Demand Response Enabling Technologies For Small-Medium Businesses

A Technical Report prepared in conjunction with the
2005 California Statewide Pricing Pilot
R.02.06.001

Submitted to:

Mark S. Martinez
Manager, DR Program Development

Southern California Edison Company
2244 Walnut Grove Avenue
Rosemead, California

Prepared by:

Lockheed Martin Aspen
2277 Research Boulevard
Rockville, Maryland

April 12, 2006

Contents

Contents (Continued)

Contents (Continued)

1. INTRODUCTION AND SUMMARY

1.1 PURPOSE AND SCOPE OF STUDY

There is a general consensus among energy policy makers in the United States that electricity end-users should be given an economic incentive to reduce peak electricity demand by closely linking retail electricity prices to wholesale prices on a real-time basis. The preferred mechanisms are either real-time pricing (RTP), where the retail price is the wholesale price plus a "delivery charge," or an advanced form of time-of-use (TOU) pricing called "critical peak pricing" (CPP) whereby the price of electricity rises to a very high value during "demand-response" (DR) events.[1] These events are usually triggered when electricity demand becomes large and very expensive generating units must be called upon to avoid a supply:demand imbalance at the transmission-system level, and hence are regional is scope. When the time comes when a large number of customer facilities are able to automatically respond and reduce load, it is likely that more localized DR events will be triggered when power demand approaches the load-supply capability of a distribution substation.[2]

Time-differentiated pricing tariffs require more sophisticated revenue meters that are presently used for most residential and "small-business" customers, and deploying such meters to all these customers would require a sizable financial investment. As a result, the California Public Utilities Commission (CPUC) is proceeding at a measured pace toward this policy goal,[3] considering recommendations made by the state's invest-owned electric utilities. Sophisticated meters are already deployed for large customers, and hence there are basically no impediments to this segment of responding to RTP or CPP tariffs. Also, most large customers already have the type of computerized controls that can be readily adapted to react automatically to reduce power demand during DR events. The smaller, "mass-market" customer segments have neither such "enabling technology" nor sophisticated revenue meters.

The current situation in California therefore is:

- Large customers are ready for large-scale, price-based DR programs, having both enabling technologies available and sophisticated metering.
- Enabling technologies are available to permit residential customers to participate in reliability-based DR programs or in those triggered by high prices, but it is not possible to actually impose a high retail price at times when wholesale prices are

---

[1] Presentation by Arthur H. Rosenfeld, California Energy Commission (CEC) Commissioner, at the Utility Energy Forum, Granlibakken Conference Center, May 6, 2005.

[2] Investigations of whether DR can defer the scheduling of specific distribution-system upgrade projects is being conducted in California and in the Pacific Northwest, New England, and Mid-Atlantic regions.

[3] California PUC Decision 05-11-009 dated 11/18/05, closing the Rulemaking on policies and practices for advanced metering, demand response, and dynamic pricing (which had started in 2002); and identifying future activities related to demand response. The future activities identified in the decision include: (1) deciding whether to make a CPP tariff mandatory for large customers, (2) authorizing large-scale DR programs for the 2006-2008 period, (3) authorizing the utilities to proceed with their respective plans for deploying advanced metering technologies, (4) developing more rigorous, standardized procedures for estimating the magnitudes of load reductions achieved by DR event, and (5) developing standardized methods for assessing the cost-effectiveness of DR programs.

high without also deploying a capability to meter electricity usage during each hour or shorter time intervals.

The customer segment that remains between the two is the "small-medium business segment," a term used to define nonresidential (i.e., commercial, institutional, or industrial) facilities with peak seasonal demand in the ~10-kW to 200-kW range. Facilities at the low-end of the range have electricity end-uses that are closely similar to those of the residential sector, and facilities near the high-end are similar to those of large customers. This sub-segment has excellent DR potential because many facilities have additional end-use equipment that can be controlled economically, increasing the per-facility DR "yield" at a relatively low additional cost.

The purpose of the present study is to examine the small-medium customer segment and identify the current status of enabling technologies that could be deployed in each of its sub-segments in either reliability-based or price-based DR programs, once advanced metering and RTP or CPP rates become available.

Under contract with Southern California Edison, Aspen Systems Corporation investigated enabling technologies and systems that are now available or which may shortly become available to:

(1) Dispatch an instruction to a group of small-business facilities that a (DR) event should be initiated;

(2) Cause the total electric demand at the facilities to be automatically reduced for the desired duration; and

(3) Expeditiously acquire sufficiently accurate load data to enable the calculation of estimated load reductions at each facility, as well as the aggregate load reduction for all facilities.

A DR enabling-technology system will repeatedly and successfully implement all three steps. Note that these steps involve two communications-hardware linkages (one outbound from a central command station to a dispersed set of facilities, and the other inbound from the facilities to the central command point) and a set of control devices located at the facilities that participate in DR events.

1.2 SUMMARY OF FINDINGS

- DR enabling technologies applicable to the small-business segment for dynamic pricing programs are in their infancy. The number of applicable technologies is growing rapidly, and therefore this report represents a "snapshot" of the market at one point in time.
    - Several control-device technologies are adding communications linkages to form fully functioning systems. A prime example is the case of wireless communications linkages being used to control dimmable ballasts, thereby enabling temporary reductions to be made in the amount of power used for indoor lighting. (Lighting is a major power end-use in the small-business segment, and thus far its potential as a DR resource has seldom been tapped.)
    - Many new types of communications technologies and protocols are coming forward. One of the most promising is the use of "mesh wireless networks" to carry control signals to various end-use equipment items.
- A key challenge for the implementation of all enabling technologies is to be cost-effective. The total cost to install and maintain the technology must be less than the value of the benefits received by the parties who pay for the installation and maintenance.
    - The larger the facility the larger the demand savings, and economies-of-scale result in lower installed costs per kW of reductions.
    - Maintaining the system includes ensuring that it is ready to operate during DR events and has not failed while in standby mode.
    - Many benefits are difficult to quantify accurately. A recent report prepared for the International Energy Agency[4] cites the following benefits:
        - Lower wholesale electricity prices;
        - Reduced price volatility;
        - Risk management (i.e., a physical hedge against extreme system events that are difficult to incorporate in planning and valuation frameworks;
        - Reduced electricity expenditures by utility customers, [5] combined with increased customer choice and customer risk-management opportunities;
        - Reduced emissions of pollutants;
        - Supplier market-power mitigation.
        - Reduced T&D system capital, operation, and maintenance expenses; and
        - Potential for revenues to aggregators of DR resources.
    - A number of systems provide benefits to the utility customer beyond participation in DR events, and these benefits often are as important to the

[4] "DRR Valuation and Market Analysis, Volume I: Overview," report prepared for the International Energy Agency Demand-Side Programme, Task XIII: Demand Response Resources, by Daniel M. Violette, Ph.D., Rachel Freeman, Chris Neil, M.S., January 6, 2006.

[5] In this report we use the term "utility customer" to refer to the organization that (1) owns or controls one or more facilities that receive electricity via a utility's distribution grid, and (2) has the authority to decide whether to participate in a specific DR program and have "enabling technologies" installed at the facilities.

customer as the benefits derived from participating in DR events. Examples include programmable thermostats, which can reduce the facility's heating and cooling costs during all winter and summer months, and sophisticated energy management systems that have both routine control functions and routine monitoring.

- The earliest applications of DR enabling technologies in this segment were "spill-ups" into its lower portion (i.e., facilities with peak demands in the ~10-kW to ~40-kW range) from large-scale applications of radio-controlled-switch technology in the residential sector.[6] With the advent of programmable communicating thermostat (PCT) systems (remotely-controlled "smart thermostats") about 5 years ago, the same "spill-up" has occurred.
- Currently, there is a significant amount of "spill-down" into the upper half of the small-business segment (i.e., facilities with peak demands in the 100-kW to 200-kW range, but mostly in the upper-third of this range) of systems that incorporate sophisticated energy-management controls from their primary application in the large-business segment.
- Additional enabling-technology systems will become available as the DR potential of the mid-range of the small-business segment is more widely recognized, with many of these systems being simplified (i.e., lower-cost) versions of the sophisticated EMS-based systems now used in the large-business (>200-kW) segment. In addition, remotely-controlled switches and "smart thermostat" systems will continue to be used in the smaller facilities that have relatively few items of equipment to be controlled.

[6] It should be noted that the early radio-controlled switch technology was not a fully integrated system because expeditious acquisition of accurate load data with which to calculate load reductions of individual participants was missing.

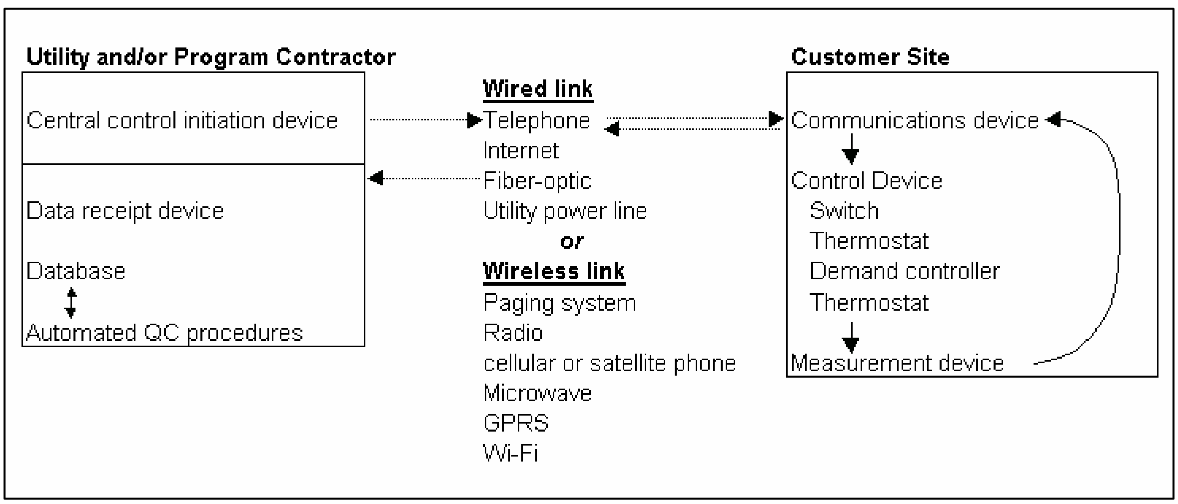
2. SYSTEM REQUIREMENTS

DR programs are intended to either (1) reduce system-wide electricity demand when wholesale electricity prices are high and/or electricity supply at the system level is challenged for any reason, or (2) reduce electricity demand in the relatively small portion of a utility's service territory—the area served by one or more individual substations that are approaching safe operating limits set by the power-carrying capacity of specific circuits or transformers.

All dispatchable DR systems require the following three components, as shown in Exhibit 2-1:

1. Control device or devices (switch (es) or relay(s), thermostat(s), a digital demand controller [DDC] or energy management system [EMS]) located at participating facility that can modify the operation of equipment in a way that reduces average electrical load during DR control events.
2. Communications linkages for (a) initiating and terminating DR control events, and (b) retrieving load data (and optionally, other data) on both control-event days and non-event days. These linkages may involve either a direct connection (land-line telephone, Internet, fiber-optic or co-axial cable, utility power lines) or wireless transmission (pager network, cell-phone, satellite phone, microwave, GPRS, FM or AM radio, Wi-Fi), and include appropriate transmitting and receiving equipment at both a central dispatch location and the participating facility.
3. Database in which to store all data obtained from participating facilities, located on a computer or server.

Exhibit 2-1: System Requirements Diagram



In addition, a successful system should have procedures for (a) periodically reviewing data values to verify control device operational readiness, and (b) using the collected data to calculate load reductions achieved during each control event.[7] Ideally, these procedures should be performed automatically with minimal human involvement.

[7] Additional data, such as outdoor temperature on each data-collection day, may also be required.

2.1 GENERAL BACKGROUND

"*Demand Response*" (DR) is the term currently used to describe techniques used by utilities and transmission-grid operators to accomplish temporary, short-duration reductions in the electric power demand of a building or isolated item of equipment (e.g., an irrigation or well pump), or a group of buildings and end-use equipment. Historically, two techniques have been used:

- **Interruptible Rates**. This technique consists of providing an economic incentive to large customers who voluntarily agree to reduce power demand by a certain amount for a given period of time when the utility requests the reduction. In return for this contractual agreement, the customers are charged a lower-than-standard-tariff price for all the electricity they consume. This special tariff is limited to large customers for two reasons:
  1. ***Metering Expense.*** The utility needs to be able to verify that the load reductions have actually taken place at each participating facility, in accordance with the contractual agreement. Large customers typically have interval meters that record usage every 15 minutes, and the utility typically has the ability to obtain data from these meters at any time via a telephone, Internet, wireless, or other communications channel.
  2. ***Communications to Initiate Control Events.*** The utility needs to notify each participating facility—often by telephone—a certain number of hours prior to the needed start of the curtailment period. The practicalities associated with making these calls tend to limit the number of participants to customers with large peak demands who are willing and able to provide large demand reductions.
- **Direct Load Control.** This technique was originally focused at the small-user mass market, primarily residential customers with split-system central air-conditioning (AC) units,[8] and was widely used during the 1980s. Many utilities have kept the systems active, and are currently upgrading and expanding them. The utility installed a power relay and special radio-signal receiver on the outdoor units (or on the rooftop AC unit in the case of a typical small-business), wired such that when a coded signal is received the power-supply circuits supplying the AC units are interrupted.

  When a load curtailment is needed (which is primarily on a hot summer day), the utility causes the signal to be transmitted in such a way that that the AC units are "off" for 10 to 15 minutes, and then allowed to operate for an equal period of time (or in some cases a bit longer). In many program deployments the coded signals are able to address specific receivers, such that when half the AC units are "off" the others are permitted to operate, which results in an approximately uniform load reduction over the duration of the DR event. If the participating customer has an electric water heater or a swimming pool pump, additional control units can be installed to remotely turn them "off" completely during the DR events.

  Participation was/is voluntary. The financial inducement is typically a fixed payment (or a billing credit) of $5 to $8 during each of four summer months, for each item placed under remote utility control. Although customers typically could not override the control actions, there was no way to ensure that specific participants had their AC units operating

[8] Some small businesses were also enrolled in these programs, but generally 90 percent or more of the participants were residential customers, and the commercial customers were "very small" (i.e., 10 to 20 kW peak demand).

at the time when a given DR event occurred. It was also not always possible to get feedback that the radio signal was received and control action taken, or to get accurate information shortly after the event concerning how much load reduction had occurred. Instead, an "impact evaluation study" was/is performed periodically (every year or every few years). Special meters are installed on the AC units of a sample of participants to obtain load data, and these data are analyzed to determine the average load reduction for all AC units in the sample during one or two DR events. The result is then multiplied by the total number of controlled AC units to obtain the total reduction for each event.

Modern enhancements to direct load control (DLC) are discussed in detail in Section 4. In short, technological developments such as these have made DLC potentially more cost-effective for the small-business segment:

- Less expensive and more reliable utility-to-customer communications linkage (e.g., paging networks or Internet instead of radio).
- Special remotely controlled thermostats instead of remotely controlled relays as the primary control device at small-business facilities in the ~10-kW to 50-kW range.
- Two-way communications to reduce the cost and increase the accuracy and timeliness of (a) knowing which sites actually participated in a control event, and (b) measuring load reductions at all participating sites.
- Relatively low-cost energy management systems combined with two-way communications linkages that are ideally suited to perform a variety of monitoring and control functions at small-business facilities in the ~50-kW to 200-kW range.
- Optimized cycling combined with pre-cooling of the participating premises.

Renewed interest in DR has been sparked by evidence—more frequent power outages—that the nation's T&D grids have not kept pace with demand growth. The Federal Energy Regulatory Commission (FERC) has cognizance over transmission grid operations and tariffs, and during the past several years has issued several new regulations that have the goals of (1) creating competitive wholesale electricity markets, and (2) improving the reliability of the electricity grids. One of the FERC's initiatives has been to oversee the creation of Independent System Operators (ISOs) to run the power grid in several regions of the U.S., especially those where state regulatory agencies have "restructured" investor-owned electric utilities, requiring them to separate the generation, transmission, and distribution functions. The ISOs have shown considerable interest in DR, seeing it as an important way to help maintain system reliability (i.e., avoid voltage reductions and blackouts) as well as for keeping prices from escalating to extreme levels when power demand begins to approach available generating capability. DR programs developed and offered by the ISOs include an opportunity for both larger customers and aggregations of smaller customers to participate in the wholesale market.

The ISOs in the Northeastern U.S. have begun to encourage utilities, customers, and independent third-parties to participate in the various DR programs that they offer. In particular, customers and third-parties (who aggregate the loads of multiple customers)[9] can participate directly in

[9] DR programs often specify a minimum load reduction, but allow load reductions at multiple facilities to be aggregated and represented by one agent (the "aggregator") who is responsible for delivering the total reduction

some ISO programs, without utility involvement. In some areas, the local electric utilities have designed additional programs to fulfill their ISO-required obligations concerning reliability.

In addition to market changes and the increased—and growing—acceptance of DR by key stakeholders, there have been significant advances in control and communications technologies, including miniaturization approaches that have reduced their costs. As is described in Section 4, these advances have opened the door for more sophisticated and robust DR solutions, especially those that are applicable to small businesses.

2.2 EXECUTION OF LOAD CONTROL ACTIONS

In general, demand-response actions can be executed either manually or automatically. Manual execution is practical for large facilities where the assigned responsibilities of one or more individuals are centered on managing the energy-related operations of the facility. As was noted in Section 1, some DR programs that involve manual execution are voluntary (i.e., the customer can choose whether to participate on a given day). In some programs, the customer submits a competitive bid to the utility or the transmission grid operator some hours before the time when a load reduction is desired, citing an amount of kW load reduction they are willing to provide and the price they want to be paid.

Generally, manually executed programs have been more or less successful when they are offered to large industrial customers, but much less successful in the case of large commercial buildings. In the case of small businesses and homes, ***automatic execution*** is necessary if reliable results are to be achieved. Managers and employees at small businesses are fully occupied with routine duties and cannot be expected to reliably manually execute certain non-routine actions at a certain time, actions that may require constant attention over a period of hours. In the case of a home, no one may be there when the signal is received informing that a DR event is scheduled to begin, and even if someone is there, they may not actually see the message, and if they do see it, they may not know exactly what to do.

2.3 ENABLING TECHNOLOGIES FOR HOMES AND SMALL BUSINESSES

The generally accepted approach in the case of the homes and small businesses is to install a DR enabling technology system that (1) receives the signal that a DR event is scheduled to begin at a specific time, and is to last for a specified period; and (2) executes control functions that automatically reduce the average electrical demand during the term of the DR event. The "enabling technology" provided to these customers should have the following functional characteristics:

- The utility or other DR service provider must be able to dispatch (i.e., order via some form of real-time or near real-time communications) demand reductions at thousands of facilities.
- The demand-response system needs to provide data (i.e., data feedback of some credible type) that can be subsequently analyzed to quantify the magnitude of the demand

when it is called for. The agent also receives the incentive paid by the ISO (if there is one). The aggregator is sometimes an independent party, and sometimes a corporation that operates a large number of stores or restaurants.

reduction achieved. Ideally, these data should be available shortly after a DR event has occurred.

- The system must be reliable—meaning that a high percentage of the expected or "contracted-for" demand reduction is actually achieved when a DR event occurs. The economic consequences for the participating utility customer, as well as for the utility or third-party aggregator, can be severe if load is not reduced. A means for periodically verifying operability of the enabling technology is highly desirable, but the verification activity—if there is one—must be low cost and non-intrusive.
- An aggregated system must be capable of delivering load reductions that are significant in magnitude (i.e., a few MW if the need is to prevent overloading a distribution substation, and tens of MW or more if the purpose is to reduce total system load[10]).
- The entire process of recruiting, screening, and enrolling participants; installing and commissioning control and communications devices; operating and maintaining the system; and performing M&V to estimate and report load reductions, must be cost-effective. This means that the benefits for all parties (the participating customer, the utility or third-party aggregator) must be greater than the costs they incur.
- Be non-disruptive during operation – the participating utility customer does not want his or her customers and employees to be inconvenienced during control events, or for merchandise to be damaged or degraded. Therefore, sudden or large changes in temperatures and lighting levels must be avoided.
- Be minimally disruptive during installation – the participating utility customer does not want his or her customers and employees to be inconvenienced while equipment is being installed, and may insist that installation activities in "public areas" only be done during non-business hours if these activities are perceived to be potentially disruptive.
- Be economical – the cost of the technology may be entirely or partially borne by an electric utility or a third-party aggregator,[11] and therefore it is this entity and not the utility customer that makes the assessment to determine that the overall benefits that result from being able to remotely initiate load reductions at customers' facilities are greater than the sum of all costs associated with achieving this capability. The installed cost of the enabling technology—together with the communications infrastructure needed to deliver the signal that initiates each DR event, and to obtain a measurement of the amount of load reduction that was achieved at each facility—is likely to be a significant cost component. However, it is essential to recognize that the cost of installing control and communications equipment may be less than half the total cost of a program. Other

[10] Several different programs are usually operating simultaneously to deal with system-wide problems, so the total effect is much greater than the effect of any individual DR program.

[11] Some DR Programs are designed such that the utility or a utility contractor markets the program, recruits participants, installs and maintains enabling technologies (including communications linkages), pays any cash incentives to participants that are required under program rules, obtains performance data, and calculates the magnitude of aggregate demand-reduction using pre-established methods and protocols. Other programs allow third-parties to perform these functions, either separately from the utility or under a utility's auspices. In the latter situation, a non-utility organization "aggregates" load reductions achieved at the facilities of a group of utility customers. The third-party may be a single customer, for example a corporation that operates a number of similar facilities such as a chain of retail stores, restaurants, convenience stores, or gas stations.

items that often significantly contribute to the total cost include recruiting and qualifying participants, paying incentives, continually ensuring the installed technology is operational, and assessing the magnitudes of the load reductions achieved during DR control events.

Two points are very relevant with regard to the last item:

First, the cost of the enabling technology must be judged relative to the magnitude of the load reductions it achieves, and the latter is a function of the type and size of facility where the technology is installed.

Second, an enabling technology is a system that includes—in addition to control devices that are installed at the customers' facilities—bi-directional ***communications linkages*** between (1) the utility or third-party aggregator who operates a DR program targeted at small-commercial customers, and (2) the utility customers whose loads are being reduced. It should be noted, however, that there are options and alternatives with regard to the bi-directional communications linkages. Various technologies can be deployed for these purposes.

Outbound message(s) to initiate control events. Basically, there are two different ways to initiate a DR event: (1) a short time before the event is to begin, send a message that informs controllers located at the customers' facilities that a DR event is to begin at a specified time and end at a specified time, or (2) send an initiating message at the time when the event is to begin, and then send a second message when the event is to terminate. In either case, the communications link must be fast and reliable, and it should not require human actions (such as listening to a message delivered via telephone or reading a fax) at the customer facilities.

Inbound message(s) to report control event results. Here, many options and alternatives can be considered. From the point-of-view of the utility or third-party aggregator, the ideal would be a low-cost communications that provides:

1) During the control event, confirmation that the initiating signal was received, load-reduction actions have been taken, and that electric demand is actually reduced.
2) Immediately after the control event, data that shows the load profile[12] during the event at each facility, and information whether the customer took any action to override or limit the load reduction.

The concept of tradeoffs comes strongly into play because the cost of reliably acquiring accurate data and information *for each participating facility during and immediately after each DR event* may be much higher than the cost of receiving this data and information somewhat later. Therefore, the value of rapid measurement of reduction must enter the assessment equation. This trade-off is illustrated by an approach taken in the case of remotely controlled relays that cycle the operation of central air-conditioning units and electric water heaters in the residential sector. The number of participants in any given utility's service area is so large that the cost of having two-way communications was judged to be not worth the value of *ever having data concerning the load reductions achieved at each participating home*. Instead, the feedback "communications link" for each control event is very imprecise and indirect: Impact evaluations are performed

[12] At a minimum, the load profile should show average hourly load, or load over time periods that are of significance to the DR beneficiary.

periodically[13] to ascertain load reductions at a statistically significant sample of customer premises, and the results are then imputed to all homes that are listed as participants at the time of each event.[14] (This is not mentioned because we advocate such an approach, but rather merely to illustrate that some technologies use a method for reporting DR-event results that is quite unlike the ideal described above.)

