SMART BUILDINGS AND INTERNET OF THINGS (IOT) IMPACT ON ELECTRICAL CONTRACTING

ELECTRI INTERNATIONAL
THE FOUNDATION FOR ELECTRICAL CONSTRUCTION INC.

Hisham Said, Associate Professor of Construction Engineering and Management in the Department of Civil Engineering, Santa Clara University.

ABOUT THE AUTHOR

Hisham Said is an Associate Professor of Construction Engineering and Management in the Department of Civil Engineering at Santa Clara University. His research interests include construction industrialization, prefabrication, trade contracting, and construction logistics. He is a recipient of ASCE EXCEed Fellowship, ASCE CRC 2012 Best Paper Award, and AGC Faculty Internship award. In 2013, Dr. Said received ELECTRI International's Early Career Award to study "Industrialization of Electrical Contracting: Supply Chain and Logistics Management." He then received an ELECTRI International grant for his 2015/2016 investigation on "Identifying BIM Related Costs Due to Changes", researched with Justin Reginato (Sacramento State University). Dr. Said has been an invited guest speaker to present his applied research at leading industry professional meetings and conferences, including NECA's 2017 Convention and the 2017 Multi-Trade Prefabrication Conference. His research has been disseminated in more than 50 papers in top, peer-reviewed academic journals and conference. Dr. Said received his B.Sc. and M.Sc. in Structural Engineering from Cairo University, and his Ph.D. in Civil Engineering (CM focus) from the University of Illinois at Urbana-Champaign.

ACKNOWLEDGEMENTS

The author would like to thank ELECTRI International's Task Force members for their commitment, positive feedback, and enthusiasm.

John Wright, Co-Chairman
Alterman, inc.

Phil Santoro, Co-Chairman
Schneider

Tricia Ferry
VEC

Steve Killius
Legrand

Luke Jackson
ERMCO

Tim Speno
E2E Summit

Mark Mandarelli
Sprig

David Moeller
Graybar

ELECTRI COUNCIL

PRESIDENT'S COUNSEL - *$1,000,000 or more*

Contractors
- *The Hugh D. 'Buz' and Irene E. 'Betty' Allison Trust, Hugh D. 'Buz' Allison, d.*
- *The Richard W. and Darlene Y. McBride Trust, Richard W. McBride**
- *The Al and Margaret Wendt Trust, Albert G. Wendt*, d.*

NECA Chapters and Affiliates
- *National Electrical Contractors Association*, John M. Grau*

Manufacturers, Distributors, Utilities and Affiliates
- *Schneider Electric / Square D, Neal Lyons*

PROGRAM GUARANTOR - *$500,000 or more*

Contractors
- *McCormick Systems, Jack McCormick*

NECA Chapters and Affiliates
- *Electrical Contractors Trust of Alameda County, Thomas F. Curran*

Manufacturers, Distributors, Utilities and Affiliates
- *The Okonite Company, Bruce Sellers*

AMBASSADOR - *$450,000 or more*

Contractors
- *Southern Contracting Company, Timothy McBride*

COMMISSIONER - *$400,000 or more*

NECA Chapters and Affiliates
- *San Diego County Chapter NECA, Bob Davies, Jr.*

DIPLOMAT - *$350,000 or more*

NECA Chapters and Affiliates
- *Boston Chapter NECA, Joseph H Bodio*

Manufacturers, Distributors, Utilities and Affiliates
- *Eaton Corporation, James L. Golly*
- *Graybar, Edward Deems*
- *Trimble, featuring Accubid Products, Sarah Miller*

ENVOY - *$300,000 or more*

Contractors
- *O'Connell Electric Company, Walter T. Parkes* and Michael Parkes*

NECA Chapters and Affiliates
- *Northeastern Illinois Chapter NECA, Craig Martin*
- *Northeastern Line Constructors Chapter NECA, George Troutman*
- *Northern Indiana Chapter NECA, Anthony J. Maloney, III*
- *Santa Clara Valley Chapter NECA, Michael Jurewicz*
- *Western Pennsylvania Chapter NECA, Robert J. Bruce*

Manufacturers, Distributors, Utilities and Affiliates
- *Greenlee / A Textron Company, Paul McAndrew*
- *Viewpoint Construction Software, Karl Rajotte*

REGENT - *$250,000 or more*

Contractors
- *Cannon & Wendt Electric Company, David E. Fagan*
- *Capital Electric Construction, Robert E. and Sharon Doran* - In memory of Robert E. Doran, Jr.*
- *John R. Colson, TX*
- *Maron Electric Co., Jerold H. Nixon, d., and Eric F. Nixon*
- *Miller Electric Company, H. E. "Buck" Autrey* **, David Long and Henry Brown*
- *Robert L. Pfeil, d., IN*

NECA Chapters and Affiliates
- *Chicago & Cook County Chapter NECA, Eric F. Nixon*
- *New York City Chapter NECA*, Stephen Gianotti*
- *Northern California Chapter NECA, Greg E. Armstrong*
- *Puget Sound Chapter NECA, Michael J. Holmes*
- *Southeastern Michigan Chapter NECA*, Thomas Mittelbrun, III*

Manufacturers, Distributors, Utilities and Affiliates
- *ABB Installation Products, David Dean*
- *MCA, Inc., Heather Moore*

CHAMPION - *$200,000 or more*

NECA Chapters and Affiliates
- *Greater Toronto Electrical Contractors Association, Paul Sheridan*
- *Illinois Chapter NECA*, Terry Buhs*
- *Los Angeles County Chapter NECA, James Willson*
- *Northern New Jersey Chapter NECA, Henry J. Sassaman*

GOVERNOR - *$150,000 or more*

Contractors
- *Bana Electric Corporation, Stephen Bender*
- *Center Line Electric, Inc., Clyde Jones*
- *Brian Christopher, OR*
- *Clennon Electric, Inc., Lawrence H. Clennon*
- *Cogburn Bros Electric, Inc., Larry Cogburn and Ron L. Cogburn*

- *Ferndale Electric Co., Arthur Ashley*
- *J. Ranck Electric, Inc., Jeremy Rowley*
- *Kelso-Burnett Company, Stefan Lopata*
- *Lone Star Electric, Mark A. Huston*
- *M. J. Electric, LLC, Edward Farrington*
- *McPhee, Ltd., Michael E. McPhee*
- *Michels Corporation, Gerald W. Schulz*
- *Pieper Electric, Richard R. Pieper, Sr.**
- *Quebe Holdings, Inc., Dennis F. Quebe*
- *Sidney Electric Company, John S. Frantz*
- *The Superior Group, A Division of Electrical Specialists, Gregory E. Stewart*
- *Turner Electric Service, Inc., Robert J. Turner, II*
- *United Electric Company, Inc., Dan Walsh*
- *VEC, Inc., Rex A. Ferry*
- *Zenith Systems, LLC, Michael B. Joyce*

NECA Chapters and Affiliates

- *Atlanta Chapter NECA, Rilo Stephens*
- *Cascade Chapter NECA, Dave Ginestra*
- *Central Indiana Chapter NECA, Steven Gottfried*
- *Dakotas Chapter NECA, Ed Christian*
- *Eastern Illinois Chapter NECA, Gregory Outsen*
- *Electrical Contractors Trust of Solano & Napa Counties, Gregory D. Long*
- *Finger Lakes New York Chapter NECA, John Amicucci*
- *Greater Cleveland Chapter NECA, David Haines*
- *Kansas City Chapter NECA, Kenneth C. Borden*
- *Long Island Chapter NECA, Donald Leslie, Jr.*
- *Michigan Chapter NECA, Michael L. Crawford*
- *Oregon-Columbia Chapter NECA, George Adams*
- *Oregon Pacific-Cascade Chapter NECA, Thomas Kyle*
- *Penn-Del-Jersey Chapter NECA, Kenneth R. MacDougall*
- *South Florida Chapter NECA, James G. DiLullo*
- *South Texas Chapter NECA, Leslie M. Moynahan*

Manufacturers, Distributors, Utilities and Affiliates

- *GE Lighting, Mark Lovdahl*
- *Legrand North America, Steve Killius*
- *Lutron Electronics Co., Inc., Richard Angel*
- *Panduit Corporation*

FOUNDER *- $100,000 or more*

Contractors

- *Abbott Electric, Inc., Michael C. Abbott*
- *ADCO Electrical Corporation, Gina M. Addeo*
- *Alcan Electrical & Engineering, Inc., Scott Bringmann*
- *Allison Smith Company LLC, Chris Reichart*
- *Alterman, Inc., John C. Wright*
- *Amaya Electric, John Amaya*
- *ARS Proyectos, Mexico, Carlos Anastas*
- *B&D Industries, Inc., Clinton Beall*
- *Bagby & Russell Electric Co., Franklin D. Russell - In memory of Robert L. Russell*
- *Baker Electric, Inc., Ted N. Baker*
- *Berwick Electric Company, Doug Berwick – to honor the leadership and passion that Jim Peterson has provided for the growth and success of Berwick Electric Co.*
- *Big State Electric, Vincent Real*
- *Boggs Electric Company, Inc., Michael H. Boggs*
- *Daniel Bozick, d., CA*
- *Bruce & Merrilees Electric Co., Jay H. Bruce*
- *Richard L. Burns*, d., FL*
- *Carl T. Madsen, Inc., Rocky Sharp*
- *Chewning & Wilmer, Inc., Carson Rogers*
- *Christenson Electric, Inc., Sonja Rheaume*
- *Collins Electric Company, Inc., Kevin E. Gini*
- *Continental Electrical Construction Co., David A. Witz*
- *Ben and Jolene Cook, TX*
- *Corona Industrial Electric, Herbert P. Spiegel - A tribute in memory of Flora Spiegel*
- *CSI Electrical Contractors, Inc., Steve Watts*
- *Thomas F. and Alana Curran, CA*
- *Daniel's Electrical Construction Company, Inc., Thomas G. Ispas*
- *DiFazio Power & Electric, LLC, Robert DiFazio*
- *Divane Bros Electric Co., In memory of William T. Divane, Sr. and Daniel J. Divane III*
- *Edward G. Sawyer Company, Inc., Joseph J. McCluskey, Jr.*
- *Egan Company, Duane Hendricks*
- *Electric Power Equipment Company ****
- *Electrical Corporation of America, Donald Laffoon*
- *Empire Electric, Inc., Kellie Holland*
- *ERMCO Electrical and System Contractor, Greg Gossett*
- *Ferguson Electric Construction Co., Jim Schneider*
- *Fisk Electric Company, Orvil Anthony**
- *Fuller Electric, Earl Restine – Honoring our founders and family*
- *Giles Electric Company, Inc., Bradley S. Giles*
- *Gregg Electric, Inc., Randy Fehlman**
- *Gurtz Electric Company, Frank Gurtz - In honor of Gerald Gurtz*
- *Hardt Electric Inc., Peter D. Hardt*
- *Harrington Electric Co., Thomas A. Morgan*
- *Holmes Electric Company, Michael J. Holmes*
- *Eddie E. Horton, TX*
- *Hunt Electric Corporation, Michael Hanson*
- *Jamerson & Bauwens Electrical Contractors, Inc., Kenneth J. Bauwens*
- *Johnson Electrical Construction Corporation, Donald Leslie, Jr.*
- *Jordan-Smith Electric, Travis A. Smith*
- *L. K. Comstock & Co., Inc., Ben D'Alessandro*
- *L.L.D. Electric Co. (Hyslop Shannon Foundation), Tom Morton*
- *Lighthouse Electric Company, Inc., Todd A. Mikec*
- *The Lindheim Family, Michael Lindheim**
- *Long Electric Company, Gregory D. Long*
- *Mark One Electric Company, Inc., Carl J. Privitera, Sr.*
- *Mayers Electric Company, Howard Mayers*
- *McCoy Electric, Max N. Landon*
- *MJM Electric, Inc., Mark J. Mazur*
- *MONA Electric Group, David McKay*
- *Motor City Electric Co., Richard J. Martin**
- *Newkirk Electric Associates, Inc., Ted C. Anton*

- *OEG, Jeff Thiede*
- *Parsons Electric Company, Joel Moryn*
- *Peter D. Furness Electric Co., John F. Hahn, Jr.**
- *Potelco, Inc., Gary A. Tucci*
- *Pritchard Electric Co., Tom Braley*
- *R. W. Leet Electric, Inc., Tim Russell*
- *Red Top Electric Company Emeryville, Inc., Michael C. Curran - In honor of George T. and Mary K. Curran*
- *REX Electric & Technologies, LLC, Jim McInerney*
- *Robertson Bright, Inc., Wally Budgell*
- *Roman Electric Company, Phillip G. Rose*
- *Rosendin Electric, Matthew J Englert*
- *Sargent Electric Company, Frederic B. Sargent*
- *Schultheis Electric / TSB, Inc., Tim Schultheis*
- *Gerald W. Schulz, WI*
- *Service Electric Company, Brian Imsand**
- *Shaw Electric Company, David W. Kurtz*
- *Sprig Electric Company, Inc., Pepper Snyder*
- *St. Francis Electric, Robert Spinardi*
- *TEC-Corp / Thompson Electric Co., Skip Perley - In memory of Alfred C. Thompson*
- *Toomer Electrical Co., Inc., Ronald J. Toomer*
- *Tri-City Electric Co., Inc., D. R. "Rod" Borden, Jr.**
- *Triangle Electric Company, Roy C. Martin*
- *Truland Systems Corporation ****
- *Truland Walker Seal Transportation, Inc.****
- *United Electric Company, Inc., Jarrett D. Hayes*
- *Universal Systems, Gene W. Dennis*
- *Whitehead Electric Company, Christopher Foster*
- *Zwicker Electric Company, Inc., David Pinter*

NECA Chapters and Affiliates

- *Alaska Chapter NECA, Larry Bell*
- *American Line Builders Chapter NECA, Richard V. Miller*
- *Arizona Chapter NECA, Joe Graham*
- *Atlantic Coast Chapter NECA, Robert Zahn*
- *Canadian Electrical Contractors Association, Colin Campbell*
- *Central Ohio Chapter NECA, Brian Damant*
- *East Tennessee Chapter NECA, Mike Young*
- *Greater Sacramento Chapter NECA, Frank Schetter*
- *Iowa Chapter NECA, Angela Bowersox*
- *Kansas Chapter NECA, Shawn Smith*
- *Milwaukee Chapter NECA, Dave Washebek*
- *Minneapolis Chapter NECA, Duane Hendricks*
- *Missouri Valley Line Constructors Chapter NECA, Joe Mitchell*
- *North Central Ohio Chapter NECA, Jason Walden*
- *North Florida Chapter NECA, Katie Enkiri*
- *North Texas Chapter NECA, Steve Hargrove*
- *Rocky Mountain Chapter NECA, Rusty Gonzales*
- *San Francisco Chapter NECA, Leonard Lynch*
- *Southeastern Line Constructors Chapter NECA, C. Stephen Gaines, Jr.*
- *Southern Colorado Chapter NECA, Sue King*
- *Southern Indiana Chapter NECA, Jeff Hayden*
- *Southern Nevada Chapter, NECA, Donald Campbell*
- *Southern Sierras Chapter NECA, David Shankle*
- *St. Louis Chapter NECA, Robert Senf*
- *West Virginia-Ohio Valley Chapter NECA, Ted Brady*
- *Western Line Constructors Chapter NECA, Jules W. Weaver*
- *Wisconsin Chapter NECA, Daniel Shea*

Manufacturers, Distributors, Utilities and Affiliates

- *3M, Ryland Marek*
- *Acuity Brands, Inc., Christopher "Sully" Sullivan*
- *Cerro Wire, LLC, Stewart Smallwood*
- *Cree Inc.*
- *Crescent Electric Supply, Tim Rooney*
- *E2E Summit, Timothy Speno*
- *Electrical Training Alliance, Todd Stafford*
- *Elliott Electric Supply, Greg Fitzgerald*
- *Encore Wire Corporation, Kevin Kieffer*
- *Allen W. Estes, III, WA*
- *Focus Investments Advisors, Andrew Wasa*
- *Forest Lighting, Jian Ni*
- *General Cable, Brian Moriarty*
- *Ideal Industries, Inc., Matthew Barrett*
- *Mayer Electric Supply, Kyle Walters*
- *Milwaukee Tool Corporation, Brett Wilson*
- *Mosaic Learning, Michael Callanan*
- *Moss-Adams LLP, Buddy Wall*
- *Paradigm Sales Group, Brett Bauz*
- *Philips Lighting*
- *Rexel/Gexpro, Chris Chickanosky*
- *San Diego Gas & Electric, James Boland*
- *Sonepar USA, Mick Upchurch*
- *Southwire Company LLC, Tom Feissle*
- *Thomas Industries, Inc.*
- *United Rentals, Kevin Parr*
- *Werner Company, Lenny Colasuonno*
- *WESCO Distribution, Inc., John Muenchen*

* denotes founding member of ELECTRI'21 COUNCIL (1989-1990) ** denotes first contributor *** denotes no longer in business d. denotes deceased.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This ELECTRI International study was inspired by the exciting technological advancements of the internet of things (IoT) and their impact on making buildings smarter and more efficient. The study had an overarching goal of developing short- and long-term strategies for the electrical construction industry to prepare for the new era of smart facilities made possible by IoT technologies and systems. The researcher's extensive data collection process included interviews, an online questionnaire, case studies, and technology taxonomy modeling. All the collected data and wisdom from this process served as the basis for developing **a comprehensive roadmap for electrical contractors (ECs),** shown in Figure 1.

This roadmap includes vision-driven strategies to help the EC industry **transform into master system integrators (MSI) who can deliver increased value to their clients, expand their revenue streams, and improve the employment and development of their workforce.** The roadmap strategies considered 11 market challenges and 9 technological opportunities of smart buildings. As such, the completed roadmap includes 7 technology strategies (TS), 9 business strategies (BS), and 7 workforce strategies (WS). The roadmap strategies are explained thoroughly in the report. The main highlights include:

1. As ECs transform more into MSI roles in smart buildings, they will be more responsible to protect their clients from cyber security threats. The good news is that ECs can apply already-existing cybersecurity standards and practices to integrate the building IP-based control systems into the client enterprise IT network.

2. Just as lighting was a major business gateway for ECs in energy-efficient buildings, lighting will also be the gateway to make buildings smarter and more connected. Smart lighting fixtures will become more agile and modular in order to integrate diverse sensor devices that can provide room-level control of the indoor environment.

3. Transforming into an MSI is a gradual strategic effort for ECs to expand their focus from mere electrical and power systems to holistic building system integration. This gradual effort includes both partnering with current system integrators to observe their practices and offering building automation engineering and installation services.

4. The greatest revenue stream potential from smart buildings will be created from services that are beyond the EC's current comfort zone. These services include building system integration and performance monitoring, which both require more focus on customer satisfaction and new contractual arrangements.

5. IoT-interoperability between the different smart building systems will stay a challenge for building systems integration. As such, ECs' success in offering MSI services will greatly depend on partnering with limited manufacturers whose systems are compatible with seamless integration and communication.

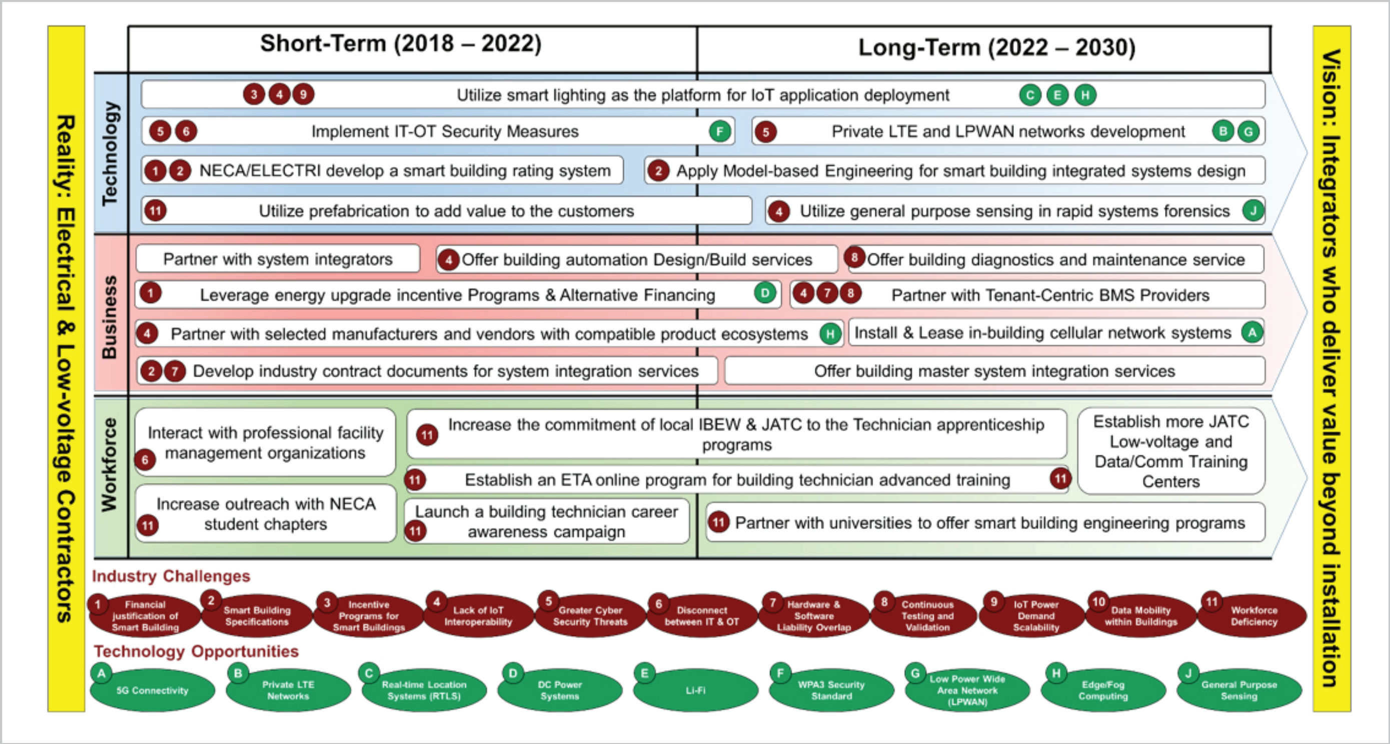
6. As an alternative to offering MSI comprehensive services, ECs can specialize in installing and leasing private in-building and campus-wide wireless communication systems that are created by the greater need for IoT connectivity and 5G networks. These private networks include low-power wide-area network (LPWAN) and distributed antenna systems (DAS).

7. NECA and IBEW need to offer incentives for local JATCs to increase their commitment to low-voltage and video, data, and voice (VDV) training until they can be sustained and justified by the local work volumes.

8. To offer MSI services, ECs will need a new breed of engineering and design workforce who can be recruited and trained by partnering with two-year and four-year college institutions.

9. ECs will need to modify and increase their K-12 outreach effort to make new workforce generations aware of promising and diverse career opportunities within the smart building market.

Figure 1: Smart Building Roadmap for Electrical Contractors



CHAPTER 1

OVERVIEW OF THE SMART BUILDING INDUSTRY

INTRODUCTION

Smart living and work environments are not really a new frontier for the architectural, engineering and construction (AEC) industry. Automation and control systems have been installed in buildings for decades to help facility managers remotely access and control the heating, ventilation, air conditioning and lighting systems. Also, low-voltage systems established the medium to construct reliable audio, video, and security systems. **But, what is beyond remotely controlling and automating the buildings?**

Reaching beyond mere remote automation of buildings is achieved through the recent technological leaps in the Internet of Things (IoT). Increasing the intelligence of the built environment requires installing more sensors and actuators throughout the building both to collect relevant data of the building performance and its tenant and to respond to business and operational needs. ***IoT refers to the concept of establishing a local web-accessible network of sensors and devices that proactively exchange data. The real emergence of the IoT was made possible by the convergence of four main technological advancements:*** 1) the ***increasing processing power of embedded platforms*** that replaced the microcontrollers and allowed running algorithms on the devices and sensors; 2) the development of ***reliable and light operating systems*** for the embedded platforms, supported by large ecosystems of developers and applications; 3) the development of ***standard wireless communication protocols*** with low-power requirements, like ZigBee and Z-wave; and 4) the ***growth of viable commercial cloud computing platforms*** that provide data warehousing, artificial intelligence tools, and security measures.

With the advancement of IoT technologies, electrical contractors (ECs) can seize new business opportunities but they also face non-traditional business challenges. It is inevitable that these smart facilities will become more complex and challenging projects for ECs to construct with integrated work scopes beyond the traditional old trade boundaries. Moreover, ECs have opportunities to deliver new, value-added, higher margin services to customers and to develop a closer relationship with their customers than in a typical 'install and go' scenario. These additional services have been in higher demand, due to cost saving, energy efficiency and monitoring/maintenance demands.

This chapter provides an overview of smart buildings, in terms of their attributes, challenges, requirements, and the potential roles of ECs in constructing these buildings.

METHODOLOGY

The researcher performed a set of unstructured interviews with representatives from electrical construction firms, manufacturers, distributors, facilities management, and training programs to develop a clear assessment of the current smart building industry. Table 1 lists the individuals who participated in the interviews and their professional affiliations. The interviews involved the following open-ended questions:

1. What is YOUR definition of smart buildings? How different they are from net-zero energy buildings?
2. Please briefly explain the services your company provides that are relevant to smart buildings?
3. Please explain the role of your position in the company.
4. What are some examples of intelligent or smart building systems your company has installed?
5. What are the unique design and construction challenges with smart buildings?
6. How do you see the future role of electrical contractors in the smart building market?
7. Do you think the current electrical construction workforce is prepared for the speculated growth of smart building industry?

Table 1: The Industry Interviews

Company	Participants
Alameda Country JATC	Byron Benton *(Training Director)*
Alterman	Art Salinas *(VP Technologies)*
Aruba (hp)	David Logan *(VP, Strategic Initiatives)*
CommScope	Jason Bautista *(Global Workplace Solutions)*, Morne Erasmus *(Connectivity Solutions)*
Corning	Bob Basil *(Solution Architect)*
Distech Controls	Stefani Szczechowski *(Business Development Manager)*
Electrical Training Aliance	Marty Riesberg, *(Director)*
ERMCO	Luke Jackson *(Building Automation Manager)*
Graybar	David Eckell *(Emerging Technology Manager)*, Steve Boschert *(Product Category Manager)*
Legrand	Manny Linhares *(Director of IoT Strategy)*
Lutron	Jeremy Forster *(Sales Manager)*, Eric Lind *(pre-project services)*, Rhodes Baker *(PM)*
NorCal Sound/Comm JATC	Terry Monroe, *(Training Director)*
Oracle	George Denise *(Director of Facilities)*, Doug Bartl *(Real Estate Director)*, Francisco Ruiz *(Facilities Technology Director)*
SAP	Larry Morgan *(Director global facilities)*
Schneider Electric	Mohamed Sadek *(Connected Products Future Offer Manager)*
Sprig Electric	Mark Mandarelli *(President)*, Tim Martin *(VP Low Voltage)*, Bill Aguirre *(Group Executive, Low Voltage)*, Joyce Leedeman *(General Foreman)*

In addition to the interviews, the researcher conducted an extensive review of relevant articles and reports available online from professional and industry organizations. The process also included a review of the studies and reports done by the European Union Energy commission, such as the work on the Future Internet for Smart Energy (FINSEY) project. The following sections summarize the industry review findings.

WHAT IS A SMART BUILDING?

It initially seems a trivial question, but what does a "smart" building eventually mean? How is a smart building different from sustainable buildings or zero-net energy buildings?

Based on the performed interviews and the literature review, the following definition is proposed:

> ***"Smart Buildings contain integrated and optimized systems, services, and facility management that dynamically create a productive, cost-effective, and healthy environment for the occupants."***

The core objectives of a smart building are not new; they were just not satisfied by previous technologies. Energy and sustainability are still high priorities in smart buildings, but they are achieved by *optimizing the management of the facility* and *facilitating the comfort of the tenants* and users. The IoT technologies made it very feasible for the industry to reach unprecedented levels of building intelligence by increasing the sensing covering within the building and providing advanced real-time analytics. Data and analytics are critically needed to connect the building organization stakeholders on the three extremes: facilities operations, executive officers, and building users. As millennials enter the workforce, the new generation of building facility managers and engineers will be more willing to gamify their practices and introduce more smart building and IoT technologies into their practices. **Smart buildings allows for moving beyond remotely controlling the building to the point where the building itself communicates back to the facility manager and building users with useful insights and alerts.**

It is worth noting the difference between smart building design and smart building systems. Buildings can be smartly designed by integrating an array of passive sustainable concepts that capitalize on local environment conditions to optimize building performance and tenant comfort. This might include integrating natural lighting, vitalization and thermal potential into the design of the building and its systems. However, as the name implies, passive design approaches usually require a static climate with not many seasonal variations - not a realistic assumption for most buildings. **Conversely, smart building systems leverage smartly-engineered passive design approaches by making the building systems dynamically adapt to both environmental conditions and tenant needs.** With their intelligent sensors and controls, smart buildings can dynamically channel available natural lighting, ventilation and thermal potentials to reduce the building's energy footprint and improve tenants' wellbeing with less facility operational complexities and burden.

The manufacturers interviewed provided the most comprehensive description of smart buildings, due to their active market research programs that connect customer real needs to the latest technologies. However, the EC representatives interviewed focused mainly on the installation and networking aspects of smart buildings.

SMART BUILDING SYSTEMS

Many smart building technologies and solutions exist. Therefore, they should be examined in relation to the main functions of the building and end-user needs. Table 2 lists the main common building systems as categorized under eight building functions: energy, user comfort, security, safety, audio/visual, IDC (IT, data, and communication), transportation and business. The installation of these systems has historically fallen under two business groups in the electrical contracting firms: low-voltage and building automation. The possible reasons for this strategic business distinction include the fact that building automation controls have been implemented earlier than the low-voltage systems, so some ECs have already created their building automation groups ahead of the smart building movement.

> *In today's environment, it is minimally expected to have sophisticated building automation in new buildings, regardless of the smartness level of the building. However, most low-voltage systems are still considered luxurious amenities that are installed in large buildings such as Class A offices, healthcare, and hospitality. As such, this work volume difference between low-voltage and building automation systems may justify creating their separate business groups within the EC firm.*

Table 2: Smart Building Systems as organized by their Typical Business Groups

Building Functions	Business Groups	
	Low-Voltage Systems	Building Automation
Energy	Submetering, Smart plugs & Power Strips, BTU Meters, Energy Management Systems	
User Comfort	Window Shading, Window Solar Films, Occupancy Sensors, Tenant Comfort Feedback	HVAC Controls, Lighting Controls
Security	Access Control, Video Surveillance	
Safety	Mass Notification	Fire Alarm
Audio/Visual	Digital Signage, VoIP, Sound Reinforcement, Video Distribution	
IT, Data, and Comm	Structured Cabling, Data warehousing, Distributed Antenna System (DAS)	
Transportation	Parking Management, Electric Vehicle Charging Stations	
Business-related	Real-time Location Tracking, Vending Machine Controls, Smart Pool Controls	

Control system communication protocols and Integration software products are very essential for a smart building to reach the most potential and benefits out of its individual systems. Due to market competition, manufacturers of every building system procured their products compatible with their proprietary communication protocols. In the late 1990s, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) developed BACNet (Building Automation Control network) data communication protocol as the industry standard to allow the integration between different building control systems. It was initially intended to be a generic standard to integrate all building control systems, but gradually ended up mainly adopted for heating, ventilation and air conditioning (HVAC) systems.

Subsector industry groups have developed other standardized communication protocols such as LonWork, Dali, ModBus and others shown in Table 3. Besides protocols, integration platforms are important to assimilate seamlessly the automation data coming from the different building devices and perform insightful analytics for facility managers and engineers. Tridium Niagara is currently the most dominant integration platform in the industry. However, other platforms provide similar competitive capabilities, such as Fin 4.0 (by J2Innovations and acquired by Siemens), KMCCommander (by KMC in partnership with Intel and Dell), and EcoStruxure Building Operation (by Schneider Electric).

Table 3: Standard building automation communication protocols[1]

Protocol	Year Developed	Medium	Application	Standard
BACNet	1995	Cable	HVAC, lighting, fire protection, and physical security (access control, intrusion)	ANSI/ASHRAE 135, ISO 16484-5
Lonworks	1999	Cable	HVAC, lighting (interior and exterior), process control, home automation	ISO/IEC 14908, ANSI/ CEA-709/852
KNX	1999	Cable & Wireless	HVAC, lighting, security, remote access, blind and shutter control, visualization, and energy management.	ISO/IEC 14543-3, ANSI/ASHRAE 135
DALI	2000	Cable & Wireless	Lighting controls (ballasts, low-voltage transformers, photoelectric cells, motion detectors, wall switches)	IEC 62386
Clipsal C-Bus	2008	Cable	Mostly for lighting control, but can be used for electrical loads (control pumps, motors, etc.)	N/A
Modbus	2004	Cable	Building, infrastructure, transportation, and energy applications.	N/A
M-Bus	1990s	Cable & Wireless	Meters, valves and actuators for water, gas, heat, and electrical services.	EN 13757
OPC	1996	Cable	Security, lighting, elevator, and HVAC.	N/A
oBIX	2005	Cable & Wireless	Mechanical and electrical systems	N/A
EnOcean	2008	Wireless	Occupancy sensors, lighting controls, key card switches.	ISO/IEC 14543-3-10
ZigBee	2007	Wireless	Room and HVAC controllers, as well as door/window contacts and occupancy sensors.	IEEE 802.15.4

1. Adopted from "Guide to Open Protocols in Building Automation" published by Schneider Electric in 2015

UNIQUE DESIGN AND CONSTRUCTION CHALLENGES OF SMART BUILDING PROJECTS

Even with the opportunities created by the latest great developments of smart buildings, the industry faces customer, financial, workforce, security and technological challenges.

