INTELLIGENT BUILDINGS AND BIG DATA

CABA

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Intelligent Buildings and Big Data

There is a consensus in the industry, that the proliferation of intelligent devices and internet technologies has created an exponential increase in the volume, velocity, and variety of data. This phenomenon is commonly referred to as 'Big Data'. Current data management systems are not capable of processing this new influx of data, and as a result companies are forced to ignore the majority of the data available. The goal of this research is to examine new tools and resources that can help companies filter, analyze, and use Big Data collected from intelligent and integrated buildings. Leveraging Big Data will enable a better understanding of customer behaviors, competition, and market trends. Research on utilizing Big Data from building systems is crucial to staying competitive in this dynamic connected marketplace. A detailed Research Prospectus is available upon request.

This report was prepared for CABA by **Navigant Research**.

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3.1 ABOUT THIS REPORT

The Continental Automated Buildings Association (CABA) commissioned Navigant Research to study new tools and resources emerging in the market to help companies filter, analyze, and use Big Data collected from their intelligent and integrated buildings. Leveraging Big Data will enable a better understanding of customer behaviors, competition, and market trends. Research on utilizing Big Data from building systems is crucial to staying competitive in this dynamic connected marketplace.

Navigant Research and the Steering Committee first convened via a webinar in July 2014, 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 a broad stakeholder online survey.

The outcomes of this collaborative research project will provide a clear understanding of the opportunities and solutions of managing data derived from intelligent buildings. This research examined how data from intelligent buildings can be more efficiently filtered, analyzed, and ultimately used by all segments of the industry. This information will eventually lead to greater productivity, reliability, efficiency, and operational control of intelligent buildings.

3.2 SPONSORS

Navigant Research and CABA would like to acknowledge the CABA member sponsors listed below, and the respondents who helped make this research possible. We would also like to take this opportunity to thank the CABA member sponsors and CABA, as well as all those organizations that contributed their valuable time and information. In particular, we appreciate the trust and transparency shown by respondents willing to share confidential information. Without the help of all these organizations it would not have been possible to produce such an in-depth and detailed study. Ruby sponsors (EcoOpera Systems, Inc., Honeywell International, Inc., Jonson Controls Incorporated, Schneider Electric, Inc.) we provided the opportunity to present a case study in this report.

The final presentation was delivered by webinar in February 2015

3.3 ROLE OF THE STEERING COMMITTEE

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

3.4 ABOUT CABA

The Continental Automated Buildings Association (CABA) is an international not-for-profit industry association, founded in 1988, dedicated to the advancement of connected home and building technologies. The organization is supported by an international membership of over 300 organizations involved in the design, manufacture, installation and retailing of products relating to home automation and building automation. Public organizations, including utilities and government are also members. CABA's mandate includes providing its members with networking and market research opportunities. CABA also encourages the development of industry standards and protocols, and leads cross-industry initiatives.

Please visit http://www.caba.org for more information.

3.5 ABOUT NAVIGANT RESEARCH

Navigant Research is a market research and advisory group that provides in-depth analysis of global clean technology markets with a specific focus on the commercialization and market growth opportunities for emerging energy technologies. The team's research methodology combines supply-side industry analysis, end-user primary research and demand assessment, and deep examination of technology trends that impact the rapidly-evolving energy services and infrastructure sectors.

Our client base includes Fortune 1000 multinational technology and energy companies, government agencies, utilities, investors, industry associations, and clean technology pure plays. We provide these companies with market research reports, custom research engagements, and subscription-based research services.

Navigant Research is focused across four research programs: Smart Energy, Smart Transportation, Smart Utilities, and Smart Buildings. The Navigant Research analyst team comes from a diversity of industry backgrounds and leverages deep analytical skill sets in covering emerging technology and energy markets. Together, the team brings a wide range of capabilities to help clients build successful strategies in these sectors, from engineering and technology assessment, to corporate strategy development, to classic quantitative and qualitative market research methodologies. Research analysts are not only experts and thought leaders in their current areas of market coverage, but also bring a broad perspective from years of experience in related technology and energy businesses. This is further enriched by the expertise of Navigant Consulting's Energy Practice, with hundreds of professionals engaged in all aspects of the energy economy.

Please visit http://www.navigantresearch.com for more information.

3.6 INTRODUCTION

Big data is a topic of debate on the next frontier in business intelligence, and there is a growing interest in focusing the discussion on intelligent buildings. The reality, however, is that intelligent building solutions already represent an evolution in facilities and business operations management from the legacy systems that lead the landscape.

3.7 THE CHALLENGE OF BIG DATA IN INTELLIGENT BUILDINGS

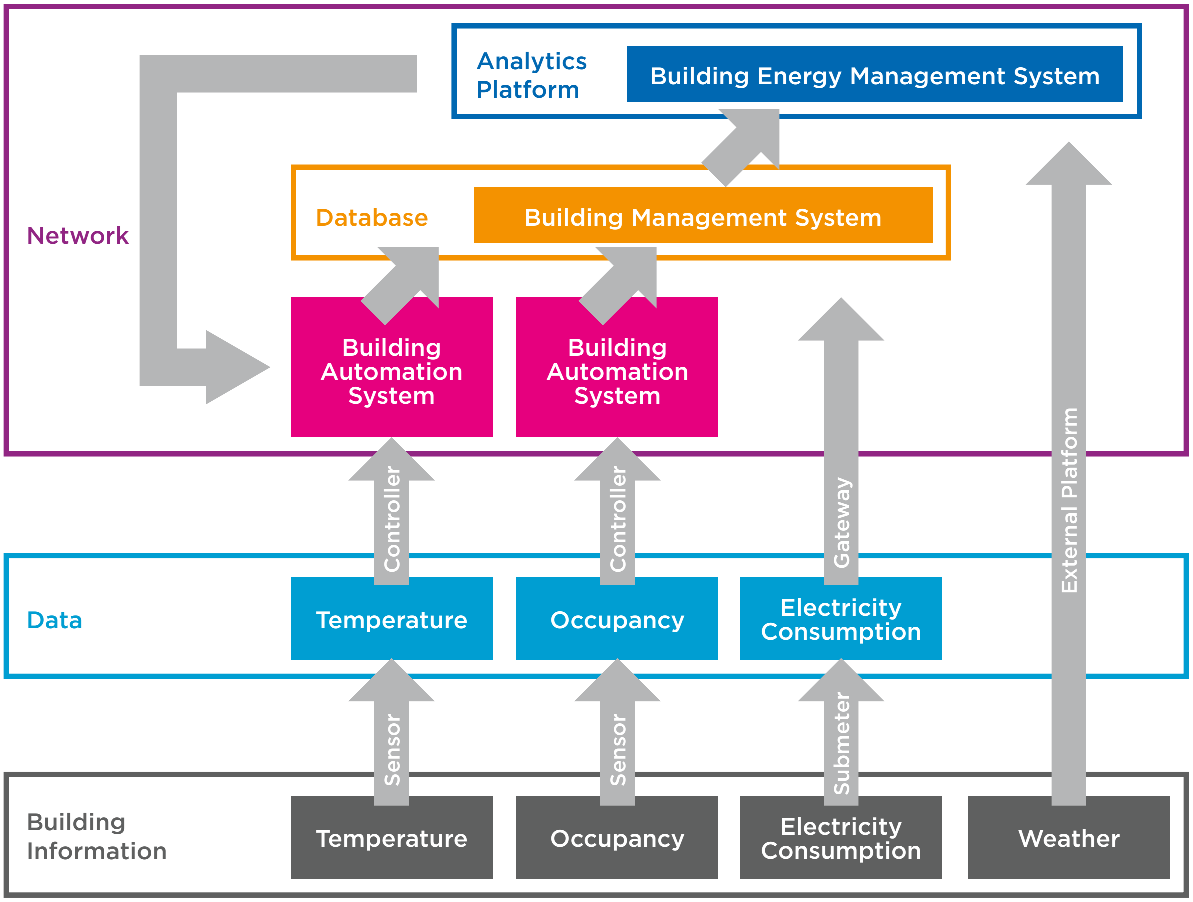
The challenge for big data solution providers is to help end-users understand the added benefits of big data and what differentiates these solutions in terms of business value to help accelerate the market from investment by innovators today and move toward early adoption in the medium term.

The term big data has become increasingly popular in recent years. Despite the hype, there is no single, cohesive definition. In general, the term refers to data that exceeds the capacity or capability of current or conventional methods and systems. In other words, the notion of "big" is relevant to the current standard of analysis. While there are various definitions depending on the industry in question, many seem to agree on the following characteristics that identify big data: volume, velocity, and variety.

3.7.1 Defining Big Data in Intelligent Buildings

Traditionally, building control has taken a top-down approach with integration between different systems, such as HVAC and lighting, occurring at a supervisory level. However, analytics solutions are beginning to shift the architecture of building systems to a more distributed platform with hybrid and predictive control based on multiple inputs and outputs from multiple systems. Current solutions focus mostly on energy management. However, building data analytics can also provide cost savings through optimized O&M as well as improved occupant comfort.

Figure 3-1 Generic Building Data Flow



(Source: Navigant Research)

On its own, big data, or any data for that matter, cannot actually solve any problem or do anything. It is only through the collection, integration, and use of the data in analysis that value can be provided, turning data into information and ultimately knowledge. Big data analytics can, therefore, be viewed as the tool that gives business value to large data sets.

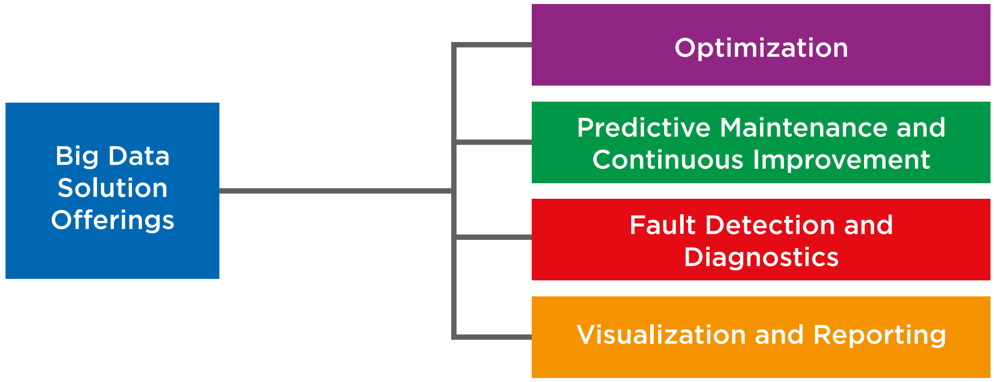
It is necessary to provide a clear definition of big data in the intelligent buildings context in order to support the market analysis and revenue forecasts, both critical deliverables for this research. Big data in intelligent buildings is, therefore, defined as:

> The next generation in business and operational intelligence derived from the analysis of data integrated across multiple streams or sources for the purposes of overall system understanding, performance, and optimization.

In addition, throughout this report, the term big data encompasses both the solution architecture and associated analytics. Big data analytics is an extension of the analytics that have brought new insight to key decision makers exploring opportunities for investment and operational management changes.

Furthermore, characterizing big data solutions for intelligent buildings by offering type helps provide a framework for assessing technology maturity, integration complexity, and the value proposition for different customer segments. There is a wide array of big data solutions in the market, but Figure 1.1 illustrates the four offering categories that are applicable to the intelligent buildings market.

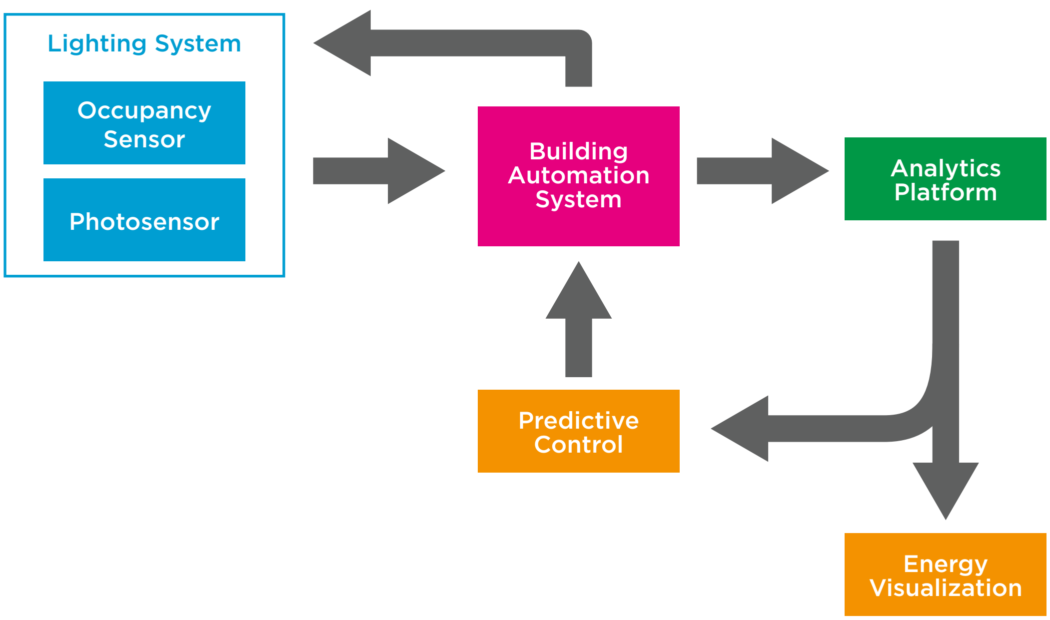
Figure 3-2 Big Data Solution Offerings for Intelligent Buildings



(Source: Navigant Research)

As an example, the deployment of the analytics process on a lighting control system similarly consists of capture, integration, analysis, and action. However, the data captured from the system would come from occupancy sensors and photosensors. Like in the HVAC deployment, this data is integrated through a BAS and then analyzed on an analytics platform.

Figure 3-3 Example Analytics Process for Lighting Applications



(Source: Navigant Research)

Lighting controls demonstrate the benefits that big data can provide to energy efficiency. However, there is a broader opportunity for big data in intelligent buildings that extends beyond energy into other operational benefits.

3.7.2 Business Case

Big data solutions change the paradigm for managing facilities, energy consumption, and business operations. Traditionally, building control has taken a top-down approach with the integration between different systems, such as heating, ventilation, and air conditioning (HVAC) and lighting, occurring at a supervisory level. However, big data analytics solutions are shifting the architecture of building systems to a more distributed platform with hybrid and predictive control based on multiple inputs and outputs from multiple systems. This new approach gives executives strategic decision-making support tools that offer holistic insight into enterprise-wide operations and building conditions.

The economic impact of big data solutions for intelligent buildings is the paramount concern of potential customers in the marketplace. Big data solutions in each of the four offering categories (detailed in Section 3.7) will only gain market penetration if the vendors can effectively communicate the financial savings or new revenue opportunities associated with the investment. Figure 6.7 summarizes the key benefits of each offering category as well as specific benefits for two key customer segments: enterprise/office and retail.

Figure 3-4 Customer Value Propositions for Big Data Solution Offerings

	Visualization and reporting	Fault Detection and Diagnosis	Predictive Maintenance and Continuous Improvement	Optimization
Key Benefits for the End User	• Economic metrics on efficiencies • Benchmarking • Customized data presentment	• OPEX savings • Prioritized fault management • Time-saving equipment management	• Capital planning • Efficient utilization of O&M human resources • Eliminate building drift	• Economic risk management • Sustainability / GHG improvements • Integrated energy and business strategies
Office / Enterprise	• Enhanced portfolio visibility for the C-suite	• Enhanced tenant comfort and retention	• Increased asset value of intelligent buildings	• CSR demonstration • Space utilization
Retail	• Comparative OPEX	• Customer comfort	• Reduced maintenance services costs	• Customer movement • Branding

(Source: Navigant Research)

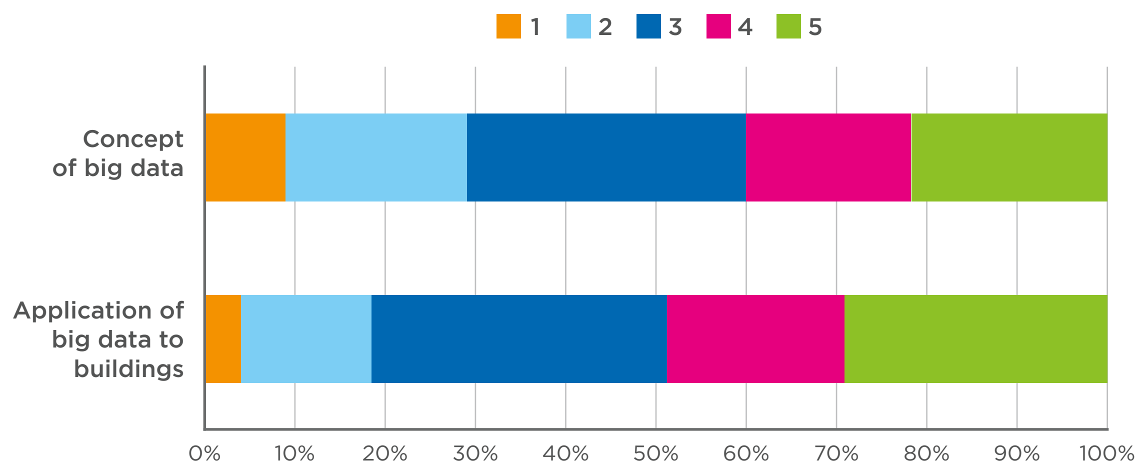
The economic benefits of big data begin with the savings associated with energy efficiency but expand to savings from streamlining O&M, more strategic capital planning, and space utilization. There is an overarching benefit of risk management inherent in big data as well. Big data solutions will help customers plan for facility improvements, monitor ROI of investments, and manage the environmental impact of their operations to hedge potential risks associated with regulatory compliance or corporate commitments.

3.7.3 Market Maturity

The market for big data in intelligent buildings is nascent. Research indicates that nearly all aspects of big data in intelligent buildings, from its definition to the description of its business value, differ depending on where one sits in the marketplace. This research suggests there is a chasm between the technology and end-user readiness for big data in the intelligent buildings context. Despite the need for market education and awareness, there are innovators investing in big data and demonstrating proof-of-concept in the field. Generally speaking, the near and midterm opportunity in North America centers on the retail and enterprise/office markets, in which the economics of investment are balanced by investment costs and end-users' maturity. It is worth noting that there are energy management solutions in the market that address the opportunities for energy and operational efficiencies in single offices, but in the big data context, when referring to the office or enterprise/office segment, Navigant Research is referring to the more complex management challenges associated with building portfolios.

The surveys and interviews conducted to inform this research provide valuable insight into the market maturity from both the supply and demand side of the equation. It is evident there is room for education to help promote the business value of big data in the intelligent buildings context, as illustrated in Chart 1.1.

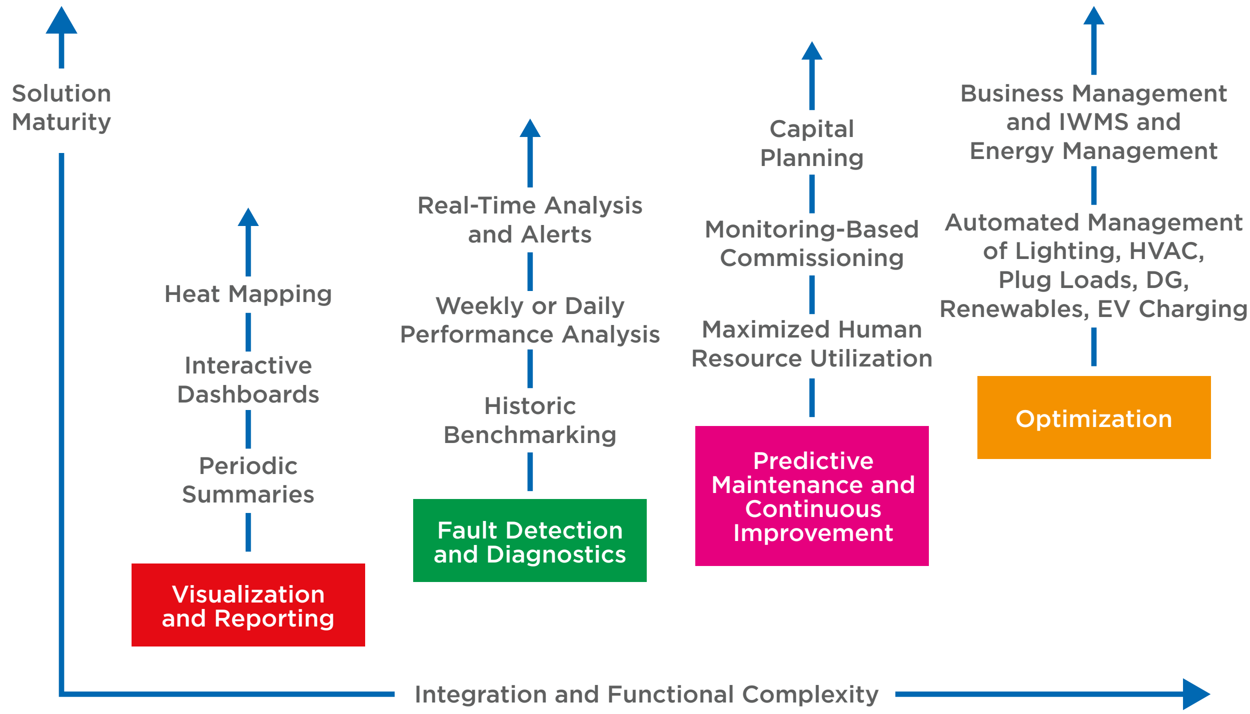
Chart 1.1 On a scale of 1 to 5, where 1 is not knowledgeable at all and 5 is extremely knowledgeable, how do you rate your knowledge about the concept of big data and the application of big data to buildings? (n=400)



(Source: Navigant Research)

Building owners and business executives are utilizing a mix of legacy tools and new intelligent building solutions that fall under each of the four offerings categories; however, new big data solution offerings can provide more holistic insight, which is unmatched by previous versions of the offerings. Figure 6.3 illustrates how solutions in each of the four offering categories fit into the roadmap toward big data. The important takeaway in reviewing the roadmap to big data is that these next-generation offerings provide the most sophisticated analytics to deliver insight and direct action for the greatest economic gain and strategic value from a portfolio or enterprise perspective.

Figure 3-5 Big Data Solutions and the Convergence of Facilities, Business, and Energy Management



(Source: Navigant Research)

3.7.3.1 The Big Data Reference

The CABA Building Data Reference provides a quantitative backbone for the market status of big data in buildings. It defines the level of component-based capturing of data rates, volume, and integration of current intelligent building solutions. By creating scenarios with varied primary building activity, building size, and level of integration, the reference creates a picture of the varying amount of building data in the existing building stock and what future data resources will look like. As a result, this report provides estimations of data size, volume, and velocity in retail and enterprise/office environments: the two key customer segments for big data in intelligent buildings.

3.8 RESEARCH APPROACH

This research is focused on how big data translates into the intelligent buildings context and whether these new solutions will help keep businesses competitive in the increasingly connected and dynamic marketplace. A combination of different types of primary research examined market perspectives on big data in order to project near and midterm opportunities in intelligent buildings. The findings present a new understanding of customer behaviors, competition, and market trends that will shape the adoption of big data solutions.

3.8.1 Methodology

The perceptions of big data in intelligent buildings presented in this report reflect the insight gained through the feedback of 34 interviews and 400 survey responses with a mix of technology and service providers and end-users. This primary research helped clarify how much data is needed and what kind of big data offerings can support the mission-critical requirements for building operations.

3.9 MAJOR FINDINGS

This research concludes that big data in intelligent buildings represents a pinnacle in energy and operational management. These solutions provide comprehensive and strategic decision-making support with automated systems' optimization through the integration of energy management and business intelligence tools.

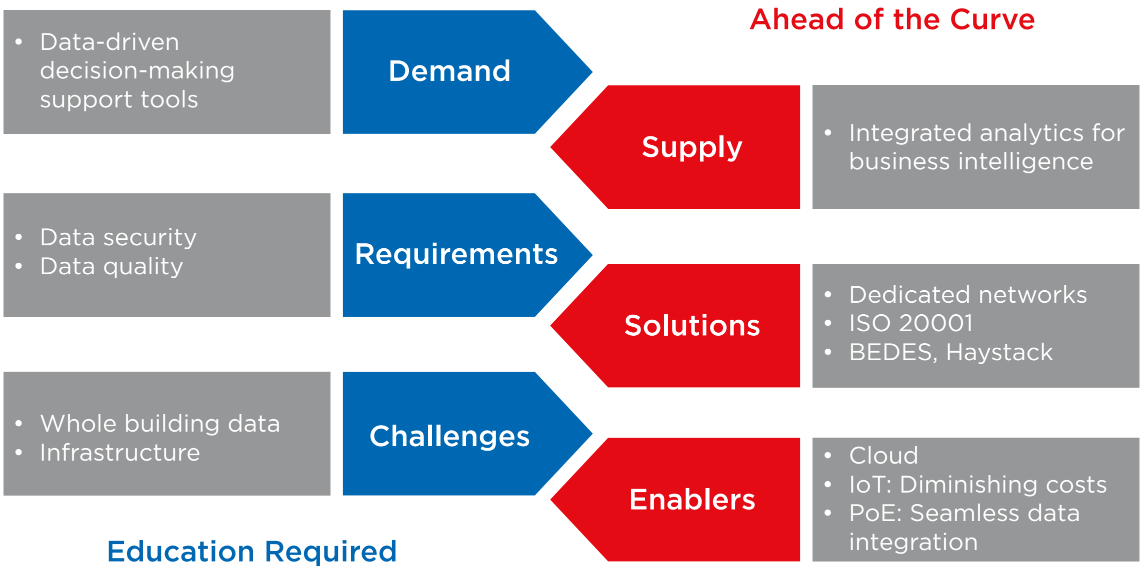
The following general conclusions reflect the perspectives shared between both the interviews and online survey:

- Customers prioritize investment on the economic impacts over all other benefits.
- The majority of decision makers in the intelligent buildings market do not know how to define big data or understand the potential benefits of these new solutions.
- Data security is a major concern for customers, and technology providers have an opportunity to demonstrate how standards and procedures can protect businesses investing in big data solutions.
- Those interested in big data require transparency in the ROI of building and operational improvements.
- There is a lot of low-hanging fruit in building and operational improvements – many customers can still benefit from periodic reporting and analytics on existing building systems, and, as a result, many customers are not ready to adopt fully integrated big data solutions.

The market for big data in intelligent buildings is, however, nascent, and there is a chasm between customers and solution providers. The majority of decision makers in the intelligent buildings market do not know how to define big data or understand the potential benefits of these new solutions. Indeed, many customers can still benefit from periodic reporting and analytics on existing building systems, both of which fall far short of a big data solution. Customers prioritize investments based on economic impacts, thus many are not ready to adopt fully integrated big data solutions. Transparency in the return on investment (ROI) of building and operational improvements is critical to drive adoption of big data in intelligent buildings.

The supply side of the market is ahead of the curve, while there is a substantial need for customer education before investment will significantly increase. Figure 1.2 summarizes the central demand-side dynamics and opportunities for supply-side response. Big data solution providers have an opportunity to address the key dynamics of their customers with sufficient education and demonstrations.

Figure 3-6 Market Dynamics for Big Data in Intelligent Buildings



(Source: Navigant Research)

It is generally understood that C-suite executives demand new decision-making support tools to guide the biggest strategic decisions and that these tools must leverage an increasing depth and breadth of data. Big data analytics is well-positioned to bring unprecedented visibility and insight to executive decision makers.

Survey respondents, providing the perspective of end users, were primarily concerned with cost. When asked to rate different factors when making improvements to buildings, saving money was rated higher than reducing energy consumption or increasing occupant comfort.

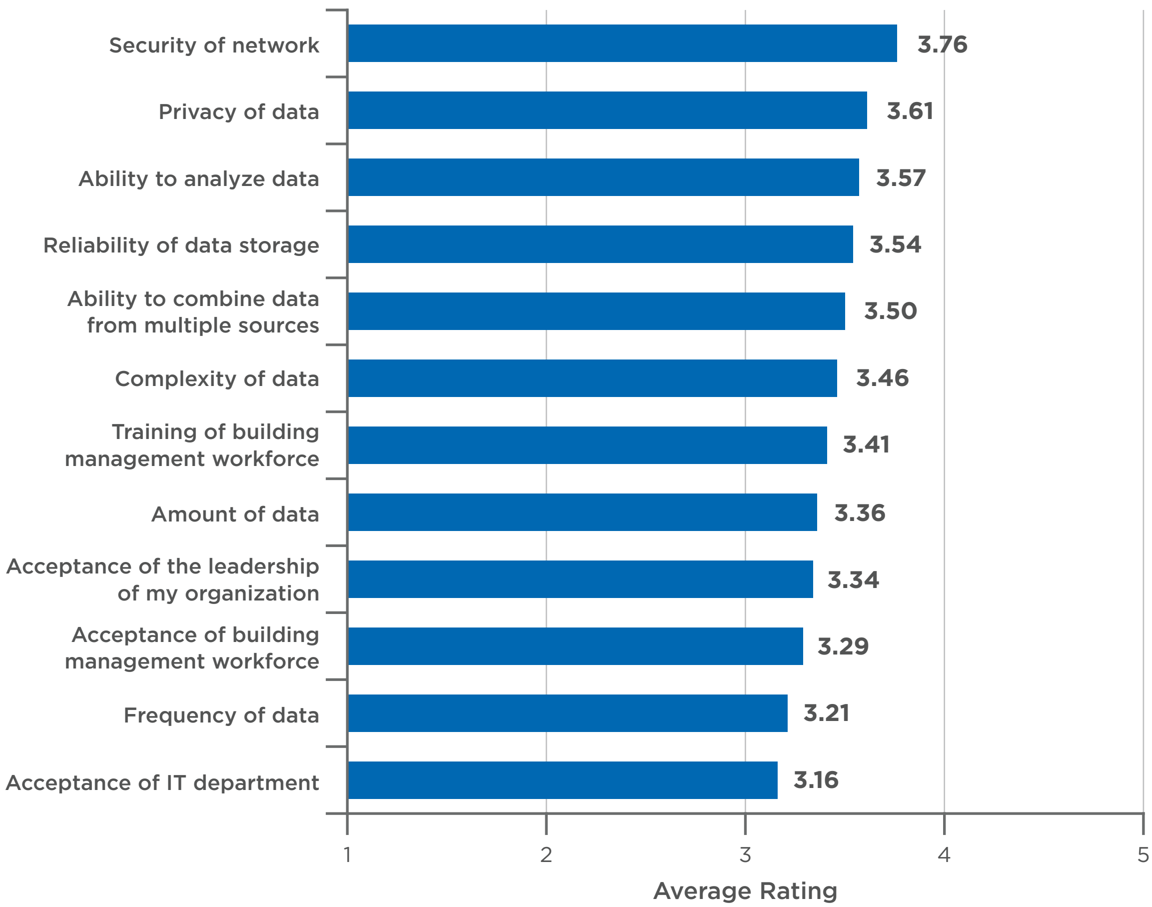
Chart 5.2 On a scale of 1 to 5 where 1 is not important at all and 5 is extremely important, please rate how important the following factors are when making improvements to your building. (n=400)

(Source: Navigant Research)

Additionally, respondents seemed unclear about big data. More than 20% of respondents indicated that they were unfamiliar with analytics. When asked to rate their level of knowledge about big data, 39.8% of respondents indicated a level of 1 or 2 out of 5. When asked to rate their level of knowledge about the application of big data to buildings, 48.8% of respondents indicated a level of 1 or 2 out of 5.

When asked to rate issues regarding data collection, security and privacy were rated the highest. Interestingly, respondents were least concerned with getting acceptance from the IT department. Getting acceptance from leadership and building management staff were also rated comparatively low, with fewer than half of respondents indicating that they were concerned or extremely concerned.

Chart 3.3 On a scale of 1 to 5, where 1 is not concerned at all and 5 is extremely concerned, how concerned are you about the following issues as it relates to data collected in your building? (n=400)

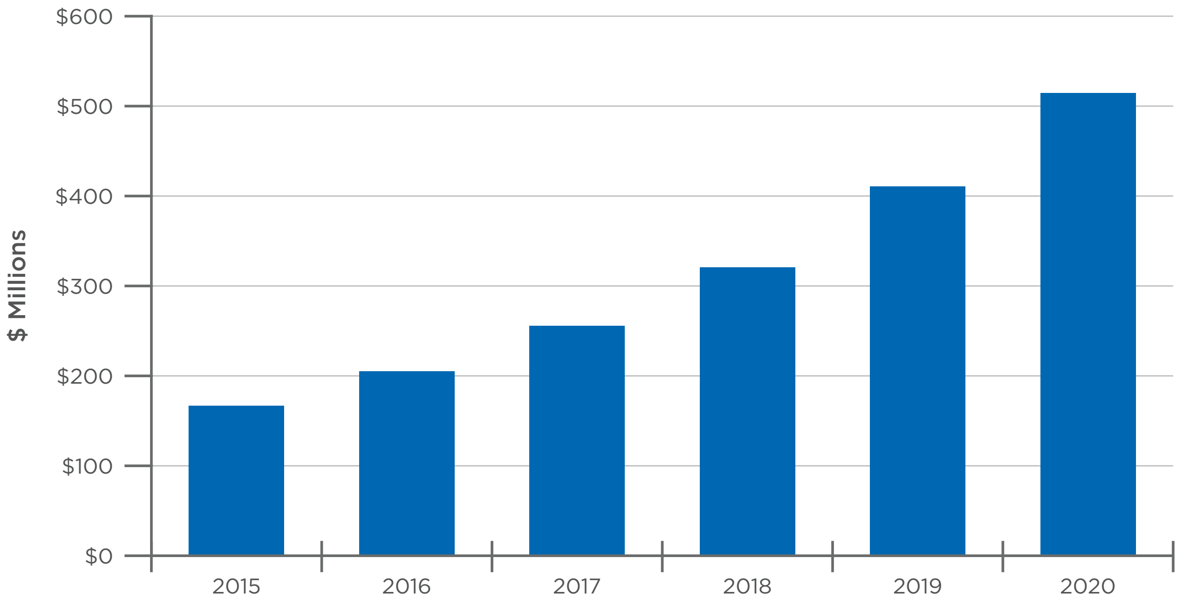


(Source: Navigant Research)

Again, the big data in intelligent buildings market currently in North America is in the beginning stages. Only innovative customers have adopted the solutions entering the market. There are robust signals of continued growth, and it is estimated that market revenue will increase to 2020 with a 24.5% compound annual growth rate (CAGR). Adoption will be supported by the economic benefits associated with the energy and operational efficiency generated by big data in intelligent buildings.

The revenue from big data in intelligent buildings in North America will reach $170.5 million by 2015 and grow to $511.7 million by 2020. The biggest share of the market is tied to the software, which represents more than 50% of the market in 2020. Chart 1.2 presents the topline forecast for big data in intelligent buildings. Greater detail on revenue for the software, services, and hardware system components and key customer segments, including retail and enterprise/office, are provided in Section 7 of this report.

Chart 1.2 Big Data in Intelligent Buildings Revenue, North America: 2015-2020



(Source: Navigant Research)

From both the survey and interviews, it is apparent that the stakeholders across the big data ecosystem have differing perspectives on what big data is and what it means for their business. This is a challenge for those wanting to sell products into this space. What is needed is a series of educational campaigns by vendors, alone or as a group, that focus on a few sets of intelligent building stakeholders. These campaigns would focus as follows:

- » **Building and property managers**: Education on how analytics can aid automation, optimization, and operational performance.
- » **Portfolio and property managers**: Define the cloud – this concept is amorphous by nature so it is important to define where, physically, data is being stored. Also, the benefits of onsite data processing versus cloud-based processing and analytics are needed for each solution offering.
- » **All stakeholders**: Address the security and privacy concerns associated with building sensors.
- » **All stakeholders**: Provide more case studies, reporting the CAPEX and OPEX of solutions, the role and investment needed for site energy or property managers, and a real-time view into cost savings. This last point underscores the natural variable performance of BASs. Buildings respond to occupants and the external environment; addressing how a complex (or expensive) system fares in normal and stressed times is beneficial.

3.10 OVERVIEW OF REPORT CONTENT

Sections 2 through 7 of this report provide greater detail on the market dynamics shaping the future for big data in intelligent buildings, including:

- » The conceptual framework of building controls, the role of analytics, and how big data analytics changes the management paradigm
- » Examples of the business value for big data in other industries and what these cases represent for the intelligent buildings market
- » The role of big data in building automation and energy efficiency
- » Details on the system infrastructure requirements for deploying big data solutions
- » An overview of the process of big data systems integration
- » Summary of the market barriers and customer perspectives on big data challenges
- » Detailed findings from executive interviews (34) and online surveys (400)

3.11 CASE STUDIES

The following case studies highlight three innovative approaches to utilizing Big Data for energy and business optimization in healthcare and manufacturing. Honeywell, Eco Opera, and Schneider Electric have helped their clients realize the benefits of Big Data in the Intelligent Building framework.

At the Montefiore Medical Center in New York State, Honeywell deployed its Attune solution to achieve unprecedented real-time visibility into system performance that maximizes energy and operational efficiencies. In Vancouver, Eco Opera engaged the Coastal Health Authority and demonstrated the strategic benefits of comprehensive Energy Management Information System (EMIS) with the EcoCEO platform. In South Carolina, Schneider Electric generated proof of concept at home with its deployment of Building Analytics at its own manufacturing facilities that produces motor control centers (MCCs). These three case illustrate the cost savings that customers can realize through optimized operations via energy efficiency, streamlined O&M, and heightened executive oversight with sophisticated analytics running on Big Data.

3.11.1 Vancouver Coastal Health Authority Case Study – Eco Opera

Figure 3-8 Eco Opera Systems at Vancouver Coastal Health Authority

(Source: Eco Opera)

3.11.1.1 Key Highlights

- » Showcases the benefits of the comprehensive Energy Management Information System (EMIS), EcoCEO, as a platform to optimize the building systems operation process

3.11.1.2 Features

- Building systems performance optimization achieved through combination of ongoing commissioning and a performance measurement and verification (M&V) process at the whole building and/or building systems and equipment level
- Generation of customized weekly and monthly building systems performance reports
    - Weekly reports utilized for systems performance validation and/or systems fault detection
    - Monthly reports offering detailed trend analysis and identification of systems operation efficiency improvement opportunity
- Facility maintenance group's continuous participation in this process is ensured through time-balanced commitment (five-minute review of the weekly reports and one-hour review of the monthly reports)

3.11.1.3 Project Overview

Vancouver Coastal Health Authority is a regional health authority serving more than 1 million people in British Columbia. An innovator in medical care provision, research, and instruction, the organization has also taken steps to maintain and develop facilities that emphasize occupant comfort and efficient operations.

Located in Sechelt, British Columbia, St. Mary's Hospital's expansion building is a 59,000 square foot healthcare facility that opened in 2012. This project was built to accommodate the expanding emergency and diagnostic imaging departments and new inpatient beds. The hospital expansion includes labor and delivery rooms, as well as an intensive care unit.

As a Leadership in Energy and Environmental Design (LEED) Certified Gold facility, it incorporates a range of sustainable technologies including a solar photovoltaic (PV) system, ground-source heat pump heating and cooling, numerous heat recovery loops, an envelope and glazing system, high efficiency lighting, and integral lighting controls. Through its sustainable design, this facility is North America's first carbon-neutral hospital.

CES Engineering Ltd. acted as the LEED Commissioning and M&V Authority for this project. Eco Opera Systems Inc., deployed EcoCEO on this site in response to the New Construction LEED M&V Credit requirements.

3.11.1.4 Facility Details

- Client: Vancouver Coastal Health Authority
- Address: 5544 Sunshine Coast Highway, Sechelt, British Columbia, Canada
- Building Occupants: 500 to 800
- SF of Building: 59,000 SF
- Building Type: Medical

3.11.1.5 EcoCEO Solution from Eco Opera Systems Inc.

The Eco Opera software solution is a comprehensive enterprise EMIS driven by the EcoCEO energy intelligence engine. EcoCEO supports energy management activities related to achieving continual improvements in facility energy, operational, and cost performance.

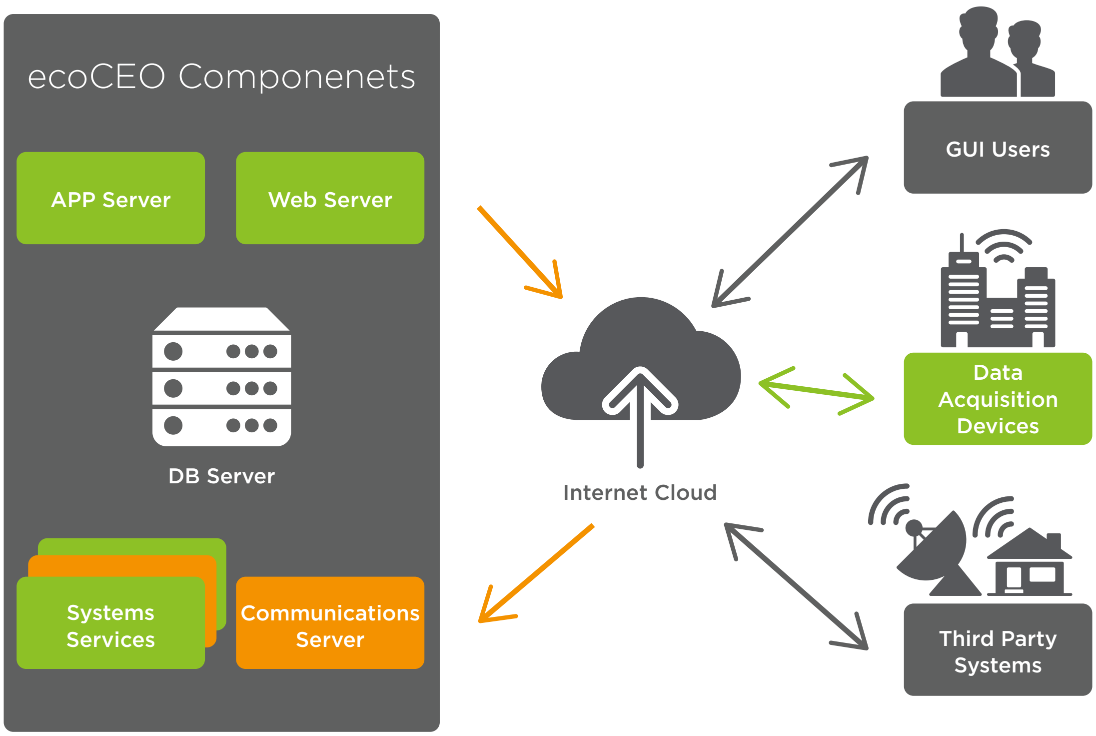
Developed as a fully configurable and scalable solution, EcoCEO allows for comprehensive energy monitoring, targeting and reporting (MT&R) and enhanced support for energy management, M&V, operations and maintenance (O&M), commissioning (Cx) and re-commissioning (RCx), and other custom processes through data acquisition and archiving, analysis, and reporting.

EcoCEO was developed based on industry guidelines and best practices, and produced through Canadian, European, and U.S. federal government research programs.

EcoCEO is offered as a Web-based software as a service (SaaS) or as a turnkey standalone system. The system provides unlimited scalability from standalone projects to worldwide building portfolios. Featuring full integration with BASs, EcoCEO functions as a central repository of facility data, a holistic analytical engine, and a user frontend.

The Eco Opera solutions architecture contains typical Web application server components (web, application, communication, and database servers), as seen in Figure 1.5.

Figure 3-9 EcoCEO Components



(Source: Eco Opera)

Eco Opera Systems currently utilize a number of specific products and modules in relation to continuous commissioning, fault detection, and M&V processes. The EcoCEO suite contains six different aspects: EcoOptimizer, EcoLEED M&V, EcoTrack, EcoQuest, EcoDas, and EcoKiosk. The St. Mary's Hospital project leveraged EcoDas, EcoTrack, EcoLEED M&V, and EcoOptimizer.

