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Intelligent Buildings and the Impact of the Internet of Things

LANDMARK RESEARCH PROJECT

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Intelligent Buildings and the Impact of the Internet of Things

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ACKNOWLEDGEMENTS

This study was made possible thanks to the insights and support of the Continental Automated Buildings Association (CABA). The authors wish to acknowledge the support of CABA staff: Greg Walker, Research Director, for his management of the project and Ron Zimmer, President & CEO, for his recognition and promotion of this important topic. The Steering Committee contributed their time and industry expertise to the project at numerous Web conference meetings and through interim and final review of the surveys and this extensive report. The organizations and their representatives included:

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ES.1 PROJECT BACKGROUND AND INTRODUCTION

This executive summary presents top-level trends and conclusions from the CABA Landmark Study "Intelligent Buildings and the Impact of the Internet of Things". CABA commissioned IHS Markit to undertake this research project on behalf of the Intelligent Buildings Council (IBC), a working group of CABA. The research and report has been created by IHS Markit, a leading analyst research firm, for the Continental Automated Buildings Association (CABA). CABA is a leader in initiating and developing cross-industry collaborative research under the CABA Research Program.

About the Report

CABA has two councils, the Connected Home Council (CHC) focusing on residential homes, and the Intelligent Buildings Council (IBC) focusing on larger commercial buildings. Each council produces one collaborative Landmark Research project per year which is fully funded by CABA member sponsors. Each Landmark Research project is directed by a Steering Committee made up of project sponsors. The Steering Committee provides feedback and input throughout the course of the research to help define the scope, direction, and methodology. CABA and the project Steering Committee commission a research firm to conduct the research while CABA provides project management.

The Intelligent Buildings Market is a rapidly evolving segment that is being influenced by a number of emerging trends. CABA's IBC participated in several sessions to generate topics and select the IBC Landmark Research project for 2016. Several excellent ideas were generated, the top three topics were voted on, and "Intelligent Buildings and the Impact of the Internet of Things (IoT)" was selected as the Landmark Research Project for 2016.

Following selection of the topic for the Landmark Research Project for 2016, CABA released a formal Request for Proposal (RFP). The CABA selection team narrowed down candidates who responded to the RFP to the top two finalists. Along with initial funders of this research, CABA commissioned the research to IHS Markit.

Role of the Steering Committee and Funders

The Steering Committee represented a cross-section of solution providers in the Intelligent Buildings marketplace. Representatives from each organization joined IHS Markit and CABA on regular collaboration calls to ensure the research scope met the project objectives. The Steering Committee played a vital role in outlining the research product in terms of defining the required content on the research approach including the development of the interview scripts and survey guides. In addition, the Steering Committee received a draft of the research and their review and feedback was valuable in creating the final product.

IHS Markit and CABA would like to acknowledge the CABA member funders listed in Figure ES1, and the respondents who helped make this research possible. We would also like to take this opportunity to thank the CABA member funders 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.

Figure ES.1 CABA and funders of this research

Source: IHS Markit

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 350+ 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.

About IHS MARKIT

IHS Markit (NASDAQ: INFO) is a world leader in critical information, analytics and expertise to forge solutions for the major industries and markets that drive economies worldwide. The company delivers next-generation information, analytics and solutions to customers in business, finance and government, improving their operational efficiency and providing deep insights that lead to well-informed, confident decisions. IHS Markit has more than 50,000 key business and government customers, including 85 percent of the Fortune Global 500 and the world's leading financial institutions. Headquartered in London, IHS Markit is committed to sustainable, profitable growth.

Overview and Methodology

Two main primary research processes were used for this report: extensive interviews with industry participants (ecosystem interviews) and an on-line decision-maker survey of businesses in Canada and the United States.

Ecosystem interviews

A series of detailed phone interviews were conducted with key decision-makers at a number of different types of organizations, across the following organization types. The percentages provide only a guide:

- 30 percent were leading building supply-side solution providers.
- 20 percent were from large North American facility management service providers and large owners.
- 30 percent were from organizations specializing in IoT solutions for enterprises and industry, 50 percent of them were from established suppliers, 50 percent from disruptors.
- 20 percent were from other players on the supply side of the building automation industry, such as system integrators, connectivity solution providers, etc.

The names of the companies interviewed cannot be revealed. Interviewees were assured confidentiality, as they were often discussing product or service plans and detailed strategic information. IHS Markit conducted 20 in-depth interviews for this study.

North American decision-maker survey

IHS Markit, in conjunction with the CABA project Steering Committee members, developed an on-line decision-maker survey to assess attitudes towards intelligent buildings and the impact of IoT.

The survey targeted 150 building, facility and IT managers and owners/operators from a broad sample of building sizes, types, and geographies in both the United States and Canada.

The aim of this survey was to understand decision-maker views on the impact of a range of IoT topics on intelligent buildings. These topics ranged from real-time monitoring and control of building systems to the role of data analytics in building management. The topics were framed within the context of the five main themes outlined in Section 2.

The survey consisted of 20 questions, two open-response, and the balance being closed-response. It was intended that the survey took 15–20 minutes to complete. For these >150 responses, the project steering group decided that:

- An artificial skew was to be created in the sample in order that approximately 33 percent of responses were from Canada, allowing for greater statistical analysis of the results by country than a purely population-driven sample frame would give.
- As well as traditional building or facilities managers, the survey was also to target responses from IT managers within enterprises or buildings and from building owners to reflect the trends in convergence between them. 25 percent of responses were proposed to be from IT managers, 25 percent from building owners
- The remainder of the survey targeted a representative sample by vertical industry (sector), facility size, and sub-region in Canada and the United States.

It should be noted that the Steering Committee was split on whether to include the industrial/manufacturing sector within the survey. By a narrow margin, it was decided to include this sector; however, IHS Markit has endeavored to analyze the results with and without industrial/manufacturing included, to assess whether the inclusion affected the general picture presented by the responses.

Report Structure

Chapter One provides the reader with an introduction to the IoT ecosystem; then drills down into the part that intelligent buildings play in it. The chapter links up some of the key conclusions taken from Chapter 3 of this report. It is broken down into:

- Overview of IoT ecosystem
- The place of intelligent buildings in the IoT ecosystem
- The building automation market
- The connected commercial lighting market
- The physical access control market
- The commercial closed-circuit television (CCTV) market

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Chapter Two starts with an overview of the main analysis, drawing on ecosystem interview and decision maker survey results, analysis and recommendations, to provide a comprehensive summary of the key trends relating to IoT and intelligent buildings.

After the summary, it then explores the main themes identified by the project Steering Committee. During the initial project Steering Committee meetings, the committee identified these themes as central to the development of the roadmap for IoT in intelligent buildings.

IHS has attempted to simplify the 20 issues identified by CABA and the Steering Committee for the purpose of the scope into five main themes, each of which are examined by application and market segment. These themes were developed by the project Steering Committee and shown below.

The scope of this study focused on the IoT within intelligent buildings and thus the results presented on these five themes should be analyzed with this in mind. It is not the intention of this research to suggest that the IoT does not have implications in the wider ecosystem; however, it is possible a wider view of how an intelligent building can support wider IoT initiatives is out of the purview of these interviewees.

Chapter Three presents the overall roadmap for IoT in intelligent buildings. For each main theme, the chapter presents an overview of the research findings along with recommended actions for each main supplier group.

Chapter Four comprises an analysis question by question of the decision-maker survey from the end-user research carried out by IHS Markit, and designed in conjunction with the CABA Project Steering committee members. Again, this is structured to analyze the five main themes agreed by the Project Steering committee.

Appendix A provides the discussion guide used for the ecosystem interviews and the questionnaire used for the decision-maker survey.

Appendix B provides a glossary of terms.

Appendix C provides a list of references.

ES.2 SUMMARY OF KEY FINDINGS

The key findings of the research are discussed in this section with each subsection corresponding to findings within each chapter of this report.

Although there are many factors that will influence the pace of IoT adoption in commercial buildings, several key themes revolve around defining a high value of the IoT in the intelligent building. However, value is relative especially since there are many stakeholders in the intelligent building ecosystem, and different IoT implementations have the ability to create value for each of them.

- Access to data continually drives technology innovation within the intelligent building: Historically the collected data has only been viewed or used by a particular group of individuals, usually on-site, via specialized equipment. As we move to IoT standardized devices, a whole range of individuals can access building data, for a variety of purposes; ultimately driving a wide range of new technology solutions for the intelligent building.
- Overarching trends will impact the development of the commercial market ultimately determining levels of investment available to support IoT adoption including governments or regulatory bodies placing value on IoT technology solutions that can have a measurable impact on their cause, such as energy performance or the health of building occupants.
- A fundamental shift in business strategies from both building operators and suppliers to better support the adoption of IoT solutions signals the value both put on IoT in the intelligent building.

KEY TRENDS IN IOT AND COMMERCIAL BUILDING TEDCHNOLOGY MARKETS – SECTION 1

Internet of Things Overview

It is important to note that the IoT is not a specific device or technology – it is a conceptual framework, driven by the idea of embedding connectivity and intelligence in a wide range of devices. IHS defines an IoT device as one with some form of embedded connectivity that allows it to be directly connected to the Internet (that is, it is IP-addressable) or allows it to connect (be tethered) to an IP-addressable device. This connection can be wired or wireless. These devices can include a range of sensors as well as some type of user interface (UI); but neither a sensor nor a user interface is required under this definition.

The overall ecosystem of IoT is reviewed in ES.2, The ability to collect vast amounts of data in near real-time from this broad range of intelligent connected devices is the foundation of the IoT. This data can then be accessed directly, or via the cloud; and unique value propositions can be created through the application of complex analytics and big data techniques. In this way, the IoT can, and will, be used to provide unique value propositions and create complex information systems which are greater than the sum of the individual components.

Figure ES.3 illustrates the size of the IoT market opportunity. It is projected that by the end of 2025, there will be around 70 billion IoT-connected devices and that annual shipments will have reached 18 billion devices per annum. There are several factors that IHS considered in the development of these projections, which are discussed in more detail in Chapter 1. These include:

- Near-term effects of the sluggish global macroeconomic environment, with a slow housing market and constrained CapEx
- Development of appropriate business models (for each market subsector)
- Consumer acceptance and decreasing costs of connected devices
- IPV6 implementation
- Long-term evolution (LTE network upgrades)
- Advances in processor technologies.

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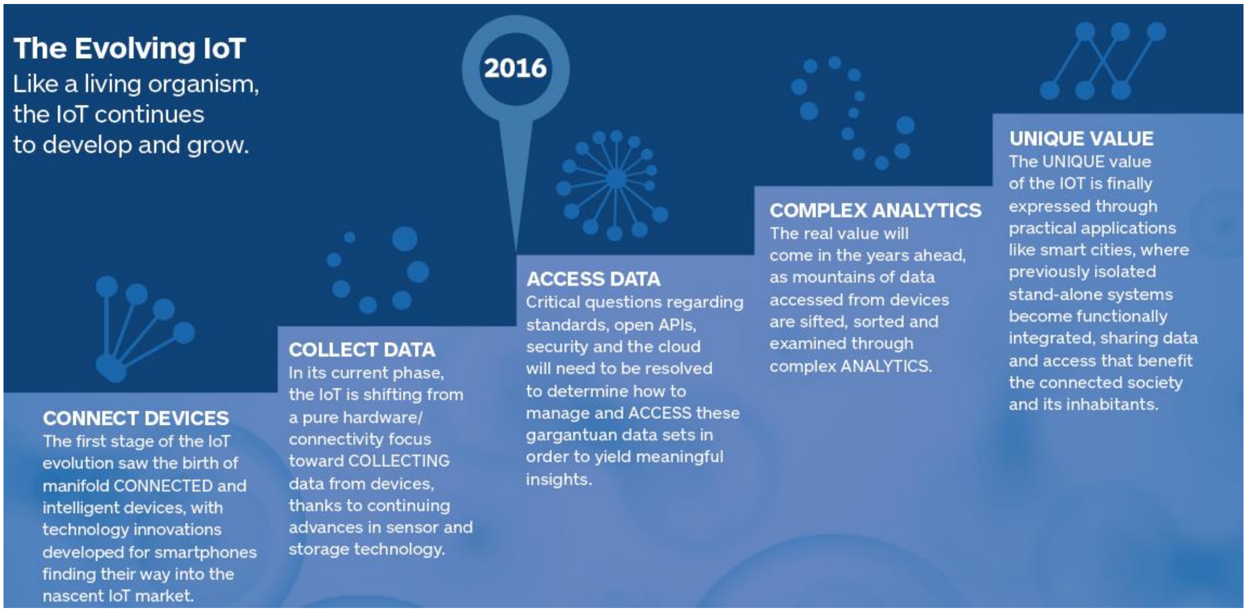
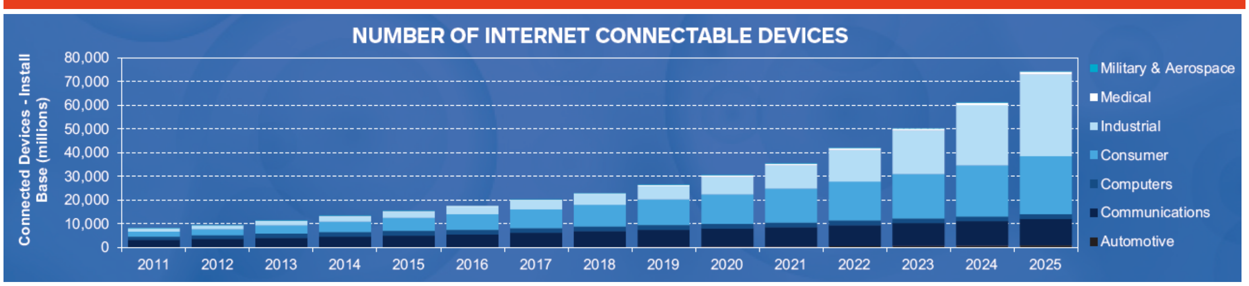
Figure ES.2 Overall IoT Opportunity and Drivers



Source: IHS Markit © 2016 IHS Markit

Figure ES.3 Overall Development of IoT Devices



Source: IHS Markit © 2016 IHS Markit

Introduction to the Development of the Intelligent Building Market

A number of overarching trends will impact the development of the commercial building automation market over the next five years as well as the adoption of IoT to move to an intelligent building:

- Commercial construction spending growth
- Policies, legislation and regulation
- Building certification programs and organizations
- Refurbishments of existing buildings
- Building owner and facility manager requirements
- Education and industry knowledge

More interesting is to look at the key developments of technology being deployed within intelligent buildings and map these developments against the overall IoT ecosystem map as presented in Figure ES.4. It is important to highlight that innovation is driving every layer of the ecosystem at the same time, although interoperability and standardization are trends continually highlighted.

Figure ES.4 Where technology development meets the Intelligent Buildings IoT Ecosystem

IoT Ecosystem	Technology Development	Resulting Industry Technical Challenges
Connecting Devices	Wireless:- Wireless transmission will play an increasingly important role in the specification of building automation systems. However, this will mainly take the form of field-level devices, such as sensors, actuators, and thermostats. The management level of building automation systems will remain wired, because of high bandwidth requirements and the frequent transmission of data within the management level. Protocols used for building automation systems: • EnOcean, ZigBee, Z-Wave • BACnet, LonTalk, KNX technology, Modbus	• Network security • Cybersecurity concerns
Collect Data	Open Protocols: There is a steady move in the building automation industry towards more open products; however, there is a need for these protocols to be Internet Protocol (IP) compatible. This is achieved through vendors using common communication protocols, such as, BACnet, LonWorks, KNX, or Modbus. This enables end-users and system integrators to select best-of-breed equipment and solutions without having to be tied to one vendor for the sake of ensuring compatibility.	• Interoperability challenges • Interoperability moves beyond connectivity and through to analytics.
Access Data	This study would suggest that middleware was a solution to overcoming compatibility issues in the past - The connection between the sensors and the software and different building systems is starting to be taken for granted. A future trend could be towards eliminating the middleware and creating a direct connection between the field devices and the enterprise level. The current connection based on middleware will no longer be necessary as the edge devices and nodes become IP-compatible, as we will not need the translation of data from field devices to IP-standardized enterprise software and hardware. The main difference between collecting and accessing data is the range of users that can access the data. As the industry moves to IoT standardized devices, a whole range of individuals (building owners, facilities managers, utilities, insurance companies, employers, etc.) can access building data, for a variety of purposes,	• Driving cloud computing • Mobile applications • Dashboards • Visualization
Complex Analytics	Building analytics used in intelligent building is defined as software that provides diagnostics to evaluate the performance of a building. The diagnostics are based on data that has been collected from building sensors and utility meters. Includes both building optimization and fault detection analytics. Developing the edge control layer in the intelligent building could be viewed as another initiative that could be used as a tool to allow for complex analytics at the edge of the network, which would help alleviate data storage problems as well.	• Supporting demand response • Intelligent buildings platforms need to interact with BMS

Source: IHS Markit @2016 IHS Markit

DEEP DIVE ANALYSIS OF KEY THEMES – SECTION 2

This chapter combined the research obtained from the decision-maker survey with the information from the ecosystem interviews to address the main themes that were developed by the Project Steering committee. Analysis of the five main themes as follows:

Theme 1 - Realizing the value of IoT

Summary of key message: As technology developments throughout the IoT Ecosystem have come to fruition and continual innovation drives solutions, adoption of IoT solutions in intelligent buildings remains dependent on proving the value of IoT. Although the ecosystem interviews gave perspective on what the suppliers to the industry believed would be of value, the decision-maker survey illustrated this was not always in line with what the customer was actually looking for.

Suppliers often referred to the new and innovative functions that IoT could bring, such as location-based services, pervasive sensing, scenario creation, etc. However, the results from the decision-maker survey illustrated that often the most important developments were to enhance the more traditional building system functions.

It should be noted that the survey only captured a snapshot of viewpoints related to the value added by IoT; but there are many stakeholders in the ecosystem, and different IoT implementations can create value for each of them. For instance, there is value in upgrading and enhancing existing building automation systems with retrofits, although the full functionality and benefit will not always be realized; for that particular project the value in upgrading may be high. Obviously going all-in with construction of a new building is the best approach, but this is not always practical.

Impact of IoT as key issue for the industry to address: Analytics, Dashboards, Real-time Monitoring and Control, Centralized Management, Convergence of Systems, Adaptive Automation, User Interface, Business Case and Economies of Scale, Stakeholder Analysis

Theme 2 – Data Security & Storage

Summary of key message: Concerns remain over attacks, which currently limits the types of technologies chosen to support, with data privacy and storage challenges. IoT and the development of cloud services have opened up new opportunities and business models for ecosystem suppliers to the commercial building systems market. However, many of these new services and business models are predicated on the data generated by the building systems being stored remotely and potentially analyzed by third parties.

Suppliers interviewed indicated they were rolling out or had rolled out cloud-based services for their customers. The decision-maker survey shows that the majority of the sample respondents (68 percent) were not willing to store their building systems' data on third-party systems. Of those that were willing, 11 percent of the total respondents restricted the types of data the third parties could store.

Impact of IoT as key issue for the industry to address: Cybersecurity, Privacy, Data Storage, Data Sovereignty, Gateways and Data Centers, Edge to Cloud Services, Remote Accessibility, Ability to gather and normalize data from disparate systems

Theme 3 – Standardization

Summary of key message: A consistent issue that affects IoT in all application areas is interoperability, and the vast array of standards and technologies that are used to connect devices. Connectivity is at the core of IoT; however, the lack of common standards is also one of its greatest barriers. Interoperability is a concern for both wired and wireless, but it is becoming more of an issue as more wireless retrofit solutions are being introduced to the market, adding to the existing mix of wired protocols. This is the key reason driving the critical need for both wired and wireless solutions to be IP-compatible.

Based on results from the survey, between 18 percent and 27 percent of respondents (depending on system type) used only wireless solutions for individual systems. Physical access control was the system type where wireless only was most prevalent. Lighting was the system type where wireless only was least prevalent.

Impact of IoT as key issue for the industry to address: Interoperability and Open Standards, Cover Connectivity, Middleware Platforms, APIs, etc.

Theme 4 – Ecosystem

Summary of key message: Open ecosystems and cross-vertical, cross-value chain collaboration are crucial in the IoT because much of the proposed innovation and value is due to "mash ups" (e.g., integration) of data from diverse sources, ranging from connected machine and sensor data and traditional ERP/CRM systems, amongst others.

Despite companies reporting they would like a more centralized control of systems, results from the decision-maker survey indicate there are still a number of barriers to achieving this: there are multiple routes to market and the numerous types of customers are buying in different ways.

Impact of IoT as key issue for the industry to address: Existing Players, Emerging IoT Suppliers, Channels to Market, Development of overall supplier ecosystem and the disruption from IoT, Education and Engagement, Emerging revenue models for services

Theme 5 – Business Processes

Summary of key message: At the moment, there are two clear examples of changes in the current business practice of many companies in the intelligent building market in direct response to this increase in control of a building; they are the changing roles of facility managers and a focus on service instead of hardware from suppliers.

The facility manager's role is changing to more of a cooperative partnership with IT in the near to medium term with the facility manager taking on more and more IT responsibility, knowledge and domain expertise as the market matures and the lines between the roles continue to blur in the longer term.

Impact of IoT as key issue for the industry to address: Role of facility managers versus IT managers, Changes in training, roles, processes

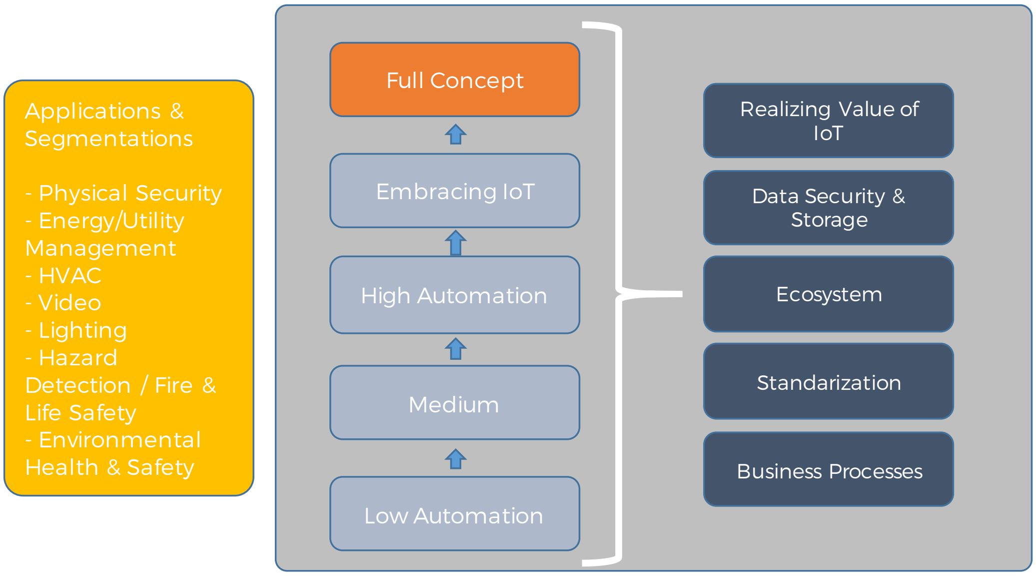
INTELLIGENT BUILDING ROADMAP & RECOMMENDATIONS – SECTION 3

IHS Market has used the data collected from this research to plot a roadmap for intelligent buildings. The roadmap is defined by the respondent groups that have been pulled out in this report and outlined in the previous section. How to move along this roadmap is the key to realizing its full potential. For each major segment, the attitudes, solutions and views relating to the five main themes are examined. Figure ES.6 expresses this map graphically.

Achieving a full-concept intelligent building is a significant step; one which few organizations can claim, as the investment is high to adopt both the leading-edge solutions and centrally controlled solutions. Key attributes for organizations to target adopting a full concept intelligent building include:

- Target companies having nearly all main building functions automated – HVAC, energy management, hazard detection, physical security, lighting and CCTV.
- The systems would also employ leading-edge features, with high levels of systems performing based on building occupancy, location-based set points, external inputs (weather forecasts and energy pricing), integration with A/V equipment, analytics, predictive maintenance, etc.
- It is expected that a mix of solutions for data storage and analysis will be used. Some organizations are expected to have embraced cloud computing using third-party infrastructure to store and analyze data. However, the high level of negative feeling about this means that on-premises or company-owned infrastructure will still be a likely chosen solution.
- Most advanced users have current frustration about interoperability problems and the lack of standardization. Pushing features that demonstrate how these problems can be overcome and that show compliance to industry standards, such as Haystack, will help.

Figure ES.5 Intelligent Building Roadmap - Embracing IoT in Intelligent Buildings



Source: IHS Markit © 2016 IHS Markit

DECISION MAKER SURVEY SUMMARY ANALYSIS – SECTION 4

The conclusion is that some of the potential of IoT is seen as merely 'nice to have'. The most important things that suppliers need to communicate in their marketing are: exactly how IoT will impact the

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bottom line; how it will reduce the energy consumption of buildings; and how it will allow building owners to improve overall financial planning. Table ES.1 highlights the advantages with clear ties to ROI are currently the most attractive to users. Once these points have been made, they can be supplemented by stating other, less obvious advantages that are of interest, but just viewed as 'nice to have'.

A similar message was given from the results to question 2.3, where 11 applications were presented to respondents and they were asked to rank them all from 1 to 7, where 1 was extremely valuable and 7 not of value at all. The results are shown in Figure ES.6. Again the author concludes that the more traditional, more obvious applications have the greatest value for decision makers. Information on the building system status and the likelihood of failure were the applications that received the highest scores. The more imaginative, less obvious applications, such as "ability to create rules / algorithms based on the needs of your building", "integration with weather systems for historical comparisons as well as future energy & maintenance forecasting" and "use of advanced algorithms to recommend location-based set points based on usage and occupancy" were generally viewed as significantly less valuable.

IHS Markit devised a scoring system for each response that allowed the responses to be normalized on a 10-point scale for comparison purposes. To do this, each response was given a score. Four was given for a selection of option 5, three for option 4, two for option 3 and one for option 2, A score of zero was given for option 1. The score was combined for all responses across all building system types. The total was then re-based so that the system type that had the lowest score was set to zero and the system type with the highest score set to 10. The results are displayed in Table 4.10.

Table ES.1 Most attractive advantages that IoT in building automation can bring

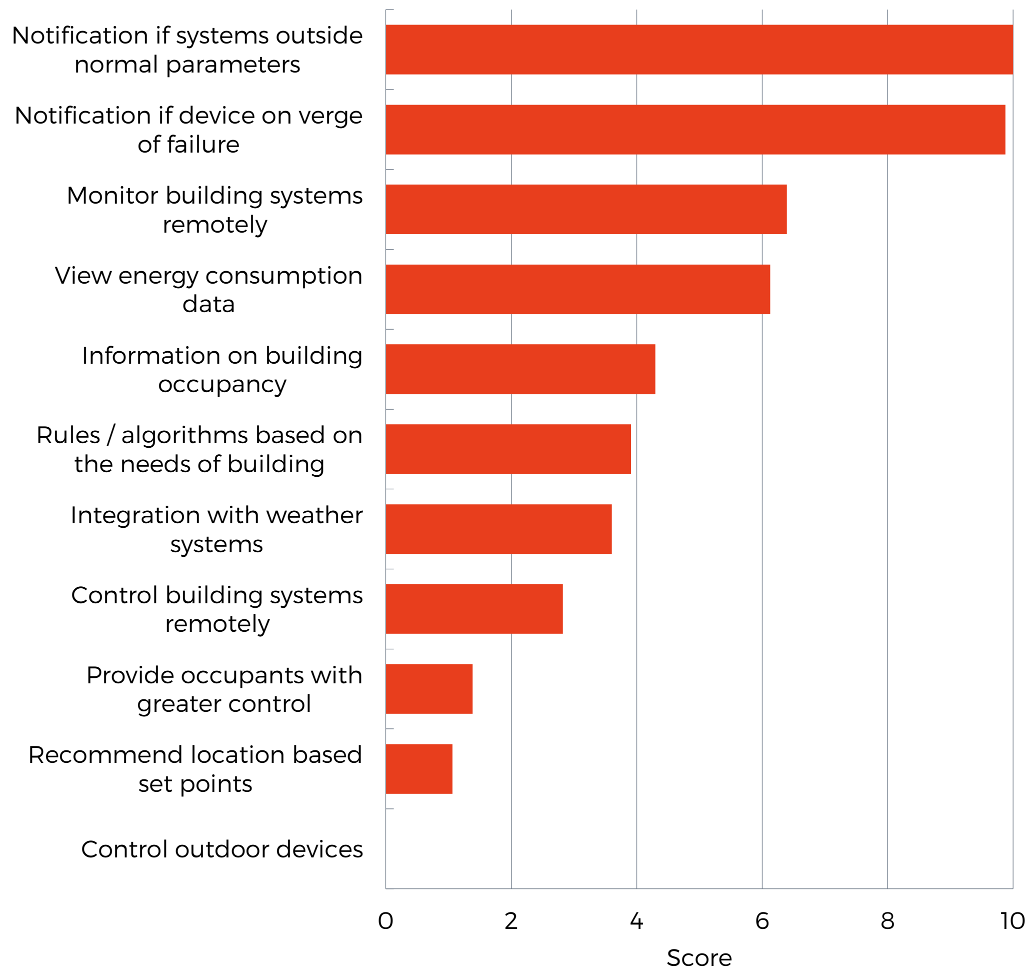
	Total	Industrial	Non Industrial	Auto High	Auto Med	Auto Low
Reduce energy consumption	7.9	8.7	7.6	8.8	5.5	10.0
Improve operational efficiency	4.5	4.9	4.4	4.1	3.9	5.4
Enable predictive maintenance	3.7	3.1	4.0	3.1	4.2	3.2
Improve financial planning	10.0	10.0	10.0	10.0	10.0	8.2
Provide remote access	0.4	-	0.6	0.8	0.5	0.7
Future proof	-	0.3	-	0.5	0.1	0.4
Increased use of sensors	0.4	0.3	0.5	3.2	-	-
Open standards	1.7	2.2	1.6	1.0	2.8	0.6
Increase building performance data	3.9	4.5	3.8	6.6	3.7	2.4
Improve occupant comfort	1.0	1.2	1.0	1.0	0.6	2.2
Improve occupant safety	0.1	0.4	0.1	-	0.3	0.9
Improve tenant/employee productivity	2.0	3.7	1.5	1.7	1.7	3.0
Increase building resiliency	2.1	0.9	2.5	4.2	2.1	1.0

All respondents, n=150 Source: IHS Markit

Figure ES.6 focuses mainly on the value of IoT solutions for operations and not for occupants. Several interesting conclusions can be pulled from this one question posed to decision-makers:

- The top four applications were all those that are relatively well documented for how intelligent buildings could function. The slightly more out-of-the-box functions, such as occupancy information, weather system integration, and location-based set-point recommendations, were scored lower, but did receive more than 30 percent of respondents ranking them within the top three.
- When analyzed by major segment, there was little variation in the profile of those applications that scored higher or lower. One slight difference was those that already fell into the high automation segment did value a little more the newer types of service listed above; indicating that their attractiveness is perhaps linked to awareness of what they can potentially offer.
- Geolocation in a building is an IoT application and could possibly be considered in the "information on building occupancy" category in the below table, if there is the ability to do highly accurate indoor location utilizing mobile devices and enterprise WLAN access points. However, the question does not specify this type of use case.
- It is interesting to note that remote monitoring ranks high on the list although remote control is much lower, which may be due to cost and equipment lifecycles instead of a large reaction to cybersecurity measures. Remote monitoring can be relatively easily added with wired or wireless retrofit components (sensors), but remote control generally requires replacing more expensive pieces of equipment with systems that are compatible with remote control.

Figure ES.6 - Application Value - Score



All respondents, n=150

SECTION 1

KEY TRENDS IN IOT AND COMMERCIAL BUILDING TECHNOLOGY MARKETS

INTRODUCTION

This report presents findings and conclusions from the CABA Landmark Study "Intelligent Buildings and Impact of the Internet of Things". The executive summary of this report includes the following background on this research:

- About the Report
- Introduction and Project Background
- Role of the Steering Committee and Funders
- About CABA
- About IHS Markit
- Overview and Methodology of Research
- Report Structure

Section 1 is intended to provide the reader with an introduction to the Internet of Things (IoT) ecosystem, the IoT within the intelligent building, and then to briefly review how intelligent buildings play in the wider ecosystem (as this last segment is out of scope of the interview questions for this research). The chapter links up some of the key conclusions taken from Chapter 3 of this report. It is broken down into:

- Overview of IoT ecosystem
- The place of intelligent buildings in the IoT ecosystem
- The building automation market
- The connected commercial lighting market
- The physical access control market
- The commercial Closed-circuit television (CCTV) market.

1.1 INTERNET OF THINGS OVERVIEW

The world is becoming increasingly digital, driven by the potential for near-ubiquitous connectivity, continually decreasing costs of processing and sensor solutions, and the ability to use the internet to facilitate communication between electronic devices. As such, we are in the early stages of the IoT – a technological evolution that is based on how connected devices can be used to enhance communication, automate complex industrial processes, strengthen customer relationships, and provide a wealth of information that can be processed into useful actions aimed to make our lives easier.

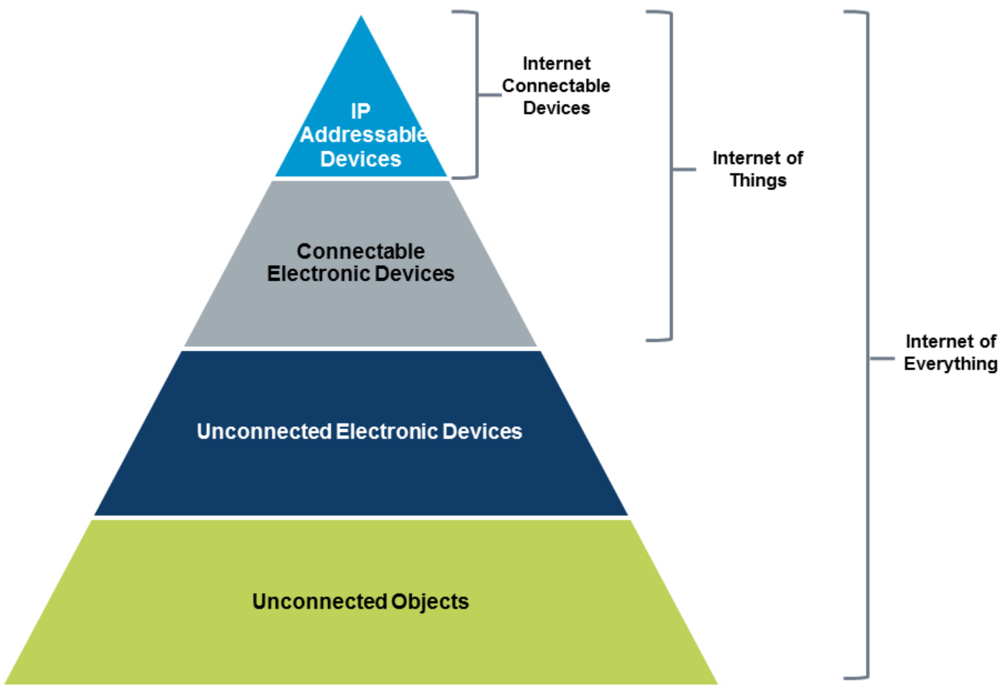
The term "Internet of Things" was first used in 1999 by Kevin Ashton as part of a theoretical concept for increasing the potential of automating systems by assigning computer data representing the location and status of objects in the physical world. His initial approach involved a much greater reliance on RFID tags for physical objects, to allow them to be inventoried and tracked with little to no human interaction for a more robust system for automating replenishment and inventory control systems. The concept has been expanded and now encompasses concepts such as condition monitoring, automated control, location-based services, and even augmented reality.

Internet of Things definition

It is important to note that the IoT is not a specific device or technology – it is a conceptual framework, driven by the idea of embedding connectivity and intelligence in a wide range of devices. IHS defines an IoT device as one with some form of embedded connectivity that allows it to be directly connected to the Internet (that is, it is IP-addressable) or allows it to connect (be tethered) to an IP-addressable device. This connection can be wired or wireless. These devices can include a range of sensors as well as some type of user interface (UI); but neither a sensor nor a user interface is required under this definition.

The ability to collect vast amounts of data in near real-time from this broad range of intelligent connected devices is the foundation of the IoT. This data can then be accessed directly, or via the cloud; and unique value propositions can be created through the application of complex analytics and big data techniques. In this way, the IoT can, and will, be used to provide unique value propositions and create complex information systems which are greater than the sum of the individual components.

Figure 1.1 - Internet of Things Hierarchy



Source: IHS Markit © 2016 IHS Markit

IHS has included both unconnected objects as well as unconnected electronics devices in this hierarchy. The reason for this is to show the distinction between the extent of the "Internet of Things" as well as the "Internet of Everything," which is even broader in scope. In many ways, the Internet of Everything (IoE) is closer to Kevin Ashton's original definition of the IoT, with technologies such as RFID being used to tag even unconnected, non-electronic objects, to allow them to be identified, and potentially to interact with, IoT devices.

Based on this definition, machine-to-machine (M2M) communication is included as a sub-set of the IoT overall. IHS defines M2M as communication between machines, devices, and equipment with little or no direct human interaction. The transmission of data and information between these machines and devices can occur over a wired, wireless, or hybrid network. In the context of the IoT, many other types of interactions are included as well: machine-to-people, people-to-machine, machine-to-objects, people-to-objects, etc.

The current interest in the IoT from a device and connectivity standpoint is in the potential for devices and objects to move from one category to the next. Many see this as the immediate growth opportunity for IoT: the diverse array of devices and objects that will incorporate connectivity to allow them either to connect directly to the Internet, or to be tethered to a device that can.

It is important to note that categories shown in Figure 1.1 and described in the following sections represent Total Available Market (TAM) segments and define potential IoT market opportunity rather than the current connectivity status.

IP-addressable devices

An IP-addressable device is any device that can connect to the Internet directly and has a unique IP address. Internet-connected devices can range from an IP-addressable sensor module and telemetry devices (such as an M2M module) to powerful computing devices with a full operating system (OS) and a rich UI (usually a smartphone or laptop).

Connectable electronic devices

Devices in the "connectable electronic device" category can connect directly to another device and transmit some level of information. However functionality can vary widely, and is often restricted to a specific existing use-case. One example is a wireless speaker that can be used for playing an audio stream from another device. What is interesting about devices that fall into this category is they already have some level of connectivity built in, and could potentially play a larger role in the broader IoT ecosystem in the coming years. For example, the wireless speaker in the previous example could potentially be incorporated into a smart home network and broadcast alerts from other devices within the home.

Unconnected electronic devices

These devices currently cannot communicate or transmit data to other devices. Since they are electronic devices, the potential exists to begin incorporating connectivity in them, either when they are manufactured, or through retrofitting using an add-on module. As the price of wireless integrated circuits (ICs) has fallen, many manufacturers have begun to look at adding connectivity as a way to differentiate their products, as well as to offer new services. Recent examples in this category are personal printers and television sets in the consumer sector, and streetlights and parking meters in the industrial category.

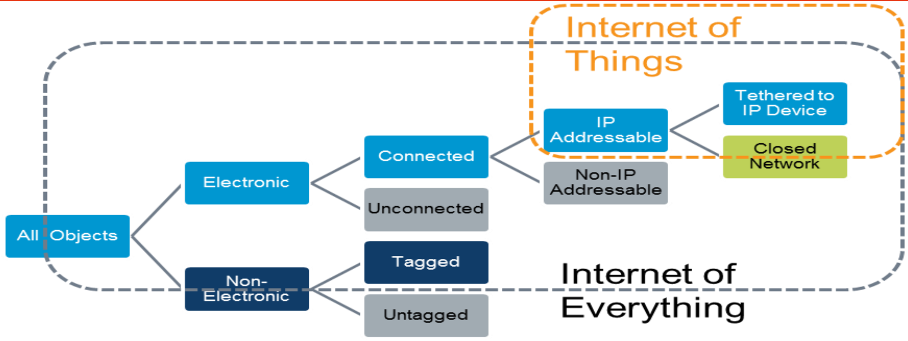
Unconnected objects

This category encompasses all of the other physical objects in the world, from desk chairs to pet collars. Depending on the IoT/IoE use-case, methods to allow these objects to be recognized as part of the IoT/IoE could range from basic RFID tagging to adding complex M2M modules with environmental sensors.

This is a potentially vast segment of the market, which IHS does not forecast at present because it is challenging to size accurately, and because the forecast itself would not convey a meaningful view of the market potential at any point in time. However, when considering the possibilities for IoT over the long term, there is good reason for optimism that eventually it will be a world of trillions and not billions of connection points. The use-cases are limited only by the imagination.

This hierarchy of connected devices is illustrated in Figure 1.2

Figure 1.2 - Connected Devices Hierarchy



- **Unconnected Objects:** Desk, chair, soda can, fire hydrant, animal collar, shipping pallet, buildings, etc.
- **Unconnected Electronic Devices:** Calculator, streetlight, vending machine, coffee maker, blood pressure monitor, etc.
- **Connected/Tethered Electronic Devices:** Audio headset, printer, computer monitor, DVD player, licensed mobile radio unit, etc.
- **IP-addressable Devices:** Tablet PC, smartphone, Infotainment head unit, smart meter, EV charging station, home health hub, etc.

Source: IHS Markit © 2016 IHS Markit

Approach to categorizing the Internet of Things

The IoT ecosystem divided into seven main categories, which are shown in Figure 1.3. This report focuses on the intelligent building roadmap and the part that IoT has to play in it. Although IHS has defined one category as 'industrial, in reality devices that interact with the IoT ecosystem from several of these categories, including communications, and IT. Therefore it is important that the reader understands the market drivers across the ecosystem; and how the ecosystem interacts with the intelligent building.

Figure 1.3 - IHS Approach to Categorizing IoT Market Segments

Automotive
- Infotainment
- Under-the-hood

Communications
- Consumer Customer-Premises Equipment (CPE)
- Enterprise Customer-Premises Equipment (CPE)
- Last-mile Access
- Backbone
- Mobile Handsets and Infrastructure

Information Technology
- Desktop
- Server
- Portable Computing (Netbook, Notebook & Tablet)

Medical
- Consumer Medical
- Imaging
- Other Medical

Industrial
- Building Automation
- Commercial Transportation
- Retail Electronics
- Industrial Automation
- Lighting
- Power & Energy
- Security
- Test & Measurement
- Other Industrial & Commercial

Consumer
- Home Appliance
- Home Automation
- Home Consumer Electronics
- PC Peripherals & Office Equipment
- Portable Consumer Electronics
- Smart Toys
- Sports & Fitness
- Other Consumer

Military & Aerospace
- Commercial aerospace
- Military equipment

Source: IHS Markit © 2016 IHS Markit

Ecosystem development and market opportunity

Figure 1.4 illustrates the size of the IoT market opportunity. It is projected that by the end of 2025, there will be around 70 billion IoT-connected devices and that annual shipments will have reached 18 billion devices per annum.

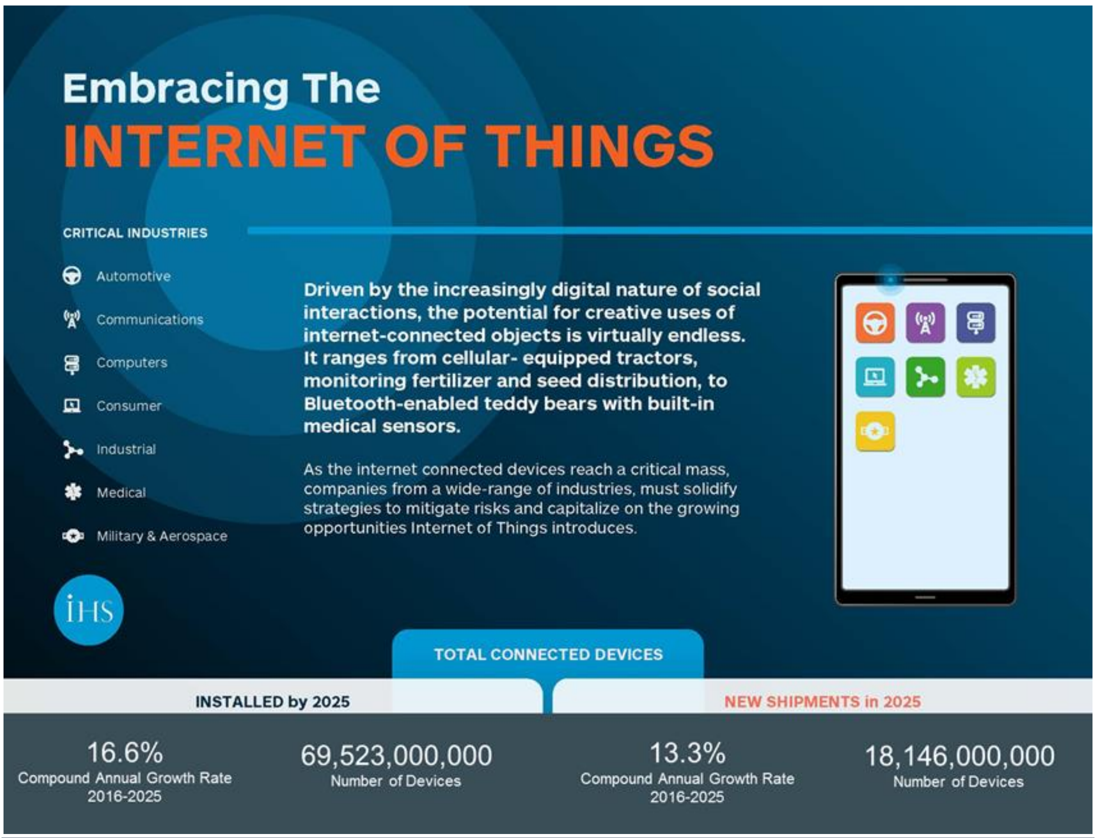
There are several factors considered in the development of these projections. These include:

- Near-term effects of the global macroeconomic environment
- Development of appropriate business models (for each market subsector)
- Consumer acceptance
- IPV6 implementation
- LTE network upgrades
- Advances in processor technologies.

Although the first three factors represent potential barriers, the last three are seen more as enablers of a broader ecosystem of internet-connectable devices.

The following section provides some additional discussion for each of these factors and gives some context for how they affect the internet-connectable device market overall.

Figure 1.4 - Overall IoT Opportunity and Drivers



Source: IHS Markit © 2016 IHS Markit

Potential barriers

Although the following issues represent very real barriers to the growth of the market for Internet-connected devices, all of them are surmountable given enough time, creative thinking, and careful implementation. Consumer education will be a key point, as will careful evaluation of the business model to avoid advocating change for change's sake. In particular, IHS believes that the next two to three years will see slow uptake as a result of the following:

Global economy – According to the latest Global Industry Outlook from IHS Economics and Country Risk, the global economic recovery is still sluggish, although there are some bright spots, especially related to the industrial sector. A few points to consider:

- The economic outlook remains mixed, with the situation continuing to differ markedly between regions. For the near future, increasing global growth in economic activity will be driven by the more developed regions, notably the United States. Gross domestic product (GDP) growth rates will be higher in developing economies, notably China; however, the projected growth rates will be lower than in recent years.
- Europe is very slowly dragging itself out of recession. Real GDP in the Eurozone is projected to increase by 1.5 percent in 2016. This improvement is based on expected improvements in financial markets, stronger fiscal conditions, and the benefits resulting from structural reforms. However, following the UK referendum vote to leave the European Union, there is heightened uncertainty and a forecast weaker economy for Europe in general, and for the United Kingdom in particular, in 2017 and beyond.
- The outlook in the United States remains stronger than in Europe and real GDP is forecast to grow more strongly in 2016 and 2017, by 1.9 percent and 2.4 percent, respectively. Export markets are improving, and the positive effects of the unconventional gas and oil boom are feeding into the general economy, though the recent slump in oil prices has reduced the net benefit. The pace of capital spending is increasing, but the rate of growth is forecast to be slower than in previous cyclical recovery periods.
- Japan's economy has been struggling, in part, with disappointing exports as the world economy continues to falter. Real GDP is currently predicted to grow by 0.5 percent in 2016 and by a further 0.7 percent in 2016; a weaker yen will help exports, though increases in sales tax will restrain consumer spending.
- GDP growth in China is forecast to be lower than historical levels for the next few years. Growth is predicted to be 6.6 percent in 2016 and 6.3 percent in 2017. China's economy is not yet on solid ground, with very high local government debt and vulnerabilities in banking and real estate. The focus of Chinese policy is shifting to a degree from industrial production to consumer infrastructure and domestic demand, consistent with maintaining financial stability.

Limited consumer spending – This will have the greatest effect on the uptake of consumer devices, and on consumer interest in new types of connected devices, including; smart appliances, home automation, and connected consumer devices, especially those that will require additional data plans.

Sluggish housing market – New home construction is predicted to remain stagnant, which will have an effect on all the equipment categories associated with smart homes, including home automation, smart appliances, and smart metering. Consumers are far more likely to implement these technologies as part of a new home purchase than to retro-fit existing homes and/or upgrade existing appliances.

Constrained industrial capital expenditure (CapEx) – Although IHS believes that the potential for industrial Internet-connected devices is considerable, there is a fair amount of uncertainty over how long this market will take to fully realize that potential. When considering the near-term forecasts in particular, it is important to consider the global economic climate and its damage to the near-term prospects for connected devices. In particular, IHS forecasts that the next one to two years will continue to see slow uptake as a result of constraints on industrial CapEx.

Lower industrial capital expenditure means less frequent equipment upgrades and fewer implementations of new technologies. IHS does predict some spending on new, more advanced industrial automation and related technologies, specifically in the areas that would improve efficiency and offer a quick ROI. However, strong growth is not predicted until nearer 2019.

Business models – As indicated in the previous section, a compelling business case with a solid ROI is required for equipment manufacturers, end-users and service providers that are considering investment in Internet-connected devices. Although some business models are well defined and easily quantified (improvements in factory automation to increase productivity and efficiency) others are not as clear-cut. For example, when considering the market for smart appliances, a situation exists whereby manufacturers do not want to commit fully to integrating connectivity into their product lines until the corresponding smart grid infrastructure exists to support it. At the same time, the lack of smart appliances is one of several factors hampering the uptake of the smart grid. One reason for this is that it is unclear if consumers want this integration enough to pay a premium for the smart grid, because it has not been made clear to the average consumer how it would be used to create value for them, and how much that value would be.

This is not a situation that is unique to the smart home, and exists for other markets ranging from smart TVs to connected telematics.

