Industrial RetroCommissioning (RCx)

Lead Author: Chris Smith, PE, CEM, Energy 350
Co-Author: Ray Hawksley, Energy Trust of Oregon

ABSTRACT

RetroCommissioning (RCx) is the process of making existing mechanical systems operate more efficiently, without replacing major systems or components. Historically RCx has been associated with commercial buildings, but large, cost-effective savings opportunities also exist in the industrial sector. With leadership and incentives from Energy Trust of Oregon, the industrial sector has proven to be a productive and cost effective means to achieve meaningful energy savings. While equipment and processes are more complex in the industrial sector than they are in commercial, this complexity actually increases RCx opportunity. This is because the complexity of industrial systems tends to hide RCx opportunities that would be more obvious in simpler systems. In this respect, RCx has a greater impact potential in the industrial sector and has been deployed successfully in the northwest. This paper aims to explore the following:

- Overview of RCx program structures
- Where programs should focus resources to obtain cost-effective savings from retrocommissioning
- Success stories and several lessons learned from past projects and different program structures

Key takeaways for the reader will be to:

- Understand where an RCx program has the greatest impact, and common areas of opportunity to focus on
- View case studies that highlight successful examples of RCx applied to the industrial sector
- See the marketing value that cost effective RCx wins provide in engaging the customer, which opens doors to greater participation in other program offerings

Introduction

While RCx has typically been a commercial building endeavor, Energy Trust of Oregon has effectively brought RCx to the industrial sector. As an RCx service provider, Energy 350 has successfully implemented nearly 20 RCx projects at industrial facilities in Oregon over the past 4 years. This has crossed a broad spectrum of industrial sub-sectors including high-tech, pulp & paper, food processing, chemicals and others. It has also branched out from the traditional HVAC focus of RCx. While HVAC is a major component of industrial RCx, other systems successfully served include compressed air, refrigeration, process heating and cooling, clean room environmental control systems, pumping, vacuum pump systems, etc.

While the endeavor has been highly successful, it has also had the learning experiences that are inherent with exploring new territory. This paper will explore lessons learned both programmatically and technically to begin to document best practices for industrial RCx.

Background

Energy Trust of Oregon's industrial program is managed in-house, utilizing of a pool of highly skilled energy efficiency engineering contractors to deploy various services to customers. Contracted services include general program delivery, technical experts to provide studies and technical assistance, and service providers to provide specialized services such as Strategic Energy Management, ISO 50001 and RCx. In 2014, the program delivered over 162 Million kWh and 1.2 Million Therms of net savings. (Energy Trust 2014)

The program relies on a "high touch, boots on the ground" approach to delivering the program to customers. This approach has been able to deliver significant resources despite the regions low electric rates, averaging approximately $.06/kWh for industrial customers.

Over the past 4 years, Energy Trust has delivered RCx services to approximately 20 industrial customers. Through this experience, they have experimented with program design, target customers, technical screening and service delivery approach.

Experiments in Program Design

In experimenting with program design, Energy Trust of Oregon has tested several approaches to offering RCx to their industrial customers over the years. We provide an overview below which highlights the advantages and barriers discovered during the test phases of various approaches to RCx.

Turnkey Approach

Energy Trust began the program with a turnkey approach that provided technical assistance as well as free implementation of low cost measures.

Overview of turnkey approach. Energy Trust provided the following services, offered through their service providers:

- Recruitment of customers.
- Conduct an RCx study.
- Review measures with customers to gain their buy-in.
- Subcontract to Trades contractors to implement measures approved by the customer. Energy Trust would work with the contractor of the customers choosing. Typically customers have a contractor that they know and trust.
- Conduct functional testing to ensure that the measures have been implemented properly.
- Quantify energy savings and document all activities in a final report.

Since the measures being targeted were low cost RCx measures, Energy Trust devoted a small budget to cover 100% of the cost of implementation through Trades contractors. This was in-lieu of incentives being paid directly to the customer.

