Demand Response Opportunities in Industrial Refrigerated Warehouses in California

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ABSTRACT:

Industrial refrigerated warehouses that implemented energy efficiency measures and have centralized control systems can be excellent candidates for Automated Demand Response (Auto-DR) due to equipment synergies, and receptivity of facility managers to strategies that control energy costs without disrupting facility operations. Auto-DR utilizes OpenADR protocol for continuous and open communication signals over internet, allowing facilities to automate their Demand Response (DR).

Refrigerated warehouses were selected for research because: They have significant power demand especially during utility peak periods; most processes are not sensitive to short-term (2-4 hours) lower power and DR activities are often not disruptive to facility operations; the number of processes is limited and well understood; and past experience with some DR strategies successful in commercial buildings may apply to refrigerated warehouses.

This paper presents an overview of the potential for load sheds and shifts from baseline electricity use in response to DR events, along with physical configurations and operating characteristics of refrigerated warehouses. Analysis of data from two case studies and nine facilities in Pacific Gas and Electric territory, confirmed the DR abilities inherent to refrigerated warehouses but showed significant variation across facilities. Further, while load from California's refrigerated warehouses in 2008 was 360 MW with estimated DR potential of 45–90 MW, actual achieved was much less due to low participation. Efforts to overcome barriers to increased participation may include, improved marketing and recruitment of potential DR sites, better alignment and emphasis on financial benefits of participation, and use of Auto-DR to increase consistency of participation.

Introduction

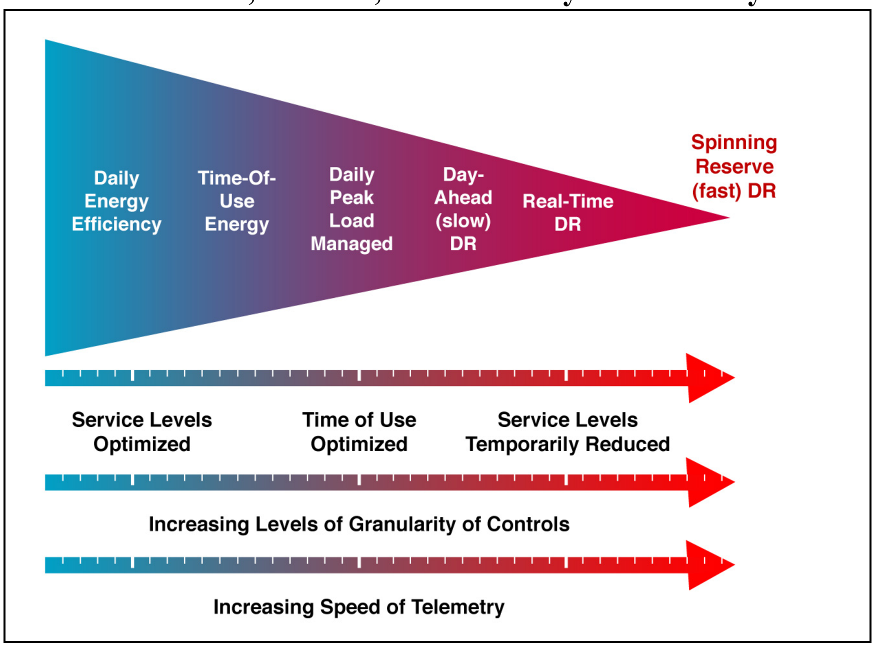
Lawrence Berkeley National Laboratory's (LBNL) Demand Research Center (DRRC) selected industrial refrigerated warehouses for study because refrigeration loads account for approximately 16% of the food industry's total energy use (Richman 2009). Industrial refrigerated warehouses (referred to hereafter as "warehouses") are good candidates for undertaking energy efficiency and demand response initiatives to manage their electricity use (Lekov 2009), because:

1. Electricity accounts for a large fraction of their operating expenses with the major power demand ordinarily occurring during utility peak periods, yet they are capable of accommodating low power operation for up to a few hours if needed.
2. The processes in these facilities are limited in number and well understood.
3. Some refrigerated warehouses already have the control systems required for load management programs, as well as experience in energy efficiency.
4. The experience with some of the demand response strategies proven successful in commercial buildings may be applicable to these facilities also.

Energy efficiency (EE) and demand response (DR) have different core objectives. EE programs primarily seek to reduce client energy use on a permanent basis through the installation of energy efficient technologies. DR on the other hand is a set of actions taken to reduce electric loads when contingencies, such as emergencies or grid congestion or peak loads, occur that threaten supply-demand balance, and/or market conditions occur that raise electric supply costs. DR programs are designed to improve the reliability of the electric grid and to lower the use of electricity during peak times to reduce the total system costs. However, EE and DR share certain benefits. Reducing peak demands may also yield energy savings, and most energy efficient technologies yield some peak demand savings (CPower n.d.).

