SMART BUILDINGS

SUMMER EDITION

CONSULTING - SPECIFYING engineer eBOOK

GRUNDFOS

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Know these three steps when defining an EV fleet's goals

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Understand three things when designing an electric vehicle (EV) fleet for a city

In 2021, the federal government set a goal of having 500,000 electric vehicle (EV) chargers constructed by 2030. Its plan allocated $7.5 billion to install EV chargers across the country. The government earmarked $2 billion of these funds for states and cities. The plan's intent is to incentivize cities, in the form of grants, to electrify their fleets. To secure these grants, cities are required to submit an EV infrastructure plan that lays out their needs to electrify their fleets.

Kimley-Horn and Associates EV planners have identified three challenges that typically arise when creating EV infrastructure plans for municipal infrastructure.

1. High-level, interdepartmental coordination and alignment

Each city comprises of several departments (e.g., police, fire, water, aviation, etc.). These departments all have fleet vehicles that are used in different capacities (e.g., sedan, light duty, heavy duty, etc.). With cities mandating electrification of vehicle fleets, departments pose different constraints and objections based on factors like fleet usage, political beliefs and fear of workflow disruption.

As planners, consulting engineers must coordinate with the various departments and craft an executable plan that best serves their varying needs. In many cases, engineers facilitate interdepartmental coordination and city employees are required to negotiate between the departments so that the established plan can best serve everyone. This sometimes requires concessions to be made to meet critical goals for the federal grant submission.

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2. Emergency preparedness

Municipalities are required to have a contingency plan in place for when the electrical grid fails due to natural disasters or high peak demands. Each city prepares in a manner that it feels best supports its needs. Clients differ in needs regarding emergencies. One city client wants 96 hours of backup power, while another may not need any.

Figure 1: This shows the three challenges faced by cities when creating electric vehicle (EV) infrastructure plans. Courtesy: Kimley-Horn and Associates

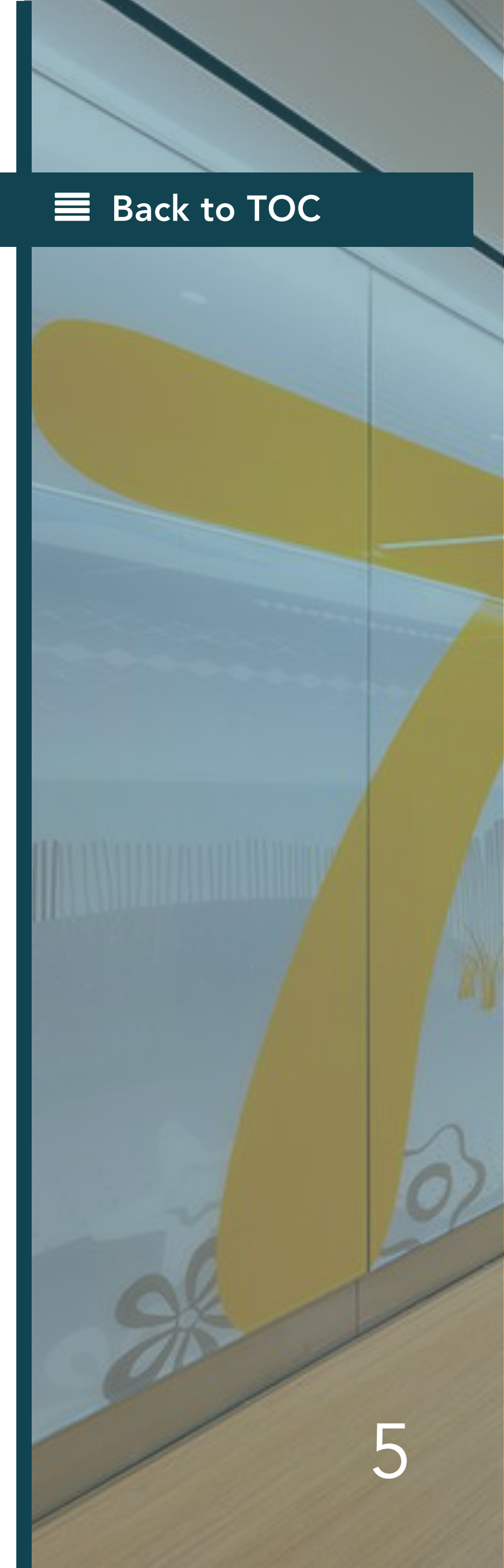
The simple reality is that to charge the vehicles in a city's fleet, the electrical grid needs to be continuous and operational. However, grid failure is likely to follow when these natural disasters occur. Many of the vehicles in the city fleets are used by first responders and these personnel and their vehicles are required to be operational during emergencies and even during sustained grid outages.

The EV infrastructure plan must provide power contingency for when the grid fails. The simplest solution is a diesel generator that can generate electricity and charge the vehicles. Unfortunately, a diesel generator does not meet the carbon-neutral goals that many cities have.

There are varying emergency preparedness options depending on the city's budget and goals. Whether the right option is a battery energy storage system (BESS), a hybrid solution that includes BESS and an interconnected solar array or other alternative energy fuel solutions such as hydrogen fuel cells, natural gas generators or a combination of all solutions, the engineering firm is responsible for bridging the gap between the cities' goals and its budget for their EV infrastructure plan.

3. Procurement of vehicles to match infrastructure investment timelines

Cities are in a difficult position because it needs to take advantage of the federal EV grants while they exist. However, the EV market's economics and supply chain differ from the time frame for grant use. In many cases, cities spend millions of dollars on EV infrastructure that allows them to charge their fleets, but they cannot yet purchase a fleet of EVs that meets their needs.



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For instance, Kimley-Horn and Associates experts worked with a city in Arizona that placed an order for 84 light-duty EV trucks more than two years ago, which has yet to be filled and no procurement date is scheduled. Due to the limited supply of light-duty EV trucks, cities are faced with the possibility of making a significant investment without knowing when it will see the investments come to fruition.

EV charging goals

The push to reach the goal of a half-million EV chargers across the country is lofty. This goal could be a lucrative opportunity for those who support the planning, design and installation of these chargers, namely consultants and construction companies. However, due to the unique circumstances associated with executing a plan of this magnitude, this opportunity comes with challenges.

A transformation in transportation is taking place in the United States. EVs are the way of the future and challenges will arise as this transformation occurs. There is no manual for cities to implement EV infrastructure plan. Most cities do not have subject matter experts on staff because EV chargers have only been installed domestically for about a decade in the U.S.

Cities need help from consultants and EV experts nationwide. EV consultants will take the lead in finding solutions that overcome these challenges. As daunting as one side of the coin is, the other is filled with abundant potential.

Daren Peterson, PE

Daren Peterson, PE, *is an EV Planning Engineer at Kimley-Horn and Associates. He enjoys partnering with cities across the country to help them plan for the electrification of their fleets.*

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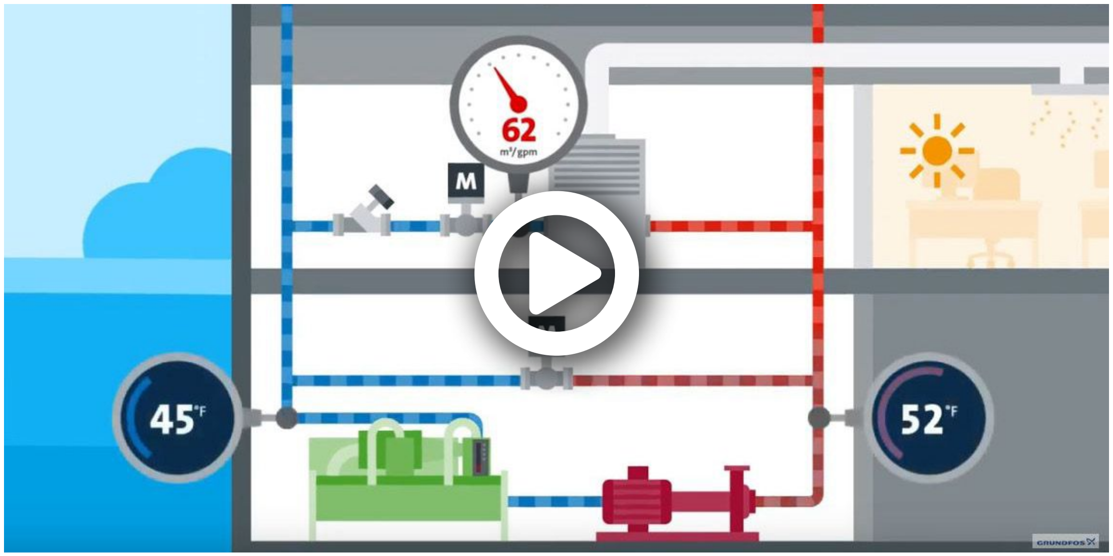
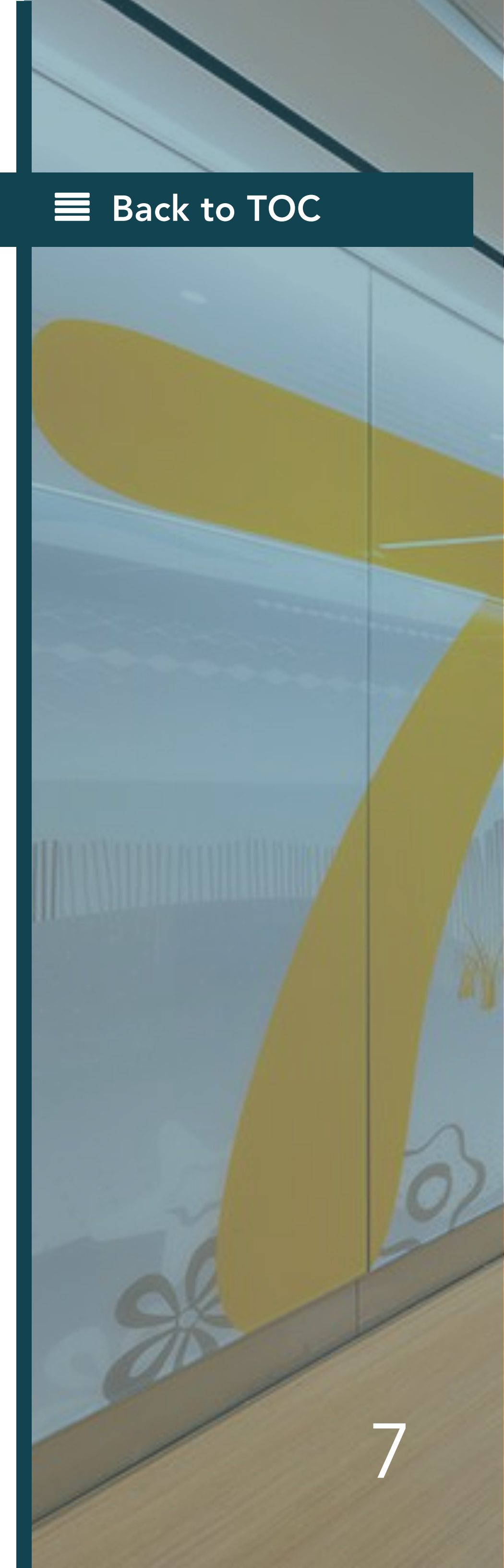


Grundfos Distributed Pumping A New Approach to HVAC Design

Accurately controlled cooling systems are crucial to maintaining an efficient, comfortable building. But this accuracy can be difficult to achieve with standard valve-based chilled water systems. These systems face challenges with balancing and poor dynamic flow regulation, which leads to severe energy loss, inadequate climate control and uncomfortable occupants.



Engineer HVAC systems with ASHRAE 241 in mind

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ASHRAE 241 instructs mechanical engineers about how keep infectious aerosols minimized

Is your engineering team ready to mitigate COVID-19 and other infectious aerosols? While watching the webcast HVAC: IAQ and IEQ is a much more complete overview, reviewing this transcript of the presentation helps define the topic better. It has been edited for length and clarity.

This information was presented by Emmy Riley, CEM, BEAP, WELL Performance Testing Agent, Energy Engineering Team Leader & Account Manager, Cyclone Energy Group, Chicago.

