Pacific Gas & Electric Company Dimming Ballast and CALCTP Midstream Trial Assessment

March 11, 2015

Submitted to:

Pacific Gas & Electric Company

Attn: Doreen Caruth
245 Market Street
Mail Stop N4Q
San Francisco, CA 94105
415.973.7535
D6CX@pge.com

Submitted by:

TRC Energy Services

Jennifer Barnes
Farhad Farahmand
Michael Mutmansky
David Douglass-Jaimes

www. trcsolutions.com

Contents

EXECUTIVE SUMMARY

The Pacific Gas & Electric Company (PG&E) Dimming Ballast and California Advanced Lighting Controls Training Program (CALCTP) Midstream Trial Program ("the Trial") provided rebates to contractors for the installation of dimming ballasts with at least 20 percent task tuning and the ability to be combined with individual or bundled control solutions. In addition, contractors were eligible to receive a bonus rebate for installations that were completed by a CALCTP-certified contractor or electrician to ensure proper installation of these products in the field. The goal of the Trial was to prime the lighting market in advance of the new Title 24 regulations that require dimming ballasts, basic controls, and certified commissioning for controls as part of most non-residential retrofits. PG&E provided rebates to installation contractors through the Trial from September 2013 to June 2014. Seven projects were installed through the Trial ranging in size from eleven ballasts to over 5,000.

PG&E engaged TRC Energy Services (TRC) to conduct an assessment of the Trial. TRC assessed the Trial through a cost-effectiveness analysis and interviews with commercial lighting manufacturers, lighting contractors, end-user facilities managers and occupants, and PG&E account executives.

Key Findings

The key findings from the Trial are summarized below.

- Manufacturers, contractors, and PG&E account executives reported they were satisfied with the Trial, and all reported that feedback from their customers indicated that the customers were satisfied with the Trial as well.
- Manufacturers, contractors, and account executives reported that customers have not had any complaints, and are generally satisfied with the new control systems. Facility managers reported being "satisfied" with the energy savings, and "very satisfied" with the energy use and lighting performance data that the control systems provide.
- Trial program projects resulted in higher than anticipated energy savings because the projects employed multiple control strategies that take advantage of the dimming ballast capabilities. Projects employed especially short occupancy delay times and systems were commissioned to ensure controls were working properly.
- Proper installation achieves greater savings potential of advanced controls. Contractor understanding of the technical aspects of the lighting system, and understanding of the intent of the lighting controls helps to ensure that the system is properly installed and performing most effectively for the occupants.
- Based on the monitored energy savings from two of the participating projects, the Trial was highly cost effective with a Total Resource Cost test of 2.42 and a Program Administrator Cost test of 5.33.
- The Trial successfully motivated the end-user customers to install the projects. The rebates and the short program window were influential in convincing the end-user customers to install projects.

- Facilities managers like and are using the controls and metering capabilities and are using them to both monitor the system operation and make adjustments in response to occupant feedback or requests.
- Some occupants reported minor problems with the operation of the lighting control systems, particularly after hours. However, none of these complaints rose to such a level of urgency that led the occupants to report the problems to facility managers.
- Non-union contractors reported difficulty completing the CALCTP trainings. One contractor said that his non-union status made it difficult to find available classes and that union participants suggested that it was not appropriate for him to attend the trainings.

Recommendations

Based on findings from the assessment, TRC recommends that PG&E consider the following recommendations:

- Continue to support contractor training and certification. The new multilevel lighting control requirements in the Title 24 Standards highlight the need for knowledgeable lighting professionals, and structured training sets a good minimum standard.
- Work to overcome non-union contractor barriers to CALCTP certification. Utilities could support CALCTP and possibly other quality training programs, by sponsoring classes within their service territories, at their energy centers, or through third-party entities that will not restrict course availability.
- Support sufficient commissioning and human comfort factors in the installation of future dimming ballast and advanced lighting controls projects. Dimming ballast and advanced lighting controls projects should include the necessary commissioning, including post-occupancy feedback on controls operation and function collected directly from the occupants.
- Explore the programmatic potential for systems that incorporate advanced controls to maximize energy savings. These systems include monitoring capabilities that the end user could use to track energy savings in support of calculated incentives.

1. INTRODUCTION

The PG&E Dimming Ballast and California Advanced Lighting Controls Training Program (CALCTP) Midstream Trial Program (the "Trial") provided rebates to contractors for the installation of dimming ballasts with at least 20 percent task tuning and the ability to be combined with individual or bundled control solutions. In addition, contractors were eligible to receive a bonus rebate for installations that were completed by a CALCTP-certified contractor or electrician to ensure proper installation of these products in the field.

Starting in July 2014, California's Building Energy Efficiency Standards (Title 24 or Standards) began requiring basic controls like occupancy sensors, daylight controls, and dimming capabilities in most retrofit and new construction applications. The goal of the Trial was to prime the lighting market in advance of the new Title 24 regulations that require dimming ballasts, basic controls, and certified commissioning for controls as part of most non-residential retrofits. The PG&E Dimming Ballast and CALCTP Trial program focused primarily on non-residential office customers since this is the biggest market for dimming ballasts in linear fluorescent fixtures.

PG&E engaged TRC Energy Services (TRC) to conduct an assessment of the Trial. In this report, TRC assesses the Trial through interviews and cost-effectiveness analysis.

1.1 Background

Dimmable Ballasts

Dimmable ballasts offer the potential to reduce energy consumption through smarter operation of fluorescent lamps by reducing wasted energy from over-lighting spaces. Dimming ballasts enable fluorescent fixtures to be dimmed continuously, resulting in energy savings and improved work experience for end-users. By incorporating building controls like photo sensors and occupancy sensors with dimmable ballasts, users can achieve their full savings potential. There are three primary control strategies for using dimmable ballasts to save energy:

- Tuning – Reduced light output to avoid over-illumination that can be achieved by factory preset reduction in light output level or field set permanent reduction in light output level;
- Occupancy Sensors (vacancy sensors) – Sensors used to dynamically adjust light levels based on occupancy in an area; and
- Daylight Harvesting – Use of photocells to sense natural sunlight in an area and to then dim or shut down lights if enough daylight is present.

California Advanced Lighting Controls Training Program (CALCTP)

The CALCTP is a statewide initiative aimed at increasing the use of lighting controls in commercial buildings and industrial facilities. Through proper installation, advanced lighting controls improve energy efficiency in commercial facilities and save significant dollars. CALCTP will educate, train and certify licensed electrical contractors, and state certified general electricians in the proper programming, testing, installation, commissioning and maintenance of

advanced lighting control systems in commercial facilities. As mentioned previously, PG&E provided a bonus rebate for installations that were completed by a CALCTP-certified contractor or electrician.

PG&E Dimming Ballast & CALCTP Midstream Trial Program

PG&E provided rebates to installation contractors through the Trial from September 2013 to June 2014. The Trial offered several levels of rebates for measure installation and using a CALCTP-certified contractor, as follows:

- Dimming ballasts with 20 percent tuning received a rebate of $10 per ballast;
- Dimming ballasts with 20 percent tuning and occupancy sensors OR daylight harvesting received a rebate of $25 per ballast; and
- Dimming ballasts with 20 percent tuning, occupancy sensors, AND daylight harvesting received a rebate of $30 per ballast.

