quickly shut off currents in response, preventing fires. Tighter integration of buildings with utility grids will cause common grid issues like electric arcs to arise in buildings, requiring them to respond accordingly with solutions such as AFDD.
- **Over-the-Air Software/Firmware Updates:** Many security vulnerabilities in building technologies today exist due to the preponderance of outdated, legacy systems. Upgrading these systems can require time-consuming software updates or expensive product replacements. Currently, more software providers are increasingly offering over-the-air software updates, which can future-proof an application by allowing for remote security updates.

The idea of GEBs may seem difficult for many building operators today, given the sheer amount of technologies and business model changes that is required. However, buildings cannot ignore the value potential of grid interactivity, and must start to consider the energy needs of their buildings in the context of broader North American power distribution and transmission systems. By augmenting IBEMS solutions with grid interactivity, operators can achieve massive cost and energy savings.

4.3.4 A Roadmap to Grid Interactivity in Buildings

Regional policies, occupant demands, and increasing electrical loads are all trends converging on buildings that emphasize the importance of grid interactivity. However, as explained throughout this section, equipping a building to autonomously shift loads in response to signals from utilities can be a difficult and expensive undertaking, especially for buildings who have just begun their technology modernization journeys. Therefore, buildings should consider a phased approach to upgrading their IBEMS maturity, culminating in GEBs:

- **Stage 1—Intelligent Buildings:** First, buildings should focus on modernizing critical energy-consuming functions, lighting, and HVAC, while upgrading all devices to comply with the latest energy efficiency standards and be remotely-controllable and managed. This will allow devices to collect and share energy consumption data for further efficiency gains.
    - **Key Requirements:** Fully controllable LED fixtures, HVAC systems with direct digital controls, building automation/management systems
- **Stage 2—Energy-Efficient Buildings:** Then, buildings should install submetering infrastructure and invest in technologies to allow for centralized data storage systems. This step is key for buildings to visualize load profiles in relation to time-of-day utility price signals.
    - **Key Requirements:** Advanced metering infrastructure, IBEMS with data storage and business intelligence features, interoperable device communication
- **Stage 3—Energy-Producing Buildings:** Before realizing grid interactivity, buildings should invest in distributed energy production and storage capabilities. This will allow the building to reduce its dependence on external utilities by producing and shifting DER loads to off peak windows. In addition, it allows buildings to offload generated power to utility grids.
    - **Requirements:** Battery or thermal energy storage systems, energy generation systems (e.g., photovoltaic, CHP), controllable DER load analytics systems
- **Stage 4—Grid-Interactive Buildings:** Only buildings equipped with intelligent devices, energy efficiency measures, and energy storage capabilities can achieve advanced grid interactivity, where software and machine learning automatically configure load profiles and DERs to maximize energy consumption in buildings in response to utility signals.
    - **Requirements:** Digital aggregators/overlays, advanced AI and machine learning, central building controls, embedded occupancy sensing systems

Regardless of their current GEB maturity, building operators and owners should prioritize investing in technologies and systems to prepare for the distributed energy future. With GEBs, utilities, buildings, and cities can create a sustainable, more efficient future that enables Smart Cities applications.

Notes:

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5. THE CHANGING IBEMS FUTURE WILL BEGET WINNERS AND LOSERS

In Spring 2020, the COVID-19 pandemic struck North America, shuttering business, and buildings across the continent as governments enforced lockdowns and stay-at-home orders. Now, as occupants begin to return to work, they are re-entering buildings with new needs, concerns, and fears. Building operators, even those skeptical of new technologies, are looking to follow public health recommendations and mitigate the spread of the virus by implementing new business practices and emerging technologies. However, the true effects of this change on IBEMS remains unclear.

5.1 THE IMPACT OF THE COVID-19 PANDEMIC ON IBEMS

Perhaps biased by political beliefs, there exists little consensus on how the COVID-19 pandemic will affect energy consumption and management in buildings. Two dichotomous beliefs arise:

- COVID-19 will **decrease** energy consumption in buildings, due to fewer occupants in buildings as offices implement staggered work schedules and work-from-home policies
- COVID-19 will **increase** energy consumption in buildings, as operators implement technology applications such as people counting and air sanitization, which have higher energy demands

These competing trends will likely manifest themselves differently depending on each building's specific region, function, and demographics. For example, mission-critical industrial buildings might increase their energy usage as they automate tasks, while buildings with technology start-ups might decrease their energy usage as some of those start-ups choose to work from home. In addition, the effects of COVID-19 on energy in buildings will likely differ over time.

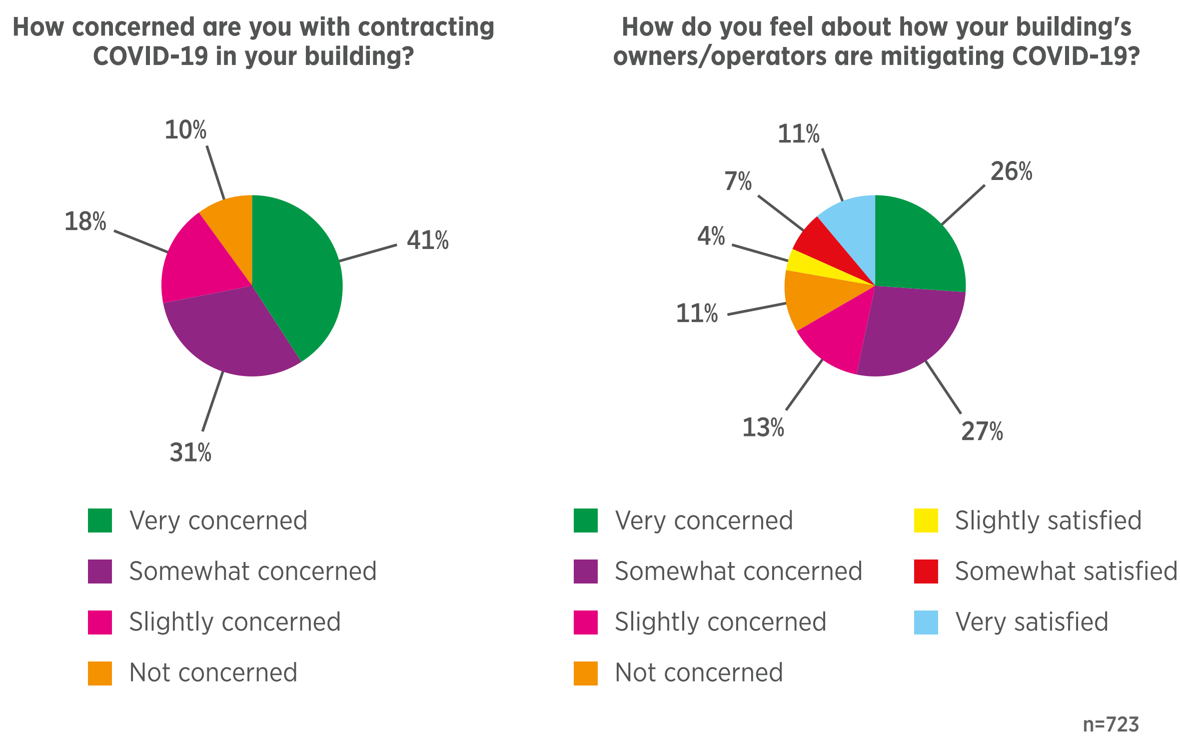
> "In the short term, energy management in buildings will be less of a concern, as people will not be in buildings as much as before and energy use will decrease. In the medium-term, energy consumption will increase as buildings adopt systems to introduce 100% outside air and add extra sterilization and ozone-generation systems. In the long term, building operators will be more conscious of energy concerns after taking that big hit and will want to recapture some savings."
>
> -Smart and Sustainable Building Specialist, Dewberry

While COVID-19 might change life in buildings, the need to manage energy usage and costs will remain.

5.1.1 Occupants are Concerned with COVID-19, Forcing Operators to Act

Buildings owners and operators would undoubtedly prefer life to return to normal after the COVID-19 pandemic, but the concerns of their occupants will ultimately force them to react. As seen in Figure 5.1, most building occupants are concerned with contracting COVID-19 in their building.

Figure 5.1 Occupants are Concerned With COVID-19



Source: CABA Intelligent Building Energy Management Systems 2020 Report

In addition, most respondents (66 percent) indicated that they were very, somewhat, or slightly concerned with how their buildings are responding to COVID-19. As these concerns grow, and occupants leverage their buying power to influence COVID-19 response technology procurement, operators must respond or risk losing their tenants.

5.1.2 Pandemic-Response Technologies are Rising in Buildings

In response to these concerns, suppliers have developed and are promoting technology-based solutions to make each key aspect of building life safer and healthier. As shown in Figure 5.2, new technologies can help improve building life and mitigate COVID-19 in the "New Normal".

Figure 5.2 Technologies to Enable COVID-19 Mitigation

Working and Collaboration	Entry	Breaks and Socializing	Comfort and Cleanliness	Getting Around
Virtual Meetings	Keyless & Touchless Entry	Contactless Payment	Air Circulation & Monitoring	Touchless & On-Demand Elevators
E-Learning & Training	Facemask Detection	Digital Ordering	Ambient Temperature Control	Automated Room Access
Virtual Whiteboards	Fever Detection	Voice-Enabled Coffee Makers	UV & Disinfecting Robotics	People Counting & Spacing Analytics
	Contact Tracing	Contactless Vending Machines	Touchless Hand Sanitizer Stations	

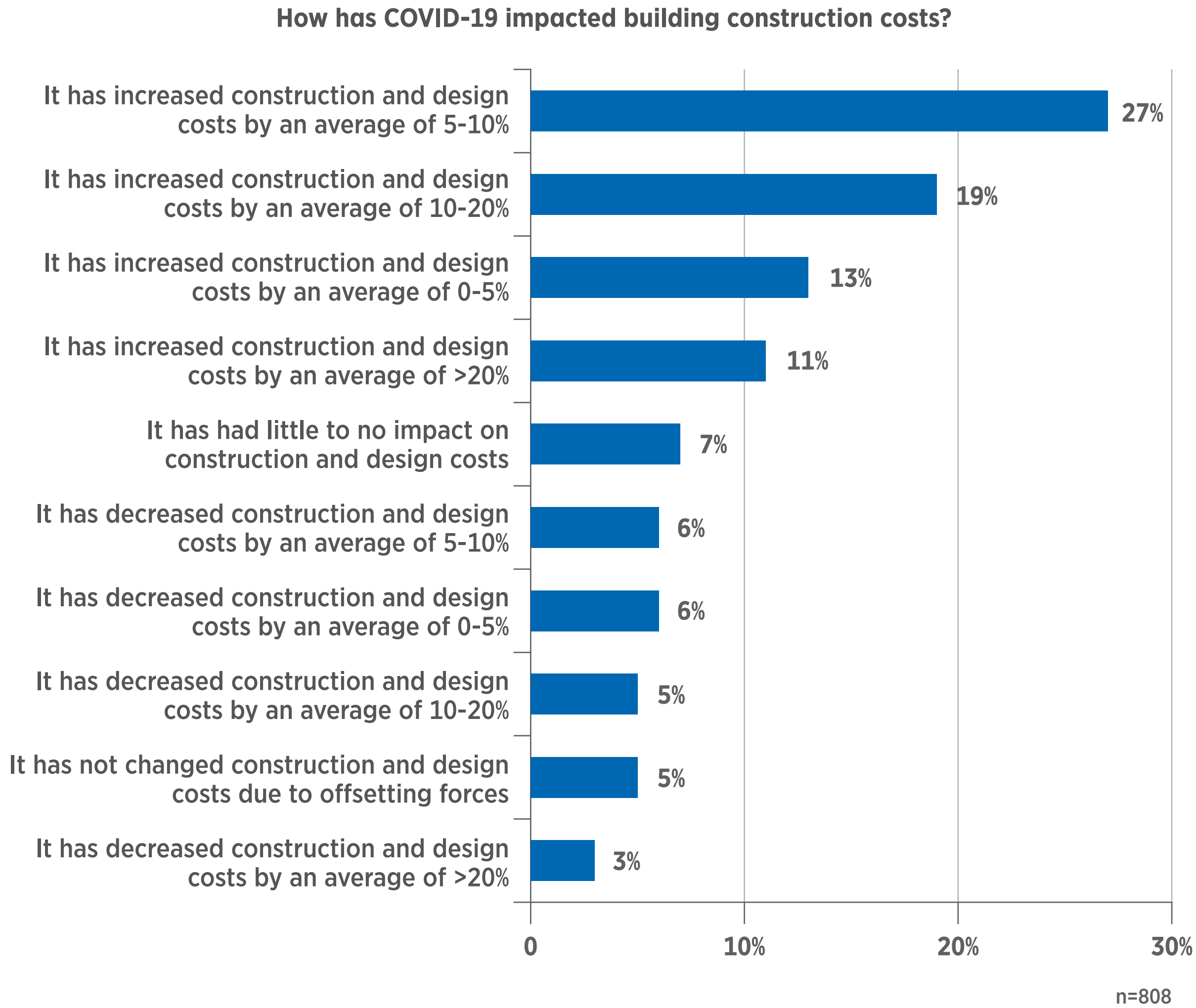
Source: CABA Intelligent Building Energy Management Systems 2020 Report

New technologies in buildings can enable contactless functions and consistent air quality circulation and filtration. In addition, the combination of these technologies can enable healthier buildings while improving the efficiency of buildings functions. For example, an automatic temperature screening system with biometric access control capabilities can recognize an entrant, clear them of COVID-19 symptoms, and then automatically call an elevator to take them to the correct floor—all without having the entrant touch any surface or have a face-to-face interaction with building staff/personnel.

