

# **Commissioning for LEED® Projects: Realizing the Perils and Potential of “Innovative” HVAC Systems and Equipment**

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## **Synopsis**

LEED® and similar programs often lead to the application of innovative systems and equipment that have not been produced or installed for as long as, or in similar quantity to standard systems and equipment. Consequently, designers, vendors and installers are all relatively unfamiliar with the applications. The result of this is an increased risk of problems that threaten the very essence of the intended outcome. Therefore, commissioning throughout the design and construction of such projects may be doubly important and should be practiced at a rigorous level.

This paper presents a concise summary of this concept with suggestions for specific areas to focus on when commissioning innovative systems. It explores the reasons behind the symptoms and prospects for addressing the problems in the short- and long-term. Examples from a project utilizing 42 unitary heat recovery systems employing two different heat recovery technologies, completed under a local program similar to LEED as well as other projects illustrate the special need for commissioning that innovative systems engender, detailing successes and areas where more attention was needed.

The goal of these innovative systems is to save energy and provide equal or better indoor environmental quality. Too often, theoretical gains are not realized in the final product. The reasons span from design and specification through manufacturing, installation, operation and maintenance. Fortunately, the practice of commissioning is poised to address all of these aspects. It simply needs to be focused more intently when innovative systems are involved.

## ***About the Author***

Adam Wheeler, PE, president of South San Francisco-based Sherrill Engineering, Inc., started commissioning building systems in 1994 and has dedicated his practice to it since 1997. He has found that his background in energy conservation, controls and HVAC design, combined with his experience both as a contractor and a design professional prepared him well to take on the challenges of commissioning. He has also found that commissioning is a great way to do something proactively about many of the frustrating problems that face building occupants, owners, contractors and design professionals. At this time he has personally completed over 150 commissioning design reviews and commissioned over 30 small, medium and large projects for research, educational and commercial clients.

## **Introduction**

LEED and similar programs seek to transform the way buildings are constructed and operated to reduce negative impacts such as those associated with non-renewable energy use. Such a transformation requires a transformation of buildings' systems and equipment away from current standards. Thus, non-standard or "innovative" systems and equipment must be employed. For a successful transformation of "business as usual," it is crucial that the new types of equipment and systems employed have a high rate of success in achieving the stated goals "on the ground" over their full life cycles. Otherwise, people will conclude that the transformation is either too difficult or even impossible.

However, the innovative equipment that must be employed has not been produced or installed for as long as or in similar quantity to standard equipment. Consequently, manufacturers, designers, vendors, installers and building owners are all less familiar with the equipment than they are with more "standard" applications. The result of this is a much-increased risk of errors or problems, from the beginning to the end of the process, that threaten the very essence of the intended outcome. Luckily, the commissioning specialty has developed to address exactly these sorts of problems, albeit at a more "standard" risk level. Therefore, commissioning throughout the design and construction of such projects may be doubly important and should be practiced at an intensive level for best results. This is critical not only for the protection of the investment being made in an enhanced construction process for a particular building, but also for the protection of the goals and reputation of the green building movement as a whole in the long term.

### ***What is an "Innovative System?"***

Market forces, with a relatively minor regulatory element, largely drive the evolution of "standard" building equipment and systems. In order to compete, manufacturers and engineers must provide products with the lowest possible first cost that are reliable and also offer low operating cost. Innovations that set equipment apart from the competition in terms of performance must generally be justified by a very strong and quick return on investment and require huge investment before economies of scale are achieved. In this conservative environment an innovation must surpass a very high barrier to displace a time-tested approach, reach economies and other advantages of large-scale production and become incorporated as a "standard" procedure. Before this happens, the equipment or systems in question must go through a transformation period (think of "beta testing") where those who adopt the innovation incur the associated heightened costs and risks. When a force that is essentially non-market, such as LEED, drives or accelerates the application of innovations, the barrier is lowered and there is a tendency for those innovations to pervade the market at an earlier stage of development. This is likely to extend the transformation period where adopters incur some of the burdens associated with un-tried or less-tried approaches.

