Recessed LED Downlights

ET11SCE3010 Report

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Southern California Edison's Design & Engineering Services (DES) group is responsible for this project. It was developed as part of Southern California Edison's Emerging Technologies Scaled Field Placement Program under internal project number ET11SCE3010. DES project manager Yun Han conducted this technology evaluation with overall guidance and management from Teren Abear. For more information on this project, contact yun.han@sce.com.

Disclaimer

EXECUTIVE SUMMARY

Recessed light-emitting diode (LED) downlights save energy when they replace incumbent incandescent, halogen, or Compact Fluorescent Lighting (CFL) downlight technologies (SCE ET07.15 – Residential LED Downlights study). There are different types of LED downlights such as LED retrofit kits that fit into existing cans, full LED downlight kits, and screw-in replacements that work the same as the incumbent technologies, from the customer's perspective.

Southern California Edison (SCE) conducted the recessed LED downlights Emerging Technologies (ET) Scaled Field Placement project to explore whether LED downlights can achieve market penetration in SCE service territory, targeting customers who make lighting system purchasing decisions.

SCE deployed and tested LED retrofit kits and LED screw-in replacements at six customer sites with high foot traffic: two hotels, a timeshare, two homes, and a mall. A light meter was used to measure the intensity of the light and customer surveys were conducted before and after installations.

Even though the hotels operate 24/7, replacing their CFLs with LEDs did not provide significant savings because the delta in watts between the two lighting choices was small. The residential customers' existing lights were incandescent lamps, which resulted in a large delta, but the lights were operated for too few hours to take advantage of the energy savings potential. Table 1 shows the annual energy savings for the five sites.

TABLE 1.SUMMARY OF ENERGY SAVINGS

	Site	Technology	Watts (W)	Delta Watts (W)	Operating Hours (hrs)	Annual Energy Savings (kWh)
1	Hotel #1	RCFL	15.0	4.5	8,760	39.42
		LED	10.5			
2	Timeshare	CFL	26.0	18.0	541	9.74
		LED	8.0			
3	Residential #1	Incandescent	60.0	50.5	541	27.32
		LED	9.5			
4	Hotel #2	RCFL	15.0	3.0	8,760	26.28
		LED	12.0			
5	Residential #2	Incandescent	65.0	54.0	541	29.21
		LED	11.0			

During the procurement and installation of LED downlights, some barriers and issues were encountered. Screw-in directional LED lamps had a limited number of bulged reflector-type lamps available in the correct lumen package. LED PAR38 seemed to have more lumens than the smaller LED PAR30 lamps, which made it difficult to replace a 65-Watt (W) PAR38 incandescent lamp that needed fewer lumens with the LED PAR38 offered. A 6” LED retrofit kit that was procured for this project actually had a 6.125” diameter and did not fit into a 6” existing hole. Lastly, the Energy Star’s® qualified list currently contains no lamps or fixtures that can replace a 1,500-lumen fixture.

Survey responses were mostly positive and customers were happy with the new lights. Many stated that the light levels were significantly improved as shown in the light readings. A couple of pre-install comments included “uneven” lighting in the space that was also improved with LEDs. Overall, LEDs had a positive impact with better lighting space and energy saved.

One of the customers pointed out that as the incandescent lamps were dimmed, they glowed warmer, unlike LEDs that stay at a constant color temperature. Finally, the variety of fixture types and lamps available for both traditional and LED downlights can make the purchase confusing.

LED downlights do save energy, but the savings may not be sufficient to give customers a reasonable payback in some situations. Wattage reduction and how long the lights operate are major factors that should be analyzed before making a purchase. SCE recommends that perceived and real market barriers are addressed through training at SCE’s Energy Education Centers, and that numerous customer support options be offered by LED manufacturers.