5.1.3 Buildings are Paying More for COVID-19 Mitigation

In the constructor's survey, architects also lacked a consensus opinion on how COVID-19 would affect the prioritization of energy management and sustainability in buildings. However, they indicated that the pandemic has increased the cost of constructing buildings (Figure 5.3).

Figure 5.3 COVID-19 has Increased the Cost of Constructing Buildings



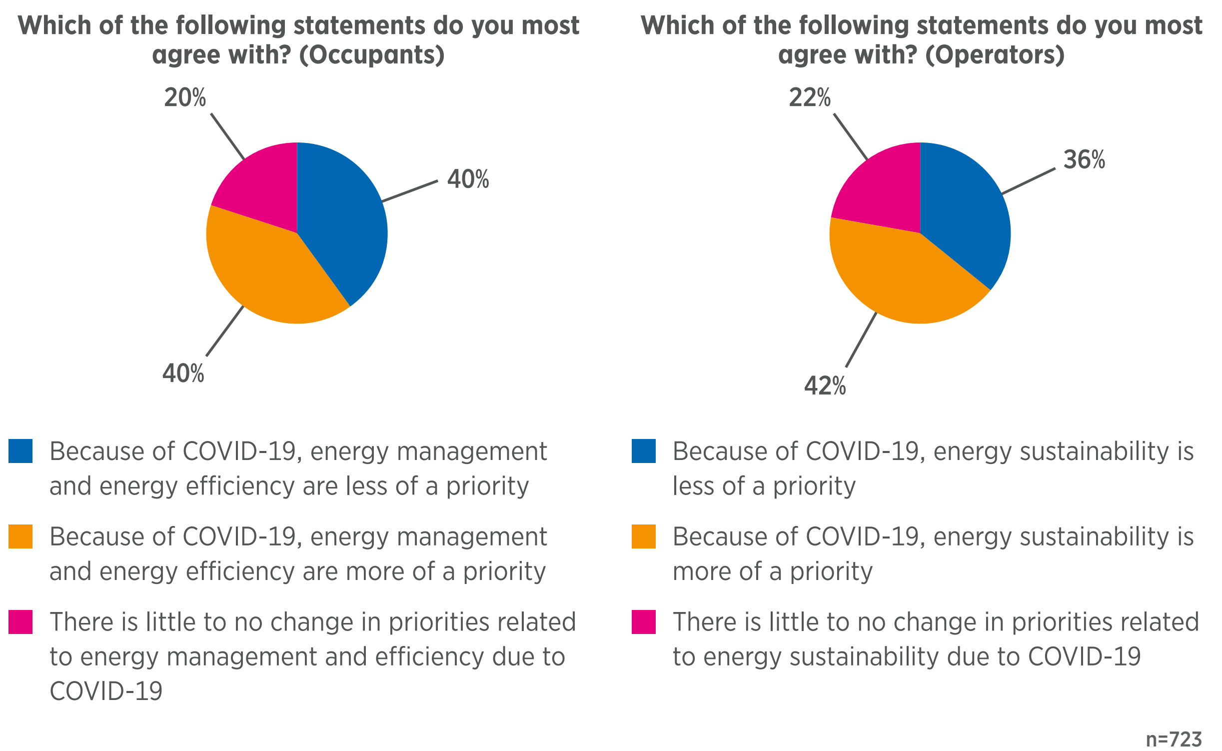
Source: CABA Intelligent Building Energy Management Systems 2020 Report

While most architects and integrators believe that COVID-19 mitigation will only slightly increase construction costs, almost one third of respondents indicated that it has increased costs by more than 10 percent. Building operators, who already possess limited capital to invest in new technologies, now must account for increased construction costs and recoup the costs through rent increases. In this case, energy-related cost savings can help operators recoup construction costs while enabling new technologies to create a more healthy and efficient buildings environment.

5.1.4 The Effect of COVID-19 on Energy Management Remains Unclear

When building occupants and operators were surveyed to determine the effects of COVID-19 on energy management and sustainability priorities in buildings, differences of opinion emerged (Figure 5.4).

Figure 5.4 The Effects of COVID-19 on IBEMS Priorities Remains Unclear



Source: CABA Intelligent Building Energy Management Systems 2020 Report

Most occupants and operators have an opinion of whether COVID-19 affects the prioritization of sustainability and energy management in buildings. However, there exists a relatively even split between those who believe that it will de-prioritize or increase the prioritization of these energy-related factors. Overall, these indicators show that energy management and sustainability will continue to be top-of-mind in buildings, even as COVID-19 changes how buildings function in society.

5.2 ACROSS THE IBEMS VALUE CHAIN, PLAYERS NEED TO ACT NOW AND WITH AN EYE TO THE FUTURE

As the fragmented, value-inhibiting IBEMS market begins to consolidate and evolve, players across the Intelligent Building ecosystem will have the opportunity to emerge as key enablers of this market and unlock new, higher-margin energy-related revenue streams from emerging services and analytics. As shown in Figure 5.5, IBEMS market participants need to improve the value of their IBEMS solutions while fostering a collaborative ecosystem aligned on IBEMS standards and best practices.

Figure 5.5 Strategic IBEMS Market Evolution Roadmap

Solution Development

1. Develop additional IBEMS pricing mechanisms for cost-conscious customers, including as–a-service/subscription models and revenue-sharing agreements
2. Universally adopt BACnet over Modbus, and work to adopt common naming standards (e.g., Project Haystack). Include product guides with clear instructions for data collection, BAS integration, and "easy win" energy best practices
3. Explore cost-effective packaged/bundled solutions, such as integrated LED lighting systems with smart meters, occupancy sensors, lighting controls, and smart shading systems included, perhaps by leasing hardware equipment

Ecosystem Development

4. Collaborate with COVID-19 response technology providers in order to make their systems interoperable with IBEMS, allowing operators to monitor their energy consumption
5. Work with governments and utilities to establish a common roadmap to GEBs, by asking for utility cost-recouping allowances, subsidies and incentives for building owners and operators, and common cybersecurity protocols and standards
6. Develop programs for buildings-enabled microgrids in Smart Cities, where buildings flexibly collaborate with utilities grids to maximize renewable energy and DERs while offloading excess energy to other Smart Cities technologies, such as electric vehicles

Recommended Development Timeline

Source: CABA Intelligent Building Energy Management Systems 2020 Report Systems 2020 Report

However, recommendations differ by player type, as each seeks to capture the IBEMS market.

5.2.1 OEM Strategic Recommendations

For OEMs, the value of building appliances and equipment will shift to the software and services that leverage the data that these systems produce. Although it might seem counter-intuitive in the near term, breaking up closed ecosystems and enabling "plug-and-play" based interoperability between devices and systems will help spur the overall IBEMS market and incentivize operators to buy more complex, expensive systems over time. As this occurs, OEMs can embed their systems with energy usage monitoring and sensing. In the long-term, edge analytics and AI inferencing will allow OEMs to drive significantly higher margins from their products.

- Short-Term
    - Embed devices with energy usage monitoring capabilities and data-collecting sensors, such as occupancy sensors
    - Leverage open, interoperable data sharing protocols to allow products to be easily integrated with software and BMS/BAS, regardless of their brand
    - Embed security protocols and privacy protections on devices (e.g., de-identifying personally identifiable information (PII) prior to it being stored or shared)
- Medium-Term
    - Explore adding predictive energy analytics capabilities that leverage occupancy sensing, so devices can predict and share their future energy needs to utilities
    - Integrate data-sharing capabilities with other devices, allowing device configuration settings to operate in concert with other buildings devices, with a single interface
- Long-Term
    - Shift selling models to "as a service" or subscription models that leverage equipment leasing, allowing products to be bundled and lowering CAPEX costs to operators
    - Add over-the-air software updates and remote maintenance and support
    - Bundle related products together (e.g., Smart shading systems, lighting systems) for a lower-cost, more integrated offering
    - Acquire or develop analytics capabilities and begin to sell value-added software

In short, OEMs need to move away from inhibitive legacy business models, such as closed ecosystems, and shift their products towards interoperable, data-collecting equipment. Then, over time, they can explore bundling solutions to drive volume and ultimately augment traditional product-based offerings with value-added software and services that leverage data from their devices.

5.2.2 Utilities Strategic Recommendations

For utilities, IBEMS is not just a new revenue opportunity—it is a necessity for survival. Disrupted by sustainability demands and aging, expensive infrastructure, utilities must significantly change their business models if they are to survive long into the future. To accomplish this, utilities need to integrate DERs and invest in demand-response programs. In addition, they should aggressively work with buildings and regulatory bodies to increase the adoption of DERs and grid interactivity.

- Short-Term
  - Invest in DER generation and distribution capabilities and programs
  - Evolve demand response programs and capabilities to support load flexibility and automated load shifting
- Medium-Term
  - Establish secure two-way building-to-grid communication and data sharing
  - Provide buildings attractive incentive programs to enable grid-interactivity, even taking a loss to spur this market model
  - Explore virtual audits and non-wire alternatives for all new infrastructure installations
- Long-Term
  - Sunset legacy power distribution infrastructure in favor of non-wire alternatives
  - Work with cities and communities to develop and establish sustainable microgrids that leverage energy production and storage capabilities of buildings

Changing the North American power distribution and transmission model may seem like a daunting task today, but non-wire alternatives and enabling grid interactivity can provide lifelines and revenue streams for utilities as they enable the future of distributed energy.

5.2.3 Software Provider Strategic Recommendations

IBEMS software providers today are hindered by market fragmentation and a lack of insight into real-world building operations and specifics. First, these providers should promote the adoption of a common IBEMS naming standard, which over time can position them to offer more advanced applications.

- Short-Term
  - Adopt a common data labelling and naming standard (e.g., Project Haystack)
  - Lower costs to operators with attractive pricing strategies, such as no charges until cost savings from energy efficiency are realized
  - Further tailor applications to each building's specific region, climate, and function
- Medium-Term
  - Expand the potential user base with low-code/no-code scripting and control options, and by developing unsupervised machine learning models that are provided out-of-the-box with little customization required
- Long-Term
  - Develop software applications built on top of grid-interactivity, such as the ability to automatically match utilities price signals with load shifting to optimize the cost of energy provided to a building at a given time
  - Integrate with external Smart Cities applications and use cases to provide a city-wide view of traditional and renewable energy consumption in buildings, ideally by leveraging open data platforms

Software providers need to either develop their systems as modules/add-on features to existing BAS/BMS applications, or they need to ensure easy interoperability between their applications and building controls systems. By continuing to develop applications in siloes, software providers will increasingly be pushed out of the market in favor of large, diversified OEMs and automation providers.