A newer standard that came out in July 2023 is ASHRAE Standard 241: Control of Infectious Aerosols and it came out of the sort of an extension of ASHRAE's epidemic task force that was active during the COVID pandemic and the standard itself was developed at the request of the White House. And that's why it got brought to market quickly, faster than other standards that ASHRAE has developed.

The purpose of it is to establish minimum requirements for the control of infectious aerosols. And what we're trying to do is reduce disease transmission. And this standard is talking about not proximity transmission, it's talking about in a whole building and its air distribution system. How can we help mitigate that? And it has requirements for outside air system design and it also includes recommendations on air cleaning systems.

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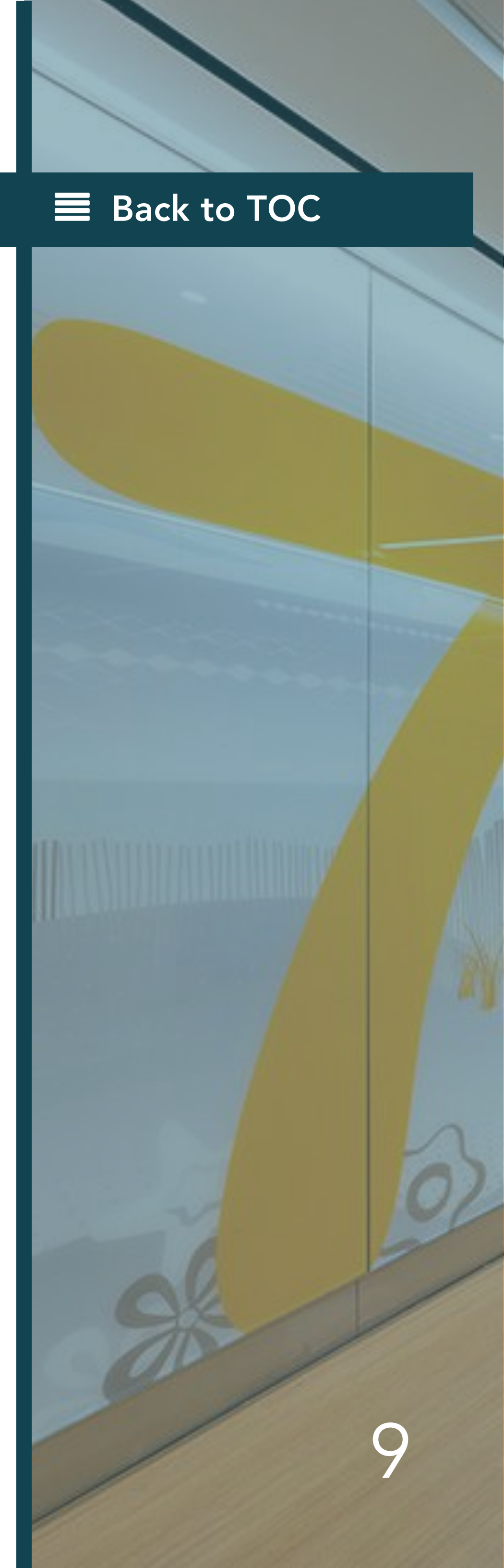
Two of the big concepts in the standard are equivalent clean air flow and infection risk management mode. And infection risk management mode, the way the standard is set up is it is like other standards, optional to adopt until unless a region adopts it as code or law.

You would identify an infection risk management mode, like if there were high levels of COVID or flu and you wanted to mitigate the spread of disease in a building, that's when this would come into place. The deliverable that comes out of using Standard 241 is called a building readiness plan, or a BRP. A prerequisite for using Standard 241 are that you need to also comply with ASHRAE Standard 62.1: Ventilation for Acceptable Indoor Air Quality already and you also need to use minimum efficiency reporting values (MERV) 11 filters or better.

There needs to be a level of filtration that is in a typical commercial range. And how you would implement ASHRAE 241 is an extensive process. It has some tools attached to it to calculate a passing or failing score or level for each zone in your building, you would do a space-by-space inventory, have the full heating, ventilation and air conditioning (HVAC) inventory including sensors. You would get testing and balancing done, have commissioning done, have lab testing done.

Then based on the assessment, you would address any deficient areas that don't meet the standard, the recommendations in the standard. The building readiness plan would be updated annually.

Consulting-Specifying Engineer



Energy Savings Soar to New Heights At The Museum Of Flight

Distributed Pumping retrofit for chilled water system keeps priceless aviation exhibits pristine

A redesign of the Museum of Flight's cooling system using Grundfos Distributed Pumping resulted in 74% pump energy savings and an auto-balanced system maintaining exact temperature in each corner of the six-story, glass-walled gallery.

Executive summary

The Museum of Flight decided to implement Grundfos Distributed Pumping chilled water system design when retrofitting their HVAC system. The solution's automatic balancing has not only generated 74% savings in pumping energy during the 2023 cooling season, but also en-

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sures the preservation of more than 40 historic aircraft from the first century of flight by reliably maintaining constant temperature throughout the museum's 3-million-cubic-foot, six-story, glass-enclosed Great Gallery.

The situation

The Museum of Flight in Seattle, WA, USA is the largest independent, non-profit air and space museum in the world and home to thousands of exhibits from the history of air and space flight.

The Museum of Flight had been running its original cooling equipment since its installation in 1987. With the equipment aging and energy costs rising, it became increasingly apparent the Great Gallery's cooling system was approaching the end of its life cycle. It suffered from poor Delta T, was poorly balanced and unable to reach the design temperature everywhere within the building – a critical factor when considering that maintaining ±2° from the set temperature is essential for the preservation of the historic aircraft.

The museum therefore decided to embark on a project of upgrading and retrofitting the gallery's cooling system, emphasizing the need to increase the energy efficiency of all its components.

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"The more we looked into Distributed Pumping, early estimates were conservatively at 40%, but as we've developed the plans further, we expect to attain even higher percentages of energy savings."
Fenton Kraft, Engineering Services Manager, The Museum of Flight

The solution

As the museum's engineers began investigating replacing the constant-speed, chilled and condensing water pumps with high-efficiency, variable-speed pumps, they became aware of Grundfos Distributed Pumping— a solution that replaces large, centralized pumps and traditional balancing and control valves with smaller, more intelligent pumps throughout the building delivering flow and pressure only when and where it's needed, automatically balancing the system, and significantly reducing energy consumption.

"It became readily apparent there was a real energy savings opportunity in Distributed Pumping, because you'd eliminate the designed-in friction and pressure drops that were necessary for our old control valves to have a good accurate control range," explains Fenton Kraft, Engineering Services Manager at The Museum of Flight. "Those valves come with an energy penalty that is pretty significant, and the main system pumps that were previously installed and even any new pumps would have to overcome that kind of pressure drop. So, as we looked at Distributed Pumping, it basically eliminated all the friction, all the pressure drop and all the horsepower requirements to overcome those."

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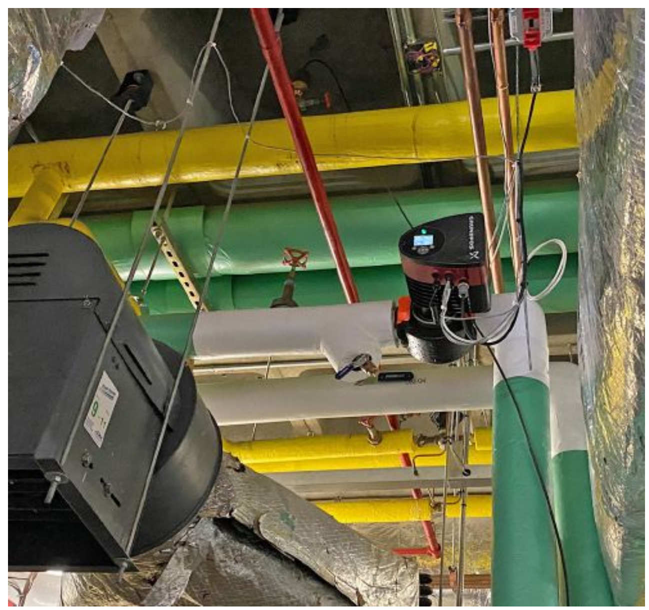
In collaboration with local sales partner Hurley Engineering and a team of Grundfos experts, an optimized Distributed Pumping system was designed with the following specification:

- 10°F chilled water Delta T
- 1 new water-cooled chiller
- 1 new cooling tower
- 1 new AHU (to extend the existing 10 AHU system)



The new chilled water system includes:

- Hydro MPC-E 2 CRE 125-1-1 (condenser water pump)
- Hydro MPC-E 2 CRE 95-1-1 (primary pump)
- 12 MAGNA3s (one distributed pump placed at each AHU, and two placed at the largest AHU)

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"With Distributed Pumping, we remove traditional balancing and control valves," describes Pavel Mirchev, Lead US Technical Engineer, Distributed Pumping. "Instead of having one pump that makes high pressure for the entire building, we have smaller primary pumps in the mechanical room, and we put a pump on every load that makes exactly the pressure and the flow that is needed. So, in this way, we put just the right amount of energy in the water, and we don't need to waste it with valves."

The outcome

The cooling system at the Museum of Flight improved its performance significantly after the conversion to Grundfos Distributed Pumping. Optimal temperatures are achieved at all locations in the Great Gallery, which has reduced the cooling system's operating hours.

For the entire 2023 cooling season (mid-April to mid-October), the new Distributed Pumping system resulted in 74% pump energy savings, equivalent to 34,000 kWh or $3,400. This does not take into account even further savings from the chiller and cooling tower energy reduction due to the optimized operation and reduced working hours.

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"This Distributed Pumping system takes out a lot of complexity that traditional pumping systems have. All the programming is built into the primary pump controller and the distributed pumps. We simply started up the pumps, about a ten-minute process for each pump, and we were up and running. We didn't have to write and develop a sequence of operations or program a controller. That's what makes these Distributed Pumping systems so turnkey and simple to operate on day one and for the life of the building."
Chris Ireland, Technical Sales Manager, Grundfos

"All through the design process, we've been able to bounce back and forth ideas and really establish an optimal design for our new system. Our experience with both our local distributor and all the various specialists at Grundfos has been exceptional." Fenton Kraft, Engineering Services Manager, The Museum of Flight

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Ten things to know about ASHRAE 90.1-2022 updates

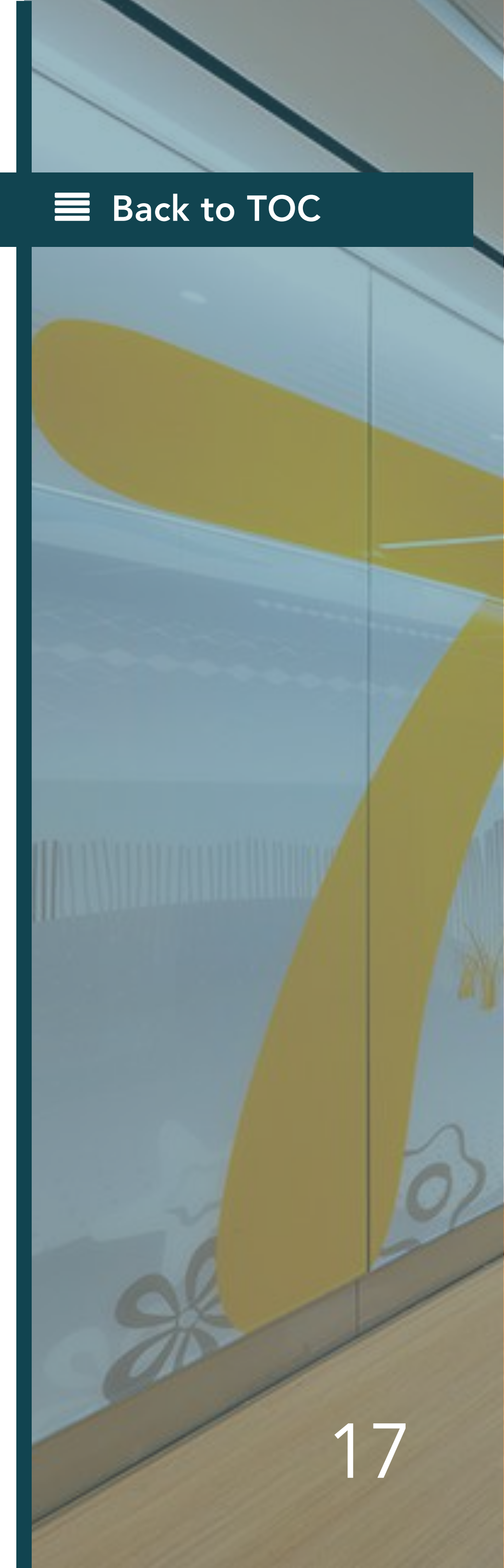
Building on the momentum of previous editions, ASHRAE Standard 90.1-2022 is leading the way toward renewable energy and decarbonization in commercial buildings

The 2022 updates to ASHRAE Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings are sweeping to say the least. If you review the addenda to the ASHRAE 90.1-2019 version, you will see that the scope of changes appearing in the 2022 version are significant: modifications and improvements to the existing language coupled with completely new material.