ACRONYMS

CCT	Correlated Color Temperature
CFL	Compact Fluorescent Lamp
DES	Design & Engineering Services
ET	Emerging Technologies
fc	Foot-candle
K	Kelvin
kWh	Kilowatt-hour
LED	Light-Emitting Diode
LTTC	Lighting Technology Test Center
lx	Lux
RCFL	Reflector Compact Fluorescent Lamp
SCE	Southern California Edison
SSL	Solid-State Lighting
W	Watt

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INTRODUCTION

LED technology, also referred to as solid-state lighting (SSL) technology, has existed for over 40 years and has been used, historically, in small indicator lamp applications, and was available only in a limited range of colors. The technology has undergone rapid advancement in the past few years and recent developments in the technology allow for a greater range of available colors, with the ability to produce white light. This advancement, along with continuing increases in performance, is enabling the technology to be used in new lighting applications.

Consumers have taken note of the advancements in this technology, resulting in increasing demand in numerous market segments, primarily because of the potential for energy savings. Other studies of the technology in various applications yield promising results, but also reveal shortcomings. A recent Emerging Technology Assessment project conducted in 2009 showed that LED recessed downlights can perform as well as their incumbent technology while providing energy savings. The purpose of this study was to place LED downlights in high-visibility areas to gain market exposure among potential customers who are unaware of the benefits of this technology as well as to identify or address any barriers to market acceptance.

BACKGROUND

Incandescent, halogen, and compact fluorescent lamps (CFLs) have been the common technology installed in recessed downlights. The bare lamps are installed into existing cans with socket options that include Edison-based screw-ins, GU-24, and pin-based lights. Recessed cans are also available in various sizes, ranging from 4” to 8” in diameter. Downlights make up 41% of the lighting market and are used such places as common areas, lobbies, and offices. Therefore, LED downlights offer great potential to reduce energy use and peak demand.

Unlike baseline lighting, LED downlights come in different form factors. LED retrofit kit consists of an LED light engine integrated with a trim that uses the existing can and replaces the existing reflector and trim. Some downlights offer proprietary kits that require removal of the existing can and trim. Finally, a screw-in directional lamp also serves as a downlight in an existing fixture. All of the variations in recessed LED downlights serve the same purpose of lighting the general area, but each has its own benefits, as discussed in this report.

This project deploys recessed LED downlights in various market sectors where they can gain market traction in SCE service territories. The project targets the customers who work or live at the site and who make the decision to purchase a lighting system. Sites include a timeshare, hotels, a mall, and residential customers.

Installing the downlights in the field gives insight into the benefits and barriers customers experience when purchasing, installing, and using the product. This Scaled Field Placement project also benefits the Energy Efficiency program by accelerating adoption of the technology and gives SCE an opportunity to survey the customers about their experiences with new LEDs. While this project focuses on gaining market traction through customers, energy savings is also evaluated.

PROJECT/PRODUCT EVALUATED

Field evaluation of the recessed LED downlights was conducted at six customer sites across SCEs service territory. The sites include two hotels, a timeshare, a mall, and two residential homes. The commercial sites chosen were part of a large corporation where the LEDs could gain higher visibility across the nation. Working with residential customers promoted LEDs through their friends and family.

TECHNICAL APPROACH/TEST METHOD

SCE conducted all tests in the field, as described in the following sections.

FIELD TESTING OF TECHNOLOGY

The field evaluation consisted of a pre and post customer survey and foot-candle (fc) readings that spot-checked illumination where the LEDs were installed at the customer sites. Because the LED downlights had already been proven to work, this project did not fully assess the feasibility of LEDs.

TEST PLAN

Before the LED downlight installation, a survey was sent to the customers with a set of questions about the brightness, color, affects, recommendations, problems, and some miscellaneous notes. Upon installation, the same survey (found in Appendix B – Survey) was sent to the customers for their responses   SCE encouraged the customers to share the survey with employees and other customers.

The FC readings were measured at four to nine different points near and around the lights. Each point was marked with a piece of tape to take measurements at the same spot after the LEDs were installed. Because the lights were located inside rooms or hallways without windows, the sun did not interfere with the readings at most sites. Residential homes required waiting until dark to take the measurements. The readings from the light meter were recorded.

Figure 1 shows the light meter and measurement points at a customer site.