In addition, a bonus incentive of $15 per ballast was provided if the project was installed by a CALCTP-certified contractor.

Seven projects were installed through the Trial ranging in size from eleven ballasts to over 5,000. Ballast installations and rebate type are summarized in Table 1, which shows that only two of the combined six incentive possibilities were undertaken.

Table 1. Installation Sites

Installation Site	Dimming Ballast Measure	Dimming Ballasts Installed
1	20% Tuning + Occupancy Sensor	11
2	20% Tuning + Occupancy Sensor	12
3	20% Tuning + Occupancy Sensor	16
4	20% Tuning + Occupancy Sensor	40
5	20% Tuning + Occupancy Sensor + Daylight Harvesting + CALCTP Certified Installation	765
6	20% Tuning + Occupancy Sensor + Daylight Harvesting + CALCTP Certified Installation	1,881
7	20% Tuning + Occupancy Sensor + Daylight Harvesting + CALCTP Certified Installation	5,020
	Total Installations	**7,745**

Because of the limited time frame and project funding, the program managers focused outreach to dimming ballast manufacturers. Two dimming ballast manufacturers and four commercial lighting contractors participated in the Trial. It is notable that the manufacturer whose products were installed at the three largest sites (sites 5, 6, and 7) worked with their installation contractors to secure the CALCTP certification and qualify for the bonus rebate.

1.2 Objectives

The objectives of this assessment are to:

- Solicit feedback from commercial lighting manufacturers, contractors, and PG&E sales representatives regarding their experiences with the Trial;
- Solicit feedback from end-user customers (both facilities managers and occupants) regarding their experiences with the products and systems installed through the Trial;
- Assess lighting manufacturer, contractor and end-user customer understanding of and experience with dimming ballasts, basic controls, CALCTP, and Title 24 code requirements;
- Conduct a cost-effectiveness analysis of the Trial;

- Create a case study focusing on one installation that highlights the benefits of complying with the Title 24 code requirements, including energy savings, non-energy benefits, and a pay-back analysis;
- Provide recommendations for future program design, given new code requirements and limits on claimed savings; and
- Understand how the loss of prescriptive incentives for lighting projects would affect customer retrofit projects and the manufacturers' and contractors' businesses.

1.3 Methodology

TRC used the following methods to assess the Trial:

- In-depth telephone interviews were conducted with the following stakeholders:
  - Two commercial lighting manufacturers whose products were used in the Trial
  - Two lighting contractors who installed dimming ballasts with controls through the Trial
  - Two facilities managers who had dimming ballasts with controls installed in their buildings
  - Three lighting end-users who work and/or operate the dimming ballasts with controls
  - Two PG&E account executives who represent the Trial participants
- Cost-effectiveness analysis using the Total Resource Cost[1] test and Program Administrator Cost test (PAC test).

A detailed methodology for each activity is presented in Section 4.1.

[1] A common industry abbreviation of Total Resource Cost is TRC. To avoid confusion with TRC Energy Services, this report does not use the abbreviation.

2. FINDINGS

2.1 Interviews

This section summarizes feedback from the in-depth telephone interviews with Trial participants and other stakeholders.

Participant experiences with the Trial

Interviews included discussion of participants' and other stakeholders' experiences with the Trial program, including project outcomes, commercial end-user customer satisfaction, the program administration, rebates and processes, and the implications of the potential elimination of PG&E's program offerings. (Interview guides are included in Section 4.2.)

Commercial Lighting Manufacturer Interviews

TRC interviewed two commercial lighting manufacturers whose products were used in the Trial program. Both manufacturers reported that customers are very happy with the program projects and there have been no customer complaints. One manufacturer also noted that they had very strong existing relationships with the customers and the site representatives prior to the program.

TRC asked these manufacturers if the loss of PG&E prescriptive lighting rebates, due to the code change, would affect their business. One manufacturer reported that the loss of some PG&E prescriptive incentives will make it harder to sell retrofit projects to customers. The manufacturer added that the prescriptive incentives were an easy way to sell projects to customers, and now they will have to calculate energy savings, making it more difficult to know exactly what the customer benefit will be. The other manufacturer reported their business model was not dependent on utility incentives, but acknowledged that the incentives are helpful in selling projects, and that customers like them.

Overall, both manufacturers were very satisfied with the Trial program. One reported that the Trial program was successful for them considering how quickly it was put together, and how briefly it was implemented.

Commercial Lighting Contractor Interviews

TRC interviewed two commercial lighting contractors that completed some of the larger projects in the Trial program. Both contractors reported they were already familiar with the controls systems that the Trial program used on their projects and were able to successfully install them. Both contractors reported they were very satisfied with the Enlighted control system, and have had more success with the Enlighted system than with systems from other manufacturers. Both contractors also reported that they would use the Enlighted control system again in the future.

Both contractors reported that their customers are very happy with the system, and both noted that they would be following up with the customers to ensure that everything was going well with the new systems.

TRC asked these contractors if the loss of PG&E prescriptive lighting rebates, due to the code change, would affect their business. Both contractors reported that they were very concerned about the elimination of PG&E prescriptive lighting incentives, and reported that incentives are often essential to convincing customers to proceed with retrofit projects: "*If we lose those incentives, it's going to be a huge challenge to sell these projects.*" Another contractor reported that projects have been cancelled in the past when incentives were not available. When asked for any additional thoughts or comments on the Trial program, both contractors reiterated the importance of the incentive programs to their businesses, and for retrofit projects in general.

PG&E Account Executive Interviews

TRC interviewed two PG&E account executives about their experiences with the Trial program. The interviews covered program administration, rebates, and processes, as well as experiences working with the manufacturer and contractors. The interviews also covered the perceived end-user commercial customer satisfaction with the Trial and systems, the potential implications of eliminating PG&E's prescriptive commercial lighting program offerings, and end-user commercial customer perceptions of Title 24 Building Energy Efficiency Standards regarding dimming controls. The account executives reported they only worked with the Enlighted control system in the Trial.

Both of the account executives reported that there were challenges with this Trial program. One stated that it was only offered for a very short amount of time, making it difficult to recruit and complete projects within the allotted program timeframe. The account executive added that this was not technically due to the Trial program, but was difficult to explain to the customer. One account executive noted that contractors passed on the CALCTP bonus rebate to the customers to help sell the projects. However, since the bonus rebates were not paid until the projects were verified, customers needed to wait a long time to receive these payments. One account executive also reported that one of the required pieces of documentation for the tuning controls was not clear to contractors, but did not elaborate.

Both account executives described positive experiences working with the contractors and the manufacturer. Both mentioned that both the manufacturer and the contractors were very responsive, and the process went smoothly despite the accelerated timeline of the Trial.

Both account executives also reported that the customers were very happy with the results of their installed lighting systems. One account executive reported that one project was delayed due to challenges the contractor had completing the training required for CALCTP certification, and these delays resulted in some customer frustration. The account executive suggested that this may have been the result of the manufacturer selling the project to the customer before the contractor was fully CALCTP-certified, or that the program requirements had not been clearly communicated to the manufacturer and contractor.