Some examples of equipment and systems in use today that we consider "innovative" to varying degrees because they do not appear to be "standard" procedure follow:

- Heat recovery systems
- Evaporative cooling
- Stack-effect cooling
- Ground-source heat pumps
- Thermal energy storage
- Underfloor air distribution
- Low temperature air distribution
- Daylight / dimming
- Local renewable energy (photovoltaic, solar thermal, wind, etc.)

### ***What do LEED and similar programs require from Commissioning?***

The LEED Rating System and similar standards generally call for development and execution of a commissioning plan covering commissioning of energy using building systems and equipment. While various guidelines are referenced, the intensity, or level of detail of the effort remains open ended and is largely left up to the commissioning provider to determine, within the owner's budget allotment. It is very important that the intensity of the commissioning effort be closely tailored to the nature of the systems and equipment being commissioned for optimum results. Innovative equipment and systems require an intense level of commissioning because they are relatively unfamiliar to designers, installers, operators and even their manufacturers. They simply are not produced or used in the quantity that "standard" systems are and are usually evolving faster. Consequently there is more that can "go wrong" along the way from concept to operation. LEED effectively calls for the application of innovative systems and equipment but does not spell out the relative intense scrutiny they often require through every step of the design and construction process.

### ***Why Are We Here? (Why has Commissioning Become Important)?***

Commissioning of buildings as a specialty distinct from the designers' role is relatively new and practiced in a wide variety of "flavors." There is a growing consensus that "we need it" – but many who believe also find it hard to define exactly what "it" is. To understand why innovation necessitates a more intense level of commissioning, and what forms this might take, it is helpful to consider some of the forces responsible for the growth of commissioning as a distinct specialty.

### ***Increasing Complexity / Capabilities of Controls (and other systems)***

One factor that has been driving the need and growing practice of commissioning over the last decades is the "microchip revolution." This has provided us with the sophisticated direct digital controls (DDC) systems that are now used in virtually all buildings of substantial size. These controls bring formerly impractical operational sequences into the realm of the feasible. Now if you can imagine it, the control system can probably do it. The inevitable result is many instances of greatly increased complexity in order to achieve improved building performance.

Coupled with the proprietary nature of the control marketplace and the rapidly evolving nature of computers, this has resulted in a situation where it is close to impossible for an HVAC design engineer to maintain a detailed understanding of the different manufacturers' DDC offerings. This makes specifying controls for competitive bidding much more difficult than it was when a control system would be built up of standard off-the-shelf pneumatic components. The solution many designers have arrived at is to specify the control system in terms of written descriptions of performance, and leave the actual application engineering of the system to the vendors resulting in a "design-build" type of scenario for the control system. So the complexity of the system means that there are lots of little things that can go wrong, often without being noticed by someone who's not really looking for them, and the designers (and other parties) who are not control specialists are not qualified to analyze or understand their operation. Furthermore, the controls contractor may now find themselves as the only players equipped to truly comprehend their product, managing the conflicting interest of optimizing this esoteric system's design and operation and optimizing their profit outlook. On a more limited scale, complexity of building systems has increased also in recent decades, and burgeoning code requirements contribute to both of these trends. This leaves the building owner unacceptably exposed to the risk of operational problems as experience has shown. Enter the commissioning provider, bringing the necessary control system expertise in a role as the owner's advocate.

### **Increasing Specialization of Designers**

Compounding the challenge of assuring the quality level of complex building systems, our culture seems to drive professionals to become more and more specialized as time goes on. Hence, the mechanical engineer who in a bygone era might "babysit" his design as it is implemented now finds that productivity demands that he stay at his desk producing more designs instead. His proposal for field construction services may have been a victim of cost-cutting. He may not have a good understanding of the function of the DDC system provided anyway, or of certain other complex subsystems such as variable frequency drives (VFDs). But the result is nobody with detailed design understanding in a position to verify the proper implementation of the design. And a corollary is designers with less "real-world," hands-on field experience of what may happen when their designs transform from a pile of paper into a 3-dimensional life-sized building. Both of these trends mean more potential problems for building owners. Commissioning providers are working to identify and correct any such problems as early as possible and boost the quality level of the completed building project.

