Supermarket Controls and Commissioning: Uncovering Hidden Opportunities

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ABSTRACT

Over the past 3 years, Portland Energy Conservation, Inc. (PECI) has investigated a full range of energy savings retrofit opportunities in over 900 grocery stores ranging from convenience stores to supermarkets. Research shows that there is tremendous potential for supermarket refrigeration controls. In one of the largest supermarket chains, a survey of 50 stores showed that the majority had control systems but that the control strategies were not implemented correctly, providing an opportunity for savings of up to 335,000 annual kWh per site. This opportunity was hidden because the building operators believed that they already had the full benefits of controls. By taking a programmatic approach to the technically complex arena of refrigeration controls, PECI identified and captured enormously cost-effective savings opportunities.

Refrigeration control technologies offer the opportunity to modulate energy use in response to fluctuating refrigeration loads. In addition, they offer built-in monitoring and remote management capabilities. New opportunities that combine supermarket control systems with demand response and management technologies are especially attractive. PECI has developed a pragmatic approach that tackles the technical complexity of control systems optimization within a simple program structure, ensuring high participation and long term energy savings. This paper describes the most popular controls and the savings potential for proper installation and commissioning. In addition, it will highlight practical program implementation strategies that have cost-effectively saved customers millions of dollars in this energy-intensive market sector.

Introduction

Food stores in general present an attractive target for energy efficiency efforts because they are so energy intensive. At 48.7 kWh/square foot, they have the highest energy intensity of any of the building types in the 1999 CBECS survey.[1] In addition, compared to many segments of the commercial market, ownership is relatively consolidated. Just 56 firms account for 80% of the groceries sold in the U.S. [2] With high energy intensity and consolidated ownership, targeted programs are feasible and cost-effective. For supermarkets in particular, cost-effective controls technologies to reduce energy usage are readily available. As the cost of controls systems has dropped, the capabilities have expanded, so that controls systems today are capable of implementing and monitoring multiple energy and demand management strategies.

This paper reviews the most promising supermarket refrigeration control technologies, discusses the current market conditions, and describes a resource acquisition program design that

[1] The next highest intensity building end use is food service, at 34.2 kWh per square foot. CBECS Table C10, Electric Consumption and Expenditure Intensities, 1999.
[2] See "An Examination of the Potential for Low-energy or Zero-energy buildings in the Retail Food Market." In the proceedings of ACEEE Summer Study 2006.

successfully saved almost 14 million kWh in San Diego, CA in 2005. For the purposes of this paper, "supermarkets" are loosely defined as grocery stores of 40,000 square feet or greater with multiplexed compressor systems. The majority of participants in the San Diego program were stores from a national chain with a centralized management; however, regional chains and independent supermarkets also participated and the program design described worked for them as well.

The Opportunity

Supermarkets use about three times as much electricity per square foot as office buildings.[3] Since 30% to 50% of their energy use is in refrigeration, capturing savings in this area offers huge potential. One might think that good business practices would lead supermarkets to capitalize upon these savings. Indeed, most supermarket owners are acutely aware that energy costs are important. Energy and maintenance is typically 2% of sales, often equal to or greater than their profit margin. (Zazzara & Ward 2004, 2)

Most large chain supermarkets have a centralized management group that is involved in energy related decisions, particularly for purchase decisions. For ongoing operations, the large supermarkets may outsource the energy management functions to energy management and consulting companies. These companies provide an array of business consulting services, from engineering to project management. Energy management and consulting companies may specify system set-up and monitor energy use. These companies may also manage capital projects from hiring contractors, to purchasing equipment, to helping the customer find financing.

Despite these efforts to monitor and manage energy use, PECI's audits and subsequent implementations showed huge savings, up to 335,000 kWh per store, over half of which were readily available through implementing controls and optimizing controls strategies. These opportunities appeared in large chain and independents alike. This study discusses a program that worked mainly with large chains. Smaller independents that participated showed the same savings opportunities and even greater need for assistance in capturing the savings.