Both account executives reported that internal communication was successful during the program, and that the PG&E program manager was responsive and accessible. However, one account executive mentioned that they only found out about the program from the manufacturer, rather than through internal PG&E communication, though the program managers reported that the Trial intentionally targeted manufacturers. This account executive expressed a desire for better internal communication on program offerings like these. One

account executive also mentioned that they would like to still be able to offer their customers rebates for dimming ballasts, but they expect that would no longer be an option under the new Title 24 Standards requirements.

Stakeholder Experience with CALCTP and Title 24 Requirements

Interviews also included discussions of participants and other stakeholders' experiences with the CALCTP training and certification processes, and the impacts of the 2013 Building Energy Efficiency Standards, Title 24, which went into effect on July 1, 2014.

CALCTP

Manufacturer Experience

Both commercial lighting manufacturers reported that they had worked with the CALCTP-certified contractors in the Trial program previously. One manufacturer reported that all of the contractors they worked with were CALCTP-certified, and that manufacturer was happy with the training process. However, the other manufacturer reported that the contractors they worked with had inconsistent experiences with the CALCTP trainings. One manufacturer reported that a union contractor had no problems getting access to the necessary trainings, while a non-union contractor had great difficulty completing the training, because they were unable to find any organization offering the final course. The manufacturer noted that they flew this contractor to San Diego because that was the only place the training was being offered. This manufacturer also reported that they were surprised that this required course was focused on how to market CALCTP certification, and did not advance contractors' technical knowledge of controls. This manufacturer reported that one of the contractors was very happy with the CALCTP training overall, while the other contractor was frustrated with the process and difficulty of getting into the trainings. Overall, both manufacturers reported that the training provided a solid foundation on how different control types worked.

The interviewer asked manufacturers how likely they were to use CALCTP-certified contractors in the future. Because, one manufacturer had only worked with CALCTP-certified contractors, he could not say whether he had a preference for certified contractors. The other manufacturer reported that they are likely to use CALCTP-certified contractors if their customers require it, but will likely not enlist CALCTP-certified contractors without added incentives. This manufacturer also noted that one of the contractors they use most often is CALCTP-certified and that they would continue to use this contractor, although not specifically because of the certification. This manufacturer also stated that CALCTP certification guarantees a higher caliber contractor.

Contractor Experience

Both contractors interviewed reported that they are CALCTP-certified. Both contractors reported they were non-union, and both reported difficulties with the CALCTP training. One contractor stated that the difficulties with the training were specifically related to being non-union. This contractor reported that trainings were often only open to union members, and when he was able to get into training classes other attendees questioned why he was there. The other contractor found the entire CALCTP training process confusing. However, both contractors reported that the information in the trainings was useful. One of the contractors also reported that they have set up a special division within their company to support CALCTP-specific work,

and that many other contractors are coming to them in order to team with a CALCTP-certified contractor. The other contractor reported that their practices have not changed significantly as a result of becoming CALCTP-certified.

Title 24 Code Requirements

The Title 24 code sections related to dimming ballasts (sections 130(b), 130.1(d), 141(b)2I, Table 141-E, and Table 141-F) can be summarized as requiring multi-level lighting controls in most major interior spaces. In many cases, the Standards will require fluorescent lighting to have a dimmable function. Pilot participants and other stakeholders were asked how this code change would impact their business.

Manufacturer Experience

Both manufacturers reported that the new lighting controls requirements in the Title 24 code Standards have resulted in increased interest in their products. One manufacturer explained that their products are specifically designed in response to these code requirements, as a low-cost and simple alternative, and that new customer interest in products has increased since the 2013 Standards went into effect. The other manufacturer reported that the new requirements are increasing customer awareness of lighting controls. However, this manufacturer also noted that customers find the new requirements confusing.

One of the manufacturers supported the idea of using CALCTP certification as a compliance path for acceptance testing in the Standards. However, the other manufacturer indicated that requiring CALCTP certification as part of the Title 24 Standards could be very problematic considering the difficulties that one of the contractors faced in accessing the trainings necessary to complete the certification.

Contractor Experience

When asked about the new Title 24 Standards that require more lighting controls, one contractor expressed a very negative outlook, and explained that compliance with controls requirements has increased the costs of retrofit projects: "*We had to rebid to meet the new code requirements and it more than doubled the price of our system.*" This contractor added that they are trying to find ways to avoid triggering the code requirements in their retrofit projects. The other contractor was unsure of the impact of the new code requirements, as the contractor was still trying to understand all of the new requirements. However, both contractors supported the idea of using CALCTP as a compliance path for lighting controls acceptance testing in the Title 24 Standards.

PG&E Account Executive Experience

Both account executives reported that the new Title 24 code requirements will be very difficult for customers to adopt going forward. Both stated that retrofit projects will be more expensive, and less likely to move forward under the new requirements. One account executive suggested that the new requirements will reduce retrofit projects and new construction. The other account executive stated that it will be it very difficult for PG&E to meet its energy savings goals because the goals have stayed the same yet the savings they can actually claim have been reduced under the new requirements. One of the account executives reported that one of their

customers refused to retrofit their existing T12 lighting because of fears of triggering the new code requirements.

End-Use Customer Product and System Feedback

Installation

Two facilities managers were interviewed to collect feedback on the retrofit process and results of the lighting retrofit. Both managers reported they were approached by the lighting controls manufacturer with an energy savings proposition that suggested the energy savings and payback were attractive. Both managers stated they were interested in the opportunity and researched the information that the manufacturer presented, and decided to try the lighting controls as a limited project to test the implementation of the lighting controls in their facility. One manager reported that they decided to test renovation (control installation) on one floor, review results, and possibly implement more if the results reasonably matched their expectations.

Both facilities managers reported that the energy savings and payback were their primary motivation for implementing the lighting controls. Title 24 requirements were not reported to be factors in their decision because the lighting retrofits were completed before the newest Title 24 code went into effect on July 1, 2014.

Both facilities managers reported mostly positive experiences with the contractors during the lighting retrofits. However, one manager reported some problems with fixture and ceiling damage until the contractor was fully familiar with the retrofit work and the care needed to avoid damage to the workspace (at which point the issues were resolved). Facility managers reported that both projects were completed by electrical contractors at night after business hours.

Both facilities managers reported that their experience with the manufacturer (who was on-site to commission the lighting controls and provide training for the controls interface) was excellent, and the training they received enabled them to understand the controls interface and monitoring dashboard adequately to collect energy savings and other useful information.

Neither facilities manager reported any real challenges introducing the system into their management operations. The facilities managers had researched the technology and had received training through the manufacturer on the operation of the control system monitoring software. The lack of any identified problems suggests that the users are receiving adequate information to best use the lighting controls system effectively.

Operation

Both facilities managers reported that the granularity of the information and sophistication of the controls capabilities are some of the best aspects of the controls system. They added that the granularity enables reporting on both the lighting operation and the individual controls adjustments per luminaire for the entire facility. This enables adjustments for individuals who may need more light, and also generates operation and status information with enough detail to identify problems or failures in the system. While these are not specifically energy savings benefits, they are considered to be benefits of the system according to facilities managers.

Both facilities managers reported that they are very likely to install lighting controls on future projects. One stated that they have already added additional projects on their campus to implement these controls in more lighting equipment.

The facility managers stated that the lighting retrofit has been a positive experience and that they are satisfied with the results. They also reported that they had not received complaints from the occupants after basic adjustments were made to accommodate light level preferences. As noted below, occupants did have certain issues but had not yet reported any problems to facility managers.

