SMART BUILDINGS

SPRING EDITION

CONSULTING - SPECIFYING
engineer
eBOOK

Contents

CONSULTING - SPECIFYING engineer eBOOK

Important considerations from the history of modern building control systems

Building controls technologies, open communication protocols and networked internet protocol evolved to create a relatively easy means to integrate multiple control systems

Heating, ventilating and air conditioning (HVAC) control systems, also known as building management systems (BMS) or building automation systems (BAS), have changed significantly over the years. The primary function of the BMS is to control air handling units, boilers, chillers, cooling towers, space temperature controls and other related building HVAC control systems.

As buildings evolve and are increasingly more sophisticated, the requirements of integrating additional control systems to the BMS also increases. This can include lighting control, electrical power monitoring systems and plumbing equipment. Understanding how these various systems can be connected to a seamlessly integrated control system can increase building performance.

Evolution of BMS control system solutions

One of the most noticeable evolutions with building control systems, is the way information is transferred within their controllers and displayed on the graphical user interface (GUI), such as an operator workstation (OWS) or a thin client. See Figure 1 for an example of a proprietary BMS network architecture diagram. During the development of the various BMS control systems, it was up to each independent BMS vendor to

Back to TOC

Back to TOC

determine the communication method and protocol in which data would be sent and received.

For example, unique communication protocols would not allow the control system of Vendor "A" to transfer data to the control system of Vendor "B." As a vendor's proprietary solution, these communication protocols can be very restrictive. Therefore, a building owner who would like a BMS installed at a facility would need to decide which BMS vendor should be selected, understanding that this would require a long-term commitment. If a building owner later decided to use another BMS, it would be expensive to replace the existing controls in the building, including the BMS controllers, field devices, OWS and wiring.

Alternatively, a communication gateway could be installed to translate the BMS information between two different control systems. This solution would require a significant amount of programming to configure communication links and could have reliability issues, as the gateway is a single point of failure.

An owner might decide to change BMS vendors if they were not satisfied with the control system performance or if there were issues with the service agreement, such as high cost or slow response time. This is not the most desirable solution due to the expense of additional changes to an existing control system. Since there would not be any competition in the selection of a controls system contractor for renovation work, this is typically subject to increased cost for services as well.

Owners of larger facilities could decide to use multiple control systems, which would allow for competition between the vendors. However, this solution can be cost prohib-

Back to TOC

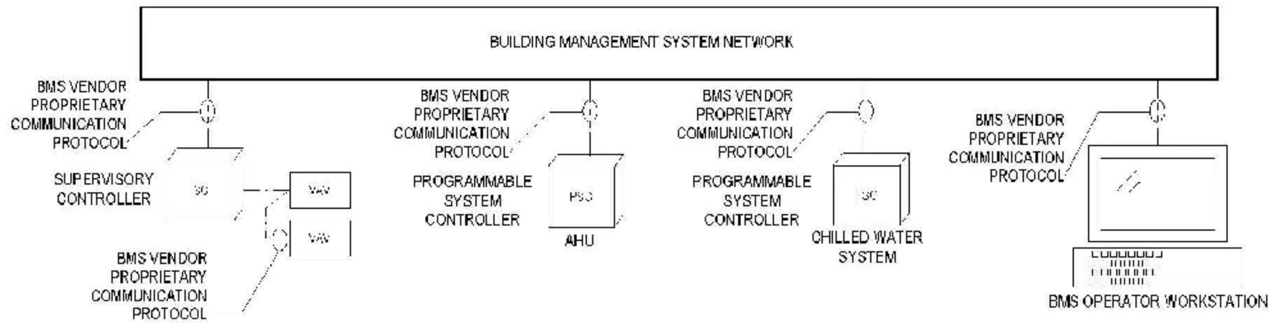


Figure 1: This example shows a proprietary building management system vendor network diagram. Courtesy: HDR

itive as well, since this would require the duplication of the OWS, communication wiring, spare parts and potentially another programming language.

The answer to these common challenges was the creation of a nonproprietary "open" protocol that could be shared among all BMS manufacturers, leading to BACnet International.

Creation of BACnet

Building automation and control networks, or BACnet, was developed by ASHRAE in the 1980s as the open protocol solution for BMS control systems. ASHRAE allowed for the sharing of the BACnet protocol amongst all BMS vendors, as documented in ASHRAE Standard 135: BACnet — A Data Communication Protocol for Building Automation and Control Networks, which granted building owners more flexibility. To ensure compliance of BACnet communication among the various BMS vendors, the BACnet Testing Laboratories was established as an independent organization to verify that the control devices meet the ASHRAE Standard 135 requirements and confirm communication inoperability.

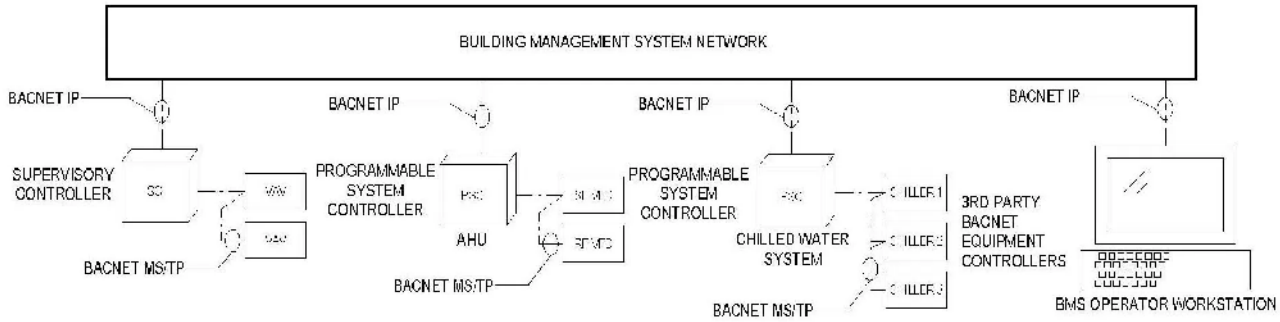
Back to TOC

Both BMS vendors and equipment manufacturers could reap the benefits from using BACnet. For example, the BMS could use the BACnet protocol to communicate with the manufacturer's factory installed control systems for boilers, chillers and variable frequency drives. Using the BACnet communication with third party equipment is a more cost-effective option, since a communication wire could transmit multiple control signals associated with equipment parameters, whereas previous monitoring of HVAC equipment would require a dedicated wires for each control signal or a communication gateway. See Figure 2 for an example BACnet BMS network architecture diagram.

Even though the BACnet protocol allows for a nonproprietary communications protocol, it still has limitations. While the use of BACnet establishes a common protocol for communication, it does not solve the problem of allowing building users to modify the system on a controller level. The BMS vendor would still use proprietary software to startup and commission the system, which will not allow the end user to adjust later, on the local controller level. The owner would only have access for adjusting via the GUI. For some building owners that might not be an issue. However, for buildings that have ongoing renovations, this would be detrimental.

