Design & Engineering Services

INTEGRATION OF DEMAND RESPONSE INTO TITLE 24 FOR COMMERCIAL REFRIGERATION SYSTEMS

Phase1: Demand Response Potential

DR 09.06.01 Report

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What's Inside…

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ABBREVIATIONS AND ACRONYMS

ASH	Anti-sweat heaters
CEUS	Commercial End Use Survey
CPUC	California Public Utility Commission
DOE	US Department of Energy
DR	Demand Response
ECM	Electronically commutated motor
EE	Energy Efficiency
FDA	US Food and Drug Administration
IC	Ice cream
LT	Low temperature
MT	Medium temperature
PG&E	Pacific Gas & Electric
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SMUD	Sacramento Municipal Utility District

EXECUTIVE SUMMARY

The goal of this project is to estimate the Demand Response (DR) potential for centralized refrigeration systems in California's Title 24 Energy Efficiency Standards for Residential and Nonresidential Buildings.

A short-term study was conducted to estimate the total DR potential of centralized refrigeration systems in Southern California Edison (SCE) service territory. This included an estimation of the prevalence of facilities with centralized refrigeration systems, contemplation of market acceptance factors, an exploration of potential DR strategies, and a determination of system-wide DR potential for each strategy.

Using the Customer End Use Survey (CEUS), the total demand of refrigeration systems in applicable market segments was estimated to be 517 MW. Four DR strategies were investigated: temperature reset, day-ahead temperature pull-down, lighting reduction, and evaporator fan cycling. The lighting measure is fairly straightforward and could achieve a 21,000 kW reduction with 10% market adoption (mainly limited to display case lighting). There are some concerns with effects on merchandising when lights are turned off, but these could probably be overcome with minimal efforts. Application to refrigerated warehouses may not provide additional DR potential because current Title 24 regulations limit lighting to the minimum necessary for safety purposes.

For the temperature reset, temperature pull-down, and fan cycling strategies, there are serious concerns about applicability to different types of equipment, food safety issues, and impact on customer economics. For example, medium temperature spaces would most likely not be included in such a strategy because of their inherent vulnerability to food spoilage. It appears that the most likely candidate for these strategies is low temperature spaces. Initial estimations suggest that temperature reset has a 15,500 kW DR potential at 10% market acceptance for these market segments. However, the methodology employed here does not take into account the duration of the DR period and may significantly overstate actual savings. Savings for fan cycling strategies could not accurately be estimated because of their dependence on site-specific factors. More data on the temperature characteristics of warehouses undergoing DR events is needed before a more accurate estimation of DR potential can be determined for these strategies.

All four strategies need to be investigated more thoroughly before they can be pushed into code. The impacts of DR on refrigerated space performance must be studied before implementation because of the potential problems associated with food safety. Once this performance data is known and better DR potential estimates can be made, industry participation in this effort will be crucial to ensure that a code effort is successful.

INTRODUCTION

This project seeks to validate and establish demand response (DR) potential for refrigerated systems. It is part of a multi-phase, multi-year effort to evaluate the potential for DR to be incorporated into the California Building Energy Efficiency Standards (Title 24) for commercial lighting systems, residential building controls, commercial buildings controls, and commercial refrigeration systems.

This project aligns well with the objective of Southern California Edison's (SCE) SmartConnect^{TM} by fostering and accelerating the availability of DR-ready appliances in the market place. Furthermore, this project supports the California Public Utilities Commission (CPUC) goal of zero net energy for residential new construction by 2020 and commercial new construction by 2030.

Phase 1 of this potential three-phase effort addresses the DR potential for refrigerated systems; if Phase 1 yields encouraging results, Phase 2 will demonstrate DR capabilities and strategies for refrigerated systems; and if the demonstration is successful, Phase 3 will develop a Title 24 Codes and Standards Enhancement initiative to recommend DR requirements for refrigerated systems.

This report reviews the findings from Phase 1 to estimate DR potential for refrigerated systems. This phase entails assessing the demand reduction associated with refrigerated systems, the population statewide and within SCE service territory, and the market/consumer acceptability of DR strategies associated with refrigerated systems.

TECHNOLOGY DESCRIPTION

Centralized refrigeration systems are used in many different building types to satisfy larger-scale cooling needs of SCE customers. In the commercial sector, refrigeration is generally used to preserve perishable food products through the supply chain. The main customer groups using centralized refrigeration systems are refrigerated warehouses, supermarkets, convenience stores, and restaurants. Several factors within the systems will determine their degree of DR potential.