Ultimately, all electricity customers may have sophisticated meters that not only record demand over relatively short time intervals (e.g., 15-minutes), but can also (1) transmit the readings to the utility when queried, and (2) receive load-curtailment and/or price signals and relay them to the customer and/or to control equipment that is programmed to take specific actions to reduce demand when either a curtailment signal is received or the price reaches one or more thresholds. Such a system would greatly simplify the requirements imposed on DR enabling technologies. However, because this type of ultra-sophisticated metering and communications system is relatively expensive, installations are relatively rare—but are becoming increasingly popular.

It should be noted that, in addition to obtaining the load profile that occurred during the DR event, the utility or third-party must also obtain sufficient load data to determine the "baseline load profile" (i.e., an estimate of what the load profile would have been during the period when the event occurred, if it had not occurred).[15] Data to determine the baseline load profile is usually obtained prior to the DR event, so that it is available for determining the magnitude of load reduction, which is the numerical difference between the baseline profile and the DR-event profile.

2.4 SIGNAL AND DATA TRANSMISSION

One of the fundamental issues raised by the widespread deployment of DR enabling technologies in the mass markets (residential sector and small-business segment) is the need to: (a) send a signal to initiate the DR events; and (b) quickly and automatically collect, retrieve, and analyze interval load data from potentially tens of thousands of homes and hundreds or thousands of non-residential facilities. In addition to being used in an analysis to assess the magnitude of the demand reductions actually achieved during each DR event, the retrieved load data can also be used for such applications as pin-pointing the location of power outages, load forecasting, load research, bill reconciliation, and exception/outlier identification.

There are a variety of options available today for creating a communications infrastructure for acquiring meter data from geographically distributed locations. A growing number of utilities are installing automatic meter reading (AMR) systems with the capability to retrieve interval load data "on-demand." As noted in Section 4.4, the newest of the AMR systems feature "smart meters" that can be also used to initiate control actions.

Some of the options for accomplishing the task of retrieving load data from a large number of facilities are illustrated in Exhibit 2-2 and described below:

---

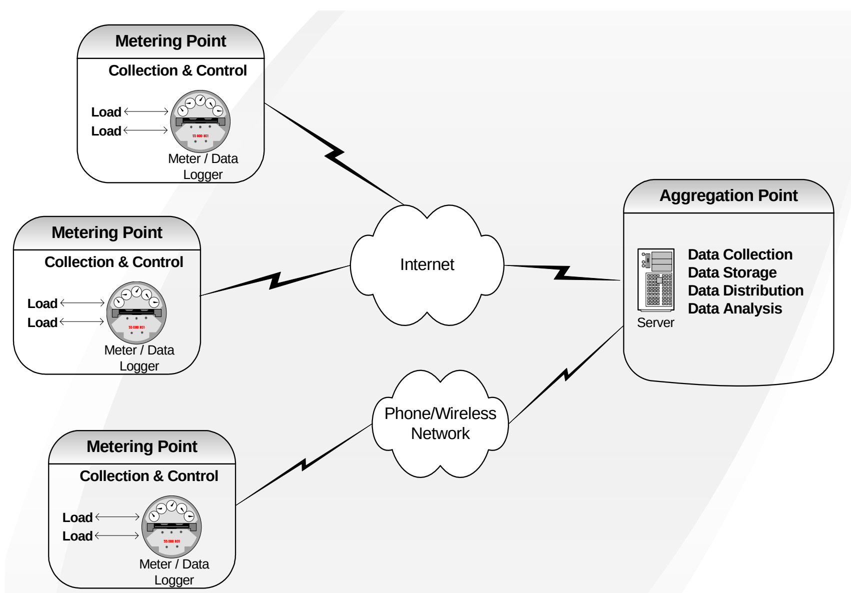
[13] The frequency of assessing impacts varies from utility to utility, from state to state, and from one ISO to another. It ranges from obtaining measurements for each event, to measurements for a few events per year, to once per year, to once per 3-5 years.

[14] Some utilities and third-party aggregators are diligent about policing the list, determining which of the installed receivers and switches are still working, and repairing those that have failed, and some are lax about performing these tasks.

[15] Program rules typically specify how the baseline load profile is to be calculated.

- **Utility AMR Systems**. The utility could install advanced metering infrastructure (AMI) to accommodate the CPP, RTP, or TOU tariffs (and for other reasons as described previously), and provide the data to the third-party aggregator or other party who is responsible for preparing an accurate estimate of the load reduction achieved during a DR event.
- **Local Area Networks (LAN).** A device to collect load and other data may be connected to the host facilities' LAN (if there is one), and the data subsequently made available from the parent organization's server.
- **Dial-Up.** If the device is remotely located, another option is to have the device make a regular phone connection to the server to transfer data. This method would use a standard modem for the transmission of data over phone lines. Again, two choices are available for making this transmission:
  - **Wired Connection.** The device is directly connected to a landline phone supplied by the local phone company.
  - **Wireless Connection.** The device is equipped with a wireless modem and dials out whenever necessary to connect to the phone network.

Exhibit 2-2: Data Collection and Aggregation Architecture



- **Power-line Carrier.** Some electric utilities have used this technology for many years to control switches at substations. More recently, the technology has been refined to be used for high-speed data transmission, Internet and cable-TV access, and for remote control of equipment at customer premises. In this method, which is also known as "broadband over power lines" (BPL), a high-frequency analog carrier signal operating at 20 kHz to 35 MHz is superimposed over the 60-Hz alternating-current line voltage. Voice or digitized data transmission involves modulating the carrier signal. The carrier signal may not be continuously present—it may be injected only when the alternating line voltage is close to zero (i.e., crossing the voltage axis).

- **Internet.** If the device is remotely located, an increasingly popular way of transmission is by making a connection to the server over the Internet. Options for doing so include:
  - **Wired Connection.** The device is directly connected to the Internet, perhaps through a landline provided by the local phone company.
  - **Wireless Connection**. The device is outfitted with a wireless modem and antenna, which enables it to connect through a service provided by a wireless means. Carriers such as Cingular support an "always-on" connection mechanism through the GSM/GPRS[16] protocol, while carriers such as Sprint use the CDMA[17] protocol. The device modem would have to be capable of supporting the appropriate protocol.
- **Pager Network.** A two-way pager network is another means for transmitting load data to the central aggregation server.

[16] Stands for Global System for Mobile Communications, one of the leading digital cellular systems. GSM uses narrowband Time Division Multiple Access (TDMA) technology, which allows eight simultaneous calls on the same radio frequency.

[17] Stands for Code-Division Multiple Access, a digital cellular technology that uses spread-spectrum techniques. Unlike systems that use TDMA, CDMA does not assign a specific frequency to each user. Instead, every channel uses the full available spectrum. Individual conversations are encoded with a pseudo-random digital sequence.

3. THE SMALL BUSINESS SEGMENT'S APPLICABILITY FOR DEMAND RESPONSE

3.1 FACILITY TYPES

The "small-business" segment of the market consists of a wide variety of facility types, ranging from office buildings and retail stores, to education (schools), restaurants, manufacturers, lodging (motels and small hotels), warehouses and wholesale distributors, service-providers (shoe repair, dry cleaners, vehicle repair, equipment rental), and assembly/entertainment (movie and stage theaters, libraries, houses of worship, parking garages). Exhibit 3-1 shows the approximate distribution of facilities by type.

Exhibit 3-1: Distribution of Small Business Facilities By Type

Facility Type	Percentage
Retail	26
Office	18
Education	14
Restaurant	7
Manufacturing	7
Warehouse	5
Health Care	2
Lodging	1
Miscellaneous	20
Total	**100**

Because refrigeration virtually always represents a significant electrical load in certain types of retail facilities (e.g., grocery stores, convenience stores, meat and seafood markets, beer and wine stores, florists), two types of retail stores are frequently distinguished:

1) Those that sell perishable items that require refrigeration,
2) Those that sell only non-perishable goods (e.g., clothing and hardware stores).

Actual small-business facilities often are combinations of multiple types:

- Hotels/motels sometimes combine lodging, restaurants, and parking garages;
- Large office buildings sometimes contain restaurants and parking garages;
- Gasoline stations (non-perishable retail) often also have convenience stores (perishable retail);
- Automobile dealerships, which combine retail with vehicle repair services;
- Warehouses typically incorporate some office space;
- Manufacturing facilities typically incorporate both office and warehouse spaces.

3.2 ELECTRICITY END USES

All small business facilities have indoor lighting equipment that potentially could be controlled to help reduce peak electricity demand, and nearly all of the facilities have HVAC (heating, ventilation and air-conditioning) equipment that could be controlled to reduce seasonal peak demand. (Further information concerning these two end-uses is provided below.) Other end-uses that are candidates for control but which are not uniformly present are:

- Refrigeration (includes, coolers, freezers, and ice-makers of various types and sizes)
- Water heating (which is applicable only when electricity is the energy source)
- Miscellaneous pumping (e.g., decorative water fountains, water-well pumps, sewage pumps, irrigation pumps).

Indoor Lighting

As is shown in Exhibit 3-2, virtually every type of lighting fixture can be controlled as part of a DR program. Most of the controls were originally intended to accomplish energy savings, but they also function to accomplish DR load reductions. Cost remains a major barrier for both types of applications, however, and the lighting industry is working to reduce this barrier. (Some of the control technologies are described further in Section 4.4.1).

Exhibit 3-2: Lighting Fixture Control Technologies

Fixture Type	Type of Control	Availability
Incandescent	On-off	Readily available.
	Dimming	Readily available.
Fluorescent – standard ballast	On-off	Readily available. Timer, EMS, and photocell-controlled exterior and interior fixture controls.
	On-off with tandem wiring	Available, particularly in new CA buildings, as T-24 requires such wiring in most cases.
	Step-level dimming	Available. Panel-level control for retrofits via continuous-wattage autotransformer (CWA) or "wave choppers."
	Dimming	Under development.
Fluorescent – dimming ballast	Dimming	Available.
HID – standard ballast	On-off pulse start	Available. Short (1-2 minute) re-strike time.
HID – bi-level ballast	Step-level dimming	Available. CWA with capacitor and switch ballast.
HID – dimming ballast	Continuous dimming	Available. Panel-level control via: o Variable voltage with CWA transformers or "wave choppers." o Variable-reactor current control. o Fixture-level control via electronic ballasts.

The interior lighting end-use provides an interesting challenge: the load is significant during daytime hours, but it is desirable that lighting levels in occupied areas need to be more-or-less uniformly dimmed in order to avoid negative impacts on business operations. If the lighting fixtures have a dimmable feature built in, or are wired such that alternate fixtures or every third one can be separately controlled, lighting reductions during DR events are easily accomplished. However, most pre-2000 buildings are not configured in this way, and the costs and disruptions that rewiring would entail tends to eliminate this end-use. Therefore, controlling air-conditioning and refrigeration end-use loads (plus electric water heating when it is found) in larger "small businesses" has generally been the most viable approach. It should be noted, however, that a number of new lighting technologies are expected to enter the market during 2006 (see Section 4.4.1) and to be cost-effective. Therefore, the situation is likely to be quite different after these technologies have been successfully demonstrated.

HVAC Systems

Most facilities with peak demands under 200 kW use packaged air-cooled HVAC systems. These systems have four major power-using components that operate during the summer months: compressors, condenser fans, supply fans, and exhaust fans. Condenser-fan operation is tied directly to refrigerant heat-rejection needs, and therefore these fans operate whenever the associated compressor operates. Also, code-related fresh-air requirements, control-system stability concerns, and economics (i.e., small savings) tend to constrain applying controls to reduce power use by the supply and exhaust fans in other than large buildings.

Most U.S. utilities are "summer peaking" (i.e., the system peak demand occurs during the summer months, or during times when air-conditioning (AC) units are operating. Because AC units represent a large electric load (the combination of the compressor and the associated condenser fans), most DR enabling technologies involve reducing the AC load by either shifting the thermostat setpoint or causing the units to run intermittently (i.e., cycle off and on). (Large units may have two compressors, but at least one will shut off.) In the rare instance where a chiller system is used instead of packaged air-cooled HVAC systems for air conditioning, each thermostat directly affects ventilation airflow, and the changed airflow gradually reduces chiller power, and this subsequently also reduces electricity usage by cooling tower fans and pumps. The load reduction is more gradual and its magnitude depends on the specific design of the HVAC system.

Utilities that are "winter peaking" generally (1) are in climates where winter temperatures dip to low temperatures, either briefly or for extended periods, and (2) electric space heating is relatively common. In these situations, electric heating units are controlled.

Exhibit 3-3 provides a graphical depiction of electricity end-uses in several common small-business facility types.

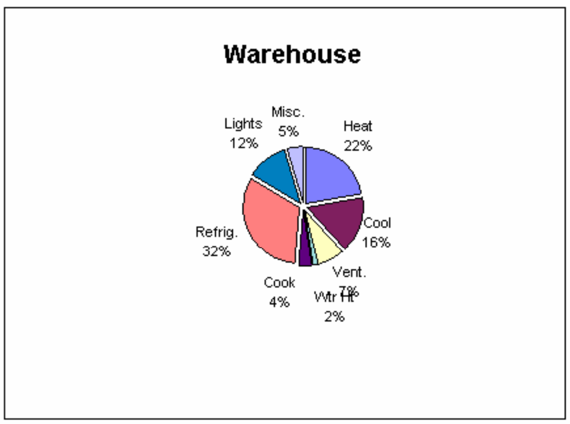
Exhibit 3-3: Distribution of Electricity End-Uses in Small Business Facility Types (annual kWh/sq.ft.)

Building Type	Heat	Cool	Vent.	Wtr Ht	Cook	Refrig.	Lights	Misc.	Total Bldg.	Source
Warehouse	2.9	2.0	0.9	0.2	0.5	4.1	1.5	0.6	6.5	1
School	1.9	1.3	0.9	0.8	0.2	0.2	3.8	0.5	9.6	2
Miscellaneous	4.2	2.7	0.9	0.6	0.4	2.8	1.8	0.8	12.3	1
Retail	0.6	2.2	1.2	0.1	0.1	0.6	6.7	1.5	13.0	2
Small Office	0.6	2.7	0.9	0.2	0.2	0.2	6.0	4.0	14.7	2
College	4.8	2.5	1.6	1.8	0.2	0.6	3.4	1.3	16.1	2
Lodging	3.6	2.7	0.9	1.2	0.3	1.3	3.9	2.4	16.4	2
Health	7.3	6.8	2.7	2.3	1.2	0.7	5.0	1.6	22.3	1
Restaurant	6.2	10.3	2.7	6.3	11.8	9.1	7.7	2.7	43.4	1
Grocery	6.2	5.2	2.0	1.0	2.4	17.4	10.7	1.3	52.5	1

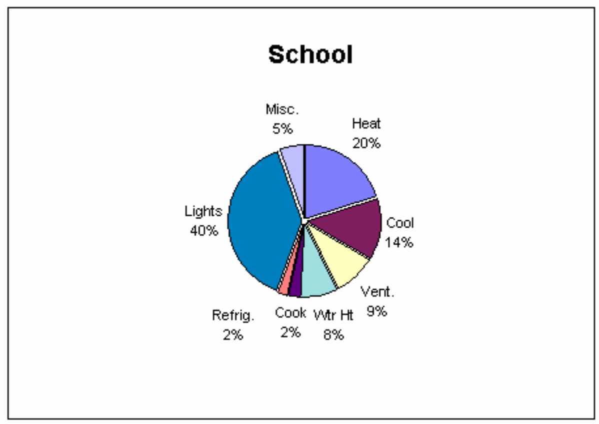
Sources:

1. From *Putting Energy Into Profits: The ENERGY STAR Guide for Small Business*, U.S. EPA, p. 13-14, downloaded at www.energystar.gov/ia/business/small_business/energyintoprofits.pdf 1/25/06, which in turn cites the source as "aggregated from the Electric Power Research Institute's COMMEND User's Manual, US DOE Commercial Building Energy Consumption Survey, and Aspen Systems Corp. research data." Data is national. Note: Total for the building type is less than the sum of equipment because not all buildings have all equipment.

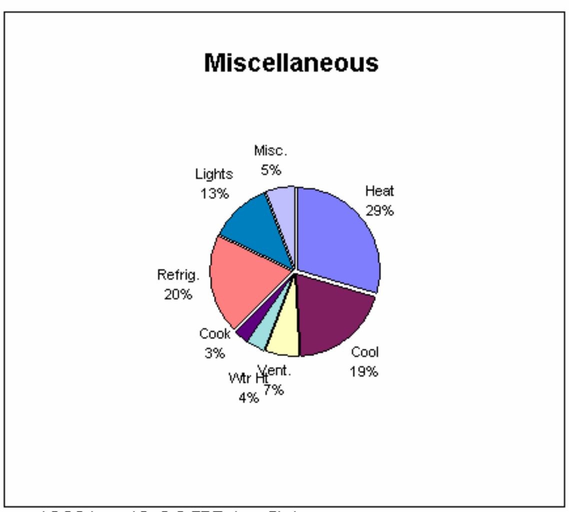
2. From *Enhanced Automation, Technical Options Guidebook: Money & Energy Saving Resources from the California Energy Commission*, Pub. No. 400-02-005f, Appendix p. 54, which in turn cites: "The data were collected from the California energy demand forecast," and references *California Energy Demand, 2000-2010*, California Energy Commission. Publication # 200-00-002. July 14, 2000. The provided data is not part of the referenced report itself. Data is California-specific.



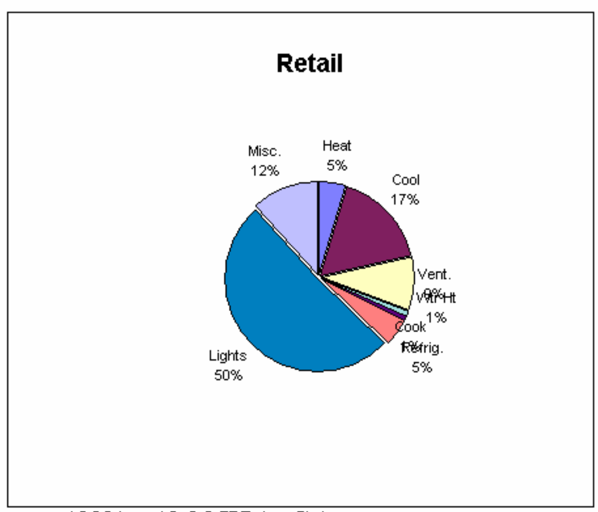
100% = 6.5 kWh/sq.ft./yr.



100% = 9.6 kWh/sq.ft./yr.

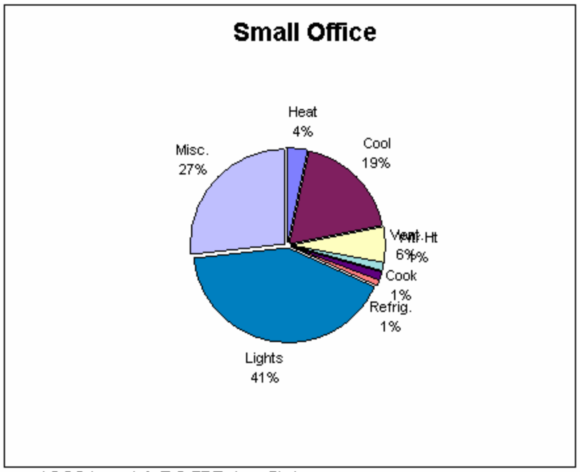


100% = 12.3 kWh/sq.ft./yr.

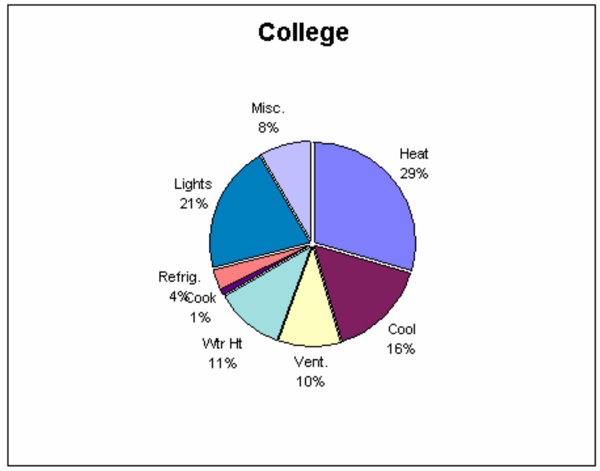


100% = 13.0 kWh/sq.ft./yr.

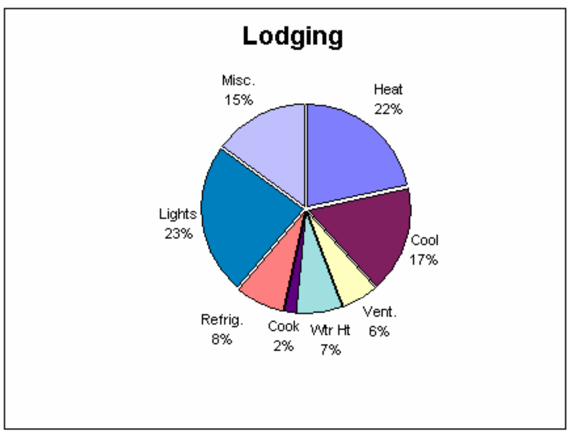
Exhibit 3-3: Distribution of Electricity End-Uses in Small Business Facility Types (Continued)



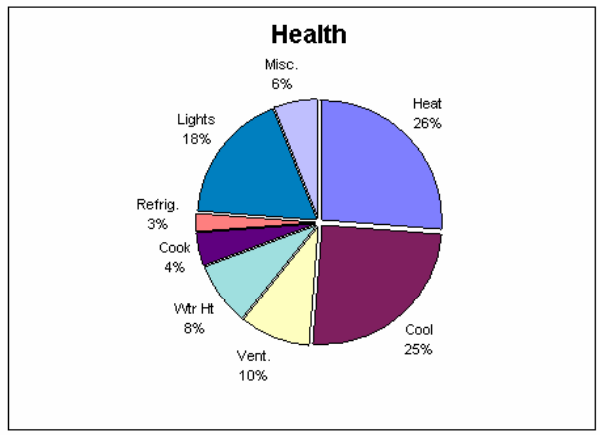
100% = 14.7 kWh/sq.ft./yr.



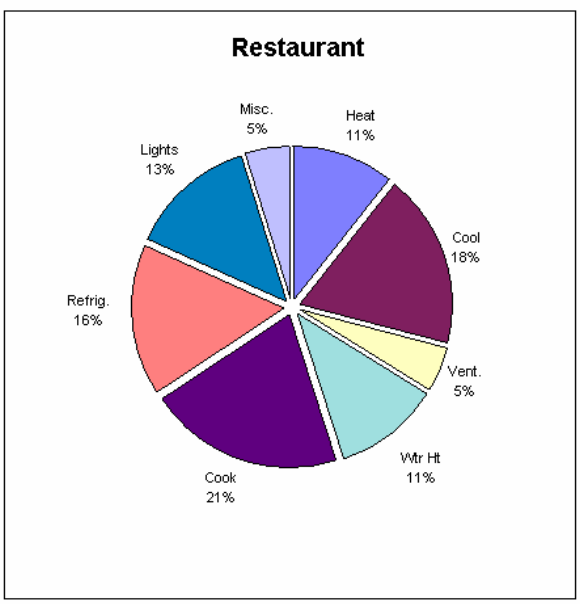
100% = 16.1 kWh/sq.ft./yr.



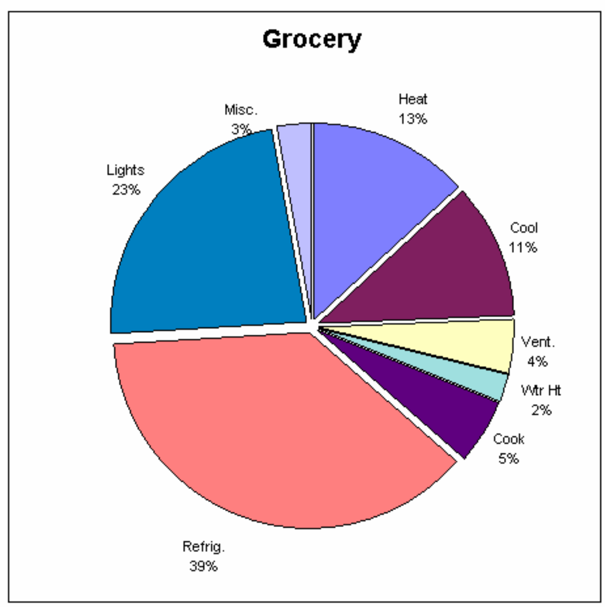
100% = 16.4 kWh/sq.ft./yr.



