Where's the Beef in Continuous Commissioning? Results from 140 Buildings in Commercial Property and Higher Education

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ABSTRACT

Persistent commissioning, also known as Continuous Commissioning® or Monitoring-based Commissioning, uses technology to mine savings from a stream of data from building management systems. It has proved to be an effective approach to delivering verifiable savings for commercial and institutional customers. Continuous monitoring of the building uncovers savings opportunities over the life of the project, which typically runs for at least three years[1]. In our experience, well-qualified buildings can deliver 11-20% of the addressable energy spend (i.e. energy consumption that is visible from the monitoring data-stream).

The successful project combines automated data mining with experienced engineering support. The engineering support is a critical component. Many facility teams are resistant to dashboards, however sophisticated, because they lack the time, skills, and/or budget to take action on the information.

In this paper we discuss the driving factors behind persistent commissioning, the settings where it has proved successful, the details of how savings are delivered, the challenges and strategies to overcome them, and finally, some thoughts on the design of incentive programs to support persistent commissioning.

All commissioning activities deliver non-energy benefits. While the energy industry has developed robust EM&V procedures for energy savings from commissioning measures, the procedures for non-energy benefits are a work in progress. As a result, this paper focuses exclusively on the energy savings.

We note that this approach is now moving from the early adopter phase into early majority, where cautious facility teams can rely on solid case studies over multiple years. This is an opportune time to be considering the role of persistent commissioning in a program portfolio.

Introduction

Definitions

Building owners and operators in every sector are being asked to reduce operating costs while meeting ever-expanding energy standards. This paper discusses one approach, persistent commissioning, that is successful for large buildings and campuses with an engaged facility team.

The California Commissioning Collaborative has taken great pains to define the terms used in commissioning. To begin, when "Commissioning" is applied to *new buildings*, we mean "an intensive quality assurance process that begins during design and continues through

[1] Ideally, the monitoring lasts for the life of all measures uncovered. We (EnerNOC) simply do not have enough data points for extended monitoring. We also see that commercial arrangements for monitoring are subject to changes in budgets, policies, and management that may cut short the project before the end of measure life.

construction, occupancy, and operations. Commissioning ensures that the new building operates initially as the owner intended." (Portland Energy Conservation Inc., 2006)

In this paper, we discuss commissioning as applied to *existing buildings only*. The typical approach is called retro-commissioning (RCx), which is a systematic quality assurance process applied to a building, with the goal of improving its operation and maintenance to get to optimal building performance. RCx typically focuses on no-cost and low-cost savings measures[2] (i.e. measures where the payback is less than 12 months).

The Need for a Persistent Approach

Why is persistent monitoring beneficial in this context? Any quality assurance process runs into the same problem: how can one monitor the quality of a complex system by sampling? RCx suffers from two sampling problems:

- Scope. A typical large building has over 5,000 endpoints that are being controlled and monitored: everything from valves to fans to pressure sensors to temperature sensors. It is rarely cost-effective to run the analysis on all of these points during a one-time study.
- Timing. A retro-commissioning study is typically performed once every 3-5 years and lasts only a few months. If the building changes in any way in those 3-5 years, the RCx process will have less impact. For example, a sensor can fail the day after the RCx report is submitted, and this may not be addressed until the next study.

A classic story from our experience illustrates the problem. At a California university campus, our team was engaged with retro-commissioning. As we entered the M&V phase, there was a brief power outage in the building. As a result, the AHU (air handling unit) controllers switched from a carefully calibrated sequence of operations to their default setting of 24x7 operation. Fortunately, this was immediately seen in the M&V data. However, had this power outage happened 2 months later, the 24x7 operation could have persisted for months before the facility team uncovered the problem.

What is needed is a solution that addresses both the scope and timing problems by using technology to apply the rigor of retro-commissioning across the entire scope of the building on a continuous basis. A couple of terms have come into common usage:

- Continuous Commissioning®[3] is a specific approach that was created at Texas A&M University
- Monitoring-based Commissioning, or MBCx, is a different approach popularized in California in the partnership between the IOUs, the University of California system, the California State University system, and California Community Colleges.

In order to avoid confusion with these specific approaches, this paper uses the term "**persistent commissioning**" which is a continuous process of commissioning buildings and their equipment,

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[2] In this paper, the term "measure" applies to a specific activity to reduce energy consumption such as changing a control sequence or repairing equipment.