5.2.4 Recommendations for Buildings Owners/Property Managers

Lastly, building owners and property managers need to continue to prioritize energy management and sustainability at all stages of building construction and operation. They need to educate tenants and building staff as to the benefits of IBEMS and lay out clear strategies to meet energy and carbon goals.

- Short-Term
    - Invest in IBEMS, eliminating manual energy management processes
    - Augment buildings with energy storage and renewable energy generation
- Medium-Term
    - Augment lighting controls and shading systems to better enable energy use visibility and automated controls for energy savings
    - Work with governments and utilities to develop financial incentives and revenue-sharing agreements for grid interactivity
- Long-Term
    - Augment security controls on GEB-related devices and applications to ensure that device vulnerability do not implicate external power grids
    - Allow occupants and tenants to ability to individual configure energy usage on their floors and allow them to set and meet additional sustainability goals

Ultimately, building owners need to be creative about how they can upgrade their building's technology infrastructure and capabilities in a cost-effective manner. This requires close collaboration and innovative revenue-sharing models with governments and utility operators.

5.3 CONCLUSIONS & FINAL REMARKS

In conclusion, the IBEMS market is fragmented today, with operators struggling to choose between many products that require a significant amount of technical knowledge. Although IBEMS adoption is relatively high, both with standalone EMS software applications and integrated in larger BAS/BMS systems, operators are struggling to gain value from these systems.

Currently, IBEMS solutions frustrate operators due to their prohibitive costs, difficulty of use, lack of easy integration with buildings data, and their ultimate inability to articulate their value or provide an immediate, tangible return on investment (ROI). These issues all stem from a lack of visibility of the suppliers into real-world building operations, pain points, and specific data types. Greater two-way knowledge and collaboration can help these devices provide more value to buildings.

For IBEMS applications to truly mature, they need to consider the context of the buildings in perspective of the external electrical power generation, distribution, and transmission systems. in North America. Massive energy savings and an effective integration of renewable energy generation and storage needs close collaboration and two-way data sharing between utilities and buildings. For this new business model to emerge—that of grid-interactive efficient buildings (GEBs)—utilities, governments, and building operators need to align on the proper incentives and develop a feasible roadmap.

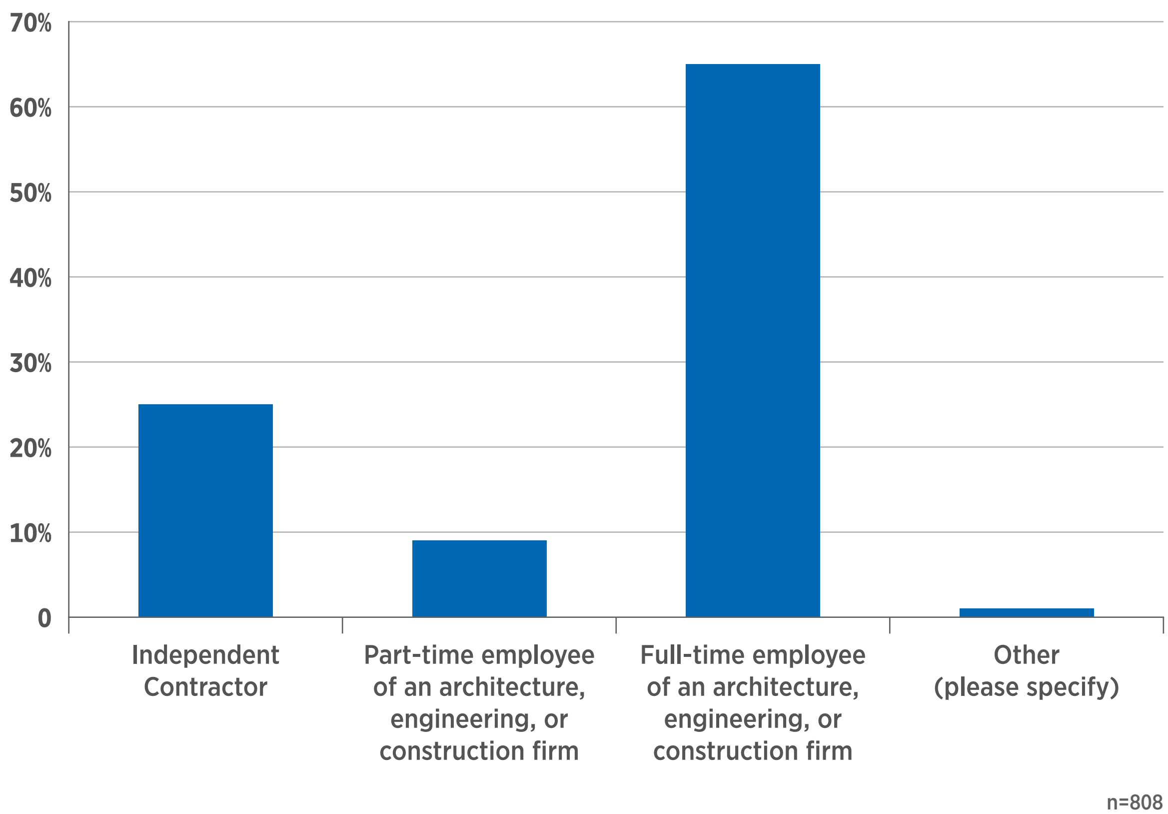
Like almost every aspect of modern life, the IBEMS market evolution has been impacted by the COVID-19 global pandemic, as occupants fear for their health and operators clamor to adopt contactless technologies and better air quality filtration systems. While the true effect of COVID-19 on the prioritization of energy management and sustainability remains unclear, energy management will continue to be a huge part of buildings as more energy-intensive technologies are adopted.

For buildings, the path to energy efficiency exists, but it may not be clear how to achieve it. Therefore, all Intelligent Building ecosystem participants need to come together and collaborate on energy management best practices. The future of Smart Cities and the health of the environment depend on it.

APPENDIX A: DETAILED SURVEY DATA

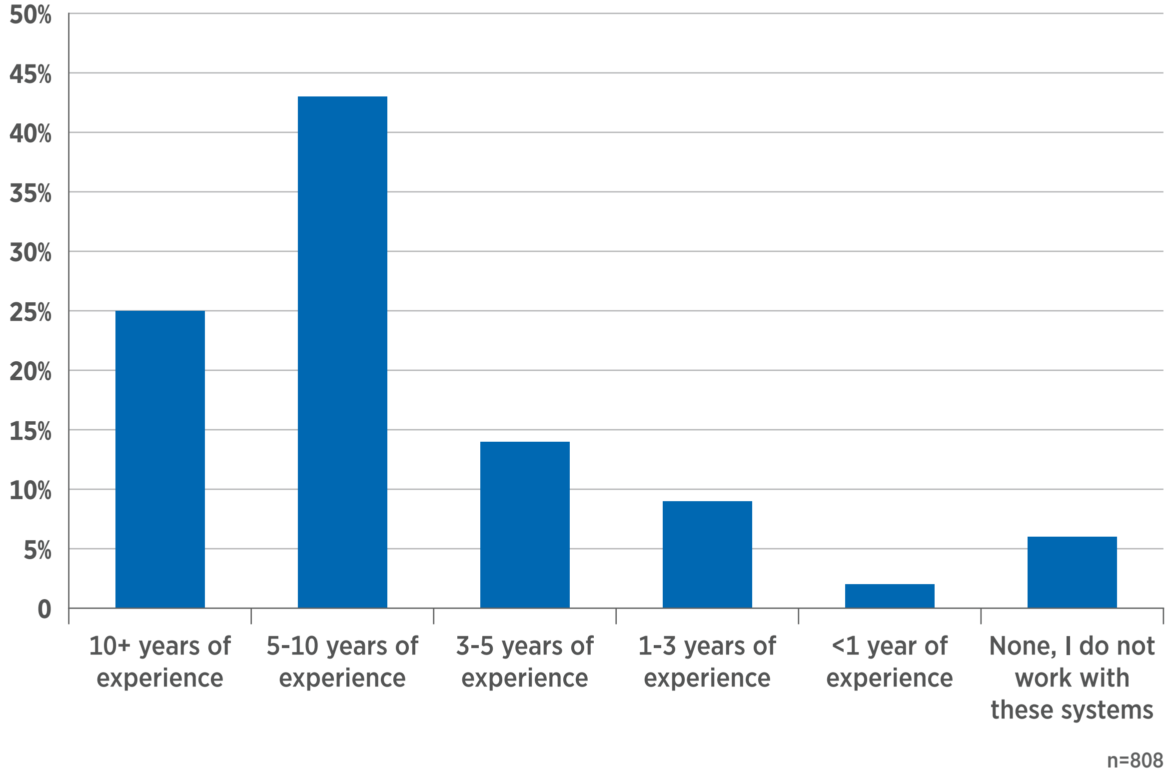
Architects/Constructors

Figure A.1 Are you an independent contractor, or are you part of a larger construction, design, or architecture firm?



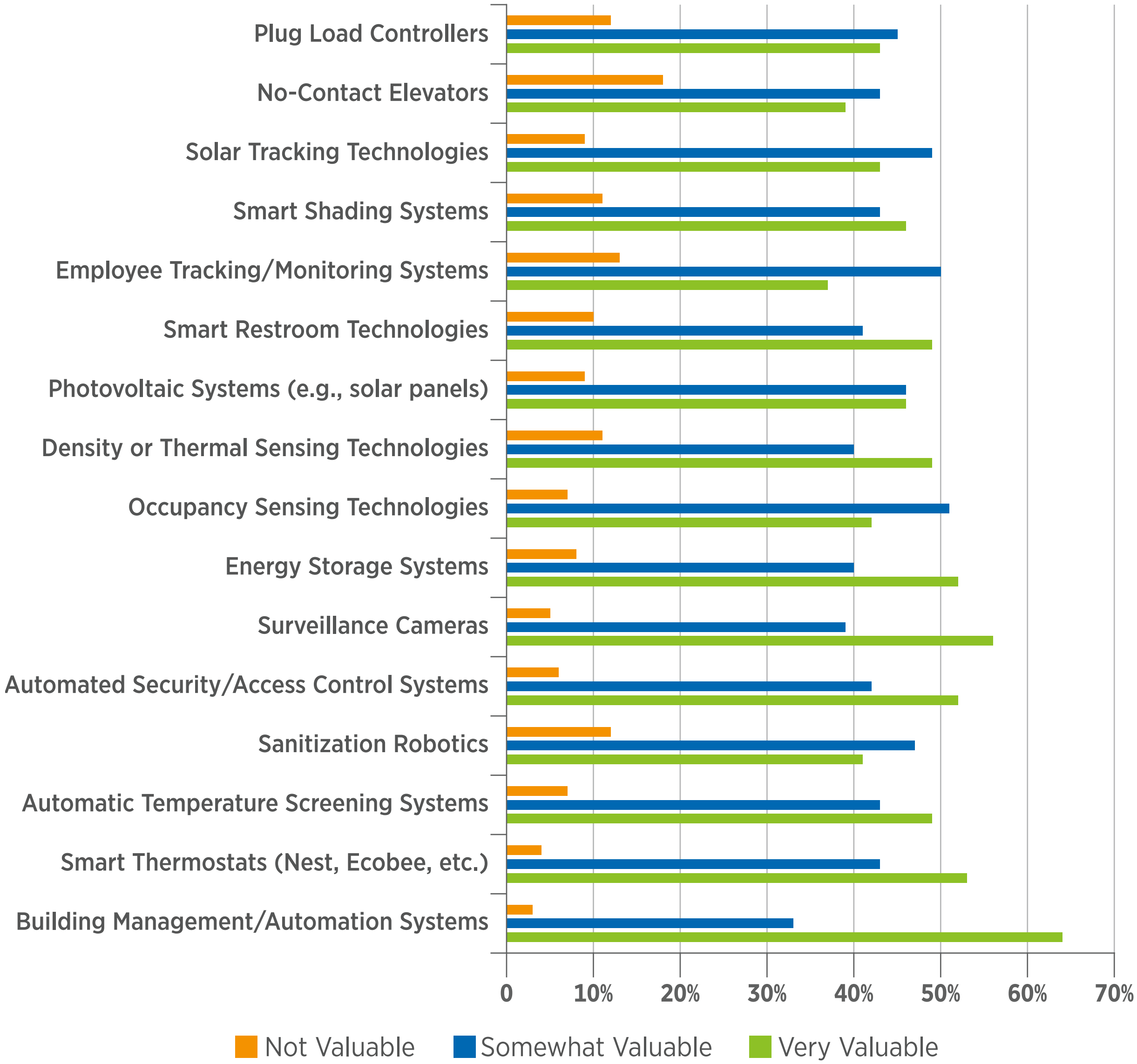
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Figure A.2 How many years of experience do you have with operating, implementing, or configuring building energy management systems?