100% = 22.3 kWh/sq.ft./yr.



100% = 43.4 kWh/sq.ft./yr.



100% = 52.5 kWh/sq.ft./yr.

3.3 NUMBER OF FACILITIES

The U.S. Department of Commerce compiles a series of databases that show economic activity in each state, as well as in each county within each state. These data are readily available at the Census' Website, and include the number of establishments in each NAICS category.[18] The data are disaggregated in terms of employment categories. Exhibit 3-4 displays a summary of the number of "small business" establishments in California, disaggregated in terms of:

- Size, using employment as a proxy. Two size categories are used: 1 to 9 employees, which approximate roughly 10-kW to 35-kW peak demand, and 10 to 99 employees, which approximates facilities in the 36-kW to 200-kW peak-demand range.[19]
- Whether significant refrigeration loads are present.

Exhibit 3-4: Small Businesses in California

Business Type	Total	1 to 9 Employees	10 to 99 Employees
Without Refrigeration	711,352	545,247	166,105
With Refrigeration:	96,750	55,300	41,450
Total:	**808,102**	**600,547**	**207,555**

Source: 2003 NAICS Database, U.S. Census Bureau

As was discussed previously, the most common DR practice in small-business facilities that do not have significant refrigeration end-uses is to use a "smart thermostat" (i.e., one that has a communication linkage to enable remote changes to setpoints, to initiate DR events, and sometimes also has a communications linkage to report compressor runtime) to reduce air-conditioning usage and loads during DR control events. One the other hand, when a facility's peak demand is greater than about 35 kW—and especially when significant refrigeration end-uses are present—use of an EMS or DDC to accomplish load reductions is often economic because the magnitude of the savings is large enough to justify the added expense of installing an EMS or DDC. Exhibit 3-5 provides data on the number of facilities by type in this important sub-segment of the overall small-business market.

Use of an EMS or DDC is often an economic DR solution also in the case of commercial-sector facilities in the demand >~35-kW size range that do not have significant refrigeration end-use loads, because control of multiple AC units, numerous ventilation fans, and a large number of lighting circuits (as well as other miscellaneous end-uses) offers good opportunities for load control every day of the year. Industrial-sector facilities offer fewer opportunities because (a) they typically have only small air-conditioning loads, and (b) owners are reluctant to interrupt the operation of equipment that is directly associated with production throughput. This is not to say that opportunities do not exist, but rather that they are more difficult to identify, and when they are identified, to convince owners that they can be interrupted or cycled without adverse consequences occurring.

[18] The North American Industrial Classification System (NAICS) is the successor to the formerly used set of Standard Industrial Classification (SIC) codes that was used until 1997.

[19] The correlation between employment and peak demand varies greatly with facility type.

Exhibit 3-5: Breakdown of Larger California Small Businesses with Refrigeration and Facility Demand > ~35kW

Business Type	No. of Facilities
Manufacturers (subset w/Refrigeration)	675
Schools	1,470
Nursing & Residential Care Facilities	2,130
Wholesale Distributors (subset w/Refr.)	420
Groceries	3,460
Convenience Stores	455
Gas Station w/Convenience Stores	1,700
Meat Markets & Seafood Markets	175
Beer and Liquor Stores	190
Full-Service Restaurants	11,160
Limited Service Restaurants	15,350
Caterers and Specialty Food Services	950
Drinking Places	760
Florists	2,555
TOTAL:	**41,450**

Source: Aspen analysis of data provided in 2003 NAICS Database, U.S. Census Bureau

4. DESCRIPTIONS OF DR ENABLING TECHNOLOGIES APPLICABLE FOR SMALL BUSINESSES

The following sections contain descriptions of DR systems that Aspen identified in our research. The descriptions presented are based on information available on company Web sites and presented at conferences, augmented in many instances by telephone interviews. We have made no attempt to validate claims or to make comparisons among alternative technologies that appear to be similar. We urge the reader to apply appropriate caution, and to seek evidence to substantiate claims. As a firm that has experience in performing impact evaluations, as well as in evaluating test results prepared by vendors, we know how difficult it is to perform a rigorous test program. We urge utilities to support efforts by vendors to demonstrate the performance of their systems when this evidence is lacking.

We have grouped the technologies in the following way:

- Systems currently deployed in the small-business segment that migrated from the residential sector, or are likely to migrate.
- Systems that are targeted predominantly to the small-business segment.
- Systems that have already or are likely to migrate into the small-business segment from the large-business segment.
- Components for systems that appear to potentially offer viable enabling technology solutions.

4.1 SYSTEMS DEPLOYED IN THE SMALL-BUSINESS SEGMENT THAT MIGRATED FROM THE RESIDENTIAL SECTOR

4.1.1 CARRIER ComfortChoice

Control and Communications Technologies

Carrier's *ComfortChoice*^{SM} *Demand Management Solution* features a sophisticated control and communications DR enabling technology to remotely change air-conditioner thermostat setpoints in residences and small-commercial facilities. The key device is a seven-day programmable digital thermostat with Internet functionality (see Exhibit 4.1-1) and two-way wireless messaging (paging). The two-way paging system communicates the system status and transfers data (temperature setpoint, ambient temperature, and hourly runtimes—minutes per hour that the thermostat calls for compressor operation) between the thermostat and the utility or third-party aggregator.

The unit operates as a standard programmable thermostat, but also features pager access through an I/O Board installed in the home/business that communicates with the thermostat and transmits and receives signals wirelessly through a commercial pager communication network. The units and corresponding control system are capable of performing either cycling control, whereby a fixed allowable maximum on-cycle per hour is maintained (typically 50%), or temperature control, whereby the setpoint of the thermostat can be remotely adjusted by a specific number of

Exhibit 4.1-1: Carrier ComfortChoice Thermostat

degrees. In terms of other infrastructure required, a customer-side Internet connection is useful but not required. For customers without Web access, the utility or third-party aggregator can remotely program the thermostat and download the settings. And, of course, the customer can program the thermostat directly onsite.

The overall system configuration showing message flows to and from the ComfortChoice thermostat is provided in Exhibit 4.1-2. When a DR event is initiated, a software program causes a broadcast pager signal to be transmitted to a receiver (I/O board with paging module) located at each participating customer's facility. The pager signal triggers a shift of the thermostats' setpoints, or initiates cycling action, which results in load reductions. A pager signal is sent back from each unit indicating that the instruction was received. The system also reports (1) operating times of the air-conditioners' compressors, and (2) whether the customer overrode the curtailment.

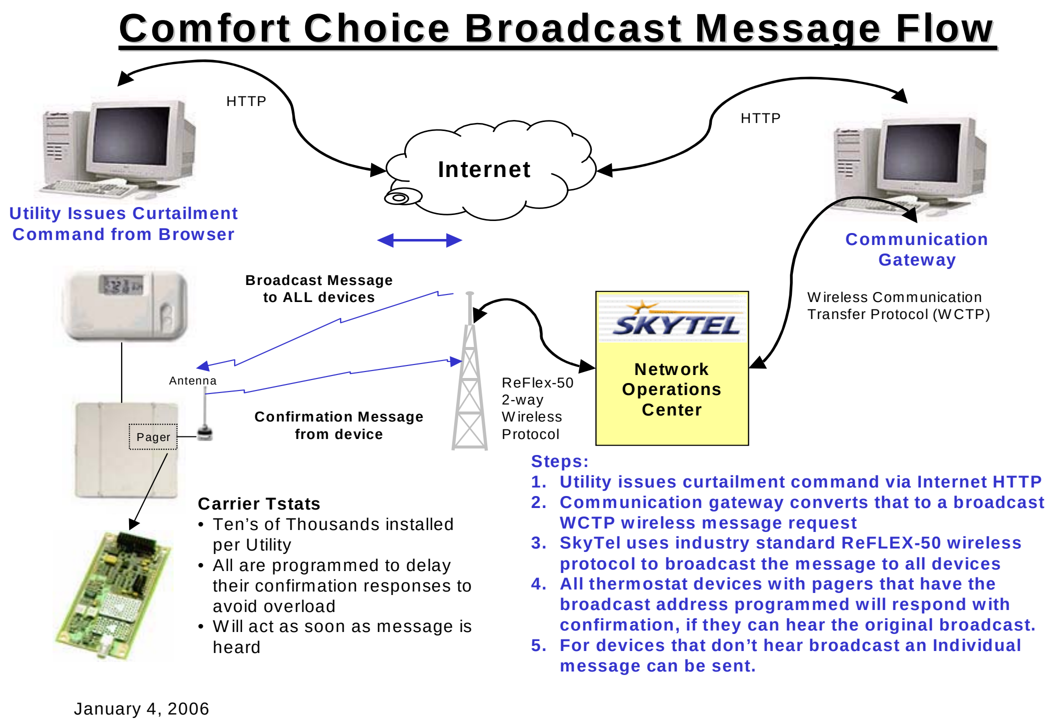
ComfortChoice Manager (CCM) is Carrier's new Web-based application designed for use by utilities in performing electricity curtailment events, and replaces Carrier's ComfortChoice (CC) software that was previously provided by Itron.

The procedure followed to estimate the magnitude of the load reduction achieved involves the following steps:

Pilots and Full-Scale Deployments

- Long Island Power Authority, 2001-2005, LIPA-Edge Program, Full-scale deployment (about 24,000 residential participants and 4,400 small business participants).
- ConEdison – 2003-2008, Residential deployment in Westchester and Staten Island. Small Business component began in 2004; at least 12,000 participants expected by 2008.
- Southern California Edison – 2002-2005, Small-business pilot (8,800 thermostats)
- San Diego Gas & Electric – 2003-2004, Residential pilot (5,000 thermostats)

Exhibit 4.1-2:



- Colorado Springs[20]– 2005-2007, Residential pilot, 100 participants in 2005, 400 expected in 2006.
- Connecticut Light & Power – 2000-2001, Residential pilot (100 homes)
- Public Service Electric & Gas – 2005 Residential pilot, 100 residential participants and 100 small-business participants.

Impact Evaluation Methodology and Results

The following methodology was developed by Applied Energy Group to estimate the load impacts in several of the program deployments listed above. Since the costs of obtaining runtime data were variable with the number of days collected, it was considered not cost-effective to collect data for every day. Rather, a hybrid comparison day analysis was developed, based on comparing the control day to a similar weather day or days (baseline) and making small adjustments where necessary to ensure a close match. The procedure consisted of the following steps:

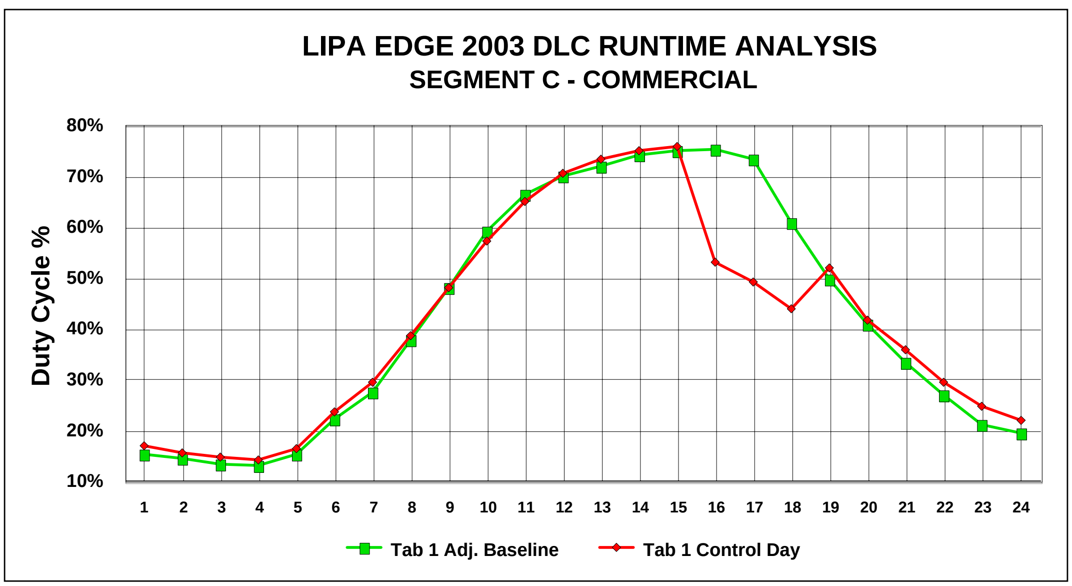
- The nameplate kW for each air-conditioning unit was obtained at the time of thermostat system installation and recorded in the master database.
- Runtime data were obtained for all units for all control days and a similar number of non-control days for use as baseline days for comparison purposes.

[20] http://www.csu.org/environment/conservation_res/energy/page7143.html

- Because the runtime data from the thermostats provides only a "percentage running" record for each hour, these data must be converted to kW load per hour. Nameplate kW is not an accurate indication of actual kW load when air-conditioning units are operating. Therefore, additional data, in the form of interval load data or spot-metering power draw, were typically obtained for a sample of air-conditioning units in the program being studied. These data were then analyzed to determine the average decrement factor to be applied to the nameplate kW of each air-conditioning unit, which is a function of outdoor temperature and other factors, such as the distribution of age and condition of the various units.[21]
- Using the runtime data for both the baseline and control days for each participating air-conditioning unit, the nameplate kW rating for each unit, and appropriate decrement factor, the load profiles on the baseline and control days were calculated. The baseline-day profile was then adjusted as described above, and the difference between the adjusted baseline profile and the control-day profile calculated and averaged to yield the load reduction as a function of time and average reduction. These values were then summed to obtain the corresponding aggregate data for all air-conditioning units.

Exhibit 4.1-3 shows a typical load-reduction plot for the system operating in cycling mode. Exhibit 4.1-4 shows the distribution of AC unit runtimes for the baseline-day and the DR-event day. Note that about 40 percent of the units were running continuously on the baseline day, but on the event day, most units were operating less than 50-percent of the time, as dictated by the control action. Exhibit 4.1-5 shows a comparison of reductions achieved by cycling and thermostat setpoint shift.

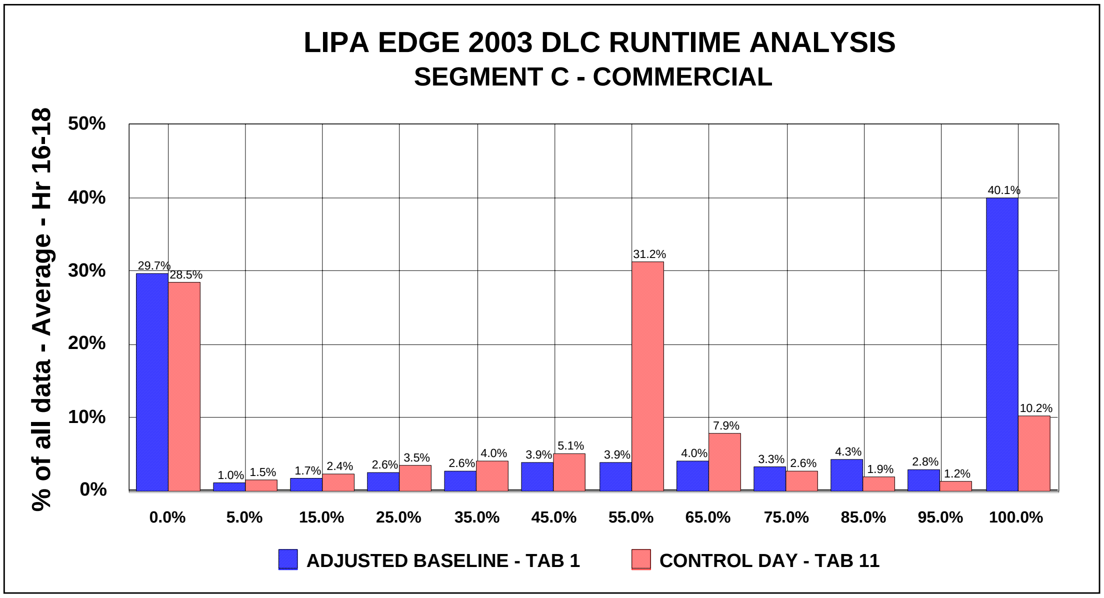
Exhibit 4.1-3: Load Reduction Achieved By Carrier System Operating in Cycling Control Mode



Source: J. Lopes, AEIC Load Research Conference, July 2004.

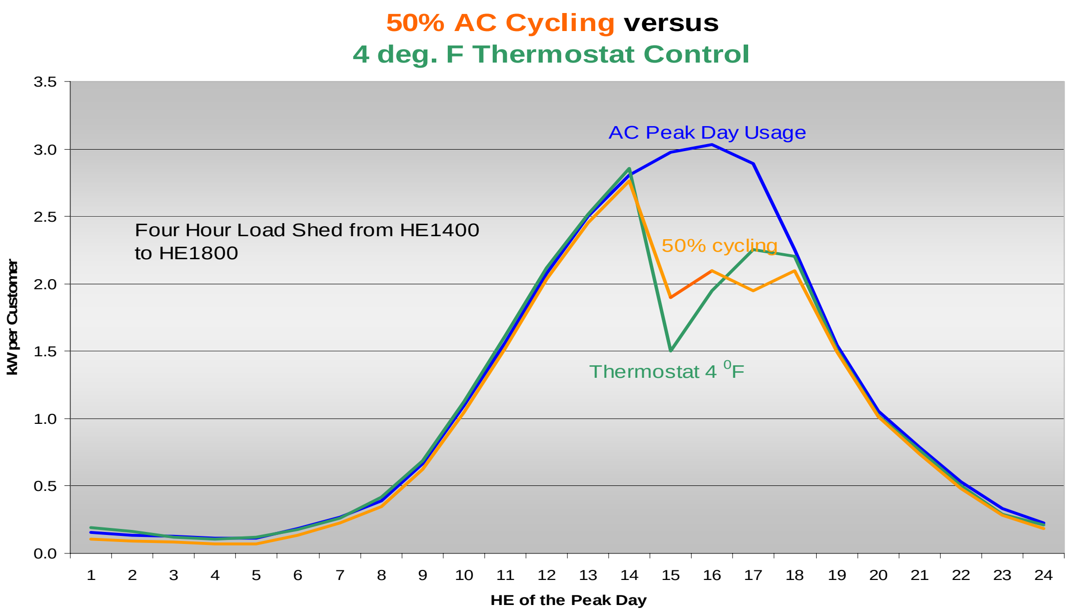
[21] In some programs the control events occur only on days when outdoor temperature is above 90°F, and for these programs the factor was calculated to be 0.85.

Exhibit 4.1-4: Run-Time Analysis of Carrier System Operating in Cycling Control Mode



Source: J. Lopes, AEIC Load Research Conference, July 2004.

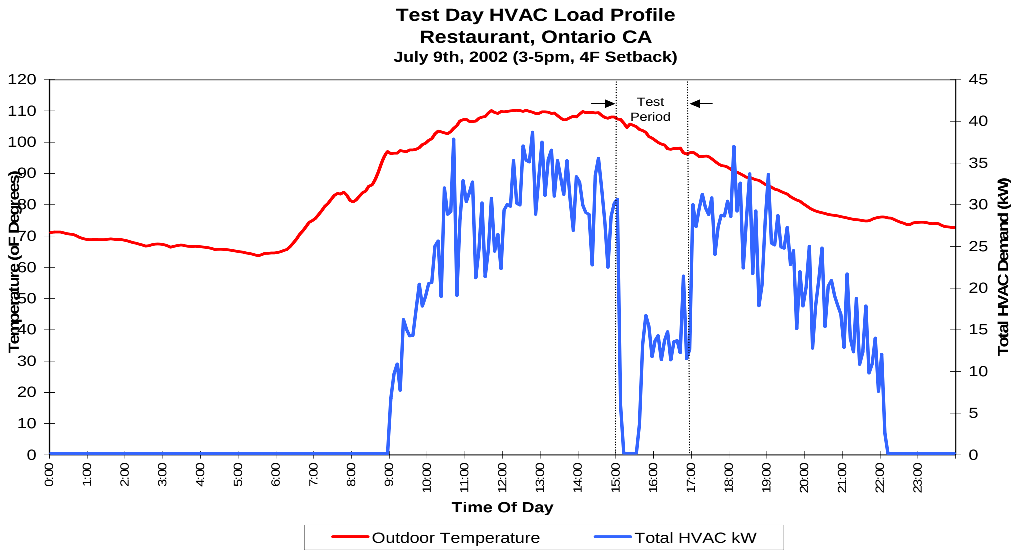
Exhibit 4.1-5: Comparison of Load Reductions Achieved By Thermostat Setpoint Shift Mode and Cycling Control Mode



Source: Presentation by M. Martinez (SCE) at the Peak Load Management Association Conference, September 2004.

Exhibit 4.1-6 shows how the electrical load of a restaurant air conditioner varies with time and outdoor temperature before, during, and after a 2-hour control event.

Exhibit 4.1-6: Restaurant Air Conditioner Load Reduction Achieved By Temperature Setpoint Shift



Source: Presentation by M. Martinez (SCE) at the Peak Load Management Association Conference, September 2004.

Information Sources: Ray Archacki, Carrier Electronics (860-674-3184)
Joseph Lopes, Applied Energy Group (631-434-1414)
www.comfortchoice.carrier.com/Files/Comfort_Choice/Global/US-en/CCM_PD_Sheet1.pdf

4.1.2 CANNON TECHNOLOGIES

Control and Communications Technologies

Cannon technologies offers software, hardware and service to address the complete portfolio of demand-response alternatives for energy consumers—ranging from residential to commercial to large industrial customers. The company states that nearly two million load-control devices have been delivered for use in 300+ electric utility programs during its 18-year operating history.

Cannon offers control technologies in the form of both remotely controlled relays ("switches") and thermostats, controlled by a one-way pager-signal communications link. The Honeywell "smart thermostat" contains the pager-signal receiver. Cannon provides a Web portal that customers and the utility or third-party aggregator can use to view information, set price "trigger levels" and other setpoints, and view messages and alerts. A business manager or residential customer can access this information from any browser connected to the Internet, and to make adjustments to energy-use parameters or from any location (e.g., adjust the "Unoccupied Mode" temperature setpoint at a business while at home).

Each device or relay can be individually setup to respond in a specific way when TOU or CPP price-levels occur. For example, San Diego Gas & Electric piloted a CPP water heater & pool pump program. By default, the customer's water heater is set to "off" when a CPP event is initiated by the utility. The customer has the option through the Web interface to setup the device to also not operate during the high-price TOU tier. The customer has the option to override any setting (e.g., to allow the water heater or pool pump to operate under special circumstances).

A summary of the Cannon Technologies products is provided in Exhibit 4.1-7. As shown in this exhibit, Cannon's control devices include multiple distributed intelligence features to maximize benefits to both the power system and customers. Individual features that are available include: True Cycle, Low-Voltage and Under-frequency Load Shed, Cold-Load Pickup, and Dual Paging-Service Providers.

- **TrueCycle®** Runtime cycle control is viewed as a method of increasing the yield of cycled cooling control by adjusting the controlling cycle time on an individual cooling system basis. The control device typically makes this adjustment based on compressor runtime data collected the hour prior to the start of the control period, applying the cycle rate to this runtime instead of clock time. Runtime control recognizes that site conditions (sun angle, shading, etc) and cooling equipment sizing have a large effect on the cooling requirements, and that these parameters may change throughout the day. Appling the control rate to the runtime rather than the clock-time results in better control of oversized air conditioners.
- **Low-Voltage and Under-Frequency Load Shed.** These features provide automatic shedding of the connected load if the supply voltage level or frequency drops below

"trigger values" set by the utility. The feature can be armed and disarmed by a system

Exhibit 4.1-7: Cannon Technology's Remote Load-Control Technologies

Technology Option	DLC Switch	Smart Thermostat
Control Equipment (Devices)	**LCR-5000**	**ExpressStat®**
Communications		
➢ Power-Line Carrier	✓	
➢ FM / SCA	✓	
➢ VHF RF (152 – 180 MHz)	✓	
➢ 900 Mhz Flex Paging	✓	✓
Standard Features		
➢ True Cycle	✓	
➢ Low-Voltage Load Shedding	✓	
➢ Under-Frequency Load Shedding	✓	
➢ Cold-Load Pickup	✓	✓
➢ ExpressCom Protocol	✓	✓
➢ Dual Paging Providers with Auto Fail-over	✓	✓
➢ Complete Over-the-Air Programmability	✓	✓
➢ Multiple Device Control	✓	
➢ Double-Pole Relays	✓	
Options/Features		
➢ Customer Override Control	**✓*1**	**✓*1**
➢ Data Storage	**✓*2**	**✓*3**
➢ Curtailment alert	**✓*4**	**✓*4**
➢ Maintenance Alert		**✓*5**

Notes:

*1. Provided through Cannon Technologies Consumer Access Software Override Functionality described below.