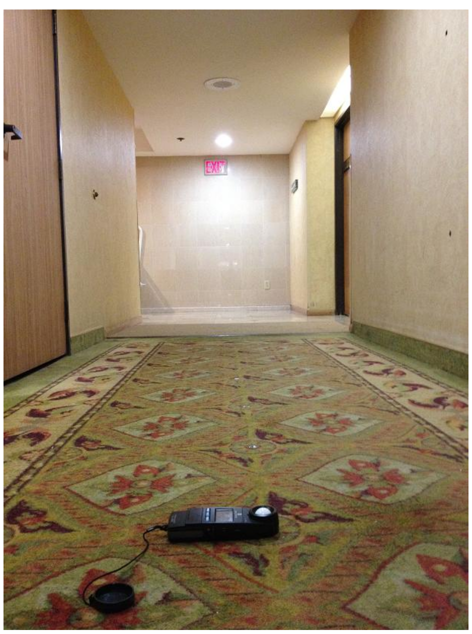


FIGURE 1. LIGHT METER & MEASURING POINTS

Variables

The variables considered in this project are defined below.

Illuminance

Illuminance is the measure of the intensity of the incident light on a surface in a given area, provided in lux (lx). For this reporting, the measurements were converted to FCs, which is a non-metric unit of illumination. One FC is equal to approximately 10.764 lx.

Light Output

Light output is the measure of light that a source provides, measured in lumens.

Instrumentation Plan

A Konica Minolta T-10 Illuminance Meter was used to measure the FCs at each installation site. This meter is designed to measure the brightness and quality of a light source striking a specific location.

EVALUATIONS

The evaluations were performed at the six customer sites as described in the following sections.

SITE #1: HOTEL #1

The Hotel #1 customer showed a great deal of interest in participating in this project because the site's downlights operate 24 hours per day. The customer had three floors of 6" recessed downlights that operated a 15-Watt (W) 700 lumen Reflector CFL (RCFL). Each floor had 85 downlights in the hallways leading to the guest rooms and the customer chose to install the lights on one floor. The RCFLs were replaced with 10.5W, 650-lumen LED downlights.

Table 2 shows the measurements taken at Hotel #1. Downlights in the hallway were arrayed in a straight line, where measurements between only two downlights were necessary. Points 1 through 5 were measured at the floor between two downlights and showed a significant rise in FCs. Points 5 through 7 were along the walls going up to the ceiling. LEDs showed lower readings at the very top of the wall because the RCFL had a wider distribution and the lamp actually protruded somewhat from the recessed fixture. This shows that a simple lumen comparison of the lamps may not be sufficient to providing an "equivalent" replacement.

TABLE 2. HOTEL #1 RESULTS

POINTS	RCFL (FC)	LED (FC)
1	7.19	9.48
2	7.65	10.18
3	7.99	10.66
4	7.96	11.42
5	4.00	5.52
6	8.45	8.69
7	4.75	3.15

Figure 2 shows Hotel #1 with LED downlights retrofitted into an existing can.

FIGURE 2. HOTEL #1 LED

SURVEY RESULTS

A couple of employees at this site had similar comments regarding their existing lighting, stating that they were dim, gloomy, and got dimmer and flickered at the end of their life cycle. Contrary to the baseline, LEDs had a much better impact on the customers. Customers did not notice any problems and the lighting was just right for the space. A combination of better lighting and energy savings is a significant improvement for this site that could lead customers to recommend this technology to others.

One survey response that was alike was the color temperature of both the CFLs and LEDs. The baseline was too warm and LEDs were somewhat warm. This issue could be solved easily with many available color temperature options.

SITE #2: TIMESHARE

The timeshare room's occupancy fluctuates throughout the season, providing an opportunity for different customers to experience the LEDs. Two similar rooms at a timeshare with seven screw-in spiral CFLs in a downlight were replaced with screw-in LED directional lamps.