Source: CABA Intelligent Building Energy Management Systems 2020 Report

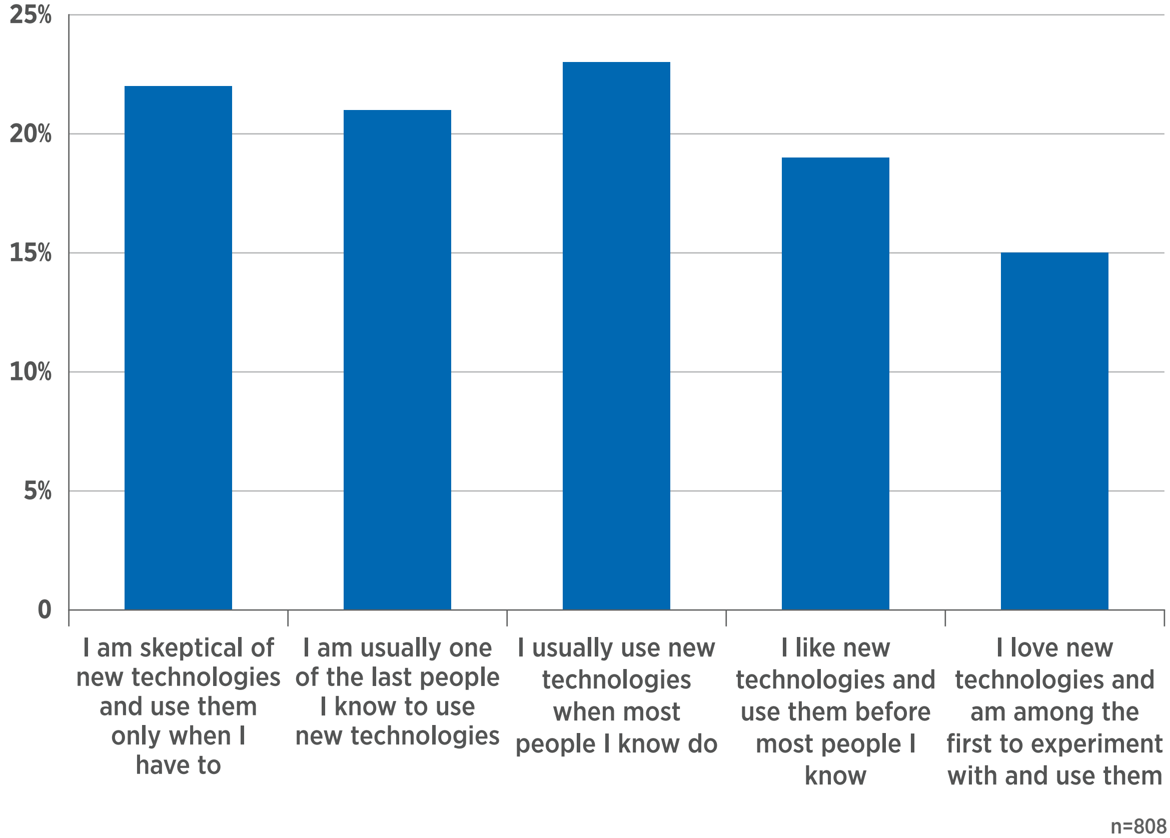
Figure A.3 Rate the following technologies or capabilities by how much value you think they would add to buildings you develop:



n=808

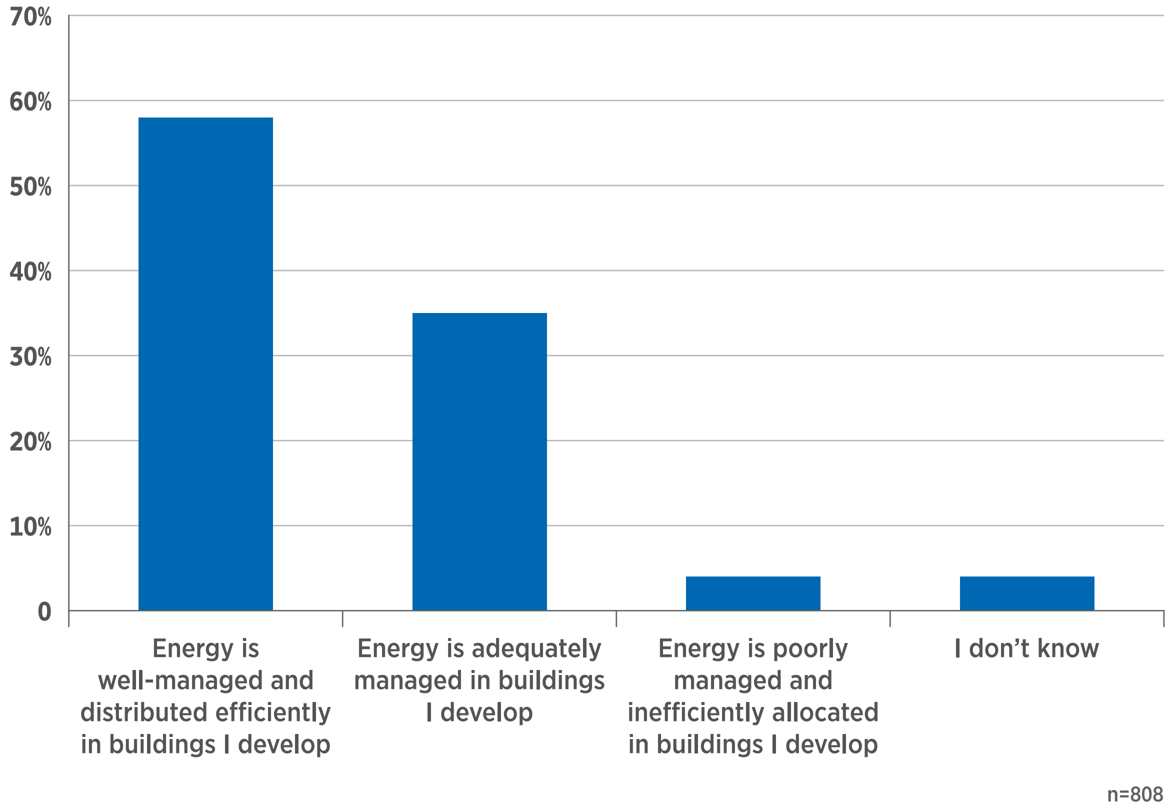
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Figure A.4 Which statement would best describe your view on technology adoption?



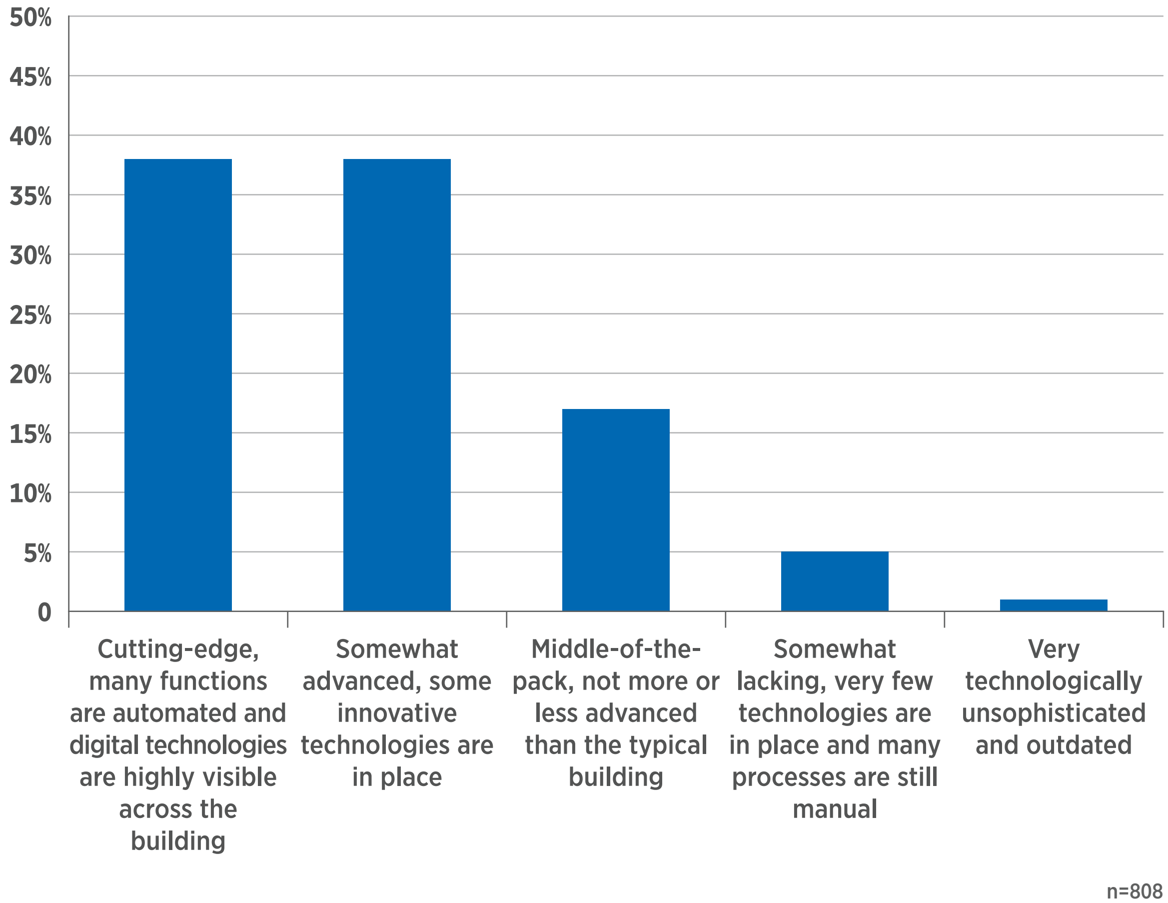
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Figure A.5 Which of the following best reflects your opinion of how energy is being managed in the majority of buildings you develop?