[3] Continuous Commissioning®, CC® and PCC® are registered trademarks of the Texas Engineering Experiment Station, a member of the Texas A&M University System, an agency of the State of Texas.

but is not governed by the specific approaches described above. In this view, persistent commissioning includes the following elements:

- monitor the building points continuously, 24x7x365
- use sophisticated software to mine the data for performance issues
- assign costs to these issues (typically excess energy spend)
- bubble up the highest priority issues
- facilitate analysis by trained engineers
- provide actionable recommendations to building operators, focusing on no-cost and low-cost measures
- deliver savings across all energy commodities (electricity, gas, fuel oil, centralized chilled water or steam, etc.).
- track project status and savings

The goals of retro-commissioning and persistent commissioning are the same – but then so are the goals of an annual check-up and an implanted pacemaker. The value is in the persistence of the results.

Overview of Buildings Studied

Our team at EnerNOC has delivered persistent commissioning to over 140 buildings covering over 39 million square feet. We have applied this process to buildings in many settings:

- Commercial office (downtown high-rises, suburban office parks)
- Commercial R&D facilities (aerospace testing, pharmaceutical labs, etc.)
- Government office (administrative centers, public buildings, judicial and correctional)
- Universities (academic buildings, dorms, labs, recreational facilities)
- Healthcare (inpatient and outpatient)
- Mixed-use (office + manufacturing)

Table 1. Summary of Buildings in the Portfolio

Education	Office & Technical	Health Care
73	64	7

In all cases, our approach is to monitor energy-consuming equipment and the settings/environment that influence that equipment. We have found that the most reliable source for the data is the Building or Energy Management System. There are many variants of these systems, but for simplicity in this paper, we refer to all of them as BMS.

However, the BMS cannot provide the whole picture for a building. For some points that are not connected to the BMS (such as large plug loads or server closets), it is necessary to introduce separate data loggers for monitoring. Finally, the building operator is concerned with total energy costs, so persistent commissioning includes metering at the whole building level for demand profiles, total energy usage, and for cross-checking the BMS.

To the degree that lighting is under central control, it is amenable to persistent commissioning, but where lighting is controlled exclusively by wall switches, there are limited options. It is important to note that persistent commissioning does not address plug-loads that have no central control (e.g. personal computers, space heaters, technical equipment, task lighting).

In all of these settings, the primary motivating factor for the building owners and operators is energy savings, or more specifically, dollar savings. However, facility teams tell us that they also enjoy other benefits from persistent commissioning:

- reduced operations & maintenance costs
- improved Energy Star scores
- reduced hot and cold calls from failing equipment
- more time to attend to preventative maintenance and other issues of occupant comfort
- reduced greenhouse gas footprints.

As mentioned above, the EM&V procedures for savings from non-energy benefits are a work in progress. As a result, this paper focuses exclusively on the energy savings.

Implementing Persistent Commissioning

We now move to the question of implementation: where does persistent commissioning work, how is it put into practice, and what savings does it find?