Both facilities managers mentioned that the changes in Title 24 code requirements did not impact the projects they completed as part of this program because the lighting retrofits were completed before the newest Title 24 code went into effect, but they recognized that the multilevel requirements for renovations will be an important factor in future renovation work. The lighting retrofits they completed as part of the project do meet the requirements of the 2013 code and facilities managers reported that their experiences with this program has provided them with useful information for future renovation projects.

One facility manager stated that the changes in the code are not necessarily a major driving factor in decision-making. This facility manager explained that the company is forward thinking, and is willing to evaluate an energy and cost savings opportunity to determine whether it meets its threshold of cost effectiveness. If it does, the facility manager is inclined to make that decision.

End-User Occupant Feedback

Three occupants of retrofitted spaces were interviewed to elicit feedback on the success of the lighting retrofits in the Trial. Two of the occupant interviews were associated with projects that retrofitted office lighting, while the third occupant interview was for a retrofit in a warehouse-style storage space.

Office Occupants

The office lighting projects included retrofit of 2x4 parabolic troffers and some indirect pendants. At one site, the occupant moved onto a new floor that had completed the lighting retrofit as part of a full renovation. As a result, the occupant did not witness the lighting retrofit process. At the other site, the occupant was informed that their space was scheduled for a lighting retrofit, but specific details were not disclosed. This retrofit was completed after hours, and there were no post-retrofit issues with the operation of the space or other construction impacts. From the occupant's perspective, the retrofit had no negative impact.

Light Levels

Both occupants reported they are in a location where nearby lighting is controlled by daylight and occupancy sensors. Both occupants observed the lighting system adjusting to the daylight conditions. Neither reported the daylight control operations as disruptive.

Both occupants reported that the light level feels "*about right*" in the space. One reported that the previous light levels felt inadequate and said that task lights were also needed to perform the visual tasks in the cubical. This space also had the cubical walls replaced, reducing the wall

height from approximately five feet to four feet, which, TRC notes, can help considerably with both light level and uniformity. Therefore, it is impossible to attribute the benefits solely to the lighting upgrades. The combined benefit of the architectural and lighting changes is that the lighting feels adequate in the space and requires no supplemental sources. The other occupant reported that she felt the space was "*cheerier*" when she uses an additional task light, but only feels the need to use it at night.

One occupant stated that the lighting retrofit was a definite improvement over the previous system, and that the lighting produces less glaring conditions, though TRC notes that the occupant's perception may be caused by other aspects of the retrofit project, like surface materials or cubicle wall height. This occupant also stated that the lighting did not require any supplementation during the day (when the daylighting is supplementing the space).

Occupancy Sensors

Both occupants reported they witnessed lighting system operations, which enabled them to observe the occupancy sensor *off* or *dimming* functions. In both cases, this was perceived as a negative aspect of the lighting system; both respondents felt that the occupancy sensors should function somewhat unnoticeably, as changes to the lighting were perceived as feeling unsettling or disruptive.

The lighting system was reported to function primarily in an on-demand manner, following the occupant around the room, turning on the lights, and then extinguishing them after a fairly short delay. TRC observes that this operation suggests the possibility of aggressive energy savings in the controls system setup. However, the occupant found the aggressiveness of the short delay times after regular hours to be somewhat disconcerting, and reported that the lighting system makes the space "*eerie*" at night. The second occupant reported that the lighting controls in their space are also set aggressively, but the sensors near their desk may be improperly commissioned or possibly in a poor location because the sensors will regularly lose them, and will dim the lights while they are (still) working. The occupant reported having to wave their hands at the sensor to re-activate the occupied mode and bring the lights back.

Both occupants reported that the luminaires near them have an audible relay "*clunk*" or "*click*" sound when the lights are turning on or off after hours, and found that sound disconcerting. During the day, lights were set to remain on and dim back when unoccupied, so the relay sound was not heard. The occupants did not hear a similar sound in the previous lighting system.

One occupant reported that the knowledge that the lighting system is saving energy and company resources is a positive result and improves the company's profitability. Additionally, the occupants indicated that the energy savings are beneficial for the environment, which is a secondary benefit.

Overall, both occupants indicated that the commissioning of the occupancy sensor systems may need more attention to improve their overall satisfaction with the function of the lighting system. Neither of the occupants reported making requests to the facilities management team to make corrections or adjustments to the light levels or the controls system. However, one occupant stated that she had thought about it, and is likely to do so after discussing the system operation with the interviewer.

Warehouse Occupant

The warehouse retrofit occupant was the decision-maker on the retrofit, and was familiar with all of the details of the retrofit ahead of the replacement work. This occupant reported having other motivations for the retrofit project beyond the energy savings opportunity. The primary motivations included correcting the problems that resulted from a poorly executed lighting retrofit four years prior to achieve energy savings.

According to the warehouse retrofit occupant, this facility completed a retrofit project about four years ago in which the 400 watt high intensity discharge luminaires (approximately 455 watts with ballast losses) in the warehouse were replaced with approximately 40 linear fluorescent luminaires with six lamps each. Occupancy sensors were installed at each luminaire location to reduce the lighting during unoccupied periods. However, this project failed because the system was prone to early lamp failure. Based on the description of the problems experienced, TRC believes that the system employed instant start ballasts in the luminaires, which were controlled by the occupancy sensors and led to many early lamp failures. The warehouse retrofit occupant reported that he disabled the occupancy sensors and ran the lighting system with a time clock only.

In this context, the most recent retrofit through the PG&E Trial was anticipated by the owner to resolve the lamp failure problems, and also permit energy savings to reduce the utility bill by re-implementing the controls in the space. The warehouse does not have daylighting, and so installed occupancy sensors with a reasonably short delay time (about four minutes), and task tuning of the high light level. This tuning was set to approximately 80 percent for occupied conditions. During business hours, the occupancy sensors drop the power to 20 percent when unoccupied, maintaining a reasonable light level in the aisles for visual navigation before an occupant enters the aisle and the lights rise to the 80 percent level.

This system does employ dimming ballasts and occupancy sensors, but does not have smart lighting controls that are capable of monitoring the lighting system.

Overall, the occupant reported that the project was a success and the system appears to be functioning according to expectations. The occupant reported that the lighting system appears to be providing equivalent light levels to the previous system, but that the energy savings are much greater because the controls are being implemented (unlike the previous system, in which the controls were overridden). The occupant said that there have been only a few lamp failures in the first six months of the project completion, compared to between five and ten lamp failures per week with the previous system. The occupant also reported that the savings in time and materials for this retrofit are already considerable.

The warehouse retrofit represents one of the possible positive outcomes of a contractor training program. The previous project did not have a specifier/contractor who knew that the interaction of instant-start ballasts with the constant "*ON/OFF/ON/OFF*" switching of occupancy sensor controls would result in premature lamp failures, and ultimately a problematic retrofit. A properly trained contractor would have identified this incompatibility, eliminating the need for the second round of retrofits. Additionally, the occupant reported that the contractor made modifications to the locations of the occupancy sensors to eliminate false triggering of the luminaires in the aisles until an occupant actually enters the aisle.