The customer experience. Customers tend to be very grateful for the support and it can often help better engage them in energy efficiency in general, as well as with the program administrator and their service providers. Unlike more traditional energy efficiency opportunities, RCx tends to be very inexpensive to implement. This allows even cash strapped

customers to implement energy efficiency improvements. It also gives facility managers a success story to take to their management, which results in:

- Improved standing of the facility manager with upper management. This positive feedback can motivate facility managers to seek out more efficiency projects.
- Seeing the success of RCx, management may take an interest in energy efficiency, which can result in budget availability for future energy efficiency projects.

Advantages and caveats to the turnkey approach. The turnkey approach is a highly effective delivery mechanism, but is a fairly heavy-handed approach for a utility efficiency program compared to more traditional delivery models. In effect, it is a direct install program for large, complex customers and measures. To deliver properly requires a high level of expertise to dive deep on complex systems and manage risk while making changes to these systems. It also requires a highly cooperative approach to working with customers to gain their buy-in and ensure that any changes are well vetted prior to being implemented.

A key component of the success of this approach is that there is never a handoff to the customer, so the implementation rate is nearly 100%. Industrial RCx is a complex undertaking that, when handed off to the customer, often languishes. The turnkey approach is able to shepherd the project from concept through completion and avoids the risk of delay or inaction inherent with the more traditional implementation handoff to the customer.

Technical Assistance and Incentives Based Approach

In experimenting with a less "hands-on" approach, Energy Trust adopted a more traditional approach that offers RCx studies, incentives, and implementation assistance. This approach avoids the potential liability associated with the turnkey approach, but is subject to attrition between the study and implementation phase when the ball is in the customers court.

The incentive based approach begins with an RCx study to identify measures, analyze savings & economics, etc. The study is then presented to the customer, along with an incentive offer. While Energy Trust offers technical support in an advisory role, it is up to the customer to take the next steps towards implementing the project.

Barriers to incentive based approach. The handoff to the customer has created some "dry wells" of studies that have been done without the customer implementing the project. Though reasons for not moving forward vary from customer to customer, we believe the barrier is not due to financial constraints. Often, RCx measures have paybacks spanning several months, and Energy Trust will provide up to 90% funding for measures that are implemented within 90 days. More common explanations for dry wells are:

- Time – RCx (and other efficiency opportunity) is generally not part of the core job responsibility of a facility manager or specific system owner, and as such, it can easily fall to the back burner indefinitely.
- Complexity – RCx measures, particularly in an industrial setting are complex and nuanced. It can be difficult for a facility manager to take the ideas of an RCx agent and run with them.

Case Studies from the Field

To illustrate the types of activities that can be encompassed through industrial RCx, we'll provide some real world examples from projects that have been implemented.

Industrial Refrigeration

Particularly with large Ammonia systems, significant RCx opportunity exists in industrial refrigeration. Refrigeration systems are very energy intensive, and tend to be very complex. This complexity can hide significant opportunity for energy savings through RCx. In this example, an unnecessarily low suction pressure setpoint was requiring an additional compressor to run. The setpoint was incrementally raised over a few days without impact to production. In this case, a simple setpoint change was able to shut down a lightly loaded compressor and save approximately 75 kW, or over $25,000 annually. Figure 1 shows the impact.