Figure 3-10 Eco Opera Systems

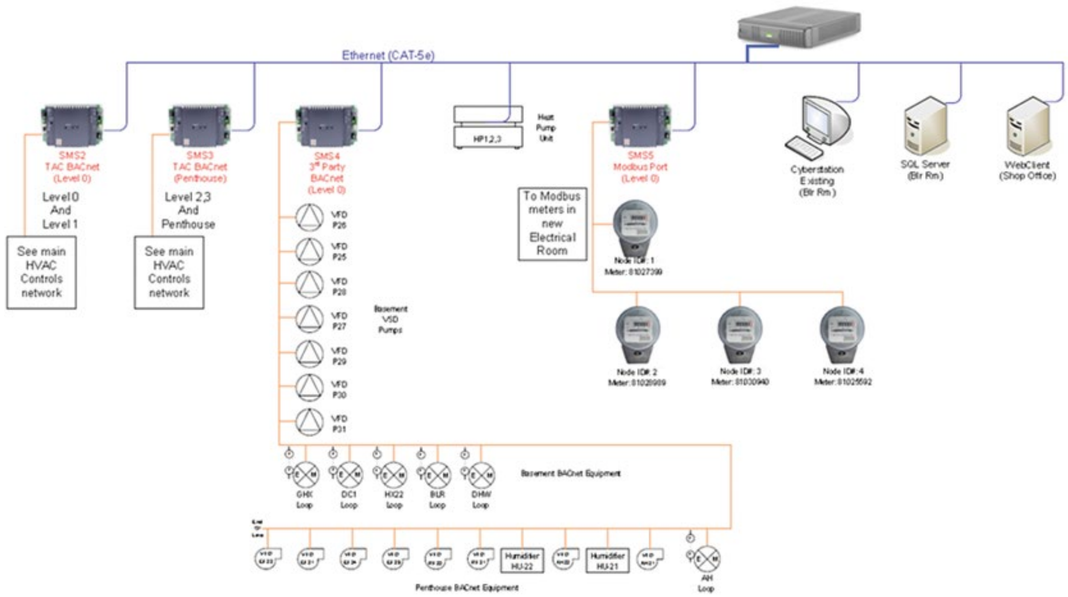
(Source: Eco Opera)

3.11.1.6 Project Stages

Utilizing Eco Opera's data acquisition system, EcoDAS, a centralized data acquisition system was created for St. Mary's Hospital to optimize performance. HVAC building management system (BMS) controls, third-party BACnet equipment devices, and Modbus electrical submetering were integrated into an Ethernet BACnet network. EcoDAS was then connected to a common Ethernet BACnet network.

EcoDAS was configured to collect a data sample of around 700 BMS data points from the building control system and 32 energy submeters on regular 3- to 5-minute intervals. The collected data was automatically uploaded to a cloud-based server for analysis and storage.

Figure 3-11 Eco Opera System Schematic



(Source: Eco Opera)

3.11.1.7 Whole Building Level Analysis (EcoTrack)

EcoTrack was deployed to monitor and track energy consumption and demand via a central electrical meter and central British thermal unit (Btu) meter that measured indirect gas energy from the existing boiler plant feeding this new expansion building.

EcoTrack also incorporated weather analysis for a specific reporting period. Outdoor air temperature sensor data, meteorological average weather file data, and weather station data were analyzed in relation to a number of heating degree days (HDDs) and cooling degree days (CDDs) in order to normalize the effect of external heating and cooling load for specific monitoring period (1 month).

EcoTrack monitored the extrapolated annual Energy Utilization Index (EUI) (kWh/m^2), energy consumption (kWh), and peak demand (kW) for a selected reporting period. Actual, baseline, and national averages were compared for the specified period of time.

Overall, St. Mary's Hospital performs about 55% better by consumption than the national average hospital (Actual EUI 278 kWh/m^2 versus the national average EUI 439 kWh/m^2).

EcoTrack incorporated other performance monitoring features like heat map analysis and time-of-day demand profile to identify average hourly electrical and gas demand for 7 weekdays in a specific reporting period. Consequently, every Tuesday was determined as a critical day in a week, and average daily electrical demand was consistently above 200 kW between 8:00 a.m. and 9:00 p.m.

Chart 3.12 Hourly Electrical Demand Heat Map of Reporting Period

	SUN	MON	TUE	WED	THU	FRI	SAT	Hourly Avg
Midnight	137	159	160	155	137	142	145	148
1:00 AM	134	145	156	146	131	136	140	141
2:00 AM	131	139	143	140	134	129	138	136
3:00 AM	129	131	131	137	134	131	137	133
4:00 AM	125	127	134	138	133	128	140	132
5:00 AM	130	125	138	140	135	132	137	134
6:00 AM	129	132	142	141	133	131	137	135
7:00 AM	130	137	166	154	149	141	143	146
8:00 AM	151	175	192	171	165	154	151	166
9:00 AM	169	183	187	175	168	155	164	172
10:00 AM	165	181	190	176	172	166	162	173
11:00 AM	162	184	191	177	168	169	161	173
Noon	165	186	192	178	172	169	162	175
1:00 PM	168	189	193	179	175	173	168	178
2:00 PM	176	195	195	147	164	174	170	174
3:00 PM	176	194	196	47	123	175	173	155
4:00 PM	184	197	192	182	177	177	178	184
5:00 PM	187	198	194	182	178	179	180	185
6:00 PM	190	195	194	183	181	181	179	186
7:00 PM	191	199	195	187	179	180	180	187
8:00 PM	187	192	195	182	180	182	183	186
9:00 PM	184	192	194	176	169	169	174	180
10:00 PM	173	178	173	162	159	160	162	167
11:00 PM	165	173	163	152	147	150	150	157
Daily Avg	159.89	171.16	175.26	158.49	156.79	157.60	159.00	

(Source: Eco Opera)

3.11.1.8 Systems Level Analysis (EcoLEED M&V and EcoOptimizer)

EcoLEED M&V was deployed to monitor and track energy consumption breakdowns for major energy categories as per the LEED energy model. Lighting, fans, pumps, space heating, space cooling, and plug load energies were monitored for a specified reporting period.

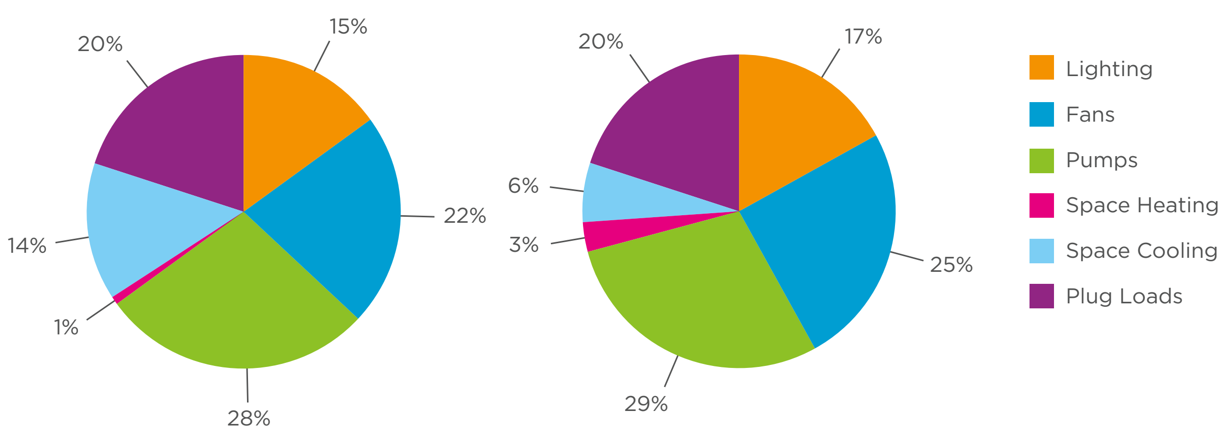
Chart 3.13 Energy Use in St. Mary's Hospital

The electriciy is utilized by the following energy use categories:

	Reporting Period					Year to Date				
	Max Demand (kW)	Min Demand (kW)	Average Demand (kW)	Total (kWh)	Percent Total	Max Demand (kW)	Min Demand (kW)	Average Demand (kW)	Total (kWh)	Percent Total
Lighting	32.2	16.9	24.3	18,089	15%	36.3	13.3	25.0	141,075	16%
Fans	49.3	25.3	35.7	26.596	22%	61.0	23.1	38.1	214,917	25%
Pumps	56.3	10.6	45.2	33,670	28%	61.0	1.2	44.7	252,186	29%
Space Heating	18.2	0.0	1.2	917	1%	31.2	0.0	4.4	24,569	3%
Space Cooling	61.2	1.3	23.4	17,420	14%	61.2	0.7	8.9	49,914	6%
Plug Loads	58.7	0.0	32.8	24,441	20%	76.9	0.0	30.8	173,646	20%

(Source: Eco Opera)

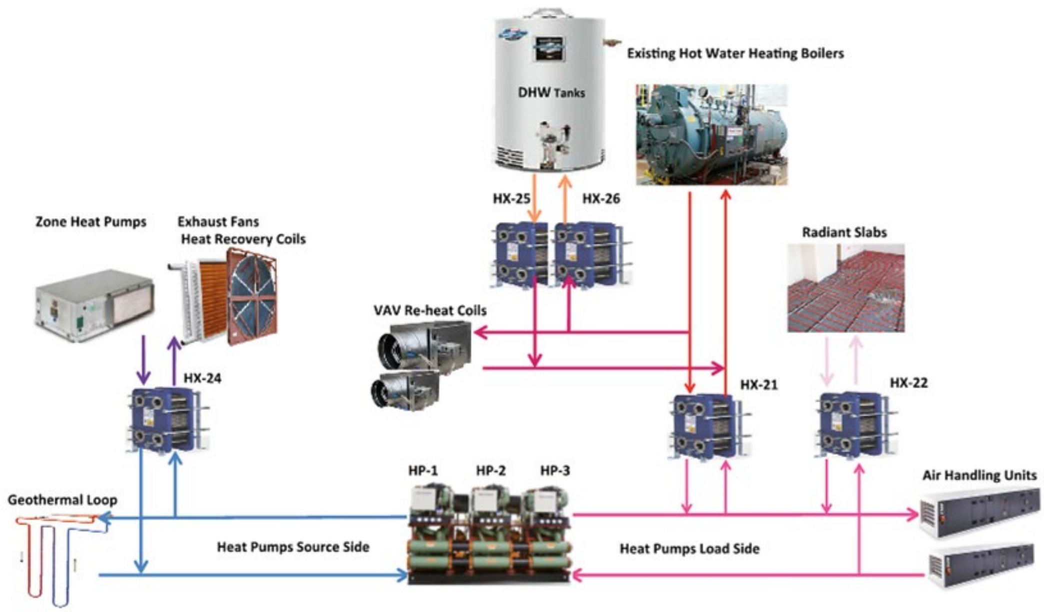
Figure 3-14 Relative Energy Load for St. Mary's Hospital



(Source: Eco Opera)

In St. Mary's Hospital, EcoOptimizer was deployed to monitor and track energy consumption and performance characteristics at the system and/or equipment level. The expansion building has an extensive hydronic system, as depicted in Figure 1.11.

Figure 3-15 St. Mary's Hospital Hydronic System Diagram



(Source: Eco Opera)

Due to the interconnected nature of the hydronic systems for this facility it is possible to maintain zone temperatures while multiple pieces of heating and cooling equipment operate simultaneously in heating and cooling mode. The EcoOptimizer tracks the performance of each heating and cooling plant and other energy sources and identifies opportunities for improvements and energy waste reductions.

EcoOptimizer measures the granular performance of every sub-system, including: heat pump load and source loop, zone heat pump water loop and heat recovery loop, radiant slab loop, air handling unit (AHU) system economizer, outdoor air flows and over ventilation, VAV box operation, and airflow demand ventilation.

3.11.1.9 Key Achievements

- » Developed measurable key performance indicators for quantifying optimum performances of individual building systems, heating and cooling plants, and the whole building
- » Facility operators are empowered with the knowledge of what it takes to operate the building systems efficiently
- » Building systems' performance monitoring is included in the regular operations and maintenance (O&M) business practice
- » Optimum performance is maintained persistently

3.11.1.10 Performance Optimization Opportunities

While St. Mary's Hospital performs about 55% better by consumption than the national average hospital, ongoing analysis of the systems operation parameters identified the following opportunities for improvements and/or systems faults:

- » Occasional simultaneous heating and cooling in the AHU system
- » Unnecessary boiler system interaction with central heat pump loop system
- » Central heat pump systems frequent cycling between heating and cooling modes of operation
- » Suboptimum heat recovery
- » Suboptimum solar panel performance

- Potential over ventilation
- Suboptimum AHU supply air temperature control
- Night set back control loop is not incorporated

Implementation of the above noted operational adjustments could result in an additional 15% in energy consumption reductions.

3.11.2 Seneca Manufacturing Facility – Schneider Electric

Figure 3-16 Schneider Electric's Seneca Manufacturing Facility

(Source: Schneider Electric)

3.11.2.1 Key Highlights

- Showcases Schneider Electric's Building Analytics service to diagnose system inefficiencies, save energy, and cut costs in the Seneca, South Carolina manufacturing facility

3.11.2.2 Features

- Building Analytics service automatically analyzed the plant's data on performance, comfort levels, and energy and maintenance every 5 minutes
- Building managers can access pre-designed daily diagnostic reports to pinpoint building system irregularities, avoidable costs, building comfort impacts, and more
- A complete ROI is typically achieved within 18 months using the Building Analytics service

3.11.2.3 Project Overview

The city of Seneca occupies 7.1 square miles in the foothills of the Blue Ridge Mountains in the northwest corner of South Carolina. The 2010 census recorded a population of 8,102 for Seneca, and the National Register of Historic Places lists a number of the city's residential and commercial properties.

Seneca is also home to one of Schneider Electric's manufacturing facilities. This particular plant manufactures motor control centers (MCCs), which are used in applications ranging from equipment for production lines and oil rigs to equipment used in wastewater treatment plants.

The manufacturing facility operates multiple shifts throughout the week and on weekends. Thus, controlling the cost to heat, cool, and light a large, open facility with high ceilings while also maintaining desired comfort levels year-round can present a variety of challenges. For example, average temperatures in Seneca range from wintertime lows in the 30s to summertime highs in the 90s.

Implementing Schneider Electric's Building Analytics managed service offered the Seneca plant new ways to quickly address maintenance, comfort, and energy issues for its HVAC system.

3.11.2.4 Facility Details

- » Client: Schneider Electric
- » Location: 1990 Sandifer Boulevard, Seneca, South Carolina 29678
- » SF of Building: 280,000 SF
- » Building Type: Manufacturing facility

3.11.2.5 Building Analytics Service from Schneider Electric

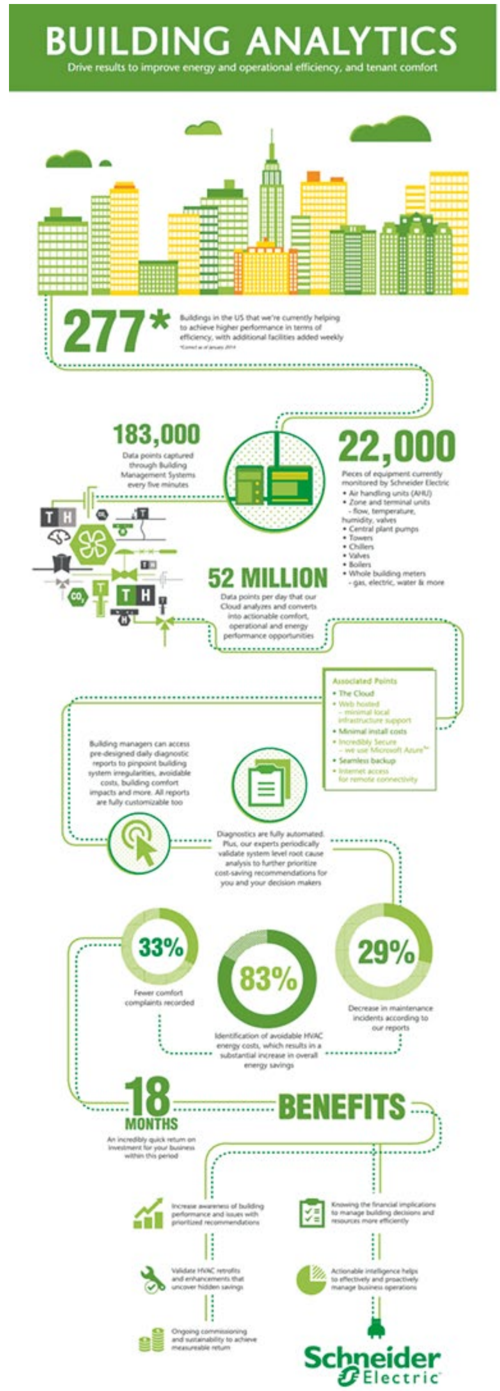
Building Analytics helps to reduce facility operating costs over time and achieve results by targeting maintenance efforts. This is achieved through four key steps: identification, expert review, execution, and validation.

Through identification, stakeholders can access automated diagnostic results for instant visibility into the most costly issues for their facility and can direct maintenance resources accordingly. An engineering analyst aggregates diagnostic results, tracks progress, and consults with stakeholders on harder to solve problems. Internal team members or external vendors are then directed to address mechanical issues and cost savings opportunities. The data generated by the Building Analytics service then determines if problems were effectively resolved or require further attention.

Building Analytics can reduce the cost of facility operations primarily in utility cost savings, maintenance efficiency, and operational improvements. For example, the service has achieved savings up to US$286,000 from fault detection in a ventilation system at a research laboratory. Another project at a community center saw a 23% ROI from commissioning rooftop units to reduce operational costs.

In the case of the Seneca plant, Building Analytics resulted in US$9,000 in energy savings from heating and cooling improvements, a 29% decrease in maintenance incidents, a 33% decrease in comfort incidents, and customized root cause reports generated to facilitate troubleshooting and planning.

Figure 3-17 Building Analytics Design Features



(Source: Schneider Electric)

3.11.2.6 Project Stages

Using its own Building Analytics service, Schneider Electric began to send information from the Seneca plant's building systems directly to the company's cloud-based data storage. Building Analytics then diagnosed building performance, identified equipment and system faults, and located areas for improvement for sequence of operation and energy use at the Seneca plant.

Instead of relying primarily on monthly checkups to track performance, comfort levels, and energy and maintenance data, Building Analytics automatically analyzed the plant's data every five minutes. Guided by the Schneider Electric team of building engineers and analysts, the facilities staff discovered that the Building Analytics service was able to diagnose and troubleshoot HVAC equipment issues that were previously undetected.

For example, some compressors were short cycling, causing premature compressor failure and unnecessary wear and tear on contactors due to small deadbands (i.e., intervals where no action occurred). Additionally, some units wasted energy due to setpoints that did not take building occupancy into consideration when determining heating and cooling needs.

Building Analytics not only evaluated the system's performance, comfort levels, and energy and maintenance data, but also prioritized areas for improvement and validated repairs to optimize building performance. Built on scalable software architecture and leveraging fault detection and diagnostics as well as other advanced diagnostics, Building Analytics ranked recommendations to achieve the most effective remedies and energy savings for the Seneca plant.

Customized reports provided insight into avoidable costs, trend analysis, and prioritization of energy maintenance and comfort issues along with recommended actions. Those reports pinpointed which systems and equipment had irregularities and then prioritized them based on energy cost, severity, and comfort impact.

As of October 2014, Schneider Electric had certified five manufacturing facilities in the U.S. Department of Energy's (DOE's) Superior Energy Performance program.

The Seneca, South Carolina plant received a Platinum level designation by improving its energy performance by more than 15%.

Schneider's Smyrna, Tennessee facility also received a Platinum rating, and three plants earning Silver ratings – located in Lincoln, Nebraska; Lexington, Kentucky; and Cedar Rapids, Iowa – with an improved energy performance of more than 5%.

With the Building Analytics service, those responsible for building and equipment performance at the Seneca plant have both local and remote access to detailed information about the plant's systems operations. Moreover, staff can now be more proactive in optimizing the building's systems and energy consumption.

3.11.2.7 Key Achievements

- The Schneider Electric plant realized an 83% decrease in avoidable energy costs related to HVAC operations
- $9,000 in energy savings from heating/cooling improvements
- 29% reduction in maintenance incidents
- 33% decrease in comfort incidents
- Customized root cause reports for ease of troubleshooting and planning
- The Building Analytics service paid for itself during the first year by providing automated and sophisticated analysis combined with quarterly recommendations to eliminate energy waste

SECTION 4

OVERVIEW ON BIG DATA

4.1 ABOUT THIS REPORT

The Continental Automated Buildings Association (CABA) commissioned Navigant Research to study new tools and resources emerging in the market to help companies filter, analyze, and use Big Data collected from their intelligent and integrated buildings. Leveraging Big Data will enable a better understanding of customer behaviors, competition, and market trends. Research on utilizing Big Data from building systems is crucial to staying competitive in this dynamic connected marketplace.

Navigant Research and the Steering Committee first convened via a webinar in July 2014, 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 a broad stakeholder online survey.

The outcomes of this collaborative research project will provide the Steering Committee members a clear understanding of the opportunities and solutions of managing data derived from intelligent buildings. This research examined how data from intelligent buildings can be more efficiently filtered, analyzed, and ultimately used by all segments of the industry. This information will eventually lead to great productivity, reliability, efficiency, and operational control of intelligent buildings.

4.2 SPONSORS

Navigant Research and CABA would like to acknowledge the sponsors listed below and the respondents who helped make this research possible. We would also like to take this opportunity to thank the sponsors and CABA, as well as all those companies that contributed their valuable time and information. In particular, we appreciate the trust and transparency shown by respondents willing to share confidential information. Without the help of all these organizations it would not have been possible to produce such an in-depth and detailed study. Ruby sponsors (EcoOpera Systems, Honeywell, International, Jonson Controls Incorporated, Schneider Electric) we provided the opportunity to present a case study in this report.

The final presentation was delivered by webinar in February 2015.

4.3 ROLE OF THE STEERING COMMITTEE

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

4.4 ABOUT CABA

The Continental Automated Buildings Association (CABA) is an international not-for-profit industry association dedicated to the advancement of connected home and building technologies. The organization is supported by an international membership of over 300 organizations involved in the design, manufacture, installation and retailing of products relating to home automation and building automation. Public organizations, including utilities and government are also members. CABA's mandate includes providing its members with networking and market research opportunities. CABA also encourages the development of industry standards and protocols, and leads cross-industry initiatives.

Please visit http://www.caba.org for more information.

4.5 ABOUT NAVIGANT RESEARCH

Navigant Research is a market research and advisory group that provides in-depth analysis of global clean technology markets with a specific focus on the commercialization and market growth opportunities for emerging energy technologies. The team's research methodology combines supply-side industry analysis, end-user primary research and demand assessment, and deep examination of technology trends that impact the rapidly-evolving energy services and infrastructure sectors.

The firm's client base includes Fortune 1000 multinational technology and energy companies, government agencies, utilities, investors, industry associations, and clean technology pure plays. Navigant Research provides these companies with market research reports, custom research engagements, and subscription-based research services.

Navigant Research is focused across four research programs: Smart Energy, Smart Transportation, Smart Utilities, and

Smart Buildings. The Navigant Research analyst team comes from a diversity of industry backgrounds and leverages deep analytical skill sets in covering emerging technology and energy markets. Together, the team brings a wide range of capabilities to help clients build successful strategies in these sectors, from engineering and technology assessment, to corporate strategy development, to classic quantitative and qualitative market research methodologies. Research analysts are not only experts and thought leaders in their current areas of market coverage, but also bring a broad perspective from years of experience in related technology and energy businesses. This is further enriched by the expertise of Navigant Consulting's Energy Practice, with hundreds of professionals engaged in all aspects of the energy economy.

Please visit http://www.navigantresearch.com for more information.

4.6 INTRODUCTION

Big data is a topic of debate on the next frontier in business intelligence, and there is a growing interest in focusing the discussion on intelligent buildings. The reality, however, is that intelligent building solutions already represent an evolution in facilities and business operations management from the legacy systems that lead the landscape. The challenge for big data solution providers is to help end-users understand the added benefits of big data and what differentiates these solutions in terms of business value to help accelerate the market from investment by innovators today and move toward early adoption in the medium term.

Big data is a powerful concept and is changing the ways that both business and engineering are performed, as well as how people think about data. Sections 2.2 to 2.6 introduce the concept of big data and describe how it is currently being applied in different technological and scientific domains.

4.7 DEFINING BIG DATA

The term big data has become increasingly popular in recent years. Despite the hype there is no single, cohesive definition. In general, the term refers to data that exceeds the capacity or capability of current or conventional methods and systems. In other words, the notion of "big" is relevant to the current standard of analysis. While there are various definitions depending on the industry in question, many seem to agree on the following characteristics that identify big data: volume, velocity, and variety.

The volume of data from various sources has been increasing exponentially in recent years due to technological innovations and the decreasing cost to store data. As the velocity of data streaming from different sources continues to increase at an unprecedented speed, reacting quickly enough to capitalize is a challenge for most organizations. Data variety is a key aspect of big data. Aside from traditional numeric data sets, unstructured data such as email, video, audio, and financial transactions must all be managed together. In addition to the increasing volume, velocities, and varieties of data, the variability of all of these is leading to new challenges in data management and analysis, as analysts and end-users have to manage both large and small data forms, both fast and slow data, and simple and complex data schema in one setting. In the past, data analysis was more siloed and consistent; this is no longer universally the case in many domains including that of intelligent building management.

It is necessary to provide a clear definition of big data in the intelligent buildings context in order to support the market analysis and revenue forecasts, both critical deliverables for this research. Big data in intelligent buildings is, therefore, defined as:

> The next generation in business and operational intelligence derived from the analysis of data integrated across multiple streams or sources for the purposes of overall system understanding, performance, and optimization.

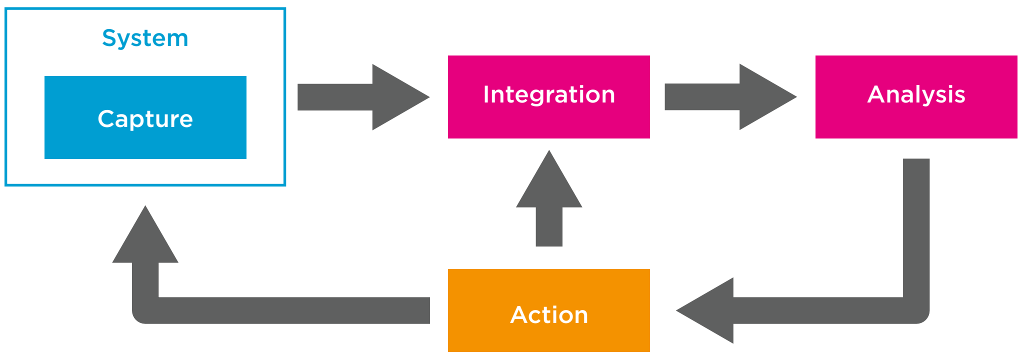
In addition, throughout this report, the term big data encompasses both the solution architecture and the associated analytics.

Big data analytics is an extension of the analytics that have brought new insight to key decision makers exploring opportunities for investment and operational management changes. Section 2.3 presents how analytics have helped elevate building science and set the stage for how big data analytics can further the business improvements underway.

4.8 ANALYTICS PROCESS

Information technology (IT) tools have been introduced into the building management industry as new offerings for decision-making support. Analytics includes the software layer and underlying algorithms that enable building owners, managers, and operators to make more strategic decisions based on a more holistic insight into how their facilities are operating. Fundamentally, this process requires data from a system to be captured, analyzed, and communicated in order to direct changes that meet specific business objectives. Actionable insight typically requires several sources of information, either different types of data captured from one system or external data that can be combined with captured data. As a result, the analytics process requires integration of data after capture. Once integrated, the data can be analyzed. Finally, the results of the analysis can be used to undertake action that better optimizes the system.

Figure 4-1 Analytics Process

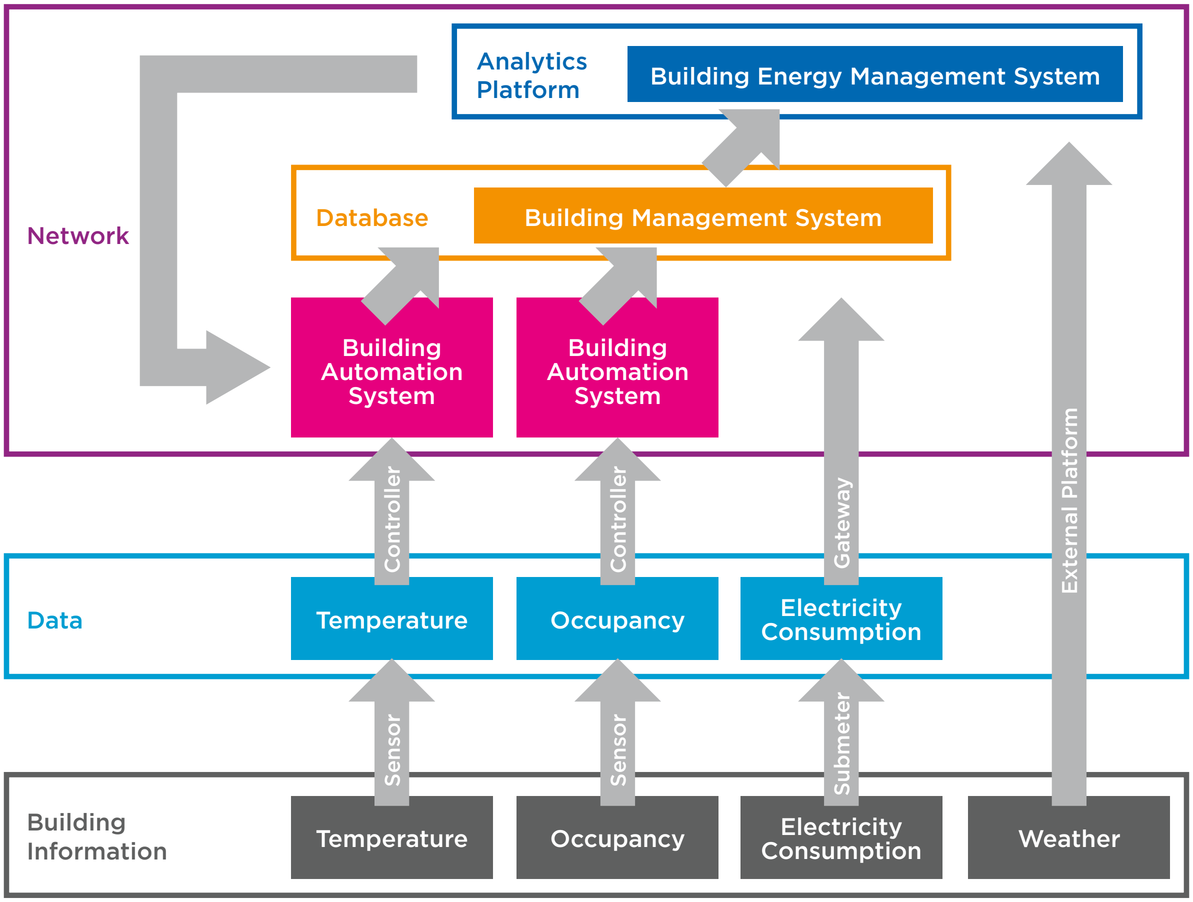


(Source: Navigant Research)

4.9 BUILDING DATA FLOW

Traditionally, building control has taken a top-down approach with integration between different systems, such as HVAC and lighting, occurring at a supervisory level. However, analytics solutions are beginning to shift the architecture of building systems to a more distributed platform with hybrid and predictive control based on multiple inputs and outputs from multiple systems. Current solutions focus mostly on energy management. However, building data analytics can also provide cost savings through optimized O&M as well as improved occupant comfort.

Figure 4-2 Generic Building Data Flow



(Source: Navigant Research)

Data capture starts with sensors. Sensors track internal building conditions such as temperature, occupancy (for the purpose of controlling lights and other devices, as well as security), humidity, air quality (e.g., carbon dioxide (CO_2) sensors), and energy consumption. Sensors play a critical role in building analytics as they limit the volume and quality of data collected. Several sensor strategies exist in analytics solutions from providing bundled hardware and analytics software to the sensor level to only providing software and leveraging existing sensor infrastructure.

Once data is collected from the sensors, it is aggregated on a building network through the use of controllers and gateways. This integration of building data streams can occur through controllers as part of a building management system (BMS) or with a data logger.

Data analysis occurs either on-premise on a local server or with a cloud-based service, though the market is moving overwhelmingly to cloud-based models, given the ease of updating versions and scaling offerings compared with traditional software. Most analytics solutions compare energy data with external data sources such as weather and temperature data, average building performance data for specific facility types, and building occupancy and space utilization data, while others uncover opportunities to improve efficiency. Some software systems can provide predictive analytics to anticipate future conditions based on past performance and avoid unforeseen facility management issues.

Central to the flow of data through a building are the topics of data streaming, storage, computer processing, databases, and data structure. Data streaming refers to the steady transfer of data, such as interval data regularly generated and transmitted by electric submeters. Data structure refers to a pre-defined model to efficiently use data. Data available in buildings resides on a spectrum ranging from completely unstructured data like an emailed complaint of an occupant being too hot or too cold to structured data such as the temperature reported at a specific sensor. Storage is the centralized warehousing of all data that is captured. Storage can occur as a physical media on the building premise or it can occur remotely as part of a cloud service. Storage refers to both structured and unstructured data. A database is a structured set of data that is in storage. Computer processing is the execution of a computer program to change or analyze data.

4.10 BIG DATA ANALYTICS

The term big data can refer to many things. For some, it refers to the data, the bits themselves, as a virtual object to possess. For others, it implies the analysis of large volumes of data that can be applied to a single, large source (as in terabytes of hertz-level data of wind speed from a single anemometer) or analyzing multiple sources of data of different types for discovery.

The computer science industry was one of the first to truly embrace the concept of big data and advanced analytics. Many large companies have been working to define the concept and understand how it can be applied to their products and society at large. Various definitions have emerged; for example, Oracle defines big data as the derivation of value from traditional relational database-driven business decision-making, augmented with new sources of unstructured data. Intel has developed their own definition, which states that big data opportunities emerge in organizations generating a median of 300 terabytes of data per week; the most common forms of data analyzed in this way are business transactions stored in relational databases, followed by documents, email, sensor data, blogs, and social media.

On its own, big data, or any data for that matter, cannot actually solve any problem or do anything. It is only through the collection, integration, and use of the data in analysis that value can be provided, turning data into information and ultimately knowledge. Big data analytics can, therefore, be viewed as the tool that gives business value to large data sets.

4.11 BIG DATA EXAMPLES

Big data can unlock significant value by making information transparent and usable at a much higher frequency. As organizations create and store more data in digital form, they can collect more accurate and detailed performance information and, therefore, understand how to boost performance. Leading companies are using data collection and analytics to conduct controlled experiments to make better management decisions. Big data can also be used to improve the development of the next generation of products and services. For instance, manufacturers are using data obtained from sensors embedded in products to create innovative after-sales service offerings such as proactive maintenance. The use of big data in the realm of intelligent buildings touches on several of these topics. Despite various applications, big data is the term increasingly used to describe the process of applying serious computing power – the latest in machine learning and artificial intelligence – to massive and often highly complex sets of information. The understanding and perception of big data analysis as it applies to the intelligent building space will be the subject of subsequent sections.

Certain industries more naturally require the use of big data analytics based on the amount of data they work with on a regular basis. In a building, however, data may need to come from outside of the building itself, as sensor data from a single building may not provide the requisite volume of data. Big data did not start out of a vacuum, rather as the amount of data and the complexity of necessary analytics increased, the term was born. Several industries have been working with what can be considered big data for the last decade or so. Pharmaceuticals are a prime example of an industry that naturally entered into big data. As a result of highly complex research and development (R&D) projects, the industry has always generated massive amounts of data. Advances in analytic capabilities in recent years have allowed this data to provide valuable insights. For example, decoding the human genome originally took 10 years to process; now it can be achieved in less than a day. The DNA sequencers have divided the sequencing cost by 10,000 in the last 10 years, which is 100 times cheaper than the reduction in cost predicted by Moore's Law. Additionally, as a result of organizing and storing the results from thousands of lab tests, data can be mined to spot unwanted drug interactions, identify the most effective treatments for individual patients, and predict the onset of disease before symptoms emerge.

4.11.1 Financial Services

The financial services industry has embraced big data analytics more than most others. Results of a 2013 survey indicate that 71% of financial services firms are using big data and analytics, up from 35% just two years earlier. One reason for the popularity in this sector is that often there is little differentiation or competitive advantage between competing firms. Big data delivers a desperately needed competitive advantage to an industry still struggling, after the worldwide financial crises, to return to profit margins of old. The use of big data analytics in the financial services sector exists at many levels to identify any possible insights that can provide a competitive edge. For example, ANZ Banking Group is rolling out a digital assistant that regional bank managers will use to sift through every bit of information they have about a client, their own services, and updated market trends to make smarter, faster, and more personalized recommendations for their two million wealth management clients.

Despite widespread adoption, the financial services industry lags behind others in the kind of analytics capabilities that are crucial in handling the unstructured data that makes up so much of big data. Data streaming from social media, blogs, and Internet commentary can provide insights not found in the structured data that has traditionally been the focus. For instance, only 18% of firms can analyze texts such as written customer service reports. This could be a real problem since the analytics hardware and software is maturing, but the skills needed to use them are in short supply.

4.11.2 Government

In March 2012, the Obama Administration announced the Big Data Research and Development Initiative to explore how big data could be used to address important problems faced by the government. This marked a major step forward in the government's use of big data across multiple areas. The initiative is composed of 84 different big data programs spread across six departments. While this announcement brought government big data programs into the spotlight, agencies have been working to fully utilize the data at their disposal for some time. Perhaps the most transformative result of the government's increasing attention to big data has been the democratizing of information that was once difficult to access. As governments continue to tap into big data technologies, open data platforms will become customary as people, business leaders, and policymakers come together to determine how their country should be governed.

For instance, the Green Button Initiative is an industry-led effort developed in response to the U.S. federal government's call-to-action to provide utility customers with easy and secure access to their electricity usage data in a computer-friendly and easy-to-use format. Energy consumers, third-party software/application developers, public institutions, energy efficiency organizations, and utilities/energy service providers will all benefit from the increased visibility of detailed electricity consumption data.

IBM has an entire service offering dedicated to working with all levels of government agencies to tackle their data analytics challenges. Big data analytics can improve efficiency and effectiveness across the broad range of government responsibilities by improving existing processes and operations and enabling completely new ones. A major focus for IBM's work with big data in government has been identifying fraud and waste in tax collection programs. By incorporating a large variety of structured and unstructured data from both internal and external sources, IBM's big data platform can help tax agencies more accurately determine who should be investigated for fraud or denied refunds by helping to detect new deception tactics, uncovering multiple identities, and identifying suspicious behavior. IBM also works with government agencies on crime prediction and prevention to gain a deeper understanding of persons of interest, crime and incident patterns, location-based threats, etc. in order to predict and prevent crime.

4.11.3 Marketing

Big data is a natural fit for the marketing industry. As a result, it has been embraced by many companies, which are generally cited as prime examples of the concept. Marketing professionals are motivated to understand as much about their potential customers and their thought processes as possible; they are also diligent in collecting all available information. The rise of e-commerce and the Internet as a shopping tool have provided marketers with more information than was thought possible a few decades ago. Consumers spend hours every day on the Internet and leave behind large amounts of information about who they are and what they seek. Their daily Internet journeys reveal their online interests, the content of their communications, the purchases they make, and so on. While these consumer actions are similar to what goes on in the real world, on the Internet this information can be collected, recorded, and analyzed, which opens the door to the use of big data and advanced analytics.

Big data has also revolutionized the customer engagement process for many companies. Companies can now understand not only who their customers are but also where they are, what they want, how they want to be contacted, and when. Data also helps companies post-sale by discovering what influences customer loyalty and what keeps them coming back again and again. By storing, organizing, and making available this information, companies can determine optimal marketing spend across multiple channels and continuously optimize marketing programs through testing, measurement, and analysis. Big data has been described as an investment that every company must take to close the gap between the data that is available to them and the business insights they are deriving from that data.

4.11.4 Meteorology

The use of sensors and data analytics has been instrumental in meteorology for many years. However, like many fields, technological advances in sensors and analytics software have led to significant breakthroughs. When the Sloan Digital Sky Survey (SDSS) began collecting astronomical data in 2000, it amassed more in its first few weeks than all data collected in the history of astronomy. Continuing at a rate of about 200 GB per night, SDSS has amassed more than 140 terabytes of information. When the Large Synoptic Survey Telescope, successor to SDSS, comes online in 2016 it is anticipated to acquire that amount of data every five days. This exponential increase in the ability to collect data has provided scientists with enhanced abilities to predict weather and its effects on lives.

Research scientists in IBM's Deep Thunder weather analysis project have been using both real-time and historical data to simulate the effects of winter storms on the metropolitan area. Using a computer simulation, they set up a three-dimensional grid of thousands of city blocks in New York City. This makes it possible for them to run calculations that produce precise weather forecasts for a particular locale. Using this capability, the team was able to predict with remarkable accuracy the snowfall totals in New York City during the mammoth snow storm that blanked the northeastern United States in February 2013, and also to predict accurately when the snowfall would start and stop. Another example of Deep Thunder's big data analytics in meteorology comes from South America. Rio de Janeiro, because of its climate and terrain, has recurring flooding and landslide problems in many hilly neighborhoods. Researchers used data describing the physics of the atmosphere to create a mathematical model of how storms are likely to unfold in Rio. With it, they can predict up to 40 hours ahead of time how much rain will fall in a particular location, with 90% accuracy.

4.11.5 Retail

The retail industry has been an active and visible participant in the big data world over the last several years. Walmart, one of the world's largest companies by revenue has devoted significant resources to understanding how to capitalize on this concept. Throughout 11,000 stores worldwide, the company handles over 1 million customer transactions every hour, feeding databases estimated at more than 2.5 petabytes. The company's goal is to tap into social buzz to help with decision-making on aspects like inventory and assortment. Social buzz typically precedes retail buzz. Through social media, people are constantly expressing their thoughts on new or upcoming products on social apps. There are both good and bad things said, thus social media is really a direct real-time feedback channel to the company from many customers. However, there are many challenges as well; the language used in social forums is heavily informal, unstructured, and often ungrammatical, and filtering that helpful insight out of the huge amount of noise can be difficult.

A second example of big data used in the retail world comes from another major American company. Several years ago Nike began incorporating sensors into many of its shoes. The sensors are marketed as an additional value by allowing runners to measure their pace and workout distances. However, that is not the only reason the company did this. Nike executed the concept because they wanted to have more information about their customers. The sensors collect data about how the shoes are utilized, what kinds of surfaces they are being run on, how often they are being worn, and then transmit that information back to Nike. Once the consumers have used their shoes long enough, the company can proactively reach out and sell them new shoes. This also allows the company to store data on the durability of various products by understanding how they are being used by target demographics and how long they last under varying conditions. Real-world feedback of this type is improving product development for Nike.

SECTION 5

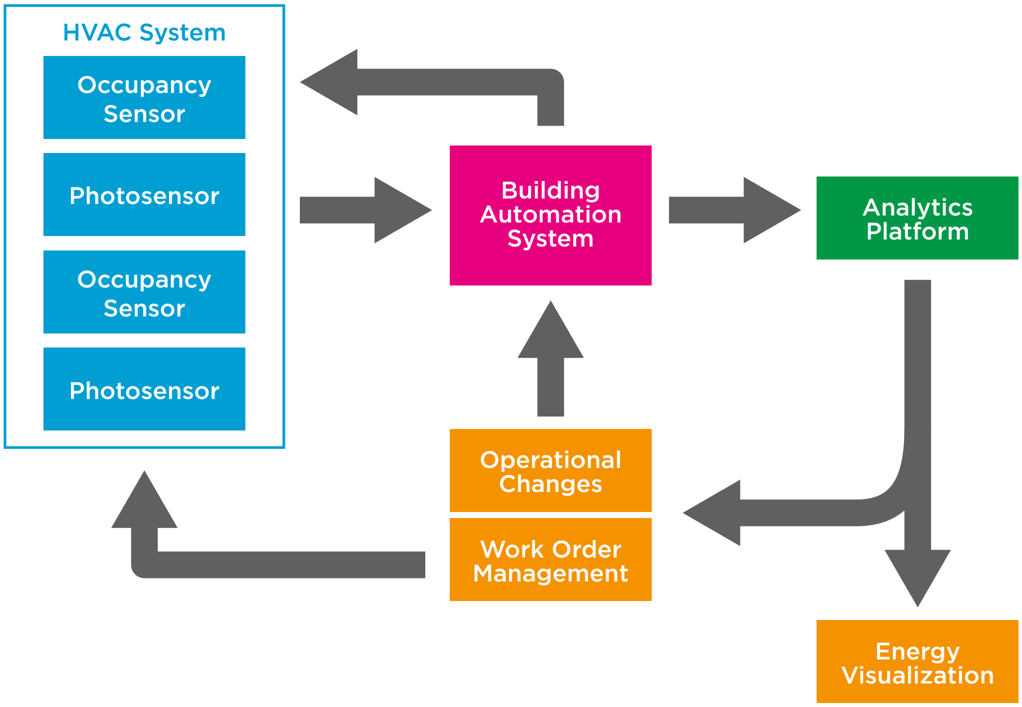
THE CASE FOR BIG DATA IN INTELLIGENT BUILDINGS

5.1 INTRODUCTION

Within a building the analytics process of capture, integration, analysis, and action must be employed in order to provide analytics-based control strategies. Traditionally building control has taken a top-down approach with integration between different systems such as HVAC and lighting occurring at a supervisory level. However, integration is beginning to occur at lower levels with some analytics relying on multiple inputs from multiple systems.

