Final Report

Lighting Controls Training Assessment

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Executive Summary

Experts agree that there is great potential for energy savings through more efficient lighting and lighting control systems in California nonresidential buildings. A recent publication[1] theorized that developing installers' skills specific to advanced lighting controls can go a long way toward realizing those potential savings.

This *Lighting Controls Training Assessment* takes a largely qualitative look at manufacturer training and specialized energy training centers, specifically the California Advanced Lighting Controls Training Program (CALCTP). Other projects underway look at other, related issues.[2]

Project Focus

The overarching questions this assessment addressed are:

- What issues do installers face in the field that can have an impact on the quality of installations?
- What is work quality in the context of lighting control installations; how can this be measured?
- How do the lighting controls installation training opportunities available to the general population of installers compare in terms of key characteristics, specifically comparing CALCTP installer training and manufacturer training?

See *Research Questions* (p. 28) for a summary of the specific research questions we addressed and the information sources for each question.

Through the course of this assessment it became clear that many manufacturers who provide installer training for the general population of installers also provide more rigorous training for installers who are members of in-house installation teams or are employed by manufacturer agents, value-added retailers (VARs) or other organizations closely affiliated with the manufacturer. This includes training for individuals in the affiliated organization who serve as certified technical representatives, certified field technicians, and certified commissioning agents for the manufacturer.

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1 Jackson, Cori / California Lighting Technology Center, Doug Avery / Southern California Edison, and Mark Ouellette / ICF Inc. *California's Advanced Lighting Controls Training Program: Building a Skilled Workforce in the Energy Efficiency Market*. ACEEE Summer Study on Energy Efficiency in Buildings, 2012

2 The *Advanced Lighting Controls Systems Pilot Program,* sponsored by SCE and SDG&E, takes a quantitative look at some of the costs and benefits of requiring skill standards for lighting control systems installers. PG&E is sponsoring an Advanced Lighting Controls Systems (ALCS) Calculator Tool Trial. This trial seeks to validate and verify the accuracy of the energy savings generated from the Tool, diagnose issues in the initial version of the Tool, and assess contractor experience and satisfaction using the Tool.

The training that manufacturers provide these affiliated installers is qualitatively different from the training they offer to the general population of installers: it takes significantly longer to complete, includes extensive hands-on practice, requires that the participant demonstrate competence regarding specific performance criteria, and often includes on-site observation and verification of competence, on-the-job during two or more installation projects.

Since this project was focused primarily on training and work quality for lighting controls installation projects in general, we did not do an in-depth assessment of the training required of installers who are employees of the manufacturer or a closely affiliated organization.

It is important to keep this in mind when reviewing the discussions about manufacturer training. That is, we are speaking of the training that manufacturers offer to the "general population" of installer; we focused on training that any installer can participate in, not training that is provided only to installers who are a formal part of a manufacturer's sales and installation channel.

Approach

Three major activities helped us address the research questions this project encompassed:

1. In-depth interviews with lighting controls installation training providers — specifically manufacturers and CALCTP

   Through internet research, initial interviews with manufacturers, and input from industry experts, we identified a list of six manufacturers most likely to provide robust, in-depth training related to lighting controls installation.

   Although we attempted interviews with all six of those manufacturers, we were unable to schedule with one of them, so we extended our selection to others identified as installer training providers. In the end, we interviewed seven manufacturers. Five of them were on the original list of six we attempted to interview and the other two were on the extended list. According to one industry expert, the seven manufacturers we interviewed represent more than 90% of the California advanced lighting controls market.

   Another of our interviews was with a Senior Project Manager at ICF International, the implementer for CALCTP. In addition, during initial information gathering the team conducted a site visit to the CALCTP training center in Southern California, interviewing two of their instructors and examining the training laboratories and boards that are used to teach students how to wire lighting control components.

   The process of identifying a sample frame for manufacturer interviews was described in a sampling memo for this project (see *Appendix A: Manufacturer Interview Selection Criteria Memo*.) The list of manufacturers considered, and finally selected, is in that memo, and the table of manufacturer information appears as a table with additional information in Appendix A, along with the original sampling memo. In addition, in Appendix E we provide a list of a wider range of lighting controls training that is based in other institutions.

2. In-depth interviews with installers who had completed lighting controls installation training from manufacturers or CALCTP or both

   Installers who had received only manufacturer training or both CALCTP and manufacturer training all had received training from at least one of the six manufacturers on our initial list as the most likely to have training comparable to CALCTP.

   We identified installers who completed only CALCTP training or both manufacturer *and* CALCTP training from the CALCTP website, which lists CALCTP-certified individuals and companies. The installers who had completed only manufacturer training were identified with the aid of the program manager for the *Advanced Lighting Controls Systems Pilot Program*.

   We conducted a total of 15 installer interviews. The majority (eight) of the installers had both manufacturer and CALCTP training. (Of the remaining seven, four had only CALCTP training and three had only manufacturer training.) During interviewee recruitment, we confirmed or determined the types of training that the interviewees had actually completed. .

   We considered it an advantage that most of the installers we interviewed completed both manufacturer and CALCTP training. Installers who attended both types of training were in a unique position to make comparisons and to identify the relative strengths and weaknesses of both manufacturer and CALCTP training.

3. A "Work Quality" workshop held with IOU lighting and controls program managers

   Based on information we learned from manufacturers and installers, and augmented by guidance from experts in the areas of lighting control systems and the California Building Energy Efficiency Standards (Title 24 Part 6) we identified seven key elements of work quality that affect how well systems provide potential energy savings and outlined ways in which these elements can be measured. We then reviewed this information in a web-based workshop with IOU program managers and solicited their feedback.

   We refined the definition and measurement methods based on input from the IOU teams represented in the workshop, and anticipate that this will serve as input to the SCE and SDG&E *Advanced Lighting Controls Systems Pilot Program* that assesses the impact of minimum skills requirements for lighting controls installers.

   See *Table 15: Possible Ways to Measure Work Quality* (p. *76*) for a summary of the elements and ways they can be measured.

Defining "Work Quality"

Given that a major goal of this assessment revolves around "quality lighting control installations," it is useful to provide an overview of what we mean by "quality" in this context. The following description of quality was developed as a result of all the major activities of this assessment including: input from IOU Program Managers, discussions with lighting subject matter experts (SMEs), and in-depth interviews with installers and manufacturers. Generally speaking, work quality in the context of a lighting control system includes:

- **Design** — The plans and specifications meet the customer's needs and objectives, complies with code, and communicates effectively to the installer.
- **Installation** — The installation follows general electrical work-quality standards (basic wiring techniques, grounding, etc.) and conforms to (good) design with adjustments as necessary to address the specific requirements of the space (HVAC vents, columns, and other obstacles).
- **Code Compliance** — The project meets all relevant code requirements, including Title 24 Part 6 mandatory measures and prescriptive requirements for nonresidential indoor lighting.
- **Commissioning** — For new construction projects, the project conforms to all the Title 24 Part 6 Commissioning requirements; for alterations and retrofits (which do not require commissioning under Title 24 Part 6), check, inspect, and test all relevant system components to verify that the installed system performs as desired and is ready to hand off to occupants.
- **Functionality (Acceptance Testing)** — The system operates as intended, responding to "triggers" (occupancy/vacancy, outdoor lighting levels, time of day and day of week, etc.) as specified and not responding to "false triggers" (noise from vents, people walking outside the controlled area, etc.).

  Typically, functionality of lighting control systems is verified through the Title 24 Part 6 Acceptance Testing procedures. These procedures are documented in the code for a variety of control system types and must be conducted by a certified Acceptance Test Technician (ATT)[3]. See *Acceptance Testing* (p. 75) for more information.
- **Persistence** — The system continues to operate and perform as intended over the life of the equipment.
- **Occupant Satisfaction** — At best, the controls enhance occupants' experience of the lighting system; at worst they do not frustrate, irritate, or hamper occupants.

Note that this description is provided here as context for the following sections of this report. The *Findings: Work Quality* section of this report (p. 79) provides additional information supporting this definition and notes some suggested metrics for each element contributing to work quality.

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[3] Acceptance Test Technician (ATT) refers to a role specified by Title 24 Part 6. This role is filled by individuals who have met rigorous certification standards, demonstrating that they are conversant with the relevant code and can execute the acceptance tests as specified in Title 24 Part 6.

There are two types of ATTs specified by the current (2013) Standards: Lighting Controls Acceptance Test Technicians and Mechanical Acceptance Test Technicians. Throughout this report, we use the term to refer to certified Lighting Controls Acceptance Test Technicians. See *Acceptance Testing* on p. 73 for more information on Acceptance Testing and ATTs.

Conclusions and Recommendations

The following summarizes our conclusions and recommendations based on what we learned through all the project activities. This is exactly the same content as is presented in the body of this report. These recommendations are qualitative in nature due to the limited sample size and study budget, and should be mindfully applied to only Advanced Lighting Control System related concerns. It is important to not generalize these recommendations to other non-residential applications.

Conclusions re: Training	Related Recommendations
1) The CALCTP *Installer Technical Course* seems to fill an important gap in the lighting controls installation arena. Some of the specific gaps that CALCTP training can address include: ■ Some installers work on projects using products from manufacturers that do not provide installer training on their controls. There appears to be no appropriate source of relevant training for these installers other than the CALCTP training. ■ Many installers work on projects that include components from multiple manufacturers. Even the best available installation training from manufacturers does not include much if any content on how to work with heterogeneous controls configurations, and none of the manufacturer training has hands-on practice with "mixed-manufacturer" installation. The CALCTP course does include components from multiple manufacturers and includes hands-on labs working with them. ■ Many installers have very demanding schedules and do not have the time or patience to "hunt down" appropriate training for multiple resources. Even when manufacturers provide "general concept" or Title 24 Part 6 training that would help installers regardless of the products they work with, it often is difficult to identify and enroll in that training. The CALCTP course provides a "one-stop-shop" for most of the essentials.	**Continue to support the CALCTP efforts to provide training for lighting controls installers.** Specific kinds of support to consider include: ■ Provide classroom space for CALCTP-oriented training activities ■ Fund deliveries of the course at IOU customer training centers ■ Explore with CALCTP other appropriate ways in which the IOUs may be able to support the installer training effort. This this may include discussions around: ▫ Sources of funding for updating and enhancing the training ▫ Alternatives for developing online self-study update modules that would qualify for continuing education credits ▫ Ways to help encourage collaboration with manufacturers who provide training on a range of brands, current technology, etc.

Conclusions re: Training	Related Recommendations
2) It is uncertain whether the CALCTP training is having a significant impact on skills and knowledge of the individuals who complete the training. The current training design for the CALCTP *Installer Technical Course* measures what participants know and can do at the end of the training. It does not measure participants' entry-level knowledge and skills (except for ensuring a minimum baseline prerequisite). It is possible that many individuals who choose to participate in the course are already well versed in the areas the course addresses. (People who are interested in controls may tend to seek out training and information on the topic, and may have already reached competence through other avenues.)	**Encourage CALCTP to consider ways to measure the likely impact of the training on participants' competence.** One approach that could reasonably provide useful information about the overall impact of the CACLTP training on individuals who participate in the training is to conduct a pilot evaluation study that could use a pre-test / post-test design to determine whether the people who come to the training already are competent or whether they develop significant skills and knowledge as a result of the training. Some general guidelines for a valid pre- and post-test to address this issue are outlined under "2.3. Assessment of Training Impact on Competence" in the "Assessment Yardstick." Similar to the current CALCTP certification test, **it would be very helpful and informative to consult a psychometrician**[4] for this pre-test design. A psychometrician could provide: ■ Guidance on test methods and construction if pursuing a pilot using a pre-test / post-test configuration ■ Recommendations for other approaches to effectively and efficiently meet the goal of measuring the likely impact of the CALCTP training on overall workforce competence

[4] A psychometrician is an expert in objective measurement of skills and knowledge, abilities, educational achievement and other aspects in the cognitive and affective domains. Many psychometricians focus on areas specific to adult learning, behavior change, and certification.

Conclusions re: Training

3) The CALCTP *Installer Technical Course* is well-designed and executed; however, there are areas with potential for improvement in the existing training.

Installers we interviewed cited a number of specific suggestions regarding improvements to the course content and delivery.

The most pressing was to keep the content and equipment boards up to date.

- The curriculum for CALCTP was developed in close association with lighting controls manufacturers and other stakeholders. This meant that the curriculum and the equipment boards used in training were up to date in the beginning.
- While the training is frequently updated to address factual errors and remove references to obsolete technology, there have been five major updates since 2008, with the last major update in 2013. However, the technology is constantly evolving, and this gives rise to two problems:
  - Equipment boards are very expensive, so it is probably not feasible to update them often enough to keep the program completely current.
  - Although manufacturers are involved at some level for all updates of CALCTP programs and continuing education, heavy manufacturer involvement is not built in to the program on an ongoing basis.

  This leaves the program vulnerable to being outdated over time.

Another area of possible improvement is to **make it easier for potential participants to find deliveries in their areas**.

- Some installers indicated it was difficult to get enrolled in the course, largely because they didn't know when and where it was being offered.
- The CALCTP website does not prominently display a calendar of upcoming deliveries. (Rather it suggests the user contact CALCTP to learn of courses being held in their area.)

Related Recommendations

Support CALCTP efforts to enhance and update the training.

- Encourage CALCTP to review the specific recommendations suggested by the installers interviewed in this assessment. (See pp. 54, 56, and 58.)

  It should be noted that some of these comments may have already been addressed through revisions since the installers participated in the training; other comments may be addressed via the major revision that currently is under way.

  In addition, some comments may be "outliers" that wouldn't add much value to the course. A thorough and objective review of the comments should be made before specific changes are targeted.
- Explore ways to encourage manufacturer participation in CALCTP training. (See #4 below.)
- Consider other approaches to providing ongoing support activities noted under conclusion #1 above.
- Explore ways to provide broad and consistent marketing and outreach for the CALCTP installer training, making access easier for all installers and contractors.

Conclusions re: Training	Related Recommendations
4) Manufacturer and CALCTP installer training have important — and different — strengths. Some of the major strengths of the CALCTP installer training is that it includes: ■ A variety of control types; variety of brands ■ How different brands of products can be appropriately configured together in one system ■ Extensive hands-on practice and assessment Some of the major strengths of manufacturers' installer training include: ■ In-depth exploration of product-specific requirements and considerations ■ Frequent updates to reflect the latest (manufacturer-specific) technology	**Explore ways to support training that combines "the best of both worlds."** Consider ways to provide a coherent learning experience that capitalizes on the strengths of both CALCTP and manufacturer training. One approach for accomplishing this would be to: ■ Establish the CALCTP training as the foundational component of the curriculum ■ Provide manufacturer-specific modules as recommended "advanced" components of the curriculum ■ Encourage installers to complete a manufacturer-specific module before engaging in projects that use that manufacturer's controls ■ Ensure the "full" curriculum is clearly presented in terms of a recommended learning path (pre-requisites, foundational course, and manufacturer-specific deep-dives, including extensive hands-on practice) on the CALCTP website and in all marketing and outreach communications. It is useful to note that as of fall 2015, CALCTP is developing a continuing education program, in collaboration with major lighting manufacturers, which will address emerging products and control strategies.

Conclusions re: Training	Related Recommendations
5) One of the most frequently cited barriers to quality installation is a function of poor lighting control system design. All of the installers and several manufacturers indicated that the lighting designs often are inappropriate or inadequate: all too often the plans are not customized to the customer needs and project configuration, don't comply with code, and provide insufficient detail for installers to execute properly. Lighting system plans may be developed by people in a variety of roles, most often architects, lighting designers, design/build lighting contractors, or engineers. Engineers were most often cited by installers as the source of inadequate or inappropriate plans, but it is unclear whether that was a general term they employed (assuming an engineer developed the plans) or it really does indicate an electrical engineer drew up the plans. Regardless, it is possible to have "good installation of a bad design," which is something outside the installer's scope of responsibility.	**Consider supporting training (and other related resources such as quick references or decision tools) to help improve nonresidential lighting system designs.** There are other related efforts that should be explored before finalizing any plans for such training: ■ The Statewide Codes and Standards Compliance Improvement (Energy Code Ace) team is actively pursuing "designer" training in 2016. ■ The Energy Code Ace website currently has two online self-study courses focused specifically on Title 24 Part 6 mandatory measures and prescriptive requirements for nonresidential lighting. ■ The California Lighting Technology Center (CLTC) has developed Lighting Guides specific to nonresidential applications, and delivers training on lighting technology and code requirements. ■ CALCTP has begun development of a course focused on lighting system design. (This project currently is on hold due to funding issues.)

Conclusions re: Work Quality	Related Recommendations
6) Work quality as described in this report has the potential to help ensure lighting control projects realize their energy-savings potential. Evidence of work quality can be assessed at various stages of a project. ■ During the design or design/bid phase, key system design elements can be verified, as shown on the plans and related documentation. ■ Immediately after a project, issues directly associated with installation quality, code compliance, and functionality can be verified. ■ After some time (six month, a year, or longer) has passed since the installation was completed, issues associated with persistence and occupant satisfaction can be assessed.	**Consider requiring evidence of work quality before and after installation for incentivized lighting control projects, especially when these activities are consistent with the adopted codes.** ■ This implementation can be built into existing program processes such as conducting reviews at **Rebate Reservation or Equivalent** (before project start) for sample projects to collect baseline data. In addition, design quality and evidence of documentation that effectively communicates between design and installation teams could be assessed by reviewing materials that documents the following:[5] ▫ Evidence of required permits ▫ The customer's project requirements (energy efficiency goals, hours of operation, and expectations for equipment and systems) ▫ Lighting system design intent— a written explanation of how the design meets the customer's project requirements (including energy savings calculations if appropriate) ▫ Sequence of operation ▫ Statement of goals and rationales of the design that can be referenced by the installer in case unforeseen issues arise, making it inadvisable or impossible to install as designed. ■ At **Project Completion** it is feasible to measure key aspects of work quality by requiring: ▫ Relevant Acceptance Test forms (NRCA-LTI-##-A) signed by a certified Acceptance Test Technician (ATT). ▫ Commissioning documentation (for new construction only) For the upcoming High Opportunity Projects and Program (HOPP) implementation, these requirements are also consistent with the intent of AB802 requirements.