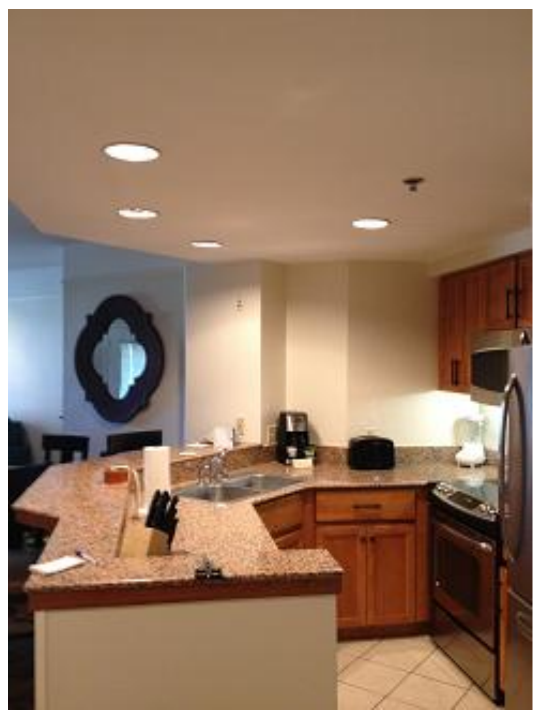
At the time of the visit to the timeshare, rooms were currently being refreshed with new paint, lights, etc. The existing lighting was a 15W, 950-lumen spiral CFL. Given the fixture efficiency of approximately 50%, an 8W, 486-lumen LED screw-in directional lamp was chosen to replace the CFL. On the day of the installation, a vacant room was offered for testing but did not have the same wattage CFLs, as these rooms had not been refreshed. The baseline changed from a 15W to a 26W CFL, hence the large variation in the light measurements, as shown on Table 3. The measurement points at this site were along the countertop in four different points spread out evenly and one point at a small table nearby.

TABLE 3. TIMESHARE RESULTS

POINTS	CFL (FC)	LED (FC)
Room #1		
1	52.01	32.09
2	49.54	26.21
3	43.43	25.86
4	38.29	24.21
5	16.85	11.49
Room #2		
1	34.02	22.53
2	37.11	23.65
3	39.06	24.55
4	44.60	28.64
5	15.46	11.78

The 26W CFL outputs more light than is needed. A typical light bulb used in recessed cans is a 15W CFL. Figure 3 shows the installation of CFL and LED screw-in lamps in a downlight application. The pictures are not representative of the light intensity because the camera auto-exposes the scene to maintain the same brightness.

CFL



LED

FIGURE 3. TIMESHARE CFL & LED

SURVEY RESULTSDUE TO A LACK OF RESPONSE FROM THE SITE, SURVEY RESULTS ARE NOT AVAILABLE.SITE #3: RESIDENTIAL CUSTOMER #1

Residential customer #1, like many potential residential customers, could benefit by switching from 60W incandescent reflector lamps to LEDs. The kitchen had hard-wired CFLs installed due to building codes. The living room, dining room, and office all had 60W incandescent lamps on dimmers, which can be replaced. Ten total downlights were replaced at the house, with four LED downlights retrofitted into the living room, as shown in Figure 4.

