Pursuing Perpetual Project Performance Persistence: Lessons from the Field

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ABSTRACT

Utility-incentivized, pay-for-performance custom energy-efficiency project savings are typically claimed based on first-year savings and an assumed lifetime. Despite measurement and verification validating first-year savings, not all projects live up to their long-term potential. Over the course of the Energy Smart Industrial program's 11-year history, engineers have returned to sites where capital projects installed, kilowatt-hours measured and verified, to find measures that no longer operate as designed. This impacts savings reliability, which affects both the program funder and the site's bottom line.

While formal risk-management strategies have been developed for use with large projects, typical energy-efficiency projects do not have the savings magnitude to merit such attention. Programs that involve continuous project monitoring can quickly identify issues; however, capital projects lack the same level of follow-up. Holistically incorporating error-proofing strategies into existing systems can protect savings with little additional administrative cost. This paper identifies some of the situations that typically lead to loss of savings, and examines some lessons learned that sites and implementers can apply to their whole portfolio of capital projects to ensure savings resilience.

The Quixotic Quest for Quality

Comprehensive energy-efficiency programs feature components encouraging both capital projects and strategic energy management (SEM). While capital projects have been a long-time mainstay of energy-efficiency programs, even most pay-for-performance programs rely on one-time measurement and verification of first year savings. While energy savings measure life is treated as if it is a single value (e.g, 10 years), this is the median of the bell-curve distribution of effective useful life. Not every project will endure for the full measure life, and some will last much longer. Generally, individual projects have no further follow-up unlike SEM, where continuous monitoring and reassessment are built into the program design.

However, programs that have long relationships with utilities and their customers can have visibility into the lifespan of capital projects. The Energy Smart Industrial (ESI) program, sponsored by the Bonneville Power Administration (BPA) is one such program.

BPA is a nonprofit federal power marketing administration based in the Pacific Northwest and markets wholesale electrical power from 31 federal hydroelectric projects in the Columbia River Basin to over 120 utility customers. As part of its statutory mandate, BPA promotes energy efficiency as the lowest-cost resource for meeting load growth. As such, BPA provides incentives for projects that have verifiable energy savings.

In 2005, BPA recognized the need to boost the industrial sector's contribution to the region's annual energy-conservation goals (Amundson, Martin, and Whitchurch 2017). The ESI program, which launched October 1, 2009, is a comprehensive program serving utility customers across the BPA service territory. The program uses a mix of dedicated program engineers and subcontractors to help develop and verify projects. This ongoing relationship means that engineers may return to sites after projects were installed. In some cases, conversations with site staff would include updates on how previous projects are, or are not, functioning.

The following industrial project examples presented certainly do not purport to be a comprehensive study on measure life. It should be noted that most projects are observed to operate as commissioned. While there will still be early project failures, this paper attempts to draw lessons that can be used to shift the curve, so project performance persists, if not in perpetuity, then for as long as possible.

Regularly Returning Reveals Recidivism

Although energy-efficiency projects can have multiple benefits for various stakeholders, not every project lives up to its design intent. While the energy efficiency community always has an energy perspective, most people are focused on operations, production, and keeping systems running. The examples that follow demonstrate various ways projects can be undone well after commissioning and M&V. In some cases, unexpected equipment failures occurred, in some cases work by one actor was undone by others, and in others, the project did not have enough momentum to endure for its expected lifespan. Program staff who return to the site and review project performance can help detect and resolve such issues.

One and Done?

Project managers must balance multiple requirements when specifying upgrades, and budget constraints almost always play a role in final decisions. It is well-known that incorporating energy-efficiency earlier in the design yields better results (Rossiter, 2019), but the cheaper versions can still have acceptable paybacks, especially when judged on first costs, and not taking into account lifetime-operating cost and durable commissioning.

At a wastewater treatment plant in Oregon, a primary filter was installed to remove organic matter prior to the aeration basins. In theory, this reduces energy intensity because the filtration system uses less energy than removing the organic matter through an aeration-fed biological process. At this plant, the aeration controls were not upgraded and the old dissolved oxygen (DO) sensors failed, giving erroneously low readings. This sensor failure resulted in excess blowers operating as they tried to increase the dissolved oxygen sensor readings. While this type of failure allows the system to keep running and the water treatment to continue, the energy savings are lost.