In an HVAC application, data capture can occur with temperature sensors, humidity sensors, CO_2 sensors, and electricity submeters. The building automation system (BAS) serves as the medium to integrate the data from each of these sources. Additionally, the BAS provides low-level feedback control of the system to ensure that the HVAC system is operating to its setpoints and schedule. The integrated data from the BAS can then be sent to an analytics platform. This platform provides meaningful recommendations to improve the performance of the HVAC system. The result of the analysis can provide visualization of energy use, suggestions for improvements on operational changes, and work orders to maintain equipment.

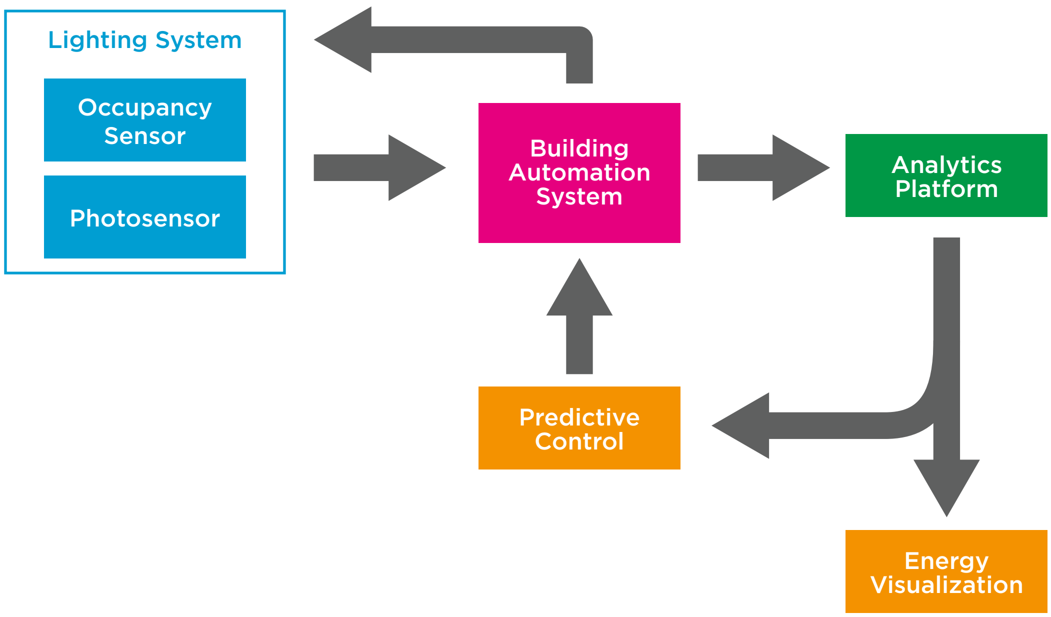
Figure 5-1 Example Analytics Process for HVAC Applications



(Source: Navigant Research)

A deployment of the analytics process on a lighting control system similarly consists of capture, integration, analysis, and action. However, the data captured from the system would come from occupancy sensors and photosensors. Like in the HVAC deployment, this data is integrated through a BAS and then analyzed on an analytics platform.

Figure 5-2 Example Analytics Process for Lighting Applications



(Source: Navigant Research)

HVAC and lighting controls demonstrate the benefits that big data can provide to energy efficiency. However, there is a broader opportunity for big data in intelligent buildings that extends beyond energy into other operational benefits.

5.2 BIG DATA AND INTELLIGENT BUILDINGS OPERATIONS

There are many reasons why organizations would choose to implement big data solutions for their buildings. The motivations for implementing big data vary based on the type of building and its use. The two primary motivations for implementing big data solutions are improving energy efficiency and optimizing building automation. While there are many overlaps in how big data can be used to achieve these objectives, there are differences, which will be explored in Sections 3.2.1 to 3.2.3.

5.2.1 The Role of Big Data in Building Automation

Big data will play an increasingly important role in building automation as advanced controls and sensors proliferate. Intelligent building systems must rely on more granular data regarding the current conditions in the areas they control. Data-enabled machine learning is necessary to create a smart building; its defining feature is the ability to be proactive in making appropriate changes to services on behalf of its users. Temperature sensors and setpoints in a building are some of the most prominent and easily accessible areas that can use data to improve inefficiencies. Examining sensor data and thermostat adjustments can provide an understanding of areas that may be overcooled or overheated and require adjustments by the occupants. Understanding this information can allow the building system to automate its settings based on the preferences of the individuals occupying that space, allowing for a more consistent temperature and less down time from discomfort. Another way data can improve the automation of a building's HVAC system is by optimizing the air handlers. As CO_2 and occupancy sensors become increasingly common, the data they provide can optimize the amount of outside air that needs to be brought into a building to maintain comfortable indoor environments.

As buildings become more automated, it is essential for architects, installers, and building managers to remain mindful of the human need to feel in control of their immediate environment. While many people appreciate the energy efficiency benefits of increased automation, they will want to engage with system controls in their space, rather than feel at the mercy of a technological hand of God. This is where data can play an important role, but more research needs to be done. It is important to have an understanding of a building occupant's reaction to automation. Ongoing monitoring of occupant adjustments to systems and the post-occupant evaluation (POE) of a building will be important to ensure that buildings meet the needs of its occupants. Similarly, the integration of building automation into operations, such as the use of a computerized maintenance management system (CMMS), will also be important. Everyone involved in building design and operation must understand that ultimately it is about service, not gadgets, and it is not about the data itself but about how the data is used to create better living and working environments.

5.2.2 The Role of Big Data in Energy Efficiency

The role that big data can play in improving building energy efficiency has been the focus of many initiatives over the last few years. Although there is a lot of excitement in the air, there is also a great deal of confusion about what these products can do and how to best deploy them. The role of big data in energy efficiency has been expanding, as the focus of energy efficiency programs shift from onsite physical assessments of buildings to more virtual and continuous monitoring. Onsite audits create the challenge of maintaining data consistency and integrity when different auditors and contractors may be used over time. In addition, the knowledge and data often reside within individual practitioners rather than being embedded within the system itself. By organizing and maintaining control of data on building performance, owners can more easily hold the auditors and contractors accountable for their work and also better inform future projects.

While one-time benchmarking or an onsite audit can provide a picture of a building's performance, it cannot capture the dynamic responses of a building over time. This is an essential piece of the energy efficiency puzzle, which requires data analytics to be successful. A big data solution for energy efficiency must provide continuous tracking and benchmarking so that building profiles are up to date as the buildings' physical systems evolve and external factors like weather and utility prices change. Constantly maintaining this data allows for a complete understanding of the impact of energy efficiency upgrades and an assessment of which future improvements will yield the best results.

5.2.3 Metrics Used for Investment

Metrics used to determine investments in big data solutions are based on the return on investment (ROI) from either energy savings, deferred/avoided maintenance costs, or other business efficiencies. Increased energy prices around the world have led to substantial focus by many organizations on reducing expenses by saving energy. Big data solutions implemented through advanced BASs or building energy management systems (BEMSs) have proven to provide substantial reductions in energy usage. A BEMS uses data to provide a complete visualization of energy usage within a building to understand where inefficiencies lie and how to correct them through changes in occupant behavior or adjustments to automated systems. Many buildings waste large amounts of energy by conditioning spaces when they are unoccupied. Even simple automation systems using occupancy data and specific setpoints can provide substantial reductions in energy costs.

Continuous monitoring of sensor data from building systems such as HVAC can identify when equipment needs to be replaced or may be about to fail. Bringing technicians onsite to service equipment can be a major expense for building owners. This type of data analytics allows a diagnosis to be made before the technician arrives, while also providing information on replacement parts and other relevant items. Data analytics solutions can also build a list of the known problems in a building and derive each piece of equipment's usage and cost, enabling a quantitative ROI-based assessment of which upgrade or investment should be implemented first.

5.3 BIG DATA AND INTELLIGENT BUILDINGS INTERNET OF THINGS (IOT)

The case for big data solutions in buildings is directly impacted by the rise of the Internet of Things (IoT)-connected devices, and building systems. Next-generation technologies such as IoT, cloud computing, big data, and data analytics are expected to be an ideal fit for the evolving smart buildings market in terms of technology, business value, and customer satisfaction. The convergence of building technologies and the IoT industry is expected to satisfy the technical demands of the smart buildings market surrounding big data and data analytics applications. Additionally, initial launches of IoT technology around personal fitness tracking and smart thermostats provide promise for big data applications in buildings. These technologies, therefore, are expected to bring more investments from vendors of both industries as a result of partnerships in the near future.

A major benefit from utilizing big data, particularly for building automation, is that it allows data on the building to become fluid versus static. Traditional systems analyze building data in a historical context to understand recent energy consumption, efficiency, and efficacy without necessarily providing insights on current conditions. Fluid data based on real-time operating conditions enables vast new opportunities to improve efficiency and product quality.

5.4 BUILDING SYSTEMS

Most systems in a modern automated building are capable of producing data, although rates at which it is made available can vary considerably based on the complexity of the system and the goals of the building owner or manager. Data available from building systems has been increasing rapidly in recent years. Modern automated buildings can provide data from HVAC, lighting, security and access controls, electricity meters, plug-loads, and more. Many automation systems and BEMSs have the ability to organize and process this information to provide insights into the building's operation. Many systems are increasingly making use of external data to understand how to maximize the efficiency of a building.

Increased functionality and complexity of building systems enables the emergence of intelligent buildings. An intelligent building is defined as a building that achieves and maintains optimum performance by automatically responding and adapting to the operational environment and user requirements by facilitating ready and cost-effective adaptation to changes in user requirements.

Sections 3.4.1 through 3.4.6 provide an overview of the major automated systems in an intelligent building. For the purposes of this report, only commercial office and retail buildings, their systems, and challenges were addressed. In Section 4, The CABA Building Data Reference, specific data types, rates, and volumes of individual systems will be presented.

5.4.1 Energy

Utility meters and building submeters are typically the primary sources of data for energy use within a building. While many submeters are used simply to measure kilowatt-hours on a once per month basis, the capabilities of submeters can be far more sophisticated. As demand for comprehensive energy management grows, so too will demand for advanced submeters that can provide a range of data with high levels of accuracy in real-time. This data can include:

- Power (W or kW)
- Current (amperes)
- Frequency (Hz)
- Voltage (V)
- Power factor
- Total harmonic distortion (THD)

The proliferation of digital smart meters and advanced metering infrastructure (AMI) has provided new opportunities to analyze a building's energy consumption using only utility metering data. Examples of this include FirstFuel, Agilis Energy, and Retroficiency. These companies provide services that use utility-provided hourly smart meter data and a building address to perform a brief building assessment utilizing readily available information on the building (occupancy, uses, permits, etc.) along with weather data and local color imagery (like those found in Google Earth) of the building to assess various building characteristics. The models then perform a remote disaggregation of the building's energy performance characteristics.

Gas submeters can also serve as a source for energy data in buildings. In systems that rely on natural gas for heating, electricity monitoring does not provide a full picture on overall energy consumption. In addition to inefficient control of systems, gas submeters can help identify physical distribution problems in a building.

Submeters provide valuable data about energy generated onsite and also enable participation in demand response

(DR) programs. For buildings with solar panels, submeters provide information on levels of generation which can be used for building energy management. Additionally, buildings that participate in DR programs can leverage submeter data to provide granular actions for demand events.

5.4.2 HVAC

Data from HVAC systems is generated by sensors located throughout the building. The main types of sensors commonly used to support HVAC systems measure temperature, airflow, humidity, and occupancy. However, HVAC data can also include information on the operation of equipment, such as whether pumps or fans are running and how much power they are drawing. The two most commonly measured parameters inside buildings are temperature and humidity; as a result, many sensors are capable of measuring both in the same unit. Temperature sensors are generally located within rooms or specific zones of a building. However, they are often also found inside ducts that deliver and remove air in HVAC systems outside the building itself and in the systems that measure the temperature of heated or cooled water inside pipes. Temperature sensing is extremely simplistic and an area where little innovation has taken place. For this reason, the basic analog sensors found in ducts and strapped to pipes, for example, are merely points that are checked to make sure the building is functioning correctly.

While an occupancy sensor is most commonly used to turn on lights when it detects human movement within its field of view, a thermal sensor array can also be used to reduce the thermostat setpoint when the monitored space is unoccupied. For this reason, thermal sensor arrays, which have the ability to count people, provide the most granular information. Airflow measuring devices, typically located in duct work, are used in traditional HVAC systems for basic balancing and thermal comfort. CO_2 is another commonly measured parameter in HVAC systems. As people exhale, CO_2 levels in a building begin to rise. Sensors can be used to indicate CO_2 levels so that ventilation systems deliver enough outside air to building occupants while eliminating certain amounts of moisture and odor that inevitably build up.

5.4.3 Lighting

Similar to HVAC systems, data from lighting systems comes from sensors located throughout a building to optimize operation. Modern lighting control systems primarily utilize sensors to measure occupancy and light levels in a given location, allowing the system to automatically adjust light output to maximize efficiency. Occupancy sensors for lighting systems are similar or often times the same sensors used by a building's HVAC system. Occupancy sensors for lighting control are quite common and come in a variety of different configurations for both indoor and outdoor applications.

Photosensors are the other primary type of sensor used by lighting control systems and are less common than occupancy sensors. Indoor photosensors are based around a light-sensitive photocell that is usually made of silicon. This photocell produces an electrical current in proportion to the amount of light that strikes it. The photosensor also includes some type of lens to collect and focus the light and internal electronics to convert the output from the photocell into a control signal. Some photosensors are fully integrated units that mount to the ceiling or are attached to a luminaire. Other versions have the sensing part for ceiling mounting and separate electronics that can be located in a more convenient place for commissioning access. Photosensors can also be used to enable daylighting, the dimming of lighting systems when natural light is present, and smart glass, which automatically darkens to limit the amount of light in a building.

Several lighting control manufacturers have begun placing a greater emphasis on data analytics to improve the functionality of their products and to differentiate from competitors. One noteworthy company is Sensity and their NetSense Platform. The platform utilizes an advanced distributed computing architecture where each light-emitting diode (LED) light fixture is equipped with sensors and a fully functioning processor able to run software instructions. When networked together in a NetSense network, these fixtures collectively gather and process data about the surrounding environment, enabling analytics that transform the raw data into actionable information. Additionally, companies like Daintree and Enlighted are integrating networked lighting controls with cloud-based energy management. Companies across the industry are also utilizing data from lighting fixtures for other purposes such as security, parking management, tracking shipments, retail customer analytics, and monitoring environmental conditions.

5.4.4 Security and Access Controls

Data from security and access control systems within buildings is often less utilized than data from HVAC and lighting systems. The level of sophistication of a building's security and access control system varies greatly depending on the type of building and its occupants. Much of the data from security and access control systems comes from access control stations and card readers at entrances. These can be numerical keypads, key switches, radio frequency (RF) or magnetic strip card readers, or biometric input devices. This data can also have some value when properly stored, allowing organizations to see who has been in certain areas of a building and when. Data also comes from sensors for occupancy and door/window opening as well as camera and video systems. Data from camera and video systems may provide the most opportunities for meaningful analytics while also generating the most sensitive privacy concerns. Video systems can be used in conjunction with HVAC and lighting systems to measure occupancy and accordingly shut off or turn down systems. While the utilized data in this case (occupancy) is not sensitive, the raw video itself must be kept secure during analysis and storage.

5.4.5 External Data

The primary types of external data utilized in automated buildings are utility prices, weather, and benchmarking versus similar buildings. Building automation and energy management systems utilize weather data to anticipate the requirements of a building system. For example, a building's HVAC system will have vastly different requirements depending on the outside weather conditions. The level of sophistication can vary considerably; some systems are capable of predicting advanced metrics such as the solar heat in different parts of a building.

Utility prices are also an important factor in automated building systems. Knowing current utility prices allows automated building systems to manage consumption by shutting down non-essential systems or areas of a building in response to peak demand rates. This is primarily a factor only in areas where the utility offers time-of-use (TOU) pricing. Understanding local utility policies also allows buildings to participate in DR programs and earn additional revenue for building owners. Building managers can also utilize data on the performance of similar buildings in their area to measure the effectiveness of their efficiency programs. This has proven to be an effective tool in the residential sector. Companies such as OPower provide homeowners with information on how their energy consumption compares with neighbors. Similarly, companies such as EnerNOC provide larger enterprises with energy consumption reports.

5.4.6 Ancillary Systems

As intelligent buildings evolve, a growing number of new systems need to be connected to the building system. In particular, the data associated with these ancillary systems require both building and generated data, which can be used for building optimization. Microgrids, for example, are increasing in number; at the end of 2013, they accounted for about 685 MW of capacity and need building occupancy and energy data for their management. Additionally, electric vehicles (EVs) provide new sources of data integration. They are becoming increasingly popular as amenities in commercial buildings and have a profound impact on the energy management of buildings. Similarly, Wi-Fi and cell service are now being offered by some buildings as a service in the lease. This data is not yet utilized for building optimization.

Ancillary systems have their own approaches to data management outside a building's control. At this time, these systems are not formally integrated into intelligent building optimization or management, but this is certainly possible in the future.

5.5 DATA INTEGRATION

Once data is collected from sensors, it needs to be integrated. Integration of building data streams can occur through controllers as part of a BMS or with a data logger. One of the leading controllers on the market that is often used to integrate building data is the JACE box manufactured by Tridium (part of Honeywell). The JACE box connects systems based on a range of open protocols, including BACnet and LonWorks, as well as proprietary protocols in order to enable coordinated control of diverse building systems. However, data loggers, such as those sold by 38 Zeros, can provide low-cost ways to centralize data regardless of a building's installed automation system.

Data analysis occurs either on premise on a local server or with a cloud-based service, though the market is moving overwhelmingly to cloud-based models given the comparable ease of updating versions and scaling offerings compared with traditional software. Most analytics solutions compare energy data with external data sources such as weather and temperature data, average building performance data for specific facility types, and building occupancy and space utilization data while others uncover opportunities to improve efficiency. Some software systems can provide predictive analytics to anticipate future conditions based on past performance and avoid unforeseen facility management issues.

5.5.1 Building Communication Protocols

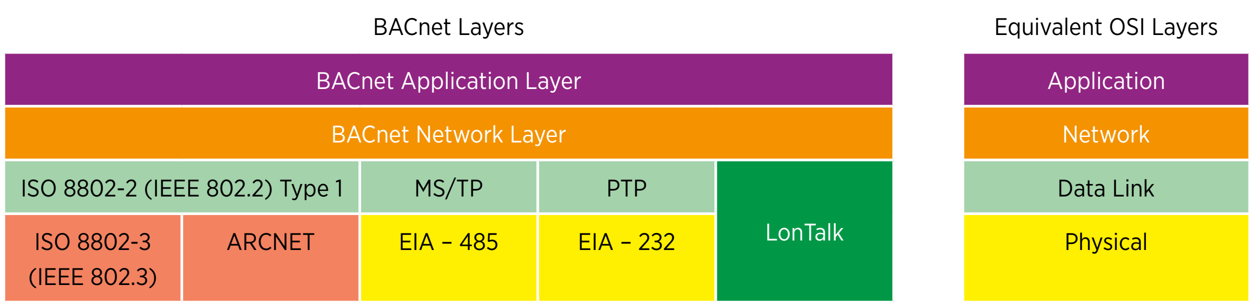
Integration of data relies upon communication between different pieces of a building. The building controls market is shifting to the use of open building communication protocols, with both large and small vendors moving to support the use of technologies that allow greater interoperability, choice of device suppliers, and ability to confidently plan for future expansion. The open standards currently in use are discussed in Sections 3.5.1.1 through 3.5.1.8. Current open building communication protocols are focused on enabling data to be available to the building network and transfer that data from one device to another. However, the context of that data is not adequately addressed by protocols. Labelling of data points to ensure that, for instance, supply air temperature has the same variable name across a building is rare. As a result, integrating data from multiple data sources is cumbersome, even with open building communication protocols.

5.5.1.1 BACnet

BACnet is a standard communications protocol for building automation and control networks developed by ASHRAE under the auspices of the Standing Standard Project Committee 135 (SSPC 135). BACnet was formalized as an ANSI/ASHRAE standard in 1995 and, in 2003, achieved the status of International Organization for Standardization (ISO) standard 16484-5. BACnet has emerged as the leading open standards-based building automation protocol, with increasing adoption rates across a wide range of applications worldwide.

BACnet is organized as a four-layer protocol, with equivalent application, network, data link, and physical layers. BACnet operates over a wide variety of physical and data link layer protocols, including Ethernet, ARCNET, twisted pair wiring, LonTalk, and an increasing number of other options, including ZigBee wireless.

Figure 5-3 BACnet Collapsed Architecture



(Source: BACnet International)

BACnet is increasingly being used for HVAC, lighting, fire and safety, security and access control, and related systems such as elevator systems. The BACnet standards provide behavioral descriptions for a large number of specific devices and have become the foundation for systems offering true multivendor interoperability.

BACnet specifies up to 50 types of objects, which represent a range of devices or values, and enjoys the support of nearly 700 vendors around the world. It can be set up to use the serial version of the protocol, known as BACnet Master Slave Token Passing (MSTP), which uses serial communication technology such as RS-485, LonTalk (in which BACnet uses LonTalk to convey BACnet messages), or Internet Protocol (IP) (BACnet/IP), which uses Ethernet as the physical layer communication technology.

5.5.1.2 LonWorks

LonWorks is a networking platform that was developed for the needs of control applications, including BASs. LonWorks technology was developed by Echelon Corporation starting in 1988. It has subsequently been adopted as a standard by ANSI, The International Electrotechnical Commission (IEC), and the ISO standards bodies for a wide range of applications.

The LonTalk protocol incorporates all seven layers of the Open Systems Interconnection (OSI) model into a single, cohesive system. It is designed to operate over twisted pair wiring or power line communications (PLC), and supports transceivers for fiber optic and RF communications. LonWorks also supports tunneling over IP networks and the wide range of physical layer protocols under IP such as Ethernet.

LonWorks, though available as a pure software implementation, is almost always implemented within specialized processors known as Neuron chips, which offload virtually all the protocol processing. Neuron chips were developed by and are available from Echelon, though they are also available from a variety of other suppliers under licenses from Echelon. LonMark International was formed as a trade organization in 1994 to provide an independent authority for standardization, certification, testing, education, and promotion of products using the LonWorks platform.

LonWorks is widely adopted in the building controls industry. Despite being accepted among open industry standards, it continues to face criticism as a proprietary solution due to Echelon's control of the underlying intellectual property. The relatively tight control of LonWorks by Echelon and LonMark International is credited with easing multivendor network implementations. However, BACnet has been gaining momentum at LonWorks's expense due to the perception that BACnet is a more open solution. In practice, it is not uncommon for both protocols to be deployed in a given BAS network.

In October 2013, LonMark International announced the expansion of the LonWorks protocol to better address the needs of the Industrial IoT. The change in interoperability guidelines and device profile architecture supports the connection between existing buildings control networks and IP-based networks. As a result, a variety of wired and wireless transport protocols can be directly integrated with existing building controls networks that already use the LonWorks/LonTalk architecture – without the need for gateways, which can be costly to purchase and install.

5.5.1.3 KNX

Konnex, or KNX as it is often abbreviated, is a standardized (EN 50090, ISO/IEC 14543), OSI-based network communications protocol for intelligent buildings. KNX is the successor to, and convergence of, three previous standards: the European Home Systems Protocol (EHS), BatiBUS, and the European Installation Bus (EIB or Instabus). It is administered by the KNX Association, which has more than 300 member companies worldwide. The association offers a product certification process that guarantees that different products from different manufacturers operate and communicate with each other.

KNX devices are arranged in a bus topology, in which sensors or actuators that are used to control switching, dimming, and timers related to lighting, HVAC, and other building systems are connected along a bus. KNX defines several physical communication media, including twisted pair wiring, PLC, RF, infrared, and Ethernet. The standard is designed to be independent of any particular hardware platform and can be controlled by anything from an 8-bit microcontroller to a PC.

KNX is most widely utilized in Germany but is often deployed throughout Europe in specific areas, particularly in installations where previous protocols (such as EIB or BatiBUS) are being upgraded or expanded.

5.5.1.4 BatiBUS (France)

BatiBUS is a low-cost building control protocol most often used in France. It is described in the French Standard NFC 46620. The protocol has achieved certification as a Comité Européen de Normalisation Électrotechnique (CENELEC) standard. It uses Layers 1, 2, and 7 of the OSI model and communicates over twisted pair cable.

BatiBUS is a completely open protocol and does not require proprietary chips in order to implement. It uses Carrier Sense Multiple Access with Collision Avoidance (CMAS-CA), a technology that allows data collisions to occur but will send the higher priority message through. The supported 4,800 baud data rate is relatively slow but sufficient for most building automation and control applications. BatiBUS has converged with EHS and EIB to form the KNX standard.

5.5.1.5 EIB

EIB is a protocol is similar to BACnet and is managed by the EIB Association. The EIB protocol supports the monitoring and control of functions and processes such as lighting, window blinds, HVAC, load management, signaling, monitoring, and alarms. The EIB system allows the bus devices to draw their power supply from the communication medium, like twisted pair or PLC technology. A serial-based communications protocol, EIB manages devices placed into a complex bus that can be divided into different trees that fit on the structure of buildings, with a maximum of 65,536 connected devices.

EIB Bus devices are generally built up from two parts: the bus coupling unit and the application module that manages processes in the building automation. The bus coupling unit is a decentralized bus manager in each device and provides electrical features, as well as data coupling to the Bus, in order to allow the separation of application hardware and software from the Bus communication system. Meanwhile, an application module manages the process in the building or house. An EIB network may be connected via gateways to external networks. This connection may be done at the backbone, the main line itself, or any other line.

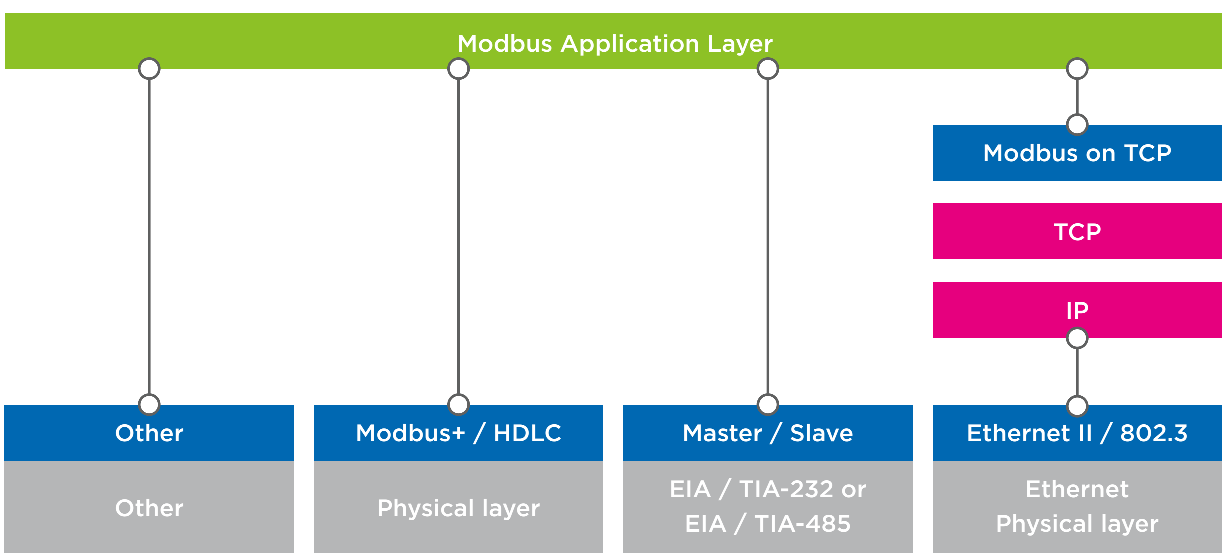
5.5.1.6 DALI

DALI stands for Digital Addressable Lighting Interface and is a protocol aimed at defining a set of controls for lighting ballasts, transformers, LEDs, and other lighting technologies. DALI is defined as a standard by the IEC and the National Electrical Manufacturers Association (NEMA) for the United States. DALI is perhaps the most ubiquitous controls platform for lighting, with adoption greatest in European applications. However, DALI is solely a lighting control protocol and cannot be used to control other systems such as HVAC or security and access devices. As a result, gateways must be used in order to integrate devices using DALI with other systems, which can make full BAS integration somewhat more challenging and complex.

5.5.1.7 Modbus

Modbus was developed in the 1970s for PLC to control manufacturing and assembly line equipment. It is an open standard and is available on a royalty-free basis. Modbus is generally used in electronic devices in the manufacturing and process industries. Primary applications with BASs involve the development of gateways to ensure maximum interoperability with older HVAC systems that utilize Modbus.

Figure 5 4 Modbus Protocol Stack



(Source: Modbus Organization)

Furthermore, building operators will often select Modbus gateways for use with older electric meters in order to extract data from these devices for use in energy analysis software or within a building management system (BMS). By purchasing gateways, significant cost savings can be achieved by not having to rip out and replace existing meters with new ones that speak BACnet, LonTalk, or other more modern protocols.

5.5.1.8 oBIX

The OASIS Open Building Information eXchange, or oBIX, Technical Committee is an emerging initiative to define Extensible Markup Language (XML) and web services-based mechanisms for building control systems. Largely driven by the desire to incorporate IP functionality across the entire spectrum of devices used in a BAS, oBIX is designed to allow direct control of devices from the IT enterprise network via a web services interface specification.

The oBIX committee notes that although currently established protocols, such as BACnet and LonTalk, can be used over transmission control protocol (TCP)/IP networks, true integration remains a challenge, largely around the configuration of routers, firewalls, security, and compatibility with other network applications. As a result, the goal of the technical committee is to adopt and standardize oBiX as another option for building managers and control system vendors to easily connect building automation and control devices and networks into the larger IT network. As of July 2013, four committee specification drafts of the oBIX specification are out for public review.

5.5.2 Big Data Systems

The ability to analyze vast qualities of data streaming from state of the art building systems is outside the realm of typical abilities of building managers. As a result, there is a trend toward outsourcing building data analytics. In some cases advanced BEMSs are able to provide all the analytics capabilities required by a building manager. However, to analyze the more detailed data from specific systems within a building that do not relate to energy consumption, original equipment manufacturers are offering their own services to building managers. For example, data monitoring and analytics solutions providers can monitor equipment data and provide that data to remote expert engineering analysts to aggregate diagnostic results, track progress, and consult with stakeholders on harder to solve problems. This provides benefits for both building owners and manufacturers. Building owners benefit from expert analysis to maintain their equipment at the highest levels, while manufacturers have vast amounts of real world data on the performance of their products.

Companies are emerging whose business revolves around managing and analyzing big data on behalf of building owners/managers. A leading company in this space is Splunk based in San Francisco, California. The company's goal is to provide a value-added layer of business intelligence to building control systems that allow facility managers, asset managers, and other stakeholders to gain actionable intelligence from the data coming from what can be thousands of devices.

5.5.3 Data Volume and Velocity

The volume of data generated by a building is dependent on the sophistication of its automation systems and the number of sensors utilized to measure conditions. A standard for many building systems is to measure conditions every 15 minutes, resulting in 96 data points generated per day. While that is common between different building systems, the number of devices or sensors varies by system. Security and access controls systems typically have many more data collecting devices (including cameras) than HVAC or lighting systems. However, the volume of data generated by building sensors in a single building may not be large enough to enable big data solutions. Often, data from outside a single building, such as meteorological data or data from building systems in other buildings is needed. Data from building occupants can also add depth to building data volume. This occupant data can come from traditional feedback sources such as thermostats as well as more innovative interfaces like surveys or smartphone apps.

Additionally, the size of the data collected varies by system. Again, security and access controls systems that utilize video cameras have much larger data sets than the simple readings from sensors measuring occupancy or air quality conditions. The volume of data generated by building systems dictates how organizations will store the data. Many choose to outsource their data storage to equipment manufacturers or other third-parties that also perform much of the analysis and provide insights. Others elect to keep their data in-house by integrating data centers into their facilities.

The problem presented by the volume of data is in its management. There is no basis for energy managers to know how to do this, but it is required in order to apply analytics-based solutions to energy management. Possible solutions to the management of data include data historians and cloud-based data loggers.

5.6 INFLUENCES ON THE APPLICATION OF BIG DATA IN BUILDINGS

The use of big data analytics in buildings will vary based on many factors. The size, location, age, and intended use of a building are just some of the factors contributing to how big data can be utilized to improve operations. These factors create different requirements for the environment inside of a building and what functions are needed to satisfy occupants. Certain types of buildings are able to be much more automated than others based on the needs of the building's occupants. As much as data can play a role in the operation of efficient, automated buildings, it can also aid in the design process to ensure a conceptual building will operate efficiently based on data from existing buildings.

5.6.1 Building Use

The intended use of a building and the activities of its occupants will determine the effectiveness of a big data solution and the best way to implement it. These factors typically determine the level of automation and the sophistication of a BMS. The type of BMS system will then determine how easily a big data solution can be implemented and how effective it can be. As data analytics solutions require sufficient amounts of data to be streaming from connected building systems, a robust communications network is essential for effective data analytics.

The pattern of use of a building will also have a direct impact on average energy expenses. For example, a big box retail store that operates through peak electricity demand periods during the day and early evening will likely incur demand charges from the local utility. These demand charges can make up a significant portion of a building's total energy cost and are the target of many energy efficiency programs. The rise of utility DR programs, particularly automated demand response (ADR) is driving the need for more advanced building energy management and analytics solutions. Advanced energy management systems utilize internal data from building systems along with external utility time rates and DR signals to determine when certain loads can be shed within a building, thus avoiding costly demand charges. This type of analytics is also a key factor in the rise of energy storage systems for commercial buildings. Data analytics allows onsite battery systems to know when to charge or discharge based on current utility rates and the needs of the building. As the focus of this project is office and retail buildings, requirements for those applications are explored in Sections 3.6.1.1 and 3.6.1.2.

5.6.1.1 Office

A common characteristic of office buildings is that the occupancy rates over time can be predictable. This allows for a level of automation that cannot be achieved in other types of buildings. Office buildings also have the advantage of distinctive zones with different occupancy rates and needs. For example, a building can be broken out into office spaces that are occupied on a standard schedule (9 a.m.-5 p.m.), conference rooms and shared spaces such as kitchens and bathrooms that will have variable occupancy rates, and areas that are rarely occupied and need less conditioning such as stairwells and unoccupied offices. Each type of zone can be set to different parameters and automation schedules for building systems such as lighting and HVAC. Data from sensors located in each individual zone can provide a detailed picture of occupancy and conditions over the course of the sensor's lifetime to feed into the BAS, improving scheduling and efficiency. For instance, data from thermostat corrections in each office space allow the system to understand the preferences of individual occupants and adjust settings automatically minimize discomfort and to limit the need for human correction.

Areas with variable occupancy in office buildings can benefit more from data analytics and continual correction. Conference rooms have variable occupancy rates; thus, installing occupancy sensors can tell the building's HVAC system when the room is occupied and how many people are present, allowing for the ideal amount of conditioned air to be delivered. Occupancy data analytics can allow an intelligent system to understand when regularly scheduled meetings will occur and can even sync with that room's digital calendar to pre-condition spaces in advance of meetings. Sensor data can also enable automation of the lighting system to maximize efficiency. Data from occupancy sensors tell the system which areas are rarely occupied to allow for lighting levels to be greatly reduced. Photosensors to measure light levels also play and important role by providing data on the amount of ambient light coming through windows, again allowing the system to reduce artificial light and save energy. Over time, photosensor data combined with external weather data can provide an estimation of the required energy for lighting in different parts of a building based on the amount of sunlight that will likely be available on a given day.

5.6.1.2 Retail

Considerable value can be generated through utilizing big data in retail buildings. Due to the variable occupancy rates and specific needs of retail environments, data analytics can provide insights to optimize the operation of building systems. Variable occupancy rates in retail spaces present challenges not found in other types of buildings. Energy efficiency efforts have made common the practice of dimming lights and turning down HVAC temperature setpoints when certain areas are unoccupied in many types of buildings. This practice, however, will not work effectively in retail spaces. To encourage customers to view different products and move to all areas of a store, there must be sufficient light and comfortable temperatures to create an inviting atmosphere.

Recent studies have indicated that the temperature inside of a store or shopping center can have a considerable effect on customer purchasing behavior. Data has shown that customers are more likely to purchase a product and be willing to pay a higher price for it when they feel physically comfortable. A study published in the *Journal of Consumer Psychology* found that people tend to have a better perception and a better image of products they see when the thermometer displays warm and pleasant temperatures. This means that building managers must ensure spaces are properly conditioned to keep customers warm and thus more likely to purchase products. This can be particularly challenging for retailers such as grocery stores that must keep certain areas of the store uncomfortably cool to maintain product freshness.

Big box retail stores also face the challenge of having stores up to one-quarter million SF in size. Sensors located throughout a store can provide valuable data to optimize a building's HVAC system to ensure that appropriate temperatures are maintained in different areas while taking into account occupancy and the needs of products located in certain areas.

5.6.2 Property Portfolios

Property portfolios with a dedicated management staff can benefit greatly from big data solutions. Organizations with large portfolios of buildings generally have large energy expenses and are looking for ways to reduce energy consumption to save money and improve their image. The geographic diversity of a building portfolio creates challenges for facility managers that can be aided by the use of big data analytics. One example of an organization taking advantage of building automation and data analytics to optimize their portfolio is Microsoft's main campus outside of Seattle. Implementing big data analytics solutions has allowed Microsoft to reduce its annual energy budget by approximately $1.5 million, and not every building has been brought online yet.

Microsoft's main campus consists of 125 buildings that encompass around 30,000 building system components. Together these systems account for nearly 2 million points with systems ranging from HVAC to lighting to power monitoring connected to sensors; in a 24-hour period these systems produce half a billion data transactions. Microsoft's initial project was a pilot program encompassing 2.6 million SF to build an analytics blanket of fault detection algorithms layered on top of the different BMSs and reporting back to the operations center. This system is advantageous because it can collect and report data from buildings with different BMSs. This program provided the expected benefit of reduced energy consumption by identifying equipment such as air handlers that were not operating optimally. In addition, the analytics blanket changed the way facilities are managed overall. With the different building systems reporting faults immediately, the team can have a real-time information feed of what is going on in the buildings, what needs to be fixed, and what the potential costs are of not fixing it. The system prioritizes faults based on cost, so a seemingly small fix might be ranked ahead of a larger one due to the overall financial impact; the system also provides the ability for the team to do repairs before problems are even reported. The next step is to have the system produce its own work orders.

5.7 BIG DATA SOLUTION OFFERINGS

The earliest forays into energy and sustainability management software addressed basic reporting and visualization of building energy-related data as an alternative to spreadsheet-based tracking of enterprise energy consumption. The wave of interest in carbon management software leading up to the 2009 Copenhagen Climate Summit accelerated the development of systems that were straightforward to use for non-engineers and offered simple visualization and reporting features so that companies could generate carbon emissions reports without cumbersome spreadsheets. Although the lack of international carbon regulation stymied demand for pureplay carbon management software, it paved the way for the development of enterprise energy management tools that allowed companies to visualize and analyze their energy consumption. These tools continue to be the most common and sophisticated capabilities and are starting to be rolled out generally to sit on top of these functions.

5.7.1 Visualization and Reporting

Visualization and reporting represents the minimal version of building analytics. It has no control capability; rather it provides information to building managers or occupants and relies on awareness and behavioral impact to make changes to building systems or building use. Visualization uses basic utility, submeter, and other sensor data to provide graphical representations of energy consumption, sometimes in real-time depending on data availability.

5.7.2 Fault Detection and Diagnostics

Fault detection and diagnostics (FDD) identifies performance anomalies and equipment faults due to erratic performance. FDD allows problems in equipment to be identified and remedied before it impacts building operation. For instance, the blow motor of an air handling unit (AHU) may be close to failing and could be detected by an FDD algorithm based on the current the motor is drawing. This problem could be fixed before the unit fails completely.

5.7.3 Predictive Maintenance and Continuous Improvement

Predictive maintenance and continuous improvement requires the application of FDD-based algorithms that track individual control and equipment performance on an ongoing basis to detect anomalies in system performance and reports faults to the facility manager. It determines when maintenance should be performed based on actual conditions rather than a time-based preventative maintenance routine; this allows a change in the facility's management from reacting to problems that arise while also preventing problems from arising. Moreover, because IT is increasingly being built into facility management service processes, building analytics services can potentially be directed to facility management services to coordinate maintenance schedules.

5.7.4 Optimization

Optimization uses real-time conditions to fine-tune and control building systems by changing setpoints and schedules. This approach can provide energy savings in the operation of equipment and reduce performance drift as well as improve occupant comfort.

5.8 BIG DATA CHALLENGES

The use of big data analytics systems presents new challenges for all industries, but its application to the building industry creates additional obstacles. Technology for buildings is slow to be developed and slow to be adopted. Additionally, increased automation and massive amounts of potentially sensitive data create both security and privacy issues. The proliferation of open standards-based building systems has allowed for accelerated innovation to increase automation and efficiency. There are many benefits to open standards: compatibility of products, customization, avoiding being locked in to one manufacturer, interoperability, competitive costs, more support options, etc. At the same time open and transparent standards seem to increase the vulnerability of BAS networks, seemingly providing all of the information hackers would need to assess vulnerabilities and create potential approaches for an attack. Challenges are also presented by the need to transmit data to a third-party for monitoring and analysis, as well as storing data and making it available for future analysis. Issues over privacy and security both arise about access to data, but they connote different concerns. Privacy relates to a fear of being observed, whereas security relates to the fear over the wrong party having access to observation data.

5.8.1 Privacy

Big data in the context of automated buildings does not come with the serious privacy concerns found in other areas. Compared to big data from Internet browsing activity or cell phone location, for example, there are limited serious privacy concerns from building data. However, there are still several privacy challenges associated with building data, one of which relates to occupancy schedules. Occupancy schedules for different parts of a building are some of the most valuable data points to maximize the efficient operation of a building. A serious privacy issue may arise when occupancy data is being generated by video cameras used for both security and to measure the number of people in a given space. While the data being used by a BAS (number of people in a given location at different times) is not sensitive, the raw video used to generate that data can be. It is imperative that video footage be securely stored or erased once the necessary data has been extracted. There has been a push by governments in certain regions to address this issue. Some governments have mandated that this type of video-based data cannot leave their home country, which has led many companies to store the information onsite. This type of concern is driving a rise in modular data centers being deployed within the owner's building to keep sensitive data onsite and minimize security and privacy concerns.

5.8.2 Data Security

Concerns related to intelligent buildings utilizing big data solutions are similar to the challenges presented to other highly automated, networked systems. As more devices are connected to the Internet and begin communicating over networks, there is increased vulnerability to cyber threats. For building systems such as HVAC control, electrical distribution, lighting, elevators, etc., the threat is disruption of critical building infrastructure, which also impedes or can halt normal operations. By disabling or physically altering building systems, an attacker can disrupt processes such as manufacturing. Depending on the building use and building control system, a security threat may be related to life safety – e.g., disrupting emergency power, lighting, and HVAC in a critical healthcare space. Threats of this nature to building systems are not just hypothetical. The infamous Stuxnet cyber-attack in 2010 affected programmable logic controllers, a controller that is commonly used in building elevators, pumps, drives, and lighting equipment. While many cyber security efforts have been designed to protect newer buildings with high levels of IT networking and automation, older building may actually be the most vulnerable. Most traditional BMSs are not secured; in fact, many legacy BMSs have back doors that allow the BMS manufacturer or local control contractor to monitor, manage, or update the systems. In others, the security settings were never turned on, even though they were available.

Utilizing big data analytics solutions can increase the risks to building systems by providing more points to potentially infiltrate a system. Big data solutions require large numbers of sensors and other forms of distributed intelligence to provide information on conditions that affect building systems. These sensors are often wireless and Internet-connected to provide easy interoperability and installation, but this leaves them more vulnerable to cyber security threats. Another security challenge posed by big data solutions is how to securely transmit building data to third-parties responsible for analysis. Many equipment manufacturers offer services to monitor the data streaming from their products to help identify faulty equipment and necessary repairs before they become a problem. This can represent a security concern and a potential avenue for access to building systems. Once data has been initially analyzed it must be stored and maintained as part of the big data system to provide historical context and insight into future conditions. This also presents a challenge as stored data could provide the insights attackers need to access building systems.