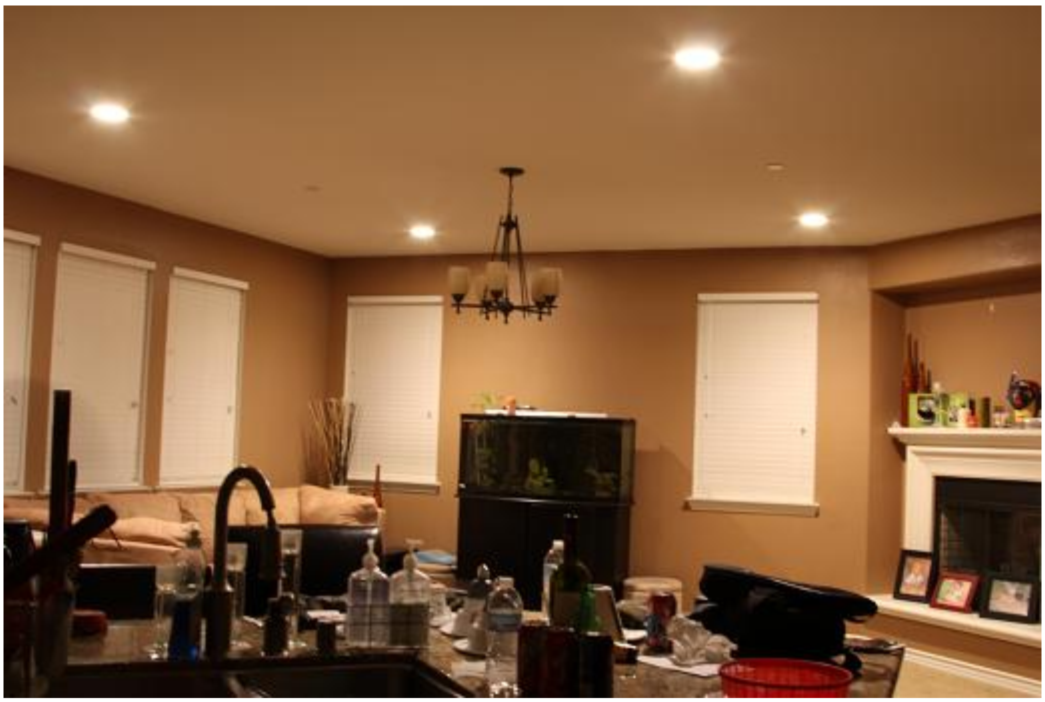


FIGURE 4. RESIDENTIAL CUSTOMER #1 LED RETROFIT

Existing lights were 60W incandescent 650-lumen lamps, and were replaced with a 9.5W, 575-lumen LED downlight. Table 3 shows significant improvement in all three rooms. With more light than before, the home saved about 85% in energy use and had the potential to save more by using the existing dimmers. The measurement points in all the rooms were taken at the work plane; coffee table in the living room, desk in the office, and dining table in the dining room.

TABLE 4. RESIDENTIAL CUSTOMER #1 RESULTS

POINTS	CFL (FC)	LED (FC)
Living Room		
1	4.27	7.37
2	3.88	6.99
3	3.09	6.51
4	3.29	5.90
Office		
1	7.32	12.99
2	7.92	13.84
3	8.27	13.92
4	8.16	15.52
Dining Room		
1	5.78	10.28
2	6.33	10.80
3	6.40	11.10
4	6.42	11.45

SURVEY RESULTS

The response from the customer was positive after replacing the incandescent lamps with LEDs. Before the installation, the incandescent lamps were somewhat dim with uneven lighting and the customer would not have recommended them to others. The LEDs had a positive impact with just the right amount of light, and the customer would recommend them.

One of the responses from the homeowner was that the color of the LEDs looked odd and green when dimmed very low. The light meter reads chromaticity coordinates that show the quality of the color, but does not detect anything unusual when measured at the dimmed work plane.

SITE #4: HOTEL #2

Hotel #2 had many CFLs in the lobby and meeting rooms. The intention was to replace all the screw-in CFLs with screw-in LEDs and the pin-CFLs with LED downlight retrofit kits.

Existing pin-CFLs in the lobby were in open-style housings, as shown in Figure 5, which required retrofit cans to install the LED downlights. The open-style housing was molded into the dry wall and measured 6” at the opening. A 6” retrofit can measured at 6.125” and did not fit into the housing. Although the existing housing could have been cut, modification to the existing housing was avoided due to cost and disruption to the customers for a project that only required a short test.

Open Style Housing

Retrofit Can

FIGURE 5. LED RETROFIT KIT

Thirty-four screw-in RCFLs in a downlight were in Hotel #2's lobby, and six screw-in RCFLs were in the meeting room. The RCFLs in both locations were 15W, 680-lumens. These were replaced with 12W, 600-lumen LED screw-in directional lamps. Figure 6 shows the lobby where the screw-in LEDs were installed.

FIGURE 6. HOTEL #2 LED SCREW-IN

The readings in the lobby were very close for RCFLs and LEDs. Although surrounding lights could not be turned off, both technologies were tested under the same ambient conditions. In the meeting room, the LED measured very high right below the light due to the 25° beam angle and lower ceiling. Screw-in directional lamps tend to come in narrower beam angles unlike the RCFLs that are available in wider beam angles. The measurement for this site was taken on the floor at various points from right below the lamp to around the lamp.

