Energy Management Planning for Healthcare Facilities

Optimizing building performance and energy savings

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The Cx Associates' team of energy consulting experts understands the special operational needs and requirements of today's healthcare facilities. Find out more about how we put our deep experience in energy, sustainability, and facility performance to work for you.

"Cx Associates design review is grounded in reality. Design documents express the intent of the engineer and may not capture the long-term objectives of the owner in terms of sustainability, maintenance, manageable operating costs and energy efficiency. Cx Associates points out the alternatives to help ensure we get what we need when the project is built."

David Keelty

Director, Facilities Planning and Development
University of Vermont Medical Center

With constrained operating budgets, complicated building systems, and high energy demands – healthcare facilities require energy management. For a hospital averaging a 5% margin, every $1,000 in energy savings has the same bottom line impact as a $20,000 increase in revenue. All too often, the facilities staff does not have the time or resources to identify and develop energy efficiency opportunities that will improve building system functionality and save operating costs. With many years of hands-on building commissioning work and energy efficiency program evaluations, Cx Associates has the expertise to help you reduce operating costs by identifying, planning, and verifying energy efficiency upgrades.

This quick guide will introduce energy benchmarking, efficiency, and special considerations for hospitals and healthcare facilities.

ABOUT US

We specialize in building commissioning; retro-commissioning; building system efficiency upgrades; and energy program design, verification, and evaluation.

Our experience gives us unmatched insight into the design, construction, and verification of building systems that meets Owners' needs and expectations while optimizing energy performance. Cx Associates' level of rigor and our detailed methods for verifying new construction are unparalleled in the Northeast. We find energy use reductions and cost savings where others don't – we are serious about efficiency. *Ensuring building performance is our mission.*

Cx Associates' Principals, Jennifer Chiodo, P.E., LEED AP BD+C; and Matt Napolitan, P.E., CCP, CPMP, LEED AP BD+C have over 45 years combined experience in the design, construction, commissioning, and operation of high-performance buildings. Cx Associates specializes in commissioning, LEED certification, energy analysis, and carbon management. Our business is focused on helping our clients lower operating costs, improve productivity and reduce the environmental impacts of their operations.

- CHAPTER 1 -

Benchmarking is Good for Everyone

The only way we can know how good (or bad) our buildings are is to benchmark them.

In the fall of 2012, benchmarking was on Jennifer Chiodo's mind. She had been reviewing the project submissions for the Vermont's Greenest Buildings Awards and was quite impressed by what some teams were achieving in designing and operating energy efficient buildings that use far less than "typical" buildings. Consider, the only way we can know how good (or bad) our buildings are, is to benchmark them. Benchmarking is a process where we calculate the annual energy intensity (kbtu/sf/yr) – adjusted to reflect weather variations from "normal" which is known as "normalizing" the data for weather. This number is like the building's miles per gallon and can be used to find out whether the building is an energy sipping hybrid, a typical mid-sized sedan or a guzzling SUV.

Before sharing a little about the projects submitted for the awards, starting with residential, Jennifer shares the results of her own home benchmarking exercise.

Residential Benchmarking

On the positive side, Jen's home is designed to be passive solar, has 6" studs and when she replaced the boiler a few years ago, she installed an energy efficient low mass oil boiler with indirect fired hot water. And, the house is reasonably well controlled with four separate heating thermostats. Seems like it shouldn't be too bad, right?

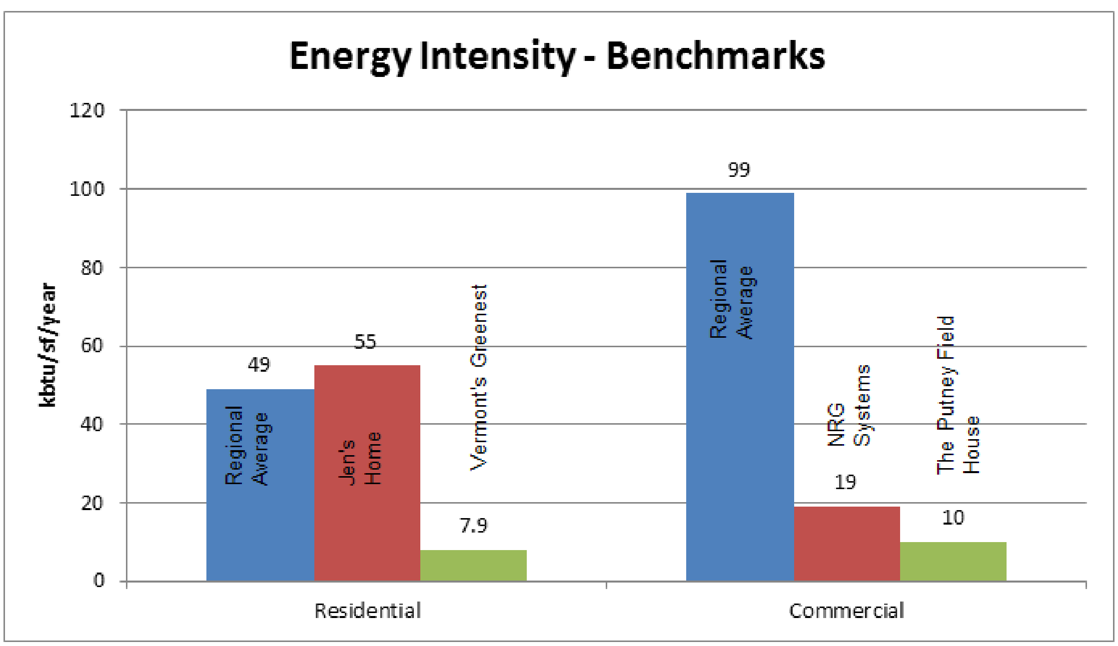
The negative side is – the house has a deteriorating shell and failed windows resulting in drafts and radiant discomfort in the winter driving the heating set-point higher in occupied areas, a damp basement with air quality issues, R-19 fiberglass insulation in the attic and an uninsulated foundation. How bad are the energy impacts of these known failings?

The home energy consumption includes oil and wood for heating, propane for cooking, and electricity for everything else. A rough calculation found that the home's normalized EUI is 55 kbtu/sf/year. While she does not have dryer and uses efficient lighting and appliances – the home uses more than the regional average for homes which is 49 kbtu/sf/year.

In contrast, The Charlotte House, designed by David Pill and winner of a Vermont's Greenest Building Award has an energy intensity of less than 8 kbtu/sf/year! When the solar and wind energy from the site is factored in, the home is a net energy generator (it makes more energy than it uses). Looks like Jen may have some work to do. And while she knew it before, doing the math makes the problem glaringly apparent.

Commercial Benchmarks

There is far greater variety in commercial building types and two buildings with very different occupancies had extremely low energy intensity. NRG Systems of Hinesburg, Vermont submitted both the original building and addition with an energy intensity of about 19 kbtu/sf. This is truly remarkable for a state of the art facility that houses offices with significant data processing requirements, light manufacturing, a warehouse, and a variety of employee amenities. The commercial building recipient of the Vermont's Greenest Building Award is the Putney School Field House which uses only 10 kbtu/sf/year and also produces more energy on site than it consumes making it another net energy generator. The occupancy is likely lower, as are the need for computers and other systems essential to a facility like NRG Systems. These remarkably successful projects have key team members in common – William Maclay Architects and Energy Balance working on the approach to efficiency.



These projects demonstrate what can be achieved and give us a goal to which we must aspire. They provide the needed amenities, allowing people to work and live comfortably, and do so while actually providing a net benefit to the planet. If we all start benchmarking our homes and businesses, we will learn where we fall on the scale and we can begin our energy diet by finding and implementing energy efficiency measures. This will help us bring our energy intensity down to the point, where like the awardees, we may be able to use renewable sources to generate more energy than we consume on our building sites.

