INTEGRATION OF DEMAND RESPONSE INTO TITLE 20 FOR REACH-IN REFRIGERATORS AND FREEZERS

Phase1: Demand Response Potential

DR 09.05.05 Report

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ABBREVIATIONS AND ACRONYMS

DOE	Department of Energy
DR	Demand Response
SCE	Southern California Edison
Title 20	California's Appliance Efficiency Regulations

EXECUTIVE SUMMARY

This project assesses the demand response (DR) potential associated with reach-in refrigerators and freezers and the potential to assess the potential for DR capable commercial refrigerators and freezers to be included in California's Appliance Efficiency Regulations (Title 20). This project may follow up with demonstrations of the DR strategies identified, and could ultimately lead to the development of code language, phases 2 and 3, respectively.

Reach-in refrigerators and freezers are capable of responding to a DR event by allowing the temperature of the unit to float. This can be accomplished through a variety of strategies including cycling, temperature resets, and pre-cooling. The success of each of these strategies is reliant upon the amount of float possible, yet there is very little information on this topic. The float will be impacted by the strategy, the thermal mass of the unit, and the usage profile.

Absent information on the duration of the DR event, the potential for each of these strategies is very similar. The major difference in the pre-cooling strategy is that there is a concern that the refrigerator could be pre-cooled too much, causing the food to freeze and lowering the market acceptance. The total DR potential was determined by using the market information and demand profile for each unit, as well as the estimates of market acceptance. The range of potential, for each strategy, is given in Table 1.

TABLE 1. DR STRATEGY POTENTIAL SUMMARY

STRATEGY	MINIMUM POTENTIAL (KW)		MAXIMUM POTENTIAL (KW)	
	SCE	CA	SCE	CA
Cycling	1,126	2,252	56,275	112,550
Temperature Reset	1,126	2,252	56,275	112,550
Pre-Cooling	1,126	2,252	25,436	50,872

DR for residential refrigerators is a viable option, with manufacturers already working to incorporate the requisite equipment. However, it does not appear to be the same with commercial units. It is recommended that further studies be done to determine the product temperature as a function of time while the unit is off. Also, since these strategies are similar in nature, (e.g., result in unit shut off), it is recommended that a survey be performed to provide insight into the preferred strategy for the customer.

INTRODUCTION

This project seeks to validate and establish demand response (DR) potential for reach-in refrigerators and freezers. It is part of a multi-phase, multi-year effort to evaluate the potential for DR to be incorporated into the California Appliance Efficiency Regulations (Title 20) for a series of 13 commercial and residential appliance categories from home office equipment to reach-in refrigerators and freezers.

This project aligns well with the objective of Southern California Edison's (SCE) SmartConnect™ by fostering and accelerating the availability of DR-ready appliances in the market place. Furthermore, this project supports the California Public Utilities Commission 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 reach-in refrigerators and freezers; if Phase 1 yields encouraging results, Phase 2 will demonstrate DR capabilities and strategies for reach-in refrigerators and freezers; and if the demonstration is successful, Phase 3 will develop a Title 20 Codes and Standards Enhancement initiative to incorporate DR requirements for reach-in refrigerators and freezers.

This report reviews the findings from Phase 1 and estimates the DR potential for reach-in refrigerators and freezers. This phase entails assessing the demand reduction associated with reach-in refrigerators and freezers, the population statewide and within SCE service territory, and the market/consumer acceptability of DR strategies associated with reach-in refrigerators and freezers.

TECHNOLOGY DESCRIPTION

A reach-in refrigerator or freezer is defined as an upright, refrigerated cabinet with solid or glass doors. Glass door refrigerator/freezers can be used in a variety of settings as either storage or for merchandising, whereas solid door refrigerator/freezers are typically found in commercial kitchens and are used for storage purposes. For the purposes of this report only solid door refrigerator/freezers are investigated.

The cabinet is served by a refrigeration system which can either be self-contained within the unit or located remotely. The units served by the remote condensing unit are assumed to be part of a larger refrigeration system, and thus would be incorporated into the overall commercial refrigeration system, falling under the purview of Title 24. Therefore, only self-contained units are considered in this study.