2.2 Cost-Effectiveness

TRC assessed the Trial cost effectiveness through the Total Resource Cost test and Program Administrator Cost (PAC) test using a simplified version of the E3 calculator[1] developed by PG&E. TRC determined that the Trial is very cost-effective by both measures, with a Total Resource Cost test of 2.42 and a PAC of 5.33. Table 2 presents these results alongside PG&E's original pre-pilot estimates using deemed savings and cost values.

Table 2. Cost-Effectiveness Results

Test	Deemed Estimate	Revised Estimate
Total Resource Cost	0.62	2.42
Program Administrative Cost	1.04	5.33

The "Deemed Estimate" results from using the pilot *ex ante* savings claim and associated incremental measure cost (IMC). The "Revised Estimate" values were based on a combination of calculator inputs prepared by PG&E and updated values estimated by TRC using information from the Trial projects. Specifically, TRC used project proof of purchase documentation and discussions with equipment manufacturers to estimate measure costs. Revised energy savings were estimated using project monitoring data from two sites relative to an existing conditions baseline. These input parameters are given in Table 3 below. Administrative costs, rebates, and the timing of the installation of measures were based on actual Trial data, while PG&E work paper values were used for net-to-gross and estimated useful life. A detailed methodology is presented in Section 4.1.2.

TRC notes that the savings from the two projects were high as a result of an aggressive controls approach. In addition, TRC did not verify the baseline conditions assumed in the monitored savings data provided through the controls systems. Therefore, other dimming ballast projects may not achieve similar levels of savings if they are not implemented as aggressively and/or the baseline conditions are not as favorable.

Differences Between Deemed and Estimates Savings and IMC

TRC's cost effectiveness analysis resulted in an update of the deemed estimates used in the Trial work papers. As shown in Table 3, the updated values for IMC and energy savings are notably different than the deemed estimates. This section discusses the reasons for these differences.

[1] Available at: https://ethree.com/public_projects/cpuc4.php

Table 3. PG&E Deemed Estimates Compared to Revised Estimates (per ballast)

Measure	Data description	PG&E deemed estimate	Site-reported
20% Tuning + Occ Sensor	Gross measure cost	$86.58	$241.78
	IMC[1]	$65.71	$220.91
	First year kWh savings	84	719
20% Tuning + Occ Sensor + Daylighting	Gross measure cost	$139.08	$193.19
	IMC[1]	$118.21	$172.32
	First year kWh savings	128	725

[1] *Note that the (IMC is calculated as the difference between gross measure cost (GMC) and base measure cost (BMC). The BMC for all estimates is $20.87 (the value deemed in the PG&E work paper). The IMC is the cost figure input into the Total Resource Cost calculation.*

The work papers for the Trial indicate that the energy savings estimates are based on a meta-study of lighting controls studies that was conducted in 2011 by Lawrence Berkley Laboratory. [2] The Trial used the tuning savings as the sole source of energy savings, which, the work paper conservatively assumes to be 20 percent, while the LBL study shows approximately 36 percent energy savings on average. The total savings observed in the Trial projects result from the combination of several different controls strategies in addition to institutional tuning. With no other combined controls measures included, the savings predictions in the work paper is understandably low.

Furthermore, the PG&E work paper assumes code baseline controls for the "before" condition. The impact of the differences in lamp and ballast wattages, changes in occupant sensor delay times, and the addition of daylighting, are difficult to establish without accurate metering of the affected areas in the baseline condition. It benefits the controls manufacturer to show large savings due to their system, and it is difficult to verify or challenge assumptions that the commercial lighting manufacturer's energy savings calculator is making for baseline conditions. In an overdesigned lighting system, excess loads can be trimmed to a comfortable level easily, achieving up to 50 percent savings simply due to tuning. Thus, the high controls manufacturer reported savings estimates are not unreasonable, but are dependent on the actual baseline condition of the buildings.

[2] Williams, A., Atkinson, B., Garbesi, K., & Rubinstein, F. (2011) A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings. Lawrence Berkeley Laboratory.

The site-reported IMC may be higher than the deemed IMC for two reasons; the work plan treatment of labor for dimming ballast commissioning, and the cost of functionality in the controls systems that extend beyond a minimally code-compliant system:

- The work plan assumes that the ballast installation cost is equal for a fixed output and dimming ballast, including 20 percent tuning. However, fixed output ballasts cannot accommodate tuning, and thus do not have any costs associated with tuning commissioning. As a result, the site reported labor costs are likely higher than predicted due to the time spent tuning the ballasts.
- The controls system includes more functionality than a minimally code-compliant dimming ballast system. For example, the controls system includes a control module for each ballast, ties each ballast into a building-wide network for control and data collection, and displays these controls and data via a graphical user interface. These functionalities and associated costs are not required for a minimally code-compliant system based on the 2013 Code. Since the work plan estimates costs associated solely with dimming ballasts and sensors, any extra hardware and installation costs associated with this functionality is not included in the deemed IMC estimate.

3. CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the key findings from the Trial assessment and TRC's recommendations for future activities for PG&E.

3.1 Conclusions

Participants and other stakeholders were satisfied with the Trial. Manufacturers, contractors, and PG&E account executives reported they were satisfied with the Trial, and all reported that feedback from their customers indicated that the customers were satisfied with the Trial as well. Facility managers reported positive experiences with manufacturers and contractors, and stated that projects were completed with minimal interruption of day-to-day activities.

Participants are satisfied with the control systems. Manufacturers, contractors, and account executives reported that customers have not had any complaints, and are generally satisfied with the new control systems. Facility managers reported being "*satisfied*" with the energy savings, and "*very satisfied*" with the energy use and lighting performance data that the control systems provide. Occupants also reported that they are satisfied with the control systems. However, some of the improved light quality may have resulted from increases in light levels and uniformity, and not solely from the result of the new lighting controls.

Energy savings were higher than PG&E projected because projects leveraged multiple lighting control strategies. Trial program projects resulted in higher than anticipated energy savings because the projects employed multiple control strategies that take advantage of the dimming ballast capabilities. Projects employed especially short occupancy delay times, particularly after hours, and systems were commissioned to ensure controls were working properly.

Proper installation achieves greater savings potential of advanced controls. Contractor understanding of the technical aspects of the lighting system, and understanding of the intent of the lighting controls helps to ensure that the system is properly installed and performing most effectively for the occupants. When occupants are satisfied with the lighting controls system operation, they are less likely to request changes to the settings or disable the system. A properly functioning lighting and control system is likely to have higher persistence of savings, as the controls are unlikely to be changed unless there is a perceived problem that needs to be addressed.

Based on the monitored energy savings from two of the participating projects, the Trial was highly cost effective. TRC determined that the Trial is very cost-effective with a Total Resource Cost test of 2.42 and a Program Administrator Cost test of 5.33.

The Trial successfully motivated the end-user customers to install the projects. Contractors and PG&E account executives reported that the rebates and the short program window were influential in convincing the end-user customers to install projects.

Facilities managers like and are using the controls and metering capabilities. The controls enable them to both monitor the system operation and make adjustments in response to occupant feedback or requests. The low incidence of reported problems suggests that the users

are receiving adequate training and information from the manufacturer to use the lighting controls system effectively.