DIFFICULTY TO QUANTIFY THE IMPACTS OF SMART BUILDING SYSTEMS AND JUSTIFY THEIR INVESTMENTS

Despite the clear understanding of the impact of smart building technologies, facility managers find it difficult to quantify such impacts and justify (for their executives) the capital investment in these technologies. Facility management professionals started using a concept called *"3-30-300" (JLL 2014) to describe the impact of their facility improvements. This is a rule of thumb that organizations typically spend around $3 per square foot per year for utilities, $30 for rent and $300 for payroll.* While these values are not just archetypes, they reflect a fair reflection of the reality that businesses face with their facilities. It is clear that building energy upgrades can reduce the $3-average utility expenses. Smart system upgrades can result in higher space utilization (savings in the $30-average rent) and better workspace productivity (more out the organization's $300-average payroll).

It is easy to quantify the impact of energy upgrades (e.g. how many kWh are saved by installing solar panels or LED lights), but this is not the case for smart IoT system investments.

Although people spend about 90% of their time in buildings, quantifying the impact of the indoor environment quality on the occupants' well-being is not easy to quantify (Al horr et al. 2016). Numerous studies reported a clear correlation between building environment, comfort level, and productivity. Dr. Jacqueline Vischer's work (2003) developed an environment conceptual model comparing physical, psychological, and functional comfort of the workspace to the effectiveness and productivity of the individual and collective workforce. Different industry studies (Comfy 2016) reported productivity gains between 2.7% and 8.6% when employees have greater control of their work environment. Despite these conceptual and empirical understandings of the comfort-productivity relation, there is no objective numerical approach to quantify the impact of IoT comfort and building automation technologies on the building tenant nor to calculate the financial return of investing in such technologies.

OWNERS STRUGGLE TO SPECIFY SMART BUILDING CAPABILITIES AND REQUIREMENTS

Most clients and facility owners are not well aware of the capabilities and requirements of smart buildings. Building owners and operators are slow to adopt smart technologies for several reasons. Some are simply not aware of them. Those who are aware of them may never have used them and may view them as too complex. Once they start using these technologies, they may be unprepared to manage the new equipment and software and they may find the learning curve too steep. Most operators have little to no experience analyzing large amounts of building performance data. They (and the building owners) may not like realizing they have been operating their buildings inefficiently for years. A commitment from electrical manufacturers, NECA and IBEW to reach out to local and regional customer bases in the form of training/seminar programs could help develop a greater understanding and awareness of the technologies in mid-size commercial real estate markets.

Besides the hard task of quantifying smart building goals, it is equally hard to specify the design and construction requirements of smart building technologies in the form of project contractual documents. Even now, building systems are still engineered, procured and installed in silos by different firms, even under the integrated project delivery (IPD) lean approach. This includes the automation of each system that is either engineered in-house or subcontracted to a specialized automations firm. For example, mechanical contractors can subcontract (from their contract) automation work to either a building automations firm or an electrical contractor. This traditional construction approach to smart building infrastructure pushes down most implementation details and technology choices to multiple levels of contractors. In turn, these professionals design, procure, and implement infrastructure systems without any collaboration of effort or choices across disciplines.

However, the increased complexity of smart buildings requires bundling all automation and control systems in a single package to ensure interoperable integration of the different automation systems. Also, a successfully integrated system will add greater value to the overall project as opposed to each individual design discipline that uses embedded technologies to monitor and control its respective systems.

For example, lighting and HVAC have many overlapping features, such as zone occupancy sensors and schedules, front-end visualization software, tools for setup and configuration, Ethernet and fiber-optic cabling, and communication protocols. These similarities present an opportunity to remove duplications and minimize the number of devices required to accomplish the same goal; automation tasks can also be streamlined once the systems are live. All of this adds up to eliminated waste. Similar observations can be made in other smart building systems, such as access control, closed-circuit TV, life safety, utility metering, and solar and energy storage. **The importance of eliminating inefficiencies and minimizing waste in any building is no longer a value add. Today, it is a necessity for the long-term lifecycle management of any smart building.**

As such, industry groups have started implementing and advocating for a dedicated division in the Construction Specifications Institute (CSI) MasterFormat standard, called Division 25: Integrated Automation, to coordinate the design and construction of building automation systems. Division 25 was added in the 2004 updated version of the CSI MasterFormat. The key aspects covered by Division 25 include:

- *Open system design (but it is based on Tridium)*
- *BACNet/IP is the main communication protocol*
- *BTL certified devices*
- *The existence of "system integrator" role, which can also be replaced by a Controls Contractor*
- *Niagara Compatibility Statement (NiCS)*
- *Big emphasis on HVAC and lighting*
- *Individual system integrators for building automation (Distech controls) and lighting controls (Acuity Brands).*
- *2D CAD submittals, no integration into BIM.*
- *BACnet Protocol Implementation Conformance Statements (PICS)*
- *Control System Diagrams*
- *I/O Point Lists*
- *Warranty for hardware and material, software modifications are expected during the warranty period.*
- *Lighting controls are programmed first before building controls.*
- *Double usage of occupancy sensors (lighting + HVAC)*
- *User interface requirements.*

In its early days of implementation, industry reaction to the use of Division 25 has generally been subdued. It was a totally new division unlike many of the older spec divisions that were just renumbered and revised. It did not have the detailed specifications found in other specification divisions such as structural, mechanical and electrical. Also, there was some confusion as to which divisions were to carry parts of building systems. This does not mean that Division 25 has not been used but that it has been underutilized and typically addressed much later in the design process. Still, Division 25 holds the potential to facilitate better programming, design, and construction of new smart building systems.

ABSENCE OF INDUSTRY INCENTIVE PROGRAMS FOR SMART BUILDING INVESTMENTS

Another barrier to smart building prevalence is the long replacement cycle for building infrastructure. It is all too common for building systems to undergo upgrades only at the point of failure. In many cases, this occurs later than the system's expected useful life due to the lack of capital funds dedicated to building upgrades (JCI 2016). This barrier is even more apparent for smart building upgrades based upon the following two main causes:

- *The lack of established quantification metrics for smart building performance. Unlike energy efficiency upgrades, it is hard quantify the impact installing IoT technologies has on achieving the real goals of smart buildings (i.e. user comfort and facility operational efficiencies). It is easier to quantify the kilowatts saved for building energy upgrades, making it easy to justify such work financially.*
- *The lack of tax incentives is a barrier to investment. Without incentives, many building owners require more evidence that smart buildings are worth the high costs, especially in underrepresented applications such as small- and medium-sized buildings and class B commercial real estate.*

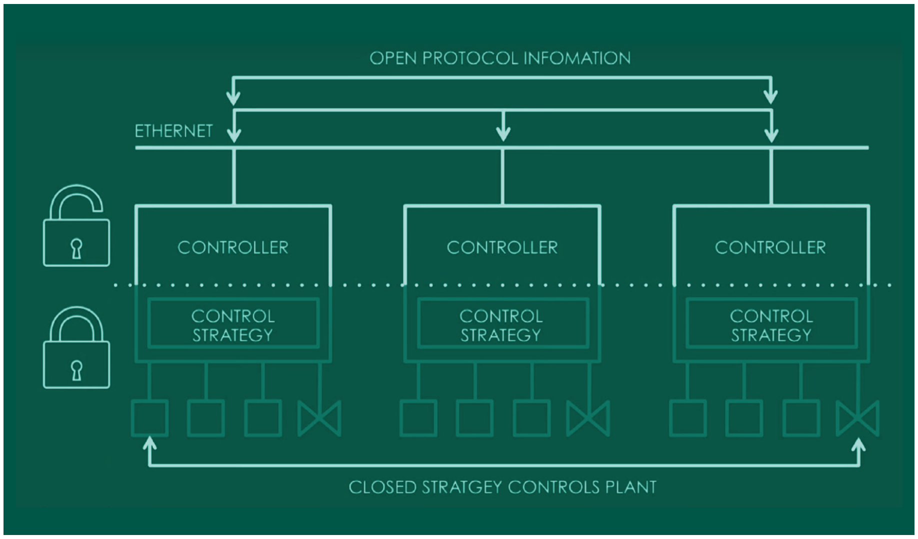
LACK OF INTEROPERABILITY BETWEEN IOT DEVICES

Despite great progress in communication standardization for smart buildings, the industry still lacks seamless interoperability between building systems and devices. True interoperability in the smart building market has not been realized due to the following issues:

- *Although open communications protocols (BACnet, Lonworks, ModBus, etc.) allow some products from different manufacturers to communicate, no single standard protocol exists that lets all smart equipment and devices communicate. While having a single protocol is not feasible in the near future, differences between existing protocols is a significant source of waste in the smart building industry.*
- *Even with great help from available integration platforms (Tridium Niagara and KMC Commander), not all data and control settings are accessible. As shown in Figure 1, these platforms allow for easy access to the control points and their data, but only those that are unlocked in the controllers by the original manufacturers. Also, proprietary protocols are still used within the hardware devices of these platforms, such as the Fox protocol of Tridium Niagara.*
- *Current well-established communication protocols (like BACNet) might not provide the desired interoperability level due to scalability issue under future large IoT implementations. BACNet was designed with a vision of connecting tens or few hundreds of devices within a building. But, IoT will push the limits and increase the number of connected devices. This, in turn, may cause performance issues when implementing BACNet protocols. These issues originate from the compatibility of the broadcast packets with standard IT infrastructure practices and the lack of scalability beyond the physical boundaries of the building to enable remote controlling and monitoring over the internet and cloud. As such, a new BACNet addendum (i.e. BACNet/IT) has been proposed and is still under development. It would resolve the scalability issues of BACNet when implemented over the IT networks and revive its interoperability role for smart buildings.*

Industry organizations have been established to develop open-source public communication standards in response to the interoperability issues with current smart building systems. Although these organizations are primarily focused on general IoT applications especially the smart home market, the success of their standards can easily encourage the commercial construction industry to change. Examples of these interoperability standards and their organizations include:

Figure 1: The mirage of open interoperability in current integration platforms[2]



Project Haystack: It is an open source initiative to develop standardize 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 smart building devices in automation, energy, HVAC, lighting, and other building systems. In February 2018, ASHRAE announced it will collaborate with Project Haystack to overcome interoperability issues with BACNet in the new proposed ASHRAE Standard 223P.

Open Connectivity Foundation: "The Open Connectivity Foundation (OCF) is creating a specification and sponsoring an open source project to unlock the massive opportunity in the IoT market, accelerate industry innovation, and help developers and companies create solutions that map to a single open specification." OCF will help ensure secure interoperability for consumers, businesses and industries.

AllSeen Alliance: "A cross-industry consortium dedicated to enabling the interoperability of billions of devices, services and apps that comprise the Internet of Things." Qualcomm kicked this off as AllJoyn and then handed the source code to the Linux Foundation where the AllSeen Alliance was born.

Thread Group: Founded by a variety of vendors, including ARM, Nest, Samsung and Silicon Labs, the Group has a mesh network based on Google Nest's protocol, designed securely and reliably to connect hundreds of products for home appliances, access control, climate control, energy management, lighting, safety, and security -- without blowing through battery life.

Open Interconnect Consortium: It brings together powerhouse chip and electronics manufacturers to collaborate on an open specification for interoperability on the Internet of Things. Backers include Atmel, Broadcom, Dell, Intel, Samsung and Wind River. OIC's goal is to create standards that will allow home computers, mobile devices, and smart appliances to work together regardless of brand, operating system, or other details.

2 Adopted from Darren Wright's lecture (from Arub), titled "Death of the Controls Industry". https://www.youtube.com/watch?v=aMCLmkfYvm0&feature=youtu.be

DISCONNECT BETWEEN IT AND OT

Operational technologies (OT) refers to control systems on the factory floor or industrial facilities. Similarly, OT in smart buildings refers to control systems and their communication mediums. At first, OT might look and feel like traditional Information Technology (IT) systems within a business enterprise, but there are several key differences between IT and OT that are becoming more apparent in the smart building field. Table 4 summarizes the differences between the IT and OT groups, differences that impose challenges when these groups need to collaborate in a new smart building project. Acknowledging these differences is a vital first step for the success of the smart building project.

Table 4: Differences between IT and OT in smart buildings

Information Technology (IT)	Operational Technology (OT)
Run by IT professionals	Run by facility managers and engineers
Critical Priorities: 1) Data Confidentiality 2) Data Integrity 3) Data Availability Main concern: cybersecurity	Critical Priorities (flipped): 1) Data Availability 2) Data Integrity 3) Data Confidentiality Main concern: Continuous operations
User-centric communication	Machine-to-machine communication, but starts to include some user experience aspects
Unpredictable traffic behavior	Predictable traffic behavior
Devices are assigned IP addressed dynamically	Devices have static IP addresses
Remote access is kept to the minimum	Remote access is needed for vendors and operators
Stronger position within the enterprise	Weaker position within the enterprise

GREATER CYBER SECURITY THREATS

IoT-based smart buildings require the convergence of IT and OT groups. This imposes greater cyber security threats on the enterprise and its assets. The massive cyber hack on Target (the commercial chain store) was indirectly attributed to the HVAC maintenance company in one of the stores. Although the BMS was not directly hacked in this specific incident, it confirmed the increase of IT cyber threats due to the expansion of the IT security perimeter beyond traditional boundaries.

Building owners are growing increasingly concerned about cybersecurity, including the potential for widespread disablement and safety concerns for building occupants once a building's management system has been connected to the Internet. These concerns are justified as the number of security breaches has increased as buildings have become more interconnected. In late 2016, IoT devices contributed to a major cyberattack, temporarily disabling services such as Twitter, Spotify, and PayPal (Peterson 2016). An analysis of the vulnerability of smart buildings by Frost & Sullivan (2015) stresses the importance of the IT and operational technology (OT) industries collaborating to develop and implement strategies to mitigate cybersecurity threats.

Smart buildings impose the highest risks on the enterprise's IT system when system devices are easily searchable by hackers and are not protected behind firewalls or secured links. Friendly "hacking" search engines are already available online to search for assets (devices) with public IP addresses that are accessible over the internet. Examples of these friendly hacking search engines include: Shodan (https://www.shodan.io/), Censys (https://censys.io/), and ZoomEye (https://www.zoomeye.org/). A simple search using these websites will return a significant number of non-protected publicly accessible building automation assets in any location in the world. If this is a scary finding available from some amateur tools, consider the results of experienced hackers targeting the assets of multi-billion dollar companies.

Mitigating cyber threats in smart buildings is feasible but would require changing historical OT practices and redrawing IT-OT responsibility lines. When BACNet IP was first introduced, no passwords were required to access building automation devices. Also, control system passwords are usually not hard to crack. BACNet Broadcast Management Device (BBMD) is a very critical asset in building automation systems as their hacking can be a huge vulnerability to the whole IT and OT network. Cyber security frameworks have been implemented for decades and do provide great effectiveness against most threats. However, applying these security frameworks and standards will likely take away some of the freedom that operation managers and engineers enjoyed when running the automation systems.

GREY LIABILITY BORDER BETWEEN SOFTWARE AND HARDWARE INSTALLATIONS

The performance of the smart building is dependent on both hardware installation and software deployment. ECs are well-accustomed to hardware installations due to wide experience with low-voltage systems and the existence of their training curriculum. However, there might be issues with the firmware/drivers installed in the controllers or the integration platform deployment. In addition, performance issues with the building systems may originate from some networking problem, especially in the points where OT converges with the IT network. All these hardware, software, and networking problems fall into the territories of different project participants, when there is no involvement of a master integrator.

CONTINUOUS TESTING AND CERTIFICATION OF SMART BUILDING SYSTEMS

With all the projected IoT installations, a building transforms from a physical environment into a large complex electronic instrument that is expected to provide the anticipated user experience (UX). To avoid faulty data and analytics, building systems need to be tested and validated on a continuous basis. This requires significant training of the facility management team or service-contracting with a master system integrator.

POWER DEMAND REQUIREMENTS FOR SMART BUILDING IOT

A hidden cost of deploying IoT devices in smart building is supplying the power to these devices over their life time. The devices will be powered either by batteries, energy harvesting, or Power of Ethernet (PoE). Each of these power supply alternatives comes with its own challenges. A low-energy IoT device will require changing its batteries every 7 years (Farnell 2017). Multiply that by the large number of devices and the facility management team can end up with another tedious task responsibility. Energy harvesting is a passive approach to batteries, but this is not reliable as it depends on the availability of the harvest energy source (light, heat, etc.). Both batteries and harvested energy provide limited power supply to the devices, which constrain their impeded computing power. On the other hand, PoE will require extending a CAT 6 cable to each smart device. This will impose installation challenges when scaling up to large IoT-based smart buildings due to cable bundling and run length limits.

INCREASED DATA MOBILITY REQUIREMENTS AND IMPEDIMENTS IN BUILDINGS

The sustainable and green building movement resulted in tighter building envelopes that impede the signal strength of cellular network service for users inside the building. Data mobility has increasingly become a requirement in buildings that serve public users, such as sport arenas, convention centers, hospitals, airports, etc. Building visitors may still need access to their cellular data inside buildings for convenience or cyber security reasons. The need for data mobility inside buildings will increase the complexity of smart buildings by requiring installation of distributed antenna systems (DAS). With the introduction of faster cellular networks and small cell technology, DAS systems will be more granular and compete for the limited power and space resources within the smart building.

THE ROLE OF THE ELECTRICAL CONTRACTING INDUSTRY IN THE SMART BUILDING MARKET

Through their experience with low-voltage and building automation systems, ECs have accumulated a sufficient foundation to expand into the smart building market. In the early 2000s, ECs started penetrating into the growing market of low-voltage systems (O'Mara 2007), and became the trusted installers for video surveillance, data communications, and access control. Electricians had the versatile skill set that made it easier for them to learn to become low-voltage installers, not the other way (Finley 2006). As more buildings migrate from pneumatic to electronic controls, ECs have conquered the market of building automation by installing the control systems for HVAC and life safety systems. The energy-efficient building movement made ECs a critical trade partner to engineer and install renewable energy systems. Finally, NECA and IBEW have relentlessly invested in their Electrical Training Alliance (ETA) programs to keep electricians and technicians on top of the required knowledge and skills in low-voltage systems, building automation and renewable energy.

Manufacturers plays a significant role in advancing the smart building market through research, development, and standardization. Manufacturers have the financial and staffing capacity for the critical research and development (R&D) needed to commercialize the latest IoT technologies. But, their R&D should focus on the end-customer needs, not solely for the sake of introducing new technologies. In addition, manufacturers have slowly committed to standardization after decades of legacy systems and proprietary communication protocols. They should continue their contribution and commitment to industry standardization groups to ensure their future growth and the advancement of the whole smart building market. The industry has witnessed increased merging and acquisition events in the last years, where large manufacturers acquire small innovative IoT and integration platform firms. Despite their industry-wide efforts, manufacturers need to partner with regional and local electrical contractors to communicate directly with project owners and install their smart building products and systems.

Electrical contractors are at a tipping point to pursue more roles and opportunities in the growing market of smart buildings. The industry is going through the same hesitation as it did when ECs debated entering the low- voltage systems market in late 1990s. Now, there are NECA electrical contractor members with dedicated low- voltage system groups and other members who just specialize in low-voltage systems. With low-voltage and building automation groups, ECs are already on the forefront of installing the latest systems of smart buildings. Some ECs have in-house certified network designers and engineers to provide design-assist to owners during the project development and engineering phases. However, ECs need to be more open to the possibility of playing the master systems integrator to grow further in the smart building market. There are already a few cases of electrical contractors (mostly small size) who transformed into master system integrators primarily to oversee the design and engineering of the different control systems.

WORKFORCE TRAINING AND DEVELOPMENT

The current NECA/IBEW training programs have already prepared (over a number of years) the curriculum and materials that can be used to prepare their workforce for the smart building market. For years, the installer/technician (ITech) classification has been available for IBEW members who are interested in low- voltage systems, dealing primarily with video, data, and voice (VDV). As shown in Table 5, the Electrical Training Alliance (ETA) has prepared a three-year training curriculum for the ITech career path. It can be adopted by local Joint Apprenticeship and Training Committees (JATCs) to train their apprentices.

Table 5: Installer/Technician Curriculum of the Electrical Training Alliance (ETA)

Topic	1st Year	2nd Year	3rd Year
Blueprints	✓		
Code & Practices	✓	✓	
DC Theory	✓		
Fiber Optics	✓		
Installer/Tech Job Information	✓		
Orientation	✓		
Structured Cabling	✓		
Test Instruments	✓		
Mathematics	✓		
AC Theory		✓	
Fire Alarm		✓	
Grounding		✓	
Power Quality		✓	
Local Area Networks		✓	
Paging & Voice Evacuation		✓	
Security Systems		✓	
Telephony		✓	
Building Automation			✓
Closed-Circuit TV (CCTV)			✓
Nurse Call Systems			✓
RF Communications			✓
Semiconductors			✓
Sound Reinforcement Systems			✓

For the workforce review, the researcher utilized available data from the Electrical Training Alliance (ETA) annual survey in concert with the conducted interviews. A total of 270 local JATCs responded to the survey conducted by ETA in 2017. The survey was well-detailed with over 150 questions related to the apprenticeship program, membership, pay rate, and the demographics of the different IBEW labor classifications, including installers/technicians. This survey was useful to investigate workforce training issues further during the interviews.

Despite NECA/IBEW training efforts, interviews raised some workforce issues related to the lack of adequate building automation training, the local availability of qualified technicians, and their readiness to obtain industry certifications and credentials.

- As shown in Table 5 on the previous page, ETA ITech curriculum lacks in-depth training on building automation systems (BAS). Building automation training requires covering important topics related to HVAC Basics, space condition controls, air handler controls, energy conservation control strategies, fire/safety systems, DDC Controllers, and Field Devices. This important topic is covered only in the 3rd apprenticeship year while one of its underlying topics (fire alarm) is covered in the second year. As mentioned by one interviewee, "BAS is a real specialty, that is more specialized than lighting controls". Some local unions acknowledged this gap and established their own training centers supported by local NECA members and jurisdictions, such as the Net-Zero Energy Center (NZEC) in San Leandro CA, and the Net Zero Plus (NZP) Center in Los Angeles CA.

- Although the ITech curriculum is nationally available by ETA, it is not implemented in the local JATC programs or is only partially implemented. Some interviewees complained they could not find IBEW ITechs in some locals. As shown in Table 6, the largest number of installers/technicians and their apprentices are found in large metropolitan areas with sufficient local VDV work, as identified in the ETA survey data. Others complained they experience some ambiguity in terms of the requirement of local IBEW to utilize inside wiremen for low-voltage installations. These observations were supported by some of ETA survey data. Around 47% of local JATCs reported in the survey they had no Installer-Technician program in their locals. However, 71% of those who do not have Installer-Technician programs use ETA material and courses for training the local VDV workforce. 65% of those who do not offer the Installer-Technician programs attributed this to the low volume of the local VDV work. 35% of them do not need the program because they use inside wiremen for all VDC work.

Table 6: Local IBEW unions with large Installer/Tech membership and programs as reported in ETA's 2017 Annual Survey

Local Union	State	City	Master Technicians	Senior Technicians	Technicians	Installer/ Technicians	Installers/Technicians Apprentices
164	NJ	Jersey City	0	0	0	575	73
48	OR	Portland	0	0	0	441	80
595	CA	Oakland	0	0	0	365	61
441	CA	Santa Ana	0	0	0	357	71
292	MN	Minneapolis	352	60	94	247	254
38	OH	Cleveland	0	34	0	235	24
1186	HI	Honolulu	0	0	0	199	179
46	WA	Seattle	0	0	471	190	174
302	CA	Pleasant Hill	0	0	0	176	21
26	DC	Washington	0	0	0	149	21
354	UT	Salt Lake City	0	0	0	145	47
481	IN	Indianapolis	0	6	16	136	24
340	CA	Sacramento	0	5	6	132	46
716	TX	Houston	0	0	100	130	0
363	NY	New City	5	0	0	102	0
8	OH	Toledo	0	0	0	101	47
494	WI	Milwaukee	0	0	104	93	19
34	IL	Peoria	0	0	0	90	9
76	WA	Tacoma	0	0	0	89	13
102	NJ	Patterson	0	0	0	85	11
357	NV	Las Vegas	0	180	0	82	29

- Some ECs have to invest time and money in training their IBEW workers to obtain the credentials and certifications required by their customers and manufacturers. Even if the technicians were very competent in different smart building systems, their JATC apprentice programs did not require or recommend that they obtain some of the industry credentials needed for certain projects. Table 7 lists some of these credentials, required either by the project owner in the issued specifications or by the manufacturers to provide their warranties. As such, ECs have had to provide their in-house training or use manufacturer's training to help their technicians be up to date on the current technologies and obtain their credentials.

In addition to the trade workforce, some ECs hire engineers and designers for their low-voltage and building automation operations. These professionals, mostly with college degrees, also need specialized credentials and certifications (see Table 7) to qualify to design cabling, networks, and control systems. Having these professionals in-house is a significant cost center for the EC, but these professionals are critical to provide design-assist and master integration services. However, recruiting and retaining them is challenging to find the right talent interested in building construction careers.

Table 7: Industry certifications related to smart building construction

Organization and its Certification	Data & Ccomm Networks	Ccomm PM	Copper Cable Inst.	Optical Fiber Eng	Optical Fiber Inst.	IT Security	A/V Eng.	A/V Inst.	Solar PV	Wireless Networks
BICSI Registered Communications Distribution Designer (RCDD)	✓									
BICSI Registered Telecommunications Project Manager (RTPM)		✓								
BICSI Data Center Designer Consultant (DCDC)	✓	✓								
BICSI Outside Plant (OSP) Designer	✓			✓						
BICSI Installer 1 (INST 1)			✓							
BICSI Installer 2, Copper (INSTC)			✓							
BICSI Installer 2, Optical Fiber (INSTF)					✓					
BICSI Technician (TECH)		✓	✓		✓					
AVIXA AV Certified Technology Specialist - General (CTS)		✓					✓			
AVIXA AV Certified Technology Specialist – Design (CTS-D)							✓			
AVIXA AV Certified Technology Specialist – Installation (CTS-I)								✓		
ASIS Physical Security Professional (PSP)						✓				
ETA Broadband-Voice over Internet Protocol (B-VoIP)			✓					✓		
ETA General Communications Technician (GCT)			✓							
ETA ARINC Installer, Technician (AFI/AFT)					✓					
ETA Data Cabling Installer (DCI)			✓							
ETA Fiber Optics Designer (FOD)				✓						
ETA Fiber Optics Installer (FOI)					✓					
ETA Fiber Optics Technician (FOT)					✓					
ETA Information Technology Security (ITS)						✓				
ETA Network Systems Technician (NST)	✓									
ETA Wireless Networking Technician (WNT)										✓
ETA Photovoltaic Installer (PVI)									✓	
FOA Certified Fiber Optic Technician (CFOT)					✓					
FOA Certified Premises Cabling Technician (CPCT)			✓		✓					✓
FOA Certified Fiber Optics Specialist (CFOS)					✓					
SCTE•ISBE Broadband Premises Installer (BPI)			✓					✓		
SCTE•ISBE Broadband Premises Technician (BPT)			✓					✓		
SCTE•ISBE Broadband Premises Expert (BPE)		✓	✓					✓		
SCTE•ISBE Broadband Wireless Specialist (BWS)										✓
SCTE•ISBE Broadband Fiber Installer (BFI)				✓						
SCTE•ISBE Business Class Services Specialist (BCSS)			✓					✓		
SCTE•ISBE Broadband Distribution Specialist (BDS)			✓		✓					
SCTE•ISBE Broadband Transport Specialist (BTS)					✓					
SCTE•ISBE Broadband Telecom Center Specialist (BTCS)								✓		
SCTE•ISBE Digital Video Engineering Professional (DVEP)							✓	✓		
SCTE•ISBE Internet Protocol Engineering Professional (IPEP)	✓									

SMART BUILDING RATING SYSTEMS

Smart buildings lacks an established rating system to help in its spread in the industry, similar to the great progress of sustainable and net-zero energy buildings. LEED helped advocate and formalize the sustainable building design and construction movement. Other similar initiatives helped advance the commitment to net-zero energy buildings. Due to the complexity of defining smart buildings, no reliable rating system currently exists to quantify and rank the intelligence of the buildings. As shown in Figure 2, very few systems existed and most of them failed to continue or have been solely used for the market and public outreach of a manufacturer. The only proposed smart building rating system is still under development by the European Union, called Smart Readiness Indicator (SRI). Even if it becomes ready for use, it may not gain popularity without industry-wide support (similar to LEED). It is expected the SRI system will face implementation challenges in the U.S. due to differences in industry composition and energy regulations.

Figure 2: limited availability of smart building rating systems

BUILDING INTELLIGENCE QUOTIENT (BiQ)	• Inactive
Honeywell THE POWER OF CONNECTED — Smart Building Score™	• Developed & applied in India • Used mainly for Honeywell's PR
SMART READINESS INDICATOR (SRI)	• Under development by the EU • Manual finalized in 8/2018 • Requires approval of the European Commission

CONCLUSION

This comprehensive review of the smart building industry revealed great opportunities and challenges for electrical contractors to expand into this growing market. Over the last several decades, electrical contractors have accumulated valuable experience with low-voltage and building controls. This will be useful to expand the electrical contracting industry footprint into the smart building market. However, numerous challenges face such expansion related to:

- *The owners' struggle to specify their smart building requirements*
- *The absence of financial incentives beyond energy upgrades*
- *The cultural and priority disconnects between informational and operational technology groups*
- *The increasing cyber security that comes with connecting building automation systems to the IT network*
- *The blurred liability lines between hardware and software installations*
- *The critical requirement for continuous testing of smart building systems*
- *The challenge of providing reliable and efficient power supply to the large IoT devices*
- *The increased cellular data mobility requirements within the buildings*

REFERENCES

Al horr Y., Arif M., Katafygiotou M., Mazroei A., Kauskik A., Elsarrag E. (2016). *"Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature."* International Journal of Sustainable Built Environment, Elsevier, 5(1), 1 – 11.

Comfy (2016). *The Comfort Productivity Connection.* https://www.comfyapp.com/blog/the-comfort-productivity-connection/. Last accessed 8/24/2018.

Farnell element14 (2017). *Calculating Battery Life in IoT Applications.* Date published: 4th May 2017. https://uk.farnell.com/calculating-battery-life-in-iot-applications, last accessed 8/24/2018.

Finley B. (2006). *"The Reluctant Electrical Contractor: Here's why more electrical contractors don't dig low-voltage wiring."* Electrical Wholesaling, Link: https://www.ewweb.com/news-watch/reluctant-electrical-contractor, last accessed 7/17/2018.

Frost & Sullivan. (2015). *Cybersecurity in Smart Buildings: Inaction Is Not an Option Anymore.* Mountain View, CA: Frost & Sullivan. www.switchautomation.com/wp-content/uploads/2015/12/Cybersecurity-in-Smart-Buildings_-Discussion-Paper.pdf.

JCI (Johnson Controls, Inc.). 2016. *The 2016 Energy Efficiency Indicator (EEI) Survey: Global Summary.* www.johnsoncontrols.com/-/media/jci/insights/2016/be/files/be_2016_eei_global_summary.pdf?la=en.

Jones Lang LeSalle (JLL) (2014). *Green + Productive Workplace.* A white paper by JLL, http://www.us.jll.com/united-states/en-us/Documents/Workplace/green-productive-overview.pdf.

O'Mara D. L. (2007). *"Low-Voltage Contracting: what's in it for you?"* Electrical Contractor Magazine, published online February 2007, Link: https://www.ecmag.com/section/miscellaneous/low-voltage-contracting-whats-it-you, last accessed 7/17/2018.