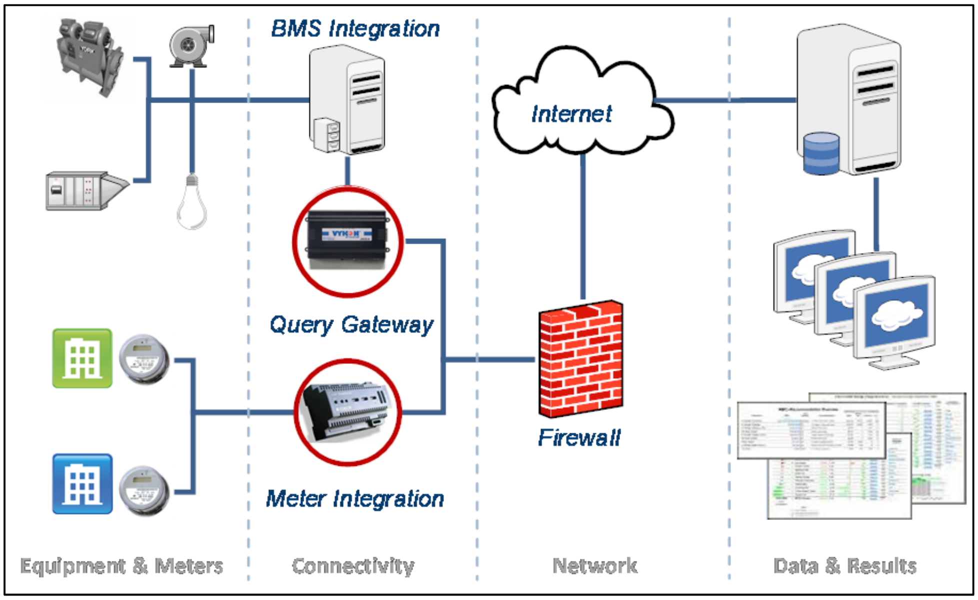
Connecting the Building

Persistent commissioning is built on a stream of data from the building. So it is critical to establish data-streaming as quickly as possible in the project. Fortunately, the tools of the trade have advanced considerably in the past few years, from the connectivity options in the BMS, to the broader adoption of BACnet (a data communication protocol for building systems), to the standardization of gateway devices, to the increasing "Internet of Things" in buildings. Figure 1 on the following page is an example of the connectivity for a typical building.

Types of Data Collected

The data-stream from the BMS includes control signals (e.g. fan on/off), sensor readings (e.g. duct pressure, outside air temperature), equipment status (e.g. damper open, fan speed, valve position), and energy consumption (e.g. kW used).

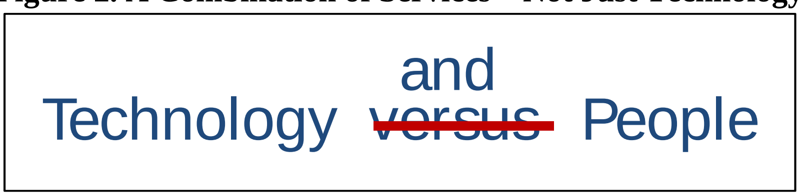
Figure 1. Connecting the Building (Internal EnerNOC Diagram)



Identifying Measures

We have found that connecting the building and displaying information is simply not enough. Persistent commissioning is sometimes presented as a "rich dashboard experience" with relatively little engineering services. But in our experience even the best facility teams need solid engineering assistance, combined with a consistent process for implementing measures, to achieve savings.

Figure 2. A Combination of Services – Not Just Technology



Why do dashboards and reports on their own not deliver the expected savings in this setting, as they appear to do for residential customers (Allcott, 2011)? Facility teams report multiple reasons[4]:

- Building occupants can be very sensitive to changes, creating a host of problems for the facility team. A typical home-owner can make some energy-saving changes then quickly revert if the result is unacceptable. The facility engineer does not have this luxury.
- The facility team is often constrained by budgets, staff time, or staff expertise. Dashboards are simply not aware of these constraints, so can deliver a sequence of recommendations that the facility team will never implement.

[4] For more discussion on this point see: http://www.greentechmedia.com/articles/read/Guest-Post-The-Energy-Dashboard-Delusion-Part-1/

- Facility teams are proud of their role while also being sensitive to job security. Any serious approach to energy savings in buildings must address these concerns carefully. By contrast, the typical homeowner is the CFO, the building manager, the chief engineer, and the occupant.

To overcome the caution of the facility team, we begin projects with a targeted RCx mini-project including the typical tasks of pre-functional testing, review of sequences of operations, and assessment of equipment not connected to the BMS (e.g. decentralized lighting). This mini-project serves the dual purposes of identifying an initial set of measures while establishing a core relationship with the facility team.

When the BMS data-stream comes online, the RCx project team then continues with a regular process of recommendations and review for the duration of the engagement, typically an initial period of three years, which may be extended. The on-the-ground experience from the mini-RCx project ensures that recommended savings measures align with the expectations of the facility team.

The real value of the technology is in data mining, where gigabytes of data can be rapidly parsed for high-priority issues that merit an engineer's attention. The challenge, of course, is that buildings are complex systems that demand sophisticated rules for trapping real issues, avoiding too many false positives. At the same time, the volume of data is not the same as, say, daily transactions for a large commercial bank. Vendors have taken a variety of approaches to balancing the necessary sophistication of data mining with the cost of software development.

What Does Persistent Commissioning Find?