Some end users reported frustration with the occupancy controls, particularly after hours. These issues included minor problems operating the lighting control systems, problems being detected by the occupancy sensors, dissatisfaction with the after-hours settings, which turned all lighting completely off when sensors did not detect occupants, and an audible "*click*" sound that was distracting. However, none of these complaints rose to such a level of urgency that led the occupants to report the problems to facility managers. These findings suggest that the overall occupancy sensor commissioning in these spaces appears to be less than ideal. It is difficult to establish a perfectly functioning system with just one run of the controls, especially before the occupants have had time to become familiar with the lighting control system.

Non-union contractors faced challenges completing CALCTP certification. Both contractors reported difficulty completing the CALCTP trainings. One contractor said that his non-union status made it difficult to find available classes and that union participants suggested that it was not appropriate for him to attend the trainings, making him feel unwelcome.

3.2 Recommendations

Based on findings from the assessment, TRC recommends that PG&E consider the following recommendations:

Continue to support contractor training and certification. The new multilevel lighting control requirements in the Title 24 Standards highlight the need for knowledgeable lighting professionals, and structured training sets a good minimum standard.

Work to overcome non-union contractor barriers to CALCTP certification. Work with CALCTP to ensure that training courses are available to all interested contractors and lighting professionals. Utilities could support CALCTP and possibly other quality training programs, by sponsoring classes within their service territories, at their energy centers, or through third-party entities that will not restrict course availability. Utilities should ensure that trainings are available regularly and throughout the state.

Support sufficient commissioning and human comfort factors in the installation of future dimming ballast and advanced lighting controls projects. Occupants and building owners may override or disable lighting controls that are disruptive or bothersome. Proper commissioning can correct these problems. The utilities should ensure that dimming ballast and advanced lighting controls installation contractors are properly trained. Trainings should include sufficient discussion of proper commissioning for lighting controls, consideration of human factors in programming controls, such as the types of activities in the space, and appropriate delay times. Dimming ballast and advanced lighting controls projects should include the necessary commissioning, including post-occupancy feedback on controls operation and function collected directly from the occupants. This feedback should be gathered after the occupants have had time to experience the operation of the controls, perhaps one to two months.

Explore the programmatic potential for systems that incorporate advanced controls. These systems facilitate multiple controls strategies to maximize energy savings from lighting controls.

In addition, these systems include monitoring capabilities that the end user could use to track energy savings in support of calculated incentives.

4. APPENDIX

4.1 Methodology

This section describes the methodologies TRC used to conduct the assessment of the Dimming Ballast Trial.

4.1.1 Interviews

TRC conducted in-depth interviews with Trial participants and market actors. The objectives of these interviews were to:

- Solicit feedback from commercial lighting manufacturers and contractors regarding their experiences with the Trial;
- Solicit feedback from the PG&E account executives regarding their experiences with the Trial;
- Solicit feedback from end-user customers (building managers and occupants) regarding their experiences with the products and systems installed through the Trial;
- Assess lighting manufacturer, contractor and end-user customer understanding of and experience with dimming ballasts and basic controls in linear fluorescent fixtures and CALCTP;
- Assess lighting manufacturer, contractor and end-user customer awareness and understanding of Title 24 code requirements.

The interviews focused on the stakeholders of the three largest installations because these installations were completed by CALCTP-certified contractors and these stakeholders likely had more interaction with the Trial.

TRC developed unique interview guides for each interviewee type. TRC sent advance emails requesting interviews and offering an incentive in the form of a $100 gift card to all participants except the PG&E account executives. Interviews were conducted between August and November of 2014 and generally lasted approximately 10 to 30 minutes in length. Table 4 details the number and type of interviews completed.

Table 4. Interview completions by stakeholder type

Stakeholder	Number of Participants	Interview Targets	Interview Completions
Commercial lighting manufacturers	2	1	2
Commercial lighting contractors	4	2	2
End-user customers / installation sites (Facilities managers and occupants)	7 (sites)	5	5
PG&E sales representatives	4	2	2
Total	17	10	11

4.1.2 Cost-Effectiveness Analysis

As presented in Section 2.2, TRC assessed Trial cost effectiveness by the Total Resource Cost[3] test and Program Administrator Cost (PAC) test using a simplified version of the E3 calculator[4]. This modified E3 calculator was developed by PG&E's Demand-Side Analytics Group as a tool to assist the Lighting program managers to develop the Trial. TRC developed the calculator inputs as described in the sections below.

The following sections describe the sources of calculator inputs or the methodologies used to develop the inputs, where applicable.

Installation Timing

Table 5 illustrates the timing of the ballast installations, using applicant data.

[3] A common industry abbreviation of Total Resource Cost is TRC. To avoid confusion with TRC Energy Services, this report does not use the abbreviation.

[4] Available at: https://ethree.com/public_projects/cpuc4.php

Table 5. Ballast installation timing

Dimming Ballast Measure	2013 Q4	2014 Q1	2014 Q2	2014 Q3
20% Tuning + Occupancy Sensor	63	16	0	0
20% Tuning + Occupancy Sensor + Daylight Harvesting + CALCTP Certified Installation	0	0	4,968	2,698
Total				**7,745**

Rebate Costs

Rebate costs were $25 per ballast for task tuning and occupancy sensors and $30 for task tuning, occupancy sensors, and daylighting. Projects received an additional $15 per ballast if the project was installed by a CALCTP-certified contractor.

Administrative Costs

PG&E provided TRC with the costs for administering the Trial. The costs cover planning and development of the Trial, outreach to PG&E account executives to educate them on the Trial, manufacturer, contractor, and participant and end-user support during the recruitment and installation of projects, and processing and delivery of the rebates. Two PG&E Product or Program Managers were supported by a third-party consultant who provided time from two of their employees. These costs were incurred over the full 2013 calendar year through July 2014 and are provided in Table 6 below.

Table 6. Administrative cost summary

Employee	Full-Time-Equivalent Spent on Trial	Monthly Rate	2013 Cost (12 months)	2014 Cost (7 months)	Totals
PG&E Employee #1	0.15	$8,333	$15,000	$8,750	$23,750
PG&E Employee #2	0.15	$5,833	$10,500	$6,125	$16,625
Consultant #1	0.25	$14,783	$44,349	$25,870	$70,219
Consultant #2	1	$5,000	$60,000	$35,000	$95,000
		Total	**$129,849**	**$75,745**	**$205,594**

Incremental Measure Cost

The PG&E project team provided application documentation to TRC, including project invoices for most projects. It was necessary to estimate some of the project cost elements because the proof of purchase documentation was inconsistent across the projects (as shown in Table 7). TRC estimated the missing cost components, as follows:

- Various costs were unavailable for installation sites 1 to 4. These costs, shown italicized and shaded in Table 7, were estimated from the available data. Specifically, the labor cost from site 1 was used to estimate a per ballast labor cost that was applied to sites 2 to 4. The equipment costs from sites 2 to 4 were used to develop a per ballast equipment cost that was applied to site 1.
- The commercial lighting manufacturer associated with installation sites 5 to 7 provided invoices with detailed labor costs in the project documentation, and verbally reported costs of $31.85 per ballast to TRC. TRC added an 8.125 percent sales tax to the ballast costs.

The resulting average gross measure costs are estimated to be $242 per ballast for sites 1 to 4, and $193 per ballast for sites 5 to 7. TRC estimated costs separately for the two groupings of projects because of the different scales. We believe that it is reasonable for the costs to be lower for the larger projects because it is likely that these installations benefitted from economies of scale.