As noted, this study covers both refrigerators and freezers. However, in a recent rulemaking the Department of Energy (DOE) utilized three product classifications: medium temperature (refrigerator), low temperature (freezer), and ice-cream temperature. This rulemaking covered all commercial refrigeration equipment, yet was driven primarily by the display cases. Given the assumptions noted previously on door types and condensing unit types, the units investigated are not for display purposes, and likely would not operate at the ice-cream temperature. For the purposes of this report, only medium (refrigerator) and low (freezer) temperatures will be considered.

CURRENT ENERGY CODE REQUIREMENTS

As previously noted the DOE recently completed rulemaking on commercial refrigeration equipment, which will become effective January 1, 2012. However, this rulemaking did not establish new performance levels for self-contained refrigerators and freezers (only ice-cream temperature and remote condenser units were impacted). As a result, the existing Title 20 code levels remain intact.

As of January 1, 2006, 2005 Title 20 requires that all solid-door, reach-in refrigerators and freezers be manufactured to the ENERGY STAR specification or CEE Tier 1.[1] These specifications are shown in Table 2.

TABLE 2. TITLE 20 STANDARDS FOR REACH-IN REFRIGERATORS AND FREEZERS

Equipment Description	California Energy Commission 2005 Title 20 Daily Energy Usage (kWh/day)
Solid-Door Reach-In Refrigerator (CEE Tier 1)	$\leq 0.100V^{\dagger}+2.04$
Solid-Door Reach-In Freezer (CEE Tier 1)	$\leq 0.400V^{\dagger}+1.38$

†Where V is the internal volume in ft^3.

DEMAND PROFILE AND ENERGY CONSUMPTION

In order to determine the energy consumption, a representative size must be determined for these refrigerators and freezers. Based on the assumptions made in the work paper[2] associated with this equipment, there are four basic classifications, each of which is given a representative size. The maximum amount of energy consumption allowed by the Title 20 regulations was selected to determine the energy consumption, based on the future nature of incorporating DR into code. Table 3 highlights the classifications, representative sizes and energy consumption for the refrigerators and freezers.

TABLE 3. CLASSIFICATIONS (SIZES) AND ENERGY CONSUMPTION FOR REACH-IN REFRIGERATORS AND FREEZERS

	UNDER-COUNTER	SINGLE-DOOR	DOUBLE-DOOR	TRIPLE-DOOR
Typical Volume (ft^3)	10	24	44	72
Energy Consumption-Refrigerator (kWh/day)	3.04	4.44	6.44	9.24
Energy Consumption-Freezer (kWh/day)	5.38	10.98	18.98	30.18

To determine the demand drawn by these units, specification sheets from various manufacturers were obtained. These provided the voltage and amperage for the various sizes of refrigerators and freezers. Using these values, the power draw was determined. The results of these calculations are shown in Table 4.

TABLE 4. DEMAND DRAWN BY REACH-IN REFRIGERATORS AND FREEZERS

	UNDER-COUNTER	SINGLE-DOOR	DOUBLE-DOOR	TRIPLE-DOOR
Demand- Refrigerator (kW)	0.414	0.827	1.085	1.360
Demand- Freezer (kW)	0.596	1.192	1.681	2.502

MARKET SIZE

As part of this research, no single market study was found that provided figures on the exact number of reach-in refrigerators and freezers in the market. However, 2008 shipment data for ENERGY STAR refrigerators and freezers was found.[3] Given the requirement for all equipment sold in California to meet ENERGY STAR standards, it is assumed that the ENERGY STAR data can be interpolated to determine market size. The findings show that 126,000 solid door refrigerators and 67,000 solid door freezers were sold in 2008. Based on commercial energy consumption it is estimated that 9% of all sales are to the state of California. Using this data point 11,340 refrigerators and 6,030 freezers are assumed to enter the market each year. According to the work paper, the use life of this equipment is classified as 12 years; assuming constant annual shipments are made, this leads to a total market size of 136,080 refrigerators and 72,360 freezers in California. Simplistically, it is assumed that SCE's service territory would have 50% of the market.