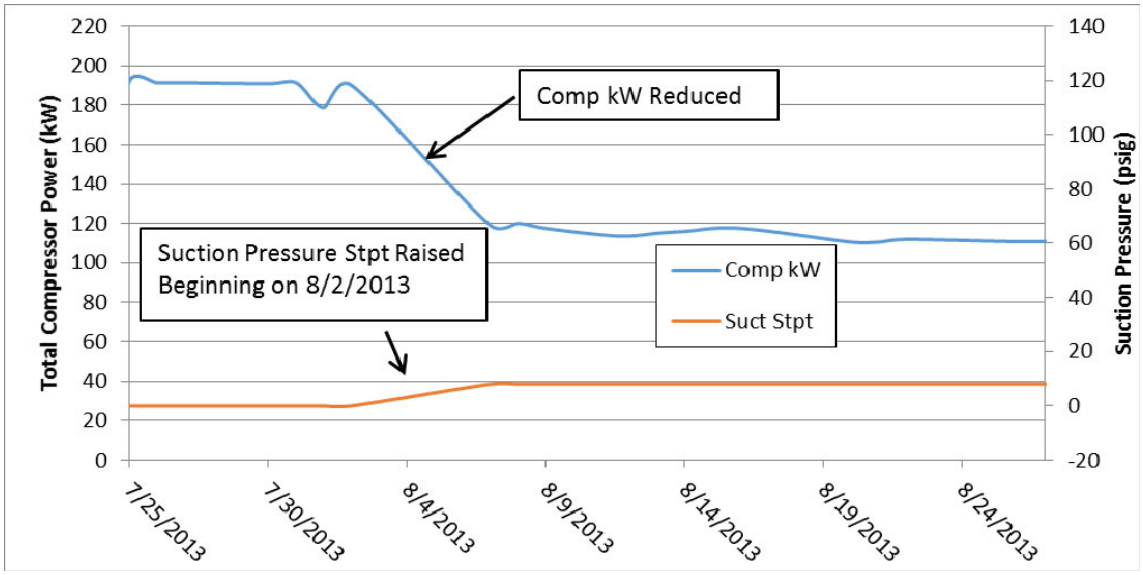

Figure 1. Trended Compressor Power and Suction Pressure during an RCx engagement.

Pulp & Paper

The pulp & paper industry typically has a large number of Motor Control Center (MCC) rooms that require cooling. This typically adds up to several hundred tons of cooling across a mill. In this case, the MCC cooling units were water cooled with flow control valves to maintain refrigerant head pressure. While metering power on a sample of units, we reduced the head pressure mid-way through the monitoring period. Figure 2 shows the resulting reduction in compressor power starting in early August when the change was made. Considering there were nearly 100 MCC cooling units in this facility, this added up to substantial amount of savings.

A typical pulp & paper facility has several thousands of hp in pumps, many of which are redundant or lead/lag. We often find that both pumps in a lead lag configuration will run all the time, even if only one is required most or all of the time. The ideal solution in this case is to automate the sequencing such that the second pump only operates when required to maintain

process conditions. In most cases, this will result in only one pump running most (or all) of the time, and with proper sequencing, will have no effect on process. Figure 3 shows a sequencing example of (2) 125 hp pumps, both of which previously ran most of the time. Notice that after sequencing was automated, the second will now operate only in the rare event that it is required.