OPERATING TEMPERATURE

Refrigeration systems are designed to operate within specific temperature ranges based on the type of product involved. Three temperature designations are commonly used to distinguish between the different types of systems: medium temperature (MT), low temperature (LT), and ice cream (IC). Design temperatures and applications are shown in Table 1.

TABLE 1. TEMPERATURE DESIGNATIONS

EQUIPMENT CLASS DESIGNATION	RATING TEMPERATURE	APPLICATION
MT*	38°F	Perishable fresh foods (meat, dairy, deli, produce)
LT*	0°F	Frozen foods (vegetables, juices, frozen dinners)
IC*	-15°F	Ice cream

COMPONENTS

Central refrigeration systems take slightly different forms depending on the type of facility they are in. For the most part, the components used are consistent, though there may be variations in size and quantity of certain equipment as required by the particular end use.

Compressors – compressors perform mechanical work on a refrigerating fluid to take advantage of its thermodynamic properties and provide cooling to a space. This report only addresses remote compressors. [Self-contained equipment is addressed further in separate reports – DR 09.05.01 (display cases), DR 09.05.03 (vending machines), DR 09.05.04 (walk-in coolers), DR 09.05.05 (reach-ins), and DR 09.05.06 (ice machines).]

Condenser fans – condensers reject the heat absorbed by the refrigerant from the cold space to the ambient environment. Typically, the condenser is air-cooled and requires a fan to blow air across it. In larger remote systems, there may be an evaporatively-cooled cooling tower or other device used to reject heat, but all commonly require some sort of fan to provide continuous airflow.

Evaporator Fans – circulate air through the cooling coil (evaporator) into the refrigerated space. When fans are turned completely off, the refrigeration system alone is incapable of cooling because air movement is required for heat transfer.

Defrost heaters (LT only) – evaporator coils become frosted during normal operation due to entrainment of warm, moist air from surrounding areas, people, and product perspiration. Many LT systems use electric resistance heaters to melt the ice and reopen airflow paths. Defrost cycles are typically initiated by a time clock (i.e., 4 times a day) and terminated either by a time clock (i.e., 45 minutes of defrost) or a temperature sensor (i.e., air leaving the evaporator has reached 42°F). Larger more complicated systems may use other defrost methods such as hot-gas or cool-gas defrost.

Lights – illuminate the refrigerated space for workers (walk-ins/warehouses) or product for merchandising purposes (display cases). Walk-ins and warehouses typically use the minimum space lighting as required by Title 24 to overcome safety concerns. Display cases use T8 fluorescent lamps, but newer efficient technologies such as LED, fiber optic, and cold cathode lighting are now entering the market.

Anti-sweat heaters (ASH) – prevent condensation formation on exposed surfaces of display cases and walk-in doors. Typically, ASH is located in the door frames and around the perimeter of doors. Condensate on the frames can cause doors of LT cases to freeze shut, which puts door gaskets at risk of being torn. The condensate may also drip off of the cold surfaces and onto the floor, creating slip hazards. Condensate on the inside surfaces of glass doors causes the door to fog up, obstructing the customer's view of products inside the case. (DR opportunities for ASH are covered in a separate report, DR 09.05.02.)

SYSTEM CONFIGURATION

Refrigerated warehouses – typically have separate spaces dedicated to different temperature groups. Some facilities may be completely dedicated to one temperature group. Large remote compressors operating at a particular temperature setting are tied to multiple evaporator fan coils in the dedicated space. Pre-coolers are often used to rapidly cool product before it enters the warehouse. Many warehouses are coupled with food processing activities. Because of the critical nature of the systems, most facilities have redundant systems in case of catastrophic failure of a system.

Supermarkets - A typical supermarket remote system contains several compressor racks, each with multiple compressors, which are piped either in a loop or direct circuit to display cases and walk-in coolers and freezers. The racks accommodate the evaporators by maintaining the lowest suction temperatures for the group. Typically, 3 to 5 compressor racks are employed to provide all refrigeration in the supermarket. Each compressor rack may have from 3 to 5 compressors serving a series of loads with nearly identical evaporator temperature.