Peterson, A. (2016). *"'Internet of Things' Compounded Friday's Hack of Major Websites."* Washington Post, October 21. www.washingtonpost.com/news/the-switch/wp/2016/10/21/someone-attacked-a-major-part-of-the-internets-infrastructure/. "

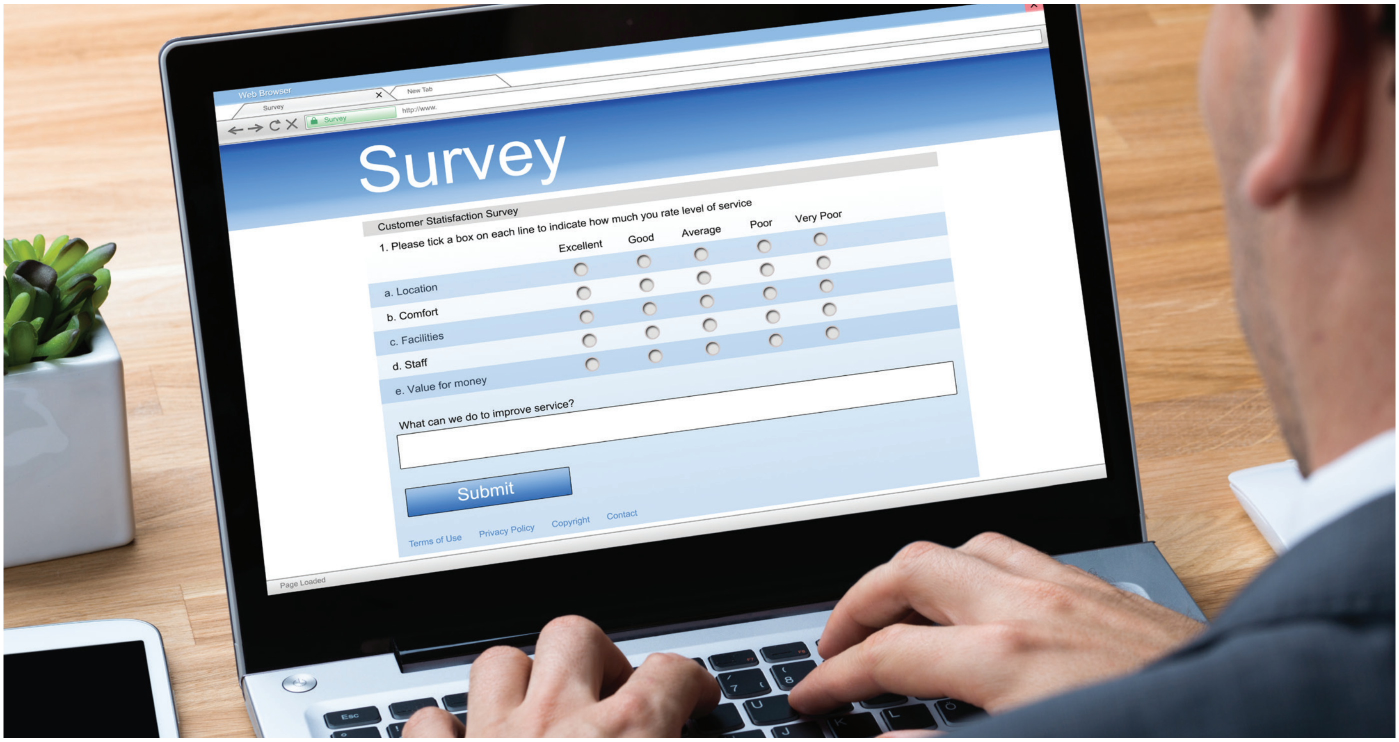
Vischer, J. C. (2003). *"Designing the work environment for worker health and productivity"*. In Proceedings of the 3rd international conference on design and health (pp. 85–93). Montreal, Canada.

CHAPTER 2

ONLINE SURVEY OF ELECTRICAL CONTRACTORS' CURRENT EXPERIENCE WITH SMART BUILDINGS

INTRODUCTION

The purpose of the online survey was to assess the current experiences, business practices, and workforce training needs of a sample of electrical contractors who are involved in the smart building market. The results of this survey should complement the findings of the overall market assessment completed and reported in Chapter 1. The survey data were analyzed using exploratory statistical techniques and visual trends to identify commonality among the different variables and derive critical insights that can help in developing roadmap strategies and tactics.



METHODOLOGY

The survey included 19 questions designed to explore the attributes and relations of the different services, business volume, industry segments, and building system experiences of the electrical contractors involved in the smart and sustainable building market. The survey questions were formulated in a neutral way without implying the assumed hypotheses of the survey. Questions ranged from simple test/number fields, multiple choice, checkboxes, and scales. The survey collected the following specific information:

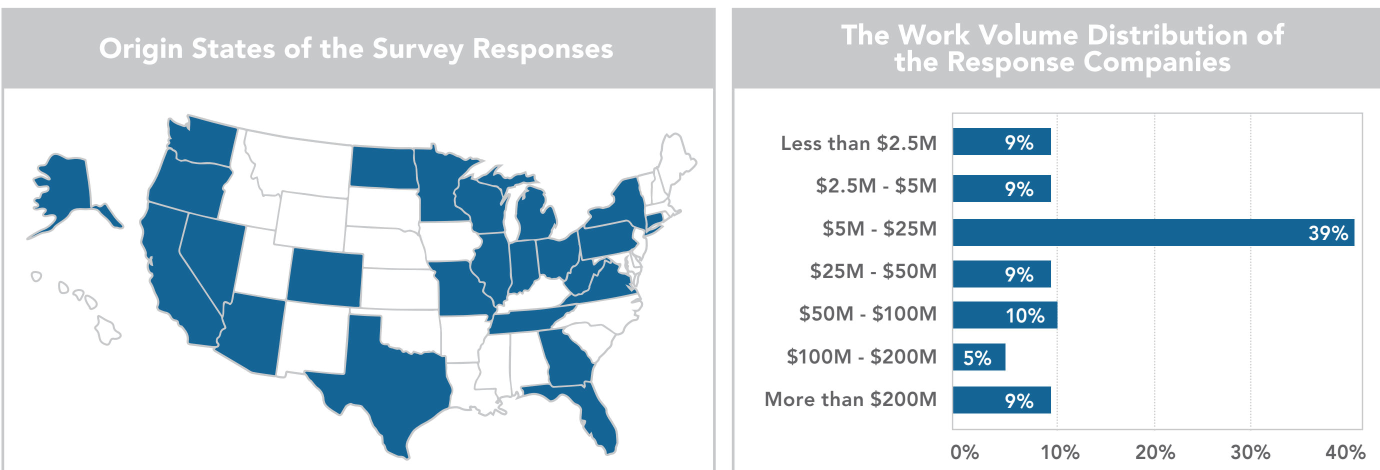
1. Respondent attributes: name, contact information, and work title.
2. Company attributes: location (city and state), work volume (in $), and company type (engineering, electrical contractor, mechanical contractor, general contractor, building system integrator).
3. Services offered by the company, such as design, building automation controls, BIM, commissioning, engineering, installation, prefabrication, and maintenance.
4. Market segments served by the company, such as biotech and pharmaceuticals, office buildings, data centers, education, entertainment, green energy solutions, hotels, industrial, and others.
5. Specialty work performed by the company, such as access control, audio/video, building automation, CCTV, data networks, electrical wiring, energy storage, HVAC, HVAC controls, intrusion detection, lighting, lighting control, and others.
6 Feasibility of the different contractor types to serve as building master systems integrator (MSI) in a smart building project.
7. The design and engineering responsibility of the building control systems (to be done by a single integrating firm, by separate engineering firms, or by different trade contractors as a design-assist service).
8. The existence of trained credentialed technicians and professionals in the different fields related to smart buildings, such as audio/video, communication, copper cabling, data centers, IT security, optical fiber, solar, and wireless networking.
9. Satisfaction of the respondent and his/her affiliated company with training offered by the JATC in the areas of building control, copper cabling, fiber cabling, security systems, and system troubleshooting.
10. Existence of an in-house expert or lead to help the company strategize for the smart building market.

The survey was implemented in Google Forms. The sample of potential respondents was formed using the Judgment sampling technique (Fink and Kosecoff 1985. The online questionnaire link was sent to NECA's email list, which includes about 3,000 electrical contracting firms. The first email was sent on May 14, 2018 and the final response was received on June 12, 2018.

RESULTS

During the short data collection period, a diverse sample of electrical contractors accessed and completed the questionnaire, as shown in Figure 1. The researcher received a total of 108 responses (a response rate of around 3.5%) This was reduced to 93 valid responses after removing duplicate entries and those with incomplete information. Time and resource limitations of this study prohibited an increase of the response rate. Similar industry-wide surveys have also reported low response rates because of the voluntary nature and the large population of possible respondents (Galloway 2006, Rasdorf et al. 2010). However, the diversity of the collected sample can be considered representative of the electrical contracting industry as a whole. Responses came from 24 populous states with major metropolitan areas, and their work volumes ranged from small (<$5M) to large (>$200M). Most responses (42%) came from companies with work volumes between $5 million and $25 million. California was the home of 21.5% of the sampled companies. The sample included 75 electrical construction companies, 3 engineering firms, 1 general contractor, 11 system integrators, and 3 data/comm contractors.

Figure 1: Distribution of the survey responses

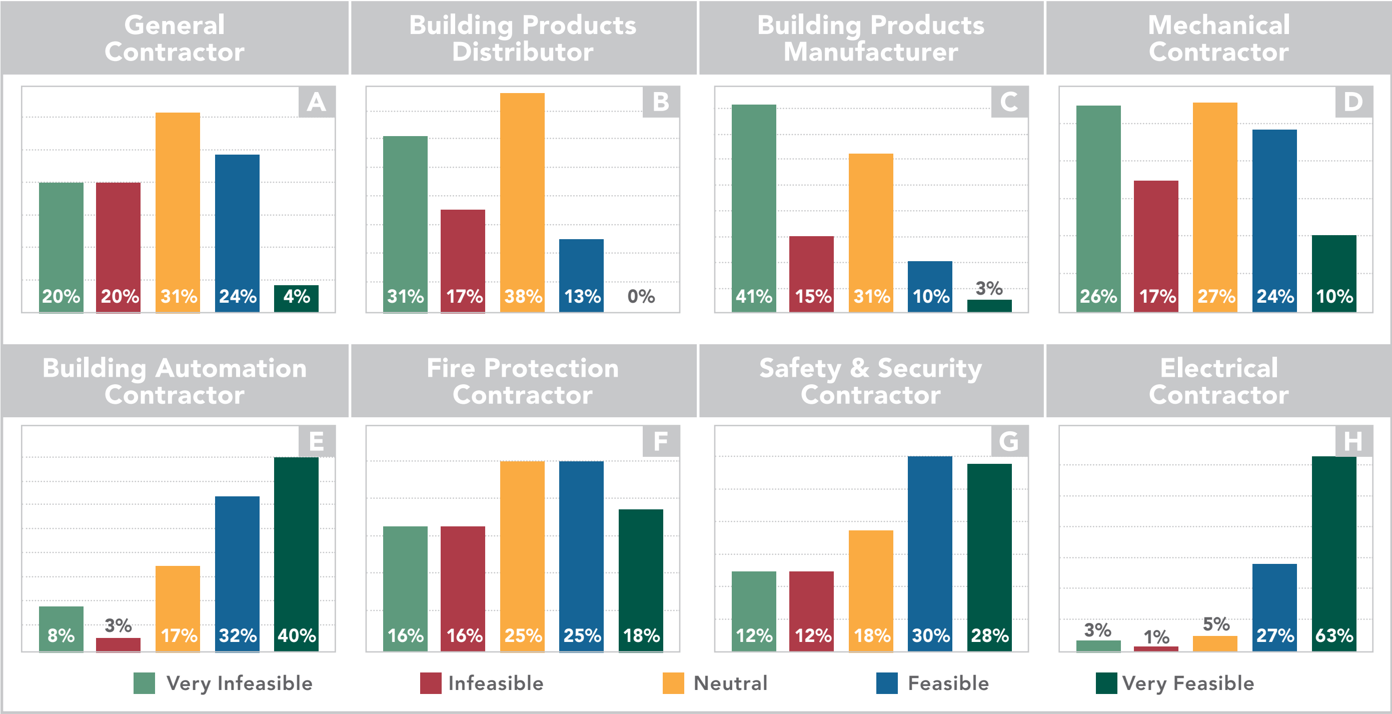


Survey data were analyzed to identify any clear trends and clusters of the sampled companies and their business and workforce practices. Different trends were evaluated by visualizing the data plots in Microsoft Excel, and the statistically significant clusters were identified using IBM SPSS statistical software. The following subsections present the main trend and cluster observations from the survey data.

Data showed that ECs are aware of their potential in the smart building market as master system integrators (MSI), but they also recognize competition from other trade contractors to claim this role. Figure 2 shows the summary data of survey responses (mostly from electrical contractors) to the following question: ***"Please evaluate the feasibility of each of the following project participant to serve as the systems integrator in a smart building project."*** 63% of the respondents believe it is very feasible for electrical contractors to assume the MSI in a smart building project, as shown in chart h. As an average, electrical contractors are considered between feasible and very feasible to fulfill the MSI role.

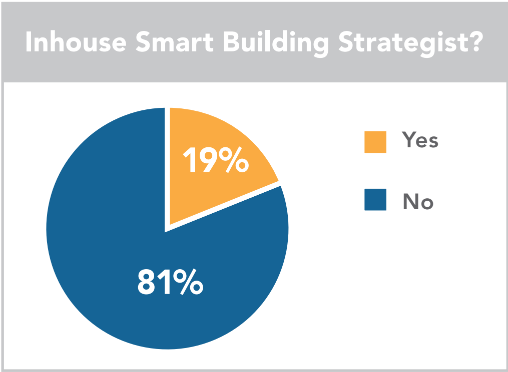
Respondents confirmed the possibility of other project participants to act as project MSI, but with less potential and capabilities compared to electrical contractors. 40% of the respondents believe building automation contractors can act as MSI, probably due to the significant impact of their control systems on the energy efficiency of the building. As an average, building automation contractors were ranked between neutral and feasible to act as MSI for a smart building. The third possible project participant to act as MSI was the safety and security (S&S) contractor, with 28% of the respondents confirming it is very feasible for S&S contractors to take on the integration role. This finding can be attributed to the fact that systems installed by the S&S contractors have direct interaction with the building tenants and their daily tasks, which is an integral part of the smart building scope. For example, some security companies (such as ADT) have easily infiltrated the smart home automation market through their existing user interaction portals that can be expanded beyond basic security functions to include other automation tasks, such as lighting, comfort, and energy.

Figure 2: The feasibility of different project participants to serve as Master Systems Integrator (MSI)



Despite the ECs' great potential in the smart building market, most of them do not dedicate in-house personnel to strategize on their future business plans. As shown in Figure 3, only 19% of the respondents stated they have a fully- or partially-dedicated staff in their company to coordinate smart building market strategies. Having this strategist in-house can help in challenging the fear of change within the company, learning about the smart building new technologies, and identifying the unique market expansion opportunities that can relate to the company's existing business strengths and limitations.

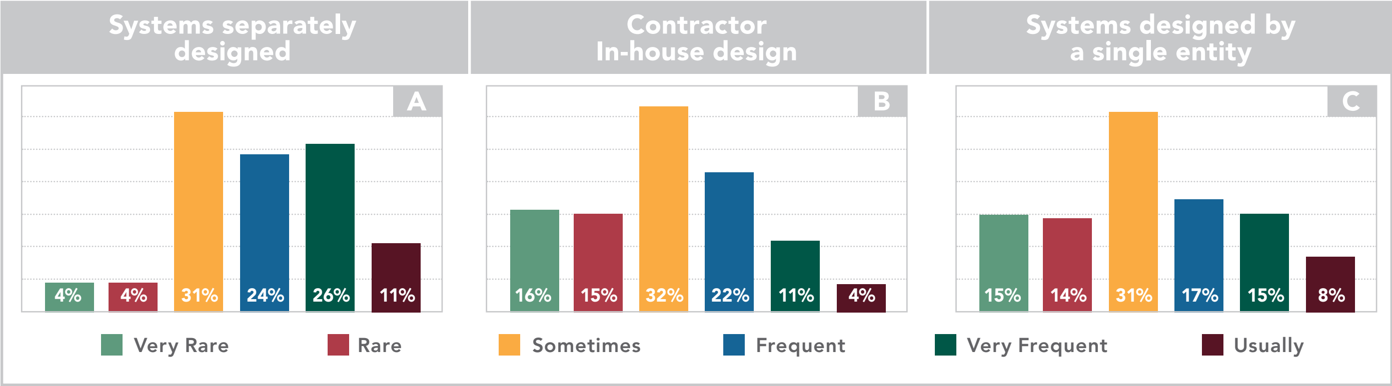
Figure 3: The existence of in-house smart building strategists in the sampled companies



Building control systems are still designed in a silo-based approach without realizing the potential benefits of their integrated design. Figure 1 summarizes responses for the following question: ***"In your experience, how frequently did you witness each of the following design team configurations in terms of responsibility of designing the building automation and control system (HVAC, lighting, fire alarm)?".*** The available answers were: very rare (less than 5%), rare (5% – 10%), sometimes (10% - 25%), frequent (25% - 50%), very frequent (50% - 75%), and usually (more than 75%). 61% of the survey participants agreed that building control systems are designed separately in more than 50% of their projects (See chart a in Figure 4).

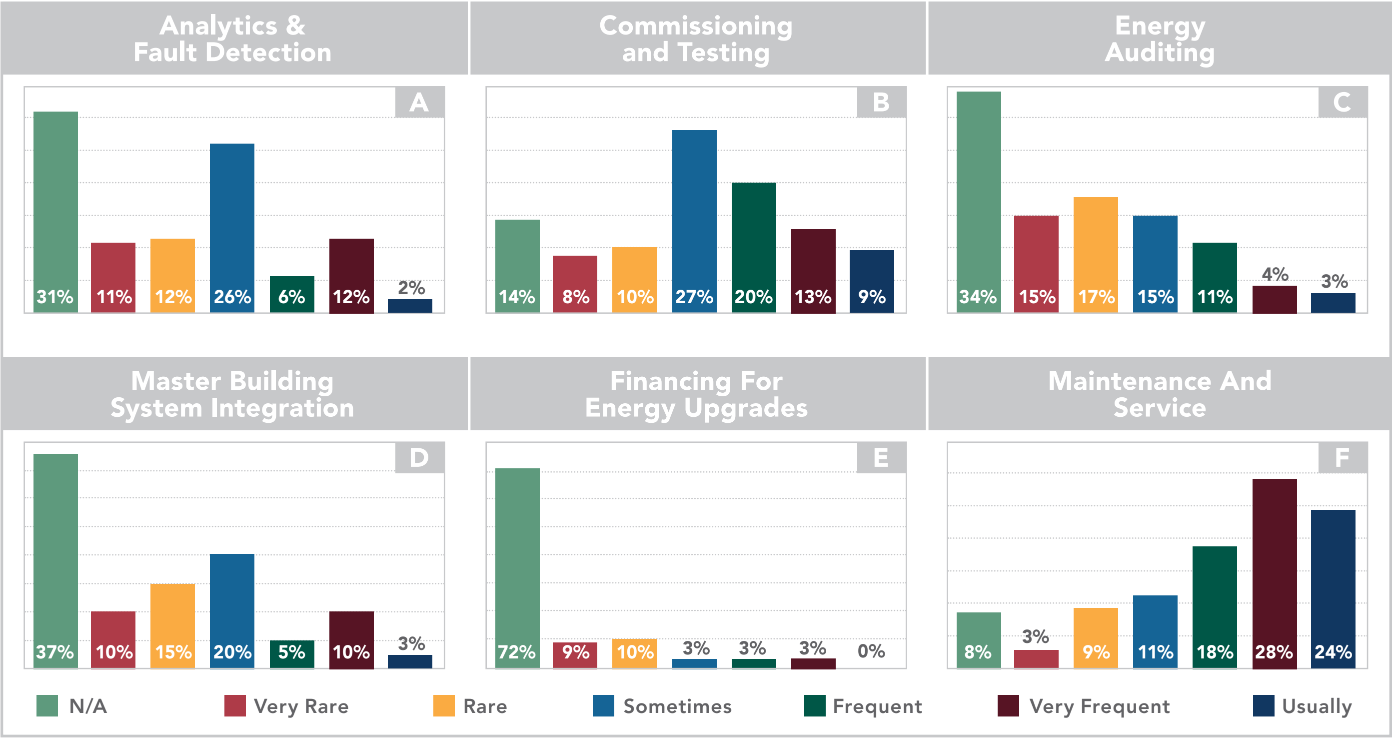
Fewer responses showed these systems as designed or engineered by the trade contractors or by a single entity that plays the role of project MSI. This represents both a challenge and opportunity for electrical contractors to take on a more integral role in smart building projects. The shown data confirmed that project owners are still used to separating the project work scope into the traditional trade packages. However, ECs can present themselves as MSI who can integrate and coordinate the engineering and installation of the hardware and software of smart buildings for the optimal performance of the building systems. The use of MasterFormt Division 25 can be the contractual standard that can help in formalizing the MSI services, responsibilities, and liabilities.

Figure 4: How are the different building system controls (HVAC, lighting, fire alarm) are currently being designed?



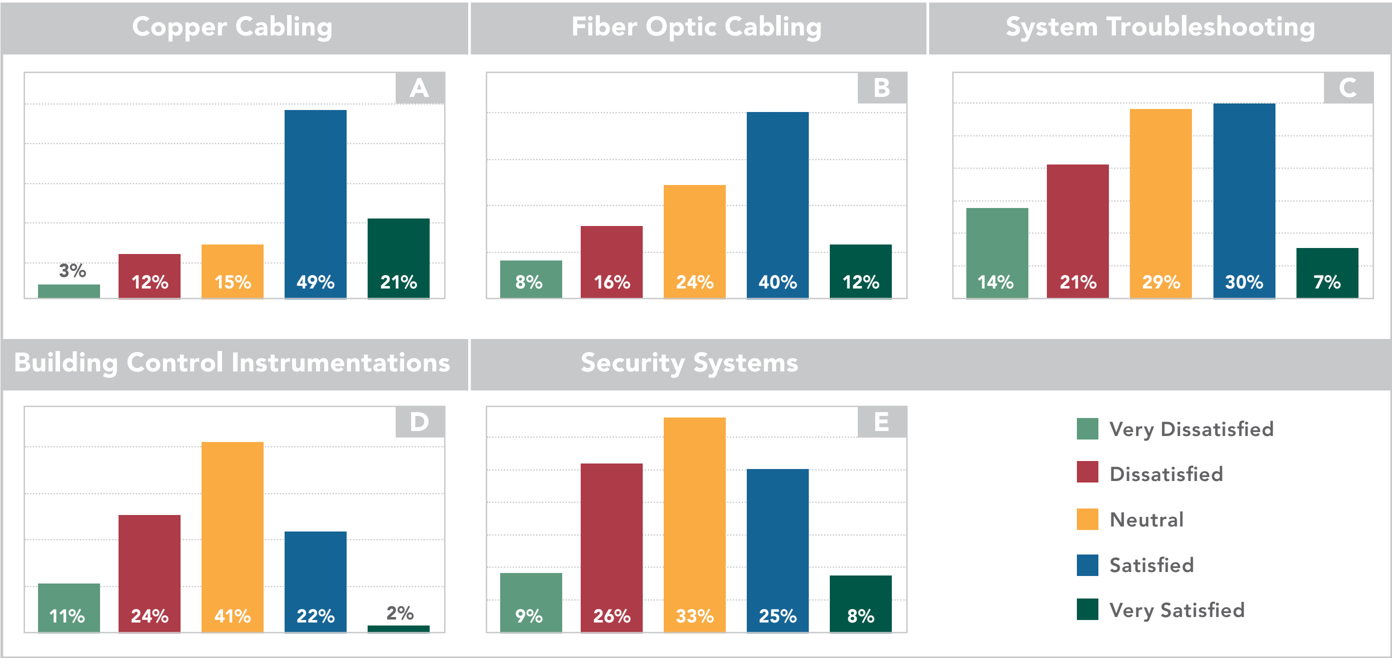
Electrical contractors interact with facility managers mainly through traditional maintenance services. Consequently, ECs are missing other service opportunities that will be more relevant and valuable for smart building owners. Figure 5 depicts the data trends from the answers to the following question: ***"Please indicate how common for your company to perform the following facility management and development services: …".*** It is clear the vast majority of respondents (92%) offer facility maintenance service to varying degrees, as shown in Chart f. However, other "proactive" and customer-focused services are offered by respondents at the same levels of facility maintenance. These services include analytics and fault detection, commissioning, energy auditing, financing in energy upgrades, and systems integration. Maintenance services can represent the entry door for ECs to approach facility owners and managers to consider the other services, but this requires higher levels of customer engagements than the current project-focused interactions.

Figure 5: The frequency of offering preconstruction and facility management services



Respondents were satisfied with most cabling installation training offered by the JATC, but they noted less satisfaction levels for other skills that are very relevant to smart building projects. As shown in Figure 6, 70% of the respondents were satisfied and very satisfied with the copper cabling installation (chart a), while fiber optic installation received a less rating for those satisfaction categories (52% combined, see chart b). However, training curriculum related to system troubleshooting, building controls, and security systems received an average of "neutral" satisfaction rating. It appears the JATC training program is more focused on the foundational installation aspects of the building systems that are popular for the different apprenticeship tracks, such as inside wiring and tech installation. Building controls and security systems are already covered by the technician/installer training program, but is offered in only half of the local JATC programs, as indicated by a recent survey conducted by the Electrical Training Alliance (ETA).

Figure 6: Satisfaction levels with JATC training in different skill areas related to smart buildings



The statistical classification of the responses were matched with the existing industry groups of electrical and low-voltage contractors. A two-step statistical clustering operation was applied to the response data in SPSS software, and the data were found to follow three main groups, as shown in Table 1. Cluster 1 of the responses (about 23%) represents the traditional inside electrical wiring company that is also involved in lighting new installations, renovation, and controls. Cluster 2 (about 15%) represents low-voltage contractors who install access control, CCTV, Audio/video, intrusion detection, and structured cabling systems. Cluster 3 (about 32%) represents hybrid companies with experience in both electrical and low-voltage installations. Finally, the rest of the responses (about 30%) did not significantly follow any of the three main clusters.

Table 1: Clustering of the survey responses based on the installed building systems

	Cluster 1 Traditional Electrical (23.2%)	Cluster 2 Low-voltage (14.6%)	Cluster 3 Hybrid (31.7%)
Electrical wiring	✓	–	✓
Access control	–	✓	✓
Lighting new installation	✓	–	✓
CCTV	–	✓	✓
Lighting renovation	✓	–	✓
Light controls	✓	–	✓
Solar energy	–	–	–
Audio/Video	–	✓	✓
Intrusion detection	–	✓	✓
Structured cabling	–	✓	✓
Natural lighting & auto shades	–	–	–
Building automation systems	–	–	–
HVAC	–	–	–
HVAC controls	–	–	–
Energy storage	–	–	–
Fire Life	–	✓	✓

CONCLUSION

This strategic roadmap is intended to provide electrical contractors, NECA and IBEW with short- and long-term strategies to prepare well for the future IoT-based smart building market. The roadmap connects industry challenges and technological opportunities to 23 strategies over three main paths: technology development, business transformation, and workforce development. The roadmap also presents a blueprint for ELECTRI International, through which each proposed strategy can be studied in further detail through a series of research projects under the larger theme of smart building market preparedness.

REFERENCES

American Council for an Energy-Efficient Economy (ACEEE) (2017). *Smart Buildings: Using Smart Technology to Save Energy in Existing Buildings.* Report A1701 coauthored by Jennifer King and Christopher Perry. Download link: http://aceee.org/research-report/a1701, last accessed: 9/20/2018.

Wired Score (2018-a). *The Value of Connectivity: What is the Cost of Poor Digital Infrastructure for Commercial Real Estate.* Wired Score Company, download link: https://info.wiredscore.com/value-connectivity-commercial-real-estate, last accessed: 9/20/2018.

Wired Score (2018-b). *Wired Certification Guidelines: Simplifying your Connectivity Design Process.* Wired Score Company, download link: https://info.wiredscore.com/ty-wired-certification-guidelines-development-redevelopment?submissionGuid=7340431c-f5b9-403f-a110-c17a7374bd2f, last accessed: 9/20/2018.

CHAPTER 3

CASE STUDIES

INTRODUCTION

The purpose of collecting case studies is to identify the practical applications and challenges of smart building in term of technology and project delivery. As the vision of a true fully-integrated smart building is still not attained, this research will consider both nationally- and internationally-renowned energy efficient and sustainable buildings that were built with smart and integrated building systems. The case studies will illustrate the role of smart systems in high-efficiency buildings and their integration approach. This will then complement the findings of the other research data collection tasks (interviews and questionnaire) to result in a solid understanding of smart building systems, their requirements, and capabilities.

METHODOLOGY

The researcher identified eight case studies from different sources including a) suggestions from interviewees or taskforce members; and b) green and zero-net energy (ZNE) buildings as recognized by different industry organizations, such as New Buildings Institute (NBI), National Institute of Building Sciences (NIBS) and Continental Automated Buildings Association (CABA). Data on each case study were collected in two main approaches. For the first three case studies, data were collected though site visits to the building and touring the major spaces and smart systems with the facility managers and owners of these buildings. Data for the other five case studies were collected from published detailed reports and articles that provided sufficient descriptions of the building, smart features, and its project delivery approach.

Each building systems and features of each case study were identified in a tabular format and related to three main general smart building objectives: 1) achieving energy efficiency; 2) facility management efficiency in terms of streamlined operations and control of the building systems; and 3) tenant interactions in terms of their data sensing, providing feedback to building users on building performance, and empowering them on controlling their environment.

In addition to the individual project case studies, the research collected a business case study of a NECA contractor's experience with expanding into the smart building and automation system markets.

CASE STUDY 1
ORACLE BUILDING IN SANTA CLARA CAMPUS

OVERVIEW

Location: Santa Clars, CA.

Area: 120,000 SF

Project Type: R&D Office building, new construction.

Completion Year: 2016

Cost: N/A

Building Features	Energy	Facility Management	Tenant Interactions
Electrochromic-glass smart windows that tint automatically based on the sun position and angle (by View)	✓		
Operable window shading system that is tied to the View smart tinted windows	✓		
Smart LED lighting with occupancy and ambient light sensors (by Enlighted)	✓		
Smart electrical sub-meters for the major panels and the server rack rows in the data center.	✓	✓	
BTU sub-meters for heating, ventilation and cooling equipment	✓	✓	
Smart data center system with real-time monitoring of server rack temperature and humidity	✓		
Digital dashboard to display energy production and consumption information		✓	✓
Building systems management (BMS) that integrates different system data (by Tridium)		✓	
Building intelligence, analytics, and control platform (by IBIS)		✓	

Oracle's Building 10 is a three-story 120,000 sq. ft. structure built to house more than 550 occupants, a data center research lab, a café, a classroom space, and other necessary office amenities. Oracle has a large real estate and facility management team with approximately 60 employees including technicians, administrators, facility engineers, and facility managers. The facility management team has accumulated a very valuable experience in specifying and managing advanced building automation systems, integrating these systems into the enterprise IT network, and utilizing the system data to derive useful insights on building space usage and systems' performance. Unlike the other building owners, Oracle did not focus on onsite energy generation, but rather on systems efficiencies, IoT innovations, and facility performance continuous validation. Such operational and building efficiencies qualified the building to receive LEED Gold certification from the USGBC and Energy Star Certified.

This building represents an interesting case of how systems are integrated during the design and construction phases with the objective of integrating their data for intelligent operations and facility management analytics. The facility management (FM) team formulated the project IoT specifications by matching desired functionalities to available systems and products. For example, the FM team wanted to track space utilization and automate space conditioning and lighting based on the occupancy level. To achieve this, they selected a smart lighting system (Enlighted) that integrates occupancy and ambient light sensors into the LED lighting fixtures. The data from Enlighted's occupancy sensors have been integrated into the BMS platform (Tridium) and used to control the variable air volume (VAV) units in the corresponding rooms. Within the smart lighting fixtures, the LED are dimmed based on the sensed occupancy and ambient light levels.

Another example of interesting integration was achieved between the electrochromic-glass smart window system (supplied by View) and the mechanized shading system. The View smart window system comes with an advanced building-roof-top sensory station that determines the sun's altitude, angle, and foot-candle. Data are fed internally within the View system to dim the window glazing, and are also shared within the BMS platform to open and close the shading system by setting its set point to be 1900 foot-candle. All these systems were installed with clear goals, mostly related to facilities management efficiencies, while maintaining the security of the IT network. The FM team uses data from electrical sub-meters and BTU metering for continuously validating building performance. All of these IoT-based systems are connected by a dedicated network that is segregated from the IT network in order to eliminate most of the possible cyber security threats.

Although these integration examples seem simple, there were multiple learning trials to overcome inter operability issues between the different systems. This was facilitated by having another facility management control layer on top of the BMS platform. This top control layer was facilitated by an analytics cloud-based product, called IBIS (by Integrated Building Solutions), which provides multiple advantages of utilizing only existing BMS platforms. First, IBIS proved to be much simpler than the utilized BMS platform (Tridium) in terms of the simplicity of user interface and hiding complicated data integration functions (which are still done by Tridium). The IBIS solution uses data collected by the BMS platform to provide easy automation within and between the systems.

Second, the IBIS solution provides controlled accessibility to the building data and automation with varying privileges given to different stakeholders. For example, the data center research lab was able to access the temperature, humidity, electrical sub-metering, and BTU metering data of the research space within the IBIS solution, with limited privileges on data accessibility and systems control.

Third, the IBIS solution provides a continuous commissioning module that statistically analyzes building data to create regression models of building performance and energy consumption.