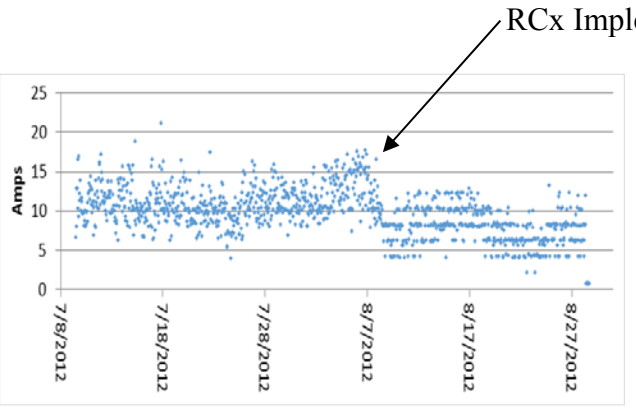

Figure 2. MCC Cooling Head Pressure Reduction

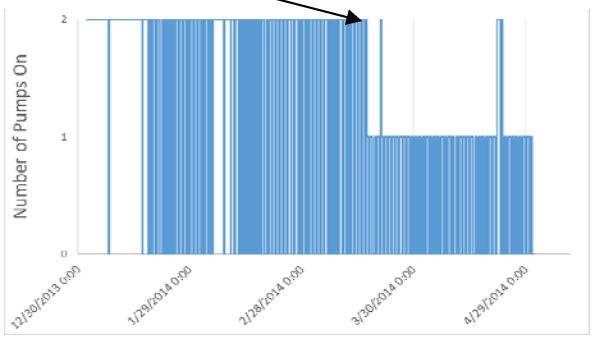

Figure 3. Pump Sequencing Programming

Central Plant Heating and Cooling Plants

Centralized chilled water and boiler plants are commonplace in the industrial sector. They're also very large energy consumers and very complex, all of which contribute to their excellent RCx potential. In this example, we found failed triple duty valves on three out of four large secondary chilled water pumps. This was causing all four of the large pumps to run all the time. The triple duty valves were repaired and a differential pressure reset at the pumps was programmed. Since then, no more than two pumps have ever been required. Figures 4 and 5 show the pre and post case control graphics.

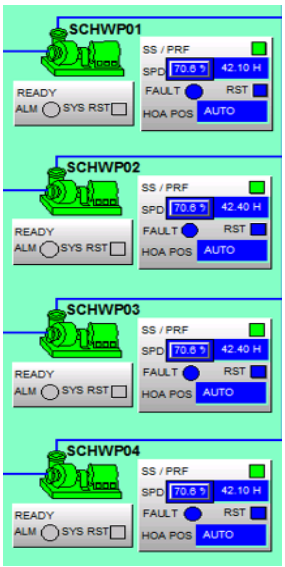

Figure 4. Baseline SCHW Pumps all Running

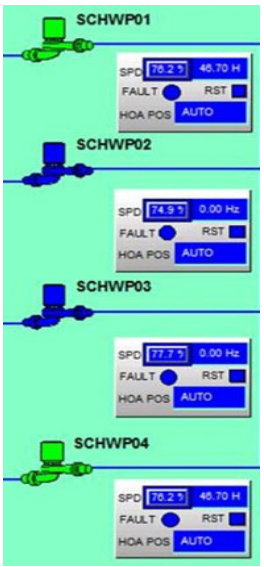

Figure 5. Post RCx SCHW Pumps only 2 running

Compressed Air

Nearly every industrial facility has compressed air, and most of them contain RCx opportunity. In the next example, the site's existing VFD air compressor was using inlet valve modulation instead of adjusting speed to meet partial loads requirements. A VFD compressor should vary its speed to efficiently meet partial loads, until it reaches minimum speed. When air demand is less than the minimum speed air flow, the compressor should cycle between loaded and unloaded. Figure 7 shows pre and post real power logging of the compressor and the effect speed variation had on total unit power.