Two tables below provide some insight into how persistent commissioning delivers results. Table 2 discloses the source of some typical savings measures that we find in a building, broken out by the cost of the measure. Table 3 shows that persistent commissioning finds many different types of savings opportunities which can be broadly divided into fault detection (i.e. malfunctioning or poorly calibrated equipment) and operational changes (i.e. equipment scheduling, equipment setpoints, behavioral changes). Table 3 shows average values across all buildings we have studied so may not apply to any one building.

Table 2. Savings Accrue from No-Cost, Low-Cost and CapEx Measures

Category	Examples
No Cost	• Optimize chiller scheduling • Add night-time setback on chiller supply temperature to reduce unnecessary cooling • Implement algorithm for static pressure reset on AHU • Implement algorithm for supply air pressure reset • Repair damaged actuators or dampers on air-side economizer
Low Cost (<1 year payback)	• Repair leaking valve in chilled water loop • Change AHU speed-drive fan belt from V-belt to more durable and more efficient Synchronous Belt • Rebalance minimum outside air fraction on air-side economizer (includes installing a modulating damper actuator)
Small CapEx (1-2 year payback)	• Install variable frequency drive to facilitate reduced fan speeds during partial load conditions • Replace bag filters with sealed frame filters in AHU to reduce static pressure and allow fan's VFD to operate at lower speeds. • Install isolation dampers in fan system in certain tenant spaces to avoid unnecessary conditioning during unoccupied conditions

Table 3. Savings Derive from Fault Detection and Operational Changes

Fault Detection		Operational Changes	
Control Error	22%	Cooling Controls	18%
Sensor Error	9%	Schedule	15%
Damper Error	6%	Retrofit	14%
Setpoint Error	3%	Heating Controls	2%
Other	7%	Other	4%
Sub-Total	47%	Sub-Total	53%
		Total	100%

The $20,000 Chess Club and the $9,000 Valve

A couple of examples help to illustrate the persistent commissioning process. The first example is in a university setting. Our data showed that an AHU in a classroom building was running 24x7. Since the building was properly cooled during the day, there had been no complaints from occupants, so the team had not noticed this condition. We recommended a night setback to the facility team who implemented the change. This is a typical RCx finding. However, over the next few weeks, we noticed that the AHU *reverted* to 24x7 operation. Our alert engineer noted that this reversion happened at an odd time, 5 pm on a Tuesday evening. The facility team quickly discovered that the Chess Club met in the building at that time. Feeling uncomfortable, they asked the janitor to fix the cooling. Using a broomstick, the janitor reached up to the override switch and pushed it to manual.

Realizing that this was a repeating problem, the facility team installed a padlock on the manual override to prevent a recurrence. The persistent monitoring ensured that this particular problem did not come back, and that the same problem did not happen elsewhere on campus.

A remarkable thing about this story is that the AHU could have run 24x7 for months or years without the facility team being alerted. Taking hours of operation into account, we estimated that disabling the manual override resulted in $20,000 of annual energy savings for the university. And the cost to implement this measure? A $5 padlock fixed the problem.

A more prosaic example recently came up in a high-tech office. Our fault-detection algorithms found that two AHUs were supplying air that was consistently cooler than the setpoint. The fault is a chilled water valve that does not close completely – the BMS thinks that it has stopped cooling the air but chilled water is still flowing. The facility team would never notice this because the reheat coils at each end-point delivered comfortable air to occupants, and because the building has a ring-duct system that mixes supply air from multiple AHUs.

Our calculations show that a simple repair to the valve delivers $9,000 in annual energy savings. In this case, persistent commissioning found the problem in one location, ensured that the repaired valve is closing completely, and monitors all the chilled water valves to ensure that the problem does not occur elsewhere in the building.

The Program Perspective

While RCx is becoming accepted as a standard offering in utility energy efficiency programs, the first question that prospective program managers ask about persistent commissioning is: How do you measure success?

Our main approach is to use International Performance Measurement and Verification Protocol (IPMVP) option B: calculated equipment-level savings. Both customers and program partners want to be sure that savings recommendations are credible. As a result, our engineers take great care to calculate savings from each measure based on actual measurement from streaming BMS data and realistic assumptions about building operations. For example, a chiller optimization measure will account for actual operating schedules as well as expected year-round temperature variations.

There are some individual measures where IPMVP option A is available, such as lighting replacement, since the program can use deemed savings that the program manager pulls from other programs.

In general, the California Commissioning Collaborative has done an excellent job with guidelines for calculating equipment-level savings.