The updates demonstrate how ASHRAE's Technical Committees continue to partner with industry stakeholders to drive improvements in the efficiency of heating, ventilation and air conditioning (HVAC) equipment and processes used in buildings.

Many of the additions in the 2022 standard are appearing for the first time in a minimum-efficiency U.S. code or model energy standard. One of the key strengths is providing tools to the design and construction community. The use of these tools will result in buildings that are more efficient and lower carbon emissions.

ASHRAE 90.1 is the de facto standard for energy efficiency in buildings. It is a "code-ready" standard, meaning local jurisdictions can tailor it and use it as their energy code. The standard has been around since 1975 and has been adopted in the U.S. and around the globe.



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According to the Building Codes Assistance Project (BCAP), 38 states have adopted ASHRAE 90.1. Also, international energy standards — very close in content and scope to Standard 90.1 — are used in India, Canada, Mexico, Dubai, Singapore, Ireland, Hong Kong and other locations.

Finally, in addition to being a template for municipal and state codes, it is also an integral part of the Green Building Initiative – Green Globes and the U.S. Green Building Council LEED, which is the most widely used green building rating system.

Integration into other codes and guidelines is a big part of why the standard is so widely used. For example, ASHRAE 90.1 is used as a starting point or basis for most building energy code requirements in the United States, such as the International Energy Conservation Code, which uses 90.1 as

Table 1: Energy efficiency credit measures

ID	ap section	Measure name	IECC 2021	Proposed IECC 2024
E01	13.5.2.2.1	Envelope performance (90.1 Appendix C basis)	New	
H01	HVAC performance (TSPR) [Future]	New		
H02	13.5.2.2.2	Heating efficiency	C406.2.1-3	Expanded
H03	13.5.2.2.3	Cooling efficiency	C406.2.2-4	Expanded
H04	13.5.2.2.4	Residential HVAC control	New	
H05	13.5.2.2.5	DOAS/fan control	C406.6	Modified
W01	13.5.2.2.6	SHW preheat recovery	C406.7.2	Same
W02	13.5.2.3.1 a	Heat pump water heater	C406.7.4	Modified
W03	13.5.2.3.1 b	Efficient gas water heater	C406.7.3	Same
W04	13.5.2.3.1 c	SHW pipe insulation	New	
W05	13.5.2.3.2	Point of use water heaters	New	
W06	13.5.2.3.3 a	Thermostatic balancing valves	New	
W07	13.5.2.3.3 b	SHW submeters	New	
W08	13.5.2.3.4	SHW distribution sizing	New	
W09	13.5.2.3.5	SHW shower drain heat recovery	New	
P01	13.5.2.3.6	Energy monitoring	C406.10	Same
L01	Lighting performance	Future		
L02	13.5.2.5.2	Lighting dimming and tuning	C406.4	Expanded
L03	13.5.2.5.3	Increase occupancy sensor	New	
L04	13.5.2.5.4	Increase daylight area	New	
L05	13.5.2.5.5	Residential light control	New	
L06	13.5.2.5.6	Lighting power reduction	C406.3.1-2-3	Expanded
Q01	13.5.2.7.1	Efficient elevators	New	
Q02	13.5.2.7.2	Efficient commercial kitchen equipment	C406.12	Same
Q03	13.5.2.7.3	Fault detection and diagnosis (FDD)	C406.11	Same

Table 1: Analysis on energy efficiency credit measures developed by Pacific Northwest National Laboratory (PNNL). Courtesy: PNNL

the basis for compliance. Additionally, under the United States Energy Policy Act of 2005. In 2009, ASHRAE 90.1 was mandated to be used by federal agencies as the minimum energy efficiency requirement for new federal buildings.

What has changed in ASHRAE 90.1-2022?

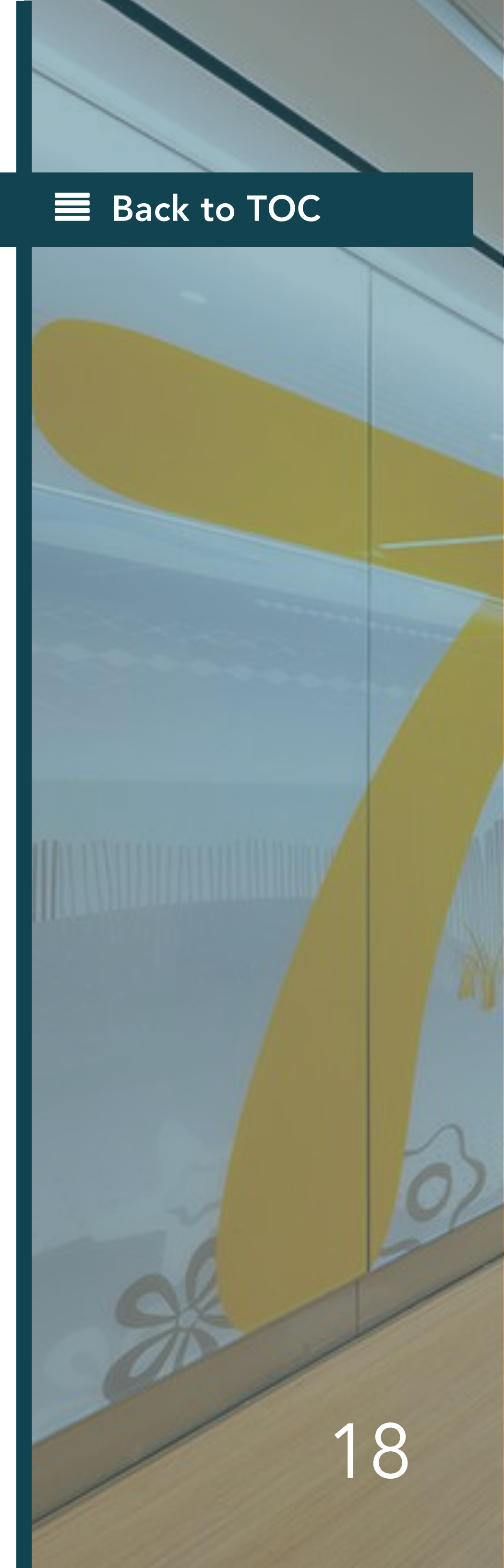
In developing the 2022 edition, ASHRAE followed the processes and procedures that they have for all the past versions. But for Standard 90.1-2022, there are significantly more content additions and revisions. Here are 10 changes engineers should pay attention to.

1. Mechanical system performance path rating (MSPR) method

One of the most important changes to the ASHRAE 90.1-2022 is the introduction of a new compliance path, MSPR, included in Chapter 6. HVAC systems that are allowed to use this approach do not have to meet all of Section 6 prescriptive requirements.

To illustrate this, if an HVAC system is designed without the required outdoor air economizer, it can still comply by using higher efficiency cooling systems or by reducing fan energy as compared to a reference system. The in-depth engineering and calculations are contained in a completely new Normative Appendix L, where the terms total system performance rating (TSPR), TSPRp (proposed) and TSPRr, (reference building) are used.

TSPR is a ratio that compares the annual heating and cooling load of a building to the annual energy consumed by the building's HVAC system. TSPRp is used for the proposed design; TSPRr defines the rating for the reference building the methodology behind this new compliance path has similarities to the 90.1 Normative Appendix G,



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Performance Rating Method. They both use a baseline (reference) and proposed building models that are used for energy simulation. Both paths also incorporate predefined equipment efficiencies and system control.

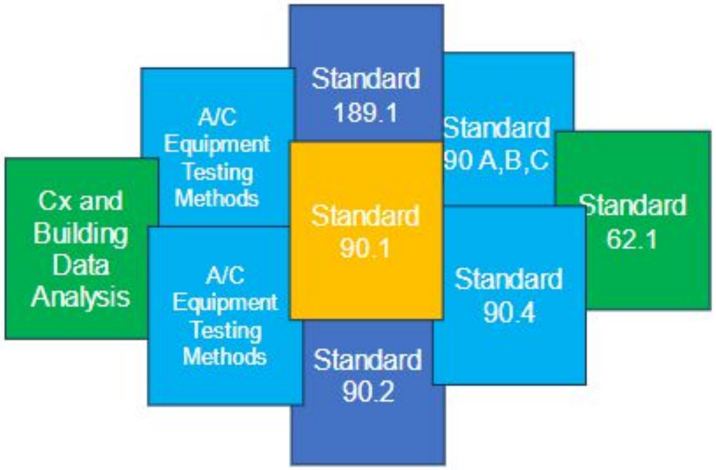

Figure 1: ASHRAE Standard 90.1 is part of a comprehensive compendium of many interrelated, ASHRAE documents, covering many aspects of building energy performance. Courtesy: kW Mission Critical Engineering

However, there are significant differences between the two. For example, Appendix L is used only for comparing a reference and proposed design and does not allow HVAC system efficiency trade-offs with building envelope, plug loads or lighting systems. These types of trade-offs are allowed in the Appendix G compliance path.

Using the Appendix L compliance path also streamlines the energy modeling process. One example is using simplified thermal blocks (rectangle, L-, H-, U- or T-shape) in the energy model. Where actual building shape does not match these predefined shapes, simplifications are permitted. Also, Appendix L provides detailed design parameters on efficiency and other operational characteristics of the equipment and systems.

To illustrate this, tables in Appendix L define many of the HVAC system parameters, including fan control, minimum zone airflow fraction, occupied outdoor air, energy recovery ventilator, condenser heat rejection, cooling pump (primary) power, chilled water

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temperature and many others. Each one of these parameters has numerical values and text information.

The big idea behind these data is to build a reference model using predefined values, resulting in a straightforward modeling process, minimizing time and effort in calculating energy use. After the energy performance of the proposed design is complete, the final part of the process gets underway: using the mechanical performance factor (MPF).

2. Climate zone and building type

In most buildings, these variables have the greatest impact on energy consumption.. This is where MPF comes in. The Pacific Northwest National Laboratory (PNNL) developed an analysis and recommendation report that introduced MPF. The U.S. Department of Energy developed Commercial Reference Buildings, which is an analysis for reference buildings. These reference buildings are instrumental in energy modeling and provide complete descriptions for building energy analysis.

In calculating MPF, PNNL revised the HVAC system parameters for each of the building prototypes, with the intent of generating energy modeling parameters that are just “good enough” — minimally code compliant. The TSPR calculation includes the MPF factor in verifying the proposed system has greater efficiency than the reference system. (TSPRp must be greater than the TSPRr, which is divided by the MPF). It is a simplified performance trade-off method for HVAC systems where no building trade-offs are needed.

