A Demand Response Solution for Underserved Mid-Size Commercial Customers

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INTRODUCTION

Demand Response (DR) programs offered by utilities and grid operators have tended to focus on attracting either residential or large C&I participants; those with peak demands greater than 200 kW (and often greater than 500 kW). Most residential programs involve reducing air-conditioner use, and often include some very small C&I [under 40 kW] participants and a smattering of larger customers.

No DR programs have explicitly targeted "mid-size" (40-kW to 200-kW) customers, mostly because there was no apparent enabling technology to accomplish remotely initiated load reductions. During 2004 and 2005, Southern California Edison (SCE) funded Aspen Systems Corporation[1] to (1) undertake a pilot DR program using commercially available Dencor digital demand controller (DDC) units coupled with Carrier Corporation's DR signal dispatching infrastructure, and (2) perform research to catalogue all enabling technologies that could be used in DR programs targeted toward mid-size customers. The pilot was not a stand-alone effort, but was part of a large, two-year SCE program designed to assess Critical Peak Pricing (CPP)[2] in the "small commercial" sector, as an element of the Statewide Pricing Pilot that was already underway.

The primary objective of the special pilot program was to determine the magnitude of the load reductions that could be achieved in various types and sizes of facilities during high-price CPP events. Secondary objectives included projecting technology cost-effectiveness based on the pilot program savings and estimated future implementation costs, and evaluating customer receptiveness to the DDC enabling technology.

THE CALIFORNIA STATEWIDE PRICING PILOT

The California Public Utilities Commission (CPUC) authorized the state's electric utilities to implement a Statewide Pricing Pilot during 2003-2005 to investigate and learn how various customer segments react to pricing signals in CPP tariff designs. The "small commercial" segment consists of facilities with peak demand under 200 kW. Customers in this segment that

1 Aspen Systems Corporation was acquired by Lockheed Martin Information Technology in January 2006.

2 Under a CPP tariff, customers pay a very high price during the 50-100 hours per year when wholesale prices are high or power-supply conditions are critical. Prices in other hours are reduced such that the tariff is revenue neutral if the average customer does not change their electricity-usage profile. However, if the customer reduces load during CPP events, the CPP tariff results in a smaller annual electricity bill. Alternative rate designs included different ratios of the high CPP price to average price, and different event duration.

participated in the study were on the CPP-V tariff, a schedule that provides a 4-hour notice in advance of CPP events.

To enable customers to respond to the variable pricing incorporated in the CPP tariff, SCE provided some participants with equipment that would automatically react to the pricing signals and reduce power demand by shifting air-conditioner set-points upward by 2 – 4°F. As part of a separate large DR pilot program, SCE already provided one type of demand response (DR) technology—a Carrier programmable communicating thermostat with two-way pager communications—to more than 8,000 customers in the small non-residential sector (10 to 200 kW).[3] A sample of these customers had been recruited to participate in the State Pricing Pilot. As part of another pilot, large customers (>200 kW) that already had energy management systems (EMSs) were recruited.[4] The point of the Lockheed Martin (LM) pilot program was to fill the void between these two technologies by evaluating a dispatchable load controller that would empower the large population of medium-size businesses to participate effectively in DR programs.

SCE provided LM with contact information for the SPP small-business participants. LM proceeded to call these customers and recruit participants in the special pilot. Because this was a pilot with a statistical sample selected for research purposes, the participant pool was representative of the entire small business segment and not just a selection of the most suitable candidates for the DDC enabling technology.

Demand Response-Enabling Technology. LM proposed integrating a mature, off-the-shelf digital demand control (DDC) technology manufactured by Dencor with Carrier's pager-based communication network to implement control events. The Dencor DDC (Model 300C) has been marketed to small businesses, especially convenience stores, for more than 15 years to reduce monthly demand charges. LM proposed to make this device's control functions dispatchable (i.e., operable only during DR events), rather than "always on," by linking it to the pager-signal receivers already installed as part of the in-place Carrier system.