[5] A permit is required for any project that triggers Title 24 Part 6, which includes virtually all lighting controls installation projects. The other items listed under this bullet typically are part of the Commissioning process required for nonresidential new construction. For retrofits, these documents (except the permit) are not required by code, but are a crucial component of ensuring the design meets customer needs and that the design intent is communicated to the installation team.

Conclusions re: Work Quality	Related Recommendations

6) Work quality as described in this report has the potential to help ensure lighting control projects realize their energy-savings potential (continued)	**For incentive programs in which significant long-term energy savings is a major consideration, consider evaluating the "Persistence" element of work quality.**
	
	If it seems reasonable to measure "persistence" for selected lighting projects, methods of verifying performance in an evaluation study after six months or a year could include:
	
	■ Perform a walkthrough of the job site to:
	  ▫ Observe the operator interface to verify the control strategy is still in place and operating
	  ▫ Check a sample of sensors and controls to confirm they still are in place and functioning as intended
	  ▫ Survey occupants and operations personnel to determine their satisfaction with the system and identify any issues that may hinder ongoing performance per the design.
	  ▫ Analyze meter data to confirm energy savings and control system function
	
	These study activities can also be included in the evaluation activities to support the SCE and SDG&E Advanced Lighting Control Pilot initiatives.

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Background

The California Energy Commission reports that in California "lighting consumes, on average…35% of a commercial building's total electricity use." While there is great potential for significant energy savings through more efficient lighting and lighting control systems, much of this potential goes untapped. In the case of advanced lighting controls technology, Jackson, Avery, and Ouellette (2012) argued that a large part of this is attributed to insufficient skills training in advanced lighting controls.

Jackson, Avery, and Ouellette supported development of a sector strategy[6] that provided a great deal of guidance on how to promote the realization of this potential. That strategy also pointed to education and training as key components to achieving this end.

In addition, CPUC Decision 12-05-015 provided considerable direction in this area. This decision specifies data gaps, and tasks the Investor Owned Utilities (IOUs) to collect a variety of relevant data:

> *"Therefore, we direct the utilities to include in their applications the following information regarding HVAC quality installation, CALCTP-certified installations, and any other sector strategy-induced skill standards identified by then:*
>
> *(1) Data or estimation of the incremental customer cost, if any, of requiring skill standards;*
>
> *(2) Data or estimation of the average and range of permitting/compliance costs across permitting jurisdictions in the IOUs' service territories;*
>
> *(3) Data or estimation of impacts, if any, mandatory skill standards would have on program participation rates;*
>
> *(4) Data or estimates of the incremental energy savings and customer cost savings over the life of the equipment; and*
>
> *(5) Any other potential benefits associated with higher standards, such as fewer call-backs, lower frequency of customers overriding control systems, lower life-cycle costs, and increased consumer uptake of measures based on higher quality and certainty."*

These questions can be addressed from many angles and they are the subject of multiple projects. Further, education and training for developing skills referenced by all of the documents cited can come from myriad sources. The impact of installation quality is being addressed by the *Advanced Lighting Controls Systems Pilot Program,* sponsored by SCE and SDG&E. These pilots and studies will consider savings impacts as well as some costs associated with installing this technology well.

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[6] Jackson, Cori / California Lighting Technology Center, Doug Avery / Southern California Edison, and Mark Ouellette / ICF Inc. *California's Advanced Lighting Controls Training Program: Building a Skilled Workforce in the Energy Efficiency Market*. ACEEE Summer Study on Energy Efficiency in Buildings, 2012

Education and training, as they affect skills and standards, is a much broader endeavor, and this certainly applies to the area of lighting controls. There are numerous educational institutions and other sources that can and do teach their students about energy-efficient technologies, with lighting controls a relatively small piece of that. There are other courses of study that are more specialized and that are offered at a multitude of different types of organizations, including community colleges, four-year colleges and universities, unions, IOU energy centers, and industry organizations (trade and professional). A listing of these education and training sources, as they are available for both HVAC and lighting, can be found in, *PY2013-2014 California Statewide Workforce Education and Training Program: Contractor Training Market Characterization* (Opinion Dynamics, 2015), sponsored by the Energy Division of the CPUC. A selection of those programs that address lighting controls is provided in *Appendix F: A Broader View of Lighting Controls Training*.

Some of the above mentioned courses — especially those that are less specialized — are directed at individuals who are beginning in the field, such as students and apprentices. However, after they have degrees or are certified by the state, further training may be necessary to update their skills and knowledge, or to provide them with specialized skills and knowledge. Certainly many of the sources listed above can and do provide both, but the larger share of the post-licensing or post-degree training is more likely to come from specialized training centers or manufacturers. The study focusing on manufacturer training and specialized energy training centers, specifically the California Advanced Lighting Controls Training Program (CALCTP), is covered in this report.

This team was tasked with addressing some questions in response to D.12-05-015 identified above. (See italic text previous page for a summary of the Decision.) Our study, the *Lighting Controls Training Assessment,* covers these questions:

- What issues do installers face in the field that can have an impact on the quality of installations? That is, to what extent is training in advanced lighting controls technology, design and installation needed?
- What is work quality in the context of lighting control installations; how can this be measured?
- How do the available lighting controls installation training opportunities compare in terms of key characteristics?

Overview of Manufacturer and CALCTP Training

The following provides a high-level overview of the variety of training available through manufacturers and CALCTP.

Manufacturer Training

Manufacturer installer training can be grouped into three main categories:

- Formal training that is available to the general population of potential installers
- Formal training, often certification training, that is available only to the manufacturer's employees or affiliates (e.g., VARs)
- Ad hoc manufacturer training that is provided onsite during installation to installers working on projects featuring the manufacturer's products (essentially on-the-job coaching)

The focus of this assessment is formal training available to the general population of installers, considered potentially comparable to the CALCTP Installation training. (See *Project Focus* on p. 1 for a discussion of the range of manufacturer installer training and why this project focuses on training available to the general population.)

Even within the category of training targeted to the general population of installers, the duration, objectives, depth and breadth of content addressed, and instructional rigor varies widely by manufacturer—and sometimes within a single manufacturer. Specific characteristics of selected manufacturers' installer training for the general population are discussed in more detail under *Findings: Training & Certification,* beginning on p. 47.

Training available only to the manufacturer's employees or affiliates was not within the scope of this project, but comments from manufacturers who offer this type of training, as well as others who are familiar with such training from some manufacturers, lead us to believe that it typically is multiple days in duration, includes extensive hands-on practice with the relevant equipment, and incorporates performance-based testing to verify that participants have met the training objectives.

Ad hoc, onsite training provided by some manufacturers in support of selected projects also was outside the scope of this assessment. The criteria used to determine which projects warrant such support were not clearly communicated during the manufacturer interviews and seem to vary by manufacturer. In general it seems that "high value" projects (determined by project cost, market visibility, market strategy, and similar considerations) are candidates for ad hoc installation support and training. During this process, one or more manufacturer representative works one-on-one with the installers to ensure they are able to successfully complete the installation to the project (and manufacturer) specifications.

CALCTP Training

CALCTP offers five courses in the areas of lighting control system installation and acceptance testing:

- Installation
  - "Installation" for electricians
  - "Systems" for mid-level electrical contractor managers
  - "Business development" for top level electrical contractor managers (marketing, planning, customer support)
- Acceptance Testing
  - Field technician (Acceptance Test Technician or ATT) training
  - ATT employer training

CALCTP also is developing an "Advanced Lighting Control Specifier" course targeted to architects, engineers, lighting designers and design-build professionals. (CALCTP estimates that this course is 25% complete as of late March 2016.)

In addition, as of third quarter 2015, CALCTP was developing two new programs intended to improve the amount and persistence of energy savings from lighting control projects: the CALCTP Building Operator Program and the CALCTP Continuing Education program. The Continuing Education program will be provided directly by manufacturers and will address emerging products and control strategies. Delivery is anticipated to include both online and traditional classroom instruction.

The "Installation" training for electricians was the focus of this assessment. This course is available to state-certified general electricians and licensed electrical contractors. The instructor-led course provides approximately 40 hours of instruction consisting of lecture, discussion, and hands-on labs. In addition, there is a prerequisite set of online courses published and made available by the Lighting Controls Association. These prerequisite courses address basic lighting control concepts in approximately 20 hours of self-study training, and successful completion is confirmed by passing a pre-test before an individual may begin the Installation course.

Methods

This assessment was composed of four major activities:

- **Initial information gathering** to refine our understanding of the project goals and provide a focus and establish a sampling approach for upcoming in-depth interviews
- **In-depth installer interviews** to gain insight from the "front line" about what is actually happening on lighting control systems jobs—what challenges they face, the value of the training they received, their perspective on the value of certification, and their views on quality installations
- **In-depth manufacturer and CALCTP interviews** to learn more about the training available to lighting controls installers as well an additional perspective on quality issues related to lighting controls installations
- **Work Quality Workshop** to present a definition of "Work Quality" to IOU program personnel and CPUC ED staff and advisors based on what we learned during the assessment and suggest some possible approaches to measuring work quality, and solicit input on the definition and appropriate metrics from the IOUs

Table 1 below provides an overview comparison of the initially planned activities and the actual activities conducted. Following the table is a detailed description of each of the four main activities.

Table 1: Summary Comparison of Planned and Executed Activities

Activity	Plan	Actual
Initial Information Gathering (First Quarter 2015)	**unspecified**	**11**
Interviews with IOU staff	unspecified	9 prg mgrs from 3 IOUs
Manufacturer training center site visit	unspecified	1
CALCTP training center site visit	unspecified	1
Installer Interviews (Late Second; Early Third Quarter 2015)	**(20)15**[7]	**15**
CALCTP training and manufacturer training	5	8
Only CALCTP training	5	4
Only manufacturer training	5	3
Neither manufacturer nor CALCTP training	5	0
Training Provider Interviews (Manufacturer and CALCTP) (Fourth Quarter 2015)	**6**	**8**
Manufacturer training providers	6	7
CALCTP	unspecified	1
Work Quality Workshop (Fourth Quarter 2015)	**(unspec.) 1** [8]	**1**

[7] Although the initial (Phase One) project plan specified 20 interviews, the Phase Two workplan revised the quota to 15, and contracted payment was adjusted to reflect the change.

[8] The Phase One project plan did not include a Work Quality Workshop; it was added in Phase Two.

Initial Information Gathering

When this project began, the researchable questions and goals were partially defined. Many research concerns were identified by stakeholders, but there was a limited budget. Thus, the team conducted a first round of in-depth interviews with Lighting, Workforce Education and Training (WE&T) and non-residential rebate program managers from all three IOUs. Following these interviews the team had a clearer picture of the most important expectations for this project, which guided further data collection efforts.

IOU Program Manager Interviews

The assessment team conducted interviews with nine program managers for lighting and controls programs at three of California's IOUs (Pacific Gas and Electric Company, San Diego Gas & Electric and Southern California Edison). For each utility, we interviewed at least one representative from each of three program areas:

- Lighting market transformation program managers
- Workforce Education and Training (WE&T) programs
- Non-residential rebate programs

They indicated they were interested in the following research areas, which are the focus of this assessment:

- Characterize and evaluate lighting controls installer training available from manufacturers and CALCTP (included in the study)
- Compare training experiences between CALCTP and manufacturer-trained installers (included in the study)
- Define what various stakeholders mean by quality design and installation of lighting controls (not included in the study)

Manufacturer Research

Identifying manufacturers who offer installer training that is potentially comparable to the installer training offered by CALCTP was a crucial step in this assessment project. Early in the project, we developed and applied selection criteria to determine which manufacturers we would focus on during the in-depth interviews.

Development of Selection Criteria

For the task of selecting manufacturers that have training programs that are potentially comparable to CALCTP training, we established several criteria for the manufacturers to identify which we would investigate further with in-depth interviews. Given the study budget constraint, selection criteria were necessary. These selection criteria were summarized in a memo and distributed to the IOUs and CPUC Energy Division staff and advisors for comments in June 2015.

One overarching objective is to conduct a comparison of training efforts with similar depth and robustness, using CALCTP as the benchmark. By using these selection criteria, some lighting manufacturers offered only on-line training and were not included in the sample frame.

The sample frame included manufacturers that satisfy the criteria we list here:

1. **Manufacturers with product lines that offer complete lighting control systems or that manufacture the "brains" of the control system**

   This study focuses on training efforts that offer a "system view" of the lighting control system. Manufacturers with product lines based solely on one or two individual components, rather than a complete system, are less likely to offer training that is comparable. These manufacturers were not considered in the sample frame. Manufacturers of the lighting controls' "brains" would most likely have to coordinate with other products manufactured by other companies, and would thus be likely to provide comprehensive training that could be comparable to CALCTP. They were also considered candidates for in-depth interviews.

2. **Manufacturers that offer formal training**

   CALCTP training is delivered in a classroom setting with an established curriculum and dedicated course material. A major indicator of what we count as formal training is whether or not there is a classroom component. Some manufacturers only offer informal training, via ad hoc presentations or responses to specific questions or coaching at an installer's request. These types of performance interventions can be very effective, but they do not lend themselves to systematic evaluation of the type addressed by this project because they, by definition, vary widely based on the situation. Therefore, these manufacturers were not considered in the sample frame.

3. **Manufacturers with a significant market share in sales**

   Manufacturers with significant market share would be most likely to have a training program that was large and detailed enough to be comparable with CALCTP Installer training. (See *Appendix F: Overview of CALCTP Installer Training* for a summary of the objectives, structure These manufacturers would also be the most likely to answer questions about what constitutes work quality and how it might be measured or observed.

Data Collection for Selection Criteria

The sample frame was developed using the internet to search for lighting controls manufacturers. This resulted in an initial list of more than 100 manufacturers, which was refined to a master list of 36 manufacturers that logically might meet the selection criteria. See *Appendix A: Manufacturer Interview Selection Criteria Memo* for the listing of 36 manufacturers and their ratings on the selection criteria.

As we researched the manufacturers to add to our sample frame, we collected as much information about the manufacturer, including its products and its training, as was available on the internet. From this preliminary research, we could eliminate many manufacturers on the master list of 36 based on whether the product line offered a complete lighting control system (the "brains" of a system) or individual components that are not central to the lighting controls' whole system.

When sufficient manufacturer information was not available on the internet, we made calls to the manufacturer to supplement the data on selection criteria; these calls only inquired about their product line and their available training. Based on this information, we could eliminate additional manufacturers that did not provide formal training, and establish a "short list" of six manufacturers that seemed most likely to offer robust classroom training that represents the depth and breadth of the CALCTP installer training.

Manufacturer Site Visit

In addition to the preliminary research to identify manufacturers most likely to provide robust, comprehensive controls installation training, and the in-depth telephone interviews conducted with those manufacturers, members of the assessment team conducted a site visit to a manufacturer with a training center in Southern California.

During this visit, we discussed with one of the training facilitators the training options that were available to the "**general public**" of installers and considerations regarding training participants.

CALCTP Research

We conducted a preliminary interview with the individual responsible for managing the CALCTP Installer training, and scheduled a site visit to the CALCTP training center in Southern California. During the visit, we:

- Conducted interviews with two of their instructors
- Examined the training laboratories and boards that are used to teach students how to wire lighting control components.

During our visit, we also received the CALCTP *Installer Training Course* workbooks and the handouts that are used during the hands-on lab training.

Developing the Sample Frame for Installer and Manufacturer Interviews

As described in *Manufacturer Research* (p. 18) above, we identified a list of six manufacturers most likely to provide robust, in-depth training related to lighting controls installation.

This "short list" of manufacturers not only served to guide our manufacturer interviews, but also served as the basis for categorizing the installers we interviewed as having experienced manufacturer training:

- All the installers we interviewed as representing "manufacturer-only training" or "CALCTP and manufacturer training" had participated in training provided by at least one of the manufacturers on the short list of six.

  See *Installer Interviews* (p. *21*) for more information on how the sample frame was established.

- We also tried to interview appropriate representatives from each of the manufacturers on that list, and successfully completed interviews with five of the six — plus two others who seemed to meet the selection criteria (summarized on p. 18), although we did not identify them as such based on our preliminary information.

Installer Interviews

Our initial intent was to interview electrical contractors. The point was to get insights from the front lines about what is actually happening on lighting control systems jobs. The idea was not to fully characterize the state's lighting controls contractors, but to get insights from their perspective. Because we wanted the ground-level perspective, we selected for interview mainly people who actually install these systems, and a few who design them. Over the course of the interviews, we learned that contractors are usually not the ones actually installing the systems, unless they were a one-person shop. For the most part, electricians do the installations. Typically, one or more electricians work for a contractor and work is performed under his license, and he is ultimately responsible, but the true "front line" is usually the electrician. Thus, we changed our language to reflect this reality. Almost all of our interviews were with installers; only a few of them were contractors.

The installer interviews focused on two main objectives:

- Get input on their perspectives on available installer training and the potential value of installer certification.
- Get input on the elements of quality work in this field. In other words, what constitutes "work quality" in the field of lighting controls?

The initial project plan led the research team to seek five interviews each with contractors/installers from four groups; those with:

1. CALCTP training/certification and manufacturer training
2. CALCTP-only training/certification
3. Manufacturer-only training
4. Neither training type

It quickly became clear that no manageable sample frame was available to reach the fourth group. Since that group was least important to the goals of the study, it was dropped; and we sought to interview 15 installers, evenly divided among the remaining three groups.

Two of the groups included CALCTP training and certification, so the program's website, which lists CALCTP-certified individuals and companies, became the primary source for those installers. For those with only manufacturer training, we initially expected to get installers from cooperating manufacturers. That strategy proved unworkable in the timeframe of the project because we experienced so much difficulty getting manufacturer interviews that the project timeline forced us to complete the contractor/installer interviews before the manufacturer interviews. The team then approached the program manager for the SCE *Advanced Lighting Controls Systems Pilot Program* to help us identify installers participating in that program. We learned that not all of those installers had CALCTP training. We ultimately found three from that program that did not have CALCTP training, but did have manufacturer training, and that were willing to be interviewed.