3. MPF tables

ASHRAE Standard 90.1 also includes MPF tables for site energy, source energy and carbon emissions. The addition of MPF allows for an expanded performance-based

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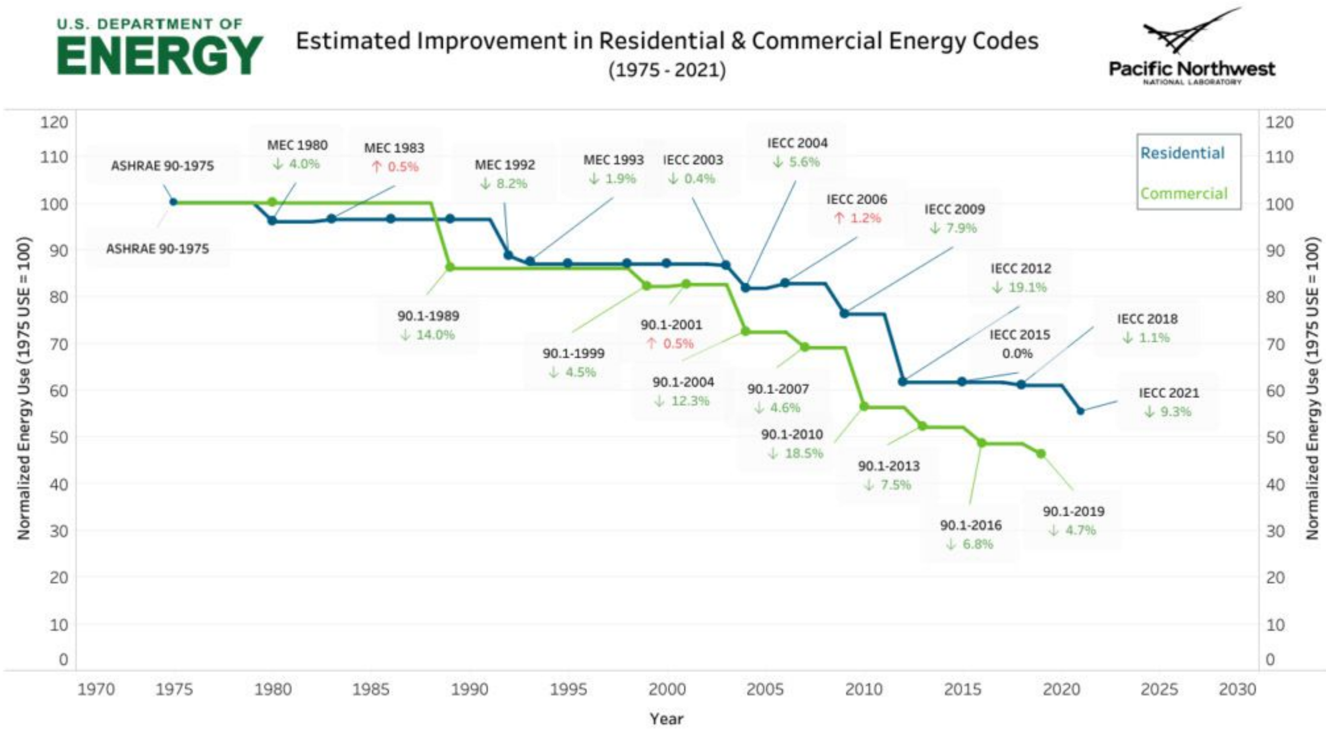

Figure 2: Estimated improvement in energy savings for specific model codes. Courtesy: U.S. Department of Energy

approach that includes credits for renewable energy sources and reduced carbon emissions.

4. Modeling at part-load

In addition to renewable energy and carbon emission calculations, ASHRAE has incorporated detailed data on modeling chiller performance at part-load. When modeling energy performance of air- and liquid-cooled chillers, the energy modeling professional requires several input parameters including chiller full-and part-load performance.

Some of these data are not available when the energy modeling process starts. This requires the use of predefined curves that are integrated into the simulation software.

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This results in inconsistent calculations from project to project for energy performance. To tackle this problem, a new Appendix J was added to the 2022 standard. This appendix includes fit curves developed by PNNL for different types and sizes of air- and liquid-cooled chillers. This approach creates a consistent methodology when modeling energy performance of air- and liquid-cooled chillers.

The following data comes from Normative Appendix J in ASHRAE 90.1-2022. It includes the values and the calculation methodology for the performance curves, including coefficients for cubic polynomial, quadratic and polynomial equations, applicable to the following chillers:

- Air-cooled.
- Liquid-cooled positive displacement.
- Liquid-cooled centrifugal.

Each set of performance curves includes:

- EIR-f-T: Energy-input-ratio modifier as a function of temperature.
- EIR-f-PLR: Function of a chiller’s part-load ratio (cubic polynomial equation).
- CAP-f-T: Capacity modifier as a function of temperatures.

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5. Building envelope

The envelope will undergo fewer modifications over the life of a building when compared to HVAC and lighting systems. Previous editions of Standard 90.1 allowed for energy consumption trade-offs between systems and the building envelope components.

These trade-offs now have a backstop, limiting the amount that can be used for the envelope. ASHRAE received comments from different jurisdictions that led up to this revision. The concern is building envelope will be in place for much longer, increasing long-term energy use.

The 2022 edition also has several new technical requirements for the envelope such as thermal bridging, insulated metal panels, wall solar reflectance and roof replacement. Other envelope categories have a direct positive effect on HVAC system energy use: air leakage requirements and envelope commissioning. Increasing the integrity and thermal performance of a building's envelope will reduce overall energy use and increase occupant comfort.

6. Mechanical efficiency tables and system definitions

The efficiency tables in Standard 90.1 list the minimum energy efficiency requirements of HVAC and other equipment types. The metrics apply to specific equipment types (e.g., water-cooled chillers, packaged air conditioning units, heat rejection equipment) and define how the metrics are used in determining compliance to the standard. As performance of HVAC equipment continues to improve and new design approaches are developed, the metrics and how they are used in the different compliance paths have evolved resulting in more precise results from the calculations.

ASHRAE 90.1-2022 continues this by departing from simpler, but less accurate, metrics. There are different reasons for this evolution. One is using metrics that more closely match the performance characteristics obtained from equipment testing. Another is using a more realistic frequency of outside air temperatures, generating performance results that are specific to the project's climate zone. To illustrate this, the energy efficiency ratio metric has evolved into integrated energy efficiency ratio, which includes part-load equipment performance.

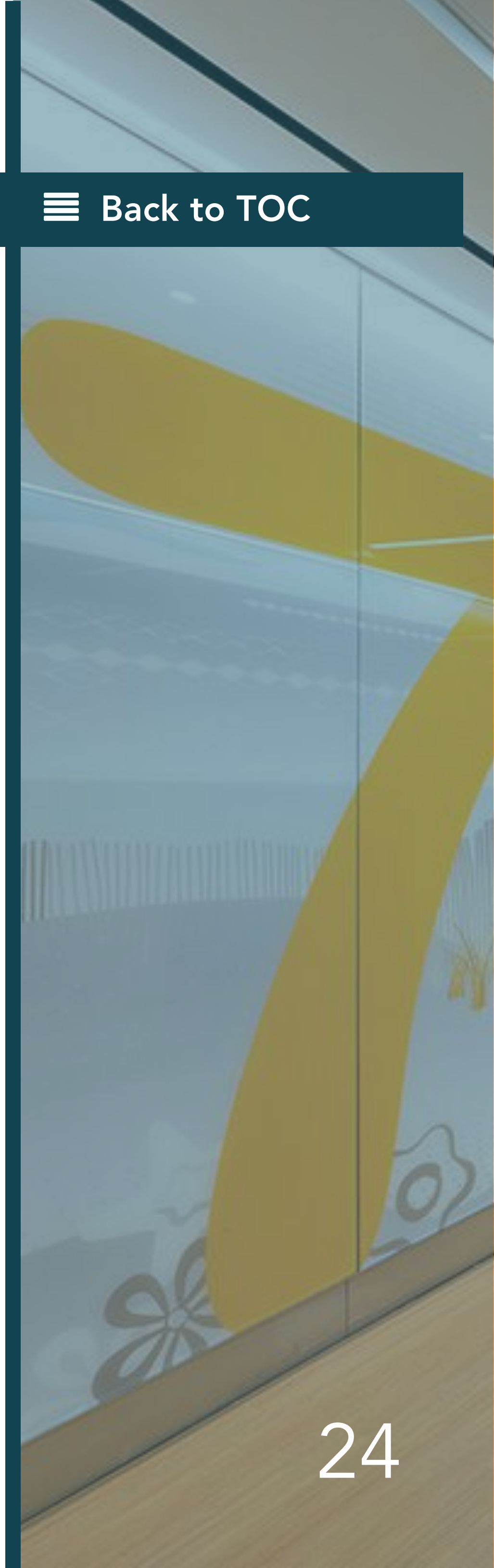
The 2022 edition also has several updates to the parameters and applicability of HVAC systems and controls such as demand control ventilation, setback controls, garage exhaust systems and controls, ceiling fan efficiencies, dehumidification control, energy recovery ventilation requirements, dedicated outside air system exemption and expanded airside economizers.

7. Energy credits

Energy credits are new to ASHRAE 90.1-2022, not appearing in any of the previous editions. In addition to meeting all base energy code requirements, energy credits are an additional prescriptive method for demonstrating compliance with an estimated 5% additional energy cost savings. Using energy credits provides flexibility for the building designer. The 2022 edition lists specific measures that correspond to the credits., including measures on energy efficiency, renewable energy and load management. PNNL published a report in 2022 analyzing the energy and cost savings from the energy credits that are in the new standard.

8. Lighting

In addition to the indoor agricultural grow lighting, other significant changes to lighting show up in ASHRAE 90.1-2022. The definition of exterior lighting now extends to



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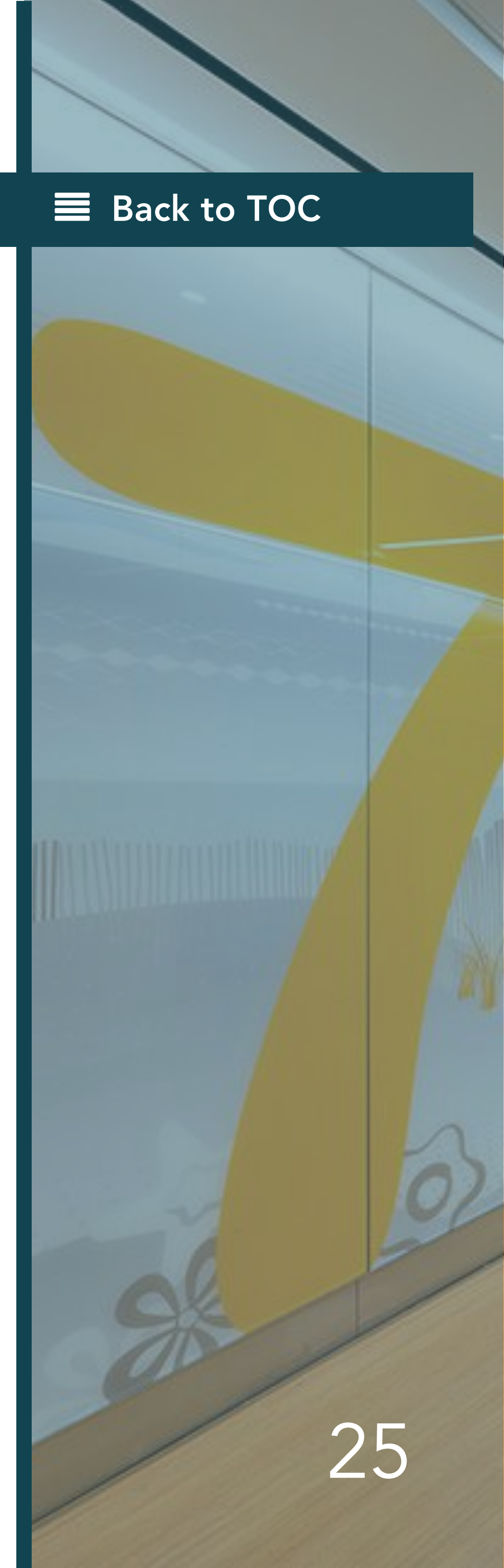

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the building site. This change makes a big difference in the energy consumption that is calculated for the building. In the previous editions of Standard 90.1, site lighting was defined as lighting fed from an electrical panel that is a part of the building. So, any parking lots, walkways and other exterior lighting would not be included unless it came from the building.