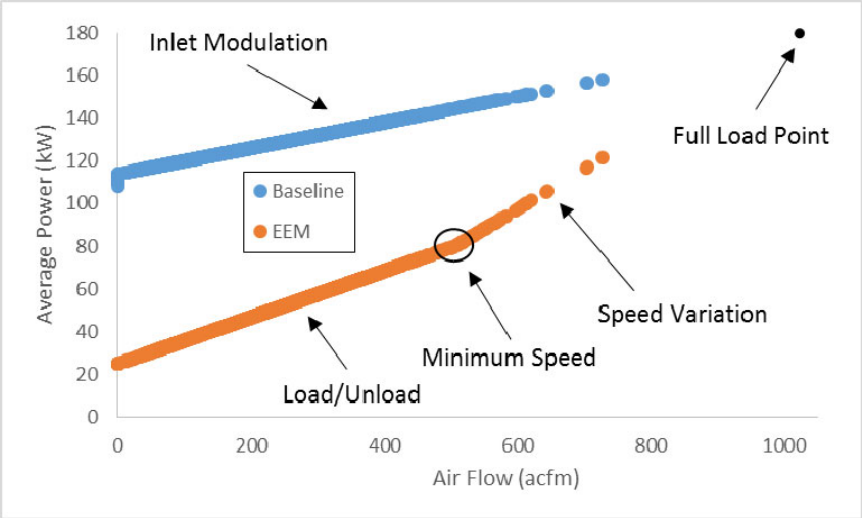

Figure 7. Power logging of a VFD air compressor pre and post RCx

Another example is a high tech facility that operates a compressed air system with four oil-free rotary screw compressors controlled with a cascaded pressure loading sequence. The pressure setpoints for loading and unloading the compressors were too close to one another, resulting in an extra compressor intermittently running during most operating hours even though it was not needed. The solution was simply a minor change to the compressor sequencing, which eliminated the loading of the extra compressor during most hours. Figure 8 shows the pre and post RCx compressor plant power profile.

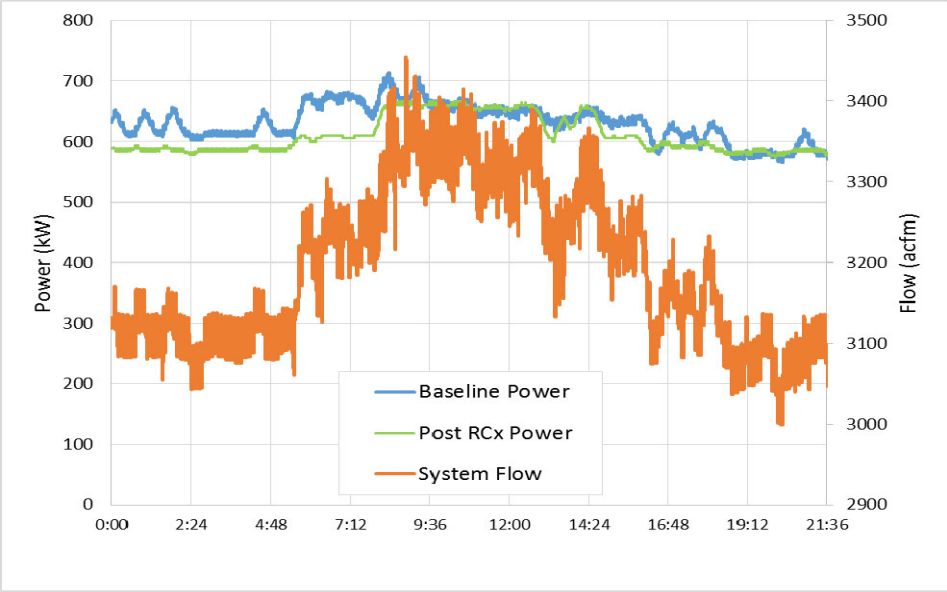

Figure 8. Compressed air pre and post RCx power profile

Water & Wastewater

Municipal water supply and wastewater treatment facilities can be extremely large energy users. Additionally, the complexity of these facilities provides plenty of opportunity for improved energy performance through RCx. In this example of a municipal pump station, the storage tank fill strategy and the pump operation was modified simply through controls programming. These improvements were made in one day by facility staff and were able to reduce annual energy consumption by 11% with no capital costs. Figure 9 shows metered pre and post energy usage.