Given the difficulty of finding installers with manufacturer training, but not CALCTP training, and given that we were finding that most CALCTP-certified installers/contractors also had manufacturer training, the research group received permission to move away from the initial project plan quota of five per group. However, we maintained the overall quota of 15 interviews.

As described in the section of this report on sampling manufacturers (see *Manufacturer Research*; p. 18), several criteria were used to select the manufacturers that would be approached for participation in this study, one being the inclusion of a classroom component. We used taking training from those manufacturers to qualify installers to participate in the "In-depth Installer Interviews" part of this study. Specifically, to qualify as having received manufacturer training either alone or also with CALCTP certification, the manufacturer involved would have to come from that list of major manufacturers of lighting controls systems, or at least to manufacture the "brains" of the system.

In the end, we completed 15[9] installer interviews, confirming and/or determining during the interviews the type of training the installers had completed:

- CALCTP-trained only (4)
- Manufacturer-trained only (3)
- Both CALCTP- and manufacturer-trained (8)

That is, 12 of the 15 installers interviewed had completed CALCTP training, and 11 of the 15 had completed manufacturer training. The fact that over half (8 of the 15) of the interviewed installers had completed both CALCTP and manufacturer training was by design, and considered an advantage relative to the goals of this project: Only installers who had completed both types of training had a sound basis for comparing the two types of training and identifying the strengths and weaknesses of both.

It also is interesting to note that some installers who completed both types of training believed the manufacturer training to be the better of the two, while others preferred the CALCTP training. In short, among installers who had both types of training, there was no clear trend in their perceptions regarding which type of training was better.

While this sample frame "over-represents" CALCTP training as a proportion of all nonresidential lighting controls installers in California, the study team determined this was appropriate because one of the underlying goals of this study was to consider CALCTP training in the context of overall installer training opportunities available to the general population. Therefore, it was necessary to over-sample those with that type of training. Screening a random sample of electricians and electrical contractors to get enough installers of the type we needed would have been cost prohibitive, and was not necessary given our goals.

[9] In addition to the 15 completed interviews, we addressed approximately half of the interview questions with one individual, who had to leave before the interview was done; we were unable to reschedule a time with him to finish the interview. This "half interview" is not included in the count of completed interviews.

As noted earlier, those who were included in the manufacturer-trained groups had indicated they had received training from at least one of the six manufacturers identified.

Two of the interviewees were designers (engineers) rather than installers. We called them at a time when we were learning that most installers do not do design work, so we decided to conduct those interviews to be sure we had some coverage of design work from a designer.

See *Appendix B: Background Characteristics of the Interviewed Sample of Installers* for more information on the interviewees.

Manufacturer and CALCTP In-depth Interviews and Review of Materials

Given the scope of the project, we targeted interviews with six manufacturers that met the go-no criteria (#1 and 2 listed under "Development of Selection Criteria" on p. 18), and started from the top of the list in terms of "number of positive factors," to identify manufacturers most likely to have installer training opportunities comparable to the CALCTP installer training. In addition, we conducted an interview with an individual responsible for CALCTP training to ensure we addressed the same questions across all training providers under consideration.

Scheduling manufacturer interviews was difficult: It was extremely challenging to engage their attention then schedule a time that the appropriate individuals were available for an interview. In addition, two of the manufacturers in our first interviews turned out to have installer training only for installers who are closely affiliated with that manufacturer (e.g., in-house installers, authorized manufacturer field technicians, or "commissioning agents" who are certified to program and test that manufacturer's control systems).

Therefore, we reached out to two more manufacturers to try to schedule in-depth interviews with them. Two of the three had agreed to an interview, but we were unable to schedule an interview within a reasonable time frame for one of them; the third was unresponsive to our requests.

As a result, we conducted a total of seven manufacturer interviews, two of whom provide specialized installer training for affiliated installers/contractors or value added retailers, but not training for the "general population" of installers (e.g., journeyman electricians).

See *Appendix A: Manufacturer Interview Selection Criteria Memo* for details regarding the manufacturers we interviewed and the one we attempted to interview but were unable to schedule.

Training Evaluation Criteria and Interview Guide

A primary purpose of the in-depth interviews with manufacturers and CALCTP was to gather information that would help us assess the training in several areas. To that end, we developed four "yardsticks," each of which focused on a specific area of evaluation:

1. Adult Learning Principles and Practices
2. Assessment (measurement of successful completion of the course and measurement of knowledge swing resulting from the course)
3. Availability / Accessibility
4. Learning Focus and Objectives

See *Appendix C: Lighting Controls Installer Training Evaluation Yardsticks* for the complete training evaluation yardsticks.

Since our initial information gathering indicated that some manufacturers might be sensitive to questions about their training offerings, we structured an interview guide using open-ended questions that would allow us to address the evaluation criteria and other important areas while

maintaining an open and friendly approach. This also enabled us to follow up on issues of interest that arose, but were not directly related to the training evaluation criteria.

Each interview was conducted by a team of two instructional design experts with extensive experience in training evaluation and one or two engineers with expertise in the field of lighting controls. Every interviewee was assured that we would keep individuals' responses confidential. That is, no comment or answer will be attributable to a person or manufacturer.

During each interview we asked to receive copies of the manufacturer's installer training materials. When provided, we did a review of the materials to confirm characteristics that were described orally during the interview (e.g., frequency and types of review and practice, topics covered, training objectives addressed, structure and organization of the training).

The training evaluation yardsticks and associated interview guides were submitted for review to IOU program managers and EM&V staff and representatives from the CPUC Energy Division. See *Appendix D: Interview Guide for Lighting Controls Installer Training* for the questions we addressed in the telephone interviews.

How the Yardsticks Are Used for Scoring

Each of the four yardsticks is divided into "dimensions," or major aspects of an evaluation area. For example, "Adult Learning Principles and Practices," as used in this assessment, has four dimensions:

1. *Adult Learning Principles and Practices*
    - *1.1. Performance-based objectives*
    - *1.2. Practice and feedback opportunities*
    - *1.3. Modalities engaged during the training*
    - *1.4. Structure and organization*

Each of these dimensions is "scored" based on specific evaluation criteria. For each criterion, a course may score 1 (yes), 0 (no), or "na" (not applicable). If a criterion is not applicable to a given course, that criterion is not considered in the scoring. A course's overall score in a dimension is determined by the actual score divided by the total possible score.

For example, let's consider the "Performance-based Objectives" dimension of the Adult Learning Principles and Practices yardstick. This dimension is evaluated on three criteria, as shown in *Table 2: Example of Scoring a Dimension on the Training Evaluation Yardsticks* below.

Let's say one review results in "yes" for all criteria, while another results in "yes" on two criteria and "no" on a third criterion. This means the first review results in a score of 100% (3/3) for that dimension, while the second review results in a score of 67% (2/3).

Table 2: Example of Scoring a Dimension on the Training Evaluation Yardsticks

1.1	**Performance-based Objectives**	**100%**	**67%**
	1.1.1 TPOs parallel to job requirements	1	1
	1.1.2 Apply level or higher	1	1
	1.1.3 EOs build to TPOs	1	0

The scoring was conducted by two different raters, both independently scoring the training materials and information gained from interviews. Both raters are instructional design (training) professionals, and both are experienced in criterion-referenced training evaluation using similar instruments.

If there was a discrepancy between the raters' scores, they met to discuss their scoring rationale and agree on an appropriate resolution.

Type of Training Identified for Review

Manufacturer installer training can be grouped into three main categories:

- Formal training that is available to the general population of potential installers
- Formal training, often certification training, that is available only to the manufacturer's employees or affiliates (e.g., VARs)
- Ad hoc manufacturer training that is provided onsite during installation to installers working on projects featuring the manufacturer's products (essentially on-the-job coaching)

Since one of the underlying goals of this study was to assess the role of CALCTP installer training in the controls installation marketplace, the study team determined it was appropriate to focus on manufacturer training that is available to the general population of installers, as is the CALCTP training.

- Only training that is available to installers who are not manufacturer employees or formal affiliates can be considered comparable to the CALCTP training in terms of accessibility to the general population of installers.

  If electricians want to build their skills related to lighting control installation, it is not reasonable to expect them to meet all the criteria necessary to become a value added retailer or a manufacturer's field representative.

- Manufacturer certification training available only to employees or affiliates is proprietary.

  Although manufacturers would discuss this training's general characteristics, the actual training materials were not made available to the evaluation team.

- Ad hoc, on-the-job coaching is provided only to some installers working on some projects for some manufacturers.

  Not only is it not available to the general population of potential installers, it would not have been feasible to assess this type of informal training within the scope and schedule of this project. Finally, this type of training would not qualify as potentially comparable to and/or redundant with CALCTP training.

Work Quality Workshop

Included in the scope of this project was developing a working definition of "work quality" and "installation quality" as they relate to lighting control installations and identifying ways in which it can be measured. The intended purpose of this information is to be able to apply it in future lighting controls projects as criteria to assess the quality of the installations, and to encourage and sustain energy savings.

We gathered information from installers and manufacturers regarding quality issues in lighting controls installation projects as well as how quality could be measured. We then refined and augmented this information with input from experts in lighting systems and Title 24 Part 6 as it pertains to lighting system requirements.

We summarized this information and used it as the basis for a workshop conducted with IOU program personnel, via a webinar format. We have incorporated feedback resulting from that workshop into this report under *Defining "Work Quality"* (p. 4) and under *Findings: Work Quality* (p. 71).

Research Questions

The overarching questions this assessment addressed are:

- What issues do installers face in the field that can have an impact on the quality of installations?
- What is work quality in the context of lighting control installations; how can this be measured?
- How do the lighting controls installation training opportunities available to the general population of installers compare in terms of key characteristics?

The specific questions we aimed to address during our in-depth interviews with installers and manufacturers, as well as the review of training materials, were designed to help us understand the characteristics of the installers we were interviewing, ascertain the issues that affect installation quality, learn installers' thoughts of requiring minimum competence or certification, and determine how the training for installers in general provided by manufacturers and CALCTP compare to each other.

Many of these questions were addressed by more than one source, as noted in Table 3 below and on the following page.

Table 3: Research Questions and Data Sources

Research Question	Data Source
General characteristics of installers who receive training	
■ How long have the installers been working on the lighting control designs and installations?	■ Installer interviews
■ What is the education and training background of lighting control installers?	■ Installer interviews
Issues that have a significant impact on lighting control installation quality	
■ What difficulties do installers face in lighting control design and installation?	■ Installer interviews ■ Manufacturer interviews
■ How do installers — or manufacturers — define "work quality" and "installation quality"?	■ Installer interviews ■ Manufacturer interviews
■ How might "installation quality" be measured?	■ Installer interviews ■ Manufacturer interviews
Perceptions about CALCTP training and certification	
■ What benefit do installers associate with CALCTP installer training?	■ Installer interviews
■ What is the value of CALCTP installer certification?	■ Installer interviews
■ Are there other CALCTP certified electricians in your firm?	■ Installer interviews [CALCTP-trained only]
■ Are the lighting control projects meeting CALCTP-Certified Project requirements? [CALCTP-trained installers only]	■ Installer interviews [CALCTP-trained only]
■ How can the CALCTP installer program be improved?	■ Installer interviews [CALCTP-trained only]

Research Question	Data Source
High-level comparison of lighting controls installation training	
▪ Which lighting manufacturers offer specific lighting control training or certification training? What is the scope and depth of the various trainings?	▪ Program management interviews ▪ Internet research ▪ SME interviews [10] ▪ Installer interviews ▪ Manufacturer/CALCTP interviews
▪ How does manufacturer installer training compare with the CALCTP installer training?	▪ Installer interviews [manufacturer- and CALCTP- trained only]
▪ What are the specific performance objectives for training associated with installers?	▪ Manufacturer/CALCTP interviews ▪ Review of training materials
▪ What instruments (written exams, hands-on performance, etc.) are used to measure an individual's performance on the requisite competencies and behaviors?	▪ Manufacturer/CALCTP interviews ▪ Review of training materials
▪ Must any specific training requirements be met before an installer may have access to a given manufacturer's lighting control products?	▪ Manufacturer/CALCTP interviews ▪ Review of training materials
▪ What, if anything, is required to maintain certification or meet requirements of installers over time?	▪ Manufacturer/CALCTP interviews ▪ Review of training materials
Detailed comparison of key characteristics likely to have a significant effect on workforce performance	
▪ How does the training offered to the "general population" of installers by CALCTP and by manufacturers compare in terms of key characteristics likely to have a significant effect on workforce performance? ▫ Training design (selected adult learning principles) ▫ Assessment of learner's exit-level competence and of change in skills/knowledge as a result of the training ▫ Availability / accessibility of the training ▫ Learning focus and objectives of the training	▪ Manufacturer/CALCTP interviews ▪ Review of training materials

[10] Subject matter experts we interviewed to help us identify manufacturers who offer installer training available to the general population and the scope of that training include: Mark Ouellette, Senior Project Manager, ICF International, Teddy Kisch LC, Senior Project Manager at Energy Solutions, Vireak Ly PE, Program Manager of Lighting Market Transformation and Lighting Innovation at SCE, Rubio Rubio, LEED AP, Owner of On Target Electric, Mike Goodwin, Project Manager at Herzog Energy/Herzog Electric.

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Findings: Issues in the Field

In our interviews with installers and manufacturers, we learned about the kinds of issues that affect the quality of lighting controls installation. These issues can be grouped into five categories discussed below:

- Customers and Supply Chain
- Lighting Design Issues
- Code Requirements
- Technical Issues
- Common Installation Errors

Two factors to consider when reviewing the following discussion of the issues the installers described are the size of the project and when the project occurred. Both of these can have a significant influence on the quality of the installation and the issues that installers encountered.

- **Size of the project** — Neither installers nor manufacturers distinguished between large or small, simple or complex projects when they were discussing the issues they encountered. Manufacturer involvement and support typically varies depending on the value of the project, with large projects likely to be of higher value (price-point, visibility, etc.) — for new construction and retrofits.

  The type of support provided by manufacturers (design reviews, customized training, pre-installation checks, etc.) could affect the issues installers encounter on the job, with more support likely leading to fewer problems.

- **When the project occurred** — Many of the installers interviewed have been doing projects for many years.[11] It is uncertain whether their reports are based on memories of installations before the current 2013 Title 24 Part 6 code cycle. For example:

  - Do customers not see the value of controls although they are required by law and will be checked by a local enforcement agency?
  - Has the new requirement for Title 24 Part 6 Commissioning helped minimize some of the issues?

[11] Over half (eight) of the installers interviewed had more than 15 years of experience in lighting controls, with another three having six to 15 years of lighting controls experience. See *Appendix B: Background Characteristics of the Interviewed Sample of Installers* for details about experience levels and other characteristics of interviewed installers.

Customers and Supply Chain

Both customers and members of the lighting controls supply chain can hinder appropriate installation of lighting controls.

Table 4: Customer and Supply Chain Issues

Customers	Supply Chain
Customers can be a force against adequate controls: ■ Are very cost-conscious: ▫ Want to avoid advanced controls ▫ Would choose a non-certified installer if the bid was lower ■ Rarely request lighting controls; don't recognize following: ▫ Title 24 Part 6 requirements ▫ Potential energy/cost savings and other benefits	Members of the supply chain can obstruct lighting controls projects: ■ Pre-sales personnel often don't understand or "sell" the need for lighting controls. Some may even "sell against" control systems. ■ Wholesale reps can hinder contractors during the quote process: ▫ Excessive demands for information ▫ Lack of per-unit pricing information ▫ Mark-up on manufacturer price, adding cost but little or no value

Customers and End Users

The central issue that installers face in nonresidential projects is that many customers do not perceive value in lighting controls, usually due to a lack of knowledge.

Customers typically want the cheapest job done, so they don't want to spend money for lighting controls, and they especially don't want to spend the extra money that a certified installer might charge for doing this work.

They are also largely unaware of the long-term benefits of lighting controls and of Title 24 Part 6 requirements. Customers often communicate wishes that are contrary to the requirements of Title 24 Part 6, and the contractor must try to negotiate a balance between the two. Four interviewees mentioned these issues specifically.

When asked about customer requests for controls, most interviewees indicated that customers rarely ask for controls. At least ten of the 15 said customers rarely or never requested controls. One said customers almost always want occupancy sensors, but don't want a full lighting control system. Another said that more recently customers are vaguely aware of controls and they ask about them. Still another said that customers sometimes, though rarely, ask for dimming in certain specific rooms.

Four installers said that they have no way of knowing what the customer asked for because they are not involved at that stage of the process. They only install the systems as designed.

Asked whether customers start with a negative view of lighting controls, the same four installers had no opinion about this because they don't have contact with the customer at the early stages of the job, when they make their wishes known. However, among the others, most said that, to the extent that customers know anything about controls, they begin the process not wanting them, almost entirely because of the additional cost of equipment and installation. They see it as an unnecessary expense. Another interviewee chalks this pattern up to "typical American short-term orientation."

One interviewee indicated that some customers do have past experience with older versions of controls and control systems, and the experience was negative. He believes the issues that produced negative experiences have since been solved, but the customers' negative view of controls persists.

Finally, one interviewee's experience is that customers often don't like daylighting controls, and no one likes controlled receptacle requirements, i.e., the outlet that has to be controlled by a motion sensor or a time clock.

Supply Chain

One installer interviewed elaborated on the point that customers generally don't want lighting controls by saying that these views are often amplified by the engineers. This installer has worked with engineers who talk against control systems, arguing that controls are expensive and there are a lot of problems with wireless systems. This installer thinks that these views are shared by general contractors and utility representatives. Customers, who are usually quite uninformed about controls, are highly influenced by this input. His experience is that this type of message has held up about 20% of his projects. He views general contractors as the worst possible people to explain and "sell" the customer on lighting controls.