In general, controls offer strong energy savings. Equipment is designed, built, and installed to run at worst case conditions (design conditions), providing owners with safety and assurance of adequate cooling on even the hottest days. Instead of steady state operation and design conditions, controls can dynamically modulate energy use to match loads, eliminating waste without jeopardizing the performance of the crucial refrigeration systems. In addition, they can reduce wear and tear on compressors by allowing them to run less and at lower pressures. Finally, because of their sophisticated and automated nature, controls offer the potential for precise demand response and demand management.

Common refrigeration controls measures include:

- Optimizing system setpoints to run at higher suction pressures and lower minimum condensing temperatures
- Allowing suction pressures to float above setpoint (Floating Suction Pressure Control (FSPC))
- Use of a differential temperature strategy for condenser controls (Floating Head Pressure Control (FHPC))

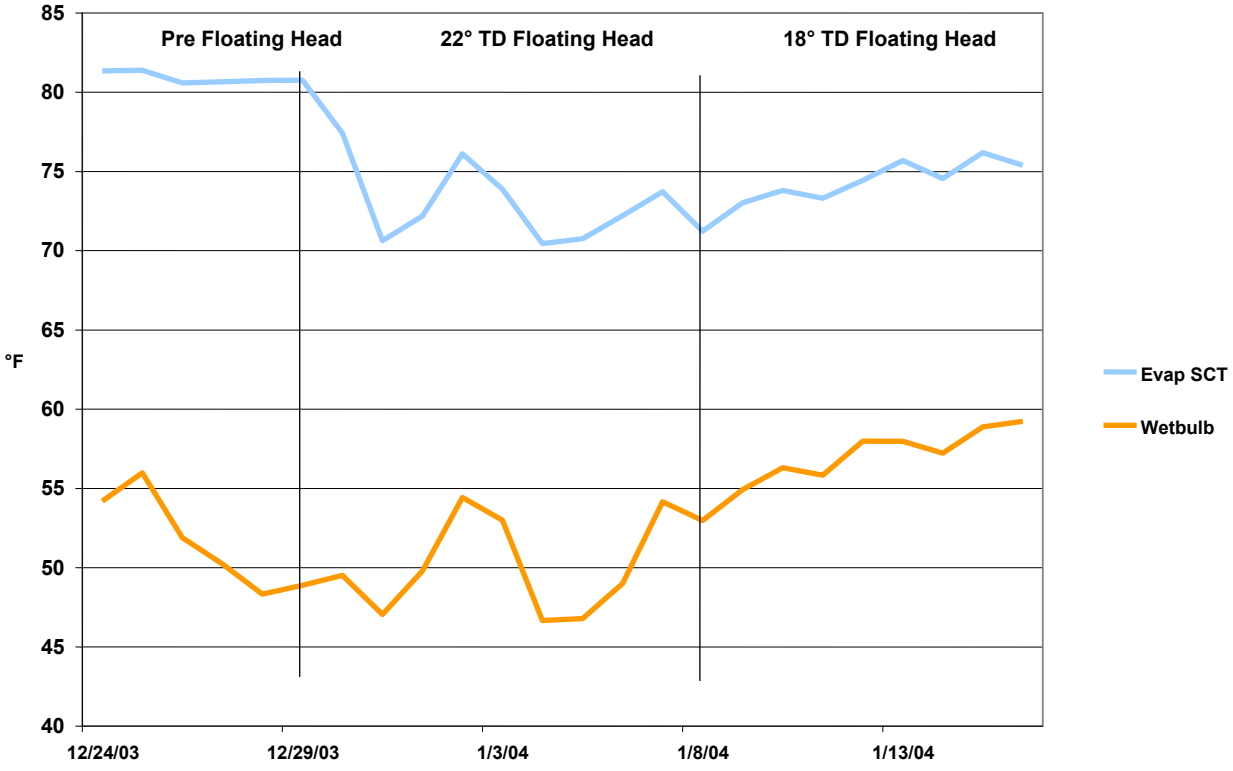
[3] Electric EUI for office buildings is 15 compared to 50 for grocery stores. Value from Cal-Arch benchmarking data for Climate Zone 8. The same value is obtained for California as a whole. http://poet.lbl.gov/cal-arch/