TABLE 5. HOTEL #2 RESULTS

POINTS	CFL (FC)	LED (FC)
Lobby		
1	8.32	9.10
2	10.93	11.73
3	8.55	8.28
4	11.84	11.77
Meeting Room		
1	3.49	4.82
2	4.49	14.45
3	5.21	12.67
4	5.51	19.22
5	4.91	4.33

SURVEY RESULTS

Due to lack of response from the site, survey results are not available.

SITE #5: RESIDENTIAL CUSTOMER #2

Residential Customer #2 had 19 65W incandescent bulged reflector downlights around the house that were replaced with 11W, 600-lumen LED downlights. Due to such a high baseline, the LED downlights provided great energy savings potential for the customer. Similar to Residential Customer #1 results, the results for Customer #2 showed higher FC readings at most measured points. Measurement points were all taken in various planes; kitchen counter in kitchen, floor in the living room, and countertop of the bar.

TABLE 6. RESIDENTIAL CUSTOMER #2 RESULTS

POINTS	CFL (FC)	LED (FC)
Kitchen		
1	24.54	29.05
2	20.90	26.55
3	18.34	23.81
4	9.71	13.28
5	8.21	8.95
Living Room		
1	2.34	3.30
2	2.82	4.13
3	3.35	4.56
4	3.06	4.27
5	2.55	3.77
Bar		

Points	CFL (fc)	LED (fc)
1	19.22	18.19
2	20.05	21.13
3	16.79	21.14
4	20.04	23.01
5	21.66	23.60

Figure 7 shows the kitchen with eight downlights converted to LEDs. This particular LED downlight came with bezel color options. The existing incandescent downlight trim had a black bezel that was matched for the LED downlight.

Figure 7. Residential Customer #2 LED Retrofit

The response from the customer was neutral on the brightness, color, and the impact of both technologies after replacing the incandescent downlights with LEDs. The customer's wooden furniture glowed with a rich warm color under the incandescent lamps, a feature that was lacking with the LEDs. This was most likely due to the inherent nature of the design of the white LEDs used. One of the ways to produce white light[i] is to use blue chips and yellow phosphor. This method may not fully produce the red component of the spectrum. As a result may have a reduced color rendition[ii] performance; therefore, the rich warm wood finish is not achieved.

The customer also had existing dimmers installed on all the lighting circuits. The incandescent lamps' color gets warmer as the lights are dimmed. The correlated color temperature (CCT)[iii] of an incandescent from 2,700 Kelvin (K) can drop to 1,800K when dimmed to 20%. However, when dimming the 2,700K LED, the CCT stays constant throughout, not giving a warmer glow. This may be a barrier for some people, but not everyone notices the difference.

SITE #6: MALL

The mall was lit with 48W triple-tube CFLs with 3,200 lamp lumens. According to the photometric data, the existing downlight can with the combination of the CFL only provided 1,468 lumens. The fixture efficiency was less than 50%, which wasted much of the light but was an advantage for LEDs. The LED lumens were measured at the fixture level, which provided absolute lumens coming out of the fixture. A 27W, 1,500-lumen LED downlight was the only fixture available on the Energy Star's qualified list that provided enough light to replace the CFLs.

The existing downlight could not be retrofitted with an LED and no LED retrofit kit was available with the correct specifications. The only option was to purchase a full LED downlight, which had two parts with a light engine and a frame to hold the light engine in place. This was a proprietary kit and enabled the light engine to be replaced separately, leaving the frame and the power supply intact with the ceiling. Although this was a good option, the $350 price per fixture and the fixture temporarily being off the Energy Star's qualified list during the time of the project stopped this project from moving forward.

FIGURE 8. MALL LIGHTING

ENERGY SAVINGS

Table 7 shows the energy savings for all the sites used in this study. Energy savings can be a deciding factor when switching to LEDs. Both Hotel #1 and Hotel #2 operate 24/7 with a CFL baseline.