The FM team faced different scalability issues when trying to integrate the IoT system at a full scale of a whole building. For example, the large number of LED smart lighting fixtures resulted in some issues in communicating the collected data to the BMS system. These LED lights communicate to two gateways on each floor through a wireless communication technology (similar to ZigBee). The gateways are hardwired to a single control unit for the whole building that is connected to the BMS. However, this single control point created a bottleneck for communicating the lighting sensor data. The issue was resolved afterward by the vendor.

CASE STUDY 2

ZNE TRAINING CENTER

OVERVIEW

Location: Santa Leandro, CA.

Area: 45,000 SF

Project Type: Vocational, Renovation.

Completion Year: 2013

Cost: $13 M

Building Features	Energy	Facility Management	Tenant Interactions
Roof monitors to provide natural daylighting, ventilation, and passive heating.	✓		
Solar tubes to provide natural daylighting	✓		
Operable windows to provide natural ventilation	✓		
Integrated passive and active ventilation systems controlled by the BMS	✓		
Thermal insulation (R-19) applied over the roof plywood deck	✓		
Three 4 kW DC wind turbine	✓		
113 kW DC solar tree canopy with	✓		
Variable Refrigerant Flow (VRF) system for efficient and energy-efficient heating and cooling of the occupied spaces.	✓		
Plug load minimization by using energy-efficient computers	✓		
Dimmable T-8 fluorescent linear pendants and LED industrial area lamps	✓		
Lighting occupancy sensors	✓	✓	✓
Night-flushing space overcooling using water barrels and mass temperature sensors	✓		
Single occupancy sensor to control thermal conditioning and lighting	✓		✓
Building management system (BMS) used to program and integrate the different building systems	✓	✓	
Building performance, monitored by a 3rd-party systems integrator	✓	✓	
Digital dashboard to display energy production and consumption information		✓	✓

IBEW Local 595 and NECA's Northern California Chapter collaborated and established a world-class training center. It is housed in a showcase smart energy-efficient building, where electrical apprentices learn hands-on skills in installing the latest building electrical and energy systems. The Zero Net Energy Center (ZNEC) was built with two goals in mind. First, it will be proof that an old commercial building (originally built in 1981) can be retrofitted to achieve the zero net energy goal, the same goal that CA set for its new residential construction by 2020 and new commercial construction by 2030. Second, the ZNEC showcases the capabilities of electrical contractors in the area of zero-net energy systems by building a functional, cost-effective ZNE building that also houses the apprenticeship program that trains future electricians on the cutting-edge energy systems.

The building exceeded its energy goals in the first years, achieved through an iterative integrated design process that incorporated multiple energy systems and solutions. In its first year, the ZNEC exceeded its net energy goal by having a surplus (negative) energy use intensity of 5.49 kBtu/ft2. The impressive performance of the building can be attributed to the integrated design process that involved the different stakeholders and their design ideas to end up with the final concept of the smart building integrated systems. The project team assembled early in t he programming phase, including the lighting designer, mechanical engineer, structural engineer, renewables designer, and general contractor. Multiple design charrettes were performed with building users to identify design requirements and alternatives. The implemented design alternative exhibits high levels of system integration, including the following passive and proactive approaches:

- *The design team took advantage of the required seismic upgrade to construct new roof monitors and account for the solar panel structural loads.*
- *The selection of the VRF HVAC eliminated the need for roof-top AC units, thereby reducing the seismic upgrade cost.*
- *The mixed-mode ventilation system automatically integrates active ventilation (mechanical system) with passive natural ventilation through BMS-run control sequences.*
- *A single occupancy sensor system is used to control both the HVAC and lighting systems.*
- *The roof monitors serve multiple energy efficiency aspects: natural ventilation, natural lighting, light source for the indoor mass thermal wall, and support platform for the solar PV panels.*

CASE STUDY 3
NZP TRAINING CENTER

OVERVIEW

Location: Commerce, CA. (Greater LA)

Area: 144,000 SF

Project Type: Vocational, Renovation.

Completion Year: 2016

Cost: $15.5 M

Building Features	Energy	Facility Management	Tenant Interactions
Cool roof technology installed to reduce solar heat gain	✓		
Thermal insulation (R-30 & R-19) applied to the roof-ceiling space	✓		
Solar screen wall as a passive measure to reduce thermal gain while allowing natural light	✓		
Electrochromic glass tints automatically when solar exposure is highest	✓		
100% LED lighting	✓		
EV charging stations	✓		
500 kW solar PV system	✓		
Advanced weather monitoring station	✓	✓	
Utility-scale micro-grid with computerized demand response capabilities	✓	✓	
26 kW Battery energy storage system (Samsung)	✓		
Building management system to monitor & control building systems	✓	✓	
Lighting occupancy sensors	✓	✓	✓
Building performance is monitored by a 3rd-party systems integrator	✓	✓	
Digital dashboard to display energy production and consumption information		✓	✓

IBEW Local 11 and NECA's Los Angeles County Chapter collaborated to establish a cutting-edge training center to prepare the new apprentices on clean green energy systems. The fruit of this collaboration is the Net-Zero Plus (NZP) Electrical Training Institute and its unique facility, considered the nation's largest net zero plus commercial building retrofit. The facility is both a training center and a living example of how others can retrofit buildings to improve the nation's energy ecosystem.

The original facility was built in the 1960s, and its renovation required three years of planning and design to set up the project goals and the building systems that will act as a living laboratory of how a net-zero building would look and perform. During these three years, the project team worked collaboratively to develop a base building energy model, goals setting, daylight model, energy production and storage modeling, and life cycle costing model. The renovation was done in phases, as funding become available. First, the solar PV rooftop panels and early generations of LED lights were installed. Other renovation work followed over the years, including storage batteries, computerized micro-grid, solar PV parking pavilions, newer generations of LED lights suitable for high ceiling training spaces, roof insulation and the façade.

The building earned its NZP name due to its pioneering micro-grid capabilities that once represented the largest commercial grid outside of military uses. The building uses 185,500 kWh per year and generates more than that, earning it a net-zero rating. The sole energy generation source is the PV solar system, which covers part of the building and parking lot. In addition, the micro-grid is composed of 4 PV combiner boxes, DC wiring, 3 inverters, energy storage batteries, distribution boards, and EV charging stations. The facility is under continuous monitoring and validation by a system integration firm, which was involved early in the project during the planning, design and construction phases.

CASE STUDY 4
ENVIRONMENTAL INNOVATION CENTER (EIC)

OVERVIEW

Location: San Jose, CA.

Area: 56,000 SF

Project Type: Institutional, retrofit and new construction.

Completion Year: 2014 & 2016

Cost: $27.1 M

Building Features	Energy	Facility Management	Tenant Interactions
Dimmable LED parking lot lights	✓		
Sixteen solar tracking skylights and 11 solar light tubes.	✓		
1,164 PV solar panels (599 kWh annually)	✓		
Four wind turbines installed (5 KW total)	✓		
Electric vehicle (EV) recharging, bike racks, carpool parking.	✓		
Efficient envelope (R19 wall SIPs, R30 ceilings, operable windows, cool roof)	✓		
Smart irrigation system with satellite connectivity		✓	
SolarEdge SE1000-CCG-G plus weather station	✓	✓	
Building energy demand monitoring system.	✓	✓	
Occupancy and air quality sensors control lighting and HVAC run times.	✓	✓	✓
The building management system (BMS) is connected to the central BMS of the City of San Jose.	✓	✓	
Online dashboard to visualize the solar system generation.	✓	✓	✓

The EIC is a public educational and environmental center, owned by the City of San Jose, CA. The Center was designed to achieve zero-net energy (ZNE) performance. The project involved retrofitting an old 46,000 SF warehouse and expanding it by 10,000 SF. The building is currently occupied by three tenants: Prospect Silicon Valley (a technology demonstration center); a Habitat for Humanity ReStore retail center; and a Santa Clara County collection center for household hazardous waste.

An important part of the project's success was the phasing of the project design and grant funding. The City segmented the project into three different funding packages. The early phase was tied to a grant related to site work and street trees; Phase 2 work was with the design team; Phase 3 solar was added as design build. If done all at the same time, this project would not have been as possible nor as fundable. The City was able to secure a mix of local and national funding which made possible many of the project's various environmental features. These funds included the federal New Markets Tax Credit (NMTC), the San José's Integrated Waste Management Fund, the California State Recycling Department grants, and the Economic Development Administration (EDA) grants. The NMTC funding required an innovative project delivery approach, in which the City of San Jose created a nonprofit organization to own the property and sell the granted NMTC to investors in exchange for project funding at the end of the tax credit, at which time the nonprofit will transfer ownership to the City.

CASE STUDY 5
THE VF OUTDOOR CAMPUS

OVERVIEW

Location: Alameda, CA.

Area: 160,000 SF

Project Type: Office building, New construction.

Completion Year: 2012

Cost: $40 M

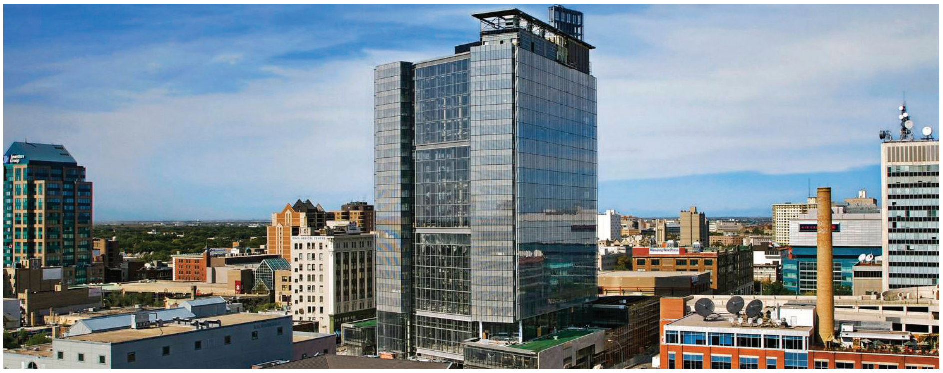
Building Features	Energy	Facility Management	Tenant Interactions
Exterior sunshades work to block hot, high-angle sun in the summer.	✓		
Interior light reflectors help increase daylighting penetration inside the buildings	✓		
Light sensors (15 ft. away from the windows) adjust the electrical lighting level	✓		
Exterior wall insulation and double-glazed windows	✓		
Indirect-direct evaporative cooling (IDEC) system	✓		
Variable frequency drives for the fans of the air handling units	✓		
Five cylindrical wind turbines	✓		
856 kW photovoltaic system (on roof, window shades, parking carports)	✓		
Demand-control ventilation system based on carbon dioxide sensors	✓		✓
Occupancy sensors to control lighting and plug loads	✓		✓
Energy Management System (EMS) by Alerton	✓	✓	
Onsite sustainability manager to guide the tenants on energy saving steps			✓
BACNet server to combine the data of the 4 buildings *(water usage, electrical sub-metering, and energy generation)*		✓	

VF Outdoor is a company that owns multiple fitness and outdoor fashion product lines. The VF Outdoor 14-acre campus in Alameda, California, comprises four office buildings and there is a plan to design and build a fifth building. The four buildings have a total area of 160,000 SF with a variety of space uses, such as offices, a fitness center, a café, and an outdoor training area. The entire campus was designed to achieve a zero-bet energy (ZNE) goa. But, it is not completely a ZNE building as it is still dependent on a gas supply to the café and gym facilities. The VF Outdoor Campus in Alameda was one of the company's first facilities to pursue its goal aggressively to use 100% renewable energy by 2025. The project was financially possible with the help of an Alameda Municipal Power rebate, based on the amount of excess solar energy (kWh) put back into the grid.

The VF Outdoor Campus in Alameda was one of the company's first facilities to pursue its goal aggressively to use 100% renewable energy by 2025. The project was financially possible with the help of an Alameda Municipal Power rebate, based on the amount of excess solar energy (kWh) put back into the grid.

The lessons learned from this project illustrate the need for more proactive monitoring and predictive analytics to optimize the performance of the individual systems and the whole building. The IDEC HVAC system proved to be effective, especially in the project location (San Francisco Bay Area), where no sudden weather changes occur. However, the system showed slow reaction to sudden extreme weather changes, which required the manual operation of the system and resulted in less comfort for occupants some days of the year. This issue can be solved by connecting the system to a weather station or predictive weather services that can adjust operational settings in anticipation of any extreme weather events. Also, some tenants have misused the operable windows or left them open while the HVAC is operational. Manual operable windows can be convenient for tenants to adjust their space environments, but window sensors can be installed and integrated into the BMS to avoid running the HVAC system in the zones that are conditioned using the operable windows.

CASE STUDY 6
MANITOBA HYDRO PLACE



OVERVIEW

Location: Winnipeg, Manitoba, Canada.

Area: 695,000 SF

Project Type: Office building, New construction.

Completion Year: 2009

Cost: C$278 M

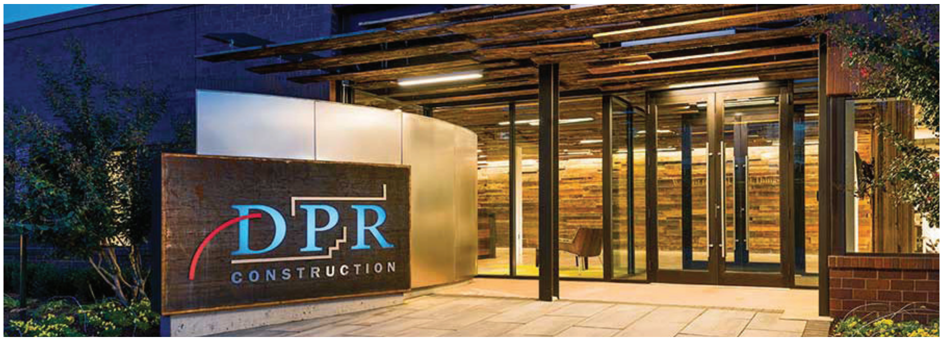
Building Features	Energy	Facility Management	Tenant Interactions
Thermal capacity of the concrete (35,600 cubic meters) reduces the use of heating energy loads at night.	✓		
Radiant heating/cooling system are imbedded in the concrete slabs.	✓		
Double façade curtain walls create daylighting and energy efficiency.	✓		
Operable windows on the outer curtain wall are controlled automatically based on air temperatures, light intensity, and wind speeds.	✓		
Three 6-story high winter indoor gardens provide fresh air.	✓		
80-ft. high water curtain for humidification and dehumidification by automatically changing the water temperature in summer and winter.	✓		
25,000 sensor points and meters feed the BMS with data.		✓	
Fully-dimmable energy efficient lighting.	✓		
370-ft high solar chimney helps in ventilating the exhaust air in the summer and recycling its heat in the winter.	✓		
Geothermal system is made of 280 boreholes (each 370 ft. deep) to draw excess heat or cold from the soil.	✓		
Two onsite weather stations feed climate data into the BMS.		✓	
Building management system to monitor & control the building systems.	✓	✓	
Employees can control lighting dimming levels from their computers.			✓

The Manitoba Hydro Place (MHP) is the first LEED Platinum Certified building in Canada and is considered the country's greenest and most energy-efficient building. The MHP is 75% more energy efficient than a typical office building in Winnipeg, equivalent to CAD$1.5 million annual operational cost savings. The building is owned by Manitoba Hydro, the major energy generation company. It adopted a progressive integrated project delivery (IPD) system to be able to achieve its ambient six core goals that were formulated in the IPD team charter, including: 1) create a supportive workplace environment for the employees of Manitoba Hydro; 2) create an energy-efficient design to achieve a 60% reduction in energy consumption using Canada's Model National Energy Code of Buildings (MNECB); 3) create a design that achieves LEED; 4) develop signature architecture integrated throughout the building; 5) achieve a high level of urban integration to revitalize the downtown area; and 6) employ a cost-effective building design solution that has measurable benefits to Manitoba Hydro in terms of comfort, operations, and maintenance. Although the building's main inspiration is energy efficiency, the last charter goal clearly indicates dependence on smart building technologies to achieve built environment efficiency at all levels of the enterprise.

The MHP is a living example of smart building design that utilizes energy efficient systems and advanced building management controls to switch Winnipeg's extreme climate from being a challenge to being an enabler of energy efficiency and tenant comfort. The temperature in Winnipeg has a significant swift of 126° F between the summer (95° F) and winter climate (-35° F). However, the City receives an abundance of wind and sunlight compared to the other Canadian cities. The engineering team came up with a creative smart building design that features several passive energy-saving approaches to use sunlight and wind to create a comfortable and healthy indoor environment with minimal energy loads.

These passive approaches included: 8-story high water curtain, solar chimney for the full height of the building, indoor winter gardens, and double façade curtain walls. These passive approaches, however, required about 25,000 control and measurement points that are connected and controlled by an advanced building management system (BMS). Combined with the building controls, the passive building features can become more responsive to account for the large temperature swings. The outside operable windows are opened and closed automatically based on wind speed and temperatures inside and outside the building. The water curtain temperature is controlled automatically to humidify the air in winter and dehumidify it during summer months.

CASE STUDY 7
DPR REGIONAL OFFICE



OVERVIEW

Location: Washington, D.C.

Area: 20,000 SF

Project Type: Office building, Renovation.

Completion Year: 2016

Cost: Undisclosed

Building Features	Energy	Facility Management	Tenant Interactions
Twenty four solar tubes bring daylight to interior spaces	✓		
141 kW rooftop solar PV system	✓		
100% LED light fixtures	✓		
Dedicated outdoor air system (DOAS) system with heat recovery chiller	✓		
Heating/cooling radiant sails in the ceiling with a nice architectural look	✓		
Blue power outlets to identify “switched” outlet locations	✓	✓	
Solar hot water panels to assist in hot water production	✓		
Plug load monitoring at all workstations to reduce plug loads (EnMetric)	✓	✓	
Smart lighting system, equipped with motion sensors, photocells and automated dimming.	✓	✓	✓
Control sensors to track the energy use of different HVAC and lighting devices (Honey well and Senseware)	✓	✓	
A digital dashboard provides real-time information on energy and water consumption (supplied by Lucid)	✓	✓	✓
Smart conferencing systems (Barco ClickShare, Sonos, Evoko)			✓
Integrated building management system		✓	

The national large general contractor, DPR, has shown its commitment to sustainable and zero-net energy values by renovating multiple company regional offices with the highest green and energy-efficient standards and certifications. In total, DPR has renovated four regional offices (Phoenix, San Francisco, San Diego, and Washington D.C.), with the goal of getting them net-zero certified by the International Living Future Institute (ILFI). All of these projects received the certification, including the final renovated office in the Washington D.C. area that is very close to officially getting the certificate.

DPR assembled a project team following the integrated project delivery (IPD) process with the following four identified objectives: 1) create an office of the future that invigorates our people and encourages creative work practices; 2) incorporate sustainable strategies that contribute to the health and wellbeing of the environment and our people; 3) make data-driven decisions based on cost-analysis, payback studies and team member expertise; and 4) build a living laboratory where DPR can showcase technologies, products and systems, along with a robust educational program. The buildings achieved multiple certifications in addition to ILFI, including being in the top 4% of the Leesman+ workplace accreditation, LEED 4.0 Platinum certification, and the International WELL Building Institute™ (IWBI).

DPR achieved its goal of making data-driven project decisions by benefiting from data generated from the smart systems in DPR's previous NZE projects. For the Washington office project, the project team utilized the plug load data from the three other DPR ZNE buildings to make realistic assumption for the energy model created. They also analyzed the sub-meter data of the different building uses, such as typical workdays, event days, and training days. In addition, life-cycle cost data were critical in selecting the different building systems and prioritizing them to minimize the project budget. Energy modeling and cost estimates confirmed the small energy savings of installing additional insulation to the building, so an early decision was made to reallocate budget resources to buy more PV panels instead of investing in better building insulation.

CASE STUDY 8
THE EDGE BUILDING

OVERVIEW

Location: Amsterdam, The Netherlands

Area: 360,000 SF

Project Type: Office building, New construction

Completion Year: 2014

Cost: 74M Euros

Building Features	Energy	Facility Management	Tenant Interactions
Large atrium to maximize natural lighting and ventilation	✓		
The building orientation was optimized based on the sun's daily path	✓		
Operable opening on the building façade provides good thermal mass and shading	✓		
Highly-insulated glass façade	✓		
65,000-SF PV solar panels installed on the roofs of the Edge and rented neighbor buildings	✓		
450 m below ground aquifer provides geothermal energy for office heating	✓		
6,500 PoE LED lights with embedded sensors (motion, temperature, light and air)	✓	✓	✓
28,000 sensors to collect building performance and tenant comfort attributes		✓	✓
Mapiq mobile apps and tablets for tenants to manage their workspaces		✓	✓
Building management system (by Schneider Electric)	✓	✓	
Online dashboard (by Microsoft Power BI) to visualize the BMS data		✓	✓

The Edge building is considered the smartest and greenest building in the world, as it achieved the most historical points (98.6/100) in the BREEAM (Building Research Establishment Environment Assessment Methodology) green building rating system. The Edge also is a true showcase of how high levels of IoT connectivity is achieved between building operations, management, and tenant comfort. The Edge was the brainchild of developer OVG Real Estate (the property owner) and the main building tenant, Deloitte, a global accounting and professional services provider. In the Edge, Deloitte found the innovative property that can fulfill its employment growth, optimize workspace utilization, and satisfy the tech-driven lifestyle of the new millennial workforce. As such, Deloitte was able to have the Edge accommodate 2,500 employees who share 1,000 "hot" desks. Deloitte was able to reduce the amount of space per employee from 41 SF to 25 SF while improving employee comfort and satisfaction.

The EDGE's smart and sustainable systems achieved unprecedented levels of energy efficiency and empowering interactions with the tenants. With the help of its large PV solar system and geothermal aquifer, the Edge uses 70% less electricity than a typical office building and produces more energy than it consumes. The building features one of the early smart lighting innovations, in which Phillips custom designed the PoE-powered LED lighting fixtures to be equipped with different sensor types (motion, temperature, light and air). These lighting sensors are a group of a total of 28,000 sensors of every imaginable type. All have individual IP addresses and are connected and managed by the same facility management system. This large number of sensors allows the indoor environment control to be significantly granular, down to only 200 SF per a single control zone. It allows employees to personalize both the lighting and temperature of their workspaces with a smartphone app while also collecting workspace environment data to reduce energy consumption. The facility's operation was also optimized through the use of analytics with the collected data. Facility management time can be reduced by being informed on a timely basis which coffee machines needed to be filled and which underutilized toilet rooms can be skipped.

The highly integrated project delivery approach of the Edge was a key factor for enabling the highest levels of interoperable and shared building intelligence. The manufacturers and vendors of the main building system collaborated earlier in the project design phases to allow the integration of their system platforms and data to provide useful insights and information on building operations and tenant activities. This synergy between key drivers at The Edge was instrumental in the final product they were each able to deliver. For example, Mapiq was then a young company specializing in IT-driven workplace occupancy services. Deloitte invited Mapiq to develop a customized mobile app to deliver an activity-based management of the employee workspaces. Mapiq collaborated with Phillips and Schneider Electric to utilize and integrate the data streams from their sensors. This integrated vendor collaboration empowered building tenants to automate a wide range of their daily office tasks from the Mapiq app, such as finding the location of meetings, reserving rooms, adjusting lighting levels, changing the room temperature, finding a free parking space, reserving lockers, and even operating the coffee machines.

BUSINESS CASE STUDY
NECA CONTRACTOR INVOLVEMENT IN THE SMART BUILDING MARKET

ERMCO, a NECA contractor, kindly shared its experience working in the smart buildings market in terms of its services, workforce development, challenges, and project examples.

MARKET OPPORTUNITY RECOGNITION

ERMCO recognizes the promising business growth possibilities in the smart building automation market, expected to grow to $99.11 billion by 2022. The demand for controls engineers, programmers, integrators and installation technicians has significantly increased over the past 20 years and will continue to rise. Most experts agree the shortage of these experts will be the most challenging aspect of advancing in this sector of the electrical industry. ERMCO is taking the lead as a role model for other NECA contractors to embrace the opportunity to provide these building automation services, especially because ERMCO and many other NECA contractors are already installing the systems in most major building projects.

ERMCO has embraced this challenge and understands Direct Digital Controls as an opportunity to grow and diversify its business portfolio by offering complete automation systems to its clients. In its interview, ERMCO noted, "This market also offers the opportunity for service and reoccurring revenue streams that were typically not available to us as an electrical contractor." ERMCO now has a full-service automation team able to design, program, integrate, install and service building automation systems throughout the life of a building. ERMCO is also positioned to leverage IoT and building data to provide data-driven solutions for the building Owner and/or Property Manager to make better decisions for the life of the building.

MARKET CHALLENGES

ERMCO has identified two main challenges for its expansion into smart buildings and the automation system market. First, <u>rapidly changing technology in building automation products and software can leave behind experienced contractors</u> if they are not focused on continuous training and learning. This contractor's partnership with system manufacturers is key to staying on top of the latest technology and receiving the most current training needed to engineer, integrate and install smart building automation control systems. Second, ERMCO is challenged to identify, recruit, and train building automation engineers and professionals with the required skills and knowledge. To address this situation, ERMCO seeks to develop partnerships with companies that specialize in and are efficient at delivering building automation design and integration services.

SAMPLE SMART BUILDING PROJECTS

1) Salesforce Tower

- This facility is the largest high-rise building in Indianapolis.
- The project started in 2016 and is still in progress as of the date of this report.
- Opened in 1990, the Salesforce Tower (formerly known as the Chase Tower) was dealing with aging pneumatic automation systems that were becoming increasingly difficult to service and support.
- When Salesforce moved into the building as its major tenant, the timing was right to take the opportunity to upgrade to direct digital controls from the existing systems.

- ERMCO's Scope of Work:
  - Entry Turnstile System – for increased safety and security for the building's occupants.
  - Access Control System – a Niagara-based system that replaced the existing one and provided added control for the turnstile system, all major points of entry to the building and elevator control. The system has over 100-Blue Tooth Enabled, iClass card readers and 35,000 users.
  - CCTV System – a Niagara-based system that replaced the existing analog cameras in the main facility. Additional cameras were added to increase monitoring capabilities.
  - HVAC Control –Niagara-based systems that provide full DDC control for 20 floors of the 49 floors of office and retail space.

2) Brownsburg Community School Corporation

- ERMCO represented Brownsburg School District as the (FMSI) and served as the controls expert for the school corporation and as it replaced aging and proprietary control systems that offered no freedom of choice.
- As project FMSI, ERMCO helped the building owner by offering yearly maintenance, engineered submittals, drawings, programming, owner training and commissioning resources.
- Brownsburg was able to conduct a competitive bidding process for the procurement of the control systems and to rely on ERMCO's expertise to integrate the system into one pane of glass by using its FMSI Services.

3) Goodwill Industries of Central & Southern Indiana

- As new retail stores open at the rate of approximately five per year, ERMCO provides automation systems for HVAC, Lighting Control and Analytic Monitoring of their Electric Service tied back to the BMS.
- Over forty Goodwill retail locations are now integrated into a Niagara web-based system for easy management and control.

4) St. Vincent Boon Village

- ERMCO provided complete HVAC controls, BMS Integration, and Analytic Monitoring of gas, water, electric for this 20,000 square foot medical office building.

CONCLUSION

The eight case studies provided documentation of the integrated building systems and their design strategies in a sample of smart building in the U.S. and abroad. Table 1 summarizes the design aspects of each case study building in terms of the number of building features that are related to energy generation and efficiency, improved facility management operations, and feedback and control interactions with building tenants. The case studies revealed two types of building intelligence traits: smart building design and smart building operations.

Smart building design implies extensive and integrated design effort early in the project development phases wherein various engineering, construction and facility stakeholders collaborate to design the building so as to streamline between its systems and remove any wasteful redundancies. Smart design does not really depend on high-tech building control systems, as building performance can be maximized with passive design approaches, like maximizing the use of natural ventilation and lighting to improve indoor comfort levels. On the other hand, smart building operations require high levels of building controls, especially in today's workforce culture of flexible and high-tech spaces.

Smart building operations demonstrate a dynamic facility that interacts with the building operator and tenants, as well as one that autonomously adapts and changes its system settings to react to changing environment and use conditions. For example, the Manitoba Hydro Place, with its many passive energy and ventilation passive approaches, exhibits smart building design, but its systems do not proactively interact with the facility operator and tenants. On the other hand, smart building operations are clearly shown in the Edge Building due to the various ways the building interacts with its facility management staff and users.

The case studies revealed the building systems that have been commonly used and have almost guaranteed features for smart and efficient building operations, which include: 1) solar PV systems; 2) occupancy and light sensors; 3) energy-efficient lighting; and 4) building management systems. Also, the business case study (ERMCO) confirmed the findings from the other research tasks (interviews and roadmap) about the smart market opportunities and challenges for electrical contractors.

Table 1: Summary Cross-Comparison among the Collected Case Studies

Case Study	Energy-related Features	FM-related Features	Tenant-related Features
1: Oracle Building in Santa Clara Campus	6	5	1
2: ZNE Training Center	15	4	3
3: NZP Training Center	13	6	2
4: Environmental Innovation Center (EIC)	10	6	2
5: The VF Outdoor Campus	11	2	3
6: Manitoba Hydro Place	10	3	1
7: DPR Regional Office	11	6	3
8: The Edge Building	8	5	4

CHAPTER 4

SMART BUILDING MODELING AND OPPORTUNITIES

INTRODUCTION

This chapter presents a generic knowledge model of smart buildings and the technological opportunities that are expected to have a positive impact on the future growth of the market. Before developing a roadmap for the smart building industry, it is important to capture the current knowledge and present it as a common language to describe the systems, components, and capabilities of smart buildings. During this knowledge capturing exercise, the researcher identifies future opportunities related to technologies and standards that would help in overcoming the current challenges of smart buildings (Chapter 1), to teach the full potential and vision of what a smart building can deliver to its enterprise and occupants.

SMART BUILDING KNOWLEDGE MODELING

Smart building knowledge was captured through the different tasks of this research project and presented in a common language that can be easily shared and communicated. The System Modeling Language (SysML) was used to model the smart building systems and their functionalities visually. SysML is a general-purpose modeling language (Valdes et al. 2016) for model-based systems engineering (MBSE). It supports the specifications, analysis, design, validation and verification of a wide range of systems and systems-of-systems (SoS). MBSE tools can establish new collaborative environments to facilitate the process of sharing and managing the knowledge of technologically-challenging projects and products. This is needed to develop efficient and effective system solutions (Johnson et al. 2008). The developed knowledge model in this research project is a foundational effort to enable further tasks: 1) a common approach to describe the scope of smart buildings, their systems, connectivity, and functionalities; 2) utilizing MBSE in the construction industry to specify design requirements and develop solution hierarchies for buildings that are becoming more complicated and interconnected with the increased introduction of IoT technologies; and 3) an educational tool for trade training to provide the "big picture" perspective of smart buildings and their capabilities to complement the focused knowledge on systems installation.

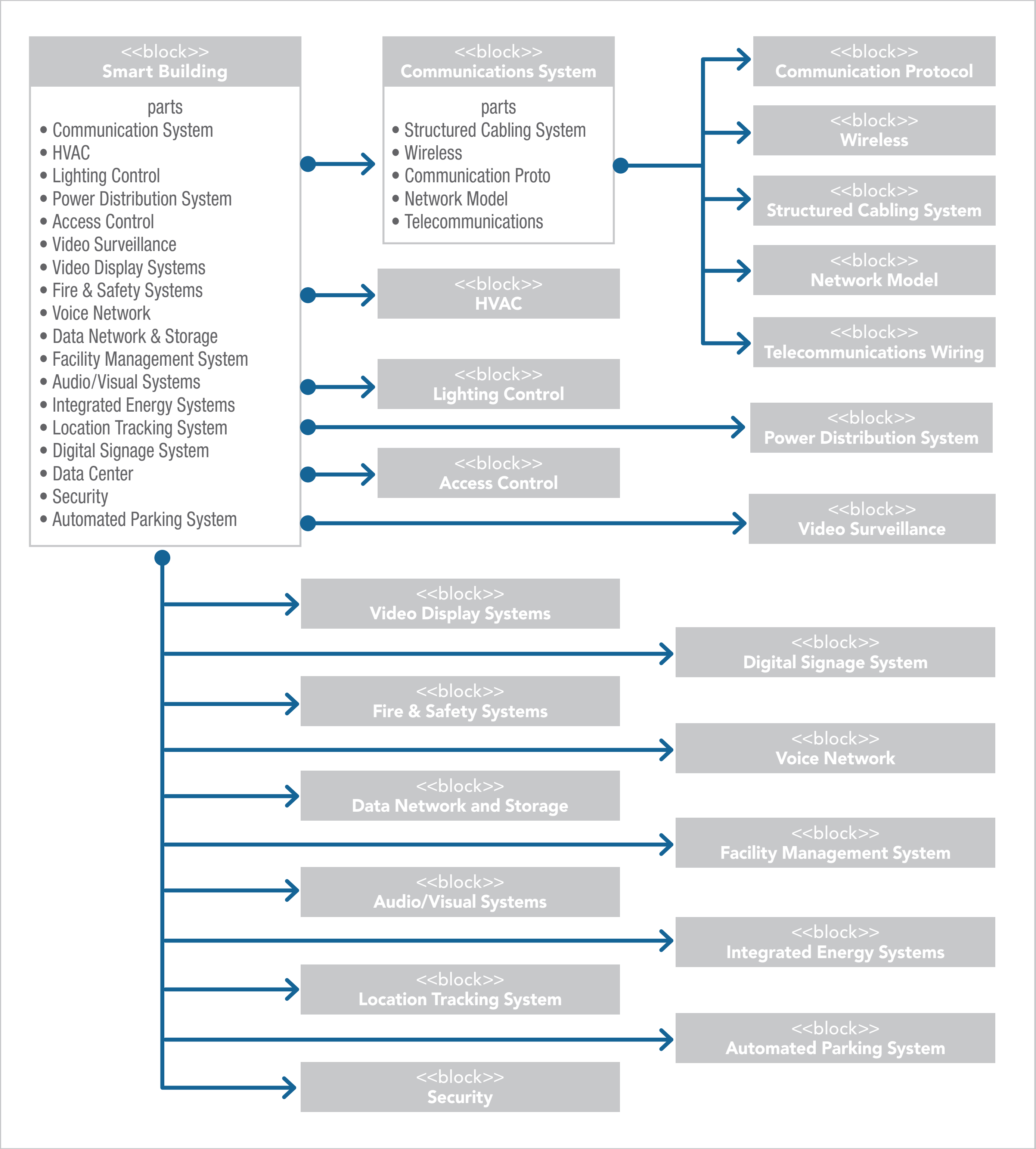
The researcher used two main types of diagrams in the SysML knowledge-based model of the smart buildings. These are shared online for the NECA and ELECTRI communities to access, utilize, and provide feedback. A set of Block Diagrams and Use Case Diagrams were developed to describe the systems and functionalities of smart buildings. The model is published online and can be accessed using the following link[1], hosted on the researcher's web domain. This model is available publicly to the ELECTRI industry community and NECA members. The model is a living document and will be updated, based on the feedback received from the community and the technological changes in smart building systems.