- Optimization of heat reclaim equipment and strategies
- Control of condenser VFD and fan staging
- Off hours shutdown of unused cases and refrigerated areas
- Evaporator fan controls
- Defrost controls
- Anti-Sweat Heater Controls (ASHC)

In some instances, a single central control system can manage all of the control strategies above in addition to controlling HVAC and lighting in multiple zones, all the while monitoring, logging, and allowing remote implementation of new controls strategies or demand reduction measures. Since different controllers have different capabilities, it is important that program implementers select the right system. Different stores have different monitoring and maintenance strategies so a short and long-term view is essential in choosing the right control hardware.

One of the largest energy savings comes from floating head pressure control, a strategy that allows the condenser to take advantage of cool ambient temperatures and additional condenser capacity to minimize the amount of energy required by the compressor. Figure 1 below demonstrates that by allowing the saturated condensing temperature (SCT) to dynamically follow the ambient conditions, the compressors work only as hard as the situation requires.

Figure 1. System Temperatures: Pre- and Post – Floating Head Control



In the graph for the period from 12/24 to 12/29, the SCT is fixed above 80°F regardless of the actual ambient conditions. The compressors must work to raise the refrigerant to the SCT, in this case almost a 40 degree difference. When floating head pressure control is implemented,

the first temperature difference was programmed at 22° (12/29 to 1/08), allowing the SCT to drop to 22° above ambient, thus reducing compressor kW usage. As the ambient temperature changes over time, the SCT "floats" to stay within 22 degrees. On 1/08, the programming was adjusted to further tighten the temperature differential, allowing for further compressor kW reduction. Even on a systems 'design day' or worst case operating conditions, the controlled system will use significantly less energy.

Studies have shown savings of 14% combined compressor and condenser energy consumption for floating head pressure controls with variable frequency drives (VFDs).(Singh 2006, 7) In PECI's experience in California, depending on climate, condenser capacity, baseline conditions, and programming expertise, floating head pressure controls can often save a supermarket from 75,000 to 150,000 kWh annually. The same controller can be used to float the suction pressure to achieve an additional 30,000 – 60,000 annual kWh of savings.

The same supermarket controls that provide for daily refrigeration management are also designed to perform demand response or demand management. Since these controls can be programmed to change setting based on time, preset conditions or a remote call to action, they can immediately activate load shedding strategies such as temporarily shutting off all anti-condensate heat, reducing lighting levels, rescheduling defrost cycles until off-peak hours, and turning off refrigerated case lighting. Note that none of these load shedding strategies compromise case temperatures or product safety. When remote wireless enabled, demand response strategies can be implemented at multiple sites within minutes of receiving notification from the utility. Demand response to a call for load shedding may be as much as 20-50 kW per store. In a metropolitan area with over 200 stores, 4,000-10,000 kW is a significant load to shed from the utility grid!

San Diego Case Study

As part of a resource acquisition program, PECI surveyed 104 supermarkets in the San Diego area. The intent was to quickly and cost-effectively capture energy savings from retrofits and controls. Two major supermarket chains and several independents were included.

An initial survey of opportunities found that there were multiple retrofit opportunities, particularly in the areas of relatively new technologies such as electronically commutated motors (ECMs) in walk-ins, variable speed drives for refrigeration and HVAC units, and a surprising amount of basic lighting upgrades. The program's investigation of controls found that almost 40% of the existing controls were not floating head and suction pressures at maximum efficiency either due to programming errors or missing components. There was even more opportunity for anti-sweat heater controls. Although most stores understand the need for anti-sweat heater controls, often when a line of cases is upgraded or the floor plan is revised, the controls are not checked and re-established. On average, the total savings available through commissioning controls and other retrofits was 335,000 annual kWh per site, and 25 kW of peak demand savings. Figure 2 shows a summary of the retrofit and controls opportunities.