Consumer acceptance – A third, critical factor that is directly related to this is consumer acceptance of a broader range of Internet-connected devices. One of the potential benefits for consumers (and businesses) of a more connected-device ecosystem is that they can expect more tailored services, products, and even billing statements. However, this requires information to be shared, sometimes with multiple parties. This report often returns to this theme. In general, the feedback from the consumer survey is positive, in that if handled correctly, concerns about privacy and data sharing can be surmounted. However, after cost, respondents to the survey saw loss of privacy as the greatest barrier to purchasing smart home products; so it is a real issue that consumer IoT ecosystem suppliers need to address carefully.

Potential enablers

IPV6 implementation – One of the important enablers for the overall growth of the Internet-connected device ecosystem is the transition from Internet Protocol Version 4 (IPv4) to Internet Protocol Version 6 (IPv6). This is important because each Internet-connected device must have a unique address. The IPv4 protocol used a 32-bit address scheme, which maxed out at 4.29 billion unique addresses. The IPv6 protocol uses a 128-bit address scheme, which can potentially accommodate 3.4×10^{38} addresses. This will be critical, as the number of connected devices continues to increase, approaching the 20 billion, and in time, the 50 billion device mark.

Although the IPv6 rollout is under way, the transition is expected to take several years. While implementations are accelerating in developed countries, many emerging markets are only beginning to consider a migration plan.

LTE network upgrades – One of the main areas of interest for wireless M2M (both consumer and industrial) is the use of cellular networks. For consumer devices, including tablets and laptops, higher speed networks are critical, because rich media streaming is extremely bandwidth-intensive. When considering the potential for cloud-based services and applications, the capabilities of LTE networks are important. In general, the demand placed on cellular technology from consumer and M2M applications are very different. For most consumer devices, including smartphones and tablet PCs, the data rates required to provide a satisfactory experience typically necessitate 3G or 4G connectivity. With these technologies, users can access a true mobile broadband experience that enables functions including Web browsing, social networking, and access to multimedia content. IHS estimates that in 2015 over half of the world's active mobile subscriptions were on a 3G or LTE networks.

Conversely, the data requirements of most industrial M2M vertical markets are much more modest. Most large-scale applications, including EFT-POS machines, security alarms, and electricity meters, transfer only limited amounts of data at infrequent intervals. Modules using 2G air interface technologies (GPRS, EDGE) are generally more than capable of providing the required data transmission rates.

There are increasingly M2M applications that demonstrate a need for the higher transmission rates provided by 3G and 4G modules. In 2015, this development was limited to a few M2M vertical markets including consumer automotive (specifically for infotainment systems), fixed wireless terminals, and digital signage. IHS predicts that as M2M markets mature from 2015 to 2020, there will be corresponding increases in the development of more data-intensive applications in many vertical markets, which will contribute to the increase in 3G and 4G module shipments from 2013 to 2019.

Given the limited data requirements of most M2M applications and the lower cost of 2G modules, it would seem that the uptake of modules using more advanced air-interface technologies will remain limited in M2M communications. However, an emerging consideration, which must be taken into account and which will act as key driver for the use of 3G and 4G modules, is network obsolescence. Mobile operators will begin to phase out older 2G networks in the coming years so they can reallocate spectrum to newer 3G and 4G networks.

For the most part, future-proofing is less important in consumer devices, which are generally replaced every 24–36 months. It is important in M2M applications incorporating cellular technology, because devices and systems are often designed to have a longer life span. In the case of automobiles, electricity meters and many infrastructure-related devices, this could reach up to 10–15 years. Any equipment manufacturers choosing to use a 2G technology must therefore consider the possibility that they might need to replace legacy embedded modules, or simply have to "turn off" a service to existing customers. One notable example of this occurred in 2008, when General Motor's OnStar had to terminate service to approximately 500,000 subscribers in North America whose systems still used analogue cellular technology. IHS forecasts future-proofing will have a greater impact on the global M2M module market closer to 2019, as more carriers in Europe and Asia enhance their 3G and 4G networks. However, the issue is clearly already having an influence in the North-American market, where AT&T has taken measures to move existing M2M customers to 3G and is no longer certifying new M2M applications for use on its 2G spectrum.

Advances in processor technologies – IHS considers one of the most important issues related to Internet-connected devices is the potential to enable Internet connectivity in a wide range of devices which previously were unconnected. This is most relevant to the industrial sector and the related medical sector. As devices that were previously not internet-connected begin to make the transition to becoming IP-addressable, the importance of low-power processors which can be implemented in a wide range of industrial applications will be critical. Not all of these previously unconnected devices will have ready access to power, and will need to rely on batteries, driving the need for highly efficient, low-power processors.

The first key point is that connectivity processor prices continue to fall because of the introduction of a new product mix with growing performance at lower average selling prices. Processor performance continues to improve and connectivity stacks for nodes continue to drop to much lower processing requirements than for previously generic host controller connectivity stacks. Combined, this is bringing down the total cost of adding connectivity to a device. What this means for manufacturers and businesses which are looking at the cost of adding Internet connectivity to a device is that they can get a powerful processor for less money, or possibly even move down a processor class (32-bit to 16-bit, or even 8-bit) for even less, while still meeting the communications processing requirements.

The second key point is that the power-management capabilities of these processors, especially the ability to use a power-saving state, such as hibernation or sleep, can be especially important for industrial devices. Many of these new internet-connected devices, especially those classified as nodes, will have a battery operating life as long as five to ten years or have energy demands low enough to be sustained by regenerative power sources including solar panels. This is a far cry from consumer devices, which generally have more ready access to power, and much shorter replacement cycles, so the natural cycle of processor improvements keeps these devices performing at a high level.

The industrial sector has many subsectors, each of which has a considerably different ecosystem with different criteria for processor selection. As a whole though, industrial machinery and commercial equipment markets generally evolve more slowly; and the most important specifications tend to be for safety, reliability and longevity.

Vertical IoT ecosystem development

The industrial sub-sector is the part of the IoT ecosystem projected to offer the largest market opportunity, with a projected 28 billion IoT connections by the end of 2025. It is also the sector most relevant to this report as it includes many of the device types affected by IoT in intelligent buildings, such as in building automation, power and energy, commercial physical security, and industrial automation. The following parts of the IoT ecosystem are captured in this sub-sector and discussed further in Figure 1.5:

- Building automation.
- Commercial transport.
- Retail electronics.
- Industrial automation.
- Commercial and street lighting.
- Power and energy.
- Commercial security.
- Test and measurement.
- Other industrial.

Figure 1.5 - IoT in Industrial Applications

Source: IHS Markit © 2016 IHS Markit

1.2 THE BUILDING AUTOMATION MARKET

This section of the report looks to give the reader a top-line overview of the state of the building automation market. IHS Market defines this market as:

- Building automation controllers (including: fixed function controllers, configurable controllers, programmable controllers, programmable logic controllers, variable air volume controllers, wireless controllers, IP controllers, field controllers, and management controllers)
- Building management software
- Building automation sensors (including: temperature sensors, humidity sensors, air quality sensors, pressure sensors, occupancy, light and motion sensors, multi-function sensors, and wireless sensors)
- Building automation actuators (including: damper general purpose, damper fire and smoke, variable air volume actuators, valve actuators, water valve actuators, wireless actuators, water valve actuators, and IP actuators).
- Building automation human machine interface (HMI) screens
- Building automation gateways

A number of overarching trends summarized in the following pages, will drive the commercial building automation market over the next five years:

- Commercial construction spending growth
- Policies, legislation and regulation
- Building certification programs and organizations
- Refurbishments of existing buildings
- Building owner and facility manager requirements
- Education and industry knowledge
- Technology trends

Policies, legislation, regulation and certification

Policies, legislation, regulation and certification directly affect demand for building automation equipment. The following reviews recent notable changes.

Policies, legislation and regulation stipulate mandatory rules for building owners and other construction stakeholders; changes may have a very large effect on the market for building automation equipment. For example, legislation could require a building to have a certain product installed, such as a carbon monoxide sensor in an underground car park. Alternatively, legislation could also stipulate that new buildings remain carbon neutral by a given date. In this instance, building automation systems will form a critical part of meeting this legislation, ensuring each new building is carbon neutral. As a result, there is often correlation between new pieces of legislation and sales of building automation equipment.

Below is a list of notable policies, legislation and regulations that may influence the building automation equipment market:

Legislative activities

- The Australian Carbon Tax – From July 1st 2012, the Australian Federal Government introduced an emissions trading scheme (referred to as a carbon tax), charging $23AUD per ton of carbon dioxide emitted by selected fossil fuels. This incentivizes building owners to reduce carbon dioxide emitted by their buildings to reduce tax payments based on their energy consumption.
- Mandatory Energy Performance Certificate (EPC) in the United Kingdom – As of January 9th 2013, all newly constructed commercial buildings must have an EPC. The EPC will include recommendations for increasing the energy efficiency of the building.
- Commercial building lighting in France – From July 1st 2013, all office buildings, shops, malls and other commercial buildings are required to close windows and turn off all interior and sign lighting from 1 am to 7 am.
- The first statewide green building code in the United States was the 2010 California Green Building Standards Code which aimed to establish minimum green building standards for the majority of residential and commercial new construction projects in the state.
- In May 2014, Germany launched a new Energy Savings Ordinance, or EnEV 2014. From 2015 on, the regulation required the replacement of oil and gas boilers that are older than 30 years if they are not subject to one of the many exemptions. It might bring solar thermal an increased market volume, as new fossil boilers are often supplemented by solar collector systems. But in the case of new buildings, the regulation favors heat pumps, making it likely for solar thermal to lose market share.

Standards

- The WELL Building Standard (WBS) – This standard a set of specifications conceived by the International WELL Building Institute (IWBI) for measuring and certifying aspects of the built environment impacting the health and well-being of the building's occupants. The WBS measures seven different variables within the buildings impacting the occupants' health, including; air, water, light and comfort, etc…
- Paris and Cisco launched a pilot using Cisco Energy Management (CEM) collecting data to be used to better understand the city's energy consumption. The CEM gathers information for selected buildings from sensors which collect data on humidity, noise level, and other variables. The data is then used by Paris for multiple purposes including improving buildings' efficiency.
- The Kyoto Protocol - A globally applicable protocol that sets country-specific targets for reducing green-house gas (GHG) sources. As commercial buildings are a major contributor to GHG emissions, governments worldwide have been prompted to introduce measures to cut emissions of GHG by commercial buildings.

Policies

- The California Public Utilities Commission (CPUC) – The CPUC has targeted all non-residential buildings to be energy neutral by 2030.
- Public disclosure of energy consumption in New York – Commercial building owners in New York must publicly disclose the energy consumption of their buildings. With energy consumption now publicly visible, companies will be incentivized to reduce energy consumption to show a public commitment towards reducing the environmental impact of their company.
- European Energy Performance Directive 2010/21/EU – Aims to promote better energy performance of buildings within the European Union, taking into account the outdoor climate and local conditions, as well as indoor climate requirements and cost effectiveness.
- The Development of Green Buildings in China – The Chinese government has set a goal of having green buildings account for 30 percent of new construction projects by 2020.

- Launched in January 2013, the Green Deal is the UK government's flagship program to help improve the energy efficiency of British homes and businesses. The Green Deal makes it possible for some of the cost of improvements to be paid for from resultant savings on energy bills. The Green Deal provides a framework of accredited market participants, through which people pay for some of the cost of improving their homes and businesses using a type of loan which is paid back with the savings they can expect to make on their fuel bills. It is hoped that by 2020 the Green Deal initiative could save UK homes and businesses 4.5 metric tons of carbon dioxide ($MtCO_2$) per year, while helping millions to improve the comfort of their homes and control rising energy bills. While the Green Deal initiative will take time to establish itself, the early signs are encouraging and includes contracts worth over £130 million under Energy Company Obligation (ECO) brokerage. Nearly 3,000 companies have also been approved to operate under the Green Deal.

Building certification programs and organizations

Building certification programs and organizations are a source of industry standards. Typically they are region-specific, such as EU Eco-Management and Audit Scheme (EMAS), Emirate Energy Star, and Comprehensive Assessment System for Built Environment Efficiency (CASBEE); but may also be internationally recognized, such as Leadership in Energy and Environmental Design (LEED). While there is no legal requirement for building owners and builders to conform to certifications, there are several advantages associated with gaining them.

These advantages include:

- Increased chance of successfully gaining tenants – A LEED-certified building is often believed to be an attractive proposition for potential tenants. Gaining this certification shows that both the efficiency of the building and the comfort of the tenants have been carefully considered by the building owner. As well as increasing the likelihood of filling the building with tenants, the building owner may also be able to charge higher rent based on lower energy costs.
- Eligibility for grants – Some grant systems reward the building owner or builder for adhering to a green certification. The grant can aid the ROI or be used to fund further improvements to the building. An example of this can be found in China, where commercial buildings that conform to the '2 Star Rating' receive a one-off grant of 45RMB per square meter of green space, while commercial buildings that conform to a '3 Star Rating' receive 80RMB per square meter of green space.

Below is a list of building certification programs and organizations that may influence the building automation equipment market:

- Continental Automated Buildings Association (CABA) – CABA is a not-for-profit industry association. It is an organization supported by an international membership of 350 plus organization involved with the design, manufacture, installation and retailing of products related to home and commercial building automation.
- World Green Building Council (GBC) – The World GBC is a coalition of Green Building Councils. Its mission is to facilitate building industry moves towards sustainability. The World GBC also provides support for local councils with its local green building initiatives. The World GBC also promotes the World Green Building Week and Common Carbon Metrics project. The World GBC collaborates with international bodies, including: The United Nations Environment Programme (UNEP) Sustainable Building and Climate Initiative (SBCI), The Sustainable Buildings Alliance (SBA), and the International Union of Architects (IUA).
- European Union Eco-Management and Audit Scheme (EMAS) – EMAS was established in 1995 to ensure better management of environmental issues and continual improvements in environmental performance of companies and other organizations.
- Building Research Establishment's Environmental Assessment Method (BREEAM) – BREEAM assesses and rates buildings based on recognized measures which are set against established benchmarks to evaluate a building's specification, design, construction and use. BREEAM is used by clients, planners and development agencies, investors, developers, property agents, design teams and facility managers.
- Green Globes – Green Globes was developed using BREEAM in 1996, creating an assessment and rating system for buildings. Since 1996, the rating and assessment system has undergone various iterations. Since its creation, the Green Globes systems have been endorsed by CABA and in 2005 was accredited by the American National Stands Institute (ANSI).

- The WELL Building Standard (WBS) is a set of specifications conceived by the International WELL Building Institute (IWBI) for measuring and certifying aspects of the built environment impacting the health and well-being of the building's occupants. The WBS measures seven different variables within buildings, which impacts the occupants' health, including: air, water, light and comfort, etc…
- Leadership in Energy and Environmental Design (LEED) – LEED is an internationally recognized green building certification system. Developed by the US Green Building Council (USGBC), LEED is intended to provide building owners and operators with a framework for enabling green building design, construction, operations and maintenance.
- American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) – ASHRAE is an international organization which aims to advance heating, ventilation, air-conditioning, and refrigeration. ASHRAE provides research and development as well as training publications. Since June 1987, ASHRAE Standard Project Committee (SPC) 135 has actively developed the BACnet protocol.
- The Emirates Energy Star – Is an organization in the Middle East that awards certification based on the percentage of energy savings made in a building. The goal of Emirates Energy Star is to reduce the carbon footprint of buildings in the United Arab Emirates (UAE).
- Comprehensive Assessment System for Built Environmental Efficiency (CASBEE) – CASBEE is a Japanese certification program that measures and assesses energy efficiency in commercial buildings.
- Historically, building certification has been focused primarily on building envelope, construction methods and waste management. However, increasingly more attention is being paid to electronic technologies commonly found in a building, such as building automation equipment. As electronic equipment becomes more widely adopted, certification programs could increasingly require building automation to be used in commercial buildings.

Refurbishment of existing buildings

A refurbishment project typically includes a replacement of existing building automation equipment, or the installation of a new building automation system in a building that previously had no building automation equipment.
The following benefits have been identified:

- Enhanced value – Installing new building automation equipment typically enhances the functionality of an existing building automation system. Installing a new type of sensor, for example, can provide increased accuracy of measurement, or new building management software may include the latest in building analytics to drive energy efficiency.
- Extended life of legacy equipment – By partially installing a new building automation system, the existing building automation equipment can be used over a longer period of time. Typically the field devices are left in place and the management controller (also known as the supervisory controller) is replaced. This costs less than completely replacing an entire system, and ensures that the initial investment of the previous building automation system is fully realized.
- Reduces risk of system failure – By either partly or fully refurbishing a building automation system the possibility of failure is reduced. This is most important for mission-critical sites, such as data centers, laboratories and hospitals.

Refurbishment projects are an important influencer of the building automation equipment market. In regions where new commercial construction is limited, market growth is more dependent on retrofit projects. Examples of regions where there are many retrofit projects, include: Western Europe, Japan and North America.

Markets that favor retrofit projects over new installations typically present different characteristics for suppliers of building automation equipment. These differences include:

- Service and maintenance contracts – Building automation equipment manufacturers that also offer system integration services may reduce the cost of their equipment to be more competitive with their project bids. Once a project is won, the vendor will typically recover any losses through the service and maintenance contract. Revenue from service and maintenance contracts is more lucrative in markets where there is a high proportion of refurbishment, as the contracts represent a reliable source of income, whereas sales of equipment are less predictable.
- Value-added services – A building automation equipment manufacturer may wish to add value to its building solutions. Value-added services, which include building analytics and remote

monitoring services, can introduce a new revenue stream for the building automation vendor, and also creates more value for the consumer.

- Building automation gateways – Connecting legacy building automation systems to new equipment can be a technical challenge. For example, an existing system may be using a proprietary protocol such as N2 (Johnson Controls) or S1 (Siemens), while the new system will be using BACnet. To connect the two systems a gateway appliance will be required. Several building automation equipment companies specialize in gateways used for refurbishing building automation systems; examples include The S4 Group and FieldServer Technologies.
- Wireless transmission – Reducing the cost of installation will often make a vendor more competitive when bidding for a contract. Building automation equipment using wireless transmission can be used to reduce installation costs because no cabling is required. Furthermore, as this reduces installation time, the disruption to occupants is reduced. Minimizing disruption during refurbishment projects is often a key concern for end-users.

Requirements of building owners and facility managers

There is a growing facility-management resource gap with commercial buildings. This is a result of companies cutting the number of staff responsible for facility management to reduce overheads. Furthermore, the technical development of building automation systems has outpaced the knowledge, experience, and training of many facility managers.

To some extent, subcontracting facility management can solve the facility management resource gap; however, third-party facility management companies may also seek to reduce staffing costs. This strain on facility managers is creating demand for remote access to building automation systems, ease of navigation and use, as well as time-saving measures. This opens the door to analytics in support of preventative and eventually predictive maintenance as the technology monitors equipment so the scare human resources can focus on higher value tasks. Offsets lack of training/specific system operations knowledge.

Funding

Raising the capital for building automation refurbishment projects is a key requirement for facility managers.

Building automation vendors can assist in raising funds by demonstrating the ROI generated by retrofitting the existing building automation system. Typically, this is accomplished by quantifying the energy savings a new building automation system could bring over the existing system. This data is then passed on to the ultimate decision-maker in the customer's organization.

Several national and local government authorities are offering tax incentives or loans for the refurbishment of new buildings or existing facilities to increase energy efficiency. Examples include:

- AlabamaSAVES (US) – The Alabama Department of Economic and Community Affairs (ADECA) is offering a minimum loan of $50,000USD for refurbishing existing facilities. The type of refurbishment is not specific to building automation systems. The initial source of the funding was the American Recovery and Reinvestment Act (ARRA).
- Green Building Incentive Program (US) – Anaheim Public Utilities (APU) is offering commercial, residential and institutional rebates on new construction and refurbishment of green buildings. Values of the rebates include up to $75,000USD for commercial green buildings; up to $100,000USD for residential green buildings; and up to $30,000USD for LEED certification.
- The American Institute of Architects (AIA) publishes a list of State and Local Green Building Incentives (rebates, grants, discounts, etc.) some of which can be significant tax abatements for LEED certification.
- 179D Federal Tax Deductions (US) – A building owner or builder is eligible for a tax deduction if a 15 percent saving in energy consumption through improvements made to building systems is shown. Improvements to lighting systems; heating, ventilation and air-conditioning (HVAC) systems; or the building envelope can result in a savings up to $1.80USD per square foot of building space, which apportion based on the achievement in savings by Envelope.
- Business Premises Renovation Allowance (BPRA) UK – The BPRA was introduced in 2005 and is designed to incentivize bringing derelict or unused properties back into use. BPRA gives an initial allowance of up to €20 million per project for costs on converting or renovating unused business premises in disadvantaged areas. The scheme is due to end in 2017.

Education and industry knowledge

Technical understanding and appreciation of the benefits of building automation systems is increasing amongst building owners and builders. Some building owners are proactively opting to refurbish their building stock with building automation systems while they are vacant so as to attract future tenants. An increased understanding of building automation equipment is driving the penetration of systems and their complexity in commercial buildings.

While it is apparent that education and industry knowledge is increasing, it is by no means increasing at the same rate globally. During research discussions for this and previous editions of the report, several respondents noted that technical understanding was higher in the United States, Germany and Northern Europe; while it was lower in Africa, South America and Asia (excluding Japan and South Korea). One explanation for this is that green building legislation and regulation is not as strict in these countries. Furthermore, regions that experience low variations in temperature or humidity or have significantly lower energy costs, and arguably require less complex building automation systems.

Technology trends

Wireless

Wireless communication in sensors, actuators and controllers is lowering the cost of installing building automation systems by reducing the amount of wiring required in new and refurbished building automation systems.

Analyst note – Wireless transmission will likely play an increasingly important role in the specification of building automation systems. However, this will mainly take the form of field level devices, such as sensors, actuators and thermostats. The management level of building automation systems will remain wired, because of high bandwidth requirements and the frequent transmission of data within the management level.

Wireless devices are typically more expensive than their wired equivalents, however; reduced installation costs actually reduce the total cost of ownership. The average price of a wireless device continues to fall, which is creating further demand. An additional advantage of not having to pull wires is the limited disruption to occupants through quicker installation times. Wireless devices vary by how they are powered. The three main approaches to powering wireless devices are:

- Wired power – The advantage of wired power is that there is an uninterrupted power supply (not counting power cuts), meaning that the transmission of data can be at a high frequency, typically 2.4 GHz, and that the signal strength of the device is sufficiently high to be received over extended distances and through obstacles. This option is typically used for devices with high power consumption, such as wireless actuators. Devices powered by wire can be considered wireless if the data transmission is wireless.
- Battery power – The advantage of this type of wireless device is that transmission can be at a high frequency, typically 2.4 GHz, and that the signal strength of the device is sufficiently high to be received over extended distances and through obstacles. This option is typically used for devices with low power consumption, such as sensors. A disadvantage of using a battery is that it must be replaced regularly, which adds to the cost of servicing the building automation system. Low battery life has limited wireless penetration in the past. As battery life increases, and technology developments reduce power consumption, the lifespan of a battery in a wireless device is expected to increase.
- Energy harvesting – Energy harvesting is defined as sourcing energy from energy sources external to the device. Types of energy harvesting used in building automation systems include: photovoltaic (converts light to energy), pyroelectric (converts changes in temperature to energy), and piezoelectric (converts mechanical stress or movement to energy). The advantage of using energy harvesting is that even if a battery is fitted into the device, the battery does not need to be replaced as it is charged from an external source. This reduces maintenance costs. A disadvantage of using energy harvesting is that the strength of the signal is typically lower than with a battery or wired power device. Transmission from energy harvesting devices is typically restricted to burst rather than continuous transmission. This is based on limited energy availability; and varies by the type of energy harvesting.

While technologies like Wi-Fi, EnOcean and ZigBee have been in the market for quite some time, one wireless technology which has seen growing interest over the past year is cellular communication. Large cellular companies, like Verizon and AT&T have begun to acknowledge the additional revenue streams that can be generated through M2M communication and have started to look at the building automation market. Cellular is viewed as a more secure communication as it will not be tied into a building's network and, therefore, limits potential access points into the network. Currently, cellular communication only seems to have a few deployments, which seem to be at remote locations where a company has no other choice but to use a cellular-type modem to make a connection. One example is the cell towers of the cellular companies, which have to monitor different cooling and equipment measurements to make sure the tower is in working shape. IHS believes that cellular connectivity will gain some traction over the forecast period in niche applications.

Wireless protocols

The majority of wireless protocols are moving towards becoming IP-addressable (more in following section), especially in network environments such as building automation. Ultimately, wireless developments and increased adoption are huge enablers for IoT in building automation. There are a number of proprietary wireless protocols that are in use of building automation equipment. However, as we move to IP-addressable technologies, the push for standards is increasing the number of protocols serving this market.

There are a number of devices that are using wireless in buildings, with the significant technologies listed below. In addition, there are devices using WiFi, LoRa and cellular technologies; however, at the moment adoption of these technologies have not crossed a large number of devices in the building system and remain relatively niche. It is worth mentioning that both Bluetooth Low Energy and Thread have their sights on connected lighting, including the commercial space. Significant technologies include:

- EnOcean - EnOcean is an energy harvesting wireless technology, operating in the 868 and 315 MHz frequency bands. It enables wireless sensors to draw the required power to operate from their surroundings. EnOcean is arguably the most widely used open wireless technology using energy harvesting deployed in building automation systems. EnOcean has recently added the 2.4 GHz band as well.
- ZigBee - ZigBee is a standards-based wireless platform, positioned to provide for the needs of remote monitoring and control applications. The ZigBee Alliance is an association of companies working together to enable wirelessly networked monitoring and control products based on an open global standard. Wireless devices using ZigBee are predominantly battery- or line-powered.
- Z-Wave - Z-Wave is a wireless communications standard designed for home automation applications. While the primary application of Z-Wave is home automation, a small proportion of installations are in commercial building automation systems. The Z-Wave Alliance is a consortium of 160 manufacturers who have agreed to build devices using the Z-Wave standard.

IP technology

Internet protocol (IP) controllers and field devices continue to gain traction in the building automation equipment market. The benefit of using IP transmission over analogue is that the device can use existing IP or Ethernet networks in a building. This eliminates the need for a separate network for the building automation system, thus reducing the total cost of installing a building automation system in both refurbishment and new building projects. A further advantage is that an IP network has a high degree of scalability and flexibility. This allows for the number of devices on the network to grow.

There are disadvantages in using IP for building automation applications. An example includes the consumption of bandwidth of the IP network by the building automation system. Typically this will mean that the installer will need to add extra ports to the network.

When deploying IP technology, several building owners and integrators prefer to install a dedicated network for the BAS as opposed to piggybacking the existing corporate infrastructure. Having the BAS on the same network as the corporate infrastructure carries too much of a security risk for some individuals; as it allows for another point of access for hackers. This point is further explored in the network security section of this appendix.

Another advantage of IP not mentioned in the previous edition is that IP allows better access to the infrastructure; as IP networks can be easily interfaced to smartphones and tablets unlike deployments over twisted pair which cannot.

Network security

In recent years, there have been a number of high profile cases of building automation systems being hacked. For the most part, this was done to highlight inherent weaknesses in the system rather than by any malignant intent. The issue stems from an IP building automation system being an open door to the rest of the network. This can include: video surveillance and access control systems; fire control systems; sensitive internal files and other IT systems.

An example of a case includes the hack of the Australian Office of Google. In this case, passwords for access control panels for the office were obtained through hacking the building management system. This highlights the potential danger of poor security of building automation systems.

As a consequence of high-profile security breaches, building management software developers are enhancing the security of their products, and releasing updates to existing installed systems. However, it is up to end-users to update their systems for changes to take effect. The consequence of such public events is increased fear of using building automation systems on an IP network.

Cybersecurity concerns

The following findings highlight the growing action on behalf of enterprises to take steps to address cybersecurity concerns, which is sourced IHS Markit and our 2016 "Next Generation Threat Prevention Strategies and Vendor Leadership North American Enterprise Survey" conducted in September 2016.

- 64 percent of organizations participating in IHS Markit's enterprise security survey plan to increase spending on Web security, acknowledging that the majority of threats enter their networks via unsafe web browsing
- Respondents' top drivers for deploying new security solutions are protecting against data theft, data leakage and advanced threats
- When asked to name the top vendors for a variety of important security buying metrics, respondents rated Cisco tops in 9 of 10 criteria; IBM and Microsoft weren't far behind, however

Companies of all sizes and types are bombarded with security attacks that compromise identity and private data, affecting user and network performance. The last six years have produced an incredible volume of significant, damaging and newsworthy threat events that have everyone looking for breakthroughs in security performance: from 2014 to 2015, nearly 2 billion personally identifiable records were stolen.

In the midst of the current heightened threat environment, many businesses are transforming their IT infrastructures, moving data and applications to the cloud and likely opening up new security holes. Current attacks have moved beyond network risk and to physical risk as well. In industrial facilities there have been several attacks where cyber-attackers gained access to the office network, they compromised it and gained access to the production systems. This led to component and system failures, eventually leading to the blast furnace being shut down incorrectly. It was the unscheduled shutdown which caused the severe damage. It highlights that cybersecurity is a real concern not only to enterprise IT, but also to operational IT. While the company had IT security software in place, this only went so far. Employee vigilance is also needed to ensure the security measures are fully effective. Cybersecurity is often overlooked in operational facilities and is often seen as the responsibility of the office IT team.

Middleware

Middleware is the software layer between a device and software. The primary application of middleware is to communicate data from devices to a software program. An example of middleware used in building automation systems is Tridium's Niagara AX software.

The functionality of building management software is increasing. The connection between the sensors and the software and between different building systems is starting to be taken for granted. IHS believes a future trend could be towards eliminating the middleware and creating a direct connection between the field devices and the enterprise level. Building management software would run more like an operating system similar to Microsoft's Windows operating system, rather than a program in its own right. Instead of Microsoft Office or other programs and applications, the building operating system would house the analytics dashboard program.

Mobile applications

Mobile applications allow end-users to monitor and control their building systems remotely. This includes accessing and managing building management software remotely. The advantage of mobile applications is that the people responsible for managing and controlling a building do not need to be on-site to perform their duties. This allows a facility manager to cover a large portfolio of buildings while remaining mobile.

Mobile applications have been a talking point in the building automation industry for several years. Despite this, they have yet to find widespread adoption. The primary application has been for demonstrating systems, with mobile applications being used more as a sales tool than as a regularly used feature of a system. However, if end-users do start to make more regular use of mobile applications, this could increase their reliance on automated reporting and remote management.

A question on the lips of many in the building automation industry is: Where will mobile applications be installed? For example, many companies do not like the idea of purchasing an application and then having it installed on the personal cellphone of an employee as they believe it can create risks if the phone is lost or stolen, or even if the employee allows their child to play with the phone. A solution for this problem is through setting up HTML5-based portal pages for the system. This allows a building manager to log into the building automation system quickly from any mobile device to monitor and change set points without having to pay for or install any software on a device.

Interoperability

Interoperability refers to the ability for building systems and software from different vendors to communicate with each other. A building can have any number of systems and equipment from different manufacturers. Furthermore, an end-user may have many buildings, each with equipment from different manufacturers. This can cause difficulty when installing new systems.

There is a steady move in the building automation industry towards more open products. This is achieved through vendors using common communication protocols such as BACnet, LonWorks, KNX, or Modbus. This enables end-users and system integrators to select best-of-breed equipment and solutions without having to be tied to one vendor for the sake of ensuring compatibility.

The push for standards in the industry is supported by a number of groups. There are any number from various verticals helping to support interoperability and standardization of IoT; and in building automation both IIC (Industrial Internet Consortium) and the OCF (Open Connectivity Foundation) have been active in addition to others. Even more promising is that several of these groups have started to join efforts to support this shift and collaboration across the industry, which will only propel solutions for interoperability.

The following is a list of some of the open protocols used for building automation systems:

BACnet

BACnet (Building Automation and Control Network) is an ASHRAE, ANSI and ISO standard communication protocol used for building automation. BACnet was designed to allow interoperable communications of building automation systems. It was also designed to allow control over applications, including heating, ventilation, air-conditioning, lighting, access control, fire detection systems and other associated systems and equipment.

As with all protocol specifications, BACnet defines how data is represented on the network and how the services move data from one BACnet node to another. BACnet was created so that devices from various manufacturers could work together with minimal integration. The BACnet protocol has the following features:

- BACnet uses an object-oriented approach to standardize the representation of processes and data within a device.
- BACnet provides standard services to access the data within a device.
- BACnet provides multiple interfaces to accommodate small, medium, large and enterprise systems.

BACnet uses the following physical link layers: PTP (point-to-point), MS/TP (master-slave/token-passing), ARCNET and LonTalk. BACnet uses objects to represent data on a network. Some of the objects defined include: analog input, analog output, analog value, binary input, binary output, binary value, multi-state input, multi-state output, calendar, event-enrollment, file, notification-class, group, loop, program, schedule, command and device. Although BACnet is a certifiable standard, certification is not required.

LonTalk

LonTalk is a registered trademark of Echelon and is the underlying protocol of the LonWorks platform. All LonWorks devices communicate with each other using the LonTalk protocol. Many of the LonWorks devices use Echelon's Neuron Chips. In 1999, Echelon released a reference implementation of the protocol for use on any processor. LonTalk is a global standard (ISO/IEC 14908), European Standard (EN 14908) and Chinese standard (GB/Z 20177/1-2006).

The protocol was designed to enable peer-to-peer (distributed control) or master-slave (hierarchical control) networking in control devices from different manufacturers. Interoperability between LonTalk devices is achieved through transmitting, broadcasting, and receiving messages between LonTalk devices. When the protocol was published, the Protocol Patent License Agreement was created to ensure equipment from manufacturers not using Echelon's Neuron chips would be interoperable with all other LonWorks devices. The agreement ensures such products do not infringe on Echelon protocol patents.

The LonWorks platform uses twisted pair, power line, and IP tunneling as the physical layer of the network.

KNX technology

KNX technology is a worldwide standard for applications of building control, including: lighting, shutter, security systems, heating, ventilation, air-conditioning, monitoring, alarming, water control, energy management, metering and other systems.

KNX technology is an approved European Standard (EN 500900 and EN13321-1), International Standard (ISO/IEC 14543-3), Chinese Standard (GB/Z 20965), and US Standard (ANSI/ASHRAE 135).

The KNX Association is the creator and owner of KNX technology. Membership of the association is royalty-free. However, all equipment bearing the KNX brand is certified in order to guarantee system compatibility, interworking and interoperability. In July 2014, the KNX Association had 348 members in 37 countries.

The physical communication media used by the KNX technology protocol are twisted pair, power line, radio frequency and IP/Ethernet.

KNX offers different step-in levels for projects. Easy installation (E-Mode) is for configuration by non-KNX qualified electrical contractors. Configuration is done with a central controller with limited functionality. System installation (S-Mode) is for KNX-trained contractors and integrators. Installation and configuration of the system is carried out on a PC using the KNX Engineering Tool Software (ETS).

Modbus

The Modbus protocol was first developed by Modicon, a manufacturer of programmable logic controllers that is now owned by Schneider Electric. Modbus is now used as an open protocol, with the primary application being the industrial sector.

Since April 2004, developments of Modbus have been managed by the Modbus Organization. The Modbus Organization is a group of independent manufacturers that work together to develop the Modbus protocol.

In May 2011, the Modbus Organization joined the Wireless Cooperation Team (WCT). The goal of the WCT is to develop a wireless gateway specification based on WirelessHART and the emerging ISA SP 100.11a standard.

Many building automation systems use multiple protocols, as integrators prefer certain protocols at different levels of the system. For example, a common system is to see LonTalk and KNX at the field level and BACnet at the management level. This occurs because an integrator might think, for a particular system, the smaller data packets of LonTalk running the HVAC controls and KNX running lighting controls at the field level will allow for a quicker flow of information and cut down on engineering time; while BACnet at the management level will make sure that the information is stored and processed in a common way.

Cloud computing

Cloud computing is the provision of information services, such as software, data processing or analytics, and storage, via the Internet or virtual private network (VPN). Through cloud computing, end-users can reduce the provision of onsite computer processing power, data storage, and individually licensed software. This can save the end-user considerable time and money in not having to manage software and equipment. Furthermore, cloud computing can be accessed from anywhere, providing there is sufficient internet access.

Apart from the aforementioned advantages, there are no operational differences in running building management software via cloud computing. During the research process for this report, several participants noted that some end-users were not willing to send building data externally. This is due to security concerns regarding access to the building data once it has left the company's network. At present, deployments of building management software via cloud computing remain rare. Penetration is expected to increase as end-users become more reliant on cloud computing as the backbone of their IT systems.

Big Data and data analytics

'Big data' remains a buzz word in the information technology industry. The term 'big data' refers to a collection of complex data sets. The value of big data comes from its potential to generate useful information; typically, this is done by identifying trends in the data sets using data analytics.

Building analytics used in intelligent building is defined as software that provides diagnostics to evaluate the performance of a building. The diagnostics are based on data that has been collected from building sensors and utility meters. Additional sources of information can include real-time and historical weather forecasts. Once collected, the data is normalized and stored in a database.

Several large information technology companies have been extending their big data and data analytics solutions; examples include: IBM, GreenPlum (a division of EMC) and Oracle. This investment in big data and data analytics is a sign of growing acceptance and use by both governments and the private sector. As organizations become more familiar with using big data and data analytics for marketing and financial applications, they may be encouraged to use analytics for operational applications as well. This may assist building analytics vendors to overcome the challenge of limited customer knowledge of the service, as well as help to prove the potential ROI of using data analytics. Building analytics can be categorized into two groups: Building optimization and fault detection.

- *Building optimization:* Building optimization analytics are used to evaluate and optimize the operation of heating, ventilation and air conditioning in a building. For example, a cold front is forecast to pass over a building at 2 pm. This triggers the building to reduce cooling, and allow the internal temperature of a building to rise within the tolerance levels of the occupants. Once the cold front has arrived, the internal temperature of a building can be changed by varying the ventilation of the colder external air. Once the cold front passes, the building system reverts to normal operation. This process means that the building saves on heating and cooling for a short period of time. Over a year and across a building portfolio, this can result in large energy savings.
- *Fault detection:* Fault detection and diagnostics (FDD) identify faults as soon as they occur as well as the cause of the fault. This reduces onsite service time and maintenance, as engineers know precisely what is broken. It also reduces the potential discomfort of occupants as the fault is repaired sooner. Furthermore, fault detection and diagnostics can be set to proactively test the operation of equipment; this can be used to identify when a piece of equipment has a defect that might not have triggered a fault. An example of such fault detection and diagnostics is Gbot by Pacific Controls. The future potential of fault detection could lie in fault detection based on trend analysis, which would include dispatching maintenance staff based on the likelihood of a fault developing (predictive or conditions-based maintenance).

Remote monitoring services

Remote monitoring services are defined as a sub-contracted facility management service that includes report creation and monitoring of a building by an external party. This saves the user staffing costs. Furthermore, remote monitoring of other systems, such as access control and video surveillance, can be offered by the same external party. This effectively outsources monitoring of a large proportion of a building's systems, which can save a company considerable money. The benefits associated with using remote monitoring services include:

- Remote monitoring services can be offered as a 24-hour service; this offers out-of-hours coverage for customers with critical systems, such as data centers or laboratories.
- Having an external party responsible for monitoring the building provides an element of insurance. This means that in the event that something crucial goes wrong in the building, there is another company to hold responsible.
- As well as auditing and reporting, service providers can remotely control building systems for a customer. This application has primarily found success in small buildings such as retail sites where there is no onsite maintenance staff. This reduces the cost of having to send maintenance personnel to the building site.
- Remote monitoring services can incorporate building analytics so the auditor has access to a buildings analytic system running in a customer's building.

Dashboarding and visualization

Dashboarding and visualization are defined as the graphical representation of building data and building systems. Examples include showing the real-time energy consumption of a building or depicting a virtual map of a building which can include heating, ventilation and air-conditioning (HVAC) equipment. The graphics are typically presented on one of the following electronic display devices: personal computers, smart phones, tablets or public-facing electronic displays. The benefits associated with using dashboarding and visualization include:

- Public-facing dashboards are a means of informing occupants of a building about its energy consumption. This approach can be used to reduce consumption through promoting more efficient behavior, such as turning off lights and monitors when no one is in a room. One example of a public-facing dashboard used for this purpose is a restaurant in Australia which displayed the carbon dioxide emissions produced as a result of the restaurants' energy consumption. According to the provider of the public-facing display, presenting the carbon dioxide emissions to the staff of the restaurant encouraged them to adopt more energy efficient behavior.

- The environment is an emotive subject; if an organization can sufficiently prove that its operational practices are sustainable, it may help to raise its profile. This can be achieved by displaying building and operational data on public-facing displays. An example of this was the 2010 Winter Olympics in Vancouver, where a public-facing dashboard provided by Pulse Energy monitored eight of the main facilities used for the event to showcase the sustainability measures used.
- A problem facing building owners managing portfolios or a campus of buildings is that they have to use BMS Systems from a number of providers. This is common in colleges or universities where construction of new buildings, or refurbishment of older buildings, is staggered over time. The problem with having a number of different BMS Systems is that managing the buildings and viewing building data is more time-consuming, as the facility manager has to switch between different BMS Systems. Centralizing the management of monitoring buildings onto one platform overcomes this problem and can be achieved by using a graphical software interface. Graphics software companies that offer such products include J2 Innovation.
- Building automation and HVAC equipment vendors can differentiate their hardware and software solutions through incorporating photorealistic graphics. While a customer or system integrator does not necessarily buy a solution based on the appearance of the software, the look and feel of the graphical display can be used during demonstrations as a means of showing the level of sophistication of a solution. Typically, high-end graphics used by building automation and HVAC equipment vendors are designed by graphic design companies rather than the building automation and HVAC equipment vendors. QA Graphics is an example of a graphic design company.

While dashboarding and visualization vendors typically focus on software development, DG Logik has recently launched a hardware appliance. The functionality of the appliance includes hosting the graphical software, data acquisition and data storage.

Smart grid and demand response

The smart grid is defined as utility supply infrastructure that has the ability to match and manage generation of energy efficiently. One of the main features of the smart gird is demand response.

Demand response is where mechanisms exist to manage the energy that customers consume. Typically, the mechanism is based on the customer's side, an example being a facility manager dimming the lights in a building to reduce electricity consumption. One application of demand response is where renewable energy resources are used. The output of renewable energy resources, such as wind farms, varies. As such, the use of the smart grid manages the consumption of energy to avoid blackouts, while also minimizing the amount of extra capacity required.

A further application of demand response is to manage times of high demand for energy, such as in the morning when building systems switch from a low occupancy setting to a high occupancy setting. Demand response can be used for this application to distribute the demand for energy over a longer period of time. This decreases the maximum peak of demand, meaning that a utility can have a lower maximum capacity grid. Manual demand response programs (where participants manually lower set points or turn off equipment) have gained more use, while automated demand response currently has a lower penetration.

The term 'smart grid' has been used for almost a decade; however, as yet there have been few large-scale deployments. IHS forecasts that smart grid deployments will increase as countries depend more on renewable sources of energy.

Intelligent buildings will likely play an important role in the development of the smart grid. Building automation systems and energy management systems can provide automated meter readings (AMR) of electricity, water and gas consumption; and following predetermined schedules, can shed load based on pricing signals from the utility company.

For smart grids to be fully adopted, it is important for the building and the grid to share information. The building management system requires a way to represent and exchange pricing signals, understanding load management requests and represent and exchange information about the response of the building(s) (load shedding, load shifting, local energy generation, etc.). However, the current problem is how the two systems communicate with each other. ASHRAE believes BACnet should play the leading role in integration between smart grid and building automation while LonWorks believes it can hold a similar leading role. Until this issue is resolved, integration between smart grid and building automation systems will remain in pilot projects rather than mass market adoption.

In recent years, significant progress has been made in the development of products with two-way communication capabilities that will help the BMS Systems to communicate with smart grid systems. One of these products is two-way communicating electricity meters. Two-way electricity meters are able to send and receive data from a remote source. This definition can include meters with remote prepay functionality, disconnect switches, time-of-use (TOU) functionality and many more functions. Combining two-way communicating meters with smarter appliances and other technologies are viewed as the first step toward smart-grid implementation.

Development of microgrids

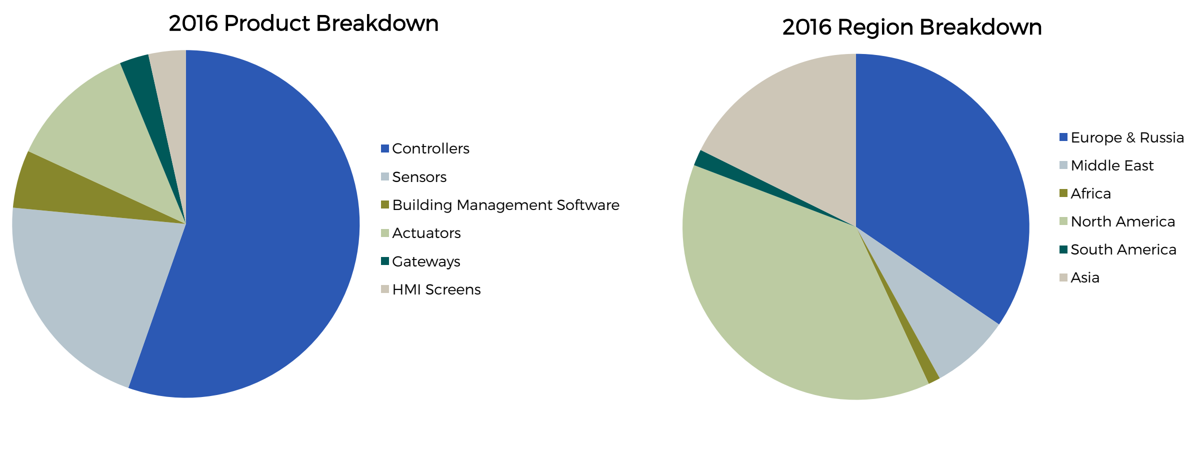
The concept of microgrids is becoming widely talked about throughout many industries. IHS considers two very distinctive types of 'microgrid':

- Rural electrification – small grids that are developed in remote communities to provide power. These will typically consist of one or more generators (often diesel, PV, wind) interconnected with several buildings, homes or simple loads. These will often also feature a battery to store power.
- Resiliency – Sections of a larger conventional grid (could be a community or a large building/campus) that can be isolated and operated independently in the event that the grid fails. These will typically utilise distributed generation (e.g. PV, diesel genset, wind) and/or battery storage to enable this. There is some discussion over whether a home with PV and battery that can operate 'off-the-grid' would in fact be a very small microgrid.
- Resiliency microgrids are a common topic in the USA, where universities, jails, military bases, etc. are considering this for energy security purposes, and in some cases because the economics of self-generation are favourable.

Figure 1.6 presents an overview of the world market for building automation equipment. Key points:

- IHS estimates that the world market for building automation equipment is forecast to be worth $5.9 billion in 2016 and controllers were the largest market, accounting for $3.1 billion.
- EMEA remained the largest market for building automation equipment in 2015, Asia was estimated to be the smallest market; however, it is forecasted to be the fastest growing of any region.
- Revenues from retrofit and refurbishment projects driven by the American and EMEA markets are forecast to be surpassed by revenues from new in 2018.

Figure 1.6 2016 Building Automation Equipment Market Size - Millions of USD



Source: IHS Markit © 2016 IHS Markit

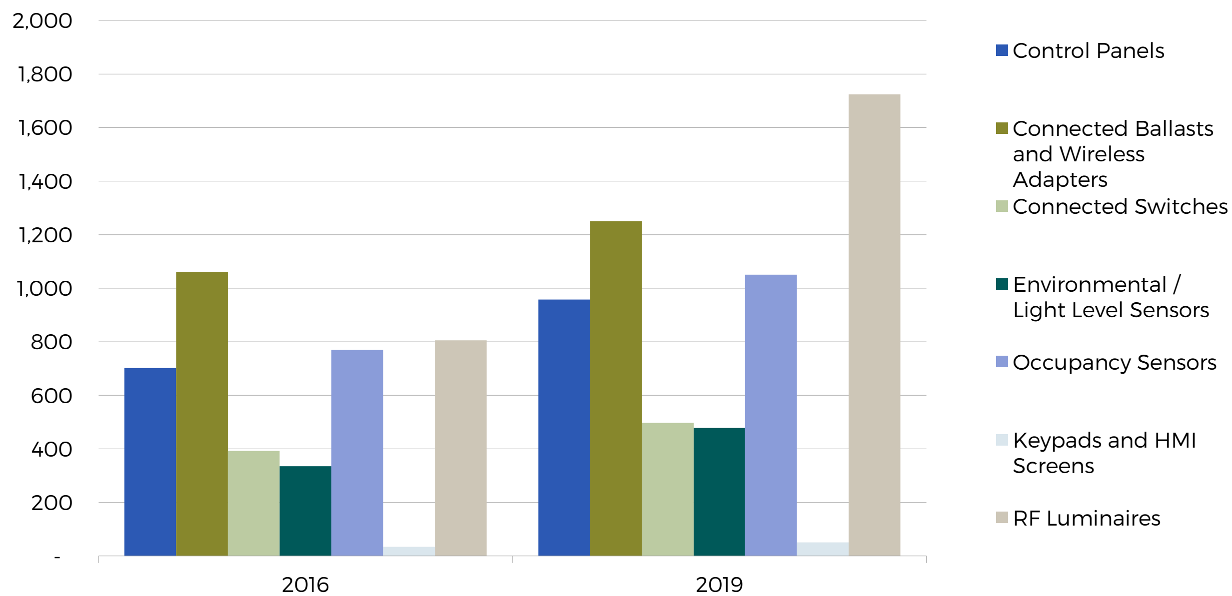
1.3 THE CONNECTED COMMERCIAL LIGHTING MARKET

A connected lighting system is a series of connected nodes connected to one control panel or wireless hub. Although a connected lighting system can contain multiple control panels as part of a distributed system (since each of these panels controls its own set of nodes), A lighting system is a single control panel for a series of nodes, which means a building could, in theory, contain a series of distributed controls, all connected to one IP server system.

Figure 1.7 presents an overview of the world market for connected lighting in commercial applications. The key points to note are:

- IHS estimates that the world market for connected lighting in commercial applications is forecast to be worth $4.1 billion in 2016. This figure excludes central controllers and gateways as gateways help "bridge" disparate systems or communication protocols but typically do not control a system.
- The construction market and economic conditions are perhaps the two most important factors for the market for smart lighting and lighting controls, particularly in commercial applications.
- EMEA leads the world in the deployment of connected street lights, with nearly half of the global spending, with Americas trailing slighting and Asia lagging current spending, although it is expected to make significant investments in the future.