Convenience stores/restaurants – Most convenience stores and restaurants use self-contained refrigeration equipment (covered under other DR projects as indicated above). Some use remote condensing units where a single compressor is tied to a single piece of equipment, while others use smaller versions of supermarket rack systems with multiple compressors tied to multiple pieces of equipment. Display cases and walk-in coolers and freezers are the most common remotely served pieces of refrigeration equipment for these customers.

Because only a small percentage of these customers have centralized refrigeration systems and these systems are fairly small in size, in depth analysis of their DR potential is not warranted at this time. The main DR opportunities are captured in the other reports and focus on the appliances served by the refrigeration systems (i.e., display cases and walk-ins).

CURRENT ENERGY CODE REQUIREMENTS

The US Department of Energy (DOE) does not currently regulate energy efficiency or DR aspects of centralized refrigeration systems. Several efforts have recently placed regulations on some refrigeration end use appliances, such as display cases and walk-in coolers and freezers. However, these efforts have not addressed regulation of remote refrigeration equipment due to the wide variance in types of systems and the inherent complexity of creating regulations that address all configurations.

California's Title 24 Building Code currently regulates energy efficiency aspects of refrigerated warehouses with total cold and frozen storage areas of 3,000 square feet and larger (see Appendix for full text).[1] There is no direct regulation of DR measures, but several of the requirements discussed below affect the need for or viability of DR-specific regulation.

Underslab Heating – Electric resistance underslab heaters are not allowed unless they are disabled during summer on-peak periods.

Evaporator Fans – Evaporator fan motors must be electronically commutated motors (ECM) equipped with variable speed controls that respond to space conditions, unless tied to a single compressor without unloading capability.

Condensers –

- Evaporative condensers must meet specific design wet bulb temperature constraints depending on local design wet bulb temperatures.
- Air-cooled condensers must meet specific design dry bulb temperature constraints depending on the temperature designation of the refrigerated space.

- Condenser fans for evaporative or air-cooled condensers must be continuously variable speed, and all fans on the same condenser loop must be controlled in unison.
- Condenser fan motors must be permanent split capacitors or ECMs.

Compressors – Compressors must be designed to operate at a minimum condensing temperature of 70°F or less. The speed of screw compressors greater than 50 hp must be controllable to be less than or equal to 60% of full load input power when operated at 50% of full refrigeration capacity, except for plants with more than one dedicated compressor per suction group.

DEMAND PROFILE AND ENERGY CONSUMPTION

Because of the wide variation in application and size of facilities, demand and energy consumption for central refrigeration systems cannot be easily reported as a single per-site value. Approximations of energy consumption for the different facilities using central refrigeration systems are available from the Commercial End-Use Survey (CEUS).[2]

Refrigerated warehouses – The CEUS reported annual average statewide energy intensity for refrigerated warehouses to be 20.02 kWh/ft^2, of which 13.44 kWh/ft^2 is devoted to refrigeration. The statewide summer demand profiles are shown in Figure 1.

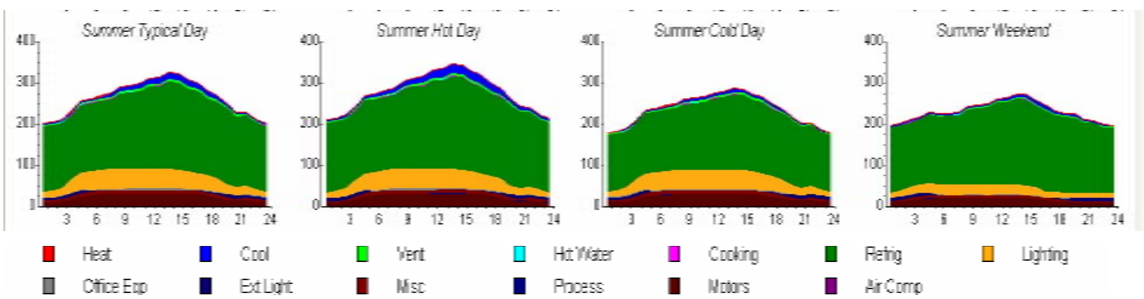

FIGURE 1. STATEWIDE REFRIGERATED WAREHOUSE DEMAND PROFILE

Supermarkets – The CEUS reported annual average statewide energy intensity for food stores to be 40.99 kWh/ft^2, of which 22.42 kWh/ft^2 is devoted to refrigeration. The statewide summer demand profiles are shown in Figure 2.