In order to use the size classifications identified previously, some assumptions need to be made about the distribution of sizes in the market. It is stated in the work paper that single-door units are the most prevalent, with about twice as many as the double-door units, which are the second most commonly used units. Based on this assertion it is estimated that 50% of the market uses a single-door unit, 25% uses a double-door unit, and under-counter and triple-door units account for 12.5% each. Table 5 details the market size by classification for both SCE service territory and statewide.

TABLE 5. MARKET SIZE BREAKDOWN

TYPE	REGION	UNDER-COUNTER	SINGLE-DOOR	DOUBLE-DOOR	TRIPLE-DOOR
Refrigerators	SCE Territory	8,505	34,020	17,010	8,505
	Statewide	17,010	68,040	34,020	17,010
Freezers	SCE Territory	4,523	18,090	9,045	4,523
	Statewide	9,045	36,180	18,090	9,045

MARKET BARRIERS

As is the case in all refrigerated food storage applications, the single greatest barrier is food safety and compliance with FDA Food Code, which requires that all fresh foods be kept below a maximum temperature of 41°F to prevent spoilage. It will be required for any DR strategy to maintain this maximum temperature threshold. Additionally, since freezers are also being considered in this report, another market barrier is maintaining the temperature of the food to below freezing, 32°F. In either case these temperature barriers are set to maintain food quality and any DR strategy that creates unnecessary liability will not be accepted by the market.

DEMAND RESPONSE STRATEGIES AND POTENTIAL

For the purpose of this evaluation, the demand response potential is defined as:

EQUATION 1. DEMAND RESPONSE POTENTIAL

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

STRATEGY 1 – CYCLING

STRATEGY DESCRIPTION

This strategy cycles the refrigerator and freezer on/off for a pre-determined set of time. It requires the installation of communication equipment that is able to receive a signal and in turn respond to it. The amount of cycling influences the duration that the DR event is able to sustain. The lower the amount of cycling, (e.g., 25% as opposed to 75%), the more constant the temperature of the food. However, there is no data currently available on how cycling affects the temperature, so no recommendations can be made on the cycling factor.

TECHNICAL DEMAND REDUCTION

Absent an analysis of duration of the event response, it is assumed that this strategy sheds the entire draw of the unit. Table 4 details the demand for the different sizes of refrigerators and freezers: these values are the technical demand reduction potential.

MARKET ACCEPTANCE

Foreseen barriers of acceptance for this DR strategy include compliance with FDA food code. The cycling factor plays a major role in the ability of the food to maintain temperature and comply with code, so the amount of cycling also impacts acceptance. Absent an understanding of the cycling, it is estimated that the market acceptance is somewhere between 1 and 50%.

DEMAND RESPONSE POTENTIAL

Using Equation 1., the technical potential, market size and breakdown, and various acceptance factors the DR potential was determined. The results of these calculations are shown in Table 6.

TABLE 6. DR POTENTIAL: STRATEGY 1 - CYCLING

TYPE	SIZE	1% ACCEPTANCE (kW)		5% ACCEPTANCE (kW)		10% ACCEPTANCE (kW)		20% ACCEPTANCE (kW)		50% ACCEPTANCE (kW)	
		SCE	CA	SCE	CA	SCE	CA	SCE	CA	SCE	CA
Refrigerators	Under-counter	35	70	176	352	352	704	704	1,408	1,761	3,522
	Single-door	281	562	1,407	2,814	2,813	5,626	5,627	11,254	14,067	28,134
	Double-door	185	370	923	1,846	1,846	3,692	3,691	7,382	9,228	18,456
	Triple-door	116	232	578	1,156	1,157	2,314	2,313	4,626	5,783	11,566
	Total	617	1234	3,084	6,168	6,168	12,336	12,336	24,672	30,839	61,678
Freezers	Under-counter	27	54	136	272	271	542	543	1,086	1,356	2,712
	Single-door	216	432	1,078	2,156	2,156	4,312	4,313	8,626	10,782	21,564
	Double-door	152	304	760	1,520	1,520	3,040	3,041	6,082	7,602	15,204
	Triple-door	114	228	570	1,140	1,139	2,278	2,278	4,556	5,696	11,392
	Total	509	1,018	2,544	5,088	5,087	10,174	10,175	20,350	25,436	50,872