Figure 1.7 Global Market for Connected Lighting in Commercial Applications - Millions of USD



Source: IHS Markit © 2016 IHS Markit

This report has adopted the following definitions:

- **Control panels:** The following devices under are included in the classification of a control panel: relay panels, wireless hubs, central processors (for the residential market), and other control panels that connect to a series of nodes and provide control functionality.
- **Connected switches:** Devices integrated in the lighting control system to accept user control signals (on-off, dim, scene, etc.). Please note that this category does not include keypads.
- **Standalone switches:** These are simple devices that are not integrated into the lighting control system but are used to turn traditional lighting systems on or off or control a simple analogue dimming system. These devices are included in this report to show the total available market for lighting control.
- **Connected ballasts, drivers and wireless adapters:** Ballasts and drivers are devices which regulate the current supplied to a light source. This category contains all types of ballasts and drivers, including those that regulate current to fluorescent, HID, halogen, LED and other lighting

technologies. Only ballasts and drivers that contain connectivity technology, such as DALI, DSI, or a wireless technology such as ZigBee, to enable control of the current via a centralized system, are included in this category. Wireless adapters can be used to add wireless connectivity to existing light sources or ballasts, making them controllable. For the purpose of this report, only ballast/wireless adapters that are shipped as part of a lighting system were included.

- **Occupancy sensors:** An occupancy sensor is a heat-sensitive or ultrasonic device that reacts to moving heat sources or ultrasonic feedback within its monitored field. These devices then control the on-off function of a lighting source. In this report, only occupancy sensors that are shipped for use in lighting control systems were included.
- **Environmental sensors / Light-level sensors:** An environmental sensor is one that detects the level of light either internally or externally to enable controllers and control panels to adjust lighting levels in accordance with available natural light. These devices can also be used to control blinds to modify the amount of natural light in a room. In this report, only environmental sensors that are shipped primarily for use in a lighting control system were included.
- **Keypads and HMI screens:** An HMI screen is an electronic display device used to visualize data from a lighting control system. Keypads are multifunctional display devices that allow the user to control the lighting system with analogue or digital interfaces.
- **RF-enabled lamps / luminaires:** These contain RF or powerline technology inside the light or light fixture in the residential application. Lamps are an easily removed light source that can be retrofitted into existing fixtures. They are generally shipped either with a remote control, or with a gateway to add functionality, such as "cloud" access.
- **Dimmable LED lamps / luminaires:** These are LED bulbs or fixtures that are able to be dimmed either by varying the voltage to the device externally or through an in-built controller.
- **White temperature-tunable LED integrated luminaires / lamps:** These are LED fixtures and bulbs that allow users to change the white color of the device on a sliding scale, from cool whites (similar to fluorescent lights) to warm whites (similar to most incandescent lights).
- **RGB color-changeable LED luminaires / lamps:** These are LED fixtures and bulbs that allow users to change the light output color.
- **Retrofit connectivity module:** A retrofit connectivity module is typically a photocell replacement module (normally NEMA-compliant), that adds connectivity functionality to an existing light. This can either contain power-line technologies, such as LonWorks or wireless technologies.
- **New-build connected lights:** These devices are new light fittings/replacement street lights that contain connectivity technology to enable their control

Key drivers for the commercial connected lighting market

Although the global economy has yet to fully recover from the downturn, the world smart lighting and connected lighting control market has seen steady growth for a number of years. Although growth has remained relatively slow over the past year because of a general slowdown of commercial construction (particularly in the Americas), it is now poised to accelerate as consumer and business confidence returns to the construction industry and the wider economic environment.

Newer technologies, for example, wireless solutions (which typically reduce the installation costs in refurbishment and upgrade projects) are also influencing growth in the market for smart lighting and connected lighting controls.

The construction market and economic conditions

The construction market and economic conditions are important influences on growth in the smart lighting and connected lighting market. Although the rate of construction has only a limited effect on growth in the residential market for smart lighting and connected lighting, it has a far greater effect on the commercial market. Much of the growth of the commercial smart lighting and connected lighting control industry is down to government legislation for new commercial buildings; high commercial construction growth means high demand for newer, more efficient systems. Furthermore, a strong economic climate means more capital is available for investment in new lighting systems.

Refurbishment of existing buildings and infrastructure

Most regions already have a heavily developed commercial building stock predating modern lighting control, with a few exceptions. Therefore, one of the largest markets for these technologies will be for retrofit solutions. For the purposes of this report, a refurbishment project may mean replacing existing smart lighting technologies within a building or street light infrastructure, or installing smart lighting solutions where there was no previous automation or control technology. By refurbishing an existing lighting control system, building owners and users gain the following benefits:

- Enhanced system performance – Although switching from older technologies including fluorescent and CFL to LED lights can grant higher relative energy savings, building owners and users, by installing lighting control technologies, can make considerable savings relative to the level of complexity of the system installed.
- Enhanced value – When a lighting control system is installed in a building, it increases the inherent value of the property; building managers can therefore not only attract more customers, but can charge a higher rent. A building with energy saving technologies installed is also eligible for rebates from various company initiatives.
- Extended life of legacy equipment – Partially installing a system means the existing equipment can be used for longer. Typically, the field devices are left in place and the management controller (also known as the supervisory controller) is replaced. This costs less than completely replacing an entire system and ensures that the initial investment of the previous system is fully realized.
- Reduced risk of system failure – By either partly or fully refurbishing a system, the possibility of failure is reduced. This is most important for mission-critical sites, for example, data centers, laboratories and hospitals. In addition, the control systems generally save energy by turning lights off when not in use; reducing the average use time further decreases the probability of failure.

Refurbishment projects are an important influence on the market, particularly in regions with limited new commercial construction, where the local smart lighting and connected lighting market depends on refurbishment projects. Regions with a particularly high proportion of refurbishment projects include Western Europe, Japan and North America.

Legislation and building certification

Legislation is the key driver at the moment in the uptake of intelligent lighting controls for commercial and multi-dwelling residential applications, particularly in North America and Western Europe, where legislation is arguably far stricter than in other parts of the world. In 2002, the Department of Energy in the United States selected the ANSI/ASHRAE/IESNA Standard 90.1-1999 as the commercial building reference standard for state building energy codes; since then, most states have adopted the codes. Others have accepted a different code entitled IECC, which includes an ASHRAE-based compliance alternative. Some states have adopted their own energy codes (for example, California, with its Title 24 code).

Both ASHRAE and IECC require that all buildings with floor space of more than 5000 square feet must have automatic lighting shutoff control. This can come in the form of occupancy sensing, time scheduling, or signaling from a wider control network (either a dedicated lighting control system or a building automation system).

California's Title 24 legislation is widely regarded as the strictest in the world; and, although a few other states are looking to adopt similar standards, most US states in the United States have less strict regulations; that has slowed adoption in the Americas.

Legislation in other parts of the world is not quite as strict; this has led to a lower uptake of lighting control systems in total system deployments. However, some industry experts have commented that in EMEA, most noticeably in Western and Northern Europe, the average intelligence of commercial lighting control systems is greater, with widespread use of more sophisticated controls which have features, including: sensors, switches and natural light regulation. Below are examples of some of the main regulations that are a driving force behind lighting control solutions:

- In the United States, the Energy Independence and Security Act 2007 (originally called the Clean Energy Act) was passed in January 2007. Its objectives included increasing production of clean renewable fuels and the energy efficiency of products and buildings. The Act set a goal that new commercial buildings built after 2025 would have a zero net-energy use.

- The US Department of Energy's Building Energy Codes Program (BECP) was established in 1991. BECP promotes stronger building codes and helps local states to adopt, implement and enforce them. One of the codes most relevant to building automation is Standard 90.1-2010. Published in partnership with the ASHRAE, it requires a new building will require 30 percent less energy than one built to the 2004 standard.
- European standard EN 15193 specifies the metering and calculation method to be used for the evaluation of the amount of energy used for lighting in buildings. The standard can be applied to existing buildings and to the design of new and renovated ones. EN 15193 also promotes energy-efficient artificial lighting systems and the efficient use of daylight.
- In Brazil, the National Electrical Energy Conservation Program (PROCEL) was issued to help combat waste in the production and use of electrical energy. The policy promoted energy-efficient lighting and actions to reduce energy consumption during peak hours. The PROCEL also helps use of low-interest financing for major energy-efficiency projects.

Legislation is one of the major drivers in the uptake of lighting control in the North-American market; however, elsewhere there is not the same level of legislation to require commercial buildings to adopt lighting control systems. Although adoption is increasing, the return on investment can be around five years without subsidy, so many companies and building managers do not wish to invest in such a system when the lease on the building or floor may only be a year or two. If a company is particularly keen to follow green initiatives and save energy with the lighting system, the ROI is far better if the investment is concentrated on converting from older lighting technologies to LED.

Building certification programs and organizations

Building certification programs and organizations are a source of industry standards. Typically, they are specific to a region (for example, EMAS, Emirates Energy Star, and CASBEE); but may also be internationally recognized (for example, LEED). There are several advantages associated with gaining certifications:

- More likely to gain tenants – A LEED certified building is often believed to be an attractive to potential tenants. Gaining this certification shows that both the efficiency of the building and the comfort of the tenants have been carefully considered by the building owners. As well as increasing the likelihood of gaining tenants, the building owner may also be able to charge a higher rent based on lower energy costs. For a prospective tenant, the low energy and maintenance costs will be an attractive proposition.
- Eligibility for grants – Some grant systems reward the building owner or builder for adhering to green certification. The grant can aid ROI or be used to fund further improvements to the building. An example of this is in China, where commercial buildings that conform to the '2 Star Rating' receive a one-off grant of 45 RMB per square meter of green space, while commercial buildings that conform to a '3 Star Rating' receive 80 RMB per square meter of green space.

Building certification programs and organizations that may influence the building automation equipment market include:

- Continental Automated Buildings Association (CABA) – CABA is a not-for-profit industry association. It is supported by an international membership of 350 plus organization involved with the design, manufacture, installation, and retailing of products related to home and commercial building automation and lighting controls.
- World Green Building Council (GBC) – The World GBC is a coalition of Green Building Councils. Its mission is to facilitate the building industry moving towards sustainability. The World GBC provides support for local councils with its local green building initiatives. The World GBC also promotes the World Green Building Week and Common Carbon Metrics project. The World GBC collaborates with international bodies, including the United Nations Environment Programme (UNEP), Sustainable Buildings and Climate Initiative (SBCI), The Sustainable Buildings Alliance (SBA), and the International Union of Architects (IUA).
- European Union Eco-Management and Audit Scheme (EMAS) – EMAS was established in 1995 to ensure better management of environmental issues and continual improvements in the environmental performance of companies and other organizations.
- Building Research Establishment Environmental Assessment Method (BREEAM) – BREEAM assesses and rates buildings based on recognized measures which are set against established

benchmarks to evaluate a buildings specification, design, construction and use. BREEAM is used by clients, planners and development agencies, funders, developers, property agents, design teams and facility managers.

- Green Globes – Green Globes was developed using BREEAM in 1996, creating an assessment and rating system for buildings. Since 1996, the rating and assessment system has undergone various iterations. Since its creation, the Green Globes systems have been endorsed by CABA; and in 2005 it was accredited by the American National Standards Institute (ANSI).
- Leadership in Energy and Environmental Design (LEED) – LEED is an internationally recognized green building certification system. Developed by the US Green Building Council (USGBC), LEED is intended to provide building owners and operators with a framework for enabling green building design, construction, operations and maintenance.
- American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) – ASHRAE is an international organization which aims to advance heating, ventilation, air-conditioning, and refrigeration. ASHRAE provides research and development, and training publications. Since June 1987, ASHRAE Standard Project Committee (SPC) 135 has actively developed the BACnet protocol.
- The Emirates Energy Star – An organization that awards certification based on the percentage of energy savings made in a building. The goal of the Emirates Energy Star is to reduce the carbon footprint of buildings in the United Arab Emirates (UAE).
- Comprehensive Assessment System for Built Environmental Efficiency (CASBEE) – CASBEE is a Japanese certification program that measures and assesses energy efficiency in commercial buildings.
- WELL Building Standard – The WELL Building Standard takes a holistic approach to health in the built environment addressing behavior, operations and design.

Historically, building certifications focused primarily on the building envelope, construction methods and waste management. However, more attention is being paid to electronic equipment and technology in a building, including lighting controls. As electronic equipment becomes more important, certification programs could increasingly require lighting controls, similar to the legislation in the United States.

Price of energy

Energy prices have been steadily increasing in most parts of the world as extraction of fossil fuels becomes more difficult and as demand on electricity grids increases. This has caused energy prices to rise year over year, driving owners of commercial building owners to reduce the amount of energy that their buildings consume. Although the price for oil has been very low since late 2014, it is forecast to start rising again; the decrease in oil price was not reflected in the price for energy to the extent that it could have been. IHS forecasts the total energy used for general illumination will fall to 2.75 trillion kilowatt-hours (kWh) by 2020, down from over 3.5 trillion kWh in 2014. Overall, the installed base of general lighting (which covers homes, businesses and street lights) accounted for 15.9 percent of net electricity generated in 2014. Changing the lighting technology from the more commonly used incandescent, halogen and fluorescent lighting sources, to newer, more efficient sources including LED lighting can reduce energy costs, and intelligent lighting control can further reduce the energy used.

Costs, investments, and payback

In some countries, for example, the United States, reimbursements and incentives are available to building owners to reduce the cost of installing lighting control systems; cost and a poor ROI are major disincentives. In regions where reimbursement and incentives are available, it makes more commercial sense to install these systems to reduce the energy a building uses while reducing the initial outlay associated with installing a lighting control system. According to the Consortium for Energy Efficiency, lighting control rebates have tripled in the United States since 2009. Incentives are currently available in 47 of the 50 states; they cover the majority of lighting control solutions.

During the research for a previous report, an MEP (mechanical, electrical and plumbing) engineer suggested:

"Typically, seven years payback is at the very high end for what people will go for; because, after seven years, the energy rates could be anything and management will have likely changed. Sometimes a government user or very long-term user of building will take a longer payback of eight to ten years but this is rare. A one- to two-year payback is like a slam dunk and will almost always be implemented. However, what has happened quite a lot is that, if we find a one- to two-year payback for some systems,

we will couple that with another upgrade with a six- to seven-year payback. The project is twice as big, but the payback is an acceptable four to five years."

One consultant suggested:

"Money is a big factor. Right off the bat, the owners often do not see the benefits, because they want an instant payback. Some owners see the value in investing; but this is often derived from a comfort level achieved from other projects. Others are not comfortable yet and don't like the idea of investing."

Non-traditional methods of financing which can be used to fund lighting control solutions include:

- C-PACE. For example, Los Angeles Commercial Building Performance Partnership Program.
- ESPO financing.
- Energy-efficiency loans.
- Energy service agreements.
- PACE programs.
- On-bill utility financing.

Education and industry knowledge

Technical understanding and appreciation of the benefits of a lighting control system in a building is increasing amongst building owners and builders. Some building owners are proactively opting to refurbish vacant buildings with smart lighting systems to attract future tenants. An increased understanding of smart lighting is driving the penetration of systems, and increasing their complexity, in commercial buildings.

Installer and contractor technical ability is a concern in the industry. For example, in Germany, electricians are taught how to install and commission controls during their standard electrical installation training. However, this is not the case in other countries, such as the United Kingdom. The route to market in countries where standard electricians do not install controls can be very different. In the United Kingdom, for example, many of the controls are installed by system houses that work in partnership with or act as subcontractors to the major electrical contractor. Teaching controls as part of standard electrician training could promote growth in the market for lighting controls. There has been some progress in achieving this, but it is still not at the level it needs to be.

Many manufacturers are making their equipment and solutions easier to install, so less qualified contractors can install controls. Manufacturers are removing the requirement to program the system fully, by increasing the use of block programming in software tools and by creating systems that use self-learning control equipment (for example, Cree's SmartCast Technology) to commission the solution. This reduces the expertise and installation time required to install and commission lighting controls.

IHS estimated the world market for connected lighting equipment in commercial applications to have been worth over $3.35 billion in 2014, and is forecast to grow at a compound annual growth rate (CAGR) of 13.3% to over $6.27 billion in 2019.

Lighting control systems are increasingly becoming more distributed. This enables different spaces within the solution to be personalized and provides more detailed data across the system. Therefore, with more zones per system, unit shipments of connected switches, sensors and keypads are forecast to increase faster than shipments of the controls themselves.

Many control panels apply dimming and switching to a zone or series of fixtures. All the fixtures in the zone are dimmed or switched on and off at the same time. This is the most basic and common form of lighting control. Fixture-level control is achieved by controlling the individual ballasts and drivers, enabling the user to switch or dim individual fixtures rather than entire zones. Some solutions wire each fixture individually to the controller or control panel; others have the controller and sensor built into the luminaire itself; and yet others are beginning to follow the 'Internet of Things' approach, where each luminaire is assigned an IP address. During research, it became apparent that there are many different views on fixture-level control.

The benefits of fixture-level control are predominantly related to commissioning the solution when it is first installed and to re-commissioning a space later. For example, when a building is first constructed, the architect or specifier may have designed functional working spaces for the occupants; however, once the occupants move in they decide to move the desk locations around. A traditionally designed system would not be able to cope with this, but soft integration (created by fixture-level control) allows the solution to be highly flexible. An example of this is the Rosebank Project in South Africa. The disadvantages of fixture-level control are mainly related to the additional cost and requirements of such a solution. Adding fixture-level control will often add either to the wiring and equipment cost or to the installation time.

One of the main benefits of a wireless control system is that it is far easier to integrate this fixture-level control into the system than into a wired system, particularly in a retrofit application. This also allows for a cheaper and more efficient installation process. In projects under around 100,000 sq. ft. it is often cheaper to install a wireless control system as there is no need to install control cables into the walls and ceiling. However, for larger projects, it becomes more cost-effective to install a wired system, as some of the scaling issues of the wireless system, including range and signal interference, become apparent.

Central controllers are used in a variety of building sizes and applications to switch, dim, schedule and generally provide control of lighting systems. They are predominately provided by companies with a strong affiliation with the industrial automation market. They often provide more flexibility than simple control panels. They can also act as the gateway to other building systems including the blind controls, façade control and building automation systems. Many central controllers can communicate with more than one connectivity standard or protocol (DALI, KNX, LonWorks, etc.), as well as using 0–10 V links to control ballasts. However, there is a trend in the industry towards 'cloud-control' applications. This is where the central controller for the lighting system is not located on the site, but is instead housed on a server and accessed through the Internet, or in the case of a small satellite office of a larger company, in a larger central office.

Gateways remain a vital part of the lighting control market as new builds as well as expansions of current systems continue to use the product. Not only do they provide the versatility to control lighting in a location remote from the central controller, but they also provide a 'bridge' for the wireless control system in an area. In new builds, there is also a tendency for integrators to use multiple protocols, one at the field level and one at the management level, which suggests that gateways will, in the future, be used to translate data. In expansions, integrators sometimes have to deal with other protocols, which might be proprietary, as well as the field/management level dynamics.

The increasing use of keypads and HMI screens is because of the greater emphasis on usability. Keypads give the users and occupants of a space within the zone/space itself more control. They are more popular in high-value commercial properties. Despite the growth in the use of both keypads and HMI screens, the market for HMI screens may start to contract towards 2019 as more and more commercial systems turn to mobile devices including tablets and smart phones. With tablets and smartphones, building managers no longer need to walk over to a controller to check readings. Instead, the building manager can carry on with other tasks and use a smartphone to input an IP address and check data points from anywhere within a building. For this reason, HMI screens are forecast to play less of a role in the industry and will be used sparingly in niche deployments, where they are more cost-effective than giving mobile tablets and smartphones to several employees or groups.

Generally, prices of products across the entire commercial market have not fallen much for many years. This is forecast to continue from 2015 to 2019. However, price erosion will remain moderate as wired controls providers see increased pressure from more competitive wireless solutions. The exception to this is the price of the wireless controls, sensors and switches themselves. As the interest in wireless has increased, the price of wireless equipment has fallen.

1.4 PHYSICAL SECURITY EQUIPMENT AND SERVICES

Within the definition of physical security equipment and services, he following equipment types were included:

- Video surveillance: For professional video surveillance, analogue security cameras, DVRs, NVRs, network security cameras, video encoders, video management software (VMS), CS-mount lenses, camera housings, CCTV controllers/keyboards and motorized camera positioning mounts.
- Access control: Readers, control panels, credentials, software and electronic locks.
- Intruder alarms: Intrusion sensors, control panels, keypads and accessories.
- Entrance control (vehicle): Gate operators, rising bollards, road blockers, barriers, garage door operators, and parking systems.
- Entrance control (pedestrian): Entrance gates, full-height turnstiles, optical turnstiles, interlocking doors, revolving security doors, security booths, speed gates, and tripod barriers.
- Enterprise storage: External DAS, internal DAS, SAN, and NAS storage device hardware which are used for video surveillance applications. This category does not include DVRs or NVRs and VMS software.

Services include:

- Video surveillance as a service (VSaaS): A customer pays on a yearly, quarterly, or monthly basis to view live or recorded video surveillance data off-site to the location of the security camera; and the video is used for self-monitoring surveillance and business applications.
- Access control as a service (ACaaS): A customer pays on a yearly, quarterly, or monthly basis to have a server managing the access control system, at a third-party location. There is no software or server located on the customer's premises.
- Remote monitoring services: Professional alarm monitoring, connected alarm monitoring services, video monitoring for large commercial businesses, and personal emergency response systems (PERS) monitoring.
- Security systems integration: Design and consultancy, installation, service and maintenance, and equipment (intruder alarms, physical access control and video surveillance).

Figure 2.7 displays the market for physical security equipment used in commercial settings in 2015 and 2020 by region. Figure 2.8 displays the market for services. Note the market data for services includes those sold into the residential sector. The data for equipment has had the residential market component removed. Some of the key market trends for each of the component products and services are outlined below.

Video Surveillance

A range of technologies are increasingly being adopted to improve image quality, including advanced low-light functionality, wide dynamic range, and improved resolution. Demand for higher-definition video surveillance is driving the market for IP-based network cameras and HD CCTV cameras. There is a large shift to IP-based cameras in the market, which appears to be happening faster than some people in the industry expected. A major factor is vendors offering more HD CCTV (often referred to as HD analog) alternatives to traditional analog cameras. These cameras generally have a lower price than traditional analog cameras. Despite the high growth rate of the HD CCTV category, still 53 percent of all security cameras shipped in 2015 were network cameras. IHS Markit forecasts this to increase to 89 percent in 2020.

Access Control

Software is changing rapidly in the access control market as demands for mobility, user interface and cloud-based solutions are beginning to be implemented. "Mobility" is driving change across the technology sector as end-users demand more control over their service regardless of where they are. Mobility means access control software suppliers can no longer assume that security personnel will be behind a desk monitoring a system; this is changing how software is presented and how it is delivered.

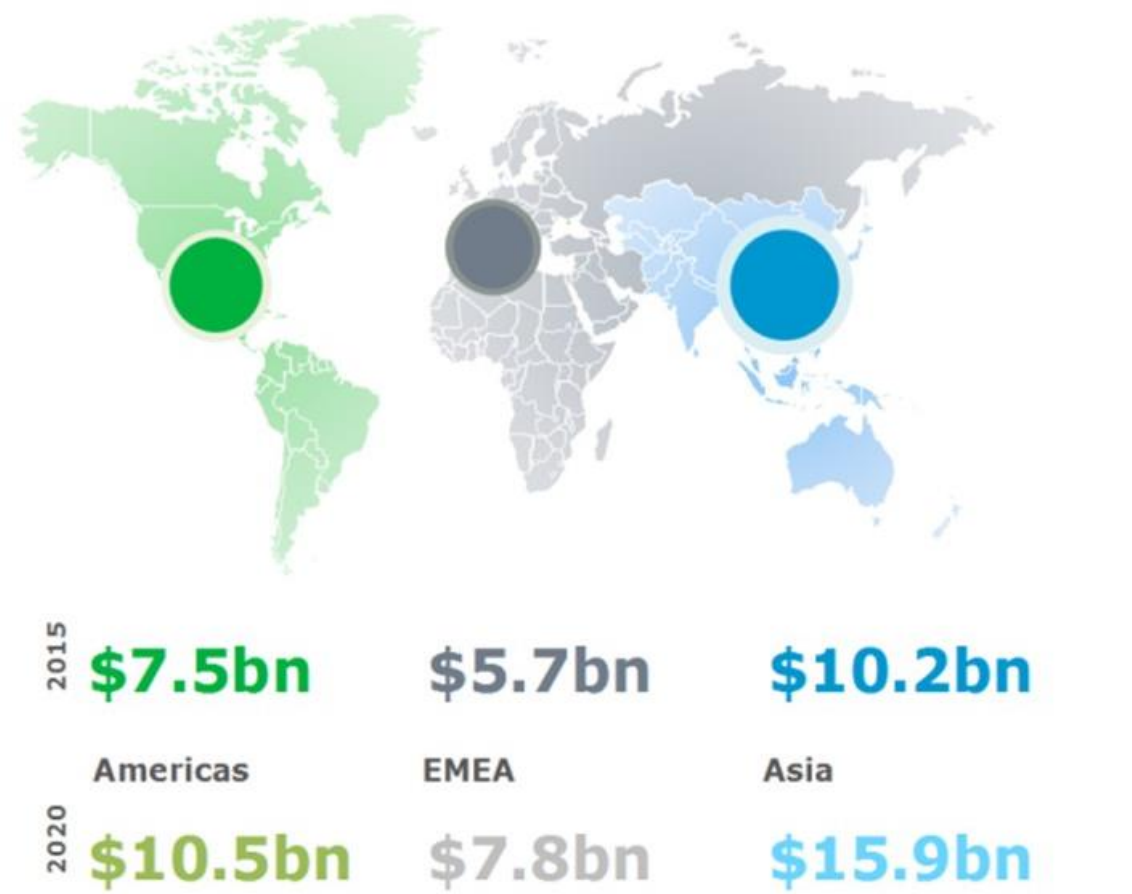
Entrance control (pedestrian and vehicle)

Traditional speed gates use dry contacts and are not required to provide live information which could be updated regularly. With the continued uptake of IP technology throughout security networks, speed gates with IP functionality can now be part of an end user's secure network, communicating with a variety of systems as part of a total security solution.

Enterprise storage

SAN systems are the largest category of enterprise storage used for video surveillance storage. Centralized storage architecture linked to geographically distribute smaller storage systems is increasing in popularity as an architecture for the largest video surveillance deployments.

Figure 1.8 Physical Security Equipment Market Size



Source: IHS Markit © 2016 IHS Markit

VSaaS

Major drivers of the market for VSaaS include enhanced functionality than traditional surveillance solutions; this allows end-users to access video from multiple sites over a wide geographic area; and the recurring monthly revenue model, which considerably lowers the upfront costs of adopting video surveillance. Barriers restricting growth in the VSaaS market include limited internet bandwidth in certain vertical markets and territories, and lack of end-user awareness. The development of more sophisticated compression algorithms and improvements to infrastructure will gradually overcome these barriers. Major marketing efforts are also underway to educate end-users on the benefits of VSaaS.

ACaaS

The roll-out of more and more IP-enabled equipment has meant that access control solutions are increasingly connected; this, coupled with declining hardware prices, has led solution providers to search for new revenue streams. Access control as a service will play an increasingly important role not only in generating repeat revenues for providers but also in unlocking new markets; especially in small and medium enterprise spaces that were previously unwilling to invest in a solution because of the upfront cost.

Remote monitoring services

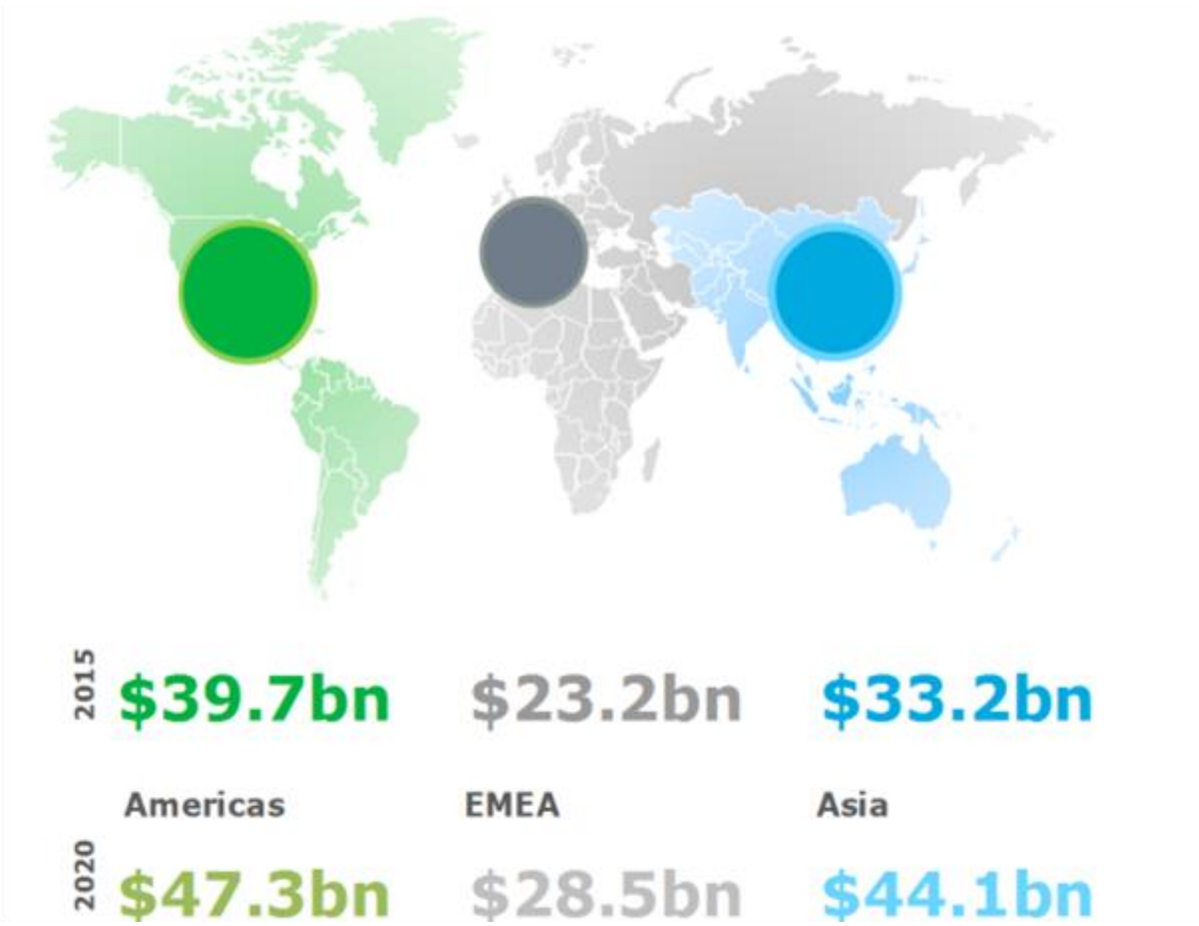
Connected systems allowing increased functionality can act as a key differentiator in the market, and providing additional revenue opportunities for suppliers. North America is leading adoption and EMEA is set to follow. Commercial video monitoring is becoming an increasingly feasible alternative to manned guarding, as improvements in telecom infrastructure and video analytics make these services more reliable and effective.

Security systems integration

The service and maintenance market is forecast to be the fastest-growing sector in all three regions from 2015 to 2020. Service and maintenance contracts generate regular, predictable revenues, and allow the integrator to develop its relationship with the customer, increasing its chances of winning future business. System integrators will move increasingly to an OpEx business model.

Supply of physical security equipment and services is extremely fragmented. No one supplier commands more than 5 percent of the market. Leading suppliers are Tyco International, ADT, Hikvision, SECOM International, Honeywell International, ALSOK Group, UTC Climate Control and Security, Stanley Convergent Security Solutions, Bosch Security Systems and Dahua Technology. However, there is a long tail of other suppliers focused on this market, typically supplying specifically into one equipment.

Figure 1.9 Physical Security Services Market Size



Source: IHS Markit © 2016 IHS Markit

SECTION 2

DEEP DIVE ANALYSIS OF KEY THEMES

INTRODUCTION

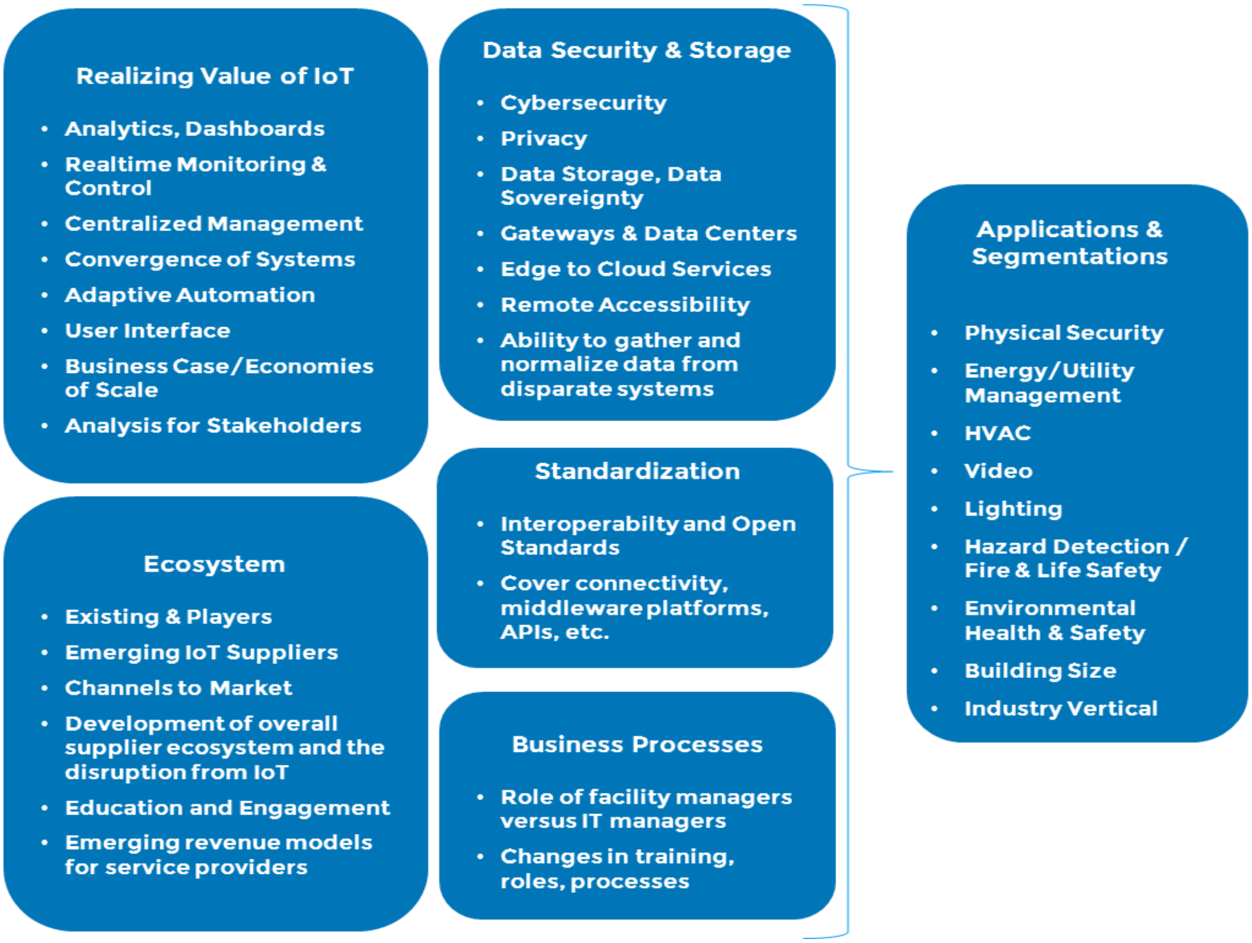
This chapter combined the research obtained from the decision maker survey with the information from the ecosystem interviews to address the main themes that were developed by the project Steering Committee.

Within the original RFP from CABA, the scope of the research was left deliberately broad in order that the project Steering Committee would be able to influence the report specification to address their specific needs. The scope at the highest level was to "Examine the Impact of IoT on Intelligent Buildings". Alongside this around 20 issues were identified that potentially could be addressed within the research.

These are listed below:

- The use of data analytics to create valuable insights from building data
- Mobile dashboards to visualize key building data from mobile devices
- Physical security (video surveillance, entry management)
- Cybersecurity in buildings
- Cloud storage versus on-site versus hybrid
- Real-time monitoring and control of building systems
- Energy efficiency improvements
- Centralized management and convergence of building systems through the use of IoT
- Edge-to-cloud services in buildings
- The role of adaptive automation
- The similarities and differences between new build versus retrofit IoT applications
- Interoperability, including open versus proprietary IoT systems and protocols
- User interface: mobile versus PC versus dashboards
- Role of gateways and data centers
- Wired versus wireless solutions
- Emerging IoT players in the industry
- Business analysis and value proposition for each stakeholder group
- Inhibitors to building IoT industry growth. Evolutions of industry IoT standards
- Barriers towards adoptions of IoT solutions

IHS has attempted to simplify this for the purpose of the scope into five main themes, each of which are examined by application and market segment. These were developed by the project Steering Committee and represented in the graphic below.



2.1 REALISING THE VALUE OF IOT

To understand the value of IoT within an intelligent building, it is first worth outlining the current state of many building systems solutions. At present most systems are relatively standalone with limited interaction between HVAC, energy management, security, and fire and life safety systems. Similarly, building owners, operators, and facility managers with portfolios across multiple buildings or sites, may also be working with different suppliers for the same system type across different buildings and sites, and again typically suffer because there is limited interoperability across these different systems; so each is controlled and monitored as a standalone system.

So the major advantage that IoT could potentially bring to the building itself is the ability to have more centralized control across system types and across systems supplied by multiple manufacturers. There are many hurdles to overcome to achieve this, such as interoperability and data security. These are examined in specific detail in later sections. However, from the perspectives of suppliers, the ecosystem and decision-makers, this overarching theme of centralized control is central.

The scope of this project should be referenced when reviewing this section as the findings are limited to the value of IoT within an intelligent building. There are new value propositions for IoT such as asset tracking, location services, and wayfinding in retail; however, the scope of this research and building professionals that were interviewed did not explore these wider ecosystem implications.

The ecosystem interviews conducted for this research all supported this, particularly those with suppliers. Traditional large building systems suppliers all placed a significant emphasis during the discussions on new solutions that allowed for a greater level of cross-system control and monitoring. Similarly many of the new disruptive suppliers to the market were developing platforms that would sit across the various system types used in the building, to provide centralized control and monitoring.

However, the question then remains: Once this is possible and achieved, what value does it bring to the building owners, operators, and managers? Although the ecosystem interviews gave perspective on what the suppliers to the industry believed would be of value, the decision-maker survey illustrated if this was not always in line with what the customer was actually looking for.

During the ecosystem discussions, suppliers often referred to the new and innovative functions that IoT could bring, such as location-based services, pervasive sensing, scenario creation, etc. However, the results from the decision-maker survey illustrated that often the most important developments were to enhance the more traditional building system functions. This is illustrated in Table 2.1.

Table 2.1 summarizes the scored results to question 2.1 of the decision maker survey. It illustrated that of 13 potential advantages offered to respondents, the ones that were the most appealing were using IoT to "improve financial planning (CAPEX and OPEX)" and "reduce energy consumption & spend". These two were ranked considerably higher than any other potential advantages. The lowest scoring advantages were the more 'creative" ones raised by many of the ecosystem suppliers, such as:

- Provide remote access to building systems
- Future-proof technology investment
- Increased use of sensors to allow greater occupancy-based automation
- Move facility management systems to open standards
- Improve occupant comfort
- Improve occupant safety
- Increase building resiliency via energy generation and storage

Table 2.1 Most attractive advantages that IoT in building automation can bring

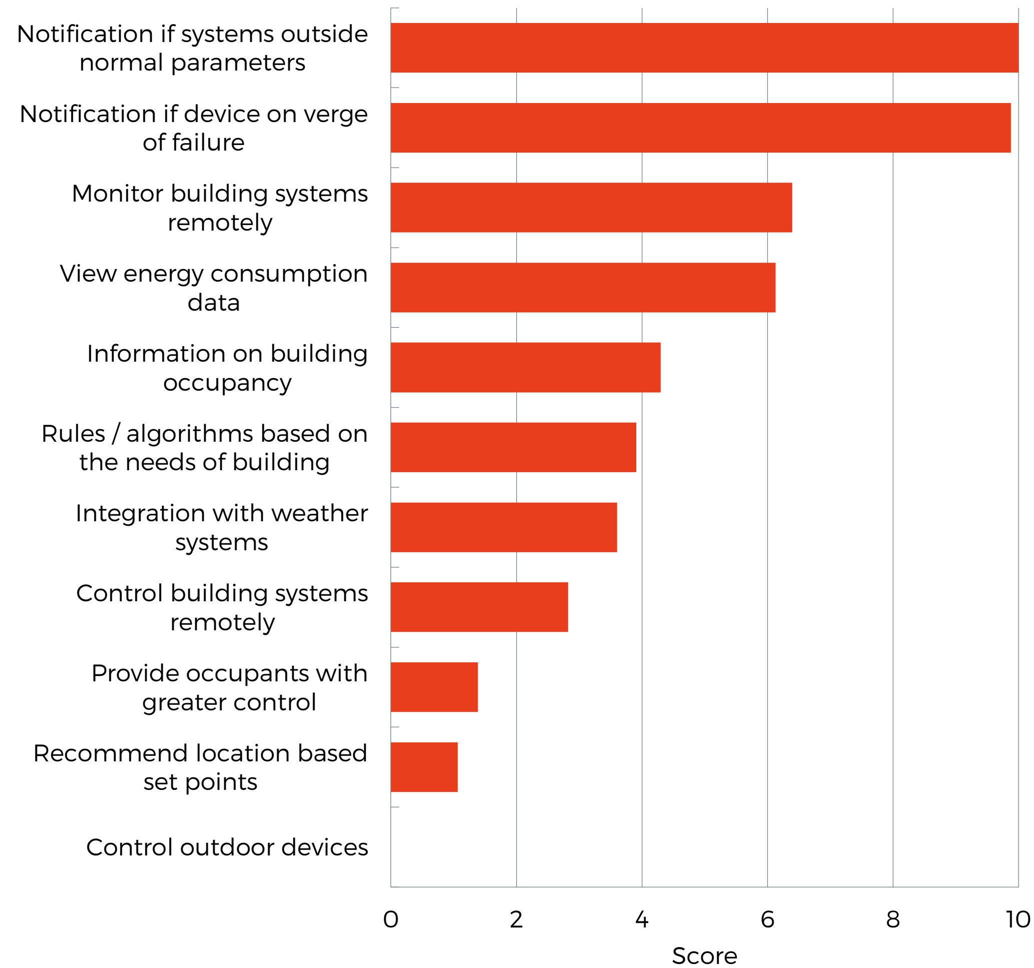
	Total	Industrial	Non Industrial	Auto High	Auto Med	Auto Low
Reduce energy consumption	7.9	8.7	7.6	8.8	5.5	10.0
Improve operational efficiency	4.5	4.9	4.4	4.1	3.9	5.4
Enable predictive maintenance	3.7	3.1	4.0	3.1	4.2	3.2
Improve financial planning	10.0	10.0	10.0	10.0	10.0	8.2
Provide remote access	0.4	-	0.6	0.8	0.5	0.7
Future proof	-	0.3	-	0.5	0.1	0.4
Increased use of sensors	0.4	0.3	0.5	3.2	-	-
Open standards	1.7	2.2	1.6	1.0	2.8	0.6
Increase building performance data	3.9	4.5	3.8	6.6	3.7	2.4
Improve occupant comfort	1.0	1.2	1.0	1.0	0.6	2.2
Improve occupant safety	0.1	0.4	0.1	-	0.3	0.9
Improve tenant/employee productivity	2.0	3.7	1.5	1.7	1.7	3.0
Increase building resiliency	2.1	0.9	2.5	4.2	2.1	1.0

All respondents, n=150 Source: IHS Markit

The conclusion is that some of the potential of IoT is seen as merely 'nice to have'. The most important things that suppliers need to communicate in their marketing are: exactly how IoT will impact the bottom line; how it will reduce the energy consumption of buildings; and how it will allow building owners to improve overall financial planning. Once these points have been made, they can be supplemented by stating other, less obvious advantages that are of interest, but just viewed as 'nice to have'.

A similar message was given from the results to question 2.3, where 11 applications were presented to respondents and they were asked to rank them all from 1 to 7, where 1 was extremely valuable and 7 not of value at all. The results are shown in Figure 3.1.

Figure 2.1 - Application Value - Score



All respondents, n=150 © 2016 IHS-Markit

Again the author concludes that the more traditional, more obvious applications have the greatest value for decision makers. Information on the building system status and the likelihood of failure were the applications that received the highest scores. The more imaginative, less obvious applications, such as "ability to create rules / algorithms based on the needs of your building", "integration with weather systems for historical comparisons as well as future energy & maintenance forecasting" and "use of advanced algorithms to recommend location based set points based on usage and occupancy" were generally viewed as significantly less valuable.

Real-time monitoring and control; and centralized management

Real-time monitoring and control is the ability of building owners, operators, facility managers, and (to some extent) other building occupants to control building systems in real-time, typically using centralized control systems. This is at the center of most automation systems but it is important and the future evolution of this function was a key factor that the steering group for this project identified as a subject to be investigated via this survey.

Again the results to Question 2.3 of the decision maker survey support the importance of this type of feature. The leading IoT-related applications ranked by survey respondents were all related to having real-time visibility and control of building functions, as illustrated in Table 2.1.

There was a slight nuance from the responses regarding remote monitoring and control from off-site locations. Although being able to monitor systems remotely ranked as important, the control elements were ranked as less so. This implies perhaps that respondents would prefer to action changes from on-site control.

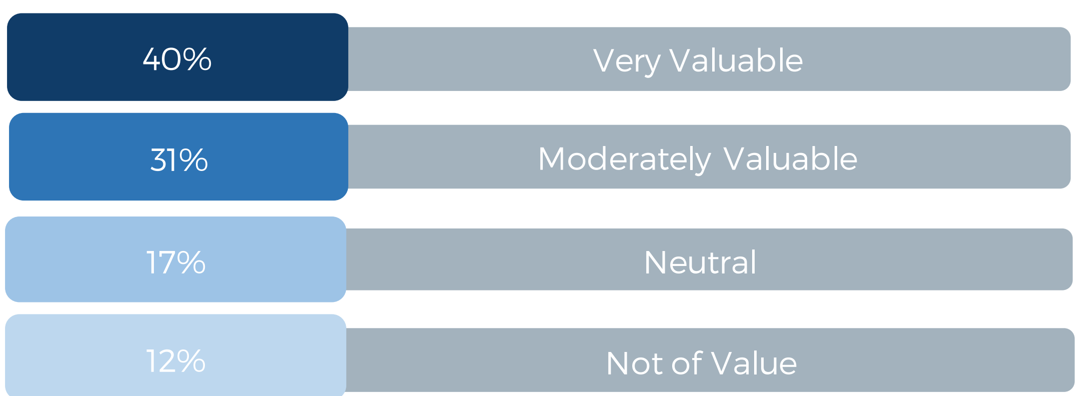
However, IoT has the potential to make it much easier to control building systems. As mentioned earlier, most systems already have at least some element of real-time monitoring and control. What needs to occur to realize the full value of IoT is for this to move from control of individual systems in individual buildings, to a more cross-system, cross-building/campus control.

The ecosystem interviews all supported this direction of travel in terms of system developments. Large incumbent suppliers, such as Siemens, Johnson Controls, and Schneider Electric all recognized the need to have centralized control across system types from different suppliers; they either had solutions or were developing them to make this possible. Furthermore, new platform suppliers were also offering solutions that would perform this function, offering a platform that would sit across different system types from multiple suppliers and give the user a single dashboard to interface with them all.

These cross-system control solutions are not without challenges though. As discussed later in this chapter, the many connectivity standards used in building systems means that providing solutions that bridge them all to give real-time visibility across the whole portfolio of building systems presents a significant barrier. Furthermore, many of these platforms are cloud-based solutions where data travels one way, from the building to the platform, often for data security reasons. Therefore this only gives the ability to monitor systems real-time across the portfolio of solutions. The control element is not always there and so only some of the advantages of IoT are being realized. The trade-off here is less functionality in return for a system that will meet the security requirement placed by many IT departments. However, a solution to work around this will need to be developed to realize the full potential of IoT. Two-way flow of data between platforms and building systems is needed to build systems that offer true adaptive automation.

The concept of having one platform to control all systems real-time across building functions was examined in Question 2.5, where respondents to the decision maker survey were asked to give their views on the value of a single solution to control all building functions. Figure 2.2 illustrates these results; it is clear that there is a strong demand for such platforms, a positive indicator for new platform suppliers addressing this market and incumbents developing solutions alike.

Figure 2.2 - Respondents' level of value in single system to control all systems



All respondents, n=150 © 2016 IHS-Markit

User interface

The user interface for building systems can vary significantly depending on the level of automation within the building. At the simplest level, a lighting system can be controlled by a simple, traditional light switch. At the other end of the scale, lighting and all other building systems are controlled via one interface; and in many cases, control is limited to predetermined parameters that rely on information from occupancy sensors, thermostats, meters, etc. However, as systems become more sophisticated and integrated, the question on how best for the user to interface with devices becomes more complex.

The ecosystem interviews tended to support the trends that one common interface would be required that had a consistent look and feel. This one interface would then be replicated across devices types used to control systems. So if a user were to interface via a dedicated workstation or via a tablet PC, the look and feel of the interface would remain consistent. Most centralized systems being offered by large system suppliers or independent platform suppliers tend to follow this format. If anything, the opinions from ecosystem interviews tended to downplay the importance of how the user interface would vary across device types. The mantra was that users in everyday life are becoming increasingly accustomed to being able to access everyday functions (e.g., banking, online shopping) and other business functions (CRM tools, accounting tools) across laptops, workstations, tablets and PCs alike through a user interface with a common look and feel; and that this will translate naturally into the building system marketplace.

One view echoed by a number of solution providers was that different device types will tend to be used in different scenarios. The central workstation would be used for more complex building control functions and when system parameters were set; whereas facility managers would check specific parameters or work in the field within the building using other remote devices, such as smart phones and tablets.

The results to the decision maker survey did bring this issue back down to basics to some extent. It asked respondents to indicate the preferred two device types for interfacing with a range of building functions (Question 2.4).

The device types put to respondents were:

- A simple dedicated device, e.g. a thermostat for energy management, a room HVAC control panel, a light switch
- A sophisticated dedicated device, e.g., centralized lighting control panel, centralized HVAC control panel, centralized access control panel
- An on-site PC/laptop/workstation
- An off-site PC/laptop/workstation
- A smart phone that can be used from any location
- A tablet PC that can be used from any location

Figure 2.3 illustrated the results and show a consistent picture where 'a sophisticated dedicated device, e.g., centralized lighting control panel, centralized HVAC control panel, centralized access control panel' was the number one ranked interface for five of the six system types examined. The second ranked interface for five of the six systems was 'An on-site PC/laptop/workstation'. Lighting was the only application that had a different result; but it was still the same two solutions with their order reversed.