The concept of the "electricity value chain," seen in Figure 1, encompasses the portfolio of actions that industrial facilities can undertake relative to their electricity use, defining EE and DR at six levels of service, distinguished by the magnitude, type, and rapidity of response. For DR events (right region of Figure 1), both the timing and quantity of electricity are important considerations. DR events are best managed when accurate and timely information is available about production and service level changes. The arrow below the service level description indicates that the ability to perform DR is enhanced with greater granularity of controls. An example is the use of electric load reductions using variable frequency drives rather than on-off control. The bottom arrow on telemetry indicates that remote signals for DR have varying requirements. Day-ahead DR is less demanding than the speed required for day-of DR or telemetry for fast ancillary services (McKane 2010).

Figure 1: Service levels, controls, and telemetry in Electricity Value Chain



Thus, DR can be viewed in practical terms as a temporary reduction in electricity usage in response to external factors such as peak loads on generation and transmission resources; while energy efficiency is a permanent, or near permanent, reduction in the electricity usage of a process with no appreciable drop in the quantity or quality of service level (McKane 2010). For the day-ahead DR time frame (also known as peak load management) utilities often employ Time of Use (TOU) pricing programs to create financial incentives for customers (including industrial refrigerated warehouses, the focus of this paper) to voluntarily reduce their energy use during peak demand events. Since such demand response participation is not mandatory, the degree of participation from any facility reflects:

a. The technical and operational capabilities of the individual facility (often dependent on the particular industry sector, and sub-classifications within that industry sector) to shed or shift loads without adversely affecting their operations.
b. The relative importance to the company of environmental issues and corporate social responsibility.
c. Awareness and ability to incorporate peak pricing into energy usage planning.
d. The relative benefit of utility incentives offered, vis-à-vis the capital and operational expense involved in executing energy management measures.

OpenADR is a protocol for continuous and open communication signals provided over the internet, to allow facilities to automate their DR without the need for manual signals. Automation of DR improves the reliability of day-ahead DR participation by requiring facilities to "opt out" of participation in a DR event, rather than the "opt in" approach used for manual DR. Such automation is also more or less essential for faster response DR including ancillary services. Research at DRRC has found that industrial facilities which have implemented energy efficiency measures and have centralized control systems can be excellent candidates for Automated Demand Response (Auto-DR), due to equipment synergies and receptivity of facility managers to strategies that control energy costs without disrupting facility operations. Auto-DR strategies can be implemented as an enhanced use of upgraded equipment and facility control strategies otherwise installed as energy efficiency measures. Conversely, installation of controls to support Auto-DR may result in improved energy efficiency through real-time access to operational data (Piette 2008).

Methodology

This paper presents the case studies of two warehouses, and field data from nine additional warehouse customers of Pacific Gas and Electric (PG&E), with analysis of load sheds and shifts in response to day-ahead notification DR events. Secondly, this paper describes the opportunities and limitations associated with DR opportunities in warehouse facilities. Also discussed is an overview of the physical configurations and operating characteristics of warehouses, in the context of to the observed load sheds and shifts from baseline usage.