*2. Total control time is stored in the unit and can be retrieved into a Palm based PDA.

*3. Unit runtime and shed time are collected and stored in the thermostat. Data can be retrieved into a Palm based PDA.

*4. A Curtailment Alert can be provided to customers via e-mail, Web page, IVR, or fax.

*5. The ExpressStat® provides an LCD display directing the customer to call for support if the device communication system is not working.

operator command on a feeder, substation, area, and other group basis. The value to the utility is to increase the reliability of the power-delivery system by reducing brown-outs[22] and outages in specific service areas.

- **Cold-Load Pickup.** This feature provides power system support after a system outage. The Cold Load Pickup delay time is assigned during installation, or can be sent as a command to a group of devices. After a power failure, each device sheds the connected load and randomly selects a start delay that falls within the cold-load delay time.

[22] "Brown-outs" are deliberate reductions in the voltage on power lines to reduce loads. It is an undesirable technique because it causes many motors to overheat. The term is intended to be contrasted with a blackout (total loss of power).

- **Dual Paging-Service Providers**. Devices are configured for communication from two commercial paging companies at one time. This feature improves communication reliability and provides the utility or third-party aggregator with multiple sources for communication. If the device does not receive a signal from one paging provider, it will automatically switch to the back-up paging service.

Pilots and Full-Scale Programs

Alliant Energy (IA, WI)

Large multi-state direct load control program:
- Residential AC cycling control
- Small-commercial AC control using ExpressStat thermostats

Ameren (MO)

Residential CPP pilot:
- Residential HVAC control with ExpressStat thermostats
- Integration to legacy Cellnet AMR system
- Customer Web access for:
  - Thermostat programming
  - CPP education
  - Critical peak response strategy selection
  - Interval meter data

Cinergy (OH)

Large (50,000 unit) residential AC cycling program

City of Shakopee (MN)

Direct load control program:
- Residential and commercial HVAC and electric water-heater control
- Reading system load at substations
- Hosted Yukon

Com Ed (IL)

Large direct load control program:
- Residential HVAC control
- Commercial HVAC control (Chicago Public Schools)

Dakota Electric (MN)

Large direct load control program
(Over 50% of summer peak demand under direct control)
- Residential HVAC, electric water heater, and pool pump control

Duke Power (NC)

Large distributed-generation control program
(Over 350 MW of DR capacity)

Hawaiian Electric (HI)

Large direct load control program:
- Residential/small-commercial electric water heater control
- C&I notification and energy buy-back
- Line under-frequency control

Idaho Power (ID)

Large residential AC cycling program

Indianapolis P&L (IN)

Large residential AC cycling program

Kansas City Power & Light (KS, MO)

Large (14 MW) residential ExpressStat thermostat program:
- Residential HVAC control
- Customer Web access for:
  - Thermostat programming
  - Program education

Louisville G&E (KY)
Large residential AC cycling program

MidAmerican Energy (IA)
Large direct load control program featuring residential and small-commercial HVAC control

Nevada Power (NV)
Large direct load control program:

- Residential HVAC switch and thermostat control
- Customer Web access for:
  - Thermostat programming
  - Program information

San Antonio CPS (TX)
Large residential ExpressStat thermostat program:

- Residential HVAC control
- Customer Web access for:
  - Thermostat programming
  - Program education

Toronto Hydro (Canada)
Large residential and small-commercial program, targeting 130 MW in new DR capacity over the next three years:

- Residential HVAC and electric water heat control
- Commercial HVAC control
- Distributed generation control

WE Energies (WI)
Large direct load control program:

- Residential HVAC and electric water heater control

Wisconsin Public Service (WI)
Large direct load control program

- Residential HVAC switch and thermostat control
- Field retrofit program for legacy system upgrade
- Critical Peak Pricing pilot
- Customer Web access for:
  - Thermostat programming
  - Program education

Xcel Energy (MN, CO, TX)
Large multi-state direct load control program

- Residential HVAC switch control
- Field retrofit program for legacy system upgrade
- C&I notification and energy buy-back
- Critical Peak Pricing Pilot with ExpressStat thermostats

Information Sources: Charles Parsons, Cannon Technologies, Inc. (763-253-5549)
www.cannontech.com

4.1.3 COMVERGE

Control and Communications Technologies

Comverge offers two types of control technologies: remotely controlled relays (“switches”) and “smart” programmable thermostats, and offers communications links that feature either “one-way” or “two-way” systems.

The remotely controlled relay product line was acquired some years ago from Scientific Atlantic. This product was the mainstay of the original DR programs that were deployed during the 1980s and 90s. About five million units were installed in homes (~95-plus percent) and perhaps 50,000 or so in small businesses, in what were then called DLC (direct load control) programs. The relays controlled mostly split-system central air-conditioning systems, with a small percentage installed on electric water heaters. The thermostat used in the Comverge system was formerly made by Honeywell, but Comverge recently announced that in the future it would use a White-Rogers thermostat. (White-Rogers is a division of Emerson, with whom Comverge has a strategic partnership agreement.)

The one-way (dispatch) communications link now uses VHF paging. Older legacy relay controls used radio-frequency signals. The two-way communications link is commonly bundled as part of the company’s MainGate C&I gateway system. The gateway includes a collar at the electric meter housing that provides AMR capability and is coupled with the “smart” thermostat and relays that control the electric water heater, non-essential pumps, lights, etc. The system enables price-responsive load control and uses VHF paging and telephone uplink.

Pilots and Full-Scale Deployments

- Austin Energy – 2005, about 10,000 units, ongoing full deployment of one-way thermostats. Customer had purchased 40,000+ of the Honeywell one-way thermostats over a 4-year period; now buying the new one-way White Rogers thermostats.
- Tampa Electric – 2005, 250-home residential pilot, Main Gate product.
- PSE&G – 2005, 750-home residential pilot, Main Gate product.
- Gulf Power – 2001 - 2002, Full-scale residential deployment (see detailed information below).
- New England ISO

Gulf Power’s Critical Peak Power Program

The utility had three goals for initiating the program: 1) utilize existing generation and distribution resources more effectively; 2) increase customer satisfaction through savings; and 3) provide peak-load reductions. The program was initiated in 2001 and has more than 3,500 residential customer participants.

The system utilizes Comverge’s Maingate gateway interfaces and Honeywell thermostats. The thermostats can curtail two discretionary loads using relays, which receive power line carrier control signals on existing home power wiring. Initiating signals are sent to individual homes via a VHF pager signal. The customer’s phone line is used as the data-return path. The gateway has the rate schedule and time periods preset. The thermostat is the primary customer interface, but the customers can also program the settings through the Internet. The discretionary loads are typically domestic hot water and pool pumps.

The Good Cents Select program requires interval meters with 15-minute resolution. The customer must also have a phone line available as a data return path. Signals sent to individual homes are sent through a VHF pager signal.

The critical peak price is set using marginal costs, system loads and temperature profiles, and other factors. Critical prices can be called at any time. In addition to summer curtailment needs, Gulf Power operations dispatches critical peak price for wintertime cold load pick up, which overloads substations.

Gulf Power's value proposition for commercial customers under its proposed pilot is that participants receive: 1) utility savings using a time of use rate and critical peak price structure; and 2) choice and control over energy purchases. There is no provision for participants to override controls.

Analysis of residential pilot data showed demand reductions of 2.1 kW per household during summer and 2.7 kW per household during winter. Gulf Power estimates impact is measured by comparing a sample group of participating customers with a control group that also has interval metering but does not participate in the program. Participants show annual bill savings of about 15 percent.

Information Sources: ***www.comverge.com***

4.1.4 LIGHTSTAT

Control and Communications Technologies

The LIGHT**STAT** system consists of remotely controlled thermostats that have a dry contact to allow one or more additional loads to be controlled. This load might be an electric water heater or one or more lighting circuits. (In general, interior lighting is controlled only when ceiling fixtures are wired such that every-other fixture or every third fixture can be turned-off.)

The thermostat settings are remotely adjusted via a Web portal that sends an instruction via the Internet to a pager-signal transmitter operating on 930-MHz frequency. Thus, communications to the thermostat is similar to the Carrier, Comverge, and Cannon approach.

LIGHT**STAT** has been primarily marketing the system for two applications: (1) demand response, and (2) remote control of thermostats by a corporate manager who is responsible for energy management at a group of facilities (e.g., a retail chain or restaurant chain). In the case of DR applications, the electric-load data-collection component is not part of LIGHT**STAT**'s system. The concept requires that either each participating facility has an interval meter, or that a statistically valid sample of facilities be metered.

LIGHT**STAT** has introduced a new product (not yet listed) that provides two-way communication over a corporate wide-area network (WAN). The system communicates using IP protocols behind a secure network subject to corporate IT requirements.

Pilots and Full-Scale Deployments

- Allegheny Power (Pennsylvania) – 2002/3, Residential and small-commercial pilot.
- Southern California Edison (SCE) – 2005, small pilot about to start.
- SCE – 2003, Restaurants pilot.

The Allegheny Power Pilot showed the following results for two retail stores during a 4-hour DR event during which the thermostat setpoints were raised 3°F.

Floorspace	Air Conditioning RTUs	Load Reduction
8,000 sq.ft.	18 tons (three @ 6-tons)	4.1 kW (Avg.)
10,000 sq.ft.	20 tons (four @ 5-tons)	5.3 kW (Avg.)

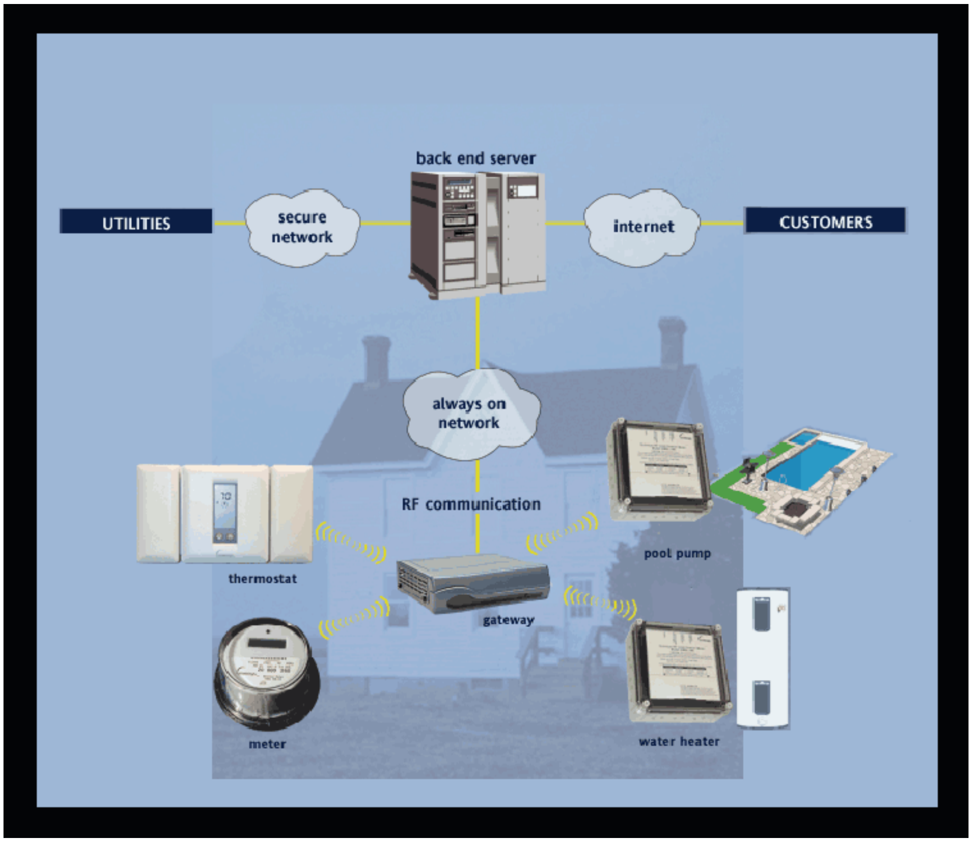
Information Sources: Ron Eigenbrod, President, LightStat, Inc. (800-292-2444, x-226)
www.lightstat.com/products/utility.asp

4.1.5 INVENSYS CONTROLS – GoodWatts

Control and Communications Technologies

Invensys Home Control Systems has developed the Home Manager™ coupled with the GoodWatts™ Service offering. The Home Manager is an "always on" home control system that monitors and manages major residential loads. It is designed to reduce the peak demands of the home while maintaining acceptable customer comfort levels. As shown in Exhibit 4.1-8, the Home Manager operates over a wireless network with a residential gateway communicating with the major loads in the home.

Exhibit 4.1-8: Home Manager System architecture



The gateway is attached to a broadband network that connects each home to the distribution utility or energy service provider serving the home. This network creates a direct link between the energy supplier and all the major loads in the home.

The in-home network supports a wide array of monitoring and control points including:

- Whole house interval metering
- HVAC thermostat monitoring and control
- Sub-metering and control of other major loads (such as pumps and electric water heaters)
- Net metering for effective management of distributed generation assets

Metering functions comply with ANSI C12 requirements.

Homes subscribing to the GoodWatts service permit their controlled loads to be shifted through either scheduled or specific DR programs offered by the utility or ISO. Under GoodWatts control, loads in a home would operate normally during off peak hours, but might be restricted during peak load periods. Thermostat setbacks can be performed using a utility-specified temperature ramping rate, and pumps can be shut-off during peak-demand periods. Water heaters and other major loads can be similarly controlled.

The customer may program a major load, such as a pool pump, to run a set number of hours, but generally is indifferent to the exact time that the pump runs. Items such as pool pumps are reprogrammed to run for the same number of hours desired by the consumer, but the utility or energy provider will dictate which hours of the day that the pump will operate. The net result is that the energy provider does not lose energy sales and the consumer does not have a loss of functionality.

The utility can offer a payment based on the actual contribution by each home. Using the revenue-grade interval metering capabilities of the system, the utility is able to compute the actual load reduction provided by each load in the home each day of the billing period, using historic device-level load data as baseline, and to subsequently credit the customer for the total demand reductions achieved. The GoodWatts system can be used to monitor and control onsite generating units, including photovoltaic, wind generation, and engine-generators installed at customer homes. All of the Home Manager meters are capable of detecting and reporting bi-directional power flow.

Today, the Home Manager system is designed to provide monitoring and control of these major loads with the potential to expand to other points of control in the future, thus expanding its sphere of control and home automation capabilities. Home security and appliance performance monitoring are two features that may be added in the future.

Invensys is a leading supplier of residential appliance controls in North America, and has been working with major appliance manufacturers to make ‘smart appliances’ a reality. Invensys is also a leading manufacturer of residential and commercial-grade thermostats for the global marketplace, and has for decades been a major supplier of components to leading commercial HVAC control companies. The Home Manager provides soft load control of HVAC systems by using the temperature ramping capabilities of the “variable dead-band” thermostat. This thermostat manages the environmental comfort range in the home by varying the set point over a range of settings in tenths of a degree.

In addition to performing its comfort control functions, the thermostat provides the homeowner with an easy to use interface to override curtailments if the optional “opt-out” capability is provided. It not only has the ability to display the price of energy at a given time, but also provides a useful indicator as to whether the price being charged is considered low, medium or high. The company believes that by providing pricing information to the homeowner, additional load reductions of discretionary loads will be promoted. Other visual indicators using LED lights on the thermostat can be used to alert the homeowner to high price energy periods.

The Home Manager’s “always on” broadband network connection allows the utility or energy service provider to know exactly how much load-reduction is available from each participating end use device in a home, and to aggregate that load up to a circuit, substation, or system level.

The utility can target load reductions to specific geographic areas, and manage demand more closely by getting verification of each control request as the curtailment commands are initiated. This ability to know exactly how much water heater, pool pump and HVAC load is currently available for shifting off peak permits a finer level of selective control to be performed. In addition, water heaters and pool pumps can be targeted for control first, leaving HVAC controls as the last level of control.

Pilots and Full-Scale Deployments

Although the Invensys DR system is primarily targeted at residential applications, the pilots have generally also had a few small-business participants, and there appears to be no reason why participation by small-businesses cannot be expanded.

- Philadelphia Electric Company – Residential Pilot involving approximately 120 participants during the 2002-2005 time frame.
- Nevada Power – Residential Pilot involving approximately 200 participants (began in 2003).
- Mason County PUDs Nos. 1 and 3, Clallam County PUD, and Bonneville Power Administration – Invensys (350 participants) and other technologies currently being installed as part of the Olympic Peninsula DR Pilot Project being managed by the Pacific NW National Laboratory (PNL).

Information Sources: Mike C. Anderson, General Manager, GoodWatts/Invensys Controls (925-962-9585)
Goeff Williamson, Vice President, Invensys Controls (650-575-9572)
www.invensys.com

4.2 SYSTEMS TARGETED EXCLUSIVELY AT THE SMALL-BUSINESS SEGMENT

This section contains information about the only two DR technology solutions that appear to have been developed specifically for the small-business segment.

4.2.1 DENCOR, INC.

Control and Communications Technologies

The Dencor digital demand control (DDC) unit reduces a facility's peak demand by (1) continuously sensing the total facility demand; (2) comparing the actual demand with a preset demand target; and (3) if actual demand rises to the preset target, temporarily interrupting the operation of equipment to prevent further load increases. More specifically, the Dencor DDC limits a facility's peak electric power demand by:

- Preventing certain equipment from running continuously when intermittent operation will have no adverse consequences.
- Preventing equipment that cycles "on" and "off" from cycling in a random fashion, which sometimes results in all or most equipment operating simultaneously.

Dencor manufactures two "families" of DDC units: the Model 200, which is suitable for residential applications, and the more sophisticated Model 300 series, which is designed for small businesses with multiple loads to be controlled. Three different versions of the Model 300C DDC unit are available:

- One with eight double-pole/double-throw (DPDT) power relays (24A; 120/240 Vac) that can control up to 16 individual single-phase circuits.
- One with 16 DPDT power relays that can control up to 32 individual single-phase circuits.
- One with 24 low-voltage thermostat-control relays.

The specific end-use equipment to be controlled is selected in consultation with the facility owner or manager. In general, the objectives are that demand-control operations (1) be unobtrusive and undetectable by facility occupants, and (2) not affect the quality of any food items or other products whose quality is potentially affected by temperature changes. It is desirable that the equipment items selected have significant power draws, so the relay actions result in meaningful savings. Equipment typically selected for control includes electric water heaters, air-conditioning units, and refrigeration compressors as well as anti-sweat heaters, which prevent condensation on the glass doors that provide customer "reach-in" access to products stored in refrigerated cabinets or cases. (As was noted previously in Section 2, interior lighting circuits are seldom interrupted because of two reasons: (1) the action would be noticeable and possibly distracting unless done in a gradual dimming action; and (2) the existing lighting equipment usually does not have dimming capability, nor is it wired in a way that enables alternate fixtures (or every third fixture) to be turned off.)

Each equipment item controlled by a relay is assigned an operational priority. Maximum "off" times and minimum "on" (or run) times can also be assigned for each relay. A relay that controls an electric water heater is typically assigned a low priority, which means it can be turned off for a period of an hour or more. Air-conditioning units are typically given a low priority, but are permitted to be “off” for only about 10 to 15 minutes at a time. Experience shows that refrigeration equipment can be off for 15 to 20 minutes without the temperature of stored food rising by more than a few degrees, if at all.

The operation of end-use equipment is accomplished by wiring the relays to either interrupt the power supply to the equipment or intercept existing thermostat or control circuits on the equipment.

The user can choose from a variety of control strategies. Relay actuation (and corresponding load interruptions) can be prioritized or timed (with fixed on and off times, and/or minimum “on” times, and/or maximum “off” times).

A special feature of the Dencor DDC is its ability to monitor temperatures and use these data to temporarily suspend control of the monitored load if temperatures rise to a pre-selected “trigger-point.” More specifically, when the controlled load is the refrigeration system or air conditioner, the temperature within the refrigerated or conditioned space is continuously monitored. If the temperature should rise to a preset level, control is automatically suspended until the temperature is reduced to below the set point. This prevents degradation of food quality, ice-cream softening, or occupant discomfort.

Operating records gathered from hundreds of unit-years of Dencor DDC operation show that these units typically reduce monthly peak demand during the summer months by about 30 to 40 percent of the amount of controlled load, or 10 to 20 percent of total facility demand. Demand reductions in cool-weather months are smaller than in summer months, of course, because peak demand is smaller when air conditioners are not operating, and refrigeration equipment is operating more efficiently.

The Dencor DDC has internal memory that stores a record of loads, control actions, and monitored temperatures. These data elements can be periodically downloaded via a telephone, cable, or wireless modem and associated communications link. This communications link can also be used to remotely program the unit and to change target set points.

The Dencor 300C controller is typically mounted near the main electric distribution panel in a customer’s facility. A key input is a signal that is proportional to the instantaneous power demand of the host facility. (This signal can be either a “kyz pulse” from the revenue meter or a signal generated from voltage and current measurements. The latter approach is most frequently used, with the current reading obtained by means of current transformers placed around the incoming power cables.)

The Dencor DDC is claimed to have essentially the same level of sophistication as the more expensive energy-management and building-automation systems that are used in large facilities (e.g., hospitals, malls, factories, large retail and office buildings), but it is packaged and priced for facilities in the small to mid-size market (i.e., 50-kW to 150-kW demand).

The Dencor 300C DDC has the capability to become operational to reduce facility loads only when a low-voltage control signal is present at a pair of terminals, and to be “off” at all other times. The unit can also be programmed with two different target load set-points: A lower one that is operational when a low-voltage control signal is present,[23] and one that is operational during other times. Therefore, to use the Dencor 300C units to reduce facility loads during DR events, all that is needed is a communications linkage to remotely trigger the low-voltage control signals at the controllers installed at all participating facilities (one DDC at each facility).

A wide variety of communications linkage could be used to actuate a relay closure that then causes the low-voltage control signal to reach the Dencor units: a wireless signal (e.g., radio, pager, Wi-Fi, or cell-phone), the Internet, or a signal conveyed by a power-line carrier (PLC) signal, possibly conveyed to a "smart meter" with two-way communications capability.[24]

Pilots and Full-Scale Deployments

A pilot program was conducted for Southern California Edison (SCE) by Aspen Systems Corporation[25] during 2004 and 2005. Dencor DDC units were installed at 19 small-business facilities that were also participants in the portion of the Statewide Pricing Pilot that was being managed by SCE. These small businesses all had Carrier two-way "smart thermostats" with remote dispatching of setpoint adjustments during CPP events (as described in Section 4.1.1). During CPP events, Aspen sent an initiating signal via an e-mail message that caused an additional pager signal to be sent to the I/O boards. The latter signal actuated a control relay that sent a voltage signal to the Dencor unit, which in turn initiated load-reduction control actions during the duration of the event. (A wired connection ran from the Carrier I/O boards to the Dencor controllers.)

Relays in the Dencor DDC units were connected to the following equipment:

- Rooftop air conditioners
- Walk-in coolers
- Walk-in freezers
- Reach-in coolers
- Ice makers
- Electric water heaters

A series of seven CPP events involving 10 facilities was conducted during a 5-week period beginning in late August 2005. The 10 facilities included restaurants (3), offices (2), services, retail (2), small grocery (1), and beverage sales (1). The 10 facilities had an average baseline demand of 54 kW (individual facility baselines ranged from 15 kW to 147 kW).

Impact Evaluation Methodology and Results

Aspen Systems used the following procedure to develop estimates of the load reductions achieved during each of the 10 control events. After each event Aspen remotely downloaded 4 days' of demand and temperature data for each facility via the phone modem. Then, the following four-step procedure was used to estimate the baseline load for each facility and for each 2-hour control event:

- Identify a day when the average demand over the noon to 2:00 p.m. period was within 5 percent of the average demand over the same period on the control-event day. (Closely

[23] This period can also be defined by pre-programmed times of day corresponding to the on-peak billing period.