Two interviewed installers reported problems with lighting sales representatives at the wholesale level. They are experienced as gatekeepers, adding extra expense as well as being a time sink. These representatives ask for a lot of information and hold up the quote process. They also add a mark-up to the manufacturer's price. Lighting representatives can determine access and pricing in a way that at least one installer felt kept him from getting the products he wanted. While we do not know the details about the kinds of projects these installers were recalling, or the specific role of the wholesalers in those projects, a recent market characterization study[12] notes that lighting distributors play a variety of roles, with some taking on responsibility for doing calculations and helping with specifications. It is easy to imagine a knowledgeable installer experiencing these types of distributors as intrusive and expensive.

One interviewed installer experiences a major obstacle in getting per-unit pricing from some manufacturers. This keeps him from being able to quote prices accurately. He finds it necessary to work with only one manufacturer due to this problem.

[12] Evergreen Economics and Research Into Action, *SCE/PG&E Basic/Advanced/LMT Program Process Evaluation: Commercial Lighting Retrofits –Targeted Research Final Report*, October 11, 2013

Another "supply chain" issue raised by the installers was that manufacturers do not provide sufficient and detailed enough training, and expect contractors to relay the information to others. One said that the training he received from manufacturers was not sufficient to allow him to design systems independently. (Note that another installer in the context of comparing manufacturer training to CALCTP training said that the manufacturer training he received was sufficient to design and sell controls projects.)

In summary:

- Nonresidential customers generally are not advocates of lighting control systems.
  - Some perceive lighting controls as an added and unnecessary expense.
  - Some are "lighting control averse" and "Title 24 detractors" because of previous bad experiences with controls and the Title 24 Part 6 enforcement process.
  - Others may be swayed by engineers and others involved in the pre-design or design stage of the project who "sell against" lighting control systems.
  - Few customers request lighting controls; those who do ask for controls ask for occupancy/vacancy sensors (and occasionally dimmers).
  - Some may not be aware of the value proposition or do not trust the anticipated benefits of a lighting control system implementation.

  These issues likely are more pronounced in control-specific retrofits since Title 24 Part 6 requires lighting controls in new construction and lighting system alterations.
- Many people in the supply chain can make it more difficult for installers to provide appropriate lighting control systems to customers.
  - Designers (engineers) and others who should logically be promoting effective lighting controls are reported by at least one installer to be doing the opposite.
  - Some wholesalers make it difficult for some contractors or installers to obtain the desired products in a timely and cost-effective manner.

Lighting Design Issues

Lighting design is a complex matter, and this study is not focused on that. However, installation issues overlap with design, and to that extent, we discuss them here.

Table 5: Lighting Design Issues

Poor Design	Poor Communication
■ Design and specifications often are done by engineers who: ▫ Do not fully understand lighting control products and design requirements ▫ Do not adequately understand Title 24 Part 6 ■ Some specific design issues that installers identified are that some designers: ▫ Don't tailor the design to the customer's needs and applications ▫ Omit detail regarding placement — or specify inappropriate placement — of sensors and controls ▫ May specify systems using products that will not work together ▫ May miss important — or misinterpret — Title 24 Part 6 requirements	Even if the design is good, it may be poorly communicated to the installers: ■ Plans/drawings often lack appropriate detail, such as: ▫ Control types and locations ▫ Primary and secondary sidelit daylit areas and skylit daylit areas ■ The design concept and intent (narrative) rarely is communicated.

Poor Design

When it comes to design, one interviewee summed it up with, "There is a gap in the market for lighting control design." This gap leads to installation problems that installing contractors must solve in the field. While this study did not set out to study optimal lighting design requirements, this topic was mentioned quite often by the study participants as a major concern. More research in this topic may be required, perhaps in the form of a needs assessment.

Lack of Knowledge Specific to Lighting Controls

Several installers listed engineers who design lighting systems as one of the problems they have with installation. They experience these system designers as being relatively uneducated and inexperienced with current lighting controls products and designs. The system designers also are often unfamiliar with Title 24 Part 6 requirements or have different interpretations of them than do installers. Some think that engineers especially neglect daylighting controls in their system designs.

Another manifestation of designers' lack of understanding of lighting control systems is that they sometimes specify products that don't work with other products that they have specified — or they specify products that are designed for another space type. For example, consider these comments by two interviewees:

> *"… occupancy sensors or photocells are designed for a given area, but when there is difficulty with the sensor [it's typically] a poor application…It's not a problem when we design our own or we suggest a sensor. It's when a sensor has been specified by some other party."*

> *"A lot of engineers don't even understand how the systems work, they are putting things on drawings that don't make sense, are incomplete or are way overboard."*

Inattention to Job-specific Requirements

Some installers mentioned that the design engineers sometimes use computer software to do a standardized design, or cut and paste instructions from manufacturer instructions rather than design for the building and customer specifically.

On one occasion this resulted in the design showing a one-to-one replacement of fluorescents with LEDs, but the LEDs were so bright that there was too much light, and promised savings would not be achieved. While this particular issue does not directly relate to lighting control systems, it was raised by an installer as an example of how lighting system designs may not be well thought out and may not meet job-specific requirements.

Another example of inattention to job-specific requirements that was mentioned is an area where workers are assembling small parts and need a lot of light. Installing dimmers in this kind of area is wasteful because a lot of light is always needed when there are workers present. Failing to account for this was a failure to understand the work process and task-specific needs.

Daylighting controls, which should be designed specifically to the building's windows and skylights, came up often as an issue. Frequently these controls are not spelled out on the plans or the way they are designed does not reflect the "reality" of the building. Another concern cited is that the various daylit areas are not specified on the plans, but the lighting for these areas must be on different circuits so they can be controlled separately.

Another example an installer cited as a lack of customization is that the plans for a small building may call for daylighting controls which are not necessary for a small building, but are needed for a large building. (This may be a misunderstanding on the installer's part: Under current (2013) Title 24 Part 6, all new nonresidential lighting installations must meet mandatory requirements for automatic daylight controls, where electric lighting is adjusted in response to the presence of daylight. This is true regardless of the size of the building, although there are exceptions based on the watts/ft^2 in both new construction and alteration projects.)

Omission or Misinterpretation of Title 24 Part 6 Requirements

A number of interviewees made general statements about engineers' lack of knowledge and understanding of Title 24 Part 6, such that the designs do not always align with the code, and disputes occur as a result. They also indicate that the whole field is still working out how to interpret various provisions, because there is room for disagreement.

One installer, who is certified as an Acceptance Test Technician (ATT)[13], told us that nine out of 10 of the projects he reviews are failed at the desk or phone call level because after asking a few simple questions, such as whether the lighting has dimmers, or whether there are daylighting controls in the system, the installer says these things are not there; thus the job is failed at that time.

He described many such phone calls where the installer says he has installed the system as designed by the engineer, and the engineer indicates that it is the contractor who is responsible for making the project comply with relevant codes. The contractor takes the position that the engineer should be responsible for making the design compliant with code, and they reach an impasse.

Poor Communication

An important element of the design process and its effectiveness is the communication of the design to the installer. Installers report that this is a common failing.

Lack of Details or Inappropriate Details

As noted above, installers report that sensors and controls are not being incorporated in the plans, citing a lack of specification, inaccurate drawings, or the addition of disclaimers that say contractors have responsibility for some design functions and for meeting Title 24 Part 6 requirements.

Installers also indicated that plans often do not include daylighting controls, even though they are mandatory for daylit areas in nonresidential projects.

Another common problem with daylighting controls is that the lights in daylit areas (the primary sidelit, secondary sidelit, and skylight daylit zones) should be on separate circuits and controlled separately. Often the distinction between these zones is not called out in the plans, so it's difficult to determine which luminaires need to be on separate circuits and controlled by the daylight sensors. (Title 24 Part 6 does require that the daylit zones be shown on the plans. However, it is possible that this omission "slipped by" the enforcement agency at the plan-check stage.)

Another issue that the interviewees often cited as a design issue, but that also can be an installation issue, is poor placement of sensors. Some sensors are movement or light based while others are sound based. How effective these sensors are depends on how well they are placed, and it is important to know where each should be located before installing controls.

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[13] Acceptance Test Technician (ATT) refers to a role specified by Title 24 Part 6. This role is filled by individuals who have met rigorous certification standards, demonstrating that they are conversant with the relevant code and can execute the acceptance tests as specified in Title 24 Part 6.

There are two types of ATTs specified by the current (2013) Standards: Lighting Controls Acceptance Test Technicians and Mechanical Acceptance Test Technicians. Throughout this report, we use the term to refer to certified Lighting Controls Acceptance Test Technicians.

See *Acceptance Testing* on p. 73 for more information on Acceptance Testing and ATTs.

Poor sensor placement is a design issue when sensors are not laid out in the design at all or they are specified in locations that will not be able to detect what they are supposed to detect. Some examples cited include:

- Spacing sensors incorrectly, with either too little or too much space between them
- Specifying occupancy sensors in locations where occupancy would not be detected — for example movement-based sensors placed too high for those sitting, behind pillars, or around corners
- Specifying occupancy sensors in places where "occupancy" is detected erroneously — for example, in a location that would result in the lights coming on every time a person walked through the hallway outside the room, or (for a sound-based system) the lights coming on when air blows through a vent

Little or No Communication of Design Intent

In addition to complete and detailed plans and related specifications, multiple interviewees indicated that a narrative description of the ideas behind the design would be an important element in the quality of the design and its implementation.

Title 24 Part 6 specifies commissioning requirements for new construction, including several steps intended to help minimize the impact of poor design and lack of communication about the design intent:

- Owner's or owner representative's project requirements (OPR)

  The OPR describes the energy efficiency goals, facility hours of operation (including "after-hours" needs), and expectations for equipment and systems.

  This, if provided to installers, provides important context for the project.

- Basis of design (BOD)

  The BOD is a written explanation of how the design meets the OPR — including indoor lighting systems and controls.

  This, if provided to installers, serves as the narrative description of "the ideas behind the design" that the installers we interviewed said would help improve the quality of installations.

- Design phase review

  The design phase review is held at the schematic design phase and is conducted by the design engineer (buildings <10,000 ft^2) or another engineer to verify that the actual design reflects the BOD.

It is unclear whether the lack of communication about the design intent is something primarily associated with lighting system alterations or whether the commissioning requirements are not having the desired effect.

In Summary

The lighting design and specifications often are done by engineers who don't fully understand lighting control products and design requirements. They:

- Don't tailor the design to the customer's needs and applications — including examples such as:
  - Control system needed for a large, complex building used in a small simple building (overkill)
  - Design with one-to-one replacement of fluorescents with LEDs (too much light and little or no savings)
  - Dimmers on lights used only to light detailed assemblies with small parts (an application that always needs full lighting)
- Specify systems using products that will not work together
- Omit — or misinterpret — Title 24 Part 6 requirements:
  - Omitting daylighting (or other controls) even when the code calls for it
  - Not specifying the daylit zones or inaccurately calculating daylit zones

Inadequately detailed plans and poor communication can lead to other problems for installers/contractors, for example:

- A plan that doesn't specify controls or control locations can lead to an installation that cannot pass acceptance testing.

  Installer may blame the designer; the designer may blame the installer because a "blanket statement" on plans says the installer is responsible for ensure T24 compliance.
- During construction, an obstruction was created (or a vent relocated) so the "real world" doesn't match the plans.

  If the designer had communicated the rationale behind the design, the installing contractor would have a much better frame of reference to figure out a "work around" that would not negatively affect the lighting system control.

It's useful to note that all of the manufacturers we interviewed do offer "design training" relative to control systems. We did not do detailed information gathering about design training, as that was outside the scope of this effort, which focuses specifically on installation. However, all indicated that they provide training on lighting control design — often including "hands-on" (with magnetic board and "component magnets or with pencil and paper) scenario-based activities for training participants. (This is true even of the manufacturers we talked to who do not provide installer training.)

CALCTP also indicated that they recognize the importance of a skilled and well informed lighting design community; and, in fact, are developing such training.

Code Requirements

Table 6: Code Issues

Code Requirements Can Be Challenging
Title 24 Part 6 Standards are: ■ Complex and stringent — difficult to understand and comply with ■ Perceived to have "room for interpretation" ■ Often not adequately reflected in plans installers receive ■ Difficult to keep up with, since the Code is updated every three years

Several installers we interviewed cited Title 24 Part 6 as a challenge for installers, noting it is complex, overly stringent, inflexible and legalistic. In short, Title 24 Part 6 can be difficult to understand and comply with. In addition, it appears from our interviews with both installers and manufacturers that many in the industry believe there is a lot of room for interpretation.

Few would argue that Title 24 Part 6 requirements are not complex and stringent. However, there is a misperception regarding the "room for interpretation." Informal interviews with energy consultants well versed in the Standards confirm that there were a few areas in which interpretation was uncertain when the code first took effect (mid 2014). However, the Energy Commission has since clarified virtually all of those areas.

One person we spoke with during the manufacturer interviews has been very active in supporting the lighting industry specific to Title 24 Part 6, teaching many classes on the Standards for nonresidential lighting and working with CALCTP and the California Lighting Technology Center (CLTC at UC Davis) with their training specific to Title 24 Part 6. He told of a seminar he attended where several expert lighting designers were presenting to other designers and design-install contractors. The group engaged in a lengthy and heated discussion about some of the new "requirements" and how onerous they were. However, the points under discussion were not even part of the code. Rather, they were misinterpretations somewhat akin to "urban legend."
Another significant problem that installers cited — and manufacturers echoed — is that the lighting controls system, as specified on the plans, does not comply with Title 24 Part 6. Several examples were discussed under "Poor Design" in the discussion of *Lighting Design Issues* (p. 35), including:

- Omitting controls that are mandatory per Title 24 Part 6, relying solely on a statement that the installer is responsible for compliance
- Not specifying primary sidelit, secondary sidelit, and skylit daylit zones or inaccurately calculating daylit zones
- Calling for improper sensor locations or not specifying sensor location at all

It should be noted that plans that don't meet the Title 24 Part 6 Standards should be "caught" at plan check by the enforcement agency (i.e., local building department), withholding the building permit until the plans are to code. However, it's well recognized by experts in the field of Title 24 Part 6 compliance issues that there is inconsistent and incomplete enforcement in many jurisdictions across the state.

Technical Issues

In general, keeping up with rapidly changing technology is difficult for installers, and likely other market actors as well. Some specific statements from the installers we interviewed include:

> *"It is a full time job to stay on top of technology."*
>
> *"Keeping up with the technology is the biggest challenge."*
>
> *"The most challenging aspect would be finding one system that would meet all the needs of the customer and something they could easily manage"*.

One interviewee indicated that access to certain parts of the building presents problems. He said that some systems are designed with a continuous row of fixtures that need to be dimmed, which requires control wires. The problem with this is that it requires access to spaces above the ceiling. This is expensive. However, he continues, wireless systems solve this issue and are becoming more common.

Other technical challenges cited by installers include difficulty in calculating lighting spread, finding one system that meets all customer needs (and Title 24 Part 6 requirements), and finding the right locations for sensors.

Common Installation Errors

Both installers and manufacturers cited a number of common installation errors that can be grouped into two categories: errors specific to lighting control systems, and errors in general workmanship (which a qualified electrician should have the skills and knowledge to avoid).

Table 7: Common Installation Errors

Control-system Specifics	General Workmanship

■ Inappropriate sensor location
  □ Occupancy sensors
  □ Photosensors
■ Errors in programming and DIP switch settings
■ Inappropriate sensitivity settings
■ Poor connections with RJ45 connectors or CAT-5 cables
■ Inappropriate placement of wireless gateway or controller
	■ Improper or no grounding[14]
	■ Bent or strained wires
	■ Improper strapping
	■ Poorly organized wires
	■ Lack of labeling at the panel

Control-system Specifics

All the issues listed under "Control-system Specifics" in *Table 7: Common Installation Errors* were mentioned by both installers and manufacturers. While many of these areas revolve around the kinds of issues associated with the "pulling wires" aspect of controls installation, it cannot be assumed that the interviewees were unfamiliar with programming-related requirements. Some of the installers interviewed indicated they were responsible for the full gamut of controls installation, from design through installation and verification of the system. In addition, few of the manufacturers mentioned specific installation errors associated with programming and overall system operations.

Inappropriate Component Placement

This issue of inappropriate sensor placement was discussed in "Lack of Details or Inappropriate Details" under *Lighting Design Issues* (p. 37). However, this is not solely a design issue. If there is insufficient detail on the plans, installers need to make decisions regarding sensor placement; but even if the plans specify appropriate locations for all the system's sensors, installers frequently need to make placement decisions "on the fly" during the installation.

Oftentimes, the details of the space change during construction, so the placement specified in the plans is inappropriate to the actual building. For example, a designer may place a sound-based occupancy sensor in a location that is appropriate on the drawings. However, a modification during construction placed an HVAC vent nearby. Installing the sensor next to the vent could cause "false positives," turning on the lights every time the HVAC system comes on.

[14] Technically, all electrical components that require grounding should use "a true earth ground," so we list grounding under "General Workmanship," as it is a skill that all qualified electricians should have. However, it surfaces as an issue for lighting controls more often than with many other projects because these systems often are especially sensitive and perform badly or erratically if not properly grounded.

It typically falls to the installer to make adjustments in the field so the controls can do what they are intended to do. Both the installers and the manufacturers we interviewed provided a number of examples of problem placement, especially when completed by an installer not trained in controls.

Some examples of inappropriate placement cited include:

- One installer told of non-trained installers placing occupancy sensors in the exact places that the manual switches were originally placed. This resulted in the lights not coming on until people were well into the room.
- A manufacturer told of movement-based controls being installed "backwards" with the sensor facing the wall rather than the occupied space.

Another placement issue mentioned by a manufacturer and two installers was selecting an inappropriate location for the wireless gateway or controller. That is, some installers place this crucial wireless component inside a metal box so it is unable to communicate with the other system components.

