Field Assessment of Refrigerated Display Cases Air Curtain Guiding Vanes

Final Report

ET23SWE0046


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Cypress Ltd

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Executive Summary

In January 2022, Southern California Edison (SCE) conducted a laboratory study (SCE 2022) to explore the benefits of installing air vanes on vertical open refrigerated display cases in grocery stores, the same technology being evaluated in this field assessment.

Air vanes are thin rigid strips — either a single strip or two strips — attached to the end of a grocery store's open refrigeration display shelves. These air vanes are positioned perpendicularly across the air curtain of the display case and direct airflow down, strengthening the barrier and reducing infiltration between the refrigerated space and the warm moist air outside of the display case. As detailed in the findings section of this report, the field assessment focused on four locations in different climate zones (CZs), to assess a representative sample of different display case configurations and temperatures. Overall temperatures for the open display cases ranged from 36 to 39°F. Inside-store temperatures ranged from 65°F to 72°F. Two air vane designs (0-degree angle and 17-degree angle) were used at the locations.

Given the large presence of open vertical refrigerated display cases used in grocery stores in California and also in SCE's service territory,[1] it is reasonable that if the measure achieved high adoption rates, the potential energy savings would be significant for the California commercial target market. This study concludes:

- Savings from air vanes were about 10 percent of total compressor energy consumption. Savings ranged from 9 percent to 14 percent, depending on CZ and application.
- Overall annual cost savings averaged $10.70/ft of installed air vane. This value ranged from $6.37 to $21.58/ft across CZ and applications.
- In this field assessment, energy savings averaged 16.79 W/ft of installed air vane as compared to the 17 W/ft in the lab study. Field savings values ranged from 7.42 to 26.53 W/ft across CZ and applications. The results show that on average the field assessment is within a reasonable error (five percent) of the laboratory study for average savings in W/ft.
- Overall kilowatt-hour (kWh) savings averaged 129.46 kWh/ft of installed air vane. This value ranged from 64.98 to 232.44 kWh/ft across CZ and applications.
- Based on an estimated average of 330 ft of potential air vane coverage in a typical store from a prior study (SCE 2009) and using the overall average from this field assessment, our results suggest that for a 330 ft coverage area total, the annual savings would be 42,722 kWh/yr, which is 15 percent below lab study[2] estimates. As detailed herein, the differences between a laboratory assessment and the actual field installation account for these differences.

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[1] Estimated at 10,760 stores in the SCE service territory based on the California End-Use Survey (CEUS).

[2] "A typical large supermarket could expect to save around 50,000 kWh annually, assuming 8,760 hours of annual operation time." From SCE (2022).

Abbreviations and Acronyms

Acronym	Meaning
CA	California
CARB	California Air Resources Board
CDD	Cooling degree days
CEUS	Commercial End-Use Survey
CMVP	Certified Measurement and Verification Professional
CZ	Climate one
DAC	Disadvantaged communities
DAT	Discharge air temperature
EPA	Environmental Protection Agency
EUL	Equipment useful life
F	Fahrenheit
Ft	Feet
GWP	Global-warming potential
HFC	Hydrofluorocarbons
IN	Inches
IOU	Investor-owned utility
IPMVP	International Performance Measurement and Verification Protocol
IR	Infrared
kW	Kilowatt
kWh	Kilowatt-hour

Acronym	Meaning
LAX	Los Angeles International Airport
M&V	Measurement and verification
PG&E	Pacific Gas & Electric
PML	Property management lead
ROI	Return on investment
SCE	Southern California Edison
SNAP	Significant new alternatives policy
SQ	Square
W	Watts

Table of Contents

List of Tables

List of Figures

Introduction

This CalNEXT project, “Field Assessment of Refrigerated Display Cases Air Curtain Guiding Vanes, project ET23SWE0046,” set out to analyze and report energy savings of supplemental air vanes to open refrigerated display cases. Air vanes are thin rigid strips (either a single strip or two strips) attached to the end of each grocery store's open refrigeration display shelves. These air vanes are positioned perpendicularly across the air curtain of the display case and direct airflow down, strengthening the barrier and reducing infiltration between the refrigerated space and the warm moist air outside of the display case. According to an earlier Southern California Edison (SCE) study on air vanes (SCE 2009), an average large grocery store, around 50,000 square (sq) feet (ft) in size, has about 330 linear ft of open display cases. Across the 2,800 larger stores in SCE’s service area, this represents about 900,000 linear ft of display cases.

The project included a comparison of real-world field results to a previous lab assessment (SCE 2022) on air curtain guiding vanes. The lab study showed that installing air vanes reduced display case energy consumption by 17 watts per linear foot (W/ft) for both meat and produce temperatures. This led to a 20 to 25 percent decrease in compressor power usage for meat and produce within the controlled lab environment. These lab averages do not account for factors such as coincidence or load impact when the units are placed alongside other energy-consuming systems.

The field data collected and analyzed came from site installations at four grocery store locations within SCE’s territory. The findings show that this technology’s low-cost and simple installation requirements 1) reduce power consumption at each location, 2) have an acceptable return on investment (ROI), and 3) could be adopted under a future utility incentive program. The findings underscore the potential for energy-saving innovations in grocery store refrigeration systems and alignment with California, utility, and customer efforts to increase appliance efficiency and reduce environmental impact across the industry. Documented positive results create a positive halo effect on market adoption of this underutilized technology.

This report provides background information on air vanes, project objectives, methods and approaches, and findings and recommendations.

Background

California is the top producer of agricultural products in the United States, at 13 percent of total (California Agricultural Statistics Review), and commercial refrigeration represents a significant portion of the energy consumption that is related to food storage, preparation, and sales. Additionally, retail food refrigeration is estimated at almost 45 percent of California’s hydrofluorocarbon (HFC) emissions (US EPA et al. 2016). This air vane efficiency measure is a simple and cost-effective solution that can help achieve energy reductions.

The SCE (2022) laboratory study was completed in January 2022 to investigate the potential energy benefits of installing air vanes on vertical open refrigerated display cases used in grocery stores. Results from the completed lab study (SCE 2022) found energy savings of 10 percent in infiltration load at 32°F, and nearly 20 percent at 37°F. The study found air vanes resulted in a reduction of approximately 17 W per linear ft of storage for meat and produce temperatures, corresponding to a 20 to 25 percent reduction in compressor power usage for meat and produce, respectively. Air vanes examples are shown in Figure 1,

Figure 3, and Figure 2 below.

