BUILDING PERFORMANCE METRICS

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There is a steady and determined march towards designing better and better performing buildings. The only issue with this approach is that actual building performance is not keeping up. At the end of the day, design is not the same as operation (**Figure 1**).

At Price Industries we recently experienced this first hand. Two products developed independently of each other, a fan coil and a silencer, both tested very well individually against their own rating standards. The two devices were then joined into a single assembly which increased the fan power far beyond expectation but also increased the sound levels. What seemed to be a great idea on paper greatly underperformed in the real world. Solving the issue only took a minor design change but **if the final results weren't tested, the system would have had to be reconfigured at a considerable cost (Figure 2).**

Everyone has a story about a building that underperforms and it seems it is always someone else's fault, not designed well, not constructed well, not commissioned well, or not operated well. At the end of the day, all that matters is that the owner is not served well. This leads to a discussion about "as designed" versus "as operated"; from modeling to real world results. This encompasses building performance metrics.

BUILDING PERFORMANCE METRICS

A building can be measured in many ways. There is considerable focus on energy performance (Energy Utilization Index (EUI), Net Zero Energy Building, etc) which in turn is closely linked with a building's carbon footprint. Water management is another common metric as both energy and water have the advantage of being easily measured.

The primary reason to create a built environment is to provide a safe, comfortable place for occupants to live and work. Focusing here gives us thermal comfort, indoor air quality, acoustics and lighting. This group is often referred to as Indoor Environmental Quality (IEQ). No building can be considered a success without real results being delivered across all six of the building performance metrics (**Figure 3**).

One of the first advantages of evaluating a building using these six metrics is that they are in the customer's language. A school administrator may not understand the impact of system effects on fan sound power levels in a ventilation unit, but they do understand the importance of proper sound levels in the classroom.

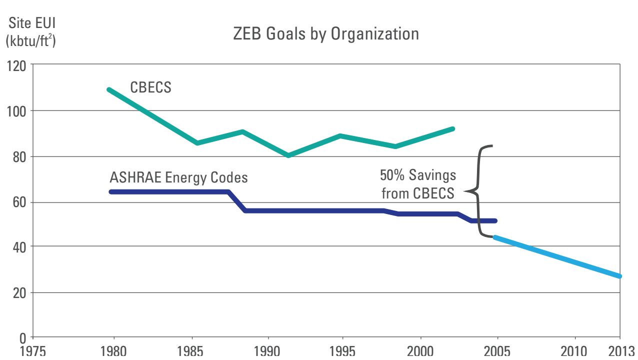

Figure 1: Modeled improvement of ASHRAE Standard 90.1 – Energy Standard for Buildings except low-rise Residential Buildings.

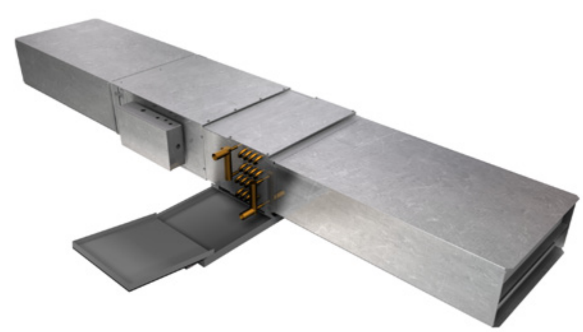

Figure 2: Price Fan Coil and Silencer combined into single assembly to increase fan power while maintaining acceptable sound levels.

Measuring a building using the six metrics can be accomplished from a basic to advanced level using Performance Measurement Protocols (PMP). The PMP were jointly developed by ASHRAE, USGBC and CIBSE, and provide excellent guidance on practical ways to make the measurements.

Once it is understood that success will be measured in terms of energy, water management, indoor air quality, sound, thermal comfort and lighting, how do we behave differently in the design, construction and commissioning phases to achieve the goal? There have been great technical advancements in the individual components that make up a building. The use of prescriptive standards has challenged the market place to constantly improve the pieces. However, the law of diminishing returns is taking over. There are only so many times the AHRI chiller efficiency targets in ASHRAE Standard 90.1 can be raised. What is important now is how the parts work together. Integration is the best path to realized performance.

However, integration is not easy. For hundreds of years, the building industry has broken down the complex issue of designing and constructing buildings into small, manageable blocks for individual teams to work on. The design team of architects, structural engineers, mechanical engineers and electrical/lighting engineers all have well defined roles. The same is true for contractors and equipment manufacturers. In the equipment world, the comfort zone manufacturers are different from the primary system manufacturers, who are in turn different from the controls contractors.

While it has made a complex issue solvable, it has not led to world class performance. Everyone tends to be too "siloed" and issues slip between the cracks. Even if nothing is missed, the imposed design constraints on the design teams can severely limit innovative designs. For example, the building envelope is a critical component of the HVAC system but the integration of these two is difficult in this current methodology.