So the clear message from the decision-maker survey was that the traditional forms of user interface were still preferred. That is not to say other formats didn't receive some interest. Tablet PCs were consistently the third most indicated device with between 28 percent and 37 percent of respondents, depending on system type, indicating it was in their top two preferred device types.

Figure 2.3 Respondents' level of value in single system to control all systems

Physical Access Control	-Sophisticated Dedicated Device -Onsite PC/Laptop/Workstation
Energy Management	-Sophisticated Dedicated Device -Onsite PC/Laptop/Workstation
HVAC	-Sophisticated Dedicated Device -Onsite PC/Laptop/Workstation
CCTV	-Sophisticated Dedicated Device -Onsite PC/Laptop/Workstation
Lighting	-Onsite PC/Laptop/Workstation -Sophisticated Dedicated Device
Hazard Detection	-Sophisticated Dedicated Device -Onsite PC/Laptop/Workstation

All respondents, n=150

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Adaptive automation and predictive maintenance

Adaptive automation is the ability for building systems to adapt automatically depending on a number of potential external influences. The concept is relatively broad in terms of scope and can range from something as simple as a thermostat being used to control a heating system to more complex systems where a whole range of external inputs are provided to systems that then react accordingly. For example, taking the thermostat example to the next stage, not only could an adaptive automation system adapt to the current building and external temperature, but it could take input from other sources such as weather forecasts, energy prices and building occupancy to manage building temperature in a more sophisticated and potentially more economical way. Adaptive automation can also be used to prolong the operational life of system components. For example, should data from a system component indicate that failure was imminent its use could be adapted to prolong operational life. Or system parameters could automatically be adjusted so that when it came to repair, the impact on the wider building functions was minimized.

Functions such as this will be vital to realize the full value of IoT in intelligent buildings. However, much investment is still needed to persuade purchasers of building systems on the value of such solutions. The results from the decision-maker survey continuously indicated little perceived interest or value in functions that would allow adaptive automation. For example in Question 2.3 where a range of applications were put to respondents, those relating to adaptive automation such as 'integration with weather systems for historical comparisons as well as future energy and maintenance forecasting, 'ability to create rules / algorithms based on the needs of your building' and 'use of advanced algorithms to recommend location-based set points based on usage and occupancy' were all ranked relatively low. That being said the wider concept of "enable predictive maintenance was ranked fifth from 13 applications in Question 2.3, so the interest is certainly there. It would just seem decision-makers are less interested in the mechanics of how this is done than the overall concept. It should be noted however, that the interest was particularly driven by those from the industrial sector; and so, although the survey was specific to respondents in the instruction to answer in the context of their building systems, the more positive views from industrial respondents could be linked to some extent with their requirements for predictive maintenance of factory automation equipment.

2.2 DATA SECURITY AND STORAGE

IoT and the development of cloud services have opened up new opportunities and business models for ecosystem suppliers to the commercial building systems market. However, many of these new services and business models are predicated on the data generated by the building systems being stored remotely and potentially analyzed by third parties. A key focus of this study was to understand how these services should be developed and to understand the views and attitudes of building owners and operators to data storage and security.

The main advantages of using cloud services in relation to building systems include:

- It allows third parties to provide real-time analytics services
- It allows aggregate control across different building locations
- It allows aggregate control over multiple system types
- It provides remote access to building data
- It allows other data streams, e.g., weather forecasts, to be merged with the building data to enable these data streams to be used to provide a further level of context and depth to the analytics
- It allows building automation solutions to be provided as a service
- A key observation from all the supply-side research was that all interviewees were rolling out or had rolled out cloud-based services for their customers. This applied to both established building system suppliers (such as Johnson Control, Siemens, Schneider Electric and Philips) and new companies that are specializing in developing cloud-based services that work alongside systems supplied by the established players. A key issue relating to this is of course customer attitudes to third parties storing, and using their data.

The data from the supply side interviews pointed to the fact that all suppliers were extremely aware of issues relating to data security and privacy that cloud-based services and IoT would in general bring, and were attempting to address them in the products they were offering; they ensured that their solutions met relevant data security standards, or sought to reduce the concern by developing solutions that received data only one way and did not directly feed data or impose control back into building systems. The interviewees from the supply side typically expressed confidence that their solutions would overcome customer concerns.

However, there was some recognition that this would vary by sector and customer size. The perception was that for smaller building owners/operators, third party access and use of company data would be more acceptable; but for some sectors, such as government-owned buildings, the challenges would be much greater.

The decision maker survey put a number of specific questions to owners and operators in relation to their views on this topic. Further, ecosystem interviews conducted with larger building owners and operators were also used to test attitudes to data security and privacy.

Table 2.2 Respondent attitudes to the use of cloud-based services for building systems

Data Storage	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
All data on-premise	47%	22%	47%	43%	57%	42%	46%	54%	50%	41%
Off-prem but Co. Owned	21%	23%	23%	22%	18%	32%	22%	12%	12%	5%
Some data 3rd party	11%	10%	9%	14%	7%	10%	10%	12%	21%	22%
All data 3rd party	21%	45%	21%	22%	18%	16%	22%	22%	17%	32%
3rd party but in country	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

All respondents, n=150 Source: IHS Markit

It shows that for the majority of the sample respondents (68 percent) were not willing to store their building systems' data on third-party systems. Of those that were willing, 11 percent of the total respondents restricted the types of data the third parties could store. For those that could store some or all data on third-party systems a further question put to decision makers established that two-thirds of this group also required that dedicated private systems would be needed to be offered by these third parties and they were not willing to use shared/public clouds.

These results illustrate a significant difference between the views of suppliers expressed in the ecosystem interviews and those from decision makers on the purchasing side. This means there is a huge barrier to overcome to realize the full potential of IoT in intelligent buildings. The whole idea of intelligent building systems using IoT relies on solution providers providing their systems as remote services. Such a hostile view from decision makers on the buying side brings into question the whole IoT concept.

To some extent, it is expected that these views will soften over time. Similar views were seen for non-building system solutions targeted at enterprises in the past, such as core-HR solutions, CRM solutions, accounting solutions, etc. Over time as these systems have become more commonplace, organizations have become less and less resistant to using third-party cloud-based systems to operate such systems. Solutions of this nature for building systems are relatively new and are targeting very traditional markets.

The negative reaction softened a little according to company size. Respondents from small and medium organizations were a little more likely to entertain third-party-operated cloud systems.

From the ecosystem interviews, it was also apparent that attitudes changed significantly when it was re-enforced that the solutions offered were just one way in terms of data flow; i.e. data would flow only from the customer organization systems to the third-party solution provider. The third-party would not then be able to have direct control of building systems. Ecosystem suppliers interviewed indicated that once this was explained to IT managers in potential customer organizations, concerns over third-party storage and the management of data were reduced significantly.

However, systems of this nature limit the full potential of utilizing IoT in intelligent buildings. Section 3.2 examines the potential of predictive maintenance and adaptive automation. To fully realize the benefits that could potentially be offered by predictive maintenance and adaptive automation, systems really need to have a bidirectional flow of data. Both rely on data from systems being analyzed and then that data being acted upon either automatically by adjusting system parameters or by alerting facility managers to change system settings or replace components, with the automated version offering the greatest efficiency advantages. So although pushing the security advantages of data flowing in one direction may open the door to more customers using IoT, it can really only be a short-term strategy if the full concept of IoT in building automation is to be realized.

Data sovereignty relates to restrictions on the country in which data can be stored when using third-party cloud services. It was raised as an issue of concern by the project Steering Committee during the scoping of this research. Ultimately; however, it was not viewed as a significant issue either in the ecosystem interviews or the decision maker survey. Few within the ecosystem discussions, either from a system supplier, IT supplier or building owner/operator expressed any concern in relation to this being a barrier to cloud adoption. None of the decision maker survey respondents indicated it was a condition of using third-party cloud services.

2.3 ECOSYSTEM

Open ecosystems and cross-vertical, cross-value chain collaboration are crucial in the IoT because much of the proposed innovation and value is due to "mash ups" (e.g., integration) of data from diverse sources, ranging from connected machine and sensor data and traditional ERP/CRM systems, amongst others. Traditional models for connected device markets face a number of interrelated challenges:

- Such applications and services are typically tightly vertically integrated and in many cases use proprietary technology.
- Data is often isolated and in silos. The developer or implementer is responsible for deploying the application infrastructure and has access to the data only from the application infrastructure.
- The pace of innovation is gated by the resources available to the developer.
- Security can be problematic. Though "security through obscurity" is in use, it rarely compares well to security mechanisms that have been vetted by a large body of participants in an open manner.

Application – Competitive environment overview

In the intelligent building market, there are many suppliers in the total ecosystem. Each application of the intelligent building is served by a different set of suppliers, with very little overlap. With regards to IoT, the question is whether the market will be disrupted in any of these individual application markets; and to what extent we will see that happen from existing players moving across the ecosystem or new IoT suppliers entering the intelligent building market. The following sections review the current competitive environment for the major application markets.

Commercial lighting

Philips is estimated to have been the largest supplier of lighting control equipment to commercial applications in 2015, with an 8.5 percent share. Leviton and Lutron are estimated to have been second and third, with 7.5 percent and 7.0 percent market share, respectively. Of the top 10 companies in the commercial market, only Legrand are solely focused on the commercial market. Acuity Brands, OSRAM SYLVANIA Inc, Panasonic and Zumtobel group are mostly focused on the commercial market, but also have some products in the outdoor and street lighting area.

'Lighting in the IoT' has recently been a major topic of conversation in lighting and communications companies. Although the concept of smart lighting in commercial applications has been around for decades, control systems are becoming steadily more complex, and the recent evolution of the IoT universe is finally helping companies outside the lighting industry see new possibilities and take advantage of the increased opportunities a smart lighting system can provide. Thanks to improved communications to the luminaires, and the occupancy, movement and daylight sensors – as well as analytics and fault detection systems – facilities managers can now not only increase efficiency, but can also even help improve employee productivity.

Current lighting control systems typically use a dedicated lighting control network, using either a wired system (such as DALI) or a wireless system. However, with the falling power requirements of new high-efficiency LED lights, it is now possible to provide both power and communications capability to a luminaire using just one connection. However, this power-over-Ethernet (PoE) capability increases the complexity of a building's Ethernet network.

The technology advances in commercial lighting and the interest in IoT are driving changes in the overall ecosystem as we see players from other markets looking to create partnerships and gain a foothold within the industry, which is happening across many verticals for the IoT. Most significantly IT vendors are taking a strong interest in the commercial building market. Examples of these partnerships in recent years include:

- Cisco announced a global strategic alliance in the late second quarter of 2015 with Royal Philips, aimed at addressing the Internet of Things (IoT) in the commercial office lighting market. Cisco, the world's largest provider of commercial networked products, is focused on providing a competitive PoE solution. In addition, in July 2016 Cisco announced a similar partnership with Cree with the same goal in mind.
- GE's Current announced the acquisition of Daintree Networks, which owns an open-standard lighting platform for smart buildings. The network is an open variant of ZigBee and joining the two solutions together is a play for GE to leverage Predix to offer analytics to intelligent buildings.

Video

The year 2013 was pivotal for the video surveillance industry, because it was when predictions of market concentration started to become a reality. It was also when the estimated market share of the top 15 video surveillance equipment suppliers jumped 10 percentage points over the previous year's share. In short, 2013 was when the video surveillance market finally started to mature. But that is not the whole story.

Supply was – and is – becoming more concentrated, but it was not primarily the result of the many acquisitions the industry has experienced in recent years. As significant as they might be to the future of the industry, the acquisitions of Axis Communications and Milestone Systems by Japanese multi-national company, Canon, had little effect on the combined revenue share of leading vendors. In fact, the organic revenue growth of Chinese supplier, Hikvision, had more of an effect on making supply more concentrated in 2015. Despite the increase in merger and acquisition activity, increased supply concentration has been caused by companies taking market share from competitors, rather than by acquiring it through mergers.

The established realities of the market are also changing, as best-of-breed product suppliers are being challenged by solution providers offering pre-integrated products. Integrators are increasingly leveraging single-vendor solutions to reduce installation costs and focus on the more profitable service and maintenance contracts. Security camera shipments are booming and are forecast to exceed 100 million units in 2016, but annual revenue growth has slowed to low single-digit rates. A war of attrition is being waged over the more price-sensitive markets.

In spite of the price pressure and extreme competition of the last few years, the competitive landscape has not changed as much as one might expect. According to the latest annual market share analysis from IHS, 11 of the same companies have remained in the top 15 global video-surveillance equipment suppliers from 2010 to 2015. The companies gaining market share are no longer the new kids on the block, they are incumbents and leaders in the market.

The video surveillance market is changing. In price-sensitive markets, like the retail and commercial sectors, price is king and margins are low. Western vendors are exiting these markets, unsure of how to make the margins necessary to sustain their businesses. The high-end value-added markets, where functionality, reliability and performance are critical, are getting crowded. This is the battleground where the majority of video surveillance equipment vendors will either meet triumph or defeat.

Physical security

As price, brand, and channel strategy continue to gain importance, the physical security industry is expected to undergo further consolidation in the security system integration market. Larger suppliers are likely to acquire smaller companies in a bid to expand their footprint in complementary geographic regions. Interestingly, having established themselves in the domestic market, many Chinese physical security brands are now starting to gain market share worldwide, increasing the price competition in many technology markets. As supply to the physical security market continues to become more concentrated, Tyco International was the largest global supplier to the equipment and services market in 2015, followed by ADT, and the biggest mover Hikvision in the third position.

Johnson Controls and Tyco International announced plans to merge in early 2016, with the deal expected to close at the end of 2016. The deal is still subject to approval by regulators and shareholders. The combined company will be known as Johnson Controls PLC and it forecasts revenues of $32 billion in 2016.

Johnson Controls is a large industrial company with 130,000 employees, operating in more than 150 countries providing products, solutions and services in three main areas: building efficiency, batteries and energy storage, and automotive. Tyco is a pure-play security and fire company with 57,000 employees, providing products, solutions and services across the security and fire industry.

This merger brings together the largest security system integration business, Tyco Fire & Security, under the control of a smaller security integrator, but overall a larger company, Johnson Controls. Johnson Controls has already announced that it is divesting its automotive business, stating that it is working to become "a building-technology, building-automation giant". This acquisition will solidify that position, bringing together Johnson Controls' building automation products, solutions and services with Tyco's fire safety and security products and integration business.

After the automotive business is sold, the new Johnson Controls PLC will get 70 percent of its revenues from physical products and 30 percent from services, according to Tyco's CEO George Oliver. Johnson Controls has an existing security system integration business which IHS estimates to be the tenth largest in the world. Meanwhile, Tyco Fire & Security is estimated to be the world's largest security integrator. The two companies would have a combined share greater than 5 percent of a global market worth around $62 billion. Despite this, the security integration supply base would remain highly fragmented, with the top 15 integrators accounting for only around 20 percent of total global revenues.

HVAC – Controllers and equipment

The HVAC market should be reviewed as two distinct areas – controllers and equipment – as suppliers for each vary greatly. This section reviews the competitive environment for each separately; but in general IHS does see convergence between the two as control is becoming critical in the intelligent building solution.

HVAC equipment – The leading manufacturers of HVAC equipment include the multinational suppliers Carrier, Trane and Johnson Controls. In the VRF (variable refrigerant flow) equipment market, the situation is simpler, with the major suppliers the Japanese manufacturers Daikin, Mitsubishi, Panasonic, Hitachi and Toshiba. Daikin has always been a major global supplier and has gained position in the American market in recent years with key acquisitions of McQuay International and Goodman Global. Major suppliers in the market, including many Japanese and US manufacturers, have recently created partnerships to gain a network of installers in the Americas. For example, Trane has a relationship with Samsung; Carrier with Toshiba; and York with Hitachi. In many developing regions, HVAC partnership, manufacturers and local regional suppliers are starting to emerge, as companies try to tap into the market while extending their product portfolios. This and other partnerships are very similar to the ones that have occurred between US and Japanese manufacturers, which are trying to bring VRF to the US market. In January 2015, Johnson Controls and Hitachi entered into a definitive agreement to form a global joint venture to combine product portfolios so that they could offer a diverse range of products for the HVAC market around the world.

HVAC controllers – The leading manufacturers of HVAC controllers include: Siemens, Honeywell, Johnson Controls, Schneider Electric, Azbil Corporation, Trend Controls, and Trane. The American market continues to be dominated by large multinational companies such as Honeywell, Siemens, and Johnson Controls. These companies have been able to use their influence in the United States to gain a foothold in the developing countries of Latin and South America. Across multiple regions, many midsized-companies in the controller market have been able to take share from the larger players. IHS believes that this can partly be attributed to larger companies providing more attention on a route to market that involves building an internal systems integration and distribution network. This change in focus has enabled mid-sized companies to win business through integrators. In Asia, the multinational corporations which dominate in EMEA and the Americas do the same, except in Japan and South Korea. Japan is dominated by local companies; and while there is an influence of some multinational corporations in the region, IHS estimates that non-Japanese companies make up less than 30 percent of the country's market. South Korea is similar in that a few local companies dominate the market and penetration by foreign companies in the market remains low.

Demand for centralized control may disrupt ecosystem

An increased demand for systems to come together with centralized control and a centralized interface could disrupt the overall ecosystem as IoT promotes interconnectivity of these disparate systems. Each of these individual systems have quite separate suppliers that now will be part of one overall ecosystem and their interactions will fundamentally change as centralized control will need to pull on feedback from each system. It has already been reported that single-product suppliers are increasingly being challenged by solution providers offering pre-integrated products. Integrators are increasingly leveraging single-vendor solutions to reduce installation costs and focus on the more profitable service and maintenance contracts.

The various changes in the ecosystem that might result from the demand for centralized control include:

- Current suppliers of one system entering other system markets
- Mergers and acquisition activity to gain competitive competence
- Partnerships across system types
- Platform need brings new players or expands existing players' capabilities

Platform need brings new players or expands existing players' capabilities

Individual application markets in the intelligent building are quite distinct areas at the moment; but the blending of control and technology could also create a greater need for a unified platform. This also includes a response to a continually increasing focus on integrating the massive, new flows of data from machines and sensors with existing and emerging data sources, to produce novel and actionable insights.

What exactly is an "IoT platform"? This is a complex question because of the ambiguity of the varied uses of the term by the multitude of players in the IoT market. IoT platforms are "cloud-based and on-premises software packages and related services that enable and support sophisticated IoT services". In some instances, IoT platforms enable application developers to streamline and automate common features that would otherwise require considerable additional time, effort and expense. In other instances, IoT platforms enable enterprises to manage thousands, millions, and even billions of devices and connections across multiple technologies and protocols. Finally, in some cases, IoT software enables developers to combine device and connection data with enterprise-specific customer and ERP data as well as data from third-party sources to create more valuable IoT applications.

Current players in the intelligent building ecosystem are looking to expand and offer a platform to widen their reach within the ecosystem without entering the other application markets with new hardware solutions.

In addition, dedicated platform suppliers are entering the market, which could significantly disrupt the market. These platform providers have the ability to focus on the differentiated and unique value the application provides and outsource common, industry-wide features and functionality. This obviously reduces the time to market, the investment and expertise needed, and the risk. Providers without existing business in the intelligent buildings market are likely to enter the market and there are already a few examples of this happening. One example, Lucid Connects, is providing a software solution that it maintains can interact with back-end systems of multiple applications in the intelligent buildings ecosystem and provides real-time analytics to building managers. Despite the larger building automation players trying to provide their own platforms, these dedicated providers are entering the market quickly. These dedicated providers will not take away building system business, but will encroach on future development of analytics businesses for individual building automation companies.

Another factor which may affect the intelligent buildings market in the future is new entrants that look at building automation as the first step to building and maintaining "smart cities". The most notable of these companies is IBM, which has a smart building initiative and believes that, based on data analysis of energy usage, it can help make cities around the world more "green." While IBM seems more interested in the data involved with buildings and could gather that data through partnerships with integrators, IBM and other companies interested in building data may find it more beneficial to enter into the intelligent building market and offer a range of services dealing with analytics.

Challenges on the road to a truly pervasive IoT driven by complexity

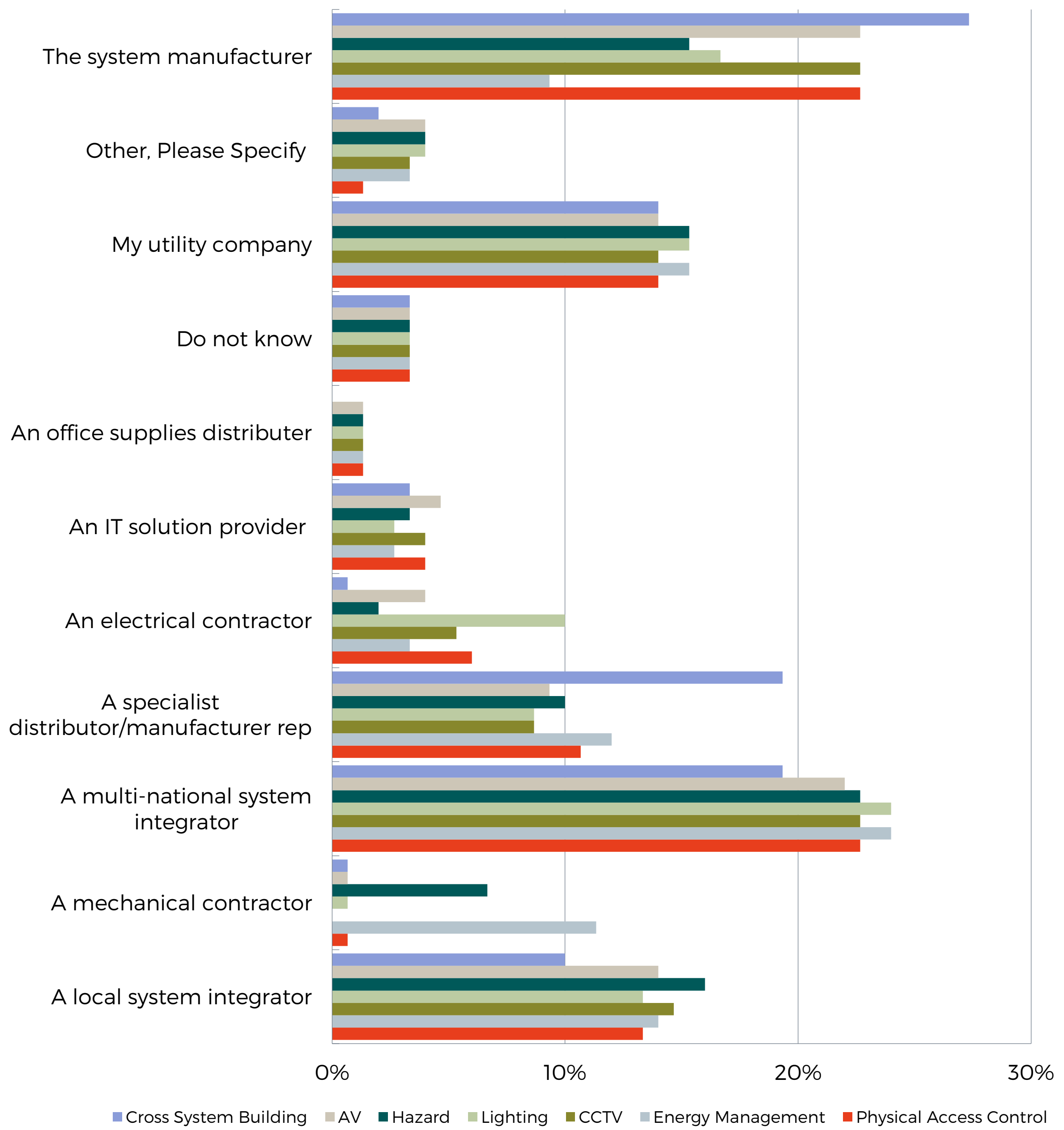
1. **Fragmented supply chains and ecosystems** make it difficult for developers and customers to determine the best partners and sources for tools, components and supporting services. Despite companies reporting they would like a more centralized control of systems, results from the survey indicate there are still a number of barriers to achieving this. They include two key factors within the ecosystem. There are multiple routes to market; depending on either the system or the customer type, customers buy in different ways. A similar message was given from the results to Question 3.1, it is evident there are a wide range of preferred solution providers.

2. **Diverse standards and technologies** make it difficult to evaluate the multitude of available technology options. For example, when a developer prefers a wireless solution, a choice must then be made between the use of licensed or unlicensed spectrum, and of using a public cellular network or deploying a private low-power wide area network or short-range wireless mesh network. These are only a few of the possible variants and consider only the physical layer of the communications infrastructure; the task is much more complex than this.

3. **The need to change fundamental business or organizational processes** engenders significant uncertainty and risk for traditional organizations implementing IoT initiatives. It is a dramatic change for a business organized on a traditional product OEM basis to adopt the processes needed to successfully implement a successful, ongoing service model with customers.

4. **There is a lack of experience in developing connected products and services** on the part of many traditional product OEMs. Continuing on the point above, many traditional organizations lack the experience and expertise needed to successfully integrate their products and services.

Figure 2.4 - Supplier - By System



All respondents, n=150

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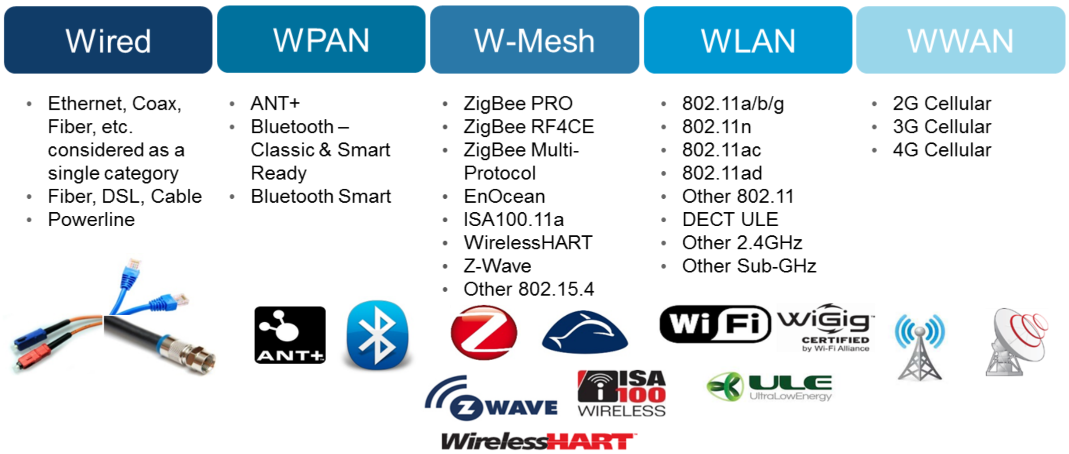
2.4 STANDARDS

A consistent issue that affects IoT in all application areas is interoperability, and the vast array of standards and technologies that are used to connect devices. Connectivity is at the core of IoT; however, the lack of common standards is also one of its greatest barriers. The diagram in Figure 2.5 outlines the many connectivity solutions used in IoT ecosystems.

Add to this the vast array of wired solutions, and the issue is amplified several fold. In building systems the wired and wireless standards are unique to some extent; in that, for some, their use is limited to just building systems and they are not used in other IoT application areas. This is partly because the dominant suppliers in the industry have been key proponents or developers of these technologies and have a vested interest in their continued use. Common wired solutions that are used include: 0-10v electrical signal, -20 mA current loop, BACnet, KNX, LonWorks, Modbus, DALI, Ethernet, DSI, Insteon, OBix, Powerline, plus a host of other proprietary wired solutions,

Figure 2.5 Wireless Connectivity Solutions Used in IoT



Source: IHS Markit © 2016 IHS Markit

A key focus of the study was to attempt to understand to what extent this fragmentation of technologies and standards would affect the use of IoT in building systems.

The decision maker survey looked in detail are the range of communication protocols used by respondents. Tables 2.3 and 2.4 below show the responses that were received when the sample was asked to specify the most common standards used for wired and wireless communication, respectively.

The responses show a number of key points:

- Many respondents were not aware of what technologies they were using, for wired or wireless.
- It is unclear if respondents completely understood question 5.1. For instance, the number of responses for lighting in the 0-10V category were noticeably low; however, some of the respondents that answered “Do not know” could fall into this category.
- Of those that did know, the most common wired solution used was BACnet; however, the spread of different wired solutions used was relatively broad.
- Of those that did know, the most common wireless solution used was 802.15.4 ZigBee. However, again the spread of wireless solution used was relatively broad.
- Depending on system type, between 18 percent and 27 percent of respondents used only wireless solutions for individual systems. Physical access control was the system type where wireless only was most prevalent. Lighting was the system type where wireless only was least prevalent.
- Depending on system type, between 25 percent and 33 percent of respondents did not use wireless at all for individual systems. HVAC was the system type that had the lowest share of respondents using wireless; and CCTV being the system type where there was the highest uptake of wireless.

Table 2.3 Wired communication protocols used by respondents

Protocol	Physical Access	Energy	HVAC	CCTV	Lighting	Hazardous
All Wireless	27%	23%	20%	25%	18%	21%
0-10v	1%	1%	1%	1%	1%	1%
0-20 mA	0%	0%	0%	0%	0%	0%
BACnet	15%	16%	19%	15%	13%	16%
KNX	4%	4%	5%	4%	4%	4%
LonWorks	0%	0%	0%	1%	0%	0%
Modbus	3%	3%	2%	2%	2%	2%
DALI	0%	0%	0%	0%	1%	0%
Ethernet	18%	15%	19%	17%	15%	18%
DSI	0%	0%	0%	0%	0%	1%
Insteon	3%	3%	3%	3%	3%	3%
OBix	3%	3%	3%	3%	3%	3%
Powerline	3%	3%	3%	3%	3%	3%
Other	1%	7%	4%	4%	16%	6%
Don't Know	21%	21%	21%	21%	21%	21%

All respondents, n=150 Source: IHS Markit

Table 2.4 Wireless communication protocols used by respondents

Wireless Protocol	Physical Access	Energy	HVAC	CCTV	Lighting	Hazardous
None, all wired	27%	28%	33%	25%	27%	30%
Bluetooth	0%	0%	0%	0%	0%	0%
EnOcean	0%	0%	0%	0%	0%	0%
Insteon	5%	8%	6%	8%	5%	5%
802.15.4 Other	0%	0%	0%	0%	0%	0%
Cellular data	1%	1%	1%	1%	1%	1%
DALI Wireless	0%	1%	1%	0%	0%	1%
WiFi/802.11	7%	3%	3%	9%	3%	5%
Z Wave	10%	6%	11%	7%	9%	7%
Other	1%	4%	2%	4%	12%	5%
802.15.4 ZigBee	16%	15%	10%	13%	9%	13%
Don't Know	33%	33%	33%	33%	33%	33%

All respondents, n=150 Source: IHS Markit

Table 2.5 summarizes a scored version of the to indicate on a five-point scale the extent to which they agreed with the statement, A score of 10 is given to the highest scoring statement in terms of overall strength of agreement from respondents. A score of 0 is given to the lowest. All other scores are proportional to the balance of responses received.

- It's important that building technology systems that I purchase allow the sensors, controllers, actuators, etc. to be connected via **both** wired and wireless communication protocols.
- I'm not concerned about the use of standards and common communication protocols as long as this does not impact the centralized management of building systems.
- It is important that the building technology system my company purchases uses a universal/standardized data normalization or tagging scheme such as Haystack
- Issues around interoperability are preventing me from investing in innovative intelligent building systems.
- I buy systems from a single vendor – issues of interoperability are resolved by this vendor of choice.

For each respondents were asked to indicate on a five-point scale the extent to which they agreed with the statement, Table 2.5 summarizes a scored version of the responses (see Chapter 4 for details on the scoring system). A score of 10 is given to the highest scoring statement in terms of overall strength of agreement from respondents. A score of 0 is given to the lowest. All other scores are proportional to the balance of responses received.

Table 2.5 Overall View on Interoperability Issues by respondents

	Total	Industrial	Non Industrial	Auto High	Auto Med	Auto Low
Open Protocols	10.0	10.0	10.0	10.0	10.0	10.0
Wireless Connections	5.2	5.9	5.1	2.9	6.0	5.4
Wired Connections	5.5	6.6	5.3	4.8	5.7	5.9
Wired & Wireless Connections	8.0	9.4	7.6	8.5	7.4	9.2
Not Concerned About Open Protocols	3.2	0.9	3.9	2.7	3.4	3.4
Universal Data Normalization (e.g. Haystack)	9.3	8.4	9.6	9.4	9.5	8.9
Preventing Me From Investing	1.8	0.0	2.4	0.3	2.8	0.2
Solved by My Single Source Vendor	0.0	0.5	0.0	0.0	0.0	0.0

All respondents, n=150 Source: IHS Markit

The table shows that the demand for the use of open protocols was extremely strong with "It's important that the building technology systems my company purchases use open communication protocols to allow for greater interoperability" being the statement that received the highest level of agreement in the scoring system. This was irrespective of respondent type. So, although the industry is plagued with fragmentation in term of communication protocols used, the demand from the buying side for systems that use open protocols would appear very strong.

The statement that received the second strongest scored level of agreement was "It is important that the building technology system my company purchases uses a universal/standardized data normalization or tagging scheme such as Haystack".

(Project Haystack is an open-source initiative to streamline working with data from IoT. It is intended to allow the standardizing of semantic data models and Web services, with the goal of making it easier to unlock value from the vast quantity of data being generated by the smart devices. Applications include automation, control, energy, HVAC, lighting, and other environmental systems. In essence, it looks to ensure that data is managed in a structured common format irrespective of communication protocol. The intention is that this will allow greater interoperability across different system types, as the data named, used, and labeled will remain consistent. During the ecosystem interviews, Project Haystack was raised by most suppliers as the vehicle to overcome the issue of multiple communication standards being used. It would also seem from the decision maker survey results that this was also the view of many of the respondents.)

The statements that received the lowest scores were:

- I buy systems from a single vendor – issues of interoperability are resolved by this vendor of choice.
- I'm not concerned about the use of standards and common communication protocols as long as this does not impact the centralized management of building systems.
- Issues around interoperability are preventing me from investing in innovative intelligent building systems.

This illustrates that respondents do not feel that the issue has been addressed by suppliers and it is one that is very important to them. However, one interesting result was the fact that it is not preventing them from investing in innovative intelligent building systems. To some extent it would appear that purchasers are resigned to the fact that the industry is plagued within interoperability issues; however, they continue to try to continue to advance their systems by working around these issues as opposed to waiting until they are completely resolved.

2.5 BUSINESS PROCESSES

Fundamentally, the level of control in an intelligent building is changing and growing, which will ultimately have an impact on business operations overall, and how businesses approach control moving forward. At the moment, there are two clear examples of changes in the current business practice of many companies in the intelligent building market in direct response to this increase in control of a building; they are the changing roles of facility managers and a focus on service instead of hardware from suppliers.

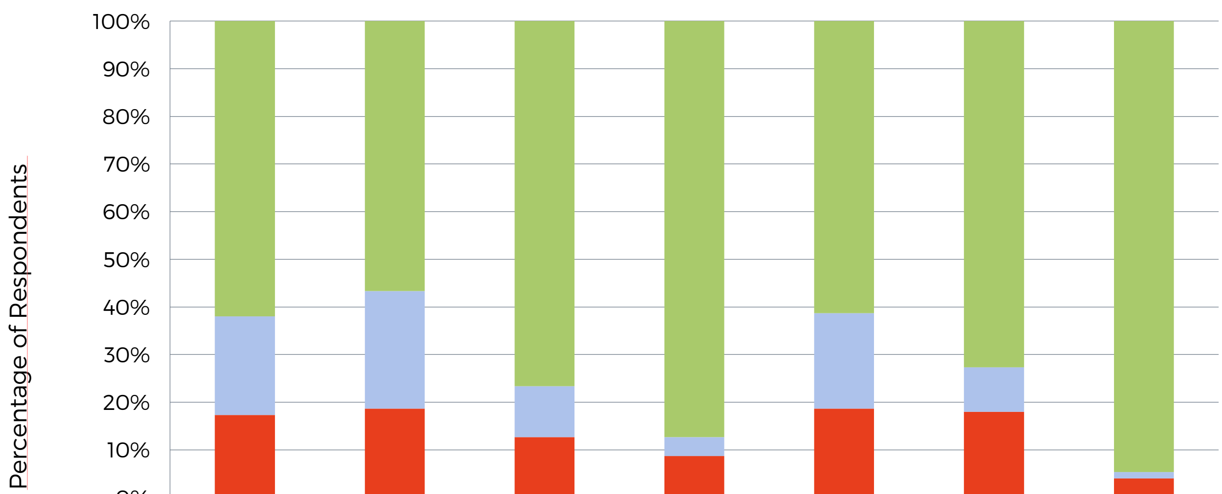
Convergence of facility manager and IT manage roles

The facility manager role in past was more focused on the physical facility and on in-house operations. However, as more sophisticated systems have entered the market there is a fundamental shift in the facility manager's role, which requires an understanding of the data coming from these systems. The large trend playing out is that IoT has blurred the distinction between a facility manager and an IT manager. Communication between different building systems will be on the same network and systems will start to become more sophisticated in terms of control and analytics.

The facility manager role will become more demanding in terms of IT capability and in selecting and maintaining third-party service providers. By using a number of services, the facility manager can pay a fee to have a system managed or hosted, removing the need to maintain that system but adding the need to maintain this additional third-party relationship. In addition, security concerns can be passed to a third-party and the additional fees charged can be added to the ongoing monthly rent. However, this is another example of the expanded responsibilities of a facility manager.

Responses through both the interviews and the survey matched clearly on this issue. During interviews it was indicated that suppliers believe the industry is moving to a more complicated facility manager's role. One question from the survey, which was answered mostly by facility managers, focused on where the greatest support would be required; the top response was that the biggest demand was to educate the facility managers. This clearly indicates that the facility managers themselves feel the need for more education as they do not yet fully understand what IoT is going to do for them.

Figure 2.6 - Ranking - Key areas of support when implementing new IoT-based systems



	Educate/ Train Work Force On Use & Maintain New Systems	Educate/ Train Facility Management On Use & Maintain New Systems	Educate/ Train IT Teams On Use & Maintain New Systems	Educate/ Train IT Teams On How to Implement New Systems	Re-Engineer Processes to Take Advantage of Savings From Intelligent Buildings	System Integration	Educating Management / Budget Holders On Value Proposition
Not Ranked	62%	57%	77%	87%	61%	73%	95%
Ranked 2	21%	25%	11%	4%	20%	9%	1%
Ranked 1	17%	19%	13%	9%	19%	18%	4%

Notes: All respondents, n=150

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"Servitization" of the industry

Three key impacts of IoT on industry

Three of the most important means by which the pervasive connectivity of the IoT will affect the economy as well as society are in the areas of automation, integration and servitization. These three features are interrelated in the sense that automation and integration are often employed in tandem to enable servitization. These three factors are explained in more detail below:

- Automation: Machines, sensors, and actuators connected to computing systems enable a large degree of process automation. Automation facilitates dramatically larger scales of data utilization as well. Proactively monitoring this data feed enables faster resolution times in instances of performance faults and minimizes unnecessary maintenance services.
- Integration: There are more benefits than simply connecting a machine and automating its performance. Integrating the data from a machine with data from other sources, such as ERP systems, greatly enhances the value derived from connecting the machine.
- "Servitization": Together, automation and integration help organizations move from being primarily product-centered businesses to being more service-oriented. This process is called "servitization". Many traditionally product-centered companies are realizing the revenue opportunities offered by developing an ongoing, service-oriented relationship with customers, for example, organizing a customer relationship on the basis of a service contract, where the customer pays for a negotiated business outcome rather than a piece of equipment.

Servitization is having a significant impact on the business processes in the intelligent building industry. At the moment, most customers are buying systems dominated by hardware, but there will be a lot of cloud-based IoT systems coming if the industry as a whole can start dealing with data security. Many suppliers, especially the large total solution providers like Schneider Electric and Johnson Controls, will increase their service business, as they expect hardware to become proportionally a smaller part of the market. The overall change in business process revolves around the increasing options of services to change operations, which many customers are struggling to understand and assess at the moment.

One example in the video surveillance market is the barrier to adoption of VSaaS. Bandwidth limitations have restricted the number of cameras that can be deployed at a given site. However, the situation has improved markedly in recent years, thanks to the proliferation of fiber networks with greater bandwidth, the rise of H.265 and other improved data compression standards, and the ongoing trend toward hybrid data storage, which enables only the most important video data to be uploaded to the cloud thus reducing upstream bandwidth usage. As technological barriers have been reduced, a lack of customer awareness has become the most frequently cited challenge to adoption by VSaaS providers. VSaaS is still emerging as a technology, and as such, the benefits of VSaaS solutions are still being communicated to the video surveillance industry. Lack of knowledge may result in customers misunderstanding not only what VSaaS is, but also its value compared with other solutions. Although awareness of the benefits and power of the cloud is increasing, effectively communicating the features and benefits of VSaaS solutions to the industry and consumers will be essential for success in the market.

One question in the survey focused on different areas where companies need help and the second most important area highlighted was a need for support in process reengineering, as presented in Figure 2.6. Facility managers do not yet fully understand how they will change their business processes to take advantage of IoT, which could be an opportunity for suppliers to offer a service to support on reengineering.

SECTION 3

INTELLIGENT BUILDING ROADMAP & RECOMMENDATIONS

INTRODUCTION

This chapter looks at each in the context of a roadmap that takes a building from a low level of automation to embracing the full "intelligent building concept". For each step, it examines the attitudes of building owners, operators and facility managers and suppliers to the main five themes.

3.1 INTELLIGENT BUILDING ROADMAP

The data collected from this research was used to plot a roadmap for intelligent buildings. IHS Markit has taken the view that the roadmap is defined by the respondent groups that have been pulled out in this report and outlined in the previous section. How to move along this roadmap is the key to realizing its full potential.

For example, the start of the roadmap is the "low automation" group of respondents in the decision maker survey. Understanding their behavior and preferences is the first step. This understanding informs how to move them along the roadmap to become 'medium automation' users.

Similarly, understanding the behaviors and preferences of the "medium automation" group is the next step; and to use this understanding to move them along the roadmap to the "high automation" group. Finally, understanding the behaviors and preferences of the "high automation" group is next. For this group, expanding the breadth of IoT-related services and products is the challenge.

For each major segment, the attitudes, solutions and views relating to the five main themes are examined.

This section explores these concepts, taking each stage of the intelligent building roadmap and discussing the behavior and preferences of the group members and the requirements needed from the industry to move them along the roadmap. Figure 3.1 expresses this map graphically. Each major stage in the map is now explored, examining the trends of the key themes associated with that location on the map and the nuances that differing attitudes and abilities bring to progression.

Table 3.1 Respondents level of Automation

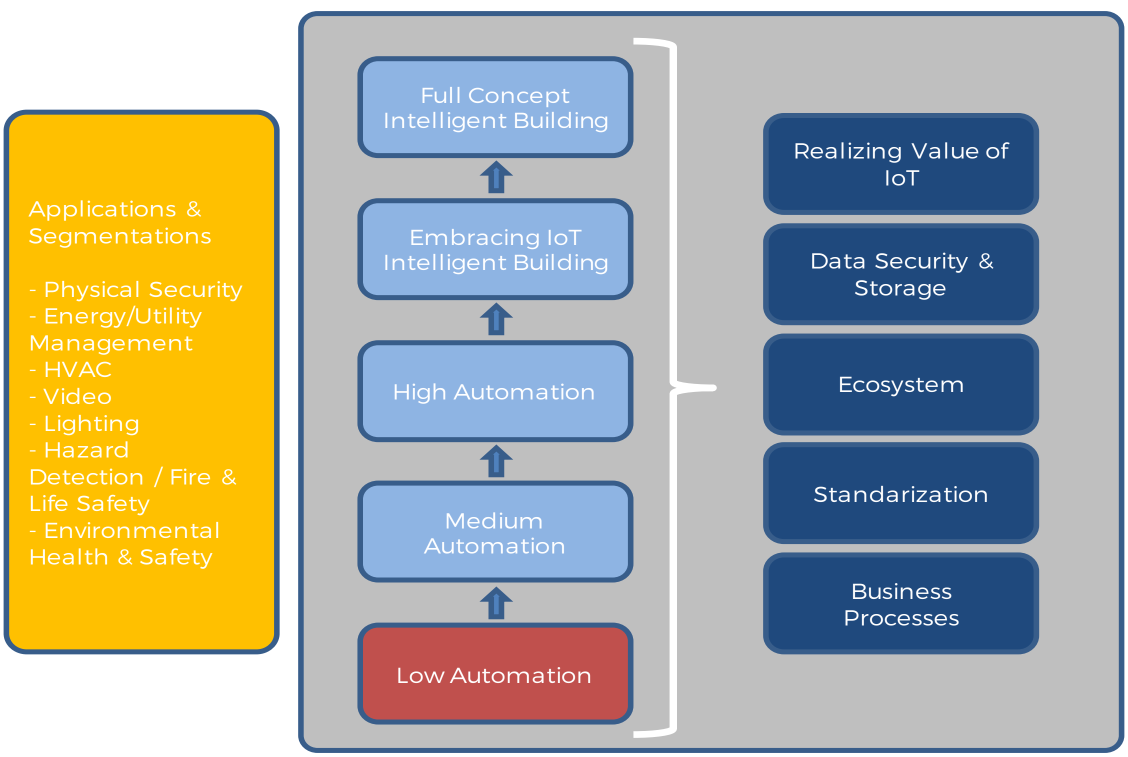
	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
Fully Automated	7%	7%	7%	9%	4%	29%	3%	0%	7%	8%
High Automation	27%	27%	16%	34%	32%	71%	23%	0%	27%	23%
Medium Automation	51%	52%	60%	40%	57%	0%	68%	56%	51%	57%
Some Automation	12%	12%	16%	11%	7%	0%	5%	34%	12%	8%
No Automation	3%	3%	2%	6%	0%	0%	1%	10%	3%	4%

All respondents, n=150 Source: IHS Markit

3.2 LOW AUTOMATION RESPONDENTS

This group of respondents indicated via their responses to Question 1.2 of the decision maker survey that they had relatively low levels of automation with respect to their main building systems. Typically there was either 'no automation' – e.g. individual devices were managed manually and with no centralized control (at the individual building level) or use of networked sensors; or there was 'some automation' – e.g., centralized control (at the individual building level) but largely manual control of systems.

Figure 3.1 Intelligent Building Roadmap - Low Automation Respondents



Source: IHS Markit © 2016 IHS Markit

Key attributes of group

From the data obtained in the decision maker survey, the points below summarize some of the key attributes of this group:

- The group **tended to be represented by respondents with smaller portfolios** in terms of physical building size. Approximately 50 percent of respondents fell into the <50,000 square feet building portfolio size compared to 38 percent for the wider sample.
- The systems with the most automation were fire life safety and physical access control.
- The group sees the **highest value of IoT** coming from reducing energy consumption.
- The group views the advantage of improving occupant safety, improving tenant/employee productivity, enabling predictive maintenance, and improving operational efficiency as more important than do the groups further along the roadmap.
- The group views the advantage of increasing building performance data, increasing building resiliency, and increasing the use of sensors as less important than do the groups further along the roadmap.
- The group does not have as high a demand in terms of **return on investment** as those further along the roadmap,
- The group places **less value in the more imaginative features** that IoT can bring, such as "integration with weather systems", "rules/algorithms based on the needs of buildings", and "recommending location based set points" than the groups further along the roadmap.
- The group has less of a grasp of the value of having all building systems controlled centrally.
- When selecting a supplier, the group places **greater importance on price competitiveness** than other groups; and places less importance on innovation, quality of service contract and breadth of portfolio.
- This group is also **more open to using off-premises third-party cloud services** to host building system data.
- The group views support with system integration as much less important than does the wider sample.

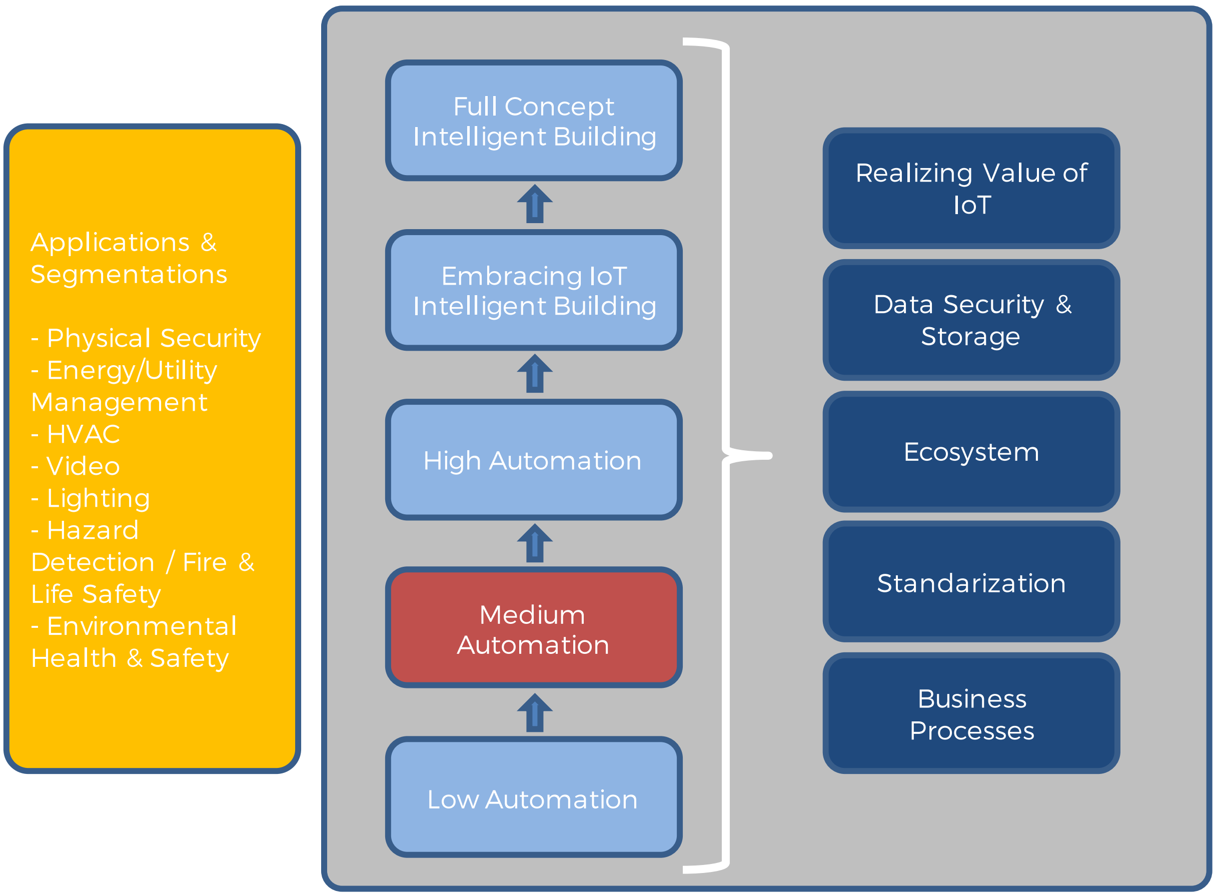
Conclusions and recommendations

- Education on the value of investment in relatively simple building automation systems is the key to moving this group along the roadmap. The group places a greater than average focus on educating facility managers rather than the workforce itself. This is an indication that respondents themselves in this group were still looking for guidance on the potential for IoT in building systems, and so greater focus on this process of education should be used when addressing this group's needs.
- The group may have some systems, such as physical access control and fire life safety that have some level of automation, but focus should be placed on educating the group on the value of automation in areas such as HVAC, energy control and lighting.
- The group has a higher representation from smaller organizations and places higher value on price competitiveness than other groups. This suggests that it often does not see the value in investing in automation systems for small premises where automation can have a lower impact on building performance.
- However, this is where IoT can address the shortcomings of legacy systems.
- The entrance of new innovative suppliers to the market with solutions that have a lower point of entry in terms of cost can open up the door to address this segment of the market better.
- The current focus remains on the fundamental benefits of building automation such as better financial planning and improving energy efficiency; and less on the more imaginative features that IoT brings.
- The group places lower than average importance on innovation which further supports this point.
- However, the group's greater openness to cloud-based, off-premises solutions provided using shared infrastructure means that lower cost solutions using these architectures can be a good fit.