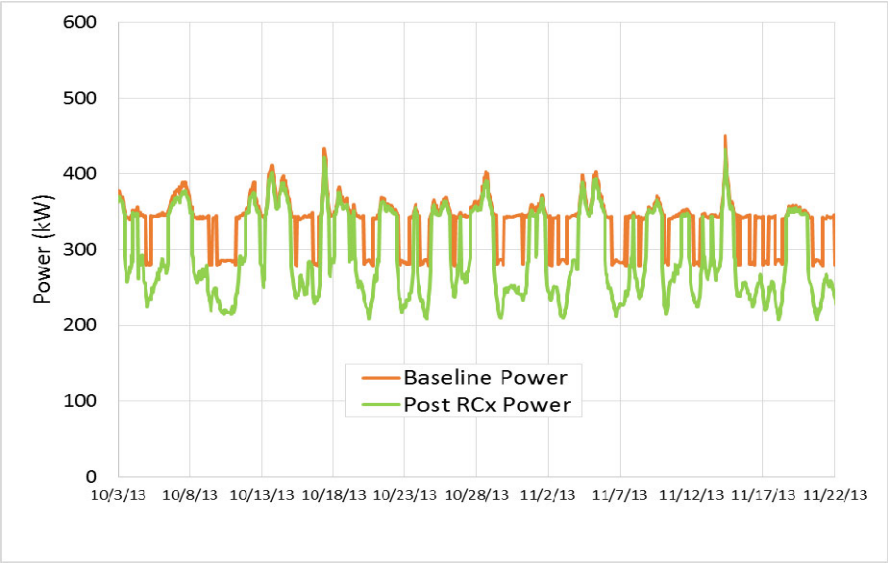

Figure 9. Energy impact of pump station control programming improvements

High Tech

The high tech sector has extremely energy intensive processes and a laser focus on production, which causes energy efficiency to take a back seat. As a result, the sector is ripe with RCx opportunity. Figure 7 shows a leaking hot water valve in a makeup air handler serving a clean room. Since clean rooms have separate cooling units, all of the heat from the leaking valve also added cooling load to the clean room cooling units. With the large airflow through these units, something as simple as repairing a leaking valve can save over $20,000 a year. It's quite common for a high tech RCx to identify over $100,000 in annual energy savings that can be achieved with very little cost. Notice in figure 10 the reheat valve that's commanded closed is heating air from 47°F to over 72°F.

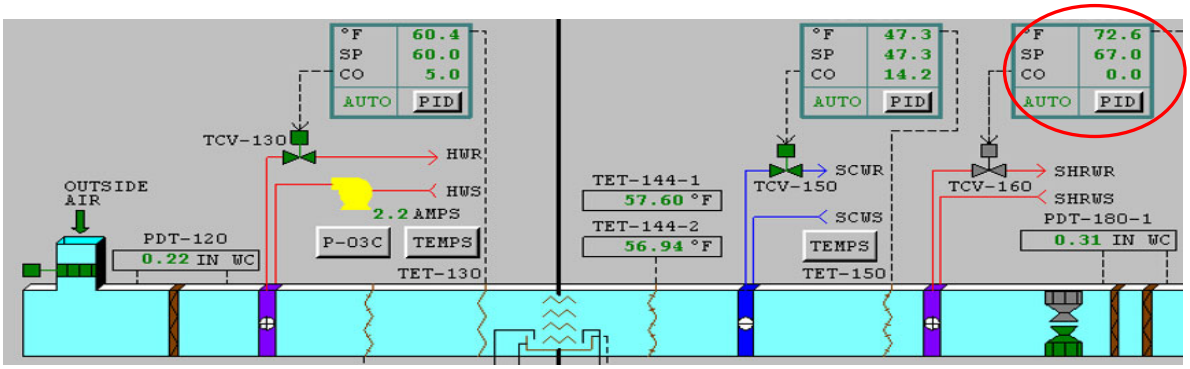

Figure 10. Leaking HW valve exceeding setpoint by over 5°F.

HVAC RCx Applied to Industry

Since most industrial facilities have significant HVAC load, much of the same RCx opportunity that would exist in an office building is also present in most industrial facilities. We typically find low cost, high savings opportunities through traditional RCx measures such as economizer repair, controls programming, sensor & valve calibration, etc. Figure 11 shows common economizer linkage failures. Figure 12 shows an Energy Recovery Ventilator (ERV) that was not providing any useful work simply because a broken belt was preventing it from spinning. Notice the dust accumulation on the upstream side of the wheel, indicating that it has been in this state for quite some time.

Figure 11. Common Economizer Failures

Figure 12. Broken belt on ERV

Lessons Learned/Best Practices

The High-Tech Sector Has Amazing RCx Potential

The high tech sector is highly energy intensive, and with a history of a laser focus on process and quality, energy efficiency has taken a back seat, creating a significant opportunity for energy savings.

Barriers to Energy Efficiency in High-Tech.