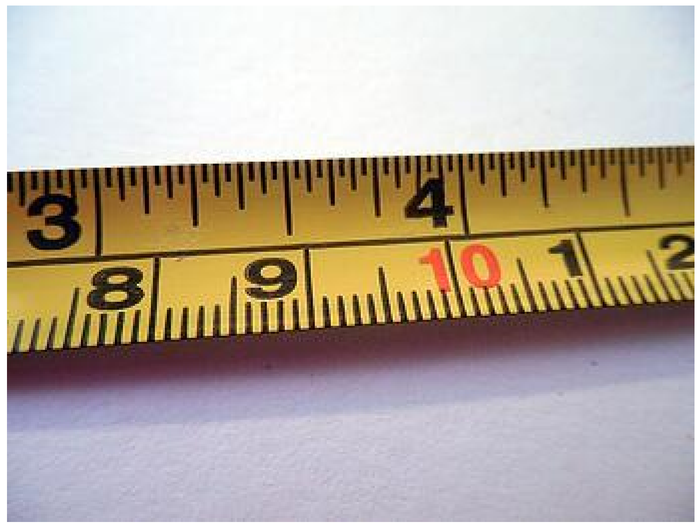
- CHAPTER 2 -

Energy Benchmarking for a Healthcare Network

Using the Energy Star Portfolio Manager online benchmarking tool, you can monitor a building's energy usage and compare to a baseline year.

In the previous chapter, we discussed why energy benchmarking is beneficial for everyone, whether it's for a residential building or a commercial building. Benchmarking allows you as the building owner to understand how your building is doing from an energy standpoint over time, while also comparing the building to other similar buildings in its class. Using the Energy Star Portfolio Manager online benchmarking tool, you can monitor a building's energy usage over time by setting goals and comparing the overall energy use intensity to a baseline year.

How does your building measure up?



Katie Mason had the opportunity for two years to benchmark the energy usage, both electric and fossil fuels, for a healthcare network, including their larger campuses as well as smaller practices. The initial step for this work was setting up the Portfolio Manager account for each property. This included filling in accurate building information (square footage, number of full-time employees, number of MRI machines, etc.) and setting up each utility meter. Once that initial step was completed, Katie regularly maintained the accounts by updating utility data and tracking the energy use intensity and the associated Energy Star score (if applicable for the building type).

Next Steps and Opportunities

In addition to the regular utility updates, a big part of this work included monitoring how the accounts were changing each time an update was completed. This is important for both buildings where the facility is actively installing measures that are designed to reduce energy usage, as well as buildings where nothing is being done from an energy standpoint.

It either allows the facility manager to see how these measures are affecting the overall building energy usage, or see if a building is increasing or decreasing in performance if no measures are being applied. For buildings where the performance is declining over a longer period of time, we suggest an energy audit service. This will consist of a walk-through to identify opportunities to reduce the building energy usage and overall operating costs. The resulting report will provide an overview of current operations and a high level cost-benefit analysis of recommended measures, similar to an ASHRAE Level 1 Audit.

It's important to note that Portfolio Manager utilizes a database of buildings that is updated over time. As energy reduction measures are becoming more common, the overall average energy use of buildings is dropping. This means that a building's energy use intensity may stay the same, but the Energy Star score could drop based on how other buildings in the database are performing.

Beyond Energy Benchmarking for a Healthcare Network

Overseeing the Portfolio Manager accounts for this healthcare network also provided Katie with the opportunity to work with the facility on the Practice Greenhealth awards. These awards "recognize healthcare institutions that have made a commitment to sustainable, eco-friendly practices." Katie assisted with the energy, water and climate categories, in which the applications are designed to utilize a large amount of information that can come directly from Portfolio Manager. She had the opportunity to see how all of the data came together and allowed this healthcare network to be recognized for its attention to detail on energy use.

Are you curious about how your building measures up to others like it? Get in touch with us for information about auditing and benchmarking your facility.

- CHAPTER 3 -

ASHE Construction in Healthcare Workshop

Having a team that understands codes and standards and how they are applied to your project is crucial.

In 2016, the Health Care Construction (HCC) Certificate workshop in Seattle, Washington event was organized by ASHE (American Society for Healthcare Engineering) and WSSHE (Washington State Society for Healthcare Engineering), and was directed towards contractors, facility managers and construction project managers in healthcare. ASHE offers many certifications, workshops and education opportunities for different audiences in healthcare.

This chapter highlights a few points from the workshop we found particularly important (there were many!).

ASHE Health Care Construction (HCC) Certificate Workshop

It is a great reminder to review all the different areas we must consider when doing a construction project in a healthcare setting. Each project is unique in different ways. The areas unique to healthcare include infection prevention, fire and life safety, specific mechanical/electrical/plumbing system requirements, medical gas systems, risk assessment and healthcare technology. The course utilized case studies and an interactive approach to encourage participants to think about possible issues that can arise throughout a project. With a large variety of contractors, facility managers and people who work directly for a hospital in the room, we found it intriguing and educational to hear everyone's approach for predicting and solving issues.

The Importance of Contractor Training

One huge take away from this workshop is the importance of a thorough contractor training process. This will allow anyone working on a healthcare project to understand how and why things are done a certain way. Without that knowledge, it's difficult to agree and comply with the additional steps that must be taken to ensure patient safety. Another aspect of this is working with the healthcare's Infection Prevention and Health and Safety group. These departments should be an active resource throughout the construction process.

Codes, Standards, and Accreditation

Having a team that understands codes and standards and how they are applied to your project is crucial. Fire and life safety building codes have very rigorous requirements particular to healthcare that exist for a reason. Codes are also constantly evolving; therefore, your design and construction team should be aware of which codes apply and what that means for how the facility is constructed. Additionally, all heathcare facilities require accreditation, which requires on-site surveys by people who understand the codes and standards.

Healthcare Technology

A section of the course was dedicated to healthcare technology. Like every industry, healthcare has become more reliant on technology (wireless systems for equipment, network connections, etc.). The requirements specific to healthcare (electrical, mechanical, coordination with other trades, spacing requirements, etc.) must be considered during the planning and construction process.

Although some of the approaches and precautions required for a healthcare construction project can seem daunting, the important thing is to remember why this approach is necessary. The entire team should have the same priority for ensuring a successful project – the safety of the hospital patients. It is crucial to emphasize how important it is for the team to work together. Each member has something different and important to contribute.

- CHAPTER 4 -

Controlling Operating Room Temperature and Humidity, and Managing Expectations

Facility managers and designers need to consider options for providing < 60 percent RH for OR users that prefer space temperatures < 68°.

Proper ventilation, airflow, temperature, and humidity are needed for successful surgical operations. The design requirements for these parameters in healthcare settings are defined by ASHRAE Standard 170, and are generally straightforward. However, OR (operating room) users often try to operate OR HVAC (heating, ventilating, and air conditioning) systems at temperatures and humidity levels outside of the standard design range. A better understanding of OR HVAC parameters would help OR designers and users achieve more effective OR functionality.

ORs must be designed to provide a space relative humidity (RH) of 20 to 60 percent, and a space temperature of 68 to 75°F. However, many surgeons prefer a space temperature below 68°F, typically as low as 64 degrees. Given the ventilation requirements, OR HVAC systems typically have enough airflow to cool OR spaces below 68°F. What they often lack, however, is the dehumidification capability to achieve a 64 degree room while maintaining less than 60% RH.

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The relationship between temperature and humidity

Unfortunately, many users and operators of OR spaces are unaware of the fact that as space temperature decreases, space RH increases. For example, a 68°F space with 60 percent RH, if cooled to 64°F, would then have a space RH of 68 percent (see Figure 1). High humidity levels (above the allowable design range) can be alarming for OR users and operators. It should be known that per ASHRAE Standard 170 the design RH for ORs is applicable only within the design range of space temperatures (see design range outlined in Figure 1).