Also, maximum power metrics for exterior lighting were significantly reduced in ASHRAE 90.1-2022, taking into consideration the use of LEDs and improved design approaches. Finally, there are several revisions to lighting control, lighting power density, daylighting and the addition of energy credits specific to lighting.

9. Expanding use of renewable energy

ASHRAE 90.1-2022 has a minimum prescriptive requirement for on-site energy using technologies such as photovoltaic panels and wind turbines. As discussed for lighting, expanding the boundary of the project also benefits on-site renewable energy systems which can now be used as credits toward energy usage, as outlined in National Renewable Energy Lab's Operational Emissions Accounting for Commercial Buildings.

10. Commitment to reducing greenhouse gas (GHG) emissions

Energy efficiency for commercial buildings is the primary purpose of ASHRAE Standard 90.1. Energy use in buildings is the greatest source of GHG in the commercial building sector and ASHRAE is the tip of the spear in improving efficiency and curbing energy consumption.

To demonstrate this, the DOE estimates the 2022 edition will reduce energy costs 19% over the 2019 edition and 48% compared to the 2004 edition. ASHRAE established the

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ASHRAE Taskforce on Building Decarbonization that focuses on decarbonization in commercial buildings. This task force has set goals for achieving net zero GHG emissions for the building sector from 2030 to 2050.

The 2022 edition now includes a methodology for using site and source energy cost in addition to carbon emission factors. This gives local jurisdictions the ability to judge building energy performance using these new factors. For compliance purposes, this method is meant to be used voluntarily by local jurisdictions where using a carbon emissions metric is not in conflict with U.S. federal law.

How does ASHRAE 90.1 remain relevant?

Why has ASHRAE 90.1 been adopted so widely and rooted in other programs? The answer is subjective but the underlying facts provide validation:

ASHRAE's "Standards Strategic Plan" ASHRAE Strategic Plan 2019-2024 provides details on the development of new standards. The strategic plan includes the language to "… provide consistent and forward-looking guidance to the standards committee to ensure that the efforts of the society have the largest possible impact on our built environment while considering the time and effort associated with their development and maintenance."

The primary strategies from the plan are:

- Anticipate industry needs.
- Maintain leadership in standards.

- Collaborate with others.
- Promote adoption of ASHRAE standards.
- Promote international use of ASHRAE standards.

ASHRAE 90.1 has been written and updated over the decades by experts in the building energy efficiency field. Being on an ASHRAE Technical Committee requires an unbiased, technically motivated approach that does not favor certain products or services, steering clear of any potential conflict of interest.

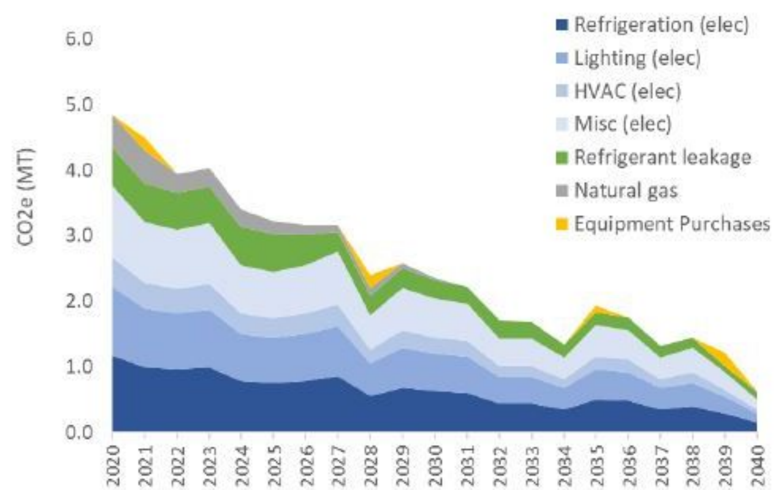
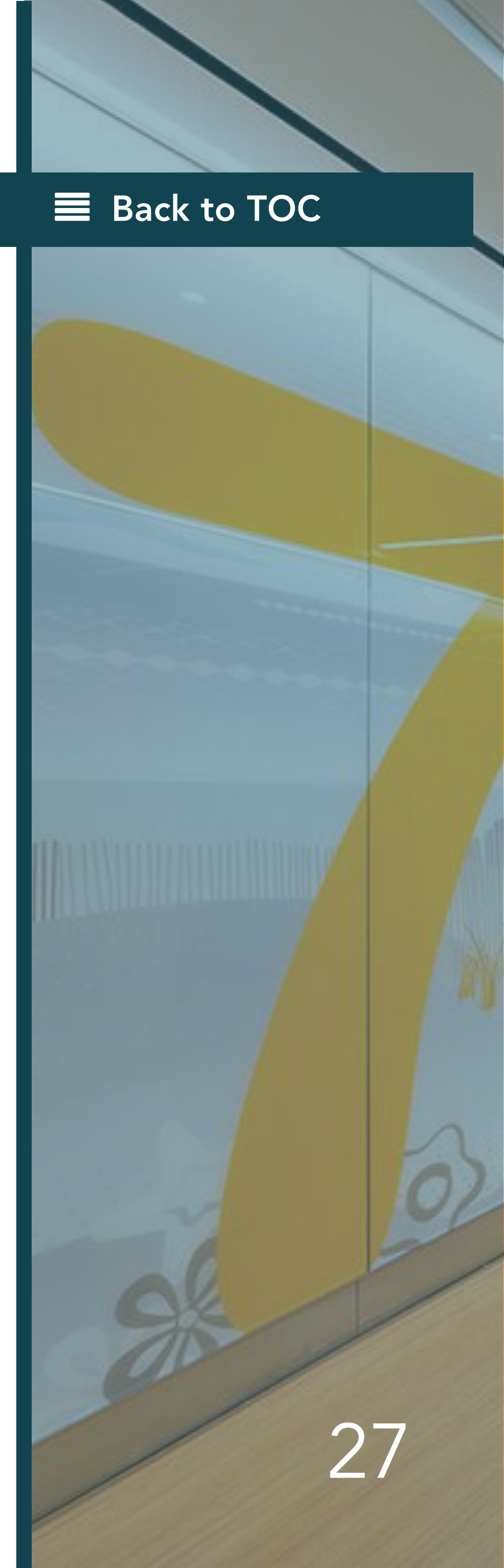


Figure 3: Example emissions reductions from energy efficiency measures, renewable energy purchases and a cleaner grid. Courtesy: National Renewable Energy Laboratory

ASHRAE's Technical Committees develop recommendations for several ASHRAE publications, including the Standard 90.1. Built into this development process is inviting the public to have a say in the documents — no affiliation to ASHRAE is required. This is important because anyone showing interest can download, free of charge, the proposed addenda and submit suggestions. All comments received during the review period are addressed. Ensuring a transparent process by inviting the public to participate reinforces ASHRAE's commit-



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ment, "to serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning, refrigeration."

A new edition of the standard is updated and published every three years, typically for content updates based on things such as new design concepts and equipment efficiency improvements. A synergistic relationship with forward thinking professionals (who are also committed to lowering energy and resource consumption in buildings), is an important part of ASHRAE's success. This is manifested by consistently debuting new energy efficiency criteria and compliance methodologies. These actions maintain the standard as the flagship of energy standards. According to the DOE, the last three editions (2013, 2016, 2019) have averaged 6% to 7% overall energy savings per edition. The 2022 edition will have energy savings of 14%.

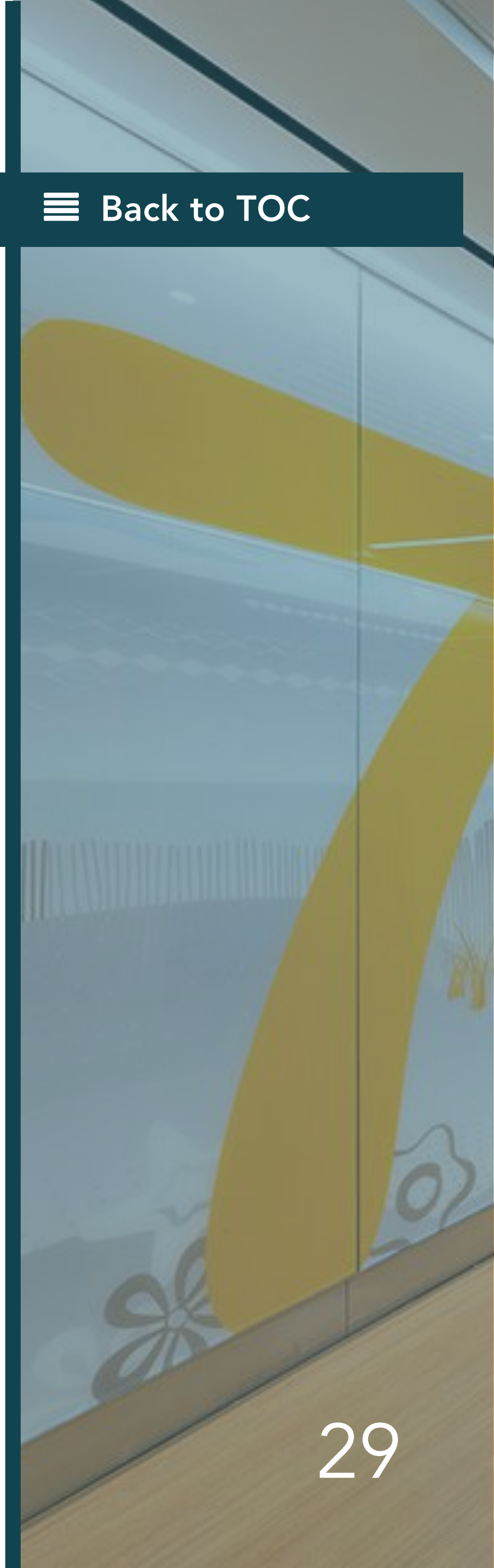
While the revisions are a representation of ASHRAE's ambitious goals to reduce energy consumption in commercial buildings, ASHRAE is making strides beyond building energy and including reduction of carbon emissions and the use of on-site renewable energy. Lowering carbon emissions by using renewables and energy efficiency strategies in commercial buildings is vital to meeting net zero goals.

Bill Kosik, PE, CEM, LEED AP, BEMP

Improving indoor air quality and energy efficiency in K-12 schools

Amidst concerns about indoor air quality and energy efficiency, K-12 schools are implementing HVAC upgrades and innovative solutions

Keith Hammelman, PE, Principal, CannonDesign, Chicago. Sean Holder, P.E., Principal, Salas O'Brien, Houston. Steven Mrak, PE, Vice President, Peter Basso Associates, Inc., Troy, MI. Johnny P. Wood, PE, LEED AP BD+C, CxA, CPD, Associate Vice President, Regional Market Segement Leader, Dewberry, Raleigh, NC.



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Describe a recent project in which you addressed indoor air quality issues to account for health concerns.

Steven Mrak: In the midst of COVID, we were approached by several public school districts that wanted help evaluating their existing building heating, ventilation and air conditioning (HVAC) systems, especially regarding air filtration and ASHRAE recommended minimum air changes. Our efforts consisted of field verification, review of existing airflow balance reports and ventilation calculations. Through our efforts, these districts were made aware of specific HVAC systems and rooms that did not meet current ASHRAE recommendations. They now have the ability to selectively target these spaces for improvements.

Johnny P. Wood: We recently have had the opportunity to help Durham Public Schools (DPS) in North Carolina replace the building automation system in several of their schools, along with a test and balance to make sure the proper amount of ventilation air is being provided throughout the building.

What unique heating or cooling systems have you specified into such projects? Describe a difficult climate in which you designed an HVAC system for a K-12 school building project.

Johnny P. Wood: We have had the privilege of including many different types of systems in our K-12 projects. Air cooled chillers, water cooled chillers, cooling towers, water source heat pumps, ground source heat pumps, hot water boilers, variable refrigerant flow (VRF) systems, built up air handling units and direct expansion cooling systems. Each of these systems have applicability to K-12 buildings, depending on the school systems they serve. In North Carolina, for instance, the climate is sometimes a

bit challenging for HVAC systems. High temperatures in summer, low temperatures in winter and high humidity require proper system design and equipment selection/application for the systems to function properly.