Case Study 1 – Amy's Kitchen

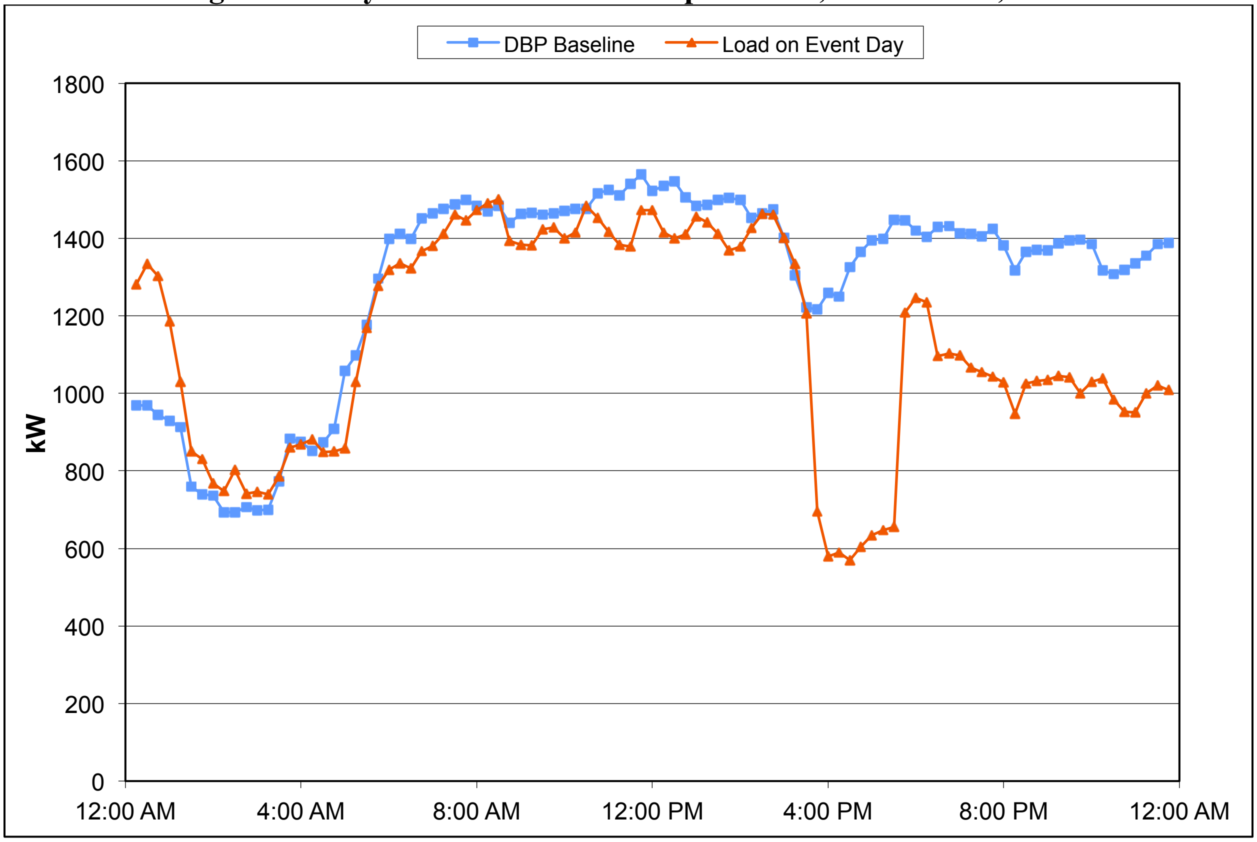
Amy's Kitchen's Santa Rosa facility, the subject of a case study by DRRC (2009), takes raw food and produces packaged meals. It includes several large cool rooms, freezers, blast freezers and a spiral freezer. In addition, there are multiple heating, ventilation, air-conditioning (HVAC) and lighting loads. Altogether, the facility's electrical end-use applications have an average aggregate baseline demand of approximately 1,600 kW with a peak demand of 1,900 kW, of which nearly 12% was accounted for by the spiral freezer alone. Several efforts to increase energy efficiency had been undertaken by the time of the study. All freezers and cool rooms have been well insulated, all light fixtures had been retrofitted with fluorescent bulbs, and occupancy sensors installed in all of the administrative offices. The entire facility was also in the process of being re-roofed with cool roof foam insulation under the roof panels. The plant has historically participated in PG&E's manual DR programs.

Amy's Kitchen elected to undertake a controls system upgrade that would enable it for Auto-DR. The controls system upgrade configuration chosen by the facility yielded better than expected results in initial Auto-DR tests with no product loss or production delays. During four separate tests conducted in December 2008, eight different electrical end-use applications in the plant were either shut off or had set-points adjusted to a pre-set hierarchy, triggered by automated signals from the utility. By installing the control system and participating in Auto-DR events the facility achieved:

- Electricity DR of 580 kW, approximately 36% load shed, which was 162 kW more than had been estimated before the tests,
- $139,200 in incentive payments based on estimated load shed, and potential additional incentives for future events, and
- Simple payback period of less than one year.

The results of one such test are depicted in Figure 2.