SECTION 6

THE CABA BUILDING DATA REFERENCE

6.1 OVERVIEW

The CABA Building Data Reference is a quantification of component-based capturing of data rates, volume, and integration of current intelligent building solutions. By creating scenarios with varied primary building activity, building size, and level of integration, the reference creates a picture of the varying amount of building data in the existing building stock and what future data resources will look like.

6.2 PRIMARY BUILDING ACTIVITY

The scope of this section includes two primary building segments: retail and office. Retail buildings are assumed to be served by rooftop units, as is typical in North America. The office buildings are assumed to be served by central chiller plants with AHUs and variable air volume (VAV) terminal units.

6.3 SIZE

A building's size affects many aspects of the data available, especially the size and density of the control points contained in the building. As a result, for the building reference, each primary building activity reference building is further segmented into two sizes: small and large. For the retail segment, the small building is defined as a single-story 20,000 SF building and the large building is defined as a single-story 150,000 SF building. For the office segment, the small building is defined as a 10-story 100,000 SF building, and the large building is defined as a 28-story 750,000 SF building.

Table 4.1 Summary of the CABA Building Data Reference

Primary Building Activity	Size	Building Area (SF)	Floors	Occupancy	HVAC Equipment
Retail	Small	20,000	1	300	Rooftop units
Retail	Large	150,000	1	2,250	Rooftop units
Office	Small	100,000	10	530	Chillers, AHUs, VAV units
Office	Large	750,000	28	3,975	Chillers, AHUs, VAV units

(Source: Navigant Research)

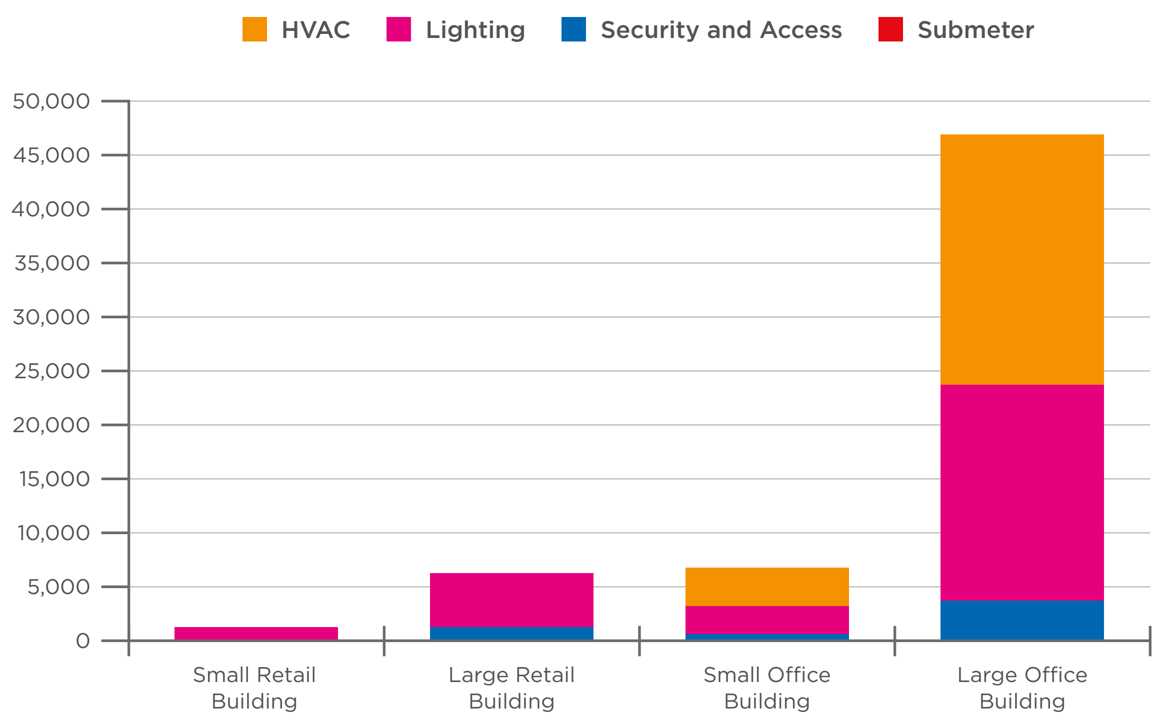
6.4 DATA VOLUME AND VELOCITY

While most buildings are data-rich environments, collecting and using that data remains a hurdle to the adoption of big data analytical strategies in commercial buildings. For example, while thermostats monitor space temperature in real time, the path that data travels could end at a controlled device. As a result, the reference buildings vary in data availability. The least amount of data available in commercial buildings is monthly meter data. Though this is not big data, it applies to many commercial buildings. A slightly more sophisticated building is able to provide interval data where consumption is reported on regular intervals, typically 15 or 30minute intervals. The reference building modeled with interval data also includes some level of submetering. A fully integrated building allows all sensor and device data to be collected centrally. Additionally, this building is able to collect data from security and access controls in addition to lighting and HVAC.

6.5 RESULTS

Not surprisingly, larger buildings provide a greater wealth of building data compared to smaller buildings. However, the principal building activity has a profound impact on the total number of points available as well. As can be seen in Chart 4.1, large office buildings represent the most complex systems with the greatest possibility for data analytics.

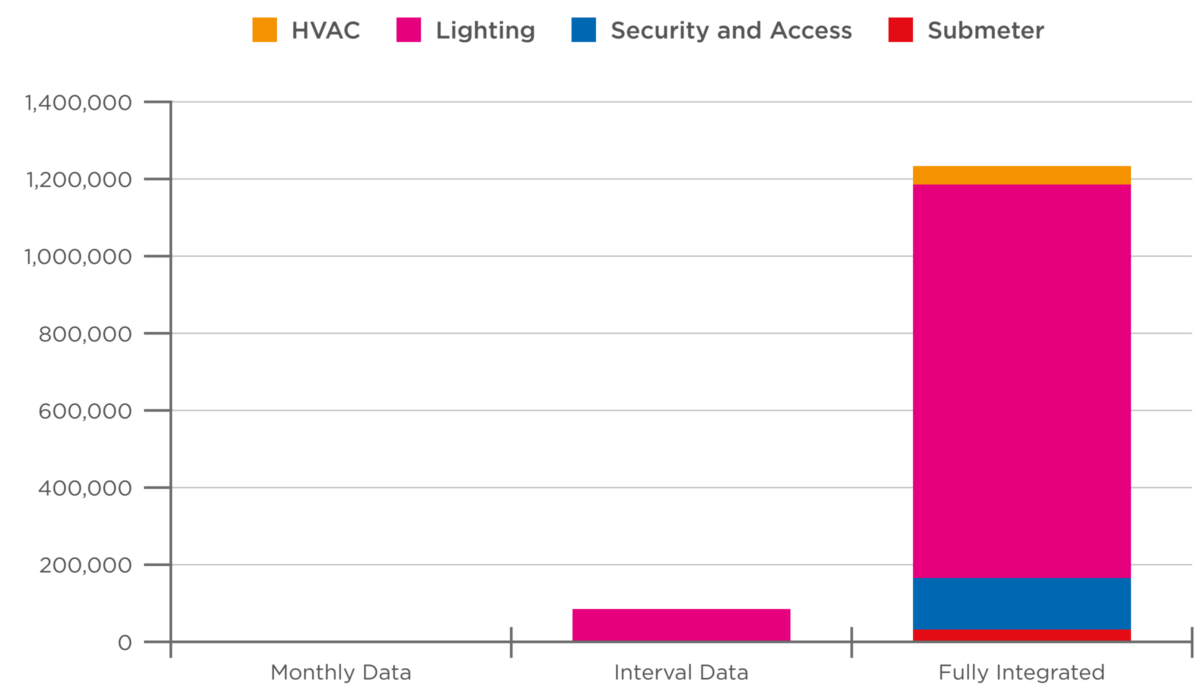
Chart 4.1 Total Number of Control Points by Building Size and Principal Building Activity



(Source: Navigant Research)

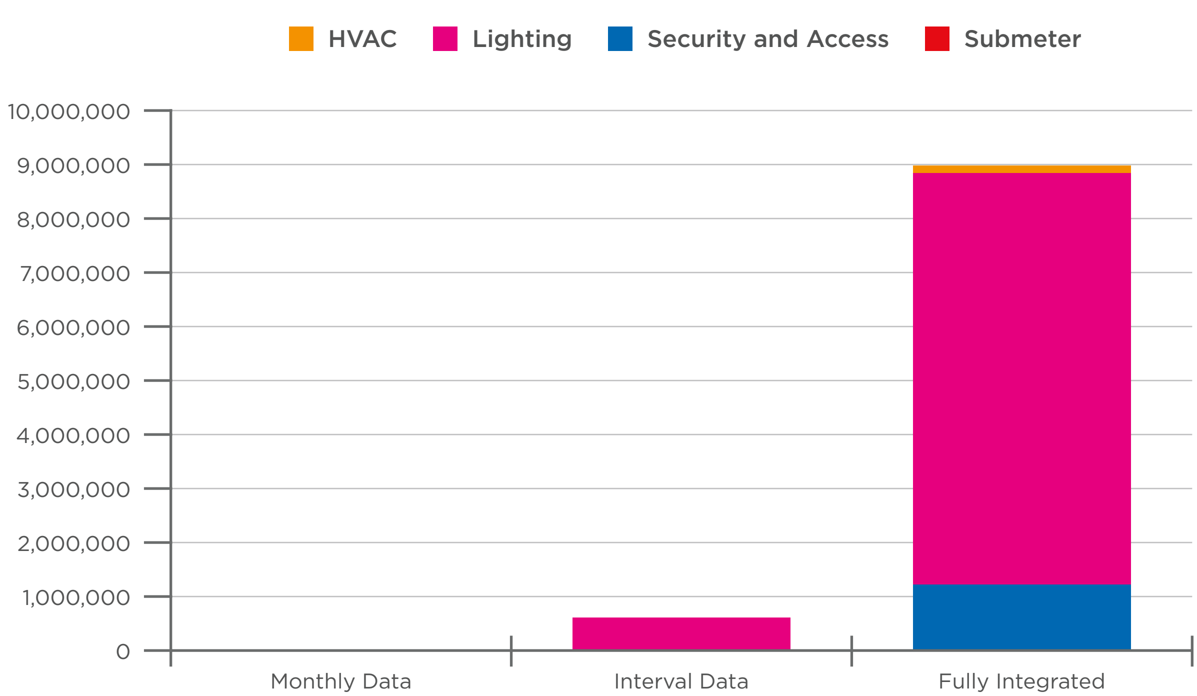
When different levels of data volume are applied to the potential number of points in a building, a greater variation in data availability is observed. As can be seen in Charts 4.2 and 4.3, fully integrated retail buildings provide approximately 17 times the amount of data transactions as ones relying on interval data. Each data transaction represents a piece of data that is captured and stored. As a result, more data transactions enable richer analysis.

Chart 4.2 Average Data Transactions per Day for Small Retail Buildings by Data Volume



(Source: Navigant Research)

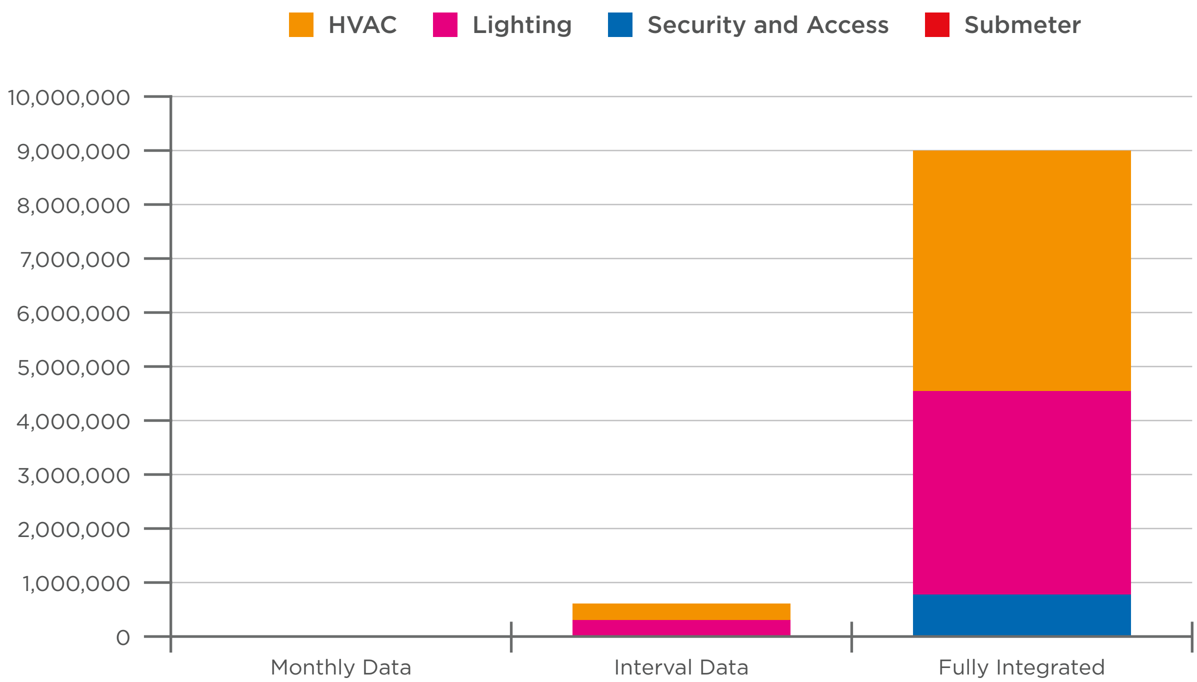
Chart 4.3 Average Data Transactions per Day for Large Retail Buildings by Data Volume



(Source: Navigant Research)

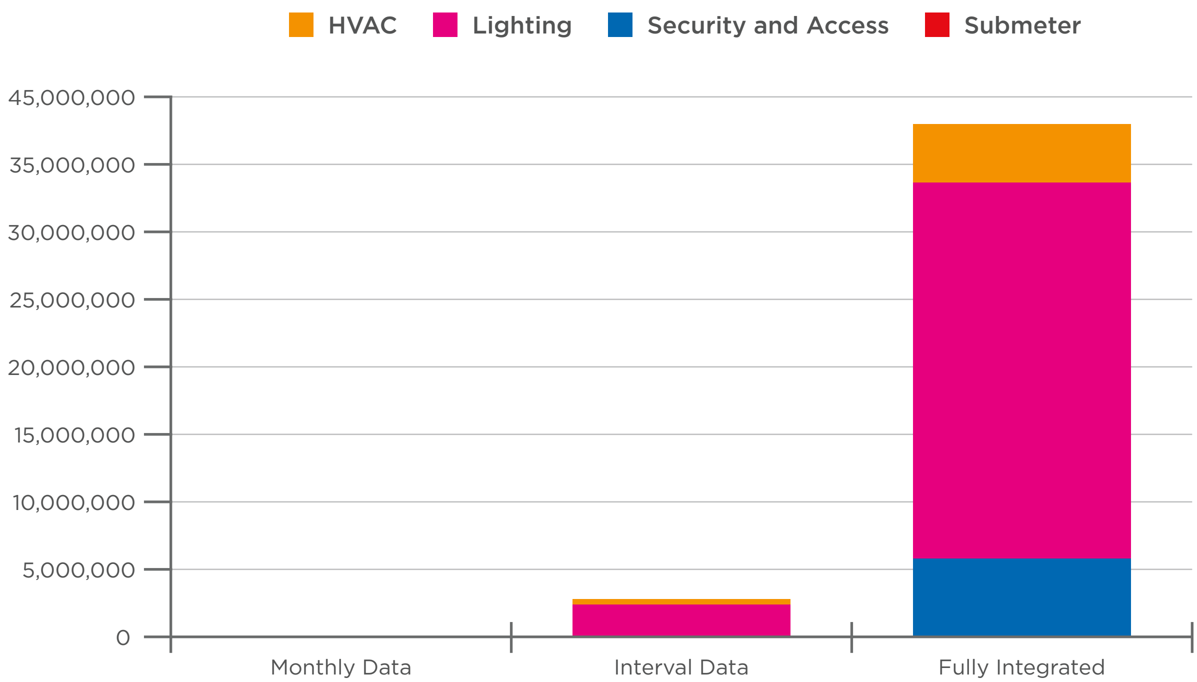
Increasing the integration of office buildings provides similar increases in data transactions. As can be seen in Charts 4.4 and 4.5, HVAC data plays a larger role in office buildings than in retail buildings. This is driven by the added complexity of the underlying system.

Chart 4.4 Average Data Transactions per Day for Small Office Buildings by Data Volume



(Source: Navigant Research)

Chart 4.5 Average Data Transactions per Day for Large Office Buildings by Data Volume



(Source: Navigant Research)

As the cost of controls hardware and storage continue to decline, fully integrated buildings will become cheaper and thus more prevalent. More importantly, with a greater share of buildings producing more data, the opportunity for combining data across multiple buildings becomes more appealing.

SECTION 7

THE PERCEPTION OF BIG DATA IN INTELLIGENT BUILDINGS

7.1 OVERVIEW

There is a perception among technology and service providers that the proliferation of intelligent devices and information technologies has opened new opportunities for innovation in building and operational management. Big data solutions utilize the volume, speed, and complexity of data generated by these new information sources to provide more strategic, data-driven decision-making. In particular, this report provides a new understanding of the customer behaviors, competition, and market trends that will shape the adoption of big data solutions.

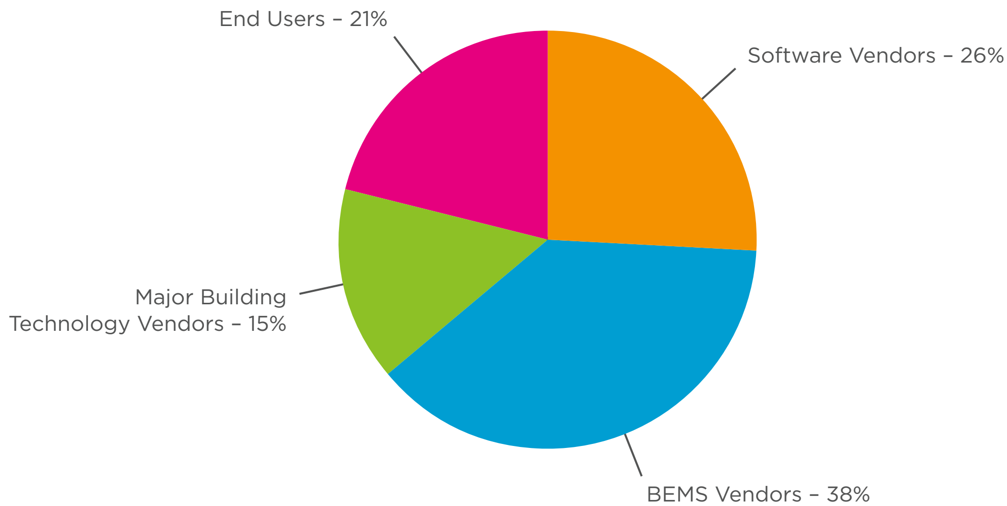
7.2 METHODOLOGY

The perceptions of big data in intelligent buildings presented in this section reflects the insight gained through the feedback of 34 interviews and 400 survey responses from a mix of technology and service providers and end users. This primary research helped clarify how much data is needed and what kind of big data offerings can support the mission-critical requirements for building operations.

7.2.1 Interviews

The research team conducted 34 interviews over the course of four months to inform the analysis of current and future market trends that will shape the opportunity roadmap and big data adoption forecast to 2020. These interviews explored perceptions on the value of big data solutions that leverage structured and unstructured data and incorporate comprehensive building and business data, advanced analytics, and machine learning. The interviews also specifically explored the value propositions and best practices for promoting big data in the retail and office/enterprise segments.

Chart 5.1 Interviews Completed by Category (n=34)



(Source: Navigant Research)

7.2.2 Survey

Results for the survey are based on an online questionnaire administered under the direction of ResearchNow in December 2014. A data set of 400 was collected from a panel of people that have some level of influence in selecting BASs or BEMSs and work for architecture, engineering, or construction firms. The survey questionnaire contained 45 questions that respondents were required to complete. The full questionnaire is available in Appendix A.

Statistical significance is defined for categorical questions as having a chi-square of less than 0.05 and defined for interval questions as a p-value of less than 0.05 from a Student's t-test.

The primary job function of respondents included facility management/building operations (36.3%), finance or accounting (27.5%), information technology (17.3%), engineering (15.0%), and sustainability or social responsibility (4.0%). About one-tenth of respondents were located in Canada, with the remainder in the United States.

For the survey, Navigant Research used the term energy management system to refer to a system that collects and analyzes building data, at the device level, that can provide information on the performance of a building.

7.3 FINDINGS

The market for big data in intelligent buildings is nascent. Research indicates that nearly all aspects of big data in intelligent buildings, from its definition to the description of its business value, differ depending on where one sits in the marketplace. Furthermore, there is a chasm between the technology and end-user readiness when it comes to big data in the intelligent buildings context. Despite the need for market education and awareness, there are innovators investing in big data and demonstrating proof-of-concept in the field. Generally speaking, the near and midterm opportunity in North America centers on the retail and enterprise/office markets in which the economics of investment are balanced by investment costs and end-users' maturity.

The following general conclusions reflect the perspectives shared between both the interviews and online survey:

- Customers prioritize investment on the economic impacts over all other benefits.
- The majority of decision makers in the intelligent buildings market do not know how to define big data or understand the potential benefits of these new solutions.
- Data security is a major concern for customers, and technology providers have an opportunity to demonstrate

how standards and procedures can protect businesses investing in big data solutions.

» Those interested in big data require transparency in the ROI of building and operational improvements.

» There is a lot of low-hanging fruit in building and operational improvements – many customers can still benefit from periodic reporting and analytics on existing building systems, and, as a result, many customers are not ready to adopt fully integrated big data solutions.

7.3.1 Interview Findings

While there were some common perspectives uncovered throughout the interview process, there were also some differences in opinion depending on where the interviewee sat in the market. In order to assess the market maturity and influences on expectations for investment, the interviews were analyzed in the four categories illustrated in Chart 5.1.

» **End-users**: The potential customers interviewed for this study were senior decision makers in the commercial real estate, government, and corporate real estate industries. The analysis of their responses was in line with those shared in the online survey, and, therefore, the results are found to be representative of the market.
   › Little understanding on the architecture and application of big data or how it differs from other intelligent building solutions.
   › Even those customers who would fall under the innovator category only focus their interest in big data solutions as pilot or test programs for the near term.
   › There is concern about demonstrating how big data solutions address data security, especially in the government segment.
   › Commercial real estate companies are increasingly interested in energy management as a means of cost containment, and, with some organizations, asset differentiation, which suggests that there is a shift in the split incentive dynamic.

The vendor interviews were categorized in three groups for this analysis: software providers, BEMS vendors, and major building technology providers. These categories do not reflect formal industry segmentation but aim to provide insight into the differing perspectives of solution providers. There are a growing number of startups providing pure-play software solutions for intelligent buildings. These technologies range in sophistication from a big data perspective but reflect a technology focus in the industry. The second category (after end-users) is labeled BEMS vendors; these interviews also reflected the growing startup segment. These vendors provide a range of offerings that include hardware, software, and services. Finally, the major technology providers offer hardware, software, and services solutions akin to the BEMS vendors but, for the purposes of this study, are looked at separately. These vendors reflect a major segment of the intelligent buildings market characterized by traditional building automation and controls companies that have shifted their solution focus and branding toward technology and innovation. The interviews illustrated differing perspectives among the vendor community, which led to the categories defined for this study. The following findings reflect common perspectives shared in the interviews:

» **Software providers**:
   › Common interest in differentiating their solution in terms of architecture and functionality – there is a trend toward marketing big data capabilities.
   › There is a common focus on communicating real-time data analytics and the value of big data.
   › Broader support for the use of big data in marketing and branding than from the other vendor groups.

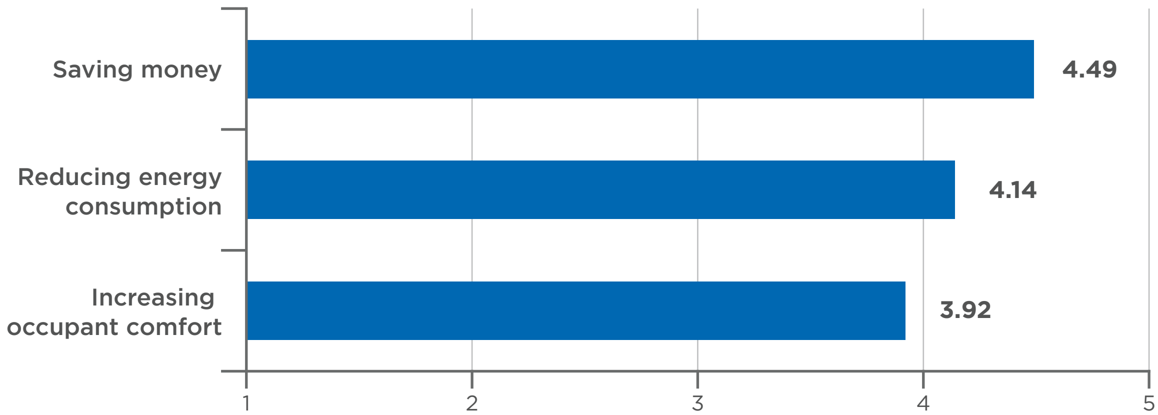
» **BEMS vendors**:
   › Greater focus on the results of investment in intelligent building solutions than on the details of the big data definition and architecture.
   › Deeper interest in niche market needs and opportunities leads to broader differentiation in solution functionality and perspectives on big data.

- **Major building technology providers**:
  - These companies have undergone an evolution in branding to offer integrated hardware, services, and software; as a result, there is an increasing focus on software, which creates more interest in big data.
  - There is a common understanding about the market immaturity but also a focus on the opportunity, with innovators looking to invest in next-generation solutions for energy and operations management; also, there is generally a focused interest in using the big data terminology for those customers.

7.3.2 Survey Findings

Survey respondents were primarily concerned with cost. When asked to rate different factors when making improvements to buildings, saving money was rated higher than reducing energy consumption or increasing occupant comfort.

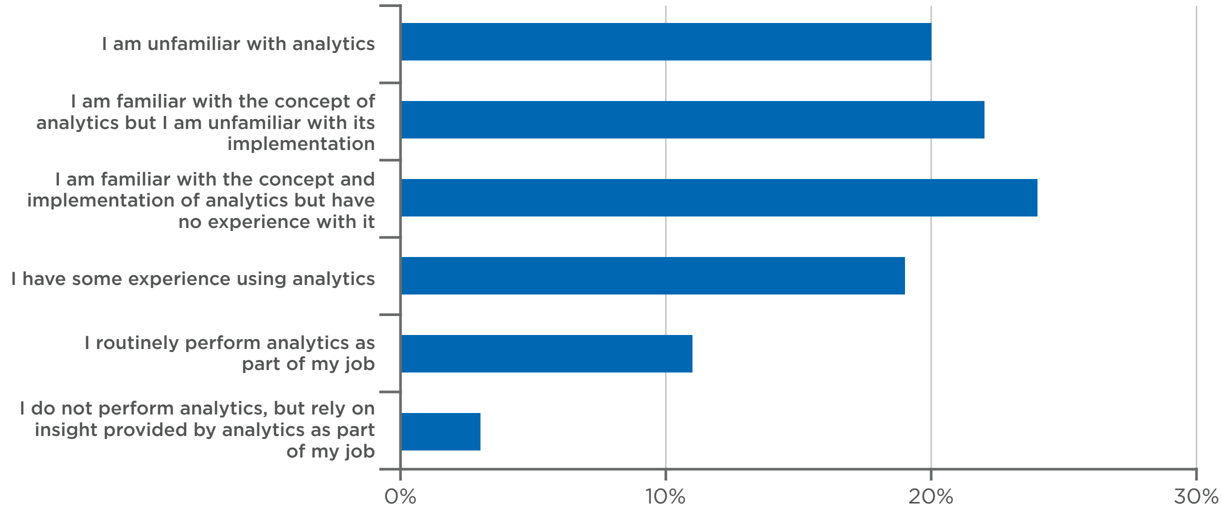
Chart 5.2 On a scale of 1 to 5 where 1 is not important at all and 5 is extremely important, please rate how important the following factors are when making improvements to your building. (n=400)



(Source: Navigant Research)

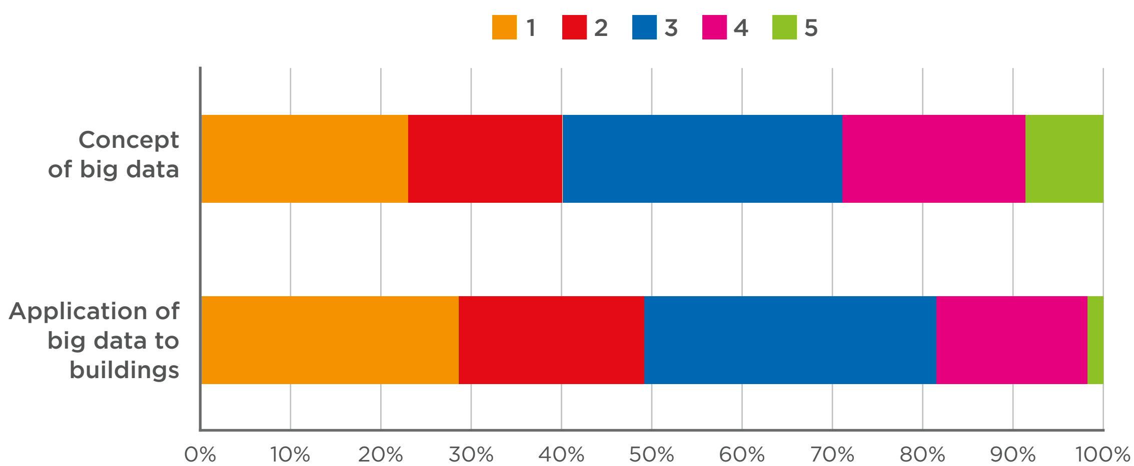
Additionally, respondents seemed unclear about big data. More than 20% of respondents indicated that they were unfamiliar with analytics. When asked to rate their level of knowledge about big data, 39.8% of respondents indicated a level of 1 or 2 out of 5. When asked to rate their level of knowledge about the application of big data to buildings, 48.8% of respondents indicated a level of 1 or 2 out of 5.

Chart 5.3 Which of the following describes your level of familiarity with analytics in relation to building management? (n=400)



(Source: Navigant Research)

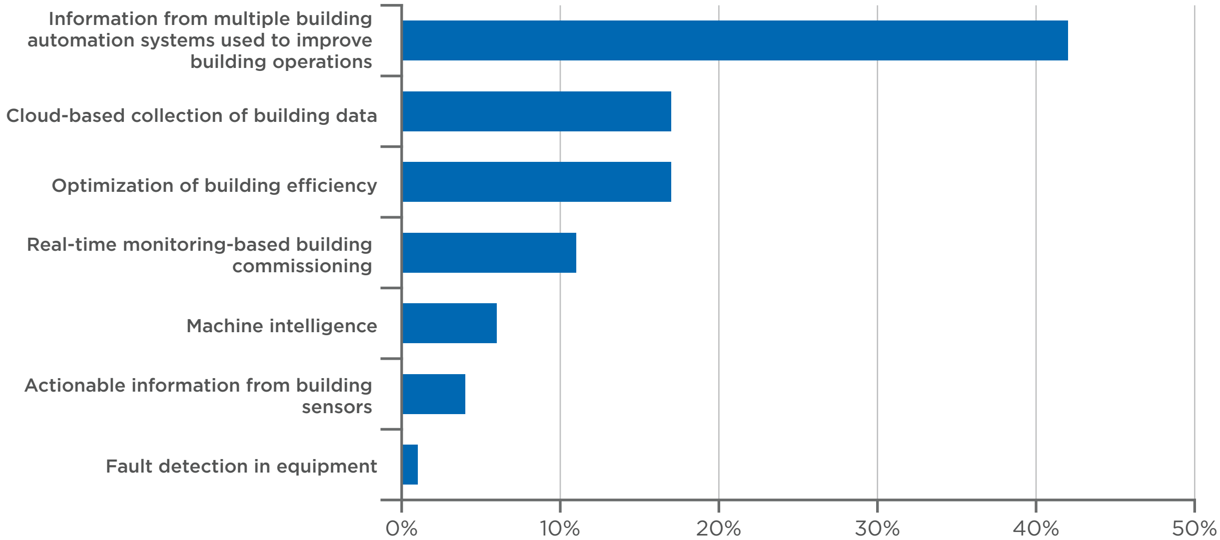
Chart 5.4 On a scale of 1 to 5, where 1 is not knowledgeable at all and 5 is extremely knowledgeable, how do you rate your knowledge about the concept of big data and the application of big data to buildings? (n=400))



(Source: Navigant Research)

However, when forced to select a definition of big data from a list, 43% selected "information from multiple BASs used to improve building operations."

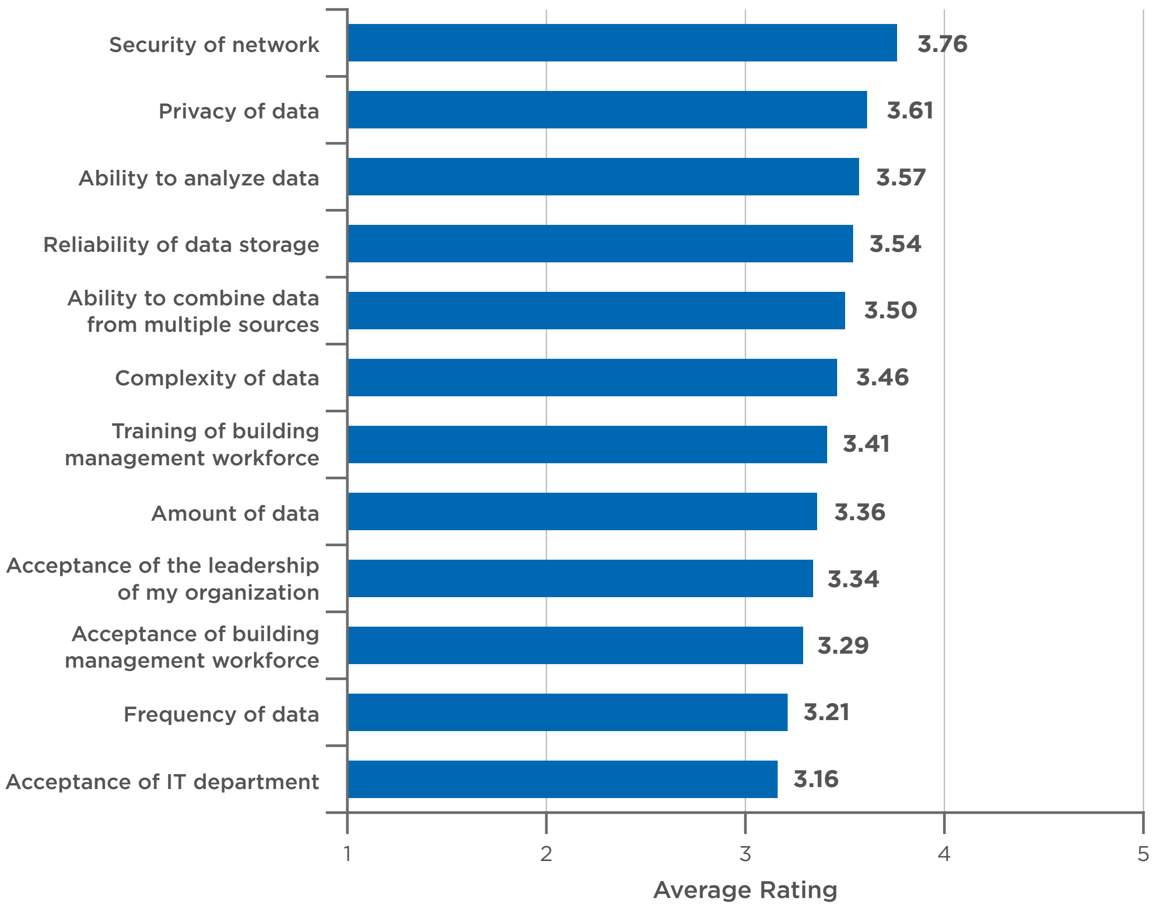
Chart 5.5 Which of the following do you think best describes big data in buildings? (n=400)



(Source: Navigant Research)

When asked to rate issues regarding data collection, security and privacy were rated the highest. Interestingly, respondents were least concerned with getting acceptance from the IT department. Getting acceptance from leadership and building management staff were also rated comparatively low, with fewer than half of respondents indicating that they were concerned or extremely concerned.

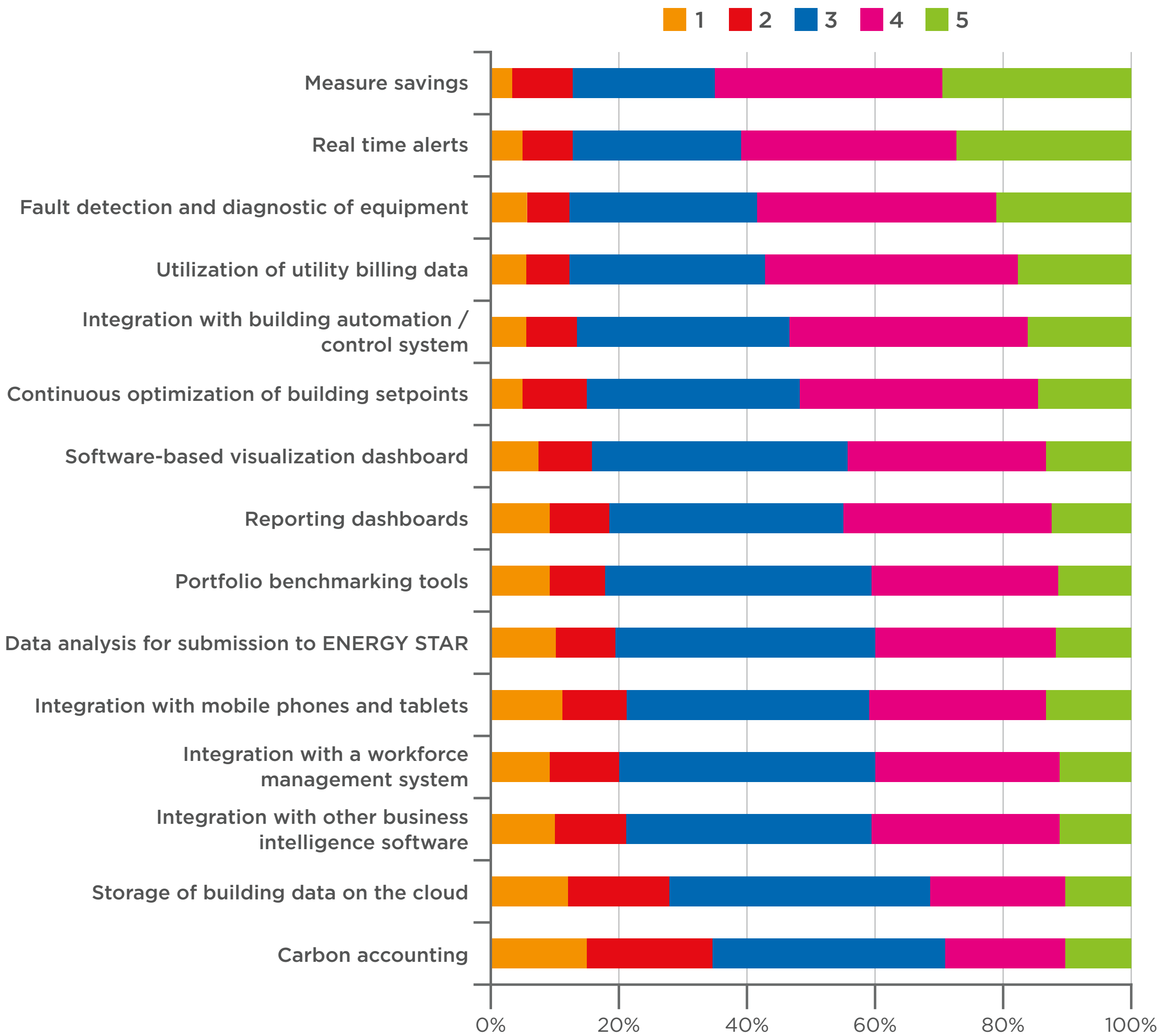
Chart 5.6 On a scale of 1 to 5, where 1 is not concerned at all and 5 is extremely concerned, how concerned are you about the following issues as it relates to data collected in your building? (n=400)



(Source: Navigant Research)

When asked to rate different possible features of a BEMS, respondents rated the ability to measure savings and receive real-time results the highest. The ability of a system to provide FDD was rated third highest by importance. But, when respondents were asked to assign a dollar value to what they thought features should cost, FDD was rated the most valuable.

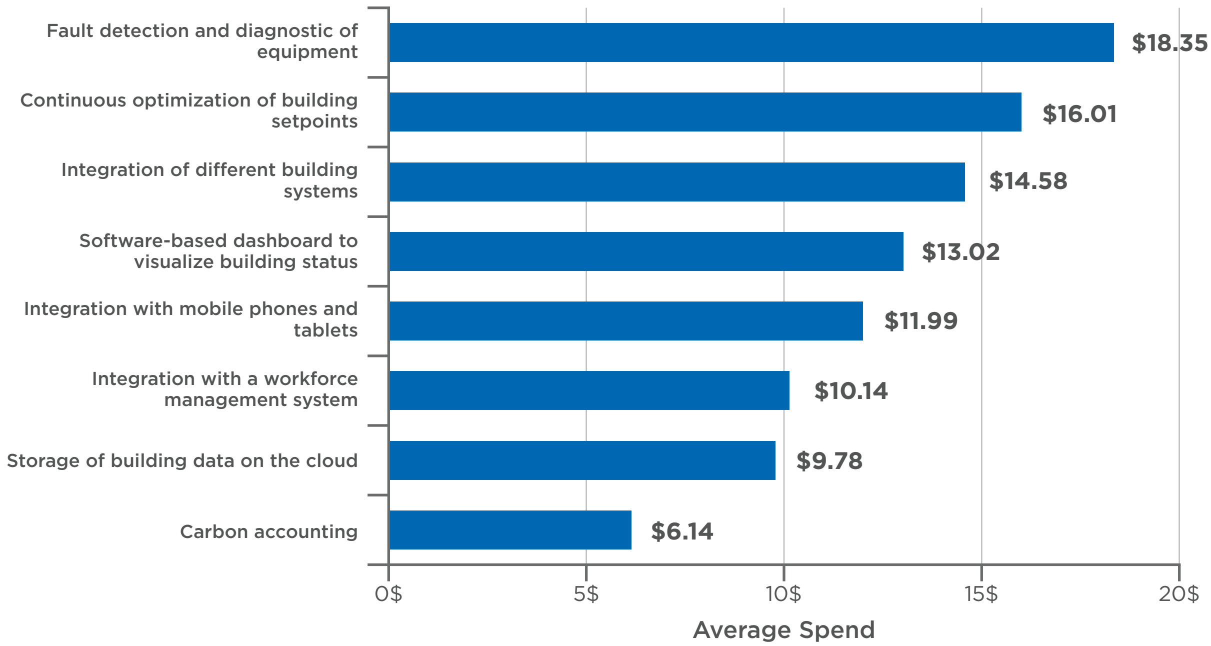
Chart 5.7 Please rank the following design characteristics or functionality of an energy management system on a scale of 1 to 5 where 1 is not at all valuable and 5 is extremely valuable. (n=400)



(Source: Navigant Research)

Storage of building data on the cloud and carbon accounting were rated the lowest in terms of importance and value. Respondents rated integration with a workforce management service similarly.

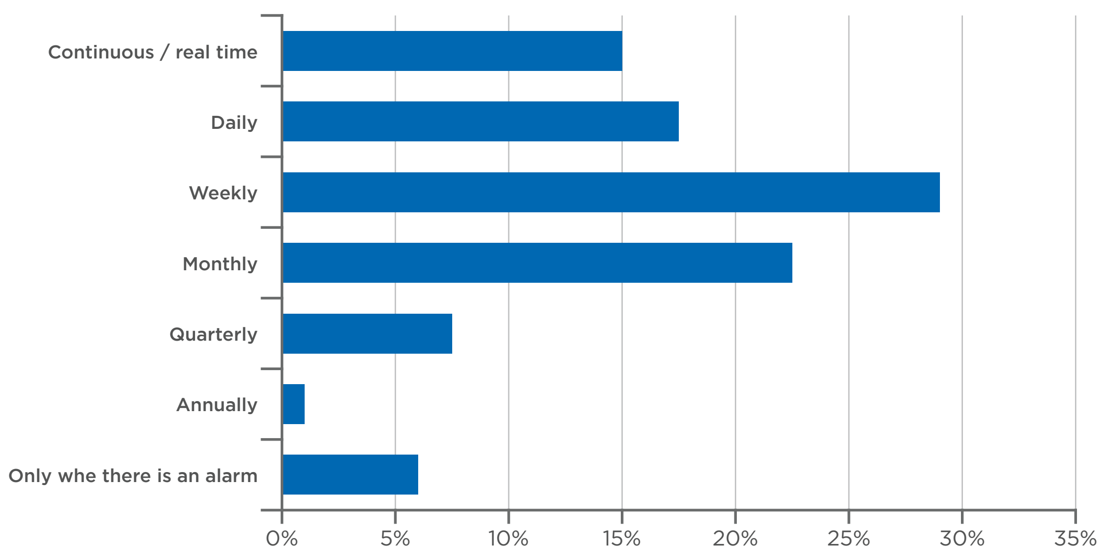
Chart 5.8 If you had $100 to spend on this energy management system, how much would you spend on each individual feature? (n=400)



(Source: Navigant Research)

A plurality of respondents (29.3%) would like reports from an energy management system weekly. However, 15.0% would like continuous reports. Combined, nearly two-thirds of respondents preferred weekly, daily, or continuous reports.