Programming and DIP Switch Settings

Programming of switches and sensors was mentioned multiple times by both installers and manufacturers as a source of installation error. Of course, the programming has to be right or the system will not function appropriately. DIP switch settings and programming sensor sensitivity were cited specifically as problems that arise during the installation process.

In fact, one manufacturer said that their field support team dealt with so many problems due to improper DIP switch settings that the company redesigned their controls so that they no longer use DIP switches. Rather they have an internal chip, which is programmed by a manufacturer-certified "commissioning agent" after physical installation is complete.

Wiring Issues Specific to Control Systems

More than one installer and manufacturer mentioned installation problems specific to the modular connectors and cabling typically used with computer systems and now frequently used with computer-controlled lighting control systems. Many manufacturers require RJ45 plugs (similar to Ethernet plugs) and category-5 (CAT-5) cable. Many electricians are not used to working with these components and may incorrectly the wire the connection. The bad connections could negatively affect functioning.

There is an alternative to these plugs in the form of a "hard termination" screw-in plug. They are easier to work with, but the RJ45 plugs will likely remain in the market and there will be a learning curve in their use.

A final issue with wiring specific to controls that was raised is that it is important that the dimming ballast must have a good connection. There can be interference, and without a good ballast connection, failure can result, often after some time has passed.

General Workmanship

None of the manufacturers interviewed noted any of the issues listed under "General Workmanship" in *Table 7: Common Installation Errors*. Although we did ask specifically about these kinds of installation issues, manufacturers indicated they were not aware of these factors being a problem, and two manufacturers indicated that they specifically do not focus on considerations associated with general workmanship because workmanship issues are governed by federal, state and local code and all electricians should be competent in these areas. It also should be noted that most of the issues under general workmanship create operational and maintenance problems that may not be evident in the near term, but will become evident over time. In addition, the manufacturer personnel we interviewed are not the same individuals who are responsible for warranty issues.

However installers cited general workmanship issues more often than other installation problems that don't overlap with design.

A particular issue that installers raised is laying the wires and cables in an organized manner "training" them so that they are not stressed over time, (i.e., that they are flowing naturally, not bent), and that the strapping be done according to code. Two reasons were mentioned supporting the importance of properly laying and strapping the wiring:

- While the system might function initially when these rules are violated, over time there could be corrosion, affecting long-term functionality.
- Doing the wiring correctly will facilitate future maintenance.

Another craftsmanship issue that came up multiple times is the importance of proper grounding, especially in lighting controls. Because of the connection to computers, grounding is a big issue. If it is not properly grounded, specifically using a true ground to earth, it will cause many problems and make it difficult to perform future maintenance. In fact, it will likely not function well over the long term if the grounding isn't right.

In Summary

One of the major areas of installation problems overlaps with system design issues: appropriate placement of system components such as sensors and controllers. Even "perfect" design cannot alleviate all need for installers to make decisions about placement because unanticipated issues often arise during the construction process.

Other control-specific issues cited by both installers and manufactures include problems with DIP switch settings and sensitivity settings, as well as poor connections with RJ45 connectors and CAT-5 cables.

Installers also frequently mentioned general workmanship issues of laying, strapping, and labeling the wires and cables inappropriately and inadequate grounding of components.

Manufacturers did not raise the issues associated with general workmanship. When asked about this, one manufacturer said they tended to avoid "basic wiring issues," as they assume that installers have demonstrated competence in this area through their licensing.

Another reason why general workmanship issues typically are not "top of mind" for manufacturers is that problems in this area may not surface until well after the project is finished.

- Control-specific issues typically would be identified during Functional Performance Testing (a Title 24 Part 6 Commissioning requirement for new construction ≥10,000 ft^2) and Acceptance Testing (required for alterations as well as new construction).

  Therefore they tend to be identified and addressed before the lighting project is signed off by the enforcement agency.

- General workmanship issues often create problems over time, but may not be evident in the short-term.

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Findings: Training & Certification

This section on findings about installer training includes two kinds of information:

- The discussion under *Overall Comparison of Available Installer Training* (p. 52) is based primarily on what we learned during our interviews with installers and manufacturers.
- The discussion under *Criterion-referenced Review of Training*[15] (p. 59) is based on a review of training material from manufacturers and CALCTP in conjunction with information from the in-depth interviews with these training providers.

In both discussions it is useful to keep in mind several issues that affected our findings and resulted in apparent inconsistencies between installers' perspective and what we learned from the manufacturer interviews and review of training material.

This section of the report concludes with a discussion of the perceived value of lighting controls training and certification.

Considerations regarding What We Learned about Installer Training

It is important to keep in mind while reviewing the discussion on training and certification that:

- There are significant differences among the offerings from different manufacturers, the training changes significantly over time, and some manufacturers offer a variety of installer training opportunities including both formal classroom training and ad hoc customized training. Therefore when an installer discusses manufacturer training, the comments may or may not refer to training that we reviewed during this project.
- When installers are characterizing manufacturer training and CALCTP training they reflect different points of view and perspective.

  This is to be expected when surveying different individuals about a given topic. In addition, to a large degree, different installers will be considering very different things when they talk about "manufacturer training" given the wide range of:
  - Lighting controls products and manufacturers
  - Training approaches across manufacturers
  - Training opportunities available from a single manufacturer

These issues are further discussed below.

[15] In a criterion-referenced assessment, performance is compared to a clearly defined and delimited domain. That is, we defined characteristics that are desirable in installer training in several "domains," as represented by the assessment "yardsticks." Then we considered several criteria associated with each dimension of a domain and determined whether or not the training reflects those characteristics.

Installer Training for the "General Population"

When considering the overall population of lighting controls installers from a manufacturer's perspective, installers can be categorized into three different groups:

- The "general population" of installers, who typically are journeyman electricians, but do not have certification training from the manufacturer

  These installers have not been certified in lighting controls by the manufacturer, though they may or may not be certified by CALCTP as lighting controls installers.

- Manufacturer-certified specialists, who have completed a performance-based course of training (Certified Technical Representatives, Certified Field Technicians, Certified Commissioning Agents, etc.)

  These installers have different job titles and specific responsibilities depending on the certifying manufacturer. What they have in common is:

  - Close affiliation with a given manufacturer
  - In-depth, controls-specific training with pass/fail performance criteria for certification from the manufacturer they are affiliated with.

    Typically, their certification requirements include on-the-job observation and coaching.

- Manufacturer-employed installers, who have completed a performance-based course of training.

  Manufacturer in-house installers also typically complete in-depth, controls-specific classroom training with pass/fail performance criteria and must complete a period of on-the-job training in which they are coached and mentored by experienced professionals.

This assessment was focused on the installer training opportunities that are available to the "general population" of installers, which is less rigorous and in-depth than the certification training that some manufacturers provide. We did not assess the training provided to manufacturer-certified affiliates or in-house installation teams. (See *Type of Training Identified for Review*; p. 26 for more information about the reasons for focusing specifically on training available to the general population of installers.)

Differences across and within Manufacturer Training

Many manufacturers offer no formal classroom training. In fact only eight (22%), of the manufacturers on our list of 36 manufacturers identified as most likely to offer formal training for installers actually offer such formal training.

However, many manufacturers do offer training other than traditional classroom training. These training options are offered in addition to traditional classroom training for some manufacturers, and are the only installer training offered by other manufacturers:

- On-the-job-site guidance and coaching with supporting materials such as checklists, instructions and spec sheets, and installation guides
- Online self-study modules and YouTube training videos
- Webinars and presentations

Even when considering a single manufacturer, there may be significant differences within that manufacturer's installer training. As noted above, several manufacturers that offer traditional classroom training for installers also offer installer training in other formats. Installers characterizing manufacturer training may be considering experiences related to "alternative" training approaches.

In addition, two manufacturers noted that the same instructor may deliver the same course in different ways depending upon the needs and interest of the audience as well as the organization hosting the delivery. For example, one manufacturer said they have a "standard" version of their primary installer course. That course may be delivered as:

- Two days of instruction covering all the content in the course materials.

  This version of the course qualifies for continuing education units (CEUs) from the American Institute of Architects (AIA).

- One day or one-half day of instruction covering the areas of most interest to the installers signed up for the class.

  Neither the one-day nor the half-day version has been approved by AIA for CEUs. Installers characterizing this manufacturer's classroom training may be considering two very different versions of the same course.

Differences in Points of Reference regarding Manufacturer Training

We asked installers who had received manufacturer training to name the manufacturer among those they experienced that provided the most comprehensive training. Our purpose in asking about the most comprehensive training experienced by our sample was to provide a focus for the questions we asked about the nature of the training and how it compared to CALCTP training.

- The interview would have been too long if we had asked all of the questions about all of the training the interviewee had received. Further, one of the aims of the project is to determine to what extent CALCTP does or does not offer more than is available by other means.

- If we were to be in a position of saying that manufacturer training covers the needs of the field adequately without CALCTP, we would want to be sure we had asked about the most comprehensive trainings available. Clearly, only the most comprehensive manufacturer training would have a chance to "compete" with CALCTP.

Some of the manufacturers cited by installers are not among the manufacturers with whom we have conducted in-depth interviews, but where our installers had training from one or more manufacturers, they also had training from at least one of the short list of six manufacturers we considered for in-depth interviews and review of training materials. (See *Manufacturer Research*; p. 18 under *Methods*.)

In fact, our screening criteria for classifying an installer as "manufacturer trained" required the interviewee to have received training from at least one of the original top six manufacturers that we tried to recruit. Where there is a lack of overlap between installer-reported manufacturer trainings and our interviewed manufacturers, it would be because we were unable to schedule

one of the manufacturers or because one of the manufacturers originally cited as a training provider did not, in fact, offer installer training to the general population.

We compare the manufacturer training providers that installers cited to the manufacturers we interviewed in Table 8 below, which shows:

- All of the manufacturers that were mentioned by installers as being among those providing some training
- How many interviewees mentioned that manufacturer

  (Some installers could not remember all of the manufacturer training opportunities they have completed. They have been getting training from manufacturers for years, and details faded with time.)
- The manufacturers that were chosen as the most comprehensive, given that they had received training from more than one.
- How the manufacturers cited by installers relates to the manufacturers with whom we conducted in-depth interviews.

Table 8: Manufacturers Cited by Installers as Training Providers Compared to Manufacturers Interviewed

Mentioned by Installers as Training Provider	Number of Times Mentioned	Number of Times Mentioned as Most Comprehensive	Status Regarding Manufacturer. Interview and Training Review
WattStopper	8	1	Completed
Leviton	4	1	Completed
Lutron	4	1	Completed
Acuity	3	2	Attempted, not interviewed
Enlighted	3	1	n/a [16]
Cooper	2	0	Completed
Daintree Networks	1	0	Completed [17]
Digital Lumens	1	1	n/a [16]
Phillips	1	1	Completed
Hubbell Building Automation	0	0	Completed

[16] Not on the list of six manufacturers likely to provide robust classroom training for installers.

[17] Not on the original list of six manufacturers, but added when we were seeking an additional manufacturer because of lack of response from some on the original list.

In summary, the two groups of installers we interviewed who had completed manufacturer training (those who completed only manufacturer training and those who completed both manufacturer and CALCTP training) all indicated that they had received training from manufacturers who were on our list of manufacturers likely to offer robust classroom training for installers of lighting control systems.

- Our manufacturer interviews did not include all the manufacturers cited by the installers as the "most comprehensive" training providers.

  As mentioned previously, all the installers interviewed had completed training from at least one of the manufacturers on our list of six targeted manufacturers. However the manufactures they cited as providing the most comprehensive training were not necessarily one of the targeted manufacturers.

  We have completed interviews with four of the seven manufacturers installers cited as providing the most comprehensive training — plus two manufacturers cited, but not identified as among the most comprehensive. In addition, one of the interviews we completed was with a manufacturer not mentioned by the interviewed installers.

- Even if there were a "perfect match" between the manufacturers that installers cited as "the most comprehensive" training providers and the manufacturers we interviewed, there would not be a perfect match between the training the installers experienced and the training we reviewed and discussed in depth with the manufacturers. For example:

  - One installer described his manufacturer training as consisting of six to eight hours of instruction conducted on-the-job with a manufacturer representative; another described his manufacturer training as three one-hour webinars.

    Both of those types of training were outside the scope and focus of this assessment.

  - As mentioned under *Differences across and within Manufacturer Training* above (p. 48):

    - Some manufacturers deliver significantly different versions of the same course
    - Manufacturers regularly update courses to incorporate their current technology

  - Most of the installers have been working with controls for a long time (see *Appendix B: Background Characteristics of the Interviewed Sample of Installers*); and training typically changes over time.

    It's very possible that an installer took a manufacturer's classroom training for controls installers some years back, and the current version of that training is significantly different from the version the installer completed.

Overall Comparison of Available Installer Training

This overall comparison of available installer training reflects information gathered from installer interviews, interviews with CALCTP and manufacturers, and the review of manufacturer and CALCTP course materials. Table 8 below provides a high-level summary; the discussion that follows provides additional detail. When reviewing Table 9, please keep in mind:

- The "Manufacturer Installer Training" column presents a consolidated view of all the manufacturer training we reviewed. (That is, classroom training offered to the general population by the seven manufacturers we interviewed.) As discussed earlier, few statements can be made that are true of all (see *Differences across and within Manufacturer Training*; p. 48).
- Details about individual manufacturers are found under *Criterion-referenced Review of Training* (p. 59).

Table 9: Summary Comparison of Manufacturer and CALCTP Installer Training Based on Interviews and Review of Training Materials

Area of Interest	Manufacturer Installer Training	CALCTP Installer Training
Learning Path	▪ Difficult to identify all options	▪ "One-stop shop"
Content Orientation	▪ Product specific	▪ Product "agnostic"
	▪ Deep dive on specific products	▪ Limited depth on a range of products
	▪ Some basic concepts and Title 24 Part 6 requirements	▪ Solid basic concepts, including information onTitle 24 Part 6 requirements
Instructional Integrity and Delivery	▪ Wide range of instructional design quality and a variety of delivery modalities ▪ Wide range of delivery styles	▪ Sound instructional design and a variety of delivery modalities ▪ CALCTP-trained instructors with a range of expertise and experience
Performance Evaluation	▪ No pass/fail evaluation ▪ No pre-test/post-test construct to measure change in skills and knowledge	▪ Results in certification via labs and post-test ▪ No pre-test/post-test construct to measure change in skills and knowledge
Accessibility	▪ Offered in numerous locations throughout the state	▪ Offered in numerous locations throughout the state
	▪ Costs range from free to $250	▪ Cost ranges from free to $500
Hands-on Opportunities	▪ Limited hands-on practice[18]	▪ Extensive hands-on practice[18]
Up-to-date Technologies	▪ Reflects latest technology	▪ May not reflect the latest technology available

[18] Installers indicated that manufacturers provided more and better hands-on training than CALCTP. However, interviews with the training providers and review of course material indicate that the installers must have been considering non-standard manufacturer training such as on-the-job demonstration and coaching.

Learning Path

A learning path describes a course of instruction required to accomplish a goal, noting the relevant training opportunities, recommending a sequence, and providing access to registration.

Although several of the manufacturers interviewed offer a full range training opportunities, they are presented in a piece-meal fashion. Interviews with manufacturers indicate that there is no single source of information about these options, recommending the order in which they should be pursued, or allowing installers to sign up for the desired courses. (This was confirmed by an internet search and review of manufacturers' sites.) Getting the "full picture" from a manufacturer's available training would require significant research and perseverance — even for a single manufacturer since there appears to be no comprehensive source of information on all of the training available by any manufacturer. Obviously, this concern is exacerbated when trying to compose a learning path from offerings by multiple manufacturers.

The CALCTP installer training, on the other hand, is a single coherent and comprehensive course, and the pre-requisite online self-study modules are clearly spelled out. Signing up for this training is signing up for the recommended training "from soup to nuts." (It should be noted that some installers indicated they had trouble learning when and where the course was offered; but once enrolled for the course, the learning path is clear.)

Content Orientation

Manufacturer and CALCTP interviews indicate that in general:

- CALCTP training is "product agnostic," presenting concepts that are not product-specific and representing products from multiple popular manufacturers.

  Addressing multiple product brands typically is of value to installers. Most installers we interviewed stated that they use several product brands, though a few try to stick to one brand. The most common reason they gave for using several brands is that some brands are more suitable for certain kinds of designs or needs. Therefore, to meet the needs of the customer and the building, installers need to be familiar with multiple manufacturers' products.

- Manufacturer training tends to focus largely on the manufacturer's products, with some notable exceptions:

  - Two manufacturers indicated that they provide general conceptual training about controls and associated design and installation considerations that is not product-specific in nature.
  - Most manufacturers indicated that they address Title 24 Part 6 requirements to some level, and one has developed and delivers in-depth training on Title 24 Part 6 lighting standards that is totally "product agnostic."

  Because of the product-specific focus, manufacturer training typically is able to go into significant depth about design, configuration, and installation requirements for those products. This level of detail can be valuable to those who are installing that brand of product.

From the installers' perspective, the overall comparison between manufacturer and CALCTP training is evenly divided in terms of both content and detail. The same number of interviewees indicated that:

- Manufacturer training addresses more relevant content and provides greater depth.
- CALCTP training addresses more relevant content and provides greater depth.
- Manufacturer and CALCTP training are roughly equivalent in terms of content and depth.

Some installers did indicate that they particularly value some specific content areas that CALCTP addresses that they felt manufacturers did not. This includes comments such as the following:

- CALCTP training shows you not only how to use and install the equipment, but explains the thinking behind the technologies, whereas manufacturers only tell you enough to install their particular equipment.

  (Note that is true for some manufacturer training, but not all.)

- CALCTP training helps in understanding requirements related to Title 24 Part 6.

  (Note that one manufacturer has developed training on Title 24 Part 6, and actually has delivered his module to CALCTP classes, at CALCTP's request, in addition to delivering the module under his company's auspices.)

- CALCTP is "a thousand times better in detail, delivery, and hands-on experience because it is more comprehensive," and it is "unbiased" (not product-specific).

  (Note that other installers indicated that they thought manufacturer training was superior in terms of detail, delivery, and hands-on experience.)