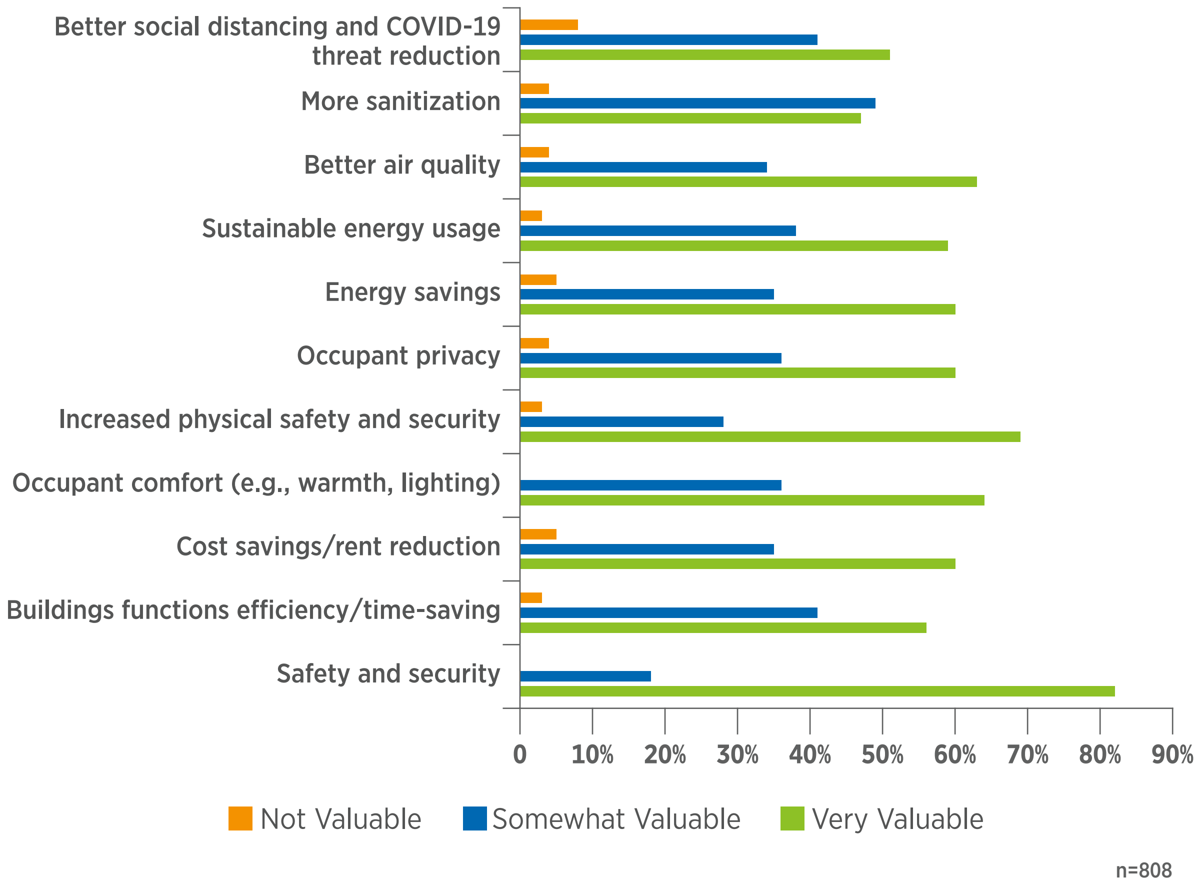
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Figure A.6 How technologically advanced do you feel the majority of buildings you develop are?



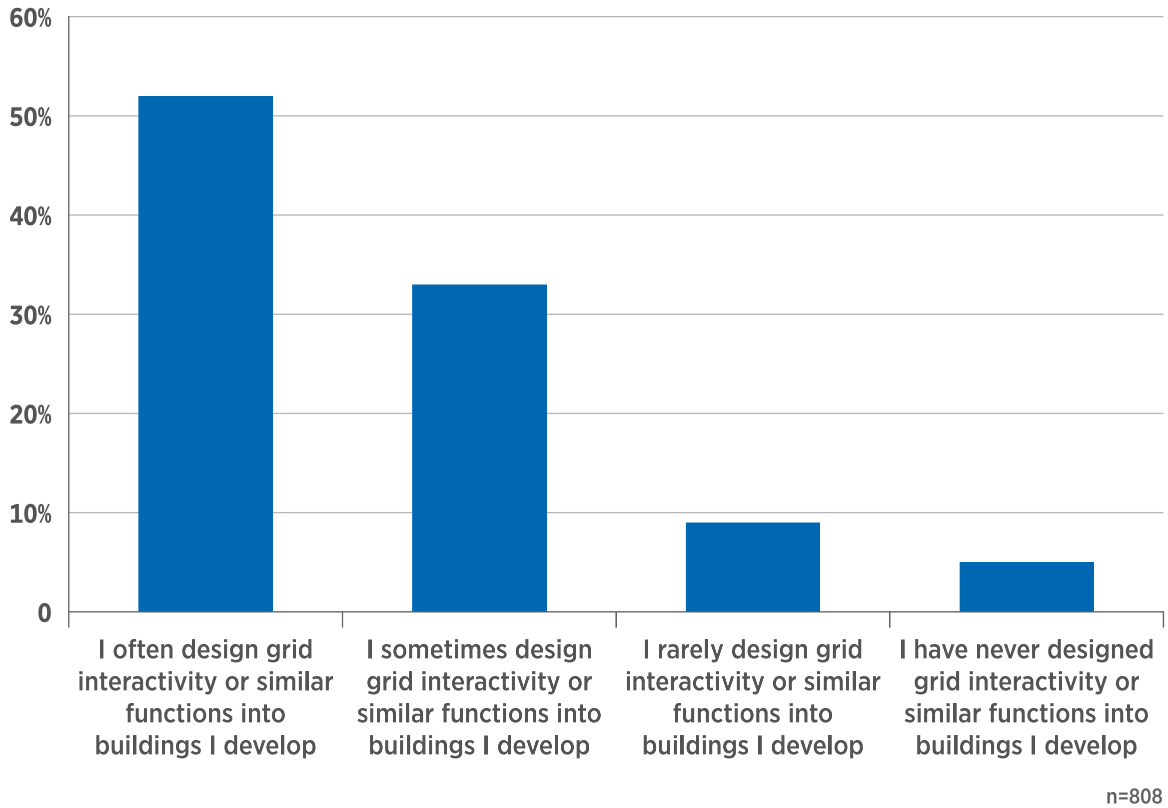
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Figure A.7 When designing a building, rank each of the following items by how much they influence how the buildings is designed:



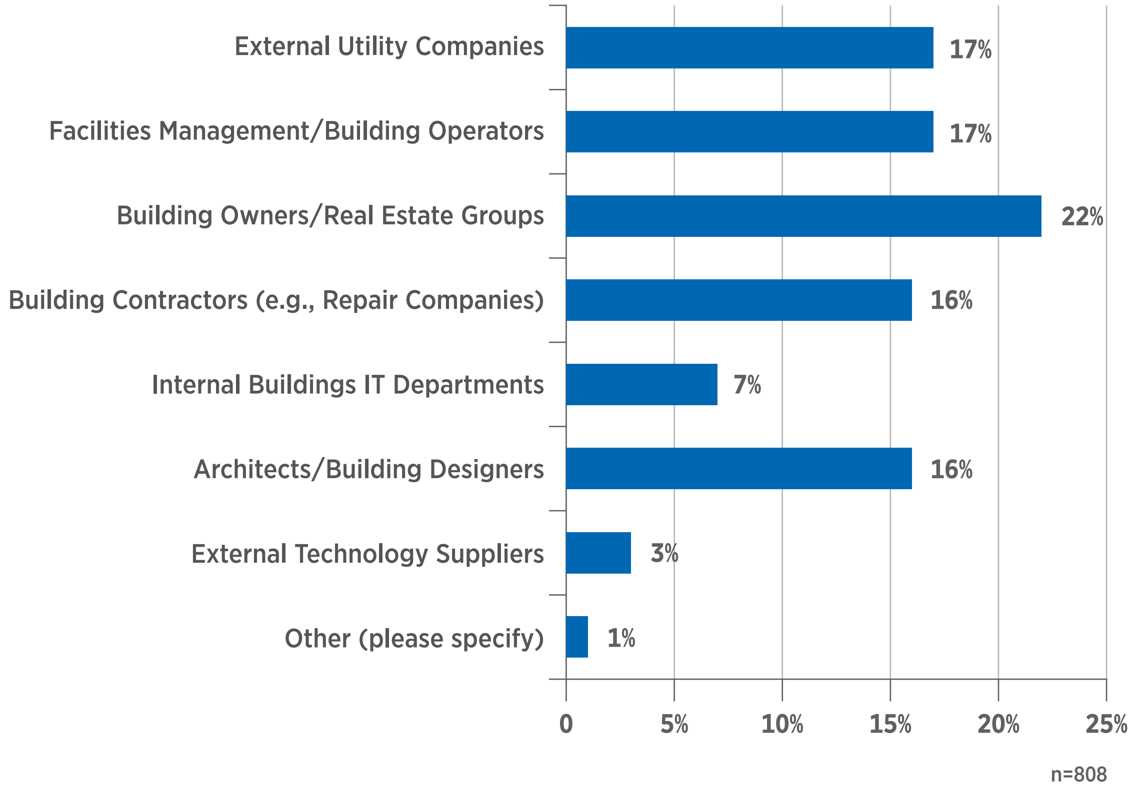
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Figure A.8 How often do you enable grid interactivity in buildings you develop?



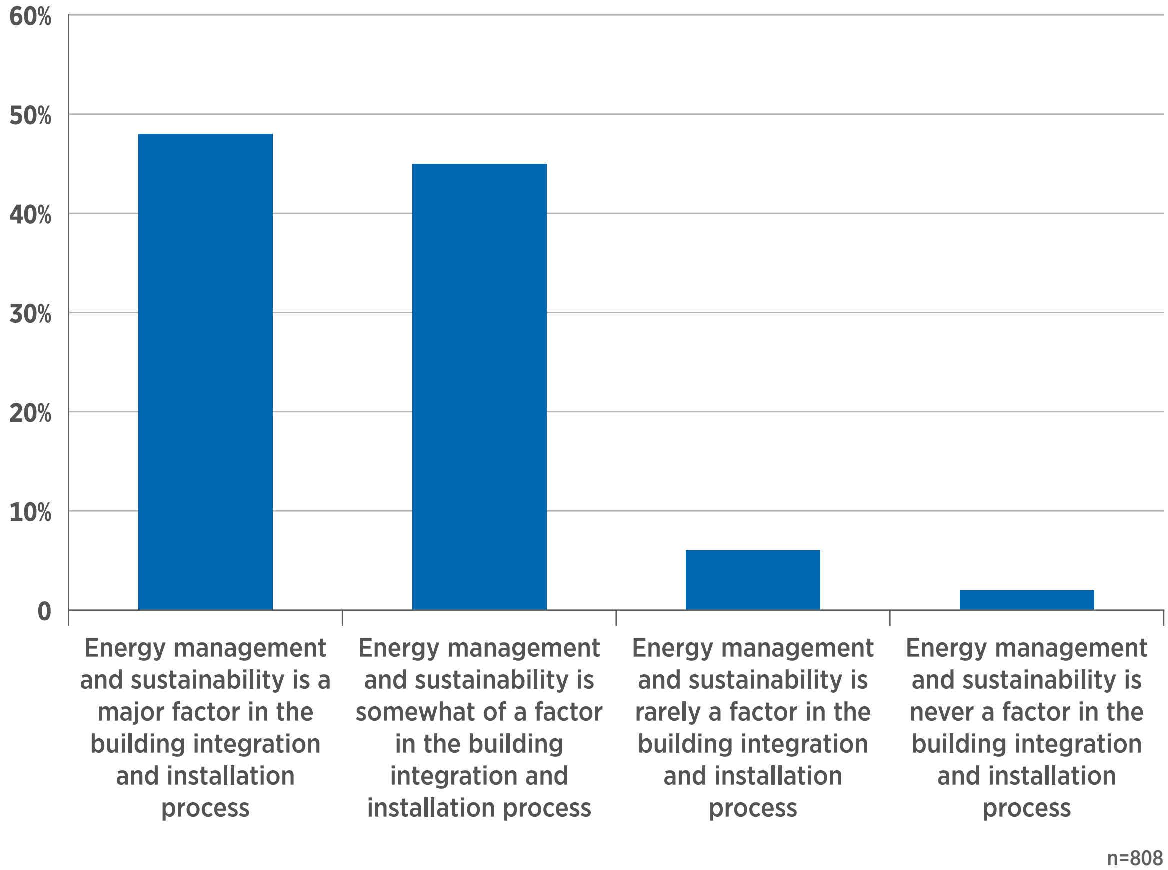
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Figure A.9 When designing a building, which stakeholder group most often prioritizes energy management and sustainability?