SMART BUILDING BLOCK DIAGRAMS

Block diagrams show the main systems, subsystems and components of a smart building, as well as the relationships between them. From its name, each block in the diagram can be used to represent a system or a component within the product or project. The blocks are connects with three main types of connectors: 1) part associations between a system and its sub-systems or components, like an HVAC system composed of boilers, chillers, air handling unit, etc.; 2) generalizations between parent and children block as their property inheritance link, like the generalization between the "Wireless" block and the "Wi-Fi" block; and 3) reference associations between blocks that have any dependencies, such as the dependency of a thermostat on Wi-Fi connectivity. Figure 1 depicts the main block diagram that shows 17 systems within a smart building. Each system is detailed by at least one sub-block diagram. In total, 30 block diagrams were developed to model a generic smart building. For example, the "Communication System" block in Figure 1 is described in more detail with 10 block diagrams to describe telecommunication wiring, structured cabling, network model, communication protocols, and wireless (Wi-Fi, Bluetooth, Cellular, ZigBee, Zigwave).

1 http://www.engr.scu.edu/~hsaid/SmartBuildingModel/

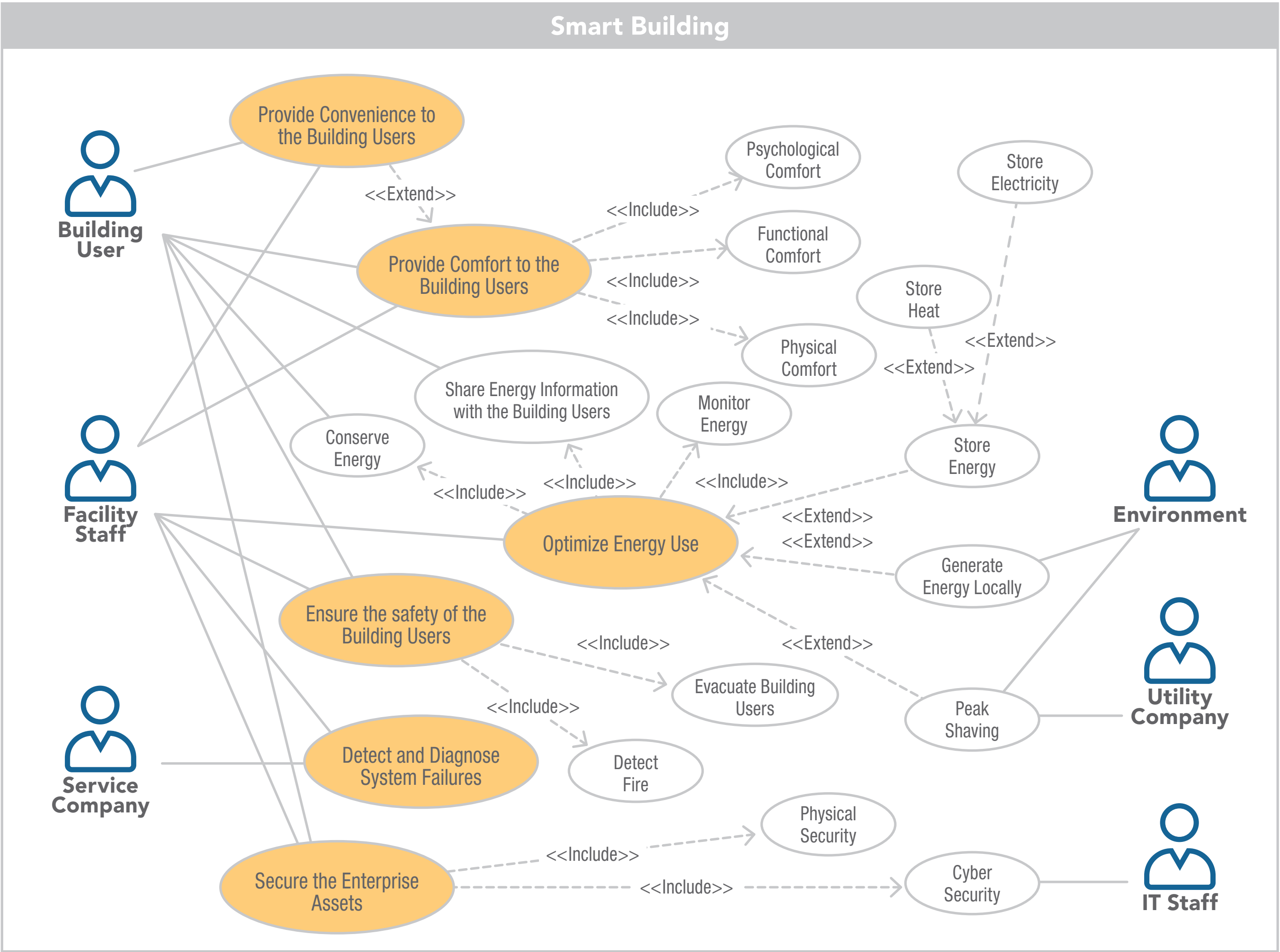
Figure 1: The main block diagram of a generic smart building showing its main systems



SMART BUILDING USE CASES

Use case diagrams are shown to describe a set of actions and functionalities that a system and its components should or can perform in collaboration with one or more external users of the system (actors). Each use case should provide some observable and valuable result to the actors or other stakeholders of the system. As shown in Figure 2, there are six use cases expected from a smart building: 1) provide comfort to building users; 2) provide convenience to building users, 3) optimize energy use, 4) ensure the safety of building users, 5) detect and diagnose system failures, and 6) secure the enterprise assets. Use cases can extend or include other use cases. The "extend" relation is a kind of specialization in which a use case extends the functionalities of its base case. For example, "Store Electricity" extends the "Store Energy" case by making it more specialized in terms of the energy form that is stored. On the other hand, the "include" relation is used to link a major use case to its subsequent functionalities, such as providing comfort to building users to include their psychological, functional, and physical comfort. These use cases represent smart building system interactions with five main actors: the building user, the facility management staff, the service company, the enterprise IT staff, and the surrounding environment.

Figure 2: The main use cases of a smart building



FUTURE OPPORTUNITIES

5G CONNECTIVITY

The fifth generation (5G) of wireless telecommunication technology will operate at significantly higher speeds and handle efficiently many more devices than the current available 4G infrastructure. 5G will achieve unprecedented speeds of 20 gigabits per second, equivalent to downloading a high-definition Hollywood movie in few seconds. It also will reduce latency (the measure of how long it takes a packet of data to be transmitted between two points) by a factor of 15. This will allow for more real-time feedback and control applications. Such speed and latency benefits are enabled by the ability of 5G to use radio frequency beyond the 6GHz spectrum of the current 4G network. 5G is expected to use radio frequencies in the range of 30 GHz to 300 GHz. In addition, 5G-equipped devices will require 90% less energy to transmit and receive data, resulting in longer battery life and more scalability levels for IoT systems. This benefit will be achieved by having the 5G network capable of easily recognizing the type of data being transmitted and adjusting the power mode accordingly. It is like utilizing a low power mode for environment sending data and higher power mode for HD video streaming.

Mobile operators have already started deploying fixed accessibility of the 5G technology, a milestone towards full deployment of the technology for all mobile devices. The high radio frequency used by 5G requires a clear and direct line of sight between the antennae. Mobile operators will need to pump in huge investments to prepare their network for 5G service. This is why 2020 is the earliest time anticipated to deploy 5G in most countries. However, some service providers claim they are deploying it earlier, but what they refer to is the 5G Fixed Wireless Access (FWA), not the true mobile 5G service. 5G FWA has emerged as one of the most predominant use cases for early 5G network rollouts. Multiple mobile operators and service providers are initially seeking to capitalize on 5G as a fixed wireless alternative to deliver last-mile connectivity at multi-hundred Megabit and Gigabit speeds, closely-comparable to fiber-based connectivity. 5G FWA will support future mobile usage and will operate to the same standards as forthcoming 5G mobile networks. This presents mobile operators with the opportunity to use 5G FWA as a means to prepare their networks for full-scale 5G network deployments.

5G networks will have a great impact on infrastructure construction and operation, but little impact on smart buildings. Already, the infrastructure industry is eagerly waiting for 5G network deployment to implement new technologies that were not feasible before. This includes smart traffic systems, public safety, autonomous cars, smart metering, and structural health monitoring. However, there is not much impact expected from the 5G network on the current approaches to constructing buildings in general. Tenants and building visitors will still expect to have data mobility within the buildings, a contemporary problem since the inception of mobile phones.

However, 5G will intensify mobility problems within buildings and will require significant investments. By the law of physics, the higher the mobile communications frequency, the shorter the range. **As such, the very high radio frequency of the prospected 5G networks will created a mobility crises within the buildings.** At such frequencies, the signal range will be very short, meaning it will be more easily interrupted by even the most common building materials.

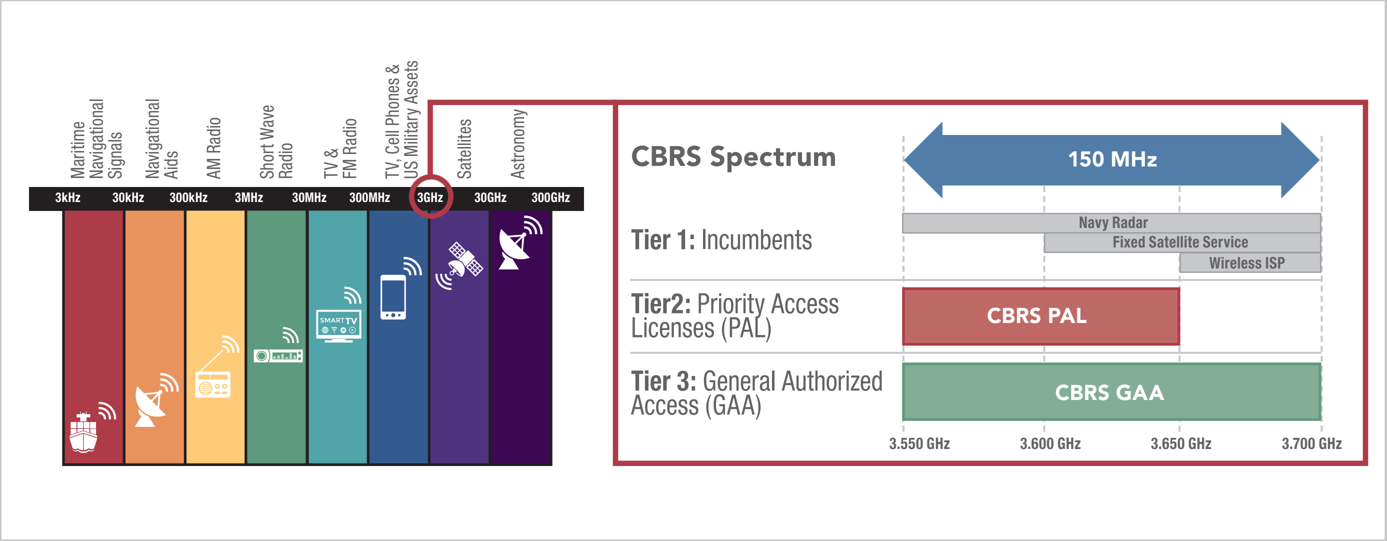
To solve the indoor mobility crises of 5G networks in buildings, the Distributed Antenna Systems (DAS) and small cells can become a much needed solution. Although people can connect through the local area network Wi-Fi, it is expected they would still prefer connecting to their 5G service for convenience and security reasons. The good thing about this problem is that we can solve it with today's technology. DAS has been traditionally used in large facilities with limited mobile signal or user crowd spikes, such as malls and sport venues. DAS will be a very viable solution for other enterprises to deploy in their buildings (e.g., offices, healthcare) when 5G networks become a reality. Small cells can be a similar alternative with much less capital investment, but will connect to only a single mobile operator. Indoor DAS and small cells impose their own challenges and opportunities. Mobile operators will be financially constrained to invest in indoor mobility networks, as they will be investing in their 5G networks. On the other hand, enterprises might not have the capacity to maintain DAS networks inside their facilities.

PRIVATE LTE NETWORK FOR IOT

Mobile communications utilize a limited range of radio spectrum, which can only be allocated not created. The radio spectrum is governed by the Federal Communications Commission (FCC) which has already allocated the entire radio spectrum (ranging from 3kHz to 300 GHz frequency) to different applications, as shown in Figure 3. However, the spectrum band used by the federal government has been underutilized over the years. As such, the FCC started the process to open an underutilized 150 MHz band (from frequency 3.55 GHz to 3.7 GHz) to be shared with private and business entities, thanks to the new latest technological development in spectrum band dynamic allocation and management. To manage this shared spectrum securely, the FCC established the Citizens Broadband Radio Service (CBRS), a regulatory framework to manage and share the open framework, using a three-tier priority approach as shown in Figure 3. The highest priority for the CBRS spectrum is granted to entities (incumbents) that have used the spectrum before, such as radars, fixed satellite stations and wireless Internet service providers (WISP). The next priority is given to public and private entities that purchase Priority Access Licenses (PAL) to obtain the exclusive right to operate part of the band. In the third priority tier, public users have General Authorized Access (GAA) to the non-exclusive right to use the CBRS band. A cloud-based Spectrum Access Server (SAS) is responsible for protecting incumbents from harmful interference from new users of this spectrum.

The industry major telecommunication manufacturers have created the communication protocols and systems for easy deployment of private LTE networks, even before the existence of CBRS. MulteFire is an LTE technology initiative and consortium that has developed a network technology that can be deployed on shared radio spectrum bands, such as the global 5 GHz unsilenced band and CBRS. MulteFire, started by Qualcomm and Nokia, is now being spearheaded by a multi-company MulteFire Alliance that includes Intel and Ericsson. It uses many of the sophisticated features designed into LTE to deliver high performance, seamless mobility and resilience, even in highly congested environments. As with Wi-Fi, multiple MulteFire networks can co-exist, overlap or be friendly neighbors in the same physical space. MulteFire is most appropriately implemented using Small Cells due to the ow transmit power typically imposed on unlicensed or shared spectrum bands. The smaller footprint of each cell leads to greater spectrum reuse, delivering high capacity in dense environments such as stadiums, malls, airports and train stations. Any device (dongles, smartphones, tablets and computers) will need to be equipped with LTE-U compatible chips to be able to connect to a MulteFire private LTE network.

Figure 3: Mobile communications over the radio spectrum and the new initiative to reopen some it for public use through CBRS



MulteFire provides greater freedom, ease, and affordability for enterprises to create their own in-building mobility networks for building users and segregated networks for the enterprise's IoT devices. The high cost of DAS or the one-operator limitations of small cells have discouraged large enterprises from creating in-building networks for building tenants to access their mobile services. However, MulteFire unleashes enormous potential for small cells to become more widely adopted and could form a useful multi-operator solution for building owners at lower cost than today's DAS by acting as a neutral host for single-operator enterprise solutions. Also, private LTE networks can be used as a security segmentation strategy to isolate smart building IoT devices (OT network) from the secured enterprise IT network.

REAL-TIME LOCATION-BASED SYSTEMS (RTLS)

RTLS is a form of local positioning system to track assets in real time, usually in indoor environments where global or cellular positioning systems cannot operate. By knowing where assets are located, processes can be streamlined, generating valuable data and letting employees focus on activities that actively bring value to the organization. The following are some example RTLS use cases and objectives in different industries:

- ***Manufacturing:*** *track machines and goods through the assembly line and identify any bottlenecks of inefficiencies.*
- ***Healthcare:*** *track the location of medical devices to help reduce wasted staff time.*
- ***Offices:*** *track employees to monitor desk utilization in flexible work environments.*
- ***Hotels:*** *guest tags can help in-room automations and employee tags can impact security and safety.*

While the RTLS application is different throughout industries, the underlying principals and system architecture remain largely the same. The RTLS is composed of two main components: the tracking infrastructure and the software application.

- *The RTLS infrastructure is composed of tags (transmitters) and readers/beacons (receivers) that communicate. Their communication is used to determine the location of the tags and their carrier. The location of each tag is determined by using the designed locations of the beacons/ readers, signal strength from the tags, and the triangulation principle.*
- *The RTLS software includes: a) the back-end control of the infrastructure and the processing of the tracking data; and b) the front-end visualization and management component that makes the tracking data actionable by integrating it to other smart building systems (such as lighting) or displaying asset trace and space utilization maps. Some RTLS vendors provide API capabilities to their systems to integrate into specialized crowd and wayfinding applications.*

RTLS systems are classified based upon the type of communication technology used to connect system infrastructure hardware. RTLS can either use radio (Wi-Fi, Ultra-wideband, ZigBee, Bluetooth, RFID) or sound (ultrasound) communication protocols. Table 1 provides a comparison between these RFID systems. The following is a brief description of each system type:

- ***Wi-Fi RTLS:*** *This system utilizes already-existing Wi-Fi access points as the beacons for locating the tags. Using differential-time-of-arrival methods, the access points are able to locate the tag.*
- ***Ultra-Wideband (UWB) RTLS:*** *UWB is the most accurate RTLS technology. It uses small, low-powered tags that transmit an ultra wide-band signal using a spark-gap-style transmitter. This instantaneous burst of energy creates a very wide signal and transmits across gigahertz of spectrum. UWB accuracy easily deteriorates in indoor environments with large metallic objects, such as hospitals and shops.*

ZigBee RTLS: *This RTLS system utilizes the same ZigBee communication used in building automation, which makes it easy to integrate location-based services into building systems such as lighting, security and access control. The ZigBee RTLS infrastructure is composed of: a) the tags (end nodes) attached to the assets or people, 2) the routers that detect the tags and communicate with them, and 3) the coordinator (queen bee) that is used to access and configure the RTLS infrastructure. The ZigBee RTLS is very flexible, cost effective, and tolerant of building obstacles.*

Bluetooth Low Energy (BLE) RTLS: *The Bluetooth beacons send out a signal that is picked up by Bluetooth devices in the area. This signal indicates the Bluetooth user's proximity to that beacon and, subsequently, the specific location. The BLE RTLS technology is more easily integrated with other enterprise systems and everyday devices due to existing widespread adaptation of the Bluetooth standard.*

Radio-Frequency Identification (RFID) RTLS: *RFID is the same technology used to track books in the library and shopping items in retail stores. A mesh of RFID readers can be placed to track the location of the tags, or checkpoints can be placed at main entrances, exists, and hallways to track tag flow.*

Ultrasound RTLS: *These are ultrasound tags and readers that provide accurate room-level and sub-room-level real-time location. Ultrasound tags broadcast a unique identification signal that is 'heard' by the ultrasound sensor receiver. The receiver recognizes the unique tag ID and transmits a small amount of data to the the existing local area network (LAN), either via POE or WiFi, to the back-end applications for data processing and visualization. Ultrasound-based RTLS is a more robust alternative in complex indoor environments (such as hospitals) than radio-based systems (ZigBee, Wi-Fi, …), where radio waves are multiply transmitted and reflected, thereby compromising positioning accuracy.*

Table 1: Comparison between different RTLS types

RTLS Type	Accuracy (ft)	Advantages	Disadvantages
Wi-Fi	9 - 15	• Wi-Fi infrastructure already exists in most buildings.	• To improve the tracking accuracy, many access points are needed beyond the regular wireless network requirements. • Increased security concerns due to the system open ends (the Wi-Fi tags). • Heavy involvement from the IT staff. • Wi-Fi tags are expensive and have high power consumption. • Difficult installation and calibration. • Requires careful site signal surveys.
UWB	0.5 – 1	• The most accurate RTLS	• Accurate tracking requires a lot of readers (every location should be covered by at least 3 beacons). • Signals can be blocked by large metallic objects. • Higher cost than other systems.
ZigBee	2 – 6	• Flexible and scalable deployment • High tolerance to building obstacles (walls, machines, etc)	• Low data rate (0.03 – 0.4 Mbit/sec) restricts its use for 2-way interactions. • Less interoperability compared to Wi-Fi or Bluetooth.
BLE	9 – 12	• Large ecosystem of devices that support Bluetooth. • Less cost compared to Wi-Fi and RFID. • The Bluetooth beacons have long range (around 100 m). • Very low power requirements	• Average accuracy for room-level tracking
RFID	9 - 12	• Very inexpensive tags (< $1 each)	• Expensive readers • Readers consume considerable energy - Requires separate CAT 6 wiring. • Very short range for the readers.
Ultrasound	1	• High immunity to electromagnetic noise and interferences. • High location accuracy.	• Requires separate CAT 6 wiring. • Applicable only to short-range line-of-sight systems.
			• The system accuracy depends on the air temperature and humidity, which affect the ultrasound speed.

From the above comparison, it is clear that BLE is the best compromise for RTLS accuracy, cost, scalability, and installation flexibility. BLE RTLS has gained great momentum recently as an attractive RTLS in wide variety of applications that do not require very high location accuracy. However, ultrasound RTLS is almost the only option for healthcare facilities where electromagnetic fields from medical devices can greatly affect the performance of radio-based systems.

DC/AC HYBRID POWER IN BUILDINGS

Smart and zero-net energy building have made it more appealing to transform the power systems within the building from AC to DC, or at least to increase the DC role in a hybrid power distribution architecture. Buildings are evolving to include more devices and systems that depend on low-voltage (class 2) power wiring (such as LEDs, thermostats, security, access control, A/V, etc.). However, the industry has addressed the new low-voltage power needs of lighting and controls systems with a kind of worst-of-both-worlds "Band-Aid" approach. Most buildings still depend on pulling AC line-voltage to the DC low-voltage devices that are equipped with AC-DC drivers and overlaying separate low-voltage controls wiring to lighting and HVAC devices.

In addition, onsite renewable energy generation systems (such photovoltaic, PV) are installed in more buildings and homes which generate power in DC not AC. Figure 4 shows a comparison between today's inefficient power distribution architecture and the envisioned ideal solution. It is clear from the comparison in the figure that there is a greater mismatch between AC and DC in the generation and consumption sides, resulting in energy losses during AC-DC conversions. While the efficiencies of power conversion are dependent upon current and voltage, conversion devices are typically "rated" between 90% and 95% or even lower. Such inefficiencies are multiplied in current power distribution architectures as conversions between the grid, renewable energies, the building's distribution, and demand devices multiply. So, on average, 5-10% of the energy is wasted in the conversion and much more with multiple conversions and less efficient conversion equipment. In summary, with the large number of DC-powered devices in buildings, and with DC generation now used in many newer structures, it seems pragmatic and logical to migrate to pure or hybrid DC-power distribution systems to eliminate conversion waste and thus maximize the use of DC power generated by renewables.

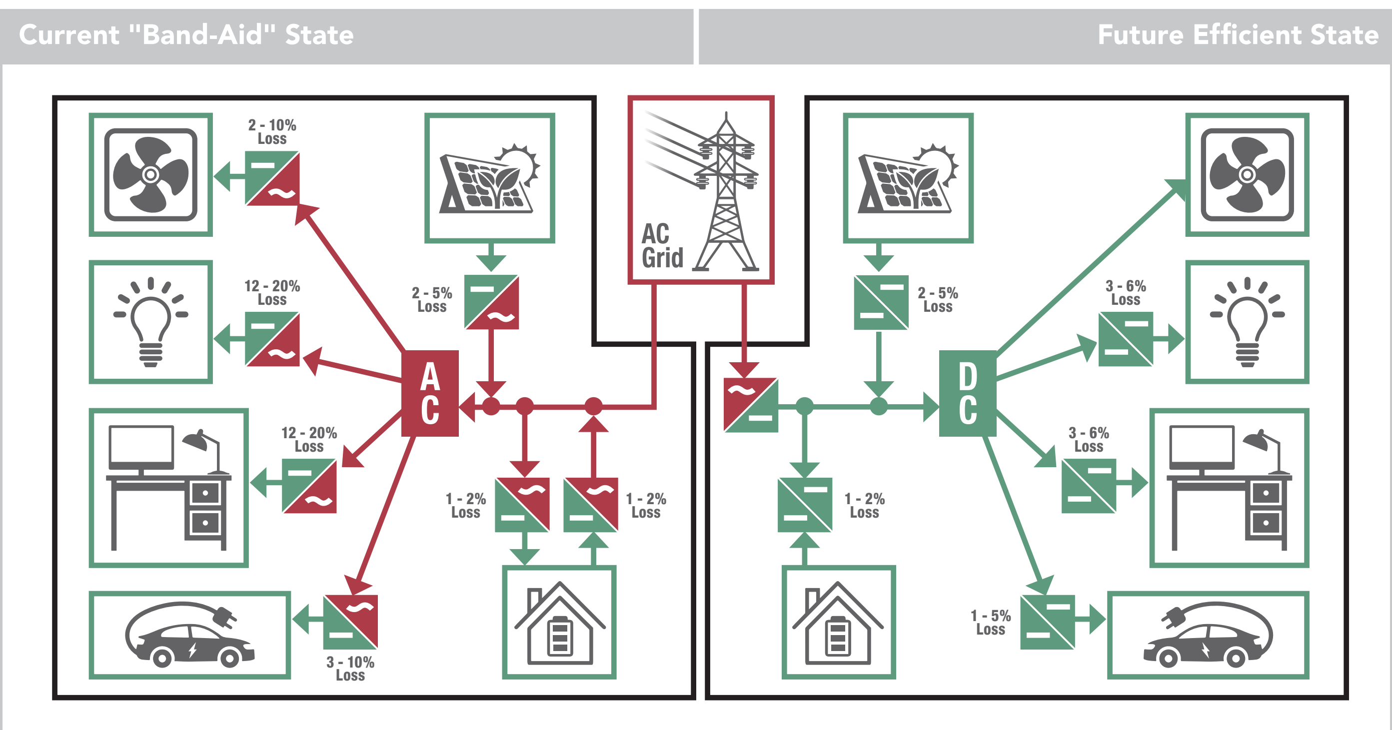
The use of DC power in buildings is not a new concept. It was applied to high-intensity power semiconductor facilities. Both the telecommunication and IT industries have used DC power in their buildings due to the large energy demand from their semiconductor devices. The telecommunications industry has been using DC power systems in their central switching facilities (48 VDC systems to serve circuit switching equipment) with great success and significant reliability. In these facilities, DC power provides numerous benefits (EPRI 2006, Knisley 2011) including improved power quality, reduced cooling needs, high equipment densities (i.e. facilities take less footprint as DC equipment connects directly to batteries), reduced heat-related failures, improved reliability, more efficient integration of on-site renewable energy generation sources, elimination of the need to balance phases or to synchronize multiple sources, and the simplification of wiring by reducing the number of breakers.

The wide-spread implementation of DC power in commercial buildings and homes is currently constrained by some market and regulatory hurdles, expected to be resolved over time as DC power is not a new concept and its scalable applications to buildings have already been demonstrated in some testbeds and cases, as discussed next. However, it will take time and effort from the industry main stakeholders (manufacturers, government research centers, advocacy groups, contractors, facility owners) to normalize the concept and increase its acceptance. Example of obstacles to wider implementation of DC-power in buildings include the following (ERPI 2006, NEMA 2018):

- ***1)** There are no arc flash regulations for commercial DC in North America. This allows for a variety of interpretations regarding clearances, access requirements, etc.*
- ***2)** Most equipment and devices (especially on the consumer and IT site) are not yet plug-ready for DC-powered buildings, and still depend on 60-Hz AC power that is converted with internal AC-DC drivers. However, manufacturers are already offering 380 VDC fans, servers/ server power supplies, and UPS units for a total DC distribution system.*
- ***3)** There are only a few building codes and standards available today that address DC systems, and those available do not provide holistic system design guidelines. Rather, they focus on individual components, such as electrified ceiling, batteries, PV, and storage.*
- ***4)** There is a lack of a sufficient ecosystem of DC system products and their standardization, such as connectors, circuit protection, and DC-based building systems (HVAC, lighting).*

The further advancement of the DC-powered building concept can be illustrated by three main industry initiatives: **the DC Components and Grid (DCC+G) research project in the EU, the EMerge Alliance, and the PoE new standards.**

Figure 4: Current status and envisioned future role of DC power in buildings



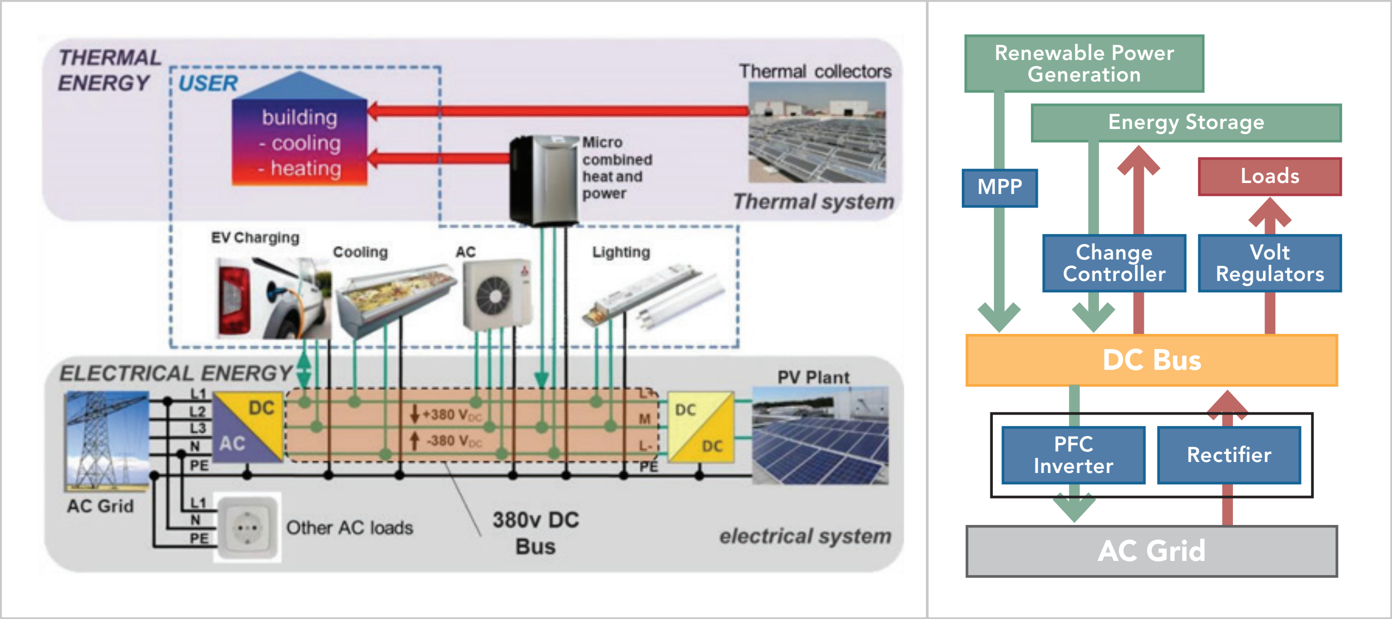
DCC+G Model and US Showcase Projects for DC-Powered Buildings

The Direct Current Components + Grid (DCC+G) was a 2012 to 2015 European research and development (R&D) project that aimed to develop innovative power semiconductors and products using them to increase the energy efficiency of commercial buildings (Weiss et al. 2015). The DCC+G project involved first designing and implementing testbeds of 2-phase low voltage direct current (DC) micro grid with supply voltages of ± 380 VDC and then comparing its performance to the traditional 3-phase 400 V AC grid architecture. Figure 5 depicts a generic mode of the implemented testbeds, composed of a main DC Bus (feed cables) that delivers energy from its onsite and offsite sources to the demand devices. The DC Bus has a bi-directional connection with the AC grid through Power Factor Correction (PFC) invertor and a rectifier to source and feed energy from/to the AC grid. The DC Bus can also be fed from a renewable power generation source (onsite PV, wind, or thermal) through an integrated maximum power point (MPP) tracker, as well as from the local electrical energy storage through a charge controller. Finally, large electrical loads (e.g., air conditioning and other building equipment) can directly draw energy from the 380 VDC DC Bus, while small low-voltage devices can be connected through volt regulators.