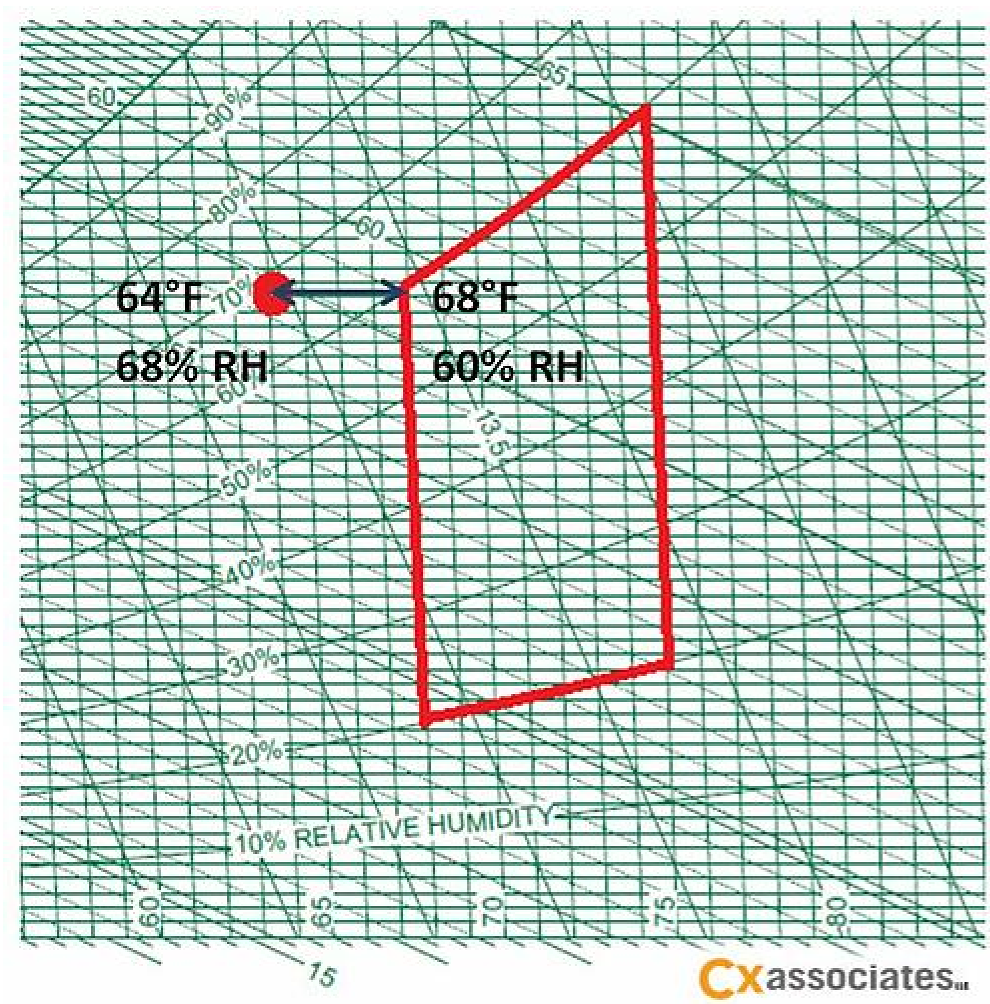


Figure 1

Healthcare facility managers are tasked with providing OR users with the required and desired space conditions. When facility managers face complaints of high RH readings at low temperatures in ORs, there is a need to educate OR users of the range of acceptable space temperature and RH levels in the OR. High RH in conditioned spaces is most likely to occur during the humid seasons of the year, when HVAC systems typically deliver supply air at 55°F and 95 percent RH. As cool supply air picks-up sensible heat from a space, the RH decreases (space conditions move on the horizontal access, from left to right, in Figure 1).

Options for meeting ASHRAE standard 170

Although the design range of acceptable RH per ASHRAE Standard 170 is explicitly limited to the temperature range shown in Figure 1, high RH in ORs remain a concern for OR users and facility managers. Therefore, facility managers and designers need to consider options for providing < 60 percent RH for OR users that prefer space temperatures < 68°F.

This first option can require significantly higher reheat energy for the air handler system, especially if other, non-OR zones are served by the same air handler system. Furthermore, this option can significantly increase cooling energy by reducing the annual hours of economizer operation (i.e., there are fewer hours in the year with lower outdoor air temperature or lower enthalpy). The second option can help to mitigate the energy impacts on the air handler system, but controllability of DX cooling can be an issue if precise and responsive compressor modulation is absent.

Problem solving together

Working together, OR designers and healthcare facility managers need to look beyond the prescriptive design requirements of ASHRAE Standard 170, and satisfy the space conditioning demands of OR users with effective and efficient strategies.

- CHAPTER 5 -

Efficient Operation of Unoccupied Healthcare Operating Rooms

According to Guidelines for Design and Construction of Hospitals and Outpatient Facilities, ventilation systems must operate at all times; however, airflow may be reduced during unoccupied hours as long as positive room pressure is maintained.

Healthcare operating rooms (ORs) are one of the most critical types of indoor environments. That means OR designers and operators tend to pay a high level of attention to OR HVAC (heating, ventilating, and air conditioning) systems. However, many OR designers and users overlook opportunities to operate OR HVAC systems more efficiently.

Required Airflow

Those involved with the design and operation of healthcare OR HVAC systems are likely aware of the minimum ventilation and airflow requirements of ASHRAE Standard 170: four air changes per hour of outdoor airflow, and 20 air changes per hour of supply airflow. These requirements are essential during surgical procedures, but what about during unoccupied hours ?

Unoccupied Healthcare Operating Rooms

Non-emergency ORs are typically unoccupied during non-business hours. During unoccupied periods, it is common, but not required, to provide full design airflow. According to the FGI 2014 Guidelines for Design and Construction of Hospitals and Outpatient Facilities (Section 2.1-8.2.2.1), ventilation systems must operate at all times; however, airflow may be reduced during unoccupied hours as long as positive room pressure is maintained.

Energy and Cost Savings

Over-ventilation of ORs during unoccupied hours results in significant, unnecessary energy consumption, for fans, ventilation air tempering, and reheat of supply air. By reducing the supply airflow during unoccupied periods, the annual supply airflow can be conservatively reduced from 100 percent to 80 percent. For an OR with 2,000 CFM of supply airflow, the annual fan energy savings would be approximately 2,500 kWh.

For an OR in Burlington VT, the reduction in outdoor air-cooling energy would be approximately 2,100 kWh (assuming 20 percent outdoor airflow and 0.7 kW/ton chiller efficiency) and the reduction in outdoor air heating energy would be approximately 19.2 MMBTU (assuming 80 percent boiler efficiency). Additionally, the reduction in reheat energy would be approximately 6.7 MMBTU. Assuming an average electric utility rate of $0.12/kWh and a heating fuel rate of $15/MMBTU, the annual energy savings would approach $1,000 per year per operating room. Space occupancy control systems (e.g., occupancy sensors and BMS controls programming) can be added to an existing BMS for approximately $2,500.

Thus, the retrofit of an existing operating room for unoccupied airflow setback can deliver a simple payback of approximately 2.5 years. At this rate of payback, space occupancy control for OR HVAC systems is comparable to the well-known low-hanging fruit of lighting control retrofits.