What types of unique building pressurization have you designed in K-12 schools? Describe the project.

Steven Mrak: Building pressurization control can vary from simple gravity relief hoods to more complex variable speed relief systems that can provide makeup air accommodations for kitchens, general restroom exhaust or process exhaust. As these needs come and go throughout the day, it becomes hard to define a "steady state" condition regarding building pressurization. To help accommodate these different scenarios, differential building pressure control can be used to vary the speed of relief fans. This uses atmospheric pressure and compares it to the pressure inside the building, controlling the speed of the relief fans to provide a consistent, usually slightly positive, differential pressure.

Johnny P. Wood: Science classrooms are designed to be negative in order to contain the air within the room. Kitchen and dining rooms are designed to be negative in order to contain food smells within the preparation and eating areas. The overall school building is designed to be positive pressurized to prevent infiltration. Building pressure is normally controlled by a differential pressure sensor inside the building. The pressure sensor is typically utilized to control the speed of a building exhaust or relief fan. What unusual or infrequently specified products or systems did you use to meet challenging heating or cooling needs? This might include active chilled beams, variable refrigerant flow, etc.

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Steven Mrak: Like most systems, VRF has its place and applications. While maybe not a solution for all situations, one instance where it brings value is with limited ceiling space. The relatively small refrigerant pipes can be routed in tighter spaces than an insulated supply duct carrying the same cooling capacity. The VRF system can also provide occupants with the level of individual control expected. Using the heat recovery type VRF systems (also referred to as a three-pipe system) can increase the overall system energy efficiency by recycling waste heat/cool around the system.

How have you worked with HVAC system or equipment design to increase a building's energy efficiency?

Keith Hammelman: HVAC systems are just one of many systems in a building that use energy within a building, but they seem to be the primary focus on how we look to reduce energy use without first looking at other passive energy users first. Even before we start looking at the type of HVAC system to install within a K-12, building we are working with the architectural team to understand building massing orientation and envelope first by conducting early modeling exercises. Once this is complete, we move on to other energy users within the building such as lighting or process loads to work with those designers on how to reduce the heat produced by these processes. From there we then also focus on the ways to reduce energy consumption and introduce energy recovery methods into the design of HVAC systems. We are pushing this system selection into the earliest stages of the design process and making sure that we are bringing the owner into these discussions.

Sean Holder: Through a balanced approach between first costs, maintenance costs and energy efficiency, we have implemented more energy recovery equipment, higher efficiency equipment and innovative HVAC system control sequences to increase a building's energy efficiency.

Steven Mrak: Implementing energy recovery devices in HVAC units has become more common practice. Beyond energy code requirements, energy recovery devices like enthalpy wheels, energy cores and plate heat exchangers are being used on smaller and smaller systems, trying to capture as much energy as possible, even down to the individual classroom unit level. While the energy savings at each unit may not be substantial, when multiplied by 30 or 40 classrooms, the savings can become real.

Johnny P. Wood: Spaces that are used off hours should be provided with independent systems and not share systems with the larger building. We make an effort to locate air handling units toward the center of the area service. This allows the ductwork sizes to be smaller, resulting in smaller fan horsepower and fan energy use.

What best practices should be followed to ensure an efficient HVAC system is designed for this kind of building?

Keith Hammelman: In order to ensure that an efficient HVAC system is designed for K-12 buildings, we start first looking at establishing an overall energy usage index for the project that will be used as a guiding factor in the design of our building systems, which includes the HVAC system. We also look at the relevant energy code and determine what is the minimum prescriptive approach HVAC systems that are stated within the energy code. From this we will use basic energy modeling to evaluate the systems as a whole, in combination with building orientation, envelope and lighting systems.

We also begin conceptual cost estimating of systems to determine how the different systems fit within the building cost models. Included in this process we work with the design team to understand the impacts to program space and square footage of the building. The impact to square footage is also included in the conceptual cost models to have a

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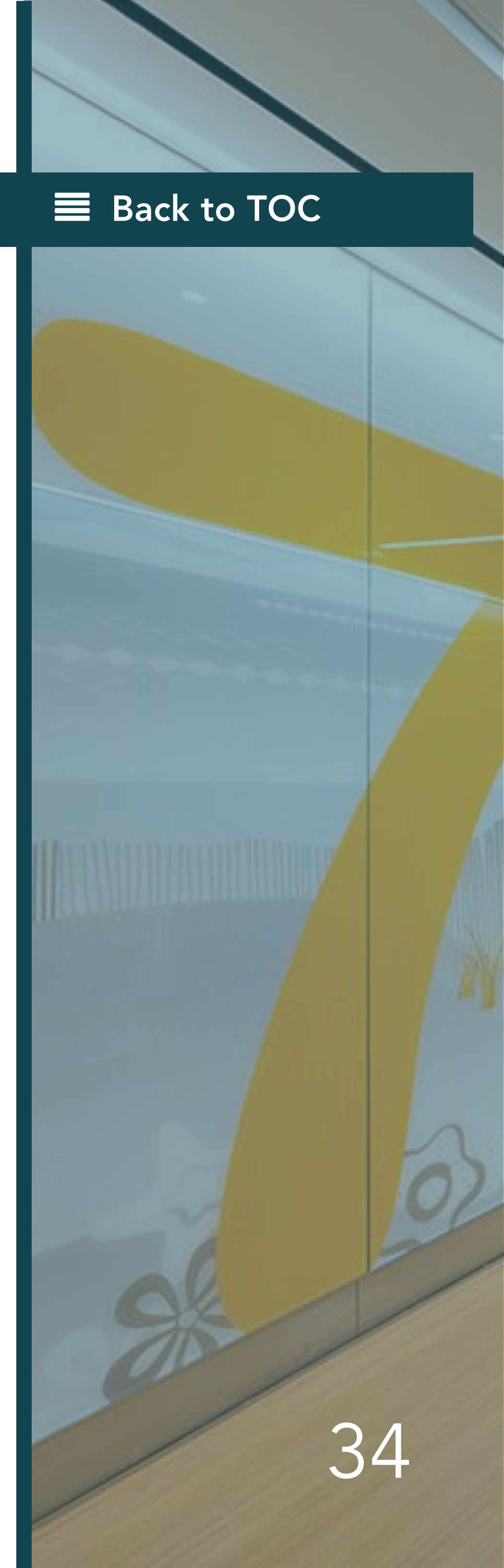

full picture of what each option would cost. Once we know the total picture of the systems, we can then make an informed decision with the district on the HVAC system.

Sean Holder: One best practice is to ensure that the school district is able to support an energy efficient system design. While many systems are highly efficient at initial installation, without continual maintenance the systems performance is degraded.

What are some of the challenges or issues when designing for water use in such facilities?

Keith Hammelman: A challenge we see in K-12 Facilities is providing for water efficiency, minimizing environmental impact and minimizing maintenance and operations while still meeting the needs of students and staff. An example of this is the design for the use of showers in a gymnasium locker room. The number of showers is often provided to meet a maximum load of occupants, community use during a disaster or other criteria that will rarely be achieved. The challenge we often see identifying how large of a water heating system is required, and we work with client to further understand the needs of the day-to-day occupant and the frequency of rare use cases to come up with a balance that utilizes resources effectively.

Johnny P. Wood: A frequent challenge is when water flush volume is reduced, flushing becomes difficult. This should be discussed with the owner before specifying these types of fixtures. On-site water reuse systems require the addition of more equipment and additional maintenance. Simple rainwater collection for irrigation has proven to be cost effective for our K-12 projects.

How to utilize suites under NFPA 101 requirements

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Suites are a great design option that allow for operational flexibility in health care facilities, while still meeting NFPA 101 requirements

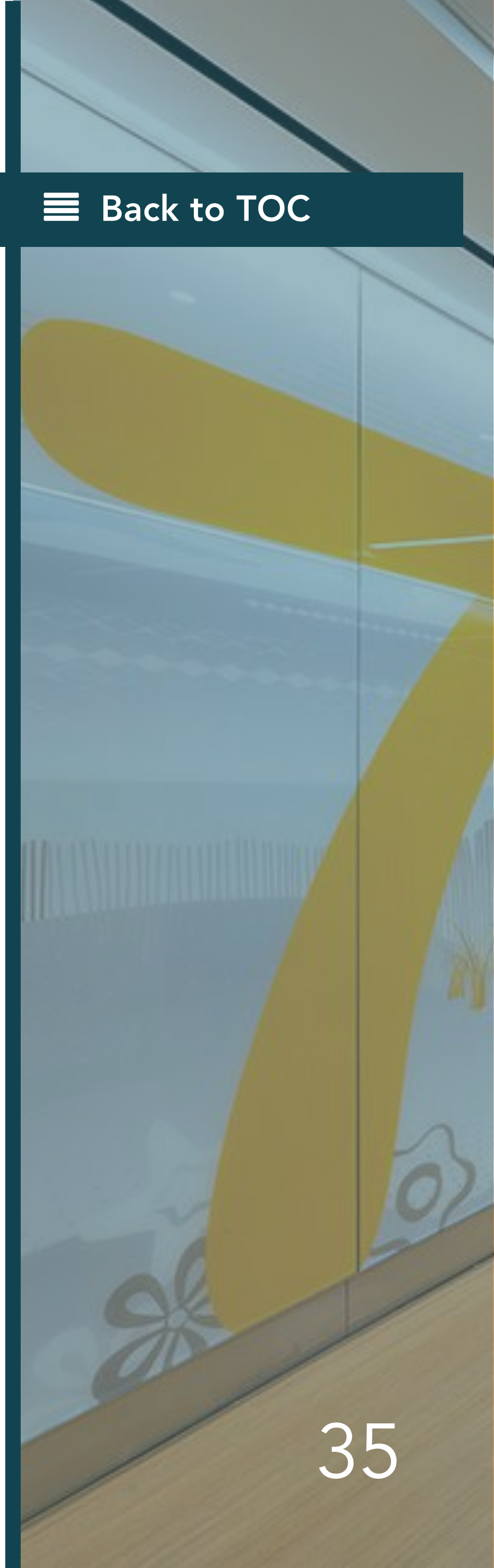
For health care facilities complying with the conditions of participation for Centers for Medicaid & Medicare Services (CMS), the 2012 edition of NFPA 101: Life Safety Code is required to address life safety requirements within a facility. NFPA 101 provides a flexible design and an operational option for a collection of rooms, called suites.

While this option is also described in the International Building Code, this article will be focused only on NFPA 101 requirements. The use of suites is unique to health care occupancies and is often a term that is used generally and misunderstood.

What is a suite?

In general, a suite is a collection of rooms that are grouped together or adjacent to each other. NFPA 101 Section 3.3.272.5 defines a patient care suite as, “a series of rooms or spaces, or a subdivided room separated from the remainder of the building by walls and doors.” While this definition has been tweaked in newer editions of NFPA 101, it remains somewhat general to allow flexibility in its use.

By grouping rooms together in a suite, the code permits certain exemptions from other requirements typical to a health care occupancy that may otherwise negatively impact patient care procedures, increase cost or result in additional inspection, testing and maintenance impacts for certain features of the facility.



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NFPA 101 defines three different types of suites — patient care sleeping suites, patient care nonsleeping suites and nonpatient care suites:

Figure 1: Suites within a hospital facility are used to comply with NFPA 101 requirements while keeping patient comfort and care as a top priority. Courtesy: Jacia Phillips, Henderson Engineers

- **Patient care sleeping suites:** Thes will contain "one or more sleeping beds intended for overnight sleeping" as defined by NFPA 101. An example in a hospital may include an intensive care unit (ICU).

- **Patient care nonsleeping suites:** These are used for treating patients, but are not intended for overnight sleeping, according to NFPA 101. Examples in a hospital may include a radiology department, an outpatient clinic within a hospital or, potentially, an emergency department.