In this case, when the site joined a SEM wastewater-focused cohort, the failure was discovered during an energy scan/treasure hunt, because the blower amps were much higher than expected. Although the system design was suboptimal and lacked sensor redundancy, the engineer believed the ultimate cause of failure was adding the energy-efficiency project on at the end, rather than including it in the design from the outset. However, adding backup sensors could have prevented this failure mode.

Some Men Are, In Fact, Islands

At an industrial wastewater treatment plant in Washington state, a single operator is responsible for treating food-processing wastewater. The aeration system control was upgraded with dissolved oxygen sensors controlling new variable frequency drives (VFDs) on the aerators. When the ESI engineer returned several years later, they noticed one of the VFDs was no longer regulating air flow. One VFD was set to full speed (60 Hz) and the other was turned off.

It turned out that the critical dissolved oxygen sensor had failed. The system operator's primary responsibility was to ensure wastewater is treated to permit levels or better. Because over-aerating the wastewater does not adversely impact water quality, fixing the broken sensor became a low priority for the plant's limited bandwidth. Building in additional system control features (i.e., redundancy, self-cleaning sensor, alarms, etc.) at the design phase, could have helped sustain and maintain project viability.

Blame the New Guy!

The good intentions of a project can be easily undone if the site does not have a culture that encourages energy efficiency or group problem solving. Troubleshooting can be tricky, and it is easy to blame problems on new or unfamiliar equipment. Removing the new equipment certainly eliminates that element of the system, whether or not it fixes the problem.

An engineer returned to a sawmill in Oregon, where an energy-efficiency project had been added to the compressed air system several years earlier. Multiple receiver tanks were integrated to allow the compressors to load less frequently. After the project was installed, energy savings were measured and verified, and a utility incentive was provided; however, one of the air compressors had a problem. Because the tank tie-in was the most recent change to the system, the facility staff decided to remove it. Although this did not fix the problem, after the tie-in was removed, it was never reinstalled.

My House, My Rules

A different cultural problem can occur if a complex system serving different purposes is not maintained with the entire system in mind. A paper mill in Washington state had 20 air compressors with a nameplate total of more than 3,000 horsepower spread throughout the site, supplying air to a network of piping, compressed air distribution system components and end-use equipment. In the baseline case, one employee would walk around twice per day to manually turn each inlet-modulated compressor ON or OFF to meet the load. The energy-efficiency project adjusted all the compressors to run load-unload and had a control system staging the compressors to meet the demand. Many other process improvement projects were completed at this site, but when the site focused on the operation of this particular system seven years after the original installation, the engineer found many of the compressors had migrated to manual control. Upon inquiry, it was determined this happened when a compressor failed — either perceived or real — to meet the demand. One operational challenge was "operator myopia;" operators would adjust the air compressor working *in their area* to get more pressure, stealing air from the rest of the system without fixing the actual issue.

The engineer also heard that operators were suspicious of the control equipment. They felt like the system was too cheap to adequately function in an industrial environment – that the project was "commercial-grade." The engineer was able to work with site personnel to regain most of the benefits of the original system design.

In this case, the mill does have good personnel resources, and a robust data historian. Spending slightly more at the outset could have helped mitigate this issue, and possibly have ensured that operators were more open to letting the system controls do the controlling. A more robust control strategy with centralized human-machine-interface would have been maintainable and a valuable asset to building trust.

Out of Sight, Out of Mind

Some energy-efficiency projects fail, not due to any production or reliability changes made by the maintenance or operations staff, but merely because the measure is well-hidden. If one item is installed, but is new or unusual and staff do not need to perform maintenance, they may be unable to identify when the measure has failed.

A dairy in Washington state replaced the existing timed drains with zero-loss drains to let water out of the compressed air tank, while minimizing compressed air losses. When the engineer returned, the compressor was short-cycling. Eventually, the program engineer returned to the site and discovered that the drain had failed and the receiver tank was full of incompressible water instead of compressed air, causing even worse energy performance than before the retrofit. This issue could be resolved by adding a maintenance check of the zero-loss drains to standard maintenance procedures with the compressed air system.

Simple Solutions Solve Some Snags

Energy efficiency upgrades such as controls and sensors are necessary parts of energy efficiency projects, but they are not always sufficient. Human beings are an important part of project success. The following stories demonstrate some examples of easy strategies that maintained persistence can be maintained.