3.3 MEDIUM AUTOMATION RESPONDENTS

This group of respondents indicated via their responses to Question 1.2 of the decision maker survey that they had medium levels of automation with respect to their main building systems. Typically there was either 'some automation' – e.g. centralized (at the individual building level) but largely manual control of systems or 'medium levels of automation' – e.g., centralized in-house control of systems at the individual building level, with networked sensors to manage some system functions automatically.

Figure 3.2 Intelligent Building Roadmap - Medium Automation Respondents



Source: IHS Markit © 2016 IHS Markit

Key attributes of group

From the data obtained in the decision maker survey, the points below summarize some of the key attributes of this group:

- The distribution of organizations with small, medium or large portfolios in this group was similar to that of the wider sample.
- The systems with the highest levels of automation were fire life safety and HVAC.
- The group sees the **highest value of IoT** coming from improving financial planning.
- The group views the advantages of enabling predictive maintenance and using open standards as more important than does the wider sample.
- The group views increased use of sensors as less important than does the wider sample.

- The group has slightly higher demands in terms of **return on investment** than does the wider sample.
- The group places **greatest value on features** such as “notification if systems are operating outside normal parameters”, “notification if device if on verge of failure” and “monitoring buildings systems remotely”.
- The group’s demand to be able to control systems centrally is similar to that of the sample average.
- The group places a higher than average value on being able to use advanced analytics.
- When selecting a supplier, the group places **greater importance on product quality** than other groups; the group further along the roadmap.
- This group is less **open to using off-premises, third-party cloud services** to host building system data than group behind it on the roadmap. For those that are willing to use third-party cloud services, it has a higher demand for private clouds than the wider sample.
- Compared with the group further along the roadmap, it places a greater value on education for facility managers. (The group further along the roadmap emphasizes more support for educating the workforce than the facility managers). The group also demands greater support in system integration than that earlier along the roadmap.

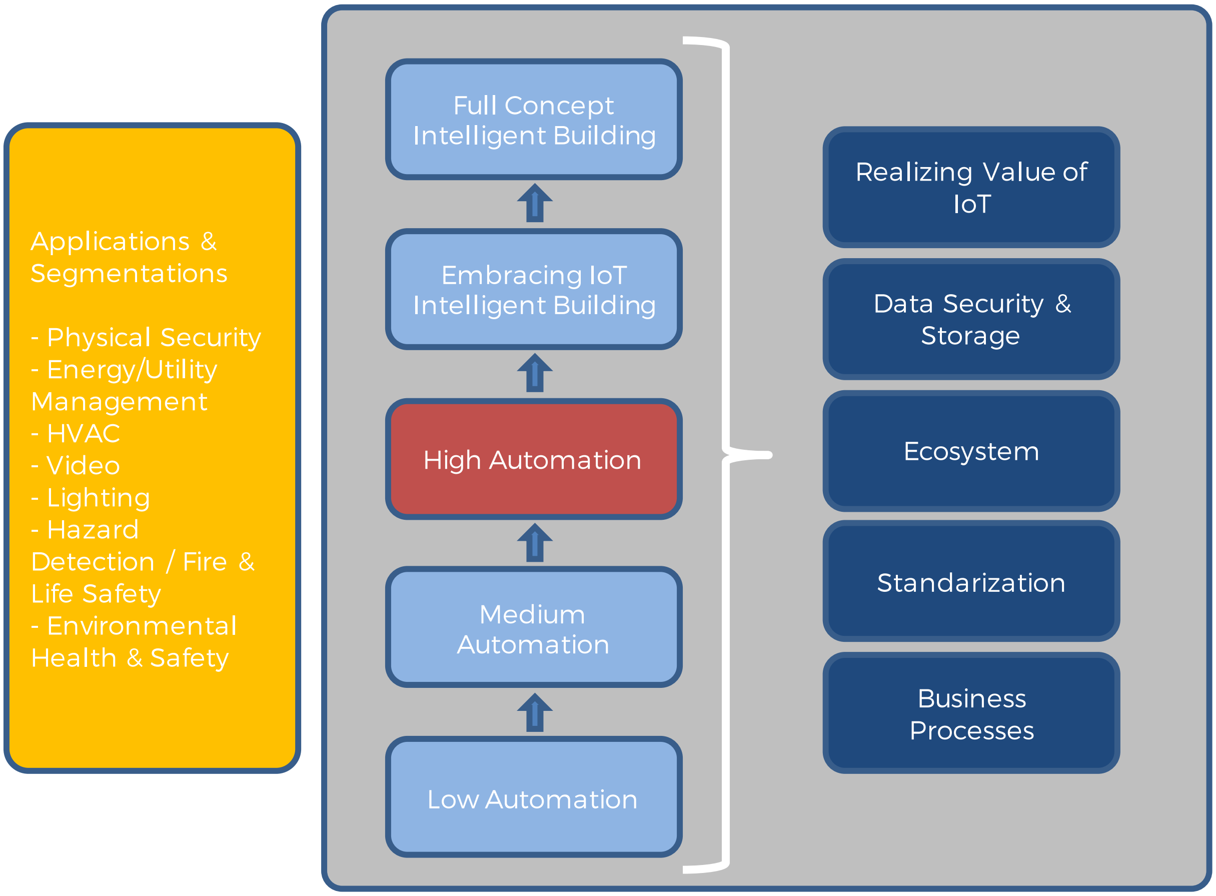
Conclusions and recommendations

- This group has already realized the value of building automation in their building operations. However, automation tends to be just in a small number of isolated areas.
- The next steps are to expand the number of systems that have some level of automation and to embed greater levels of functionality into those and existing systems.
- The decision makers still feel they are the ones to require education on the benefits of IoT, so focus should be kept on improving the knowledge and understanding of facility managers and IT managers.
- The decision-makers are, however, more aware of the benefits of advanced functions such as predictive maintenance, greater use of sensors, location based set-points, etc. Therefore, there should be more focus on these aspects than with the low automation group.
- This group is also more sensitive to data security than the low automation group, with a reluctance to use third-party cloud services to provide data analytics solutions. Therefore, when addressing customers in this group a high level of priority should be placed on the data security and resilience of cloud-based services. Initially, suppliers should push solutions where data flow is one way only, from the client premises to the cloud and not the other way.

3.4 HIGH AUTOMATION RESPONDENTS

This group of respondents indicated via their responses to Question 1.2 of the decision maker survey that they had high levels of automation with respect to their main building systems. Typically, there were either ‘high levels of automation’ – e.g., centralized in-house control of the system, at the individual building level, with networked sensors to automatically manage most system functions and providing detailed performance analytics or ‘fully automated’ – e.g., off- and on-site centralized – control (across all buildings at campus/site) of system with networked sensors to automatically manage most system functions and provide detailed performance analytics.

Figure 3.3 - Intelligent Building Roadmap - High Automation Respondents



Source: IHS Markit © 2016 IHS Markit

Key attributes of group

From the data obtained in the decision maker survey, the points below summarize some of the key attributes of this group:

- The group is similarly represented across different organization sizes (those with small, medium or large portfolios) to the wider sample. However, compared to the group at the very early part of the roadmap, it had a much lower representation of organizations with portfolios <50,000 square feet.
- For this group, higher levels of automation are much more likely to be seen in systems such as HVAC and energy management than with the groups earlier in the roadmap.
- The group sees **highest value of IoT** coming from improving financial planning.
- The group views advantages such as the increased use of sensors, and increased performance data as more important than the wider sample and, in particular, than groups at earlier stages in the roadmap.
- The group has the greatest demand for a short **return on investment** (particularly a return within two years of implementation) than the wider sample.
- Compared with groups at earlier stages in the roadmap, this group places a **higher level of value on features** such as "monitoring building systems remotely", "controlling building systems remotely", "integration with weather systems", "rules/algorithms based on the needs of building", "recommend location-based set points" and "information on building occupancy".

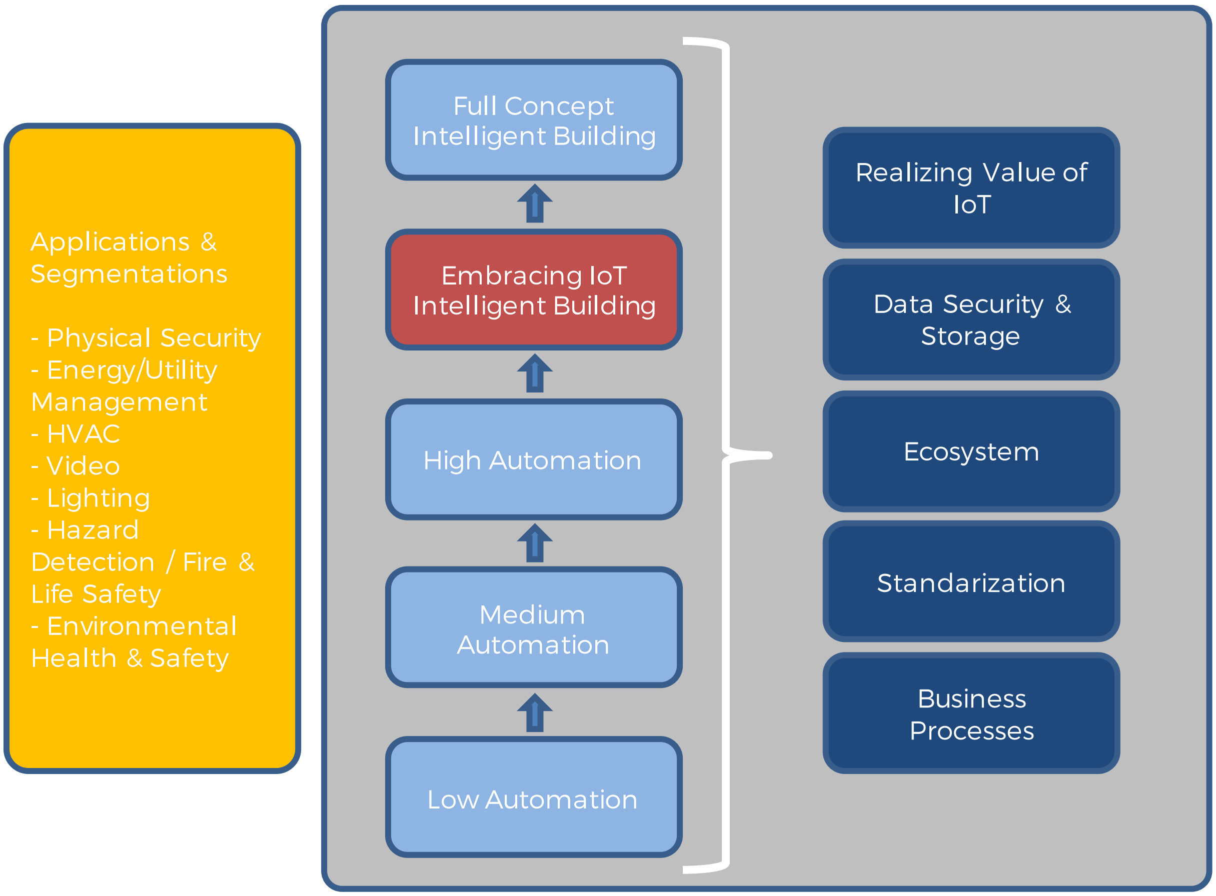
- This group's demand to be able to control systems centrally is similar to that of the sample average.
- The value this group places on being able to use advanced analytics is similar to that of the sample average.
- When selecting a supplier, this group places **greatest importance on innovation**. This was the top ranking factor. For the low automation group this was the fifth most important factor. This group was the only one that did not rank price competitiveness as the most important factor.
- This group was the least **open to using off-premises, third-party cloud services** to host building system data. It was also the most hostile in its views on using public rather than private cloud services.
- Compared with groups earlier in the roadmap, this group places a greater value on education for the workforce than facility managers. It also placed a much greater value on support of system integration compared with groups earlier in the roadmap.
- Interestingly, this group placed less value on the use of wireless systems than did groups earlier in the roadmap. It was also less likely to feel it was prevented from investing in future technologies because of interoperability issues than the wider sample.

Conclusions and recommendations

- This group already has high levels of automation built into building systems and so are the primary target is to take it to the next level with the greater functionality offered by IoT.
- There is less room to expand on the range of systems that can be automated and so the primary focus should be on expanding the sophistication of the automation solutions offered.
- As this group has a higher proportion of larger organizations with multiple buildings and sites, the feature of centralized control that new platforms and solutions offer needs to be pushed.
- At the same time, this group had the most positive views in relation to the value of advanced features such as pervasive sensing, location-based set-points, etc.
- This group was also highly tuned to seeing a rapid ROI in IoT, and so the immediate and short-term cost savings from solutions need to be pushed heavily.
- Although still sensitive to price, this group is also looking for innovation; and so unique leading-edge features that are enabled by IoT, and specific solution differentiators in relation to innovation, need to be kept prominent in marketing.
- Decision makers in this group have a greater level of confidence in their own understanding of how IoT can impact building systems. They feel that it is not themselves that need education but their building users, management and others in the ecosystem instead. So support to achieve this would also aid development of this group along the roadmap.
- Like the medium automation group, this group is highly sensitive to security and using third-party cloud services. Since larger organizations tend to make up this group, they have the scale not to be dictated to over the standard offerings of the industry and can demand more tailored solutions that would not use cloud-based solutions. To some extent, pushing on-site solutions, or at least private cloud solutions, would be the better strategy at this stage with many customers in this group.

3.5 EMBRACING IOT IN THE INTELLIGENT BUILDINGS SEGMENT

Figure 3.4 Intelligent Building Roapmap - Embracing IoT in Intelligent Buildings



Source: IHS Markit © 2016 IHS Markit

Key attributes and conclusions

- Few organizations yet sit in this group as it is largely described by its adoption of the leading edge solutions in relation to intelligent buildings and the adoption of centrally controlled solutions.
- Typically companies in this group will have nearly all main building functions automated – HVAC, energy management, fire life safety, physical security, lighting and CCTV.
- The systems would also employ leading-edge features, with high levels of systems performing based on building occupancy, location-based set points, external inputs (weather forecasts and energy pricing), integration with A/V equipment, analytics, predictive maintenance, etc.
- It is still expected that a mix of solutions for data storage and analysis will be used. Some organizations are expected to have embraced cloud computing using third-party infrastructure to store and analyze data. However, the high level of negative feeling about this means that on-premises or company-owned infrastructure will still be the solution many in this segment also choose.
- It would be best again to target organizations with large portfolios first for this group. They tend to be further along the roadmap already and best understand the benefits of IoT.
- There is frustration with the most advanced users at present about interoperability problems and the lack of standardization. It's not a "show stopper" for moving to full concept realization. Pushing features that demonstrate how these problems can be overcome and that show compliance to industry standards such as Haystack will help.

SECTION 4

DECISION MAKER SURVEY SUMMARY ANALYSIS

INTRODUCTION

This section of the report analyzes responses to questions in the decision-maker survey conducted by IHS and designed in conjunction with project Steering Committee members. The main analyses and the key conclusions from this survey are discussed in Chapter Three alongside input from the supply-side research. This chapter is intended purely to present the raw results.

In some cases, questions and response options may have been abbreviated for presentation in a table or figure. All questions are presented unabbreviated in Section 5, and in the main text preceding the table or figure. As in the earlier chapters, the report presents most survey results with analysis by segment. The segmentation used split the respondents in the following ways:

- Industrial or Non-industrial: The industrial segment included all those respondents that indicated their primary vertical was "Industrial/Manufacturing" in question SQ.3. Respondents indicating any other vertical listed in SQ.3 were put into the Non-industrial segment.
- Size: Respondents were segmented by size into 'small', 'medium', and 'large', based on their responses to question SQ.4. Respondents that indicated their building portfolio was either "<50,000 square feet, or "50,001 – 200,000 square feet" had their responses counted in the 'small' segment. Those that indicated "201,000 – 500,000 square feet" or ">500,000 to 2,000,000 square feet" had their responses counted in the 'medium segment. All others were in the 'large' segment.
- Country: Responses were segmented based on whether the respondent indicated their real-estate location was based in the United States or Canada in Question SQ.4.
- Level of automation: Responses were segmented into three categories based on the respondents' answers to Question 1.2. The responses to this question were used to allocate the respondent to one of three groups: 'high level of automation', 'medium level of automation', or 'low level of automation. A scoring system was used to drive this. Details are provided below.

Scoring system used for level of automation

Question 1.2 asked respondents to rate the level of automation for their physical security/access control, energy management, HVAC (heating, ventilating, and air conditioning), CCTV, lighting and hazard detection/environmental health & safety systems individually. Respondents could choose the responses below:

- No automation – e.g., individual devices are managed manually, with no centralized control (at the individual building level) or use of networked sensors
- Some automation – e.g., centralized (at the individual building level) but largely manual control of system

- Medium level of automation – e.g., centralized in-house control of system, at the individual building level, with networked sensors to automatically manage some system functions
- High level of automation – e.g., centralized in-house control of system, at the individual building level, with networked sensors to automatically manage most system functions & providing detailed performance analytics
- Fully automated – off- and on-site centralized control (across all buildings at campus/site) of system with networked sensors to automatically manage most system functions & providing detailed performance analytics

These responses were used to drive an overall automation score in order to segment the respondents by their overall level of automation. For each system that was ranked "No automation" a score of zero was given, a score of one for each system ranked "some automation" and so on up to a score of five allocated for those ranked "Fully automated". A total score over the five systems was then summed. Those respondents whose summed score was >16 were classed as "high automation" respondents.

Those in the 9-16 range were classed as "medium automation" and those below 9 "low automation". Analysis of most questions throughout this chapter have been examined by these three segmentation groups.

4.1 RESPONDENT PROFILE

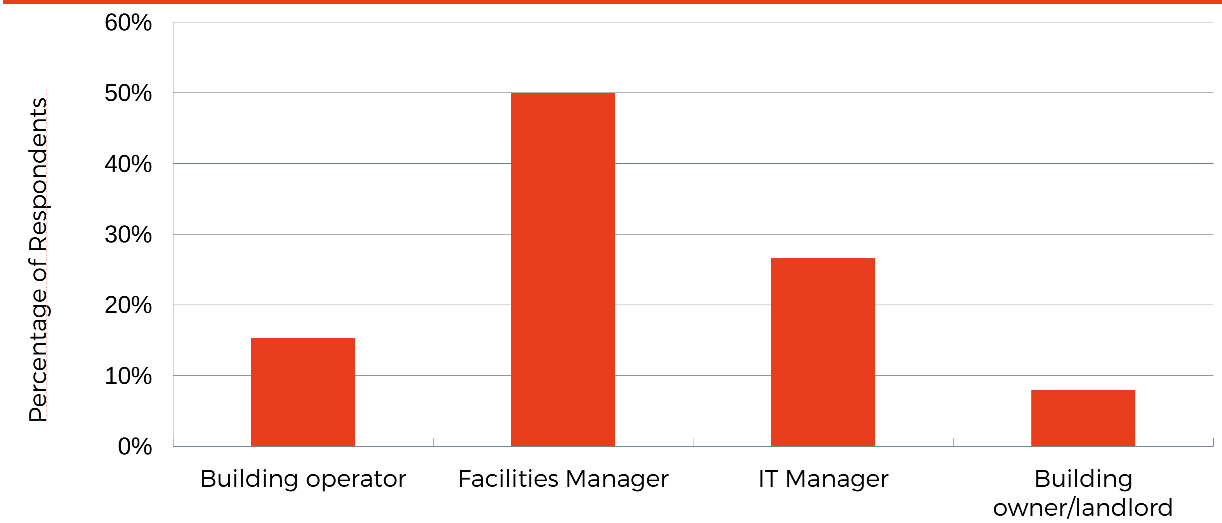
The first few questions of the survey were largely used to build up a profile of the respondent to ensure they were eligible to complete the survey and to then profile them as a respondent. The analysis of the responses to these questions is presented in this section.

Respondent job function

The following question was asked to all respondents. Figure 4.1 displays the responses to this question. Those that responded "Other – End Survey" did not continue with the survey and are not included in the analysis.

SQ.1 Please describe your job function:
1. Building owner/landlord
2. Building operator
3. IT Manager
4. Facilities Manager
5. Other – End Survey

Figure 4.1 - Respondents By Job Function



All respondents, n=150

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Purchasing authority of respondent

The following question was asked of all respondents and only those that selected option 1 completed the survey.

SQ.1 Do you have purchasing decision making or recommendation authority for any of the following system types/services Physical Security/Access Control, Energy Management, HVAC (heating, ventilating, and air conditioning), CCTV, Lighting, Hazard Detection/Environmental Health & Safety, building management platforms?

1. Yes
2. No – End Survey

Vertical industry of respondent

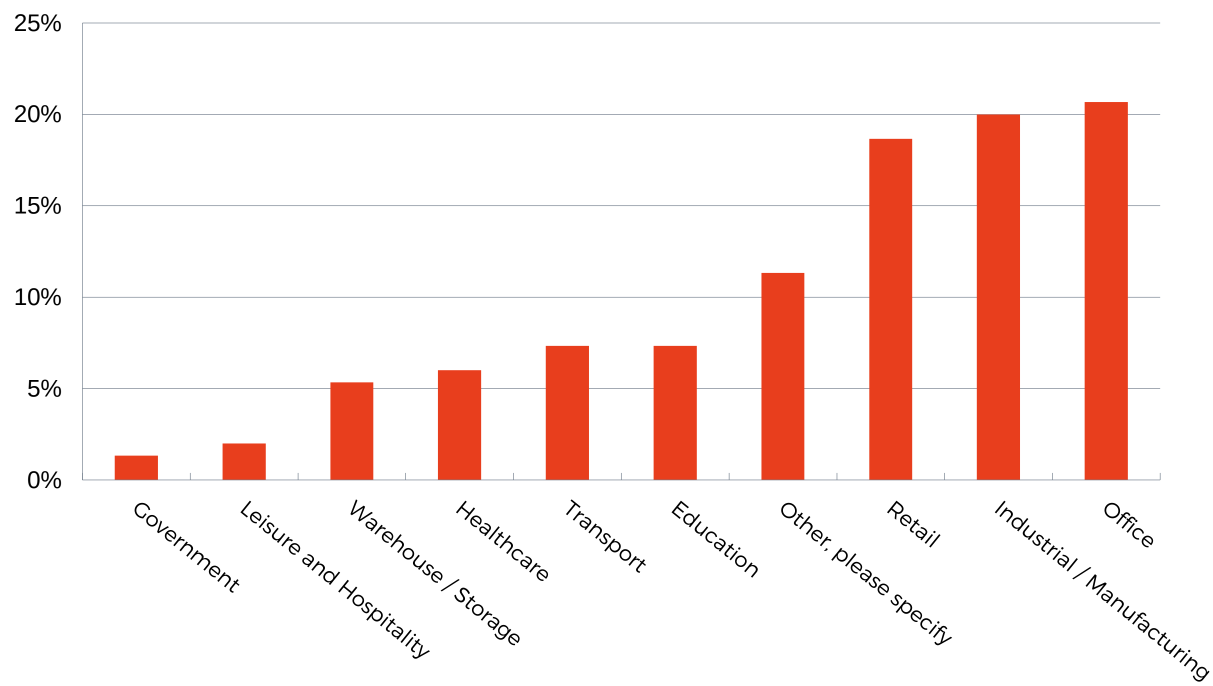
The following question was asked of all respondents:

SQ.3 Please indicate which of the following verticals best describes how the buildings you have authority over are used (PLEASE TICK ONE, IF VARIOUS ASK TO PICK THE DOMINANT USE CASE):

1. Education
2. Government
3. Healthcare
4. Industrial / Manufacturing
5. Office
6. Retail
7. Transport
8. Warehouse / Storage
9. Leisure and Hospitality
10. Other, please specify...

Figure 4.2 displays the results to this question. As mentioned earlier, the respondents have been split into two main groups based on their responses to this question. Those that selected option 4 have been categorized as "industrial" throughout this report and all others "non-industrial". Figure 4.3 displays the proportion of respondents in each of these categories.

Figure 4.2 - Respondents by Industry



All respondents, n=150

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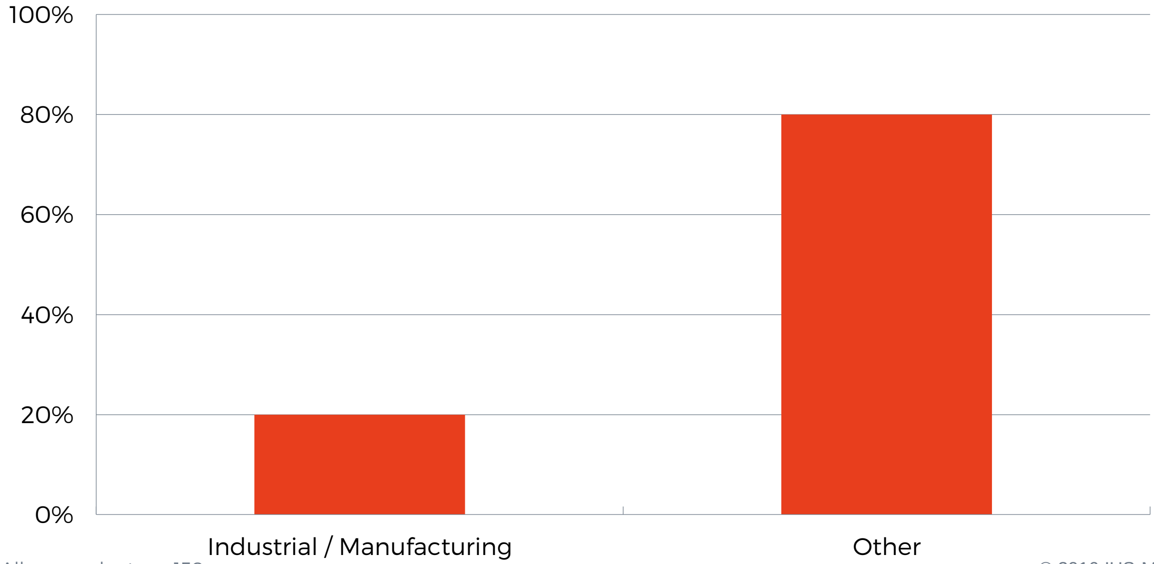
Figure 4.3 - Respondents by Industry - Consolidated



All respondents, n=150 © 2016 IHS-Markit

Country of respondent

The following question was asked to all respondents. The project Steering Committee had instructed that roughly one-third of respondents should be from Canada and two thirds from the USA. Figure 4.4 displays the actual segmentation of the respondents. Table 4.1 displays the results in tabular form with the additional industry splits outlined at the start of this chapter.

SQ.4 Which country are you located in?

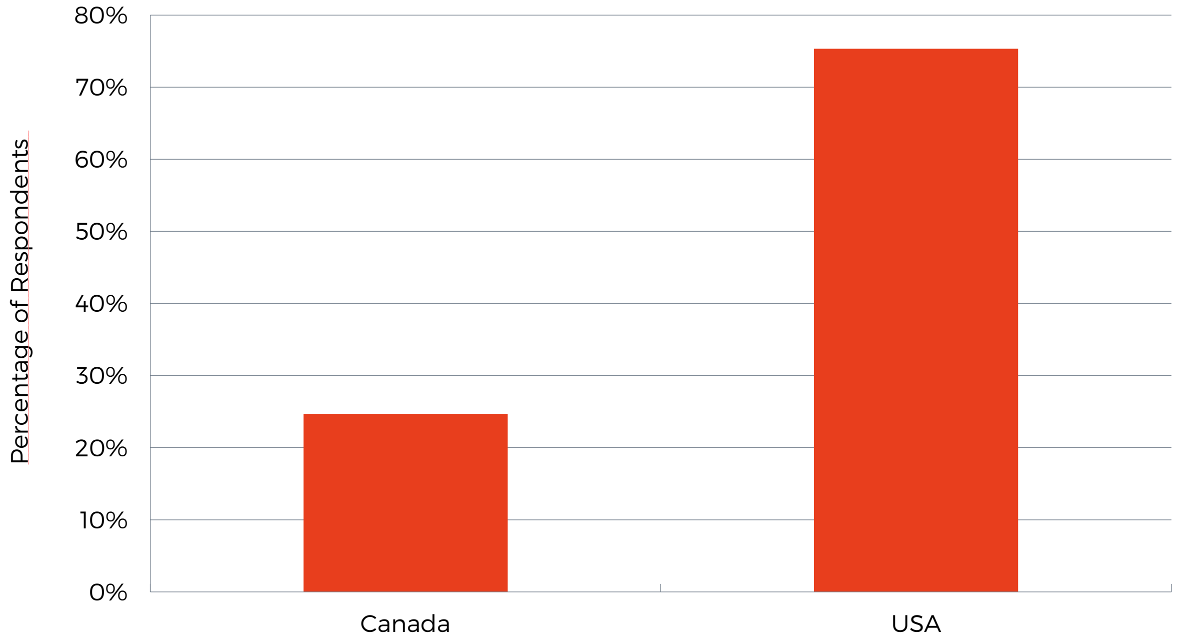
1. United States
2. Canada

Table 4.1 Respondents by industry - Consolidated

Segment	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
Industrial / Manufacturing	20%	0%	14%	25%	21%	19%	20%	21%	23%	11%
Other Sectors	80%	100%	86%	75%	79%	81%	80%	79%	77%	89%

All respondents, n=150 Source: IHS Markit

Figure 4.4 - Respondents by Country



All respondents, n=150 © 2016 IHS-Markit

Table 4.2 Location of respondent

	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
Canada	25%	28%	21%	22%	39%	32%	22%	24%	0%	100%
USA	75%	73%	79%	78%	61%	68%	78%	76%	100%	0%

All respondents, n=150 Source: IHS Markit

Size of respondent building portfolio

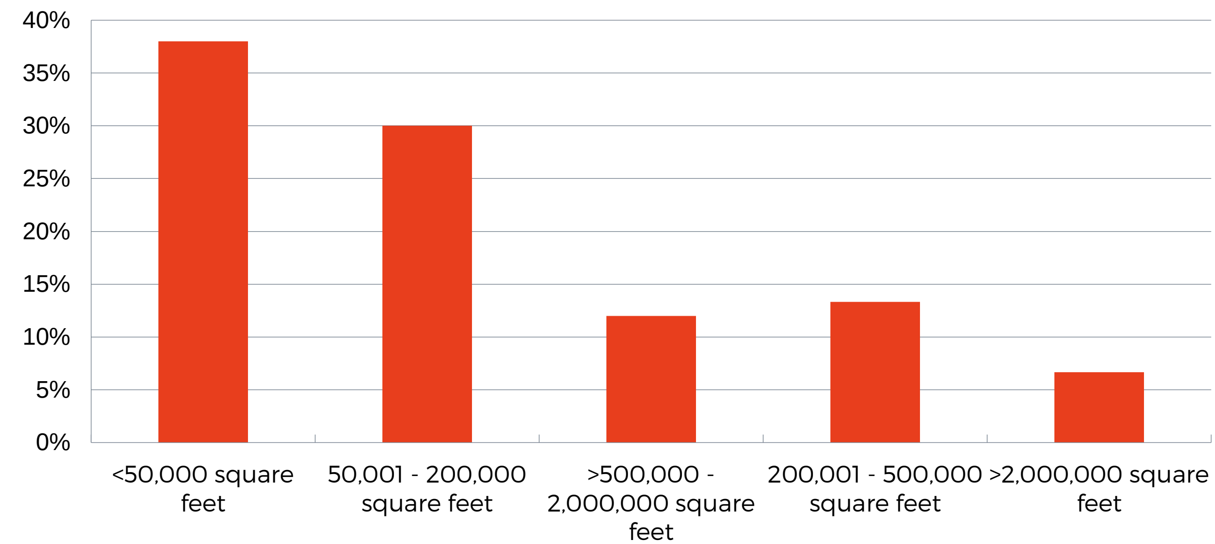
The following question was asked to all respondents. The results are presented over Figures 4.5, 4.6 and 4.7 and Table 4.3.

Q1.1 What is the overall size of the building stock for which you have purchasing influence & over how many buildings?

1. <50,000 square feet
2. 50,001 – 200,000 square feet
3. 200,001 – 500,000 square feet
4. >500,000-2,000,000 square feet
5. >2,000,000 square feet

Over _____ buildings, across _____ site(s)/location(s)

Figure 4.5 - Respondents by Building Stock Size



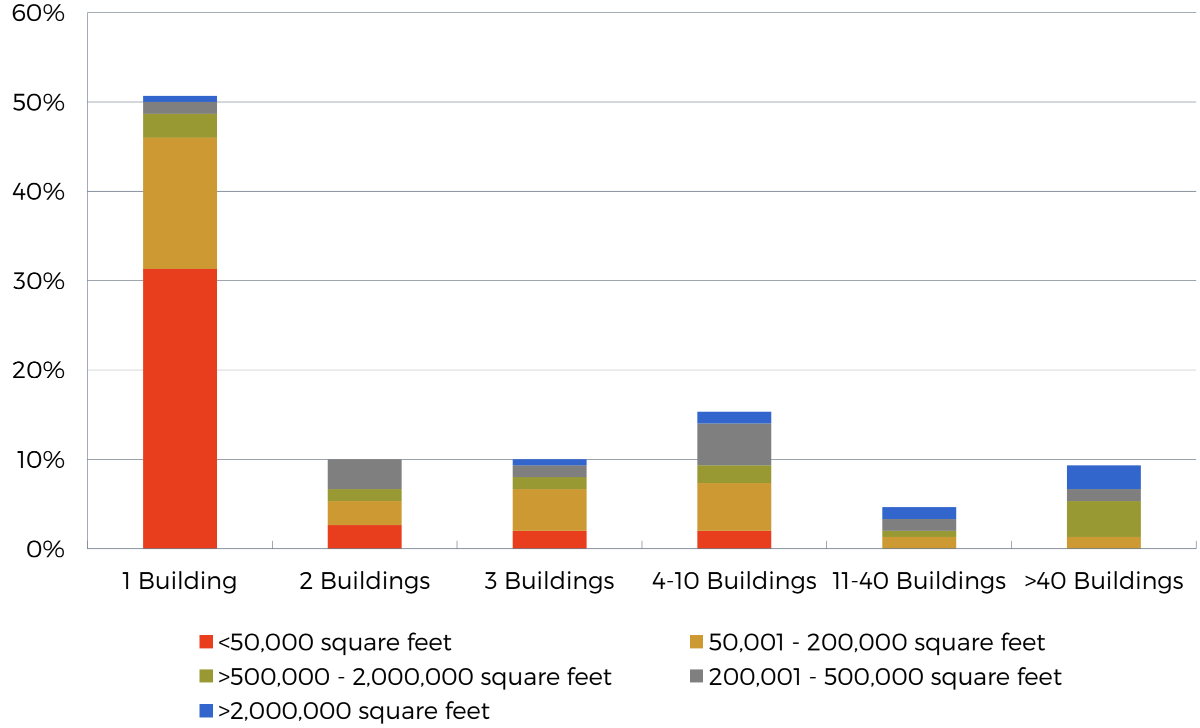
All respondents, n=150

Table 4.3 Building portfolio size by main segment

Size Square Feet	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
<50,000	38%	41%	100%	0%	0%	32%	35%	49%	38%	40%
50,001 - 200,000	30%	28%	0%	69%	0%	35%	36%	15%	30%	33%
200,001 - 500,000	13%	13%	0%	31%	0%	13%	12%	17%	13%	12%
>500,000 - 2,000,000	12%	11%	0%	0%	64%	10%	9%	20%	12%	10%
>2,000,000	7%	8%	0%	0%	36%	10%	9%	0%	7%	5%

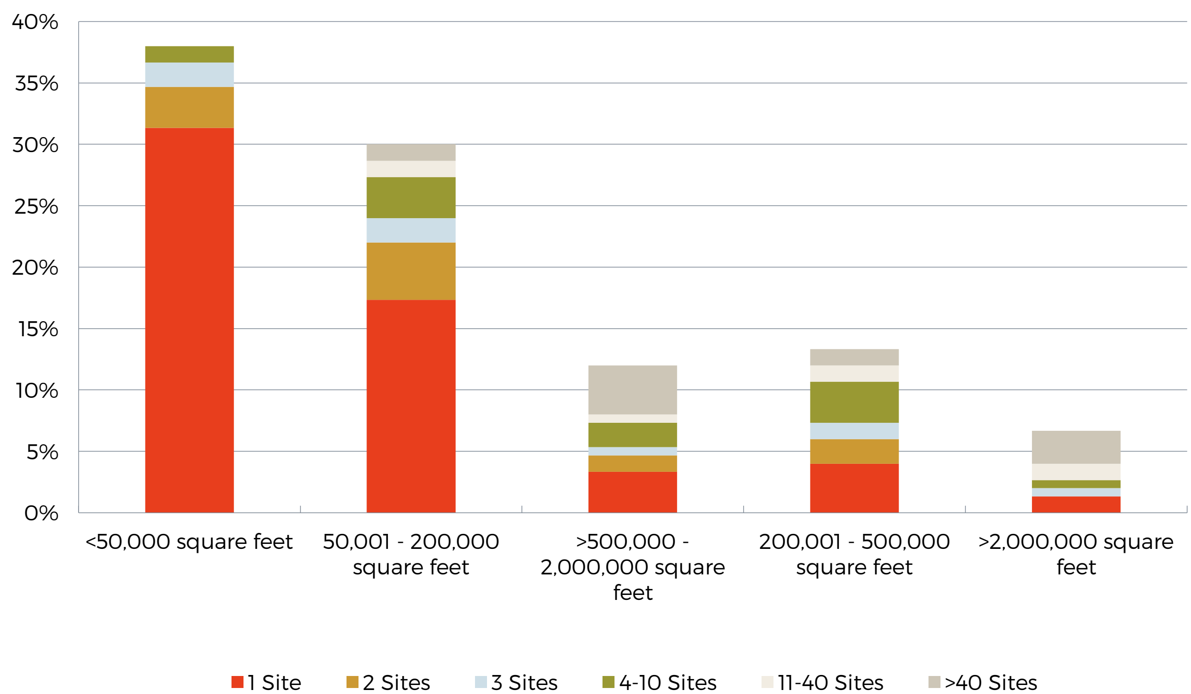
All respondents, n=150 Source: IHS Markit

Figure 4.6- Respondents by Portfolio Size - Number of Buildings



All respondents, n=150

Figure 4.7 - Respondents by Number of Sites



All respondents, n=150

4.2 REALIZING THE VALUE OF IOT

One of the key themes explored in this study relates to realizing the value of IoT in intelligent buildings. A number of questions used in the decision maker survey were used to uncover some the key trends. Within this theme, the project steering group had instructed IHS Markit to look at issues such as analytics and dashboards used to automate building functions, the use of real-time monitoring and control, centralized management of building functions, the convergence of building systems, adaptive automation, and the types of user interface required the business cases for IoT.

Level of automation

The following question was asked of all respondents.

Q1.2 For the following building functions please select the most appropriate statement to describe how their operation is controlled/automated – PLEASE SELECT ONE DESCRIPTION FOR EACH FUNCTION

1. Physical Security/Access Control
2. Energy Management
3. HVAC (heating, ventilating, and air conditioning)
4. CCTV
5. Lighting
6. Hazard Detection/Environmental Health & Safety
   For each the following drop downs –
   - No automation – e.g., individual devices are managed manually and with no centralized control (at the individual building level) or use of networked sensors
   - Some automation – e.g., centralized (at the individual building level) but largely manual control of system
   - Medium level of automation – e.g., centralized in-house control of system, at the individual building level, with networked sensors to automatically manage **some** system functions
   - High level of automation – e.g., centralized in-house control of system, at the individual building level, with networked sensors to automatically manage **most** system functions & providing detailed performance analytics
   - Fully automated – Off- and on-site centralized control (across all buildings at campus/site) of system with networked sensors to automatically manage **most** system functions & providing detailed performance analytics

Figures 4.8 to 4.13 show the results for each main building system type. Tables 4.4 to 4.9 show the result by the key respondent segments.

In order to compare the respondents' level of automation over the different system types, IHS Markit devised a scoring system for each response that allowed the responses of each system type to be compared.

To do this, each response was given a score. Four was given for a selection of option 5, three for option 4, two for option 3 and one for option 2, A score of zero was given for option 1. The score was combined for all responses across all building system types. The total was then re-based so that the system type that had the lowest score was set to zero and the system type with the highest score set to 10. The results are displayed in Table 4.10.

The table shows that for the whole sample, physical access control was the system type that had the highest level of automation. This was followed by HVAC and CCTV. Lighting had the lowest level.

When the industrial segment was excluded from the analysis, the results were similar although CCTV fell into second place above HVAC. Respondents representing large building stock portfolios had a higher level of automation in energy and HVAC applications than to the whole sample. Respondents representing organizations that fell into the high automation segment were more likely to have a higher degree of automation in lighting than the wider sample.

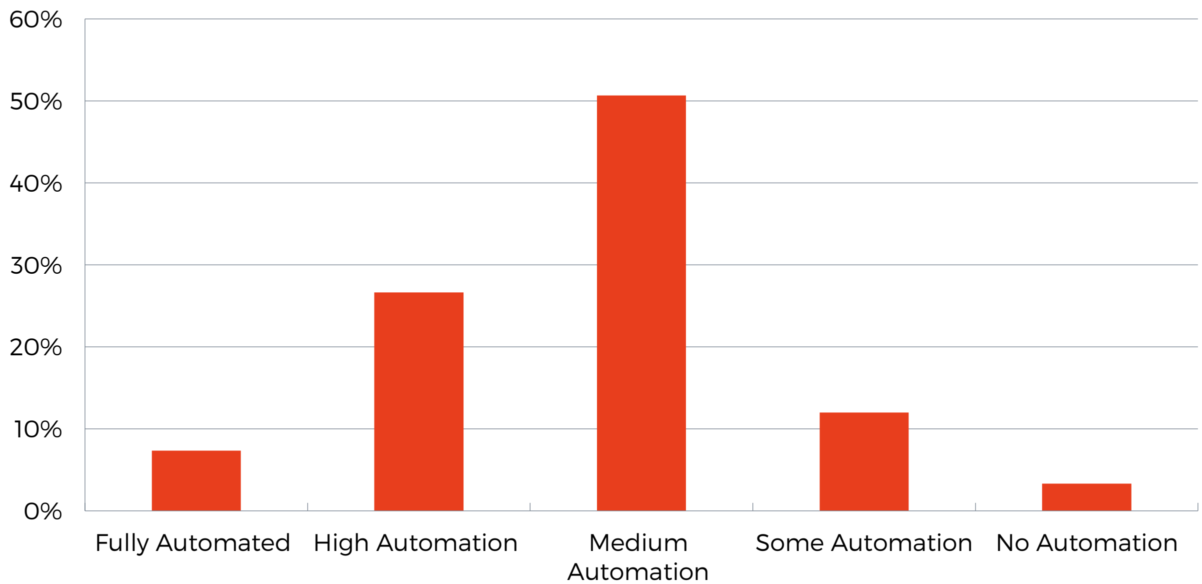
Centralized management of building functions

Respondents that answered 3-5 for more than one system in Question 1.2 were asked the following:

Q1.3 Are any two or more functions managed within the same system or does each operate as a standalone entity? Please tick as appropriate:

- No – All are separate systems
- Yes - Combination 1 - Physical Security - Energy Management – HVAC – CCTV – Lighting - Hazard Detection/Environmental Health & Safety – HR Systems – Facility Management Planning Systems (e.g. meeting room booking) – Audio/Visual Equipment

Figure 4.8 - Respondents by Level of Automation - Physical Access Control



All respondents, n=150

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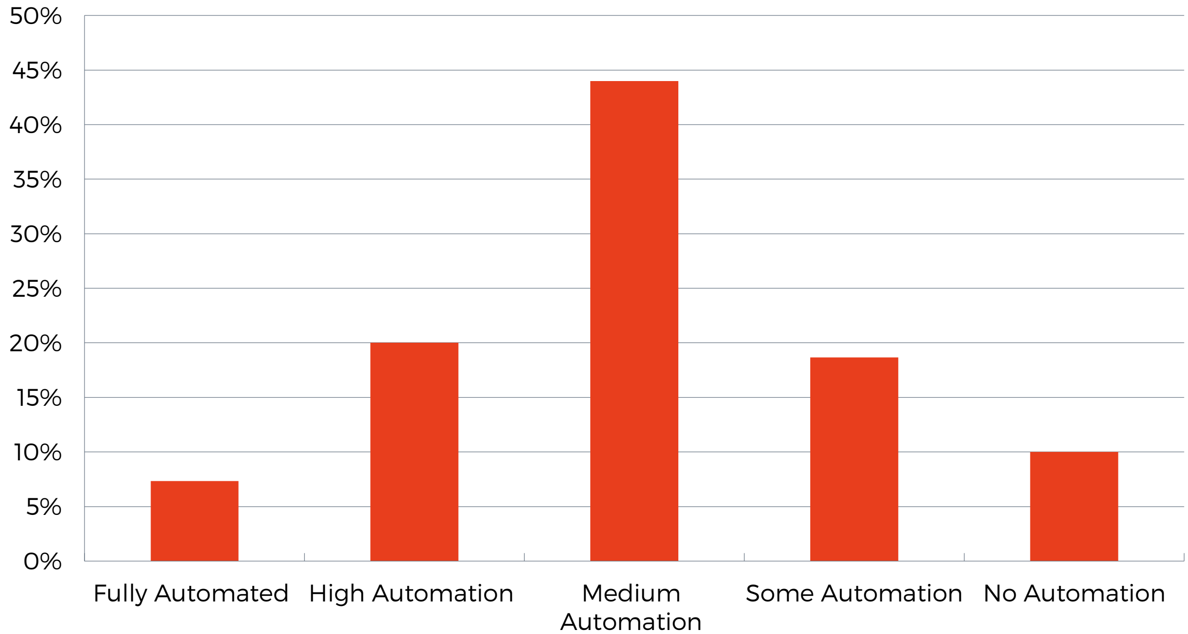
Table 4.4 Respondents' level of automation by major segment - Physical access control

	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
Fully Automated	7%	7%	7%	9%	4%	29%	3%	0%	7%	8%
High Automation	27%	27%	16%	34%	32%	71%	23%	0%	27%	23%
Medium Automation	51%	52%	60%	40%	57%	0%	68%	56%	51%	57%
Some Automation	12%	12%	16%	11%	7%	0%	5%	34%	12%	8%
No Automation	3%	3%	2%	6%	0%	0%	1%	10%	3%	4%

All respondents, n=150

Source: IHS Markit

Figure 4.9 - Respondents by Level of Automation - Energy Management



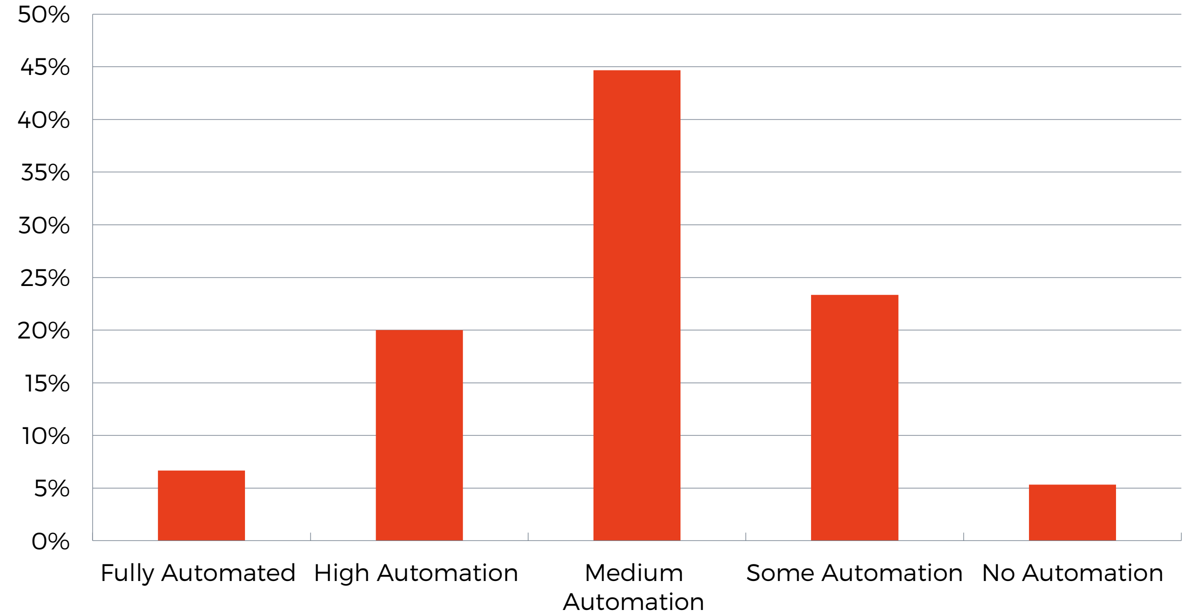
All respondents, n=150 © 2016 IHS-Markit