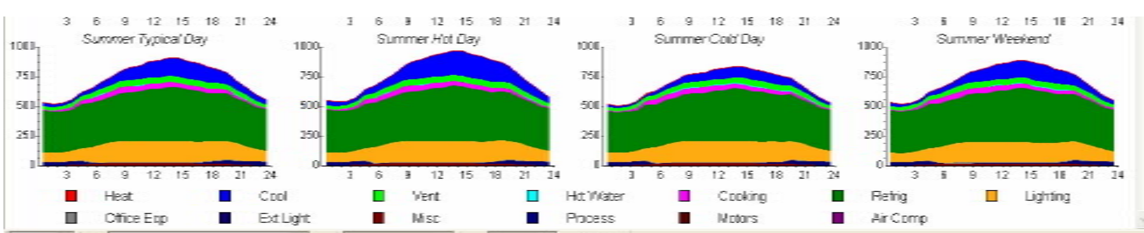

FIGURE 2. STATEWIDE FOOD STORE DEMAND PROFILE

MARKET SIZE

REFRIGERATED WAREHOUSES

The CEUS report was used to estimate the market size of refrigerated warehouses in SCE service territory and statewide, the information[3] Note that the information in CEUS was only for SCE, PG&E, SDG&E, and SMUD, and did not include other municipal utilities in California. CEUS reported 95 million square feet of refrigerated warehouses statewide, of which 30 million square feet are in SCE service territory. Table 2 contains a breakdown of refrigerated warehouse floorspace by service territory.

TABLE 2. REFRIGERATED WAREHOUSE FLOOR SPACE AND TOTAL ANNUAL ENERGY USAGE ACROSS CA SERVICE TERRITORIES

SERVICE TERRITORY	REFRIGERATED WAREHOUSE FLOOR SPACE (MILLION FT^2)	REFRIG. ENERGY INTENSITY (KWH/FT^2)	TOTAL REFRIG. ENERGY (GWH)
SCE	**30**	**15.08**	**452**
PG&E	61	12.48	761
SDG&E	2	22.72	45
SMUD	2.7	10.28	28
Total	**95.7**	**13.44 (avg)**	**1,286**

The CEUS report does not distinguish between MT and LT refrigerated warehouse space. For measures distinguishing between the two temperature groups, it is assumed that 70% of the space is MT and 30% is LT.

SUPERMARKETS

CEUS was also used to estimate the number of supermarkets and grocery stores in SCE service territory and statewide. Table 3 summarizes the total supermarket floor space and annual energy usage in SCE, PG&E, SDG&E, and SMUD service territories.

TABLE 3. SUPERMARKET FLOOR SPACE AND TOTAL ANNUAL ENERGY USAGE ACROSS CA SERVICE TERRITORIES

SERVICE TERRITORY	SUPERMARKET FLOOR SPACE (MILLION FT^2)	REFRIG. ENERGY INTENSITY (KWH/FT^2)	TOTAL REFRIG. ENERGY (GWH)
SCE	**64**	**21.74**	**1,391**
PG&E	56	23.00	1,288
SDG&E	19	22.80	433
SMUD	5.5	23.01	127
Total	**144.5**	**22.42 (avg)**	**3,240**

The CEUS report does not distinguish between MT and LT cooling loads within supermarkets. For measures distinguishing between the two temperature groups, it is assumed that 70% of the space is MT and 30% is LT.

MARKET BARRIERS

There are several over-arching factors that will impede acceptance of DR strategies by SCE customers. The concept of DR must be approached differently for refrigeration-dependent customers than many others due to the critical role of electricity in their operation. While they may be very adverse to DR in refrigeration, they must be reminded that without DR, the likelihood for extended, widespread power outages is increased. The losses resulting from such outages would likely far outweigh the impacts of DR implementation.

SCE completed a survey on barriers to implementation of DR strategies for cold storage customers in 2007.[4] The final report discusses many of the items presented here in greater detail, as well as analysis of additional behavioral considerations for DR programs.

FOOD SAFETY

The FDA Food Code requires that all fresh foods be kept at a maximum temperature of 41°F to prevent spoilage and growth of food-borne illnesses. Because most of these fresh foods are maintained at temperatures around 36-38°F, there is little room for temperature fluctuations that would result from shutting down any of the cooling equipment.

The most common DR measures for refrigeration involve turning off the refrigeration equipment, which creates the risk of exceeding allowable temperature limits. Furthermore, many of the control systems used in the field today do not operate with tight tolerances, which increase the risk that temperatures will not be maintained properly. Thus, MT refrigeration applications on the whole are not suitable for DR participation.