Source: CABA Intelligent Building Energy Management Systems 2020 Report

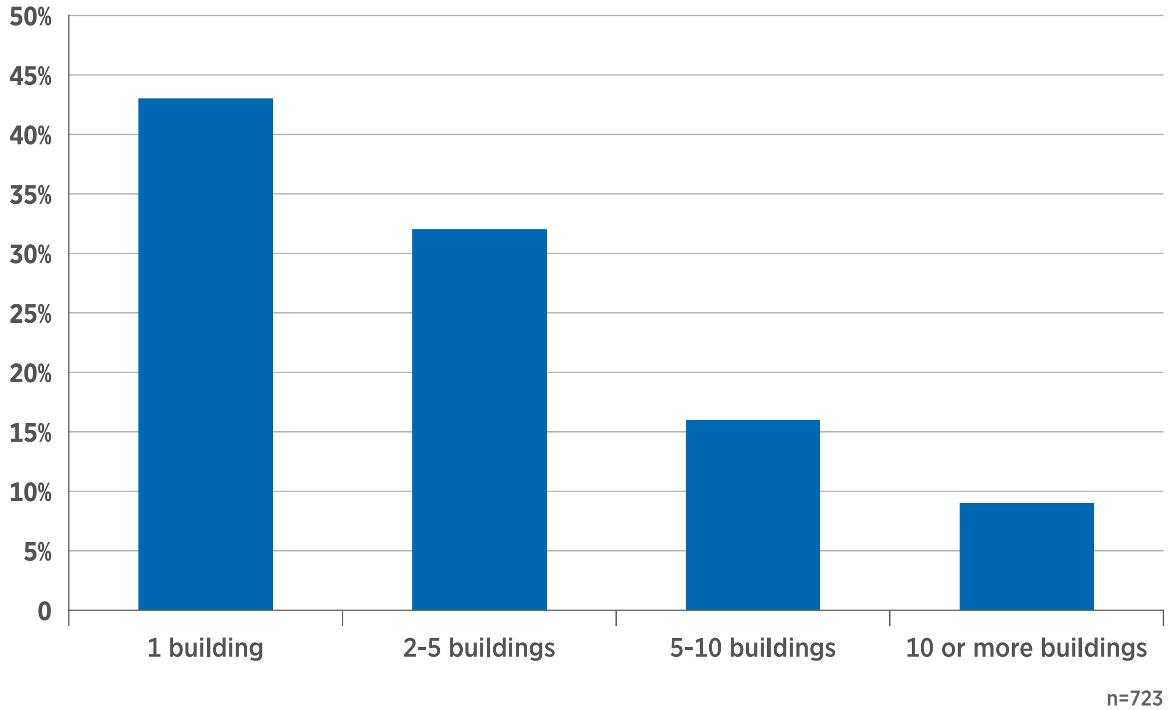
Figure A.10 Which of the following statements do you most agree with?



Source: CABA Intelligent Building Energy Management Systems 2020 Report

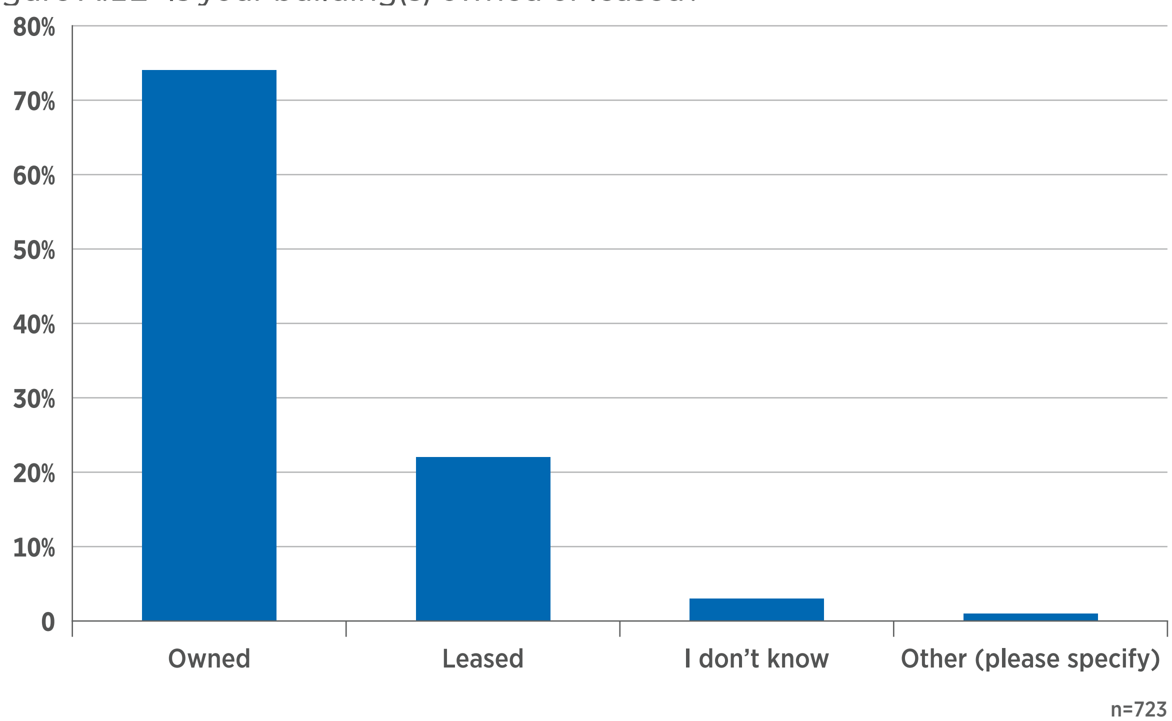
Operators/Occupants

Figure A.11 How many different buildings do you work in, or manage/operate, as part of your job?



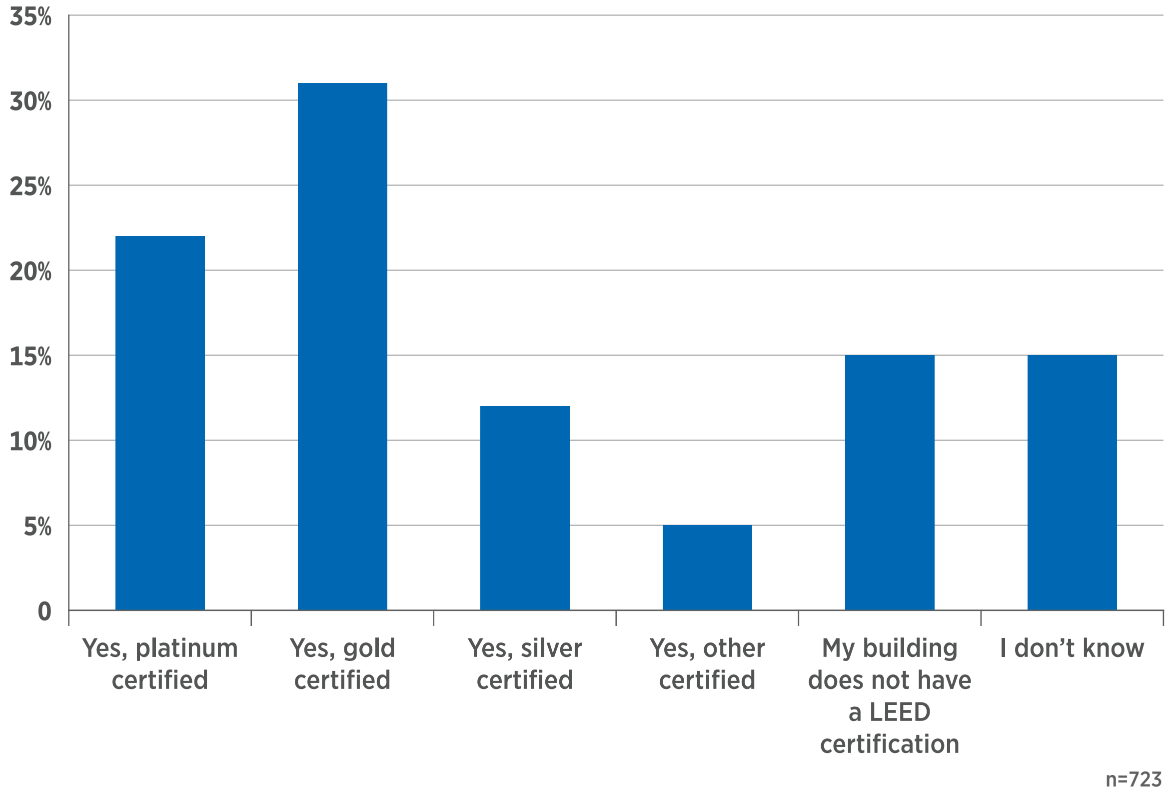
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Figure A.12 Is your building(s) owned or leased?



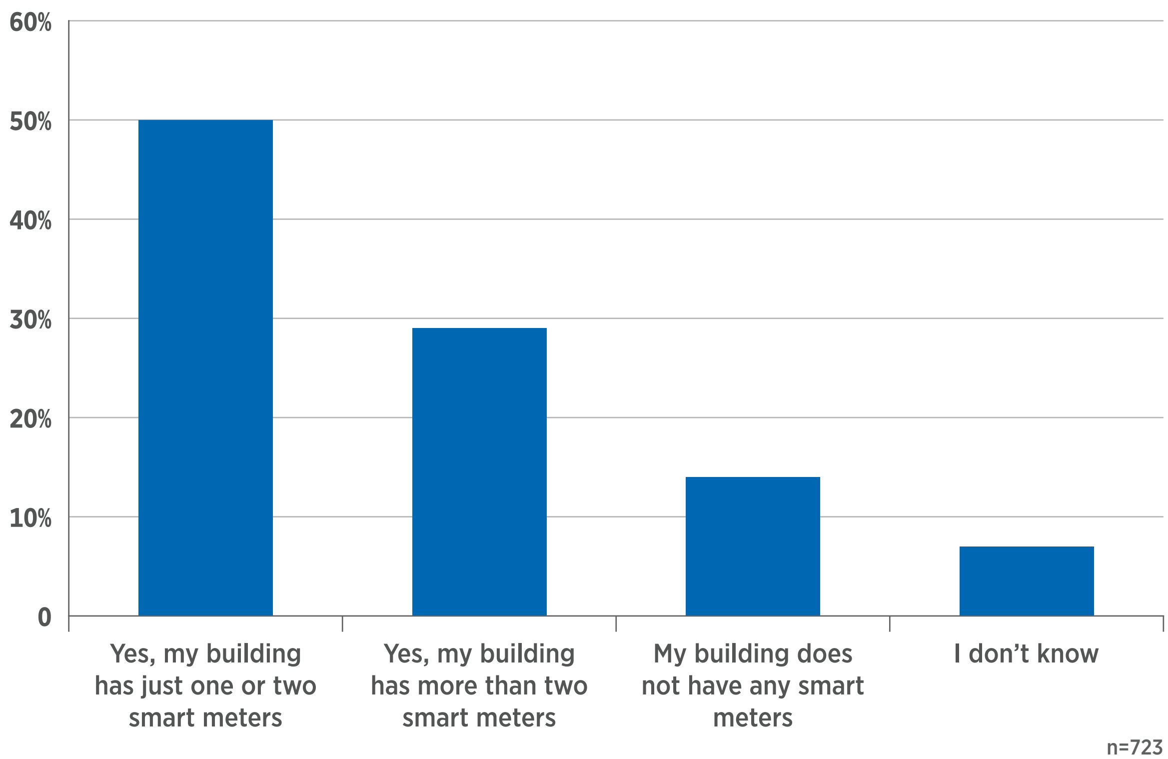
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Figure A.13 Does your building have a LEED certification, and if so, what is it?