Delivering Savings

In well-qualified buildings, we typically see savings around 11-20% of addressable energy (i.e. the energy spend visible from the data-stream) and a simple payback of less than 20 months for the persistent commissioning project. This is a compelling story for any building operator. Note that payback times are always improved by utility incentives. (It is worth adding that while payback is often derided as a valid financial metric for long-term energy savings, it is in widespread use, so that owners will often not proceed if project payback exceeds 24 months.)

Building managers are often thinking of costs per square foot, especially in the commercial sector. Table 1 shows that savings per square foot have a measurable impact, and that there is a wide range of opportunities in different settings.

Table 4. Savings per Square Foot are Measurable and Show Wide Variation

Sector	Average Savings ($/square ft)	Max Savings ($/square ft)
Higher Education	0.41	3.30
Commercial Office	0.16	1.29

Note that these savings levels include all fuels. Persistent commissioning identifies savings measures for electricity, gas, or any other commodity consumed by the building (including centralized chilled water or steam).

As mentioned above, persistent commissioning has also been applied in commercial R&D facilities, healthcare, and mixed-use buildings. Facility teams in these settings are typically more cautious, so we have fewer samples to examine. However, our "early adopters" are seeing results that are between commercial office and higher education.

Success Factors

After several years of activity, we have learned that the following factors are critical for success:

- *Continuous occupation*. Persistent commissioning creates more value in densely occupied, centrally controlled buildings like commercial real estate, hospitals, universities; there is less value at buildings that are used irregularly, like conference centers or entertainment venues.
- *Engaged facility team*. Since persistent commissioning issues a series of facility recommendations over several years, it works well where the team is looking for improvements, has some time to implement the measures, and is welcoming of outside support.
- *Visibility to end points*. Persistent commissioning relies on visibility to key energy-consuming equipment (e.g. chillers, fans) and end-points that determine energy consumptions (e.g. VAV boxes). The relevance of the connected end-points is much more important than the total number (e.g. 1000 points can be fine, even in a large building). Of course, the ability to connect to the BMS is important, so this is another example of where an engaged facility team helps to drive any necessary IT changes.
- *Early discovery*. Busy and changing facility teams simply do not know all the details of a complex building or campus. Our projects have gone well when our discovery process is extensive and begins as early as possible.

While building size has been an important factor, it has become less critical following improvements in building technology and connectivity options. Nonetheless, because persistent commissioning is resource-intensive, it is hard to make the economic case for a project in buildings or facilities where the energy spend is below $1 million annually.

Challenges

While persistent commissioning has proved successful in multiple settings, it is worth discussing some of the challenges and how they are overcome.

Challenge 1: Making the business case

In general, Persistent Commissioning projects have three cost components: an upfront deployment cost, an ongoing cost of the service, and an occasional cost of implementing measures (this is lower than with many projects because of the focus on no-cost and low-cost measures).

It has been shown time and again that utility or agency programs have a big effect on decision-making since they reduce the out-of-pocket costs to the end-customer. The increasing volume of buildings that have adopted this approach is also helpful, as the market has moved from early adopters to the early majority, where cautious facility teams can rely on solid case studies over multiple years. In general, we have also been encouraged at the adoption of persistent commissioning outside of utility programs.

One critical point to make is that shared savings approaches have not been successful. There are two main reasons for this. First, shared savings reduce the upside for the customer – the vendor takes a portion of every dollar saved – decreasing the motivation for the facility team to push as hard as possible for savings. Second, shared savings can have a perverse effect on teams not to pursue measures or to claim that the measures were known despite evidence to the contrary. We have found that variants of a fixed fee are always more effective, particularly to ensure that a building team will proceed with implementing measures.

Challenge 2: Getting measures implemented

As mentioned above, facility teams are often constrained by time, budget, and expertise. We address this issue in a number of ways:

- Ensure during the pre-sales phase that the team has executive support to focus time and resources on energy savings measures. In particular, we work with finance executives to establish a clear financial plan for the project.
- Spend time with the team during the mini-RCx project to understand the priorities and constraints. Persistent commissioning can then mesh with the team's needs, while encouraging them to meet their own goals.
- Provide a consistent process with regular check-ins that acts as a forcing function for change.
- Support the team as needed with additional calculations, implementation suggestions, vendor selection, and occasionally vendor management.