Table 4.5 Respondents' level of automation by major segment – Energy management

	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
Fully Automated	7%	6%	9%	6%	7%	29%	3%	0%	7%	8%
High Automation	20%	21%	11%	26%	25%	68%	12%	0%	20%	17%
Medium Automation	44%	45%	47%	45%	36%	3%	77%	12%	44%	47%
Some Automation	19%	19%	19%	17%	21%	0%	8%	54%	19%	19%
No Automation	10%	9%	14%	6%	11%	0%	1%	34%	10%	10%

All respondents, n=150 Source: IHS Markit

Figure 4.10 - Respondents by Level of Automation - HVAC



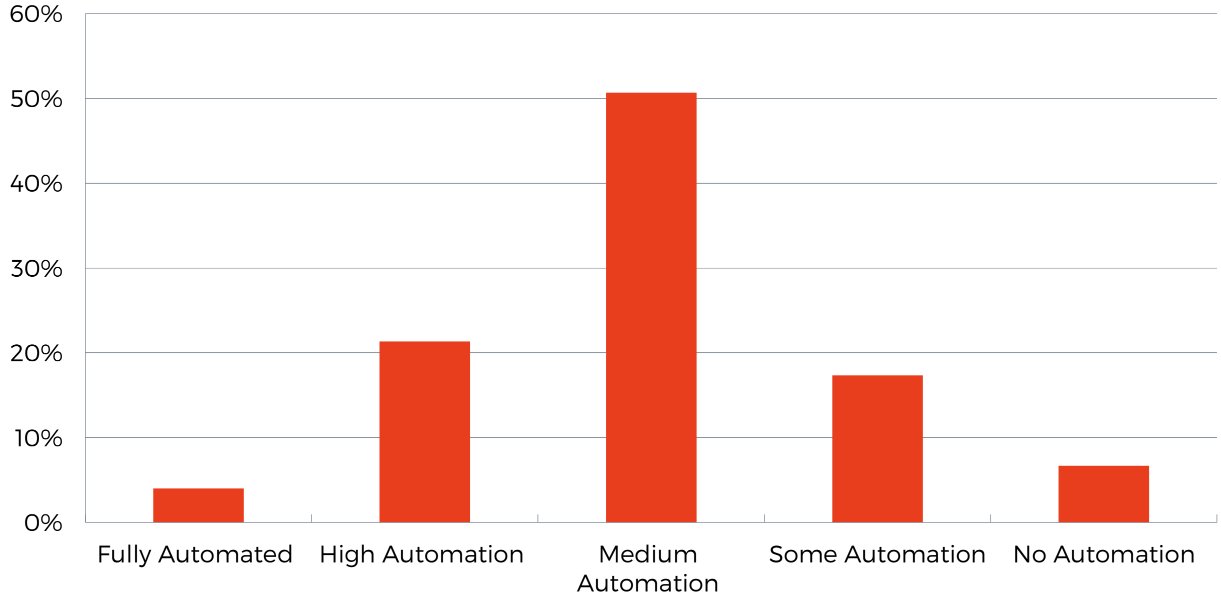
All respondents, n=150 © 2016 IHS-Markit

Table 4.6 Respondents' level of automation by major segment – HVAC

	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
Fully Automated	7%	5%	5%	9%	4%	23%	3%	2%	7%	6%
High Automation	20%	21%	14%	23%	25%	77%	8%	0%	20%	19%
Medium Automation	45%	44%	47%	42%	46%	0%	77%	17%	45%	47%
Some Automation	23%	23%	26%	22%	21%	0%	13%	61%	23%	23%
No Automation	5%	7%	7%	5%	4%	0%	0%	20%	5%	4%

All respondents, n=150 Source: IHS Markit

Figure 4.11 - Respondents by Level of Automation - CCTV



All respondents, n=150

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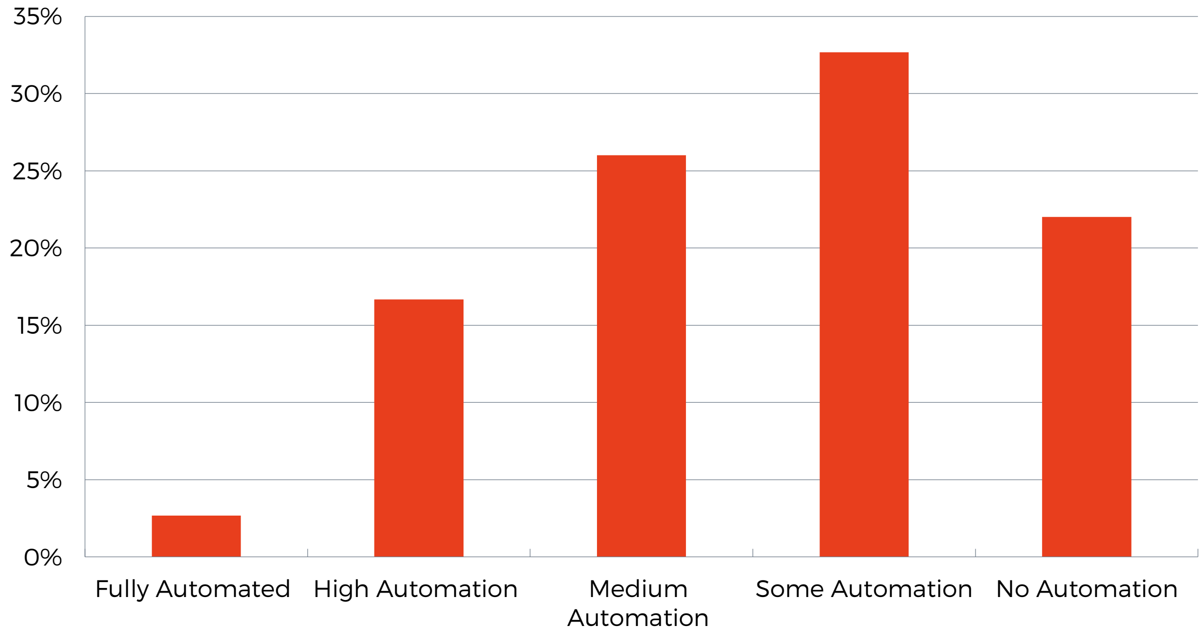
Table 4.7 Respondents' level of automation by major segment – CCTV

	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
Fully Automated	4%	3%	4%	6%	0%	13%	3%	0%	4%	3%
High Automation	21%	23%	14%	25%	29%	77%	10%	0%	21%	20%
Medium Automation	51%	50%	54%	45%	57%	10%	79%	27%	51%	54%
Some Automation	17%	18%	18%	20%	11%	0%	8%	49%	17%	19%
No Automation	7%	6%	11%	5%	4%	0%	0%	24%	7%	4%

All respondents, n=150

Source: IHS Markit

Figure 4.12 - Respondents by Level of Automation - Lighting



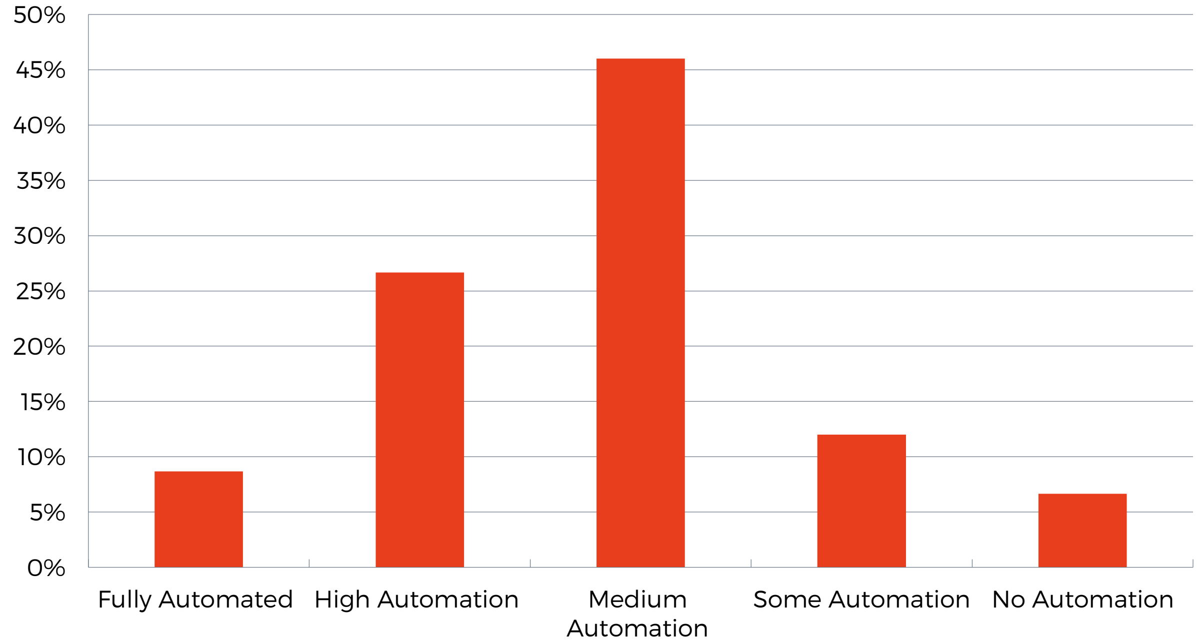
All respondents, n=150 © 2016 IHS-Markit

Table 4.8 Respondents' level of automation by major segment – Lighting

	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
Fully Automated	3%	2%	2%	5%	0%	6%	3%	0%	3%	2%
High Automation	17%	18%	14%	17%	21%	81%	0%	0%	17%	15%
Medium Automation	26%	24%	32%	26%	14%	13%	44%	2%	26%	28%
Some Automation	33%	33%	26%	32%	46%	0%	42%	39%	33%	33%
No Automation	22%	23%	26%	20%	18%	0%	12%	59%	22%	22%

All respondents, n=150 Source: IHS Markit

Figure 4.13 - Respondents by Level of Automation - Hazard Detection/Environmental Health



All respondents, n=150 © 2016 IHS-Markit

Table 4.9 Respondents' level of automation by major segment – Hazard detection / Environmental health and safety

	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
Fully Automated	9%	8%	7%	11%	7%	26%	5%	2%	9%	11%
High Automation	27%	25%	18%	31%	36%	65%	24%	2%	27%	23%
Medium Automation	46%	50%	53%	42%	43%	6%	65%	39%	46%	49%
Some Automation	12%	11%	16%	14%	0%	3%	5%	32%	12%	13%
No Automation	7%	7%	7%	3%	14%	0%	0%	24%	7%	4%

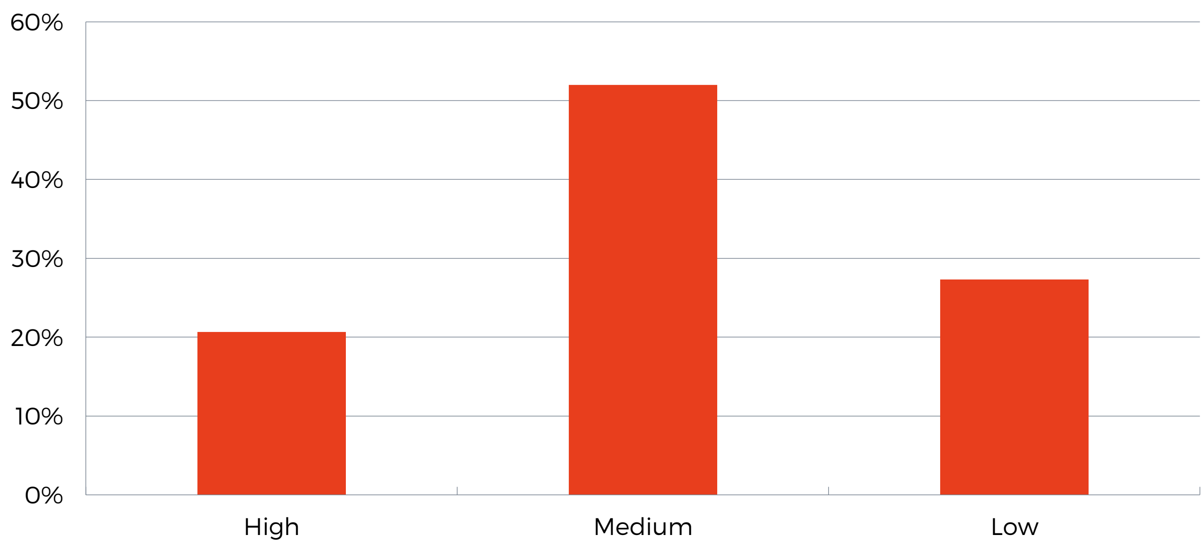
All respondents, n=150 Source: IHS Markit

Table 4.10 Scored levels of automation across system types

	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
Physical Access	10.0	10.0	10.0	9.6	10.0	10.0	10.0	9.0	10.0	10.0
Energy	6.6	6.6	5.9	7.1	6.2	9.1	3.3	7.4	6.4	6.6
HVAC	7.0	6.5	6.3	7.3	6.9	8.2	6.0	6.7	6.0	7.3
CCTV	6.9	7.0	6.1	6.9	7.7	2.7	5.7	7.6	6.4	7.0
Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hazard	9.5	9.3	8.8	10.0	8.8	5.5	8.1	10.0	7.6	10.0

All respondents, n=150 Source: IHS Markit

Figure 4.14 - Respondents Level of Automation - Consolidated



All respondents, n=150 © 2016 IHS-Markit

Most attractive advantages offered by IoT

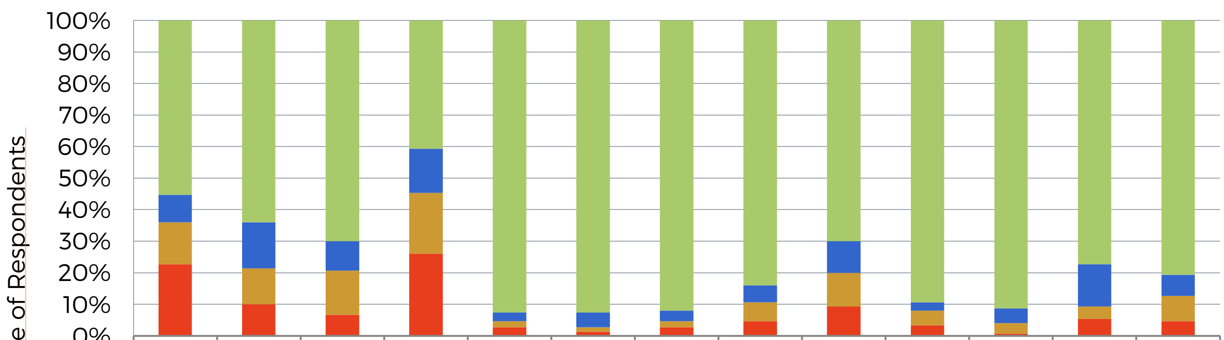
The following question was asked of all respondents. Figure 4.15 to 4.27 display the results to this question, showing for each of the 13 advantages the share of respondents that ranked it one, two, three or did not rank it within the top three.

In order to analyze this question across all 13 advantages, a scoring system was used. Each time one of the 13 advantages was ranked one, a score of 5 was given, a score of 3 was given for each ranking of two and a score of 1 for each ranking of 3. The overall scores where then re-based so the highest scoring advantage was given a score of 10, the lowest a score of 0. The results to this scoring analysis are presented in Table 4.11 and Figure 4.29.

Q2.1 IoT in commercial building management can provide a number of advantages. Please rank the three that are the most attractive to you/your organization (Rank 1, 2, 3, leave others blank)

1. Reduce energy consumption & spend
2. Improve operational efficiency by streamlining/integrating building systems
3. Enable predictive maintenance to improve system lifecycle/reliability
4. Improve financial planning (CAPEX and OPEX)
5. Provide remote access to building systems
6. Future proof technology investment
7. Increased use of sensors to allow for greater occupancy-based automation
8. Move facility management systems to open standards
9. Offer more data/information on building performance
10. Improve occupant comfort
11. Improve occupant safety
12. Improve tenant/employee productivity
13. Increase building resiliency via energy generation & storage

Figure 4.15 - Ranked Value of - Reduce Energy Consumption & Spend



	Reduce Energy Consumption & Spend	Improve Operational Efficiency By Streamlining/Integrating Building Systems	Enable Predictive Maintenance To Improve System Lifecycle/Reliabillity	Improve financial planning (CAPEX and OPEX)	Provide remote access to building systems	Future proof technology investment	Increased use of sensors to allow for greater occupancy-based automation	Move facility management systems to open standards	Offer more data/information on building performance	Improve occupant comfort	Improve occupant safety	Improve tenant/employee productivity	Increase building resiliency via energy generation & storage
Not Ranked	55%	64%	70%	41%	93%	93%	92%	84%	70%	89%	91%	77%	81%
Ranked 3	9%	15%	9%	14%	3%	5%	3%	5%	10%	3%	5%	13%	7%
Ranked 2	13%	11%	14%	19%	2%	1%	2%	6%	11%	5%	3%	4%	8%
Ranked 1	23%	10%	7%	26%	3%	1%	3%	5%	9%	3%	1%	5%	5%

All respondents, n=150 © 2016 IHS-Markit

The table shows that the most attractive advantage amongst respondents was "Improve financial planning (CAPEX and OPEX)", followed by "Reduce energy consumption & spend". These two received significantly higher scores than the other advantages.

There was then a second grouping of advantages that consisted of "Improve operational efficiency by streamlining/integrating building systems", "Enable predictive maintenance to improve system lifecycle/reliability", "Offer more data/information on building performance" and "Improve tenant/employee productivity"

The remaining advantages scored comparatively lower. The least attractive amongst respondents was "Future proof technology investment".

Table 4.11 and Figure 4.16 also shows the results by the main segments used in this report. "Reduce energy consumption & spend" was more attractive for the industrial segment where it was the most attractive feature. Respondents from the Non-industrial segment placed less importance on this, although it was still the second most attractive advantage.

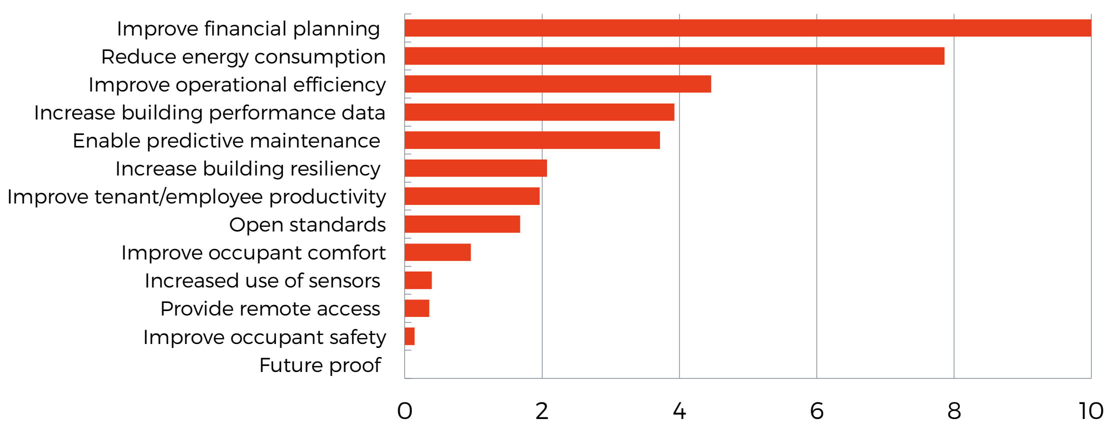
Figure 4.17 display these results graphically for a number of the key segments.

Table 4.11 Attractiveness of advantages – Scored

	Total	Industrial	Non Industrial	Auto High	Auto Med	Auto Low
Reduce energy consumption	7.9	8.7	7.6	8.8	5.5	10.0
Improve operational efficiency	4.5	4.9	4.4	4.1	3.9	5.4
Enable predictive maintenance	3.7	3.1	4.0	3.1	4.2	3.2
Improve financial planning	10.0	10.0	10.0	10.0	10.0	8.2
Provide remote access	0.4	-	0.6	0.8	0.5	0.7
Future proof	-	0.3	-	0.5	0.1	0.4
Increased use of sensors	0.4	0.3	0.5	3.2	-	-
Open standards	1.7	2.2	1.6	1.0	2.8	0.6
Increase building performance data	3.9	4.5	3.8	6.6	3.7	2.4
Improve occupant comfort	1.0	1.2	1.0	1.0	0.6	2.2
Improve occupant safety	0.1	0.4	0.1	-	0.3	0.9
Improve tenant/employee productivity	2.0	3.7	1.5	1.7	1.7	3.0
Increase building resiliency	2.1	0.9	2.5	4.2	2.1	1.0

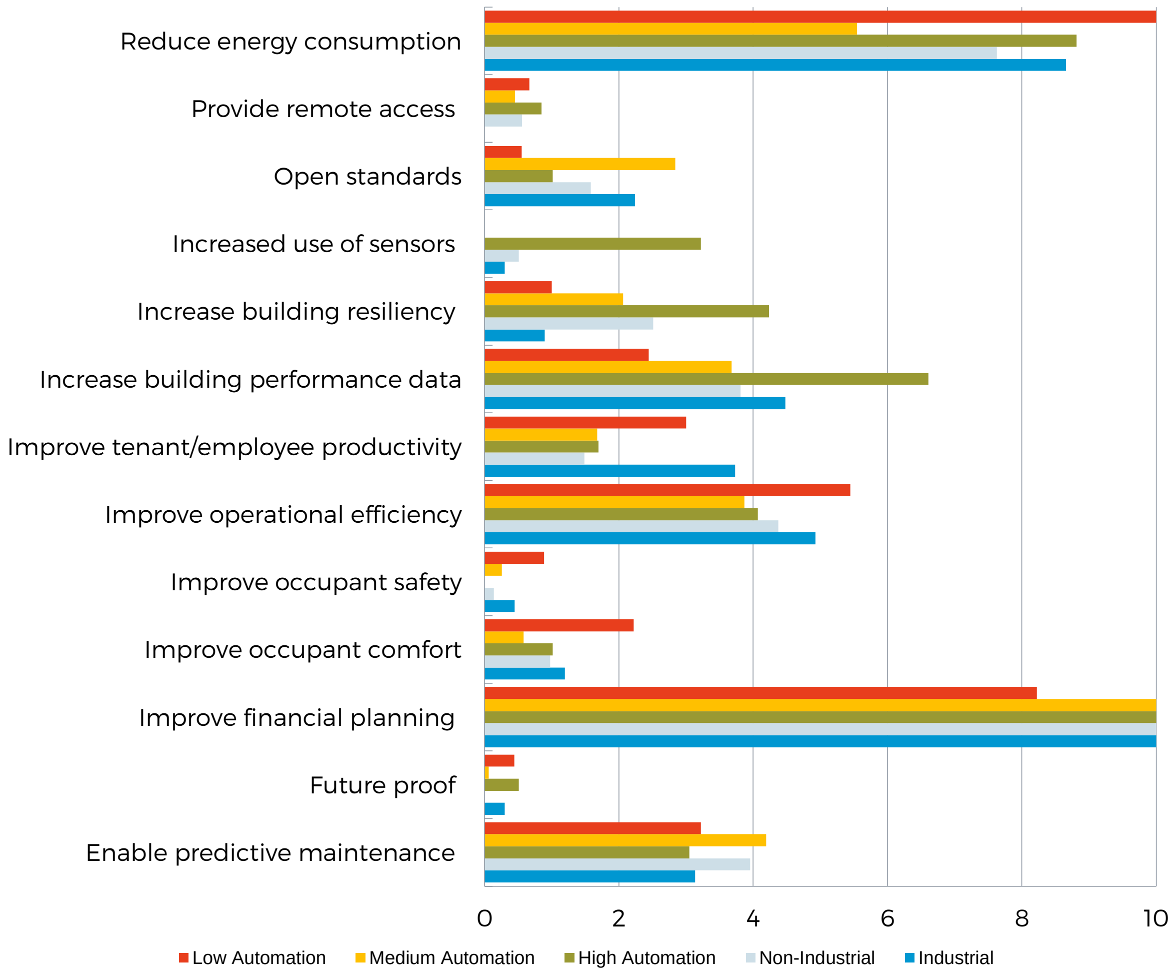
All respondents, n=150 Source: IHS Markit

Figure 4.16 - Scored Ranked Value - All



All respondents, n=150 © 2016 IHS-Markit

Figure 4.17 - Scored Ranked Value - Key Segments



Survey respondents, n=30 © 2016 IHS-Markit

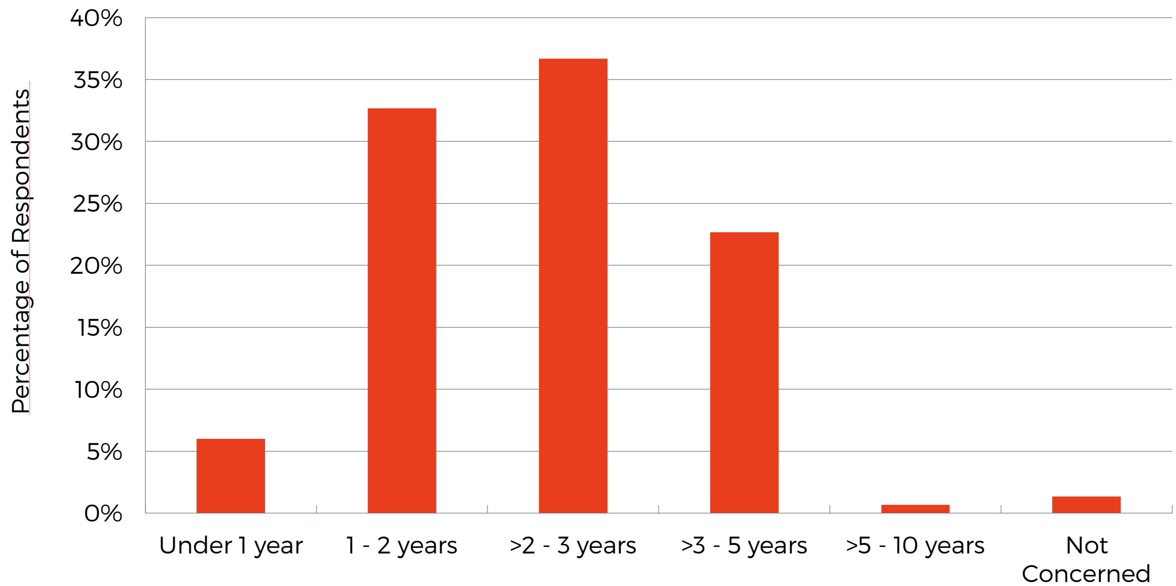
Expected return of investment period

The following question was asked to all respondents. Figure 4.18 displays the results to this question. It shows that the most popular return on investment period for this sample was ">2–3 years". In total more than 85 percent of respondents expected to get a return on their investment of three years or fewer. Table 4.12 shows the results by major segment. There was not a huge amount of variance across the segments. The most demanding was medium sized companies, the least large companies.

SQL 2.1 If you were to purchase an IoT/Cloud-based energy management system to reduce energy consumption or improve operational efficiencies, how long would you expect it to take before you see a complete return on this investment? SINGLE CHOICE

1. I am not concerned with the pay-back period on my devices
2. Under 1 year
3. 1 - 2 years
4. >2 – 3 years
5. >3 - 5 years
6. >5 - 10 years
7. Over 10 years

Figure 4.18 - Return on Investment Period



All respondents, n=150 © 2016 IHS-Markit

Table 4.12 Expected return on investment period

	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
Under 1 year	6%	7%	11%	3%	4%	6%	3%	12%	5%	8%
1 - 2 years	33%	33%	40%	26%	32%	48%	27%	32%	33%	32%
>2 - 3 years	37%	34%	35%	43%	25%	26%	42%	34%	40%	27%
>3 - 5 years	23%	25%	9%	28%	39%	16%	28%	17%	21%	27%
>5 - 10 years	1%	1%	2%	0%	0%	0%	0%	2%	0%	3%
Not Concerned	1%	1%	4%	0%	0%	3%	0%	2%	1%	3%

All respondents, n=150 Source: IHS Markit

Value of key IoT applications

The following question was asked of all respondents. The results to this question are presented in Figure 4.19 with references to the above list for category numeration. In order to analyze this question across all applications, a scoring system was used. For each ranking of 1 as score of 5 was given, 3 for a ranking of 2, 1 for a ranking of 4. No score was given to a ranking of 4, -1 was given for a ranking of 5, -3 for 6 and -5 for 7. The overall scores where then re-based so the highest scoring application was given a score of 10, the lowest a score of 0.

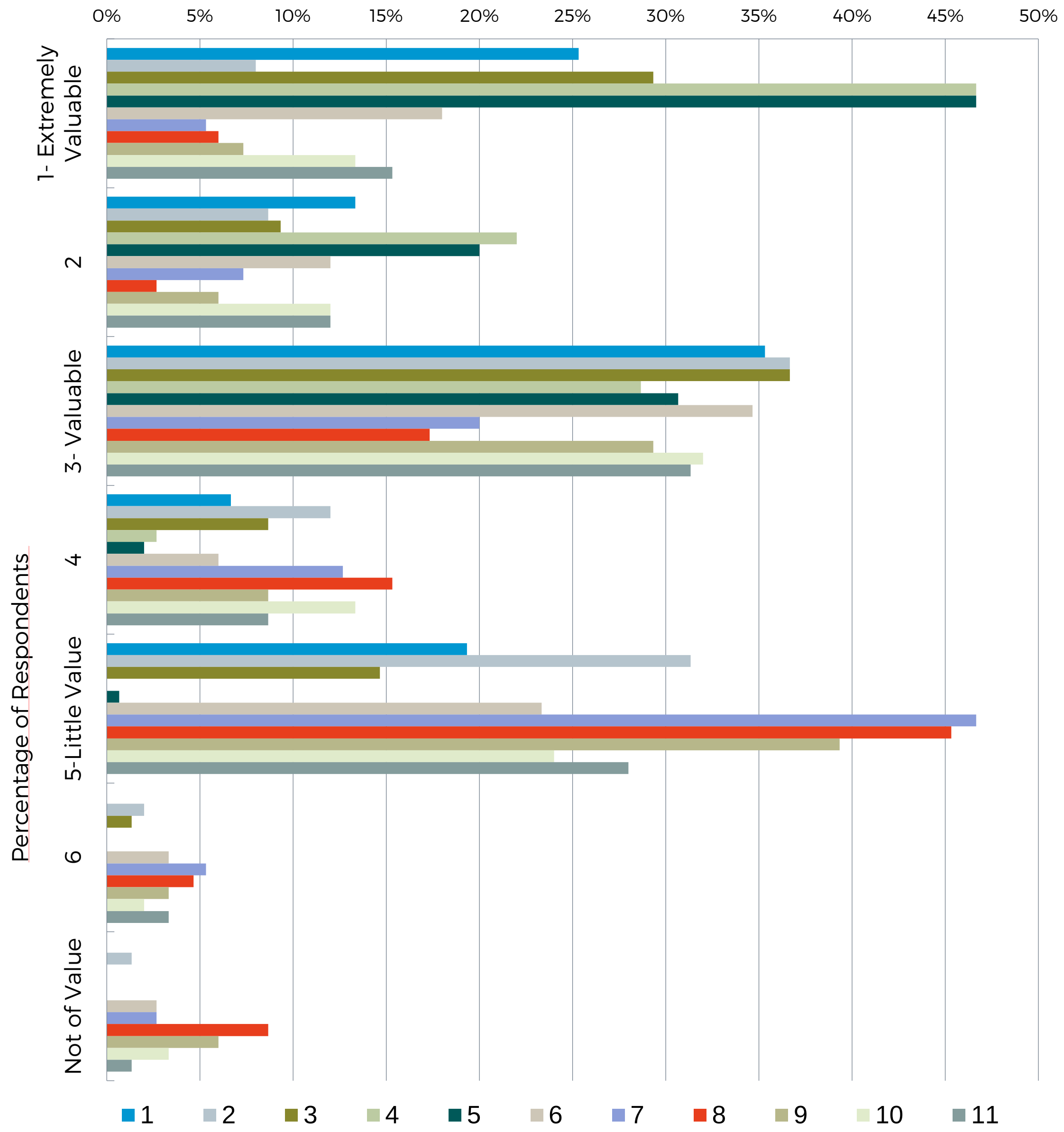
2.3 How much would you value each of the following applications?

SCALE QUESTION (1-7) Single Choice per row...

- Extremely valuable
- Valuable
- Little value
- Not of value

1. View energy consumption data for your building, such as on-going energy consumption of equipment or assets
2. Control building systems remotely
3. Monitor building systems remotely
4. Receive a notification if any building systems are operating outside normal parameters
5. Receive advanced notification if a device is on the verge of failure (or requires urgent attention)
6. Receive and monitor information on building occupancy from off-site remote locations
7. Use of advanced algorithms to recommend location-based set points based on usage and occupancy
8. Control outdoor devices from remote off-site locations, such as electrics gates, bollards, external lighting, fountains, etc.
9. Provide building occupants with greater control of systems (e.g., via location-based mobile apps)
10. Integration with weather systems for historical comparisons as well as future energy and maintenance forecasting
11. Ability to create rules / algorithms based on the needs of your building

Figure 4.19 - Application Value



	Not of Value	6	5-Little Value	4	3- Valuable	2	1- Extremely Valuable
1	0%	0%	19%	7%	35%	13%	25%
2	1%	2%	31%	12%	37%	9%	8%
3	0%	1%	15%	9%	37%	9%	29%
4	0%	0%	0%	3%	29%	22%	47%
5	0%	0%	1%	2%	31%	20%	47%
6	3%	3%	23%	6%	35%	12%	18%
7	3%	5%	47%	13%	20%	7%	5%
8	9%	5%	45%	15%	17%	3%	6%
9	6%	3%	39%	9%	29%	6%	7%
10	3%	2%	24%	13%	32%	12%	13%
11	1%	3%	28%	9%	31%	12%	15%

All respondents, n=150

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Table 4.13 Key feature level of attractiveness – Scored

	Total	Industrial	Non Industrial	Auto High	Auto Med	Auto Low
View energy consumption data	6.1	5.7	6.3	6.7	5.6	6.7
Control building systems remotely	2.8	3.3	2.7	3.9	2.4	2.8
Monitor building systems remotely	6.4	6.2	6.5	7.4	6.0	6.5
Notification if systems outside normal parameters	10.0	10.0	10.0	9.9	10.0	10.0
Notification if device on verge of failure	9.9	10.0	9.8	10.0	9.8	9.8
Information on building occupancy	4.3	4.6	4.2	5.3	4.0	4.2
Recommend location based set points	1.1	0.5	1.2	1.7	1.1	0.7
Control outdoor devices	0.0	0.0	0.0	0.0	0.0	0.0
Provide occupants with greater control	1.4	0.9	1.5	1.9	0.7	2.3
Integration with weather systems	3.6	3.9	3.5	5.3	3.7	2.3
Rules / algorithms based on the needs of building	3.9	4.3	3.8	5.9	4.2	2.1

All respondents, n=150 Source: IHS Markit

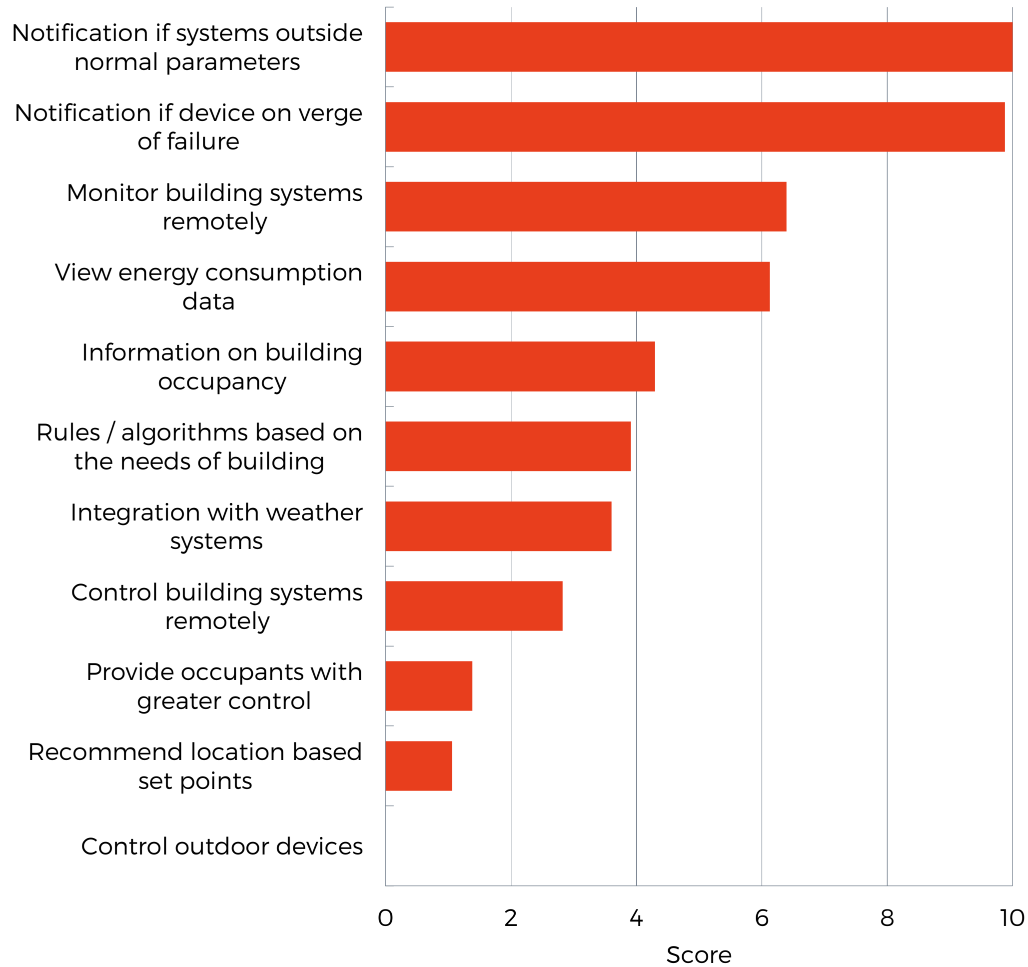
It shows that the following two applications were by far the most popular:

- Receive a notification if any building systems are operating outside normal parameters
- Receive advanced notification if a device is on the verge of failure (or requires urgent attention)

The top four were all applications that are relatively well documented for how intelligent buildings could function. The slightly more out-of-the-box functions such as occupancy information, weather system integration, location based set point recommendations, were scored lower. However, they still received more than 30 percent of respondents ranking them within the top three However, comparing the scores across applications gives some indication as to where trade-offs may be made when selecting feature sets.

When analyzed by major segment, there was little variation in the profile of those applications that scored higher or lower. One slight difference was those that already fell into the high automation segment did value a little more the newer types of service listed above. Indicating that their attractiveness is perhaps linked to awareness of what they can potentially offer.

Figure 4.20 - Application Value - Score



All respondents, n=150

Preferred devices for building system management and control

The following question was asked of all respondents: The results to this question are presented in Figure 4.21. For all of the six system types, the rankings were very similar. A sophisticated dedicated device was the most popular across all, with the exception of lighting, where an on-site PC/laptop/workstation was the most popular. This was also the second most popular device across all other applications. The overall demand for device types did show a reasonably high level of variance indicating that broad range of options is required to address all the market's requirements.

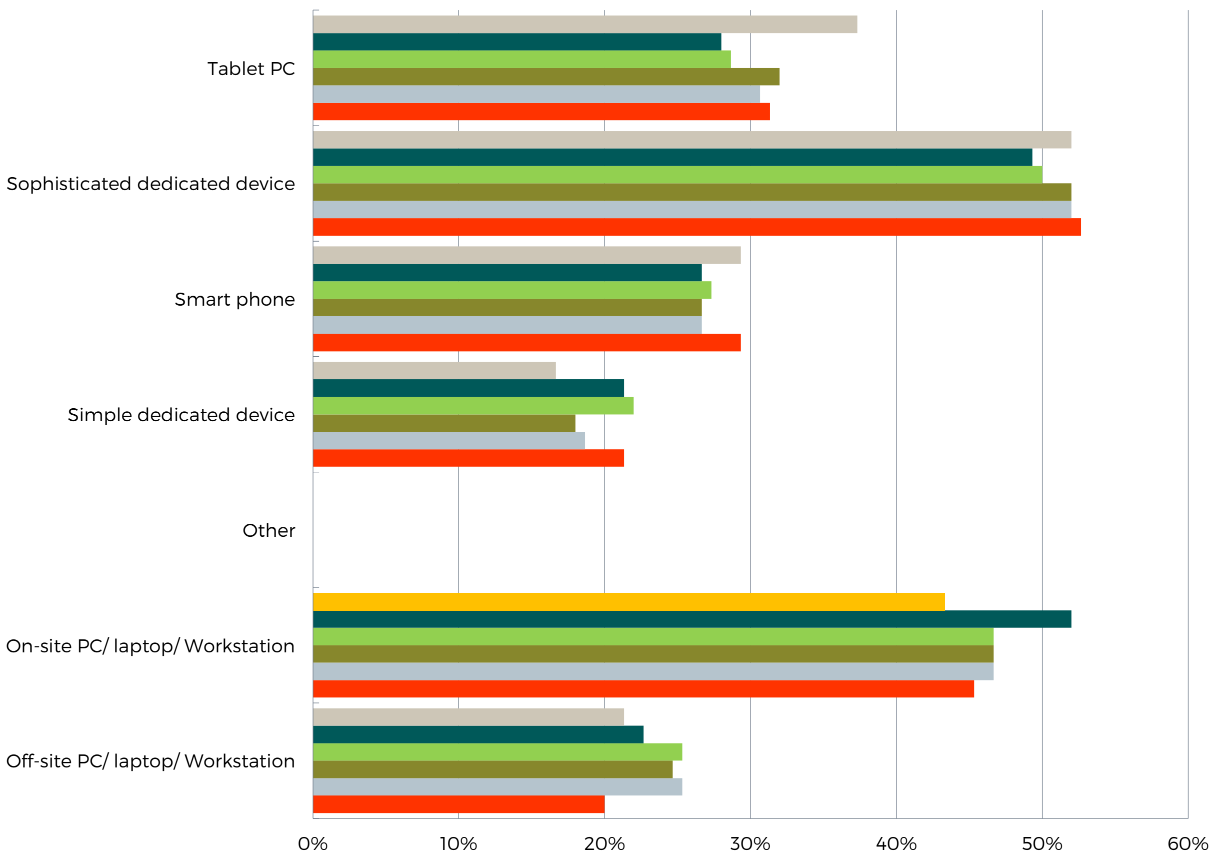
2.4 For each building management function, what are the top two devices types you'd prefer to use to manage and control the system?

1. Physical Security/Access Control
2. Energy Management
3. HVAC (heating, ventilating, and air conditioning)
4. CCTV
5. Lighting
6. Hazard Detection/Environmental Health & Safety

For each the following drop downs –

1. A simple dedicated device, e.g. a thermostat for energy management, a room HVAC control panel, a light switch.
2. A sophisticated dedicated device, e.g. centralized lighting control panel, centralized HVAC control panel, centralized access control panel
3. An on-site PC/laptop/Workstation
4. An off-site PC/laptop/Workstation
5. A smart phone that can be used from any location
6. A tablet PC that can be used from any location
7. Other, please specify (STRING)

Figure 4.21 - Preferred Interface - Building Management Function



	Off-site PC/ laptop/ Workstation	On-site PC/ laptop/ Workstation	Other	Simple dedicated device	Smart phone	Sophisticated dedicated device	Tablet PC
Hazard Detection	21%	43%	0%	17%	29%	52%	37%
Lighting	23%	52%	0%	21%	27%	49%	28%
CCTV	25%	47%	0%	22%	27%	50%	29%
HVAC	25%	47%	0%	18%	27%	52%	32%
Energy Management	25%	47%	0%	19%	27%	52%	31%
Physical Access Control	20%	45%	0%	21%	29%	53%	31%

Hazard Detection ■ Lighting ■ CCTV ■ HVAC ■ Energy Management ■ Physical Access Control

All respondents, n=150

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Attractiveness of centralized control

The following question was asked of all respondents. The results are shown in Table 4.14. It shows that more than 70 percent of respondents indicated that this was either very valuable or moderately valuable. Only 12 percent indicated they saw no value.

When examined by major segment, the results were similar and showed the larger the organization the more valuable this feature was. There was little difference between industrial and non-industrial segments. One perhaps surprising result was 23 percent of respondents from the high automation segment indicated this was of no value. For the medium and low automation segments the comparative numbers were 8 percent and 12 percent respectively.

2.5 How valuable would it be if all of the different functions related to building management could be controlled from a single app or program on your smartphone, PC, tablet or other device? SINGLE CHOICE

1. Very valuable – I would only choose a system which allows me to use a single app or program
2. Moderately valuable – I would prefer a single app or program
3. Neutral – I am happy with either
4. Not of value – I would prefer separate apps or programs

Table 4.14 Value of control via one app

	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
Very Valuable	40%	38%	40%	43%	32%	35%	41%	41%	38%	46%
Moderately Valuable	31%	33%	26%	29%	46%	32%	36%	22%	30%	35%
Neutral	17%	18%	23%	12%	14%	10%	15%	24%	19%	8%
Not of Value	12%	12%	11%	15%	7%	23%	8%	12%	12%	11%

All respondents, n=150 Source: IHS Markit

Attractiveness of predictive maintenance

The following question was asked of all respondents. The results are shown in Table 4.15. It shows that more than 98 percent of respondents indicated that this was either very valuable or moderately valuable. Only 1 percent indicated they saw no value. So compared to the previous question where a similar structure was used, the responses to this question were considerably more positive.

2.6 Intelligent building solutions allow device manufacturers to use analytics and real-time information from the systems to pre-empt expensive repair or maintenance issues, and recommend when a device needs to be serviced or repaired in order to ensure the device continues to run effectively. How valuable would this be to you? SINGLE CHOICE

1. Very valuable
2. Moderately valuable
3. Neutral
4. Not of value

Table 4.15 Attractiveness of predictive maintenance

	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
Very Valuable	75%	75%	72%	77%	75%	74%	78%	68%	74%	76%
Moderately Valuable	23%	23%	23%	22%	25%	19%	21%	29%	23%	22%
Neutral	2%	2%	4%	2%	0%	3%	1%	2%	3%	0%
Not of Value	1%	0%	2%	0%	0%	3%	0%	0%	0%	3%

All respondents, n=150 Source: IHS Markit

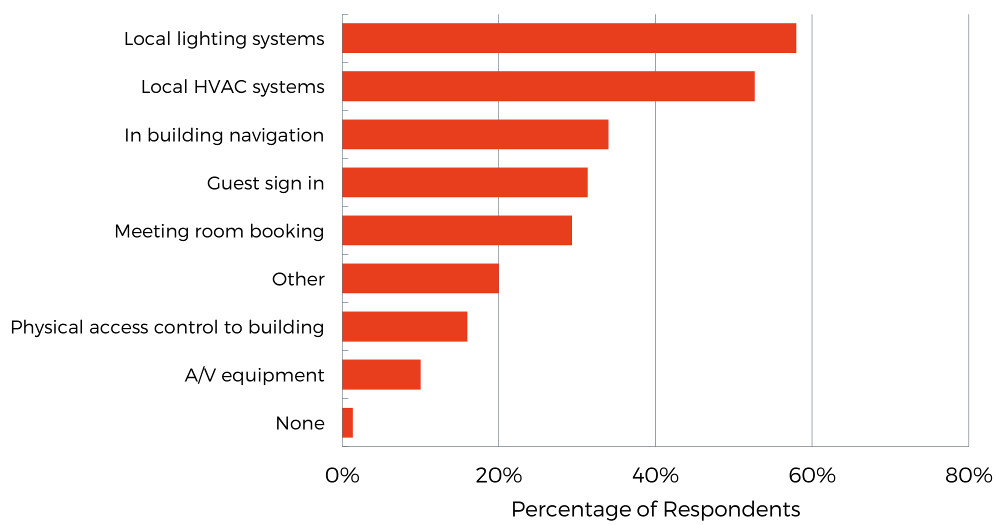
Mobile applications for building users

The results to this question are presented in Figure 4.22. It shows that controlling lighting and HVAC via mobile apps were the two most popular functions. These were the only two applications where more than 50 percent of respondents indicated that they would be interested in providing to their building occupants. Least popular were physical access to building and control of A/V equipment.

SQ: 2.7 Mobile apps can be developed for general building users/occupants to interface with the building management systems. Which of the following smartphone based app functions would you like to provide to your building users in order that they can interface with building management systems? Please tick all that apply:

1. Physical access control to building
2. Guest sign-in
3. Control of local HVAC systems
4. Meeting room booking
5. Control of local lighting systems
6. In-building navigation
7. Control of A/V equipment
8. Other, please specify (STRING)

Figure 4.22 - Level of Interest in Mobile Apps



All respondents, n=150 © 2016 IHS-Markit

4.3 SUPPLIER ECOSYSTEM

Another key theme explored in this study related to the impact of IoT on the supplier ecosystem. The following questions support the exploration of issues around this theme. The theme is presented fully in Section 2.3.

Channels use to purchase building systems

The following question was asked of all respondents:

SQ: 3.1 Please detail the manufacturer used for each of the following systems and the channel through which you made the purchase. If you do not know, please state 'Do not know'. If you used more than one for different locations, please specify the one used to the greatest extent.