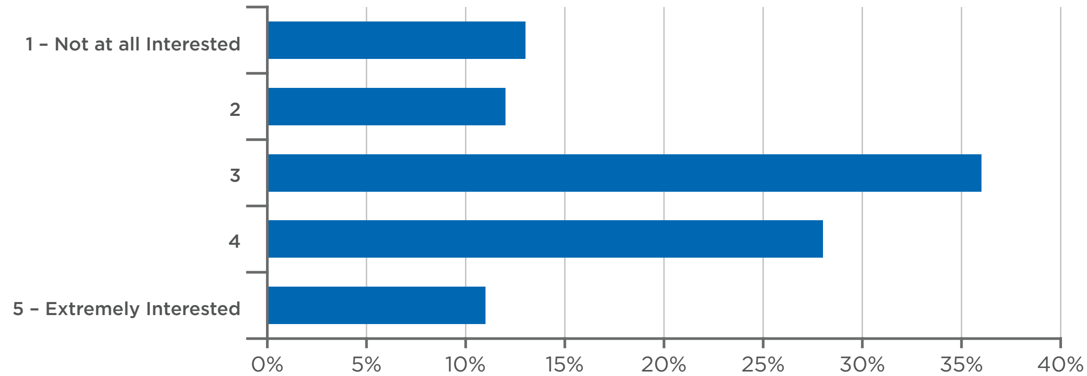
Chart 5.9 How often would you like this energy management system to provide reports? (n=400)



(Source: Navigant Research)

Overall, interest in energy management systems is high. More respondents indicated being interested than uninterested, with an average rating of 3.5 out of 5.

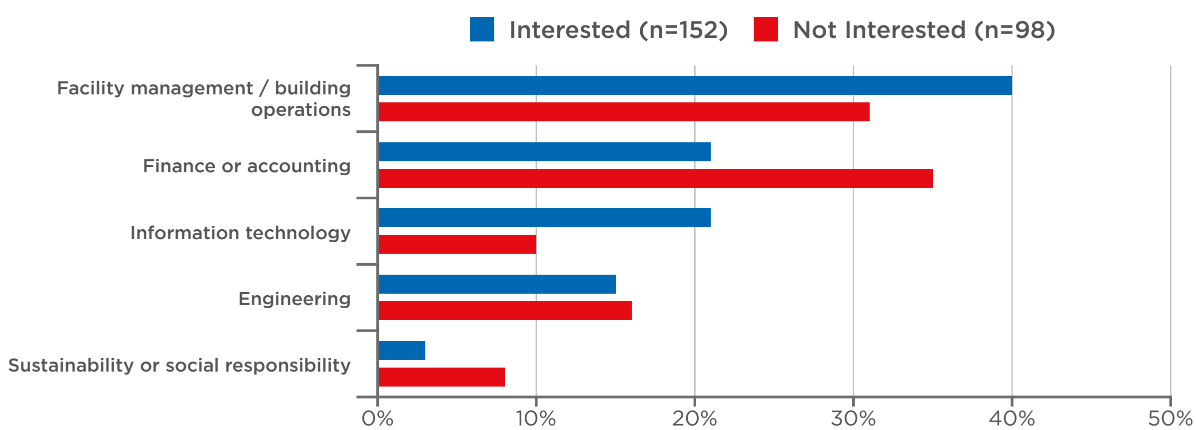
Chart 5.10 On a scale of 1 to 5 where 1 is not at all interested and 5 is extremely interested, how interested would you be in installing this system in your building? (n=400)



(Source: Navigant Research)

When respondents are divided into two groups based on their interest level in energy management systems, several differences emerge. The uninterested group is defined as those who selected 1 or 2 out of 5 when asked to rate their interest in installing a BEMS. The interested group is defined as respondents who selected 4 or 5 out of 5. There are significantly more respondents interested in building energy management whose primary job function is facility management/building operations or IT than those who are uninterested. Similarly, respondents whose job function is in finance or accounting are less likely to be interested.

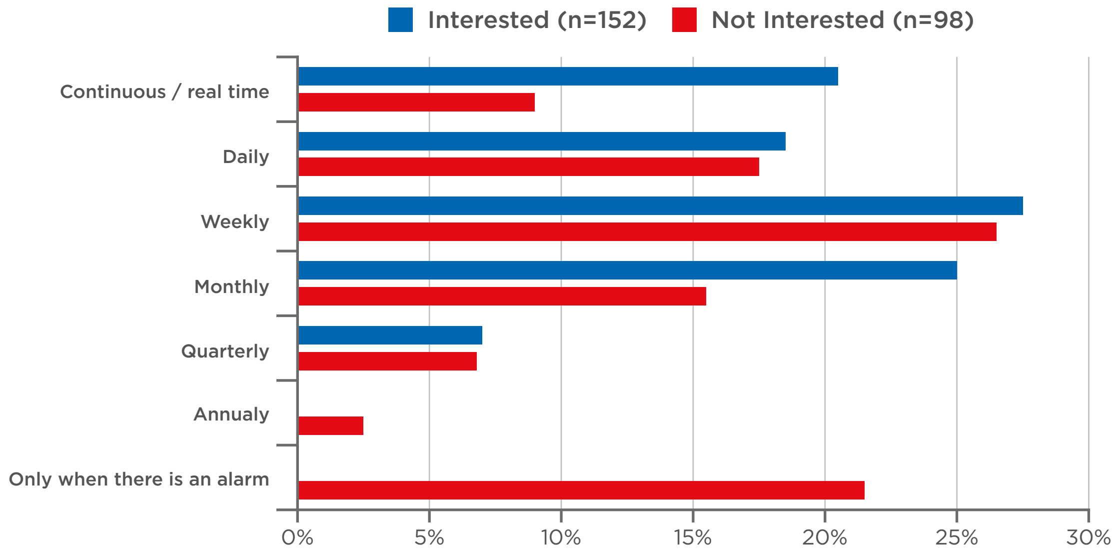
Chart 5.11 Job Function of Respondent by Interest in Energy Management Systems



(Source: Navigant Research)

Respondents who are interested in BEMSs desire a greater frequency in reports from the system. They are significantly more likely to want continuous updates. Respondents uninterested in energy management are more likely to want annual reports or reports only when there is an alarm. This could indicate that respondents who are uninterested in building energy management do not see value in frequent energy optimization.

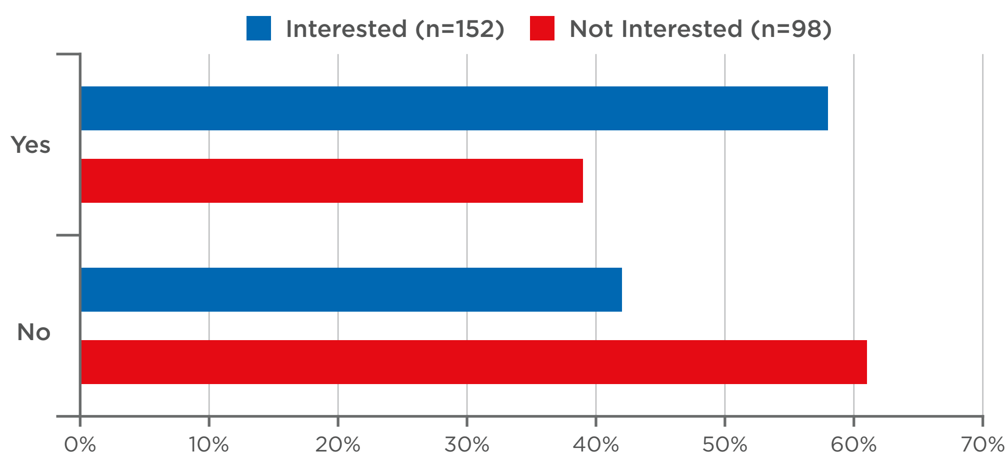
Chart 5.12 Desired Frequency of Energy Management Reports by Interest in Energy Management Systems



(Source: Navigant Research)

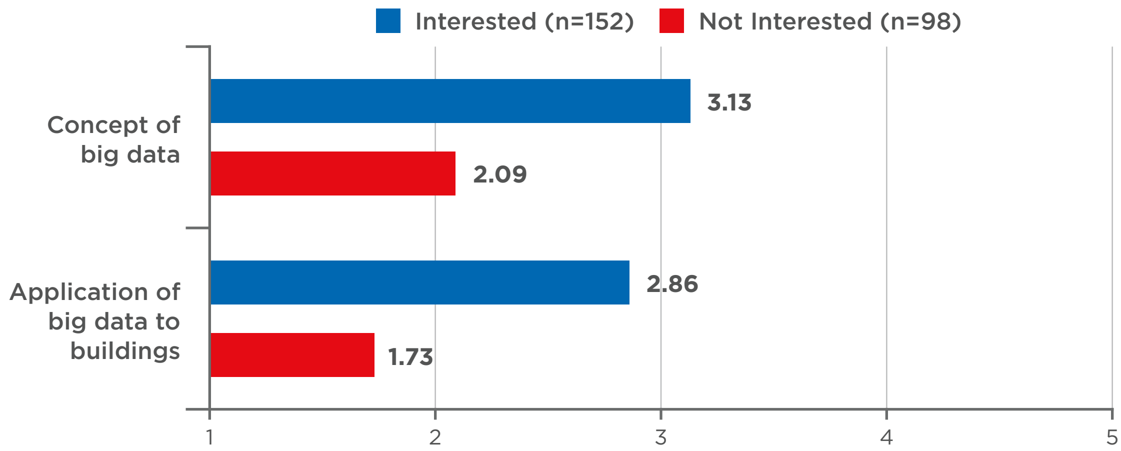
Additionally, respondents who are interested in BEMSs seem to be generally more interested in technology overall. They are significantly more likely to use cloud services already and rate their level of knowledge about big data and the application of big data to buildings significantly higher than uninterested respondents.

Chart 5.13 Use of Cloud Services by Interest in Energy Management Systems



(Source: Navigant Research)

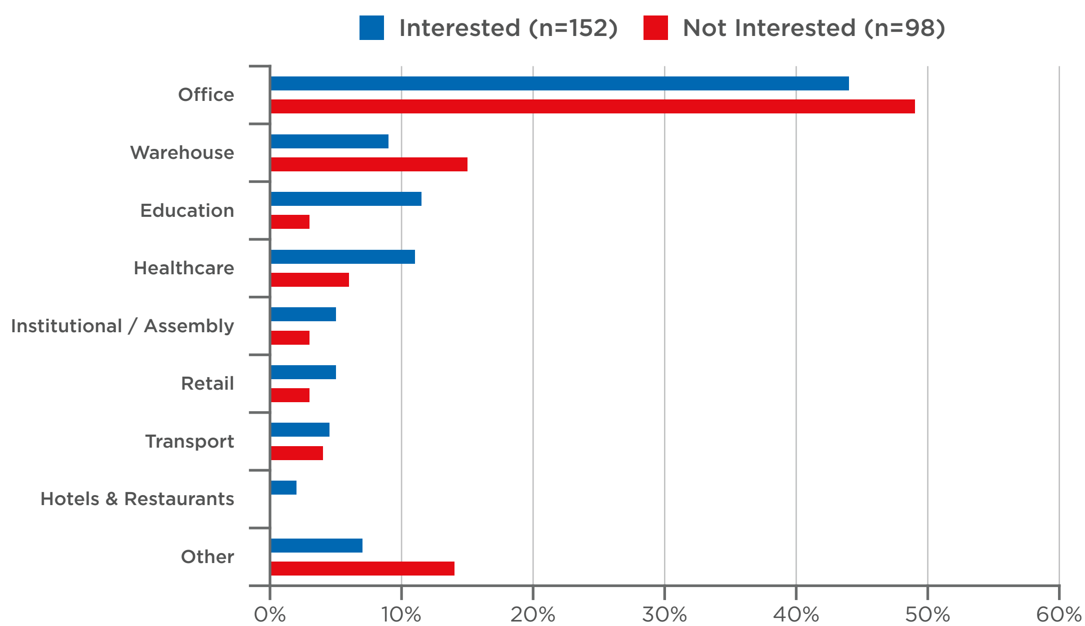
Chart 5.14 Average Rating of Knowledge about Big Data by Interest in Energy Management Systems



(Source: Navigant Research)

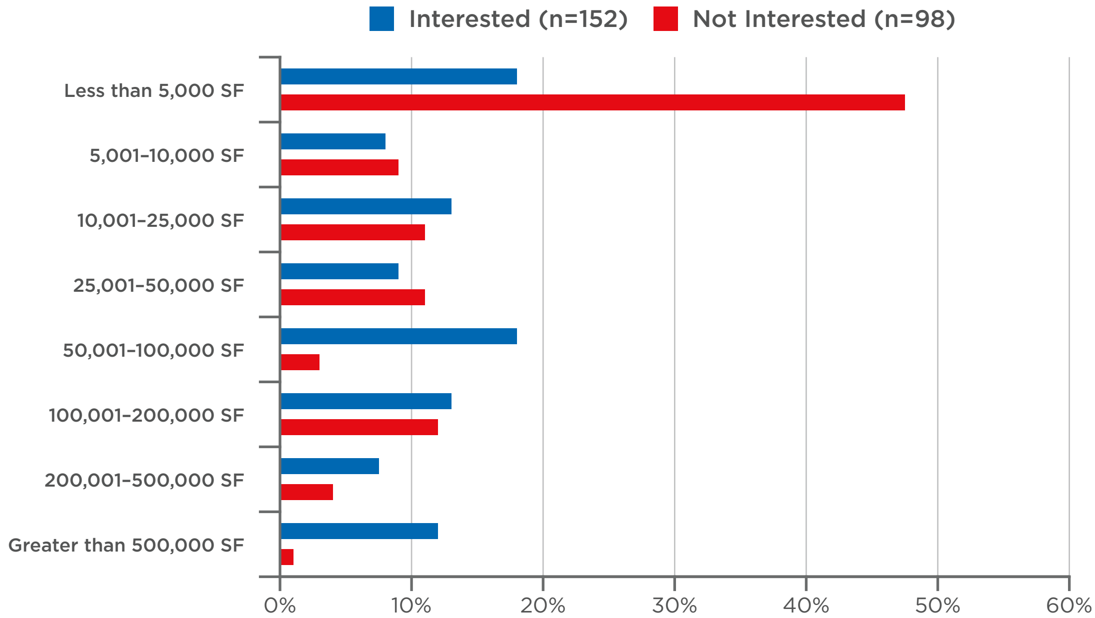
Differences in primary building activity between interested and uninterested respondents are not statistically significant. However, interested respondents are significantly more likely to operate larger buildings than uninterested respondents. Nearly 50% of uninterested respondents operate buildings that are 5,000 SF or less.

Chart 5.15 Primary Building Activity by Interest in Energy Management Systems



(Source: Navigant Research)

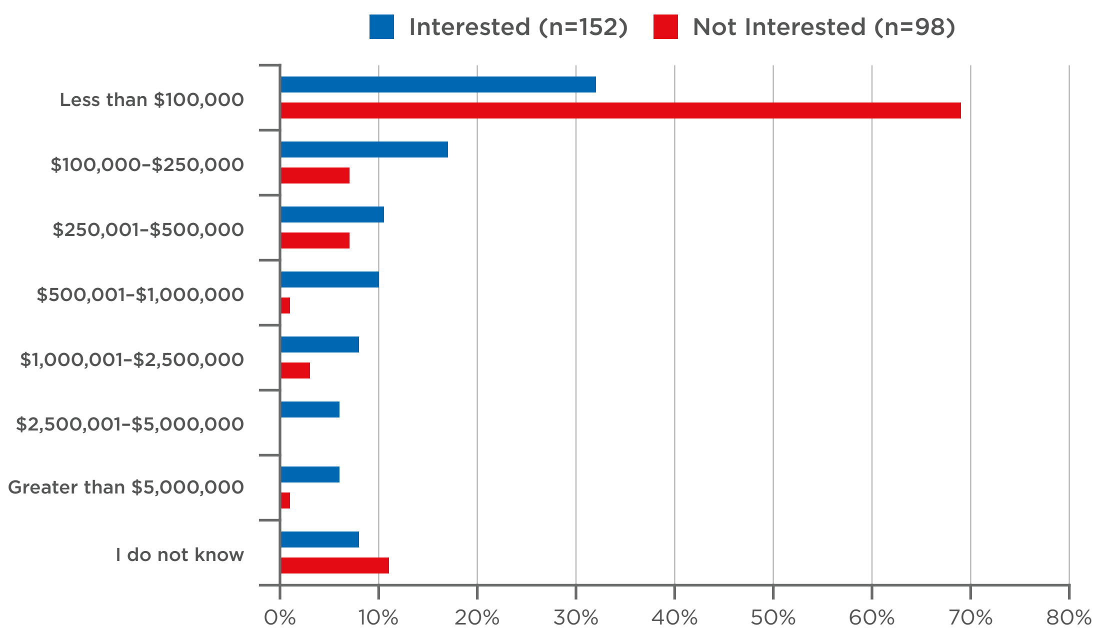
Chart 5.16 Building Size by Interest in Energy Management Systems



(Source: Navigant Research)

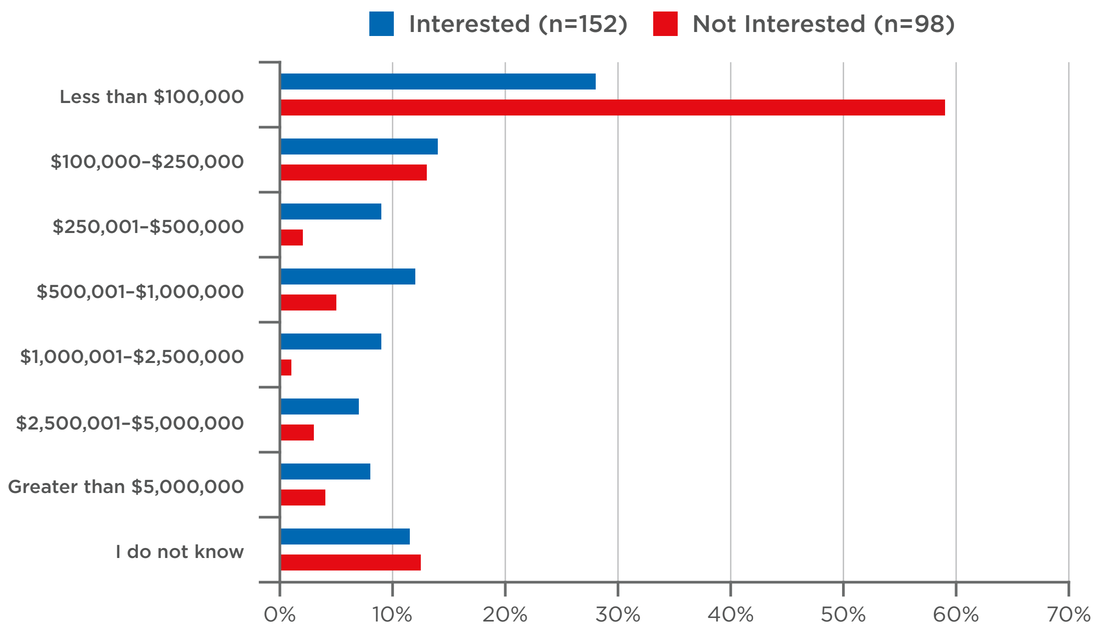
In addition to having larger buildings, respondents who are interested in energy management systems have significantly larger budgets for electricity, operating expenses (OPEX), and capital expenses (CAPEX). One of the underlying drivers in interest could be related to the absolute potential of savings available. A smaller building with lower costs will have a smaller overall potential.

Chart 5.17 Annual Electricity Spending by Interest in Energy Management Systems



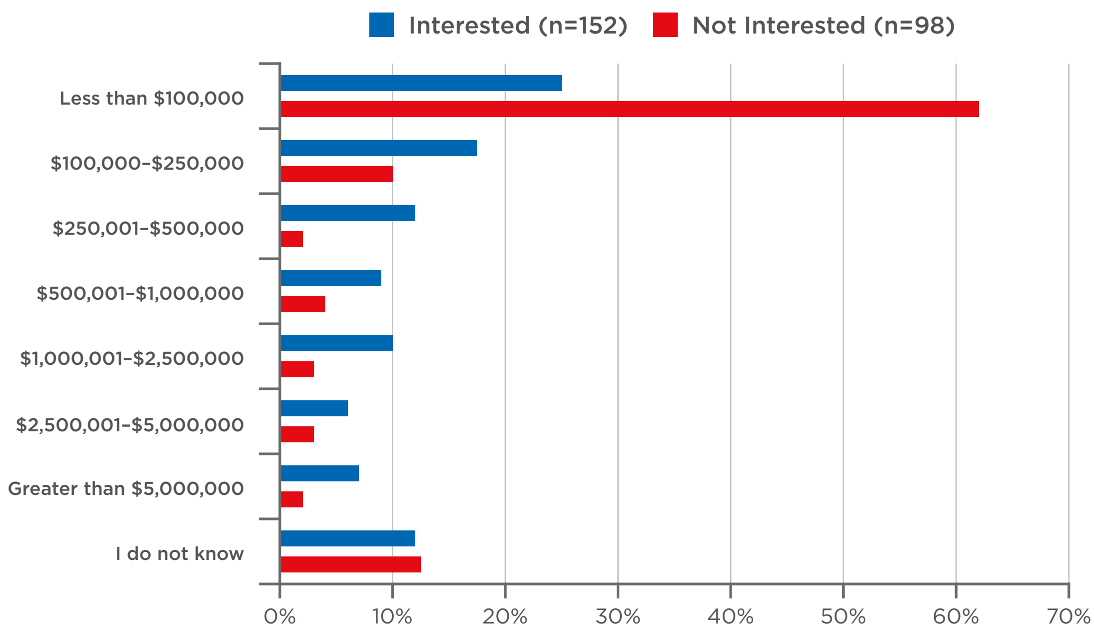
(Source: Navigant Research)

Chart 5.18 Operating Expense Budget by Interest in Energy Management Systems



(Source: Navigant Research)

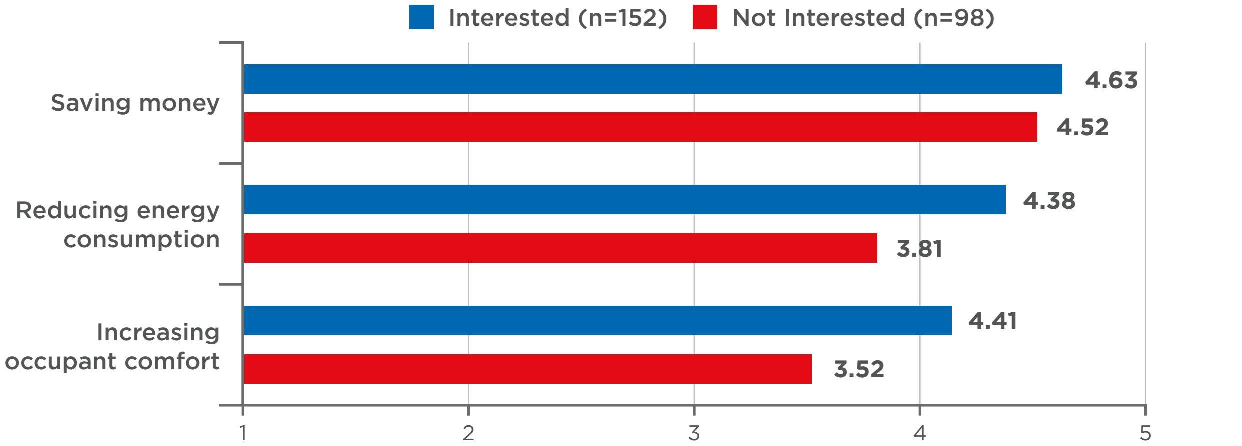
Chart 5.19 Capital Expense Budget by Interest in Energy Management Systems



(Source: Navigant Research)

Respondents who are interested in energy management systems rate the importance of reducing energy consumption and increasing occupant comfort significantly higher than uninterested respondents. Overall interest could be a reflection of the acknowledgement in the role building automation has in energy consumption and comfort.

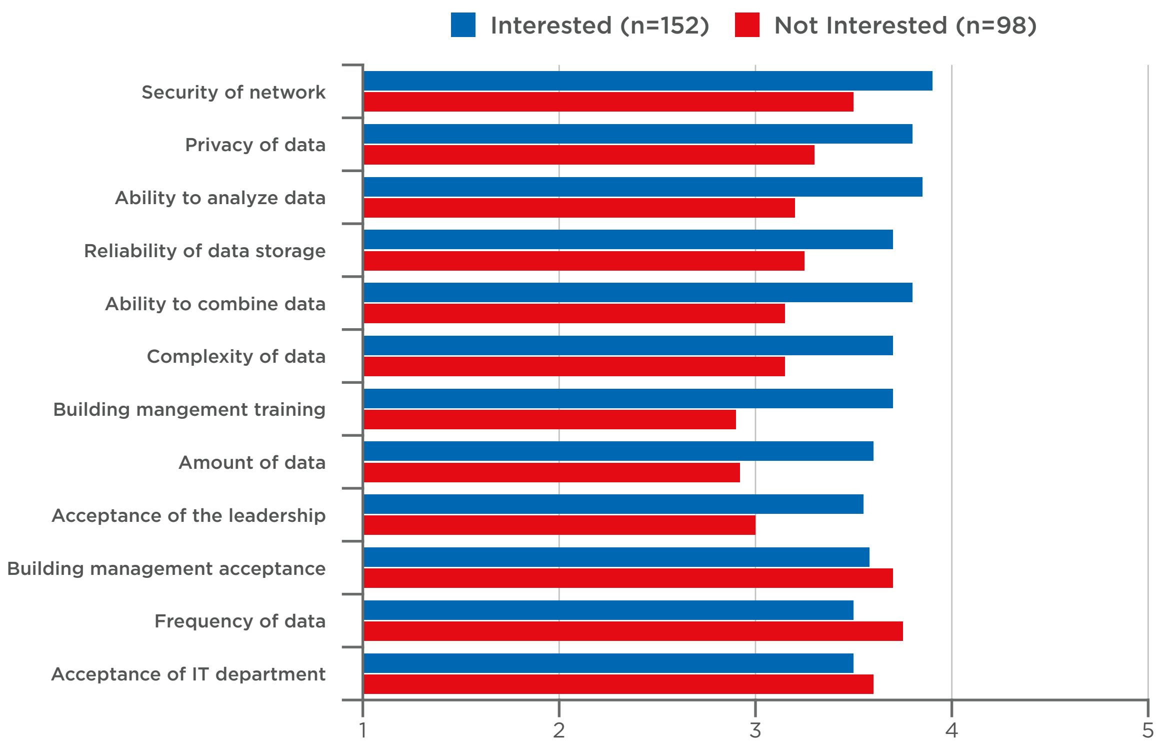
Chart 5.20 Average Rating of Importance of Factors when Making Building Improvements by Interest in Energy Management Systems



(Source: Navigant Research)

Interested respondents are more concerned about every issue relating to collecting data in a building than respondents who are uninterested in energy management. However, this difference is greatest for the training of building management and the acceptance of the IT department.

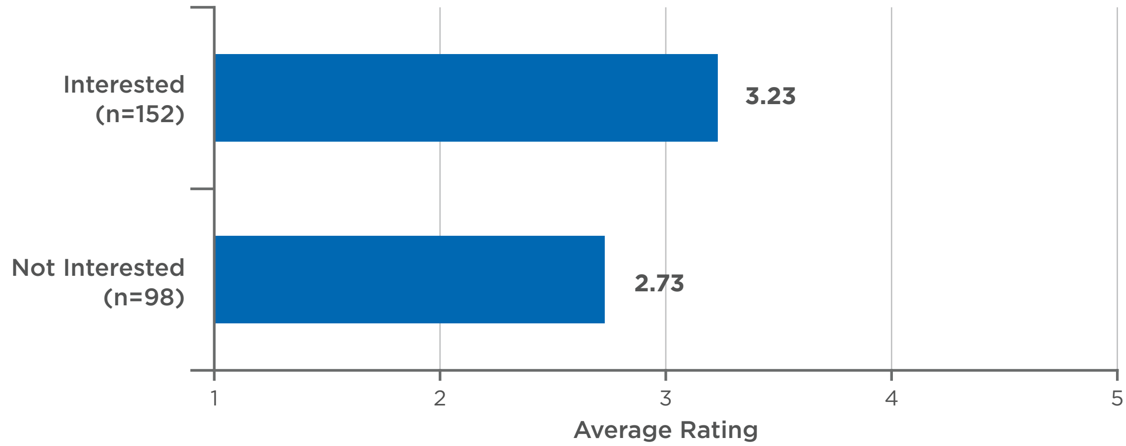
Chart 5.21 Average Concern about Issues Relating to Data Collected in a Building by Interest in Energy Management Systems



(Source: Navigant Research)

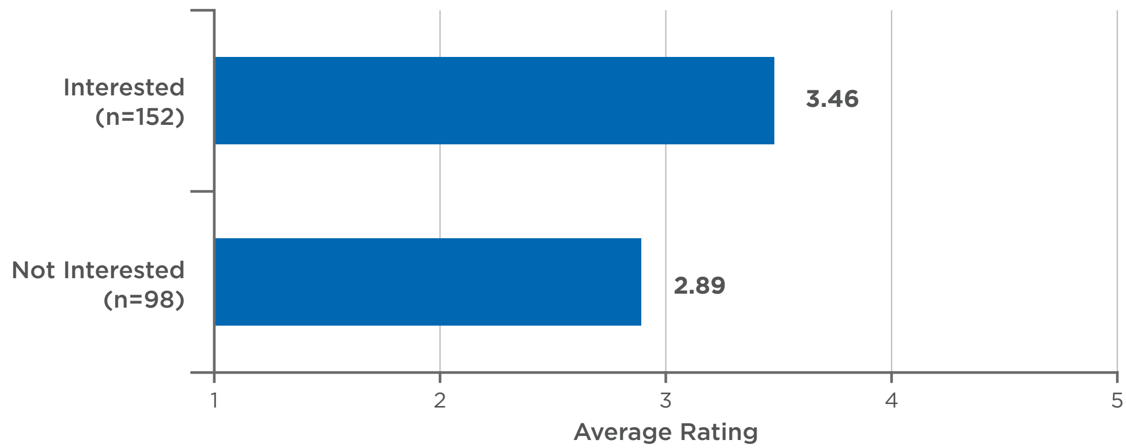
Respondents who are interested in building energy management rate the skills of their building management personnel higher than respondents who are uninterested. Also, interested respondents rate the willingness of their building management personnel to accept new technology higher than those that are uninterested.

Chart 5.22 Average Rating of Data Analysis Skills of Building Management Personnel by Interest in Energy Management Systems



(Source: Navigant Research)

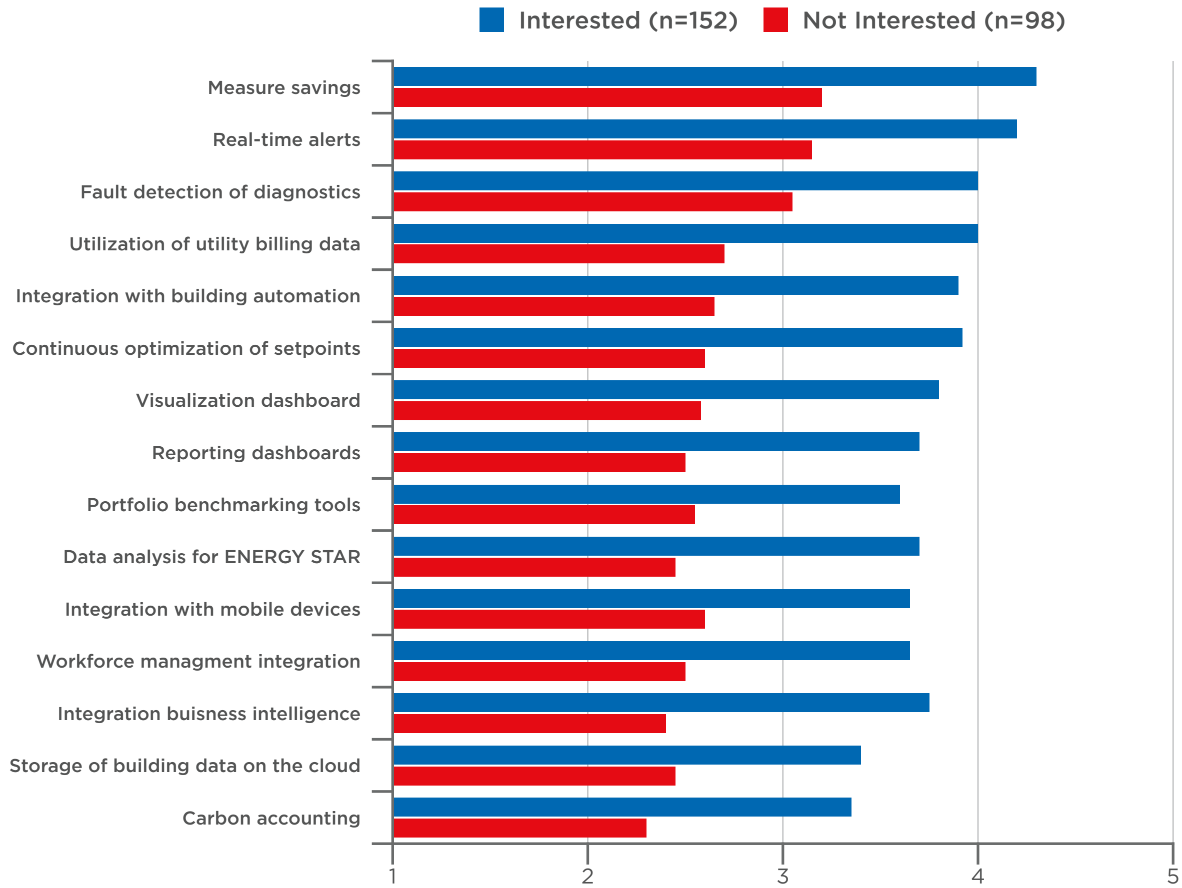
Chart 5.23 Average Rating of Willingness to Accept New Technology by Building Management Personnel by Interest in Energy Management Systems



(Source: Navigant Research)

Additionally, respondents who are interested in building energy management rate each individual functionality of an energy management system higher than uninterested respondents. The greatest difference in interest between the two groups is for integration with business intelligence and the continuous optimization of setpoints.

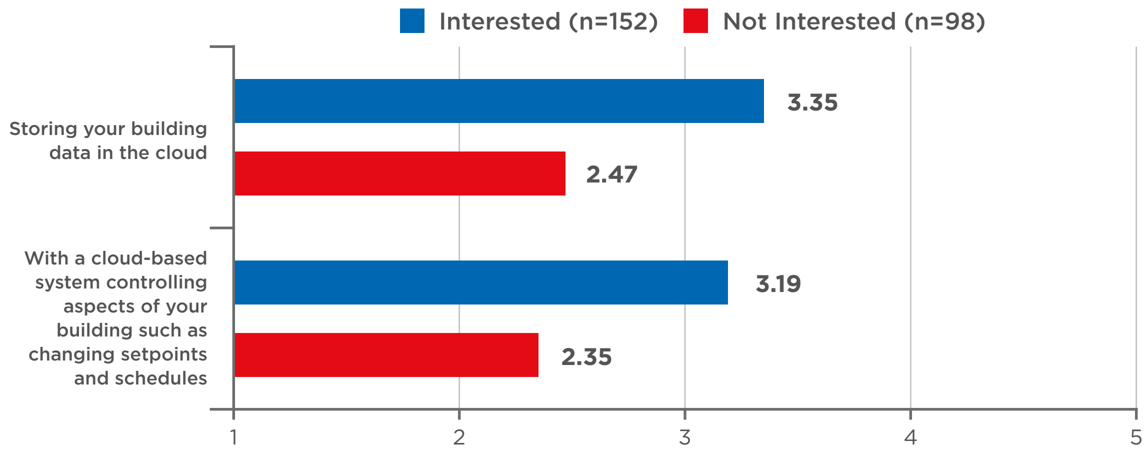
Chart 5.24 Average Ranking of Design Characteristics or Functionality of Energy Management Systems by Interest in Energy Management Systems



(Source: Navigant Research)

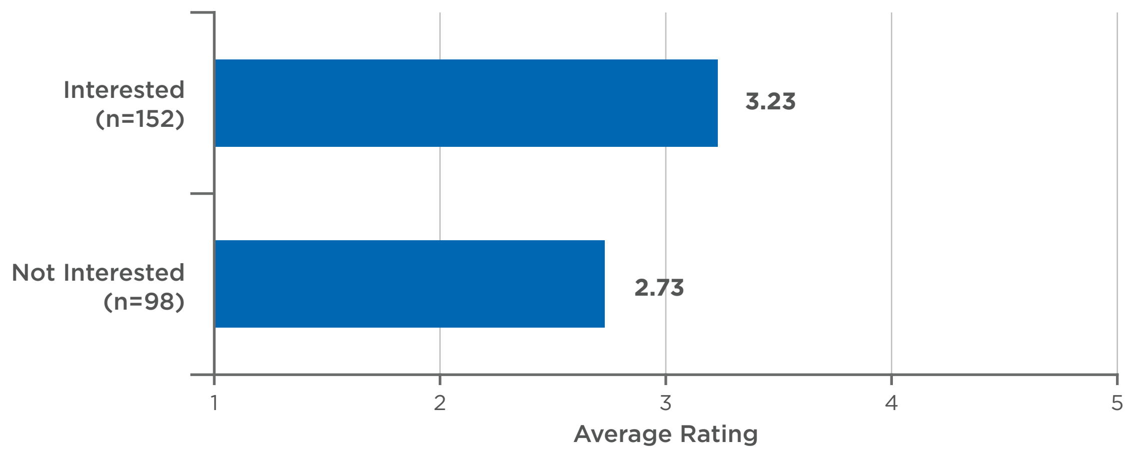
Respondents who are interested in energy management systems are more comfortable storing building data in the cloud and are more comfortable allowing a cloud-based system to control aspects of their building. Despite being more concerned with data security and data privacy than uninterested respondents, interested respondents are more willing to adopt cloud-based services. Additionally, interested respondents are more interested in sharing their building data with other buildings to provide analytics.

Chart 5.25 Average Comfort Rating for Cloud Services by Interest in Energy Management Systems



(Source: Navigant Research)

Chart 5.26 Average Interest in Combining Data with Data from Other Buildings to Provide Analytics by Interest in Energy Management Systems



(Source: Navigant Research)

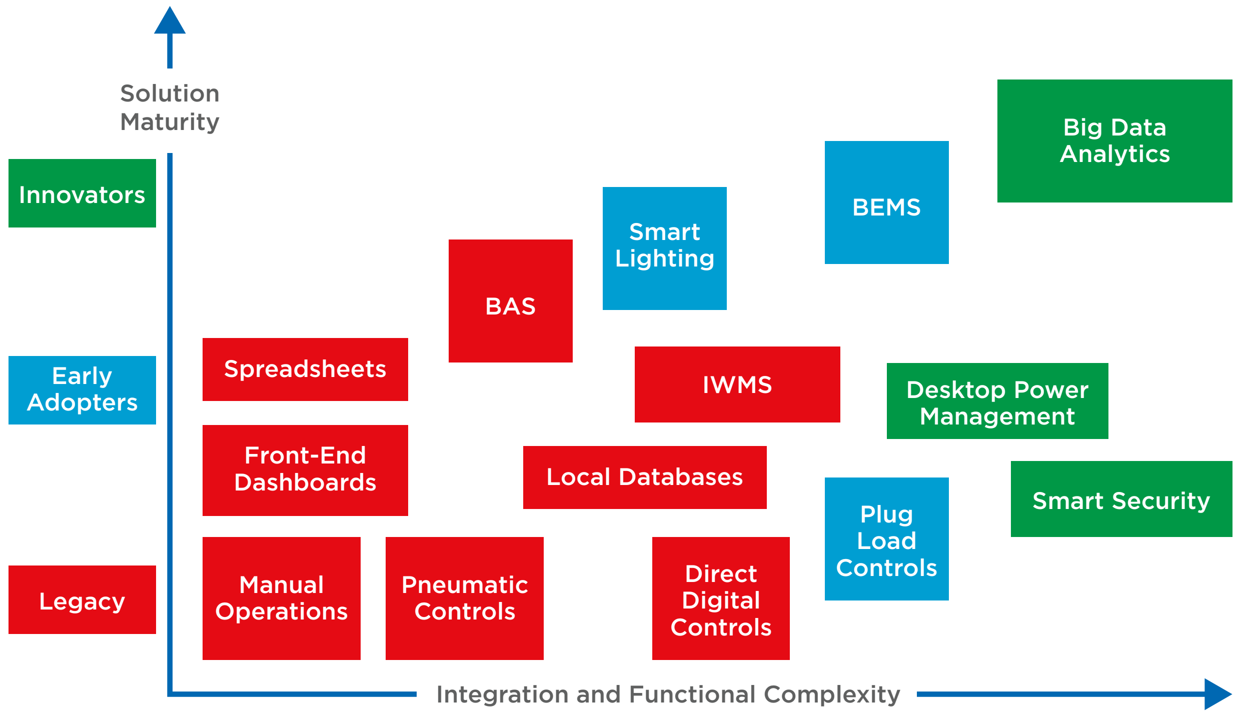
SECTION 8

BIG DATA SOLUTIONS

8.1 OVERVIEW

Big data in intelligent buildings represents a pinnacle in energy and operational management. These solutions provide comprehensive and strategic decision-making support with automated system optimization through the integration of energy management and business intelligence tools. There is a wide variety of technology designed for energy, operational, and business management that has achieved different levels of market penetration. The array of tools being used has implications for how vendors can approach potential customers for big data solutions. As illustrated in Figure 6.1 there are many tools customers use to tackle their most critical energy and operational challenges. It is important to recognize that some legacy tools such as homegrown spreadsheets or traditional building controls systems will continue to generate business value and fulfill the needs of some customer segments. In fact, in today's market, there are substantial opportunities to leverage data that is generated by legacy systems, but these opportunities are underutilized. At the same time, there are new solutions gaining market penetration by early adopters. Understanding the value proposition of these new technology offerings can provide insight into the opportunity for big data in intelligent buildings. Vendors will need to identify specific suitable customer segments and market conditions in order to promote big data in intelligent buildings.

Figure 8-1 Evolving Landscape of Business Intelligence Tools



(Source: Navigant Research)

Legacy systems may include internally developed spreadsheets and databases or third-party software solutions, but fundamentally these solutions address a specific business need and often support a siloed team or business unit. There are also new solutions entering the market that represent a shift in customer demands and reflect a technology response. Innovative energy management solutions provide a straightforward example of the next-generation tools beginning to gain traction in some customer segments. These new solutions begin to integrate across building systems, enhance automation and control technologies, and support more strategic management decisions. These technologies are gaining market share with early adopters but still fall short of the full integration and capacities of big data. In terms of market maturity, only innovators are adopting true big data solutions. Deeper assessment of what drives these innovators to utilize big data and how they perceive the business value will help set the stage for greater adoption in the longer term.

8.2 SECTOR- AND ENTRY-POINT SOLUTIONS AND PATHWAYS

Big data solutions have the potential to generate significant financial and business benefits for the intelligent buildings marketplace, and, in this phase of innovation, the retail and enterprise/office segments are best suited to transition into early adoption. There are demonstrations of big data solutions supporting corporate strategies targeting sustainability, efficiency, and, most importantly, improvements to the bottom line.

8.2.1 Retail

The retail segment is positioned to utilize big data solutions because of the industry's maturity in acceptance and utilization of big data in other avenues of its business including strategic marketing plans and sales initiatives. There is now the opportunity to bring the familiarity of big data into retail facilities' management. Major big box retailers are leading the way in bringing intelligence to facilities management and provide demonstrations of the opportunities for big data in the segment.