STRATEGY 2 – TEMPERATURE RESET

STRATEGY DESCRIPTION

A temperature reset strategy for a refrigerator/freezer relies on raising the thermostat setpoint of the unit to be raised by a pre-determined value, (e.g., 2°F, 4°F, etc.), during a DR event. Essentially, this results in the unit being shut off for some period of time, which depends on the temperature reset and the amount of unit usage. This strategy requires some form of communication equipment that is able to receive and act on a DR event signal.

TECHNICAL DEMAND REDUCTION

Absent an analysis of duration of the event response, it is assumed that this strategy sheds the entire draw of the unit. Table 4 details the demand for the different sizes of refrigerators and freezers; these values are the technical demand reduction potential.

Market Acceptance

Foreseen barriers of acceptance for this DR strategy include compliance with FDA food code. The thermostat setpoint of the unit plays a major role in the ability of the food to maintain temperature and comply with code, so the change in temperature, (e.g., 2°F vs. 4°F), also impacts acceptance. Absent an understanding of the impact that the temperature reset has on food safety, it is estimated that the market acceptance is somewhere between 1 and 50%.

Demand Response Potential

Using Equation 1, the technical potential, market size and breakdown, and various acceptance factors, the DR potential was determined. The results of these calculations are shown in Table 7.

Table 7. DR Potential: Strategy 2 - Temperature Reset

Type	Size	1% Acceptance (kW)		5% Acceptance (kW)		10% Acceptance (kW)		20% Acceptance (kW)		50% Acceptance (kW)	
		SCE	CA	SCE	CA	SCE	CA	SCE	CA	SCE	CA
Refrigerators	Under-counter	35	70	176	352	352	704	704	1,408	1,761	3,522
	Single-door	281	562	1,407	2,814	2,813	5,626	5,627	11,254	14,067	28,134
	Double-door	185	370	923	1,846	1,846	3,692	3,691	7,382	9,228	18,456
	Triple-door	116	232	578	1,156	1,157	2,314	2,313	4,626	5,783	11,566
	Total	617	1234	3,084	6,168	6,168	12,336	12,336	24,672	30,839	61,678
Freezers	Under-counter	27	54	136	272	271	542	543	1,086	1,356	2,712
	Single-door	216	432	1,078	2,156	2,156	4,312	4,313	8,626	10,782	21,564
	Double-door	152	304	760	1,520	1,520	3,040	3,041	6,082	7,602	15,204
	Triple-door	114	228	570	1,140	1,139	2,278	2,278	4,556	5,696	11,392
	Total	509	1,018	2,544	5,088	5,087	10,174	10,175	20,350	25,436	50,872

STRATEGY 3 – PRE-COOLING

STRATEGY DESCRIPTION

Pre-cooling relies on advanced warning of a DR event to cool the unit to a lower than normal temperature, so it can be shut off in order to maintain the desired temperature during a DR event. In order to accomplish this, a signal is sent well in advance of the event that allows for the unit to initiate the pre-cooling process. Then once the peak demand period is reached, the unit is essentially shut off in order to maintain the original desired setpoint. This strategy would require the incorporation of communicating equipment.

TECHNICAL DEMAND REDUCTION

Absent an analysis of duration of the event response, it is assumed that this strategy sheds the entire draw of the unit. Table 4 details the demand for the different sizes of refrigerators and freezers; these values are the technical demand reduction potential.

MARKET ACCEPTANCE

Foreseen barriers of acceptance for this DR strategy include compliance with FDA food code. However, another market barrier with pre-cooling is the desired temperature of the food. In the case of a refrigerator it cannot be pre-cooled to the point that the food is frozen.