Real implementations of the testbeds for only low-voltage devices and lighting revealed that the efficiency difference between the AC and the DC distribution system varied according to the electrical power provided by the local sources. However, AC-based systems showed, on average, a 2.7% efficiency gain. This gain could be increased to 5.5% if the renewable energy generated onsite was more than that supplied in the testbed cases. The researchers argue that even more efficiency gains can be achieved if using the 2-phase 380 VDC DC Bus to feed high-power loads such as AC and industrial cooling equipment.

U.S. research studies in DC-powered residential properties provided conclusions similar to those found in the European DCC+G project. A study in the Lawrence Berkeley National Laboratory (Vossos et al. 2014) investigated the potential savings of DC power distribution in net-metered residences with on-site photovoltaics (PV). Model comparisons were run for 14 representative cities across the United States, using hourly, simulated PV-system output and residential loads. The modeling tested the effects of climate, load shifting, and battery storage and also considered partial load conditions. A sensitivity analysis determined how future changes in power system component efficiencies might affect potential energy savings. Results showed that net-metered PV residences without storage could save 5 percent of their total electricity load by using DC-internal appliances. Those with battery storage could save 14 percent of their total load. The residence without battery storage would achieve only a modest savings because the time of peak PV production (midday) does not coincide with the peak residential load (late afternoon/evening). However, residential PV systems incorporating battery storage could achieve much higher savings because the system can both save and use the generated power in DC form. The research also found that DC energy savings are sensitive to power system and appliance conversion efficiencies.

Figure 5: Left: DC distribution architecture of a testbed commercial building, Right: DC Bus and the main conversions in the system. (DCC+G 2012)



NECA members and the ELECTRI community should wait for the results from more recent testbeds of DC-based building energy systems in the U.S. to benefit from their lessons learned. For example, the The NextHome[2], located in Detroit and run by NextEnergy, serves as a proving ground for residential DC technologies. It currently incorporates a variety of DC devices, including a PEV charger, PV system, battery storage system, appliances, HVAC, and lighting. Another interesting testbed project is the Colorado Sustainability Alliance DC Micro-grid Project[3]. The goal of this project is to demonstrate and quantify the benefits of retrofitting existing commercial office buildings to utilize DC. It will provide DC power to lighting, office electronics, and eventually HVAC, coupled to a rooftop PV + battery storage system. Finally Bosch is aggressively testing and showcasing its DC Building Grid system in the following testbed projects: 1) Fort Bragg Military Base; 2) Livingston and Haven industrial distribution facility; and 3) The American Honda Motor Company campus.

EMerge Alliance of Hybrid AC/DC Systems

The Emerge Alliance is an industry association focused on the development of building DC power technologies and standards. EMerge has already developed two standards for data/telecommunication centers and commercial spaces and it claims to be working on a third standard for residential applications.

The first standard is for data/telecom centers to simplify their otherwise unnecessarily complex power management provisions generally used in today's AC-powered data centers. As shown in Figure 6, the standard defines a generic architecture for the DC power system in typical data/telecom centers, where the power is sourced from the AC, onsite renewable energy generation assets, and onsite generators that are either AC or DC. All these energy sources are integrated using a DC Energy Control Center (ECC), which regulates energy inflows and outflows. The data center racks are powered through 380 VDC busway, that is supplied from either the DC ECC and the UPS. The EMerge Alliance is currently working on building up a portfolio of DC products that comply with this standard.

2. https://nextenergy.org/nexthome/
3. https://www.thealliancecenter.org/join-us/learning-laboratory/dc-microgrid/

The second standard is called "Occupied Space" and its goal is to create a safe low-voltage DC power distribution layer in the interior spaces of commercial buildings. The standard utilized a modular approach by standardizing the DC distribution within a typical interior space (room or office) and its connection to the major AC or DC power in the facility, as shown in Figure 7. In the heart of the occupied space lies the Power Server Module (PSM), which accepts power from DC renewables, the AC grid, and battery backup, and converts it to 24 VDC that can be supplied to the DC devices in the space, such as lighting fixtures, HVAC actuators, A/V equipment, control sensors, and USB outlets. The 24 VDC is delivered through either 2-phase cables or a DC suspended ceiling power grid. Emerge Alliance managed to get the low-voltage suspended ceiling power distribution systems included in the 2014 Edition of the National Electrical Code (NEC, Article 393), which must comply with UL2577, Standard for Safety for Suspended Ceiling Grid Low Voltage Systems and Equipment. The NEC 2014 article limits systems to a maximum of 30 VAC or 60 VDC Class 2 power. The EMerge Alliance standard is considered an expansion of Eaton's distributed low-voltage power (DLVP) system, which was primarily designed for low-voltage LED light fixtures and their controls.

Figure 6: The EMerge architecture for DC power in data/telecomm centers

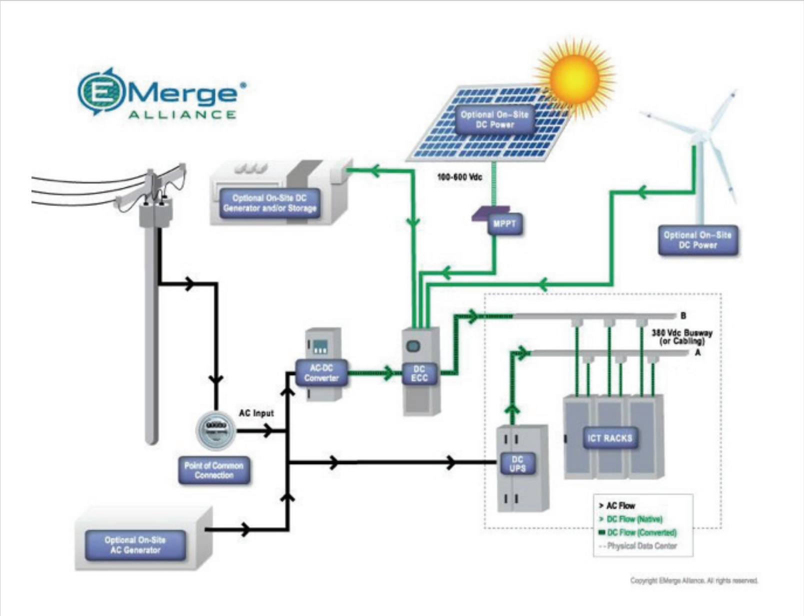
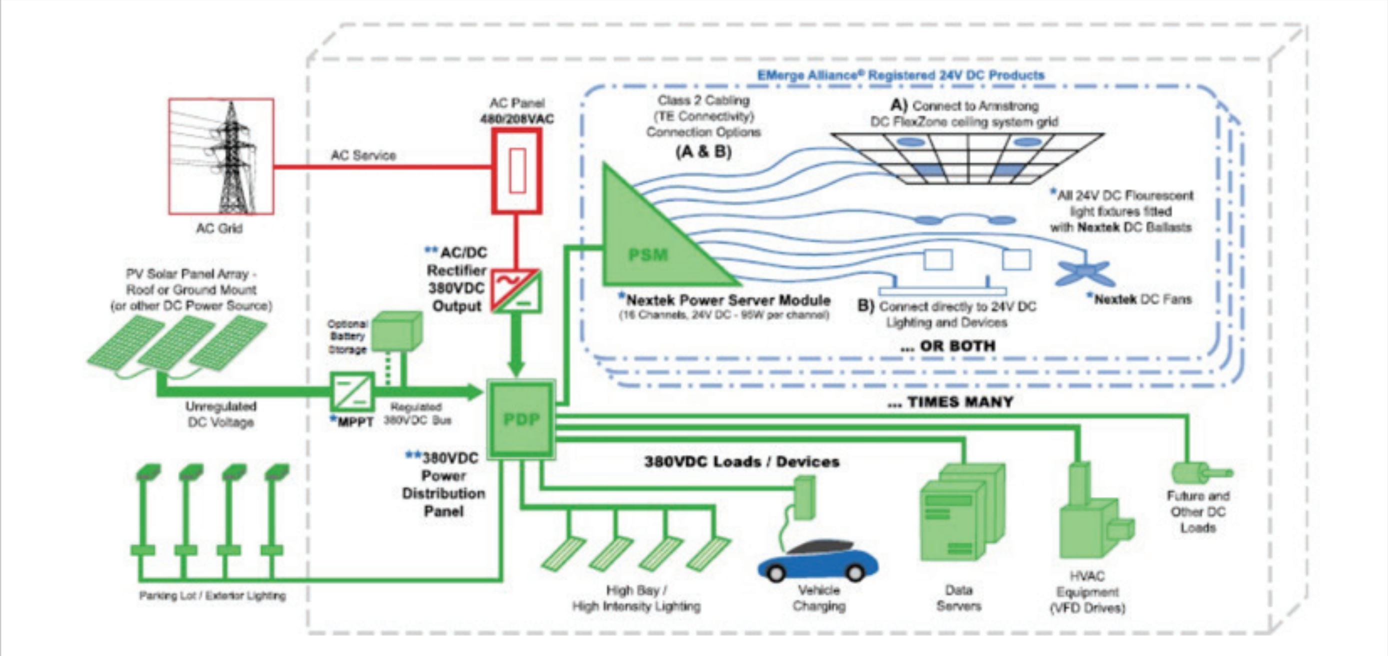


Figure 7: Schematic of the EMerge Alliance Occupied Space standard (blue part) and its connection to the building main power system

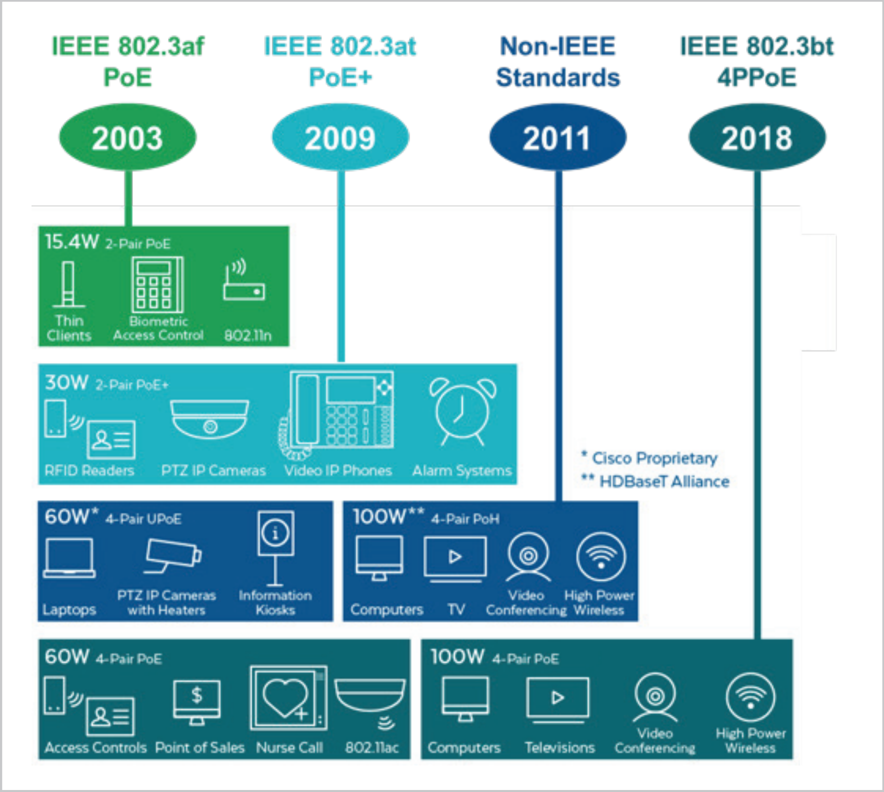


"Powering-up" PoE with New Standards

The future IoT world will require more and more data and power delivered to the devices in our work and living spaces, especially for enterprises and owners who need more integrated control on their properties. The Power over Ethernet (PoE) technology has fulfilled this need and is envisioned to keep doing so as devices become more power-efficient and industry standards are developed. After its release as an IEEE standard in 2003, Power over Ethernet (PoE) has continued its upward spiral in performance, demonstrating an ability to transfer Ethernet data at faster speeds and DC power at higher levels through the utilization of the four wire pairs in the cable. As shown in Figure 8, PoE first emerged as the IEEE 802.3af standard, which supported devices with loads up to 15.4 W, such as IP phones, access controls and Wi-Fi routers. Not long after, this standard was ratified in 2009 as IEEE 802.3at standard (or PoE+) to increase the delivered power to 25.5 W (after considering the losses from the input power of 30 W) for more devices that became more efficient, such as PTZ IP cameras and digital clock alarms. However, the industry was already ahead of the standards updating process, and new PoE technologies were developed to deliver more power and became proprietary standards afterwards. In 2011, Cisco developed the Universal Power Over Ethernet (UPOE) standard which extends the PoE+ standard to double the power per port to 60 watts. It can extend resilient network power to a broad range of devices, including IP cameras with heaters, laptops, and informational kiosks. Concurrently, the HDBaseT Alliance (established by Samsung, Sony, LG and Valens) developed the Power over HDBaseT (PoH) to extend the PoE maximum delivered power to 95W. The IEEE recently issued the newest PoE standard, 802.3bt, to formalize UPoE and PoH and their use of the 4-pair PoE capacity (4PPOE). As a reaction to the new PoE standards and applications, BICSI is working on a new standard (D044) for the installation of 4PPoE cables. It is clear from the PoE development during the last decade that there is a consistent delay between technology innovation on one side and the issuance of industry standards and codes on the other side.

PoE delivers great benefits with its increased power and data delivery. Yet, its role in DC power distribution in buildings requires a careful consideration of the needed smart building integration level. The benefits of PoE over the traditional power approach for low-voltage devices include: 1) reduced costs due to the integration of data and power into one system that can be safely installed by non-certified construction workers; 2) centralized facility management control and insights of the building systems, such as access, surveillance, and lighting; and 3) enhanced real-time adaptation of the systems to the needs of the space tenant.

Figure 8: The progression of PoE standards and their supported devices[4]



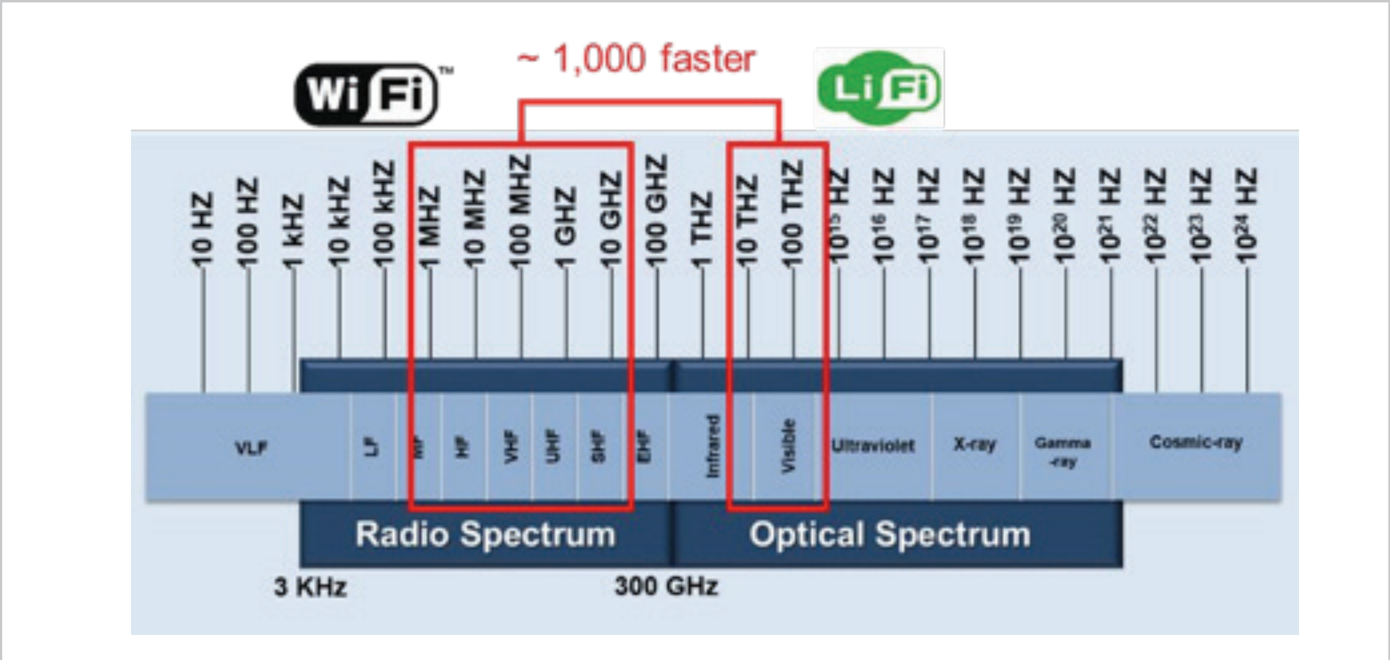
4. *Graphics were adopted from: http://blog.leviton.com/cabling-and-connectivity-power-over-ethernet*

However, it is still too early to judge PoE on its ability to deliver on these promised benefits as the IEEE 802.3bt standard is not yet fully adopted in the industry. Facility managers need to understand the efficiency difference between powering their space with PoE and distributed low-voltage (DLVP) systems. PoE is a natural fit in facility applications where data network integration is expected, such as class A offices and healthcare. The PoE user understands and appreciates a data network infrastructure designed to process analytics, optimize space utilization and control all aspects of an entire facility over one system. On the other hand, DLVP technology was designed for simplicity, in terms of its plug-and-play commissioning right after installation by the same contractor. Both PoE and DLVP systems provide the same benefits of code compliance, ease of installation, and labor/material cost savings. However, PoE systems are constrained by the power loss over long category cables (Makdessian and Hunyh 2015), so PoE cannot solely power a whole facility. It is better used when delivering power from a DLVP or AC systems to the IoT devices.

LI-FI

Light-fidelity (Li-Fi) is a new protocol for an advanced form of visible light communication that can significantly increase connectivity in the smart building environment beyond the bandwidth constraints of today's radio-based wireless communications. Most of today's work and living spaces are wirelessly connected using the Wi-Fi IEEE 802.11n and 802.11ac standards that utilize the 2.4 GHz and 5 GHz bands to, theoretically, deliver a maximum 1.3 Gbps. Even the latest uncommon Wi-Fi standard IEEE 802.11ad that utilizes the 60 GHz band can deliver up to 5 Gbps short-range connectivity. Li-Fi was developed by Professor Harald Haas at the University of Edinburgh. He is the co-founder of the leading company in this area pureLiFi. As shown in Figure 9, Li-Fi promises to deliver around 1,000 faster connectivity compared to Wi-Fi by utilizing the visible light waves (10 – 100 THz).

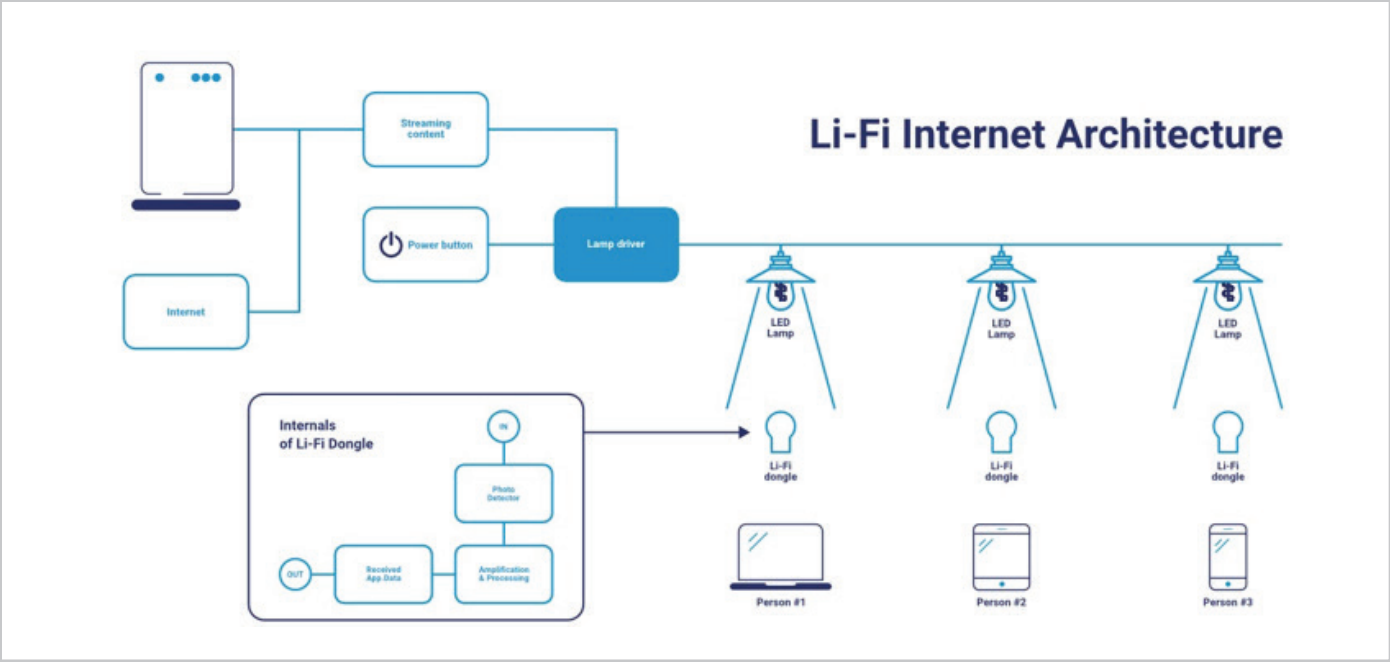
Figure 9: Comparison between the used electromagnetic spectrum of Wi-Fi and Li-Fi and potential data speed efficiencies



Li-Fi communication is done by modulating the light (or the current feeding it) at a very high speed to encode the streaming data and then decoding it in the receiving device using a photo detector. Li-Fi uses LED bulbs that flicker on and off at a very high rate not noticeable to the human eye (like a super-fast Morse code) as a medium to deliver high speed communication. As shown in Figure 10, a special lamp driver is required to deliver the data and the modulated current to the LED to send the encoded data. At the other end, the devices will be equipped with Li-Fi dongles, which include: 1) photo sensors to decode the LED light into the streamed data and 2) an Infra-red (IR) emitter to create the uplink data link from the device back to the LEDs.

Li-Fi requires no significant changes in the already existing lighting infrastructure in most smart buildings, just installation of the Li-Fi LED drivers and the utilization of the USB-based Li-Fi dongles with the connected devices. Per the first Global Li-Fi Congress[5], the technology market is expected to grow to $75 billion in 2023, with an annual growth of 80%.

Figure 10: Li-Fi Architecture[6]



Li-Fi technology is envisioned to leverage the lighting infrastructure to deliver faster and more secure connectivity in smart buildings. Besides the increased bandwidth, the advantages of Li-Fi include improved connection stability, improved security (it is hard to hack a light signal remotely), and freedom from the interference of medical and lab equipment.

However, a significant barrier to Li-Fi technology is its integration into mobile devices that cannot use the USB dongles currently available. This technological barrier is magnified as current Li-Fi solutions on the market have very limited compatibility with traditional LED luminaires and, therefore, LED driver/power electronics need to be enhanced. Also, Li-Fi, as a visual light communication standard, is very dependent on the existence of clear lines of sight between the LEDs and the devices. When Li-Fi becomes a viable connectivity solution, it is expected to work hand-in-hand with existing wireless technologies (Wi-Fi, Bluetooth, etc.) to deliver the right connectivity for the right use. Li-Fi seems to fit naturally in outdoor public use and within spaces with bandwidth demand surges, such as hotels, conference centers, and large office buildings.

5. https://www.lificongress.com/index.php?idedition=1

6. https://www.grandmetric.com/2017/11/21/light-fidelity-lifi/

WPA3 SECURITY STANDARD

All Wi-Fi networks are secured using Wi-Fi Protected Access (WPA) protocol. It is almost guaranteed that all Wi-enabled devices, routers, access points and modems utilize the 2nd iteration of the WPA protocol (WPA2). This protocol is necessary to allow two devices (i.e. the router and connected device) to recognize themselves (aka "handshake") and start a secure data exchange. This security standard was developed by the Wi-Fi Alliance, the entity responsible for certifying Wi-Fi product compliance with standardized interoperability and security requirements. WPA2 was introduced to the industry in 2014 and, since then, Wi-Fi networks have been protected if properly administered and secured.

However, IoT devices and discovered internal protocol flaws have made WPA3 very vulnerable to hacking attacks. Of the burst of IoT devices connected to Wi-Fi networks in the workplace and homes, the majority of these IoT devices are not well secured and protected. This vulnerability is caused by the fact that IoT devices do not have their own user-friendly interfaces (like monitors) to allow the user to change the device default passwords. As such, these devices are connected to the network with either no passwords or factory-installed passwords (like "admin" as the username and password). In addition, the WPA2 handshaking procedure was vulnerable to "brute-force" attacks of the KRACK (key reinstallation attacks) type in 2017. Brute-force hacking attacks utilize computational algorithms to try all possible passwords with the hope of eventually guessing the correct credentials. In KRACK attacks, the hacker tricks a device connected to the Wi-Fi network to reinstall an already-in-use key by manipulating the cryptographic handshake messages. Regardless of the security design measure implemented in the Wi-Fi, it is still vulnerable due to the existing handshaking KRACK weakness in WPA2 protocol.

In response to this security threat, the Wi-Fi Alliance released WPA3 in 2018 to eliminate the KRACK attack vulnerability and make it easier to secure IoT devices. First, WPA3 defines a new handshake that "will deliver robust protections even when users choose passwords that fall short of typical complexity recommendations." This new procedure will protect against both KRACK and brute-force attacks. Second, WPA3 will introduce some crucial features for the security of IoT devices and the whole Wi-Fi network. Details of these security measures have not yet been revealed, but it is known that they will facilitate easier setup and alteration of IoT device passwords through the use of portable devices (i.e. smart phones and tablets). In addition to enhanced protection against KRACK and IoT threats, WPA3 comes with additional security features including individual data encryption in public Wi-Fi networks (coffee shops and malls) and stronger 192-bit encryption.

LOW-POWER WIDE AREA NETWORKS

Historically, building automation and control systems have been connected using a range of hardwired (Ethernet) and short range wireless (Wi-Fi, Bluetooth, ZigBee, etc.) technologies. However, it is difficult to imagine how these will deliver the necessary scale and deployment simplicity to connect the future, huge IoT ecosystem of devices and sensors within and outside buildings. The business case of most IoT applications, including smart buildings, can be mostly fulfilled with low bandwidth connectivity with low capital and operational expenditures.

Low power wide area network (LPWAN) technology has gained considerable traction over the last couple of years to provide scalable and cost effective connectivity to IoT ecosystems. LPWAN technologies are wireless wide area networks that enable connectivity at low-throughput (narrowband) over very long distances with very low power consumption. LPWAN technology is not new. It has been used in machine-to-machine (M2M) communication networks for many years. The new attention being given to LPWAN is due to the need for low-cost, long-range, low throughput devices to support IoT solutions.

LPWAN has three main features that make it very good fit for IoT. It has a range of 5 to 40 km and the end nodes can be a long distance from the gateway, up to 10 km. LPWAN has ultra-low power consumption, so batteries that power remote sensor nodes can last up to 10 years. Finally, LPWAN is ideal for the low throughput requirements of IoT data packets, usually transmitted at no more than several hundred bits per second (bps). As shown in Figure 11, LPWAN provides a good balance between scalability (long range and low power consumption) and low bandwidth for transmitting small infrequent field data. Examples of such data include indoor air quality, energy use, water use, moisture levels, greenhouse gas emissions, indoor temperature, HVAC system status, security status/alarms, life safety status/alarms, and lighting levels. Table 2 provides a more detailed comparison between some common short-range wireless technologies (Wi-Fi, Bluetooth, and ZigBee) and a sample of LPWAN technologies (LoRaWAN and NB-IoT).

Figure 11: Bandwidth-range tradeoff for the wireless communication technologies

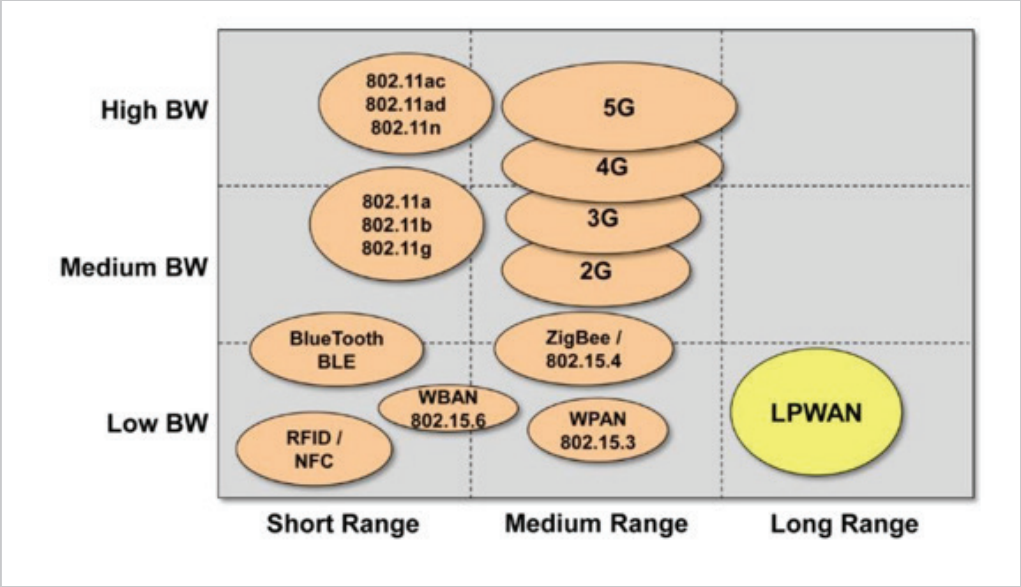


Table 2: Comparison between sample short-range wireless and LPWAN technologies

IoT Connectivity	Ideal Applications	Data Rate	Security	Cost	Range	Power Consumption
Wi-Fi	Consumer products in smart homes	1 GBPS	Low	Medium	300 ft.	High
Bluetooth Low Energy (BLE)	Consumer products in smart homes and tracking	1 MBPS	Low	Low	150 ft.	Low
ZigBee	Industrial and smart building automation	250 KBPS	Medium	Low	300 ft.	Low
LoRaWAN	Industrial, noisy environment, infrastructure long-range sensing	0.3 – 50 KBPS	Medium	Medium	9 miles	Low
Narrowband IoT (NB-IoT)	Agricultural, industrial, building devices	0.3 – 200 KBPS	High	Medium	6 – 9 miles	Low

Global demand for LPWAN technologies has been on the rise and can be separated into two solution groups: solutions operating in an unlicensed spectrum (such as SigFox and LoRa) and those operating in a licensed spectrum (such as LTE CAT-M and NB-IoT). Several French companies were spearheading this technology movement, most notably Cycleo and Sigfox, both founded in 2009. Cycleo, the company behind the LoRa technology has been bought by SEMTECH, while SIGFOX managed three years later to receive significant venture capital funding. Also, the UK had its claim to fame in the form of Neul, a company initially developing LPWAN technology for the TV market. LTE CAT-M is viewed as the second generation of LTE chips built for IoT applications, resulting in less capital investments from mobile operators as it is compatible with existing LTE infrastructure. NB-IoT (also called Cat-M2) provides similar promises of LTE CAT-M, but it uses a modulation different from LTE. This means mobile operators have a higher upfront cost to deploy NB-IoT.

LoRaWAN represents the most promising LPWAN technology for smart building applications due to its fit for the data types transmitted in smart buildings, open standards, private network deployment feasibility, and industry support. LoRaWAN provides a well-balanced LPWAN technology to transmit the smart building data that do not require quality of service or frequent communication (Mekki et al. 2018). Although LoRa is owned by a single company (SEMTECH), the LoRaWAN ecosystem includes a variety of different chip and module manufacturers, device manufacturers, base station and network server vendors, and service providers. LoRaWAN was rolled out in different mobile networks worldwide, including the US, France, Switzerland, Belgium, The Netherlands, India, Japan, and South Korea. In addition, LoRaWAN is well-suited to be used for private network deployments, similar to Wifi Enterprise networks. Such private networks can be deployed using LoRa IoT Gateways (like the ones provided by Advantech), which can support up to 500 sensor nodes at one time. As proof of its promising future, LoRa wireless technology was selected by Schneider Electric to use in its building monitoring systems, electrical load switching devices, grid monitoring systems, HVAC controls and predictive maintenance tools. LoRaWAN can be an intermediate LPWAN solution until other cellular-based solutions (like LTE CAT-M and NB-IoT) are fully rolled out by the mobile operators.