Participants. SCE and LM recruited a sample of 21 small commercial customers to participate in the pilot. Table 1 lists the business types and the loads controlled. Intensive monitoring and analysis of demand savings was performed for the 10 installations that were operational when SCE declared seven CPP control events during August and September of 2005. The authors anticipate that a full-scale targeted program would feature a higher proportion of sites with refrigeration systems under control. The Dencor Model 300C monitors the host facility's instantaneous power demand and implements load cycling when the demand approaches a pre-set level. Up to three temperature points are also monitored. Power use and product temperature data are stored and can be downloaded to a database via a built-in telephone or Internet modem.

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[3] The pilot included over 2,000 sites. See Martinez in references.

[4] Conducted by the Demand Response Research Center, which is operated for the CEC by Lawrence Berkeley National Laboratory. The study covered 36 buildings and 10 million square feet of facility floor area. See Piette in references

Table 1: Research Program Facility Profiles

Facility Type	Facility Description	A/C (Single & Multi-Stage)	Refrigeration (Walk-ins, Reach-ins, Novelty, Ice)	Water Heating	Plug Loads (Dedicated Circuits)
Restaurant	Family Style Steak House	√	√		
	Family Style Pizza #1	√	√		
	Family Style Pizza #2	√	√		
	Fast Food Mexican Food	√	√		
	Fast Food Hamburgers	√	√		
	Coffee Shop	√			
Small Grocery / Convenience	Small Grocery		√	√	√
	Liquor Store	√	√		√
Large Grocery	Catering Supply Distributor	√	√		
Retail	Furniture Store	√			
	Fabric Store	√			
	Stationary Store	√			
	Automotive Supply	√	√		
	Car Dealership	√			
Office w/ Warehouse	Multiple Tenants	√		√	
	Equipment Storage	√			
	Building Products	√			
	Equipment Storage		√		
	Equipment Rental	√		√	
Office w/ Manufacturing	Home Electronics	√		√	
	Energy Efficiency Devices	√			

System Description

The Dencor 300C manages customer demand by monitoring both site demand and temperatures associated with controlled equipment and by controlling the operation of up to 24 devices through power and/or control relay banks. The logic it employs seeks to unobtrusively control these loads by taking such measures as assuring that multiple items of equipment do not cycle "on" simultaneously, and eliminating unnecessary operation and imposing diversity. Figure 1 shows the controller and its relays.

Figure 1: Dencor 300C

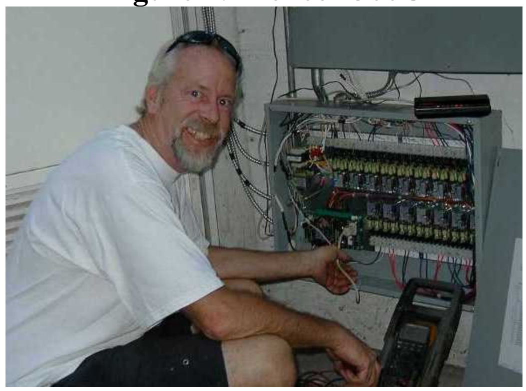


Table 2 provides a summary of the Dencor 300C unit's software capabilities.

Table 2: Dencor 300C Software Capabilities

- Pre-packaged logic for demand management of:
  - One- and two-stage air conditioners
  - Walk-in coolers and freezers, stand-alone refrigerated cases
  - Domestic water heaters
  - Outdoor lighting
  - Dimmable or switchable indoor lighting
  - Anti-sweat heaters on refrigerated cases
  - Motors driving pumps and fans
  - Back-up generators
- Multiple configurations of demand control available
  - By intensity (e.g., None, Moderate, and Critical demand control)
  - By load priority (e.g., turn off AC first, refrigerator last)
  - By shedding logic (e.g. turn off for 15 minutes vs. duty cycle)
- "Fail-off" design to release all control on malfunction
- Remotely and locally configurable
- Graphing tools show load, temperature, relay state (by minute)