Another issue is priorities. Two thirds of the key performance metrics are associated with the comfort zone yet most buildings are focused on energy use by the primary systems. It is unlikely a customer will consider a net zero energy building project a success if no one can stand to be in it. How much time is spent discussing possible methods of wringing every kilowatt out of a building compared to making sure the space will be comfortable?

Let's use an example to see how we might evaluate and meet all six desired performance metrics. Consider a 150,000 ft² office with the following target building performance metrics;

Site energy use	41,000 Btu/ft²-yr
Site water use	15 gal/ employee-day
Thermal Comfort	Meet ASHRAE Std 55 – Thermal Conditions for Human Occupancy
Sound	35 dBA
IAQ	Meet ASHRAE Std 62.1 – Ventilation for Acceptable Indoor Air Quality
Lighting	50 foot candles (fc) horizontal plane illuminance

These metrics describe a leading but not bleeding edge building. The goal now becomes to not only design a building that can meet these targets but to validate it once the building is operational. The energy target for this building would be the 25th percentile of the 2003 CBECS (Commercial Building Energy Consumption Survey) data. One of the best ways to achieve this goal is to start with energy modeling. A typical office building will divide its energy usage roughly evenly between HVAC, lighting, and plug loads. In this example the HVAC system will be a chilled beam/radiant panel system and day lighting will be used to reduce the lighting load (**Table 1**).

Table 1 – 2003 CBECS Data for Admin Office Space

Building Use	**Calculated, weighted EUI Values, Site Energy, Btu/ft²-yr Percentiles**					
	10th	25th	50th	75th	90th	Mean
Admin Office	28,100	41,100	62,000	93,000	138,000	75,000

Figure 3: Testing at Price Research Center North in Winnipeg, MB validating performance in the intended application.

ENERGY PERFORMANCE

Of all the performance metrics, energy is the one design professionals are most comfortable with and yet this is one area where studies have shown buildings consistently underperform. Some reasons this happens are;

- Energy Modeling is as much art as it is science due to the complex algorithms.
- There is almost no correlation between the sequence of operation in an energy modeling program and the sequence of operation installed by the controls contractor. Here is an example; using the same chiller, cooling tower and condenser water pump and just changing the controls strategy: a 10% change in energy performance can be achieved.
- Components used in an HVAC system (chillers, air handling units, chilled beams etc.) are all tested and optimized against a rating program. The data is generally very reliable. However, HVAC may not operate at the rating conditions. The chilled beam system being used in this example requires 50°F chilled water, not 44°F chilled water. The relationships between the components are complex, the energy modeling software assumes they will all work seamlessly, when in most cases, the pieces have never been evaluated as a system.
- Building occupants don't behave the way the modeling software simulates them. This is true for both the occupants and the operators. Even if the simulation models occupant activity perfectly, it can be expected that the activity will change with time.

Choosing a chilled beam radiant system will address reducing energy transport cost (fan and pump work) while also improving the efficiency of the chillers (typically the single largest motor in the building).

One thing that should also be included in the design is metering (including main system submetering).

The information that can be obtained during commissioning and operation will allow continuous improvement throughout the useful life of the building. ASHRAE Standard 189.1 offers excellent guidelines on metering requirements.

WATER MANAGEMENT

Water management is another one of the metrics that is well understood by the consulting community. The only issue is that benchmark data for water use in commercial buildings is sparse. The water performance target for this building came from the DOE- FEMP Water Use indices database. It considers water to be used for domestic purposes, HVAC (cooling towers, boiler make up etc.) and irrigation.

Again, the large variable is how the occupant will use water. This is particularly true in hospitality and high-rise residential buildings. Metering and submetering are key in order to achieve the desired performance metric. It will allow operational issues to be identified through trending and will also allow the occupants to be aware of their impact and make changes to their usage requirements.

INDOOR ENVIRONMENTAL QUALITY (IEQ): THERMAL COMFORT, INDOOR AIR QUALITY, ACOUSTICS & LIGHTING

The final four metrics are far more difficult to deliver.

1. THERMAL DISCOMFORT

Providing an energy balance to a control zone so it doesn't over or under heat is not that difficult. However, it does not mean the occupants will be comfortable. Studies have shown (Huizenga et al. 2006) thermal discomfort as the primary issue with building performance.

Meeting ASHRAE Standard 55 is often interpreted as trying to maintain 75°F and 50% RH. This is an energy balance goal, not a comfort goal. Standard 55 actually covers four parameters including air temperature, radiant temperature, humidity, and air movement. The most basic approach is to follow the requirement as outlined in Standard 55. Computational Fluid Dynamic (CFD) modeling and lab mock ups can further improve the design's changes of meeting the performance metric (**Figure 4**).

2. INDOOR AIR QUALITY (IAQ)

Indoor Air Quality (IAQ) is the hardest issue to predict, design and monitor. Everything at some level is a pollutant. It is impossible to measure everything so it is very difficult to know if acceptable indoor air quality has been met.