EDGE AND FOG COMPUTING

In a 2017 blog post[7], Cisco's Head of IoT Strategy, Macario Namie, wrote the following about the storage and computing demand of the growing future IoT applications:

> ***"One of the beautiful outputs of connecting 'things' is unlocking access to real-time data. Next is turning that data into information and, more importantly, actions that drive business value. In trying to do so, companies are finding themselves deluged with data. So much so that demand for vast compute and storage needs have arisen, very nicely handled by public cloud providers. But the cost of transport and speed of processing has also increased, which is challenging for many uses cases such as mission-critical services."***

Future smart buildings will contain hundreds and thousands of sensors measuring various building operating parameters such as temperature, humidity, occupancy, energy usage, keycard readers, parking space occupancy, fire, smoke, flood, security, elevators, and air quality. Collectively, these sensors capture massive amounts of data that must be transmitted to the cloud, stored, analyzed and acted upon using actuators, often in real-time, to provide a truly smart building experience. Some of this processing and actuating is extremely time-sensitive, and requires a real-time response from the field devices. Examples would include turning on fire suppression systems in response to detecting a fire event and guiding occupants to the nearest exit, or locking down an area if an unauthorized person tries to gain entry.

7. https://blogs.cisco.com/digital/cisco-and-microsoft-collaborate-to-power-intelligent-actions

This pure cloud-based IoT vision of smart buildings can face scalability and reliability issues with the further deployment of IoT devices and the growth of their data communication needs. The industry needs a different vision, cheaper and smarter than the traditional cloud-based one that typically involves gathering the data, sending them through the network to the cloud, and processing and leveraging them. Depending on the context and scope of the project, you want the data you need fast. Better yet, you need the aggregated and analyzed data fast, in the shape of actionable intelligence, enabling you to take actions and decisions, whether these decisions are human or not. So, you do not need all that data to store it and analyze it in the cloud. You only want that bit of key data traveling across your networks. Some building systems are life or mission critical and require higher availability than cloud-based solutions can achieve. Some smart building IoT systems generate significant data volumes that would swamp the building's network bandwidth.

As such, the IoT industry started the old approach of performing some basic computing in the devices themselves or somewhere in the local network close to them, instead of transmitting huge amounts of raw data for cloud computing. This old approach had the name "edge computing", often mixed with another term called "fog computing". However, edge computing and fog computing represent different approaches that can be applied separately or together to solve the growing limitations of cloud computing. Both approaches (edge and fog computing) entail moving intelligence and processing capabilities down closer to where the data originates. They differ in where that computing occurs in the spectrum between the cloud and the devices, as shown in Figure 12. Fog computing pushes intelligence down to the local area network level of network architecture, processing data in a fog node or IoT gateway. Edge computing pushes some or most of the intelligence, processing power and communication directly into the field devices like programmable automation controllers (PACs). Edge, fog, and cloud computing will complement each other, rather than competing against each other, as shown in Figure 12. It is not yet clear how these computational approaches will be deployed in smart buildings, as different architectures are presented by the leading industry organizations such as the OpenFog Consortium smart building use case (Open Fog 2018), the definition of fog computing by the National Institute of Standards and Technology (NIST 2018), and Edge X Foundry (EdgeX 2018). However, Figure 12 shows a common architecture for the distributed computing achieved by the different edge, fog, and cloud nodes.

- **Edge Node:** The edge node can represent a sensor/device with onboard microcontrollers, such as VAV, IP Camera, smoke detectors, etc. Small programs called Device Services are installed in the embedded microcontrollers to provide real-time logic and control actions. Also, the edge node and its device services screen data locally, reducing the volume of data traffic sent further into the fog and cloud path.

- **Room Fog Node:** Room fog nodes can govern a conference room, an office, an apartment or any similarly- structured closed space. The room node will have enough intelligence to discern which data require storage, based on which actions require real-time processing, which can be passed to a floor fog node, or which can be shared with another room node. It will have enough AI power to perform localized actions such as conserving energy load within an unoccupied room, to learn and maintain an occupant's preferred temperature, recognize intruders, and even recognize occupants' gestures or voice commands to provide specific comfort services.

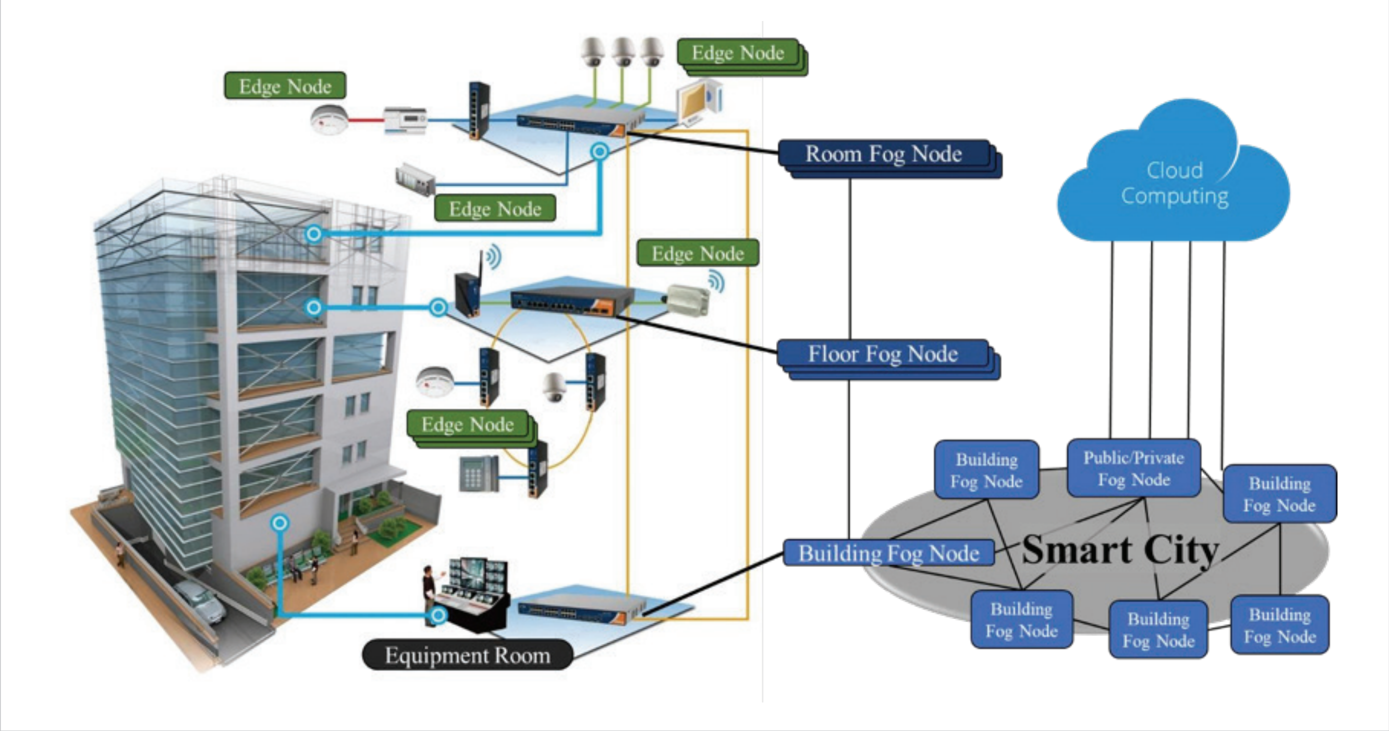
- **Floor Fog Node:** Floor fog nodes connect to many of the same sensors and actuators as room fog nodes (those that are in open areas) and to room nodes themselves. Floor fog nodes coordinate all room nodes for a given floor, exchange information with other floor nodes, and share with the building fog node any information required for optimizing the entire building, or for storage in the cloud. These enhanced capabilities require more advanced analytics and larger storage space than room fog nodes and maintain similar latency. The floor node's AI power enables constant solving of complex optimization problems, such as balancing the energy loads between different rooms.

- **Building Fog Node:** Well-architected building fog nodes communicate with fog nodes below them in the hierarchy and other building fog nodes. They ingest data from room and floor fog nodes and take slower, more deliberate actions such as setting equipment schedules, optimizing overall load on the building's systems, and communicating with the cloud.

- **Public/Private Fog Node:** Intermediate fog computing nodes can exist between buildings and the cloud, which can be owned by public or private entities. Public nodes can be owned by local jurisdictions to make smart cities and smart grids a reality by coordinating the services and utilities between different buildings. Private fog nodes can be owned by mobile network providers and operators and integrated into their future 5G towers. Private enterprises can then rent these fog nodes for AI analytics, instead of having a dedicated building fog node.

- **Cloud Node:** Cloud fog nodes provide the analytics power to train predictive models with huge, stored datasets, compare a Smart Building's performance to that of like Smart Buildings, and generate the wisdom learned from Petabytes of data collected from tens to hundreds of buildings. Also, cloud nodes will provide the ability for a Smart Building to connect to other fog nodes in the area without opening itself up to malicious hacks.

Figure 12: Edge and fog nodes deployment between the smart building and the cloud

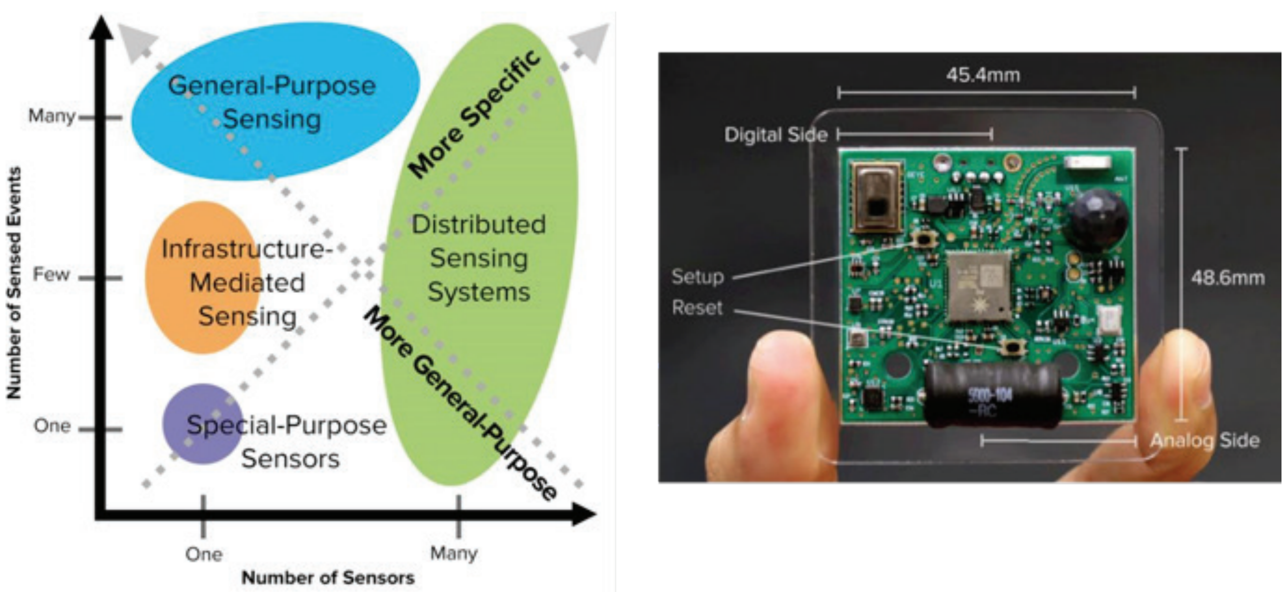


SYNTHETIC GENERAL-PURPOSE SENSORS

Sensing is the heart of IoT technology, where the real benefits of smart buildings for tenants and facility managers heavily rely on robust sensing of different facets of the indoor environment. Traditionally, smart buildings have been equipped with special-purpose sensors, with each sensor designed to measure only one particular aspect of the environment, such as temperature, moisture, pressure, air quality, ambient light, etc. Although these special-purpose sensors have performed their intended sensing function, they do not present real intelligent recognition of the events within a living or work space. These special-purpose sensors are limited to either their original equipment (electrical meter or lighting fixture) or their intended function (like sensing occupancy). Also, these sensors are not exchangeable between devices.

Researchers from Carnegie Mellon University, with funding from Google, developed the concept of *general-purpose sensing* and developed a smart sensor (called synthetic sensor) to monitor the context and activities within an environment without heavy instrumentation. As shown in Figure 13, general-purpose sensing has the ambitious goal of sensing multiple events in the environment (e.g. a room) with a single synthetic sensor that can detect the changes of multiple environmental variables (like temperature) and translate them into relevant events (like the oven is working). General-purpose sensing is considered a big improvement for most building automation control systems and can be classified as distributed sensing systems. Synthetic sensors utilize artificial intelligence to reduce the number of deployed sensors while still comprehending the sensed environment and communicating the actual events happening in the space. The synthetic sensor tag is equipped with a microcontroller, Wi-Fi antenna, USB connector, and a wide array of sensors (vibration, audio, ambient temperature, non-contact temperature, humidity, air pressure, illumination, motion, magnetic).

Figure 13: General-purpose sensing compared to other sensing approaches (left) and a picture of a synthetic sensor tag (Laput et al. 2017).



The synthetic sensor utilizes AI to support virtualization of the collected low-level data from all tag sensors into semantically relevant observations, such as calculating the number of water gallons used when hearing the sound of a faucet. This means that sophisticated AI operations are performed in the sensor tag chip and also in the cloud sever to translate the sensed data into the goal events. Also, this requires that large amounts of data need to be collected first and used to train the sensor and the server system. However, the AI training and system were very effective with an accuracy rate of more than 95% in detecting the events with the trained data (detecting the faucets, kitchen equipment, garage doors, etc.), as reported by the researchers (Laput et al. 2017). General-purpose synthetic sensing is still in development, but it does present promising applications in smart homes and commercial buildings, despite the expected obstacles. Synthetic sensors will require long AI training to be able to detect common events within an environment, but this training is expected to be easy with all the consumer data collected by Google products. This will make these sensors a very attractive consumer product for homeowners as a plug-and-play system to automate their living spaces.

Currently, synthetic sensors do not offer as many control options as fully fledged IoT-enabled appliances. But, they still provide the ability to leverage the accrued real-time intel to support contextually aware apps for the lived environment. It is very feasible to integrate a set of synthetic sensors with Google's smart Home device as the voice interface and the automation hub of the IoT enabled devices. In commercial buildings, synthetic sensors can help run smooth building operations, such as replenishing a toilet dispenser or alerting the maintenance staff about equipment that needs maintenance.

There are some privacy concerns about the audio recording of synthetic sensors, but the system was already designed to limit the processing of voice recordings to the sensor chip and not upload them to the cloud. Also, the synthetic sensor might not have the capacity to detect all the simultaneous variations that happen in chaotic or dynamic environments, like multiple machines running in a noisy room. Finally, the required AI data training means that system performance will suffer in the early times after deployments or when new variables are introduced to the environment such as updated machines or different user activities.

CONCLUSION

Buildings with smart IoT systems are evolving into technologically complicated system-of-systems that will be challenging to design and build using traditional industry practices. A model-based systems engineering (MBSE) approach can be helpful in delivering a smart building project, following the successful use of MSBE in other much more complicated systems such as automobile manufacturing and ship building. Successful implementation of MBSE is very dependent on a clear knowledge model and representation of the system, its components, and the expected functionalities. The first part of this chapter presented a knowledge model of smart buildings with a set of block and use case diagrams. These can serve as foundational for electrical contractors to implement MBSE approaches in configuring and constructing smart buildings.

In addition, future industry opportunities are presented to point attention to the potential technological advancements that can overcome the challenges identified in Chapter 1 to advance the smart building market. These opportunities were seriously considered when developing the electrical contractor roadmap to smart buildings, as discussed in Chapter 5.

REFERENCES

DC Components and Grid (DCC+G) (2012). Deliverable: D1.1.1: *Definition of scenarios and use cases.* Report JTI-CP-ENI-AC-2011-1, www.safelog-project.eu/wp-content/uploads/2016/06/D1.1.pdf, last accessed 8/27/2018.

Electric Power Research Institute (EPRI) (2006). *DC Power Production, Delivery and Utilization.* White paper, EPRI, Palo Alto, CA USA.

Edge X Foundary (2018). *A Microservice Approach to IoT Edge Computing.* Presentation by Jim White, Dell Technologies, CloudOpen conference, Beijing, China, online link: https://www.lfasiallc.com/wpcontent/uploads/2017/11/EdgeX-Foundry-A-Microservice-Approach-to-IoT-Edge-Computing-_JimWhite.pdf. Last accessed 8/26/2018.

Johnson T., Paredis C. and Burkhart R. (2008). *"Integrating Models and Simulations of Continuous Dynamics into SysML,"* in Modelica Conference, Germany.

Knisley J. R. (2011). *"DC Power to the People: Direct current power systems bring micro-grid to the office."* Electrical Construction & Maintenance (EC&M) magazine, online article, Nov. 22, link: https://www.ecmweb.com/contractor/dc-power-people, last accessed 8/30/2018.

Laput G., Zhang Y., and Harrison C. (2017). *"Synthetic Sensors: Towards General-Purpose Sensing."* In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17). ACM, New York, NY, USA, 3986-3999. DOI: https://doi.org/10.1145/3025453.3025773.

Makdessian A. and Hunyh T. (2015). *"PoE technology for LED lighting delivers benefits beyond efficiency."* LEDs Magazine, September 2015 issue, https://www.ledsmagazine.com/articles/print/volume-12/issue8/features/dc-grid/poe-technology-for-led-lighting-delivers-benefits-beyond-efficiency.html.

Mekki K., Bajic E., Chaxel F., and Meyer F. (2018). *"A Comparative Study of LPWAN Technologies for Large-Scale IoT Deployment."* ICT Express, the Korean Institute of Communications Information Sciences, Elsevier.

National Institute of Standards and Technology (NIST 2018). *Fog Computing Conceptual Model.* NIST Special Publication 800-191, NIST, U.S. Department of Commerce.

National Electrical Manufacturers Association (NEMA) (2018). *Direct Current in Buildings: A Look at Current and Future Trends.* Report NEMA DCP 1-2018, online link: https://www.nema.org/Standards/ComplimentaryDocuments/NEMA%20DCP%2012018%20WATERMARKED.pdf. Last accessed: 8/29/2018.

OpenFog (2018). *Fog Use Case Scenarios: Smart Buildings.* OpenFog Consortium Architectural Use Cases, report OPFUC002.16.18, online link: https://www.openfogconsortium.org/wp-content/uploads/OpenFog-UseCases-Smart-Buildings-Scenario-10-30-17.docx_.pdf, last accessed 8/26/2018.

Patterson B. T. (2016). *The Role of Hybrid AC/DC Building Microgrids in Creating a 21st Century Enernet. Part 1: Doing for Electricity What the Internet did for Communications.* White paper published by Continental Automated Buildings Association (CABA).

Valdes F., Gentry R., Eastman C., and Forrest S. (2016). *"Applying Systems Modeling Approaches to Building Construction."* 33rd International Symposium on Automation and Robotics in Construction.

Vossos V., Garbesi K., and Shen H. *"Energy Savings from Direct-DC in U.S. Residential Buildings."* Energy and Buildings. 68 (2014),pp. 223-231.

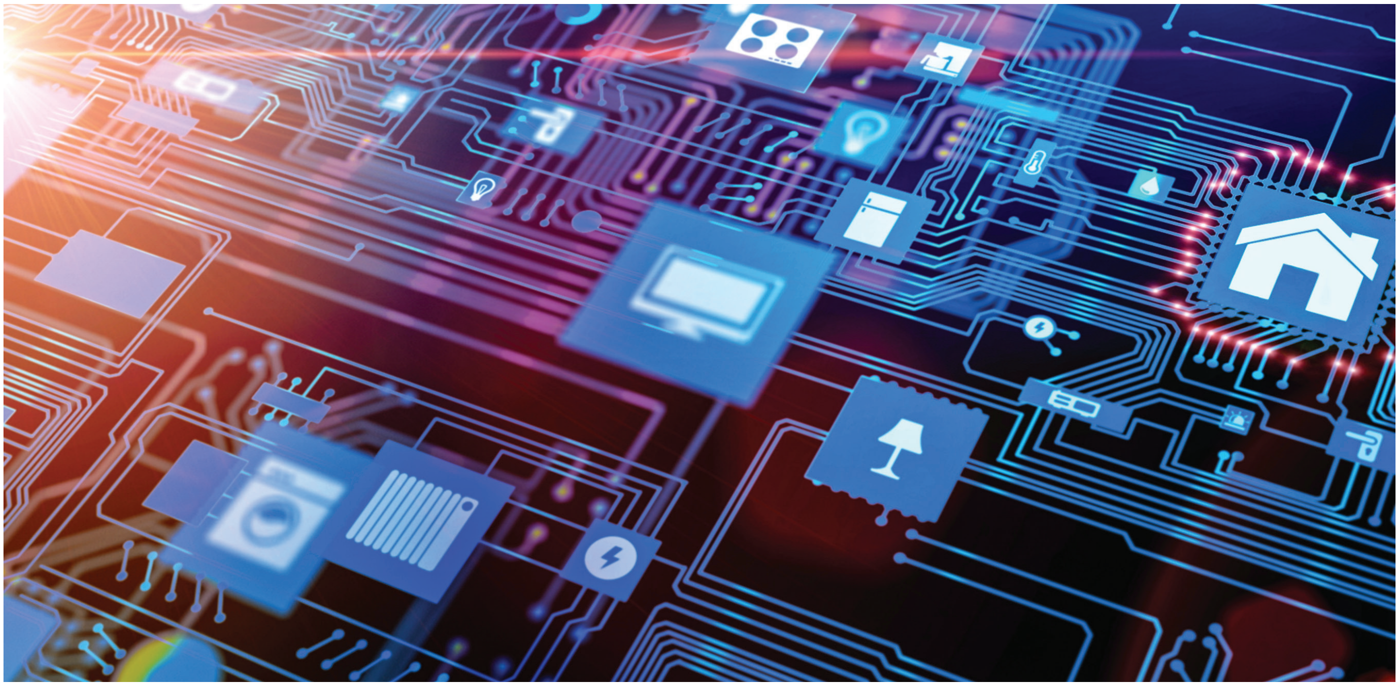
Weiss R., Ott L., Boeke U. (2015). *"Energy Efficient Low-Voltage DC-Grids for Commercial Buildings."* 2015 IEEE First International Conference on DC Microgrids (ICDCM), IEEE, Atlanta, GA, ISBM: 978-1-47999880-7.

CHAPTER 5

ELECTRICAL CONTRACTOR'S ROADMAP FOR SMART BUILDINGS

INTRODUCTION

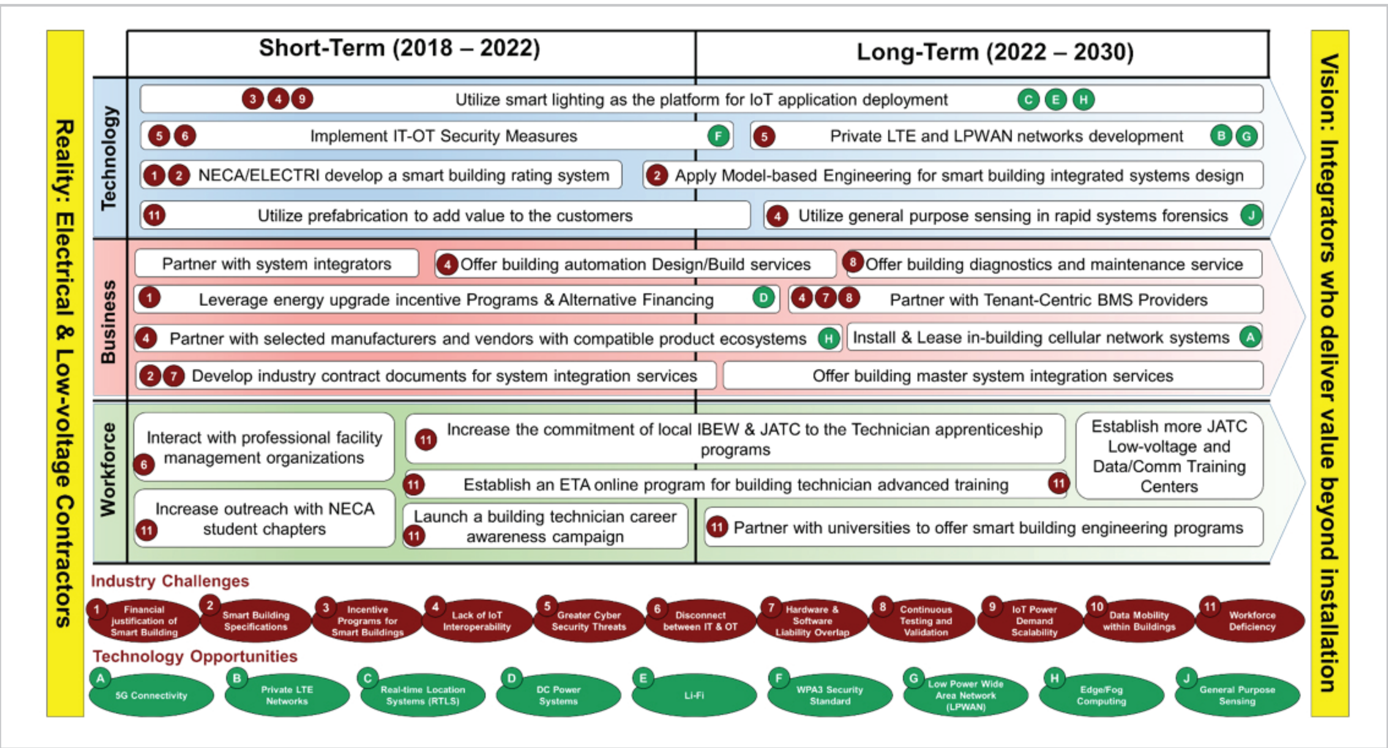
This chapter presents a comprehensive roadmap that proposes different strategies for the electrical contracting industry to increase its future role in the smart building market. An effective roadmap includes vision-driven short-term and long-term strategies that aim, through different paths, to transform the industry from its current state to a future state by utilizing the available opportunities to overcome the current challenges. The roadmap will help to align the efforts of the key stakeholders of the electrical contracting industry (NECA, IBEW, Electrical Training Alliance, local JATC programs, manufacturers) to benefit mutually from the growing market of smart buildings and the proliferation of IoT technologies.



ROADMAP

The proposed roadmap envisions a future integrated role for electrical contractors through technology plus business and workforce strategies. Low-voltage system installation capability is a prerequisite for any electrical contractor to implement the roadmap, due to the significant contemporary role of low-voltage systems in smart buildings. Offering low-voltage services has become a business necessity for electrical contractors. It is no longer an option. As shown in Figure 1, the roadmap has a vision of transforming electrical contractors into system integrators who provide value to building owners beyond design support and installation. The roadmap considers the strategies and opportunities up to 2030 to provide a realistic projection of the market's rapid technological development. The roadmap consists of seven technology strategies (TS), nine business strategies (BS), and seven workforce strategies (WS), each presented in more detail in the following subsections.

Figure 1: Smart Building Roadmap for Electrical Contractors



TECHNOLOGY STRATEGIES (TS)

UTILIZE SMART LIGHTING AS A PLATFORM FOR MODULAR IOT DEPLOYMENT

Lighting infrastructure provides the optimal platform to deploy more IoT sensors and connectivity and represents a strategic opportunity for electrical contractors (ECs) to pursue to have the greatest dominance in the smart building market. Lighting fixtures is considered the perfect edge node in the smart building IoT network due to its guaranteed use in buildings and energy supply availability. Every room requires at least one lighting fixture. This means an assured location in every space with sufficient line of sight and power abundance to deploy smart devices and sensors.

ECs should capitalize on their previous experience with lighting systems as their gateway to infiltrate the smart building market easily by delivering numerous benefits to building owners, tenants, and facility managers. Building energy codes increasingly require efficient LED lighting fixtures, which are much easier to integrate with modular and integrated sensors. ECs and lighting manufacturers need to continue improving the smart LED fixture by enabling standardized modular sensor and device installations in the lighting fixtures. Currently, lighting fixtures can be equipped with wireless integrated sensors for ambient lighting, ambient heat, and occupancy. However, lighting manufacturers can significantly add value to the market by opening their fixtures to be IoT hubs that can power additional sensors or devices and aggregate their communications as an edge computing node before their data are shared with other nodes in the building or up to the cloud. **In summary, smart lighting will be one of the main enablers for expansion into the smart building market,** due to the following benefits:

- **Granular and Precise Intelligence:** Well-architected building fog nodes communicate with fog nodes below them in the hierarchy and other building fog nodes. They ingest data from room and floor fog nodes and take slower, more deliberate actions such as setting equipment schedules, optimizing overall load on the building's systems, and communicating with the cloud.

- **IoT Power Accessibility:** Sensors will be powered directly from the LED driver in the lighting fixtures, though auxiliary power connectors that can easily be standardized between manufacturers of the lighting and sensor devices.

- **Simplicity:** Through the integrated sensing platform of lighting fixtures, the design and installation of different building control systems will be simplified. The basic integrated sensors in a single lighting fixture can be used in the control of different building systems (lighting, HVAC, audio/video, etc.) instead of installing individual control systems.

- **Scalability:** With the help of smart lighting fixtures, building system intelligence can be scaled with increased facility sizes or the number of sensing nodes. Intelligence can easily be extended to a room by installing a smart luminaire with the required sensors. Also, PoE-based lighting fixtures would facilitate this scalability by delivering reliable wired connectivity and power to the sensors

- **IoT Interoperability:** Lighting fixtures will provide a common sensing and control platform that can eliminate interoperability between the different smart building systems. Also, equipping lighting fixtures with edge computing capabilities can facilitate the implementation of IoT interoperability standards (such as Project Haystack and IoTivity) by reducing processing the raw data into fewer number of parameters that are easier to share between the devices.

- **Affordable Intelligence:** With smart lighting, it will become more affordable for facility owners and managers to instill intelligence capabilities into their building systems by avoiding the need for installing dedicated control systems. When bundled with the energy efficiency of LED lighting, the installation of smart control systems can overcome the lack of financial justification that is usually needed by the enterprise executives.

- **Increased Network Bandwidth and Coverage:** In multiple ways, smart lighting will help increase the coverage and bandwidth of the building IT network through reduced IoT traffic, granular network accessibility, and light-based connectivity. A lot of IoT sensors can be consolidated in a single light luminaire. When coupled with edge computing, this can free some of the IT network bandwidth to communicate data from the sensors. In addition, Wi-Fi wireless network coverage can be easily extended to individual rooms through their light fixtures, powered by PoE cables. In the near future, Li-Fi communication standard will replace the Wi-Fi access points with a larger number of smart lights that provide a significant increase in the network bandwidth.

IMPLEMENT IT-OT SECURITY MEASURES

Increasingly, ECs involved in smart building projects will be required to implement rigorous cyber security measures in their installation, or at least comply with the policies imposed by the IT staff of the enterprise owning the building. The following cyber security aspects should be considered when designing and installing IoT-based building systems (OT) with varying integration degrees with the enterprise IT network:

- Cyber security in smart buildings is not only about mischief behavior with the building automation devices. There is a direct impact of such mischief on the company, on the productivity of employees, and on customers. However, the project team should not spend time and effort on cyber security more than the value of the assets that need to be protected. Assets such as inventory and goods), do not have to be irreplaceable. But cyber security also includes protecting corporate reputation, financial data, customer personal information, and human lives. The cyber security risk should be evaluated by considering current threats, vulnerabilities, and consequences. For this purpose, the NIST Cybersecurity Framework[1] would be a very useful tool to implement to identify and protect the asset that can be prone to cyber-attacks.

- Existing IT and industrial security systems and standards have been effective, so ECs do not need to reinvent the wheel. ECs should become familiar with the following standards and apply them when interacting with the IT staff to install IoT facility devices: 1) NIST 800-53[2] "Security & Privacy Controls for Federal Information Systems and Organizations"; 2) IEC 62443[3] "Industrial Network and System Security", developed by the International Society of Automation (ISA). IEC 62443 (aka ISA99) can be very applicable to smart building automation due its balance between IT security requirements, OT performance requirements, completeness, and details of security measures.