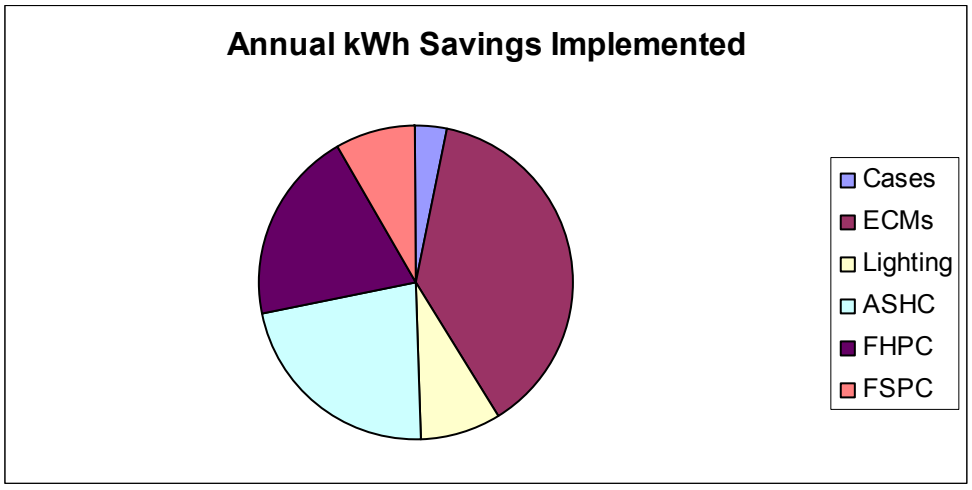
Figure 2. Energy Saving Opportunities

	Supermarket Chain 1	Supermarket Chain 2	Independents
Number of stores	42	52	10
Retrofit opportunities	1,001	1,055	371
Stores with controls, but missing sensors or proper programming	24	15	2
Failure rate of existing controls	57%	29%	20%
Anti-Sweat Heater Control Opportunities	34	20	10

The program did not investigate other control and retrocommissioning areas such as lighting controls and hood controls. Anecdotally, the program found some form of lighting control in most stores, but almost universal lack of hood controls. There are often regulations and complex air balancing requirements that affect the ability to install hood controls. However, the opportunities for lighting controls appear to be very cost-effective.

Based on the survey results, including estimates of prescriptive rebates, energy savings, and equipment costs, the decision makers were quick to act. At the time of publication, the first supermarket chain and several of the independents have implemented a suite of recommended retrofits. This delivered 14.2 million annual kWh savings, an average of 309,000 annual kWh per site. Figure 3 shows the mix of measures implemented and their relative contribution to program savings.

Figure 3. kWh Savings Obtained in San Diego Supermarkets



As shown in the chart, the top three controls measures account for half of the implemented program savings. On a store level, these savings can be implemented with a single controller performing anti-sweat heat control (ASHC), floating head pressure control (FHPC) and floating suction pressure control (FSPC). This is remarkable because in San Diego, FHPC savings opportunities tend to be smaller than in cooler climates, yet the stores in the program

saved an average of 75,000 kWh (425 kWh/horsepower)[4]. They saved an additional 174 kWh/hp by implementing floating suction controls.[5]

The program succeeded in delivering substantial cost-effective savings in less than 8 months. It worked with both the large chains and the independently owned supermarkets. The following discussion further elucidates the program approach, design and tactics on the ground that hold promise for further resource acquisition efforts.

Programmatic Approach

Many utilities already work with supermarket customers, especially large chains, to help implement efficient technologies. Often, utility account reps work directly with the supermarket chain to develop custom rebates for the stores. Despite these activities, there are tremendous cost-effective savings to be acquired in the retrofit arena, as demonstrated in the San Diego project. A programmatic approach needs to reflect the market conditions in both design and implementation.

Market Conditions

Because supermarkets have small profit margins, energy costs play a crucial role in their economic success. (Southern California Edison Refrigeration Technology and Test Center) While it is in their best interest to be energy efficient, several market conditions often prevent them from achieving that goal. Many supermarkets are missing opportunities to save energy because:

Refrigeration controls are technically complex, requiring site specific programming and customized installation. Few service technicians truly understand the underlying dynamics of the refrigeration cycle and so lack the information to understand how to properly optimize control systems for energy efficiency. Even in the largest national chains, the in-house maintenance staffs often lack the expertise to maintain, let alone program controls. Where programming is outsourced, it is often left to the refrigeration contractor in charge of equipment installation and repair. For this reason, the programming may minimize service calls, not maximize energy savings.