Timeshare and residential homes use operating hours of 541 given by the California Public Utilities Commission. Although incandescent baselines offer the highest energy savings potential, the short operating hours reduce the payback opportunity.

With a savings of 3 to 4.5W per LED, which saves $4-$6 per year in energy costs, the $100 cost of a downlight makes payback challenging.

The best-case scenario for energy savings is that the customer has an incandescent baseline that operates 24/7. Operating 24/7 with a CFL baseline, or having an incandescent baseline with a short operating time, makes the payback difficult to achieve.

TABLE 7. ENERGY SAVINGS

	Site	Technology	Watts (W)	Delta Watts (W)	Operating Hours (hrs)	Annual Energy Savings (kWh)
1	Hotel #1	RCFL	15.0	4.5	8,760	39.42
		LED	10.5			
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		LED	8.0			
3	Residential #1	Incandescent	60.0	50.5	541	27.32
		LED	9.5			
4	Hotel #2	RCFL	15.0	3.0	8,760	26.28
		LED	12.0			
5	Residential #2	Incandescent	65.0	54.0	541	29.21
		LED	11.0			

RESULTS/CONCLUSION

Installing LED recessed downlights in different sites across SCEs service territory provides a good opportunity to determine what customers think about the technology. Having multiple and varying sites also helped SCE to understand the different types of fixtures, their availability, and their limitations.

Recessed LED downlight retrofit kits are straightforward to find and install given that customers have existing cans into which the LEDs can be retrofitted. Some existing downlight fixtures are proprietary; therefore, retrofitting them requires removal of the entire system before installing new downlights. LED screw-in directional lamps are also installed into existing downlight fixtures, but some manufacturers reduce the warranty under those conditions.

During the procurement and installation of LED downlights, some barriers and issues were discovered. Screw-in directional LED lamps had a limited number of bulged reflector-type lamps available in the correct lumen package. LED PAR38 seemed to have more lumens than the smaller LED PAR30 lamps, which made it difficult to replace a 65W PAR38 incandescent lamp that required fewer lumens than the LED PAR38 offered. A 6” LED retrofit kit can actually measure 6.125” and does not fit into a 6” existing hole. Lastly, no lamps or fixtures on the Energy Star’s qualified list currently can replace a 1,500-lumen fixture.

RECOMMENDATIONS

The project's intention was to deploy recessed LED downlights in various market sectors to gain market traction. Customer surveys helped provide perspective on the lighting, which traditionally is done by the project manager responsible for an assessment study. Survey results of recessed downlights installed at customer sites also yields useful information beyond the data collected using only a lab study.

One of the responses from the customers was regarding the color of the LED when dimmed. With such a big investment, unhappy customers could create a bigger barrier to market penetration. To better disseminate this information, a "Basics of LED" class taught at the Energy Education Center should include a section on dimming.

Various fixtures and lamps are available for traditional downlights, and these can be used to accommodate LED downlights. SCE recommends that the customers understand their baseline fixtures and look for the correct LED downlights to fit their needs. Most LED companies have technical support staff who are knowledgeable about the technology and can assist customers with their lighting decisions.

The mall that was included in this project did not proceed with product installation because of the high cost of the downlight. Along with the high cost, achieving energy savings using LED downlights can be a challenge when the baseline is CFLs. Customers should conduct a cost/benefit analysis before making a LED downlight purchase.

Appendix A – Equipment

The following table shows the equipment used to test the LED lighting discussed in this report.

Table 8. LED Field Test Equipment

Manufacturer	Model	Calibration	Description	Used for	Specifications
Minolta	T10W	01/30/2012	Photometric Sensor, Handheld data logger	Illuminance (lux)	0.1-200,900 lux 0.001-29,990 fc +/-2%

APPENDIX B – SURVEY

Surveys.zip

REFERENCES

[i] http://en.wikipedia.org/wiki/Phosphor#White_LEDs

[ii] http://en.wikipedia.org/wiki/Color_rendering_index

[iii] http://en.wikipedia.org/wiki/Color_temperature