- CHAPTER 6 -

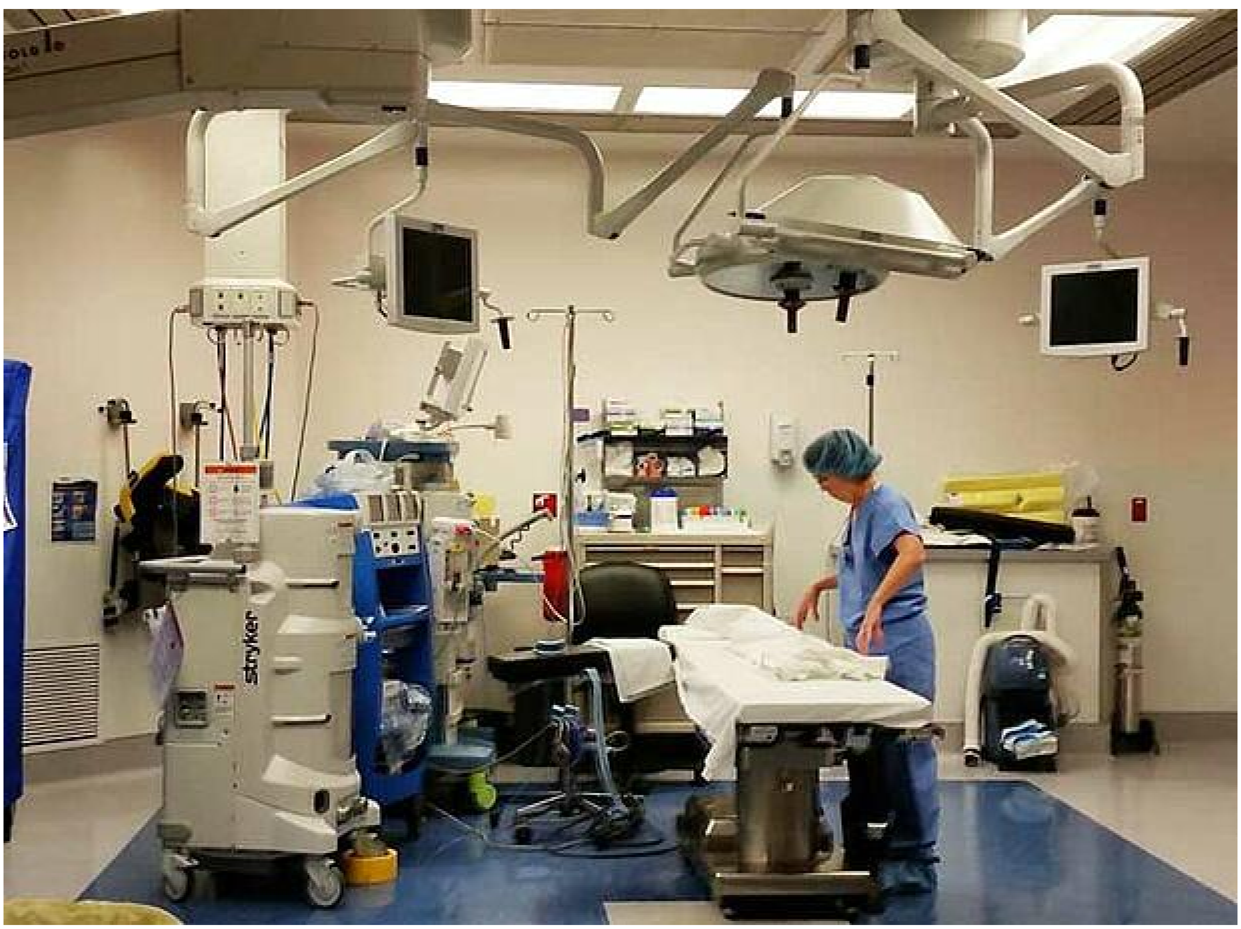
Setback Strategies for Unoccupied Healthcare Operating Rooms

Airflow setback is one of the more significant opportunities for energy savings in unoccupied ORs.

In the previous chapter, we discussed the efficiency opportunity for airflow setback in healthcare operating rooms (ORs). Airflow setback is one of the more significant opportunities for energy savings in unoccupied ORs, and is included in the American Society of Healthcare Engineers (ASHE) white paper on OR HVAC setback strategies. ASHE's "Operating Room HVAC Setback Strategies" provides guidance that warrants consideration by facility engineers. In this chapter, we will highlight and qualify some of the important insights from ASHE regarding OR HVAC setback strategies.

OR Occupancy Schedules

The occupancy schedule of ORs is directly related to the potential energy savings from OR setback strategies. ASHE recommends that facility engineers "develop a profile of actual or expected OR occupancy to help the HVAC or mechanical designer estimate order-of-magnitude savings and determine the optimal control strategy." This is a crucial first step for screening OR setback strategies and the hours of unoccupied operation will be needed to estimate the cost effectiveness of potential setback strategies.



Minimum Air Changes per Hour During Unoccupied Periods

The previous chapter mentioned that per the FGI 2014 Guidelines for Design and Construction of Hospitals and Outpatient Facilities, the required minimum air changes per hour (ACH) may be reduced during unoccupied periods as long as positive room pressure is maintained. ASHE mentions the important point that some codes do require a minimum ACH during unoccupied periods (e.g. the California Mechanical Code allows a minimum of 6 ACH). Ultimately, the design minimum ACH during unoccupied periods should be determined by the facility manager, engineer or RCX provider, and verified with the assistance of a NEBB or AABC certified air balancer to ensure that positive pressure is maintained at all times. Room pressure monitors should be calibrated so that the positive pressure relationship can be reliably monitored.

Energy Savings from Reduced Reheat of Supply Airflow

A considerable amount of energy savings from OR airflow setback can be realized from reduced reheat of supply airflows. During unoccupied periods when there is little or no heat gain within an OR space, a significant amount of reheat is likely needed to maintain the space air temperature setpoint. This is an important point that should be recognized by facility engineers and is not specifically mentioned by ASHE.

The ASHE white paper states that "less energy is needed to maintain room temperature in ORs during unoccupied periods because equipment loads are low to non-existent when the room is not in use and, because ORs are typically located in the building core, they are not affected by temperature gains and losses in the building envelope." It should be noted that setback/reduced supply airflow will reduce the quantity of airflow that needs to be cooled, dehumidified, and reheated.

OR supply airflows are typically sized for the required space ACH, which means that the supply airflow is higher than what is needed for the cooling load. When the space heat gain decreases during unoccupied periods, the supply air reheat system will require more energy to prevent sub-cooling of the space air temperature. As ASHE outlines, less energy is needed to maintain room temperature in ORs during unoccupied periods, particularly if the rate of cool supply airflow is setback/reduced, thereby mitigating an increase in supply air reheat.

Setback Strategies for Unoccupied Healthcare Operating Rooms

Many facilities managers with whom we work are hesitant to reset airflow to their ORs. “What happens when there’s an emergency case?” is a common question. This concern can be addressed with some simple controls retrofits rather than include occupancy sensors and/or manual override switches. However setbacks are implemented, it is of utmost importance that the users of the space, doctors and nurses in particular, receive adequate and recurring training on what to do in the event of a procedure off hours.

- CHAPTER 7 -

Special Considerations for Hospital Operating Room Upgrades

Space upgrades are a necessity to ensure that older buildings remain safe, functional, and cutting-edge for the users.

Space upgrades are a necessity to ensure that older buildings remain safe, functional, and cutting-edge for the users. During a recent project to upgrade the finishes of several operating rooms for a large hospital, one of our Senior Engineers acted as an owner's project manager. This chapter will discuss the coordination and construction effort involved for such a project, as well as some potential challenges.

This particular job involved installation of new flooring and wall panels, as well as demolition of the existing materials. The new system included the following characteristics, all pertinent to an operating room environment:

Coordination

When scheduling any project, the first step involves coordination with the staff who oversee the area. Due to the sensitivity of an operating room setting, this project was performed over two consecutive weekends for each room to minimize disruption to both patients and staff. Even on a weekend, closing an operating room, which is normally available for emergency cases, requires coordination and potentially a change in scheduling for the staff. Communication between all involved departments is a necessity for a successful project.

Construction

Although the construction itself is a relatively straightforward process when working with professional installers, there is still a lot of preparation work required before any construction can occur in a hospital. Most of the precautions taken are strictly with infection control and patient/staff/contractor safety in mind. From an infection control perspective, an operating room is an area that is at the highest risk for patients, therefore certain precautions are required to ensure the safety and health of hospital patients during construction and after the project is complete.

Challenges

One of the main challenges of this work is the possibility of finding something unexpected, which can occur during demolition of old walls and floors. Because there is limited time over a weekend, anything unexpected must be addressed immediately to allow for the room to be functional on Monday morning.

Another challenge is when a contractor does not understand the hospital's specific health and safety requirements and is not prepared to adequately meet the requirements. Having a contractor with hospital experience is invaluable in dealing with such time-sensitive surprises, otherwise there can be a negative impact on the schedule and serious consequences for patients and hospital staff.