There are other protocols that are considered 'open' that can be used in BMS networks. One such protocol is Modbus, which was developed by Modicon for industrial programmable logic controllers in 1979. For the commercial HVAC control system industry, Modbus is used for communication with electrical equipment, such as automatic transfer switches, switchgears, emergency generators and electric meters.

The next progression in creating a truly open hardware system, which could entail hardware solutions, software solutions or both that addresses the limitations of BACnet



and other open protocols is seen in the implementation of the Tridium Niagara system.

Figure 2: This demonstrates a BACnet system network diagram. Courtesy: HDR

Tridium Niagara open software solution

Tridium created a software solution, called Niagara, that is an open programming platform. The Niagara framework is an operating system that is installed on controllers and servers. Tridium also offers a hardware product, called a Java Application Control Engine (JACE) that the Niagara framework is installed on. However, this framework can be installed on any manufacturer's controllers. Many of the major BMS providers will carry two product lines: one proprietary system and one Niagara system.

For example, Johnson Controls has their proprietary offering, the Metasys system, and also has a Niagara offering, Facility Explorer. Certain verbiage needs to be incorporated into the specifications to prevent contractors from installing proprietary software on Niagara devices. This is important to guarantee that downstream controllers are programmable from the workbench and that the system remains fully open. This also prevents the contractors from being able to "lock out" competing vendor controllers from communicating with each other. This verbiage is called the Niagara Information and Conformance Statement (NICS) and is provided by Tridium.

Back to TOC

Back to TOC

The advantage of many different manufacturers offering a Niagara solution is that all can bid on the same project, with the same solution, while providing a future-flexible hardware environment. When bidding on new projects with the option of either a proprietary system or an open system, there may be an additional upfront cost for an open system that the owner should be aware of.

However, after the open system is installed, it will provide more competitive bidding on future projects and can thereby decrease future cost, since any Niagara certified manufacturer can service the system and controllers. Owners are not locked into one provider. In the event an owner becomes unsatisfied with the service that is being provided from a service provider, the owner can engage with a different Niagara certified service provider that may offer a more satisfactory response.

This is also an advantage when working with a customer with a large global footprint who is looking to maintain consistency across their portfolio. The customer can standardize using Niagara and the system can be installed by any Niagara certified branch, instead of being limited to only local branches in the area the buildings are located.

By allowing open programming, Niagara provides the ability to integrate with many different manufacturer's products and communication protocols. The Niagara framework can be configured and customized to suit the needs of the project. Third-party communication drivers can be installed on the controllers to enable communication with proprietary controllers with protocols from Siemens, Trane, Johnson Controls and others.

This is a powerful feature, particularly during retrofit projects. For instance, an owner may wish to upgrade the BMS, but have a prohibitive budget, making it unreasonable

Back to TOC

to replace all front-end equipment and field level controllers at one time. Niagara could be used as a potential solution to implement an incremental modernization of the equipment.

A JACE could be used to first replace the supervisory level controllers. The JACE can be equipped with drivers installed to integrate with legacy field controllers in the building. There may be different manufacturers' controllers in the building that can be integrated to the Niagara front-end. Once this process is complete, the remaining legacy controllers in the building can be replaced over the years as the budget allows.

Another benefit of a Niagara system is the ability to connect to legacy systems and controllers. The Niagara system can either communicate to the controllers through a JACE or a Niagara computer server or supervisor. The legacy controllers may have proprietary software installed, which can limit some of the functions available with a JACE, but these can still be integrated into the Niagara system using drivers. However, a JACE controller that has the Niagara workbench installed will provide more flexibility and enable the end user to use all Niagara benefits.

The flexibility of integrating different manufacturers building automation controllers and packaged mechanical equipment controllers can also be applied to different technologies. Additional gateways may be required, whether it be lighting controls, power monitoring, security or an access control system. The open platform solution of Niagara can again be used as the framework where these systems can all communicate and be visualized at a central location. See Figure 3 for an example of a Tridium Niagara network.

Tridium provides the option for customers to opt in to a Niagara Service Maintenance Agreement (SMA). The Niagara SMA is an offering that continuously provides technology updates and feature improvements to the system. This enables existing systems to be updated to fix software bugs and to be upgraded to the latest technological developments. While Niagara provides a powerful solution with many different capabilities, there are some factors that need to be considered before pursuing this product.

Major BAS providers will typically provide a line of Niagara controllers, yet these are often installed by independent contractors. These independent contractors do not always have the same accountability offered by the main manufacturer branches. The level of expertise of the independent contractors also may not be held to the same standard as a major distributer with local branches.

Additionally, Niagara has many different capabilities and functions, which must be established during design by the engineer of record or building commissioning agent for a project. The contractor must effectively implement the desired features defined by the engineer of record and tested by the commissioning authority during installation. This increases the importance of interviews during the bid process to ensure a contractor is qualified to complete the project.

When dealing with a project involving multiple different control systems, such as building automation, security and lighting, a single source control system manufacturer or vendor can streamline coordination and problem-solving. Although Niagara provides the ability for these different systems to communicate, there are challenges that can be encountered when dealing with multiple manufacturers. Coordination between the numerous parties involved can make it difficult to determine who has ownership when