Challenge 3: Connecting the BMS

Persistent commissioning relies on a steady data-stream from the building. This is not always straightforward, although technology improvements have made it easier, even in the few years that we have been delivering the service.

With some buildings, the best approach is to be honest about the opportunity at the outset. Perhaps the BMS is old, or perhaps the vendor is intransigent, or perhaps the IT team is overloaded. In those cases, we recommend retro-commissioning as a very valid alternative.

Once the team has determined that connectivity is an option, the key word is "flexibility". While standardization is an important goal, we have found that no two installations are the same. Even if the same vendor has installed the same model of the same BMS in two different buildings, the connectivity options are likely to be different. It is critical to build the time and expense of connectivity into the project plan and the project budget.

Challenge 4: Information Security

In certain settings, the question of information security is paramount. For example, defense contractors have legitimate national security concerns, while healthcare organizations need to comply with all relevant patient records regulations. In general, however, this challenge is fairly easily overcome. For a start, persistent commissioning tends not to send any data into the building, or at least it can be successfully configured without inbound data. In addition, the IT team can use multiple different protocols to export the data from the building, alongside their own firewall protections. In our experience, we have not encountered a single situation where security concerns have halted the project.

Program Design Ideas

There are a few programs around North America that address persistent commissioning, but many program managers are looking for the optimal design for such programs. We conclude this paper with a brief wish-list of program elements, driven by feedback from end-customers:

- Avoid being too prescriptive on the scope of work. Persistent commissioning is by nature an iterative process with the facility team. It is also changing rapidly as new technology comes onto the market. Focusing on results is important.
- Allow multiple industry segments into the program. Program managers have typically assigned specific measures to specific industry sectors, so it can be difficult to absorb a cross-cutting approach like persistent commissioning. However, our focus on no-cost and low-cost measures means that there is plenty of room for existing programs that focus on capital items, including standard deemed savings or custom measures.
- Allow individual customers to participate in the persistent commissioning program even if they are eligible for a different prescriptive program (e.g. you have a retro-commissioning program for hospitals, but the customer would rather pursue persistent commissioning). The important caveat is that customers choose between programs.
- Be creative about the initial project costs. As mentioned above, there are multiple cash streams associated with persistent commissioning, including a fairly sizable deployment cost. Adding some kind of upfront payment to the program can have an enormous impact on uptake. Think of this as a "base + commission" type of program, where the base payment helps customers kick-start the project, while the commission payment ($/kwh. $/therm) holds vendors & customers accountable.

- Allow persistent commissioning to follow retro-commissioning. The literature is fairly clear that buildings drift quickly after retro-commissioning (Mills & Mathew, 2009). Allow persistent commissioning to come in after retro-commissioning to ensure continued savings.
- Allow persistent commissioning in buildings with multiple accounts but one central control system. Office parks are full of low-slung buildings that are controlled together but occupied by different tenants.
- Allow incentives to span more than 1 year. The typical customer sees full project payback within 20 months, and signs up for a 3-year contract. Allowing the customer to take advantage of program incentives beyond the first year can make a big difference to payback times.
- Create a tiered program with different incentive levels for different sized buildings. The relative sizes of cash flows are different in large commercial versus small commercial buildings. Using tiered incentives in the program can address these differences.
- Ensure your organization is neutral on which measures and technologies a customer should adopt. So long as the customer is pursuing a savings goal, allow them to determine the solution that deliver the most results fastest.

Finally, if you are considering a persistent commissioning program, the Consortium for Energy Efficiency (www.cee1.org) has a whole-building committee that has created guidelines for commissioning programs of all sorts.

Conclusion

Persistent commissioning is an effective approach to savings for commercial and institutional customers. Continuous monitoring of the building uncovers savings opportunities over the life of the project, which typically runs for at least three years. In our experience, well-qualified buildings can deliver 11-20% of the addressable energy spend (i.e. energy consumption that is visible from the monitoring data-stream). However, it is important to note that savings only come to fruition when the technology is combined with expert engineering support.

Prospective customers for persistent commissioning should be qualified with a well-thought out screening process in order to maximize savings and ensure satisfaction. In our experience of working with over 100 buildings, the key success factors are an engaged facility team and a building management system that provides visibility to key energy-consuming equipment.

The typical project includes a deployment cost to set up data-streaming. Good program design should account for this early payment with some kind of upfront incentive, combined with performance payments to motivate customers and vendors.

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