- CHAPTER 8 -

Importance of Healthcare Room Pressure Relationships

Having a fresh set of eyes reviewing and testing building systems is critical. In some cases improper operation can be more than just an annoyance.

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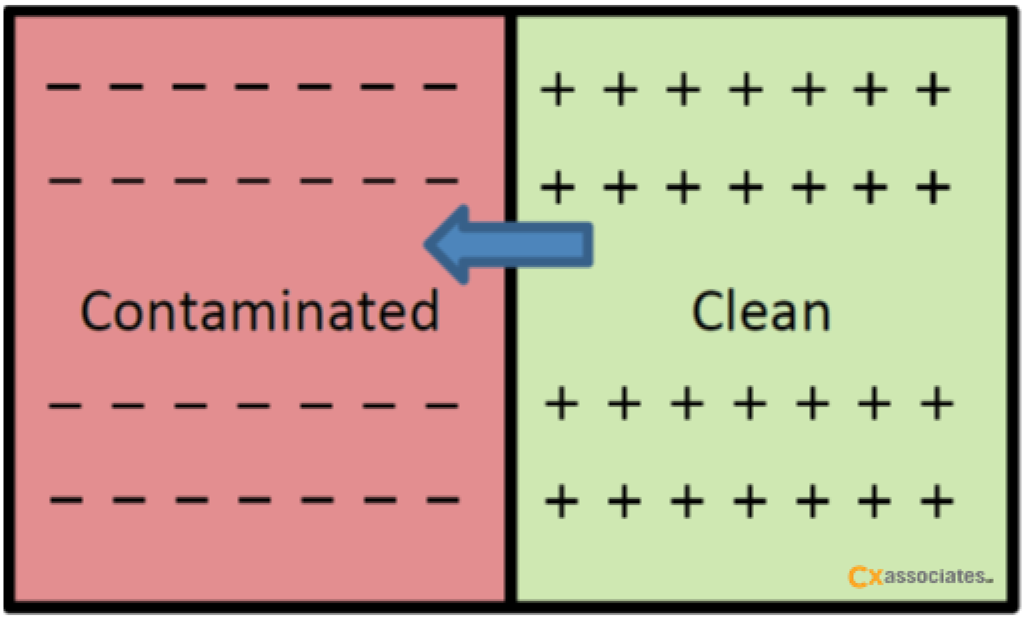
During functional testing of HVAC systems at a healthcare facility, part of our testing scope was to verify room static pressure relationships between adjacent sterile and contaminated spaces. In healthcare settings (and other settings where contamination control is critical) spaces can be designed to have more or less space pressurization with respect to one another—the result is that any air movement between spaces is in the direction from clean to dirty, and not the reverse.



Room pressure relationships in healthcare

In this particular instance, the Owner, and especially the soon-to-be occupants of the space, were motivated to move into their very nice new space as soon as possible. We received word from the construction manager that the remaining work was all complete, and all that was left was for functional testing to be completed. The controls contractor had signed off on the commissioning test docs indicating everything was functioning as designed.

We began our testing work by testing the air handling unit, followed by the air terminal equipment associated with the specific spaces which required pressurization control. There was plenty to test in our several days of field work, however given the operationally critical nature of the room pressure control, we wanted to start with that relatively early. It's a good thing we did.

Problems Identified

We found many issues, and generally none of the pressure relationships specified in the design were being maintained. The following are examples of the issues we identified:

- Review of the graphics revealed that supply/exhaust airflow setpoints were configured in reverse of their intended configuration—a space designed to have 30% more supply than exhaust airflow had 30% less resulting in an opposite pressure than specified.
- In spaces with active pressurization control (using a differential pressure sensor and closed-loop control to maintain a setpoint) reverse control logic programming existed (e.g. if space is not sufficiently negative, decrease exhaust VAV airflow).
- In one instance, the tubing from each of two adjacent spaces was connected to the differential pressure sensor backwards (resulting in the control system displaying a critical relationship in reverse sign of actual).
- Programming had not been completed for some spaces requiring active pressure control.

Once all of the controls problems were resolved, we were finally actually able to return and test pressurization control.

The testing revealed that while adjacent spaces were expected to have, in some cases, up to 0.03" w.c. (inches of water column) difference, penetrations between the spaces had not been carefully air sealed by various contractors and equipment vendors. While the pressure relationships were being maintained, it was at the cost of large volumes of air/exhaust at all times to compensate for poor air sealing. The high airflow requirements were driving the associated air handler to operate at a much higher static pressure setpoint, which resulted in much greater energy use. By air sealing the leaks between spaces, the airflow requirements were able to be reduced, thereby saving energy.

Why Is Commissioning Important?

While trades work very hard to get projects delivered on time, on budget, and built/functioning as designed, the reality is that modern buildings are very complex. Inevitably the final details of the control system configuration are crunched into the last portion of the job, and there is always pressure to get the project completed as quickly as possible. While intentions are usually in the right place, having a fresh set of eyes/brains reviewing and testing the final product is critical. In some cases, as it was in the instance described above, improper operation can be more than just an annoyance or a service call.

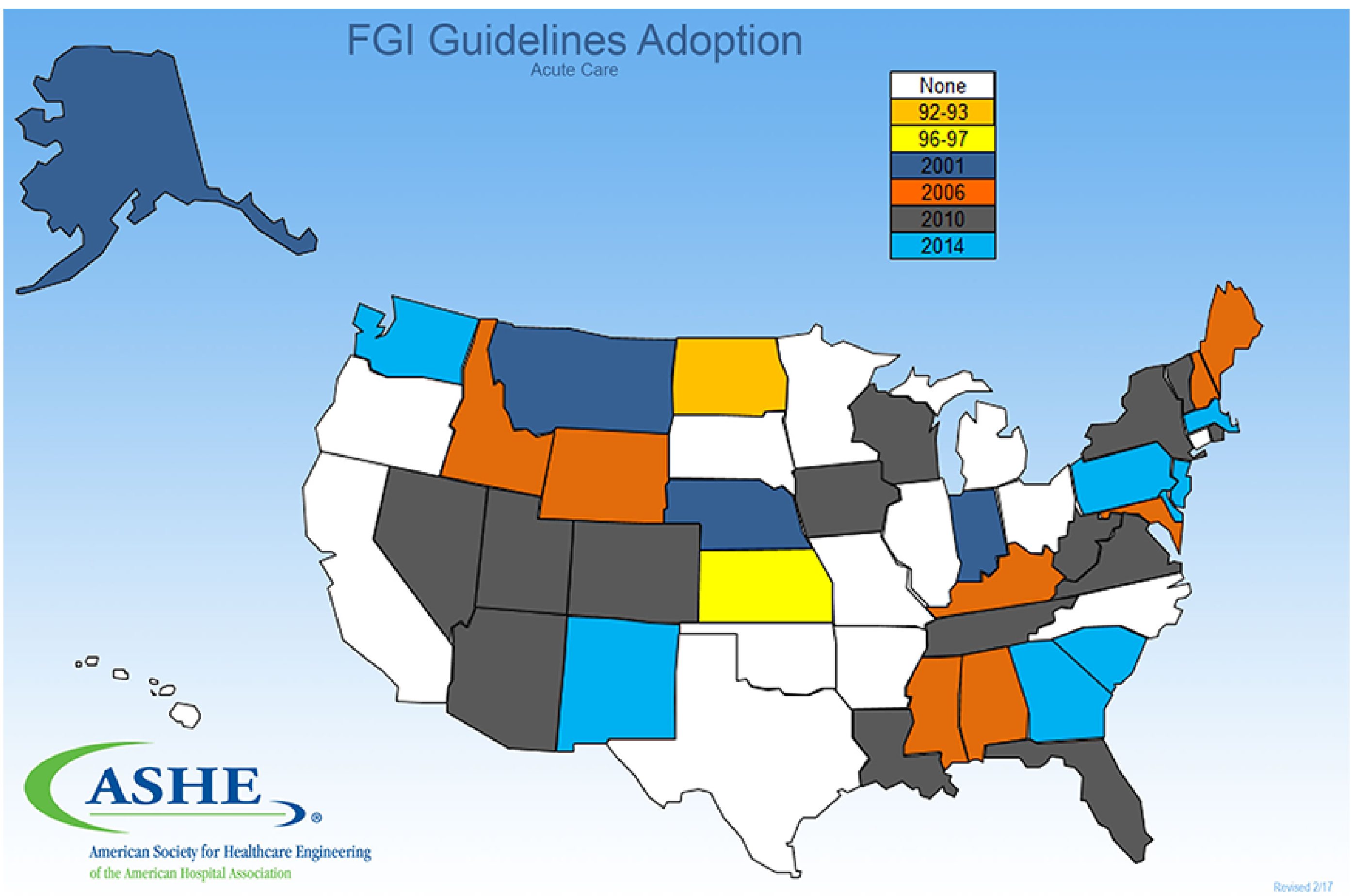
- CHAPTER 9 -

Optimizing Air Handling Units for Healthcare

ASHRAE Standard 170 is used to determine required air quantity in healthcare facilities, and there is a different method for calculating the required outside air quantity.