See *Learning Focus Dimensions* (p.65) under *Criterion-referenced Review of Training* for related details and provider-specific ratings.

Installers' Suggestions for Improving CALCTP Training's Content Orientation

The following are suggestions that installers recommended for improving and enriching the content in the CALCTP installer training:

- Provide more information about different brands and incorporate more of them in the training
- For acceptance training, provide less theory and more practical information about Title 24 Part 6, including going through the actual code

  (It is unclear whether this suggestion is specific to the portion of the installation course that overviews acceptance testing, or whether the interviewee was referring to the training for ATT certification.)

- Provide references for specific examples in the books
- Present more on placement of light fixtures, sensors, and on design generally

Instructional Integrity and Delivery

From an instructional design perspective, considering adult learning principles and practices, several manufacturers offer very sound training, as does CALCTP. (Adult learning principles and delivery modalities were not areas addressed specifically during the installer interviews, as it seemed unlikely that installers would be well prepared to discuss these issues.)

Regarding instructors' delivery (an area not feasible to address during the manufacturer interviews or review of materials), installers were again divided in their assessment.

- One preferred the instructor's delivery in the manufacturer training.
- One preferred the instructor's delivery in the CALCTP training.
- The rest who responded said they were similar.

One respondent indicated that the manufacturer instructor was more of a salesman, while the CALCTP instructor was more like a professor. Another indicated that the CALCTP instructor would benefit from being "less academic."

When considering feedback regarding instructors it is important to note that none of the training considered has only one or two instructors who deliver the training. In all cases, the actual instructor will vary depending upon location and schedule.

See *Adult Learning Principles and Practices* (p. 59) for related details and provider-specific ratings.

Installers' Suggestions for Improving the Delivery of CALCTP Installer Training

The following (listed in no particular sequence) are suggestions that installers recommended for improving the delivery in the CALCTP Installer training:

- Be sure the trainer is up-to-date and knowledgeable about Title 24 Part 6
- Make installer training more hands-on and give examples in addition to theory
- In acceptance training, make training more organized and the curriculum less confusing (Again, it is unclear whether this individual was referring to the Acceptance Test Technician course or content in the Installer course that provides a heads-up regarding what acceptance testing entails.)
- Make installer training more hands-on with new systems
- Deliver training via webinar (Note: This likely is not a practical option since so much of the course is hands-on working with the actual hardware)
- Use less academic instructors, and more knowledgeable trainers

Performance Evaluation

CALCTP installer training results in certification for those who successfully meet the performance criteria (complete the labs according to specification and pass the final exam).

None of the manufacturer courses that were the focus of this project included summative performance evaluations; that is, there was no "pass or fail" for any of the training, although:

- Some manufacturers' courses offered certificates of completion based on attendance.
- At least one manufacturer's course qualifies for continuing education units (CEUs) with the American Institute of Architects (AIA).
- Several manufacturer's courses include formative evaluations (opportunities to check students' progress so remedial action and other adjustments may be taken as necessary).

See *Assessment* (p. 62) under *Criterion-referenced Review of Training* for related details and provider-specific ratings.

Accessibility

Installers indicated that it is difficult to take time off work to get training, especially for small companies. There is a substantial cost in terms of both time and money. One installer estimated the cost at $10,000 to $15,000 for each person trained, including lost income, travel cost, and enrollment fees. (Interviews with training providers indicate that the enrollment fee for CALCTP training ranges from free to $500, and from free to approximately $250 for manufacturer training.)

Many asked that training be offered in "off hours," such as evenings or weekends. One suggested that online classes would be helpful.

Others mentioned that it was hard to find the information about when and where the classes were to be offered. One person said a web search did not produce this information. He ultimately found classes through a helpful building inspector. He said that when he did make contact with CALCTP, they were helpful.

Multiple interviewees requested that notification of upcoming courses be more widely distributed and provided further in advance. Sometimes they learn about classes only a week in advance, and it is impossible to make labor plans to compensate for the employee being away at training.

Another problem they face is finding space in classes that they learn about. Some had to travel long distances to get into classes. One interviewee said he wasn't able to get into classes in the north because he isn't a union member. (It is important to note that CALCTP administrative staff indicates that the Installer training is offered through many Northern California training venues unrelated to union affiliation.)

While the installer comments above were made in response to questions specific to the CALCTP training, interviews with manufacturers indicate the same issues would largely be true of manufacturer training. Manufacturers tend not to do broad marketing and outreach for their installer training, often relying on wholesalers to invite participants. In addition, the enrollment costs, frequency, locations, and time-of-day / day-of-week characteristics associated with manufacturer installer training is generally very similar to CALCTP installer training.

See *Availability and Accessibility* (p. 61) under *Criterion-referenced Review of Training* for provider-specific details.

Hands-on Opportunities

Hands-on practice and assessment is crucial to skills-based learning effectiveness. As a very simple, but relevant example, consider which child would be best prepared to tie his shoes by himself:

- One who had been talked through numerous illustrations and several demonstrations, but never held a shoelace in his hands
- One who was talked through several demonstrations followed by hands-on practice tying his own shoes with appropriate feedback

It is interesting to note that interviews with the training providers and reviews of materials yield findings directly opposite of the feedback provided by installers relative to hands-on:

- On the issue of hands-on experience, almost all installers give the edge to manufacturers.
- The evaluation team found that CALCTP training has extensive hands-on experience (over 50% of the training time), while classroom training offered by manufacturer to the general population had very limited hands-on with the equipment. (Several manufacturers indicated that they pass various products around the class so students can inspect it up close, and one manufacturer had one or two structured hands-on practice opportunities.)

It seems that the installers may have been considering manufacturer training other than the "standard installer training" that that is available to the general population of installers. It is possible that they were, at some time, manufacturer affiliates and received manufacturer certification training. It also is possible that they had the benefit of ad hoc on-the-job coaching that some manufacturers provide. (For a discussion of the categories of manufacturer training and the type of training considered in this project, see *Type of Training Identified for Review*; p.26.)

Up-to-date Technologies

How "up-to-date" the training is was not considered in the review of training materials. Given the project scope, it was not feasible to establish fair and objective evaluation criteria for this dimension of the training. In addition, any assessment of this issue would of necessity be based on a "snap shot in time" that may not fairly represent the "typical" state of the training. For example, the CALCTP installer course is planned to have a major update released in 2016.

We did, however, gather information from our interviews with training providers and with installers.

- Manufacturers typically update their relevant training whenever there are significant changes in the product line, keeping the materials up to date with current technologies for that manufacturer.
- CALCTP publishes new versions of the installer training approximately every 18 months, and has a module specific to advanced and emerging technologies.

  In addition, they have some online offerings that provide technical updates on lighting controls.

  It generally is not feasible for them to stay completely current with the latest technology from multiple manufacturers.

It is interesting to note that a number of installers interviewed provided unresponsive answers to the question about comparing content between manufacturers and CALCTP by talking about how difficult and important it is to keep up with technology. Installers need to take multiple trainings over time to keep up.

Installers' Suggestions for Improving CALCTP Training re: Up-to-date Technologies

A number of interviewees provided suggestions in the area of content updating. All acknowledged the difficulty any training faces in keeping up with technology. But they did have requests for more updating:

- Spend more time with manufacturers to stay up to date with new technology
- Incorporate new technologies faster
- Provide more information on LEDs, smart phones, and tablets
- Include training on room controllers
- Have more complete systems from the four big technologies
- Incorporate cubicle lighting training

Criterion-referenced Review of Training

As described under *Type of Training Identified for Review* (p. 26), this criterion-referenced review of available training focuses only on installer training that is targeted to the "general population" of controls installers (typically journeyman electricians). It does not encompass the proprietary manufacturing training provided to certified affiliates, nor does it include the training provided to installers who are in-house at the manufacturer's organization.

In addition, the results reflect only five of the seven manufacturers interviewed. Two manufacturers with whom we spoke do not provide installer training for the general population so their training offerings are not included in the following discussion. [19]

The findings summarized here reflect ratings based on four different "yardsticks" (sets of evaluation criteria) focused on four different areas (domains) that determine the likely impact of the training on participants' on-the-job performance. The evaluation yardsticks used in this assessment are:

1. Adult Learning Principles and Practices
2. Availability and Accessibility
3. Assessment (determining whether an individual successfully meets the training objectives and measuring knowledge swing as a result of the training)
4. Learning Focus

For more information on how the yardsticks were developed and scoring was conducted, see *Manufacturer and CALCTP In-depth Interviews and Review of Materials* (p. 24).

Adult Learning Principles and Practices

The "Adult Learning Principles and Practices" domain examines training characteristics most likely to determine the overall effectiveness of the training. While there are numerous criteria for effective adult training design and delivery, the yardstick used in this assessment focused on those dimensions and criteria that the instructional design experts:

- Determined were most likely to have a significant and meaningful impact on the effectiveness of installer training
- Could reasonably be assessed based on information gathered during interviews and a review of the training materials — that is, we excluded criteria specific to instructors' delivery style and management of classroom interactions because:

[19] One of the manufacturers we interviewed does not train installers at all. They do, however, train Certified Commissioning Agents who follow along after installation.

The other has no installer training per se, but they do train internal technicians who commission projects. (This manufacturer representative said he was "embarrassed that they don't offer training to contractors who install their systems" that they would be "better served if we did.")

- Assessing instructor delivery requires in-person observations of course delivery, which was outside the scope of this project.
- There are numerous instructors responsible for delivering most of the courses considered; observing one or two instructors per course would provide an incomplete picture.

Three of the courses considered (CALCTP and two manufacturer offerings) did very well in the Adult Learning Principles and Practices domain (100%, 97%, and 91%, respectively), as shown in Figure 1 below.

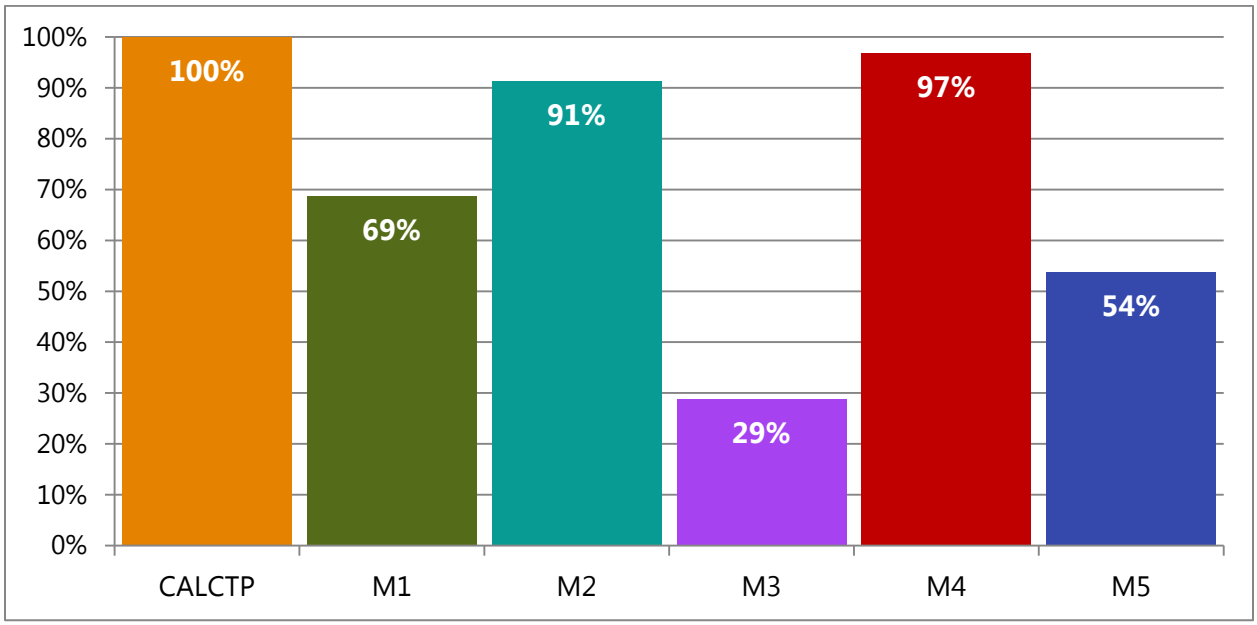
The one area identified for possible improvement in the two high-scoring manufacturer courses (97% and 94%) was providing participants a clear notion of the overall course structure and where they were in that structure ("you are here") as they proceeded through the training.

As indicated in Table 10, the two lower-scoring manufacturer courses (29% and 54%) performed poorly in this domain because:

- One did not have performance-based training objectives.[20]
- Neither had meaningful practice and feedback opportunities (dimension #1.2. Practice and feedback).
- Neither clearly indicated the logic behind the course organization (dimension #1.4. Structure conforms to instructional design principles).

For details about the individual criteria for each dimension, see *Appendix C: Lighting Controls Installer Training Evaluation Yardsticks*.

Figure 1: Overall Scores on Adult Learning Principles and Practices



[20] Performance-based training objectives indicate what the individual should be able to do as result of the training, with the "do" element reflecting on-the-job performance requirements.

Table 10: Scores on Dimensions for Adult Learning Principles and Practices

Scores on Dimensions for Adult Learning Principles and Practices	CALCTP	M1	M2	M3	M4	M5
	100%	69%	91%	29%	97%	54%
1.1 Performance-based objectives	100%	100%	100%	0%	100%	100%
1.2 Practice and feedback	100%	0%	100%	0%	100%	0%
1.3 Variety of modalities	100%	100%	90%	90%	100%	90%
1.4 Structure conforms to instructional design principles	100%	75%	75%	25%	88%	25%

Availability and Accessibility

The "Availability and Accessibility" domain looks at issues associated with installers' concerns about:

- The cost of attending training

  (Those costs include enrollment fees, travel costs, and the cost of lost work opportunities from attending training during business hours.)

- Difficulty learning about upcoming deliveries in time to schedule attending, and getting into classes they want to attend

See *Accessibility* (p. *56*) under *Overall Comparison of Available Installer Training* for more information about these issues.

Unlike the other domains addressed in the criterion-referenced review of training, we did not score the dimensions associated with Availability and Accessibility, as we were unable to determine fair and meaningful numeric scales, and the verbal summary seemed likely to be most useful.

As shown in Table 11 below, key points include:

- One manufacturer indicates his organization delivers in California up to 150 sessions per year; CALCTP and another manufacturer both have approximately three deliveries per month; two other manufacturers averaged one or two deliveries per month.

  One manufacturer has two courses or two different brands of lighting controls (a total of four courses). These are offered once a year in California.

- All but one provider hold sessions at numerous locations through the state. The exception is the provider with fewest deliveries; these classes are almost always held at the company's own facilities or an agent's facility (one in the north and the other in the south of the state).

- Enrollment costs range from free (many CALCTP deliveries and most of the manufacturers' deliveries) to $500 (some CALCTP deliveries).

- Some manufacturers have evening sessions (on weekdays), but they are few and far between.

Table 11: Scores on Dimensions for Availability and Accessibility

Availability/Accessibility	CALCTP	M1	M2	M3	M4	M5
2.1 Frequency	36 per year	150 per year	36 per year	12 per year	25 per year	4 per year
2.2 Geographies	Across CA	Across CA	Across CA	Across CA	Across CA	North & South only
2.3 Time of day, day of week	8 hr/day 5 days/week	Some evening classes	Some evening classes	Varies	Business hours	8 hr/day, rarely evenings or weekends
2.4 Costs to: 2.4.1 Enroll in course	Free to $500	Free	66% free 33% ~$150	Free	Free to $250	Free
2.4.2 Take final exam	Nothing extra	na	na	na	na	na
2.4.3 Receive updates	Voluntary online	na	na	na	na	na

Assessment

The "Assessment" domain considers two distinct aspects:

1. Whether and how well the training assesses participants' performance on established performance standards

   At the end of the training, do participants know what we expect them to know? Can they do what we expect them to do?

2. Whether the provider collects information that can be used to evaluate the affect the training has had on participants' knowledge and skill

   Did participants gain new knowledge and skills as a result of the training, or were they already competent in these areas when they came to the course?

The first area (dimensions #3.1 and 3.2 in Table 12 below) is crucial to establishing realistic expectations regarding graduates' performance on the job and is an essential component of a meaningful certification program. This area was measured on criteria typically associated with evaluating assessments for competency-based certification programs.

The second area (dimension 3.3 in Table 12 below) is important to evaluating the impact the training likely will have on the competence of the overall population. (If the only people who take the training already have the skills and knowledge the training addresses, the training will have little impact on the overall abilities of the population as a whole.) This area was assessed specifically in terms of a "knowledge and skills swing" metric based on a pre- and post-test configuration. That is:

- Test what an individual knows and can do immediately before the training.
- Test what the individual knows and can do immediately after the training.
- The difference between the two tells you how much the training has affected the individual's knowledge and skills.

Since we considered only manufacturer training for the "general population" of installers (not those employed directly by the manufacturer, nor those who are manufacturer-certified field installation technicians or commissioning agents) we cannot completely "compare apples with apples." (That is, compare certification training with certification training.) Given the training we did assess, we know:

- The CALCTP course is the only one that shows any formal assessment of performance.

  Manufacturers' installer training for the general population does not have pass/fail criteria and does not measure participants' knowledge or skills after the course.

- None of the training providers considered have a pre-test/post-test configuration to measure knowledge and skills swing as a result of the training.

  CALCTP does have a pre-test, but it is designed to verify that individuals entering the class have a basic understanding of some fundamental control concepts.

  That is, its intent is to confirm the pre-requisite is met to help ensure class time is not wasted with extensive remedial training for individuals who are completely unfamiliar with the topics at hand. It is not intended to measure pre-training competence.

For details about the individual criteria for each dimension, see *Appendix C: Lighting Controls Installer Training Evaluation Yardsticks*.