Similar to the first two strategies, the market acceptance is a function of the ability of food to maintain the temperature during the DR event, yet very little is known about how the food temperature acts during the shut-off period. For a freezer, the same acceptance range, 1-50%, is used. For the refrigerators, the additional barrier of maintaining an above freezing temperature will likely create less market acceptance and therefore is estimated to be between 1 and 20%.

DEMAND RESPONSE POTENTIAL

Using Equation 1., the technical potential, market size and breakdown, and various acceptance factors, the DR potential was determined. The results of these calculations are shown in Table 8.

TABLE 8. DR POTENTIAL: STRATEGY 3- PRE-COOLING

TYPE	SIZE	1% ACCEPTANCE (KW)		5% ACCEPTANCE (KW)		10% ACCEPTANCE (KW)		20% ACCEPTANCE (KW)		50% ACCEPTANCE (KW)	
		SCE	CA	SCE	CA	SCE	CA	SCE	CA	SCE	CA
Refrigerators	Under-counter	35	70	176	352	352	704	704	1,408	--	--
	Single-door	281	562	1,407	2,814	2,813	5,626	5,627	11,254	--	--
	Double-door	185	370	923	1,846	1,846	3,692	3,691	7,382	--	--
	Triple-door	116	232	578	1,156	1,157	2,314	2,313	4,626	--	--
	Total	617	1234	3,084	6,168	6,168	12,336	12,336	24,672	--	--
Freezers	Under-counter	27	54	136	272	271	542	543	1,086	1,356	2,712
	Single-door	216	432	1,078	2,156	2,156	4,312	4,313	8,626	10,782	21,564
	Double-door	152	304	760	1,520	1,520	3,040	3,041	6,082	7,602	15,204
	Triple-door	114	228	570	1,140	1,139	2,278	2,278	4,556	5,696	11,392
	Total	509	1,018	2,544	5,088	5,087	10,174	10,175	20,350	25,436	50,872

RESULTS

DR potential for reach-in refrigerators and freezers ranges from 1,126 kW with 1% acceptance, within SCE territory, when the unit is cycled on and off, to 112.55 MW with 50% acceptance for temperature reset statewide. Table 9 shows the range of total DR potential for the three strategies identified.

TABLE 9. RANGE OF TOTAL DR POTENTIAL

STRATEGY	1% ACCEPTANCE (KW)		50% ACCEPTANCE (KW)	
	SCE	CA	SCE	CA
Cycling	1,126	2,252	56,275	112,550
Temperature Reset	1,126	2,252	56,275	112,550
Pre-Cooling	1,126	2,252	25,436	50,872

RECOMMENDATIONS

The DR strategies in this report have not been demonstrated to be viable options. However, they rely on the incorporation of known technologies, so it is a matter of allocating resources. Each of the strategies identified in this report has a similar technical potential, since each results in the unit being shut off. These strategies differ in the amount of shut-off time of each unit as well as with the customer perception. It is recommended that, as a first step, an understanding of how the temperature of the food product fluctuates in the absence of cooling (unit off). With this knowledge, the duration can be determined for each strategy, and a single strategy can be targeted. To address the issue of customer perception, a survey that addresses the customer's reaction to a cycling strategy vs. a temperature reset strategy vs. a pre-cooling strategy can be performed. The results of this survey will provide further information to aid in targeting a single strategy.

REFERENCES

[1] 2005 Appliance Efficiency Regulations, California Code of Regulations (Title 20), page 102. California Energy Commission. April 2005. (http://www.energy.ca.gov/2005publications/CEC-400-2005-012/CEC-400-2005-012.PDF)

[2] Work Paper WPSCNRCC0001, "Commercial Foodservice Equipment: Reach-In Refrigerators and Freezers," Southern California Edison. 2009. (http://eega2006.cpuc.ca.gov/DisplayQuarterlyReport.aspx?ID=7, "SCE Workpapers 2006-2008 part 1.zip")

[3] "Breakdown of 2008 ENERGY STAR Unit Shipment Data," ICF International. October, 2009.