As Walker Calderwood discussed in a blog post, "Optimizing Air Handling Units for Energy Savings or Improved Comfort," energy savings can be realized by adjusting the amount of outside air that is introduced to an air handling unit during normal operation. In that article, Walker referenced ASHRAE 62.1 to determine what the correct amount of outside air an air handling unit should mix with the return air stream. This same principle applies to air handlers in healthcare, and in many cases, there is an even greater opportunity for savings in healthcare applications.

A different standard (ASHRAE Standard 170) is used to determine required air quantity in many space types associated with healthcare facilities, and there is even a different method for calculating the required outside air quantity of an air handler. This standard is commonly adopted in states nationwide, and also by the Facility Guidelines Institute, which many states have adopted as a standard for design and construction of healthcare facilities.



Source: ASHE - http://www.ashe.org/advocacy/orgs/fgi-adoption-map.shtml

Standard 170 offers opportunities to reduce energy in a couple of different ways, which we have implemented on different projects at Cx Associates. First, this standard specifies required air quantity in spaces through Air Changes per Hour (ACH). Air changes per hour is simply how many times per hour the total volume of air in a room will be "changed." Since air quantity is referred to in cubic feet per minute (CFM) the required air quantity to provide 1 ACH can be determined by dividing the total volume of a room in cubic feet by 60 minutes. If more than 1 ACH is needed the result of that equation is simply multiplied by the number of required air changes.

Example: A room that is 6,000 FT3 requires 3 ACH.

One air change of room volume per hour: $6{,}000\,\frac{FT^3}{hr} = 1\,ACH$

Air quantity (in cubic feet per minute) required to meet 1 ACH: $\dfrac{6{,}000\,\frac{FT^3}{hr}}{60\,Min} = 100\,CFM$

Air quantity (in cubic feet per minute) required to meet 3 ACH: $100\,CFM \times 3\,ACH = 300\,CFM$

The standard specifies a minimum outside air ACH, which determines the minimum quantity of outside air required for a space, and a minimum total ACH, which determines the minimum quantity of total recycled air and outside air for a space. Both minimum total and outside air ACH have varied over time as shown below. If we use 1978 as an example, ACH requirements have mostly stayed the same or been reduced when compared to 2013, except for patient rooms. 1978 may sound like a long time ago, but many systems still in use at healthcare facilities today were designed at this time, and are still operating under these design specifications. Energy savings opportunities exist in fan energy savings by the total ACH value being reduced, thus AHU fan speeds can be reduced since there is no longer a need to maintain the 1978 total ACH requirement. Another opportunity exists in reduction of heating and/or cooling energy since outside air ACH requirements have been reduced. Less outside air means less energy required to condition supply air.

FIGURE 5 Selected air change per hour (ach) rates over the years.[3]

	HISTORICAL AIR CHANGE RATES IN SELECTED NON-OPERATING OR ISOLATION SPACES (TOTAL ACH/OUTSIDE AIR ACH)															
	1959	1962	1964	1966	1968	1971	1974	1978	1982	1987	1991	1993	1997	2001	2006	2008	2013
RECOVERY		4	4	4	15/6	15/6	15/6	6/2	6/2	6/2	6/2	6/2	6/2	6/2	6/2	6/2	6/2
NURSERY	8 to 12	12	12	12	15/5	15/5	15/5	12/5	12/5	12/5	12/5	6/2	6/2	6/2	6/2	6/2	6/2
ANESTHETIC STORAGE	2	2	–	8	8/8	8/8	8/8	8	8	8	–	8	8	8	8	8	8
PATIENT ROOM	1.5	1.5	2	4/2	4/2	4/2	2/2	2/2	2/2	4/2	–	2/1	2/2	6/2	6/2	6/2	4/2
INTENSIVE CARE	–	–	–	–	6/6	6/6	6/2	6/2	6/2	6/2	–	6/2	6/2	6/2	6/2	6/2	6/2
LDRP	–	–	–	–	–	–	–	–	–	–	4/2	2	2/2	6/2	6/2	6/2	6/2
PATIENT CORRIDOR	–	–	–	–	–	4/4	4/4	4/4	4/2	4/2	4/2	2	2	2	2	2	2
X-RAY D&T	–	6	6	10	6/6	6/6	6/6	6/2	6/2	6/2	6/2	6	6	6	6	6/2	6/2
EXAM	–	4	4	4	12/6	12/6	12/6	6/2	6/2	6/2	6/2	6	6	6	6	6/2	6/2
MED ROOM	–	–	–	–	–	–	–	4/2	4/2	4/2	4/2	4	4	4	4	4/2	4/2
TREATMENT	4	4	4	12/6	12/6	12/6	6/2	6/2	6/2	6/2		6	6	6	6	6/2	6/2
PHYSICAL THERAPY	–	–	–	–	4/4	4/4	4/4	6/2	6/2	6/2	6/2	6	6	6	6	6/2	6/2
SOILED HOLDING	–	3	3	4	12/4	12/4	12/4	10/2	10/2	10/2	10/2	10	10	10	10	6/2	6/2
CLEAN HOLDING	–	–	–	3	12/4	12/4	12/4	4/2	4/2	4/2	4/2	4	4	4	4	4/2	4/2

Chart source: "A Brief History of Health-Care Ventilation," English, Travis R.; ASHRAE Journal; June 2016; pp 52; Copyright 2016 ASHRAE.

Another opportunity exists in one of the methods which ASHRAE 170-2013 allows the outside air quantity required for an air handling system to be calculated. Per ASHRAE 170-2013-7.1.a.6.i:

"System minimum outdoor air quantity for an air handling system shall be calculated as the sum of the individual space requirements as defined by this standard."

This varies from ASHRAE-170-2013-7.1.a.6.ii:

"System minimum outdoor air quantity shall be calculated by the Ventilation Rate Procedure (multiple zone formula) of ASHRAE Standard 62.1. The minimum outdoor air change rate listed in this standard shall be interpreted as the Voz (zone outdoor airflow) for purposes of this calculation."

The second method will often result in a higher outside air quantity for the air handling system than simply the sum of the individual space requirements as specified in in the first method. Again, less outside air means less energy to heat and cool supply air. This outside air quantity can be monitored via an airflow station installed in the air handler outside air intake and the air handling system can be further optimized by controlling it following ASHRAE Guideline 36.

Healthcare facilities often have much higher energy use intensities (EUI) than typical commercial buildings, but by leveraging the requirements and methods of ASHRAE 170-2013, Cx Associates has successfully reduced the energy consumption of air handlers at many hospitals throughout the region.

- CHAPTER 10 -

Construction Project Management Challenges in Healthcare Facilities

Unique construction challenges and approaches for preventing these challenges from adversely affecting the overall success of the project.

In a blog post, Katie Mason shared her experience as an Owners' Project Manager for a mechanical system upgrade in an office building for a large organization in Burlington, Vermont. She explains that the role provided her with several new related projects in a healthcare facility, each varying in type and having a very different effect on the overall environment of the organization. In the healthcare environment, Katie has become familiar with its unique construction challenges. This chapter will discuss a couple of these challenges and approaches for preventing these challenges from adversely affecting the overall success of the project.