Figure 2: Amy's Kitchen demand response test, December 3, 2008



Case Study 2 – U.S. Foods

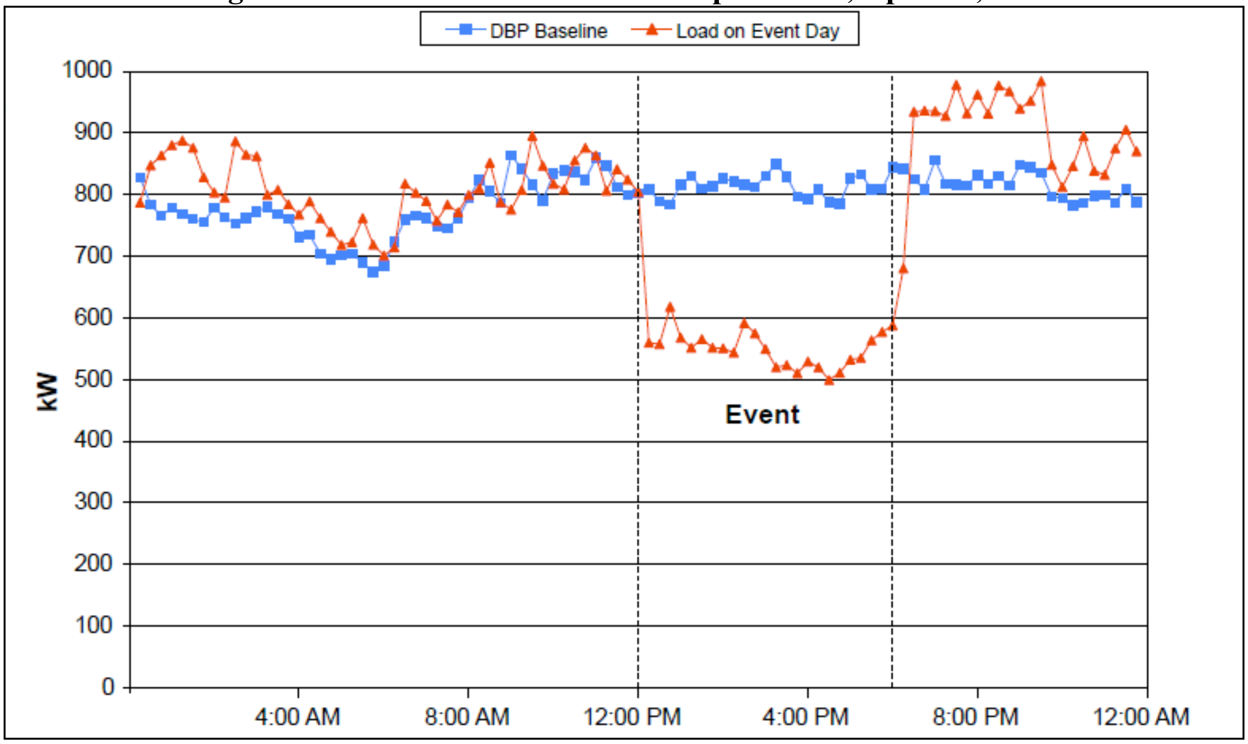
A case study was done by DRRC (2009) on US Foodservice's Livermore facility, a cold storage food distribution center of 345,000 sq. ft. with temperatures tightly controlled between -1 and +1 °F. Electricity demand for the entire site ranges from between 700 and 900 kW of which the freezer accounts for between 30 and 40%. The site has been proactive with respect to its energy consumption, and has participated in past PG&E DR programs. It has also implemented EE measures such as high efficiency lighting and motion or occupancy sensors on all lighting, including in the warehouse, private offices and conference rooms. PG&E's load shed estimation assessment identified this site as well-suited for Open Auto-DR because the freezer and HVAC systems have stable loads.

Having participated in previous PG&E DR programs, this site already had some of the controls and communications infrastructure needed to implement Open Auto-DR. The current controls system upgrade enabled the plant to fully implement Auto-DR and it was able to shed a significant part of the facility's load during the tests without any product loss or disruption to its shipping and stocking operations.

- On average, it shed approximately 25% (more than 200 kW) of its load during the period of the tests. At one point during the 2nd test, the load declined by as much as 330 kW (41% of the baseline).
- Shutting off the air handlers in the freezer had the largest impact, but adjusting the set-point on the HVAC system helped shed as much as 25 kW. By the end of each 6-hour testing period, the air temperatures near the doors in the freezer had risen by as much as 8.6 °F, while the air temperatures near the far walls of the freezer had only risen by 1.2 °F. Although the temperatures of the product remained within acceptable limits, 8.6 °F is a rather high excursion in temperature and a shorter shed period, of say the more typical duration of 2 hours, might be needed to reduce the potential impact during the hottest months when a shed would be likely to be called.
- Because the tests were conducted in April when the ambient air temperature was around 70 °F, the facility's load was not as high as it is during the summer. When adjusting for summer conditions, DRRC was able to estimate that the facility could shed up to 385 kW if an Open Auto-DR event were to occur then.
- U.S. Foodservice incurred no additional costs for installing the equipment as it received a one-time incentive payment of $71,000 based on the estimated load shed. Future participation in Open Auto-DR events would enable them to receive additional incentives.

The results of one such test are depicted in Figure 3.

Figure 3: US Foodservice demand response test, April 22, 2008



2009 CPP Analysis

In follow up of the above case studies, and as part of the continuing effort to create an improved understanding of the potentials, challenges and current state of this sector, electricity usage data from the 2009 Critical Peak Pricing (CPP) program from nine industrial refrigerated warehouse customers of PG&E (Faulkner 2010) was analyzed for load sheds and load shifts from baseline. It was comprised of facilities adopting primarily manual demand response strategies.

CPP was a time-of-use (TOU) program offered by PG&E until 2009, since replaced by other similar programs. On a DR event day, from noon to 3 pm the price was roughly triple the regular price and from 3 to 6 pm the price was roughly five times the regular price. A DR event day would be announced by 2 pm on the previous day, to allow the consumer to plan appropriate load shift and/or load shed to minimize adverse effect on plant operations.