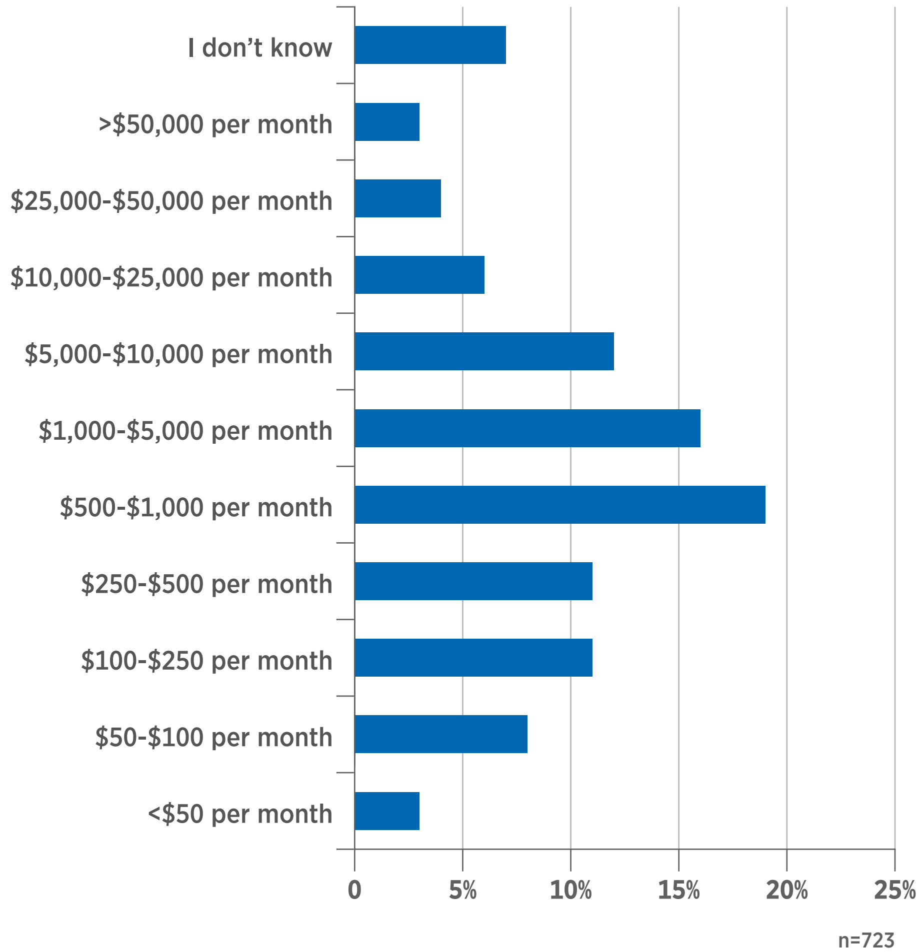
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Figure A.14 Does your building have one or more smart energy meters?



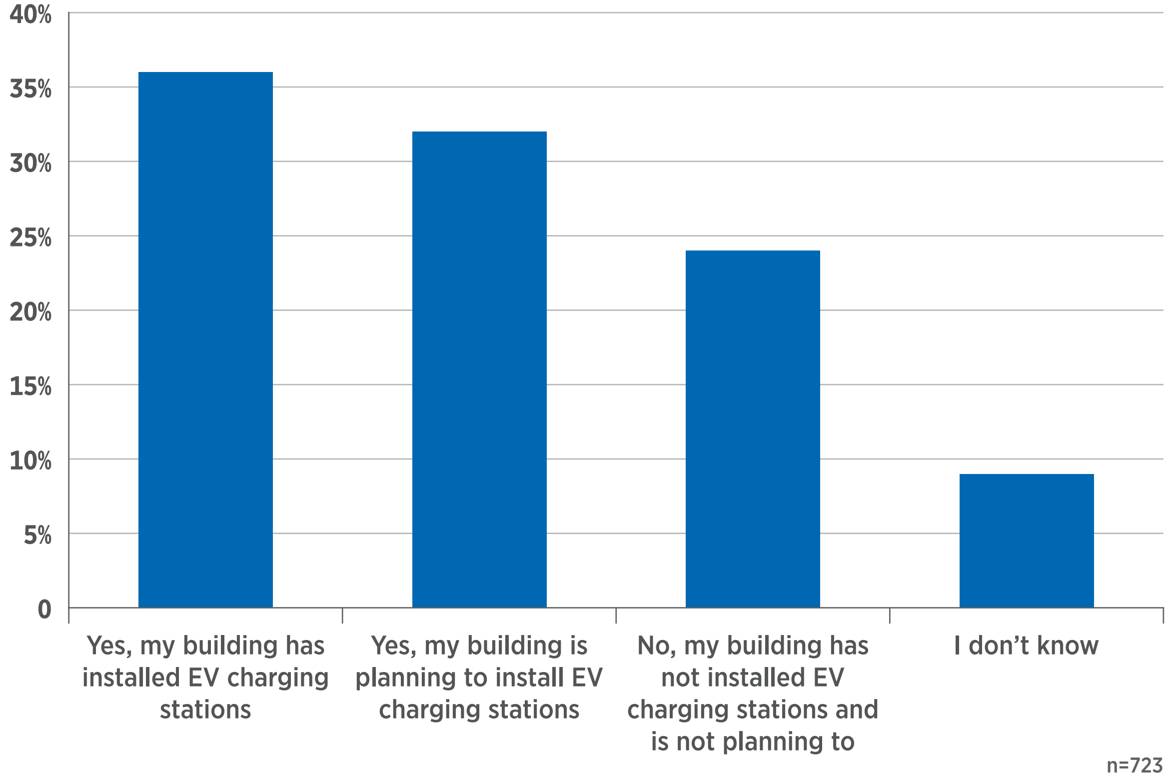
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Figure A.15 To the best of your knowledge, approximately how much is your monthly utilities bill on average?



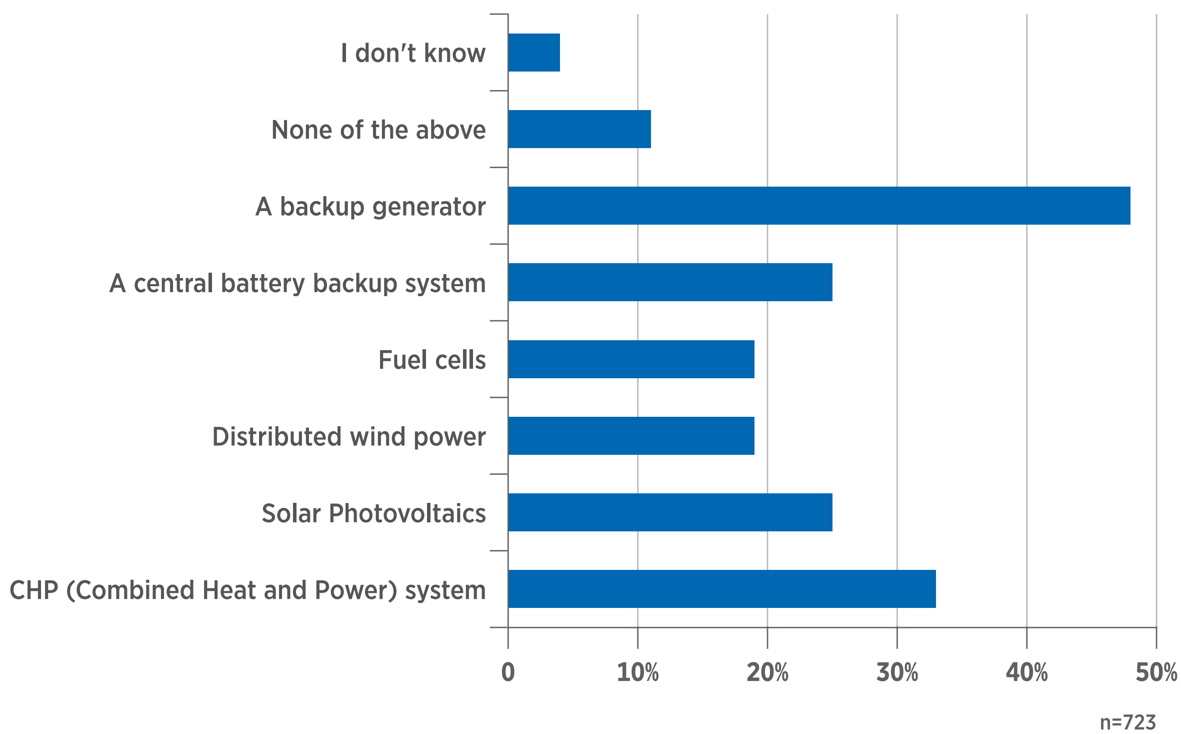
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Figure A.16 Do you plan in the next year, or have you currently installed EV charging stations for electric vehicles?



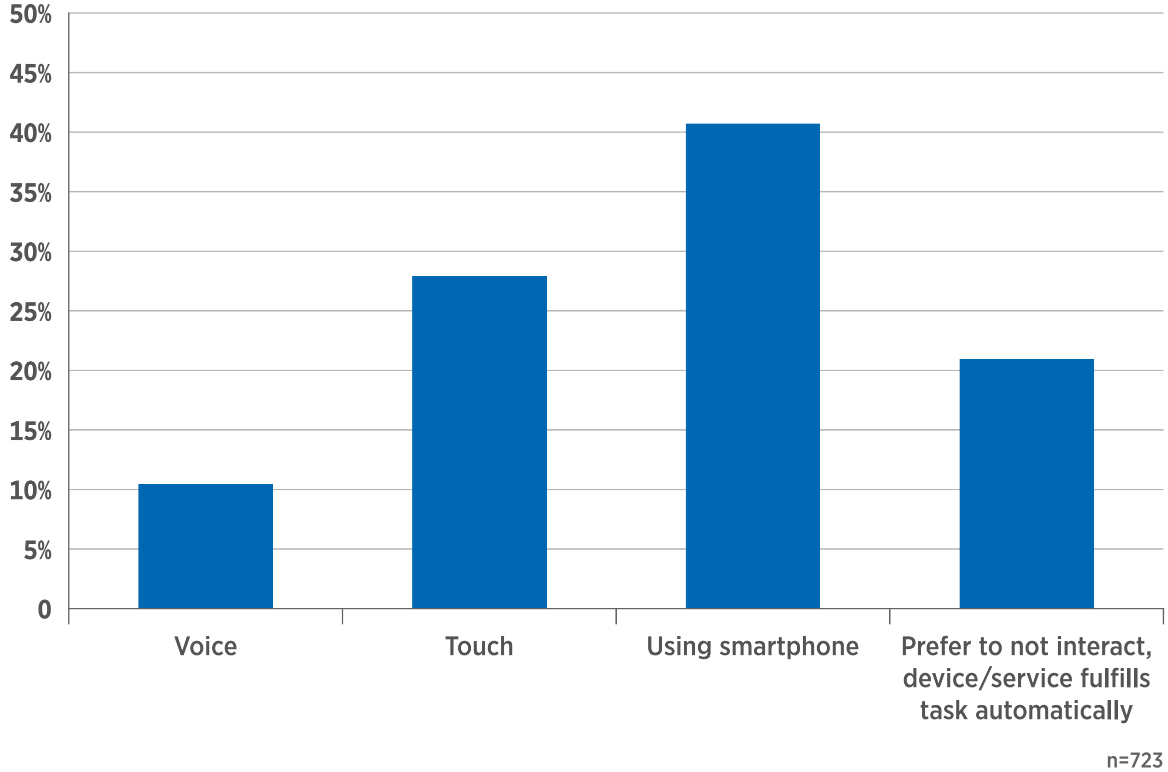
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Figure A.17 Which of the following energy generation and energy storage technologies has your building adopted?