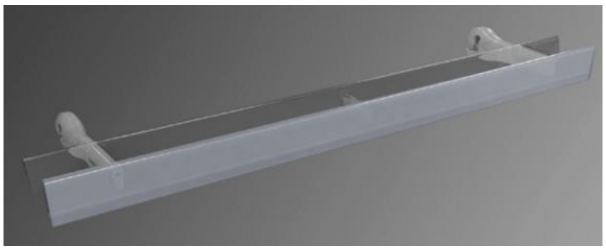

Figure 1: Air vane example

Source: From air foil manufacturer literature

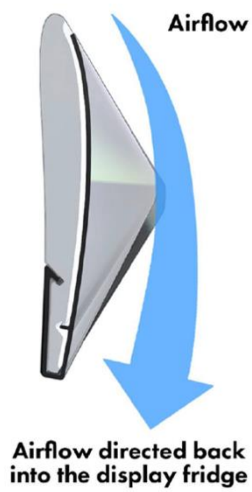

Figure 2: Example of Air Stream

Source: From air foil manufacturer literature

Figure 3: Air vane installed on shelf

Source: Air foil manufacturer literature

Shelf-edge air vane technology is applicable to new display cases and as a retrofit solution. The focus of this assessment is on retrofit technology that can make grocery store refrigeration more energy efficient. The principle of the technology is to retain air in a vertical air stream — known as the air curtain. The air curtain is the cool air supplied by the refrigeration system and flows from the top of the display case and streams between the front face of the display case shelves and the shelf's edge where the air vane technology is installed. The cool air then flows to the return air grille at the base of the display case. In traditional open-fronted display case designs, much of this cold air curtain spills out of the front of the cabinet as the vertical air stream collapses into the store, creating excess cold air. A further result is "cold-aisle syndrome," which can also increase store energy costs. Excess cold air results in an increase in energy consumption that, in the case of both local and central refrigeration systems, places an unnecessary energy burden on store refrigeration and HVAC energy use. Infiltration of un-conditioned or warmer air into the display case shelf is the largest energy-contributing component for a display case and an example is illustrated in the image below.

Error! Reference source not found. shows an infrared (IR) image of a display case from the prior lab assessment (SCE 2022) with air vanes installed (right image) and a display case with no air vanes installed (left image). This indicates how air vanes can better retain the cold air in a more compact air stream than a display case without air vanes and shows the immediate effect caused by an air vane. The IR image on the left was taken during the 37°F baseline condition, and the image on the right was in the same condition, with an air vane installed. The yellow and green curve depicts the air curtain separating the warm outside air from the cool inside of the display case. Close examination shows the air curtain on the right was pulled closer to the ends of the shelf for a larger section than that of the baseline image, indicating the air vanes had an impact on the air curtain.

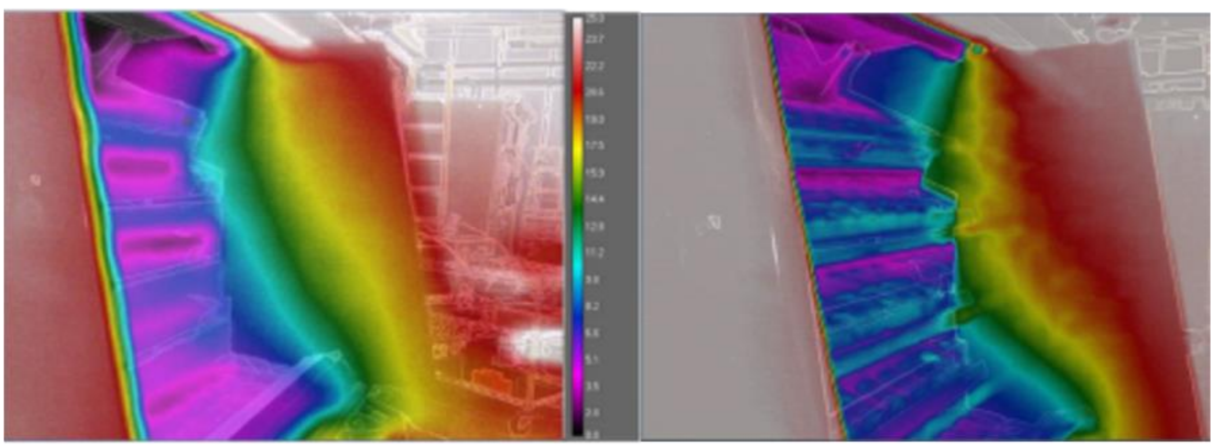

Figure 4: Infrared imagery before air vane installation (left) and after (right)

Source: Air Curtain Guiding Vanes in Refrigerated Display Cases (SCE 2022)

Open display cases are used for all types of perishable food products. There are two typical temperature set points: one for meat at a discharge air temperature (DAT) of ~32°F and the other for produce at a DAT of ~37°F.

Objectives

While the completed laboratory project (SCE 2022) did demonstrate the energy-saving potential of installing air vanes on vertical open refrigerated display cases, the question remained: do those savings translate to real-world grocery store environments? To answer this, a field evaluation under actual operating conditions was necessary. The objectives of our field evaluation were to:

- Conduct a field assessment to analyze energy savings based on approved measurement and verification (M&V) standards and report on any increased efficiency of adding air vanes to open refrigerated display cases in four grocery store locations in different CZs compared to a project baseline.
- Provide any relevant comparison to the findings in the prior completed lab assessment of air curtain vanes (SCE 2022).
- Consult with the project stakeholders at each site, store management, and the air vane provider to understand operational and maintenance considerations and report on perceived market barriers to adoption and basic incentive program design recommendations.
- Complete the site assessments of the four locations relevant to application of the air vane technology: what shelves would work, which to exclude, customer site preferences and expectations, etc.
    - Customer preference example: For the sites surveyed, the customer does not allow the vanes on any shelf lower than 43” from the floor level due to concerns over impacting product availability to consumers. Also, the customer does not install the vane on what are referred to as “pusher” shelves, which are shelves where the product is placed within bins or on hooks.
- Install monitoring equipment and collect necessary data for analysis, including weather data from appropriate web sites for analysis.
- Provide a final report outlining results.

Methodology and Approach

To analyze the energy efficiency of refrigerated display cases air curtain guiding vanes, this project provided M&V for a field installation of the designated air vane technology. The site inspections provided detailed information on each location, the number of air vanes that would be installed for each location, and an understanding of the measurements required for baseline and post-data collection. Here, we also report on relevant comparisons to prior laboratory findings. The following information provides the M&V plan in accordance with International Performance Measurement and Verification Protocol (IPMVP) as described by the Efficiency Valuation Organization (2022).

Site Designations

This CalNEXT project team installed air vanes on open grocery store display shelves identified at four locations in different California CZs:

- T3225 Long Beach, CZ 6
- T0190 South Gate, CZ 8

- T1028 West Covina, CZ 9
- T0307 Cathedral City, CZ 15

The project team included the Cathedral City location, the warmest site and the lowest store application of the technology (in vane ft) to assess any effects of higher climate temperatures. As the results indicate, data from this site fall within the overall average for all sites.

Measurement and Verification (M&V) Summary

For this project's energy efficiency technology, the air vanes, we used an IPMVP protocol combining Option A and Option B, commonly referred to as Partial Isolation Option and Total Isolation Option, respectively. We made every attempt to measure all variables needed, and the project required some regression assumptions and related stipulations to calculate savings and arrive at conclusions.