Back to TOC

Back to TOC

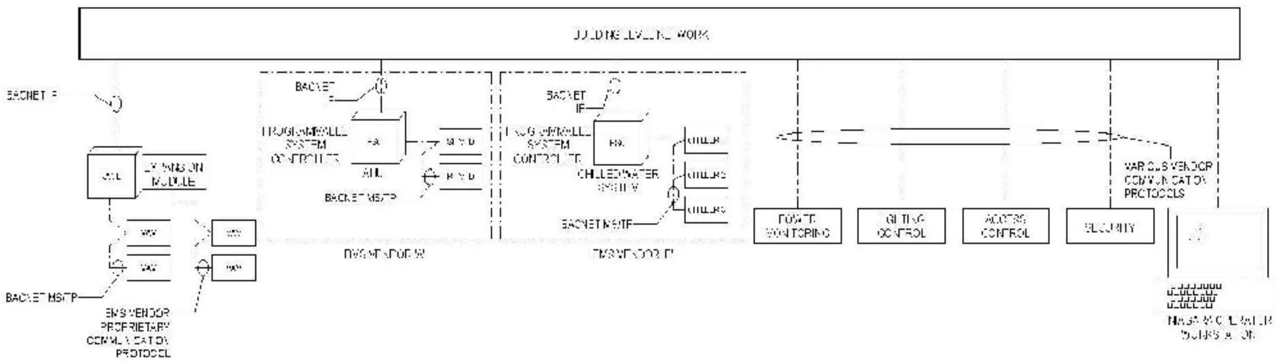


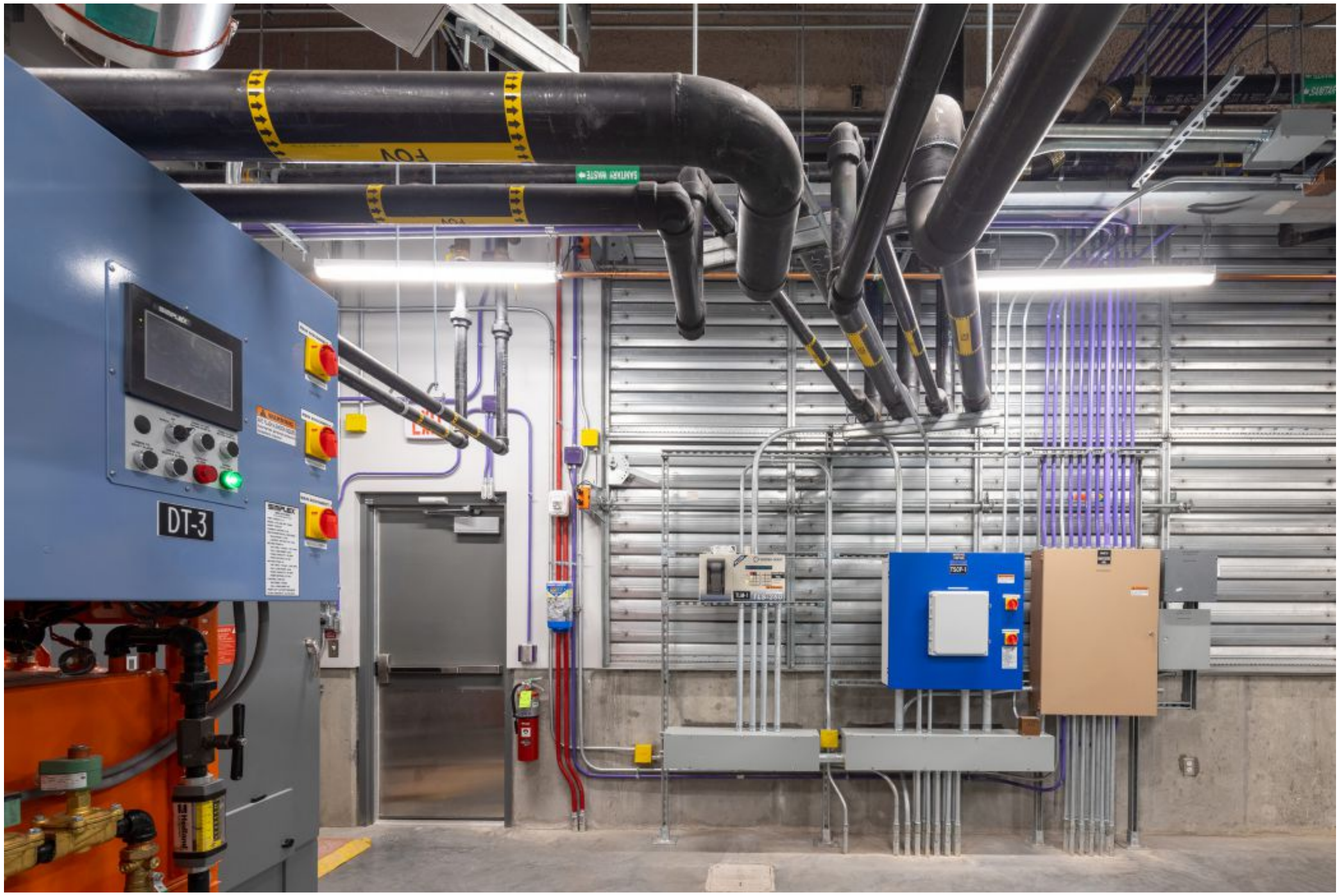
Figure 3: This is an example of a Tridium Niagara system network diagram. Courtesy: HDR

an issue arises. A single source vendor that can provide the different control systems involved has the potential to alleviate this issue.

Each device that the Niagara workbench is installed on, whether it be a server, JACE controller or Edge device, requires a license. The licenses are provided based upon device counts and point requirements. Each of these licenses comes with a software maintenance agreement that provides the updates and improvements previously mentioned. The cost of these licenses and maintenance agreements can add up when there are a lot of controllers in the building. First cost and total cost of ownership should both be presented to the client and should be considered when comparing open versus proprietary systems.

BMS integration and BACnet

BMS communication protocols and their ability to be integrated with other control systems has dramatically changed over the years, from the initial creation of the BMS vendor proprietary protocols to the "open" systems approach that allows inoperability with a multitude of control systems. When designing and specifying a control system



for a project, there is no advantage of using a proprietary protocol for new construction.

Figure 4: Control system integration as seen in a children's hospital. Courtesy: HDR, Dan Schwalm

However, it might be required in a renovation project for the controls to be easily integrated into the existing facility's control system. This will need to be reviewed with the building's owner. In some cases, it would make sense to remove the existing control system and install a new one, especially if the BMS is outdated and potentially obsolete. The most desirable solution for the BMS communication protocol is BACnet. This

Back to TOC

Back to TOC

allows for the most flexibility with communication to a multitude of BMS vendors and mechanical equipment vendors.

After selecting BACnet as the BMS communication protocol, the owner still needs to decide which BMS platform to use. The BMS platform components include the BMS OWS and BMS controllers. Vendor-specific and Niagara platforms are the most common platforms used. The vendor-specific platform is provided by the control vendors such as Johnson Controls, Siemens and Honeywell and uses their proprietary software.

The Niagara platform is provided by Tridium with "open" software capabilities, called Workbench, which can be supported by numerous control vendors. Some additional items to consider when deciding on which type of BMS platform to specify are:

- Does the building need to integrate with control systems from different vendors?
- Will the BMS need to expand, such as at a campus or is it restricted to a small environment?
- Is it important to have the freedom to select a BMS service provider and not be locked into a specific vendor?

For any new project, even where there is not a known need for the integration to multiple vendor platforms and the building owner is agreeable with selecting one BMS service provider, having a vendor-specific platform solution might prove to be best choice. For a building owner who would like the freedom to choose a BMS vendor for

service and where there is a requirement to integrate to a multitude of unique control systems, the Niagara platform should be considered.

This would allow the owner to have multiple BMS vendors bid their services, leading to a competitive price. The ability to have an open bid situation for BMS vendors can only be achieved if the building is equipped with controllers that do not use proprietary software, as these would require the use of the Niagara Workbench devices. While vendor-specific and Niagara platforms are both viable solutions, each option should be reviewed and considered with the building owner and a subject matter expert.

Joseph Lisowski
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Back to TOC

Learn about what it takes to design a smart building

By integrating a variety of systems within a building, engineers can design a building that can tackle the future

Imagine a workspace with smart controls. Book a desk, meeting room or informal break-out project space before leaving home via the office app, fully integrated with Microsoft Office 365 or Google Suite. If you choose to cycle to work, the app features route planning, hire sites and registration functionality and once you arrive you can access stacked pods for parking, door control, electric charging points and smart shower lockers.