There may be an argument that facilities holding non-perishable items, such as sodas, alcoholic beverages, sports drinks, and other beverages would be capable of withstanding more pronounced temperature fluctuations. However, the inherent danger is that the type of product in a particular location may change over time. There is no way to guarantee that a space holding soda today will not be holding milk and dairy products 6 months from now. This is especially true with display cases, but slightly less of a concern for walk-in coolers or refrigerated warehouses. Thus, it appears that utilities have the potential of incurring significant liability if MT facilities are included in any temperature-changing DR schemes.

LT and IC applications are typically able to withstand moderate changes in temperature because the products stored in them are maintained well below the freezing point and not susceptible to thawing. Thus, DR strategies are more applicable here.

MARKETING IMPACTS

The main purpose of display cases and walk-ins with glass doors is to merchandize perishable products to consumers. Any DR measures must not interfere with this purpose to the degree that they have a significant impact on the ability of cases to sell product. Historically, in supermarkets and convenience stores, marketing aspects of cases have always been more important than energy consumption or thermal performance. For example, open display cases are commonplace in every supermarket today despite the opportunity to save nearly 80% on energy costs by switching to identical cases with doors. The reason is that the merchandisers are concerned that placing a door in between the customer and the product will so drastically cut into sales that any potential savings would be overshadowed by the loss of sales. In addition, any measures that reduce visibility of products to the customer by reducing lighting levels or allowing glass doors to fog more than usual will not be accepted by the market. Therefore, research projects are currently underway to assess the sales impact of adding doors to refrigerated display cases to address the concerns voiced by the grocery industry.

COMPLEXITY

One of the biggest hurdles to overcome in widespread deployment of programs for refrigeration customers is the lack of consistent refrigeration system design, even among facilities operated by the same chain. These systems are connected to numerous types of display cases and walk-in coolers and incorporate any number of controllers using different communication protocols. The end result is that no two systems are alike and implementation of any DR strategy could require significant amounts of specialization for individual locations. This will likely increase implementation costs. Additionally, enforcing the standard will be difficult because of the complexity and variation present in the market.

COST

The grocery industry operates on very tight profit margins; usually less than 1% of sales, and energy costs typically exceed profits. As such, they require energy efficiency and DR measures to have very short payback periods. Because some of the DR strategies proposed here may be very costly to implement in a particular location, let alone across multiple facilities with many vintages and equipment configurations, the associated DR rate structure must provide sufficient incentives to meet the payback criteria.

INTRUSION INTO SALES AREA

Like most business owners, grocery store operators are very hesitant to allow work crews in their facilities during operating hours. This is especially true when refrigerated cases are involved because customers who see any type of work undertaken on a case might assume that there is a problem with all refrigerated cases and refrain from purchasing any perishable products in the surrounding area. Furthermore, depending on the kind of instrumentation required to implement a particular DR strategy, technicians may be required to access the inner workings of the case. This is very labor-intensive, requiring removal of a substantial amount of product from the case. The combination of labor intensiveness and possible after-hours schedule could significantly increase implementation labor costs, hampering the payback issues mentioned above.

LACK OF INFORMATION

A recent SCE study of barriers to DR implementation in cold storage facilities found that the major deterrent for SCE customers was a lack of information as to how various DR actions would affect their facilities. For example, they were open to the idea of changing the operation of cooling equipment during DR events and thought they might be able to operate without it for a couple hours, but didn't have concrete evidence of what the effects might be, so chose not to take any action. Even no-cost measures like closing doors were not attempted because customers did not understand the DR impact that would result from reduced cooling loads. Due to the critical nature of these facilities, more solid information on the expected impacts and limitations of DR strategies must be accumulated and shared for any DR effort to be successful.

DEMAND RESPONSE STRATEGIES AND POTENTIAL

There are three strategies for achieving DR in central refrigeration systems presented below. For the purpose of this evaluation, the DR potential of each strategy is defined in Equation 1.

EQUATION 1. DEMAND RESPONSE POTENTIAL

$$DR_{potential} = (kW_{reduction}/unit) \times (Market\ Size) \times (Market\ Acceptance)$$

STRATEGY 1 – TEMPERATURE RESET

STRATEGY DESCRIPTION

Temperature reset requires raising the thermostat setpoint temperature by a few degrees. Depending on how the refrigeration system is set up, this would either cause the compressor and condenser to cycle off because the setpoint is now satisfied, or reduce the load on a multiplex remote compressor setup, thereby reducing its power consumption. In either case, the suction pressure would be raised slightly, allowing the refrigeration system to operate at slightly higher efficiency and reduced demand.