Monitoring Measurement Period

The required measurement periods were:

- "Pre" data was collected for at least one month between May and June 2024.
- Interim data was collected from the end of the pre period until the start of the "post" period.
- "Post" data was collected for at least one month between July and August 2024.
- In each period, we collected:
    - Compressor actual three phase power (15-minute or hourly readings) for electrical service as available at either breaker, disconnect, or appropriate service input.
    - Case temperature, using an appropriate temperature logger.
    - Inside store temperature, using the appropriate temperature logger.
    - Outside air temperature, using the following sites and sources:
        - Long Beach – Long Beach Airport, KLGB
        - South Gate – Burbank Airport, Glendale, Pasadena, KBUR
        - West Covina – Ontario International Airport, KONT
        - Cathedral City – City of Palm Springs, KPSP
        - We also collected outside air temperature at the site with a temperature logger as confirmation.
    - The following additional data:
        - One year of 15-minute demand data from the utility for each location.
- One billing summary per store to verify the rate schedule.
        - Appropriate display case and inside store temperature for each location.

Measured Variables and Savings Calculations:

Several variables were measured in both pre and post monitoring periods including the following:

- 15-minute demand (and therefore energy) for full or partial compressor at each location.
- Case temperature (hourly) for all cases covered by the project.
- Inside Store temperature (hourly) for each location.
- Weather data will be collected from appropriate sites (hourly) for one year historically and through all monitoring periods.

- A five-year average annual hourly weather file will be developed from the appropriate site for the years 2019 – 2023. Appropriate data (leap year) will be removed for a complete 8,760 hourly file.
- 15-minute demand data will be collected from SCE for each location for at least one year historically and through the monitoring period. This information will be used as reference for the total load compared to the monitored load.
- Billing data was received for one store to verify rate schedule. All sites were confirmed as using the same rate schedule (TOU-GS-3).

The following describes the methodology for savings calculations:

- We sorted and filtered data using outside air temperature as the base input. Outside temperatures were sorted into "bins" of 5°F increments.
- Compressor data was filtered to correspond to the temperature bins.
- We produced scatter plots for pre and post monitoring periods
- Savings was the difference between pre and post monitoring periods using the scatter plots and any necessary regression.
- We calculated annual savings using the five-year average historical weather bins and analysis for each temperature location based on monitoring periods.
- We then adjusted data based on linear ft of installed air vanes to determine the final savings per ft.
- To convert to annual economic savings, we then sorted and filtered the data to apply the appropriate rate schedule.

Inspection and Calibration Requirements:

The project team completed inspections to verify installations of proposed projects and to determine appropriate adjustments. The following details the required instrumentation calibration for this project:

- Energy monitoring for the compressor racks was completed using Powersite® calibrated three phase power monitors.
- We monitored temperature using Hobo® Temp loggers field calibrated using a separate meter and on-site data to determine the logger was reading accurately prior to launch.

The savings calculations and final savings report herein are signed by a Certified Measurement and Verification Professional (CMVP) and all instrumentation calibration as appropriate can be provided upon request.

Findings

Table 1 summarizes the overall results. The technology provides savings in each CZ and savings varied. Other than the weather differences, these variances could be from:

- Differences in operations. From observations, each location had some differences in overall produce stocking timing and requirements.

- Differences in occupancy. Each location had differences in number of customers, time of customer access, etc.
- Differences in stocking practices. In some locations the refrigerated areas were located adjacent to warehouse and stocking supplies. The project team observed that in some cases, doors were left open for stocking which could affect the overall temperatures and flow at the refrigerated openings.
- Layout differences. As noted herein, each location had a different layout of freezer and refrigerated space. In addition, each location varied in terms of door front and open areas. One location had open frozen containers, which would also affect the overall compressor operation.

Table 1: Air Vane Savings Summary Table by Location

Location	Climate Zone	Annual Savings (kWh)	Annual Savings	Installed Cost	Simple Payback (years)	Feet Installed	Per-foot Savings	kWh/ft Savings	kWh for 330 ft	Avg. W/ft Savings
Long Beach	6	18,973.35	$1,860.67	$4,499.72	2.42	292	$6.37	64.98	21,442.48	7.42
South Gate	8	25,807.63	$1,829.58	$3,431.84	1.88	214	$8.55	120.60	39,796.82	13.77
West Covina	9	35,330.97	$3,280.11	$2,449.60	0.75	152	$21.58	232.44	76,705.40	26.53
Cathedral City	15	21,126.09	$1,398.92	$1,910.84	1.37	124	$11.28	170.37	56,222.65	19.45
Total Project		**101,238.04**	**$8,369.28**	**$12,292.00**	**1.47**	**782**	**$10.70**	129.46	42,721.94	**16.79**

In comparison to the previous laboratory study (SCE 2022), the project team found:

- The overall average savings from installed vanes was 16.79 W/ft, very similar to the previous study finding of 17 W/ft. The difference is well within a reasonable error. In this field assessment, savings did vary by site due to a variety of considerations including weather, site set-up, overall site vane application, and other factors described in this report.
- The overall 42,721 average kWh for the application for 330 ft of the technology is within about 15 percent of the calculations from the previous study. This difference is likely because in this field site study, we did not install air vanes on the lowest shelves per the store operator's request.[3] This reduced the amount of potential installed ft by more than 20 percent and certainly reduced the air flow savings from the shelf to the return. Even so, savings from this field study and the previous laboratory assessment were similar.
- The field study indicated a good potential simple payback of 1.47 years on average for the four locations, with a range of 0.75 to 2.42 years. The operators expressed some questions over product accessibility, shelf labeling standards, and overall product stability and wear. These questions were addressed once the vanes were installed: The store operators involved in this study were satisfied with the overall application.

[3] "For the sites surveyed the customer does not allow the vanes on any shelf that is below 43" from the floor level due to concerns over impacting product availability to consumers."

Table 2 below summarizes overall savings as a percentage of pre-installation data.

Table 2: Air Vane Percentage Energy Savings Summary

Location	Climate Zone	Pre kWh	Post kWh	Savings kWh	% Savings
Long Beach	6	140,224	121,251	18,973	14%
South Gate	8	310,847	285,039	25,808	8%
West Covina	9	299,363	264,032	35,331	12%
Cathedral City	15	225,320	204,194	21,126	9%
Total Project		**975,754**	**874,516**	**101,238**	**10%**

Pre Data Analysis

The pre data consisted of the kW of the compressor rack and the temperature from the selected weather site. The kW data was collected in 15-minute intervals then converted to hourly average data for analysis. The pre data indicated the following relationships between temperature and kW use, as measured by R2; more detailed analysis can be provided upon request.