Communications to and from the controller historically had been performed via dial-up calls to the on-board modem. Recently the controller has been enhanced and now can also communicate and receive instructions via modem, an external switch, an Ethernet Web connection, or an automated meter infrastructure (AMI) connection. For this pilot, use of the external switch monitoring in conjunction with the Carrier/Nextel paging system was the primary means of signaling calls for demand reduction, and the modem was used for data downloads. Figure 2 illustrates the communications technologies. The day-to-day demand management capabilities of the system were not used during the pilot.[5]

[5] The Dencor DDC unit allows for two tiers of demand control. Initial installations were performed to allow both tiers—moderate control always active to reduce peak demand charges plus more aggressive control to further reduce demand during CPP events. This approach was not utilized consistently and varied by customer. None of the later installations included the continuous moderate-level control. The results presented in this paper are based solely on comparison of uncontrolled facility load with CPP-level controlled load.

Figure 2: Controller Communications

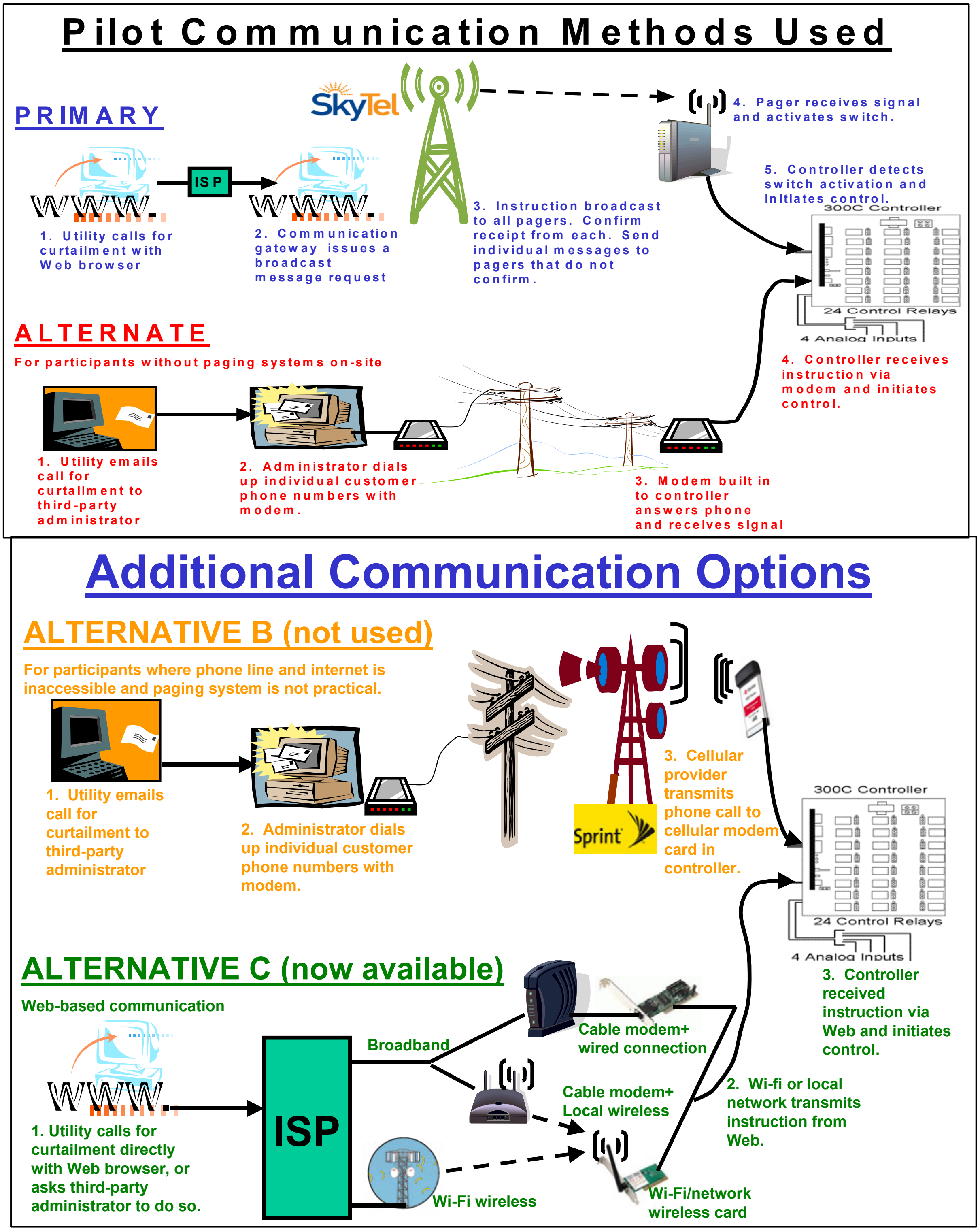
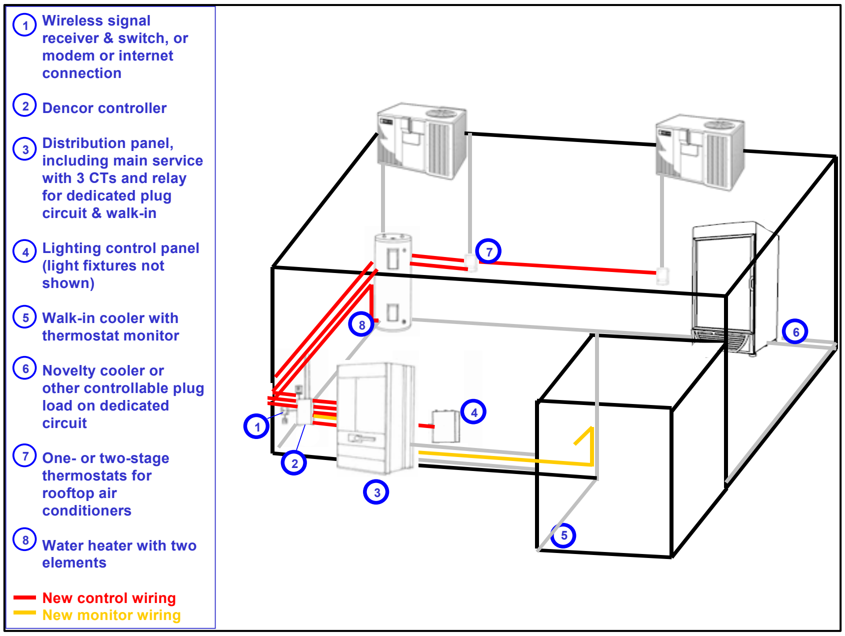