Oregon has a "Silicon Forest" region rich in high tech industry including a large number of wafer and microchip fabrication facilities. This is a sector with a unique set of challenges, and as such has been very resistant to energy efficiency. Challenges include:

- Highly critical process environments and an aversion to make any changes to support systems for fear of impacting a delicate production process.
- Evolving computer technologies lead to boom bust cycles. The uncertain outlook at any given time leads to a hesitation to invest in efficiency.
- Investment in new process equipment tends to have very favorable ROIs. Because investments in efficiency must compete against investments in process equipment, we often see simple payback requirements of one year or less.

RCx as a tool to unlock the high-tech sector. We have found RCx to be extremely valuable in breaking through to the High-Tech sector. While facilities staff are extremely risk averse and resistant to change, their trust can be earned. Once trust is earned, RCx energy savings potential is abundant. Often, over a million kWh and tens of thousands of therms can be saved with a very modest investment of program funds. Additionally, the trust and momentum earned through RCx can often carry over into capital projects, with the caveat that the aggressive payback requirements remain.

Delivery of Industrial RCx Requires a High Level of Technical Expertise and Must be Managed Closely

Industrial customers tend to be highly complex and meticulously focused on their core mission of maintaining and increasing production volume and quality. Most of the energy efficiency potential within the high-tech sector lies in systems that support delicate process equipment and very tightly controlled environmental conditions within clean rooms. Facility staff will be justifiably hesitant and will not consider any changes before trust in the RCx provider is earned. To earn the trust of high-tech facility staff will require a thorough understanding of their systems and process. Program administrators should carefully screen RCx service providers, particularly to serve the high-tech sector.

Some Level of Controls/Automation Should be a Pre-requisite in Screening Customers

We have proven that RCx can work well with a range of facility types and systems. However, without the backbone of a control system, it's very difficult to optimize systems for energy efficiency. We have tried working with customers that have no controls, or limited and

antiquated controls, with limited success. Based on our experience, we recommend that the presence of a control system be a prerequisite for RCx participation.

Consider the Human Element of Pointing Out Deficiencies in the Way Customers Operate Their Systems

It is important to approach RCx with humility and a sensitivity that you're critiquing the manner in which a customer has been operating their systems. A respectful and collaborative tone is key to gaining customer support. If they feel like they're being audited or that the RCx provider is being critical of their work, they'll get defensive and you'll risk losing the customer.

RCx is a Valuable Marketing Tool that will Lead to Increased Implementation of Capital Projects

In addition to the immediate benefits of RCx, we have observed a resulting uptick in capital projects after an RCx project. This is due to two main factors:

- Customer Engagement – RCx can provide savings that are highly cost effective and can be implemented quickly. These quick wins are invaluable in engaging facility staff and management, which will ultimately lead to increased implementation of capital measures.
- Increased Identification of Capital Opportunity – To identify RCx requires a "deep dive" into controls and mechanical systems. This thorough technical diligence at the site will inevitably lead to the identification of capital measures for customers to consider for future implementation.

Industrial RCx Tends to be More Complex than Customers Can Tackle Without the Program Taking the Driver's Seat

To present an industrial customer with an RCx study can be an overwhelming exercise for facility staff. Measures tend to be complex and nuanced and it can be difficult for customers to gain a thorough enough understanding to properly bridge the gap between study and implementation. Typically, RCx opportunity exists specifically because facility staff don't have the detailed systems knowledge required to understand how to optimize the system. An RCx study that identifies deficiencies and recommends solutions is a great first step, but this alone may still leave the facility staff without the knowledge required to either implement the improvement or communicate the scope to a contractor.

A Program Structure that Delivers Turnkey Identification and Implementation Services Works

One way to maximize implementation rate of identified RCx measures is for program administrators to offer turnkey services that allow the RCx provider to work between customers and contractors to help facilitate the implementation of identified RCx measures. This can be particularly effective if the RCx provider can contract with contractors directly, using incentives as the funding source. The facilitation of measures as a program service is key in relieving the burden of understanding and implementing the measures from the customer.