The results confirmed the DR abilities inherent to Industrial Refrigerated Warehouses, but showed significant degree of variation across the different facilities analyzed. Limited operational details are available due to lack of direct contact with plant personnel, but the following observations were made from average total facility-wide baseline electricity consumptions ranging from 150 kW to 1.3 MW. The observations made included:

1. Good sheds on most of the event days at 3 facilities implied equipment capability, operational flexibility, and commitment of plant management. In fact, one of the facilities achieved a peak 90% shed via manual DR, as opposed the more typical shed of 20-40%, but it was noted that this was primarily a food processing facility rather than refrigeration or freezer, and the shed was achieved by simply shutting down production for that period.
2. Good sheds on 2-3 of the 12 event days at 4 facilities implies inherent capability, but lack of financial incentives and/or management buy-in.
3. The remaining sites showed mixed results and in the context of limited information about the equipment and operations, no additional inferences were drawn.
4. At most of the facilities the DR was, as expected, seen to be a load shift as opposed to load shed. However, over the entire 24-hour period, most sites had energy usage lower than or equal to their baselines. This suggests that DR in refrigerated warehouses is not at the cost of energy efficiency.

A summary of the observations on which the above inferences are based, is presented in Table 1 (Facility operating data was obtained for this paper by virtue of LBNL's access to PG&E's InterAct database based on NAICS codes corresponding to refrigerated warehouses, hence facility names are not explicitly reproduced herein for confidentiality considerations). In addition to the CPP baseline, load sheds were compared against the alternate baselines of outdoor air temperature regression (OAT), with and without morning adjustment (MA).

Table 1: Summary of load-sheds by 9 industrial refrigerated warehouse customers of PG&E during 2009 Critical Peak Pricing (CPP) season (1-May-2009 to 31-Oct-2009)

Facility identifier	Average CPP Baseline	Average shed as measured by:			Indication of participation
		CPP	OAT	OAT+MA	
Site 1	864 kW	217	130	66	Sheds ranging from 10-50% on 8 of 12 CPP event days
Site 2	298 kW	262	247	257	90% sheds every event day from 12:00-15:00; Low baseline from 15:00-18:00
Site 3	516 kW	133	80	79	20-30% sheds during 11 of 12 event days (except for second consecutive CPP day)
Site 4	1258 kW	315	352	30	70% sheds on the first 2 of 12 CPP days of the season; No shed on other days
Site 5	488 kW	35	40	23	40% shed on one day only
Site 6	626 kW	93	107	63	Sheds ranging from 35-55% only on last 3 events (in August)
Site 7	299 kW	102	54	111	Large sheds on 3 of 12 events ~ 40-70% of baseline
Site 8	149 kW	21	13	28	Minor sheds on most days ~15-20% of baseline.
Site 9	213 kW	17	18	74	Did not participate in 2009