Kohl's department stores have participated in the U.S. Department of Energy's (DOE's) Better Buildings Challenge and partnered with the U.S. Environmental Protection Agency (EPA) to showcase the company's commitment to sustainability and energy efficiency. The retail chain has invested in an enterprise energy management system that optimizes the interior and exterior lighting and heating and cooling across 800 of its retail stores since 2009. In California, Kohl's has been participating in ADR programs since 2007. Kohl's enterprise intelligent energy management system is the technology enabler for the company's energy efficiency strategy. As retailers realize the benefits of centralized energy and operations management strategies, there is an increasing opportunity for big data solutions to gain market adoption.

When retailers invest in centralized big data solutions there is the opportunity to leverage weather data, utility price signals, equipment operational information, and occupancy data to fine-tune operations for the optimal customer experience while generating significant economic savings and sustainability improvements.

8.2.2 Enterprise/Office

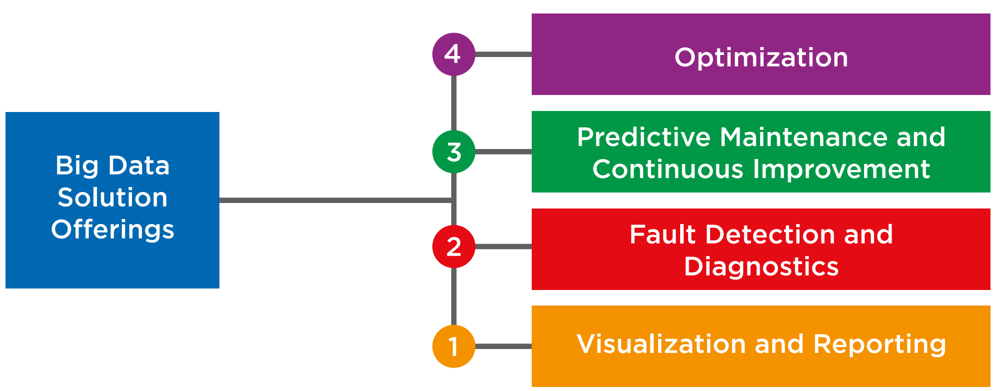
The split incentive has long been the hurdle to investment in intelligent building systems for building owners with leased space. Major commercial real estate companies are now demonstrating a significant shift in conventional wisdom through investments in enterprise energy management systems that, in certain cases, are on a clear path toward leveraging big data.

The enterprise/office segment is a strong target for big data because of the growing interest in energy management and the adoption of intelligent building technologies. The opportunity for big data in the office segment, to be clear, resides among office portfolios, also thought of as enterprise facility management. Executives from commercial and corporate real estate realize the opportunity to improve their company's bottom lines when there is optimal utilization of space, efficiency in deploying centralized O&M resources, strategic decision-making around energy procurement, and integrated business intelligence and energy management systems. Furthermore, large enterprise buildings/offices have the inherent benefit of large energy spend, which helps shape the investment profile for big data solutions.

8.3 SOLUTION OFFERINGS

Characterizing big data solutions for intelligent buildings by offering type helps provide a framework for assessing technology maturity, integration complexity, and the value proposition for different customer segments. There is a wide array of big data solutions in the market, but Figure 6.2 illustrates the four offering categories that are applicable to the intelligent buildings market.

Figure 8-2 Big Data Solution Offerings for Intelligent Buildings

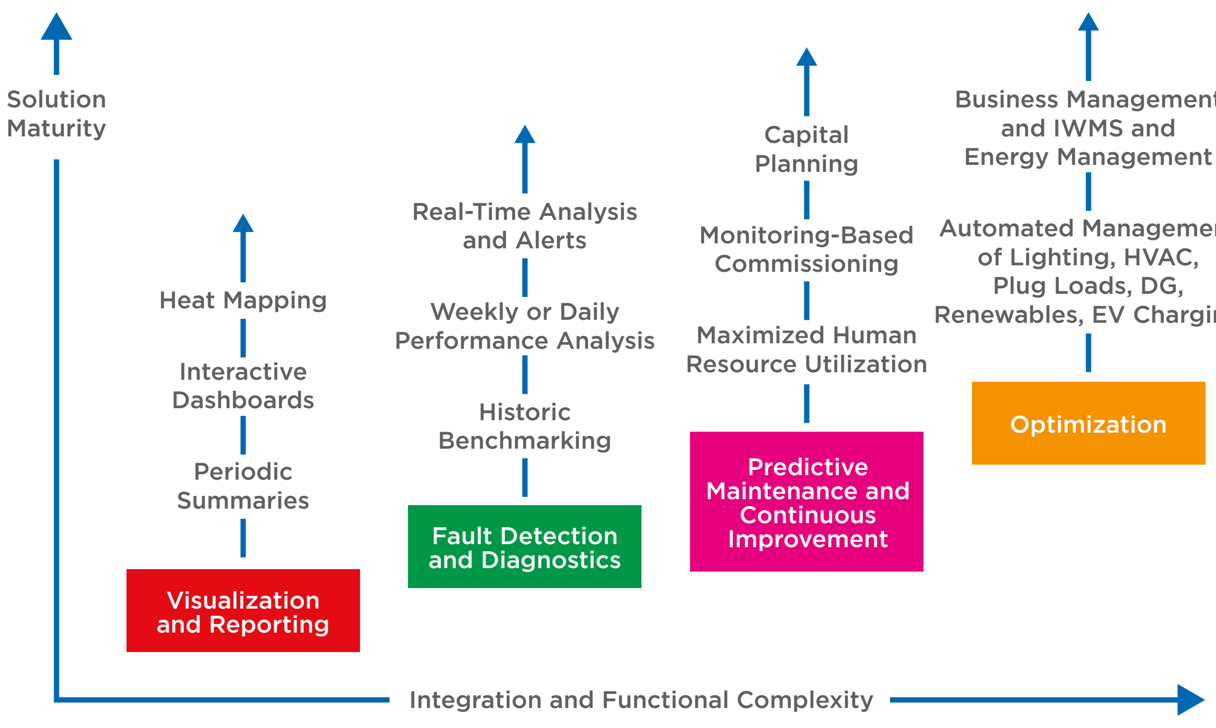


(Source: Navigant Research)

New solution offerings can be assessed with the same framework presented in Figure 6.2 as a kind of investment roadmap toward big data. Customers can deploy solutions from the four big data offerings categories, and each may vary in terms of integration complexity and technology design.

As described Section 6.1, building owners and business executives are utilizing a mix of legacy tools and new intelligent building solutions that fall under each of the four offerings categories; however, new big data solution offerings can provide more holistic insight, which is unmatched by previous versions of the offerings. Figure 6.3 illustrates how solutions in each of the four offering categories fit into the roadmap toward big data. The important takeaway in reviewing the roadmap to big data is that these next-generation offerings provide the most sophisticated analytics to deliver insight and direct action for the greatest economic gain and strategic value from a portfolio or enterprise perspective.

Figure 8-3 Big Data Solutions and the Convergence of Facilities, Business, and Energy Management



(Source: Navigant Research)

8.4 DIFFERING PERSPECTIVES ON THE MARKET

The perspectives on big data in intelligent buildings vary; there is much disagreement around market maturity, some uniform understanding of the big data definition, and even more agreement when it comes to the business case requirements for bringing these new solutions to market, as presented in Figure 6.4.

Figure 8-4 Varying Perspectives on Big Data Solution Offerings

Market Maturity
- End user
  - Growing readiness in retail
  - Enterprise benefits
- Vendor
  - Fragmented market

Big Data Definition
- Technical
  - Details for deployment = integration and infrastructure
- Contextual
  - Unnecessary for customers

Business Case Requirements
- Big data analytics
- Cost-effective deployment
- Enhanced business intelligence: decision-making support tools

(Source: Navigant Research)

First, there is broad disagreement over market maturity. On the demand side, there is little customer understanding and awareness of big data for intelligent buildings. There are innovators taking advantage of new big data solutions, but the market has yet to reach the early adopter stage. Some customer segments, such as retail, may be better positioned to apply big data to intelligent buildings because of a broader organizational understanding of the concept. Big data solutions emerged from the social media marketplace but have gained momentum in retail with firms looking to leverage vast customer data for strategic marketing and sales efforts. On the supply side there is disagreement over the branding and definition of big data for intelligent buildings, which leads to further confusion in the marketplace. Vendors are bringing new technologies and services to market branded as big data "answers" to energy and operational management challenges. Some of these offerings, however, fall short of the integration and functional complexity of true big data solutions. On the other hand, there are vendors introducing innovative offerings that leverage big data but that choose to focus branding on the business value of the technologies and services.

Second, there is some agreement among the vendor community on the technical side of the big data concept – that is, the IT architecture requirements. Big data offerings require new tools to handle unstructured data and the dimensions of data associated with the convergence of disparate systems. In addition, many technology providers have honed in on the defining characteristics discussed in Section 2.2 (volume, velocity, and variety), but there is little agreement on any threshold that shifts a solution from a traditional to intelligent to big data solution. However, the context of this definition is mostly unimportant to building owners. The customers of these solutions are more concerned about the impact of the solutions deployed in their building than how to define the solution.

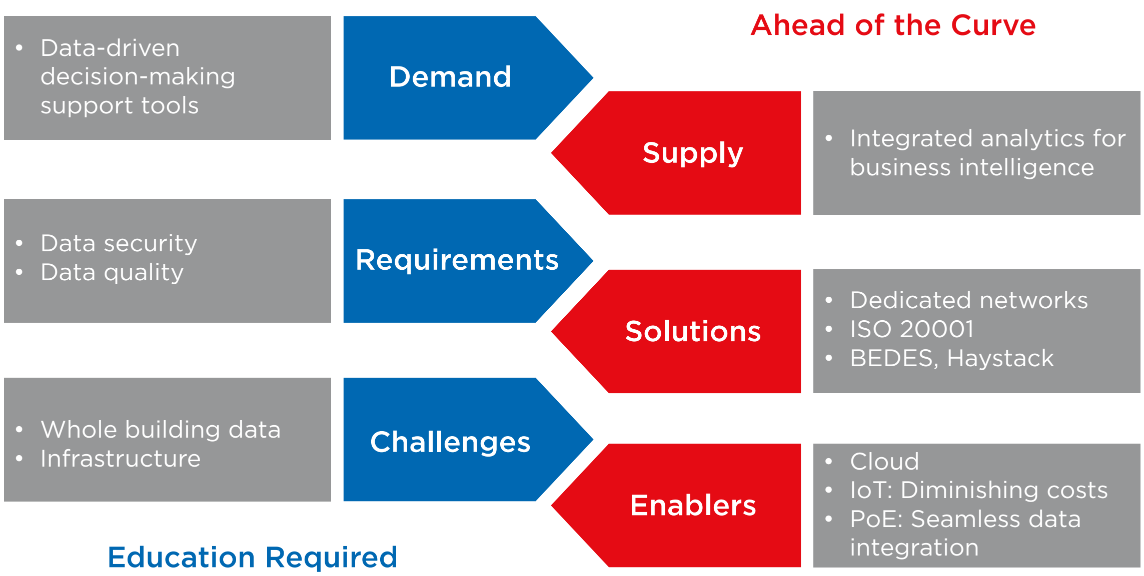
The vendor perceptions on the use of the term big data with their customers are also quite varied. There seems to be alignment between the kind of big data offering and the vendors' perception of the market readiness for the terminology. It is evident from the primary research conducted for this report, for example, that pure-play software providers generally argue the term big data is valuable in branding and customer communications, whereas offerings that have evolved from more traditional building systems may use the term internally but focus branding on the outcomes the systems promote.

Finally, there is more agreement around the business case requirements to support increasing adoption of big data solutions for intelligent buildings. Vendors agree that the value of big data is realized through analytics and the integration of systems for actionable intelligence. It is also generally understood that big data solutions for intelligent buildings must deliver better operations and efficiencies, and, in other words, support customers with better decision-making support tools that generate economic improvements. There is recognition that the C-suite is demanding data-driven insights, and, in the near term, cost-effective solutions will lead the opportunity for investment.

8.4.1 Market Dynamics

The market for big data in intelligent buildings is just emerging and there is a gap in maturity from the perspective of technology development versus customer readiness. Vendors are ahead of the curve and broadly speaking, customers need education on the business value of big data solutions before they will invest. Figure 6.5 summarizes three main areas where the chasm between the vendors and customers is most significant. Big data solution providers have an opportunity to address the key dynamics of their customers with sufficient education and demonstration to help accelerate adoption of their solutions.

Figure 8-5 Market Dynamics for Big Data Solutions in Intelligent Buildings



(Source: Navigant Research)

Executives are demanding data-driven decision support tools to support their biggest business challenges, and big data analytics can bring unprecedented visibility and insight to help elevate energy and operational efficiency.

In addition, when it comes to leveraging information about facilities and operations, customers are demanding highly secure and accurate solutions. The challenge of data security has been met with new standards and procedures that can translate into the intelligent buildings market, but the onus is on the providers to demonstrate their capabilities to interested customers. Furthermore, there are customer segments such as critical power environments (data centers or healthcare), government, and financial that demand more rigorous data security.

The challenge for data quality/accuracy in the intelligent buildings context is illustrated in the building energy management context. Traditional building control systems were defined by proprietary, single-vendor systems. The naming conventions for equipment and algorithms that defined the control strategies aligned with one vendor in the market. As the building management market evolved, demand shifted and now systems are predominately open to integration and support in multivendor models. While the trend toward openness is underway for most customer segments, there remains a challenge of data quality as customers invest in new BEMSs and next-generation support tools.

> Innovative solution providers as well as the U.S. government recognize this challenge and have responded with new initiatives to tackle data accuracy challenges. Project Haystack is a collaborative initiative aimed at tackling the diverse naming conventions, formats, and structures of

building system and device data to enable new applications and support advanced operational efficiency. Similarly, gbXML is an open schema facilitating the transfer of building properties stored in 3D building information models (BIMs) to engineering analysis tools. The DOE is also working to tackle the challenge of building data accuracy with the Building Energy Data Exchange Specification (BEDES). The DOE explains:

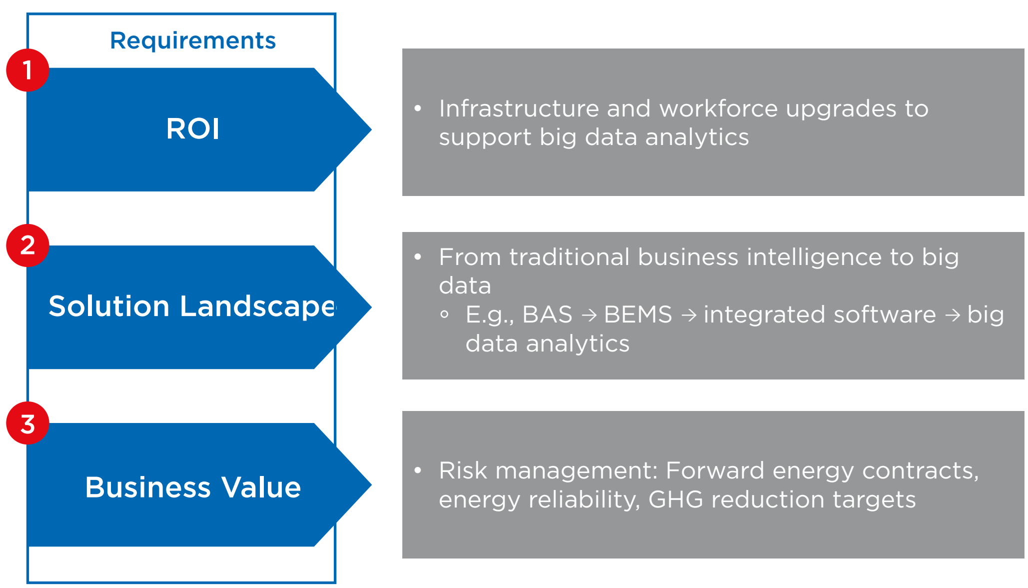
Recent technology, market and policy drivers (smart meters, energy performance disclosure laws, etc.) are resulting in a rapid increase in generation of data about buildings and their energy performance. But this data is still hard to access, aggregate, share, and utilize because it is being housed in many decentralized databases, and in different formats. In other words, the lack of common terms, definitions and exchange protocols is a significant ongoing barrier to realizing the full value of building performance data.

Finally, there are logistical challenges to integrating big data intelligent building solution offerings. In North America, the majority of the building stock is established, and, compared to other regions, there will be less new construction in the near term. The aging facilities that lead the market require infrastructure upgrades to give big data solutions access to the kind of information necessary to deliver the promises of optimization. There are technology trends underway to help facilitate the transition to intelligent building systems and eventually big data solutions. The maturity of cloud computing, the increasing presence of the Internet of Things (IoT) and Power over Ethernet (PoE) devices are each important enablers for the development of big data-driven intelligent buildings. These three forces together help deliver more cost-effective solutions for accessing and analyzing data to deliver the kind of sophisticated business intelligence offered by big data.

8.5 EDUCATION AND TRAINING OF BUILDING OPERATORS AND MANAGERS

Vendors must educate customers on the ROI, differentiation between various solutions in the market, and the business value of big data to support more widespread adoption in the intelligent buildings market. Figure 6.6 highlights current market education requirements.

Figure 8-6 Customer Needs and Vendor Opportunities



(Source: Navigant Research)

It is important to recognize that effective technology solutions are critical, but people play an important role in the investment equation. Vendors will not only need to educate potential customers on the value of hardware and software investments but also the importance of investing in services and procedures to ensure big data solutions deliver the operational and energy improvements intended.

The market for intelligent building systems is crowded and the buzz around big data has left many customers confused. Technology providers and stakeholders will need to focus on educating customers on key differentiators and aligning solution functionality and design with customer needs. There are many facilities that may not be well-suited or prepared for big data offerings, but the key is to hone in on the buildings and organizations that are, such as the retail and office/enterprise segments described in Section 6.2.

Big data offerings deliver benefits beyond the efficiencies within the walls of a single facility. Vendors will benefit from educating customers on the benefits of more strategic and holistic operational and business management across organizations. Big data offerings are positioned to help customers manage the economic risk that can manifest through new regulations, corporate commitments, or limitations on energy reliability and resiliency. Well-educated customers will be better prepared to invest in big data solutions that help manage their biggest corporate financial risks.

8.6 VALUE PROPOSITIONS FOR BIG DATA ADOPTION

The economic impact of big data solutions for intelligent buildings is the paramount concern of potential customers in the marketplace. Big data solutions in each of the four offering categories (detailed in Section 3.7) will only gain market penetration if the vendors can effectively communicate the financial savings or new revenue opportunities associated with the investment. Figure 6.7 summarizes the key benefits of each offering category as well as specific benefits for two key customer segments: enterprise/office and retail.

Figure 8-7 Customer Value Propositions for Big Data Solution Offerings

	Visualization and reporting	Fault Detection and Diagnosis	Predictive Maintenance and Continuous Improvement	Optimization
Key Benefits for the End User	• Economic metrics on efficiencies • Benchmarking • Customized data presentment	• OPEX savings • Prioritized fault management • Time-saving equipment management	• Capital planning • Efficient utilization of O&M human resources • Eliminate building drift	• Economic risk management • Sustainability / GHG improvements • Integrated energy and business strategies
Office / Enterprise	• Enhanced portfolio visibility for the C-suite	• Enhanced tenant comfort and retention	• Increased asset value of intelligent buildings	• CSR demonstration • Space utilization
Retail	• Comparative OPEX	• Customer comfort	• Reduced maintenance services costs	• Customer movement • Branding

(Source: Navigant Research)

The economic benefits of big data begin with the savings associated with energy efficiency but expand to savings from streamlining O&M, more strategic capital planning, and space utilization. There is an overarching benefit of risk management inherent in big data as well. Big data solutions will help customers plan for facility improvements, monitor ROI of investments, and manage the environmental impact of their operations to hedge potential risks associated with regulatory compliance or corporate commitments.

In the enterprise/office segment big data gives executive decision makers insight into operations that lead to continued occupancy and tenant satisfaction. Increasingly, office spaces are evolving to reflect tenant demands for not only comfort but also sustainability and energy efficient spaces. High-profile commercial real estate firms are investing in intelligent building technologies to promote new services and, in some cases, even utilize big data solutions to manage large portfolios.

In the retail segment the business case for big data centers relies on executive insight into operations to optimize the customer experience but also on the opportunity to leverage new cost savings from optimized O&M. The enterprise view of retail chain management can help executives prioritize investment, benchmark store performance, and provide new data for sustainability reporting.

8.7 VALUE PROPOSITIONS FOR VENDORS

This landmark research also explored the value proposition for vendors exploring the opportunity to offer new big data solutions in the intelligent buildings marketplace. In general, the benefits and challenges align with the market dynamics explored in Sections 6.1 to 6.5 – there is a chasm to be crossed between technology and customer maturity.

Figure 8-8 SWOT Assessment of Big Data Market Opportunity for Vendors

	Helpful	Harmful
Internal	**Strengths** • Technology maturity: Lessons from social media, retail big data • Integration capabilities	**Weaknesses** • Ability to communicate the people piece for end users • Ability to differentiate
External	**Opportunities** • Pilots and demonstrations in big retail, CRE / enterprise office • Partnerships to gain market presence and educate end users	**Threats** • Data quality: e.g., legacy BAS naming, proprietary tools, utility billing data inaccuracies • Customer lack of understanding and awareness

(Source: Navigant Research)

There is an expectation that big data solutions will have inclusive offerings that may differ in maturity but span all four categories: reporting and visualization, FDD, predictive maintenance and continuous improvement, and optimization.

8.8 INNOVATIVE BEST PRACTICES

The market for big data in intelligent buildings is nascent, and widespread penetration of solutions across the building stock in North America is not a near-term reality. In 2015, only a select group of innovative customers will invest in big data for intelligent buildings. Despite the challenges for vendors in the near term, there are examples of best practices that are engaging innovative customers and proving the business value of big data.

The interest in developing a robust market for big data in intelligent buildings stems from the fact that facilities and portfolios are data-rich environments. As they become more instrumented and systems become more integrated, the opportunity for big data will continue to grow. New solutions will help building owners and executive leadership gain actionable insight from structured and unstructured data with big data analytics. These tools will help decision makers visualize, understand, and manage their business operations with a holistic strategy.

There are some common themes in the go-to-market strategies and offering designs for some of the emerging energy management solutions that are on the mature end of the spectrum, even those on the path toward big data. As more vendors look to tap into the business case for big data in the intelligent building context, it is worth considering these two suggestions:

- **Start with energy**: The showcase smart campuses and portfolios have been successful demonstrations of big data because they have engaged executive leadership with optimization strategies that generate straightforward and quantifiable savings. Energy efficiency is a standard metric for intelligent buildings and developing an investment and integration strategy that starts with a focus on the biggest energy consumption assets has proven successful. These smart campuses and portfolios optimize HVAC operations and then integrate lighting, while leveraging big data analytics to measure ROI and deploy strategic management practices.
    - Examples include JLL's IntelliCommand, Microsoft's campus, and the GSA's Smart Buildings.
- **Big data as a service**: The actionable intelligence of big data analytics is the core of the business case for innovative customers. Big data analytics deliver value because of the sophisticated algorithms and machine learning, but the services will help transform how facilities and businesses operate. The vendors gaining traction in the market are selling their offerings in the "as a service" model that has led the technology landscape for other IT solutions.
    - Examples include the Daintree Energy Management System, WiPro's EcoEnergy, and Cisco's Joulex solution.

SECTION 9

TRENDS IN BIG DATA MARKET SOLUTIONS

9.1 FORECAST SUMMARY

The big data solutions for intelligent buildings forecast scope includes the hardware, software, and services that extend the capabilities of current business intelligence tools through the integration of systems such as BEMSs, integrated workforce management systems (IWMSs), utility billing, carbon reporting, and weather applications; the key is delivery of actionable intelligence. The revenue in the forecast does not include the hardware and software to provide building automation functionality; rather it is composed of the additional hardware, software, and services to provide actionable intelligence. As such, the forecast does not include individual control stream analytics – i.e., the controls and frontend systems for a single building system.

The revenue from big data in intelligent buildings in North America will reach US$170.5 million in 2015 and will grow to US$511.7 million by 2020. The software segment of the market – the key to big data analytics and the core enabler for generating business value – will represent 53% of big data in intelligent buildings revenue in 2020.

Enterprise/office and retail are the two largest growth opportunities for big data in intelligent buildings, representing 38% and 19% in 2020 respectively. It is important to note that the big data forecasts for these segments specifically reflect spending on new solutions for facilities and operational management. There is a separate and much larger stake in the retail segment for big data in strategic marketing and sales, but the revenue associated with those solutions is outside the scope of this study.

The revenue associated with hardware within the scope of this study includes new enabling devices such as gateways and wireless sensors but does not include servers and traditional IT hardware.

While software and services are the core of big data solutions for intelligent buildings, hardware is the critical enabler for implementation. Customers are deploying more devices, and new kinds of hardware are expected to penetrate more facilities. The share of the overall revenue forecast tied to hardware, however, is projected to grow at a tempered pace due to the rapidly declining costs of these devices. Similar downward trends in hardware costs are found in adjacent markets such as lighting controls and submetering.

9.2 METHODOLOGY

Navigant Research conducts both primary and secondary research to develop its market forecasts. Navigant Research conducted 34 interviews and 400 online surveys with key industry players and end users in the intelligent buildings marketplace to gather relevant data that shapes the current and future state of the market. Where possible, Navigant Research gathered hard annual revenue data from primary research as an input into the market sizing and forecast. Furthermore, Navigant Research accounted for the influence of other business intelligence systems that will be integrated with BEMSs as the market for big data in intelligent buildings emerges. Primary research data, secondary company information, and other market indicators such as policy and economic trends helped shape the market forecast, considering materials such as:

- Company filings and annual reports.
- Product brochures and specification sheets.
- News articles and analysis on the energy management market.
- Utility sector energy efficiency program evaluations and market characterizations.

To develop an accurate market sizing and forecast, Navigant Research conducted a thorough bottoms-up analysis of the North American intelligent buildings market. Although annual revenue activity is available for only a fraction of the total number of players, Navigant Research made estimates based on information such as number of employees, number and type of customers, square footage under management, and other readily available pieces of data.

9.3 OFFERING TYPES

While the market for big data in intelligent buildings is led by software and services, it also includes relevant hardware required to access equipment and operational data. Navigant Research defines the three offering types as follows:

- Software consists of software as a service (SaaS).
- Services include installation and integration labor as well as professional services and network operations center (NOC)-based services.
- Hardware excludes traditional building control and automation systems, servers, and IT hardware but includes new devices specifically installed for the purpose of big data solution integration.

9.4 CUSTOMER TYPES

Navigant Research segmented the big data market by customer type and provides the big data revenue forecast associated with retail and enterprise/office customer adoption.

Navigant Research determined the segmentation based on vendor information on the profile of their customer base as well as information on the growth rates by segment. Note that while each customer category maps to a common building type (e.g., retail, healthcare, or education), the actual building types in which big data solutions are installed may be diverse – even for a single customer. For example, a retail customer's sites may consist not just of stores but also of distribution centers, administrative headquarters, data centers, and customer service sites. In fact, the ability of a big data solution to normalize energy and business-related data across diverse building types is one of its key strengths in the eyes of customers.

9.4.1 Enterprise/Office

The enterprise/office market consists primarily of professional service organizations with a portfolio of buildings under management. Examples may include financial service organizations (including bank branches), insurance providers, engineering service firms, and others. It also includes companies with a diverse set of facilities that cut across multiple categories, such as pharmaceutical companies (whose facilities include research facilities, manufacturing facilities, and administrative facilities), consumer product manufacturers, etc. Some online retail companies, such as Amazon, fit into this category as well, given that they have a diverse set of facilities and few, if any, brick-and-mortar sales outlets.

For organizations with diverse building portfolios, however, the BEMS is a distinct product from the industrial automation and process management systems as well as supervisory control and data acquisition (SCADA) systems used to manage industrial processes and improve efficiency, as these systems are less focused on enterprise-level energy analysis.

9.4.2 Retail

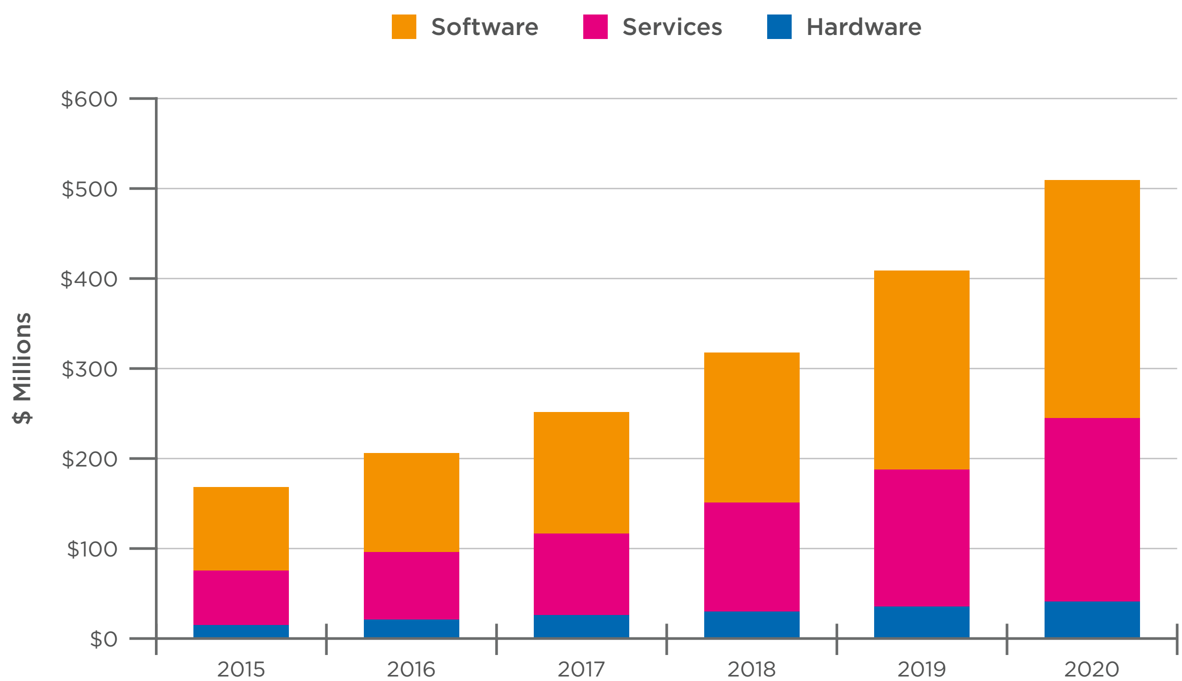
The retail sector consists of firms whose primary focus is selling merchandise at dedicated outlets. These include big box retailers, drug store chains, apparel vendors, hardware supply chains, and others.

9.5 BIG DATA IN INTELLIGENT BUILDINGS FORECAST FOR NORTH AMERICA

The big data in intelligent buildings market in North America is in the beginning stages. Only innovative customers have adopted the solutions entering the market. The market will continue to grow and market penetration will increase to 2020 with a 24.5% compound annual growth rate (CAGR). Adoption will be supported by the economic benefits associated with the energy and operational efficiency generated by big data in intelligent buildings.

The revenue from big data in intelligent buildings in North America will reach US$170.5 million by 2015 and grow to US$511.7 million by 2020. The biggest share of the market is tied to the software, which represents 53% of the market in 2020.

Chart 7.1 Big Data in Intelligent Buildings Revenue by Offering Type, North America: 2015-2020

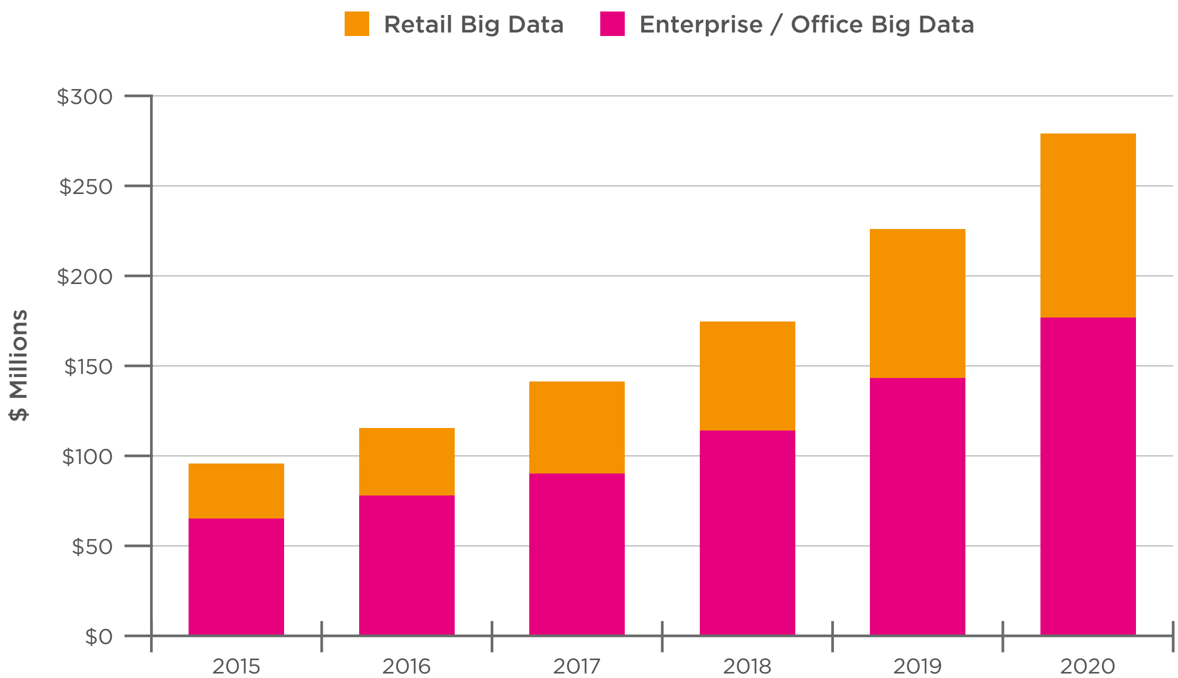


(Source: Navigant Research)

9.6 SECTORS

Revenue associated with big data in intelligent buildings for the enterprise/office and retail segments will see the greatest growth over the next five years. The business dynamics and facilities infrastructure in these two segments will help position the opportunity for big data.

Chart 7.2 Big Data in Intelligent Buildings Revenue by Segment, Select Segments, North America: 2015-2020



(Source: Navigant Research)

SECTION 10

CONCLUSIONS

10.1 OVERVIEW

Big data is a powerful concept, laden with meaning and potential. At its core, big data can be defined as the integration of multiple streams of large and/or complex data, incorporated at multiple temporal frequencies. That integration is followed by analysis of the system of focus and, ultimately, the actions taken by stakeholders of that system. Big data has been hailed as transformative to the scientific, economic, and health domains, among others. What big data means for intelligent building management is not clear. While there is great potential for big data to aid in integrated building management, there are still gaps in the understanding of big data analytics for end-users and customers. In addition, the North American commercial building stock is not technologically prepared for the integration of all that big data has to offer.

Buildings are going through a slow transition from operating with aging analog controls to high-performance machines controlled by algorithms and acting on data from thousands of data points from high-resolution sensors. At the same time, the increased focus on energy and operational cost savings has placed building management at the forefront of high-tech and SaaS investment in recent years. Most new technology deployment in BASs is focusing on single system integration and optimization, though some vendors are beginning to integrate the management of multiple systems. This multi-system integration, as well as the integration of multiple streams of data for single automation systems, is big data in the context of this report.

10.2 CURRENT MARKET FOR BIG DATA IN INTELLIGENT BUILDINGS

Given the advancement of big data in other associated domains like retail customer analysis, facial recognition software, and social media, there is considerable hype and promise about what big data can do for intelligent buildings. This promise includes the integration of data from novel sensors, like video, to the integration of thousands of streams of high-resolution sensor data. The promise of the deployment of these innovations would be massive cost savings and true optimized performance. In the future, some of those innovations may lead to gains in building performance optimization.

In the near term, buildings are at a place where basic data integration and algorithmic deployments can lead to savings and performance increase, but at more modest scales than first believed. This is due to the scale of investment and the behavior of building and facility energy managers. The opportunity for big data solutions in new construction is more apparent, as sensors can be installed during construction and building staff can be trained on delivery of systems. Building portfolios also have the potential to use big data in their overall performance, as many portfolios are composed of similar models of buildings with similar behavioral characteristics. In addition, portfolio managers will be able to take advantage of the multiple hierarchical view of the portfolio's performance through analytics and visualization tools.

10.2.1 Challenges and Recommendations

From both the survey and interviews, it is apparent that the stakeholders across the big data ecosystem have differing perspectives on what big data is and what it means for their business. This is a challenge for those wanting to sell products into this space. What is needed is a series of educational campaigns by vendors alone or as a group that focus on a few sets of intelligent building stakeholders. These campaigns would focus as follows:

- **Building and property managers**: Education on how analytics can aid automation, optimization, and operational performance.
- **Portfolio and property managers**: Define the cloud – this concept is amorphous by nature so it is important to define where, physically, data is being stored. Also, the benefits of onsite data processing versus cloud-based processing and analytics are needed for each solution offering.
- **All stakeholders**: Address the security and privacy concerns associated with building sensors.
- **All stakeholders**: Provide more case studies, reporting the CAPEX and OPEX of solutions, the role and investment needed for site energy or property managers, and a real-time view into cost savings. This last point underscores the natural variable performance of BASs. Buildings respond to occupants and the external environment; addressing how a complex (or expensive) system fares in normal and stressed times is beneficial.

The solution offerings for big data are at different levels of market readiness. Visualization and reporting are used widely in building management, albeit at different levels of sophistication and data integration. This solution offering is an important step in engaging with key stakeholders and preparing them to incorporate more advanced solution offerings. FDD is rapidly standing out as a way for facilities to quickly lower expenses associated with systems not performing to specification or in reducing the number of truck rolls. FDD of multiple systems and the analytics associated with multiple point of system failure will also lead to better performing and potentially safer buildings as rapid views of building system performance can be captured and turned into actionable alters. Predictive maintenance and continuous improvement is the current beachhead in intelligent building big data use cases. By demonstrating its value, building and facility managers would be able to prove that their buildings are performing as designed and be able to justify expenditures on planned maintenance activities. Lastly, true building optimization can help create high-performance buildings that adapt to their environment and occupants in such a way that money is saved and the occupants are unaware of any environmental controls or performance issues that may be occurring.

10.3 THE OPPORTUNITY FOR BIG DATA IN INTELLIGENT BUILDINGS

As is presented in the forecast of big data solutions, there is ample opportunity in providing big data solutions to commercial buildings. The pathway to achieving that revenue includes continued investment and innovation in technology and solutions. It also includes preparing the market, including the occupants, facility managers, and the corporate portfolio managers, for the risks and opportunities that big data provides. Focusing just on the benefits of the big data solution offerings without addressing the challenges could place distrust in those investing millions of dollars and considerable employee time in the solutions. The communication of the benefits and challenges of big data in buildings may also be more robust if the greater intelligent building ecosystem worked as a community to inform the public as to what the commercial space of the future looks like. That is, it looks like a normal commercial building but is cheaper to run, comfortable to be in, and attracts and retains tenants who enjoy their work.

SECTION 11

ACRONYM AND ABBREVIATION LIST

ADR	Automated Demand Response
AHU	Air Handling Unit
AMI	Advanced Metering Infrastructure
BAS	Building Automation System
BEDES	Building Energy Data Exchange Specification
BEMS	Building Energy Management System
BIM	Building Information Model
BMS	Building Management System
CABA	Continental Automated Buildings Association
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expense
CDD	Cooling Degree Day
CENELEC	Comité Européen de Normalisation Électrotechnique
CMMS	Computerized Maintenance Management System
DALI	Digital Addressable Lighting Interface
DOE	Department of Energy (United States)
DR	Demand Response
EHS	European Home Systems
EIB	European Installation Bus
EMIS	Energy Management Information System
EPA	Environmental Protection Agency
EV	Electric Vehicle
FDD	Fault detection and Diagnostics
HDD	Heating Degree Days
HVAC	Heating, Ventilation, and Air Conditioning
IEC	International Electrotechnical Commission
IoT	Internet of Things
IP	Internet Protocol
IWMS	Integrated Workforce Management System
KNX	Konnex
LED	Light-Emitting Diode
LEED	Leadership in Energy and Environmental Design
M&V	Measurement and Verification
MCC	Motor Control Center
MSTP	Master Slave Token Passing
MT&R	Monitoring, Targeting and Reporting
NEMA	National Electrical Manufacturers Association
O&M	Operations and Maintenance
oBIX	Open Building Information eXchange
OPEX	Operating Expense
OSI	Open Systems Interconnection
PLC	Power Line Communications
POE	Post-Occupant Evaluation
PoE	Power over Ethernet
PV	Photovoltaic
R&D	Research and Development
RF	Radio Frequency
ROI	Return on Investment
SaaS	Software as a Service
SCADA	Supervisory Control and Data Acquisition
SDSS	Sloan Digital Sky Survey
SF	Square Feet
TOU	Time-of-Use
VAV	Variable Air Volume

SECTION 12

APPENDIX A: BIG DATA SURVEY QUESTIONNAIRE

1. What country are you located in?

- » United States
- » Canada
- » United Kingdom *Terminate*
- » Australia *Terminate*
- » Other (please specify) _____________ *Terminate*

2. Please select the level of influence you have in purchasing the following products and services for your company or organization:

	I have no influence in the decision to purchase	Someone else at my company makes the decision, but I have input	I make the decision with input from others at my company	I am solely responsible for making the decision	My company does not use this product or service
Building automation systems					
Building energy management systems					
IT hardware					
IT software					
Financial and accounting software					
Customer relationship management software					

Terminate if "Someone else at my company makes the decision, but I have input," "I make the decision with input from others at my company,", or "I am solely responsible for making the decision" is not selected for Building Automation Systems or Building Energy Management Systems.

3. Which best describes your function at your company or organization?

- » Engineering
- » Facility management/building operations
- » Information technology
- » Market research Terminate
- » Finance or accounting
- » Sustainability or social responsibility
- » Sales Terminate
- » Other (please specify) Terminate

4. On a scale of 1 to 5 where 1 is not important at all and 5 is extremely important, please rate how important the following factors are when making improvements to your building.

	1 – Not important at all	2	3	4	5 – Extremely important
Saving money					
Reducing energy consumption					
Increasing occupant comfort					

5. On a scale of 1 to 5, where 1 is not knowledgeable at all and 5 is extremely knowledgeable, how do you rate your knowledge about the *concept of Big Data*?

- » 1 - Not knowledgeable at all
- » 2
- » 3
- » 4
- » 5 - Extremely knowledgeable

6. On a scale of 1 to 5, where 1 is not knowledgeable at all and 5 is extremely knowledgeable, how do you rate your knowledge about the *application of Big Data to buildings*?

- » 1 - Not knowledgeable at all
- » 2
- » 3
- » 4
- » 5 - Extremely knowledgeable

7. How do you define “Big Data”?

_____________ [Open-entry text box]

8. Which of the following do you think best describes Big Data in buildings?

- » Information attained from multiple building automation systems, such as lighting, HVAC, and access control used to improve building operations
- » Cloud-based collection of building data
- » Machine intelligence
- » Actionable information from building sensors
- » Real-time monitoring-based building commissioning
- » Fault detection in equipment
- » Optimization of building efficiency

9. **Which of the following describes your level of familiarity with analytics in relation to building management?**
   - » I am unfamiliar with analytics
   - » I am familiar with the concept of analytics, but I am unfamiliar with its implementation
   - » I am familiar with the concept and implementation of analytics, but I have no experience with it
   - » I have some experience using analytics
   - » I routinely perform analytics as part of my job
   - » I do not perform analytics, but I rely on insight provided by analytics as part of my job

10. **On a scale of 1 to 5, where 1 is does not use data analysis to make decisions at all and 5 is uses data analysis to make every decision, how much does your company or organization rely on data analysis for general business operations?**
    - » 1 – does not use data analysis at all
    - » 2
    - » 3
    - » 4
    - » 5 – uses data analysis to make every decision
    - » I do not know

11. **What do you see as the biggest barriers to the adoption of Big Data in buildings?**
    ______________ [Open-entry text box]

12. **On a scale of 1 to 5, where 1 is not concerned at all and 5 is extremely concerned, how concerned are you about the following issues as it relates to data collected in your building?**

	1 – Not concerned at all	2	3	4	5 – Extremely concerned
Reliability of data storage					
Privacy of data					
Security of network					
Amount of data					
Frequency of data					
Complexity of data					
Ability to analyze data					
Ability to combine data from multiple sources					
Training of building management workforce					
Acceptance of IT department					
Acceptance of building management workforce					
Acceptance of the leadership of my organization					

13. **On a scale of 1 to 5, where 1 is no skills at all and 5 is extremely skilled, how do you rate the *skills of the people at your company responsible for building management in understanding data analysis*?**
    - 1 – No skills at all
    - 2
    - 3
    - 4
    - 5 – Extremely skilled
    - I do not know

14. **On a scale of 1 to 5, where 1 is not willing at all and 5 is extremely willing, how do you rate the *willingness of the people at your company responsible for building management workforce to accept new technology*?**
    - 1 – Not willing at all
    - 2
    - 3
    - 4
    - 5 – Extremely willing
    - I do not know

The following questions ask about your experiences with an energy management system. We define an energy a management system as an IT-based monitoring and control systems that can provide information on the performance of some or all of the components of a building or facility's infrastructure, including its envelope, heating and ventilation, lighting, plug load, water use, occupancy, and other critical resources.