Figure 3 illustrates the types of connections and wiring runs typically required for various loads.

Figure 3: Dencor Site Installation



A Digital demand controller with sensors and optimization software has advantages over both thermostat-only control and simple direct load switches for applications in commercial dynamic pricing. A thermostat-only system manages only one type of load, packaged space air conditioners. Control of that load can directly affect occupant comfort, sometimes quickly. The tested system controls additional equipment, giving it more savings potential per site. Furthermore, the thermal mass of refrigerated cases means that more hours of control can be truly invisible to the participant and its customers, without the ambient temperature changes typical after the first hour of thermostat control and with negligible product temperature changes. Likewise, converting constant-on anti-sweat heaters to cycling reduces average power (and energy) without negative effects on most days. Combined with a measurement of the facility's instantaneous power demand as an input (the DDC has a built-in power meter), the optimization software can use the load diversity to maximize savings per site. From the program operator's perspective, the higher load reduction per site compared to a thermostat-based program means fewer sites need to participate to achieve a given DR program goal.

The software's sophisticated capabilities are both a strength and a weakness in its application as a small-business demand-response technology. The variety of possible connections require a seasoned journeyman electrician and likely an engineer to be at each site to decide what to control, whether to use control or power relays, where to run wiring, and what control strategy to employ for each relay. These requirements mean that the installation costs per site will be higher. But, the "yield" (magnitude of the overall demand reduction) is higher as well.