Upon entering the lobby, you pass through security via face recognition system or Bluetooth and if you have visitors, you can share a QR code for smooth access. To reduce energy consumption and improve sustainability ratings, the power in the meeting room turns on only when you enter and at your discretion, you can choose to set the blinds, climate and mood lighting.

If you have a delivery to the office, there are personal Amazon-style parcel lockers as well as cool storage lockers for groceries. Everything around you is working seamlessly to improve your comfort, wellness, health and productivity, with all the data collected and analysed to advance future office designs.

The future of the 21st century office is here.

Imagine a building with smart controls. Facility management teams can view, control and measure mechanical, electrical and plumbing (MEP) operating systems'

Figure 1: Smart-ready meeting rooms enable businesses to streamline day-to-day operations. Courtesy: Wind and Foster © 2022 HDR

data in a transparent, single pane dashboard format, as well as incorporate new intelligent features and expand automation as operational needs evolve over time.

There is a significant reduction of installation costs due to the elimination of expensive standalone building management network infrastructures, a growing implementation of environmental initiatives in accordance with drive to net zero, such as reducing carbon emissions alongside decreased energy costs, as well as enhanced safety and security thanks to using data from sensors and controls to coordinate access control and

Back to TOC

Back to TOC

improve fire safety.
A revolution in building maintenance.

Imagine a campus with smart controls. Building operators can track efficiencies based on live data across all real estate assets regardless of global location, including real-time carbon monitoring.

We now live in a world where it is possible to deliver efficient operations using artificial intelligence analytic tools for live equipment diagnostics leading to predictive maintenance cost reduction, as well as potential plant improvement identification. We are implementing a standard infrastructure approach across all buildings, including software, network selection and passive infrastructures, in order to be able to grow and flex campuswide smart operational solutions as client needs evolve over time.

Imagine all the progress within our reach once we advance to nationwide sites with smart controls and eventually global portfolios with smart controls. While smart technology is revolutionising nearly every aspect of the human experience, the way we socialize, communicate, travel or work, are the spaces we move through keeping up with the trends?

Is the built environment truly embracing the future with respect to smart technology?

What is a smart building?

It is essential to define a smart building. It is not enough for a facility to be equipped with a building management system (BMS); those have been around since 1970s. BMS is the starting point, yet ultimately deciphering smart classifications is the level of inte-

gration and interoperability of the building network, both user and management side, which in turn provides efficiencies and allows building owners to make live decisions about their facilities.

Figure 2: Designing a truly smart building requires early smart adoption to ensure a comprehensive interoperability of systems, as shown in the London office. Courtesy: Wind and Foster © 2022 HDR

We can distinguish three smart stages according to the key technology features implemented. The first one is a basic nonintegrated building, with standalone incoherent systems, independent reporting and multivendor supports contracts.

The second is a digital-enabled building with integrated information and communication technologies (ICT), audiovisual (AV), security, heating, ventilation and air conditioning (HVAC) and BMS networks. Benefits include integrated ICT/building network, reduced vendor support contracts, Internet of Things cloud connectivity and app-ready properties.

The third and final stage is a smart building, characterized by interoperability across all MEP and ICT systems with real-time data processing and interpretation tools, featuring big data collection and analytics, proactive reporting, device adaptive infrastructures

Back to TOC

for futureproofing and self-learning proactive maintenance, all while providing operational efficiencies with mapping out of assets for sustainability and resiliency increase, reduced costs and agile and healthier environments for more productive users.

In short, a smart building has the ability of different systems to talk to each other and interpret data.

Smart buildings require two things

There are two crucial factors that building engineering professionals need to focus on to deliver truly intelligent buildings. No. 1 is early adoption, backed by clear and open client communication from the conception stages.

Lessons learned during the ongoing delivery of a 33-story, 550,000-square-foot insurance market skyscraper in London, aiming for a BREEAM Excellent certification, is a vivid example of the difference between a smart adjusted building and a building born smart.

In an early adoption scenario, the process to developing a smart building strategy is agreed at Royal Institute of British Architects (RIBA) Stage 1, with signed off strategy report and high-level budget available before RIBA Stage 3 developed design, as well as limited spatial changes at RIBA Stage 4.

Detailed value engineering review can take place during tender period and medium-scale integration (MSI) contains detailed MEP and BMS interfaces, with mapped out topologies, scalable infrastructure and single network and vendor solution. This is the desired outcome when we work with an enlightened client who has the foresight to

Back to TOC

Back to TOC

introduce smart building design principles at the start of the project.

The late adoption timeline, with the decision to employ a smart building strategy post-design stage, reduces available options and introduces additional cost late into the project. A smart building strategy is developed in isolation, not coordinated with other design packages and thus carries a high risk, with imprecise client budget reporting and smart coordination with design team not possible until post RIBA Stage 4 design.

Figure 3: Visualizing a smart building is a valuable stage, allowing clients and engineers to pinpoint the most desirable solutions. This shows the visualization in the Chicago office. Courtesy: HDR © 2022 HDR

At time of adopting the smart solution all associated MEP BMS are already appointed, so as not to delay the construction program standalone multivendor MEP silo networks must be used, adding cost and complexity and limiting the choice of qualified vendors. Onboarding the MSI at pre-construction stage presents cost and technical challenges not previously identified to the client, thus putting an unnecessary strain on the long-term client relationship and negatively impacting retention. This scenario, an example of how not to do it, is typically experienced in the industry, resulting in effectively retrofitting a new building.

Back to TOC

The No. 2 item for delivering real smart buildings is the employment of a single engineering design solution enabled by open protocols. In the past, clients would get locked into long contracts, receiving software that they could not modify and tailor to their needs. Things have changed and now there is a requirement for protocols to be open. And here is where a uniformed smart multidisciplinary offer comes into play.

How can a digital twin help in a smart building?

For example, many vendors offer the popular digital twin modelling, yet often this amounts to merely adding an extra overlay of sensors and software on an engineering design conceived and built by someone else. The cooperation or unification, of building engineers and the smart team is crucial for features such as digital twin to work effectively and subsequently for achieving the sustainability targets in a clearly demonstrable manner. Smart is not just a representation of the physical, it is a mirror image.

Regarding digital twin technology, it is important to stress that it is an analytic tool, which sets out the parameters of the data the software is looking for. This can be put to good use when a digital twin provides asset management capability and information source for staff to view and make the final judgment call. With all the advanced technology, the people factor is still crucial and can be hindered by nonuser-friendly analytics, therefore uniformity and coherency of how data is articulated is essential.

The right mindset is necessary to avoid the mistakes of late smart adoption, while a set of standards for data unification and demand for open protocols is needed to benefit from a truly unified smart approach. As technology evolves this will encourage and enable clients to be empowered, educated and in true collaboration with industry partners, who strive to design and deliver real smart buildings until this becomes the norm.