[24] Another way to trigger events if there are several hours' notice of when the event is to begin, is to use the modem to remotely program each Dencor unit to begin controlling to a specified load set-point when the event is scheduled to begin, and to cease controlling when the event is scheduled to end. This method is not practical when there are more than about a dozen participating facilities.

[25] Now Lockheed Martin Information Technologies, which acquired Aspen Systems in January 2006.

similar average demand indicated that business activities and outdoor temperature were also similar.) Designate this the Baseline Day for a given facility.

- Calculate the unadjusted baseline for each facility as the average demand over the 2:00 to 4:00 p.m. period on the facility's Baseline Day.
- Normalize the baseline demand by multiplying the unadjusted value by the ratio of the average demand during the Noon to 2:00 pm period on the event day by the average demand over the same time period on the Baseline Day.
- Finally, calculate the load reduction as the difference between the average demand over the 2:00 to 4:00 p.m. period on the control day and the adjusted baseline value.

The results of these calculations for the August 26, 2005 control event are provided in Exhibit 4.2-1. The results show an average load reduction of 11.9 kW (22 percent of average baseline load) over the 2-hour control period.

Exhibit 4.2-1: Calculated Load Reductions for the 2:00 p.m. to 4:00 p.m. Control Event on August 26, 2005

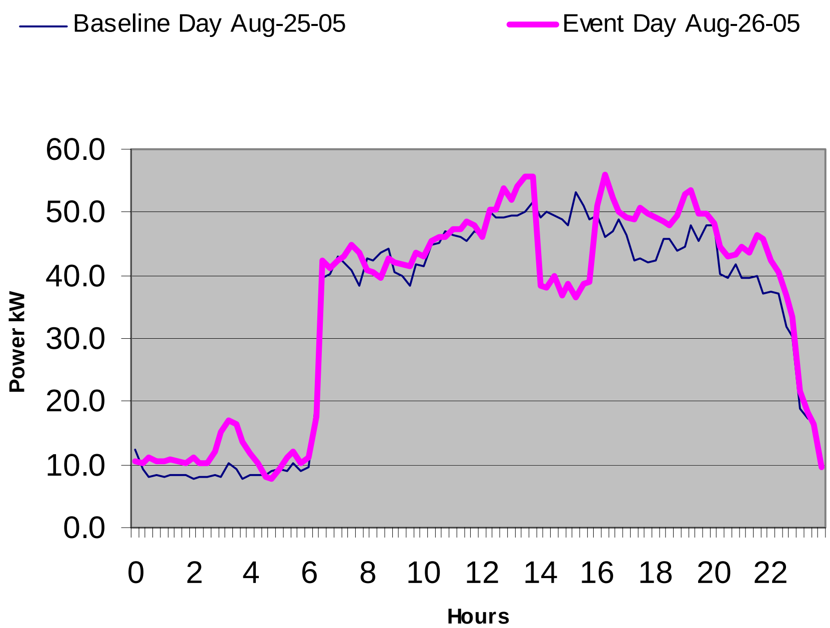
	Baseline Day		Control Day		Adjusted Baseline Demand (kW Avg)	Demand Reduction (kW - %)	
Customer Name	**Noon-2 pm Demand (kW Avg)**	**2- 4 p.m. Demand (kW Avg)**	**Noon-2 pm Demand (kW Avg)**	**2-4 p.m. Demand (kW Avg)**			
Retail Store "A"	32.5	33.4	31.8	24.0	32.7	8.7	27%
Limited Serv. Rest. "A"	49.4	49.9	52.3	38.2	52.8	14.6	28%
Restaurant "A"	104.9	105.0	102.1	88.0	102.2	14.2	14%
Beverage Store "A"	17.3	18.4	17.5	14.5	18.6	4.1	22%
Restaurant "B"	60.3	60.5	60.5	43.6	60.7	17.1	28%
Office "A"	45.7	44.7	46.0	35.0	45.0	10.0	22%
Retail Store "B"	36.3	36.4	43.8	33.9	43.9	10.0	23%
Small Grocery "A"	14.8	15.0	15.0	11.6	15.2	3.6	24%
Office "B"	171.6	171.9	147.1	118.8	147.4	28.6	19%
Equipment Rental	21.4	25.7	20.5	16.9	24.6	7.7	31%
		Totals:	**537**	**425**	**543**	**118.6**	**22%**
		Average of 10 Facilities:	**53.7**	**42.5**	**54.3**	**11.9**	**22%**

Load profiles for four of the facilities are shown in Exhibit 4.2-2 on the following two pages.

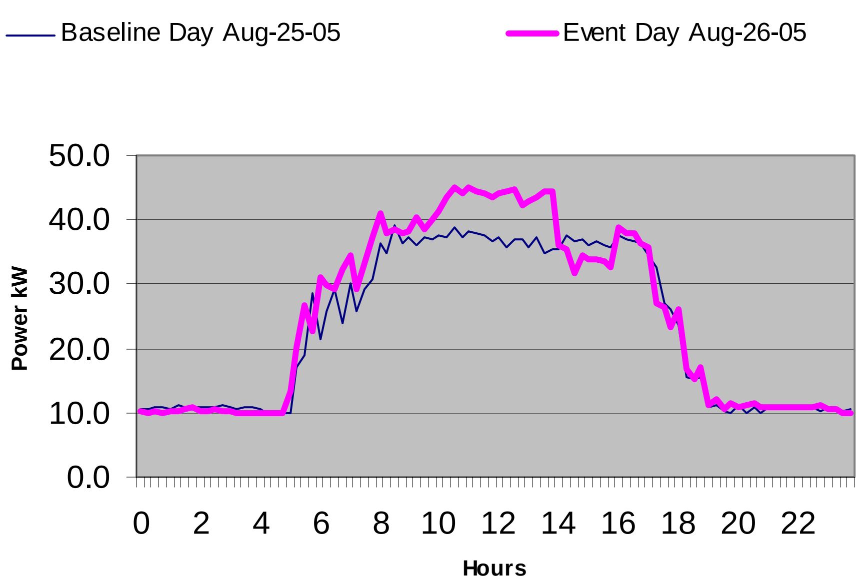
Information Sources: Matthew Essig, President, Dencor, Inc. (303-922-1888)
www.dencorinc.com

Exhibit 4.2-2: Load Profiles During the August 26, 2005 DR Event for Four Facilities Controlled by Dencor 300C DDC Units

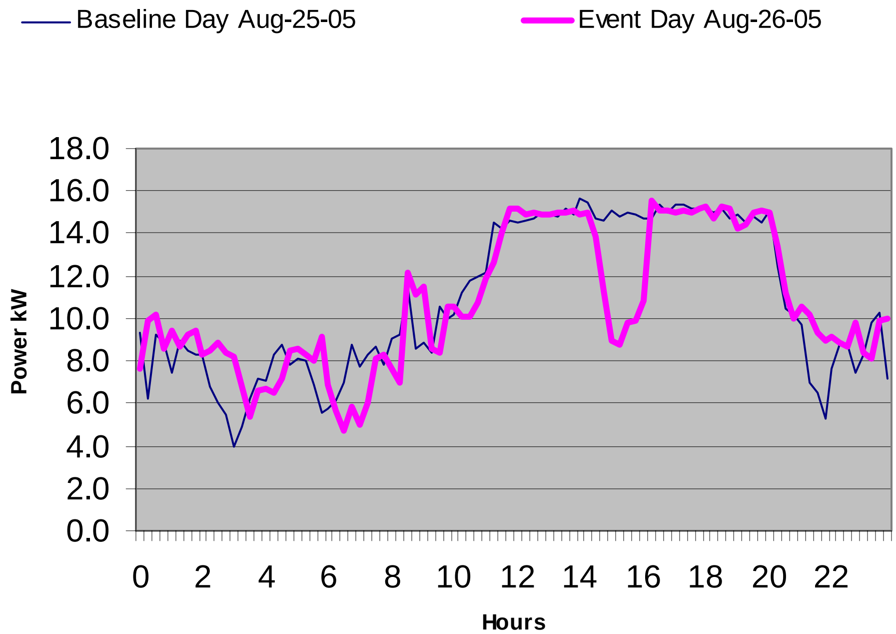
Limited Service Restaurant "A"



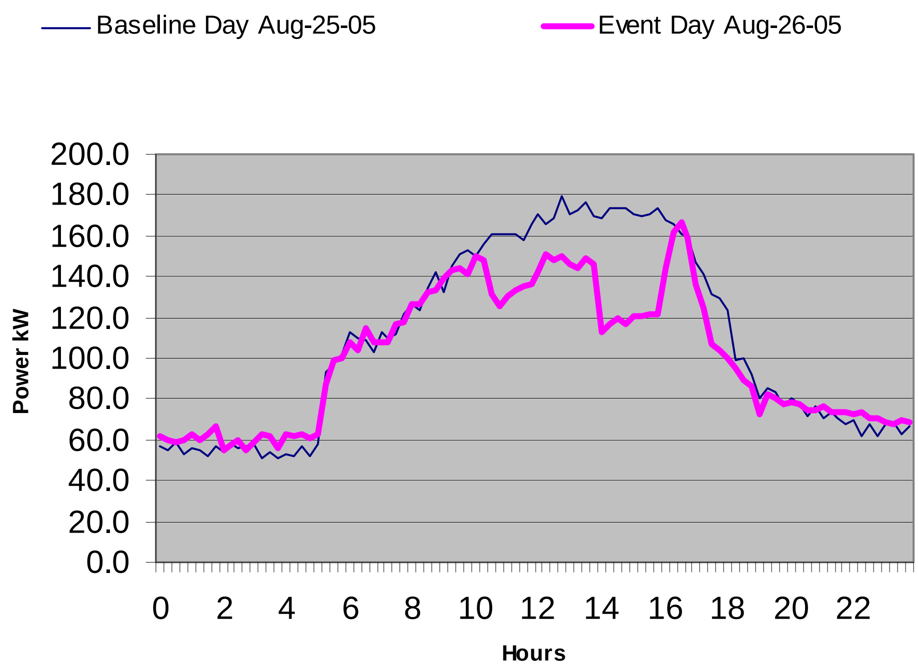
Office "A"



Small Grocery "A"



Office "B"



4.2.2 SITE CONTROLS, INC.

Control and Communications Technologies

Site Controls offers an energy management system (EMS) called *Site-Command*™ that is tailored to the needs of retail establishments, restaurants, and convenience stores. Commercial chain customers include Michaels Stores, Party City, Cheesecake Factory, Dollar Tree, Circle K, and PETCO. The system's core function is to make it easy for corporate facilities managers to configure, manage, and monitor the facilities' HVAC, refrigeration, and lighting end-uses. The resulting energy savings are claimed to justify the installation costs, which vary with the complexity of the installation but typically range from $6,000 to $12,000, with the higher price corresponding to installations with a large number of sensors and controls. The vendor reports typical payback times of 18 months to two years, plus the added benefit of monitoring and alarms. Utility energy-efficiency rebates are claimed whenever they are offered. Site Controls is currently investigating opportunities in convenience stores and other facilities with demands in the 50-kW to 80-kW range.

Exhibit 4.2-3 (below) shows the basic system architecture. Communications with the central control board (the wide, double-ended arrows) can be arranged through cell phone modems, Ethernet connections to the Internet (cable/DSL), dial-up phone lines, or the customer's virtual private network (VPN).

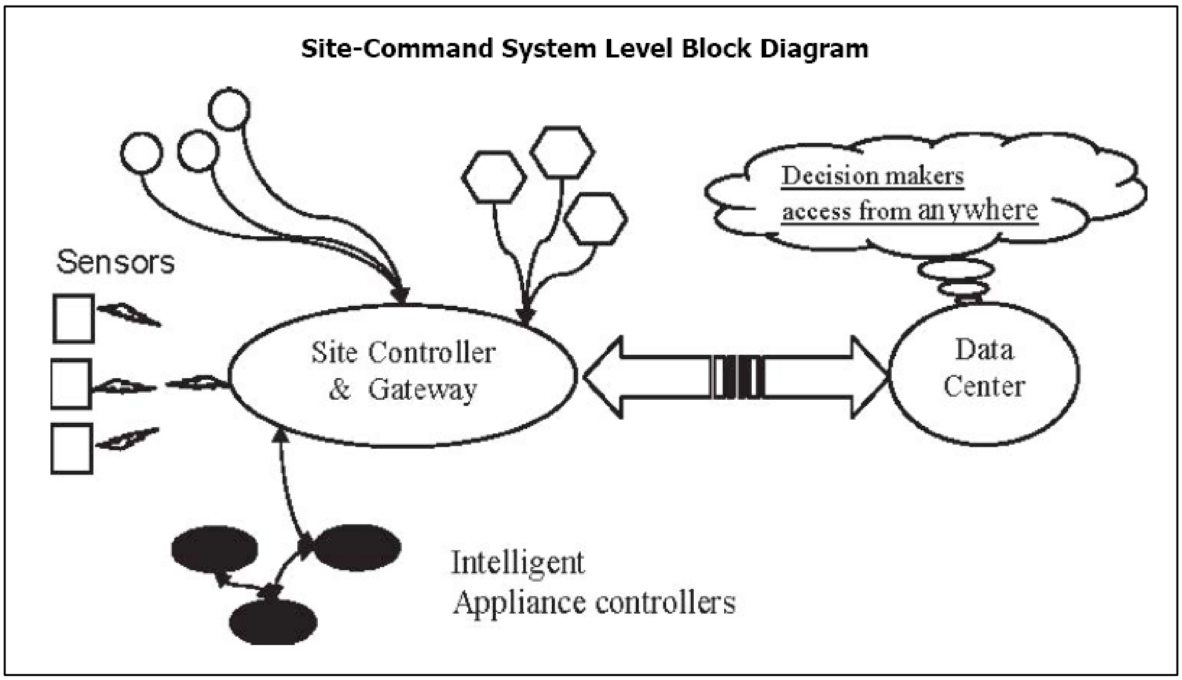


Exhibit 4.2-4 contains a list of *Site-Command*™ sensors, outputs, controls, control logic, and alarms.

Exhibit 4.2-4: *Site-Command*™ Technical Profile

Central System Hardware
- On-site "Gateway"
  - Linux architecture
  - Web, SSH, and FTP servers
  - Embedded database
- Optional touch screen panel on-site
- Wireless sensor technology

Sensors
- Facility power
- Space temperature and humidity
- Space CO_2 levels
- HVAC equipment runtime
- Lighting power and status
- Refrigeration case temperatures
- Door status / open-time
- Icemaker status / runtime
- Drink dispenser status
- Water temperature and pressure
- Level / pressure of fluids and gases
- Fuel dispenser monitoring
- Fuel tank gauge
- Vapor recovery system monitoring
- Car-Wash monitoring
- Traffic counters

Control Logic
- HVAC set-point programming schedule
- Lighting programmed schedule
- Demand-controlled ventilation
- Zone temperature averaging option
- Duty cycle management to minimize peak load

Controls
- HVAC temperature
- HVAC outside air flow rate
- HVAC humidification
- Lighting schedule
- Lighting on based on intrusion alarm
- Refrigeration temperature
- Icemaker on-off
- Fuel dispenser on-off
- Car wash on-off

Alarms
- Temperature threshold exceeded
- Door open
- Runtime threshold exceeded

User interface
- Web browser, on-site or remote
- Multiple-site management
  - Exception reports
  - Copying setup from one store to another

The Site-Command™ - Control Panel/Gateway (CPG), installed at each store location provides virtually unlimited data acquisition, logging, processing, and control capabilities. The CPG monitors building energy use and manages building loads such as HVAC and lighting, in real time by communicating with a distributed network of intelligent wired and wireless sensors installed by Site Controls. Among its many features, the system offers peak load management, which is based on programming logic to:

- Avoid simultaneous operation of second-stage cooling in rooftop air conditioners;
- Avoid simultaneous operation of other equipment that cycles;
- Activate demand controlled ventilation (if available and not continuously on); and
- Turn off selected lamps or fixtures (where existing wiring allows).

Sensors and actuators provided include a thermostat, the Digital Zone Controller (DZC)**,** distributed Input/Output Modules for HVAC and lighting control, wireless temperature sensors, and CO_2 sensor. In some applications CO_2 concentration is used to control the outside-air damper or fan. Because of the significant savings it achieves, this demand-controlled ventilation (DCV) module has become a near-standard offering. The CPG can simultaneously manage multiple protocols on several serial communication channels, facilitating the cost-effective monitoring of virtually any local device. The Internet-enabled CPG is based on a Linux architecture and includes a Java Virtual Machine, an embedded database, Web server, FTP server, and SSH server.

Actionable data is presented to local store personnel through Web-enabled PCs or PDAs. A touch-screen interface, typically installed adjacent to the CPG is an available option.

Because the system offers so much monitoring and control—including control of multiple sites—demand response with substantial impact is an option. For example, the system can be configured such that multiple stores in a given geographic area are instructed to raise their air-conditioner set-point temperatures on command, for several hours, with the amount of increase pre-established by each store's senior management (or by corporate management in the case of chains). Management may also authorize that selected lights or equipment could be de-energized during control events.

Participation in DR programs is viable because the system offers such strong monitoring and control capabilities—including the ability to remotely change equipment operation simultaneously at multiple facilities

Demand-Response Deployments

PETCO Animal Supplies, Inc. is currently using Site Controls technology for demand response in California. Previously, PETCO had installed a Novar Controls EMS in 119 California stores and participated in the state's DR program during 2002-2004. In 2005, Site Controls' *Site-Command*™ systems were installed in 20 existing stores, three headquarters buildings, and one distribution center. The system will be part of all future stores as they are built. Site Controls reports that PETCO changed vendors for three main reasons: (1) Site Controls can provide a complete animal safety service, built around the system's comprehensive temperature, humidity, and flow monitoring; (2) Site Controls generates "exception reports" that alert management when a monitored parameter (including electric demand) at a given time at any individual store deviates significantly from the average measured at that time for all stores; and (3) Site Controls can provide communications and controls to enable the stores to participate in DR programs.

Information Sources: Chris Tomasini, Site Controls, Inc. (617-314-7007) www.site-controls.com, www.fypower.org/feature/congrats/descriptions.html?recip=petco

4.3 SYSTEMS BEING DEPLOYED IN THE LARGE-BUSINESS SEGMENT

This section contains information about DR enabling technology systems that have been deployed in buildings that have peak demands greater than approximately 80 kW and often greater than 200 kW. In some cases, the system was installed only in very large buildings (>200 kW demand), but it could be deployed in "small-business" facilities in the upper half (in terms of size) of this segment: those with peak demands in the 100-kW to 200-kW range.

4.3.1 RTP CONTROLS

Control and Communications Technologies

RTP Controls is an Atlanta-based company with a product that is designed to empower commercial retailers to perform power monitoring, demand response, and real-time pricing control. The product is named the Aggregator™ because it enables companies with multiple facilities to aggregate all the electrical loads and control their energy consumption automatically, based on real-time pricing and user-defined set-points. As a "hands-off" demand-response solution, the system automates communication to stores and the generation of verification reports, while providing immediate response to market indicators and DR-event initiation signals. Typically, lighting, HVAC, and refrigeration loads are controlled.

Since the Aggregator™ is Web-based, there is one interface for organizing and managing electrical loads. Settings are saved in the system, and shed levels are customized so such that they minimize impacts on the host facilities' retail business operations. The Aggregator™ can also implement pre-cooling to prepare a store for a DR event.

The system can either shed loads directly or accomplish load reductions by interfacing with an existing building automation system. Purchase and complete installation of the Aggregator™ normally costs around $16,000 per site (roughly $10,000 for the equipment and $6,000 for installation).

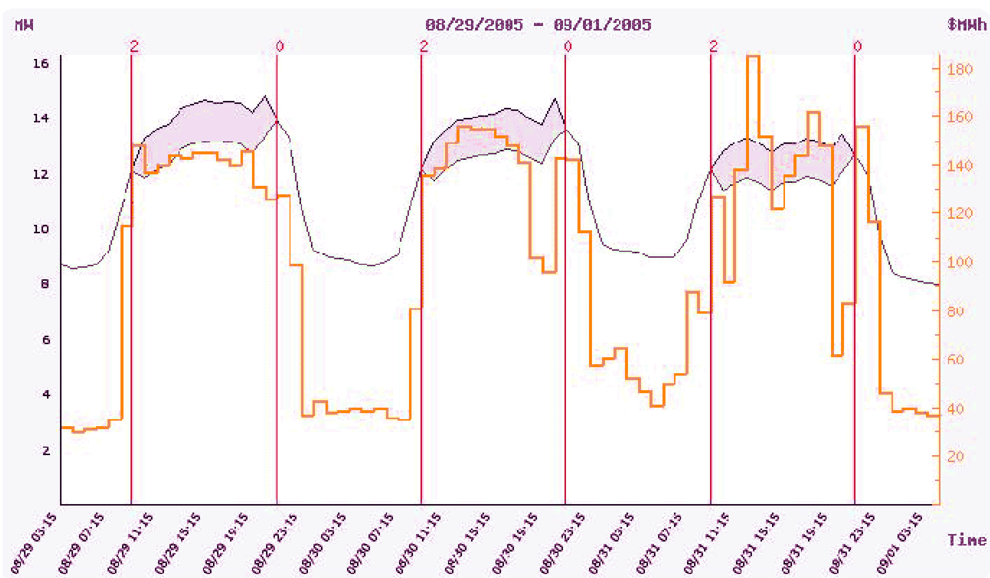
Communications to and from RTP Controls' server is carried via the Web to the retailer's corporate Web site, and then is carried over the retailer's wide area network (WAN) to each Aggregator™ system in the retailer's dispersed facilities. Daily, weekly, monthly, and instantaneous electronic reports are automatically generated to keep the retailer's corporate management aware of system operations and savings produced. The system also automatically generates demand-response documentation and e-mails the appropriate forms to the appropriate organizations.

Demand Response Deployments

RTP Controls is working closely with Toronto Hydro in Canada, and is participating in Ontario's DR initiatives through the IESO. The Aggregator™ is currently providing aggregated demand response in over 40 retail stores for the largest retailer in Canada. Each site is shedding 80-kW to 120-kW within one minute of the call for curtailment. As an example of load reduction capability and the corresponding dollar savings during a DR event, during the three-month period of August through September 2005, 18 stores shed over 800 MWh of energy and saved over $110,000 by simply not buying as much electricity during the on-peak period. In addition, owing to the DR Program for these stores, the retailer received payment for the energy that was taken off the grid as if it were produced energy, making the final savings over $220,000.

The load shed for a DR event must have a duration of at least 1-hour, and the signal is received from the three-hour-ahead price for energy. The system simultaneously checks the 5-minute market price for the real-time pricing aspect of control. For real-time pricing control, a user-defined minimum shed time (e.g., 30 minutes) is used. Exhibit 4.3-1 shows the aggregate load-shed profile for 18 stores over a 3-day time period. For these stores, the only end-uses that were controlled initially were lighting and some HVAC units, and these produced a load reduction of about 10 percent. Subsequently, multiple stages of HVAC units were controlled, and soon refrigeration end-uses will be added. RTP reports that the customer is extremely pleased with the performance of the system, and has had many favorable comments from their managers and customers. Currently, Aggregator™ systems are being installed at a rate of 8 to 10 units per month.

Exhibit 4.3-1: Aggregate Load-Shed Profile for 18 Stores



The orange line represents the price graph (scale on right side). The blue line shows the power consumption curve (scale on y axis). The grayed areas in the plot represent saved energy as a result of a DR "shed event." The vertical red lines indicate when a DR event was activated or deactivated.

Information Sources: Andrew Thomas, RTP Controls, Inc. (678 388-7620)
www.rtpcontrols.com

4.3.2 ELECTRIC CITY

Control and Communications Technologies

Electric City offers a line of energy-efficiency and demand-response products. Its core product is the *EnergySaver*™ lighting control device, which uses a series of autotransformers installed between the main power panel and subsidiary lighting distribution panel and produces energy and demand savings through voltage reduction. *EnergySaver*™ does not replace the existing lighting panel, making it most suitable for retrofits. The product can be used to control a wide range of lighting including T8 and T12 linear fluorescent, metal halide, and high-pressure sodium HID. Depending on the manufacturer of the lamps and ballasts, Electric City claims that the electrical consumption of the lighting system connected to the *EnergySaver*™ unit can be reduced by as much as 20 percent to 35 percent without visible change in the lighting levels.