TECHNICAL DEMAND REDUCTION

If the condensing unit cycles off, there would be a 100% reduction in power until the various heat sources warm the cold space to the new setpoint temperature. For remote systems tied into multiple compressor systems, there would be a reduction in refrigeration load but it would not necessarily lead to compressors shutting off completely. The duration of the off-cycle or reduced refrigeration load condition is completely dependent on the type of cold space involved and the overall cooling load effect of the surroundings, which will determine how quickly the space heats back up. For example, open display cases will reach the new setpoint fairly quickly while closed cases will take some time due to their inherent isolation from the surroundings.

To increase the duration of DR events, building codes should require increased envelope and infiltration reduction measures to minimize cooling loads. This will extend the amount of time cooling systems can be turned off without impacting product temperatures. Where sustained DR is necessary, one option might be to have multiple DR "groups" either within a site or across multiple sites. The groups could be rotated through short DR events to ensure that they have coincident off-cycle times.

Because of all the variables involved, it is difficult to predict what the actual demand reduction would be or how long it could last, especially in an aggregate sense. The most realistic way to calculate the technical potential is to estimate total kW demand for the specified cooling loads. Table 4 shows the refrigeration demand assuming that energy demand is constant over 8,760 hours of the year. Although refrigeration systems typically run 24-hours a day, 7 days a week, this method provides an under-approximation of the refrigeration demand. The main reason is that refrigeration systems have a more difficult time rejecting heat as outdoor temperature increases and most DR events happen on the hottest days of the year. Thus, potential DR savings may be slightly higher than reported.

TABLE 4. TOTAL REFRIGERATION DEMAND AND LT PORTION (ASSUMING 30% LT)

Service Territory	Refrigerated Warehouse (MW)	Refrigerated Warehouse LT (MW)	Food Stores (MW)	Food Stores LT (MW)
SCE	**52**	**15**	**159**	**48**
PG&E	87	26	147	44
SDG&E	5	2	49	15
SMUD	3	1	14	4
Total	**147**	**44**	**369**	**111**

MARKET ACCEPTANCE

A foreseen market barrier to this DR strategy is the FDA food code issues that will likely be a significant deterrent in pursuing this strategy for MT equipment. The risk of spoilage and potential for resulting illness will overshadow benefits realized in the minds of many facility operators. Application to LT equipment does not appear to be a major issue because there is a much wider acceptable temperature range and less opportunity for product quality to be reduced. However, for open LT cases or other spaces with high cooling loads, this strategy would likely result in significant temperature swings that could damage product. Thus, not all spaces would be good candidates for this strategy.

Additionally, there may be technical complications in the implementation of this strategy due to the wide array of equipment and controllers that would have to interface with the DR dispatching device.

There also may be some sector of the market that is just unwilling to relinquish any control of their equipment to a utility or other outside actor due to business, health and safety concerns.

DEMAND RESPONSE POTENTIAL

Using the LT DR potential from Table 4, the DR achieved for various adoption rates on LT equipment is shown in Table 5.

TABLE 5. DR POTENTIAL FOR STRATEGY #1 FOR VARIOUS ADOPTION RATES

	ADOPTION RATE DR POTENTIAL (MW)				
	1%	**5%**	**10%**	**20%**	**50%**
Ref. Warehouse					
SCE	0.15	0.77	1.55	3.10	7.75
CA	0.44	2.20	4.40	8.81	22.02
Supermarkets					
SCE	0.48	2.38	4.76	9.53	23.82
CA	1.11	5.55	11.09	22.19	55.47
Total					
SCE	0.63	3.16	6.31	12.63	31.57
CA	1.55	7.75	15.50	31.00	77.50

STRATEGY 2 – DAY-AHEAD DR TEMPERATURE PULL-DOWN

STRATEGY DESCRIPTION

In the event that the utility has advance knowledge that a DR event is required the next day, space temperatures may be pulled down in advance. During the DR event, the refrigeration equipment can be shut off and the temperature allowed gradually to increase over a period of time until it reaches a maximum allowable temperature.