15. **Does your company or organization currently analyze the electricity consumption of devices in the buildings you operate?**
    - Yes
    - No
    - I do not know

16. ***[Display if Q15 is "Yes"]* What is the most granular level you analyze electricity consumption on?**
    - Whole building only
    - Tenant submeters
    - Individual building systems
    - Individual pieces of equipment
    - Other (Please specify)
    - I do not know

17. ***[Display if Q15 is "Yes"]* What data sources does your company us to analyze the electricity consumption of devices in your building? Please select all that apply.**
    - Bills from the utility company
    - Data from building automation systems or building management system
    - Submeters
    - Other (Please specify)
    - I do not know

18. ***[Display if Q15 is "Yes"]* How do you analyze electricity consumption? Please select all that apply.**
    - Software-based services from a third party
    - Analysis performed by building personnel

- » Analysis performed by a third party based on utility billing history
- » Other (Please specify)
- » I do not know

19. *[Display if Q15 is "Yes"]* How often do you use information from your energy management system to configure the equipment in your facilities, such as by changing setpoints and schedules?

- » Continuous/real time
- » Daily
- » Weekly
- » Monthly
- » Quarterly
- » Annually
- » Only when there is an alarm
- » There is no set schedule
- » We do not use the data from our energy management system to configure the equipment
- » I do not know

20. *[Display if Q15 is "No"]* What reasons does your company or organization have for not using an energy management system? Select all that apply.

- » Senior leadership does not see the value of an energy management system
- » They are too expensive
- » They are too complicated to use
- » Energy management systems do not reduce energy consumption
- » We manage our energy consumption without an energy management system
- » Energy management is not a priority for my company or organization
- » We are unaware of energy management systems
- » The equipment or controls in our building will not work with an energy management system
- » The building(s) are too small to justify an energy management system
- » I do not manage enough buildings to justify an energy management system
- » Other (Please specify)

[Display Q21-Q24 if Q18 is "Software-based services from a third party"]

21. Are there metering or sensor devices installed in your building to measure the energy consumption of the following systems? Please answer yes or no.

	Yes	No	I do not know
Heating, ventilation, and air conditioning equipment			
Lighting			
Plug loads			
Computers			
Other (Please specify) ____________			

22. Does the building management system in your facility have the following equipment control functionalities? Please answer yes or no.

	Yes	No	I do not know
Integrate lighting controls			
Integrate security and access control			
Alter equipment settings during peak demand			
Track business operational data and metrics (expenditures, budgets, human resources, etc.)			
Provide visualization of energy use			
Alter equipment settings to curtail consumption during a demand response event			
Generate reports on energy consumption			
Perform automated fault detection of equipment			
Provide ongoing commissioning			
Other (Please specify) ____________			

23. *[Display if Q21 has at least 1 "Yes"]*. Approximately how many of each of the following devices do you currently manage the energy consumption of in your building?

Heating, ventilation, and air conditioning equipment: ______________ Numerical entry, must be positive integer *[Only display if Q21 has "Yes" for "Heating, ventilation, and air conditioning equipment"]*

Lighting: ______________ Numerical entry, must be positive integer *[Only display if Q22 has "Yes" for "Lighting"]*

Plug loads: ______________ Numerical entry, must be positive integer *[Only display if Q22 has "Yes" for "Plug loads"]*

24. Over what time interval is the data in your energy management system logged?

» More than once every minute
» Every minute
» Every 5 minutes
» Every 15 minutes
» Every 30 minutes
» Every hour
» Daily
» Monthly
» Annually
» I do not know the time interval
» Data is not logged in my energy management system

For the following questions, please consider a system that collects data from all of the equipment in your building (lighting, HVAC, plug loads, etc.) and combines this data with information on weather conditions and your building envelope to provide an analysis of the operation of your building.

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25. On a scale of 1 to 5 where 1 is not at all interested and 5 is extremely interested, how interested would you be in installing this system in your building?

» 1 – Not at all Interested
» 2
» 3
» 4
» 5 – Extremely Interested
» I already have such a system installed

26. [Display if Q25 is "1 – Not at all interested" or "2"] Why are you not interested in installing this system?

______________ [Open-entry text box]

27. [Display if Q25 is "4" or "5 – Extremely interested"] Why are you interested in installing this system?

______________ [Open-entry text box]

28. Please rank the following design characteristics or functionality of an energy management system on a scale of 1 to 5 where 1 is not at all valuable and 5 is extremely valuable.

	1 – Not valuable at all	2	3	4	5 – Extremely valuable
Measure savings					
Software-based dashboard to visualize building status					
Carbon accounting					
Integration with mobile phones and tablets					
Fault detection and diagnostic of equipment					
Integration with a workforce management system					
Storage of building data on the cloud					
Continuous optimization of building setpoints					
Reporting dashboards					
Real time alerts					
Benchmarking Tools to compare performance of buildings or assets across a portfolio					
Integration with other business intelligence software tools					
Integration with building automation/control system					
Utilization of utility billing data					
Data analysis for submission to ENERGY STAR Portfolio Manager					

29. How often would you like this energy management system to provide reports?

» Continuous/real time
» Daily
» Weekly
» Monthly
» Quarterly
» Annually
» Only when there is an alarm

30. If you had $100 to spend on this energy management system, how would you spend on each individual feature?

» Software-based dashboard to visualize building status: _____________ Numerical entry, must be non-negative integer
» Carbon accounting: _____________ Numerical entry, must be non-negative integer
» Integration with mobile phones and tablets: _____________ Numerical entry, must be non-negative integer
» Fault detection and diagnostic of equipment: _____________ Numerical entry, must be non-negative integer
» Integration with a workforce management system: _____________ Numerical entry, must be non-negative integer
» Storage of building data on the cloud: _____________ Numerical entry, must be non-negative integer
» Continuous optimization of building setpoints: _____________ Numerical entry, must be non-negative integer
» Integration of different building systems: _____________ Numerical entry, must be non-negative integer

[Sum must equal 100]

31. On a scale of 1 to 5, where 1 is not comfortable at all and 5 is extremely comfortable, how would comfortable are you *storing your building data in the cloud*?

» 1 – Not comfortable at all
» 2
» 3
» 4
» 5 – Extremely comfortable

32. On a scale of 1 to 5, where 1 is not comfortable at all and 5 is extremely comfortable, how would comfortable are you with a *cloud-based system controlling aspects of your building such as changing setpoints and schedules*?

» 1 – Not comfortable at all
» 2
» 3
» 4
» 5 – Extremely comfortable

33. Are you more comfortable with data being stored on a public cloud (one managed by a third party like HP, Amazon, or Oracle) or a corporate cloud that is managed by your own company?

» I am much more comfortable with a public cloud
» I am slightly more comfortable with a public cloud
» I am equally as comfortable with a public cloud as I am with a corporate cloud
» I am slightly more comfortable with a corporate cloud
» I am much more comfortable with a corporate cloud

34. Does your company currently use cloud services such as Salesforce, Google Docs, Carbonite, or Dropbox?

- Yes
- No

35. *[Display if the answer to Q34 is "Yes"]* What cloud services does your company use? Please select all that apply.

- Google Docs
- Salesforce
- Carbonite
- Dropbox
- Other (Please specify) ___________

36. How interested would your company or organization be in sharing your building data with a company that could combine this data with data from other buildings to provide analytics?

- 1 – Not interested at all
- 2
- 3
- 4
- 5 – Extremely interested

37. Which of the following energy-related tasks are you responsible for in your role at your company or organization? Please select all that apply.

- Purchasing Energy
- Making capital investments for building systems (e.g., HVAC, lighting, controls, etc.)
- Managing energy or facility-related services
- Implementing sustainability initiatives
- Other (please specify)

38. What types of building activities are in the building that houses your company or organization? Please select all that apply.

- Office
- Retail
- Education
- Healthcare
- Hotels & Restaurants
- Institutional/Assembly
- Warehouse
- Transport
- Other (please specify)

39. *[Display question if more than one answer is selected for question 37]*. What is the *primary* building activity of the building that houses your company or organization?

- Office
- Retail
- Education
- Healthcare
- Hotels & Restaurants
- Institutional/Assembly
- Warehouse

- » Transport
- » Other

40. **Approximately how large is the building that houses your company or organization?**
    - » Less than 5,000 SF
    - » 5,001-10,000 SF
    - » 10,001-25,000 SF
    - » 25,001-50,000 SF
    - » 50,001-100,000 SF
    - » 100,001-200,000 SF
    - » 200,001-500,000 SF
    - » Greater than 500,000 SF

41. **Does your company or organization operate in just one building or does it have a portfolio of buildings?**
    - » Just one building
    - » Portfolio of buildings

42. ***[Display if the answer to Q41 is "Portfolio of buildings"]* Are you involved in purchasing building automation systems or energy management systems for just one building or more than one building?**
    - » Just one building
    - » More than one building
    - » I am not involved in purchasing building automation systems or energy management systems

43. **How much does your company or organization *typically spend on electricity in 1 year*?**
    - » Less than $100,000
    - » $100,000 - $250,000
    - » $250,001 - $500,000
    - » $500,001 - $1,000,000
    - » $1,000,001 - $2,500,000
    - » $2,500,001 - $5,000,000
    - » Greater than $5,000,000
    - » I do not know

44. **What is your company or organizations annual budget for building *operating expenses* (such as electricity use and maintenance)**
    - » Less than $100,000
    - » $100,000 - $250,000
    - » $250,001 - $500,000
    - » $500,001 - $1,000,000
    - » $1,000,001 - $2,500,000
    - » $2,500,001 - $5,000,000
    - » Greater than $5,000,000
    - » I do not know

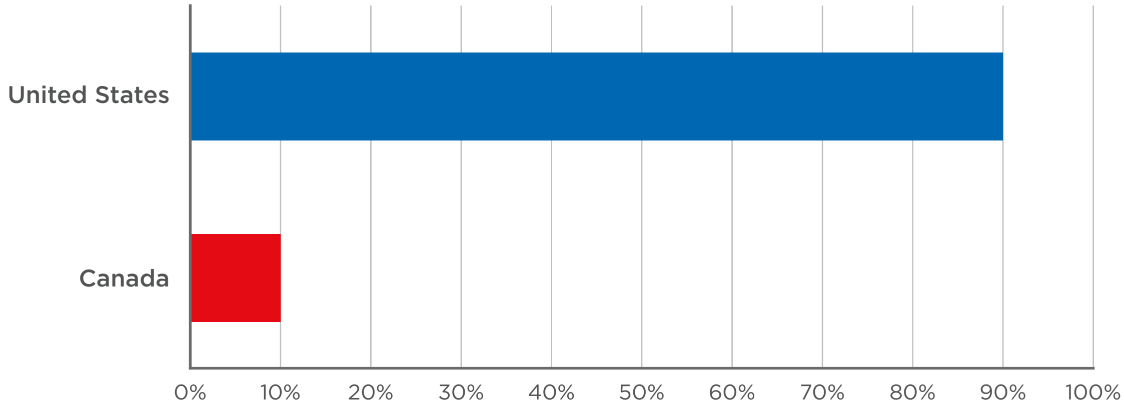
45. What is your company or organizations annual budget for building *capital expenses* (such as new equipment, upgrades, or retrofits)

» Less than $100,000
» $100,000 - $250,000
» $250,001 - $500,000
» $500,001 - $1,000,000
» $1,000,001 - $2,500,000
» $2,500,001 - $5,000,000
» Greater than $5,000,000
» I do not know

SECTION 13

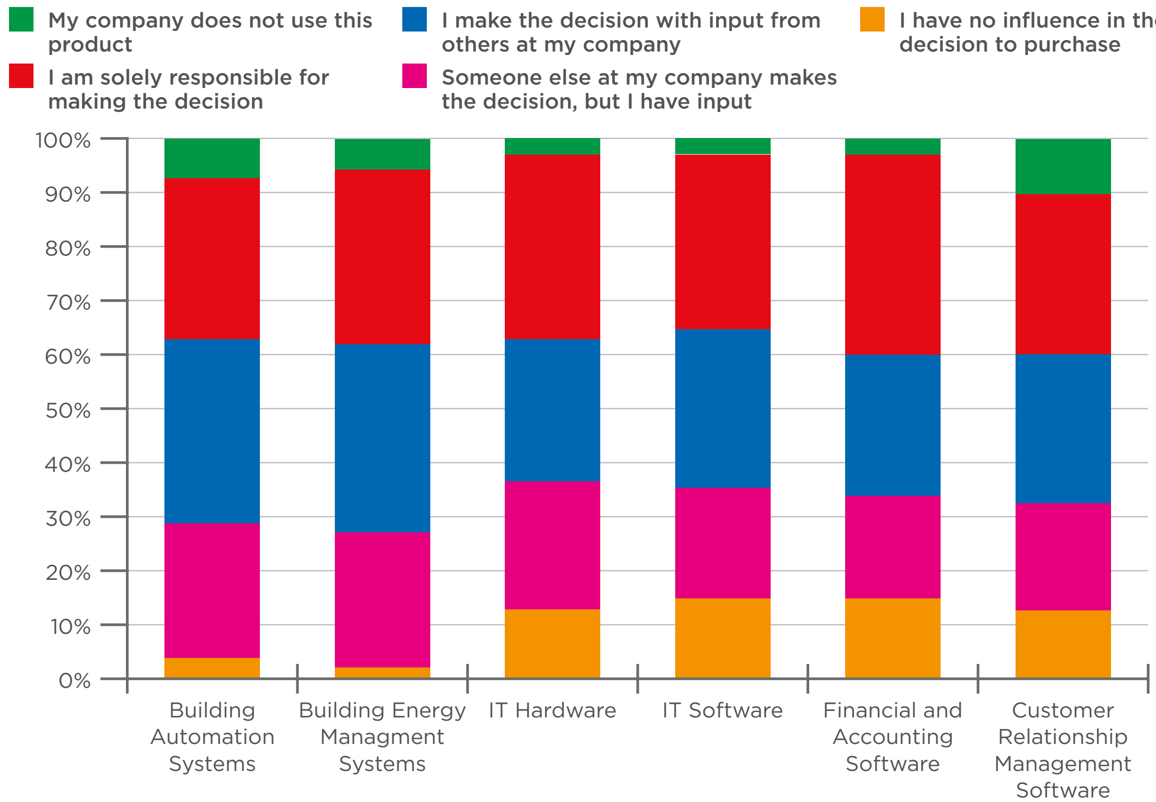
APPENDIX B: BIG DATA SURVEY RESULTS

Chart 13.1 What country are you located in?(n=400)



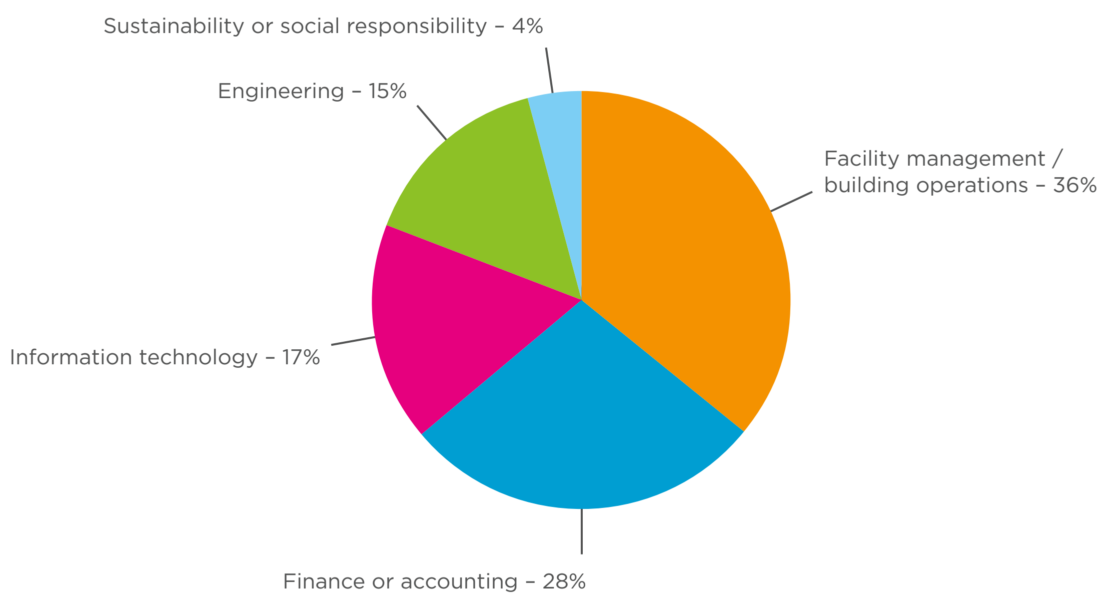
(Source: Navigant Research)

Chart 13.2 Please select the level of influence you have in purchasing the following products and services for your company or organization. (n=400)



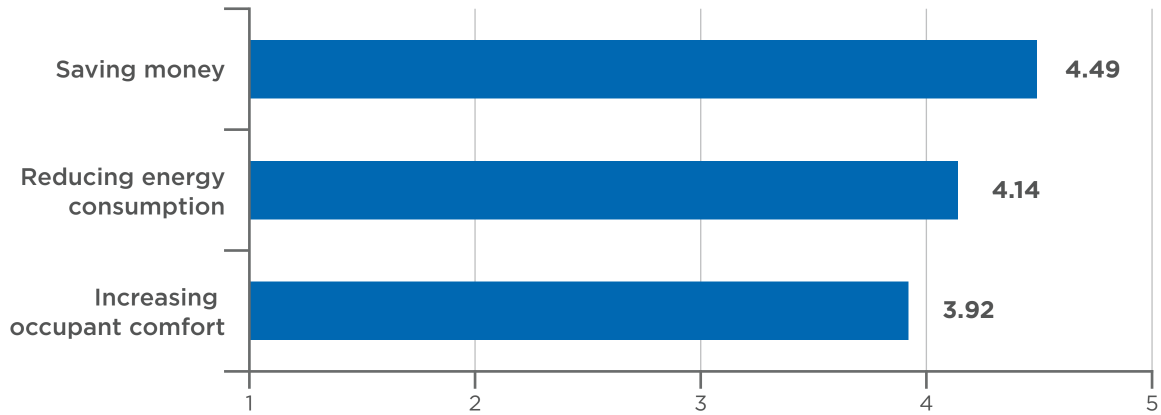
(Source: Navigant Research)

Chart 13.3 Which best describes your function at your company or organization? (n=400)



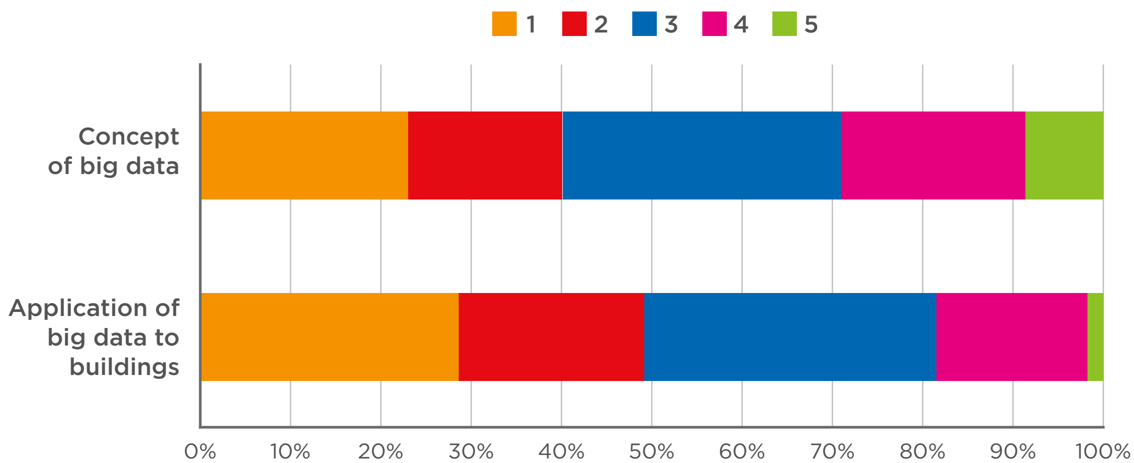
(Source: Navigant Research)

Chart 13.4 On a scale of 1 to 5 where 1 is not important at all and 5 is extremely important, please rate how important the following factors are when making improvements to your building. (n=400)



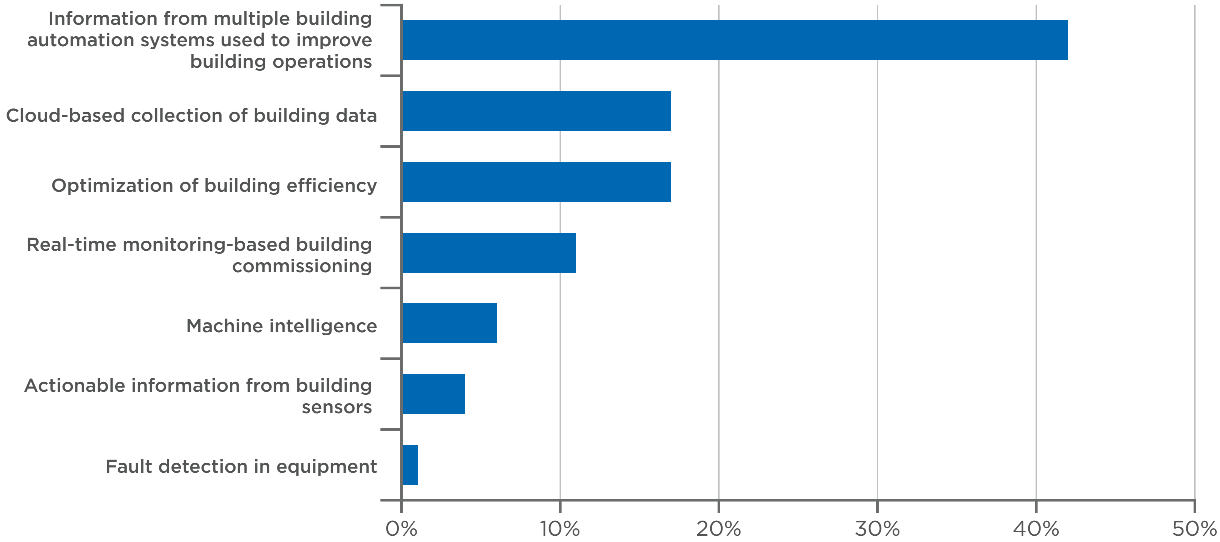
(Source: Navigant Research)

Chart 13.5 On a scale of 1 to 5, where 1 is not knowledgeable at all and 5 is extremely knowledgeable, how do you rate your knowledge about the concept of big data and the application of big data to buildings? (n=400)



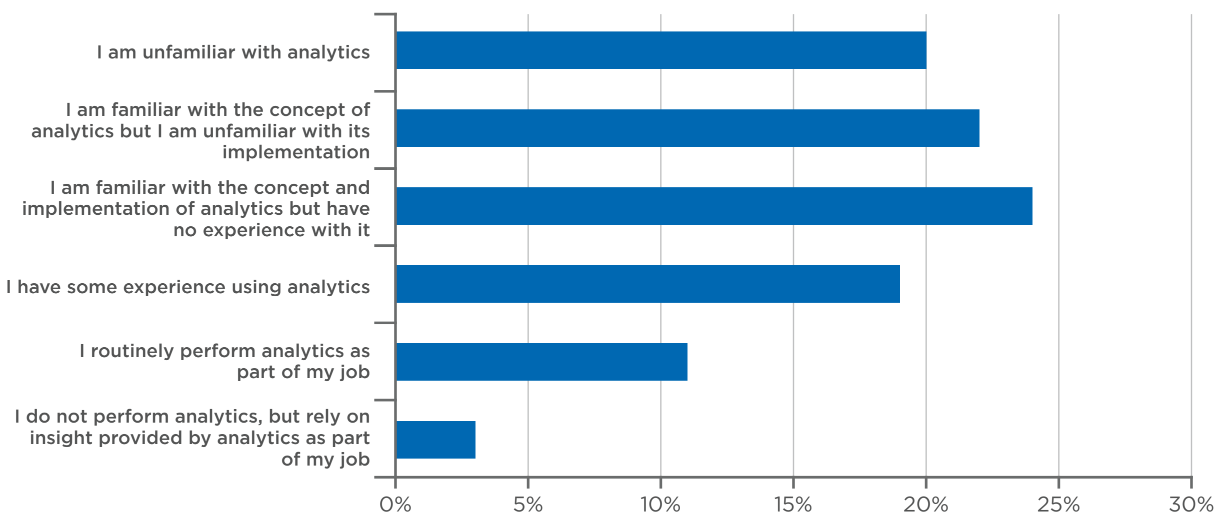
(Source: Navigant Research)

Chart 13.6 Which of the following do you think best describes big data in buildings? (n=400)



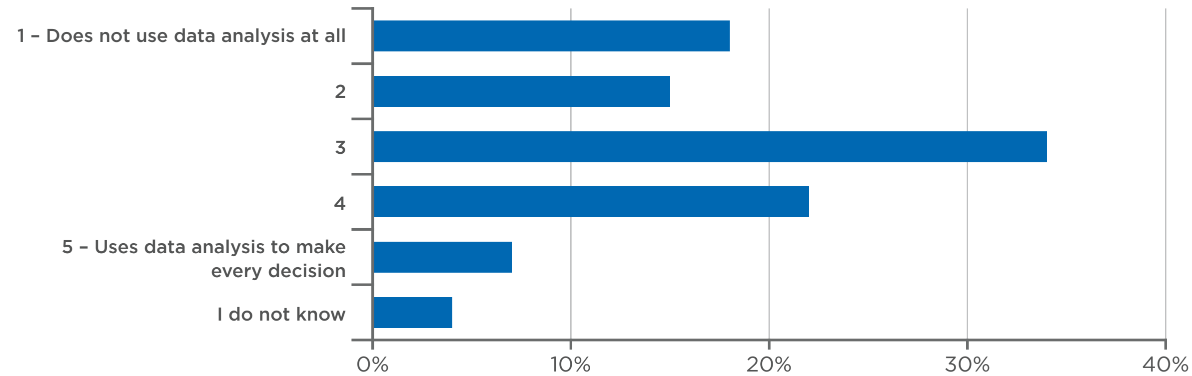
(Source: Navigant Research)

Chart 13.7 Which of the following describes your level of familiarity with analytics in relation to building management? (n=400)



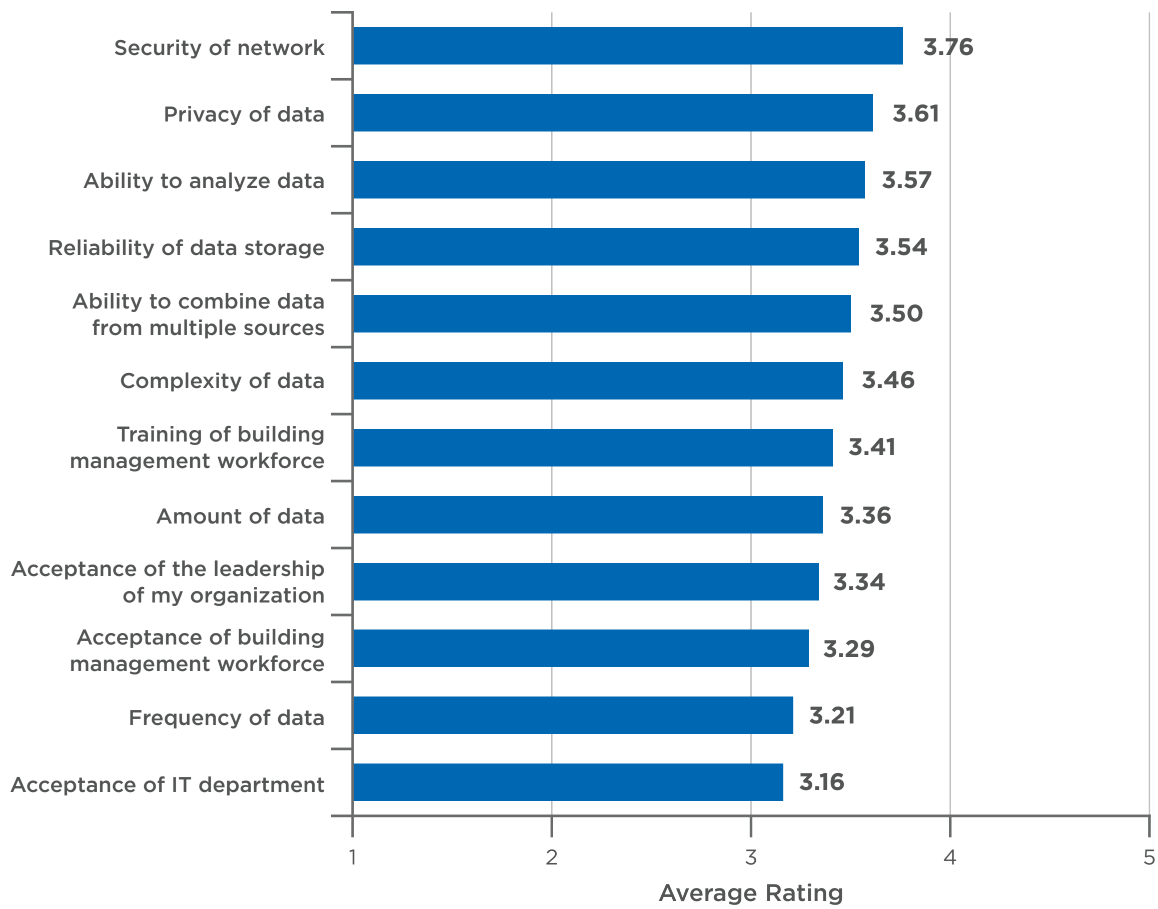
(Source: Navigant Research)

Chart 13.8 On a scale of 1 to 5, where 1 is does not use data analysis to make decisions at all and 5 is uses data analysis to make every decision, how much does your company or organization rely on data analysis for general business operations? (n=400)



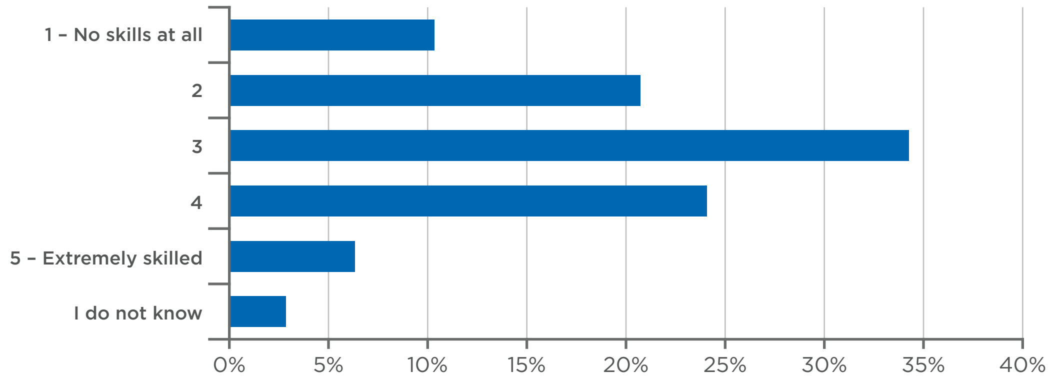
(Source: Navigant Research)

Chart 13.9 On a scale of 1 to 5, where 1 is not concerned at all and 5 is extremely concerned, how concerned are you about the following issues as it relates to data collected in your building? (n=400)



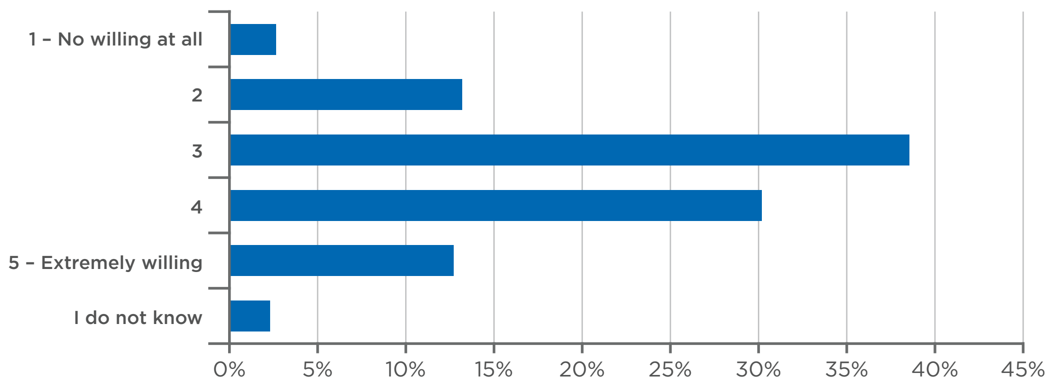
(Source: Navigant Research)

Chart 13.10 On a scale of 1 to 5, where 1 is no skills at all and 5 is extremely skilled, how do you rate the skills of the people at your company responsible for building management in understanding data analysis? (n=400)



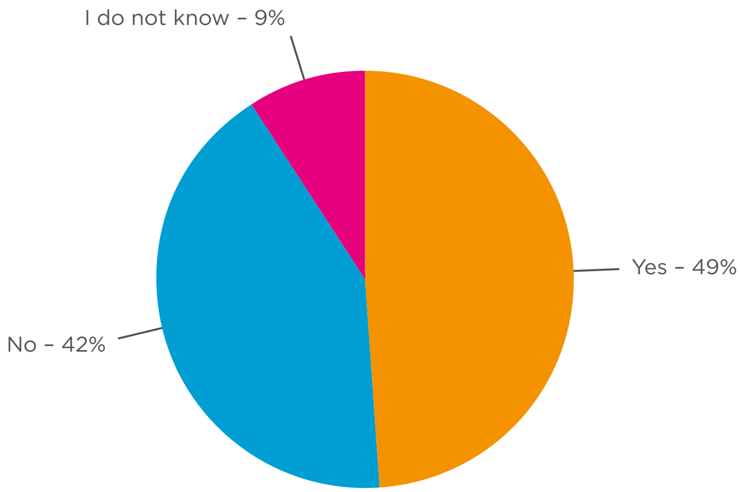
(Source: Navigant Research)

Chart 13.11 On a scale of 1 to 5, where 1 is not willing at all and 5 is extremely willing, how do you rate the willingness of the people at your company responsible for building management workforce to accept new technology? (n=400)



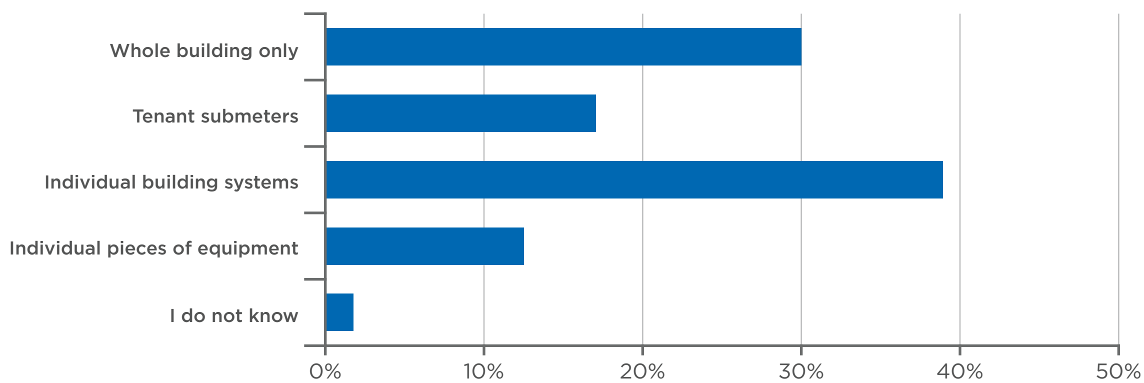
(Source: Navigant Research)

Chart 13.12 Does your company or organization currently analyze the electricity consumption of devices in the buildings you operate? (n=400)



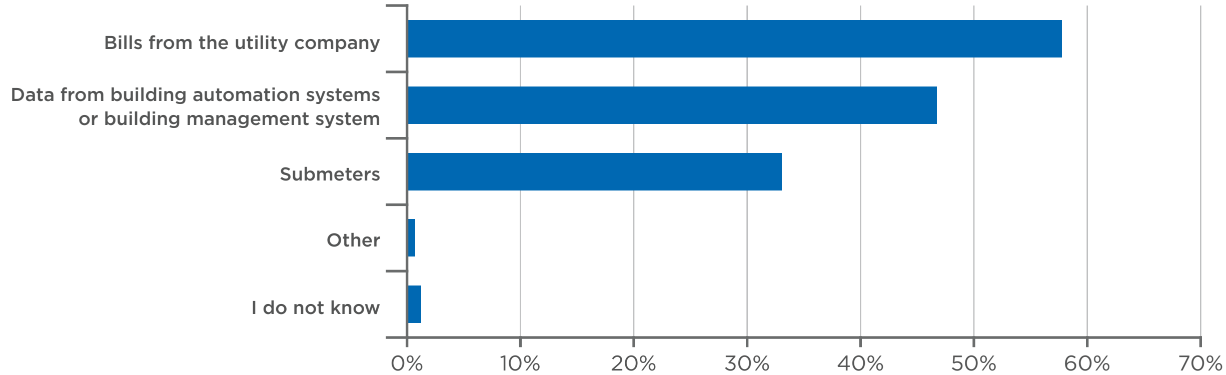
(Source: Navigant Research)

Chart 13.13 What is the most granular level you analyze electricity consumption on? (n=198)



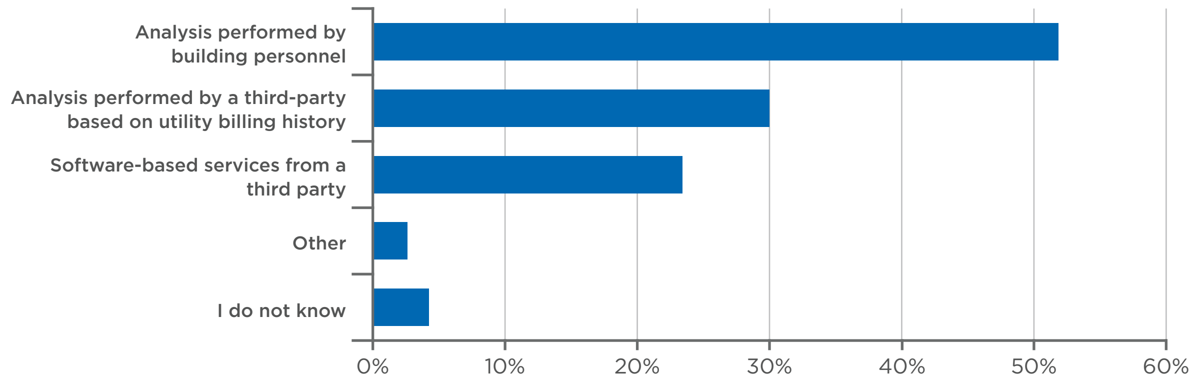
(Source: Navigant Research)

Chart 13.14 What data sources does your company us to analyze the electricity consumption of devices in your building? Please select all that apply. (n=198)



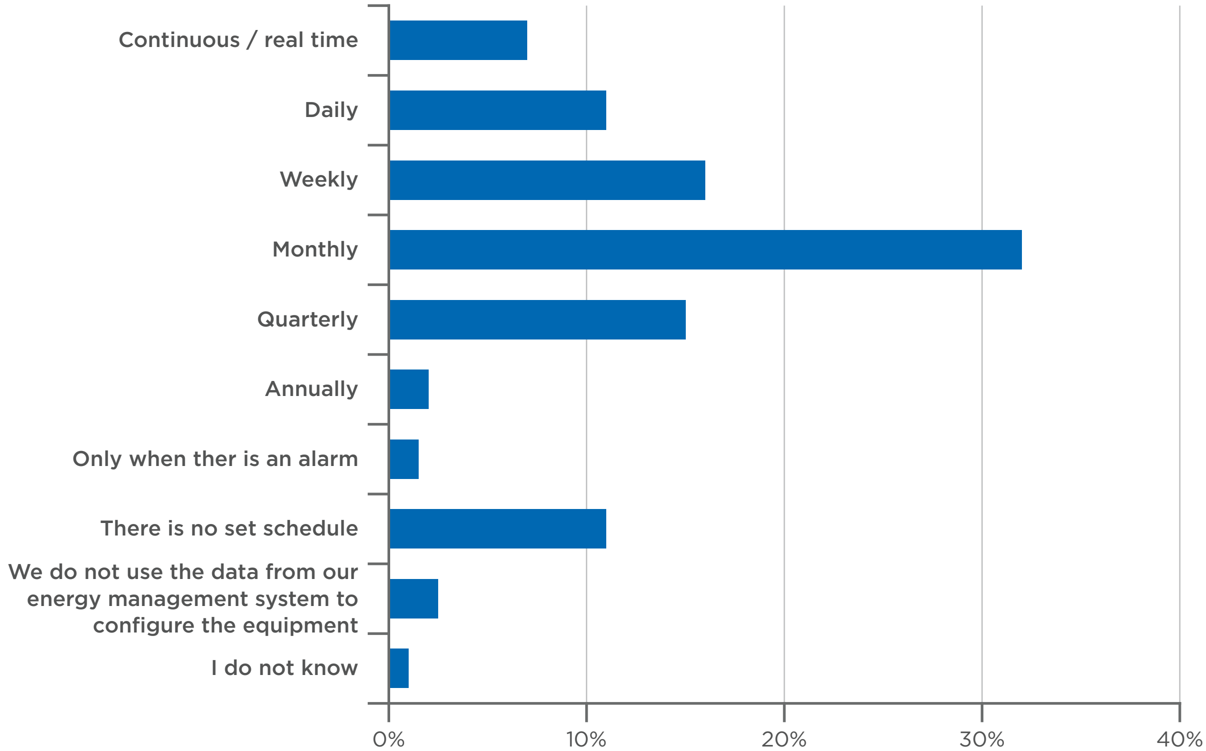
(Source: Navigant Research)

Chart 13.15 How do you analyze electricity consumption? Please select all that apply. (n=198)



(Source: Navigant Research)

Chart 13.16 How often do you use information from your energy management system to configure the equipment in your facilities, such as by changing setpoints and schedules? (n=198)



(Source: Navigant Research)