The company's *Global Commander*® product enables central control across multiple *EnergySaver*™ facilities, including programming to "select among pre-programmed global lighting control setpoints to optimize lighting loads at all connected end-user facilities" in response to real-time variable pricing or DR dispatch signals. *EnergySaver*™ is compatible with any open protocol based building automation system, including BACnet and Lonworks® systems, and can communicate over any type of network architecture, including WAN, LAN, Ethernet, Internet, PLC, fiber optics, and two-way radio. *Global Commander*® communicates through a modem, the Internet, or standard phone lines with high-speed wide-area networking.

Incorporating the *EnergySaver*™ and *Global Commander*® technologies, Electric City develops large-scale DR deployments called Virtual "Negawatt" Power Plan (VNPP®). The VNPP® allows a utility or third-part aggregator to remotely control a building's lighting systems using a managed and secure Internet connection, providing instantaneous control, measurement, and verification of load reduction—all without impacting a customer's operations or ability to do business. The voltage reduction is implemented slowly over a 20-minute period, so that lighting ballasts are not adversely affected and occupants do not sense a change. Voltage reduction equates to lower lighting levels and lower power demand.

The *EnergySaver*™ product is available for 120-V, 208-V, 277-V, and 480-V systems, and 40-A to 200-A panels. The larger 480-V/200-A devices are most cost-effective. Typical installations cost $14,000 to $20,000, with an average of $450/kW to $800/kW for installation labor, equipment, and communications. The device records and communicates back data such as voltage, current, and $/kW saved.

The *EnergySaver*™ product can be purchased by individual utility customers for cost-savings reasons, or it can be installed as part of a utility DR program. In the case of long-term utility contracts, Electric City links the *EnergySaver*™ installation sites and programs them to be dispatchable by the utility. Participants agree to enroll for 10 years, receive the device for free, and are provided a 5 percent voltage reduction (i.e., about 10 percent savings level), and agree to reduce demand 25-30 percent during control events.

Life-Time Fitness, an operator of sports and fitness centers, is using *EnergySaver*™ as a conventional lighting EMS. After average savings of 20 percent on electrical consumption for lighting were shown at a pilot site, the chain subsequently installed systems at all its facilities.

Electric City recently purchased **Maximum Performance Group** (MPG), which sells Web-based and wireless controllers for HVAC, lighting, and central cooling plants. The company's eMAC system directly measures HVAC system performance points and optimizes cooling and heating system operation. The uMAC operates and monitors lighting and refrigeration systems. Both technologies broadcast operating conditions wirelessly to a non-proprietary Web-based user interface. The system uses 900-MHz signals.

MPG's eMAC controllers are connected between the existing thermostat and the HVAC unit (or lighting systems) and monitor 140 points of systems operation on a typical package rooftop unit. These monitored points are relayed to a wireless paging network, connecting directly to MPG's servers, where the data is then transformed for Web access. Businesses with multiple locations have the ability to remotely manage and control all of their buildings' individual packaged HVAC or lighting systems from a desktop PC, using a standard Internet browser. In addition to monitoring and standard scheduling, the eMAC includes an "optimum-start") algorithm.

Although not commonly used for demand response, Electric City is planning to deploy this equipment for curtailments as part of its PacifiCorp project. The device can receive DR dispatches and will cycle equipment "on/off." Installed costs for the product are $3,500 to $4,000 per device for hardware, labor, and software. NYSERDA, LIPA and NSTAR have extended their custom incentive programs to include both the eMAC and uMAC technologies.

Through its Great Lakes subsidiary, Electric City also has a line of products that provides control and monitoring through central EMS systems for central air handlers.

Demand Response Deployments

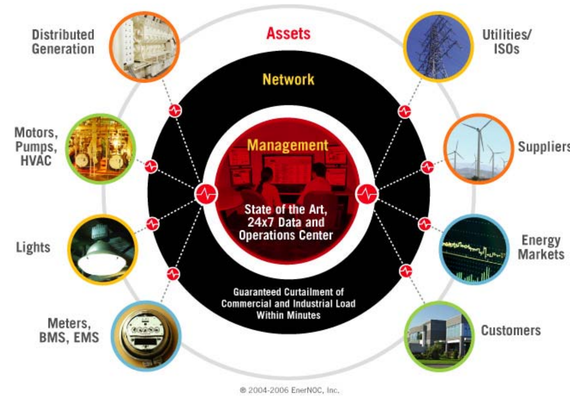
- ComEd – Early 2005, 50MW VNPP program
- PacifiCorp (Utah) – May-2005, 27 MW VNPP; Option for 50 MW
- Xcel Energy – Custom Efficiency Program
- Enersource Hydro Mississauga – October 2005, Initial 500 MW pilot

Electric City has been signing up non-residential customers to install its Energy Saver devices and participate in its VNPP initiative. The company estimates that it can deploy roughly 2,000 to 2,500 *EnergySaver*™ systems for the two VNPP programs during load-curtailment events. "Pull-through" sales have been recorded from corporations with facilities participating in the ComEd and PacifiCorp projects when systems are purchased for installation at the chain's facilities located in other utility service areas where no DR programs exist.

Information Sources: Anna M. Baluyot, Senior Vice President, Electric City Corp. (847-437-1666)
Anthony Sinople, Electric City Corp. (847-437-1666)
http://www.elccorp.com/
http://www.maxpg.com/technology/eMac.asp

4.3.3 ENERNOC

EnerNOC, which stands for Energy Network Operations Center, combines demand response, price response, distributed generation, and energy-efficiency upgrades to develop customer-specific solutions. The company aggregates the DR savings available from a large number of facilities in specific states where DR programs are offered, such as California, New York, and Massachusetts. Monitoring and control operations are centralized at the company's operations center in Boston.



EnerNOC's core market solution, Capacity on Demand™, coupled with PowerTrak®, enables energy management solutions to be tailored to fit specific needs. The technology component of EnerNOC's solution is built on an open Web services architecture that uses a group of standardized communications protocols that in turn are based on a common, non-proprietary language, SOAP/XML. PowerTrak® is a comprehensive tracking and monitoring tool for electric power, natural-gas, water, weather, and pricing. Its features include commodity profiling and alarming, bill auditing and analysis, load forecasting, forecasting, benchmarking, and scorecarding. EnerNOC has integrated its solution with a wide variety of EMS units and metering systems, including Square D PowerLogic, Itron MV90, Echelon, Emerson CPC, Com-Trol, and Altech.

At 23 Pathmark grocery stores in the Northeast, the strategy reportedly is saving an average of 50 kW per store. EnerNOC also is working with the California-based Raley's supermarket chain. At 300 Albertson's grocery stores in California, the strategy reportedly is saving 7.5 MW, or 25 kW per store with lighting and anti-sweat heater control, at a cost of $11,000 per store, or just under $450 per kW. The technologies used for the application included Engage Networks' Energy Information System and Ethernet Pulse Input Module and Invensys' Com-Trol local EMS unit. The Engage Networks system translates the call for a reduction from Albertson's wide area network (WAN) to the Com-Trol system.

EnerNOC currently does not serve small commercial businesses with their systems, but a scaled-down system is under development that will make their grocery store systems more cost-effective and suitable for other small-business such as convenience stores and restaurants.

Engage Networks' Distributed Generation Management (DGen®) is another tool for managing use of backup generators. With DGen, "generators are controlled automatically from any alarmable event such as temperature, real-time energy price, energy demand and many other pre-defined conditions."

Information Sources: Jennifer Collins, EnerNOC (617-224-9904)
www.enernoc.com
www.engagenet.com.

4.3.4 EMS INTERFACE (DEMAND RESPONSE RESEARCH CENTER)

It is common practice to install an energy management systems (EMS) or "building automation system (BAS) in large-business facilities, either when the facility is first constructed or as a retrofit. These control and monitoring devices permit a building manager to schedule the operation of lighting fixtures and HVAC equipment (and also refrigeration equipment when this is present), as well as to remotely set thermostat setpoints and other controls. Theses devices also monitor and log operating parameters (e.g., flows, temperatures, power levels) in all parts of the facility. Virtually all modern versions of these devices now have Web based "head ends" for user input and output and Ethernet connectivity.

Since these controls are already in place, the only DR enabling technologies needed for a complete system are: (1) a means for sending a "DR-event" signal to the EMS or BAS at each participating facility, and (2) a means for remotely retrieving load data from each facility.[26] (The EMS or BAS must also be programmed to take specific load-reducing actions when the signal is received.)

The Demand Response Research Center (DRRC) is funded by the California Energy Commission's PIER (Public Interest Energy Research) Program, and is managed by Lawrence Berkeley National Laboratory. The primary activity of the Center is to develop and demonstrate automated "machine-to-machine" DR enabling technologies for the large buildings segment. However, many of the communications technologies are equally applicable to the small-business sector.

An example of the projects undertaken by the DRRC is included in the description of Itron's DR activities and systems, which are presented in the next sub-section.

Information Source: Mary Ann Piette, LBL EETD Building Technologies Department, Director of the Demand Response Research Center (510-486-6286) *Findings from the 2004 Fully Automated Demand Response Tests in Large Facilities*, September 7, 2005, Piette, M. A. et al, Lawrence Berkeley National Laboratory, Sponsored by the California Energy Commission PIER Demand Response Research Center, LBNL Report Number 58178, downloadable at
http://drrc.lbl.gov/drrc-pubs1.html
http://drrc.lbl.gov/

[26] Large facilities generally have interval-type revenue meters that can be read by the utility "on-demand," and this linkage could be used to obtain load data. However, this is not a preferred approach because it requires the utility to interrupt its normal schedule for downloading and processing load readings.

4.3.5 ITRON

Itron manufactures solid-state meters for utilities and supplies automated meter reading technology and enterprise-wide software platforms. The firm also provides a wide range of consulting and analytic services. During the summer of 2005, Itron participated in a DRRC pilot project with PG&E and Lawrence Berkeley National Laboratory to demonstrate reliable and automated demand reductions in large commercial buildings, in response to Critical Peak Price (CPP) events. The project provides early indications that commercial customers can and are willing to take advantage of the economic benefits provided by time-based rates combined with automated demand response. About a dozen customers participated in the pilot and a total of six CPP events were run in August and September.

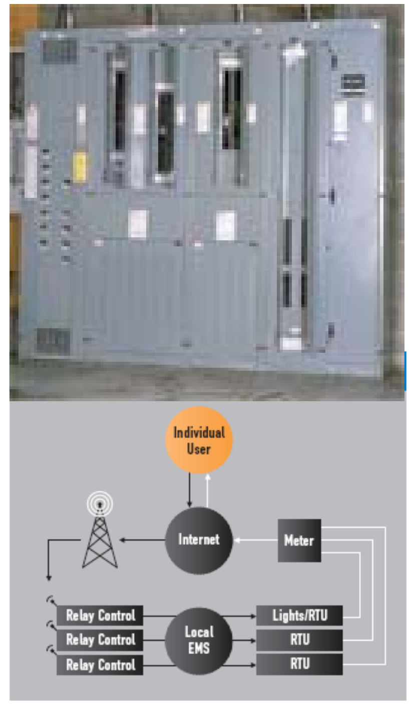
The procedure followed in the pilot project was as follows. Using Itron's *Curtailment Manager* solution,[27] PG&E notified participating customers a day ahead of a scheduled CPP event. Itron's *Curtailment Manager* also sends this notification via XML to Lawrence Berkeley Laboratory's server, from where a price-related signal can be dispatched. Each participating building's EMS is programmed to execute specific load shedding or shifting strategies based on the price signal ("Normal," "Medium," "High"). The fact that the notice is issued a day ahead provides the opportunity to modify the specific load-shedding or shifting strategies that will be executed the next day (e.g., pre-cooling) that otherwise would not be available if the notice was issued immediately prior to the control event. Customers can also log onto Itron's *Curtailment Manager* solution to view actual versus expected performance, analyze their operational strategies, and refine these strategies for future events.

PG&E has used Itron's *Curtailment Manager* solution to operate its commercial and industrial DR programs for the past four years, but this is the first summer it has been used in combination with automated demand-response control actions.

Information Sources: Matt Owens, Itron Inc., (510-844-2845)
http://drrc.lbl.gov/pubs/autodr-10-31-05.pdf

[27] Itron's *Curtailment Manager* solution was previously used by Carrier to manage the data-acquisition aspects of the Comfort Choice smart thermostat system.

4.3.6 NOVAR CONTROLS



Novar Controls is representative of a group of manufacturers that supply integrated electrical control systems to retail chains. Novar's EpiCenter product line (shown at right) combines electrical distribution panels, energy management control systems, and security systems into factory-wired turnkey packages. Hardware under control almost always includes lighting and HVAC, but it also can include segment-specific end-uses (e.g., anti-sweat heater in grocery stores).

No DR-specific products were found promoted at Novar Controls' Web site or at that of any of its competitors. However, this brand and others can be adapted through custom programming to be used in small-business chain account DR programs. The EpiCenter is Novar's large-store product; the SBS is a control-system-only product line that is targeted to smaller businesses.

The basic concept of adding DR communications linkages to existing EMS or BAS devices was outlined in Sub-Section 4.3.4 and illustrated in Sub-Section 4.3.5. In this sub-section, we describe two illustrations of the approach that involved DR initiatives undertaken by two retail chains.

The Staples office supply chain has 119 "big box" stores in Southern California. These stores have an average peak demand of 108 kW and are able to shed 23 kW each within a half-hour of issuance of a command from the company's Massachusetts headquarters via a Web site. The project cost was $320,000, or about $2,700 per store, resulting in a $114 per kW of demand reduction.

Key technologies and role players in this retrofit were:

- ♦ Cannon Technologies, paging-activated relays and Web-based interface to initiate control events (up to three levels of control are available). Cannon Technologies has been discussed previously in Section 4.1.3.
- ♦ Novar Controls, programming responsibilities, local control and powerline hardware for HVAC and lighting (pre-existing).
- ♦ Energy Logic, Inc., a consulting firm that married the technologies and secured funding from the California Energy Commission (CEC).
- ♦ Action Electric, the electrical contractor.

In a second example, 135 PETCO retail stores with an average of 211-kW summer peak demand can shed 39 kW each at a project cost of $1,119,000, or $8,288 per store, which equals $212 per kW shed. The 135 stores used a mixture of Novar Controls at some stores and Pentech

Solutions[28] control systems at others. As with the Staples DR control installations, the Novar Controls retrofits at the PETCO stores involved using Cannon Technologies' Web-based interface to centrally initiate control events, and Cannon's paging-activated relays to transmit the signals to the facilities.

As was noted in Section 4.2.2, PETCO subsequently decided to use Site Controls as system vendor. (The Site Controls system has its own communications and software, and therefore does not require a Cannon communications interface.)

Information Sources: www.novarcontrols.com, http://www.energy.ca.gov/enhancedautomation/, http://www.cannontech.com/products/drdirectcontrol.asp

[28] Pentech Solutions, developer of the eMAC system, has since been acquired by Maximum Performance Group (MPG) in 2003. MPG released a Web-enabled version of eMAC in 2004, which likely eliminates the need for partnering with Cannon. MPG in turn was acquired by Electric City in the spring of 2005.

4.3.7 BATTERY-POWERED VEHICLE CHARGER CONTROL

Control and Communications Technology

A custom-designed energy management controller turned off power to 0.75 to 10 kW battery chargers for forklifts, pallet jacks, sweepers, tugs, personal/burden carriers and golf carts during peak periods. The controller also metered the connected loads to determine the amount of resulting power reduction and communicated with program managers through dial-up or local LAN connection via Echelon LonWorks controls.

Pilots and Full-Scale Deployments

This CPUC TA/TI TPI program was implemented in 2001 in Southern California Edison's territory. The program reported 9.1 MW of demand reduction at 74 sites. The evaluator's interim report noted that actual savings might be less and was going to investigate further, but final findings in this regard were not found.

The program value was $2,000,000 making the direct investment $220 /kW. The customers were required to buy the control systems themselves, but a $150 /kW incentive was paid directly to the customers on installation, which often covered the entire cost. The customers enjoyed additional bill savings by shifting load from on-peak to off-peak periods when electric rates are lower. The success of the program was attributed to the involvement of third parties contractors that marketed the program. Over half of the customers approached agreed to participate.

VaCom Technologies, Honeywell, and QuintEvents worked together to introduce this custom-designed controller to market, train the third party contractors, and support their sales efforts.

The specific program has potential for small businesses such as golf courses and small manufacturers. The general controller, communications, and contactor bank concept could be applied beyond vehicle chargers.

Information Sources: www.echelon.com/solutions/utility/appstories/SCE.htm,
www.vacomtech.com,
http://www.nexant.com/docs/CEC/Q3_2002.pdf
(page 5-6), CEC publication 400-02-029CR.

4.4 TECHNOLOGIES BEING DEVELOPED OR ADAPTED FOR SMALL-BUSINESS DR APPLICATIONS

This section contains information about control and communications technologies that are being developed and tested for future DR program deployment in the small-business market segment. It also contains examples of equipment that is currently used in other applications, but could be readily adapted to dispatchable DR applications.

4.4.1 LIGHTING CONTROLS

The most common means of using lighting for demand response is to turn off alternate fixtures or lamps using pre-existing lighting EMS controls. This is particularly applicable in California, where for the last few years tandem wiring is required to comply with Title 24 Building Energy Code requirements.

The few lighting dimming applications of demand response undertaken thus far have involved large commercial buildings that have: (1) fluorescent fixtures with dimmable ballasts, interval revenue meters with remote-reading capability, and (3) a sophisticated EMS or BAS (building automation system) installed that controls lighting and HVAC systems, and other end-uses such as decorative fountains and refrigeration equipment. The approach has been to tie-in a communications system (typically Internet-based) to initiate load reductions by conveying a specific power-reduction instruction to the existing EMS or BAS. Upon receiving the DR-event initiating signal from the utility or third-party aggregator, the EMS immediately causes lights to dim and thereby reduces power. (Because of the high cost to retrofit existing non-dimmable ballasts with the dimmable type and to install control wiring to each ballast, application of this technology is generally limited to facilities where dimmable ballasts and an EMS to control these ballast already are in place.) Also needed is a means for obtaining load data from the existing metering system.

UNIVERSAL LIGHTING TECHNOLOGIES / ENERGY CONTROLS & CONCEPTS

A California energy-technology contractor (Energy Controls & Concepts) and a ballast manufacturer (Universal Lighting Technologies) have proposed a new lighting control system for demand response. This new system is applicable in either small or large businesses.

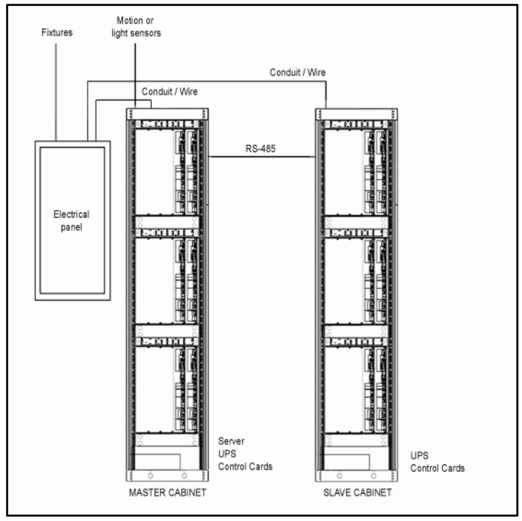
The system employs one hardware component (special dimmable lighting ballasts) and one control component that uses power-line carrier technology:

1. Within the building, control instructions are carried from a central transmitter over a PLC system instead of the usual practice of using separate low-voltage control wires. This is attractive because it makes existing buildings that do not currently have pre-wired dimming controls candidates for participation. All that is required for the new central control system are new ballasts and a PLC transmitter. This is not inexpensive, but it is a much smaller cost barrier than adding both dimmable ballasts and running control wires to each of them throughout the building. Each of the ballasts can be individually addressable, if this feature should be desired.
2. The central control system instructs dimming to occur gradually, over a 10- to 15-minute period instead of immediately. The system designers claim that users find such a change much less noticeable than step changes in output, or not noticeable at all.

SCE plans to sponsor a test of the system in an office building, in the near future.

Information Source: Steven Guthrie, Energy Controls & Concepts, Inc. (909-335-1699)

ULTRAWATT



The PowerGate digital lighting control system is primarily a lighting energy management system, but it includes features that allows multiple levels of lighting load curtailment—initiated remotely—by turning off power to selected ballasts and lamps. The system has been installed at grocery stores such as Shaw's (in the Northeastern U.S.), and at small commercial businesses, such as Munro, a manufacturers' representative that is also a distributor for UltraWatt. At two of the large installations, the installed cost was approximately $200,000.

(UltraWatt is one of many lighting energy management system manufacturers that offer similar products that can be modified for use as demand response tools.)

Information Source: www.ultrawatt.com

PHILIPS LIGHTING ELECTRONICS

It has been reported that Philips Lighting Electronics is planning to introduce a comprehensive wireless lighting control system in early 2006. The company will target both the retrofit and new construction markets. The heart of the system is ballasts with built-in wireless receivers, combined with a "mesh networks" system for control. The software is based on the open ZigBee protocol, and features a transmitter that plugs into a USB port or a PC, PDA, or notebook computer. Building managers and individual occupants will be able to change lighting levels and turn individual fixtures "off" and "on." Demand-response applications are not explicitly mentioned, but this appears to be an obvious application.

Information Source: Article titled "Wireless Lighting Control" by John Fetters, published in *Energy & Power Management*, October 2005, p.8

RETROLUX™

Retrolux™ is a revolutionary new commercial lighting system that utilizes a micro-circuitry design to drive the new T-5 lamps without the need of a separate ballast installation. This system replaces existing T-12 (40-W) and T-8 (32-W) lamps and fixtures with a new low-profile T-5 (28-W) system. In addition, each Retrolux™ system can be dimmed (through a wireless chipset imbedded in the ballast) to create a 50% reduction in lighting load.

The system is manufactured and marketed by Asian Electronics Limited (AEL), Nashik, India. No information concerning its applications (either DR or Non-DR) is available.

Information Source: http://www.aelgroup.com/retrolux.htm

Save-On Energy LCM2 Lighting Controls

Lighting EMS targeted particularly at retail and service venues with outdoor lighting: service stations, convenience stores, car washes and car dealerships. There are no demand management or response features, but these could be readily added. The company also makes and sells daylighting sensors and dimmers for dimmable ballasts.

Information Source: www.saveonenergyinc.com

EnergySolve Demand Response

EnergySolve Demand Response LLC (a wholly owned subsidiary of EnergySolve LLC) deploys energy-efficiency technologies such as Westinghouse Retrolux T-5 wireless, dimmable fluorescent lights, which provide energy efficiency and demand response in a single installation, replacing inefficient T-12 lighting. Recently, EnergySolve Demand Response was chosen to deploy the new wireless, dimmable T-5 lighting technology at 60 small-businesses under SCE's IDEEA program.

During early 2005 EnergySolve LLC acquired Nxegen, LLC, a firm that produces and deploys innovative energy-efficiency, DR, and utility billing-analysis technologies. Nxegen's smart meters are also being installed as part of lighting retrofit projects in SCE's service territory.

Information Source: S. Lynn Sutcliffe, CEO, EnergySolve LLC (732-748-9600)
www.energysolve.com

4.4.2 OTHER CONTROL EQUIPMENT

A large number of manufacturers offer control devices that have potential application in small-businesses. Therefore, the following products should be regarded as examples and not as an exhaustive inventory.

HONEYWELL

Cannon Technologies offer a DR system that features a special "one-way" Honeywell thermostat that has a built-in pager-signal receiver (see Section 4.1.2) and also features remote Web access. These thermostats receive load control instructions via a paging system. There is no return route for signals from the business to confirm signal receipt or report on amount of load shed, although a separate communication linkage can be set up to retrieve load or runtime data.

Honeywell plans to introduce a thermostat in mid-2006 that offers full and flexible two-way communications, plus interactivity with automated meter reading (AMR) and advanced metering infrastructure (AMI) equipment. The thermostat is expected use open protocol communications architecture to be compatible with virtually any other vendor's system. Pricing has not yet been established.

Information Source: Rick Schmitt, Honeywell Utility Solutions (717 235-4452) http://buildingsolutions.honeywell.com (Choose "Utilities", then "Demand Response")

POWERIT SOLUTIONS

The *Energy Director* by Powerit Solutions has traditionally been marketed as a demand management tool for primarily large industrial customers. It is conceptually similar to the Dencor DDC device (see Section 4.2.1) in that the controller monitors and attempts to limit total facility demand. When demand approaches a pre-set target, the *Energy Director* uses a bank of relays to shut off selected equipment as necessary to keep the facility's peak load from increasing above a target level. It uses rules-based logic that can be customized at each facility. It is not intended to be an energy saving device, but rather to "shave peaks and fill valleys" in order to minimize demand charges. Some energy savings are a likely byproduct, however.