Supermarket owners believe they already have operational controls. Although large supermarket decision makers have embraced the concept of controls and will tell you that they in fact, have controls, audits in supermarkets have proven that controls implementation is patchy at best. In one chain claiming they were controlling head pressure, audits found fifteen out of 52 sites that were not programmed to float head pressure, wasting 2.1 million kWh a year. Although most national chains have "implemented controls", they have failed to implement regular monitoring and recommissioning, missing out on enormous savings.

Key decision makers are faced with a host of issues that pre-empt energy efficiency. Supermarket decision makers grapple with multiple issues, including labor relations, food safety and merchandising, all of which seem more pressing than efficiency. Even where they have energy managers designated to address efficiency, the energy manager must show that an

[4] Average store in the survey was 175 horsepower. Average modeled FHPC savings of 75,000 kWh per store.
[5] Average modeled FSPC savings over 46 stores

investment in their efficiency project has a better ROI than an investment in the new merchandising upgrade. Without solid information on project costs, utility incentives, and savings estimates, energy managers' projects are at a disadvantage when competing with more familiar capital investments. As a result, most supermarkets – from the large chains to the independents - lack the time or information to implement efficiency projects.

The conditions outlined above can be addressed with an appropriate, targeted program design. Each step is essential in facilitating part of the delivery chain and ensuring that the energy savings are realized.

Program Design

The market conditions discussed above are addressed by demonstrating the tangible opportunity to corporate decision makers, connecting them to qualified controls contractors, and delivering the technical expertise to ensure proper installation, all in the context of a clearly defined set of rebates and savings projections that build trust with these decision makers. In a market transformation program, demonstration projects and performance incentives make sense. However, in a resource acquisition program like the one implemented in San Diego, it makes sense to provide any and all cost-effective assistance to get the savings. Where savings are high, as in supermarket controls, the investment in assistance pays back.

Refrigeration is technically complex - deliver technical expertise and qualified contractors. It takes hands-on technical expertise to identify refrigeration system opportunities and implement effective control strategies. Skilled technical advisors who personally identify the opportunities and verify proper installations at each site are an essential element of a successful program offering.

Relationships with knowledgeable contractors are also vital because the majority of refrigeration contractors lack the training to implement effective controls. Successful programs must tap the qualified controls contractors. Another program element that could be incorporated into a market transformation program is training for service and installation contractors so that customers can obtain energy optimization services from their existing contractors. In addition, customers should be encouraged to restructure their maintenance service contracts to require proper monitoring of specific controls, which would further motivate the service contractors to undertake controls training.

Supermarkets think they have energy efficient equipment – data shows the opportunity. To overcome owner misconceptions about their on-the-ground equipment, site specific surveys and Energy Savings Reports demonstrate the savings opportunities at each site. Although it may seem labor intensive to visit each and every site, it can be done cost-effectively by systematizing the site surveys to capture opportunities and produce compelling data quickly. By producing site specific results that attest to missing sensors or lack of programming, a program can convince decision makers to do more to improve efficiency. Rather than providing extensive detail and measured results for one site, the program design captures a snapshot of opportunities at all sites, allowing for concrete business planning and quick action on the identified opportunities.

Decision makers are hard to reach – offer objective expertise plus incentives. Because decision makers are wary of sales calls, having a utility-driven program with clearly defined

incentives catalyzes results. The utility sponsorship overcomes nervousness regarding a black box solution and a concern that contractors are motivated by self-interest and not energy savings. Finally, although one might argue that incentives should be unnecessary, experience shows that access to rebate monies, especially where they are prescriptive rebates, provides internal advocates the ammunition they need to get corporate decision making to happen.