Practically, what can be done is to start by designing to and verifying the achievement of ASHRAE Standard 62.1. It is critical to make sure that not only is there enough ventilation air being brought into the building but that there is enough being delivered to the occupied space. Ventilation air flow measurement is very helpful to ensure compliance. Measurement of CO_2 is another method to help predict indoor air quality as well as visually monitoring for any signs of mold.

The nose is a good indicator of IAQ. If it smells bad, it probably is. Proof that acceptable IAQ has been reached will likely come from occupant surveys (or email complaints which are unstructured surveys).

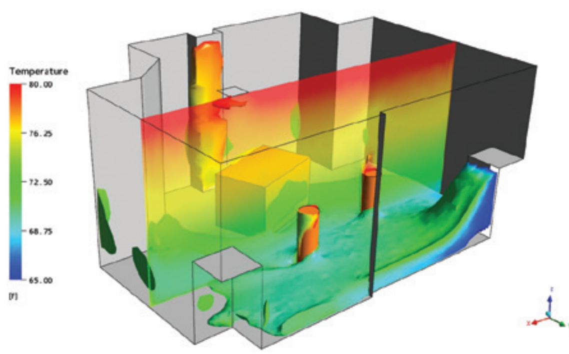

Figure 4: CFD Model of Thermal Performance

3. ACOUSTICS

Most projects do not include an acoustician and building sound performance falls to the mechanical consultant (after all, it is their systems that make the noise). Sound performance is more than just minimizing sound levels from HVAC systems as it is the occupants that are a critical sound source. The physical properties of the space will also have a huge impact on the sound quality. It may be possible to turn off all the mechanical equipment and still not understand what a teacher is saying simply because of how the classroom was built and furnished.

Choosing a 35 dBA sound level target for this building example has the advantage of being easily measured during the commissioning and operation of the building. However, the dBA sound pressure scale is not a robust measurement system. It is quite easy to have two spaces, both at 35 dBA, where one space is satisfactory and the other is not. Using a Noise Control (NC) rating system is more robust but harder to measure later on (**Figure 5**).

A good approach is to use an NC rating target and model the projected sound level from the HVAC equipment and any sound attenuation that might be required. Special care should be taken in the space to deal with sound level, frequency range, tonal issues and reverberation. For critical applications a mockup of the space may be desirable to provide the best chance on meeting this performance metric.

4. LIGHTING

Last but not least is lighting, which can represent a third of the building's energy use. Further, any lighting heat added to the space increases the work done by the HVAC system to remove it. In the building example used here, day lighting will be used to reduce overall energy consumption. Lighting will also have a direct impact on occupant performance and experience.

Daylight modeling tools can be used to ensure the building design will meet this performance metric. Power metering can be used to verify and maintain the power consumption of the lighting used in the building and light level measurements can be used to verify lighting design levels. Occupant surveys (or emails) will provide feedback on whether the performance metric met the occupant's needs.

Building Performance Metrics are an excellent way to shift the focus from "as designed" (asset rating) to "as operated" (measured rating). It serves as a reminder to describe building performance in a language the occupants can understand. Shifting the focus to building operation early in the design phase will lead to integrated design, leveraging all forms of modeling and building in measurement and verification methodology. At Price we strongly believe in a complete solution approach to building performance, from the design of the building and its components, to testing those components in a variety of situations and ensuring they are installed and functioning to the customer's specifications. Price is able to offer comprehensive testing and mockup services at both our Price Technical Center in Suwanee, Georgia and Price Research Centre North in Winnipeg, Manitoba, CA.

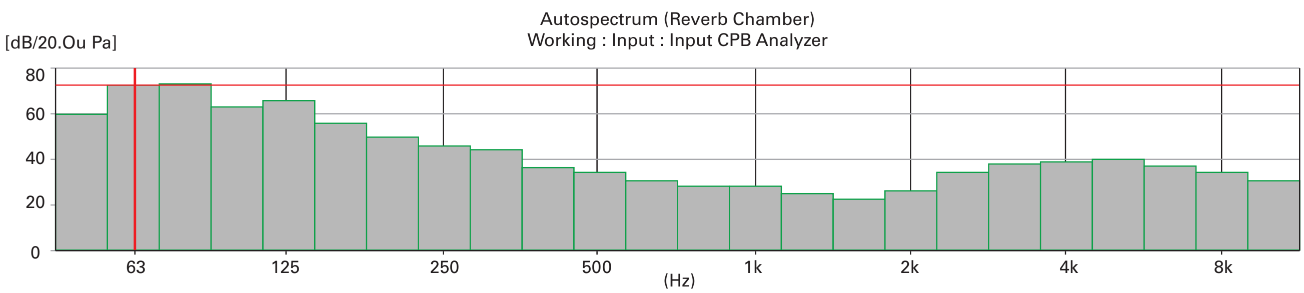

Figure 5: Sound Attenuation Modeling