There Is More Than One Way to Skin a Nuisance Alarm

At several food processing plants throughout the Pacific Northwest, a gravity-fed oil cooling system (thermosiphon) was installed to replace mechanical expansion valves. The mechanical expansion valves require a pressure differential (90 to 100 psig) to operate which can force a key refrigeration system energy parameter (discharge pressure) to be elevated simply to cool compressor oil. In several of these installations, high oil temperature alarms and shutdowns would occur, but when the operators arrived, the equipment was fine and could be restarted. Two facilities reacted to these nuisance alarms very differently. One piped the liquid-injection valve back in — eliminating the energy savings. The other facility wired a solenoid to the alarm, opening the liquid-injection valve on one of twelve compressors. so on the rare occasions when the temperature got high enough to trigger the alarm, the liquid injection valve was temporarily re-engaged until the temperature returned to normal, at which point the valve closed again. This maintained a substantial amount of savings without the operational hassle to the operators.

Money Makes the World Go 'Round

Sensors and controls are often an excellent persistence-support strategy. However, there are facilities and situations where sensor use and upkeep create substantial challenges, and using a more manual type strategy provides a better solution. A lumber mill in northwest Oregon installed a compressed-air system upgrade, which included replacing existing equipment with new VFD-trim compressors, a new dryer, and compressor-sequencing controls. After completing the project, the site participated in a pilot program to test a remote maintenance platform. Sensors monitoring pressure, flow and amperage sent signals through a wireless router to an online software accessible by the facility, compressed air contractor and energy-efficiency program. Despite everyone's high hopes, it quickly became apparent the system was not an ideal match.

The gold-standard monitoring system was very hard to maintain. Soon, several sensors failed to transmit and others emitted erroneous data. Returning to the facility to address the issues was time consuming and put a strain on the pilot-program resources. Most facility staff found the system hard to use, whereas only one staff member felt comfortable using it. Communicating status to other staff members and management became a barrier.

Management supported energy-efficiency efforts with the straightforward policy that "saving energy is money in our pockets." However, the mill was lightly staffed and following the upgrade there were periods of layoffs and continued understaffing. Tracking detailed operations and energy efficiency on subsystems like compressed air was beyond the site's bandwidth.

After the controls- and program-savvy maintenance manager moved to a sister facility, the lead electrician, facility manager, and ESI team member sat down to discuss how to create buy-in and promote savings persistence. The bottom line was literally the bottom line. Instead of tracking the specific equipment, the overall cost benefit — avoided electrical + incentive — was tracked in an Excel spreadsheet. Inputs included linear feet produced, temperature, day type (weekday or weekend) and electrical consumption. A cumulative sum-of-financial-benefits chart was created and shared with corporate monthly.