Program Implementation

Given the basic market conditions and design structure, the following program structure has been shown to be very effective in San Diego. The tactical steps show how to implement the program design for maximum results.

Perform audits. Site specific, streamlined audits scope the energy saving opportunity quickly and cost-effectively. Energy Experts experienced in on-the-ground supermarket refrigeration systems conduct a survey of each site, armed with a tablet computer and audit software to identify and quantify refrigeration opportunities. Parameters such as store operating hours, climate zone, refrigerated case characteristics, condenser information and system age provide inputs to create a store-specific assessment. The results of the audit are compiled into a report for the supermarket's key decision makers. The report defines the installed measures' costs, savings and simple payback, providing financial projections for each recommended retrofit.

For independent supermarkets, an in-depth audit for each store is essential. Refrigeration is site specific. Initially, this doesn't seem cost-effective but the savings are so high, that it is worth the time. For large supermarkets with standard configurations, a few audits may be sufficient to prove the business case. However, there continues to be value in visiting every site because store managers and their contractors do not have the knowledge or time to identify all the opportunities. PECI found that the program could identify large savings opportunities so quickly that it was more cost effective to provide all the audits and thereby fast-track the implementation. In addition, the controls retrofits were only a portion of the available opportunities, so even where there was remote monitoring enabled, it was impossible to capture all the opportunities without visiting each site.

Require maintenance-related activities. All too often, adjustments in controls do not realize their full potential because the systems are poorly maintained. Anticipated energy savings are based on the assumption that all equipment is being properly maintained. A key vulnerability is in leakage of cold air from refrigerated spaces. Programs should ensure that door gaskets, strip curtains and door auto-closers are installed and in good condition. A one time sweep to get the store in good shape is the minimum required to realize the energy savings. One could argue that these are maintenance issues that should be handled in-house. However, the reality on the ground is that the in-house maintenance staff does not have the time to keep all equipment properly maintained.

On a longer term basis, there are ideas to keep up the maintenance. Stores can establish bonuses to store maintenance departments when their equipment performs above a certain level. A program should consider incentives to outsource the installation and repair of these items. Further investigation could be done to create an incentive program for purchasing ongoing maintenance service contracts or expanding in-house maintenance standards and capacity.

Coordinate contractors. It is risky to assume that the existing refrigeration service contractor will be able to program control systems effectively. The service divisions of equipment manufacturers tend to focus on product safety and minimizing sales calls, not maximizing efficiency. Controls expertise may be found in contractors that have specialized in controls and energy efficiency, or in the energy management services division of a large refrigeration contractor. Thus, a program may have to coordinate between the controls contractor and the existing refrigeration service contractor or between two divisions of the same contracting company. Ideally, the regular service contractor should be present at installation and programming, to better understand the new controls, and to give their seal of approval. By including the service contractor in the controls installation, the customer buys future accountability: The service contractor has accepted that the new controls are saving energy without negatively impacting the system that they must maintain.

Whether using a specialized controls contractor or an existing refrigeration contractor, it is essential for the program implementers to walk through several installations with each technician to make sure that processes are set up correctly. In addition, interactions with heat reclaim and minimization of make-up air infiltration in areas of high humidity need to be investigated to make sure that there are no unanticipated side effects. Although contractor coordination takes a significant amount of time, successful programs must closely coordinate and monitor contractor activity to ensure savings.

Build in data collection. Today's controls offer the opportunity to garner extensive energy usage information. Before an installation is programmed, the contractor takes a "snapshot" of existing conditions. Post-installation points are tracked over time. Pre- and post- installation data can be compared to verify the controls are operational and optimized. Analyzing and showing decision makers site specific data reinforces the integrity of the energy savings. Once installed, post-installation checks are essential. These can be in-store, or via a modem if the supermarket has centralized data monitoring.