Figure 4: Representative CPP event day for Site 1

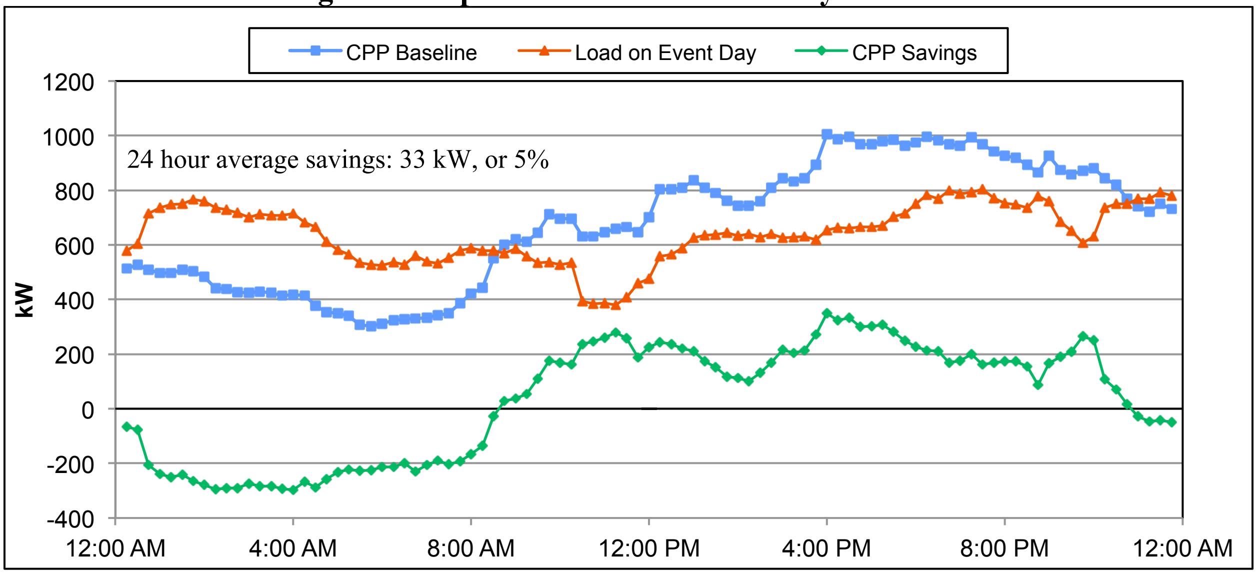


Figure 5: Representative CPP event day for Site 2

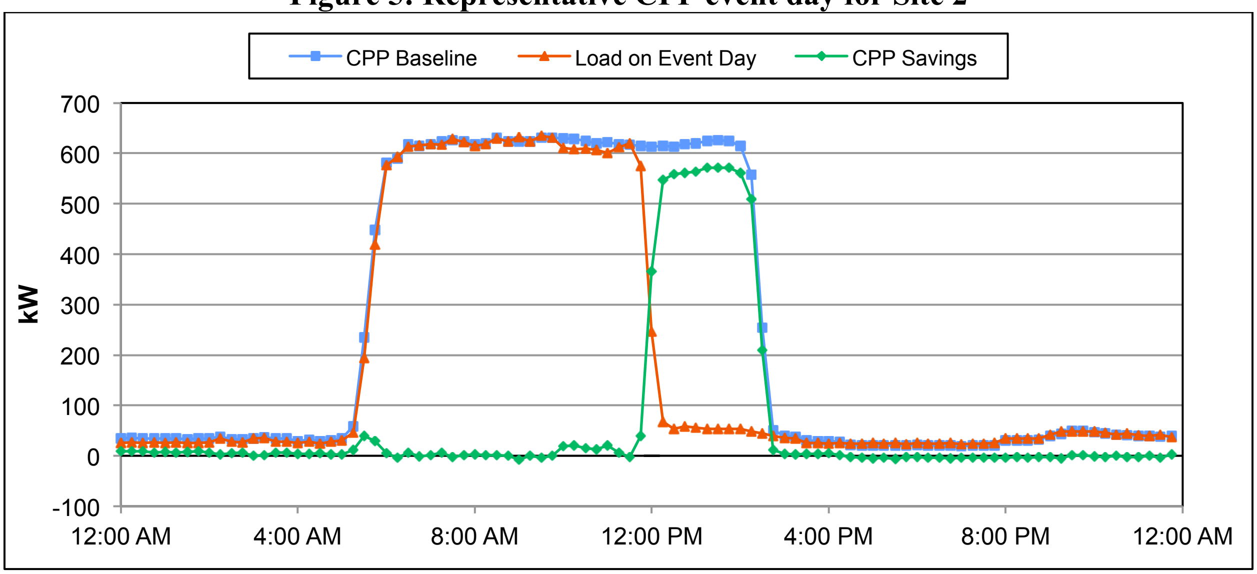