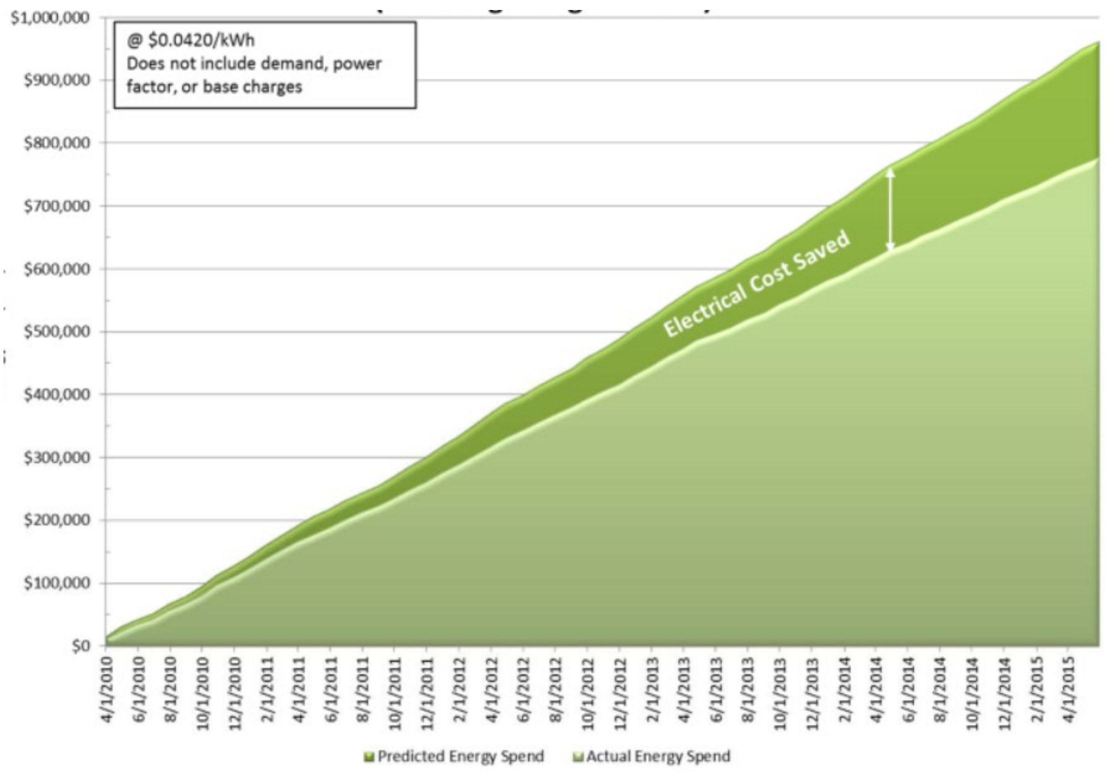

Figure 1. Cumulative financial benefit from energy efficiency efforts.

The result was additional support for energy projects and faster response to maintenance requests when costs increased because energy intensity increased. The buy-in from management was strong enough that the Lead Electrician was tasked with creating energy models for the region's sister mills. Using the same inputs and starting with program documents, the electrician was able to create viable models and keep the tracking simple enough that even those with limited Excel expertise could manage. This also led to a tour of plants where the nominated energy champion from each facility visited sister facilities to look for energy opportunities and collaboratively brainstorm solutions for the different mills.

Write that Down!

Complex subsystems such as refrigeration require balanced operating setpoints to maintain system efficiency. When upsets due to weather, maintenance or other issues arise, it is generally the responsibility of the operators to restore the system to normal operating conditions. Although energy-efficiency programs provide a completion report documenting the entire project, a streamlined table of setpoints is more useful to a working operator.

While working with a refrigeration facility on both SEM and custom projects, the facility's management team expressed concerns about savings durability due to relatively high operator turn-over. The current operators had received refrigeration system energy coaching and understood the purpose and interactions between their equipment. However, after completing a year of coaching, the facility management realized it would be hard to continuously maintain a high level of expertise.

To address this issue, a tabular summary of key equipment (i.e., compressors, condensers, evaporators, chillers, etc.), their setpoints, and key notes regarding operations and maintenance was documented on a single 11” x 17” paper. This was laminated and posted at the operators’ workstation as a simple method to maintain a baseline understanding of where the system should operate. Following these setpoints helps the facility maintain the annual savings rate of 7%.

Picture Perfect

A Washington vegetable-processing facility enrolled in a multiyear SEM engagement through their utility’s ESI offering. An energy scan (or energy treasure hunt) was initiated early in their SEM first-year participation and one of the action items identified had a significant energy-savings opportunity that would efficiently incorporate their existing refrigeration compressor sequencer. The site’s freeze-tunnel compressor motors with nameplates totaling nearly 2,000 hp and were tied into a basic sequence controller. This sequencer had the ability to stage the compressors ON and OFF based on demand. The reason the sequencer was unused and that the site refrigeration operators were responsible for turning compressors ON and OFF manually —resulting in more compressors running than necessary with multiple compressors running part loaded — was due to underlying issues with the economized compressors. During the energy scan, the issues with the economized compressors were resolved and the sequencer was put back into operation.

A protocol was developed for compressor sequencer operations, which required implementing procedures and operator training on how to effectively incorporate the controller into the daily operation of the refrigeration systems and resolve issues as they arise without reverting to manual control of the compressors. The protocol was printed, laminated and secured in an optimal location for operator viewing, as shown below.