1. Physical Security/Access Control
2. Energy Management
3. HVAC (heating, ventilating, and air conditioning)
4. CCTV
5. Lighting
6. Hazard Detection/Environmental Health & Safety
7. Audio/Visual Equipment
8. Cross system building management platform

Text string plus below drop down for each –

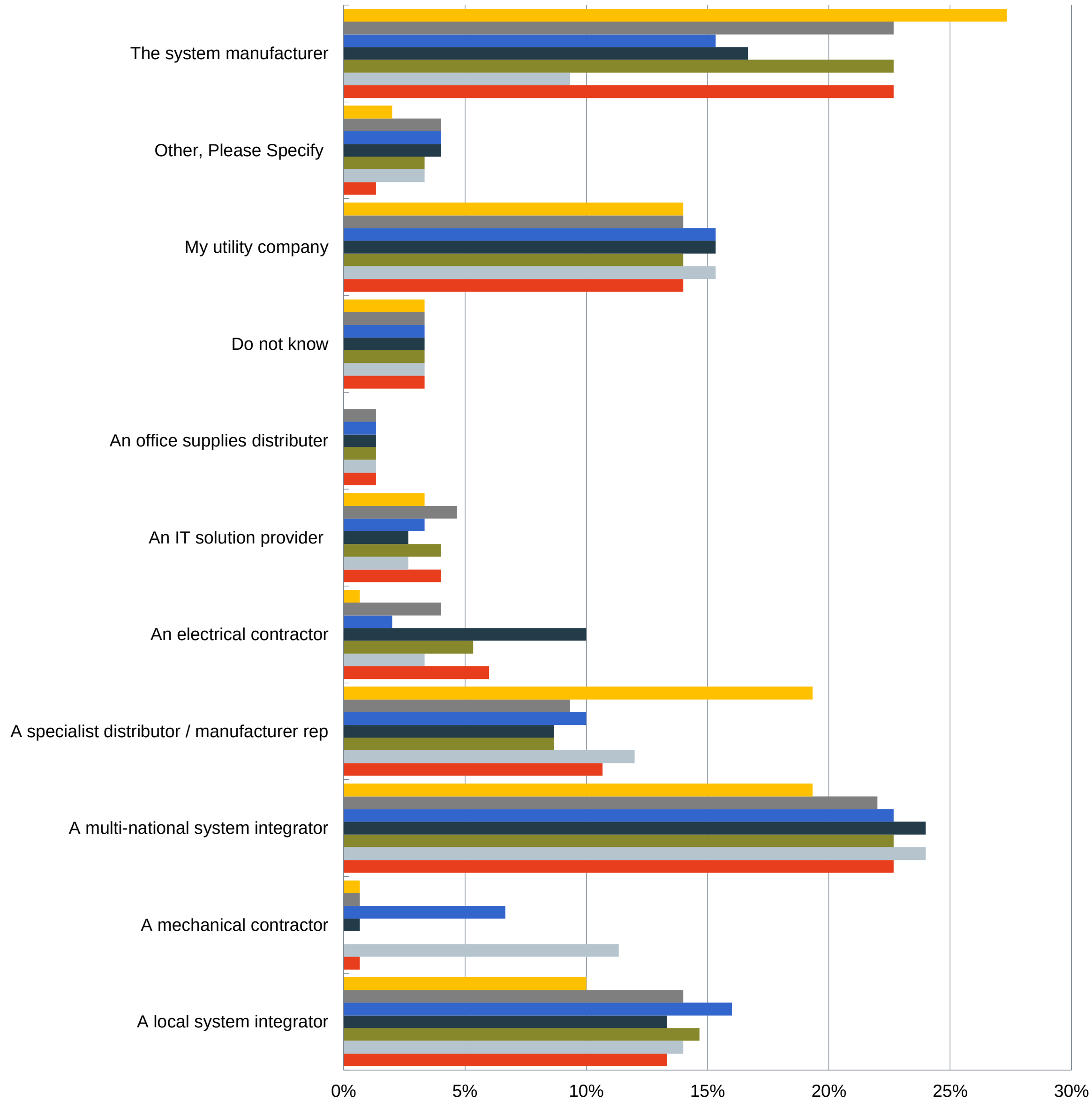
1. The system manufacturer
2. An electrical contractor
3. A mechanical contractor
4. A local system integrator
5. A multi-national system integrator
6. My utility company
7. An IT solution provider
8. An office supplies distributer
9. A specialist distributor/manufacturer rep
10. Other, Please Specify (STRING)
11. Do not know

The results to this question are presented in Figure 4.23. The top two for each system type were:

- Physical Security/Access Control – system manufacturer, multi-national system integrator
- Energy Management – multi-national system integrator, utility company
- HVAC – multi-national system integrator, mechanical contractor
- CCTV – system manufacturer, multi-national system integrator
- Lighting – multi-national system integrator, system manufacturer
- Hazard Detection/Environmental Health & Safety – multi-national system integrator, local system integrator
- Audio/Visual Equipment – system manufacturer, multi-national system integrator
- Cross system building management platform - system manufacturer, multi-national system integrator/specialist distributor/manufacturer

This shows that there is some difference between system types, so as suppliers to this market look to bring together solutions that address the full intelligent building offering, this will need to be addressed. In general, there was a significant drop off in responses for electrical contractors, IT solution providers, office supplies distributors, and mechanical contractors. The exceptions for mechanical contractors were HVAC and energy systems; and for electrical contractors, lighting and CCTV systems.

Figure 4.23 - Supplier - By System



	A local system integrator	A mechanical contractor	A multi-national system integrator	A specialist distributor / manufacturer rep	An electrical contractor	An IT solution provider	An office supplies distributer	Do not know	My utility company	Other, Please Specify	The system manufacturer
Cross System Building	10%	1%	19%	19%	1%	3%	0%	3%	14%	2%	27%
AV	14%	1%	22%	9%	4%	5%	1%	3%	14%	4%	23%
Hazard	16%	7%	23%	10%	2%	3%	1%	3%	15%	4%	15%
Lighting	13%	1%	24%	9%	10%	3%	1%	3%	15%	4%	17%
CCTV	15%	0%	23%	9%	5%	4%	1%	3%	14%	3%	23%
Energy Management	14%	11%	24%	12%	3%	3%	1%	3%	15%	3%	9%
Physical Access Control	13%	1%	23%	11%	6%	4%	1%	3%	14%	1%	23%

Cross System Building, AV, Hazard, Lighting, CCTV, Energy Management, Physical Access Control

All respondents, n=150

Criteria used for vendor selection

The following question was asked of all respondents:

SQ: 3.2 Please select the top 3 criteria when making a vendor selection (RANK 1 to 3, where 1 is the most important)

1. Product quality
2. Quality/Breadth of service maintenance contract/plans
3. Price competitiveness
4. Broad portfolio
5. Innovation
6. Interoperability of products with other suppliers
7. Historic relationships

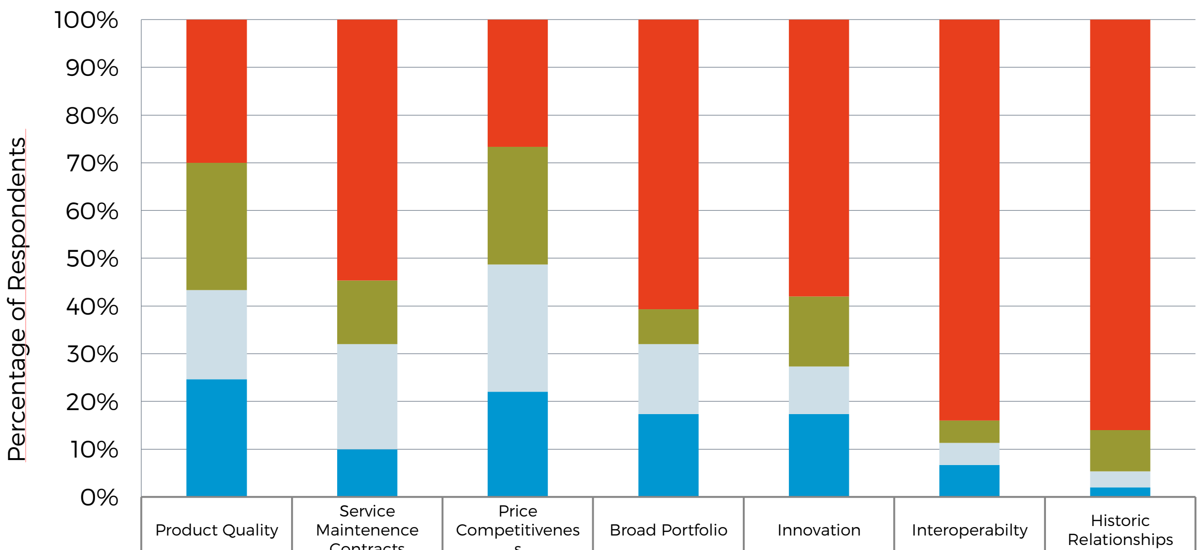
The results to this question are presented in Figure 4.24 and Table 4.16. In order to analyze this question across all criteria, a scoring system was used. Each time one of the criteria was ranked 1, a score of 5 was given, and a score of 3 was given for each ranking of 2 and a score of 1 for each ranking of 3. The overall scores were re-based so the highest scoring advantage was given a score of 10, the lowest a score of 0.

For all segments, apart from high automation, price competitiveness was the most important criterion, closely followed by product quality. There was then a drop-off in scoring, with quality/breadth of service maintenance contract/plans, broad portfolio, and innovation forming a second tier group. Interoperability of products and historical relationships then formed a bottom tier.

There were a few exceptions to the above:

- For the high automation group, innovation was the most important criterion.
- For the low automation group, innovation's score put it with interoperability and historic relationships in the lowest tier of criteria.
- Innovation was significantly more important to the non-industrial group than to the industrial.
- Interoperability was significantly more important to the industrial group than to the non-industrial.

Figure 4.24 - Vendor Selection Criteria



	Product Quality	Service Maintenence Contracts	Price Competitivenes s	Broad Portfolio	Innovation	Interoperabilty	Historic Relationships
Not Ranked	30%	55%	27%	61%	58%	84%	86%
Ranked 3	27%	13%	25%	7%	15%	5%	9%
Ranked 2	19%	22%	27%	15%	10%	5%	3%
Ranked 1	25%	10%	22%	17%	17%	7%	2%

All respondents, n=150 © 2016 IHS-Markit

Table 4.16 Vendor selection criteria – Scored

	Total	Industrial	Non Industrial	Auto High	Auto Med	Auto Low
Product quality	9.5	8.5	9.9	9.3	10.0	8.6
Quality of service contract	5.4	4.8	5.6	5.9	6.5	3.3
Price competitiveness	10.0	10.0	10.0	9.3	10.0	10.0
Broad portfolio	5.9	6.0	5.8	5.1	7.7	3.0
Innovation	5.5	3.7	6.1	10.0	6.7	1.3
Interoperability of products	1.3	4.2	0.3	1.2	1.7	0.5
Historic relationships	0.0	0.0	0.0	0.0	0.0	0.0

All respondents, n=150 Source: IHS Markit

4.4 DATA SECURITY AND DATA STORAGE

Another key theme explored in this study related to attitudes to data security and storage and how IoT would affect these issues. The following questions support the exploration of theme. The theme is presented fully in Section 2.2.

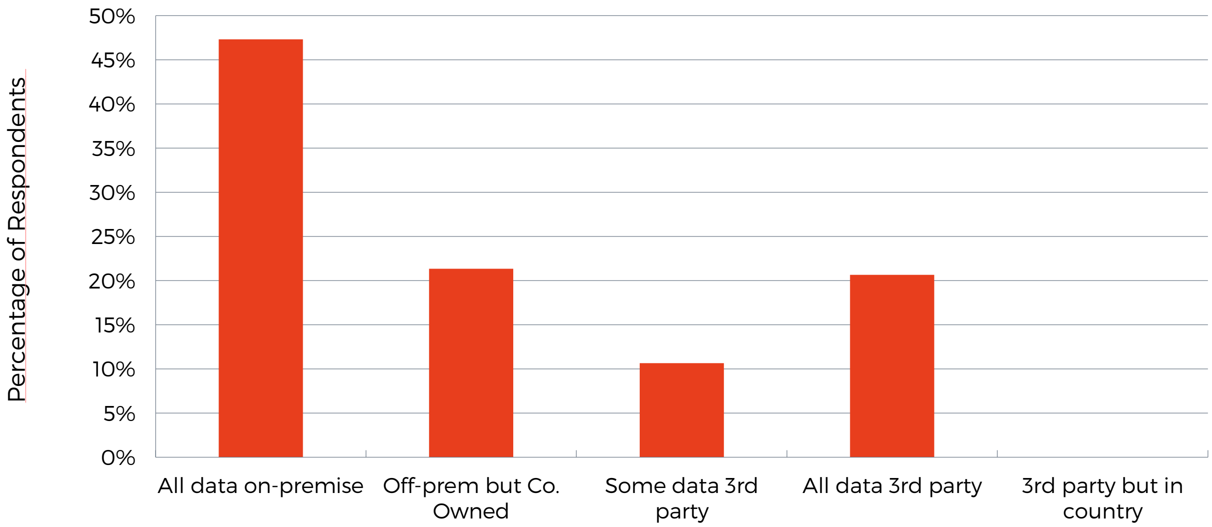
Company policy on data storage

The following question was asked of all respondents. The results to this question are presented in Figure 4.25 and Table 4.17.

SQ: 4.1 With respect to building management data (e.g. data relating to energy consumption, lighting, occupancy, security, CCTV, etc.), please select the most appropriate statement from below that reflects your company's policy on data storage – SINGLE CHOICE

1. All data has to be stored only on on-premises servers/on-premises data centers/on-premises private cloud.
2. Data can be stored off-premises but it has to be stored on company owned equipment (e.g. stored on a co-located/multi-tenant data center but utilizing company owned servers/storage)
3. Certain data from the above list can be stored on third-party-operated cloud systems/data centers, but certain data types have to remain on-premises.
4. All data from the above list can be stored on third-party-operated cloud system/data centers, provided that it is stored within the borders of the country
5. All data from the above list can be stored on third-party-operated cloud systems/data centers

Figure 4.25 - Location of Stored Building Data



All respondents, n=150 © 2016 IHS-Markit

Table 4.17 Location of stored building data

Data Storage	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
All data on-premise	47%	22%	47%	43%	57%	42%	46%	54%	50%	41%
Off-prem but Co. Owned	21%	23%	23%	22%	18%	32%	22%	12%	12%	5%
Some data 3rd party	11%	10%	9%	14%	7%	10%	10%	12%	21%	22%
All data 3rd party	21%	45%	21%	22%	18%	16%	22%	22%	17%	32%
3rd party but in country	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

All respondents, n=150 Source: IHS Markit

The results are interesting in that they show that for most respondents there were company policies in place that significantly restrict the use of cloud services. Fifty-seven percent of respondents indicated that all data must be stored on their premises. Only 16 percent of respondents indicated that all data could be stored on third- party-operated cloud systems. A further 10 percent indicated that some data could be stored on third-party-operated cloud systems. This is of particular concern for the industry since many of the future systems for providing advanced intelligent building solutions are built around cloud-based solutions. None of the respondents indicated that the location of the third-party data center was a restricting factor.

Table 4.17 dives deeper into the responses by major segment. Here the results show some more positive trends. For those respondents in the non-industrial segment, the views were less negative. For this group, 50 percent of respondents indicated that all data could be stored on third-party systems. This implied that there is a marked contrast in view on this topic between industrial and non-industrial respondents.

The results also varied by organization size, with smaller organizations tending to have a greater tolerance for cloud-based systems and large organizations having a high intolerance. It also shows a marked contract in the responses from the United States or Canada, with the respondents from Canada showing a greater willingness to use cloud-based services.

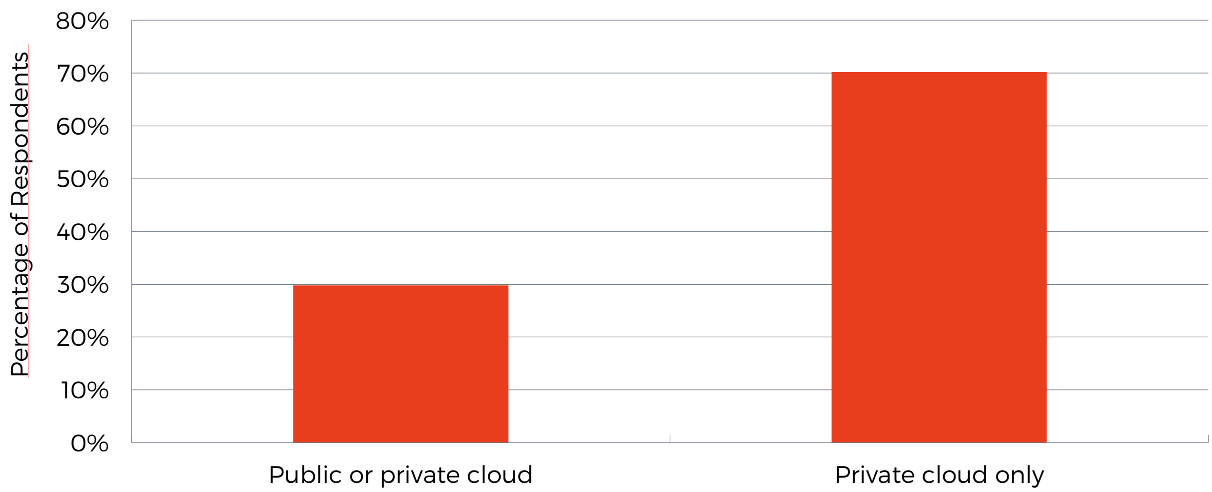
Public and private clouds

The following question was asked to all respondents that selected options 3, 4 and 5 in Question 4.1. The results to this question are presented in Figure 4.26 and Table 4.18.

SQ: 4.1 With respect to cloud services you can use, please indicate the statement from below that most reflects your company's policy on building management data storage. SINGLE CHOICE

1. Off-premises third-party-operated cloud services have to use private clouds – i.e., services delivered using non-shared infrastructure.
2. Off-premises third-party-operated cloud services can use both private and public clouds – public cloud services being delivered via shared infrastructure

Figure 4.26 - Public or Private Cloud



All respondents, n=47 © 2016 IHS-Markit

Table 4.18 Public or private cloud

Data Storage	Total	Non Industrial	Small	Med	Large	Auto High	Auto Med	Auto Low	USA	Canada
Public or private cloud	35%	34%	26%	29%	NA	13%	28%	43%	27%	36%
Private cloud only	65%	66%	74%	71%	NA	88%	72%	57%	73%	64%

All respondents, n=47 Source: IHS Markit

The results show that respondents that had indicated that they could use third-party cloud services were however restricted to using private clouds, i.e., cloud services delivered through non-shared infrastructure. Across the main segments there was a little variance in the results. Respondents that had currently low levels of automation had a greater tendency for public clouds being an option. The restriction on using public cloud services were also greater the larger the organization. There was a marked difference in responses between the United States and Canada too. In Canada, the use of public cloud services was an option for much larger share of respondents.

Data that cannot be stored on third-party operator cloud systems/data centers

The following question was asked of all respondents that selected option 3 in Question 4.1. The results to this question are presented in Figure 4.27. This question was only put to those respondents that had indicated that only certain data could be stored by third parties.

SQ: 4.2 Please tick all data types that CANNOT be stored on 3rd party operated cloud systems/data centers – TICK ALL THAT APPLY

1. Physical security/Access control data
2. Energy management data
3. HVAC (heating, ventilating, and air conditioning) data
4. CCTV data
5. Lighting data
6. Hazard detection/Environmental health and safety data
7. Occupancy sensing data
8. A/V data
9. Other, please specify

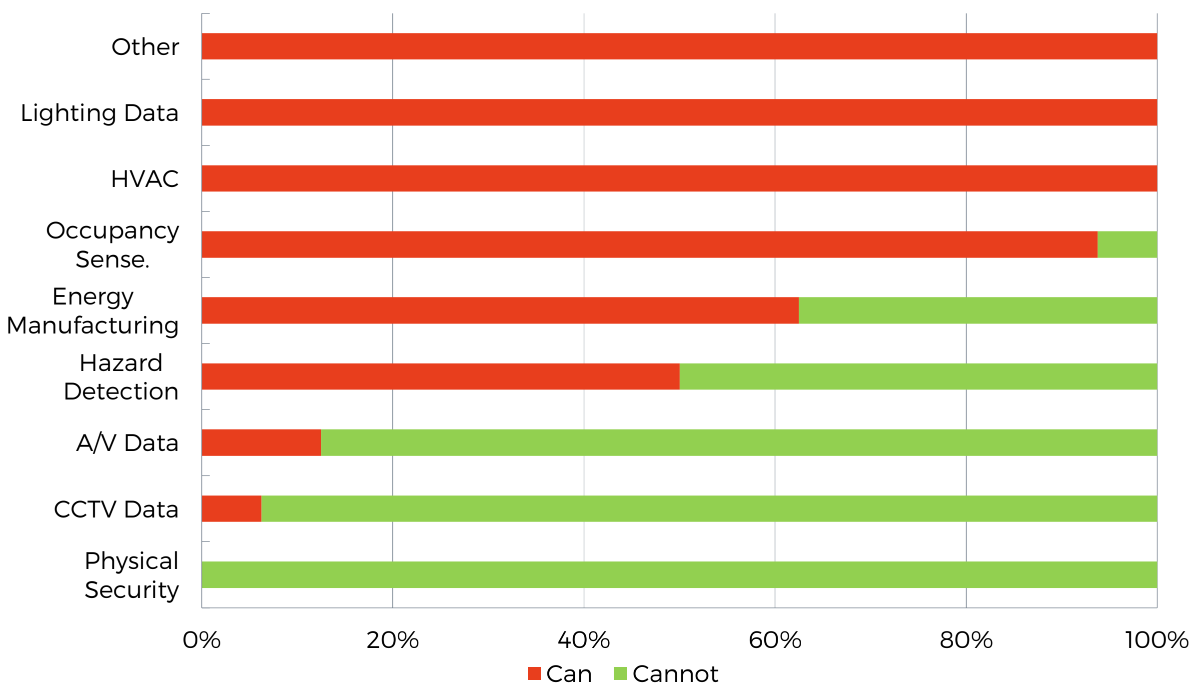
The data types that had the lowest levels of restriction, with all or most respondents indicating it could be stored on third-party systems were:

- Lighting data
- HVAC (heating, ventilating, and air conditioning) data

The data types that had the greatest levels of restriction with all or most respondents indicating it could not be stored on third-party systems were:

- Physical security/Access control data
- CCTV data
- A/V data

Figure 4.27 - Types of Data That Can/Cannot be Stored on 3rd Party Cloud



All respondents, n=16 - Caution Low Sample © 2016 IHS-Markit

Greatest barrier to data being stored on third-party clouds

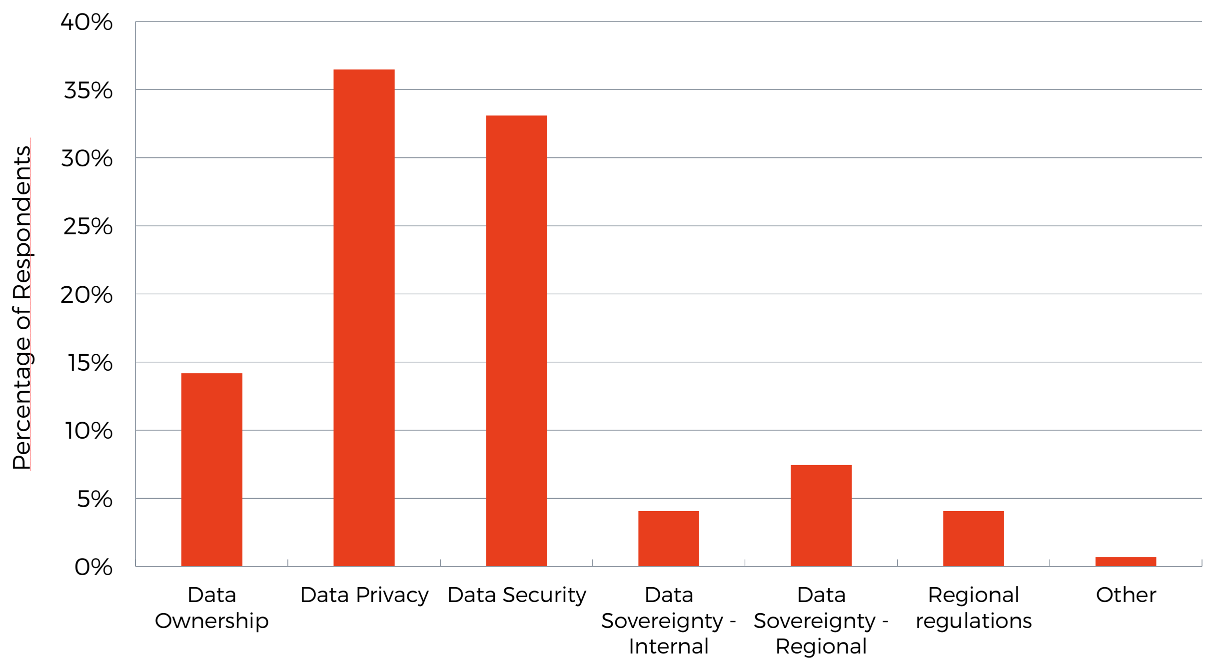
The following question was asked to all respondents that selected option 1, 2, 3 or 4 in Question 4.1a, or those that answered option 1 in Question 4.1b.

SQ: 4.3 What do you believe is the greatest barrier to your data/more of your data being stored using third-party cloud services? SINGLE CHOICE

1. Internal concerns relating to data security
2. Internal concerns relating to data privacy
3. Regional regulations/legislation relating to data storage
4. Internal concerns relating to data ownership
5. Regional regulations/legislation relating to sovereignty
6. Internal concerns relating to data sovereignty
7. Other, please specify

The results to this question are presenting in Figure 4.28. Responses were only obtained from respondents that had indicated there were restrictions on using third-party systems. It shows that "internal concerns relating to data security" and "internal concerns relating to data privacy" were the two issues that represented the greatest barrier amongst respondents.

Figure 4.28 - Greatest Barrier to Using 3rd Party Cloud Services



All respondents, n=150 © 2016 IHS-Markit

4.5 STANDARDIZATION

Another key theme explored in this study related to attitudes to standardization and interoperability of systems used in building management. The following questions support the exploration of issues around this theme. The theme is presented fully in Section 2.4.

Wired communication protocols used in building management systems

The following question was asked of all respondents. The results for each system type are presented in Figure 4.29. The combined results are presented in Table 4.19.

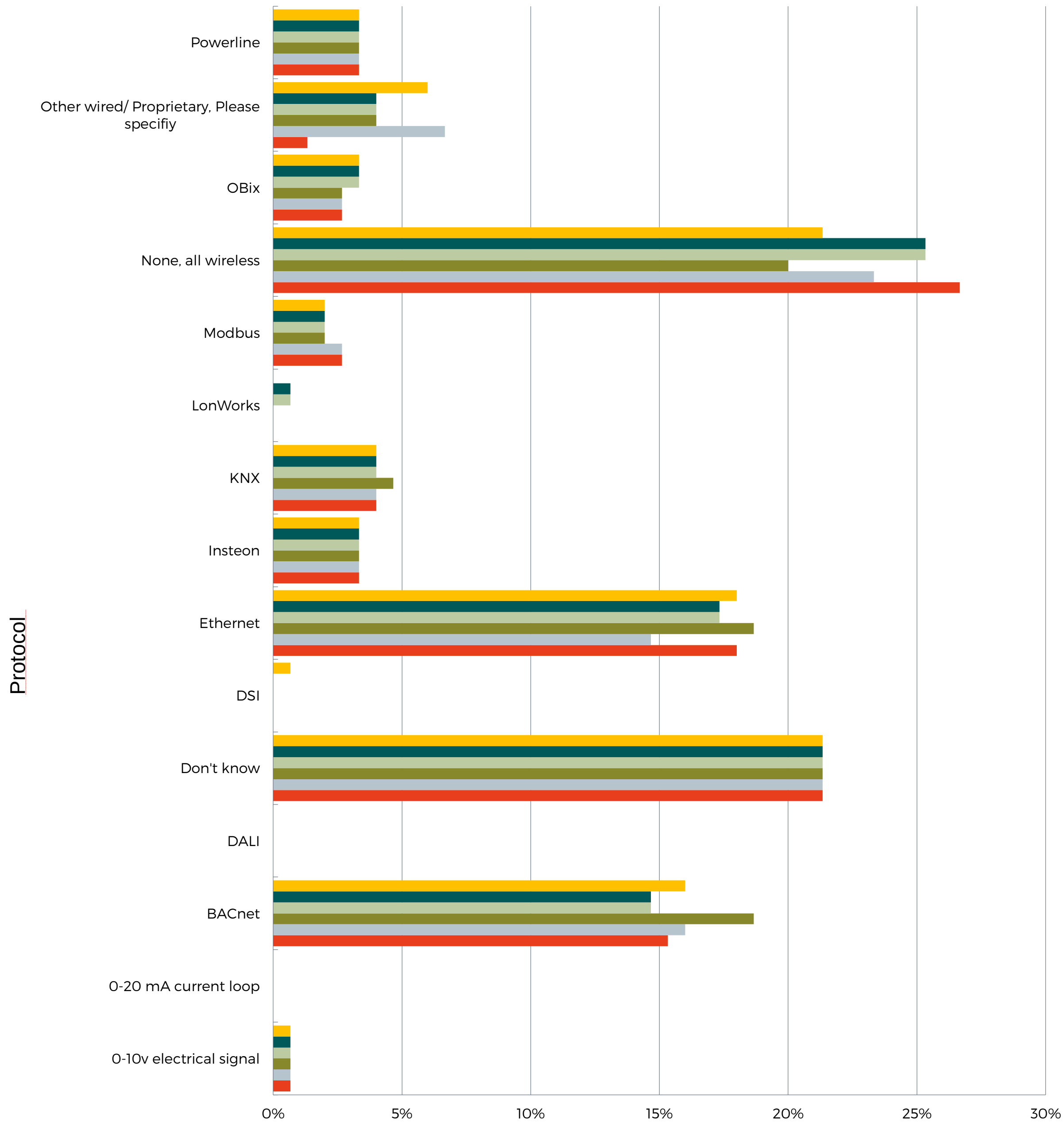
SQ: 5.1 What wired communication protocols are used on your building automation systems? SINGLE CHOICE FOR EACH SYSTEM TYPE

1. Physical security/Access control
2. Energy management
3. HVAC (heating, ventilating, and air conditioning)
4. CCTV
5. Lighting
6. Hazard detection/Environmental health and safety

For each a drop down menu with

1. None, all wireless
2. 0-10v electrical signal
3. -20 mA current loop
4. BACnet
5. KNX
6. LonWorks
7. Modbus
8. DALI
9. Ethernet
10. DSI
11. Insteon
12. OBix
13. Powerline
14. Other wired/Proprietary, Please specify (STRING)
15. Don’t know

Figure 4.29 - Wired Protocols used in Building Systems



	0-10v electrical signal	0-20 mA current loop	BACnet	DALI	Don't know	DSI	Ethernet	Insteon	KNX	LonWorks	Modbus	None, all wireless	OBix	Other wired/ Proprietary, Please specifiy	Powerline
Hazard Detection/ Environment Health	1%	0%	16%	0%	21%	1%	18%	3%	4%	0%	2%	21%	3%	6%	3%
CCTV	1%	0%	15%	0%	21%	0%	17%	3%	4%	1%	2%	25%	3%	4%	3%
CCTV	1%	0%	15%	0%	21%	0%	17%	3%	4%	1%	2%	25%	3%	4%	3%
HVAC	1%	0%	19%	0%	21%	0%	19%	3%	5%	0%	2%	20%	3%	4%	3%
Energy Management	1%	0%	16%	0%	21%	0%	15%	3%	4%	0%	3%	23%	3%	7%	3%
Physical Access Control	1%	0%	15%	0%	21%	0%	18%	3%	4%	0%	3%	27%	3%	1%	3%

All respondents, n=150

Table 4.19 Wired protocols used

Wired Protocol	Physical Access	Energy	HVAC	CCTV	Lighting	Hazardous
All Wireless	27%	23%	20%	25%	18%	21%
0-10v	1%	1%	1%	1%	1%	1%
0-20 mA	0%	0%	0%	0%	0%	0%
BACnet	15%	16%	19%	15%	13%	16%
KNX	4%	4%	5%	4%	4%	4%
LonWorks	0%	0%	0%	1%	0%	0%
Modbus	3%	3%	2%	2%	2%	2%
DALI	0%	0%	0%	0%	1%	0%
Ethernet	18%	15%	19%	17%	15%	18%
DSI	0%	0%	0%	0%	0%	1%
Insteon	3%	3%	3%	3%	3%	3%
OBix	3%	3%	3%	3%	3%	3%
Powerline	3%	3%	3%	3%	3%	3%
Other	1%	7%	4%	4%	16%	6%
Don't Know	21%	21%	21%	21%	21%	21%

All respondents, n=150 Source: IHS Markit

The results show that wide variety of wired solutions were being used by respondents, re-enforcing the view that the solutions used across and within system types is highly varied. Ethernet was the most common wired system in use, followed by BACnet. This was true for all system types with the exception of lighting. For lighting the "Other wired/Proprietary" group was the most selected, followed by Ethernet and BACnet. No other protocols were used by more than 4 percent of respondents across all system types.

It should be noted that most of the respondents that indicated they use "Other wired/Proprietary" when asked to specify indicated they had selected this option as there was limited automation within their buildings and so no communication protocols were used.

Interesting the "None – all wireless" option was selected by a surprisingly high share of respondents, particularly within the Physical security/Access control, Energy management, and CCTV groups.

Wireless communication protocols used in building management systems

The following question was asked to all respondents. The results for each system type are presented in Figure 4.30. The combined results are presented in Table 4.20.

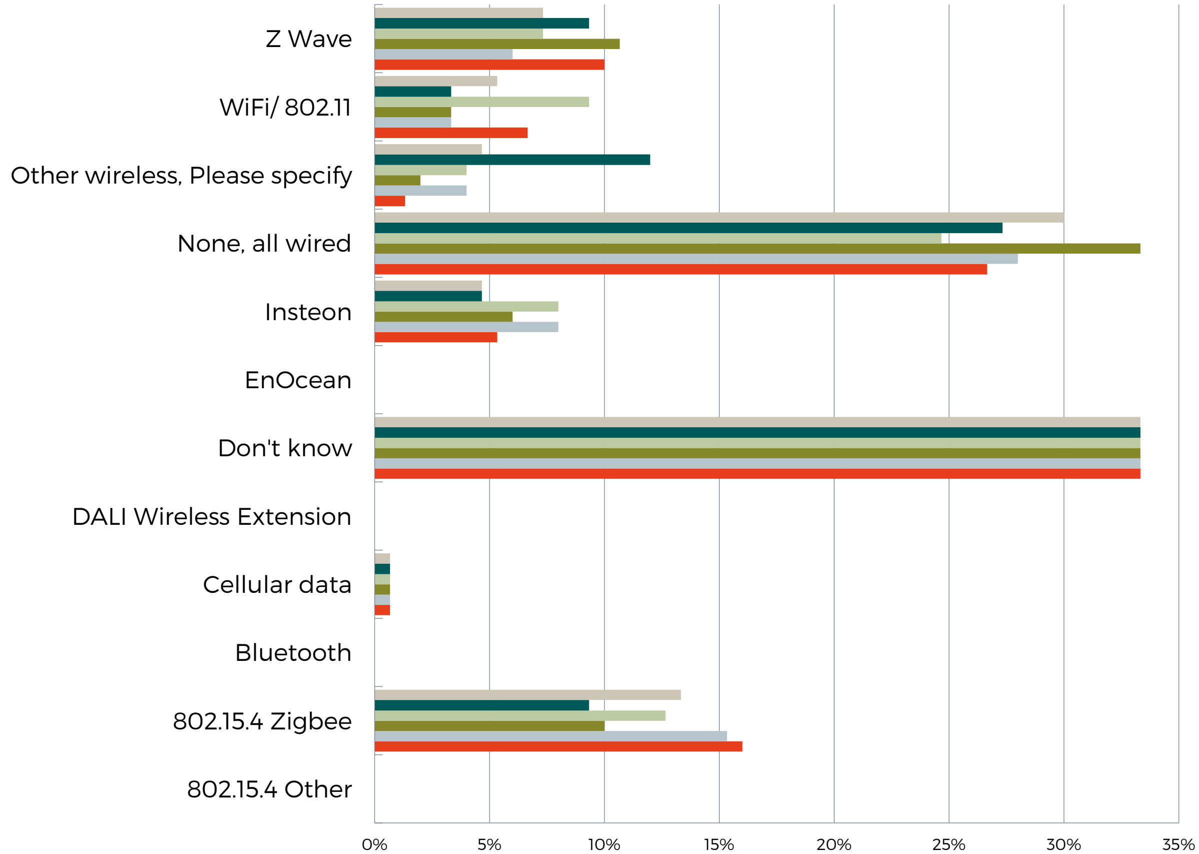
SQ: 5.2 What wireless communication protocols are used on your building automation systems? SINGLE CHOICE FOR EACH SYSTEM TYPE

1. Physical security/Access control
2. Energy management
3. HVAC (heating, ventilating, and air conditioning)
4. CCTV
5. Lighting
6. Hazard detection/Environmental health and safety

For each a drop down menu with

1. None, all wired
2. Bluetooth
3. DALI Wireless Extension
4. EnOcean
5. Insteon
6. 802.15.4 ZigBee
7. 802.15.4 Other
8. Z Wave
9. WiFi/802.11
10. Cellular data
11. Other wireless, Please specify (STRING)
12. Don't know

Figure 4.30 - Wireless Protocols used in Building Systems



	802.15.4 Other	802.15.4 Zigbee	Bluetooth	Cellular data	DALI Wireless Extension	Don't know	EnOcean	Insteon	None, all wired	Other wireless, Please specify	WiFi/ 802.11	Z Wave
Hazard Detection/ Environment Health	0%	13%	0%	1%	0%	33%	0%	5%	30%	5%	5%	7%
Lighting	0%	9%	0%	1%	0%	33%	0%	5%	27%	12%	3%	9%
CCTV	0%	13%	0%	1%	0%	33%	0%	8%	25%	4%	9%	7%
HVAC	0%	10%	0%	1%	0%	33%	0%	6%	33%	2%	3%	11%
Energy Management	0%	15%	0%	1%	0%	33%	0%	8%	28%	4%	3%	6%
Physical Access Control	0%	16%	0%	1%	0%	33%	0%	5%	27%	1%	7%	10%

All respondents, n=150

Table 4.20 Wireless protocols used

Wireless Protocol	Physical Access	Energy	HVAC	CCTV	Lighting	Hazardous
None, all wired	27%	28%	33%	25%	27%	30%
Bluetooth	0%	0%	0%	0%	0%	0%
EnOcean	0%	0%	0%	0%	0%	0%
Insteon	5%	8%	6%	8%	5%	5%
802.15.4 Other	0%	0%	0%	0%	0%	0%
Cellular data	1%	1%	1%	1%	1%	1%
DALI Wireless	0%	1%	1%	0%	0%	1%
WiFi/802.11	7%	3%	3%	9%	3%	5%
Z Wave	10%	6%	11%	7%	9%	7%
Other	1%	4%	2%	4%	12%	5%
802.15.4 ZigBee	16%	15%	10%	13%	9%	13%
Don't Know	33%	33%	33%	33%	33%	33%

All respondents, n=150 Source: IHS Markit

A large proportion of respondents (33 percent across all application areas) indicated they did not know. A large proportion of respondents also indicated they did not use any wireless standards. This varied from a low of 25 percent for CCTV to a high of 33 percent for HVAC. Of those that did specify a wireless solution, ZigBee was the most popular across most application areas. Z-Wave was the only other technology that received a significantly high response.

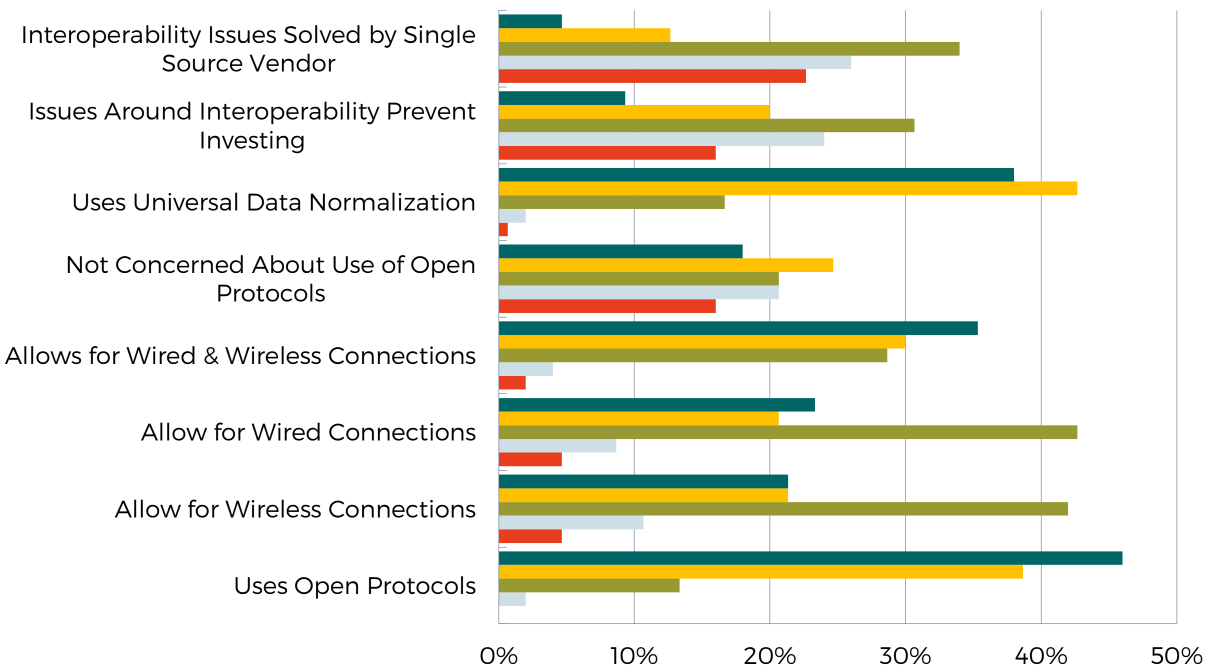
Importance of key interoperability factors

The following question was asked of all respondents. The results for each system type are presented in Figure 4.31. In order to compare results across the different statements a scoring system was used. A score of 5 was given to each response that was ranked as “Strongly agree”, 3 was given for each response of “Agree”, 0 for “Neutral”, -3 for “Disagree” and -5 for “Strongly Disagree”. The combined scores were then normalized so that the highest scoring statement received a score of 10 and the lowest a score of 0. The results to this scoring process are presented in Table 4.21 across the main segments.

SQ: 5.3 Please select how much you agree or disagree with the following statements: (Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree). GRID – ONE ANSWER PER ROW - RANDOMIZE ROW

1. It's important that the building technology systems my company purchases use open communication protocols to allow for greater interoperability.
2. It's important that building technology systems that I purchase allow for sensors, controllers, etc. be connected via (open or proprietary) **wireless** communication protocols.
3. It's important that building technology systems that I purchase allow for sensors, controllers, etc. be connected via (open or proprietary) **wired** communication protocols.
4. It's important that building technology systems that I purchase allow for the sensors, controllers, actuators, etc. to be connected via **both** wired and wireless communication protocols.
5. I'm not concerned about the use of standards and common communication protocols as long as this does not impact the centralized management of building systems.
6. It is important that the building technology system my company purchases uses a universal/standardized data normalization or tagging scheme, such as Haystack.
7. Issues around interoperability are preventing me from investing in innovative intelligent building systems.
8. I buy systems from a single vendor – issues of interoperability are resolved by this vendor of choice.

Figure 4.31 - Importance of Key Interoperability Challenges



	Uses Open Protocols	Allow for Wireless Connections	Allow for Wired Connections	Allows for Wired & Wireless Connections	Not Concerned About Use of Open Protocols	Uses Universal Data Normalization	Issues Around Interoperability Prevent Investing	Interoperability Issues Solved by Single Source Vendor
Strongly Agree	46%	21%	23%	35%	18%	38%	9%	5%
Agree	39%	21%	21%	30%	25%	43%	20%	13%
Neutral	13%	42%	43%	29%	21%	17%	31%	34%
Disagree	2%	11%	9%	4%	21%	2%	24%	26%
Strongly Disagree	0%	5%	5%	2%	16%	1%	16%	23%

All respondents, n=150

Table 4.21 Interoperability views

	Total	Industrial	Non Industrial	Auto High	Auto Med	Auto Low
Open Protocols	10.0	10.0	10.0	10.0	10.0	10.0
Wireless Connections	5.2	5.9	5.1	2.9	6.0	5.4
Wired Connections	5.5	6.6	5.3	4.8	5.7	5.9
Wired & Wireless Connections	8.0	9.4	7.6	8.5	7.4	9.2
Not Concerned About Open Protocols	3.2	0.9	3.9	2.7	3.4	3.4
Universal Data Normalization (e.g. Haystack)	9.3	8.4	9.6	9.4	9.5	8.9
Preventing Me From Investing	1.8	0.0	2.4	0.3	2.8	0.2
Solved by My Single Source Vendor	0.0	0.5	0.0	0.0	0.0	0.0

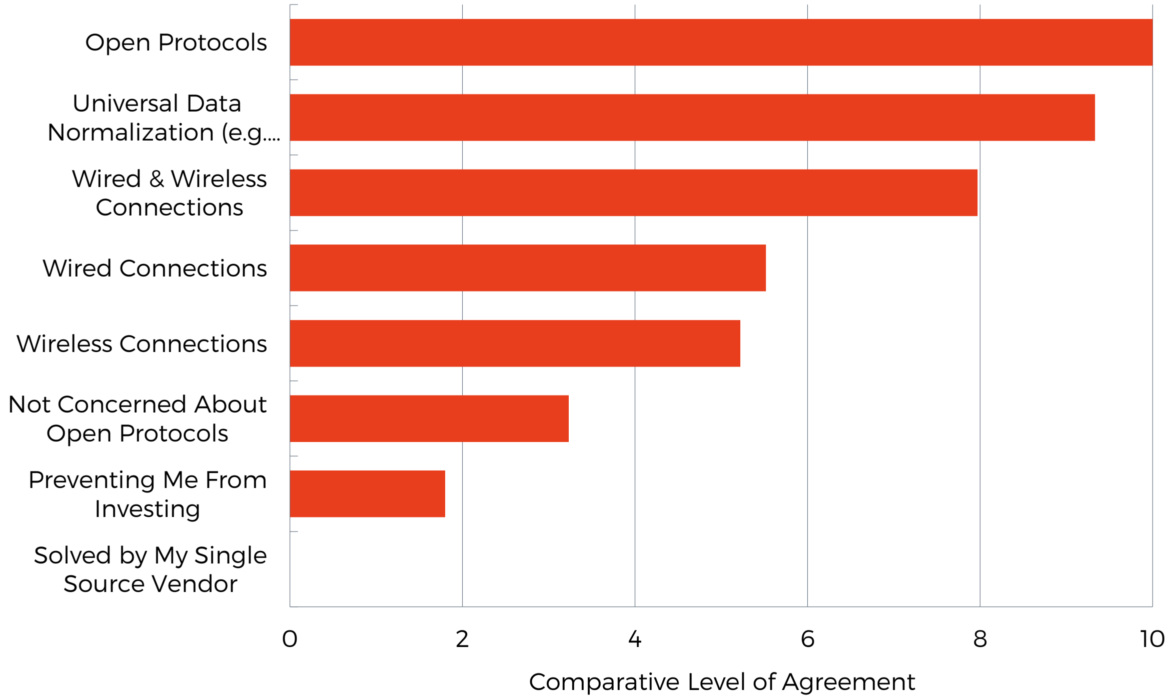
All respondents, n=150 Source: IHS Markit

The table shows that, for the whole sample, the following three statements received the highest "level of agreement":

- It's important that the building technology systems my company purchases use open communication protocols to allow for greater interoperability.
- It's important that building technology systems that I purchase allow the sensors, controllers, actuators, etc. to be connected via **both** wired and wireless communication protocols.
- It is important that the building technology system my company purchases uses a universal/standardized data normalization or tagging scheme, such as Haystack.
- For all segments, these statements were ranked 1, 2 or 3 in terms of the scoring system; and for all there was then a marked drop off in score to the next ranked statement. The two statements that received a markedly lower score than the others were:
- Issues around interoperability are preventing me from investing in innovative intelligent building systems.
- I buy systems from a single vendor – issues of interoperability are resolved by this vendor of choice.

The results tend to indicate that interoperability and the wide range of connectivity solutions offered by the market are a significant issue and one that the sample was keen was solved. However, the fact that less than 20 percent of respondents agreed with the statement that "Issues around interoperability are preventing me from investing in innovative intelligent building systems" indicates that in general it is not stopping investment. Figure 4.32 then goes on to explore the results for the overall sample size. There were no major variations by segment.

Figure 4.32 - Overall View on Interoperabilty Issues - Total Sample



All respondents, n=150

4.6 BUSINESS PROCESSES

Another key theme explored in this study related to view on how business processes would change owing to the impact of IoT in intelligent buildings. The following question was used to support the exploration of issues around this theme. The theme, along with the IHS conclusions, is presented in fully in section 2.5.

Key areas of support when implementing new IoT-based systems

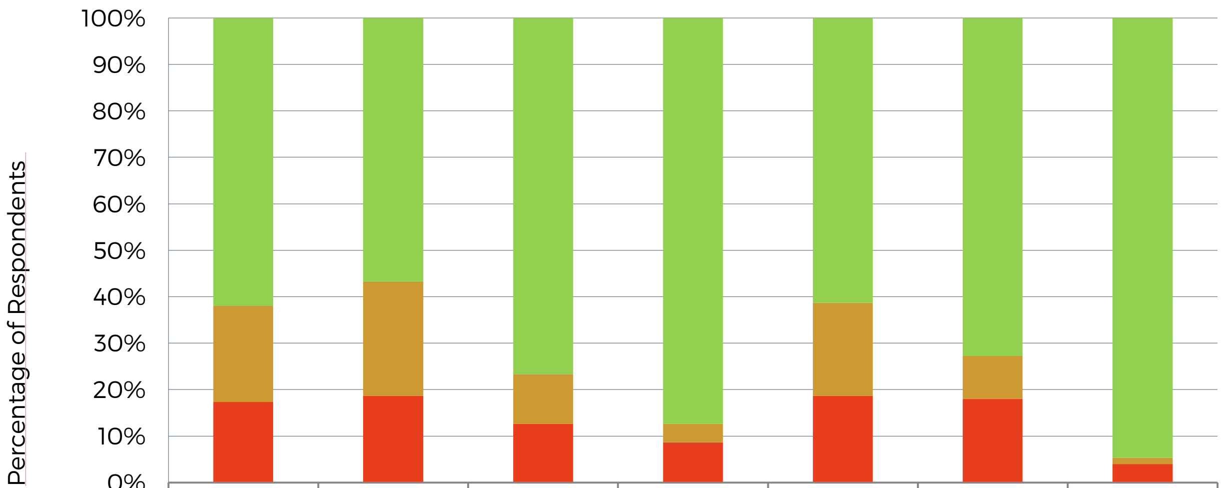
The results for each system type are presented in Figure 4.33 and combined results in Table 4.22 through a scoring system. Each time one of the nine areas was ranked one, a score of 5 was given, a score of 3 was given for each ranking of two. The overall scores where then re-based so the highest scoring advantage was given a score of 10, the lowest a score of 0.

SQ: 6.1 Providing the technology and solutions is the first step to realizing the value of more intelligent buildings, but an equally challenging factor is adapting business processes to take advantage of more intelligent/smart systems. Please indicate the top three areas for support that you would require in this transition: RANK TOP TWO 1 and 2

1. Educating/Training the work force located at the building in how to use and maintain new intelligent building systems
2. Educating/Training facility management teams in how to use and maintain new intelligent building systems
3. Educating/Training IT teams in how to use & maintain new intelligent building systems
4. Educating/Training IT teams in how to implement new intelligent building systems
5. Re-engineering processes to take advantage of savings from intelligent buildings
6. System integration

7. Educating management/budget holders in relation to value proposition
8. Support with internal policy/legal teams in relation to adapting data sharing policies
9. Finding outside support to keep up with changing technology (i.e., software) for intelligent systems.