Figure 2: Overall Scores on Assessment

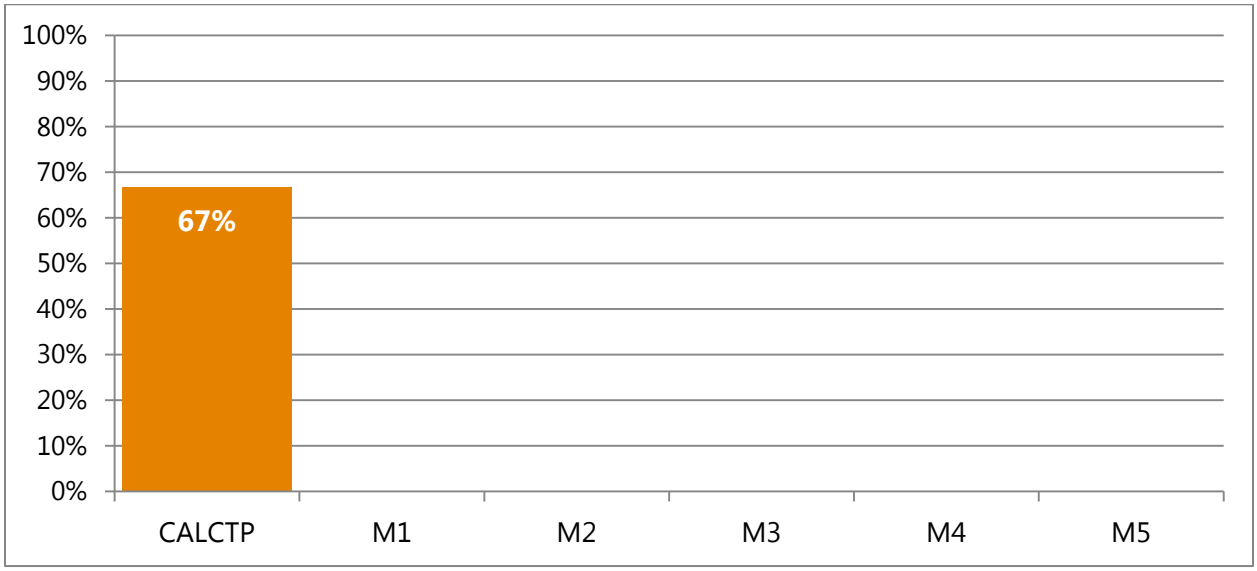


Table 12: Scores on Dimensions for Assessment

Scores on Dimensions for: **Assessment**		CALCTP **67%**	M1 **0%**	M2 **0%**	M3 **0%**	M4 **0%**	M5 **0%**
3.1	Documented performance standards	1.00	0.00	0.00	0.00	0.00	0.00
3.2	Fair assessment methods	1.00	0.00	0.00	0.00	0.00	0.00
3.3	Assessment of training impact on competence	0.00	0.00	0.00	0.00	0.00	0.00

Learning Focus

The Learning Focus domain looks at the content or topic areas addressed by the training. We considered content areas (based on input from subject matter experts and installer interviews as well as a review of the literature available from manufacturers and CALCTP) that would apply to lighting control installers in general.

We did not attempt to rate content related to product-specific requirements or how well the training addressed the latest technologies:

- It would be extremely difficult and cost-prohibitive to establish objective criteria on these areas that would consistently apply to all training providers.
- The criteria, if established, would, by definition, be volatile (products change frequently; technology advances rapidly), and we would be looking at a snapshot in time that may not fairly represent the "typical" state of the training.

For a discussion of these issues from the installers' perspective, see *Content Orientation* (p. 53) and *Up-to-date Technologies* (p. 58) under *Overall Comparison of Available Installer Training*.

Overall, the CALCTP training scored significantly better in terms of Learning Focus than did the manufacturer's courses, as shown in Figure 3 below. In large part this is because manufacturer training generally does not address:

- How to configure systems incorporating products from multiple manufacturers

  (It's not surprising that a manufacturer avoids teaching about other manufacturers' products.)

  For a related discussion, see *Content Orientation* (p. 53) under *Overall Comparison of Available Installer Training*.
- Wiring methods and techniques associated with general workmanship not specific to lighting controls

  As one manufacturer put it: "They're licensed (sic) electricians.[21] We expect they know how to do these things... (besides) that is governed by code and licensing bodies. We don't want to get in the middle of it."

  For a related discussion, see *General Workmanship* (p. 44) under *Findings: Issues in the Field*.

None of the courses "scored perfectly" in Learning Focus because none fully addressed effective wiring methods and techniques or how to conduct meaningful quality assurance on a lighting control installation, as noted in Table 13 below.

For details about the individual criteria for each dimension, see *Appendix C: Lighting Controls Installer Training Evaluation Yardsticks*.

[21] In California, electricians are not "licensed" per se; rather they are state certified as general electricians.

Figure 3: Overall Scores on Learning Focus

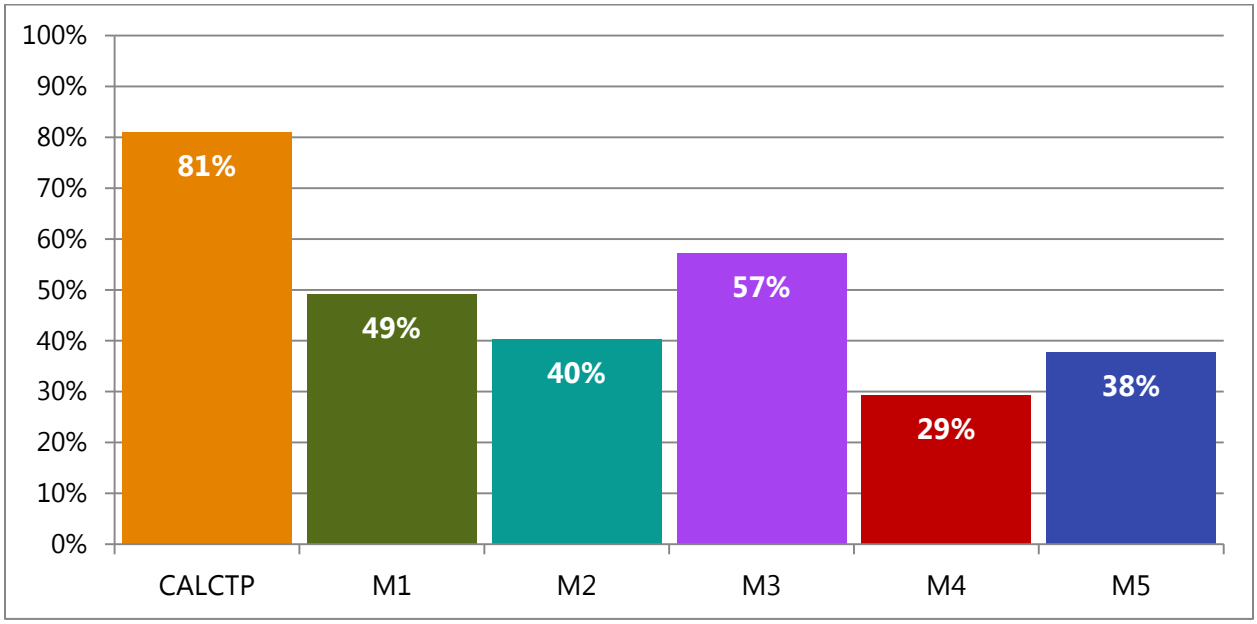


Table 13: Scores on Dimensions for Learning Focus

Learning Focus Dimensions	CALCTP	M1	M2	M3	M4	M5
	81%	49%	40%	57%	29%	38%
4.1 Appropriately places components	100%	100%	100%	100%	50%	100%
4.2 Configure components from different manufacturers	100%	0%	0%	0%	0%	0%
4.3 Determine if triggers & complies with Title 20	100%	100%	0%	100%	0%	0%
4.4 Determine if triggers & complies Title 24 Part 6	100%	80%	100%	100%	100%	100%
4.5 Install variety of control systems	100%	64%	82%	100%	55%	64%
4.6 Use effective wiring methods and techniques	67%	0%	0%	0%	0%	0%
4.7 Conduct quality assurance on installation	0%	0%	0%	0%	0%	0%

Value of Training and Certification

During the in-depth interviews with installers who were both manufacturer-trained and CALCTP-trained, we asked them to compare the two types of training in terms of value. We also asked installers their perceptions of the value of certification. This section of the report summarizes what we learned from these interviews.

While reviewing this section of the report, please keep in mind: CALCTP offers five courses in the areas of lighting control system installation and acceptance testing. (*See Overview of Manufacturer and CALCTP Training* on p. 15 for more information.)

We focused this study on installers, and that limits the types of CALCTP training we heard about from our sample of contractors/electricians.

We likely would end up talking to C-10 contractors only if the company was a one-man operation. Otherwise we were aiming for the installer, which would usually be an electrician. Keep that in mind while reviewing the following sections.

Value of Available Training

Most of the installers we interviewed indicated that they found value in lighting controls installation training — and in CALCTP training in particular.

- One interviewee said that the CALCTP training was the best training available, overall, and for some aspects of the training.
- One interviewee said that CALCTP training was extremely valuable because different manufacturers' products are incorporated, and that the instructors break down the information nicely.
- Another says that it is a good first step toward awareness of the issues.

There were, however, some who disagreed:

- One installer (who had only manufacturer training) indicated that he already knew what he needed to know to design and install lighting control systems.
- Another indicated that, while the CALCTP installer training was useful, it didn't provide significant value because it was basic and covers technologies he knew already through field experience.

  (He also indicated that he found the acceptance training not at all useful even though it did cover topics he admitted were not covered elsewhere. We are uncertain whether we has referring to the Acceptance Testing Technician certification training or the content on acceptance testing that is in the Lighting Controls Installation course.)
- A few others indicated that the same information could be learned online or through manufacturer training.

  (It should be noted that we are unfamiliar with any online training that includes extensive hands-on labs with equipment, which is an important part of the CALCTP installer training.)

It's interesting to note that all but one of the manufacturers we interviewed felt that there is real value in the CALCTP installer training and in fact, most had actively collaborated with the designers of the training during its initial development. (The "one" in the "all but one" was not very familiar with the CALCTP offering.)

Top Benefit: Understanding Title 24 Part 6

The number one value that interviewees put on CALCTP training is that it helps them understand Title 24 Part 6 and its requirements. They say that they may have learned it naturally over time, by making errors, but that would have been costly in a number of ways.

Some find it difficult to read the code even after training and feel that the field is still working out what it requires in all circumstances, but they found the training helpful.

Business Benefits

At least three interviewees cited benefits to their businesses from taking CALCTP training. Some of the benefits they mentioned include:

- They would not have been able to grow the business in the way that they have if they had not had the in-house expertise that CALCTP training provided.
- The training kept them from having to subcontract out jobs that require lighting controls.
- The training saves time in the field because they can detect and respond to issues and problems in the field more easily.
- All (the contractor's) employees are required to complete the CALCTP training to deepen their understanding of control systems and to ultimately improve the quality of lighting controls projects.

Although most installers perceived value in lighting controls installation training in general, and the CALCTP training in particular, a number said it was difficult to justify getting training from a demand point of view. Very few general contractors or customers place value on it, so having completed the training generally does not help installers win bids or get hired as part of an installation team.

Another, who had taken both types of training (CALCTP and manufacturer), reflected that there was a lot of uncertainty about the pay-off of getting trained.

In Summary

Installers identified several important areas in which the CALCTP training provided value:

- Allows working with products from multiple manufacturers
- Develops an understanding Title 24 Part 6 requirements
- Helps grow the business and reduce the need for outside subcontractors by developing the skills and knowledge necessary for lighting controls installation
- Saves time in the field by making it easier to detect and respond to issues encountered on the job
- Provides a conceptual framework of how controls work so it is easier to ensure a quality installation

All of these benefits — except the first one listed — appear to apply to selected courses in the manufacturers' installer training offerings.

Regardless of the benefits, a number of contractors find it difficult to justify the costs of completing lighting controls installation training because there is little market demand for specially trained installers.

Value of Installer Certification

The installers we interviewed had some trouble separating the value of training from the value of certification. To the extent that we were able to get answers about certification *per se*, the interviewees tended to feel there was little advantage at this time. This was especially true of those who had received only manufacturer training.

Some did say that there is an advantage in being able to fulfill California requirements related to Title 24 Part 6, and especially to becoming an Acceptance Test Technician. (Discussed under "Value of Available Training" above.)

For one, the advantage is for the field as a whole, as it ensures that there is some standardization of knowledge.

There was general agreement, though, that there is not much demand for certified installers among customers or general contractors.

In response to the question of whether CALCTP installer certification should be required for participation in utility programs, results varied depending on the training the installers had completed.

- All three installers who had only manufacturer training thought that such a requirement should not be instituted.
- Almost all of the other 12 who had CALCTP training thought requiring CALCTP certification is a good idea.

The reasons given for supporting the requirement include:

- It would raise awareness of the issues and of CALCTP
- The contractor would deliver a better product; the utility can demand good quality because they pay the incentive
- They learn so much about lighting controls, and acceptance training is especially important
- Because benchmarking is so important[22]
- It would set a standard for the field
- No reason not to

[22] Given the context in which this statement was made, we expect this installer meant that requiring certification for IOU program participation would establish minimum standards for skill.

Anyone who expressed reservations about requiring certification was almost sure to mention the time and cost burden it would place on contractors. The reservations expressed include:

- One interviewee indicated that requiring certification would make it harder to sell the system, presumably because of the extra cost the training would impose
- Some don't think certification produces a sufficient benefit for just installers
- Another indicated that requiring certification could create a supply problem

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Findings: Work Quality

The original proposed research plan the team received from the IOUs, with SCE as the project lead, included the following task as part of its scope:

> *Definition of "work quality" and "installation quality" - This study design, should explore how these questions can be studied and measured in the Sustainable Office Lighting Control Trial. At a minimum, this study should make a recommendation on how to best measure "work quality" and "installation quality."*

The research team had multiple within-team discussions and additional discussions with IOU EM&V managers about exactly what was meant by "work quality" in the context of this research, and how it is distinguished from "installation quality."

While clear in concept, it was very difficult for installers and manufacturers to answer questions about how they would define these two terms. We found it necessary to do considerable probing, and rephrasing to elicit useful answers. One of the more effective ways we found to do this was by focusing them on what would constitute poor quality in these areas; i.e., what aspects of design and installation would produce problems.

We also asked about ways to measure work quality and installation quality. These questions were even more difficult for interviewees to answer. However, most were able to offer at least some approach to measuring work quality.

That, combined with their input on quality design and installation, allowed us to produce several ideas about how to measure various aspects of work quality, which we augmented based on input from experts in the areas of lighting control systems and Title 24 Part 6 requirements for nonresidential lighting.

A Working Definition

In very broad terms, work quality for lighting controls systems can be described as:

> *"A system that meets customer lighting needs, delivers energy savings, complies with all relevant code, and continues to function as designed over time."*

Synthesizing what we learned from our interviews with installers, manufacturers, and industry experts, we can say that the quality of a lighting control system is determined by seven major elements, describe in Table 13 below. Each of these elements contributes to the quality of a lighting controls system and several overlap.

For example, a well designed system that is well documented and communicated to installers goes a long way to help ensure quality installation. As another example, a lighting controls system with both quality design and quality installation elements will contribute to the overall functional quality of the system. Yet another example, a good design will comply with Code, as will a properly installed system based on a good design. As a whole, the success of a lighting controls project is dependent on all of the seven elements identified, but there are not clear lines of demarcation between some.

In addition to these elements of quality, several installers mentioned the importance of using components that are well designed and manufactured. That is, inferior products can have an impact on how well a system performs both in the near-term and over the expected life of the system. This issue is not reflected in Table 14 because the quality of system components themselves is not factor directly relevant to **work** quality. (That is, high quality work may be performed regardless of the quality of the hardware.)

Table 14: Characteristics of Work Quality

Quality Element	Characteristics
Design	The most common quality issues associated with design have to do with plans that don't reflect the customer's application requirements or code requirements, include products that will not work together to meet the need, or lack the details that installers need to execute the design properly. See *Poor Design* (p. 35) and *Poor Communication* (p. 37) under *Lighting Design Issues* for more information.) In addition to avoidance of common design problems, simplicity and cost-effectiveness also were cited as marks of a quality design.
Code compliance	Designers and installers have difficulty understanding the specifics of how Title 24 Part 6 applies to a given project, and often feel it is overly complex and stringent. Often plans and actual installations do not comply with code, and will fail acceptance testing, which is required before a project can be approved by the enforcement agency (building department). See *Code Requirements* (p. 40) for more information.

Quality Element	Characteristics
Commissioning	Commissioning is the process of ensuring that the system and its components are designed, installed, tested, and operated according to customer (and code) requirements. Commissioning is required by Title 24 Part 6 for nonresidential new construction; it also can play an important (though not required) role in ensuring alterations and retrofits perform properly and meet the customer's need. See *Commissioning and Acceptance Testing in Title 24* (p. 74) for more information.
Installation	Most installation issues cited in our interviews overlap with design issues. This includes poor placement of sensors and controls as well as inappropriate location for gateways, receivers, controllers, and energy manager. Another commonly cited issue that overlaps design is lack of daylighting controls or inappropriate separation of circuits for different daylighting zones (primary sidelit, secondary sidelit, and skylit). After the installation issues that overlap design issues, the next most frequently cited installation issues fall under the heading of "general workmanship." This includes improper grounding (especially important in control systems), bent or strained wires, improper strapping, and poorly organized and labeled wires. See *Control-system Specifics* and *General Workmanship* (pp. 42 and 44) under *Common Installation Errors* for more information.
Functionality	Whether the system functions as intended (and as required by code) can be considered a "litmus test" of key issues associated with work quality. Poor design, lack of commissioning, and poor installation all can lead to a system not performing as it should even immediately after the system is put in place.
Persistence	Whether the system functions as intended throughout the life of the equipment is crucial to realizing the potential savings associated with the lighting control system. Even if the system has the desired functionality initially, it may fail to provide the desired functionality over time due to poor workmanship during the installation (i.e., improper grounding, stressed wires, etc.), because the occupants find the system inappropriate to their day-to-day lighting requirements, or because the system is difficult to use and maintain.
Occupant satisfaction	How well the lighting meets the needs of the people using it is another dimension of work quality. In part this is determined by how well the design addressed the customer's needs as well how well the system was installed. Ease of use and maintenance and whether the system continues to work well over time also can be factors determining occupant satisfaction.