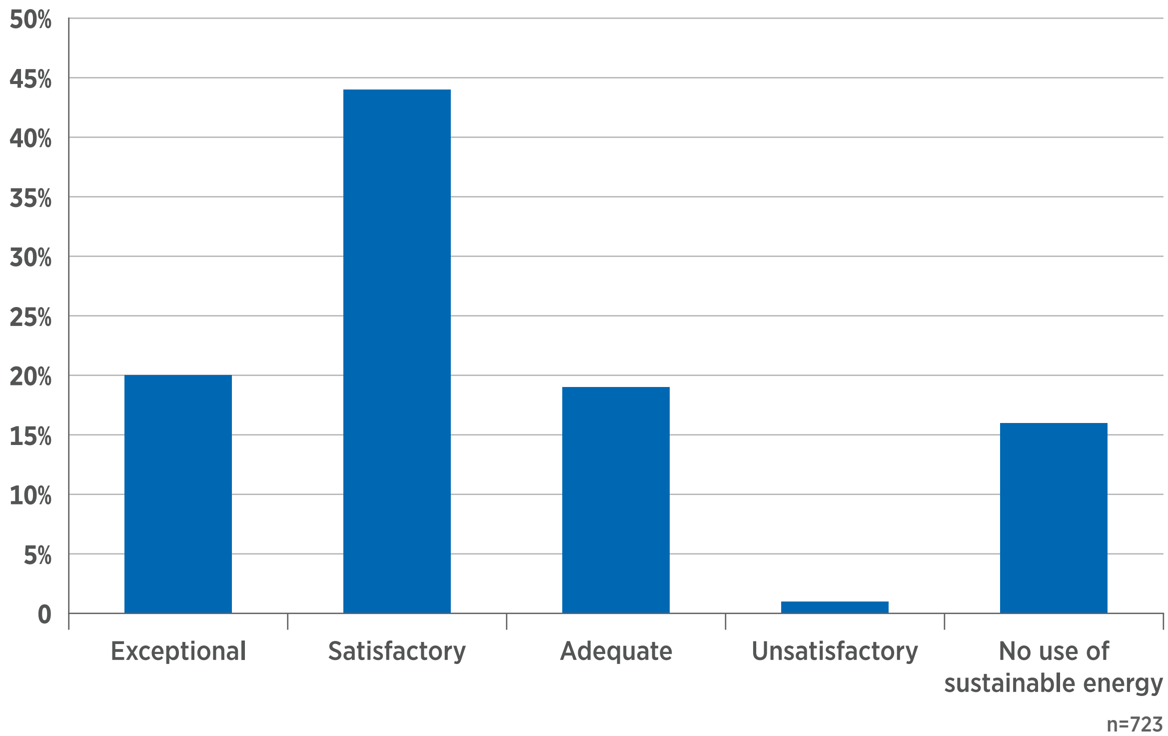
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Figure A.18 How would you prefer to control energy usage in your building?



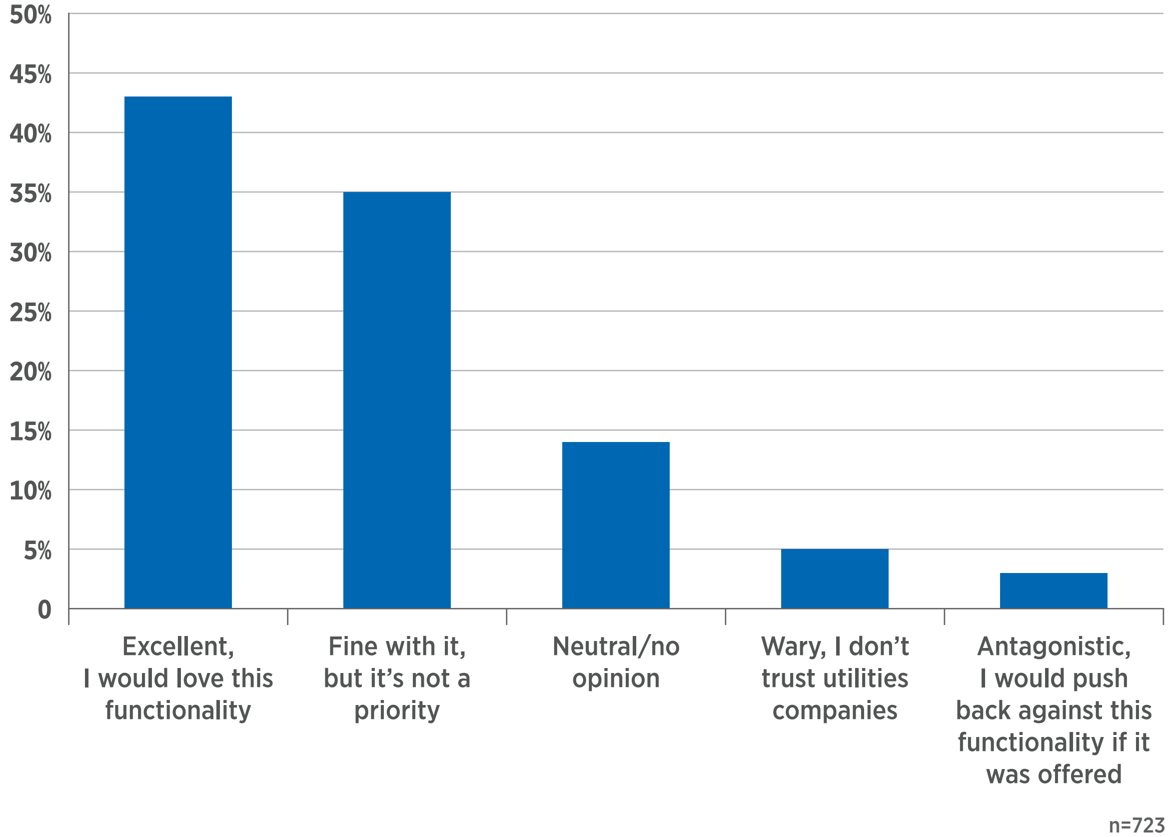
Source: CABA Intelligent Building Energy Management Systems 2020 Report

Figure A.19 How would you rate your building's use of sustainable or renewable energy sources?



Source: CABA Intelligent Building Energy Management Systems 2020 Report

Figure A.20 How would you feel about devices in your building communicating their energy usage directly with utility companies?



Source: CABA Intelligent Building Energy Management Systems 2020 Report

APPENDIX B: INTERVIEW PARTICIPANTS

Accenture
Connected Buildings Lead

CBRE
Energy Manager

Colliers International
Energy & Sustainability Manager

Dewberry
Mechanical Engineer, Smart and Sustainable Buildings Specialist

Dude Solutions
General Manager, Energy

GE Appliances/Haier
Innovation Manager

Golden Properties
Director of Operations

Intelligent Buildings, LLC
Co-Founder and Principal

Johnson Controls
VP, Global Product Development

McKenney's
Project Development Specialist

McKinstry
Regional Director

Newcomb & Boyd
Senior Consultant, Intelligent Buildings

Nexus Labs
Founder

POWERHOME Solar
Director of Utility Services

Powerley
Director of Product Management & Marketing

PSEG
Manager, Electric & Gas Asset Strategy

Tolin Mechanical Systems
HVAC Service Technician

Town of Pittsboro
City Commissioner

Xcel Energy
Director of IT Operations & Infrastructure

Z3 Controls
Vice President

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APPENDIX D: GLOSSARY

Advanced Metering Infrastructure (AMI): A group of integrated smart electrical meters that communicate over a wired or wireless network and store data in a central location.

Application Overlay: Overlays refer to application that sit on top of existing applications, allowing for data ingest and to provide a different user interface.

Arc Fault Detection Devices (AFDD): Technologies, such as circuit breakers, that can detect and quickly shut off electric arcs—electrical power breakdowns of gas that produce an electrical discharge, which can cause fires.

Artificial Intelligence (AI): AI refers to a device or computer that can perceive its environment and make actions intelligently to accomplish a task.

Bluetooth: Bluetooth is a wireless networking standard that allows devices to share data across short distances. Bluetooth is low range, but more powerful when compared with WiFi.

Building Automation and Control Network (BACnet): BACnet is a communication protocol for Building Automation and Control networks that leverage the ASHRAE, ANSI, and ISO 16484-5 standard protocol.

Building Automation System (BAS): A system that is designed to control building operations and indoor climate.

CapEx: CapEx refers to capital expenditures, which are one-time payments that an organization makes to procure or maintain its fixed assets.

Combined Heat and Power (CHP): A rapidly emerging cogeneration method that allows buildings to simultaneously produce heat and electrical power from the same source—often a thermal generation system like a boiler or steam turbine.

Data Lake: A data lake is a centralized repository that allows you to store all your structured and unstructured data at any scale.

Demand Flexibility: Demand flexibility is the capability of DERs to adjust a building's load profile across different timescales; energy flexibility and load flexibility are often used interchangeably with demand flexibility.

Demand Response: Change in the rate of electricity consumption in response to price signals or specific requests of a grid operator.

Digital Twin: A digital twin is a digital replica of a living or non-living physical entity. Digital twin refers to a digital replica of potential and actual physical assets, processes, people, places, systems and devices that can be used for various purposes.

Distributed Energy Resources (DER): Small-scale power generation or storage technologies (typically in the range of 1 kW to 10,000 kW) used to provide an alternative to or an enhancement of the traditional electric power system.

Energy Management System (EMS): An application that allows users to visualize and control energy consumption. These can either be independent applications or modules of BAS products.

Fixed Wireless Access (FWA): FWA is a 5G technology that will replace legacy fixed-line broadband solutions with 5G cellular networking capabilities. FWA promises more than 100 times the capacity of 4G networks, while eliminating the need for wired broadband connections.

Grid-interactive Efficient Building (GEB): An energy-efficient building that uses smart technologies and on-site DERs to provide demand flexibility while co-optimizing for energy cost, grid services, and occupant needs and preferences, in a continuous and integrated way.

Grid Services: Grid services refer to services that support the generation, transmission, and distribution of electricity and provide value through avoided electricity system costs (generation and/or delivery costs).

Heating, Ventilation and Air-Conditioning (HVAC): The technology used to maintain good indoor air quality and provide thermal comfort.

Independent Software Vendor (ISV): ISVs are organizations that specialize in selling software products for a variety of purposes and applications.

LEED® Certification: LEED, or Leadership in Energy and Environmental Design, is the most widely-used green building rating system.

Load Profile: A building's load profile describes when—time of day or hour of the year—the building is consuming energy (typically used to refer to electricity consumption but can also describe on-site fuel use); load shape and load curve are often used interchangeably, but all refer to the timing of energy use.

Modbus: Modbus protocol is defined as a master/slave protocol, meaning a device operating as a master will poll one or more devices operating as a slave.

OpEx: OpEx refers to operating expenditures, which are recurring or ongoing payments for running a business or developing a product.

Original Equipment Manufacturers (OEMs): OEMs refer to manufacturing companies who resell another company's product under their own name. Often, they purchase parts and equipment manufactured by another company and sell them in their own offerings.

Out of the Box (OOTB): OOTB refers to software or hardware products that are ready to be used immediately without any installation, configuration, or modification.

Peak Load: Peak loads refer to instances of maximum energy demand. In buildings, this usually refers to the time of day where the building is consuming the most energy.

Personally Identifiable Information (PII): Similar to PHI, PII is any data or information that could be linked to a specific person. The sharing of PII raises security and privacy concerns.

Pneumatic HVAC Controls: Pneumatic control systems use compressed air to receive and send the signals that control HVAC equipment.

Smart Systems: Networks of IoT devices combined into applications of increasing complexity that leverage connected nodes to create collective awareness of process or environmental conditions and enhance decision-making.

System Integrators (SIs): System integrators are organizations or individuals who work with clients to integrate and implement complex information technology (IT) systems.

Time Sensitive Networking (TSN): TSN is a set of Ethernet standards that define the mechanisms for transmitting latency-sensitive data over deterministic Ethernet networks. TSN is a data-link layer technology that, combined with other protocols, can achieve deterministic machine-to-machine communication across a variety of markets.

Transport Level Security (TLS): Transport Layer Security, or TLS, is a widely adopted security protocol designed to facilitate privacy and data security for communications over the Internet.

Ultraviolet (UV): a form of electromagnetic radiation with wavelength from 10 to 400 nm

Unsupervised Machine Learning: Unsupervised learning is a type of machine learning that looks for previously undetected patterns in a data set with no pre-existing labels and with a minimum of human supervision.

User Interface (UI): The user interface refers to the screen on a device where users can interact and control the device.

Utility Submetering: Utility sub-metering is a system that allows a landlord, property management firm, condominium association, homeowners association, or other multi-tenant property to bill tenants for individual measured utility usage.

WiFi: WiFi is a group of wireless networking standards, developed by the Wi-Fi Alliance, that are commonly used for local area networking. Devices compatible with the WiFi protocols can connect to the internet through a wireless access point.

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