- **Nonpatient care suites:** These are for suites that do not treat patients. Examples in a hospital may include administration departments, staff locker rooms or the facilities department.

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Each suite type has specific requirements because of the different occupants located within each suite.

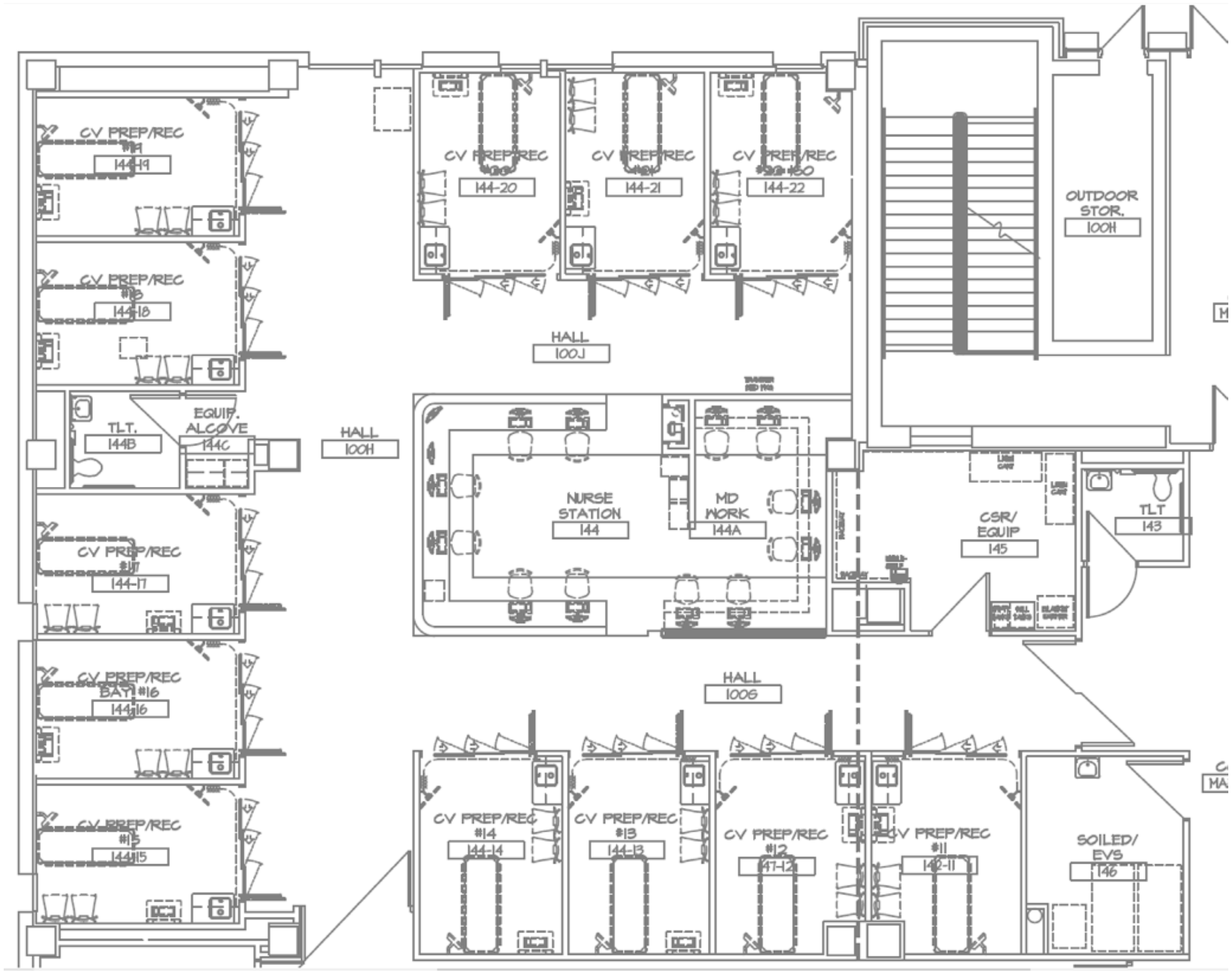
Why utilize suites?

Habitable rooms: NFPA 101 Section 18.2.5.6.1 requires, "every habitable room to have an exit access door leading to an exit access corridor." This is because most occupants in a health care facility are incapable of self-preservation and require a defend-in-place evacuation strategy. Staff is required to support evacuation, either horizontally or vertically in the facility.

Corridors, which lead to exits, become a very critical component of egress, and this requirement for discharge limits how certain departments/units in hospitals can be designed. One way to get around this requirement is by utilizing suites. Suites permit occupants to exit through several rooms to get to a point where an exit access door is required, meaning that not every habitable room within the suite is required to have direct access to a corridor. This allows designers and staff more flexibility to support patient care while still maintaining a safe environment.

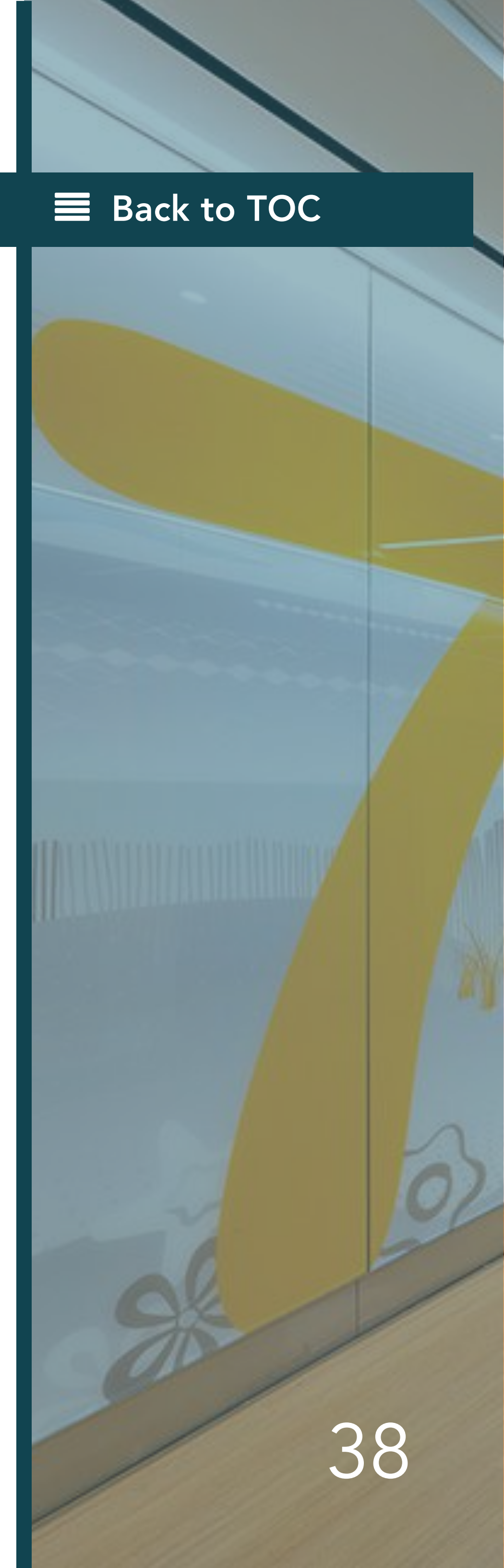
Corridors: An important feature of suites is that corridors are not required within suites. In new health care facilities, corridors are required to be a minimum of 8 feet wide with limited allowances for fixed furniture, wheeled equipment or projections.

In a suite, these circulation spaces (often called halls or something similar) indicate to the authority having jurisdiction that corridors are not part of the suite and that those requirements do not need to be met. This allows these circulation spaces to be reduced to a width that is needed for evacuation, to functionally support the space or is



at least 36 inches. This also allows for some amount of equipment to be located within the space so long as there is a plan to promptly remove or re-locate during an evacuation event), which is not allowed in a corridor.

Figure 2: This diagram shows a suite of rooms grouped together, in this case for a specific modality of treatment. Courtesy: Henderson Engineers



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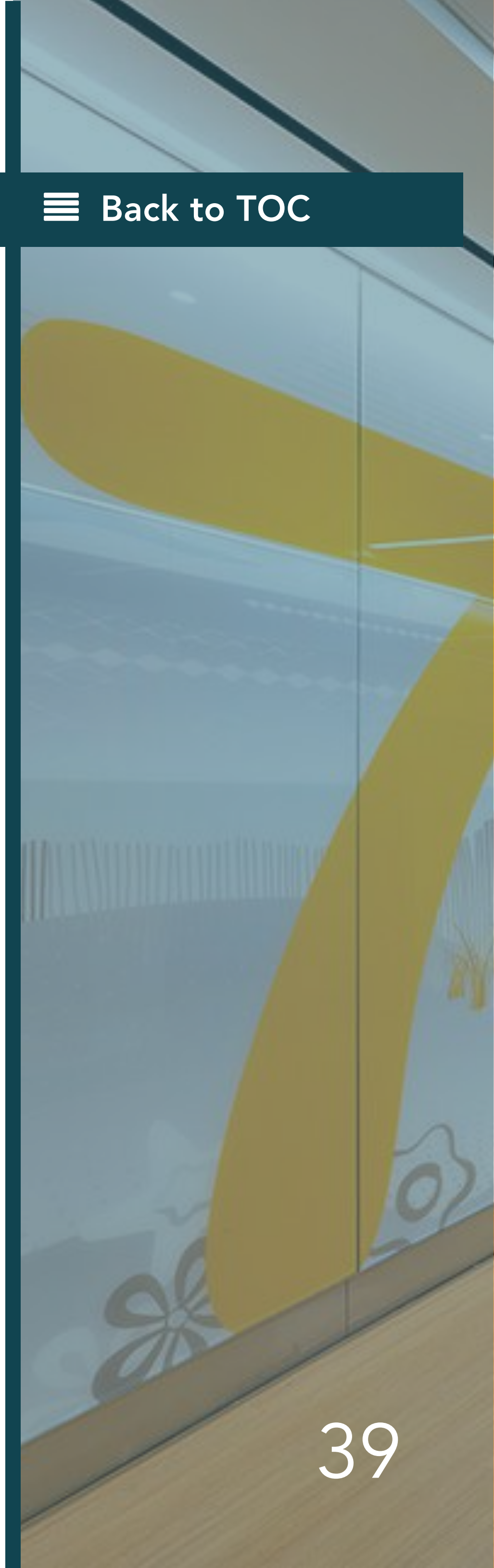

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Every corridor also requires access to two approved exits, without passing through any intervening rooms or spaces other than corridors or lobbies per NFPA 101. Suites will allow intervening rooms to be utilized before entering a corridor.

Operationally, the removal of corridors and their associated requirements are a positive for facilities staff. In a corridor, walls must be sealed to limit the transfer of smoke under NFPA 101.

Additionally, corridor doors are required to:

- Resist the passage of smoke.
- Maintain an undercut of 1 inch or less.
- Maintain positive latching.

For rooms located around a circulating space in a suite, there are no corridor walls or doors, which allows for doors that meet the functional requirements of the space (e.g., pressurized spaces) without requiring the additional inspection, testing and maintenance listed above. Walls may contain gaps for equipment or other items required for patient care or treatment.

For example, it is common to see ICU patient rooms utilizing horizontal sliding doors in lieu of traditional swinging doors. These types of doors can be provided with a latching function, but run into challenges operationally due to the need to move beds in and out of these spaces often. By utilizing suites, these doors are allowed to only meet the

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requirements needed for functionality or for other code requirements (pressurization, etc.).