- Long Beach Pre – R^2 =.9886
- South Gate Unit 1 Pre – R^2 =.9916
- South Gate Unit 2 Pre – R^2 =.9661
- West Covina Unit A Pre – R^2 =.9796
- West Covina Unit B Pre – R^2 =.9851
- Cathedral City Pre – R^2 =.9394

Table 3: Pre Average kW and Temperate Data

		Long Beach		South Gate Unit 1		South Gate Unit 2		West Covina Unit A		West Covina Unit B		Cathedral City	
Temp	Bin	Avg Temp	Avg kW	Avg Temp	Avg kW	Avg Temp	Avg kW	Avg Temp	Avg kW	Avg Temp	Avg kW	Avg Temp	Avg kW
Under 50	1							49.3	7.3				
50-55	2			55	24.2			53.4	8.1				
55-60	3	58	13.7	58.3	26.5	58.1	5.3	57.4	8.3	58.6	21.7	58.2	23
60-65	4	62.3	14.3	62.1	28.4	62	5.7	62.1	8.4	62.3	22.8	63.7	24.4
65-70	5	67.7	15.3	67.5	30	67.5	6.2	67.5	8.7	67.8	24.2	67.9	24.4
70-75	6	71	17	72.1	31.4	72	6.8	72.5	9.8	72.7	25.3	72.4	25.2
75-80	7			77.2	33.9	77.2	7.6	77.7	11.4	77.8	28.6	77.6	25.4
80-85	8			81.8	36.5	81.8	8.4	81.9	12	82.6	30.6	82.6	25
85-90	9			86	38.1	86	10.9	86.1	12.9	86.4	31.5	87.3	27.3
90-95	10											92.4	29.5
95-100	11											96.9	29.7
100-105	12											100.8	30.6
105-110	13												
Over 110	14												

Figures 5- – 10 below show pre kW and temperature data. In South Gate and West Covina, the customer used two compressor racks for the store's display cases; both were analyzed and summarized.

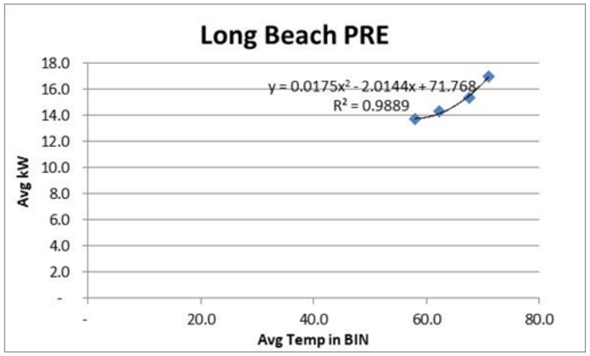

Figure 5: Long Beach Pre Regression

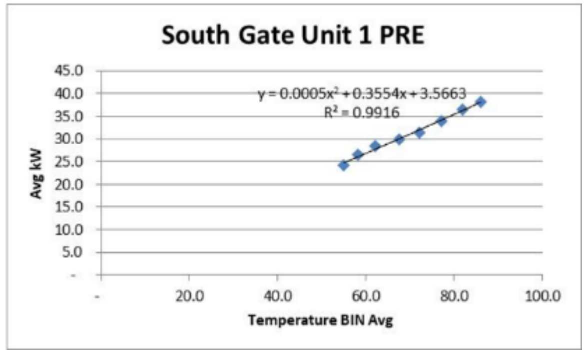

Figure 6: South Gate Unit 1 Pre Regression

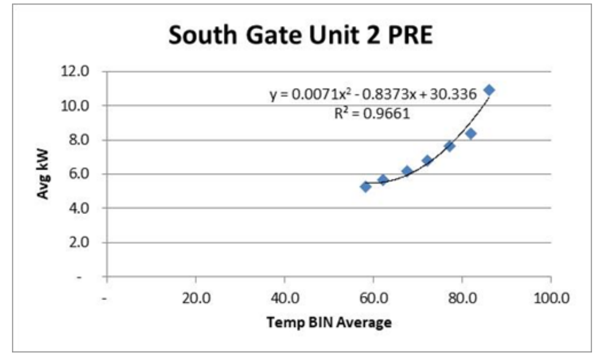

Figure 7: South Gate Unit 2 Pre Regression

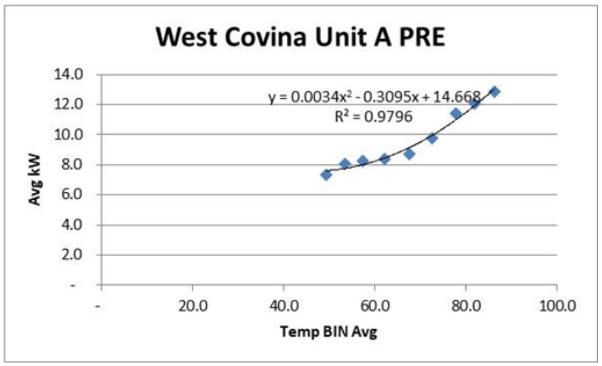

Figure 8: West Covina Unit A Pre Regression

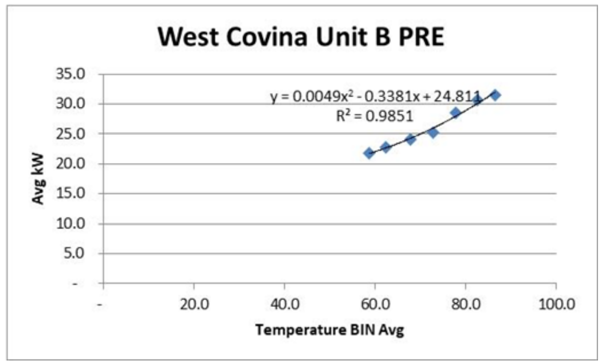

Figure 9: West Covina Unit B Pre Regression

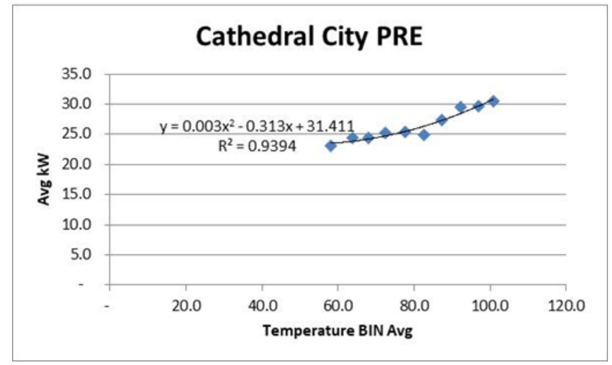

Figure 10: Cathedral City Pre Regression

Post Data Analysis

The post data was analyzed in the same manner as the pre data, indicating the following relationships between temperature and kW use, as measured by R2. More detailed analysis can be provided upon request.