Truly intelligent buildings are the way forward in the worldwide sustainability race to achieve net zero by 2050. With the growing amount of voluntary and obligatory initiatives, standards and legislations, fully integrated and smart management strategies allow developers and operators to strive to be ahead of the curve.
Smart building examples

Dynamic simulation, sustainable information charts and tracking of energy efficiency historical data help to identify and analyse a building's predicted energy consumption based on predicted and actual usage as well as different user profiles and various design options can be tested and assessed to understand their in-use operational benefits before physical implementation. The aim is to close the gap between compliance predictions and in-use operational energy; a truly connected building provides the network to achieve and exceed sustainability targets.

An important challenge industry leaders need to be mindful of is that a single smart design approach does not fit all project types. There are two primary applications.
The first one is developer shell and core with public spaces, commonly referred to as Category A, mostly concerning multipurpose multitenant buildings. This involves main plant efficiencies, carbon neutral building monitoring, converged building network and building analytics.

The second approach is Category B tenant space fit-out, including user apps, local comfort controls, desk booking and integrated meeting spaces.

An insightful example of the multitude of possibilities on offer for clients is HDR's work on a 60-story people-centered skyscraper spanning more than 1 million square feet.

Back to TOC

Back to TOC

The HDR designers provided two teams on the project:

- **Team one:** Working with the main contractor, responsible for the commissioning of Category A shell and core fit-out of the entire building. This involved commissioning a significant amount IT cabling, including fiber optics and ensuring smart usage output on each level.

- **Team two:** Working on holistic building engineering services design and Category B fit-out for a tenant leasing floors nine and 10.

The skyscraper is one of the most advanced smart buildings in the world, with its own dedicated occupant app, using Bluetooth, facial recognition and QR codes instead of traditional passes. Floors nine and 10 feature a subtle combination of a high-end working space and a gallery experience, where connecting ICT together with AV and electronic security has allowed the office to be smart ready.

Define the building's final outcome

In some cases, however, intelligent technologies are not immediately required, yet as an industry we should strive to equip these buildings for the future. The desired outcome is to deliver buildings that are smart-ready.

In London, 80 Strand is a stunning art deco-style building originally opened in 1932, located on the banks of the River Thames and Grade II Listed. HDR completed the building engineering services design together with ICT, security and provision of critical services for tech space, breathing new life and introducing 21st century technologies into one of London's most famous historic buildings.

The designs included supplying new technology equipment rooms to support the new working environment's high-speed voice and data networks, with a new fiber optic backbone to further allow for future expansion. The general office areas have a high-speed Wi-Fi infrastructure for agile working and the new CCTV and door systems, meanwhile, have been designed to be discreet yet also included onto the client's network, to take advantage of the new passive and active infrastructure, enabling flexibility with respect to cameras and door access position.

The 80 Strand, a truly smart-ready building, represents the two aspects of the engineering industry crucial to many clients: preserving the sophistication of the time-honoured design while simultaneously making a technological leap into the future.

Engineers and designers are experiencing the most significant change to how buildings are designed, built, managed and supported and more importantly how landlords and tenants use the spaces. The key for building technology design is ensuring that the external building connectivity and internal networks are both well planned tools that continue to provide scalable flexible infrastructures meeting Day One requirements and subsequently continuing to adapt and support Day Two end-point growth.

Technology in relation to building systems, such as ICT, BMS, EMS, security, HVAC and AV, will continue to advance resulting in interface and endpoints being replaced and upgraded for the life cycle of the building. It is therefore essential that the ICT infrastructure can be relied upon to accommodate changes and upgrades seamlessly in terms of bandwidth and resilience.

Increasingly as buildings become smart, the carbon footprint will reduce and sustainability targets will be achieved and exceeded. smart solutions also support well-be-

Back to TOC

ing and community, themes central to most commercial office projects, evidenced by the rising importance of certifications such as WELL Building Standards. Technology enhances user experience, human interaction with the whole build space as well as COVID-safe workplace planning and helps to embrace structural and cultural shifts in how people work and live, thus allowing tenants to benefit from the direct correlation between happiness at work and quality of workplace, increasing individual productivity and creativity.

Smart buildings are like fingerprints — they might seem similar, yet each project can have a unique approach around cost, program, client brief and intended use. To deliver timeless quality and a competitive package, it is essential to prepare a smart building strategy early in the design stage.

User experience, building information dashboards, smartphone apps, cybersecurity, open standards, sensors and integrated communication networks are key factors that inform the strategic thinking of how the building will perform. This approach has helped HDR to create value for clients, meeting their business needs while successfully integrating technologies.

Billy Marigold

Billy Marigold *is ICT Divisional Director at HDR. He has four decades in the engineering industry and more than 30 years as an information and communications technology professional.*

Back to TOC

Industrial decarbonization path is improved with retrofitting

As the urgency to address climate change has intensified, there has been a global shift towards sustainable and environmentally friendly practices. Decarbonization is at the forefront of this movement.

At the AHR Expo at McCormick Place in Chicago, decarbonization was a major topic of concern for commercial and industrial facilities. The challenge is not only to reduce emissions but also to do so while maintaining operational efficiency and competitiveness. One of the ways that vendors at AHR Expo were trying to address this was through retrofitting. This is a way to modernize existing facilities for a greener future.

Three decarbonization methods for buildings

According to conversations with different exhibitors, decarbonization in commercial and industrial settings involves adopting strategies to minimize carbon footprints.

"Decarbonization isn't just a strategy for environmental sustainability. It's an investment in our future," said Ryan Richie, EVP of business development at HealthWay.

This can be achieved through various methods, such as:

1. Energy efficiency: Implementing energy-saving measures to reduce overall consumption.

2. Renewable energy sources: Transitioning to solar, wind, hydro or geothermal energy to replace fossil fuels.

Back to TOC

Back to TOC

3. Process optimization: Innovating production processes to be more energy-efficient and less carbon-intensive.

Ryan Richie walked listeners through HealthWay's product line up. Courtesy: CFE Media and Technology

Retrofitting's role in decarbonization

Retrofitting plays a crucial role in decarbonization. It involves updating existing facilities with new technology or features to improve energy efficiency and reduce emissions.

"Retrofitting can also be cheaper and simpler than installing an entirely new system," said Rick Nadeau, vice President and senior director of training and operations at Samsung HVAC.

Key aspects of retrofitting include:

- Upgrading HVAC systems: Modern, energy-efficient heating, ventilation and air conditioning systems can significantly reduce energy consumption.

- Installing smart controls: Automated controls and sensors can optimize energy usage, reducing waste.

- Insulation improvements: Enhancing insulation in buildings to reduce heating and cooling demands.

Samsung product line up. Courtesy: CFE Media and Technology

Retrofitting opportunities for building owners, operators

The opportunities from decarbonization and retrofitting solutions are vast. Retrofitting not only contributes to the global fight against climate change, but it also offers economic benefits through reduced energy costs. Companies that embrace decarbonization often enhance their reputation by appealing to an increasingly environmentally conscious market.