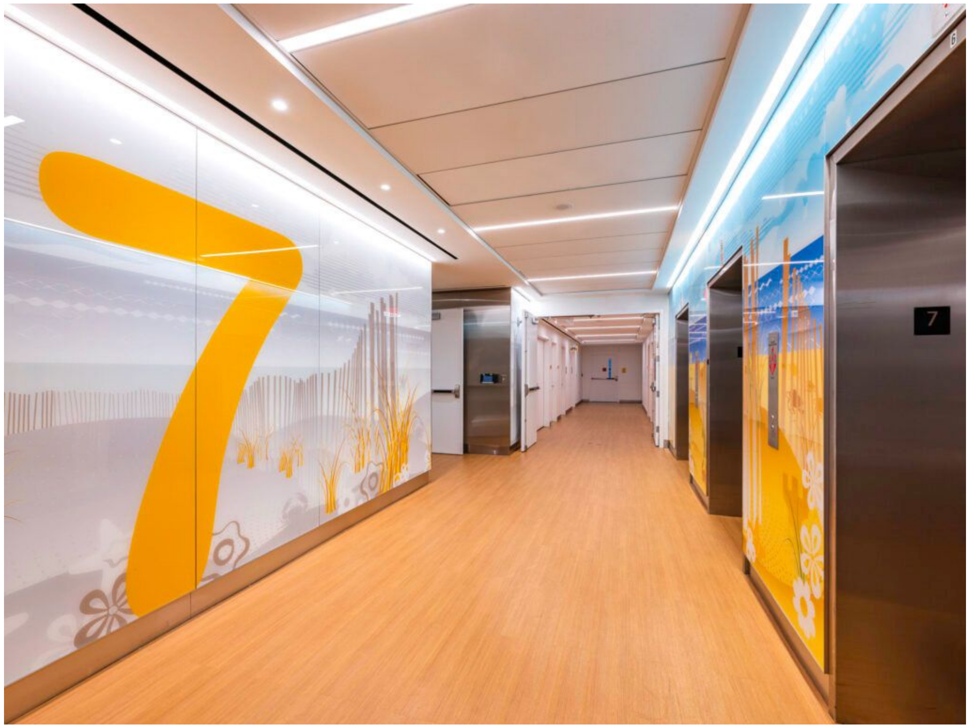

Figure 3: Every corridor requires access to two approved exits, without passing through any intervening rooms or spaces other than corridors or lobbies, per NFPA 101. Courtesy: Geoffrey Lyon, Henderson Engineers

Flexibility: Rooms in a suite do not require separation from the circulating space (unless for other code reasons, such as a hazardous room). If these rooms were outside a suite, they would need to be located directly off a corridor, which has a requirement for physical separation with a wall and door.

An example may include an opening area with treatment bays that would require walls and doors (physical separation) for each bay if located directly on a corridor. There are some exceptions for nurse stations or waiting spaces that are allowed in a corridor, but the flexibility of a suite will allow many other spaces to also be open within the suite.

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Specific suite requirements

Separation: NFPA 101 requires that all suites are separated from other portions of the building by walls and doors meeting the requirements for corridor separation. Internal walls within the suite are required to be noncombustible, limited-combustible or partitions constructed with fire-retardant treated wood enclosed with noncombustible or limited-combustible materials. They shall not be required to be fire rated unless required by other portions of the code (e.g., hazardous area).

Patient care sleeping suites: This suite type allows for patients that will be sleeping overnight; therefore, requirements are enhanced to address additional defend-in-place and/or evacuation time required.

Criteria includes the following:

- Constant staff supervision is required.
- Direct supervision is required from a "normally attended location within the suite" for the patient sleeping rooms. Any patient sleeping rooms without direct supervision requires smoke detection.
- Maximum size of 7,500 square feet or 10,000 square feet where both direct visual supervision and total smoke detection is provided.
- Sleeping suites exceeding 1,000 square feet require two remotely located exit access doors. One exit access door shall be direct to a corrido. The other can be into an adjacent suite, an exit stairway, exit passageway or an exterior door.

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- Exit travel distance from any point of the sleeping suite to an exit access door is limited to 100 feet. However, the number of intervening rooms within the suite is not limited.

Patient care nonsleeping suites: Patients treated in this suite type do not sleep overnight, which means requirements differ somewhat from patient care sleeping suites. Some considerations include the following:

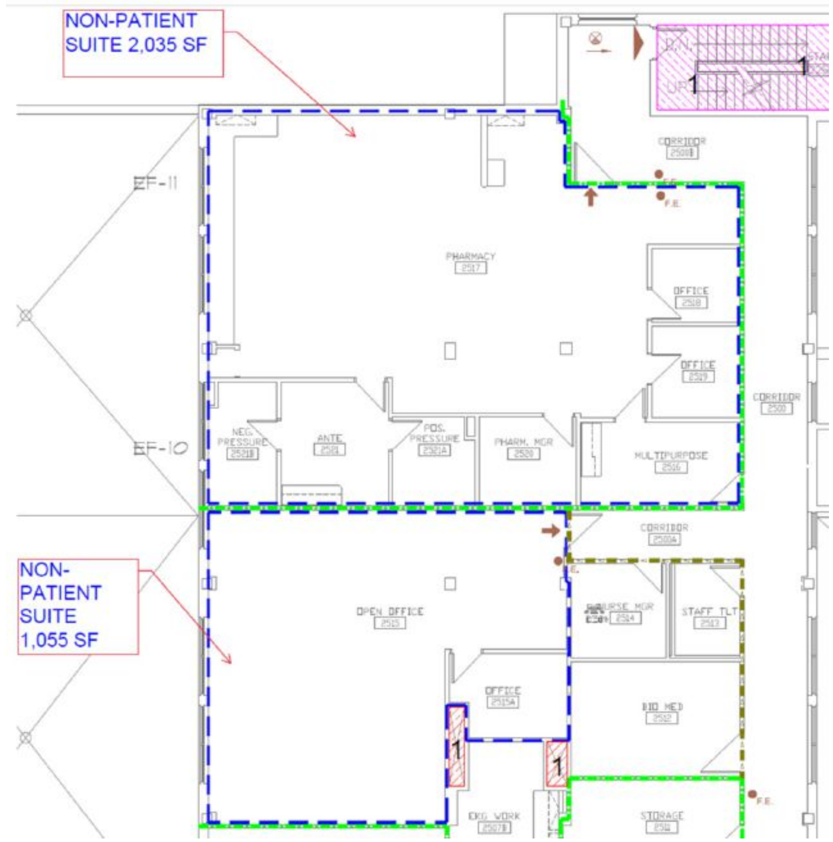
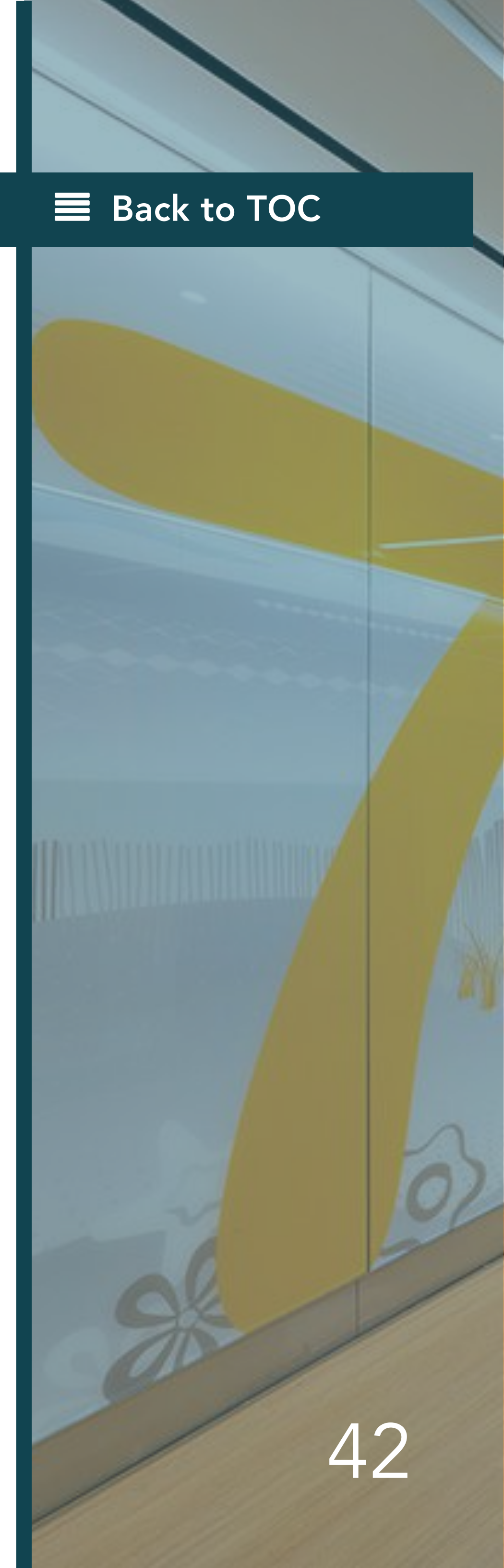


Figure 4: Nonpatient care suites have specific requirements outlined in NFPA 101. Courtesy: Henderson Engineers

- Maximum size of 10,000 square feet. Newer editions of NFPA 101 have modified this requirement to allow up to 12,500 square feet or 15,000 square feet. However, this is not currently allowed by CMS.

- Nonsleeping suites exceeding 2,500 square feet require two remotely located exit access doors. One exit access door shall be direct to a corridor. The other can be into an adjacent suite, an exit stairway, exit passageway or an exterior door.



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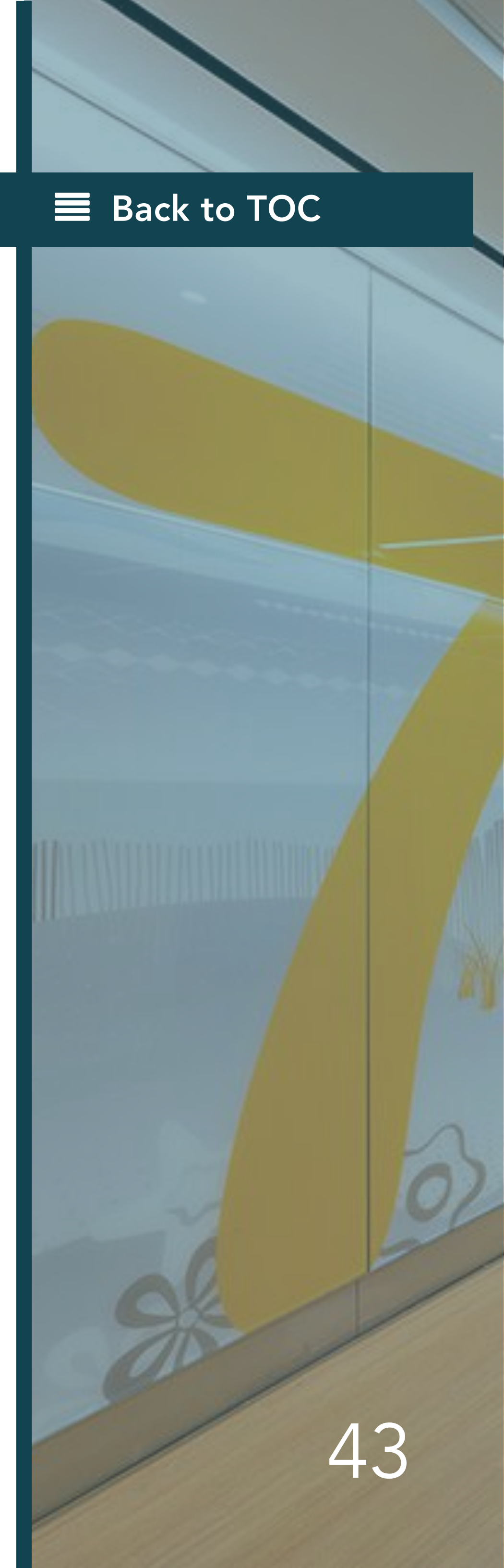
- Exit travel distance from any point of the nonsleeping suite to an exit access door is limited to 100 feet. However, the number of intervening rooms within the suite is not limited.

Nonpatient care suite: This suite type does not contain patient treatment or sleeping uses. NFPA 101 requires that the egress provisions for this suite type follow the primary use and occupancy contained within. For example, Figure 4 shows a pharmacy suite and an office suite (staff only, no patients) that are permitted to follow business occupancy requirements for egress.

Mark Chrisman

***Mark Chrisman** is the health sector executive at Henderson Engineers. A 20-year industry veteran, Chrisman oversees strategy for the company's health care projects nationwide.*



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