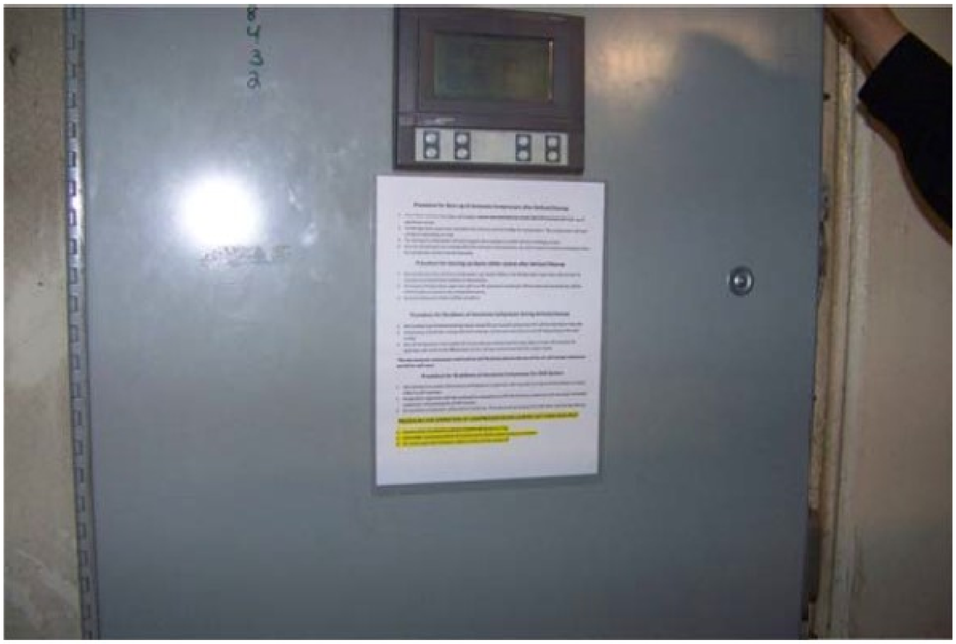

Figure 2. Protocol for compressor sequencing, posted directly below sequencer panel.

The site eventually graduated from SEM, and program engineers continue making site visits to support the implementation of energy-efficiency capital projects. They report the compressor sequence controls have continued operating throughout the years.

Takeaways: Technology + Talking Ties Teams Together (Lessons Learned)

Despite the best efforts of program implementers, changing a site's culture and getting staff buy-in is certainly beyond the bounds of a single capital project. Getting energy efficiency involved early in project design is also easy to miss and once the opportunity has passed, it may not be recoverable.

One of the benefits of long-term utility program support is that even if site personnel changes, knowledge is not lost. This can also help sites that may lose internal momentum to return to energy-efficiency programs. Trust can be established more easily if the site has a single point of contact (Eskil, Wood, and Wilcox 2011), and if the contact has site familiarity, this can also increase site comfort.

Formal failure-mode methodologies (e.g. Failure Mode Effects Analysis, or FMEA, methodology) have been developed and applied to so-called Megaprojects[1] — large industrial energy-efficiency projects (Amundson, Martin, and Whitchurch 2017) — although this level of effort is probably excessive for smaller projects. Some lessons learned from this risk analysis can be applied to other projects, and some of these actions that can be applied more generally may include:

- Anticipating the likelihood of detecting the problem.

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[1] Megaprojects are generally defined as those with savings greater than one average megawatt (Amundson 2017)

- Prioritizing measures that have a single point of failure (e.g. a setpoint, algorithm, or human-dependent procedure).
- Creating reminders about the "Why's" and "How's."

These strategic actions can take on many forms. For example, ensuring preventative maintenance procedures are updated to include periodic sensor calibration can prevent a greater control failure. Enhancing control systems with specific, abnormal-condition alarm notifications can also help remind operations staff of items that may not be their primary concern. Engineers may need to consider factors beyond mechanical ones by taking the time to contemplate the human element.

Too many capital projects rely on institutional knowledge, that is, knowledge that is not written down. This can be general knowledge about equipment: what projects were intended to do (such as daylighting), or specific historical knowledge of why a project was initially implemented. Simple reminders are a very low-cost way to enhance project performance. This can take the form of a poster about the energy-efficiency project, such as the one shown in Figure 3. This is a reminder of the good work the site has done, and a strategy to ensure general personnel have awareness and ownership of energy-saving technologies.