Measuring Success – Five Keys

But first, how is success measured for a construction project? The following list shows five items that are used to determine if a project is successful.

1. Overall quality of the product
2. Providing a safe working environment for ALL involved
3. Staying on budget
4. Keeping a good working relationship with the owner, employees, contractors, etc.
5. Completing the project on schedule

Challenges Specific to Healthcare

Success in the healthcare industry – in Katie's case a hospital - is specifically challenging as the facility is used 24/7. Many hospitals have labyrinthine corridors used by patients and guests not familiar with the facility, and often the staff as well as the guests are in an emotionally vulnerable or stressed states. Adding the complexity of construction detours, system shutdowns, and just plain imposition to this already charged situation requires excess planning, patience, and understanding from the construction team. This makes for an interesting challenge for the Project Manager!

With this in mind, here are some examples of the challenges:

Construction Wayfinding

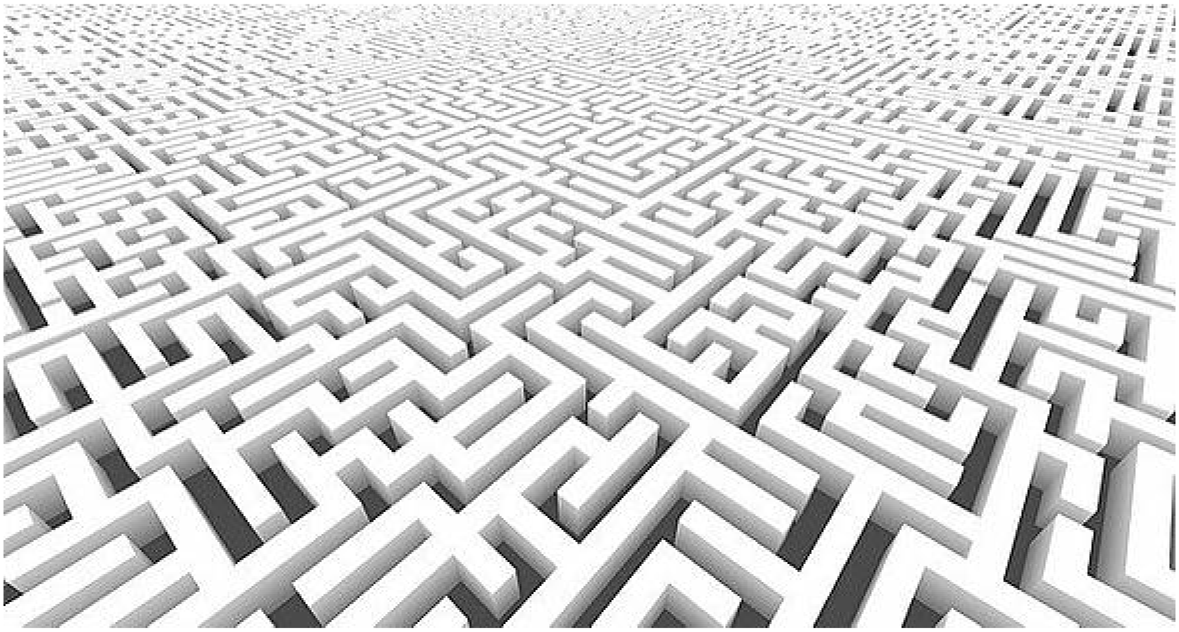


Image by Flickr user David Evers

For a recent project, a very well-traveled connector between two buildings was closed down for a life safety upgrade. Understanding the effect of closing down this corridor was discussed early on in the construction project and the team worked closely to determine the best approach for ensuring accurate patient/visitor wayfinding as well as a plan for internal transport (mainly beds). Having the right staff from the organization at the table to review these plans was very important for this project. Proper signage surrounding the construction area had to be simple, straightforward and easy to follow. Katie observed the effect of the detour signage and, even with such proper directions, found users were unsure. She found herself helping users travel around the work zone to ensure the signs were effective for everyone. In addition, the contractor worked longer shifts and weekends to make the construction schedule shorter and decrease disruption.

Shutdowns in 24/7 Occupation

Most healthcare organizations have certain departments that are occupied 24/7. This makes it very difficult to plan construction projects that could potentially require closure of the department or relocation of the department until the project is complete.

Unfortunately, shutdowns for healthcare systems such as domestic water, HVAC, and medical gas are sometimes necessary to move a project forward. Avoiding shutdowns is always the better option, but for most situations where this isn't feasible, ensuring that proper communication with all involved parties and understanding the full extent of the shutdown is very important in order to prevent unexpected issues. The construction crew wants to ensure a smooth process just as much as the people affected by the work.

Image by Flickr user Alejandro H.

Safety and the overall positive experience for the patients, visitors, staff, and contractors is a huge priority during all construction projects in a healthcare setting. Understanding that construction projects can unsettle the overall flow of the organization, it's important to approach all projects with a plan to minimize disruption in the least possible way and ensure that the necessary staff from the organization who understand how it works are part of all planning conversations to provide input and suggestions.

- CHAPTER 11 -

The Case for Monitoring Outside Air Flow in Hospitals

Maintaining proper outdoor air volume is a vital part of achieving effective infection control, as well as meeting space pressurization requirements.

It can often be an afterthought as to how much outdoor air (OA) is actually being drawn into a hospital through air handling equipment, but maintaining proper outdoor air volume is a vital part of achieving effective infection control, as well as meeting space pressurization requirements. Proper OA volumes are also a metric that can be reviewed for non-compliance during Joint Commission audits. The amount of outside air that a hospital's air handling equipment should introduce into the building is defined by the ASHRAE Standard 170, which was discussed in one of our previous chapter, Optimizing Air Handling Units for Healthcare. As we pointed out, an airflow station, when properly selected and installed, is an effective piece of hardware which can be used to monitor this outside air quantity (typically in cubic feet per minute), and the data provided by this meter can be very useful in a healthcare setting.

An Overview of Outside Air Airflow Stations

Outside air airflow stations (OA AFS) allow for better control of outside airflow, enable high/low flow alarming, and provide historical trend data. Control of outside airflow is essential on variable air volume air handling systems where the outside air flow rate can change significantly as the supply air volume through the air handler changes. When utilizing an OA AFS, a flow setpoint can be specified and controlled to via the air handler controls. As long as the controls and hardware are functioning correctly, hospital facilities staff can be confident that the correct amount of outside air is being provided to the hospital.

Outdoor airflow alarming can be used to alert facilities staff when the outside airflow rate is too low, in which case the ASHRAE 170 air change requirements will not be met and indoor air quality and infection control could become compromised. We have seen many instances in the field where air handlers have failed damper linkages and/or controls, and no outside air was being provided to the spaces they serve. In these cases, despite competent and dedicated facilities operators, the problems went undetected because without an OA AFS there was no indication to operators that outside airflow had become too low.

Modern building controls systems can and should provide at least a year of trending, and a key point to trend for as long as possible is the OA airflow. The data provided by the OA AFS can be easily made available to the Joint Commission during an audit by the facilities or engineering staff as quantitative evidence of compliance. The Joint Commission can verify that the air handler the OA AFS is installed on has been operating in compliance with their requirements.

Managing Costs and Recognizing Savings

In addition to the benefits of utilizing an OA AFS listed above, measuring outdoor air also can result in potential energy savings by reducing over-ventilation of a space, and can further allow implementation of the ASHRAE 36 guideline standardized control sequences, which can result in the highest and most reliable unit operation (see Rick Stehmeyer's blog post, ASHRAE Guideline 36 – The Next Generation Control System, for more information).

All of these benefits do come at some cost; retrofitting an air handler with an OA AFS can sometimes be pricey (though the costs vary widely by application), but the payback of proper OA volume control can also be quick. The best way to keep costs of an OA AFS low is to have it provided as an option from the manufacturer on all new air handling units. When developing a budget for a recent project, the cost of adding a manufacturer furnished OA AFS as an option on a new air handling unit was compared to a recent OA AFS retrofit - the AFS provided on the new AHU was 50% of that for a retrofit of comparable specs.