- Long Beach Post – R^2 =.9954
- South Gate Unit 1 Post – R^2 =.9773
- South Gate Unit 2 Post – R^2 =.9766
- West Covina Unit A Post – R^2 =.9877
- West Covina Unit B Post – R^2 =.9924
- Cathedral City Post – R^2 =.9589

Table 4: Post Average kW and Temperature Data

		Long Beach		South Gate Unit 1		South Gate Unit 2		West Covina Unit A		West Covina Unit B		Cathedral City	
Temp	Bin	Avg Temp	Avg kW	Avg Temp	Avg kW	Avg Temp	Avg kW	Avg Temp	Avg kW	Avg Temp	Avg kW	Avg Temp	Avg kW
Under 50	1												
50-55	2												
55-60	3									59.2	20.8		
60-65	4	63.8	14.2	63.6	27.6	63.6	5.5	63.6	5.5	63.1	21.3		
65-70	5	67.8	15.1	67.5	28.9	67.5	5.7	67.5	5.7	67.7	22.4		
70-75	6	72.1	16.8	72.3	31	72.3	6.1	72.3	6.1	72.4	24.2	74.5	24
75-80	7	77.1	18.5	77.5	35.1	77.5	7.5	77.5	7.5	77.2	26.9	78.4	24.1
80-85	8	81.9	19.6	82.6	36.4	82.6	8.9	82.6	8.9	82.6	29.6	82.5	24.9
85-90	9	87.1	20.6	87.2	36.8	87.2	9.6	87.2	9.6	87.6	31.5	88.1	27
90-95	10	92.5	21.4	91.8	38	91.8	10.6	91.8	10.6	92.2	33.1	92.5	28.4
95-100	11			96.2	38	96.2	10.9	96.2	10.9	97.2	35	97.4	29.6
100-105	12									100.5	36.4	102.6	29.8
105-110	13											107.6	29.8
Over 110	14											113.4	30.3

Figures 11 – 16 below show post kW and temperature data. As done previously, we analyzed both compressor racks in the cases of South Gate and West Covina.

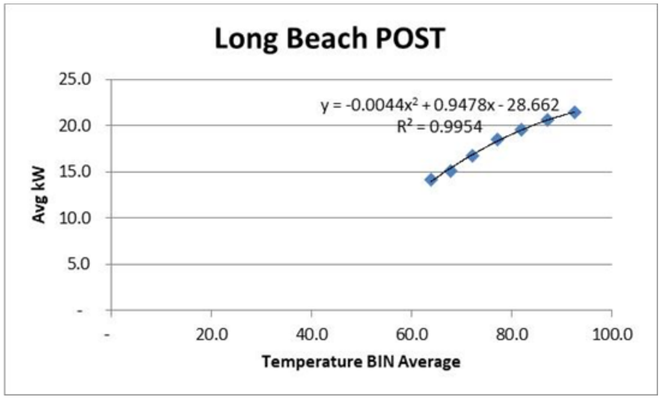

Figure 11: Long Beach Post Regression

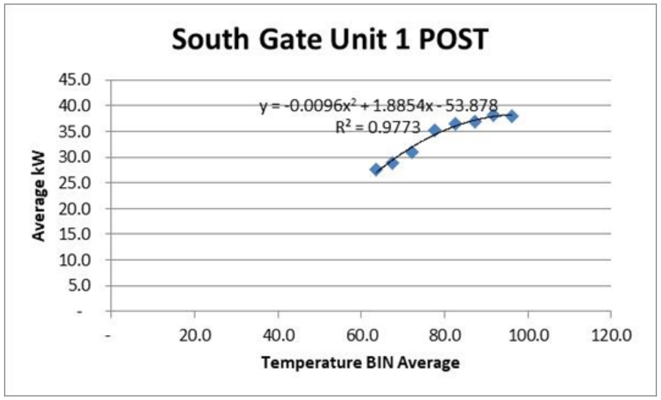

Figure 12: South Gate Unit 1 Post Regression

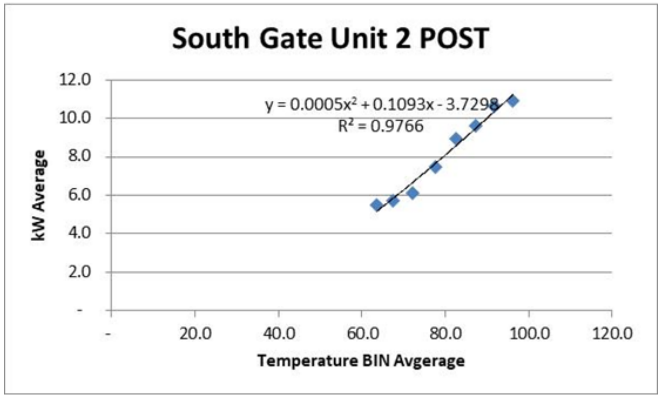

Figure 13: South Gate Unit 2 Post Regression

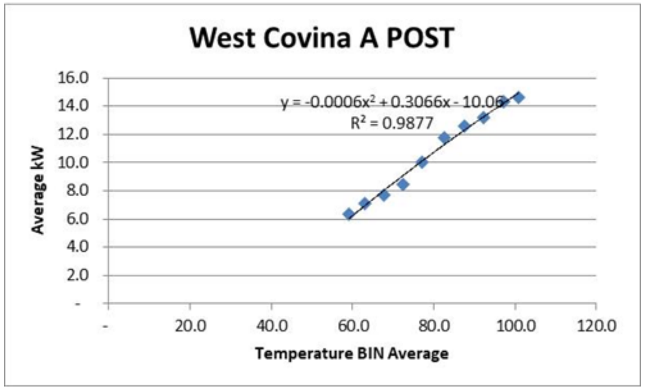

Figure 14: West Covina Unit A Post Regression

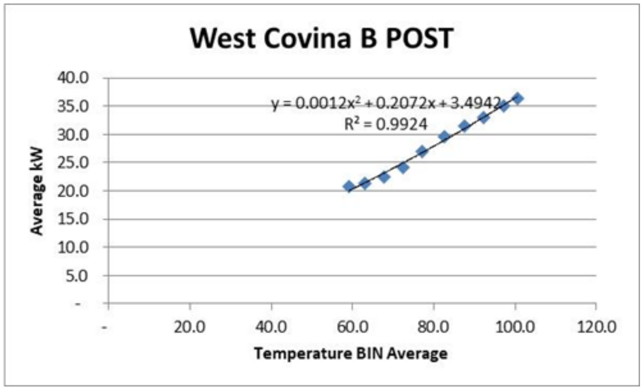

Figure 15: West Covina Unit B Post Regression

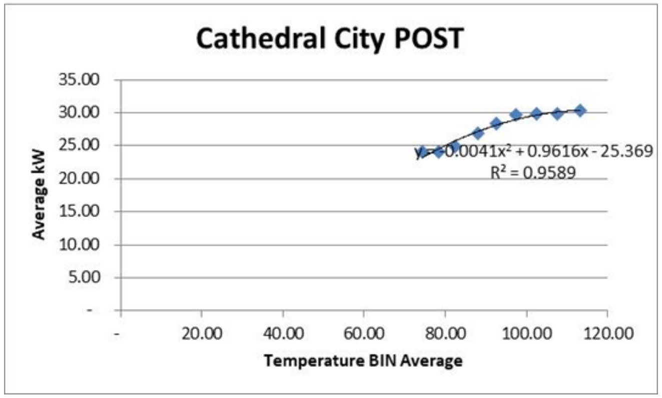

Figure 16: Cathedral City Post Regression

Annual Conversion Analysis

The project team determined annual hourly savings using the regression equations in the figures above to determine the appropriate pre and post kW using a five-year average of the weather for the specific site. Specifically, the project team:

- Downloaded an 80-month hourly temperature data file for each site from degreedays.net for the designated weather site.
- Selected five years of data; from 2019 through 2023.
- To average each hour, deleted the February 29 data from 2020.
- Averaged hourly temperature data for the five-year period.