DR Performance Results

Demand Savings. Seven CPP control events were called during the late summer of 2005, when the Dencor DDC enabling technology had been installed in 10 facilities (one participant had withdrawn). The average demand reduction achieved by the Dencor DDC system over the seven control events during 2005 was 8.5 kW, which corresponded to 16 percent of the average baseline demand of the facilities being controlled. One critical peak event was on a "hot" (mid-90s temperature) day; the others were on days when the temperatures were in the mid-80s.

The amount of reduction varied with daily peak outdoor temperature. The 2-hour control event on the "hot" day produced an average demand reduction of 11 kW (22 percent of baseline demand).

"Rebound" (post-event power demand increase) was negligible at less than 0.5 percent of baseline demand).

Figure 4 shows illustrative results—uncontrolled and controlled load shapes for the nine facilities that were participating at the time of the CPP events. The uncontrolled day for Figure 4 was selected from among all uncontrolled days as being the day that had the most similar load shape as the controlled-day shape prior the 2 pm initiation of control, and with a day that had similar weather conditions.

In reviewing the total savings per site it is important to consider that the facilities subject to control in this research study were not selected to maximize individual demand savings but rather to be a representative sample of buildings in the small non-residential segment. Two of the nine facilities in the figure have peak demands of less than 25 kW, for example. If maximizing demand savings were the objective, the pilot would have pursued a more narrowly defined subset of the facilities; all would have controllable loads greater than 50 kW. That said, the proportion of savings was relatively consistent despite a wide variety in types of equipment controlled. During the first control event for example, savings ranged from 14 to 31 percent of uncontrolled demand, which the authors consider to be a narrow range.

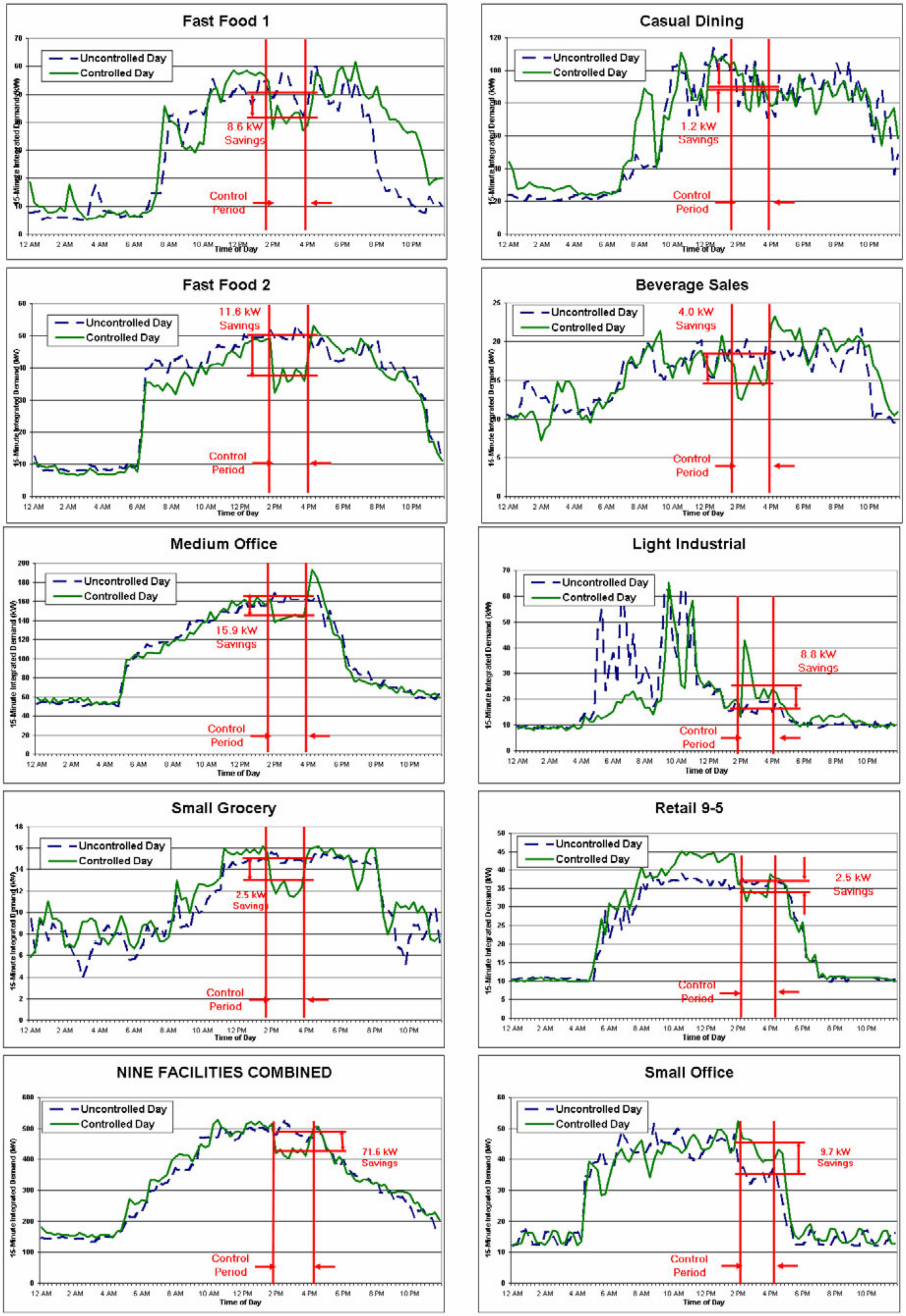
Customer Acceptance. All customers recruited for participation in this technology test had previously volunteered (self-selected) to participate in the SPP. As such, the sample is not necessarily representative of the small-medium non-residential customer population relative to propensity to join such programs.