As with the temperature reset strategy, this is most suitable for LT applications. Pulling down temperature on MT equipment can bring temperatures close to freezing (32°F), which can damage food products. The length of off time is dependent on the type of space involved and surrounding environmental effects. For example, open display cases are not good candidates because of their increased exposure to neighboring conditions. Closed cases may be better candidates due to more effective thermal isolation from their surroundings.

TECHNICAL DEMAND REDUCTION

The potential DR for this measure is similar to that for Strategy 1, but should have a longer duration due to the lower starting temperature. Because duration is not included in the DR potential calculation, there is no difference between this strategy and Strategy 1. Thus, the values in Table 4 apply here.

MARKET ACCEPTANCE

A foreseen market barrier to this DR strategy is the same issue as in Strategy 1 – risk of food spoilage. However, market acceptance may be slightly higher due to the advanced warning inherent in this strategy rather than an instantaneous change in operation.

DEMAND RESPONSE POTENTIAL

The total DR potential is the same as for Strategy 1, so Table 5 applies.

STRATEGY 3 – LIGHTING REDUCTION

STRATEGY DESCRIPTION

Upon receiving a DR signal from the utility, lights in display cases or warehouses would either shut off or switch to a dim state. Most cases in the field today are equipped with T8 fluorescent lamps that cannot be dimmed. A growing number of new cases are equipped with LED lighting, which can incorporate dimming strategies for energy efficiency gains. These dimming capabilities can be used during a DR event to provide prolonged low-power lighting.

Title 24 requires refrigerated warehouses to have specific light levels and lighting controls such that occupancy triggers lights to come on. There is no further DR opportunity here, except behavioral changes to prevent the lights from being activated. Because display cases are appliances covered by Title 20, they should not be included in the Title 24 analysis.

The technical demand reduction, market acceptance and demand response potential of lighting reduction is addressed further in the report titled “DR 09.05.01 – Integration of DR into Title 20 for Open and Closed Refrigerated Display Cases.”

STRATEGY 4 – EVAPORATOR FAN CYCLING

STRATEGY DESCRIPTION

Upon receiving a DR signal from the utility, evaporator fans would either shut off or switch to a low-power state. This strategy is most promising for walk-ins and refrigerated warehouses. It is impractical in display cases because air must be circulated at all times at a fairly constant rate in that application. The larger cold spaces can survive with less airflow for longer periods of time.

TECHNICAL DEMAND REDUCTION

It is extremely difficult to quantify the DR savings potential for this measure. The ability to turn fans off or reduce their speed is completely site-dependent and relies on a multitude of factors including the physical layout of the cold space, distance between fan coils and heat loads, distance between neighboring fan coils, arrangement of fan coils in the space, type of products stored, and density of shelving. Several reports[5, 6] have discussed evaporator fan control as a possible DR measure, but none has made an estimate of widespread DR potential because of the site specificity.

Furthermore, any facility having the technical capability to reduce fan speed as an energy efficiency (EE) measure will likely be operating them at the minimum necessary speed at all times. Thus, they may not be able to safely reduce speeds further or shut fans off without endangering product. More investigation into the feasibility of evaporator fan DR measures is necessary before potential can be determined.

MARKET ACCEPTANCE

Foreseen market barriers to this DR strategy are specific issues with space design. In current practice, large warehouses typically have all evaporator coils along one wall (or two opposite walls for very large facilities). Fans on these coils must operate at full speed to ensure airflow is able to reach all parts of the space. By implementing this strategy, there may be a potential of creating a "heat island" along one wall or in the center of the facility when fans are operated at low speed. Any Title 24 standard that includes reduced speed fan operation should also include sufficient safeguards to ensure this effect is not realized.

DEMAND RESPONSE POTENTIAL

As stated above, more technical investigation and testing is required before the DR potential can be quantified.

RESULTS

DR potential for centralized refrigeration systems range from 631 kW with 1% acceptance for temperature reset and day-ahead pull down within SCE service territory to 266,806 kW with 50% acceptance for lighting reductions statewide. Table 6 shows the range of total DR potential for the two strategies identified.