1. https://nvlpubs.nist.gov/nistpubs/CSWP/NIST.CSWP.04162018.pdf
2. https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-53r4.pdf
3. https://www.isa.org/isa99/

- Regardless of the implemented cyber security standard, IoT-based building systems should be secured from the following perspectives:
  - ***Perimeter Security:*** *The boundary of accessing the building automation system (on-premises or remotely) should be defined clearly.*
  - ***Device Hardening:*** *The different devices of the building automation and control systems should be protected, either physically or with login passwords. For example, BMS gateways and servers should be physically secured, while field devices should be secured by changing their factory-default login settings. The new Wi-Fi standard (WPA3) will make it easier to secure the many field devices without the need for a graphical user interface.*
  - ***Segmentation and Layering:*** *Segmenting the network complements the perimeter security and device hardening measures by clustering network devices into secured layers of authentication and monitoring. The optimal approach, from the IT perspective, is to connect the different IoT-based building systems to different networks. ECs and building integrators need to consider this requirement and ensure that connectivity between these different systems is still maintained through the internal segmented networks.*
  - ***Encryption:*** *Communication messages within the building automation system should utilize rigorous encryption standards. ECs should prepare for the new BACNet standard will be released with stronger encryption methods.*

PRIVATE CELLULAR NETWORK DEVELOPMENT

Long-term, it will be common for enterprises to deploy private wireless mobile networks on their premises using radio bands that are currently being democratized and shared without the licensing burden. Private cellular networks can be classified into two main types based on their bandwidth: LTE networks in the 3.5 GHz band frequency and low-power wide-area networks (LPWAN) within the 800-900 MHz band frequency. Large facilities (such as airports, hospitals, and industrial plants) will have increasing drivers for establishing private cellular networks to support their operations. These reasons include:

- **Scalability & signal coverage:** Cellular networks can be easily scalable for large properties, compared to Wi-Fi or other wireless systems. Private LTE networks can be established with antennae that require a simple setup similar to Wi-Fi access points. Private LTE networks can provide the required bandwidth for IoT applications that require large data streaming, such as the case of downloading airplane flight and maintenance logs in airports or navigation-based robotics in advanced factories. On the other hand, LPWAN can be used to cover the other IoT applications in large properties with low-data streams, such as parking sensors and building controls with virtually no worries about coverage or signal strength.
- **Security:** Private cellular networks can reduce cyber security vulnerabilities of deploying IoT-based smart building systems in two aspects. First, cellular network protocols are more secure due to the stricter encryption measures implemented in LTE. Second, private LTE networks help securing the critical IT infrastructure and assets and segmenting the IoT devices on a separate more secured network.
- **Bandwidth:** LTE and LPWAN help in freeing valuable bandwidth in the local area network to mission-critical applications of the enterprise, such as managing flight reservations or patient information. Also, private cellular networks provide additional connectivity approaches to IoT applications with varying bandwidth and mobility requirements.

DEVELOP AND SPONSOR A SMART BUILDING RATING SYSTEM

As a new market, the demand for smart buildings requires an organized effort to brand it as a product through standards setting and verification processes. Whoever establishes this brand and its standards first will lead the new market and shape its future. This has happened before with green buildings, when the Leadership in Energy and Environmental Design (LEED) certification was established by the U.S. Green Building Council (USGBC). Before LEED, green buildings were just a vague concept with no reliable and simple metrics to verify the sustainability and energy efficiency of the buildings. USGBC has grown into an international leader in the field of green and sustainable buildings. The branding of smart buildings needs a similar labeling effort from which the public and industry can understand the objectives and design possibilities of smart buildings. Having a smart building label on a facility will reflect its intelligent integrated building systems and user comfort. This branding can then be used by facility owners and real estate developers to increase their sale and lease returns.

ELECTRI International, with support from NECA and other EC industry allies, is urged to sponsor and spearhead the research, organizational initiatives and advocacy effort to establish a smart building rating system that can propel the further growth of the market. This effort entails the following steps:

- ELECTRI International should sponsor a research study to develop the smart building rating system in two funding phases first to develop the system and then validate it. Similar to LEED, the system should be simple for industry professionals to comprehend and implement. The research team is encouraged to benefit from the Smart Readiness Indicator (SRI) tool recently proposed recently in Europe as a method to quantify the intelligence of smart facilities. However, the tool should be significantly revised to reflect the bigger scope of smart buildings beyond energy efficiency, different energy landscape in the U.S., and the need for tool simplicity.

- Concurrently, NECA can set into motion the steps necessary to create a standard and certification eco system of smart buildings, utilizing the new rating system once it is developed by ELECTRI International. The new standard and certification system should have a strategic growth plan inspired by the success story of LEED and USGBC.

- The popularity and widespread implementation of the rating system will depend on advocacy efforts to educate the public and gain public and governmental support. This advocacy effort should emphasis the role of the certifying and rating smart buildings in supporting the greater effort to create smarter cities.

APPLY MODEL-BASED ENGINEERING FOR SMART BUILDING INTEGRATED DESIGN

Over time, smart building systems and requirements will be become more complicated and interdependent, requiring non-traditional engineering approaches. Industry practices for building architecture, engineering and construction (AEC) will need to evolve to be able to deal with future complex buildings and their customer requirements. Model-based systems engineering (MBSE) can be the answer to smart building complexity, as it has been a standard practice in automobile and aerospace industries. MBSE is a visual model-centric approach to abstract and "capture the user" requirements, the subsystems, parts, and behaviors of a large complex system that can help in defining, designing, verifying and communicating the system under development.

Complexity is often the root cause of systems engineering challenges. By using a visual representation of the system, relationships between different parts of the system are easier to identify and manage. The model provides a common reference across engineering disciplines, so teams may more easily communicate and collaborate during the development process. In addition, formalizing the engineering process in visual models encourages reuse and sharing of the knowledge that accumulates between projects.

Applying MBSE in smart building delivery is a long-term strategy because it depends upon the availability of clearer user requirements and the maturity of the electrical contractor as a system integrator. This research study developed an early version of the system model of a smart building (Chapter 4). It can be adopted by an electrical contractor and continuously refined to update the available technologies for a specific market (healthcare, commercial, etc.). The development of a smart building rating system would help in refining the system model by having an industry standard for user requirements. Finally, the full benefit of the MBSE will be achieved when it is used by a systems integration service provider and not be limited by the current silo structure of the project team. To advance professionally in offering smart building systems engineering, ECs need to have trained personnel who are familiar with MBSE practices. Currently, the International Council on Systems Engineering (INCOSE) is one of the leading industry organization to provide system engineering credentials based on the 2015 edition of the ISO/IEC/IEEE 15288 standard.

UTILIZE PREFABRICATION TO ADD VALUE TO BUILDING OWNERS

Electrical contractors have already accumulated varying prefabrication experience. This will be a very critical strategy to increase the value of their services to customers and to overcome some labor shortage issues. Similar to high-voltage systems, prefabrication can be very effective in constructing low-voltage systems by fabricating their common assemblies offsite for faster and safer installations onsite. ECs can utilize prefabrication in multiple approaches: 1) prefabrication shops; 2) procuring prefabricated assemblies from a specialized electrical fabricator; and 3) ordering prefabricated assemblies from manufacturers or vendors. NECA contractors have already experienced the benefits of prefabricating various low-voltage assemblies, such as communication racks, fiber optic cable harnesses, lighting fixtures, patient head walls, access control devices, and cameras with their mounting hardware. The biggest proven benefit of prefabrication is the speed of onsite installations, a great value offering to most building owners, especially for retrofit or tenant improvement projects.

Prefabrication can also solve the low-voltage labor shortage problem in multiple ways. First, prefabrication increases the overall productivity of the contractor operations, which translates into fewer low-voltage workers. Second, prefabrication, combined with flexible labor agreements, can help in maximizing the use of low-voltage technicians in one IBEW local, where assemblies are fabricated and shipped to neighboring locals for installation. Third, the prefabrication environment provides a sense of stability for low-voltage technicians, especially young millennials who would appreciate a stable and progressive work environment.

UTILIZE GENERAL PURPOSE SENSING FOR RAPID AND AFFORDABLE BUILDING PERFORMANCE FORENSICS

General-purpose sensing has a great long-term potential to provide a rapid and affordable method to assess the performance of legacy building systems to justify their upgrade. This concept can be illustrated by an analogy from vehicles with basic on-board sensors that measure oil pressure, oil temperature, electrical voltage, and other parameters and compare them to acceptable value ranges. Similarly, old buildings with legacy systems can be equipped with cost-effective synthetic sensors that can be deployed to sense room temperatures, ambient temperature of equipment, vibration of equipment, and air quality. These sensors can be deployed much faster than field sensors, with no specialized connection to the system equipment and devices. A startup technology company or an existing electrical manufacturing company can commercialize this general-purpose technology and provide AI analytic tools to analyze the data streams form the synthetic sensors and provide performance alerts and upgrade recommendations.

BUSINESS STRATEGIES (BS)

PARTNER WITH SYSTEM INTEGRATORS

Partnering with building system integrators can help an electrical contractor infiltrate into the smart building market and learn about the business practices of system integration services. To partner with building system integrators, ECs need to become familiar with the common attributes of current system integrators:

- System integrators introduce themselves with a customer-focused approach. They directly interact with the customer (building owner or facility management) and try to attain their satisfaction through continuous engagement. This mindset is different from contracting firms (including ECs) that focus on finishing the job as fast as possible with no cost overruns.
- System integrators are usually drawn from professionals with backgrounds in mechanical contracting and building automation. As such, they provide similar services related to automation controls, HVAC equipment monitoring, and energy audits.
- System integrators also support their customers by providing building analytics and timely maintenance service. Their value proposition is the ability to respond promptly to building tenants' comfort complaints by checking the status of main HVAC equipment remotely and advising the customer on the best maintenance alternatives. Few integrators would have their own maintenance service technicians.

OFFER BUILDING AUTOMATION SYSTEM DESIGN/BUILD SERVICES

Historically, mechanical contractors have offered and performed most building automation systems (BAS) work items due to their strong association with HVAC systems. However, some ECs have included the BAS work scope in their services, as these systems started to become more comprehensive and dependent on low-voltage controls and the data network. These ECs are either large firms with sufficient financial resources to acquire or establish a BAS business group, or smaller NECA-affiliated low-voltage firms that expanded their scope of services to include BAS services. ***Strategically, ECs either have to use their low-voltage experience to conquer the BAS market or wait for mechanical and automation controls to expand their BAS scope to integrate all aspects of the building low-voltage systems, such as lighting, access control, and audio/visual work scopes.*** Manufacturers, such as Schneider, have already acknowledged the strong association between low-voltage and building automation by clustering them into a single business group.

ECs should gradually grow their BAS services to maximize the benefit of the accumulated experience and reduce business risks. ECs should first offer basic field installation services re BAS controls for general and mechanical contractors. That will help ECs accumulate valuable field experience with minimal startup and commissioning risks. Moving forward, this field experience will be very crucial to expand their BAS workforce and capabilities to include engineering, design and commissioning. These later services are very critical if ECs are to offer advanced system integration services, services that will provide the most reward for those interested in the smart building market.

OFFER BUILDING DIAGNOSTICS AND MAINTENANCE SERVICES

As building systems become more intelligent and connected, the volume of data being generated by these systems will grow exponentially. This means the new generations of facility professionals, engineers, builders and service providers will be expected to learn more about data processing and analysis. Technologies like artificial intelligence (AI) and machine learning will soon play a greater role in buildings as they continue to develop and become more connected. Installing IoT-based systems in smart buildings should not be the goal, but rather the platform on which buildings will be constructed and then managed based on outcomes, not output. Currently, IoT devices in smart buildings will continue to lack true intelligence as long as large volumes of operational data are not used to provide useful facility management and utilization insights.

ECs are encouraged to consider the following tactics to offer successful building diagnostics and maintenance services:

- ECs should explore and deploy available commercial building diagnostic solutions. ECs do not have the capacity and experience to assemble the sensing hardware, communication infrastructure, and cloud-based AI analytics that are needed for reliable building diagnostics. As such, ECs need to evaluate available commercial solutions currently offered by some tech start-ups or manufacturers.

- If you are the installer of the BAS and/or low-voltage systems, consider manufacturers' products that are supported by building analytics platforms. Educate project owners on the benefits of these platforms in continuous system monitoring and performance validation.

- The ECs should offer these building analytics services for a minimal fee or even free for an initial period in order to assess the building's performance and utilize the collected data to build a case for renovating the system parts with the most performance return.

LEVERAGE ENERGY UPGRADE INCENTIVE PROGRAMS & ALTERNATIVE FINANCING

Unlike green or energy-efficiency buildings, there are no known dedicated programs for smart building system upgrades and installations. Most of the perceived benefits of smart building technologies are internal benefits to the facility owner in terms of tenant comfort and facility management efficiencies. However, there are no unique external smart building benefits for society in general beyond those that have been achieved from the current energy-efficient equipment and energy generation systems.

However, some smart building installations can be covered by the existing energy incentive programs. These can be identified from the online database of local energy efficiency incentives published and maintained by DSIRE[4]. Some examples of these incentives are listed in Table 1 (ACEEE 2017).

4. http://www.dsireusa.org/

Table 1: Examples of energy-efficient incentives that can be used for smart building upgrades

Incentive Source	Incentives
National Grid	• $75 per occupancy sensor in hotels for temperature control. • $40 per lighting occupancy and daylighting sensors.
The Eversource Mass Save	• 50% of the incremental cost of higher-efficiency equipment. • $60 per lighting control occupancy sensor. • $25 per daylight dimming sensors • $20 per step-dimming lighting fixtures • 50% of the installation cost of a Smart Energy Solution program.
Austin Energy	• $25 per plug-load occupancy sensor • $275 per KW saved from daylight harvesting lighting control • $225 per KW saved from occupancy sensors
PG&E	• $15 per plug-load occupancy sensor • 50% of the cost of retro-commissioning,
NYSERDA	• $115,000 for the installation of a Real-Time Energy Management (RTEM) system
ComEd	• Cash incentives for smart building technologies, such as occupancy sensors, lighting & building management system, demand-controlled ventilation.
Southern California Edison	• Incentives for installing building management systems

In addition to available incentive programs, ECs can utilize alternative financing to resolve budget constraints for building owners who wish to wish to upgrade their systems with smart automation controls. Smart IoT devices and sensors can help in alternative financing schemes in which the actual energy savings can be accurately monitored and calculated. Examples of these alternative financing approaches include power purchasing agreements, performance contracting, shared-savings programs, building system leasing, and build-own-operate-maintain projects.

PARTNER WITH TENANT-CENTRIC BMS PROVIDERS

Most Building Management Systems (BMS) focus on serving facility managers by maximizing their ability to integrate and control the major building system. Usually facility managers have ignored the system interaction with another important stakeholder - the building tenant. This limitation has been justified due to the facility manager's central control preference and the limited technology available to interact with individual tenants and space users.

However, recent mobile technology advancements, increased comfort expectations, and evolving sharable workspaces drives a greater need than before to empowerbuilding tenants by enabling their feedback and control of some aspects of building operations. People now expect faster responses to their needs. They cannot accept the fact that they must call the facility management to complain about room temperature. Also, providing individualized comfort to building tenants is expected to become more challenging with the increased use of shared flexible workspaces. It is now an assured fact that every building tenant is connected in some way to the Internet through a smart gadget or computer.

A new breed of tenant-centric building management systems has been developed and is starting to gain momentum in the industry. Comfy, an example of such systems, evolved from a simple mobile App into an end-to-end solution for managing all aspects of the workplace environment, such as adjusting the temperature, lighting, and reserving meeting/work spaces. Although not as comprehensive as older and more traditional BMS products (like Flywheel and BuildingIQ), Comfy succeeded in providing a viable system to collect the building tenants' feedback and integrate it into the room-level controllers. This is one reason Comfy was recently acquired by Siemens so it can expand its BMS functionality and integrate it with other IoT applications.

As a long-term strategy, ECs should partner with BMS providers who offer tenant-centric interfaces and capabilities. Facility managers will appreciate the value of installing smart building systems that are easily integrated into a tenant-centric BMS solution. ECs will benefit from this partnership in multiple ways, including getting quality training from the BMS provider on how to integrate the building systems into the BMS and utilizing some of the collected tenant data to include in building analytics and diagnostics services.

PARTNER WITH SELECTED MANUFACTURERS AND VENDORS WITH COMPATIBLE PRODUCT ECOSYSTEM

No single manufacturer will be capable of suppling all devices and products for a complete smart building system. The smart building market is increasingly growing to include different facility types with varying intelligence requirements. Depending on the targeted segment of the smart building market, the EC needs to explore and develop viable integrated building systems that can be built with compatible devices and products from different manufacturers. Compatibility is a significant challenge in the current smart building market, but it is expected to be minimized or eliminated with the introduction of IoT compatibility standards and the coming refinements of the BACNet protocol.

Some facility types, such as healthcare, have been utilizing building automation systems with proprietary communication protocols. This imposes limited alternatives for integrating other building products with open communication platforms. On the other side, smart homes depend on many more system configurations from available consumer IoT products that have been designed with strong emphasize on compatibility and certified with the major home management platforms, such as Amazon Eco, Google Home, and Apple Home.

INSTALL AND LEASE IN-BUILDING CELLULAR NETWORK SYSTEMS

5G cellular service will be revolutionary for IoT applications with high data streams, but will magnify the data mobility crisis and create a great business opportunity for electrical contractors. The escalated pressure of 5G connectivity is still a while off as it will not be fully deployed by major mobile operators until 2020. When fully deployed, 5G networks will not be able to cover most spaces inside buildings (especially those newly constructed with tight building envelopes) due to the high frequency of the 5G band.

Mobile connectivity has already become a considerable priority for average individuals, businesses, and real estate owners who already suffer from a lack of indoor connectivity even before the 5G network's full deployment. Wired Score, a digital connectivity certifier for commercial buildings, reported the following findings in its recent industry report (Wired Score 2018-a): 75% of tenants stated that poor connectivity impacts the profitability of their companies. 84% of commercial building tenants indicated they would pay more for their lease if their buildings have reliable connectivity. Because mobile connectivity has become a fifth utility for individuals and businesses, startup companies were establish to certify the data connectivity of buildings (Wired Score 2018-b).

ECs cannot wait that long for the reality of 5G to come. They should grasp the expected business opportunity by offering in-building cellular network installation and lease services to facility owners. The economic effect of sluggish indoor coverage is twofold – impacting businesses working within buildings, and also those real estate owners and managers who are trying to lure top companies into their office space. Consequently, building owners have become more inclined to invest in installing their own in-building cellular networks to increase the likelihood of leasing their properties and achieving the desired financial return.

Extending cellular networks is not a new solution, as it has been applied before in large public venues such as convention centers and stadiums now both extending the coverage and increasing the bandwidth for the large number of mobile users. In such cases, mobile network operators have some interest in covering the whole cost due to the sheer volume of users who are impacted by the low service quality. Unfortunately, there is no such incentive for mobile operators to invest in extending their networks inside the buildings, even after rolling out 5G technology. However, some companies have seen this as a business opportunity and became pioneers in installing and leasing in-building distributed antenna systems (DAS), such as Cheytech[5]. This represents a unique exemplary business model for ECs interested in additional revenue streams.

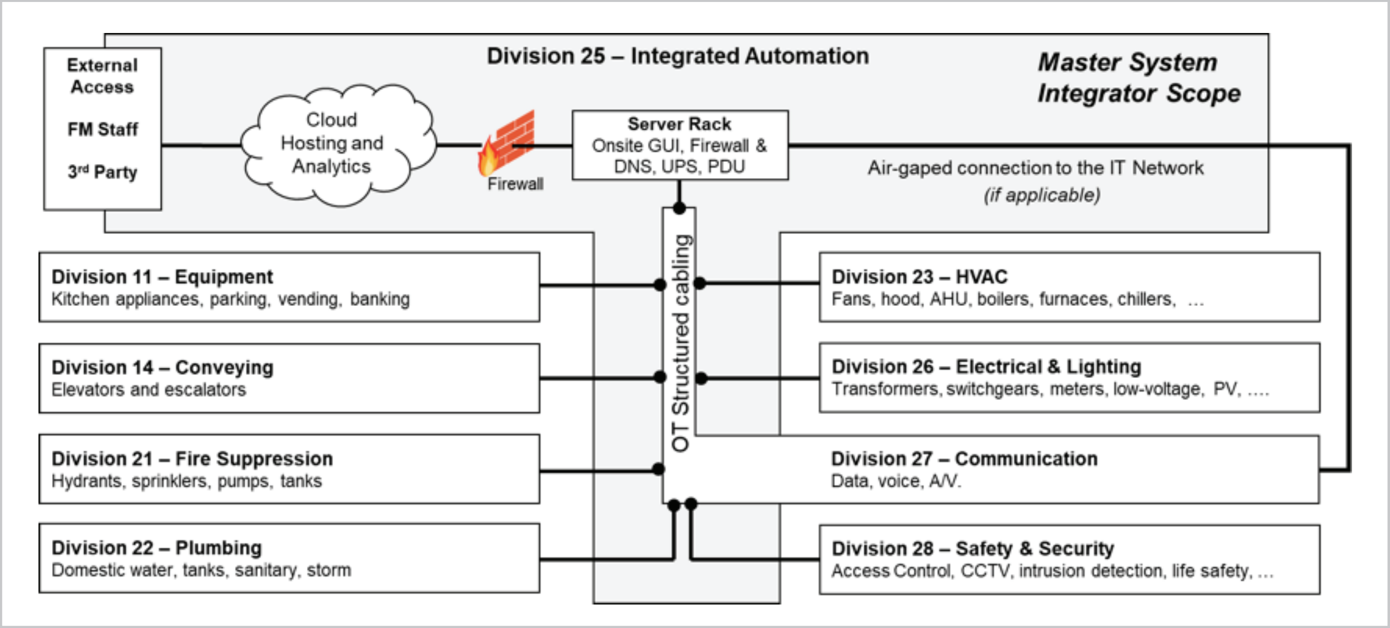
Cheytec has put together the right ingredients to install in-building DAS systems with mutual benefit for the facility owner, network operators, and DAS equipment manufacturers. First, Cheytec managed to secure signal sourcing agreements with some major cellular network major players (Verizon and AT&T) to guarantee customers a radio-frequency signal source in a very timely manner. This translates into faster, easier DAS deployment projects for facility owners. Second, Cheytec has partnered with DAS equipment vendors and manufacturers (including Ericsson, Nokia, Zinwave, SOLiD) to acquire the license-ready equipment needed to connect to the mobile networks. Third, Cheytec links building owners (looking to make capital investments for cellular coverage) to wireless carriers (looking to densify their networks efficiently). Building owners can decide to buy or lease the DAS system equipment, based on an ROI calculation tool Cheytec offers. Fourth, Cheytec has established a network of partners to plan, design, and deploy in-building DAS systems. ECs can benefit from Cheytec's model in two ways. ECs can join Cheytec's partner network and benefit from its value creation chain. Or, large ECs can follow Cheytec's path and create similar business models, based on innovative partnerships with mobile operators and DAS equipment manufacturers, to create their own in-building mobility solution services.

DEVELOP INDUSTRY CONTRACT DOCUMENTS FOR SYSTEM INTEGRATION SERVICES

Traditionally, systems integrators have become involved in construction projects based on a typical service negotiated contractual agreement with no detailed understanding of the underlying responsibilities and deliverables. Lately, more industry professionals are advocating for fully implementing Division 25 of the standard MasterFormat specifications to outline deliverables and expectations of the business entities ensuring the integrated automation of the building systems. These entities are frequently referred to as Master System Integrators (MSI). Division 25 allows the project owners to formalize the contractual obligations of master system integrators. This opens the door for more competitive and comparable proposals and, ultimately, delivers more value to building owners. Even with the existence of integrated project delivery methods, construction industry practices still depend upon the existence of solid contracts and clear specifications. As shown in Figure 2, overall automation in a smart building is procured through a two-tier specification framework in which filed control and gateway devices are procured through the corresponding trade contractor and the MSI is responsible for the integration and overall automation of these subsystems.

5. http://www.cheytec.com/

Figure 2: Specification-based mapping and integration of work scopes in smart building projects



ECs and NECA need to get involved in an industry-wide effort to help refine the available specification documents of smart buildings and develop an MSI contract agreement template. Multiple educational and healthcare institutions publish their Division 25 specification. Examining them reveals several issues worth noting for further improvements. By examining the published Division 25 specifications, facility management teams pick and choose the sections within the Division that generically apply to the organization's facilities.

For example, Duke University publishes just one section of Division (25-95) that is related to HVAC control sequences. This can lead to a false impression of a reduced work scope for MSIs. To avoid such issues, the CSI MasterFormat Division 25 can be simplified and reconfigured to remove redundant subsections. Also, most parts of the available Division 25 are drafted based on the Niagara platform. This can obstruct the positive market competition between BMS system providers and create a false interoperability status. Instead of being product-based descriptive requirements, Division 25 can be drafted to provide performance-based requirements for standardized communications, data sharing, interfacing, and analytics.

In addition to specifications, a standard contract form of agreement and general conditions needs to be articulated to develop a common understanding of MSI responsibilities and authorities. The MSI can follow a CM-at-risk contractual framework, in which the MSI joins the design team early in the project phases on a fee-based service agreement to help develop the different specifications and scope-of-works (SOWs) for the integrated trade divisions. Then, the MSI role evolves to a technology CM of the project, with possibly a guaranteed-maximum price (GMP) payment scheme. They would have an over-reaching responsibility to coordinate the installation and integration of all various sub-systems. The MSI supervisory role should be clearly stated in the contract documents of the trade specialty contractors of the integrated systems The MSI agreement with the owner should include a clear commitment from the owner's IT staff to collaborate with the MSI in configuring the building automation network (i.e OT network) with respect to its dependence on the IT network.

OFFER BUILDING MASTER SYSTEM INTEGRATION (MSI) SERVICES

Offering MSI services requires the electrical contractors to have a significant mindset shift and business practices from their traditional installation services. In MSI services, there is less emphasis on customer experience and system performance than on the quality of individual components or subsystems. As indicated earlier in this report, an MSI will have a more mixed role in the construction project by offering design, systems engineering, consulting, installations, and project management. The MSI does not wait for the project specifications to identify the work scope. Rather the MSI steps back and translates the owner's facility needs into smart building specifications that can be used for seamless systems integration. As such, ECs who are interested in entry into the smart building market, as it continues evolving and maturing, will end up spinning off new business entities to offer MSI services that capitalizes on the EC's experience with low-voltage and data/comm systems. In establishing these MSI entities, ECs should consider the following tactics:

- The MSI now has to have technically savvy engineers (on staff) who understand and can efficiently design and architect a fully integrated IT/facility solution. These engineers must know all of the current security, Ethernet, router etc. standards and be able to deploy cost-effective working systems that can adapt, scale, and change over time.

- In addition to IT knowledge, the MSI needs to have well-rounded experience with all building systems and their controls. The MSIs do not need to be expert in the detailed installation requirements of each system as this is the responsibility of the specialty trades. However, MSIs need to be the go-to expert to advise the owner and the engineering team on the best integration architectures that satisfy both owner needs and facility constraints.

- The MSI needs invest significantly in maintaining reputable training certification and accreditation of data/comm networks, system integrations, and cyber security. Doing so provides a strong statement to owners and engineers of the proficiency of the MSI in integrating the building systems efficiently, effectively and securely.

- The MSI should have strong certification and training on the different BMS integration platforms (such as Tridium, Alerton, Distech, and Siemens) and security monitoring platforms (such as Lenel and Genetec). This diverse knowledge and experience will be a selling point to facility owners who prefer not to be stuck with a single solution offering.

WORKFORCE STRATEGIES (WS)

INTERACT WITH PROFESSIONAL FACILITY MANAGEMENT ORGANIZATIONS

Electrical contractors, NECA, and IBEW are encouraged to maintain an open dialogue with the different facility management and engineering organizations to collaborate on training the future workforce for smart building engineering, construction and maintenance. The smart building workforce that will be hired by facility managers and electrical contractors share common training requirements and qualities. Together, they can maximize the benefit of currently available JATC training programs and help recruit much-needed future engineering talent. NECA and IBEW should reach out to the following main industry groups: the International Facility Management Association (IFMA) and the Association for Facilities Engineering (AFE).

INCREASE THE COMMITMENT OF LOCAL IBEW & JATC TO THE TECHNICIAN APPRENTICESHIP PROGRAMS

Per the latest ETA apprenticeship survey, 47% of local JATCs reported having no Installer-Technician program in their locals due to the low volume of video, data, and voice (VDV) work. Some of the local units even utilize inside wiremen for VDV work. It is understood that local units are training the workforce for their local markets and the needs of local ECs. Nationally NECA and ETA can provide incentive grants and technical support for some local JATCs that may not currently have the sufficient VDV market, but whose local market is expected to grow within few years. Funding for such incentive programs can be secured from federal government entities such as the US Department of Labor.

ESTABLISH AN ETA ONLINE PROGRAM FOR BUILDING TECHNICIAN ADVANCED TRAINING

The current ETA technician training program can be complemented with an online advanced training program that can be accessed and utilized by local JATC units. Troubleshooting complex smart building systems demands new skills for low-voltage electricians and technicians. The basics of checking for open circuits and testing voltage on wire pairs are no longer adequate for tracking down every problem on a data bus. Now, electricians and technicians have to understand the basic building blocks of data networks. They might find themselves deciphering Internet Protocol packet headers or analyzing line interference with an oscilloscope. Some work happens as much with software as with old-fashioned tools like wire strippers and cutters. Once a wiring system is in place, most configuration and troubleshooting can be performed with computer and data analysis tools.

Integration in smart building systems also creates security issues not present in traditional low-voltage systems. Because most LANs are Internet-connected, the possibility of malicious intrusion and hacking is also introduced. Having the knowledge to put in firewalls and take care of other basic security precautions is also becoming necessary for electricians and technicians. ETA can partner with some of the leading manufacturers to develop and offer online training modules on installing and troubleshooting their devices and systems. Also, the program can be designed to be helpful to technicians seeking credentials from contemporary industry organizations, such as BICSI and Avixa. This program should be helpful as a short-term strategy until the smart building market grows further and the need for building technicians justifies offering local technician training programs.

ESTABLISH MORE JATC LOW-VOLTAGE AND DATA/COMM TRAINING CENTERS

Some local JATC programs have had great success with their dedicated training centers for low-voltage and data/comm technicians. These can be implemented in other metropolitan areas with great growth potential for their local smart building market. The JATC programs in California have had great success with their specialized training centers, including the Net-Zero Energy Center (NZEC) in San Leandro CA; and the Net Zero Plus (NZP) center in Los Angeles CA; and the Northern-California Sound/Comm center in San Leandro CA. These separate training facilities signify the uniqueness of the technician apprenticeship and worker classification, by installing the systems that are being taught to the students as real-life demonstrations.

INCREASE OUTREACH WITH NECA STUDENT CHAPTERS

More than 30 NECA Student Chapters are proving to be a great asset for electrical contractors who want to recruit engineering and construction workforce and to utilize the intellectual creativity on campuses for research and demonstration projects. Most NECA Student Chapters have been established and housed within construction management academic programs. NECA National should encourage these student chapters to diversify and include other disciplines from within engineering and technology programs. Also, NECA Student Chapters can serve as small research and development (R&D) hubs for NECA to test smart building new products or to build small testbeds and show examples of smart building systems. This R&D effort will provide preliminary valuable insights to NECA and inspire the students through hands-on projects to consider careers in the specialized new field of smart building construction and engineering.

LAUNCH A BUILDING TECHNICIAN CAREER AWARENESS CAMPAIGN

NECA, IBEW, and ETA can join forces with other related professional organizations, including facility management and engineering to launch a K-12 awareness campaign for smart building technician career paths. The campaign should target schools with underrepresented populations to present to them a career that can be very appealing to the younger generations. The campaign would focus on the following main points to in order to achieve the greatest impact and return: 1) the technological attractive aspects of the technician career that can be a good match for a new generation with tech-savvy skills; 2) the reduced physical requirements for a technician career compared to other trades; and 3) the promising salary and job stability prospects. The campaign can utilize non-conventional approaches, such as installing IoT-based smart building systems in the targeted schools, to show the students visually the accomplishments and contributions from working as a building technician.

PARTNER WITH UNIVERSITIES TO OFFER SMART BUILDING ENGINEERING PROGRAMS

Long-term, NECA can partner with a leading university to establish a pilot smart building engineering program to educate a future cadre of engineers who are qualified to design complex integrated building systems. The university should be selected in a location with a vibrant smart building market and demand for facility engineers who are educated and trained in the critical areas of building systems, communication protocols, data networks, cyber security, systems engineering, and project management.

CONCLUSION

Survey responses and their analysis findings complied with the observations made separately from the interviews. Electrical contractors acknowledge their potential to assume more roles and responsibilities in the smart building market, due to their experience with low-voltage and data/comm system installations. However, in expanding their business into this new market, they must confront different challenges related to the traditional project delivery approaches that prohibit integrated design settings, the need to offer facility management services that are outside the electrical contractor's comfort and traditional business portfolio, and the need for more specialized workforce training than can be sustained under the current limited volume low-voltage work in most of the JATC local programs.

REFERENCES

Fink, A., and Kosecoff, J. (1985). *How to Conduct Surveys: A Step-by-step Guide.* Beverly Hills, CA: Sage, 1985.

Galloway, P. D. (2006). *"Survey of the Construction Industry Relative to the Use of CPM Scheduling for Construction Projects."* Journal of Construction Engineering and Management, ASCE, 132(7), 697 – 711.

Rasdorf, W., Grasso, B., and Bridgers, M. (2010). *"Public versus Private Perceptions on Hiring an External Program Manager."* Journal of Construction Engineering and Management, ASCE, 136(2), 219 – 226.

ELECTRI INTERNATIONAL
THE FOUNDATION FOR ELECTRICAL CONSTRUCTION INC.

3 Bethesda Metro Center, Suite 1100 Bethesda, MD 20814
T: 301.215.4538 ▪ www.electri.org