Figure 6: Representative CPP event day for Site 6

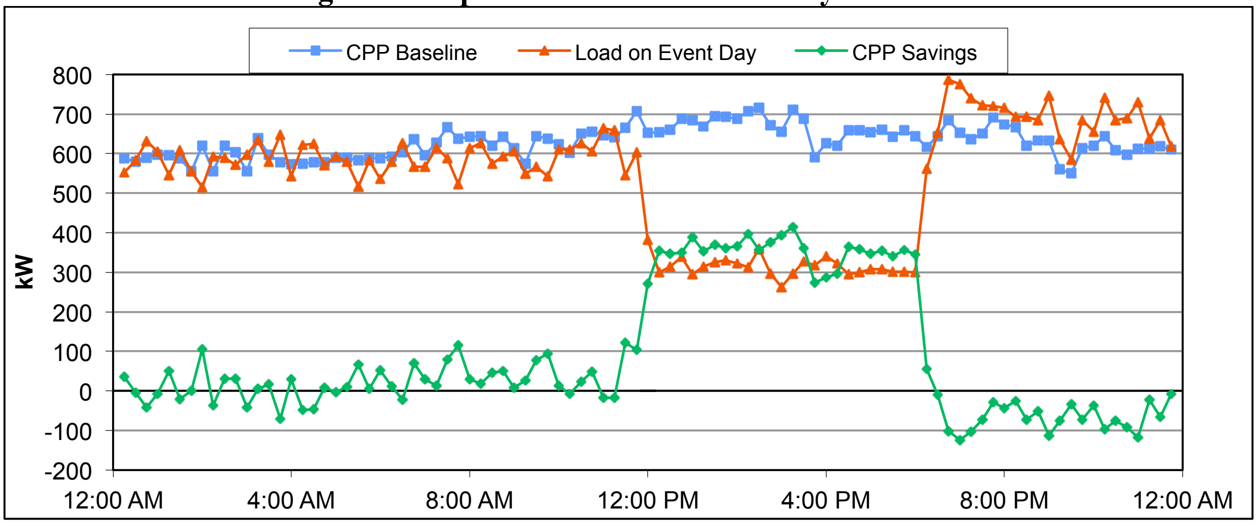


Figure 7: Representative CPP event day for Site 7

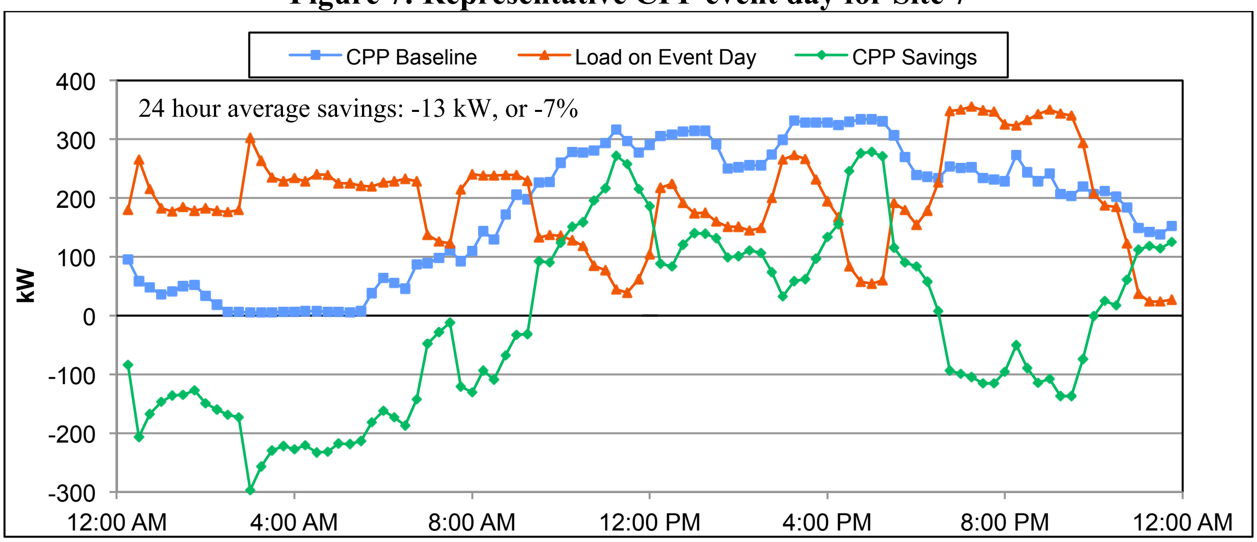
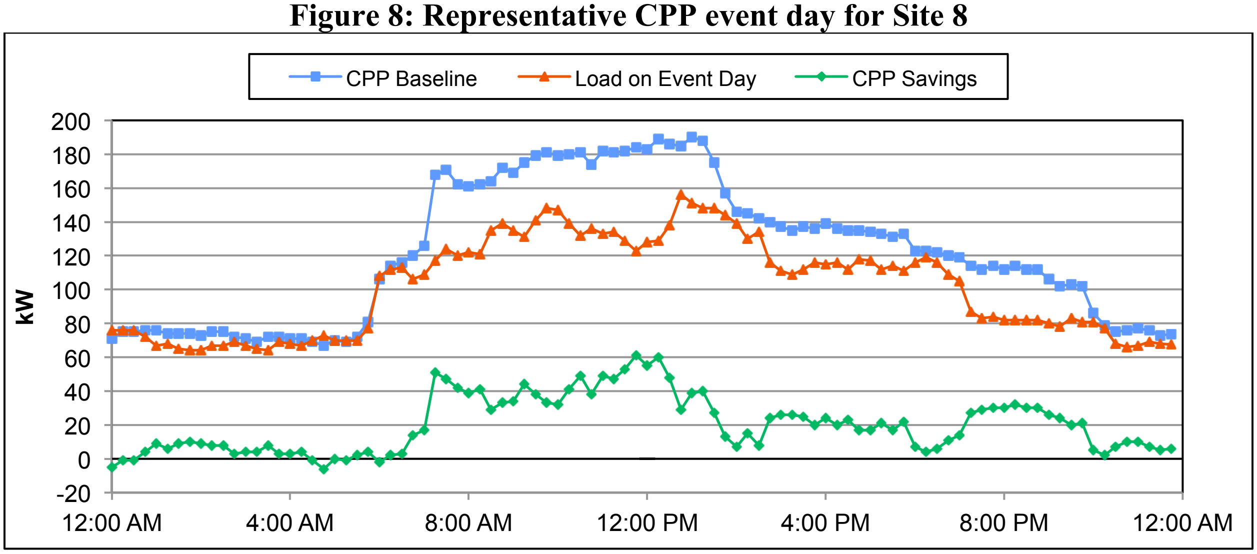