### **Increasing Competitiveness / Pace of Business / "Bottom Line" priority**

A further factor driving the growth of commissioning is what seems to be a continual gradual increase in the competitiveness of business, the pace at which things are done, and the priority of "the bottom line" (profit) in our society. All these forces can have a negative impact on quality, if allowed, and the results can be seen all around us, like on a set of HVAC design drawings, for example. So along with the growth of these forces, a corresponding growth in forces to assure acceptable quality must happen to protect the interests of building owners and users. Commissioning is part of this latter growth.

## Perils

In this section a few of the problems associated with innovative systems and equipment during design, construction and operation will be discussed. The term “Design Phase” is used here to incorporate all pre-construction design work including programming, design development, etc.

### ***Design Phase Perils***

During the design phase, architects and engineers must work together with owners and vendors to assemble plans and specifications that will enable the construction team to build a complete building. This time-tested process is not without its challenges as the design team tries to pin down a multitude of moving targets, etc. However many design firms have managed to master it and produce plans for building after building, learning lessons for the next project, until the process becomes familiar if not routine. Incorporating innovative systems and equipment adds a substantial new level of challenge to many aspects of this already challenging process, like venturing into uncharted territory or performing a trapeze act without a safety net. This calls for a heightened level of care to avoid pitfalls like unsatisfactory equipment performance, faulty application of products, inaccurate engineering estimates and other errors and omissions.

### **The Peril of Irrational Exuberance**

This may be the most basic and pervasive of all the design phase perils and is also one of the most pernicious. We all want to save energy and improve performance, but the reality is that easy gains in these areas are rare. Consequently, when considering an innovation, it is very easy to overlook some of the costs and other operating difficulties and overestimate the savings. The excitement generated by an innovative approach can also lead to losing track of the building’s operational requirements (design intent). What may sound like a good idea at first may not stand up to careful analysis. But often the analysis is not performed with sufficient rigor. For example, waste heat recovery seems like an easy area for savings. But extra motive (fan or pump) energy will generally be required to overcome pressure losses from the heat transfer medium. And the system may encounter some or all of these losses even when no heat recovery is needed or available. Certainly, most systems operate partly loaded the majority of the time. And the need for heat may not coincide with availability. Consequently, the anticipated savings may never materialize, and the risk of increasing operating cost due to malfunction or operator error is introduced.

### **The Peril of Poorly Applied Standards**

While most buildings are unique, design standards are general by nature, and at best may be tailored slightly for a particular application. When a rating system such as LEED calls for exceeding a standard, the intent is clear. However care must be taken that the standard is in fact applicable in the specific instance if the owner is to realize the value implied by the rating system. For example, a situation where comfort criteria are not stringent may be air conditioned

with great savings compared to standard comfort requirements, resulting in apparent conformance with the intent of the standard. However, the savings stem from the operating criteria rather than the system design and would be present in the absence of the standard anyway, so no addition of value through design has occurred.

## **The Peril of Unfamiliar Systems and Equipment**

When an innovative system or piece of equipment is specified, it will clearly not be the same one that worked well on the last 100 projects. Its application criteria will need to be mastered and its interaction with other systems analyzed carefully. It will not have the track record that standard systems have, making the available reference literature less supportive. Innovative equipment will not have been produced in the same volume as standard equipment, so the manufacturer will know less about the ins and outs of the equipment performance in various applications themselves. Where the designer may be accustomed to specifying rated equipment, the innovative equipment may not be subject to the same or similar ratings. Consequently, performance assumptions may need to be reevaluated and ratings verified where they are not certified by a reputable body. For example, mechanical engineers rely on ARI certification to validate manufacturers' performance claims. If a unit without mechanical cooling is substituted as an innovation, that unit may not have the ARI certification, and field performance may not match expectations.

## ***Construction Phase Perils***

The construction team must take the documents provided by the design team and from those sheets of paper and produce a complete building with myriad functioning systems and sub-systems. Numerous highly skilled and experienced craftsmen and managers work together with less skilled and experienced individuals to make this happen. These individuals and their organizations are trained and experienced mainly with a variety of "standard" designs, so innovations will change the way they must do things.