One of the company's case studies, *San Jose Mercury News*, reported savings of 554 kW, valued at $61,000 per year to the customer.

Information Sources: www.powerit-solutions.com, www.nwalliance.org/resources/documents/PTR/200411PTREnergyDirector.pdf

TRIDIUM VYKON

Tridium is the inventor of the Niagara Framework®, a software framework that integrates diverse systems and devices—regardless of manufacturer, or communication protocol—into a unified platform that can be easily managed and controlled in real time over the Internet using a standard Web browser. The Vykon Energy Suite, a set of Web-based products built on the Niagara platform, provides the user interface for energy management. The system can be used to manually or automatically control peak demand, helping large commercial and industrial customers reduce their demand charges. The vendor is developing a version of the device that enables the system to interface with DR programs offered by ISOs.

Information Source: www.tridium.com/library/whitepaper/AEE_Demand_Response_Paper.pdf
Christopher Greenwell and Christopher Jones, Tridium, Inc., "*Demand Response Strategies Employing Automatic Response of Building Equipment Systems*," presented at World Energy Engineering Conference, Austin, TX, September 2005.

CONTROLS FOR ROOFTOP AIR CONDITIONERS

Packaged rooftop air conditioners (RTUs) are ubiquitous in the small commercial sector. None of the major manufacturers (e.g., Trane, Lennox, Carrier) offer an off-the-shelf product—either hardware or software—specifically designed and marketed to control RTUs for demand response programs. None of them are believed to have such a product under development.

The major manufacturers do offer advanced energy management control systems (EMCS) for their rooftop units. An option to centralize control of multiple RTUs with a single EMCS typically is available. The central controller may be a personal computer or a standalone controller. Virtually any central EMCS can be programmed to adjust settings upon receipt of an external signal. Using this approach as a demand response technology is not a new idea. It often is a labor-intensive approach with considerable cost uncertainty, however, as it involves custom programming at each site. As was noted previously, the CEC PIER's Demand Response Research Center is developing a systematic procedure to reduce costs for such configuration, but their current focus is on the communications side for large facilities (>200kW).

Lennox—and likely other manufacturers—has a system that could be systematically and possibly cost-effectively customized for demand response applications in small-business facilities. Lennox's L-series rooftop units, which compose the majority of their RTU sales, all include "L-Connection" integrated modular controllers (IMCs). The RTU controllers typically are linked to a central Network Control Panel (NCP), which is a direct digital control system. The NCP centralizes controls of up to 31 rooftop units. It can work with non-Lennox equipment. The majority of customers with L-series RTUs reportedly use an NCP. Users can communicate with the NCP either via a dial-up telephone or local Internet connection. A single remote PC can control NCPs at multiple facilities (i.e., aggregate DR load reductions).

The Lennox Building I/O controller can be programmed to monitor a facility's power demand as measured by the utility revenue meter kW. If the building peak demand hits a programmed threshold, the system will either (a) lock out compressor stages or entire RTUs in a system directly with their "demand limiting" feature, or (b) temporarily raise the temperature setpoints for some or all of the units with their "setpoint shift" feature. Either feature can be activated remotely and for multiple sites with NCPs.

Lennox keeps track of all installed Lennox RTUs for the purposes of service and maintenance record-keeping. A DR program concept would include the following steps:

- Identify all customers in a designated region that have multiple L-series RTUs with at least 30 total tons of cooling capacity and that already use a central network control panel.
- Recruit these customers to participate in the program.
- Work with a controls contractor or with the customer's controls contractor to activate the setpoint shift or other demand-limiting features at each site.[29] Because every system uses the same hardware and software, programming costs would be minimized. There would be no hardware to buy; the biggest cost would be training and education for the customer and their controls contractor.

Lennox representatives estimated that in a new installation, modification to allow such interaction would cost less than $1,000 per site, plus installation of the communications setup and training/education.

At an average site size of 50 tons and setpoint shift savings of 0.4 kW/ton, savings would be 20 kW at a cost of about $100 /kW.

Information Sources: Mark Hess, Product Manager for Commercial Controls, Lennox (formerly with Trane) (972-497-6241)
Roger Kiesling, Lennox (909-944-4174)
www.lennoxcommercial.com
Paul Ehrlich, President, Building Intelligence Group (formerly with Trane) (651-204-0105)
Mary Ann Piette, LBL EETD Building Technologies Department, Director of the Demand Response Research Center (510-486-6286)

K-MAC DEMAND CONTROLLER

The K-MAC Phase III Demand Controller is a microcomputer-based load control system that 1) measures total electric energy consumption, and 2) controls certain electric loads to reduce demand peaks, which in turn spreads power consumption out over a longer period of time. As a result, demand (kW) will be reduced to a minimum, and may also reduce energy (kWh). The K-MAC controller coordinates equipment cycling in commercial facilities to prevent the demand peaks that occur when the following types of equipment run simultaneously:

- HVAC units
- Refrigeration units
- Water heaters
- Space heaters
- Steam tables
- Warming ovens
- Electric heating units
- Battery chargers

Bridgestone Energy Services uses the K-MAC Demand Controller as the basis for real-time metering and monitoring of facility loads, aggregating multiple loads from geographically

[29] Ms. Piette at the DRRC advised that in general the best intervention strategy for HVAC controls is one based on adjusting the key independent variable (e.g., temperature setpoint) rather than intervening in the middle of the control system's logic by adjusting a dependent variable (e.g. supply fan flow rates, compressor sequencing). This avoids undesirable and unexpected control system feedback, compensation, and conflicts.

dispersed facilities to allow for aggregate purchases of electricity in a competitive retail electric market. The Web site contains no mention of using the system for demand response purposes, but this would seem to be a straightforward application.

Information Source: http://www.brdgstn.com/kmac.htm

BRAYDEN AUTOMATION ENERGY SENTRY® 9388B

This demand-management controller is marketed to end users to help them keep their demand charges as low as possible. It is representative of the general class of generic peak demand management products that are not tailored to particular industries.

The 9388B model is targeted specifically at small businesses. It controls "up to 1000 kW," but is "generally used below 100 kW." The user sets up to 12 monthly target peak demand thresholds.

Typical facility-type applications include:

- Fast food restaurants
- Churches
- Hotels
- Offices
- Restaurants
- Gas station/convenience

Among the features that make the Energy Sentry attractive is its integration with the Southwood Electronics **WireLynx** powerline carrier (PLC) control system, which allows remote loads to be controlled without the need to run wires to each load. Single and 16-channel systems are available. The types of loads controlled are those found in small businesses:

- Parking Lot Lighting
- Landscape Lighting
- Energy Management
- Water Heaters
- HVAC
- Irrigation Pump Control
- Pools and Spas
- Vending Machine Lighting
- Tennis Court Lighting

The product has not been used for a demand response program but likely could be modified to do so in conjunction with an external signal receiver.

An optional companion 9320 Demand Monitor will display facility kW and emit an alarm if a pre-set peak value is exceeded. Optional EnergyAccess® software ($1,000) allows local access for monitoring and setting alarms.

Information Source: http://www.brayden.com/comindprod.html

EG ENERGY CONTROLS

EG Energy Controls is a Canadian company that sells four products:

- Demand Controller
- Energy Surveillance System (combines Demand Controller with communications and software)
- Variable-Frequency Drives for electric motors (four speed steps; not continuously variable)
- Lighting Dimming (uses autotransformer to reduce voltage to ballasts and lamps – a different controller model is used for specific ballast/lamp types).

The Energy Surveillance System (ESS) is a Web-based System capable of monitoring power demand at up to 2500 individual stores within the corporation's network. The ESS also contacts the meteorological station daily to gather weather information such as wind speed, temperature, humidity etc. By compiling these data, the ESS predicts energy usage for the following day.

ESS is a networked solution that operates over an existing WAN or corporate Ethernet. A server is installed in the chain's headquarters and gathers data from the stores where the ESS is installed. The user contacts the server via the corporate network and retrieves the data as required. Since the server gathers the data 24/7, the customer is assured that the data is always accurate and up to date. The customer receives e-mail alerts from the server when it notices that a load is using more or less power than expected (based on the forecast that in turn is based on the weather forecast and historic usage patterns).

No data or information from actual installations is available.

Information Source: http://www.egenergy.com

GESTELEC SERIES GES6000 DEMAND CONTROLLERS

This is another series of generic demand-controllers. It appears to be a basic setup, with either shut-off or cycling of between four and 12 loads to reduce peak demand charges. The company is based in Quebec.

Information Source: www.gestelec.com

RETAIL CHAIN HVAC AND LIGHTING ENERGY MONITORING AND CONTROL SYSTEMS

Examples:

Johnson Controls Remote Operations Center
Emerson Climate Technology's E2
Honeywell/Novar's Envoi and SBSs
Invensys Building Systems / Com-Trol's Crysalis

These systems are being addressed as a group because they are essentially the same from a demand response perspective—they have the same available inputs to receive control signals and they control essential the same types of equipment, although sometimes in different ways. None of them offer a DR-specific product or configuration. Some of the manufacturers, such Emerson and Com-Trol,[30] also have tailored variants of the listed systems specifically for convenience and grocery stores that include refrigeration and anti-sweat heater monitoring and control.

Information Sources: www.johnsoncontrols.com/cg-retail
www.emersonclimate.com/retailers.htm
www.novarcontrols.com/envoi.html
www.invensysibs.com/comtrol.shtml

[30] Com-Trol was bought by Invensys Building Systems and is now a division of Invensys. Invensys Building Systems is the London-based company that resulted from the merger of Siebe plc and BTR plc.

4.4.3 METERING, MONITORING, CONTROL, AND COMMUNICATIONS SYSTEMS

The following systems are only a small subset of available equipment. Many devices and systems have primarily been used for metering and monitoring loads; however, they typically also feature two-way communications linkages and are able to perform load-control functions (including accomplishing load reductions during DR events).

ELSTER ELECTRICITY

Elster Electricity offers the EnergyAxis® system for automatic meter reading (AMR) applications. Plans for future system enhancements include the capability to remotely control end-use loads and collect operational data (such as temperature) in addition to load data. The system consists of ALPHA® and REX® meters that communicate via an unlicensed 900 MHz radio-frequency (RF) signal. The REX® meters collect and display consumption data and transmit it to the ALPHA® collector meter. The ALPHA® collector meter then forwards all the data to an aggregation server.

An interesting feature of the system is its ability to create an ad-hoc mesh network: One ALPHA® collector meter can support a network of up to 1024 REX meters. The system uses an Elster-developed RF network that provides full two-way communications to each meter. The meters will automatically register to an ALPHA® collector meter and build out a mesh network based on the best communication path to each meter that it finds. The REX® meter, which is intended for use in the residential sector, provides kWh consumption, kW demand, time-of-use metering, critical-tier pricing, load-profile interval data, received energy, voltage, and outage counts. For three-phase commercial and industrial customers, the basic ALPHA® meter can provide two energy values (e.g., kWh & kVARh), TOU usage, kW demand, and two channels of load profiles.

Presently, communications from the ALPHA® collector meter back to Elster's MAS (Meter Automation Software) communication server can use several commercial wide-area network (WAN) options, such as telephone, cellular and packet-switched data networks. The EnergyAxis system supports full two-way communications for on-demand meter reading and other service features.

MAS provides functions such as reports for user-defined events, meter errors, warnings and statuses. It also provides GIS capability for network visualization and meter diagnostics.

The REX® meter supports remote service connect/disconnect by means of an internal control-switch option. The REX® can also be programmed to detect when demand reaches a threshold level, and if it does, to automatically disconnect power for the remainder of the demand interval. The system architecture includes the ability to add one-way battery-powered gas- or water-meter modules using the Elster RF technology. The REX® meter is also easily adaptable for use in a pre-pay metering system with an in-home display unit for customer viewing of energy-use and funds-remaining data.

A large-scale deployment of the AMR application (75,000 meters) is currently underway at the Salt River Project in Arizona. Other smaller-scale test programs and pilots in the Western States are underway at Nevada Power, Arizona Public Service, Portland General Electric, and Alaska

Village Electric Cooperative. Discussions with vendors of home and building controls are underway, with the goal of developing a complete system that can be used for DR applications.

***Information Sources*:** Greg Canada, Elster Electricity, LLC (480-288-8819)
www. elster.com

ENERGYICT

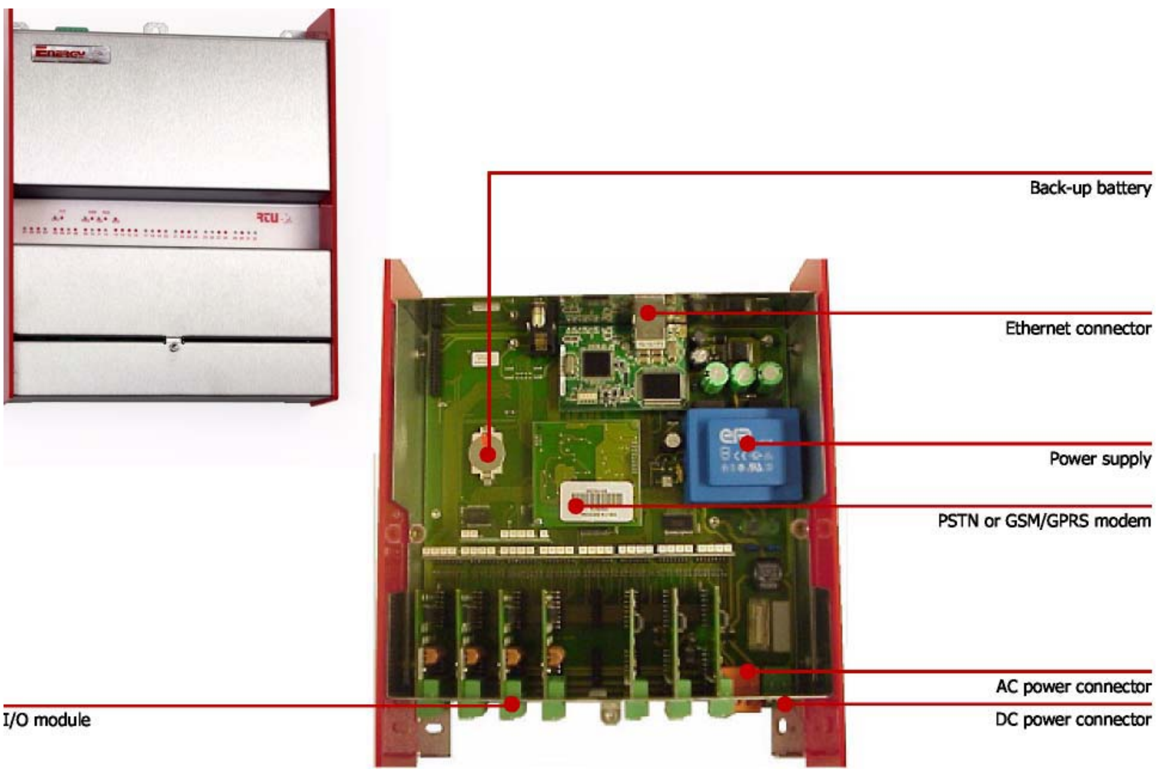
EnergyICT is an energy-management and monitoring solutions provider based in Kortrijk, Belgium, with offices in the United States, United Kingdom, Germany, Italy, France and the Netherlands. The US offices are in Raleigh, NC and Los Altos, CA. EnergyICT has over 350 major customers in all three segments of the energy market: utilities, energy service providers (ESCOs), and large commercial & industrial organizations.

The company's product line consists of three core products:

- EIServer®, for interval meter data collection, storage, and processing.
- RTU+® and WebRTUZ1® for Internet-based monitoring and control of electrical loads and other parameters.

When used individually or in combination, these devices provide the ability to participate intelligently in a variety of DR programs.

RTU+

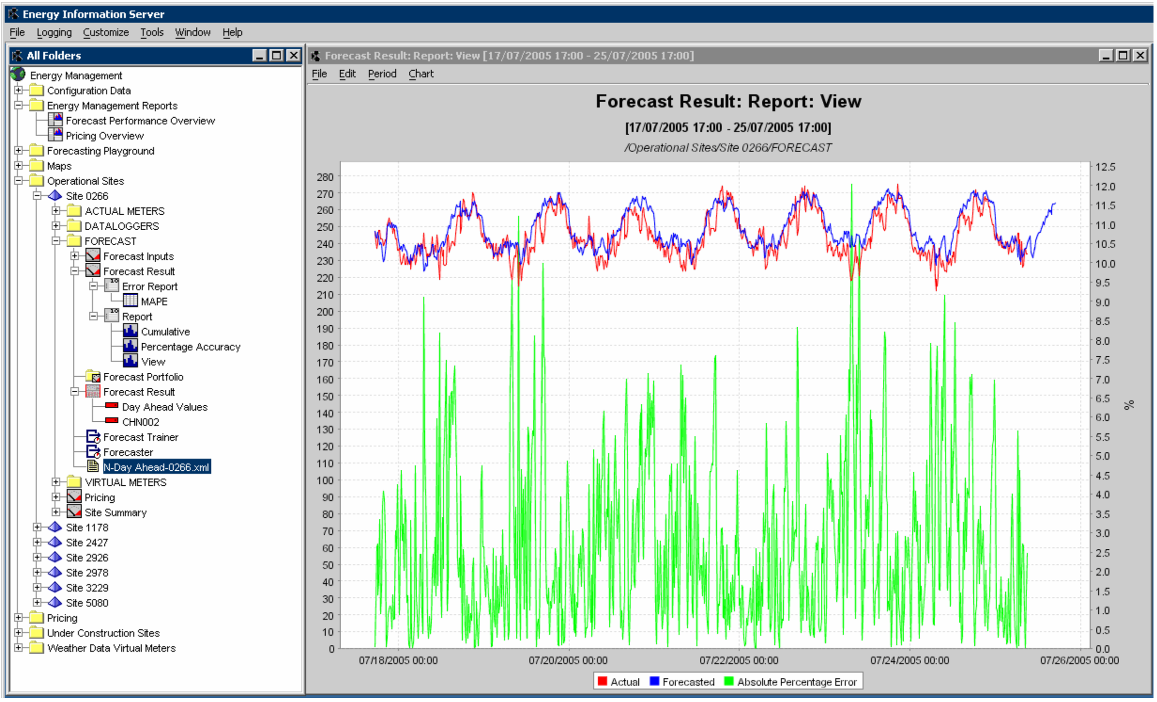


Advanced energy-management features of EnergyICT hardware and software include load profile generation, forecasting, peak-shaving, and rate simulations.

WebRTUZ1

EnergyICT's toolbox of products provides utility customers with tools for negotiating complex rates with energy providers, and—once the rates are negotiated—the same toolbox allows the customers to monitor and control their energy consumption to operate effectively within the new rate structure. For example, EnergyICT gives customers being faced with mandatory Critical Peak Price (CPP) the ability to accurately forecast their day-ahead electricity requirements and automatically calculate what the impact of the CPP is likely to be, with and without control.

Day Ahead Forecasting



EIServer's forecasting module uses neural net technology in combination with weather or production schedules to accurately predict energy consumption for one facility or hundreds of facilities.

Going one step further, EIServer®'s EIBalance® module coupled with the RTU+® control capabilities allows individual loads to be controlled in order to minimize the CPP payments. The control can be as simple as sending an e-mail to the facility manager, or complex by controlling large loads within and between a large number of facilities.

For the small customer, the WebRTUZ1/RTU+ possesses an incorporated Web server that provides the user with their own Web site on which they can analyze energy data through a simple Web browser—no proprietary software needed. The reporting tools of the WebRTUZ1/RTU+ enable the energy-use profile of a facility to be displayed in real time. Users can also download and visualize data graphically using Microsoft Excel® by using a simple WebQuery.

EnergyICT has three options through which its system can be acquired and operated:

- An end-use customer can purchase an EIServer® license directly from EnergyICT and have their in-house staff maintain and operate the system,
- The customer uses EnergyICT's ASP hosting service whereby EnergyICT hosts and maintains the EIServer® software, while the customer's staff operate the system, or
- Full outsourcing, through which one of EnergyICT's partners builds and operates the whole solution for the customer.

Information Sources: Claude Godin, President, EnergyICT USA (919-380-0630)
www.energyict.com

POWER MEASUREMENT

Power Measurement provides a line of communications-enabled electric meters (ION). The meters accept analog and digital inputs from a variety of other measuring devices, which permits the meters interface with other revenue meters and to monitor such quantities as gas or water flow, temperatures, and pressures. They can also record various power-quality parameters, such as harmonics and voltage sags and swells.

The ION meters provide a number of connectivity options. They can be connected to corporate local area networks, permitting them to send emails containing alarm messages or system status updates. They also have a built-in Web server, permitting remote, Web-based access to their configuration functions, and to their stored interval data. Meter configuration options include setting the data-collection interval. The meters also support both hard-wired and wireless connectivity options. From the viewpoint of aggregation of data at a central server, the server software (*ION Enterprise*) regularly connects to an array of meters over the appropriate communications channel and downloads the latest set of interval data.

ION Enterprise is built on the Microsoft .NET platform and uses the SQL Server database for storing data. It uses a separate communications subsystem for polling meters on a regular basis and downloading data from them. ION Enterprise provides access to the aggregated data through a Web browser. Reports are available to display load profile, cost allocation, power quality, and forecast information. ION Enterprise also allows the administrator to define events and setpoints that allow the system to identify problems based on the aggregated data.

Information Sources: www.pwrm.com

CRITICAL WIRELESS

Critical Wireless produces modular remote-terminal units that monitor up to 14 discreet signals for tasks such as operating status (running, auto/manual), fluid levels and fuel-tank breach, UPS failure, room temperature, starting battery voltage, and intrusion alarms. One user connects backup generators to the system, which provides status notification and can be launched or shutdown using the Web interface.

The Critical Wireless solution provides remote monitoring of equipment through a Web portal. It can be used to communicate back to devices to shut them off. The software has not been tailored for on/off sequencing, price signals, or similar demand response applications. The system uses the *Aeris.net* two-way cellular pager network and will also use GSM/GPRS in the future.

Information Sources: http://www.distributedenergy.com/de_0507_hot.html
http://www.criticalwireless.com/

SENSICAST

Sensicast markets wireless mesh-monitoring systems and has a solution targeted to building automation monitoring. The company targets distributed energy, hospitals and grocery warehouses. The sensors are predominantly indoor temperature, humidity, and CO; but can provide control feedback to central EMS.

Information Sources: http://www.sensicast.com/

CROSSBOW TECHNOLOGY

Crossbow Technology markets a line of smart dust (about the size of a quarter) wireless sensors used in a mesh network. Robust communication of temperature monitoring is the most popular use of the technology.

The product has been demonstrated by PNNL for building energy management. Srinivas Katipamula, a PNNL project manager, has used the technology for general-purpose monitoring and control, including chilled water control and air distribution control strategies. He has recently developed a solution for rooftop compressors, which allow them to be networked together for electricity shedding applications.

Information Sources: http://www.xbow.com/

TRILLIANT NETWORKS

Trilliant Networks, Inc. provides communications linkages that read meters and support CPP, real-time pricing, and load-control programs. The firm's "smart meters" offer access to end-use devices such as smart thermostats, water heater controls, pool pump control and load-limiting devices.

Trilliant's communications approach integrates mesh wireless with a Web portal. Trilliant provides the smart meters, wireless network, and software. Other than wireless meters and software, there are no other products listed on the company's Web site. The mesh wireless platform is similar to that of Sensicast and Crossbow, but is focused on AMR and enabled for demand response, whereas the former systems are designed for status notification.

The demand response platform is currently targeted to residential applications, but could be applied to the commercial sector with some further development efforts. A wireless mesh reader is installed under the glass of a solid-state utility meter. It will work for electric, gas, and water meters. The meter most frequently used is the Landis & Gyr *Focus*, but the technology has also worked with Itron's *Centron* meter.

A recent large-scale project involved the installation of 120,000 units (mesh reader, concentrator, and software). The average cost was $114 per meter. The mesh readers can hop signal up to 10 times before reaching a concentrator. A concentrator can handle 800-1000 readers and back haul data to Ethernet or public/private data networks such as GPRS. Readers can be equipped with either a 100-mW radio chip that can transmit 500-600 meters, or a 1-W radio chip that can transmit 2.6 km. The wireless signals are 2.4 GHz.