Decarbonization and retrofitting in commercial and industrial facilities represent a critical step towards a sustainable future.

Tyler Wall

***Tyler Wall** is an associate editor for CFE Media and Technology*

Back to TOC

How to keep smart lighting from being stupid

As smart lighting becomes more commonplace, it is important for engineers to understand the pitfalls and problems that may come with it

The most efficient light is the one that is turned off when it is not needed. The least efficient light is the one what is still turned on when it is not needed.

This simple guiding principle for lighting control systems has been at the core of energy conservation codes since their inception. However, with the emergence of new lighting control technologies and their wildly expanded functionality, engineers often get lost in the minutia of the various available control solutions and lose sight of this guiding principle.

Frequently, the result is a control system that is not cost-effective, performs erratically and does not meet the client's needs. In some cases, it may be that the controls did not perform as expected because there was not a clear understanding about what controls could and couldn't do.

How the code evolves

Changes in technology have allowed for dramatic reductions in energy use, such as the replacement of incandescent and fluorescent light sources with LED. For example, 20 years ago, the 2003 International Energy Conservation Code (IECC) and ASHRAE Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings mandated a maximum allowable lighting power density (LPD) of 1.3 watts (W) per square foot for commercial office buildings. Now, in the 2021 IECC, the LPD number is 0.64 W per square foot.

Back to TOC

Back to TOC

Figure 1: Wireless communication modules and sensors for luminaire level lighting controls are now small enough to allow for mounting in most light fixtures. Courtesy: McGuire Engineers

This represents almost a 51% reduction. Such reductions were easily achieved with the transition to LEDs. However, these types of improvements require revolutionary changes in technology and are usually the exception. Instead, incremental, marginal gains in lighting system efficiency and energy savings with each energy code revision are usually the norm. Without some other type of transformational change like the adoption of LEDs, the only way to achieve persistent incremental improvements is by increasing the controllability of lighting — to turn it off when it's not needed.

Or, in the parlance of current design trends, to increase granularity of control (i.e., be able to adjust light levels to the minimum intensity needed and to perform that control only in the exact area where it is needed). The ideal solution would be to bring that controllability down to individual lighting fixtures – to have luminaire level lighting controls (LLLC). This LLLC concept where anyone can turn individual fixtures on or off was introduced as an additional efficiency package option in the 2015 IECC (C405.2 and C406.4).

Back to TOC

What is smart lighting?

Figure 2a/b: Many wireless sensors are now battery powered which can provide significant flexibility in placement. However, batteries do not last forever and future maintenance must be factored into any design. Courtesy: McGuire Engineers

The term "smart lighting" is used and abused. Perform a search for smart lighting on the website of any big-box home improvement store, and there will be a multitude of products, usually with wireless control. However, does simply having that capability make something "smart"?

Beyond the singular characteristic of having wireless control, the functionality of those products can vary widely. Some are standalone devices, others are networked. Some have cloud-based controls while others rely on a direct Bluetooth connection to an iOS/Android app. Some allow for automation, others do not. Without a consistent definition to set clear, realistic expectations about the functional capabilities of smart lighting, confusion among the general public is unavoidable.

Absent standardization by the manufacturers, the driving force in dictating smart lighting functionality requirements, has been the prevailing energy conservation codes. While the term smart lighting is not used in IECC or ASHRAE 90.1, the IECC does have a basic framework for lighting control functionality that could be considered smart.

Back to TOC

IECC lists the following definition for LLLC:

"A lighting system consisting of one or more luminaries with embedded lighting control logic, occupancy and ambient light sensors, wireless networking capabilities and local override switching capability where required."

IECC Section C405.2 Lighting Controls and C406.4 Enhanced Digital Lighting Controls further expanded on this definition with specific functional requirements. These requirements essentially push the required granularity of control down to small groups, or individual light fixtures as in the case of LLLC. A notable omission from functional requirements listed for "Enhanced Digital Lighting Controls" is a lack of a requirement for wireless communication. Wireless capability is specifically called out in the description for LLLC. We will see that the incremental cost associated with adding LLLC functionality is a significant barrier to adoption and eliminating costly physical infrastructure, such as network cabling in lieu of wireless, is critical.

How does the industry define networked lighting controls and LLLC?

Beside industry wide standards from manufacturers, what is the driving force for developing consistent functionality standards for smart lighting? The answer is money.

The DesignLights Consortium (DLC) is an association of utility and regional energy efficiency organization through the U.S. and Canada. Its members are the same groups that control utility energy efficiency rebate programs across the country. One of its major goals is to create rigorous criteria that substantiates the inclusion of new lighting technologies in energy efficiency incentive programs.

Figure 4: Pictures of lighting control stations with and without labeling. Courtesy: McGuire Engineers

Utility rebates are frequently used to help enable projects that otherwise would not have been financially viable. DLC's requirements have successfully accelerated the adoption of LEDs by making compliance a condition of utility rebates. It is expected that this same implementation model will be applied to networked lighting controls/LLLC.

DLC has developed formal technical requirements for networked lighting control systems. Version 5 (NLC5) of these requirements was released in 2020 and updated in June 2023. The technical requirements include both "required" and "reported" capabilities. While reported capabilities are not currently required inclusions, their presence or absence needs to be documented by the manufacturer.

Many of these requirements have already been incorporated into the IECC. NLC5 also has some provisions for interoperability, but those are typically limited to communication with other systems beyond lighting.

Back to TOC

Any mention of requirements for nonproprietary implementations of industry standard communication protocols (i.e., ZigBee, Bluetooth, DALI2, etc.) for individual control components are notably absent. This lack of standardization is perceived as being a significant barrier to the wider adoption of NLC5/LLLC technology.

The cost of energy and potential benefits of LLLC

In 2022, the U.S. Energy Information Administration (EIA) estimated that lighting represents 11% of total electricity use for the commercial building sector. While increasing light fixture efficiency and controllability can significantly reduce that, what is the value of that electricity? Unfortunately, the primary barrier to LLLC adoption is that the incremental cost associated with increased lighting control granularity is not fully offset by energy cost savings.

The first challenge is being able to quantify potential energy savings in a statistically defendable manner. The U.S. Department of Energy is required, per the Energy Conservation and Production Act of 1976, to make a determination as to whether the latest version of consensus-based building energy conservation standards will improve energy efficiency as compared to the previous edition. As part of this determination, an economic analysis to quantify the associated energy cost savings is also performed.

Nationally aggregated energy cost index (ECI) savings for the 2021 IECC code revision were estimated at 10.6% (reduction from $1.32 a square foot per year to $1.18 a square foot per year). Although not specifically quantified, it is understood that the ECI savings associated with lighting are only a fraction of that total. A key point was that the analysis excluded enhanced digital controls since it did not have quantifiable impact through energy modeling.