Table 7. End-user Commercial Customer Costs

Installation Site	Ballasts installed	Controls + materials	Ballasts	Labor	Gross measure cost / ballast	Average gross measure cost / ballast
1	11	*$2,487*		$330	$256	$242
2	12	$2,141		*$360*	$208	
3	16	$2,864		*$480*	$209	
4	40	$9,238		*$1,200*	$261	
5	765	$99,916	$26,345	$26,775	$200	$193
6	1,881	$235,993	$64,778	$60,192	$192	
7	5,020	$653,521	$172,878	$140,560	$193	

Energy Savings

TRC calculated kWh savings using post-installation monitored energy savings provided by installation sites 5 and 6. The facility managers for these sites provided TRC with energy usage reports for their projects pulled from the manufacturer's control system. One report is for the month of October, and another is for the week from August 7, 2014 through August 13, 2014. The manufacturer's software monitors the control level of each ballast (or group of ballasts) and uses this information to calculate the load of the ballasts. The software then integrates this over the analysis period to calculate the energy consumption in the period. In the reports provided, that information is shown as "Energy Usage". There are three additional values shown, "Task Tuning", "Daylight Harvesting" and "Occupancy", which combined indicate the total baseline energy consumption for the space and the savings attributed to each individual measure. As a result, the monthly reports provide information as a comparison to the pre-retrofit baseline in addition to the current energy consumption calculations that are actively being monitored. There are three sources of uncertainty in the reports:

- The baseline energy is presumably established by an audit before the retrofit work is done, but the conditions of the baseline lighting system operation are not clearly defined and it may be possible to have considerable error in the estimation of the baseline. It is not expected that the baseline information is based on a rigorous monitoring period before the retrofit occurs.
- The current energy consumption is based on a calculation of the anticipated load of the ballast at any given control setting. This translation is predictable and repeatable as long as the actual ballasts used on the project are tested and a specific ballast response curve created for the control system to apply. However, if a more generic response curve is applied, error can begin to increase considerably.

- The savings attributions that are indicated in the reports are difficult to quantify accurately because the energy savings from the various controls strategies overlap. This means that if you install occupancy sensors you can achieve savings of 25 percent or if you install daylight sensors you can save 50 percent, but if you install them both together, the savings may only be 60 percent. This is because when the lights are shut off by the occupancy sensor, the daylighting savings opportunity is eliminated.

The per ballast savings estimated from the monitoring for sites 5 and 6 was applied to site 7 since these have the same measure type (tuning, occupancy sensors, and daylighting).

As noted above, the manufacturer's software estimates the savings attributable to task tuning, daylight harvesting, and occupancy sensors. TRC applied the portion of savings from task tuning and occupancy sensors (99.2 percent) to sites 1 to 4 (removing the 0.8 percent of savings attributed to daylight harvesting).

TRC used PG&E's deemed demand and therm savings estimates because the monitored data provided by installation sites did not provide reasonable demand savings estimates.[5] The energy and demand savings inputs are provided in *Table 8*.

Table 8. Annual Energy Savings Estimates

Measure	Average reported kWh	Deemed kW	Deemed therms
20% Tuning + Occ Sensor	719	0.02	-0.68
20% Tuning + Occ Sensor + Daylighting	725	0.06	-1.29

Other Calculator Inputs

TRC used PG&E's estimates for the calculator inputs:

- Indoor lighting end-use profiles
- Annual gas savings profiles
- Estimated useful life of 8 years
- Net-to-gross of 0.70

4.2 Interview Guides

The following interview guides were used to understand the participants' and other stakeholders' experiences with the Trial, assess their understanding of and experiences with

[5] Pacific Gas & Electric Company, Customer Energy Solutions Department (March 2013). Work Paper PGECOLTG176, Dimmable Fluorescent Ballasts.

dimming ballasts (including basic controls in linear fluorescent fixture) and CALCTP, and assess awareness and understanding of the recent Title 24 code requirements. The interviews began with an introduction similar to the following:

> *"Hello, we are TRC Energy Services, a consultant hired by PG&E to assess the Dimming Ballast Trial Program. We'd like to request 20 to 30 minutes of your time to provide feedback based on your experience in PG&E's Dimming Ballast Trial Program. Your feedback will not be attributed to you or your company, and will not affect your future participation in any PG&E incentive programs. In return for your time, we are offering you a $100 incentive."*

And at the end of the call, we asked for the name and address to which the incentive should be sent:

> *"As we mentioned at the start of the call, we will compensate your time with $100, which can be sent directly to you in the form of an AMEX gift card. Please verify your name and provide us with the mailing address to which we should send the gift card."*

Manufacturer

Interviewer:
Interviewee (name, title, company):
Date, time, and duration:

1. How and why did you initially become involved with this Trial Program?

2. How did you identify contractor candidates for this project? Was their participation in a contractor's union a factor?

3. What was your experience with the CALCTP training program and staff? Were there any difficulties, or was it a straightforward process?

4. How likely are you to use a CALCTP-trained contractor in the future? What are the advantages and disadvantages of using a CALCTP-trained contractor?

5. Please describe your experience working with the contractor(s). How did they respond to the CALCTP training (if applicable)? Were they proficient in working with your system? Do you think the training helped the contractors understand your system better?

6. How did you find the sites for your system installation?

7. How did you determine what types of equipment to install in these projects?

8. How would you characterize your interactions with the site representatives at the installation location? Please describe any benefits or difficulties with the sites selected for the system installations.

9. Have you received any feedback from the end-users since the systems were commissioned? Have any adjustments been necessary? Please describe.

10. Will the 2013 Title 24 code (effective July 1, 2014) affect your business or products? How so? (It requires multi-level controls for linear fluorescent lighting systems, if you replace over 40 luminaires per year).

11. Will the phase out of several PG&E incentives for lighting controls impact your business?

12. Is there anything else you would like to share about your experience with the Trial Program?

13. CALCTP has been tentatively approved in Title 24 as a method of becoming a Lighting Controls Acceptance Test Technician. Do you think making CALCTP certification required for electrical contractors is a good idea? What issues do you think this would create?

Commercial Lighting Contractor

Interviewer:
Interviewee (name, title, company):
Date, time, and duration:

1. How and why did you initially become involved with this Trial Program?

2. Are you part of a contractor's union?

3. Please describe your experience getting certified with CALCTP. Was the process straightforward or difficult?

   a. Was it a valuable experience? What was the most useful information in the training?

4. Have you changed your business practices since you received your CALCTP certification? Have you changed the recommendations you make to your customers? In what way?

5. CALCTP has been tentatively approved in Title 24 as a method of becoming a Lighting Controls Acceptance Test Technician. Do you think making CALCTP certification required for electrical contractors is a good idea? What issues do you think this would create?

6. Please describe your experience with installing and commissioning dimming ballasts, tuning, occupancy sensors, and daylight sensors. Have you encountered any challenges, or is it straightforward?

a. [IF ENCOUNTERED PROBLEMS ASK]: Tell me more about that. Were those challenges specific to the manufacturer system or the space in which it was installed?

7. Please describe your experience with the manufacturer's lighting system. What were the best aspects of the system? What were the drawbacks of the system?

8. How likely are you to specify the manufacturer's system again?

9. What are your perceptions of the end-user/building manager experience with the installation process through this trial program? How satisfied do you think they were with the process?