## **The Peril of Low-Volume Equipment Manufacturing**

Innovative equipment will certainly be produced in lower volume than its "standard" counterparts. In many cases it will be more or less custom fabricated. Lacking the template of a tried-and-true product to follow, defects traceable to poor design and manufacturing will inevitably crop up. These may not be recognized as defects until the equipment is on site, installed or even operating. Furthermore, the literature accompanying the equipment will not be as developed as standard documentation, and may lack well developed installation and startup guidelines for field personnel to follow.

## **The Peril of Installing and Starting Unfamiliar Systems and Equipment**

The individuals installing, starting and testing new building systems and equipment have likewise gained most of their training and experience with standard types and will likely be less

than prepared for changing procedures to accommodate innovation. Even if they are lucky enough to have specific installation and startup instructions, they may not read them. Chances are they will install and start innovative systems and equipment as they are used to doing with standard equipment unless a concerted effort is made to tailoring procedures to the innovation.

### ***Operational Phase Perils***

Building operators are faced with the same challenges as designers, manufacturers and installers. Without careful and thorough training on innovative systems, covering everything from design intent to manual operation and required maintenance, the innovative systems will be operated like standard systems as much as possible and may never achieve the intended effect.

## **Commissioning to Address Perils**

Luckily, the practice of commissioning has developed to provide quality assurance geared toward proper function of building systems and subsystems. Thus it is well suited to address many of the issues that come with accelerating the introduction of innovations to the building industry. Since these issues introduce new challenges and uncertainties to the process of new construction, a heightened level of commissioning is called for to catch and facilitate the correction of problems as early as possible in the process and assure a successful outcome.

### ***Design Phase Commissioning***

The commissioning provider's emphasis on functionality can make him an invaluable asset to the design team in maintaining and raising the level of quality of the design. The roles of owner's advocate and "keeper" of the design intent can provide perspective to help the application of innovations stay down to earth and connected with reality by reviewing documents with a skeptical eye and a system-wide perspective. Special attention should be given to all innovative systems and equipment to assure they are selected and applied properly and with care, appropriately for the situation and that plans and specifications are enhanced throughout to address the differences from standard applications and the unique and new requirements. The rigor of any life cycle costing or other cost-benefit analysis should be carefully scrutinized. Additionally, the commissioning provider should help the owner tailor the QC/QA program to appropriately anticipate the challenges innovations may introduce during the construction phase. This may very well include factory witness testing for innovative equipment if successful previous installations cannot be demonstrated, even if the analogous "standard" equipment would not merit such efforts. Measures such as enhanced submittal review, samples and mockups should also be considered.

### ***Construction Phase Commissioning***

The commissioning provider should consider raising awareness of the intent and nature of innovative systems and equipment among the construction team. Appropriateness of installation and startup plans should be assured and may have to be developed virtually “from scratch.” A proactive approach of facilitating the awareness of unique installation and startup requirements including access to appropriate documentation will prove more effective than a more distant contractor-driven documentation review approach alone.

### ***Operational Phase Commissioning***

As with the commissioning of any project, training is critical for the ultimate proper operation of the facility. However, with new and unfamiliar systems it is even more critical. Background such as design intent and operational theory must be included. As real learning takes time, repeated sessions over the months and even years following completion of construction are recommended.

## **Case Study Examples**

Following are some examples of innovative systems that suffer from various problems traceable to design, manufacturing, construction and/or operation. Hopefully these illustrations of typical pitfalls will help similar problems get caught and corrected earlier or avoided altogether on future projects

### ***Heat Recovery Unit Ventilators***

This case highlights 28 classroom heat recovery unit ventilators installed in Oakland, California under the Collaborative for High Performance Schools (CHPS) rating system, similar to LEED. An earlier and more focused design review might have identified flaws and faulty assumptions early enough to redirect resources more effectively. Samples, mock-ups or factory witness testing might have prevented other manufacturing related deficiencies that were discovered. And a more intensive construction phase commissioning program focused on the innovative equipment might have benefited the project schedule and improved the final installed quality.