Figure 4.33 - Ranking - Key areas of support when implementing new IoT-based systems



	Educate/ Train Work Force On Use & Maintain New Systems	Educate/ Train Facility Management On Use & Maintain New Systems	Educate/ Train IT Teams On Use & Maintain New Systems	Educate/ Train IT Teams On How to Implement New Systems	Re-Engineer Processes to Take Advantage of Savings From Intelligent Buildings	System Integration	Educating Management/ Budget Holders On Value Proposition
Not Ranked	62%	57%	77%	87%	61%	73%	95%
Ranked 2	21%	25%	11%	4%	20%	9%	1%
Ranked 1	17%	19%	13%	9%	19%	18%	4%

All respondents, n=150

The results show that three areas received significantly higher scores amongst respondents:

- Educating/Training the work force located at the building in how to use and maintain new intelligent building systems
- Re-engineering processes to take advantage of savings from intelligent buildings
- Educating/Training facility management teams in how to use and maintain new intelligent building systems

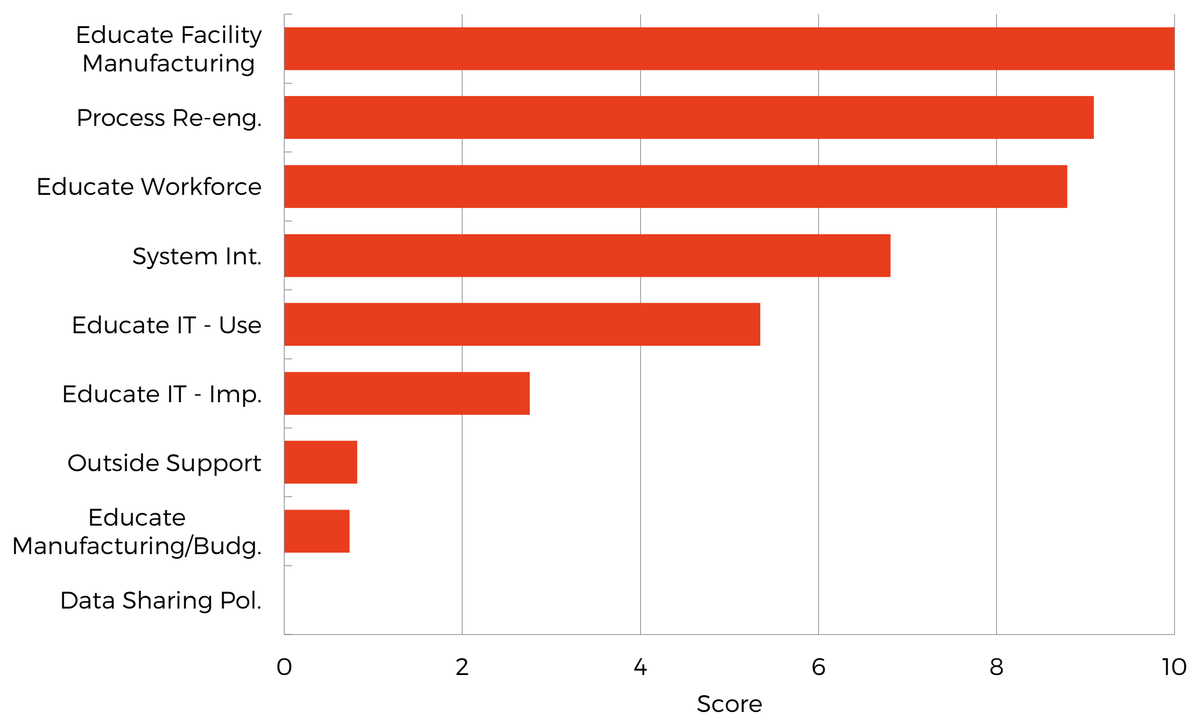
One notable difference was that ‘Re-engineering processes’ was ranked much higher by the industrial segment than by the non-industrial segment; as was ‘System integration’, although to a lesser extent.

Table 4.22 Key areas of support when implementing new IoT-based systems

	Total	Industrial	Non Industrial	Auto High	Auto Med	Auto Low
Educate Workforce	8.8	9.1	8.7	10.0	7.1	7.7
Educate Facility Manufacturing	10.0	10.0	10.0	5.6	10.0	10.0
Educate IT - Use	5.3	4.6	5.5	1.8	6.9	4.0
Educate IT - Imp.	2.8	4.3	2.4	3.0	3.1	1.7
Process Re-eng.	9.1	8.7	9.2	8.2	7.8	8.8
System Int.	6.8	6.7	6.8	9.7	6.6	2.7
Educate Manufacturing/Budg.	0.7	1.5	0.5	0.0	1.0	1.3
Data Sharing Pol.	0.0	0.0	0.0	1.0	0.0	0.0
Outside Support	0.8	1.3	0.7	1.5	0.9	0.5

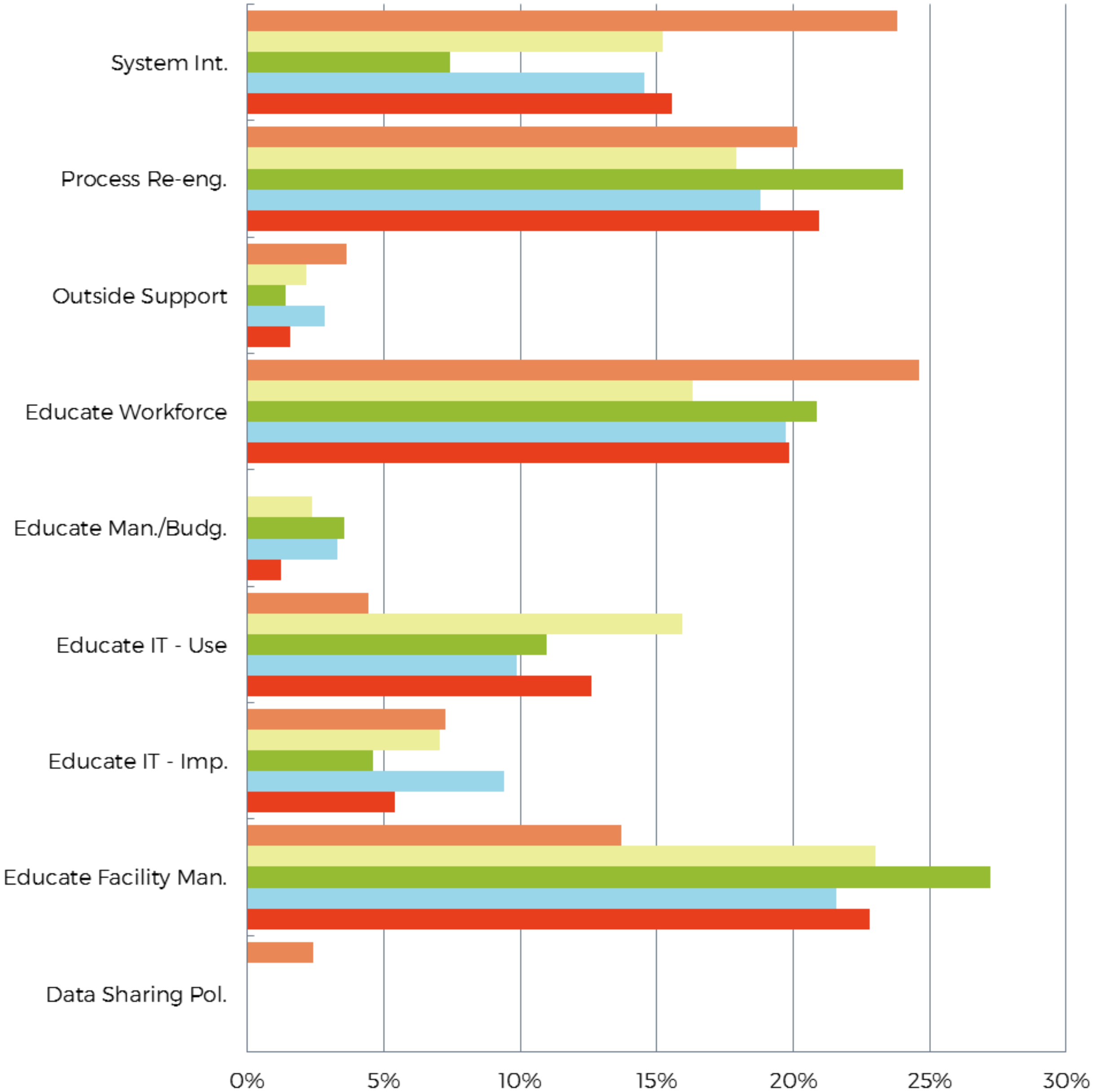
All respondents, n=150 Source: IHS Markit

Figure 4.34 - Overall View on Business Processes - Total Sample



All respondents, n=150

Figure 4.35 - Overall View on Business Processes - Respondent Type



	Data Sharing Pol.	Educate Facility Man.	Educate IT Imp.	Educate IT Use	Educate Man./Budg.	Educate Workforce	Outside Support	Process Re eng.	System Int.
High	2%	14%	7%	4%	0%	25%	4%	20%	24%
Medium	0%	23%	7%	16%	2%	16%	2%	18%	15%
Low	0%	27%	5%	11%	4%	21%	1%	24%	7%
Industrial	0%	22%	9%	10%	3%	20%	3%	19%	15%
Non Industrial	0%	23%	5%	13%	1%	20%	2%	21%	16%

Source: IHS-Markit
Sample Frame: -Non-industrial respondents, Sample Size: 120
-Industrial respondents, Sample Size: 30
-Low Automation respondents, Sample Size: 41
-Medium Automation respondents, Sample Size: 78,
-High Automation respondents, Sample Size: 31

APPENDIX A

RESEARCH SURVEY AND INTERVIEW QUESTIONS

INTRODUCTION

Two main primary research processes were used for this report: extensive interviews with industry participants (ecosystem interviews) and an on-line decision-maker survey of businesses in Canada and the United States. A series of detailed ecosystem interviews were conducted by telephone with key decision-makers at a number of different types of organizations, including building supply-side solution providers, service providers, enterprises, and the supply side of the building automation industry. IHS Markit, in conjunction with the CABA project Steering Committee members, developed an on-line decision-maker survey to assess attitudes towards intelligent buildings and the impact of IoT. The survey targeted 150 building, facility & IT managers and owners/operators from a broad sample of building sizes, types, and geographies in both the United States and Canada.

1. THE DISCUSSION GUIDE

The following topics in its ecosystem industry interviews were planned. It is intended that:
- 20-30 percent will be leading building supply side solution providers.
- 20-30 percent will be from large North American facility management service providers and large owners.
- 20-30 percent will be from companies specializing in IoT solutions for enterprises and industry, 50 percent from established suppliers, 50 percent from disruptors.
- 20-30 percent will be from other players on the supply side of the building automation industry, such as system integrators, connectivity solution providers, etc.

The discussion guide first covers some general questions, it then dives into the five key themes:
1. Realizing Value of IoT
2. Data Security & Storage
3. Ecosystems
4. Standardization
5. Business Processes

The specific questions to be asked to ecosystem suppliers are presented over the following pages. It's assumed that each ecosystem discussion will be roughly one hour long. The questions are a guide with the actual interviews intended to be a more natural discussion.

PART 1 – INTRODUCTION & CROSS CUTTING TRENDS

1. How would you describe your company relating to the building automation/intelligent building market?
2. Please provide me with an overview of the products, solutions or services that you offer to the intelligent building market?
3. What building automation/IoT applications/use-cases do you currently have solutions for?
4. What facilities problems are these trying to solve?

PART 2 - REALIZING THE VALUE OF IOT

1. Can you summarize to me how you think IoT will bring value to the commercial building market?
2. When you think of building automation, what solution types do you have in mind (don't prompt if required – physical security, energy management, HVAC, Video/CCTV, lighting, hazard detection, environmental health and safety)?
3. What systems that are currently disparate in terms of building automation do you think can be brought together using IoT?
4. How will this occur and how will IoT be used to achieve this?
5. Do you offer specific IoT platforms for building automation solutions?
6. Do you work with partners or 3rd parties in relation to IoT platform provisioning?
7. What functionality is built into these platforms (connectivity management, device management, application enablement, data management, cloud/data center platforms, etc.)? Does you solution vary by vertical/size/new/retro?
8. What sort of solutions will be put in place to analyze and control building automation systems for IoT?
9. Will there be centralized management of these solutions? If so which company types/companies do you see best placed to be the suppliers of these solutions?
10. For systems where management occurs with decentralized control, how can IoT be used to improve building management?
11. What device types will be used to interface with intelligent building solutions? Will this vary by application, building size, industry vertical?
    a. What part will the mobile handset play?
    b. Will one solution control all facets or will multiple interfaces be required?
12. How can the industry convince facility managers/services providers/IT managers of the benefits of IoT in relation to building automation? What are the key business cases? Gamification?
13. Do you think the industry has performed well in terms of this educational/business case process? What else can be done? Who should lead this? Which verticals have been the most responsive?
14. Can you provide me your vision of how predictive analytics and adaptive automation will be used in the future to make buildings more efficient?
    a. How will analytics be used for building IoT? How often does data need to be shared?
    b. What efficiencies will be gained from analytics?
    c. Are processes being re-engineered to take advantage of this?
    d. Who is providing good analytics solutions for building IoT
    e. Can you give examples of any case studies where analytics have been used successfully?
15. What would you say are the key elements in building a business case for IoT deployment in an intelligent building setting?

PART 3 - DATA SECURITY & STORAGE

3a - Privacy & Security

1. For solutions that you currently offer that use IoT in relation to building automation, how are security issues addressed?
2. Do you believe security to be a major industry concern & barrier to adoption?
3. What measures do you take to ensure security? What other measures are taken in the industry (advantages/disadvantages)?
4. What are the key privacy concerns you see in relation to IoT's use in building automation? Where does data sovereignty/data ownership fit in?
5. Do you think privacy is a key barrier to adoption?
6. How do issues around privacy and security vary by the type of building automation application in question - physical security, energy management, HVAC, Video/CCTV, lighting, hazard detection?
7. How will this vary by company size, vertical and new versus retro build?

3b. Storage, Cloud Services & Network

1. How will IoT impact the data storage solutions in relation to building automation? Will more building automation data be stored in the cloud rather than on site?
2. Do you think it will change wider practices within enterprises and other building users in terms of data storage? Why?
3. What protocol(s) do you think are optimal for device to cloud communication? Does your IoT platform allow for cloud to cloud integration of building automation data? Do you see a value in enabling this?
4. What sort of data will need to be available for remote access? How will this be enabled/provisioned?
5. What types of edge/fog processing/computing solutions will you offer/will you require in order to manage data flows between local and remote/cloud storage solutions? Are you planning on using an open standard to normalize data from disparate edge subsystems?
6. For cloud-based storage solutions (both application and data), what are the issues in relation to data sovereignty?
7. How will this vary by application, company size, vertical and new versus retro build?

PART 4 – STANDARDS AND STANDARDIZATION

1. Are you part of any particular standardization bodies either specific to IoT or building automation?
2. What is the function of these bodies?
3. To what extent do you think standardization in relation to IoT will impact its uptake in building automation?
4. To what extent is interoperability hampering the market's development?
5. Does the fact that building automation uses largely proprietary solutions for connectivity such as BACnet, EnOcean, KNX, LonWorks, Modbus, 0-10v analogue electrical signal, etc. impact this?
6. What impact will wireless have?
7. What role do standards around middleware platforms, open architectures, APIs, ontology, etc., have in creating an open ecosystem?
8. Do you actively promote interoperability? Why/why not?
9. What can players in the industry ecosystem do to aid address issues around standardization and interoperability?
10. How will this vary by application, company size, vertical and new versus retro build?
11. Do you have a vision for the technical architecture of solutions provided in relation to IoT in intelligent buildings? For example what would an architecture look like to encompass:
    a. IoT sensors & Controllers -> Protocols / gateways
    b. Middleware -> enterprise level

c. Data acquisition & Storage (Cloud base Hosting / On premises, platform, SQL / No SQL / CSV, semantic / ontology
d. Data Analytic (including the various platforms required)
e. Visualization / User interface (report / PC/ Smart devices etc.)

PART 5 – IOT ECOSYSTEM

1. Who do you see as the top 5 players in your industry?
2. To what extent do you envisage the use of IoT will disrupt this?
3. Are there emerging IoT specialists/IT solution providers that are entering your market as a result of the introduction of IoT?
4. What do you see as their key strengths?
5. Will you be partnering with new company types/solution providers in order to address the opportunity offered by IoT?
6. Will IoT impact the channels to market used by building automation customers? Why/How?
7. How will this vary by application, company size, vertical and new versus retro build?
8. What will be the business models for the different supplier types in the ecosystem?

PART 6 – BUSINESS PROCESSES

1. How will your customers' business processes need to be changed in order to fully take advantage of IoT?
2. How will this vary by application, company size, vertical and new versus retro build?
3. Will the role of facilities management and IT management change as IoT becomes increasingly important? How?
4. How will the supply side of the building automation industry aid customers in terms of demands relating to training, reorganization, business process re-engineering that IoT may bring?

PART 7 – APPLICATION DEEP DIVE

Can you give an overview of how you see IoT impacting the following application areas?

- Access control & entrance control
- Physical security/Building monitoring for security
- Lighting – Control Panels, Central controllers, Connected Ballasts/Wireless adapters, Connected Switches, Environ/Light level sensors, occupancy sensors, RF luminaires, keypads/HMI screens
- Metering/Energy Consumption/Renewables/Demand response
- CCTV
- Digital Signage
- Fire & Life Safety
- General building automation equipment – sensors, controllers, software, actuators, gateways, HMI screens

AP1.2 THE RESEARCH SURVEY

A web-based survey was executed to assess, validate and rank the value of Intelligent Building-IoT concepts and hypothesis in this research. The survey targeted 150 building, facility & IT managers from a broad sample of building sizes, types, and geographies in both the United States and Canada. The aim of this survey was to understand decision-maker views on the impact of a range of IoT topics on intelligent buildings. These topics ranged from real-time monitoring and control of building systems to the role of data analytics in building management. The topics were to be framed within the context of the five main themes outlined by the project steering committee.

The survey consisted of 20 questions, with one being open-response, and the balance being closed-response was intended to require 15-20 minutes to complete. For these >150 responses it was agreed that:

- An artificial skew would be created in the sample in order that approximately 33 percent of responses were from Canada, allowing for greater statistical analysis of the results by country than a purely population driven-sample frame would give.
- As well as traditional building/facilities managers, the survey also targeted responses from IT managers in enterprises/buildings and building owners to reflect the convergence trends. 25 percent of responses were proposed to be from IT managers, 25 percent from building owners.
- The remainder of the survey targeted a representative sample by vertical industry, facility size in Canada and the United States.

2. THE SURVEY INSTRUMENT - SCREENER QUESTIONS

SQ.1 Please describe your job function:

1. Building owner/landlord
2. Building operator
3. IT Manager
4. Facilities Manager
5. Other – End Survey

SQ.1 Do you have purchasing decision making or recommendation authority for any of the following system types/services: Physical Security/Access Control, Energy Management, HVAC (heating, ventilating, and air conditioning), CCTV, Lighting, Hazard Detection/Environmental Health & Safety, building management platforms?

1. Yes
2. No – End Survey

SQ.3 Please indicate which of the following verticals best describes how the buildings you have authority over area used (PLEASE TICK ONE, IF VARIOUS ASK TO PICK THE DOMINANT USE CASE):

1. Education
2. Government
3. Healthcare
4. Industrial / Manufacturing
5. Office
6. Retail
7. Transport
8. Warehouse / Storage
9. Leisure and Hospitality
10. Other, please specify……..

SQ.4 Which country are you located in?

1. USA
2. Canada

SECTION ONE – DEMOGRAPHICS AND PROFILING

1.1 What is the overall size of the building stock for which you have purchasing influence & over how many buildings? SELECT ONE ONLY + NUMBER FOR NUMBER OF BUILDINGS

1. <50,000 square feet
2. 50,001 – 200,000 square feet
3. 200,001 – 500,000 square feet
4. >500,000-2,000,000 square feet
5. >2,000,000 square feet

Over _____ buildings, across _____ site(s)/location(s)

1.2 For the following building functions please select the most appropriate statement to describe how their operation is controlled/automated – PLEASE SELECT ONE DESCRIPTION FOR EACH FUNCTION

1. Physical Security/Access Control
2. Energy Management
3. HVAC (heating, ventilating, and air conditioning)
4. CCTV
5. Lighting
6. Hazard Detection/Environmental Health & Safety

For each the following drop downs –

- No automation – e.g., individual devices are managed manually and with no centralized control (at the individual building level) or use of networked sensors
- Some automation – e.g., centralized (at the individual building level) but largely manual control of system
- Medium level of automation – e.g., centralized in-house control of system, at the individual building level, with networked sensors to automatically manage **some** system functions
- High level of automation – e.g., centralized in-house control of system, at the individual building level, with networked sensors to automatically manage **most** system functions & providing detailed performance analytics
- Fully automated – Off- and on-site centralized control (across all buildings at campus/site) of system with networked sensors to automatically manage **most** system functions & providing detailed performance analytics

1.3 Routing – for those that answer 3-5 for more than one system in 1.2

Are any two or more functions managed within the same system or does each operate as a standalone entity? Please tick as appropriate:

- No – All are separate systems
- Yes -Combination 1 - Physical Security - Energy Management – HVAC – CCTV – Lighting - Hazard Detection/Environmental Health & Safety – HR Systems – Facility Management Planning Systems (e.g., meeting room booking) – Audio/Visual Equipment
- Yes - Combination 2 - Physical Security - Energy Management – HVAC – CCTV – Lighting - Hazard Detection/Environmental Health & Safety - HR Systems – Facility Management Planning Systems (e.g. meeting room booking) – Audio/Visual Equipment

SECTION TWO – THE VALUE OF IOT

2.1 IoT in Commercial Building management can provide a number of advantages. Please rank the three that are the most attractive to you/your organization (Rank 1, 2, 3, leave others blank)

1. Reduce energy consumption & spend
2. Improve operational efficiency by streamlining/integrating building systems
3. Enable predictive maintenance to improve system lifecycle/reliability
4. Improve financial planning (CAPEX and OPEX)
5. Provide remote access to building systems
6. Future proof technology investment
7. Increased use of sensors to allow for greater occupancy-based automation
8. Move facility management systems to open standards
9. Offer more data/information on building performance
10. Improve occupant comfort
11. Improve occupant safety
12. Improve tenant/employee productivity
13. Increase building resiliency via energy generation & storage

2.2 If you were to purchase an IoT/Cloud-based energy management system to reduce energy consumption or improve operational efficiencies, how long would you expect it to take before you see a complete return on this investment? SINGLE CHOICE

1. I am not concerned with the pay-back period on my devices
2. Under 1 year
3. 1 - 2 years
4. >2 – 3 years
5. >3 - 5 years
6. >5 - 10 years
7. Over 10 years

2.3 How much would you value each of the following applications? GRID QUESTION: Single Choice per row, Column (score):

1. Extremely valuable
2. Valuable
3. Little value
4. Not of value

RANDOMIZE ROW (2.3.1 to 2.3.12)

1. View energy consumption data for your building, such as on-going energy consumption of equipment or assets
2. Control building systems remotely
3. Monitor building systems remotely
4. Receive a notification if any building systems are operating outside normal parameters
5. Receive advanced notification if a device is on the verge of failure (or requires urgent attention)
6. Receive & monitor information on building occupancy from off-site remote locations
7. Use of advanced algorithms to recommend location based set points based on usage and occupancy
8. Control outdoor devices from remote off-site locations, such as electrics gates, bollards, external lighting, fountains, etc.
9. Provide building occupants with greater control of systems (e.g., via location based mobile apps)
10. Integration with weather systems for historical comparisons as well as future energy & maintenance forecasting
11. Ability to create rules / algorithms based on the needs of your building

2.4 For each building management function, what are the top two devices types you'd prefer to use to manage and control the system?

1. Physical Security/Access Control
2. Energy Management
3. HVAC (heating, ventilating, and air conditioning)
4. CCTV
5. Lighting
6. Hazard Detection/Environmental Health & Safety

For each the following drop downs –

- A simple dedicated device, e.g., a thermostat for energy management, a room HVAC control panel, a light switch.
- A sophisticated dedicated device, e.g., centralized lighting control panel, centralized HVAC control panel, centralized access control panel
- An on-site PC/laptop/Workstation
- An off-site PC/laptop/Workstation
- A smart phone that can be used from any location
- A tablet PC that can be used from any location
- Other, please specify (STRING)

2.5 How valuable would it be if all of the different functions related to building management could be controlled from a single app or program on your smartphone, PC, tablet or other device? SINGLE CHOICE

1. Very valuable – I would only choose a system which allows me to use a single app or program
2. Moderately valuable – I would prefer a single app or program
3. Neutral – I am happy with either
4. Not of value – I would prefer separate apps or programs

2.6 Intelligent building solutions allow device manufacturers to use analytics and real-time information from the systems to pre-empt expensive repair or maintenance issues, and recommend when a device needs to be serviced or repaired in order to ensure the device continues to run effectively. How valuable would this be to you? SINGLE CHOICE

1. Very valuable
2. Moderately valuable
3. Neutral
4. Not of value

2.7 Mobile apps can be developed for general building users/occupants to interface with the building management systems. Which of the following smartphone based app functions would you like to provide to your building users in order that they can interface with building management systems? Please tick all that apply

1. Physical access control to building
2. Guest sign in
3. Control of local HVAC systems
4. Meeting room booking
5. Control of local lighting systems
6. In building navigation
7. Control of A/V equipment
8. Other, please specify (STRING)

2.8 Can you provide details of any new innovative building management functions that you would find useful that low cost sensing, occupancy data and connectivity could provide?

1. Open response – (STRING)

SECTION THREE – SUPPLIER ECOSYSTEM

3.1 Please detail the manufacturer used for each of the following systems & the channel through which you made the purchase. If you do not know, please state 'Do not know'. If you used more than one for different locations, please specify the one used to the greatest extent.

1. Physical Security/Access Control
2. Energy Management
3. HVAC (heating, ventilating, and air conditioning)
4. CCTV
5. Lighting
6. Hazard Detection/Environmental Health & Safety
7. Audio/Visual Equipment
8. Cross system building management platform

   Text string plus below drop down for each –

   1. The system manufacturer
   2. An electrical contractor
   3. A mechanical contractor
   4. A local system integrator

5. A multi-national system integrator
6. My utility company
7. An IT solution provider
8. An office supplies distributer
9. A specialist distributor/manufacturer rep
10. Other, Please Specify (STRING)
11. Do not know

3.2 Please select the top 3 criteria when making a vendor selection (RANK 1 to 3, where 1 is the most important)

1. Product quality
2. Quality/Breadth of service maintenance contract/plans
3. Price competitiveness
4. Broad portfolio
5. Innovation
6. Interoperability of products with other suppliers
7. Historic relationships

SECTION FOUR – DATA SECURITY/STORAGE

4.1 Part a: With respect to building management data (e.g. data relating to energy consumption, lighting, occupancy, security, CCTV, etc.), please select the most appropriate statement from below that reflects your company's policy on data storage – SINGLE CHOICE

1. All data has to be stored only on on-premises servers/on-premises data centers/on-premises private cloud.
2. Data can be stored off-premises but it has to be stored on company owned equipment (e.g. stored on a co-located/multi-tenant data center but utilizing company owned servers/storage)
3. Certain data from the above list can be stored on 3rd party operated cloud systems/data centers, but certain data types have to remain on-premises.
4. All data from the above list can be stored on 3rd party operated cloud system/data centers, provided that it is stored within the borders of the country
5. All data from the above list can be stored on 3rd party operated cloud systems/data centers

Part b: ROUTING – Only those that selected option 3, 4 & 5 in 4.1 to answer – With respect to cloud services you can use, please indicate the statement from the below that most reflects your company's policy on building management data storage. SINGLE CHOICE

1. Off-premises third- party operated cloud services have to use private clouds – i.e. services delivered using non-shared infrastructure.
2. Off-premises third-party operated cloud services can use both private and public clouds – public cloud services being delivered via shared infrastructure

4.2 ROUTING – Only those that selected option 3 in 4.1 to answer – Please tick all data types that CANNOT be stored on third-party operated cloud systems/data centers – TICK ALL THAT APPLY

1. Physical Security/Access Control Data
2. Energy Management Data
3. HVAC (heating, ventilating, and air conditioning) Data
4. CCTV Data
5. Lighting Data
6. Hazard Detection/Environmental Health & Safety Data
7. Occupancy Sensing Data
8. A/V Data
9. Other, please specify

4.3 ROUTING – Only those that selected option 1, 2, 3 & 4 in 4.1a to answer, or those that answered option 1 in 4.1 part b

What do you believe is the greatest barrier to your data/more of your data being stored using third-party cloud services? SINGLE CHOICE

1. Internal concerns relating to data security
2. Internal concerns relating to data privacy
3. Regional regulations/legislation relating to data storage
4. Internal concerns relating to data ownership
5. Regional regulations/legislation relating to sovereignty
6. Internal concerns relating to data sovereignty
7. Other, please specify

SECTION FIVE – STANDARDIZATION

5.1 What wired communication protocols are used on your building automation systems? SINGLE CHOICE FOR EACH SYSTEM TYPE

1. Physical Security/Access Control
2. Energy Management
3. HVAC (heating, ventilating, and air conditioning)
4. CCTV
5. Lighting
6. Hazard Detection/Environmental Health & Safety

   For each a drop down menu with

   1. None, all wireless
   2. 0-10v electrical signal
   3. -20 mA current loop
   4. BACnet
   5. KNX
   6. LonWorks
   7. Modbus
   8. DALI
   9. Ethernet
   10. DSI
   11. Insteon
   12. OBix
   13. Powerline
   14. Other wired/Proprietary, Please specify (STRING)
   15. Don’t know

5.2 What wireless communication protocols are used on your building automation systems? SINGLE CHOICE FOR EACH SYSTEM TYPE

1. Physical Security/Access Control
2. Energy Management
3. HVAC (heating, ventilating, and air conditioning)
4. CCTV
5. Lighting
6. Hazard Detection/Environmental Health & Safety

   For each a drop down menu with

   1. None, all wired
   2. Bluetooth
   3. DALI Wireless Extension
   4. EnOcean

5. Insteon
6. 802.15.4 ZigBee
7. 802.15.4 Other
8. Z Wave
9. WiFi/802.11
10. Cellular data
11. Other wireless, Please specify (STRING)
12. Don't know

5.3 Please select how much you agree or disagree with the following statements: (Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree). GRID – ONE ANSWER PER ROW - RANDOMIZE ROW

1. It's important that the building technology systems my company purchases use open communication protocols to allow for greater interoperability.
2. It's important that building technology systems that I purchase allow for sensors, controllers, etc., be connected via (open or proprietary) wireless communication protocols
3. It's important that building technology systems that I purchase allow for sensors, controllers, etc. be connected via (open or proprietary) wired communication protocols.
4. It's important that building technology systems that I purchase allow for the sensors, controllers, actuators, etc., to be connected via both wired and wireless communication protocols.
5. I'm not concerned about the use of standards and common communication protocols as long as this does not impact the centralized management of building systems.
6. It is important that the building technology system my company purchases uses a universal/standardized data normalization or tagging scheme, such as Haystack.
7. Issues around interoperability are preventing me from investing in innovative intelligent building systems.
8. I buy systems from a single vendor – issues of interoperability are resolved by this vendor of choice.

SECTION SIX – BUSINESS PROCESSES

6.1 Providing the technology and solutions is the first step to realising the value of more intelligent buildings, but an equally challenging factor is adapting business processes to take advantage of more intelligent/smart systems. Please indicate the top three areas for support that you would require in this transition: RANK TOP TWO 1 and 2

1. Educating/Training the work force located at the building in how to use & maintain new intelligent building systems
2. Educating/Training facility management teams in how to use & maintain new intelligent building systems
3. Educating/Training IT teams in how to use & maintain new intelligent building systems
4. Educating/Training IT teams in how to implement new intelligent building systems
5. Re-engineering processes to take advantage of savings from intelligent buildings
6. System integration
7. Educating management/budget holders in relation to value proposition
8. Support with internal policy/legal teams in relation to adapting data sharing policies
9. Finding outside support to keep up with changing technology (ex. software) for intelligent systems

APPENDIX B

GLOSSARY OF TERMS

1080i – (1080 interlaced) A video display resolution which represents vertical frames of 1080 lines. 1080i resolution is regarded as true HD television. As of 2007, 1080i was the highest pixel resolution that can be broadcast via satellite, cable, IPTV, or DTT.

1080p – (1080 progressive scan) a video display resolution which represent 1080 vertical scanning lines. 1080p offers sharper images and the highest pixel resolution for HD television. As of 2007, 1080p resolution could only be viewed from a blue-laser optical disc such as Blu-ray Disc or HD DVD. As of 2007, TV operators were not yet able to broadcast 1080p signals over satellite, cable, IPTV, or DTT.

3G – (Third generation) A term used by telecommunications companies to market wireless mobile internet services. IMT-2000 technical standards require these systems to provide peak data rates of at least 200kbit/s.

4G – (Fourth generation) A term used by telecommunications companies to market high speed wireless mobile internet services. IMT-Advanced technical standards require these systems to provide peak data rates of at least 100Mbit/s.

6LOWPAN – (IPv6 over Low power Wireless Personal Area Networks)

802.11 – (IEEE 802.11) A set of media access control (MAC) and physical layer (PHY) specifications for implementing wireless local area network (WLAN) computer communication in the 2.4, 3.6, 5, and 60 GHz frequency bands. They are created and maintained by the IEEE LAN/MAN Standards Committee (IEEE 802).

ACaaS – Access control as a service.

ADSL (**Asymmetric Digital Subscriber Line)** – A method whereby compressed digital video and audio signals are sent over standard telephone lines using a special modem. The process utilizes a high-speed, uni-directional data channel and a low-speed, bi-directional control channel, and is therefore asymmetric. It is also sometimes called "asynchronous DSL".

ADSL2 – Provides higher downstream rates of up to 12 Mbit/s for spans of less than 2.5 km (8000 ft.). More flexible framing and error correction configurations are responsible for the increased speeds.

ADSL2+ – (also referred to as ITU G.992.5) ADSL2+ doubles ADSL2 downstream bandwidth, increasing the downstream data rate to as much as 25 Mbps. ADSL2+ specifies a downstream frequency up to 2.2 MHz The result is a significant increase in data rates on shorter phone lines. See also ADSL and ADSL2.

AMI – (Advanced Metering Infrastructure) Systems in place to communicate and measure energy usage with metering devices. These systems allow two-way communication between the user and the provider, allowing commands and information to be sent to the home.

ANSI – American National Standards Institute.

ANT – ANT technology is a proprietary wireless networking protocol using the unlicensed 2.4 GHz ISM band. ANT+ refers to an interoperability function, added to the base ANT protocol, to enable 'off-the-shelf' interoperability from a range of suppliers.

APAC – (Asia Pacific) This region includes Asia and Oceania.

API – (Application Programming Interface) is a set of routines, protocols, and tools for building software applications. A good API makes it easier to develop a program by providing all the building blocks. Open APIs also promote interoperability across device manufacturers.

ARCNET – Attached Rsource Computer NETWork - a local area network protocol.

ARPU – (Average Revenue per User) Represents the revenue generated by a user within a certain period of time.

ASHRAE – American Society of Heating, Refrigeration and Air Conditioning Engineers. ASHRAE is an international organization which aims to advance heating, ventilation, air-conditioning, and refrigeration. ASHRAE provides research and development as well as training publications. Since June 1987, ASHRAE Standard Project Committee (SPC) 135 has actively developed the BACnet protocol.

A/V – Audio/Visual.

A/V Receiver – is a consumer electronics component that can connect multiple A/V devices. The A/V receiver can then be used to switch between those devices. For example, a user might connect a DVR, a game system, and DVD player all to an A/V receiver. The user would then use the receiver to select a source to be displayed on the TV set.

BACnet – Building Automation and Control Network is an ASHRAE, ANSI and ISO standard communication protocol used for building automation

BECP – Building Energy Codes Program (BECP). It was established in 1991. BECP promotes stronger building codes and helps local states to adopt, implement and enforce them.

Bluetooth – (BT, BT Smart) a wireless technology typically used in mobile devices. Bluetooth Smart is a low power version of Bluetooth designed for use by IoT devices.

BMS – Building Management System. A computer-based control system in buildings that monitors and controls the building's mechanical and electrical equipment such as lighting and ventilation.

BOM (Bill of Materials) – Essentially a shopping list given to a manufacturer's purchasing and/or sourcing department, it can refer to a list of items required to produce a product or the cost thereof.

BPL - Broadband Power Line

Broadband – Networks capable of delivering a high number of bits per second. When used in relation to cable TV, it refers to networks with a bandwidth from 550MHz to 1GHz.

CABA - Continental Automated Buildings Association.

Cable Modem – A device that permits one–way or two-way high-speed data communication over a cable network system for purposes such as internet access. A cable modem attached to a coaxial cable TV network can transmit data much faster than a typical 56 kbps computer modem.

Cable TV – TV programming and services received through a cable-wired link (co–axial, twisted pair, or fiber -optic) from a headend.

CAGR (Compound-average Annual Growth Rate) – is the geometric average rate at which a quantity grows each year over a period. It is also called "Compound Annual Growth Rate" and "Cumulative Annual Growth Rate".

CapEx – (Capital Expenditure) Funds used by a company to purchase or develop new or existing physical assets. This outlay is made to maintain or increase the scope of its operations.

CASBEE - Comprehensive Assessment System for Built Environmental Efficiency (CASBEE) – CASBEE is a Japanese certification program that measures and assesses energy efficiency in commercial buildings.

CCTV – Closed circuit television.

CEM – Cisco Energy Management.

CFL – Compact fluorescent light.

CHC – (Connected Home Council)

C-PACE – Commercial Property Assessed Clean Energy.

CPE – (Customer Premises/Provided Equipment) Represents telecommunication equipment such as telephones, DSL modems or cable modems. It can also refer to the use of a particular communication service provider with a purchased set-top box.

CPUC - California Public Utilities Commission.

CRM – Customer relationship management.

DECT ULE – (Digital Enhanced Cordless Telecommunications Ultra Low Energy) is a wireless networking technology suitable for use by battery-powered home automation devices.

DR – (Demand Response) is a system which allows an energy provider to communicate with a home via a smart meter or AMI to control or influence connected devices such as smart thermostats and other HVAC controls.

DLNA – Digital Living Network Alliance

DOCSIS (Data Over Cable Service Interface Specification) – is an international standard, developed by CableLabs and others, defining the communications and operation support interface for data over cable systems. It permits the transfer of high-speed data from, say, the internet over existing cable TV systems. Regional variants of DOCSIS exist, because of the differing frequency band allocations.

DOCSIS 1.0/2.0/3.0 – Different versions were identified to enhance the support with IP telephony and transmission speed.

DIY – (Do It Yourself) In the context of this report, this typically refers to devices and systems which are designed for self-installation, with limited technical expertise needed. This is an alternative to a professionally installed system. DIY is also used in reference to a score used during some end-user survey segmentation to assess respondents' DIY abilities.

DSL (**Digital Subscriber Line) is a** broadband modulation scheme that enables data to be transmitted over ordinary telephone lines at speeds of several megabits per second.

DVD – (Digital Video Disc; also referred to as Digital Versatile Disc) Optical disc system which stores MPEG–2 or MPEG–4 compressed video and audio on CD–style discs.

DVI (Digital Visual Interface) – A standard video connection that carries uncompressed digital video – closely related to the HDMI (High-Definition Media Interface) standard.

DVR (Digital Video Recorder) – A set-top box that can record video and store it digitally on a hard disk drive or other similar internal storage medium. Most DVRs include two tuners to enable viewing of one program while simultaneously recording another, and also have the capability to route multiple video transport streams simultaneously.

ECO - Energy Company Obligation.

EDGE – (Enhanced Data rates for GSM Evolution)

EFT-POS – (electronic funds transfer at point of sale)

EM – (Energy Management Score)

EMAS – European Union Eco-Management and Audit Scheme (EMAS) – EMAS was established in 1995 to ensure better management of environmental issues and continual improvements in environmental performance of companies and other organizations.

EMEA – is an acronym for Europe, the Middle East, and Africa.

EnEV – Energy Savings Ordinance.

EnOcean – A Wireless technology commonly used in home automation systems.

EPC – Mandatory Energy Performance Certificate (EPC) in the United Kingdom – As of January 9th 2013, all newly constructed commercial buildings must have an EPC.

ERP – Enterprise resource planning. Integrated management of core business processes, such as product planning, procurement and service delivery, through technology and software.

FCC (Federal Communications Commission) – The broadcasting and telecom regulatory authority of the United States of America.

Fiber–Optic Cable – Cable made from thin strands of glass fiber used to transmit signals using laser light. These cables offer a very high bandwidth.

Form Factor – A term used to describe the size, shape, and physical arrangement of electronics equipment.

FTTH – (Fiber–to–the–Home; also referred to as FTTP) A type of cable network which uses fiber optic cabling throughout, including the individual home.

FTTN – (Fiber–to–the–Node or Fiber–to–the–Neighborhood) A broadband architecture that provides high speed internet and other services to the home by running fiber via VDSL over the existing telephone copper lines to the home. This architecture costs less to deploy than the competing FTTP technology but in turn does not bring the full bandwidth capability of FTTH. Data rates are limited to 25–30 Mbit/s.

FTTP – (Fiber–to–the–Premises) See FTTH.

Geo-fencing – is a feature in a software program that uses GPS or radio frequency identification (RFID) to define geographical boundaries. A geofence is a virtual barrier.

GBC – World Green Building Council.

GHG – Green-house gas.

GDP – Gross domestic product.

GPRS – (General packet radio service) A data transfer communication standard for delivering information via a wireless 3G network.

GPS – (Global Positioning System) A system that provides accurate positioning information, providing the device has line of sight to at least four GPS satellites.

HD – (High Definition or HDTV) In the United States, it is generally defined as resolutions of 1080 vertical interlaced lines of resolution, or 720 vertical progressively scanned lines of resolution or higher. In Australia, it can mean anything upwards of 576 vertical, progressively scanned lines of resolution. For IHS purposes, HD is defined as a display capable of a minimum of 768 lines of resolution as defined by XGA display mode.

HDD – (Hard Disc Drive) With respect to TV transmissions, HDDs are found in DVRs and are used to store programming that can be retrieved for viewing at a later time, similar to stored data on a personal computer.

HDMI – (High Definition Multimedia Interface) HDMI is an updated version of HDTV interface that combines audio and video signals on the same DVI connection. Intel's HDCP is incorporated for content protection. HDMI can carry multi–channel audio – in either compressed or uncompressed forms – and distribute basic control data between any audio/video components. The primary benefits are high bandwidth and a single connection versus several.

HMI – Human machine interface

HSPA – (High Speed Packet data Access) is an upgrade to 3G networks used to increase packet data performance.

HTML5 – the current version of HyperText Markput Language.

HVAC – Heating, ventilating, and air conditioning.

IC – (Integrated Circuit) A circuit in which all or some of the circuit elements are inseparably associated and electrically interconnected so that it is considered to be indivisible for the purposes of construction and commerce.

IESNA – Illuminating Engineering Society of North America.

IHD – (In home Display) is an abbreviation used to describe the dedicated displays used by smart home systems to display information and/or control devices.

Insteon – A home automation communication technology using dual-mesh technology via RF and power line networks.

IoT – (Internet of Things). It is important to note that the IoT is not a specific device or technology – it is a conceptual framework, driven by the idea of embedding connectivity and intelligence in a wide range of devices. (See section 2.1.1)

IoE – (Internet of Everything) is an expansion of the Internet of Things (see Section 2.1.1)

IP – (Internet Protocol) A communication protocol that provides identification and location information for devices and computers. This can be used to transfer data across the internet.

IPv4 – (Internet Protocol version 4) is an outdated version of internet protocol.

IPv6 – (Internet Protocol version 6) is the latest version of internet protocol.

ISO – International Organisation for Standardization,

IWBI – International Well Building Institute.

KNX – KNX technology is a worldwide standard for applications of building control, including: lighting, shutter, security systems, heating, ventilation, air-conditioning, monitoring, alarming, water control, energy management, metering and other systems.

LAN (Local-Area Network) – A network whose links are no more than 500 meters in length.

Last Mile – The last mile is the final leg of delivering connectivity from a communications provider to a customer. An expression usually used by the telecommunications and cable TV industries, it is typically seen as an expensive challenge because "fanning out" wires and cables is a considerable physical undertaking. Outside the United States and the United Kingdom, the phrase "last kilometer" is sometimes used.

LEED – Leadership in Energy and Environmental Design (LEED). LEED is an internationally recognized green building certification system. Developed by the US Green Building Council (USGBC), LEED is intended to provide building owners and operators with a framework for enabling green building design, construction, operations and maintenance.

LonWorks – (local operating network). A networking solution used for building automation.

LoRA – a Low Power Wide Area Network (LPWAN) specification aimed at wireless battery operated IoT devices in a regional, national or global network.

LTE – Long term evolution, A mobile network standard.

M2M – is Machine-to-Machine communication between machines, devices, and equipment with little or no direct human interaction.

MEP – mechanical, electrical and plumbing.

MoCA – (Multimedia over Coax Alliance) A home networking solution for in-house coaxial cables. MoCA enables multiple use of data connections to television, set top boxes and entertainment devices without the need for a new cable.

MSO – (Multiple Service Operator) A service provider that operates multiple cable systems.

$MtCO_2$ - – metric tons of carbon dioxide.

NEMA – National Electrical Manufacturers Association.

North America – In the context of this report, North America refers to the United States. and Canada.

OLT – (Optical Line Termination) OLTs are located at the local exchange, and are connected to ONUs using fiber optic cables. Up to 32 ONUs can be connected to an OLT. See also ONU.

ONU – (Optical Network Unit) a fiber optic subscriber terminal usually located on the street, in a building, or in the subscriber's home.

On–Demand – The ability to request video, audio or information to be sent to the screen immediately by "clicking" on an appropriate displayed icon.

OS – Operating System

PAN – (Personal Area Network) A network of devices that typically provide connectivity within 10m of the consumer.

PERS – Personal emergency response systems.

PoE – Power over Ethernet.

PROCEL – National Electrical Energy Conservation Program of Brazil.

PTP – Point-to-point.

PC – Personal Computer.

PV – Photovoltaic.

RFID – Radio frequency identification.

ROI – Return on Investment.

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SBA – Sustainable Buildings Alliance.

SD – (Standard Definition) In the United States, it is generally meant as 480 lines of vertical resolution. In DVB–compliant countries, it can mean a video stream in MPEG–2 MP@HL. See MPEG-2.

SPC – ASHRAE Standard Project Committee.

STB – (Set–top Box) Stand–alone units which have some form of broadcast signal as an input, and an output interface to a TV receiver.

Sub-GHz Technology - Used to define a range of, usually, proprietary wireless technologies that operate under the 1 GHz frequency band

TAM – Total Available Market

Thread - Thread is a relatively new mesh network protocol that was announced to the market in 2014. The technology runs on IEEE 802.15.4 and uses 6LoWPAN to carry IPv6 natively.

ToU (Time of Use) - Some utility companies offer 'Time of Use' pricing, which means that tariffs change throughout the day depending on demand.

TR069 - (Technical Report 069) TR069 is a standard developed by the Broadband Forum that defines an application layer process for remote management of end-use devices.

UAE – United Arab Emirates.

UI – User Interface

UMTS – (Universal Mobile Telecommunications System) UMTS is a third-generation mobile cellular system developed and maintained by the 3GPP (3rd Generation Partnership Project)

UNEP – United Nations Environment Programme.

USGBC – US Green Building Council.

VDSL – (Very High–Rate Digital Subscriber Line) A type of high–speed DSL that is primarily intended to be used as the last transmission system section in a network, for VOD and Asynchronous Transfer Mode (ATM) applications over the existing infrastructure of twisted copper pair phone lines to homes and businesses.

VMS – Video management software.

VPN – (Virtual Private Network) A specific network underlying a communal network for dedicated groups. It can also be used to separate traffic from several users with enhanced security.

VOD – (Video–On–Demand) An interactive broadcast service where a consumer is able to select from a catalog of movies to receive for viewing on the home TV set, nearly instantaneously. See also NVOD.

VoIP – (Voice over Internet Protocol) An interactive service which enables voice communication over Internet Protocol based network

WAN – (Wide Area Network) in the context of this report, this refers to networks that utilize cellular, broadband or satellite communications.

Watermark – An invisible mark embedded into content that can only be detected by special equipment and cannot be removed without damaging the medium in which it was embedded. The watermark can specify encoding rules such as "copy freely," "copy once," or "copy never," and is enforced by special analog–to–digital converters (ADCs).

WBS – Well Building Standard. This standard a set of specifications conceived by the International WELL Building Institute (IWBI) for measuring and certifying aspects of the built environment impacting the health and well-being of the building's occupants.

WCT – Wireless Cooperation Team. The goal of the WCT is to develop a wireless gateway specification based on WirelessHART and the emerging ISA SP 100.11a standard.

Wi-Fi - Wireless local area network (WLAN) products that are based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards.

WiMAX – (The Worldwide Interoperability for Microwave Access) A telecommunication system which provides wireless data over far distances using several different technologies. It can also be known as an alternative technology of delivery *last mile* wireless broadband to cable and DSL.

WLAN – (Wireless Local Area Network) A wireless network whose links are no more than 500 meters in length. Generally this refers to networks using 802.11 or Wi-Fi technologies, although the term is not necessarily exclusive to these technologies.

W-Mesh – (Wireless Mesh) a wireless network, where the network nodes can all individually relay or route data to each other

WPA – (Wi-Fi Protected Access) Security protocols and certification programs developed by the Wi-Fi Alliance to secure wireless computer networks.

WPAN – (Wireless Personal Area Network) A network of wireless devices that typically provide connectivity within 10m of the consumer.

WWAN – (Wireless Wide Area Network) There are two broad groups of wireless wide-area network technologies. The first, and far more common, is the group of cellular device technologies encompassing all of the GSM, CDMA, and LTE variations. The second group uses satellites and broadcasts on radio frequencies.

ZigBee - ZigBee is a standards-based wireless platform, positioned to provide for the needs of remote monitoring and control applications in commercial and residential environments.

Z-Wave - A proprietary wireless communications standard designed for home automation applications. Z-Wave is a mesh networking technology with each node or device capable of both sending and receiving control demands.

APPENDIX C

LIST OF REFERENCES

Executive Summary

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