Back to TOC

Back to TOC

While studies have been performed by third parties, they have not yet been able to quantify LLLC energy savings relative to code baselines in a statistically significant way. A Northwest Energy Efficiency Alliance (NEEA) and DLC joint study attempted to quantify the potential energy savings associated specifically with LLLC. The study identified an average energy savings of 63% during normal business hours compared to a "do nothing" scenario, which does not meet code. As such, the quoted savings are not directly comparable to a building with a lighting control system that met the minimum requirements of one of the prevailing energy conservations codes.

Additionally, there were significant limitations in the NEEA/DLC study. The total savings were based on a sampling size of only 98 buildings with LLLC. Of the total energy savings, 37% was attributed to high-end trim, or the capability to reduce the maximum light output of a light fixture at the time of installation or commissioning, and had nothing to do with the adjustments associated with lights turning on-off and dimming during the day.

Beyond these issues, the primary downfall of this study was that the buildings included in this study were not a random sampling and the overall sample group was relatively small. While the average savings of the sample group may be valid, the savings from building to building varied widely. It is generally suggested that there are potentially significant energy savings, but a broader study with direct comparison to minimum code compliant buildings is needed to demonstrate defendable statistical trends.

The next question is: What is the material cost associated with LLLC? In 2021, NEEA published a study examining the incremental cost associated with LLLC. The study

Back to TOC

found that while costs were steadily dropping year over year, they were still substantial. The incremental cost of adding “clever” or “smart” functionality compared to the code minimum installation ranged from $29 to $70 per light fixture.

The 3/30/300 rule

As seen above, smart lighting is not a compelling investment, based on solely on energy cost savings. There are other, potentially more cost-effective energy efficiency solutions, such improving building envelope thermal performance. However, there is a real estate concept known as the 3/30/300 rule that may provide a more compelling reason for smart lighting adoption.

This concept states that there is an average order of magnitude between a company’s costs for utilities, rent and payroll per square foot per year:

- $3 for utilities.
- $30 for rent.
- $300 for payroll.

While the exact values will vary, it is expected that the relationships and orders of magnitude difference between these three items are generally valid. Based on this relationship, an incremental percentage improvement in employee productivity can have an outsized impact compared to a similar percentage improvement in energy consumption.

Numerous studies have examined the impact of tunable lighting on circadian rhythms and educational outcomes. The consensus is that controllability is a positive influence on those outcomes. However, similar evidence-based research for commercial office environments is lacking — for now.

A trend toward higher energy prices could make LLLC viable

Why would a utility company actively encourage its customers to use less electricity if its revenue is tied to selling electricity? The simple answer is that the capacity that one customer does not use can be sold somewhere else. A rebate program makes sense if the utility company can buy that capacity through energy efficiency rebates at a lower cost than what would be required to purchase that capacity from somewhere else.

EIA studies have demonstrated that economic growth in the U.S. decoupled from energy usage long ago. EIA projected that between 2019 and 2050 gross domestic product will grow at an annual rate of 1.9%, but that energy consumption will have an annual average growth of 0.3%. The net result has been reduced investment in the grid.

It is also expected that carbon dioxide emissions will continue to increase, furthering the associated risks of climate change. To this end, the federal government has passed legislation that included decarbonization efforts. So, while overall energy usage growth across the entire U.S. economy may be limited, the fuel mix (coal, gas, solar, nuclear, wind, etc.) will change to emphasis electrification and utilizing renewable generation sources.

The change in the country's fuel mix will have severe consequences. The intermittent and limited duration nature of wind and solar generation means that replacing thermal

Back to TOC

generation with renewables is not a one for one swap. Typically, multiple megawatts of renewables are needed to replace a single megawatt of traditional thermal generation. As existing thermal generation assets are retired, it is unclear if the new renewables will come online at a sufficient rate to make up this shortfall.

PJM, a regional electrical transmission organization responsible for coordinating the reliable transmission of electricity between generation companies and local utilities, issued a study that examined this shortfall issue, and the conclusions were not encouraging. While demand response and distributed energy storage are important tools in helping bridge the gap, additional resources are still needed.

Making this shortfall worse, the problem extends beyond the commercial and residential building market. The EIA typically separates energy usage into four broad categories: industrial, transportation, commercial and residential. While a significant percentage of the total energy consumption in the commercial and residential sectors already comes from electricity, that is not the case for industrial and transportation sectors. If those markets take significant steps toward electrification, the electrical capacity situation will worsen.

The solution to demand outpacing supply in a market-based economy is to raise prices. If the cost for electricity increases, some technologies such as smart lighting may become more economically viable. The logical extension of DLC's efforts to develop NLC/LLLC guidelines, is standardizing functional requirements, so it will be easier to quantify the associated energy savings. While energy costs may increase, implementation of smart lighting may also result in energy savings for consumers and recovery of some valuable grid capacity for utility companies.

Back to TOC

Back to TOC

Examples of real-life problems with smart lighting

Lighting control concepts may seem natural to an engineer, but they often are not for the general population. Most engineers assume that building occupants generally want more control over their environment. However, that ability to have extensive controllability is often more confusing than enabling. As such, in a well-designed lighting control system, most functions are automatic, and the need for direct user interaction is kept to a minimum. Where interaction is required, clear and consistent identification of what the controls are supposed to do is critical.

In the first example, a U.S. Green Building Council LEED Gold corporate headquarters project was designed with lighting system sensors controlling 50% of plug loads within offices areas. Plug load control is commonly integrated into lighting control systems per 2021 IECC and ASHRAE 90.1. The associated receptacles were properly marked "controlled" in accordance with NFPA 70: National Electrical Code Article 406.3(E).

A short time after the client moved into their new offices, complaints started. Many of the executives rarely worked in the office. As they started to use their offices, they would plug laptops, phone chargers and other equipment requiring constant power into whatever receptacle was most readily accessible.

The key problems were:

- The occupants had no previous experience with lighting-sensor controlled receptacles.
- Occupants did not know what the markings meant.

Back to TOC

- The receptacles were usually located under desks and behind other obstructions where markings were not clearly visible.

This situation could have been made better by improved training and supplemental labeling or color coding to help the occupants to determine that these receptables were different from what they are used to.

Figure 5: Integrated sensors with wireless control can offer enhanced control capabilities in retrofit situations such as in this 2×2 foot edge light LED panel, which replaced a standard 2×2 foot acrylic lensed fluorescent troffer. Courtesy: McGuire Engineers

In a second example, a networked wireless lighting control system for a commercial office space had been in service for multiple years. After what was assumed to be a power surge, the network controller rebooted unexpectedly. After the reboot, multiple wireless sensors started to function erratically and could not maintain consistent communication with the controller. The controller reported no errors after the reboot. In addition, some wireless occupancy sensors started to report low-battery conditions and it was unclear exactly which sensors were dying.