This hourly data was then used along with the regression analysis above to calculate the pre and post KW at each hourly interval. Savings were then calculated as the difference (post KW – pre KW). The following table is an example of some of this information; complete weather files and conversion can be provided upon request.

Table 5: Example of South Gate Unit 2 Jan 1 Analysis

Date	Time	5 Year Average	Bin	Pre kW	Post kW	Savings kW
1/1/2019	0.00	50.6	2	6.14	3.09	3.06
1/1/2019	1.00	51.8	2	6.01	3.28	2.73
1/1/2019	2.00	51.7	2	6.03	3.26	2.77
1/1/2019	3.00	50.9	2	6.12	3.12	2.99
1/1/2019	4.00	50.2	2	6.19	3.02	3.17
1/1/2019	5.00	49.3	1	6.31	2.87	3.44
1/1/2019	6.00	47.0	1	6.67	2.51	4.16
1/1/2019	7.00	45.4	1	6.96	2.26	4.70
1/1/2019	8.00	48.7	1	6.40	2.78	3.61
1/1/2019	9.00	53.9	2	5.83	3.61	2.22
1/1/2019	10.00	56.4	3	5.70	4.03	1.66

Date	Time	5 Year Average	Bin	Pre kW	Post kW	Savings kW
1/1/2019	11.00	58.4	3	5.65	4.35	1.30
1/1/2019	12.00	59.8	3	5.66	4.59	1.06
1/1/2019	13.00	61.4	4	5.69	4.87	0.83
1/1/2019	14.00	61.3	4	5.69	4.86	0.83
1/1/2019	15.00	62.3	4	5.73	5.01	0.71
1/1/2019	16.00	60.9	4	5.68	4.78	0.90
1/1/2019	17.00	58.3	3	5.65	4.34	1.32
1/1/2019	18.00	55.6	3	5.73	3.89	1.84
1/1/2019	19.00	53.8	2	5.84	3.60	2.24
1/1/2019	20.00	52.3	2	5.96	3.36	2.61
1/1/2019	21.00	51.6	2	6.04	3.23	2.80
1/1/2019	22.00	50.8	2	6.12	3.11	3.01
1/1/2019	23.00	49.1	1	6.34	2.85	3.49

The project team then tabulated a full annual summary of the pre, post, and savings associated with each unit at each site.

Conversion of Annual Data

The project team inputted the data from the annual hourly analysis described above into a rate model to arrive at annual dollar savings.

For this type of analysis, the project team used the GS-TOU3-D rate schedule, breaking down the data as follows:

- Summer Season
    - Weekday for On Peak Summer
    - Weekend for Mid Peak Summer
- Winter Season

Each file was then sorted or filtered by time of day to arrive at the appropriate inputs and results that are tabulated in the following tables. All these data sets can be provided upon request.

Table 6: Energy Savings

		Long Beach			South Gate			West Covina			Cathedral City		
		Value	Rate	Annual Savings	Value	Rate	Annual Savings	Value	Rate	Annual Savings	Value	Rate	Annual Savings
Energy Summary	Summer On Peak KWH	1102	0.0494	$54	440	0.0494	$22	1556	0.0494	$77	137	0.0494	$7
	Summer Mid Peak KWH	444	0.0479	$21	137	0.0479	$7	624	0.0479	$30	47	0.0479	$2
	Summer Off Peak KWH	2885	0.0476	$137	1787	0.0476	$85	6552	0.0476	$312	-57	0.0476	($3)
	Winter Mid Peak KWH	2935	0.0494	$145	3172	0.0494	$157	5909	0.0494	$292	4538	0.0494	$224
	Winter Off Peak KWH	8766	0.0479	$420	16048	0.0479	$769	13714	0.0479	$657	11798	0.0479	$565
	Winter Super Off Peak KWH	2841	0.0471	$134	4224	0.0471	$199	6976	0.0471	$328	4664	0.0471	$220
	Totals	18,973		**$911**	25,808		**$1,237**	35,331		**$1,696**	21,126		**$1,015**
Demand Summary	Facilities Demand	1.83	22.23	$488	1.86	22.23	$497	3.5	22.23	$933	1.23	22.23	$327
	Summer On Peak KW	2.14	18	$461	0.44	18	$95	3.01	18	$651	0.26	18	$57
	Totals			**$949**			**$592**			**$1,585**			**$384**
Total Annual Savings (Energy + Demand)				**$1,861**			**$1,830**			**$3,280**			**$1,399**

Table 7: Savings Summary

Site	Key elements of the savings	Percent Savings Summary	Project Saving Summary
Long Beach	65 kWh/ft in the coolest of the CZ with a 2.42 simple payback based on installed cost and the most linear ft installed.	• Pre kWh: 140,224 • Post kWh: 121,251 • Savings kWh: 18,973 • % Unit savings: 14%	• Installation cost: $4,499.72 • Installed ft: 292 • Simple payback (years): 2.42 • Savings/installed ft: $6.37 • Savings kWh/installed ft: 65 • Savings avg w/installed ft: 7.42
South Gate	121 kWh/ft with a 1.88 simple payback based on installed cost and the second most linear ft installed.	• Pre kWh: 310,847 • Post kWh: 285,039 • Savings kWh: 25,808 • % Unit savings: 8%	• Installation cost: $3,431.84 • Installed ft: 214 • Simple payback (years): 1.88 • Savings/installed ft: $8.55 • Savings kWh/installed ft: 121 • Savings avg w/installed ft: 13.77
West Covina	232 kWh/ft which was the highest kWh savings with a 0.75-year simple payback and $21.56/ft in the third most warm CZ of the four zones.	• Pre kWh: 299,363 • Post kWh: 264,032 • Savings kWh: 35,331 • % Unit savings: 12%	• Installation cost: $2,449.60 • Installed ft: 152 • Simple payback (years): 0.75 • Savings/installed ft: $21.58 • Savings kWh/installed ft: 232 • Savings avg w/installed ft: 26.53
Cathedral City	Savings of 170 kWh/ft within the hottest CZ and a simple payback of 1.37 years.	• Pre kWh: 225,320 • Post kWh: 204,194 • Savings kWh: 21,126 • % Unit savings: 9%	• Installation cost: $1,910.84 • Installed ft: 124 • Simple payback (years): 1.37 • Savings/installed ft.: $11.28 • Savings kWh/installed ft: 170 • Savings avg w/installed ft: 19.45

Temperature Summary

The project team compared temperature data collected in pre and post periods relative to the open display case temperature and inside store temperature, to ensure that the data analysis above was not affected by large differences in the display case and store temperatures (Table 8: Temperature Summary, with detailed temperature files and analysis can be provided upon request).