A Worthwhile Consideration for Healthcare Facilities

While outdoor air airflow stations have valuable benefits in all commercial buildings, they have a special note in healthcare facilities. The ASHRAE Standard, Ventilation for Acceptable Indoor Air Quality (ASHRAE 62.1) requires that minimum OA airflow is maintained in variable volume air handling equipment through the operating range.

While other solutions exist for achieving this, the most effective and reliable means of maintaining proper OA volume is by utilizing an OA AFS to measure and control it effectively. It is always worthwhile to weigh the benefits to costs of retrofitting whenever planning for installing new air handling units, and it is important to know the benefits of having an OA AFS installed on the units from the manufacturer. The OA AFS is often the victim of the value engineering process, but Cx Associates strongly believes the benefits outweigh the costs in a healthcare facility application.

- CHAPTER 12 -

Turning Big Data into Actionable Intelligence

Commissioning provides an independent test of building system operation and corrects deficiencies in those systems.

Energy efficiency program evaluation sounds so arcane, most people, likely have no idea that there are large cohorts of people (cohort is a word we use frequently in evaluation) who spend their lives verifying the results, the savings, from energy efficiency programs. Because energy efficiency program evaluation (evaluation hence forth in this chapter) is outside the realm of day to day life, most of us are completely unaware it exists. This chapter is about Jennifer Chiodo's vision for how evaluation and real life (in the commercial, institutional, industrial (C&I) building operations world) could intersect in ways that could make buildings, programs and evaluation better and lower costs for ratepayers.

Feedback Loops to Improve Efficiency

Image by Flickr user Mark Ramsay

We've written before about the need to create more effective feedback loops so that we can more effectively engage in continuous improvement of the energy efficiency services and programs we offer to C&I customers who ultimately are the largest investors in energy efficiency. Jennifer began her career as an electrical systems design engineer in San Francisco. Back in the 1980s, there was a raging AIDS epidemic and we used pencils instead of mice to draw the systems that were installed in high rise office buildings, hospitals and prisons.

While we had some engagement during construction to check on the contractors, we often walked away from the site long before buildings were occupied. The mantra of early engineering mentors was – the best building you ever design will be the one the never gets built. Rationale – no one ever finds your mistakes; no one ever complains.

When Jennifer entered the building commissioning field it was with great hope for the expansion of the feedback loop. Commissioning provides an independent test of building system operation and corrects deficiencies in those systems. Unfortunately traditional commissioning typically ends shortly after building occupancy. What we really need is sustained feedback so that we can learn how buildings work for occupants and how well they play on the grid as we endeavor to manage the aging infrastructure of our electric grid by reducing load overall and demand during peak periods.

When Jennifer first became involved in evaluation, it was in the context of helping to figure out how to comply with the New England electric grid operator's (ISO New England or ISO) requirements for energy efficiency demand reduction measurement and verification. ISO allows the reduction in electric load on the grid that results from energy efficiency to be treated just like the generation of power. Power generation is easy to meter while energy efficiency cannot be directly measured.

The Future of Evaluation Looked Bright

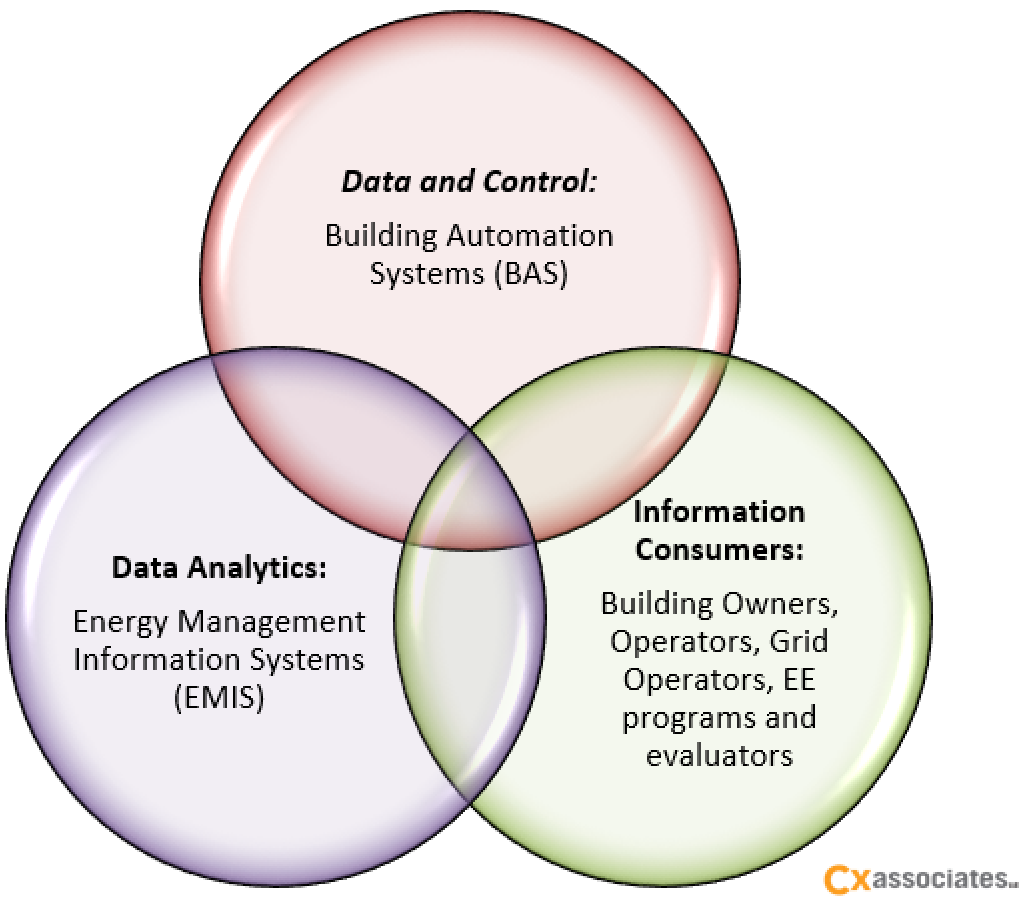
Jennifer was excited to imagine that we were going to install meters and have continuous, real time data that would prove how much energy we were saving on every project we implement. This approach would provide owners, energy efficiency programs, evaluators and grid operators with real time data about loads and the reductions in their power consumption due to energy efficiency. That concept turned out to be a little ahead of its time. But we are getting closer.

Some believe that the 15-minute interval meter data that utilities are able to garner with new advanced metering infrastructure necessary to modernize our grid, will provide adequate data and feedback. It's plausible that this may well be the case in 20 – 30 years for C&I. But the reality is that C&I buildings and systems are custom and that we actually have and should use more granular data about operations.

The Intersection of Life and Energy Efficiency Program Evaluation

C&I buildings make increasing use of building automation systems (BAS) to control HVAC systems, and increasingly such systems are able to control lighting. These are two major electric loads, and in the Northeast, the HVAC system typically includes major fossil fuel consumption as well. The BAS manages data from thousands of points throughout most medium to large sized C&I buildings. The BAS has the data, that, if mined effectively can give us a truly accurate, real-time feedback loop on building and energy efficiency performance.

As shown in the diagram below, the data from the BAS can be mined by an Energy Management Information System, which uses programming to analyze the data and provide a dashboard of actionable information to building owners and operators. In addition, this data can be used by energy efficiency programs to find and estimate the savings from upgrades, and by evaluators to validate claimed savings.



Big data is fun to say, but the reality is the consumers of big data need small packets of actionable findings so that they can continuously improve building operations and energy efficiency programs. When such systems are common, the cost of programs, energy efficiency investigations, and program evaluation will all come down. Feedback loops that support continuous improvement will be the norm. And, advanced metering infrastructure (AMI) data will just be one more data point in the assessment of building performance.

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