The key problems were:

- “Control persistence” was not present. Control persistence is defined as the ability to execute three energy saving strategies (occupancy sensing, daylight harvesting and high-end trim) in the absence of communication with the next higher networked element in the system. This functionality is a reported capability of network lighting systems as defined by DLC's NLC5 requirements.

- The individual wireless devices did not have an obvious method, such as a different colored blinking light on the device, to identify which one had a low-battery condition.
- The naming convention used to identify devices in the lighting control software interface was convoluted and did not necessarily reflect where the devices were located.
- Lack of knowledge about how to interpret error messages and interact with the software made troubleshooting difficult.

The first two problems reflect possible limitations with the lighting control equipment itself. Hopefully as standards evolve, functional requirements will become more consistent across the industry. The second two problems are more indicative of insufficient training and interaction with the client during the system setup and commissioning process.

In the last example, a tenant noted issues with trying to turn lights on/off in its offices while in the process of moving in. The lighting control system was straightforward with a dedicated button assigned to each control zone. However, the contractors were rushing to complete their work before move-in and it was noted during the punch list that only some of the control stations were properly labeled.

Back to TOC

Once the tenant realized that all the unlabeled buttons throughout their space had something to do with lights turning on and off, they resorted to button mashing to figure out what each button did. In addition, the contractor had programed a placeholder time-of-day schedule for certain common area lighting that was not approved by the tenant. As such, the lighting within the space would turn on or off at time that didn't match their normal business hours.

The key problems were:

- Installation, commissioning and training activities did not take place in a timely manner.

- Labeling of controls, which would have made the intended functionality of the system more readily apparent to the occupants, was inconsistent leading to confusion.

As lighting control systems become more complicated with additional granularity of control, these last two problems will become a reoccurring theme.

John Yoon
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Back to TOC

Unique electrical and power considerations for university buildings

Utilizing creative and flexible solutions in electrical, power and lighting systems can help meet the changing needs and loads for different buildings on college campuses

MEP ROUNDTABLE

Christopher Augustyn, PE, Senior Project Engineer, Department Facilitator, Affiliated Engineers Inc., Chicago. Matthew Goss, PE, PMP, LEED AP, CEM, CEA, CDSM, Mechanical, Electrical, Plumbing & Energy Practice Leader, CDM Smith, Latham, New York. Richard Loveland, PE, Senior Vice President, BVH a Salas O'Brien Company, Bloomfield, Connecticut. Tom Syvertsen, PE, LEED AP, Vice President, Mueller Associates, Madison, Virginia. Kristie Tiller, PE, LEED AP, Associate, Director of Mechanical Engineering, Lockwood, Andrews and Newnam Inc. (LAN), Dallas.

Back to TOC

Back to TOC

Are there any issues unique to designing electrical/power systems for these types of facilities? Please describe.

Richard Loveland: Designing electrical or power systems for these types of facilities involves addressing specific capacity requirements based on user needs. While these requirements may not be entirely unique, they do vary depending on the facility's purpose. For instance, power provisions need to accommodate connectivity demands, usage needs within laboratories and space requirements. Different areas within the facility, such as a gaming or computer classroom, may require significantly more power compared to a standard classroom or lecture hall. The key lies in understanding the programming and user needs of the building to accurately determine the appropriate electrical capacity.

What types of unusual standby, emergency or backup power systems have you specified for such facilities? Describe the project.

Richard Loveland: We have designed campus generation where large generators back up an entire campus. This allows students to remain in dorm rooms and classes to continue during a power outage. Other campuses utilize distributed generation to support the critical spaces such as dining halls and labs. But in an extended outage students may have to move to temp housing since dorms may not be supported by generators.

What are some of the challenges when designing high-voltage power systems in college and university projects?

Richard Loveland: One challenge is the diversity of loads within the campus. Understanding the various power requirements and load profiles of different buildings and facilities is crucial for properly sizing the campus distribution system. Another challenge is designing the medium voltage loop for the campus. Creating an efficient and reliable medium voltage distribution network involves careful planning and consideration of factors such as load distribution, voltage drop and equipment coordination.

How has smart lighting influenced classrooms and laboratories? What tactics should electrical engineers use when designing these systems?

Richard Loveland: This depends on the definition of smart lighting. This can be smart controls that utilize daylighting, occupancy sensing and vacancy controls. Additionally, smart lighting can involve color-changing capabilities, often utilized for branding, signage, or creating visually appealing environments in tech or gaming spaces. Another aspect is tunable white lighting, which allows customization of light color from warm to cool tones. This customization caters to individual preferences for reading and studying, ensuring optimal lighting conditions.

How does your team work with the architect, owner's rep and other project team members so the electrical/power systems are flexible and sustainable?

Matthew Goss: Our team works consistently and collaboratively with project architects and owners to ensure our systems are flexible and sustainable. We achieve this through constant and open communication. Owners and architects are part of our design review process and are engaged constantly throughout our design lifecycle. Their involvement is the only way to ensure a collaborative design that meets the needs of the owner or client.

Back to TOC

Back to TOC

The new auditorium at St. Mary's College has lighting and sound specifications that create a challenge for engineers. Courtesy: Tom Holdsworth, Mueller Associates

Richard Loveland: One aspect is achieving flexibility of furniture through floor systems that allow for adjustable layouts according to the requirements of a classroom, without being limited by the power solution. Another aspect is utilizing tunable white lighting, which can enhance student and staff focus by adapting the light color. Additionally, creating large, flexible multipurpose spaces provides versatility in usage. Throughout these processes, we closely collaborate with the design team to provide informed solutions that meet the users' needs. These are collaborative design processes.

What kind of lighting designs have you incorporated into college or university project, either for energy efficiency or to increase the occupant's experience? Discuss the use of holistic lighting or other lighting techniques.

Richard Loveland: We have incorporated color-changing lighting to enhance appearance, branding, signage and create engaging environments in tech or gaming spac-

es. Additionally, tunable white lighting allows customization from warm white to cool white, providing flexibility for personal preferences. The choice between warmer or cooler lighting for reading and studying is subjective, varying from person to person.

When designing lighting systems for these types of structures, what design factors are being requested? Are there any particular technical advantages that are or need to be considered?

Matthew Goss: The last lighting system we designed for a college/university space was for an athletic gymnasium that the university also used as a space for special events. This situation necessitated selecting a system that could meet not only NCAA athletic lighting requirements but also the special events' requirements. Because of the specific operating requirements, we chose a flexible solution that allowed for precise light level control. In addition to specific light level control, the fixtures also had to be impact rated given their installation in an active gymnasium.

Richard Loveland: When designing lighting systems for these types of structures, critical components include the presence of ceilings, ceiling heights, space finishes, finish colors and space usage. Each of these elements plays a role in determining the appropriate lighting design for the facility. The usage of the space drives the required light levels. For example, classrooms, laboratories and research spaces typically require higher light levels to support detailed work and visual clarity. On the other hand, circulation areas and general spaces may necessitate lower light levels.

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Back to TOC

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