The mesh reader receives the utility dispatch and communicates to other devices in the building. The system uses Invensys' smart thermostat and other compatible devices. The system is open standard, open architecture. Trilliant wrote the test bench software now used by the industry. Currently, Invensys also provides compatible switch products that utilize Trilliant's radio chip. Motorola also specify Trilliant products for its *Harmony* and *Datatek* systems.

The product used in larger facilities (e.g., stores and offices) features a cell reader device and communicates back through public or private carrier networks. There have been no pilots for demand response, although the AMR cell reader product has been installed by several utilities.

The residential mesh reader product has been installed at several utilities (including Ontario Hydro and Milton Hydro), but not with the Invensys DR products.

The Trilliant products have not been used yet for connecting to building EMS systems, although they could if the system will accept their radio chips. Their chips have been used with a HP iPAC and notebook computers for diagnostics.

Information Sources: Dave Havraner, Director of Sales, Trilliant Networks (818-519-8042)
http://www.trilliantnetworks.com/

POWER-LINE CARRIER / TWACS®

The *Two-Way Automatic Communications System* (TWACs®) is offered by Distribution Control Systems, Inc. (DCSI), a subsidiary of ESCO Technologies Inc. TWACS was one of the first widespread applications of power-line carrier (PLC) communication technology for transmitting data between a utility and customers' meters using the existing power lines.

The DCSI system begins with the Oracle based TWACS Net Server, which serves as the command portal between the users and the utility. It communicates via a voice-grade communication line to communications equipment located at distribution substations, as well as with transponders located at the meters. Further communications may occur between the transponders and various load-control devices and disconnect switches.

TWACS is capable of maintaining signal integrity through multiple voltage step-downs, over more than a hundred miles of feeders, capacitor banks and regulators, and is resistant to climate effects.

The TWACS signal is non-interfering with competing AMR technologies such as Turtle 1, EMETCON, CEBus, Echelon, X-10, and AS&E power-line systems.

DCSI makes a variety of transponders compatible with different manufacturers' meters and that are built for different end-use applications and interfaces. For example, the residential load-control transponder can control two switches.

Initially, these systems were developed and deployed as a method for reducing the labor and costs of regular meter reading and replacing it with a simple and secure communication path directly to the utility. Two-way communication features allow these systems be used for other activities such as demand response, load control, TOU pricing, outage detection, remote disconnect, and theft/tamper detection.

Successful system deployments have been completed with:

- Pennsylvania Power & Light, Allentown, PA, 1.2 million meters
- Rappahannock Electric Cooperative, Fredericksburg, VA, 85,000 meters

Information Source: H. Ward Camp, VP, Regulatory and Strategic Alliances, (314-895-6595)
Distribution Control Systems, Inc., an ESCO Technologies Inc. subsidiary
www.twacs.com

Nxegen / EnergySolve

These two companies recently merged and will soon offer comprehensive systems that perform DR control and communications functions. Nxegen

DR ENABLING TECHNOLOGY DEVELOPMENT PROJECT

The California Institute for Energy and the Environment (CIEE) is a utility-funded organization founded in 1989 with the mission of supporting energy-related research and development. The CIEE's *Demand Response Enabling Technology Development (DRETD) Project* was started in 2002 with funding from the CEC's PIER Program. Its purpose is to support development of new technologies that will drive down the cost of DR equipment and increase response effectiveness.

Sensors and communications are the focus of the four DRETD-funded projects, which are valued at just over $5 million:

1) Development of open standards and uniformity in statewide IT communications infrastructure applied to DR solutions. The project (at least thus far) is more a "needs assessment" than technological solutions development. Five private companies are collaborating in this project.
2) Development of a universal communications interface between sensors, actuators, and decision-making devices at a facility by using a sensor network service platform (SNSP). Prototype testing is oriented towards a residential environment. Contractor: UC Berkeley.
3) Development of solutions to prevent security vulnerabilities in DR systems, including agile/software-defined radios (SDRs), which can change communications protocols rather than using a single channel. Contractors: UC Berkeley and CyberKnowledge.
4) Development of self-powered wireless networks of miniature sensors. The project also includes developing the central system data-compilation interface and low-power relays. Contractor: UC Berkeley.

The project with the most direct application to this report is the last one. While conceptualized for residential applications, sensors that do not require wiring for either communications or power would be equally beneficial in the small-business segment. The performance and capabilities of many of the control technologies addressed elsewhere in this report would be significantly enhanced by the incorporation of wireless sensors and actuators.

The wireless communications and sensors work is truly innovative: The concept is to develop low-cost, wireless, non-intrusive, passive, temperature, current, and voltage sensors, and possibly also sensors for humidity, occupancy, carbon monoxide, carbon dioxide, and light level; each with transmitters/receivers that use less than 0.5 mW (0.0005 Watts) of power. At such low power levels, "scavenged" power from solar, wind, vibration, or other sources would be sufficient for operation.

The current state of development efforts is a radio transceiver that uses a compartmentalized operating system with a reduced instruction set (called "TinyOS") that is incorporated into a ultra-low-power wireless sensor module (a "mote") in a mesh network. UC Berkeley calls the hardware "Telos." A Telos circuit board is nominally 1-inch x 2-inch and requires 0.05-Watts when active with the radio on (~one percent duty cycle), and only 5 microwatts (0.000005 Watts) when dormant. It is powered by two AA batteries. For current sensing, a piezo-electric film would be compressed by an amount that is proportional to a magnetic force produced by the electrical current being measured. The piezo-electric film produces an output voltage that is proportional to the extent of its compression. The sensor would be connected to a mote.

The next technology under development is radio-frequency microelectro-mechanical systems (RF MEMS). MEMS currently are used in a variety of temperature, light, and vibration sensors, accelerometers, and inkjet print-heads. By integrating arrays of MEMS resonators with a common CMOS integrated circuit design into a 1-mm x 2-mm chip or "integrated node," active –state power requirements can be dropped to 0.0005 Watts. On the longer-term schedule are "PicoCubes," which would integrate the transmitter, sensors (thermistor, piezo), and power supply (solar panel plus battery) into a 1-cm cube.

The central system and actuators development is a component of the program and uses a largely conventional approach. The central system is designed for operation on a tablet PC or personal digital assistant (PDA) with Java control code, for example. The prototype 120-V single-phase switches bear a striking resemblance to X-10 devices with similar functionality. The thermostat is expected to incorporate adaptive cooling logic discussed elsewhere in this report.

The program director estimates that commercial applications are three to eight years in the future.

Information Sources: Gaymond Yee, DRETD Project Manager (510 459-6063
California Institute for Energy and Environment
Office of the President, University of California
E-mail: *Gaymond.Yee@ucop.edu*
Ron Hofmann, Project Advisor, (510-547-0375)
http://ciee.ucop.edu/dretd/
http://ciee.ucop.edu/dretd/UCB_Project_06-02-2005.pdf

5. TECHNOLOGY SCREENING

The preceding section provided information concerning a wide variety of technologies that are either currently available or are expected to become commercially available to facilitate successful small-business DR programs. This information showed that there are only a few complete systems with the capability to:

- Transmit signals to multiple facilities to initiate and terminate DR events.
- Take specific control actions in response to the control signals that cause end-use equipment to either cease operating or to operate with reduced average power demand during the duration of the DR events.
- Transmit accurate interval load data (or load-proportional data, such as equipment run-time) and other information from each participating facility to a central database.

However, the information also shows that a large and rapidly growing number of key system components are available from multiple vendors that can be combined to make a robust, fully functional system for any facility in the small-business segment.

Exhibit 5-1 proved a summary of the control technologies in terms of end-use loads being controlled and facility size (expressed in terms of the range of electrical peak demand).

In some instances the technology will be purchased by an electric utility that wants a system that satisfies a regulatory mandate that may or may not involve a DR-related tariff such as CPP tariff. (The purchase is likely to be indirect: the utility hires a contractor to purchase and install the technology and provide other services [see below]). In other instances the purchaser may be an aggregator/ESCo that wants to participate in one or more different DR programs. In yet other instances an individual small-business customer may be the purchaser.

In each situation the optimum system solution will often be determined by a combination of:

- ♦ System installed cost and annual operating cost.
- ♦ Magnitude and shape of load reductions that can be achieved.
- ♦ Additional features the system provides that the purchaser desires, such as flexibility to accommodate anticipated changes or ability to monitor parameters related to health, safety, and/or security.
- ♦ Type(s) of DR Programs in which the purchaser plans to participate (e.g., the purchaser may be an aggregator who wishes to both (a) have the electrical loads at all participating facilities automatically reduced when a CPP event is declared, and (b) bid into the voluntary load-reduction market on other days when the system load is high).

Any consideration of "installed costs" must make clear whether one is referring to the cost of installation labor and equipment only, or is also including the "program-related" costs of recruiting and qualifying participants. Similarly, annual operating costs may include only calculating and reporting the load-reduction magnitudes after each control event, or may also include "program-related" costs such as comprehensive monitoring to ensure that the technology is operational, a toll-free number that customers can call to voice a concern, paying an incentive to participants, and conducting an annual satisfaction survey of participants.

Exhibit 5-1: Segmentation of Small Business DR Control Technologies

Facility Major End Use(s)*	Facility Demand	Control Technology
Lighting	~10 kW to 200 kW	Smart Relays (to control dimmable fixtures or turn-off individual lighting circuits)[31]
	~100 kW to 200 kW	Remotely controlled autotransformer
Air Conditioning (DX type)[32] or Space Heating	~10 kW to ~35 kW	Smart Thermostat or Smart Relays (one per DX-type AC or space heating unit)
Lighting and Air Conditioning (DX-type) or Space Heating	~10 kW to ~35 kW	Smart Thermostat (for DX-type AC units) plus Smart Relay (for Lighting)
	~36 kW to 200 kW	Digital Demand Controller or Small EMS with a dispatchable control (wireless signal, Internet, PLC, etc.)
	~100 kW to 200 kW	Sophisticated EMS with a dispatchable control (wireless signal, Internet, PLC, etc.)
Lighting and Air Conditioning (DX-type) or Space Heating and Refrigeration	~36 kW to 200 kW	Digital Demand Controller or Small EMS with a dispatchable control (wireless signal, Internet, PLC, etc.)
	~100 kW to 200 kW	Sophisticated EMS with a dispatchable control (wireless signal, Internet, PLC, etc.)
Lighting and Air Conditioning (DX-type) or Space Heating and Ventilation and (optionally) Refrigeration	~100 kW to 200 kW	Digital Demand Controller or Small EMS with a dispatchable control (wireless signal, Internet, PLC, etc.)
		Sophisticated EMS with a dispatchable control (wireless signal, Internet, PLC, etc.)

* Electric water-heating can be included with any except Lighting (only).

[31] Larger buildings (typically >100 kW) generally have some type of EMS that controls the lighting equipment. When an EMS is present, the Smart Relay causes the EMS to control the lighting equipment.

[32] As was noted in Section 3, it is necessary to distinguish between two types of air-conditioning systems: those that use DX (direct expansion) units and those with chillers that produce chilled water and circulate it to air-handlers. In the case of DX units, each unit has a thermostat and a shift in thermostat set-point generally results in an immediate sizeable load reduction because the compressor shuts off. (Large units may have two compressors, but at least one will shut off.) In the case of chiller systems, each thermostat directly affects ventilation airflow, and the changed airflow gradually reduces chiller power, and this subsequently also reduces electricity usage by cooling tower fans and pumps. The load reduction is more gradual and its magnitude depends on the specific design of the HVAC system.

As was noted in Section 2, the system installed cost and operating cost of an enabling technology system needs to be judged relative to the magnitude of the aggregate load reduction that can be achieved: $/kW for installed cost and $/kW-year for annual operating cost, based on a specific number of anticipated control events.[33] These parameters are a function of: (a) the size of the technology deployment (i.e., the number of participating facilities) because of economy-of-scale effects; and (b) the specific end-uses being controlled at facilities and the magnitudes of these end-use loads, again because of economy-of-scale effects (in general, it costs no more to control a 30-kW load than a 3-kW load, but the “yield is ten times larger in the case of the former).

[33] It is sometimes the case that a purchaser will value the ancillary monitoring of certain facility-related parameters more highly than the DR benefits.

6. BEST PRACTICES

DR enabling technologies do not get deployed unless a program exists that creates incentives to both participating customers and an entity that (1) recruits participants, (2) installs a technology or combination of technologies, (3) ensures that the technology (ies) remain operational and participants remain enrolled, and (4) analyzes data collected to determine load reductions achieved during DR events. The entity that provides these services could be the utility, but most commonly it is either a contractor to the utility, or a third-party aggregator who participates in a DR program offered by a utility or ISO.

In the case of customers, the incentive may be (a) avoidance of high electricity charges that apply during events under CPP or RTP tariffs; (b) a payment or other subsidization of the cost of the technology; (c) a share of revenues received by the utility or the program-services delivery contractor that are based on load reductions achieved; (d) other benefits, such as operational savings each month or a monitoring service to enhance facility security and safety, and/or trigger an alarm if equipment failure or a power outage occurs and stored inventory may be damaged; or (e) a combination of the these items.

In the case of the entity that provides program services, the incentive may be (a) services-based or fixed payments from the utility, a state agency, and/or customers; (b) payments from the utility, a state agency, or an ISO that are based on demand reductions achieved when DR events are called; or (c) a combination of the two preceding items.

The requirements for implementing a successful DR program and system can be summarized as follows:

- The program must be customer-driven: It will fail if it doesn’t create sufficient tangible and intangible benefits for the customer.
- Impact estimates must account for other measures the customer is likely to incorporate as part of system installation or operation. In practice, this means that DR and energy efficiency measures cannot always be neatly separated.
- The technology is rapidly evolving. It is therefore advisable that flexibility, expandability, and modularity be included in the functional specifications.
- In the long run, the magnitude of equipment and installation costs will pale compared to marketing, maintenance, and transaction costs.

The following sections describe “Best Practices” in two categories: Program Best Practices and Operational Best Practices.

6.1 PROGRAM BEST PRACTICES

Experience with the operation of both energy-efficiency programs and DR programs over the past several years has served to identify features that are common to successful programs. The following is a listing of these features:[34]

- As a first step develop and document a detailed program design that is based on a well thought-out program plan and theory. This means: (1) the market is well understood and all barriers to success are identified and addressed (e.g., marketing activities will reach a sufficient number of participant prospects and will successfully inform them that program participation offers compelling benefits, there is evidence that the proposed incentive will appeal to a large number of prospects[35]); and (2) realistic expectations are identified and a realistic schedule developed. With regard to the last item, the schedule should take into account the fact that HVAC contractors are quite busy with keeping their regular customers' air-conditioning systems operating properly during the hot summer months, and therefore these trade allies cannot be scheduled to make a large number of enabling technology installations during this period. If at all possible, installation activities should be scheduled during the winter and spring, and tested on the first warm day that follows.
- Ensure that the organization responsible for managing the program is motivated to meet the demand-reduction goals of the program (i.e., provide a financial incentive and avoid implicit or explicit incentives that encourage achieving only installation goals).
- The program plan must include quality-assurance features, including means for: (1) verifying that equipment installed under the program meets specifications and operates properly when operation is required or expected, and (2) measuring and assessing progress, and to identify potential needs to alter the program design if there is evidence that some aspects are not succeeding as well as expected. The market may change over time, and therefore the program design must (a) be able to identify such changes, and (b) have sufficient flexibility to accommodate them.
- Program management roles and reporting responsibilities need to be clearly defined in the program plan document.
- Ensure that all program staff—both employees and subcontractors—are fully qualified, properly trained, and motivated to perform their duties. Training must include (a) procedures to be followed, and (b) the priority to be given to ensuring high-quality results and a high level of customer satisfaction.
- There should be a single database for tracking participating facility data, activities and key events (including load reductions achieved during each control event).

---

[34] This list is based on Aspen's direct experience operating such programs, a review of program evaluation reports prepared by various contractors, and the findings from a detailed examination of energy-efficiency program best practices that was prepared in 2004 by Quantum Consulting for Pacific Gas and Electric, acting as contracting agent for the California Public Utilities Commission.

[35] This typically requires that market research be performed before the program design is finalized.

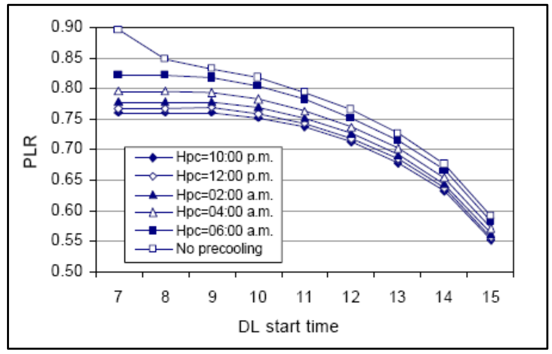
The database should be “live” before the first participant is enrolled and should include specifics concerning any complaints reported by the customer (date, person’s name, nature of complaint, resolution, date resolved, staff member(s) involved).

- The program plan should include the following features related to maintaining good participant relationships and continuing participation:
  - Avoid misunderstandings by fully explaining the program, its benefits, and its potential drawbacks, before enrolling a participant.
  - The incentive should reward full participation in control events rather than penalize overrides.
  - Have a toll-free number that a participant can call 24/7/52 that gives the participant immediate access to a program staff member.
  - Answer all incoming calls within four rings.
  - Maintain a written log of all calls and other contacts with both active and prospective participants.
  - Provide each participant with an estimate of cost savings at the end of each year.
  - Allow the customer’s electrical contractor to monitor the installation of the equipment, if desired.
  - Have all participants sign a Participation Agreement that specifies (1) the roles and responsibilities of all parties, (2) program rules, and (3) the number of control events to expect each year and when they are likely to occur.
  - Have a staff member visit each participating facility at least twice per year to (a) verify that controlled equipment has not been changed, (b) see whether new equipment has been installed that could be controlled, and (c) facility personnel have any complaints
  - Conduct a satisfaction survey each year with a statistically significant sample of participants.
- Screen potential participants to eliminate those who are not qualified before initiating marketing contacts. This saves wasted marketing efforts and expense, and also avoids wasting customers’ time.
- Incorporate case studies and testimonials into marketing activities.
- “Qualify” prospective participants before enrolling them, ensuring that (1) sufficient controllable load is available to ensure an economic installation, (2) the equipment to be controlled functions properly, and (3) communications to control equipment and from monitored equipment and meters will be highly reliable.

6.2 OPERATIONAL BEST PRACTICES

BUILDING PRE-COOLING TO ENHANCE THERMOSTAT PROGRAM SAVINGS

The concept of using the thermal mass of a building and contained equipment and furnishings (together with the building envelope's thermal insulation) to improve the "yield" of DR control approaches that reduce space-conditioning loads is a technique that is generally talked about more often than actually practiced. Recent research results[36] documented by Dr. Braun and his colleagues and students at Purdue University have quantified the additional demand savings that can be realized in the small-business segment through systematic use of pre-cooling.



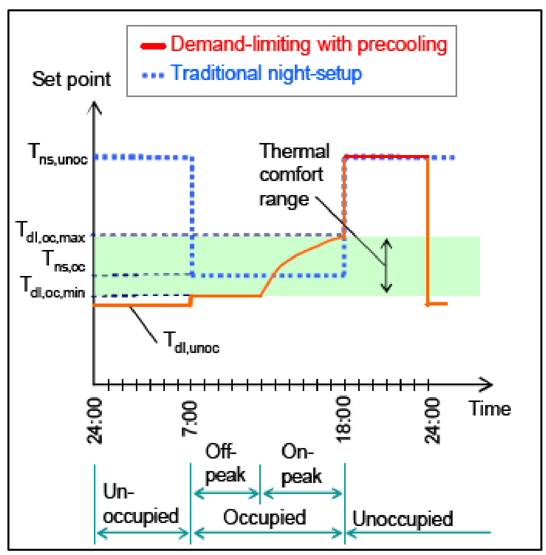
PLR = Percent load reduction
DL = Demand limiting start time (6 p.m. end time)
Hpc = Nighttime precooling start time, if any

All scenarios include precooling during occupied hours prior to the beginning of the DL start time.

In a lightweight construction small-business facility, modeled (calibrated to metered results at a real building) peak demand reductions of 25 to 45 percent of uncontrolled cooling load were realized without the temperatures exceeding the maximum temperature of the "thermal comfort range."

In particular, the researchers found that:

- Savings potential increases as the demand controlled period moves to later in the day.
- It is not necessary to hold the building at a low temperature all night in advance of a load control afternoon to make use of thermal storage.
- 32 percent savings was realized by reducing the building setpoint from 74F to 69F between 7 a.m. and 2 p.m. and gradually letting it rise to 76F between 2 p.m. and 6 p.m. An additional five percent savings was realized by also reducing the nighttime setpoint from 77F to 67F starting at 10 p.m.



36 *Development and Application of an Inverse Building Model for Demand Response in Small Commercial Buildings*, Kyoung-ho Lee and James E. Braun, Ray W. Herrick Laboratories, School of Mechanical Engineering, Purdue University, West Lafayette, IN, SimBuild 2004, IBPSA-USA National Conference Boulder, CO, August 4-6, 2004.

OVERRIDE OF CONTROL EVENTS

Where possible, provide a means for automatically overriding a control event if there is the possibility that temperatures rise to a level where occupant comfort is affected or refrigerated goods are adversely affected.

Provide program participants with a means for overriding control events, either via a direct control-related action (e.g., push a button or change a thermostat setting) or an indirect action (e.g., make a telephone call or log into a password-protected Web site). With either approach, the intent is that the customer can take action if he or she believes the load reduction is having an adverse effect on business operations, or on the health, safety or comfort of facility occupants. If the load-reduction controls have been properly programmed and the customer properly trained, override is very unlikely to occur. Nevertheless, good practice dictates that the customer "have an out" if the control event does not execute as expected.

7. FUTURE TECHNOLOGY TRENDS

Our research has identified the following trends in the evolving status of enabling technologies applicable for the small-business segment of the demand-response market:

- In the 5-kW to about 35-kW sub-segment, where the current practice is to use systems that "migrated up" from the residential sector and that control AC units only using remotely controlled relays or thermostats, future practice will see control of lighting loads and electric water heaters being included, yielding larger DR reductions at each participating facility. (Lighting is a major power end-use in the small-business segment, and thus far its potential as a DR resource has seldom been tapped.)
- Many more programs will target facilities in the ~35-kW to about 150-kW sub-segment, where small EMS and DDC units can economically control multiple equipment items in the air-conditioning, lighting, refrigeration, and electric water-heating end-uses.
- EMS-based controls will continue to "migrate down" into the 100-kW to 200-kW sub-segment from the large-commercial sub-segment.
- Manufacturers of many EMS and DDC control-device technologies will add communications linkages, and will offer fully functional DR systems. This is likely to include the HVAC control packages sold by rooftop air-conditioner manufacturers. Also, manufacturers of integrated control systems and distribution panels are also likely to add communications linkages to enable these units to participate in DR programs.
- Many new types of communications options are coming forward. One of the most promising is the use of "mesh wireless networks" to carry control signals to various items of end-use equipment. A prime example is the case of wireless communications linkages being used to control dimmable ballasts, thereby enabling temporary reductions to be made in the amount of power used for indoor lighting.
- A number of systems will provide benefits to the customer beyond participation in DR events (e.g., monitoring to identify potential security, health and safety problems). These benefits often are as important to the customer as the benefits derived from participating in DR events. Not only do the added benefits help to "sell" the installation and make it more attractive economically, but they also demonstrate that the system is fully functional, ready to act when a DR event occurs.
- As the use of price-based DR programs spreads to more customer segments and to more states, DR enabling technologies are likely to become available to end-use customers via normal distribution channels, such as electrical equipment suppliers and "big box" retail stores.

- ISOs will expand their DR programs and make it easier for aggregators of small-business facilities to participate.
- Aggregators—both retail chain owners and independent third parties—will increasingly employ central Web-based systems to simultaneously initiate DR events at multiple small-business sites.
- Software that automatically collects and scans data to verify system readiness, and to calculate load-reduction magnitudes, will be incorporated into DR enabling-technology equipment packages.
- Utilities will strongly encourage DR program marketing approaches that incorporate energy efficiency and renewable energy together with DR. The objective will be to encourage customers to undertake comprehensive energy solutions.