Table 8: Temperature Summary

Site	Long Beach		South Gate		West Covina		Cathedral City	
Description	Case Temp	Store Temp	Case Temp	Store Temp	Case Temp	Store Temp	Case Temp	Store Temp
Pre Period Average (°F)	37.3	65.6	37.4	68.5	35.1	67.3	34.8	70.5
Post Period Average (°F)	36.6	65.6	39.5	69.1	35.5	68.8	36	72.8
% Change	-2%	0%	5%	1%	1%	2%	3%	3%

Overall, these are well within error allowances, so no further adjustments were made based on the pre and post conditions related to the case or store temperatures.

Figure 17 below is an example of a typical open display case used to install air vanes and measure the energy savings impact.

Figure 17: Typical Shelf Application Without Air Vanes

Source: Air vane manufacturer

Summary of Cooling Degree Days

Table 9 details the average five-year cooling degree days by CZ based on the store location and selected weather station.

Table 9: Cooling Degree Days (five-year average)

Store Location	CZ	Total Cooling Degree Days (CDD)
Long Beach	6	1,242
South Gate	8	1,741
West Covina	9	2,176
Cathedral City	15	5,166

Source: From California weather database for selected locations

Table 9 shows that each increase in CZ results in higher cooling requirements. As determined by the analysis for this report, the savings were found to be a variable of the outside air temperature (thus Cooling Degree Days) as well as other factors.

Audit Detail

Table 10 summarizes the overall audit for application of the air vanes at each site. Below, Tables 11 through 14 present three air vane designs for different types of display case shelves. The shelves considered have angles of 0 degrees, 15 degrees, and 17 degrees, and come in two lengths: three ft and four ft. Two air vane designs were created—one specifically for 0-degree shelves, and another for shelves with significant angles, such as 15 and 17 degrees. A third air vane design was developed for "pusher" shelves, which are designed to move older products forward for easier access by customers and to reduce waste. Pusher shelves feature spring-loaded trays that facilitate first-in-first-out stocking. However, for this project, all four sites opted not to use the third air vane design for pusher shelves due to concerns about potential breakage, interference with price tags, and hindering customer access to products

Table 10: Audit Summary Air Vane Project Table

Store Location	Total Ft.	% of Total Ft.
South Gate	214	27%
Cathedral City	124	16%
West Covina	152	19%
Long Beach	292	37%
Project Total Ft	782	

Long Beach CZ 6

Long Beach has a smaller overall store footprint when compared to the other three locations. The compressor rack (Figure 18) and located inside the electrical room. Though the store has a smaller footprint than the other sites, it had the best application (number of ft) air vane technology. Long Beach in CZ 6, is the coolest CZ of all four store locations, which is a consideration for potential energy savings.

Figure 18: Long Beach Compressor

Figure Source: Long Beach site survey picture

Table 11 shows the display case description, angle of shelf, and number of display case ft with air vanes installed at the Long Beach location.

Table 11: Long Beach, CZ 6

Description	Angle	# of 4 Ft Sections	Total Feet of Display Case with Air Vanes
FRESH JUICE	0	15	60
FRESH JUICE	17	3	12
JUICE	0	4	16
BUILT FOR YOU SNACKS	0	5	20
APPETIZERS	0	6	24
FRESH MEAT	17	4	16
CREAMERS	0	5	20
HOT DOGS	0	8	32
FRESH FRUIT	0	5	20
EGGS	0	6	24
CHEESE	0	12	48
Total Feet			292

South Gate CZ 8

South Gate had a larger footprint with a larger space to accommodate freezer and refrigerated products. The refrigeration is served by two large rooftop mounted compressor systems (see Figure 19). The systems have one controller that monitors and sets temperatures for all CZ (freezer and refrigeration). Measurement was installed on the rooftop units for purposes of establishing compressor energy consumption.

Figure 19: South Gate Rooftop Unit

Figure Source: South Gate site survey picture

Table 12Table 12 shows the display case description, angle of shelf, and number of display case ft with air vanes installed at South Gate.

Table 12: South Gate, CZ 8

Description	Angle	# of 3 Ft. Sections	Angle	# of 4 Ft. Sections	Total Feet of Display Case with Air Vanes
CREAMER	0	4			12
BUTTER			0	21	84
FRESH JUICE			0	4	16
SLICED CHEESE			0	13	52
KIDS MEAL	0	6	15	4	34
DRINKS			0	4	16
Total Feet					**214**

West Covina CZ 9

West Covina has the same footprint as the South Gate location. The refrigeration is served by two large rooftop mounted compressor systems (see Figure 20Figure 20). The systems have one controller that monitors and sets temperatures for all CZ (freezer and refrigeration). Energy monitoring was installed on the rooftop units.

Figure 20: West Covina Rooftop Unit

Figure Source: West Covina site survey picture

Table 13Table 13 shows the display case description, angle of shelf and number of display case ft with air vanes installed at West Covina.

Table 13: West Covina, CZ 9

Description	Angle	# of 3 Ft. Sections	Angle	# of 4 Ft. Sections	Total Feet
EGG END	0	4			12
PASTA			0	9	36
PASTA			15	6	24
CHEESE			0	17	68
KOMBUCHA END	0	4			12
Total Feet					**152**

Cathedral City CZ 15

Cathedral City is a large retail store with one refrigeration rack mounted on the roof (see Figure 21). Based on the initial review, there is one breaker on the panel labeled MDP-2 that provides service to the rooftop unit. The energy monitoring was installed on the roof.

Figure 21: Cathedral City rooftop unit

Figure Source: Cathedral City site survey picture

Table 14Table 14 shows the display case description, angle of shelf, and number of display case ft with air vanes installed at Cathedral City.

Table 14: Cathedral City, CZ 15

Description	Angle	# of 4-ft Sections	Total Feet of Display Case with Air Vanes
FRESH & READY	0	0	0
WATER	0	0	0
FRESH FRUIT	0	16	64
BUTTER	0	15	60
Total Feet			**124**

Stakeholder Feedback

The site owner for this project is one of the largest grocery store chains in the United States, operating about 2,000 supermarkets nationwide including more than 315 stores in California. This company has established ambitious sustainability and eco-friendly standards, particularly in energy-efficiency and demand-reduction. They have announced that by 2040, all their branded products will be designed in alignment with the principles of a circular economy. A circular economy is an economic system focused on reducing waste and promoting the continual reuse of resources, as opposed to the traditional linear economy's "take-make-waste" model. The site owner is eager to position itself as a leader in curating sustainable brands and creating eco-conscious customer experiences.

During the field assessment, the primary points of contact for the project team were the company's head of refrigeration for U.S. stores and the manager of a third-party energy services provider responsible for providing and installing air vanes. The installer assessed all four sites to ensure proper product selection and installation. Additionally, the project team interacted with operational staff at the four stores during the installation and removal of monitoring equipment. Feedback from these sources was positive, with all parties supporting the installation of the measure and recognizing the energy savings benefits. They were familiar with the efficiency measure.