TABLE 6. RANGE OF DR POTENTIAL

STRATEGY	1% ACCEPTANCE (KW)		50% ACCEPTANCE (KW)	
	SCE	CA	SCE	CA
Temp Reset / Day-Ahead Pull Down	631	1,550	31,571	77,498
Lighting Reduction	2,166	22,119	108,290	266,806
Evap. Fan Cycling	Needs more technical investigation			

RECOMMENDATIONS

Strategies 1 and 2 should be pursued, but will require further research to determine exactly how different spaces would respond to DR events. The questions around duration of off-time and applicability to various space types can only be answered through detailed technical testing. To help remedy this uncertainty, building codes should require increased levels of insulation and infiltration reduction to minimize cooling loads. These strategies will likely also require significant industry involvement because their buy-in is crucial to putting standards in place.

Strategy 3 should be pursued for lighting reduction in display cases under Title 20 as recommended in DR 09.05.01.

Strategy 4 should be pursued if technical evaluations prove that evaporator fan motor DR measures are feasible.

APPENDIX A

SECTION 126 – MANDATORY REQUIREMENTS FOR REFRIGERATED WAREHOUSES

A refrigerated warehouse with total cold storage and frozen storage area of 3,000 square feet or larger shall meet the requirements of this section.

EXCEPTION 1 to Section 126: A refrigerated space less than 3,000 square feet shall meet the Appliance Efficiency Regulations for walk-in refrigerators or freezers.

Areas within refrigerated warehouses that are designed solely for the purpose of quick chilling or freezing of products with design cooling capacities of greater than 240 Btu/hr-ft^2 (2 tons per 100 ft^2).

(a) **Insulation Requirements.** Exterior surfaces of refrigerated warehouses shall be insulated at least to the R-values in Table 126-A.

TABLE 126-A REFRIGERATED WAREHOUSE INSULATION

SPACE SURFACE MNIMUM R-VALUE (°F·hr·sf/Btu)
Frozen Storage Roof/Ceiling R-36
Wall R-36
Floor R-36
Cold Storage Roof/Ceiling R-28
Wall R-28

(b) **Underslab heating.**

EXCEPTION to Section 126(b): Underslab heating systems controlled such that the electric resistance heat is thermostatically-controlled and disabled during the summer on-peak period defined by the local electric utility.

(c) **Evaporators.** Fan-powered evaporators used in coolers and freezers shall conform to the following:

1. Single phase fan motors less than 1 hp and less than 460 Volts shall be electronically commutated motors.
2. Evaporator fans shall be variable speed and the speed shall be controlled in response to space conditions.

EXCEPTION to Section 126(c)2: Evaporators served by a single compressor without unloading capability.

(d) **Condensers.** Fan-powered condensers shall conform to the following:

1. Condensers for systems utilizing ammonia shall be evaporatively-cooled.
2. Condensing temperatures for evaporative condensers under design conditions, including but not limited to condensers served by cooling towers shall be less than or equal to:

A. The design wet bulb temperature plus 20° F in locations where the design wet bulb temperature is less than or equal to 76° F,

B. The design wet bulb temperature plus 19°F in locations where the design wet bulb temperature is between 76°F and 78°F, or

C. The design wet bulb temperature plus 18°F in locations were the design wet bulb temperature is greater than or equal to 78°F.

3. Condensing temperatures for air-cooled condensers under design conditions shall be less than or equal to the design dry bulb temperature plus 10°F for systems serving frozen storage and shall be less than or equal to the design dry bulb temperature plus 15°F for systems serving cold storage.

Exception to Section 126(d)3. Unitary condensing units.

4. All condenser fans for evaporative condensers shall be continuously variable speed, and the condensing temperature control system shall control the speed of all condenser fans serving a common condenser loop in unison. The minimum condensing temperature setpoint shall be less than or equal to 70°F.
5. All condenser fans for air-cooled condensers shall be continuously variable speed and the condensing temperature or pressure control system shall control the speed of all condenser fans serving a common condenser loop in unison. The minimum condensing temperature setpoint shall be less than or equal to 70°F, or reset in response to ambient dry bulb temperature or refrigeration system load.
6. All single phase condenser fan motors less than 1 hp and less than 460 V shall be either permanent split capacitor or electronically commutated motors.

(e) Compressors. Compressor systems utilized in refrigerated warehouses shall conform to the following:

1. Compressors shall be designed to operate at a minimum condensing temperature of 70°F or less.

2. The compressor speed of a screw compressor greater than 50 hp shall be controllable in response to the refrigeration load or the input power to the compressor shall be controlled to be less than or equal to 60 percent of full load input power when operated at 50 percent of full refrigeration capacity.

EXCEPTION to Section 126 (e) 2: Refrigeration plants with more than one dedicated compressor per suction group.

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