Program recruiters found that customers needed substantial education on the CPP tariff structure, even though they already had volunteered for it, and then substantial education on how the technology would reduce their electricity bill and avoid power blackouts. Once they learned of this and possible effects on equipment performance, most readily accepted the offer to install the DDC-enabling technology.

There were few customer complaints during the course of the pilot. One of the 21 participants withdrew from the program due to space temperature control concerns. Two others customers reported that air temperatures had reached an uncomfortable level during one event. The maximum temperature and targeted maximum demand set-points were adjusted, the problems eliminated, and the customers remained enrolled.

As reported during subsequent interviews, most customers were not aware of CPP events occurring or when the enabling technology was activated.

Figure 4: Controlled and Uncontrolled Load Profiles



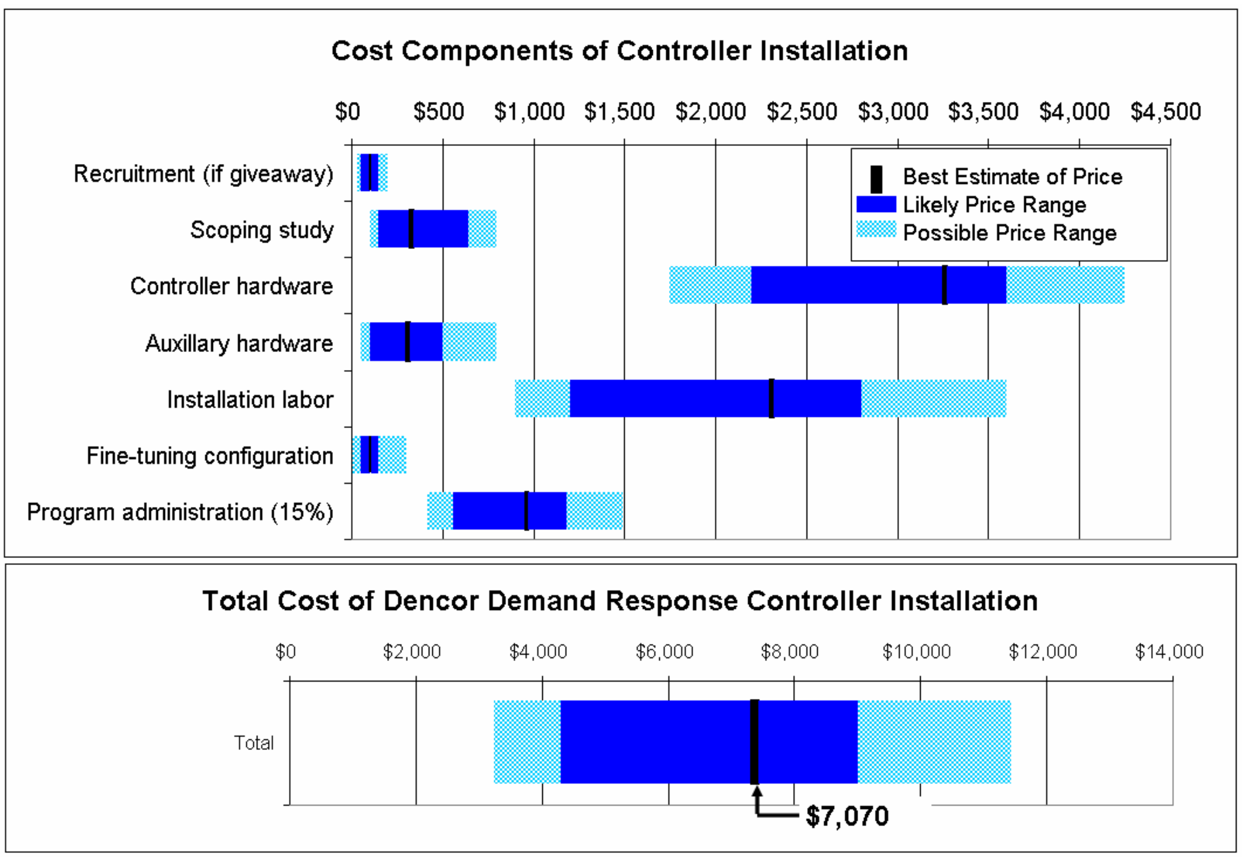
Installed Cost

In this pilot turnkey installation, the Dencor systems were provided at no cost to the participant.

Figure 5 illustrates the authors' projected range of future cost for a Dencor-based demand response technology. The cost ranges are intended to encompass both program design and site conditions variability. The basis of the cost component ranges is the authors' experience during the pilot, discussions with equipment suppliers on volume and distributor pricing, new cost-saving solutions developed during the pilot, and extrapolation of cost trends from the beginning to the end of the project to possible large-scale implementation. Actual pilot costs are not believed to be relevant due to the research nature of the project.

The program design will affect site installation costs. A high-volume program will enjoy lower equipment costs and likely have lower administration costs per installation and thus be at the lower end of the range. It also likely will result in shorter installation times as installers gain experience. It may allow the administrator to negotiate lower technician/electrician hourly rates and truck charges. On the other hand, it may require more up front payments to participants. Conversely, a market-driven program may have lower program administration costs, but high marketing costs.

Figure 5: Projected Costs



Site characteristics also affect cost independent of program type. Table 3 summarizes the above-mentioned and other factors that affect installation costs. The single biggest site cost variable is installation labor, which is in turn most affected by the distance and degree of difficulty in running wire between the controller and the various controlled loads. Some of the installation sites were large warehouses with the equipment controls at one end and the meter at the other. The lengthy wiring runs needed to connect the two are time consuming. Heavy employee foot traffic further complicates the process. Ideally the end-uses and meters should reside in close proximity. This configuration is frequently found in convenience stores, small groceries, and fast food restaurants where the facility design seeks to optimize the space requirements for building infrastructure. It is notable that these locations also have optimal controllable loads and loads other than air conditioning that can be controlled (see below).

Installing systems at multiple similar sites will lower the installation costs. Conversely, when extraordinary requirements for installations occur, installation costs increase. Some of these factors include concrete or metal walls between controlled end-uses and the meter necessitating drilling and high bay ceilings where wiring must be placed. Facilities with these types of installation challenges are best avoided if possible.