Common market barriers to energy efficiency measures — such as high upfront costs, complex installation processes, significant maintenance expenses, and potential operational disruptions — were discussed with the client's main contacts: the corporate head of refrigeration for all United States stores and the manager of the energy services provider. They did not see these barriers as relevant to the air vanes, noting the air vane's low first cost, ease of installation, and absence of ongoing maintenance requirements. However, the client did express a preference not to install vanes on any shelves below 43 in from the floor, due to concerns about possible product accessibility for consumers.

Our client mentioned that utility incentives from future programs could further accelerate the adoption of these measures by improving their simple payback, which averaged 1.47 years without incentives in this assessment. They considered, as specific benefits, obtaining a better ROI and benefiting from the consumer education and market outreach that often accompany a utility incentive program. Additionally, consistent with their corporate sustainability goals, the client expressed interest in exploring options for integrating high-efficiency, low global warming potential (GWP) refrigeration systems, such as CO_2-based systems to reduce HFC use. They are also interested in opportunities for heat recovery and cloud-based smart demand optimization tools, systems, and other programs to further enhance energy efficiency across their locations.

Conclusions and Recommendations

We draw the following conclusions from this assessment:

- Overall, our field study results align with those of the previous laboratory study, though some variations were observed due to different weather patterns and CZs.
- The field assessment indicated an average of 16.79 W/ft of installed air vane, slightly lower than the 17 watts per ft recorded in the lab study.
    - For a 330-ft coverage area, we estimate annual energy savings would total 42,722 kWh/year, which is approximately 15 percent lower than the lab study (SCE 2022) estimated.
- The field study shows that air vanes are an effective technology for achieving energy savings in open refrigerated display cases. Although some reductions in peak demand were observed, the energy savings were more consistent overall.
    - Specifically, the study found total energy savings of 129.46 kWh per ft of installed air vanes across the four stores. This figure was derived by dividing the total energy savings by the total linear ft of air vanes installed. Energy savings varied depending on climate zone, ranging from 64.98 kWh/ft to 232.44 kWh/ft. On average, the four locations experienced savings of 147.1 kWh/ft of air vanes installed.
- The study also illustrates that the applicability of air vanes in open display cases varies depending on whether a store has more enclosed display cases or open shelving[4]. While some stores are shifting more products into closed-door refrigerated areas, many sections, particularly those displaying meat, produce, and some dairy products, will still need to maintain open shelving to ensure easy access for customers.

The project team recommends:

- Considering air vane technology for inclusion in a future incentive program, preferably using a deemed approach rather than a custom program. One option would be to base the incentive on the field study's average energy savings of approximately 130 kWh per linear ft.
    - Another option could involve offering different deemed incentive amounts per linear ft depending on the CZ, resulting in varied incentive levels across different regions.
- Educating customers and key market stakeholders about the benefits of air vanes—such as potential energy savings, low upfront costs, ease of installation, and available incentives—is important for driving market adoption. Highlighting these advantages in future utility programs could pave the way for air vanes to be included in a future deemed incentive program.

The project team has included examples of an expected simple payback with and without an estimated incentive in Figure 22.

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4 Note: Even closed-door display cases can benefit from air vanes to better control the space air flow but would require added research to quantify.

Figure 22: Estimated Simple Payback with No Incentives

FIELD RESULTS (FOUR LOCATIONS):	SIMPLE PAYBACK With Incentive	=	$ 12,929 / $ 8,369	= 1.5 years

For this Figure 22 example, the simple payback period is calculated by dividing the total capital cost for all four locations ($12,292) by the total annual avoided utility costs ($8,369), resulting in a 1.5-year simple payback.

A potential deemed incentive program based on the findings from this field assessment could be structured as follows: The incentive could be determined per linear ft of installed air vanes. Given the total annual energy savings of 101,238 kWh and 782 ft of vanes installed, the savings amount to 129.46 kWh per ft across the four stores. If an incentive rate of $0.08 per kWh were applied, this would result in an estimated incentive of $10.36 per installed ft of air vane. Therefore, the total incentive for this example would be calculated as $10.36 per ft multiplied by 782 ft, leading to a potential total incentive of $8,099.

The one-time incentive in this example would reduce the customer's upfront capital cost of $12,292 by the incentive of $8,099 resulting in a total cost (with incentive) of $4,190. The simple payback with incentive would be the new total capital cost of $4,190 divided by total annual avoided utility cost $8,369 resulting in a 0.5-year simple payback.

Of course, additional factors, such as program outreach, marketing costs, and customer education, TRC and TSB would also need to be considered in determining a potential deemed incentive. These values are presented here just to illustrate how such a program based on initial assumptions could influence a customer's simple payback period and the decision to install air vanes.

Figure 23: Estimated Simple Payback with Deemed Incentive

FIELD RESULTS (FOUR LOCATIONS):	SIMPLE PAYBACK With Incentive	=	$ 4,190 / $ 8,369	= 0.5 years

Clearly, the addition of a simple deemed incentive could further encourage customers to install the measure and earn a much faster payback, which is considered important to customers who must decide to purchase and fund an efficiency measure. We have also included an example of what an estimated ROI would be based on an assumed equipment useful life (EUL) of 10 years and energy cost annual increase of two percent per year. Even without an incentive, the ROI is very attractive.

Figure 24: Example Estimated ROI Without Incentive

ROI	=	NOMINAL AVERAGE ANNUAL RETURN -------------------- TOTAL NOMINAL INVESTMENT	$ 9,164 $ 12,292	= 75%

The ROI is based on the average annual avoided energy costs of $9,164 divided by the total capital cost of $12,292 yielding a ROI of 75 percent.

Table 15: Example ROI based on 10 Year EUL

Year	Undiscounted Capital Outlay Cumulative	Undiscounted Savings Annual	Undiscounted Savings Cumulative	Annual ROI
0	$12,292		($12,292)	
1	$12,292	$8,369	($3,923)	68%
2	$12,292	$8,537	$4,614	69%
3	$12,292	$8,707	$13,321	71%
4	$12,292	$8,882	$22,203	72%
5	$12,292	$9,059	$31,262	74%
6	$12,292	$9,240	$40,502	75%
7	$12,292	$9,425	$49,928	77%
8	$12,292	$9,614	$59,541	78%
9	$12,292	$9,806	$69,347	80%
10	$12,292	$10,002	$79,349	81%
Total Capital	$12,292			
Average Avoided Cost		$9,164		

Appendix

The technical Appendix for this report is included in the electronic file submitted and not included as an attachment due to size. The electronic submittal is organized as described here:

- Savings Summary Tables. This workbook provides the overall savings summaries used for this report and derived from the detailed analysis.
- Audit Details. This file folder contains the detailed audit data for the application used for the air vane installation.
- Cathedral City Analysis, Long Beach Analysis, South Gate Analysis, and West Covina Analyses. These folders each contain:
  - Workbooks with analysis details
  - Sub folders with each site's submitted temperatures, logger temperature details and summaries, and the appropriate weather station downloaded temperatures and calculation of five-year averages.
- Utility Data – This folder contains the submitted Southern California Edison data and the rate schedule used for our analyses.

The Appendix can be provided upon request.

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