Issue rebates. Rebates serve to catalyze action. Without incentives, supermarkets are unwilling to spend the time investigating options and making control systems a priority. Change is difficult and requires incentives to push past the status quo. Although utilities have not typically offered prescriptive rebates for complex measures with variable savings, PECI found them very effective. Business decision makers prefer a known, prescriptive rebate over a potentially higher rebate that could require intrusive monitoring or involve downside risk. It is also important to include an option for the customer to release the rebate to the contractor. If the decision maker who authorizes the work has a budget for energy management, but the rebate is not going back into that budget, it may be more attractive to authorize payment to the contractor and avoid the out-of-pocket expense altogether.

Build in persistence. Once installed, post-installation checks are essential. These can be in-store, or via a modem if the supermarket has centralized data monitoring. Wherever possible, a program should encourage control system installations to include remote access via modem so that re-inspections can be accomplished from a central location. Although properly installed controls generally function without fail, a re-inspection after six months will serve to ensure that the human side of the equation has not undone the careful work of the controls contractor. If there is evidence that the control settings have been altered, it is a good idea to renew efforts to

educate all the involved parties. Many programs focus on rebating hardware in the belief that it is the only way to guarantee persistence. For control strategies, a utility might consider rebating a contract to provide connectivity to the web - a dedicated modem line that allows remote monitoring and programming by the controls contractor, and provides site specific energy data for the decision maker. In PECI's experience with larger chains, the detailed audit findings can be enough to prove the need for on-going remote monitoring: one chain has subsequently adopted universal remote monitoring of all sites and is actively tracking the systems with their new software.

Enable demand response. A supermarket controls program should not miss the opportunity to enable demand response. This will require some reorganization of program infrastructure, because demand response and energy efficiency tend to be two separate endeavors, from the utility perspective. To a supermarket customer with a potential controls installation, they are part of the same package. Financial incentives to participate in demand response could help tip the scales to get controls implemented in the first place. Once the infrastructure is in place, the control system can be set up to implement a variety of strategies, depending on the utility and supermarket choices.

Summary

Supermarket controls and commissioning offer strong opportunities for savings as shown in the San Diego program. Because control strategies are not well understood, even supermarkets with policies and practices to install controls often find that the controls are not fully implemented to maximize energy savings. Almost 40% of the 104 supermarkets surveyed, including large national chains and independent stores, lacked proper programming or critical components for the top controls opportunities – floating head pressure control, floating suction pressure control, and anti-sweat heat control. Implementation of these and other opportunities saved an estimated 309,000 annual kWh per site.

The primary market conditions that must be addressed in any controls program are the technical complexity of controls, the belief that the controls are already properly programmed, and the customer's lack of time or infrastructure to act on the opportunities. Even in large supermarket chains, with upper level management dedicated to addressing energy management, they do not have the "boots on the ground" to scout every opportunity and manage it through a retrofit.

An effective program must provide technical expertise, store specific information regarding the energy saving opportunities and project implementation support to get quick results. To ensure savings, there must be attention to all points of delivery from contractor training and coordination through post-installation verification of pre and post energy usage.

Possible avenues for further program investigation include technician training to increase knowledge of controls (for both in-house supermarket staff and for refrigeration maintenance service contractors), incentives for customers to purchase maintenance service contracts, and incentives for contractors to offer monitoring services for the smaller market players.

As utilities seek to tap new sources of savings, there is high potential for integrating demand and energy savings. Many utilities offer separate programs to address energy efficiency and demand response or management. An integrated program design would maximize the capabilities that are offered in today's control technologies.

References

Singh, Abtar. 2006. Optimum Refrigeration Controls with E2™. Available online: http://www.cpcus.com/Library/Optimum%20Refrigeration%20Control%20with%20E2.pdf. Kennesaw, GA: Emerson Climate Technologies

Southern California Edison Refrigeration Technology and Test Center. Quantifying the Effects of FDA Food Code on Supermarket Energy Use Through Computer Simulation. Available online: http://www.sce.com/NR/rdonlyres/1E536EEA-87C3-430E-BF3E-02A6A798FFA7/0/rttc4.pdf

Zazzara, Jeffrey B. and D. Ward. 2004. "Supermarket Commissioning with an Emphasis on Energy Reduction." In *Proceedings of the 2004 National Conference on Building Commissioning.* Portland, OR: PECI.