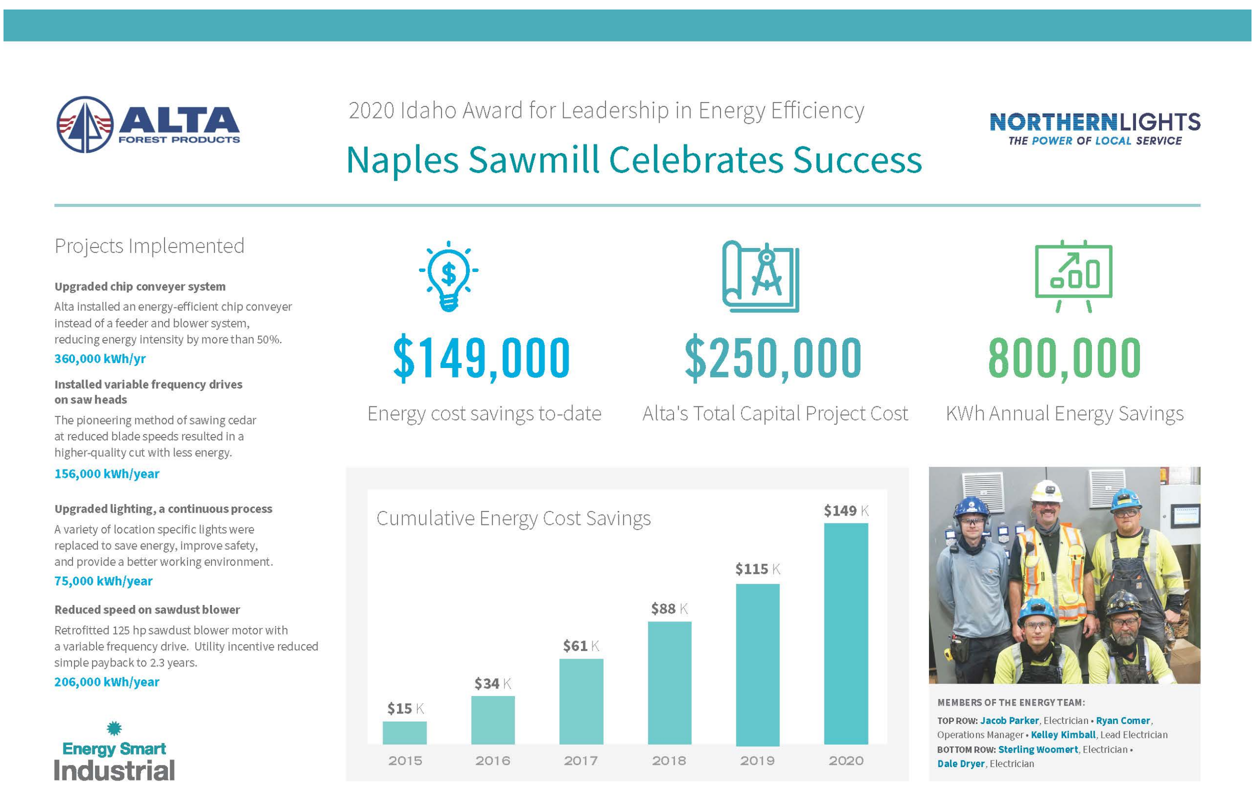

Figure 3. Sample project success poster, which reminds and inspires staff

The durability of energy efficiency projects often hinge on the people using the equipment. To help drive persistence, strategies such as designing in failure prevention early in the project and establishing regular quick maintenance or setpoint checks can help prevent multiple person-based failure points.

Continuous monitoring is an excellent way to ensure performance persistence. One way that a site can engage in this activity includes installing sub-metering equipment with performance-display capabilities as part of the project. It is particularly helpful when these costs are eligible for reimbursement under utility program rules.

Still, simple, ongoing tracking of key performance indicators or the cumulative sum of energy savings can be quite effective.

Energy management information systems (EMIS) or performance tracking systems (PTS) can help monitor project savings. But for sites not enrolled in SEM, controls systems can provide operators with system-level visibility. When staff are trained to access and use these systems, with durable and accessible documentation left in place for operator use, this can help maintain accurate setpoints and identify maintenance problems.

Repeated operator training can also remind personnel with multiple competing duties about less demanding aspects of their job and can also increase comfort with newer systems. The lack of operator comfort is an often-overlooked reason for failure. Ongoing support may be beyond the budget of a specific project, but long-term programs can support savings with return visits, or something as simple as offering lunch-and-learn-type webinars for interested parties.

Efficiency programs with consistent rules over long periods are another good way to help savings persist. When program staff have a long-term relationship with sites, they can help remind them of what happened, and why, and encourage project persistence. Program staff with site history can be particularly helpful in industrial sites that may change ownership without changing equipment or products.

In energy efficiency, as in life, there are things that can be controlled — and things that cannot. While optimism about project success is helpful, considering ways that projects can go wrong and early thinking about prevention strategies can reap great benefits with project performance persistence.

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