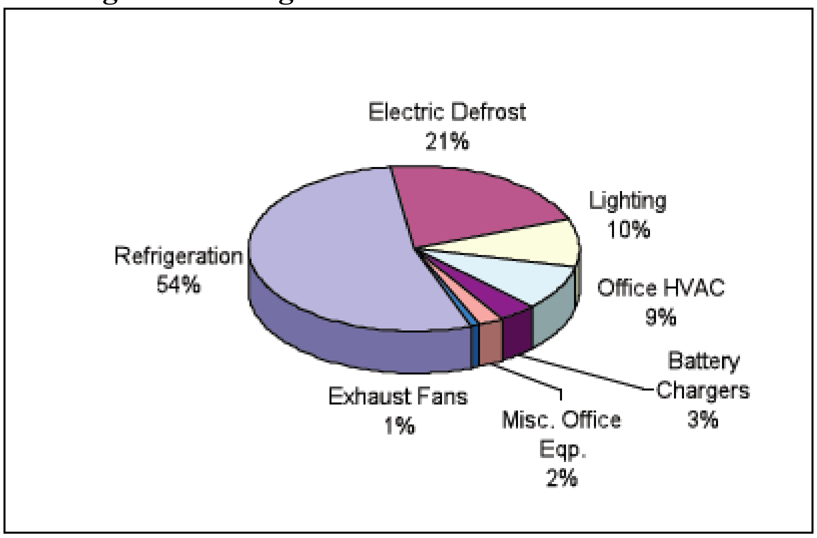
Figure 8: Representative CPP event day for Site 8



Electricity End Uses

The main energy end-uses in refrigerated warehouses are product refrigeration in cold and frozen storage areas, and buildings services (Pacific Gas and Electric Company 2007). Consequently these have been the main areas of focus for most DR and EE efforts, including at the facilities profiled above. Refrigeration accounts for over half of a typical refrigerated warehouses' end use energy. Electric defrost also contributes a significant portion of the energy use. All other services total about 25% of the end use energy in industrial refrigerated warehouses.

Figure 9: Refrigerated Warehouse End Use Load



Source: National Grid, "Demand Response Programs, Shared Demand Response Sample Audit," 2004

Conclusions

The current results confirm the opportunity in this sector and reinforce prior observations that refrigerated warehouses are excellent candidates for focusing demand response efforts (Lekov 2009). In addition, it was observed that:

1. The two case study facilities that had implemented Auto-DR programs demonstrated consistent DR results. There was more variability across the different facilities analyzed in the CPP analysis. This may stem from the fact that the latter was predominantly manual DR. Auto-DR is expected to result in greater consistency of implementation since the electric load curtailment is automatically carried out per pre-agreed hierarchy unless overrode by a human operator. Also, improved controls associated with Auto-DR may prepare facilities to be more receptive EE and DR in general due to both increased confidence in the opportunities for controlling energy cost/use and access to real-time data.
2. It was also noted that control technologies installed for energy efficiency and load management purposes can often be adapted for OpenADR protocol at reduced incremental cost (as highlighted by the US Foodservice case study.) Conversely, implementing the OpenADR protocol affords industrial facilities the opportunity to develop the supporting control structure and to trial potential reductions in energy use

that can later be applied to either more effective load management via demand response or a permanent energy use reduction via energy efficiency. Energy efficiency, load management, and OpenADR are complementary and highly compatible activities for refrigerated warehouses (Lekov).

While the electrical load from California's industrial refrigerated warehouses in 2008 was about 360 MW with a theoretical potential demand reduction ranging from 45–90 MW, sheds of this magnitude were not observed in the 2009 CPP study. In order to overcome barriers to increased participation, some of the steps that can be taken include improved marketing and recruitment of potential DR sites (in particular, conveying better alignment and emphasis on, financial benefits of participation), the use of Auto-DR to increase the consistency of participation, and potentially improved process control resulting from access to real time operational data.

In order to facilitate more effective outreach and targeting of the warehouses which are most capable of DR from technical as well as operational standpoint, the recommended next steps would be:

i. A "strategy guide" tool, which could be used as a reference by facility managers in implementing demand response, and in raising awareness to incorporate peak pricing into energy usage planning.
ii. A financial justification based on electricity cost savings resulting from participation in TOU and real time electric pricing programs vs. equipment upgrade capital costs, any additional operational costs, and operational risks.
iii. A qualitative discussion of intangible benefits and strategic value propositions, such as environmental issues and corporate social responsibility, in the context of their relative importance to a facility.

Such an exercise will also create the basis for a more cogent insight into the key factors, policies and incentives that drive electricity usage patterns in industrial refrigerated warehouses.

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