10. Have you received any feedback from the end-users since the lighting systems were commissioned? Have any adjustments been necessary? Please describe.

11. Are there any plans for you to check back with the customer to see if the lighting system is operating correctly? Please describe.

12. How do you think the 2013 Title 24 code change effective July 1, 2014 will affect your business? (It requires multi-level controls for linear fluorescent lighting systems, if you replace over 40 luminaires per year). Do you expect to see more or fewer projects? Will it change the type of equipment you specify or install?

13. How will PG&E's phase out of incentives for lighting controls (such as deemed occupancy sensors) impact your business?

14. Is there anything else you would like to share about your experience with the Trial Program?

End-user Customer

Interviewer:
Interviewee (name, title, company):
Date, time, and duration:

Questions for building managers

1. How did you get involved in the Trial Program?

2. What motivated you to make these lighting upgrades?

3. Please describe your experience working with the contractor. Did any challenges arise during the installation, or was it a straightforward process?

a. If applicable, please describe your experience working with the manufacturer.

4. How satisfied are you with the lighting upgrade?

5. What are the best aspects of the system (the dimming ballasts, tuning, daylight sensors, and occupant sensors)?

6. What challenges have you experienced with the system?

7. Based on your experience with this project, how likely is it that you would use this manufacturer's system again?

8. What lessons did you learn in working with this lighting technology?

9. What feedback have you received from the building occupants on the lighting system? How satisfied do you think they are with the system? Have you received any complaints?

10. Are you aware of the recent Title 24 building code change that took effect on July 1, 2014 requiring multi-level controls for linear fluorescent lighting systems, if you alter or modify a significant number of luminaires? How do you expect this will impact your operations or facilities management?

11. Is there anything else you would like to share about your experience with the Trial Program?

Questions for occupants

1. How were you informed that lighting upgrades were going to be made? What was your initial reaction?

2. Have you noticed any differences from the previous lighting? What are those differences? Has it affected your work?

3. Does the lighting system provide too much, too little, or about the right amount of light?

4. Have you noticed the daylighting sensors and occupant controls for the new lighting system? If so, please describe your experience with these controls.

5. What are the best aspects of the system? What are the challenges with the system?

6. Have you or will you request the building management to change anything about the new lighting?

7. Is there anything else you would like to share about your experience with the Trial Program?

PG&E Account Executives

Interviewer:
Interviewee (name, title, company):
Date, time, and duration:

1. Were there any challenges in working with the Trial Program, or was it a straightforward process?

2. Please describe your experience working with the manufacturer and contractor in the Trial Program.

3. Do you think the deemed savings levels for dimming ballasts are appropriate or not? Tell me more about that.

4. What kind of feedback did contractors provide on dimming ballasts or CALCTP?

5. What kind of feedback did contractors provide on receiving incentives through the Trial Program?

6. How do you think the recent Title 24 building code change that took effect on July 1, 2014 will impact your customers' business operations? This is the code change requiring multi-level controls for linear fluorescent lighting systems.

7. What kind of feedback have customers provided on the 2013 Title 24 regarding dimming ballasts?

8. Are there any plans for you to check back with the customer to see if the lighting system is operating correctly? Tell me about that.

9. Is there anything else you would like to share about your experience with the Trial Program?

4.3 Case Study

Oracle Enlists PG&E Trial Program to Shine a Light on Energy Savings

Oracle is one of the nation's top software and engineering companies, with offices throughout the country. Its headquarters, located in Redwood City, California, consists of multiple buildings. By early 2013, Oracle was investing significant money and energy into the facility just to keep the lights on. With advances in lighting technology creating greater opportunities for energy savings each day, and the increase in efficiency requirements under the new California building code, Oracle recognized that it was time to find a solution, and enlisted Pacific Gas & Electric Company (PG&E) to help.

Energy Code and System Performance Call for a Change

Oracle's headquarters in Redwood City, CA

According to Oracle's Senior Building Operations Manager, Chuck Stathis, Oracle's lighting system had become obsolete. While Mr. Stathis recognized the need to upgrade Oracle's lighting system, he also understood that such a retrofit would require changes beyond just new ballasts. The 2013 California Building Energy Efficiency Standards, also known as Title 24 Part 6, require multi-level controls for linear fluorescent lighting systems when altering or modifying a significant number of luminaires.[6]

Through its own internal studies, Oracle has found that employees spend between 35 and 65 percent of their time at their workstations. Thus, the company required a lighting system that would both keep employees comfortable and turn off lights as necessary.

When the Oracle team wanted to upgrade to a control-based lighting system, they engaged lighting manufacturer Enlighted for their lighting controls system, and retrofitted 764 of their fixtures. Enlighted completed the retrofit in two phases during June of 2014, which encompassed six floors across three buildings.

> "We're very satisfied with both the energy savings and the quality of light we are getting, and we plan on rolling out the system to more of our buildings."
>
> Chuck Stathis, Senior Building Operations Manager, Oracle

The newly installed GE ballasts were first tuned down, meaning that each fixture receives lower levels of power than is standard. Fixtures typically receive more power than is necessary to provide adequate lighting levels. Tuning can generate energy savings and improve comfort levels. Tuning adjustments are set manually and are not dynamic (typically reducing foot candles from 35-50 foot candles to 25-30).

The new lighting system also included an occupancy sensor for each fixture and daylight harvesting sensors. Occupancy sensors turn fixtures off when there is no motion in the nearby space after a programed period of time. Daylight sensors dim electric lighting when the natural lighting through windows and skylights is sufficient to light the space.

Cost Savings and Improved Comfort

[6] Sections 130.(b), 130.1(d), 141(b)2I, Table 141-E, and Table 141-F.

Oracle initially set the project budget at $233,000. With the aid of tax incentives and incentives from PG&E's temporary dimming ballast trial program, Oracle reduced the net cost of the project to $179,000, or $234 per fixture. Despite what seems like a high price per fixture, Oracle's expected payback period is very fast. Compared to their previous system, Oracle estimates annual electricity savings of over 770 kWh per fixture, or 580,000 kWh across the facility. The majority of the savings come from tuning and motion sensor improvements, which represent 57 percent and 42 percent of the energy savings, respectively.

Project Cost: $179,000

Annual Electricity Savings: 580,000 kWh

Payback Period: 2.5 years

ROI: 40%

At Oracle's electricity rate, the dimming ballasts provide about $72,000 in electricity savings per year. This translates to a simple payback of 2.5 years, and an exceptional annual return on investment (ROI) of 40 percent. Even without PG&E's incentives, the simple payback would have been 3.2 years. Because of the success of this project, Oracle is planning on capitalizing on the high ROI and expanding dimming ballasts to more of its buildings in the near future.

Chuck is very satisfied with the energy and cost savings, and the quality of light in the space. Enlighted completed the installation without disrupting occupants, performing work after hours. Chuck especially appreciates Enlighted's graphical user interface, which is capable of reporting the system's performance down to the fixture. These functionalities allow him to monitor his lighting system and evaluate energy use better than before. Employees have noticed the change, and are happy with it. The floor is brighter, employees have less glare on their monitors, and there is no need to manually adjust lamps in over- or under-lit spaces.

Enlighted system sensors, courtesy of Enlighted.