### **Design (equipment selection / application) Issues**

These heat & ventilation units feature a refrigerant filled “heat-pipe” for waste heat recovery from exhaust air and 3 fans (100% outside supply air, recirculated air, exhaust air) with a variable frequency drive. Due to the mild climate it seems unlikely that the extra fan energy consumed by the 3 fan motors and extra coil pressure drop can be justified by any gas savings from heat recovery over a conventional mixed air classroom unit ventilator. However these units were recommended by the manufacturer and vendor for this application. Energy consumption monitoring results appear to indicate slightly higher than average consumption.

Manufacturer's marketing and submittal literature indicated airflow volumes that could not be achieved in the field. As the data were not certified by ARI or any other industry body, there appears to be no recourse than to accept that the literature was inaccurate and reduce the classroom occupancy in accordance with the reduced ventilation.

## Manufacturing Issues

These units are unacceptably noisy for classroom use at high speed, further reducing the practical ventilation rate. Also, the motors (controlled by the VFD) appear to generate high pitched hum or whine during operation. Filtration capacity was not provided as submitted. Rather than the listed 1" standard disposable filters, the units feature 1/4" reusable filter media installed in such a way as to be very difficult to maintain. The units were shipped with multiple functional problems such as screws obstructing damper blade movement, etc. Construction issues included excessively leaky plenums, poorly attached liner and no provision for securing the units to the structure. Furthermore, the units were provided with a right-hand heating section and left-hand piping connections. To achieve this, the factory saw fit to route the uninsulated 3/4" copper hot water supply and return piping through the full 48" width of the exhaust air plenum, thus dumping heat to the outside (see figure A)! And these units are billed as innovative, energy saving "green" products!



**Figure A:** This photograph shows the bare copper hot water piping situated in the exhaust air stream of these “energy saving” units.

## **Installation Issues**

As these units were not standard classroom ventilators, the installation team, though not inexperienced, was faced with improvising several elements of the installation with results that compromised the unit performance. The supply air and return air connections stubbed out the back of the unit were not long enough to traverse the full thickness of the exterior wall. Consequently they were terminated with no connection to the exterior louvers, and exhaust air was recirculated within the wall to the supply air inlet, lowering the outside ventilation air quantity.

## **Operational Issues**

While O&M personnel were provided with documentation, the training sessions did not adequately familiarize them with the unit theory of operation and controls. Consequently they found themselves unprepared when repairs were required a year later. Furthermore the control wiring documentation was discovered to be incorrect.

## **Classroom Daylight / Dimming System**

This case highlights a three-stage step-dimming system installed in 21 classrooms with skylights.

## **Design (equipment selection / application) Issues**

The original contract drawings contained a non-applicable detail of this system. This was later corrected as a construction bulletin, but the contractor’s field personnel were not provided with the change and installed the components incorrectly

## **Installation Issues**

The installing contractor personnel were not sufficiently experienced or motivated to adjust the systems in accordance with the manufacturer’s recommendations. The light level sensors were not installed in accordance with the plans or manufacturer’s recommendations, resulting in a tendency for the lights to cycle under certain conditions. The occupancy sensor interface was never connected, resulting in the lights staying on continuously.

## **Operational Issues**

Due to poor installation, the teachers have experienced annoying malfunctions of this system and many favor removing it. The O&M staff training has not been adequate and they are not currently prepared to maintain or adjust the system, which they lack experience on as they do not have installations at any other sites.

## **Conclusions**

No reward comes without first taking a risk. But risks carry with them expenses which may be looked at as an investment toward the reward. In the case of accelerated adoption of innovative building systems as fostered by LEED and similar “green building” rating systems, commissioning may be used to mitigate the associated risks. But the expense of this mitigation or “insurance policy” should not be underestimated, as “innovative” systems merit a substantially heightened level of scrutiny. Further increased costs are incurred by the extra time required to perform design and construction tasks that deviate from standard procedures.

The accelerated adoption of innovative systems is critical to achieving the goals of the green building movement. But these systems also bring an increased risk of unsatisfactory performance largely due to their “newness.” Unsatisfactory performance of building systems poses a great risk to the long-term goals of the movement, as a reputation for poor comfort, poor energy performance or other unrealized promises would quickly steer interest away from these programs. By tailoring commissioning appropriately to the requirements of innovative systems, particularly during the transformation period, this risk to the movement may be mitigated and overcome.