Table 3: Factors Affecting Installation Cost

Major Factors That Can Increase Costs
• Long distances between controlled end-uses, meter, and phone lines
• Poor accessibility to dispatch signal (paging reception, internet, phone, or other)
• Not being able to complete advance scoping studies
• Multiple-tenant facilities
Minor Factors that Can Increase Costs
• Obstructions between meter and end-uses (e.g. inventory)
• High ceilings
• Solid masonry walls requiring penetration
• Heavy foot traffic volume in installation areas
• Decision maker or approving authority is not on site at time of installation
• Utility meter types with other than KYZ terminals
• Electrical panels in poor or below-code condition
• Non-standard voltages for meters or equipment
• Lack of available low-volume phone line or LAN/internet

There is correlation between site demand savings and installation cost—all else being equal more equipment under control means more load savings and more wiring—but it is not the dominant factor. One relay can control a 100-W or a 10-kW device.[6]

[6] The power relays are 24-Ampere single double pole-double throw relays that can control two single-phase loads or (1) three-phase delta-wired load. Control relays connected to contactors can control much larger loads.

Installation Suitability by Facility Type

Certain types of small commercial facilities best fit the profile for ideal installation candidates. These facilities all have the same basic characteristic listed in Table 4:

Table 4: Installation Suitability by Facility Type

Facility Type	Suitability	Non-AC Loads	Chains	Short Wiring Runs	High kW DR
Office Building - Single Tenant	Medium			√	√
Office Building - Multiple Tenants	Poor				√
Warehouse and Industrial	Poor				
Convenience Store	Good	√	√	√	√
Fast Food Restaurant	Good	√	√	√	√
Sit-Down Restaurant	Good	√	√	√	√
Small Grocery	Good	√		√	
Retail Space	Poor				

Suitability Colors: Poor (red) Medium (yellow) Good (green)

Convenience stores, restaurants, and small grocery stores are prime candidates – they offer high potential load reductions because they have additional controllable loads beyond air-conditioning (i.e., refrigeration, electric hot-water heaters, and optional lighting).

Chain facilities show little variance in physical configuration of its infrastructure form one site to the next. Therefore, after the first few installations at a specific chain, installations can become formulaic and efficient. Convenience stores and restaurant chains are especially suitable because not only are their layouts nearly identical from one site to the next, but they offer optimal load reduction due to their use of controllable refrigeration and hot water loads.

Warehouses and industrial facilities are seldom air conditioned (except for a small office space), and industrial facilities tend to have a lot of uncontrollable "must-run" electrical equipment (e.g., milling machines, conveyor belts, air compressors, welding units, printing presses). The savings potential is likely to be a small fraction of facility peak demand. Also, large floor areas typically requires long wiring runs and higher installation costs.

Targeted selection of small-commercial facilities that fit the ideal profile for this technology offers high-yield/low-cost electric load reductions at an attractive ($450 /kW) price.[7] Understanding the elements of that profile was a valuable insight gained during the pilot.

[7] Based on an average of 75 kW uncontrolled peak demand, 20 percent savings, and a $7,000 cost.

Programmatic Implication Conclusions

The authors believe that the SCE Enabling Technology Pilot demonstrated that:

- DDC-type controllers (i.e., small EMS controllers) can automatically produce substantial demand response load reductions during CPP events, and can fill the technology "gap" between residential and very small C&I air-conditioner controllers (e.g., "smart" thermostats and remotely controlled power relays) and large commercial EMS system interfaces.
- When the CPP tariff is properly explained, customers will understand that when combined with a technology that automatically reduces load during CPP events, the CPP tariff will result in lower annual electricity bills.

Also, as part of the pilot we conducted an extensive investigation to identify candidate advanced enabling technologies (see first item in References). We found that a large number of DDC-based technologies are available, and more will become available during the coming years.

In addition, our analysis has indicated that the DDC-type advanced enabling technology is ideally suited and economic for facilities that have at least 50-kW of controllable loads. This will result in an average installed cost of $450/saved-kW or less. Although these facilities comprise less than 10 percent of the total population of facilities in the 20-kW to 200-kW range, they also contain more than 20 percent of the DR potential. Therefore: (1) these facilities should be initially targeted by any future program to expand the CPP tariff to the small-commercial sector, and (2) installing interval meters with two-way communications capabilities at these facilities would not entail a large cost burden.

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