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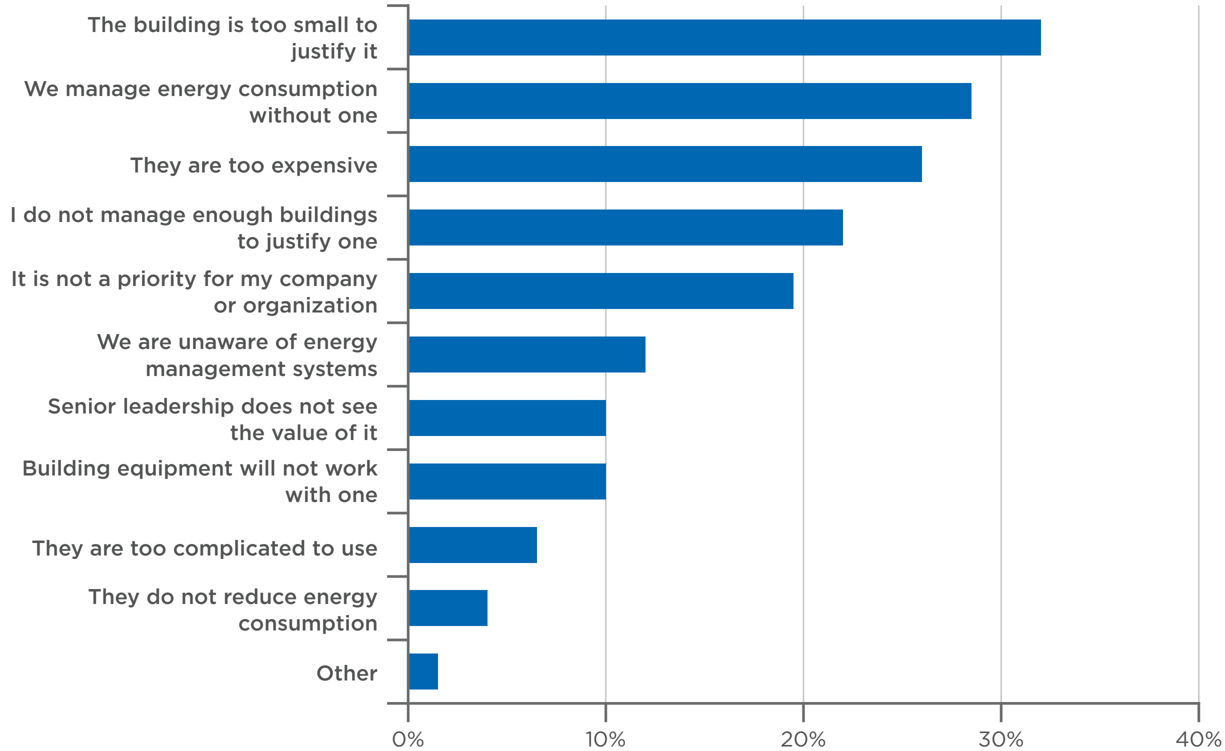
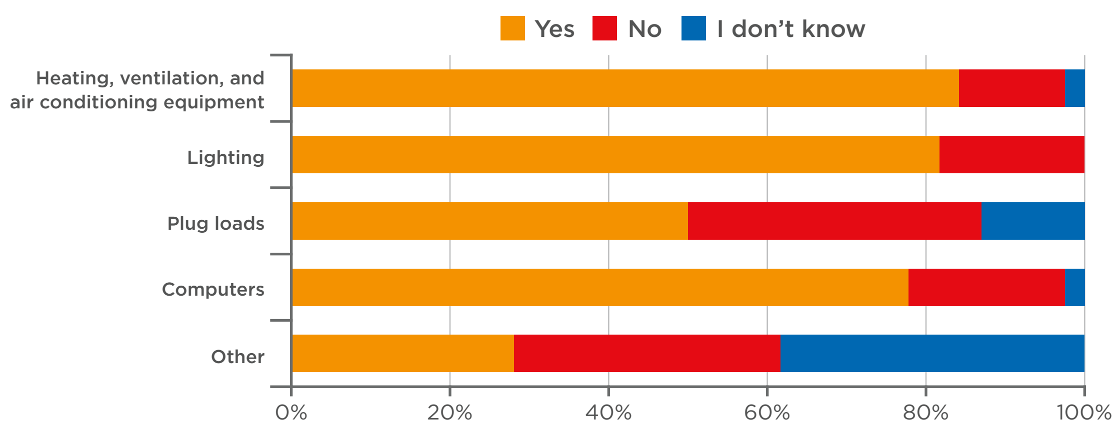
Chart 13.17 What reasons does your company or organization have for not using an energy management system? Select all that apply. (n=167)



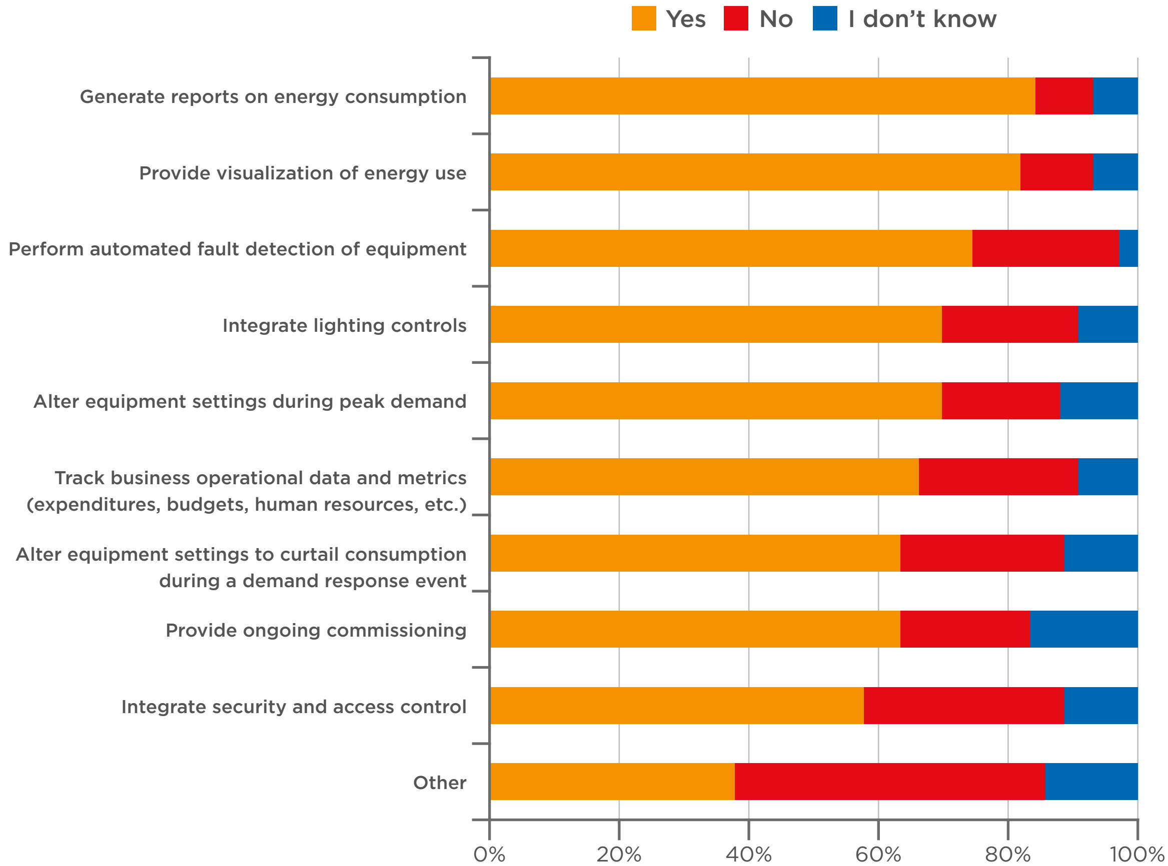
(Source: Navigant Research)

Chart 13.18 Are there metering or sensor devices installed in your building to measure the energy consumption of the following systems? (n=49)



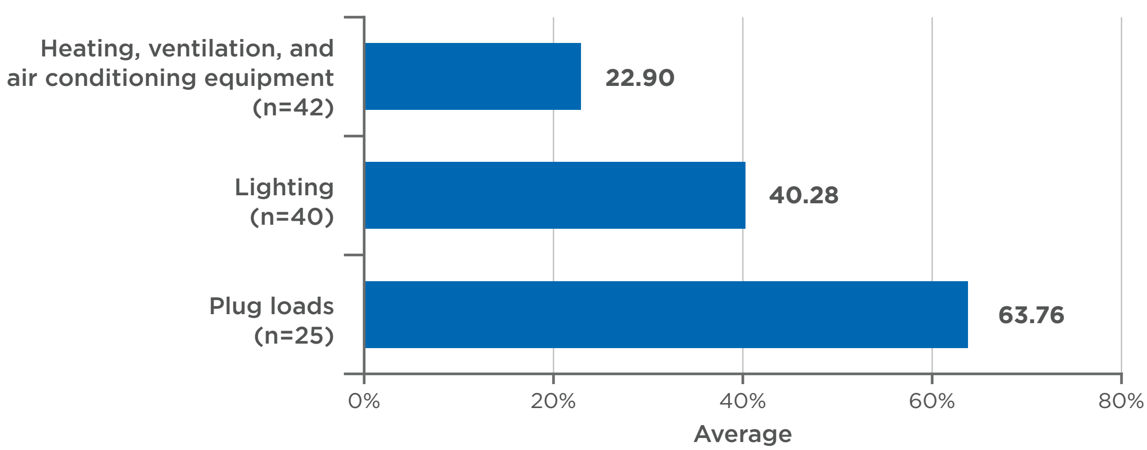
(Source: Navigant Research)

Chart 13.19 Are there metering or sensor devices installed in your building to measure the energy consumption of the following systems? (n=49)



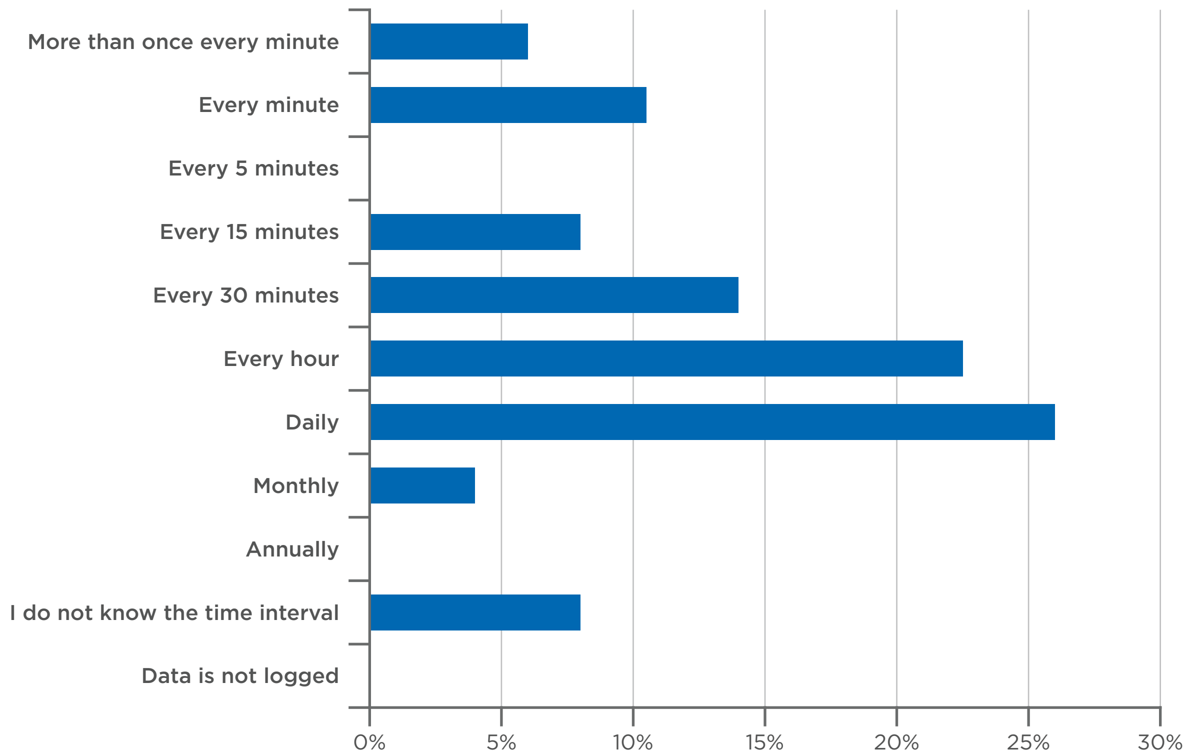
(Source: Navigant Research)

Chart 13.20 Approximately how many of each of the following devices do you currently manage the energy consumption of in your building?



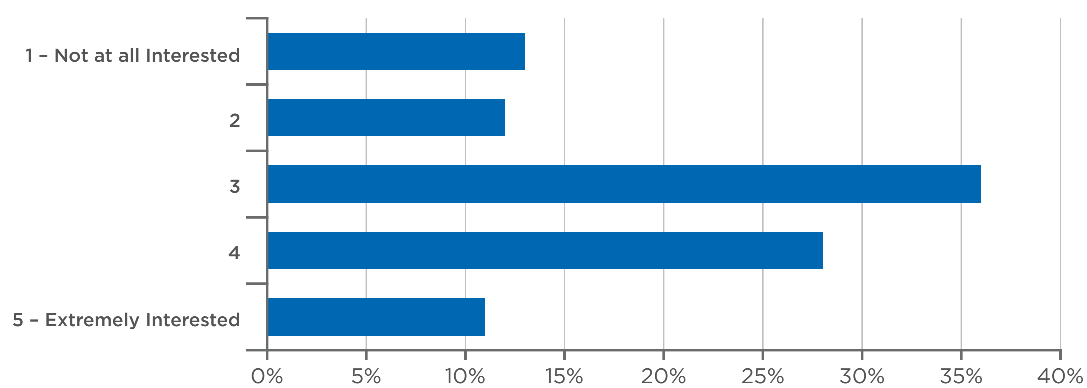
(Source: Navigant Research)

Chart 13.21 Over what time interval is the data in your energy management system logged? (n=49)



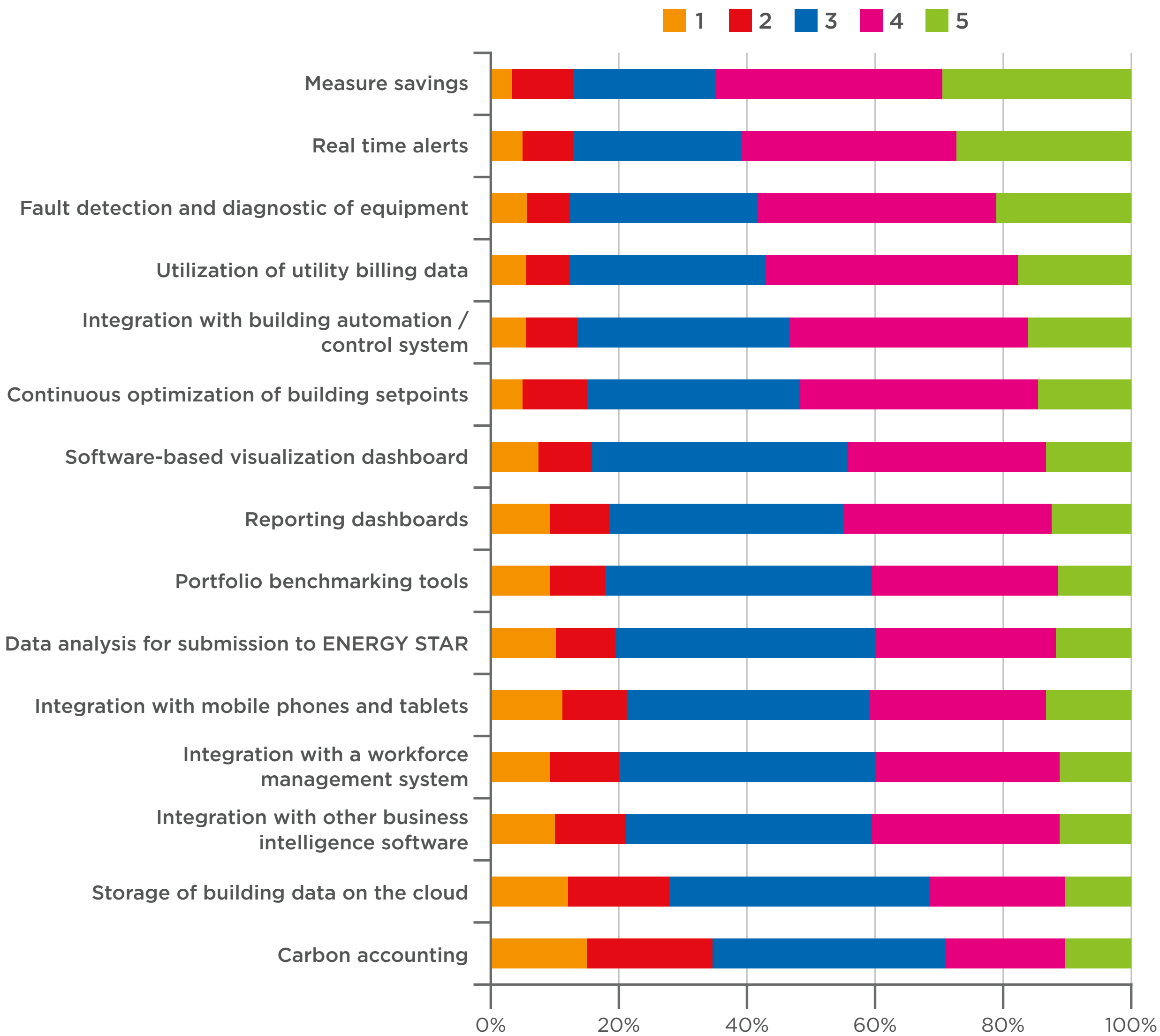
(Source: Navigant Research)

Chart 13.22 On a scale of 1 to 5 where 1 is not at all interested and 5 is extremely interested, how interested would you be in installing this system in your building? (n=400)



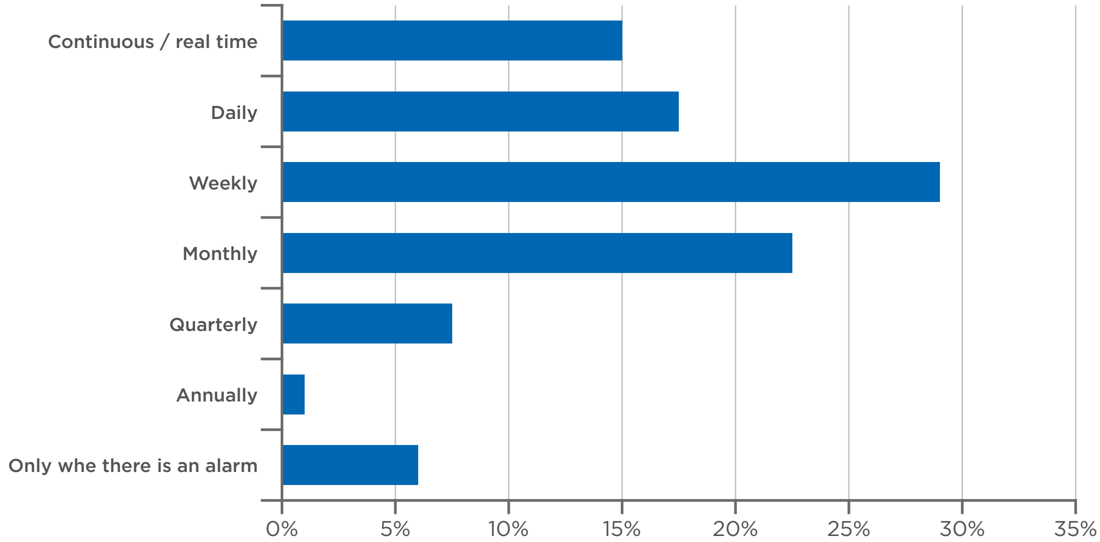
(Source: Navigant Research)

Chart 13.23 Please rank the following design characteristics or functionality of an energy management system on a scale of 1 to 5 where 1 is not at all valuable and 5 is extremely valuable. (n=400)



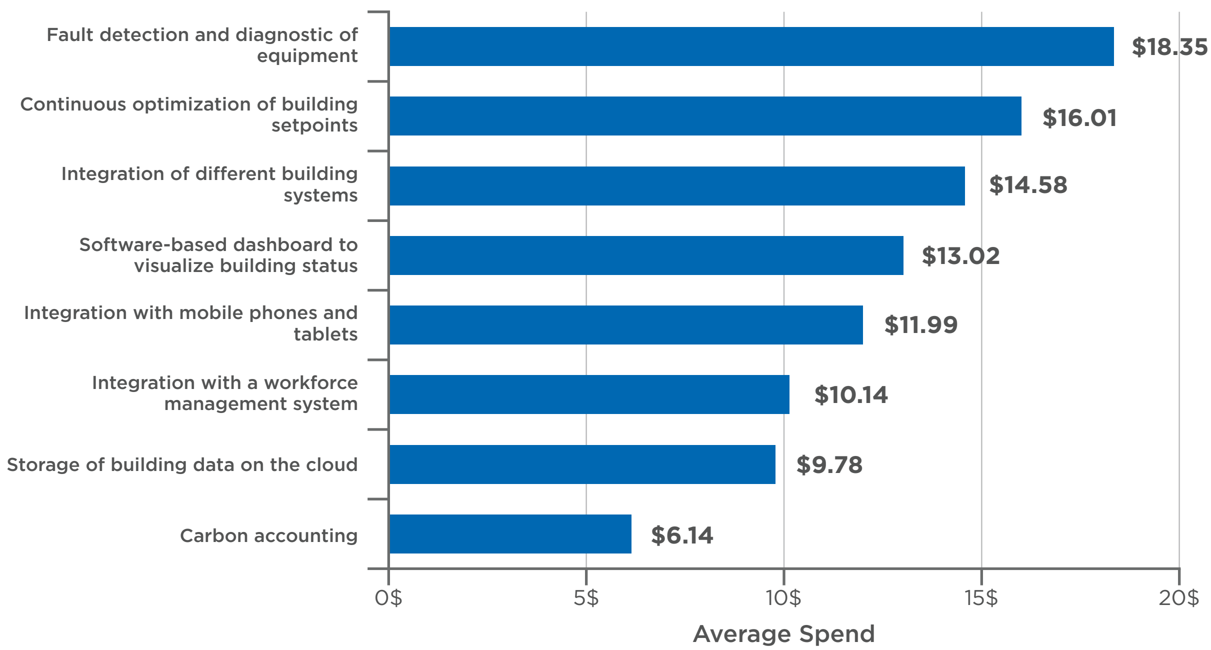
(Source: Navigant Research)

Chart 13.24 How often would you like this energy management system to provide reports? (n=400)



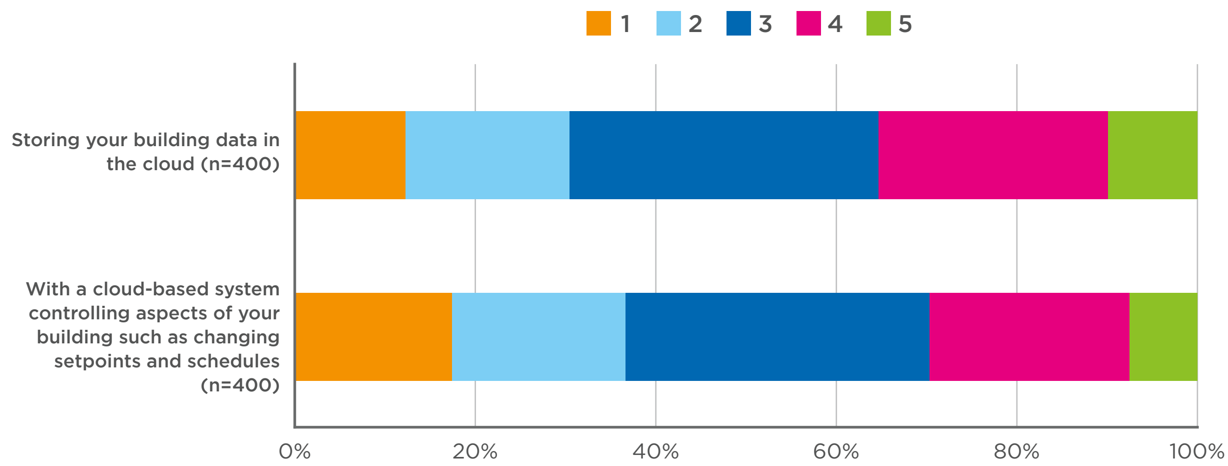
(Source: Navigant Research)

Chart 13.25 If you had $100 to spend on this energy management system, how would you spend on each individual feature? (n=400)



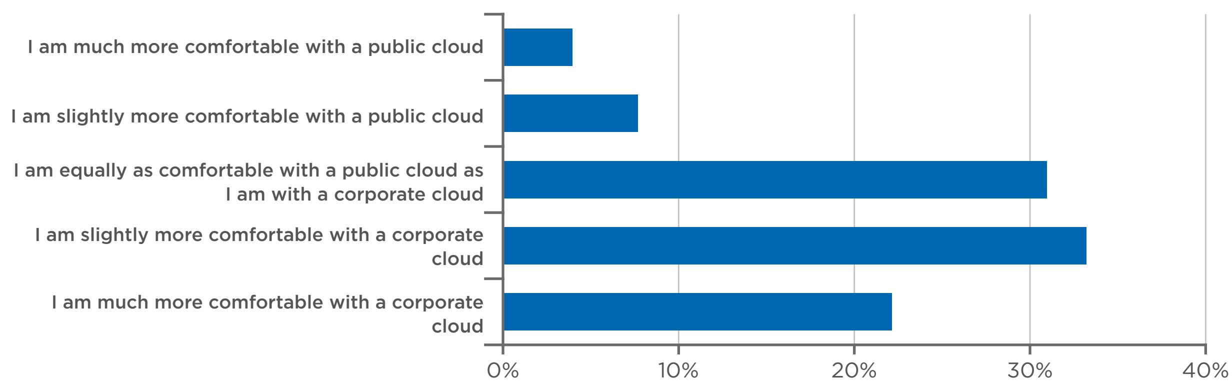
(Source: Navigant Research)

Chart 13.26 On a scale of 1 to 5, where 1 is not comfortable at all and 5 is extremely comfortable, how would comfortable are you:



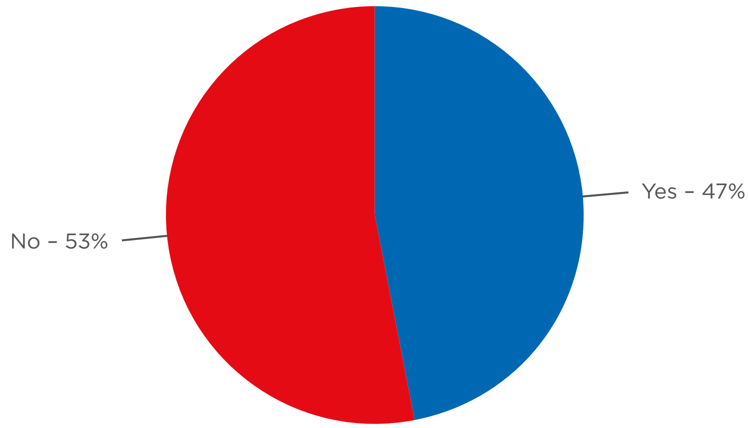
(Source: Navigant Research)

Chart 13.27 Are you more comfortable with data being stored on a public cloud (one managed by a third party like HP, Amazon, or Oracle) or a corporate cloud that is managed by your own company? (n=400)



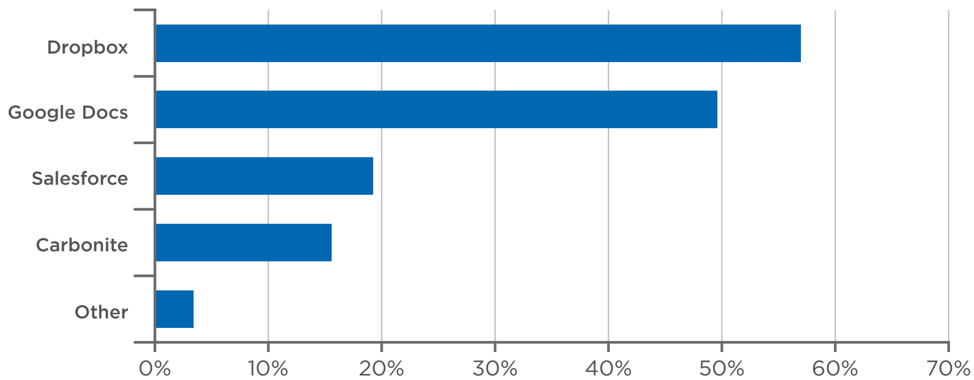
(Source: Navigant Research)

Chart 13.28 Does your company currently use cloud services such as Salesforce, Google Docs, Carbonite, or Dropbox? (n=400)



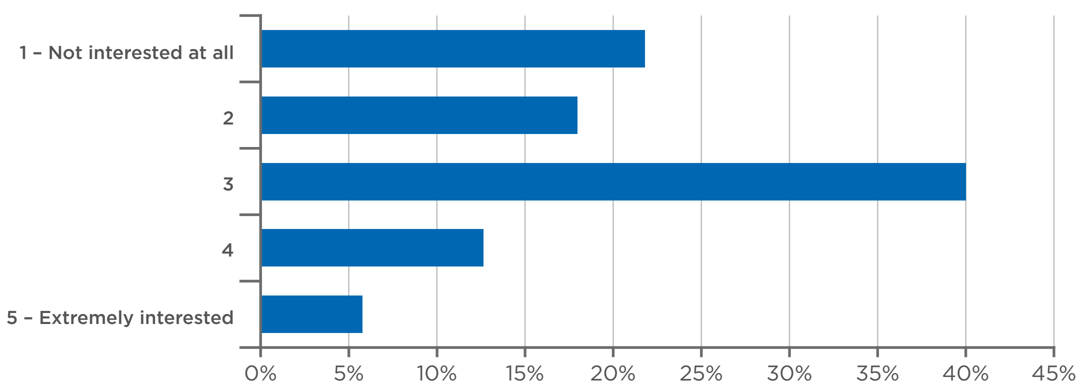
(Source: Navigant Research)

Chart 13.29 What cloud services does your company use? Please select all that apply. (n=187)



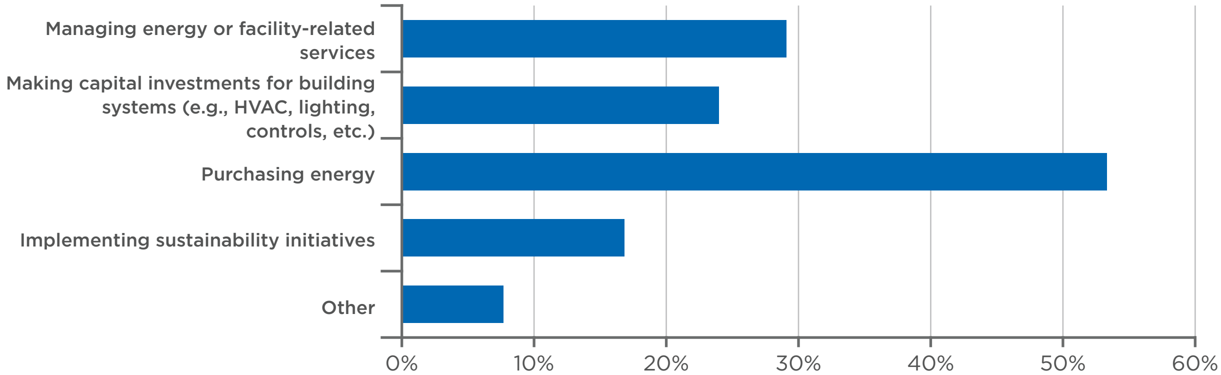
(Source: Navigant Research)

Chart 13.30 How interested would your company or organization be in sharing your building data with a company that could combine this data with data from other buildings to provide analytics? (n=400)



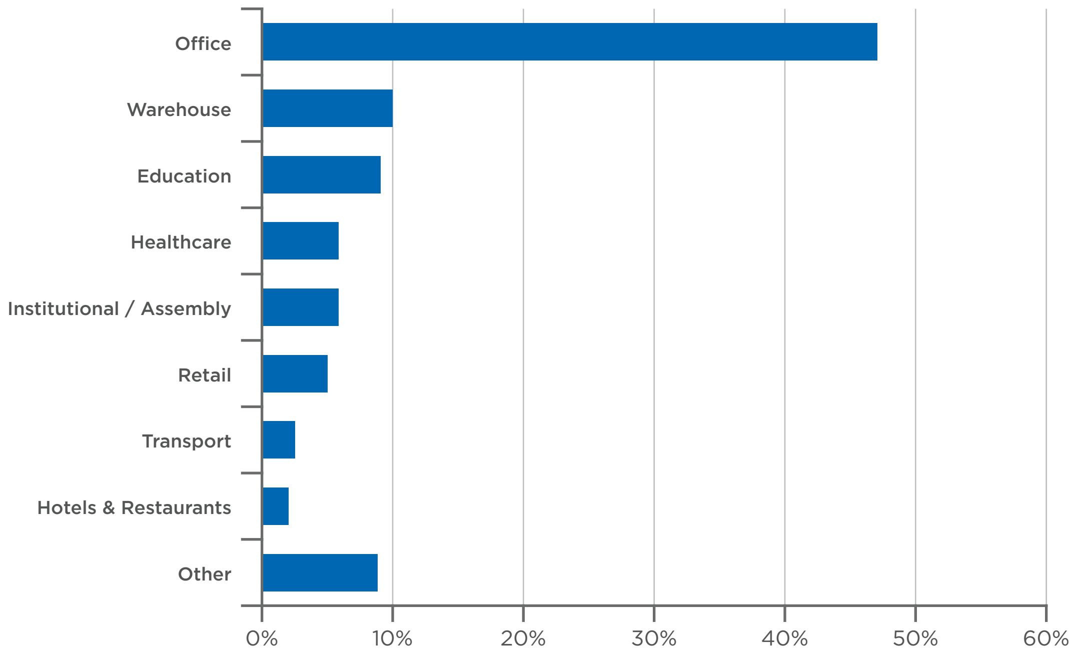
(Source: Navigant Research)

Chart 13.31 Which of the following energy-related tasks are you responsible for in your role at your company or organization? Please select all that apply. (n=400)



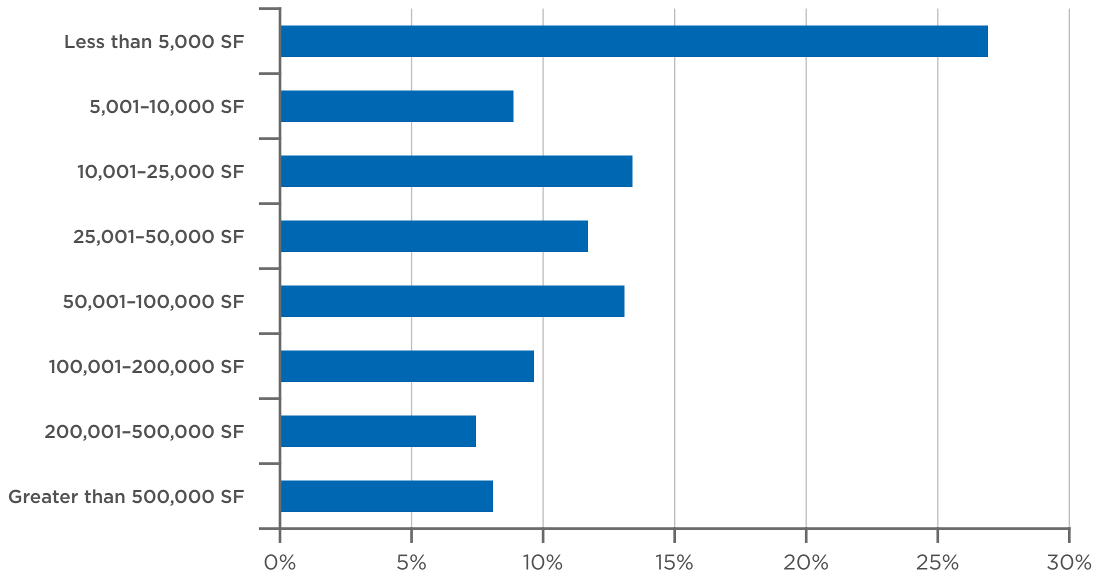
(Source: Navigant Research)

Chart 13.32 What is the primary building activity of the building that houses your company or organization? (n=400)



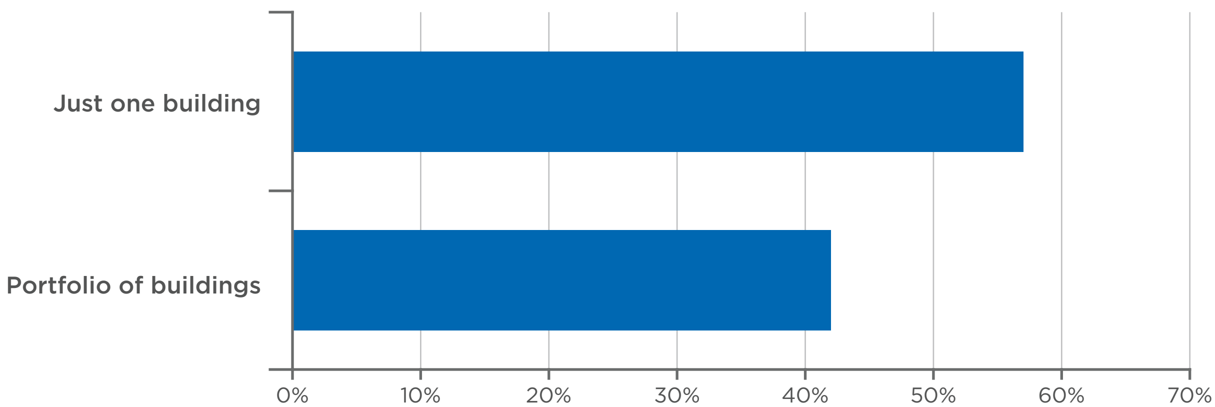
(Source: Navigant Research)

Chart 13.33 Approximately how large is the building that houses your company or organization? (n=400)



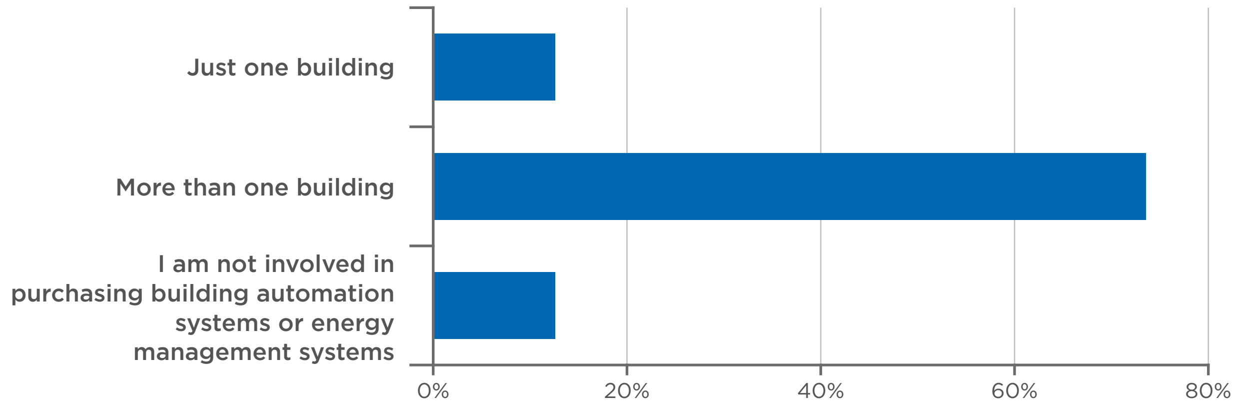
(Source: Navigant Research)

Chart 13.34 Does your company or organization operate in just one building or does it have a portfolio of buildings? (n=400)



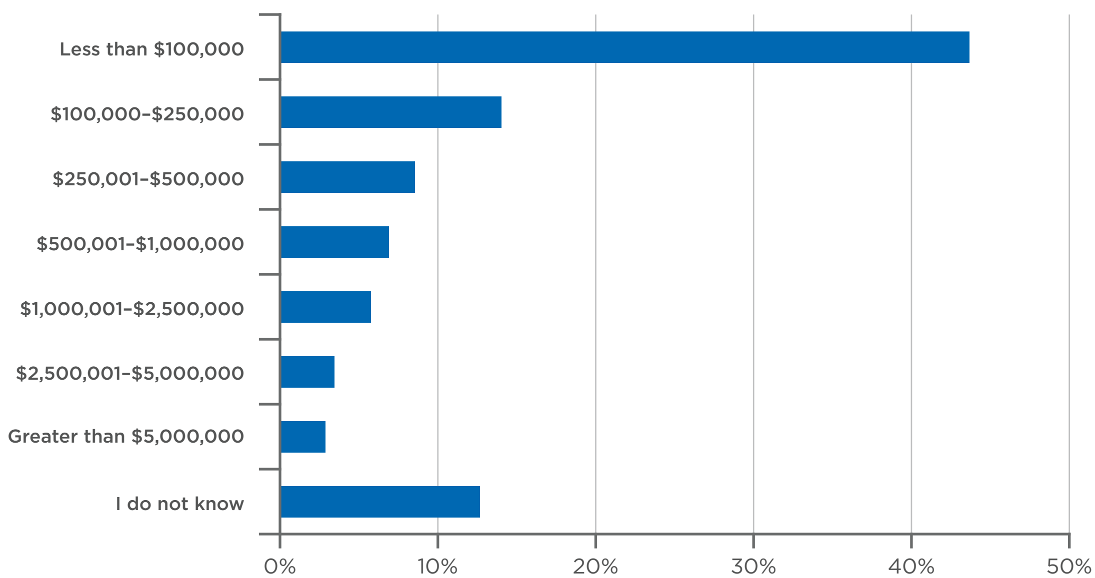
(Source: Navigant Research)

Chart 13.35 Are you involved in purchasing building automation systems or energy management systems for just one building or more than one building? (n=169)



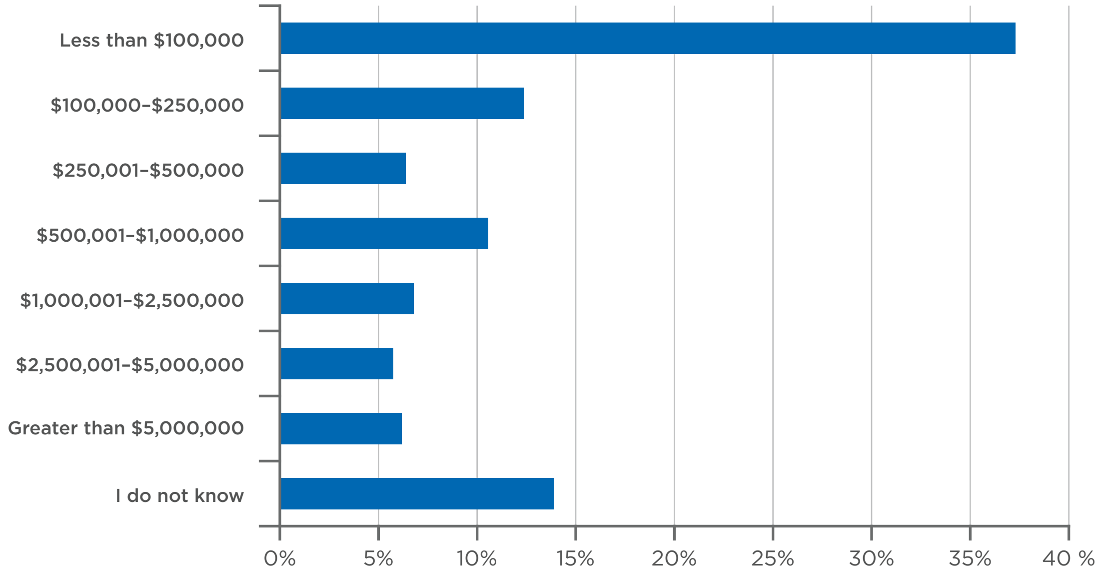
(Source: Navigant Research)

Chart 13.36 How much does your company or organization typically spend on electricity in one year? (n=400)



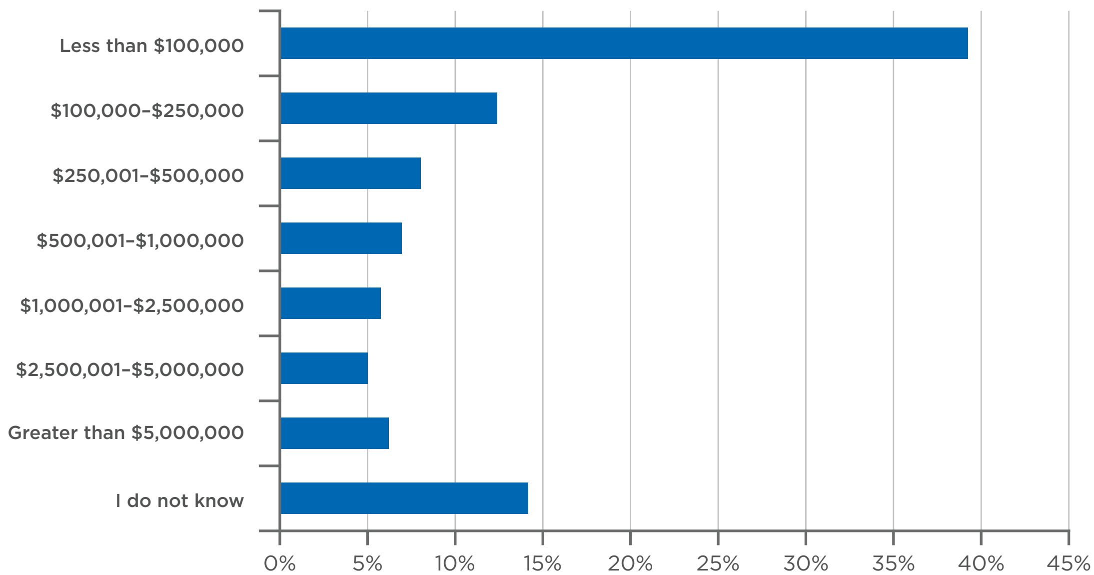
(Source: Navigant Research)

Chart 13.37 What is your company or organizations annual budget for building operating expenses (such as electricity use and maintenance) (n=400)



(Source: Navigant Research)

Chart 13.38 What is your company or organizations annual budget for building capital expenses (such as new equipment, upgrades, or retrofits) (n=400)



(Source: Navigant Research)

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