Incentives are Not Required – Delivery of Turnkey Services Can Supplant the Need for Incentives

It has been our experience that the barriers to RCx measures, particularly in the industrial sector, are not based on financial constraints. This being the case, the most effective role that program administrators can play is to bring technical expertise and facilitate the implementation process. Customers are typically very grateful to understand the opportunities and have someone facilitate the implementation of measures. In effect, the incentive to the customers is the services provided, not a check.

M&V, Realization and Persistence of Savings

The realization of intended energy savings in RCx lies within the details of implementation. This makes a verification/QC/M&V process extremely important. All measures should be subject to functional testing at a minimum. Functional testing is a process of testing control algorithms and hardware to ensure that the measures implemented are performing as intended. Rarely do contractors get all the details right on the first try. Verification should include punch list items for contractors to correct deficiencies and ensure the job is completed in a way that ensures energy savings are being realized while process, quality, and comfort needs continue to be met. If energy savings are being realized but process needs are not being met, the improvements will likely be overridden and persistence will suffer.

Persistence and measure life of RCx are highly debated subjects and areas in need of further research. Energy Trust of Oregon claims a 3 year measure life. We believe that this is a conservative estimate that is cautious due to a lack of supporting research. Since the program has been in place only a few years, we are just beginning to build enough of a data set to make a persistence study feasible. It is our hope that as more research is done around RCx measure life, Program Administrators can defensibly claim more extended measure lives from RCx. Energy Trust of Oregon is currently evaluating early RCx projects. These results, when available, will help inform measure life and persistence.

Conclusion

Industrial RCx holds excellent potential for cost effective energy savings. Additionally, it can be a valuable tool in serving hard to reach customers that may be cash strapped, or simply have shown little interest in efficiency. The marketing value of some cost effective RCx wins can lead to a more engaged customer and a number of additional efficiency projects down the road.

From a technical standpoint, we have found that nearly all system types contain cost effective opportunity. Rather than filtering or sorting participants by industry or system type, we recommend the following guidelines to screening potential customers for RCx:

- All systems that are large and complex are likely to contain RCx opportunity. Smaller systems may not contain enough savings potential to justify the cost of RCx. Simple systems may be well understood and optimized by facility staff, reducing the likelihood of RCx potential. Likely RCx candidates should have some sizable equipment that is fairly complex.
- Participants should show some willingness to make changes to their equipment. Many customers begin the process nervous that the RCx provider may not understand their

operation and as a result, may not make informed, relevant recommendations. This skepticism is natural and can be overcome by a skilled RCx provider. If however, the facility considers large portions of their equipment "off limits" to RCx and is adamantly against making changes, they are probably not a good candidate for RCx.

- Implementing RCx without a control system is difficult and will result in smaller savings at a higher cost than a similar customer with a control system. We recommend that a prerequisite for RCx participation be the presence of some level of a control system.

As program administrators implement Strategic Energy Management (SEM) programs, they should consider the complimentary value of RCx. The primary focus of SEM is to engage customers and embed a culture and corporate structure that fosters energy management. However SEM does not typically provide the detailed technical support that RCx offers. The two offerings work excellent together to cover both the technical and corporate aspects of energy management. Additionally, since both efforts are highly cost effective on their own, combining them still results in a cost effective solution that can deliver even more savings.

Nearly all utility territories in the United States contain a significant industrial base, and as such, significant industrial RCx opportunity that can be realized cost effectively. When program administrators are structuring their programs, we recommend that they incorporate the lessons learned that are discussed in this paper. Most important to an industrial RCx program's success is in structuring an approach that provides a high level of customer support, particularly in bridging the gap from study to implementation.

References

Energy Trust of Oregon. 2015. *2014 Annual Report to the Oregon Public Utility Commission & Energy Trust Board of Directors.* http://assets.energytrust.org/api/assets/reports/2014_ETO_Annual_Report.pdf