Commissioning and Acceptance Testing in Title 24

The current California Building Energy Efficiency Standards (2013 Title 24 Part 6) define two major requirements that can have significant impact on the elements defining the quality of a lighting control system: Commissioning and Acceptance Testing. We have provided a brief summary of these requirements to provide context for the upcoming discussion of how to measure quality.

Commissioning

Building Commissioning is required by code for all nonresidential new construction. While Commissioning does not focus specifically on lighting and lighting control installations, it does include these systems as well as virtually every other aspect of the building systems and components covered under Title 24 Part 6.

Although not designated as such by the code, Title 24 Part 6 Commissioning requirements can be described as either "pre-permit" or "post-permit" activities:

- The pre-permit stages of Commissioning are intended to ensure the design meets the customer's needs and the design intent and commissioning approach are clearly communicated from one stage of the project to the next.
- The post-permit stages of Commissioning are intended to ensure that the actually installed systems and components perform as intended and the customer can keep the systems and components working as planned.

Pre-permit

Pre-permit stages of Commissioning, as described by Title 24 Part 6, are:

a) Summary of Commissioning Requirements — lists the items that shall be completed during commissioning (b through h below)

b) Owner's or owner representative's project requirements (OPR) — describes the energy efficiency goals, facility hours of operation (including "after-hours" needs), and expectations for equipment and systems

c) Basis of design (BOD) — a written explanation of how the design meets the OPR (including indoor lighting systems and controls)

d) Design phase design review — a review during the schematic design phase conducted by the design engineer (buildings <10,000 ft^2) or another engineer to verify that the actual design reflects the BOD

e) Commissioning measures shown in the construction documents — a clear, detailed, and complete statement of commissioning requirements, including systems, testing scope, and contractor roles and responsibilities

f) Commissioning plan — a description of how the project will be commissioned, including commissioning goals, systems to be commissioned, and a detailed description of plans to test the systems and components

Post-permit

Post-permit stages of Commissioning, as described in Title 24 Part 6, are:

g) Functional performance testing — demonstrates the correct installation and operation of each component, system, and system-to-system interface in accordance with the Acceptance Test requirements documented in the Standard's Reference Appendices

   Functional performance testing, as part of Commissioning, is not required for buildings that are less than 10,000 square feet. However, acceptance testing of lighting controls is required when the project triggers this requirement, regardless of the size of the building.

h) Documentation and training — provides the customer with key information about installed systems (including operations and maintenance instructions)

For details on Commissioning as required by the code, see *§120.8 — Building Commissioning* in the *2013 California Building Energy Efficiency Standards*.

Acceptance Testing

Virtually every project that includes installation of lighting controls must pass the relevant Acceptance Test(s) specified in Title 24 Part 6. Acceptance testing ensures newly constructed nonresidential buildings and new construction in existing buildings conforms to energy-efficiency standards contained in Title 24, Part 6.

These tests are performed by Acceptance Test Technicians (ATT), who are building specialists who are trained and certified by Acceptance Test Technician Certification Providers and are employed by an Acceptance Test employer that provides support as well as quality control.

Acceptance Testing for lighting controls is performed by a certified Lighting Controls Acceptance Test Technician (ATT) and includes both a visual "construction inspection" and a "functional performance test" to demonstrate that the system does what it is supposed to do (that is, responds appropriately to specific stimuli and doesn't respond to inappropriate stimuli).

The lighting control acceptance tests include:

- **(General) Lighting Control Acceptance** for components such as automatic time switches and occupancy sensors (partial-off, partial-on, and those serving small zones in large open plan offices)

  The test results are documented on form NRCA-LTI-02-A and test procedures are documented in Reference Appendix NA7.6.2.3.

- **Automatic Daylighting Control Acceptance** for continuous or stepped dimming systems for control of lighting in primary and secondary sidelit zones as well as skylit zones

  The test results are documented on form NRCA-LTI-03-A and test procedures are documented in Reference Appendix NA7.6.1 and NA7.6.1.2.

- **Demand Responsive Lighting Control Acceptance** for demand response controls

  (Demand response controls may or may not be currently used to respond to high-demand situations; the potential to participate in demand response is required, actual participation is not.)

  The test results are documented on form NRCA-LTI-04-A and test procedures are documented in Reference Appendix NA7.6.3.2.

- **Outdoor Lighting Acceptance** for outdoor motion sensors and automatic shut-off controls.

  The test results are documented on form NRCA-LTO-02-A and test procedures are documented in Reference Appendix NA7.8.

Ways Work Quality May Be Measured

There are numerous ways that each element of work quality may be measured. Some of the most relevant are summarized in Table 15 below. It should be noted that we are not recommending that IOUs use all of these possible methods for incentive program participation. (See *Conclusions and Recommendations: Work Quality* on p. 85 for information about the specific methods recommended to help ensure incentivized projects reflect the characteristics of a high-quality installation.)

Table 15: Possible Ways to Measure Work Quality

Quality Element	Ways It Could Be Measured
Design	Require and review lighting design plans and specifications to answer the following questions: ■ Does the documentation include a statement of the customer's needs and objectives related to the lighting system and a description of how the system meets them? ■ Is the design intent and rationale presented in such a way that it will communicate these considerations to the installer? ■ Is the configuration appropriate to the physical space and occupancies of each space? ■ Do the plans comply with code (including designation of daylit zones)? ■ Is the system's sequence of operation documented? ■ Does the design approach appear to be reasonably cost-effective and simple to operate?

Quality Element	Ways It Could Be Measured
Installation	Conduct on-site inspections and review relevant project documentation (plans, specifications, and pre-installation commissioning documents, Certificates of Installation, Certificates of Acceptance, etc.) to answer the following questions: ■ Does the installed system conform to the (quality) design and design intent? ■ Does the placement and programming of system components make necessary adjustments for sensitivity, coverage, and special needs associated with area's occupancy type, patterns, and physical configuration? ■ Are manufacturers' installation guidelines and requirements met? ■ Does the system reflect general standards quality workmanship (employ conventional effective wiring methods and techniques, use true ground to earth)? ■ Does the system meet Acceptance Testing requirements?
Code Compliance	Review project documentation to confirm all necessary compliance documents are correctly completed and available for inspection by the enforcement agency: ■ Permit ■ Certificate(s) of Compliance ■ Certificate(s) of Installation ■ Certificate(s) of Acceptance
Commissioning	Inspect commissioning deliverables and related documentation to determine: ■ For new construction, does the Commissioning Plan and related documents include all the components specified in §120.8 and include appropriate details related to commissioning the lighting system? ■ For all projects determine: ▫ Has commissioning agent opened lines of communication with lighting controls installer? ▫ Has commissioning agent received a copy of the sequence of operation? ▫ Is commissioning agent participating in functional testing of the system?

Quality Element	Ways It Could Be Measured
Functionality (Acceptance Testing and more)	Conduct on-site inspections, review relevant project documentation, and interview relevant customer personnel to determine: ■ Does system pass the relevant Title 24 Part 6 Acceptance Tests? ■ Has installer reviewed the sequence of operation to confirm compliance? ■ Is all relevant compliance documentation available at the facility?
Persistence	Conduct on-site inspections, collect customer input, and analyze meter data to determine: ■ Does the system continue to work as designed? ■ Have key functions of the system been disabled by the customer? ■ Is it easy to maintain when necessary? ■ Has maintenance and operation training and documentation been provided to the owner?
Occupant Satisfaction	Conduct customer interviews or field a written customer feedback survey to determine whether the range of affected occupants (including building operations personnel) are pleased with the lighting and control system operation: ■ Is the system easy to use and maintain? ■ Has operational information (regular operation, adjustments, maintenance, troubleshooting) been clearly documented in an easy-to-understand manner? ■ Are lighting levels appropriate and comfortable throughout the occupancy period and for the tasks at hand? ■ Does the system continue to meet customer and occupant needs, even though those needs may have changed over time?

Conclusions and Recommendations

The following pages summarize our conclusions and recommendations based on what we learned through all the project activities.

It is organized into two main sections: Training and Certification (p. 80) and Work Quality (p. 85). Both discussions present our conclusions and recommendations in a two-column format so the linkage between the two is clear.

While reviewing these conclusions and recommendations, please note:

- This study uses qualitative methods and the data collection efforts had a fairly small sample. As such, it offers an exploration and comparison of lighting controls certification, but not conclusive evidence for any of the research questions addressed.
- By "manufacturer training" in the following discussion we are referring to the installation training offered to the "general population" of electricians.

  See *Type of Training Identified for Review* (p. 26) for more information on the categories of training available from some manufacturers and why we focused specifically on for the purposes of this project.
- The installer interviews we conducted was from a sample frame that included a higher percentage of individuals trained by CALCTP than would be found in the overall population of nonresidential lighting control installers in California.

  See *Installer Interviews* (p. 21) for more information on the sample frame for the installer interviews.

Conclusions and Recommendations: Training and Certification

Conclusions re: Training	Related Recommendations
1) The CALCTP *Installer Technical Course* seems to fill an important gap in the lighting controls installation arena. Some of the specific gaps that CALCTP training can address include: ■ Some installers work on projects using products from manufacturers that do not provide installer training on their controls. There appears to be no appropriate source of relevant training for these installers other than the CALCTP training. ■ Many installers work on projects that include components from multiple manufacturers. Even the best available installation training from manufacturers does not include much if any content on how to work with heterogeneous controls configurations, and none of the manufacturer training has hands-on practice with "mixed-manufacturer" installation. The CALCTP course does include components from multiple manufacturers and includes hands-on labs working with them. ■ Many installers have very demanding schedules and do not have the time or patience to "hunt down" appropriate training for multiple resources. Even when manufacturers provide "general concept" or Title 24 Part 6 training that would help installers regardless of the products they work with, it often is difficult to identify and enroll in that training. The CALCTP course provides a "one-stop-shop" for most of the essentials.	**Continue to support the CALCTP efforts to provide training for lighting controls installers.** Specific kinds of support to consider include: ■ Provide classroom space for CALCTP-oriented training activities ■ Fund deliveries of the course at IOU customer training centers ■ Explore with CALCTP other appropriate ways in which the IOUs may be able to support the installer training effort. This this may include discussions around: ▫ Sources of funding for updating and enhancing the training ▫ Alternatives for developing online self-study update modules that would qualify for continuing education credits ▫ Ways to help encourage collaboration with manufacturers who provide training on a range of brands, current technology, etc.

Conclusions re: Training	Related Recommendations
2) It is uncertain whether the CALCTP training is having a significant impact on skills and knowledge of the individuals who complete the training. The current training design for the CALCTP *Installer Technical Course* measures what participants know and can do at the end of the training. It does not measure participants' entry-level knowledge and skills (except for ensuring a minimum baseline prerequisite). It is possible that many individuals who choose to participate in the course are already well versed in the areas the course addresses. (People who are interested in controls may tend to seek out training and information on the topic, and may have already reached competence through other avenues.)	**Encourage CALCTP to consider ways to measure the likely impact of the training on participants' competence.** One approach that could reasonably provide useful information about the overall impact of the CACLTP training on individuals who participate in the training is to conduct a pilot evaluation study that could use a pre-test / post-test design to determine whether the people who come to the training already are competent or whether they develop significant skills and knowledge as a result of the training. Some general guidelines for a valid pre- and post-test to address this issue are outlined under "2.3. Assessment of Training Impact on Competence" in the "Assessment Yardstick." Similar to the current CALCTP certification test, **it would be very helpful and informative to consult a psychometrician**[23] for this pre-test design. A psychometrician could provide: ■ Guidance on test methods and construction if pursuing a pilot using a pre-test / post-test configuration ■ Recommendations for other approaches to effectively and efficiently meet the goal of measuring the likely impact of the CALCTP training on overall workforce competence

[23] A psychometrician is an expert in objective measurement of skills and knowledge, abilities, educational achievement and other aspects in the cognitive and affective domains. Many psychometricians focus on areas specific to adult learning, behavior change, and certification.

Conclusions re: Training

3) The CALCTP *Installer Technical Course* is well-designed and executed; however, there are areas with potential for improvement in the existing training.

Installers we interviewed cited a number of specific suggestions regarding improvements to the course content and delivery.

The most pressing was to keep the content and equipment boards up to date.

- The curriculum for CALCTP was developed in close association with lighting controls manufacturers and other stakeholders. This meant that the curriculum and the equipment boards used in training were up to date in the beginning.
- While the training is frequently updated to address factual errors and remove references to obsolete technology, there have been five major updates since 2008, with the last major update in 2013. However, the technology is constantly evolving, and this gives rise to two problems:
  - Equipment boards are very expensive, so it is probably not feasible to update them often enough to keep the program completely current.
  - Although manufacturers are involved at some level for all updates of CALCTP programs and continuing education, heavy manufacturer involvement is not built in to the program on an ongoing basis.

  This leaves the program vulnerable to being outdated over time.

Another area of possible improvement is to **make it easier for potential participants to find deliveries in their areas**.

- Some installers indicated it was difficult to get enrolled in the course, largely because they didn't know when and where it was being offered.
- The CALCTP website does not prominently display a calendar of upcoming deliveries. (Rather it suggests the user contact CALCTP to learn of courses being held in their area.)

Related Recommendations

Support CALCTP efforts to enhance and update the training.

- Encourage CALCTP to review the specific recommendations suggested by the installers interviewed in this assessment. (See pp. 54, 56, and 58.)

  It should be noted that some of these comments may have already been addressed through revisions since the installers participated in the training; other comments may be addressed via the major revision that currently is under way.

  In addition, some comments may be "outliers" that wouldn't add much value to the course. A thorough and objective review of the comments should be made before specific changes are targeted.
- Explore ways to encourage manufacturer participation in CALCTP training. (See #4 below.)
- Consider other approaches to providing ongoing support activities noted under conclusion #1 above.
- Explore ways to provide broad and consistent marketing and outreach for the CALCTP installer training, making access easier for all installers/contractors.

Conclusions re: Training	Related Recommendations
4) Manufacturer and CALCTP installer training have important — and different — strengths. Some of the major strengths of the CALCTP installer training is that it includes: ■ A variety of control types; variety of brands ■ How different brands of products can be appropriately configured together in one system ■ Extensive hands-on practice and assessment Some of the major strengths of manufacturers' installer training include: ■ In-depth exploration of product-specific requirements and considerations ■ Frequent updates to reflect the latest (manufacturer-specific) technology	**Explore ways to support training that combines "the best of both worlds."** Consider ways to provide a coherent learning experience that capitalizes on the strengths of both CALCTP and manufacturer training. One approach for accomplishing this would be to: ■ Establish the CALCTP training as the foundational component of the curriculum ■ Provide manufacturer-specific modules as recommended "advanced" components of the curriculum ■ Encourage installers to complete a manufacturer-specific module before engaging in projects that use that manufacturer's controls ■ Ensure the "full" curriculum is clearly presented in terms of a recommended learning path (pre-requisites, foundational course, and manufacturer-specific deep-dives, including extensive hands-on practice) on the CALCTP website and in all marketing and outreach communications. It is useful to note that as of fall 2015, CALCTP is developing a continuing education program, in collaboration with major lighting manufacturers, which will address emerging products and control strategies.

Conclusions re: Training	Related Recommendations
5) One of the most frequently cited barriers to quality installation is a function of poor lighting control system design. All of the installers and several manufacturers indicated that the lighting designs often are inappropriate or inadequate: all too often the plans are not customized to the customer needs and project configuration, don't comply with code, and provide insufficient detail for installers to execute properly. Lighting system plans may be developed by people in a variety of roles, most often architects, lighting designers, design/build lighting contractors, or engineers. Engineers were most often cited by installers as the source of inadequate or inappropriate plans, but it is unclear whether that was a general term they employed (assuming an engineer developed the plans) or it really does indicate an electrical engineer drew up the plans. Regardless, it is possible to have "good installation of a bad design," which is something outside the installer's scope of responsibility.	**Consider supporting training (and other related resources such as quick references or decision tools) to help improve nonresidential lighting system designs.** There are other related efforts that should be explored before finalizing any plans for such training: ■ The Statewide Codes and Standards Compliance Improvement (Energy Code Ace) team is actively pursuing "designer" training in 2016. ■ The Energy Code Ace website currently has two online self-study courses focused specifically on Title 24 Part 6 mandatory measures and prescriptive requirements for nonresidential lighting. ■ The California Lighting Technology Center (CLTC) has developed Lighting Guides specific to nonresidential applications, and delivers training on lighting technology and code requirements. ■ CALCTP has begun development of a course focused on lighting system design. (This project currently is on hold due to funding issues.)

Conclusions and Recommendations: Work Quality

Conclusions re: Work Quality	Related Recommendations
6) Work quality as described in this report has the potential to help ensure lighting control projects realize their energy-savings potential. Evidence of work quality can be assessed at various stages of a project. ■ During the design or design/bid phase, key system design elements can be verified, as shown on the plans and related documentation. ■ Immediately after a project, issues directly associated with installation quality, code compliance, and functionality can be verified. ■ After some time (six month, a year, or longer) has passed since the installation was completed, issues associated with persistence and occupant satisfaction can be assessed.	**Consider requiring evidence of work quality before and after installation for incentivized lighting control projects, especially when these activities are consistent with the adopted codes.** ■ This implementation can be built into existing program processes such as conducting reviews at **Rebate Reservation or Equivalent** (before project start) for sample projects to collect baseline data. In addition, design quality and evidence of documentation that effectively communicates between design and installation teams could be assessed by reviewing materials that documents the following:[24] ▫ Evidence of required permits ▫ The customer's project requirements (energy efficiency goals, hours of operation, and expectations for equipment and systems) ▫ Lighting system design intent— a written explanation of how the design meets the customer's project requirements (including energy savings calculations if appropriate) ▫ Sequence of operation ▫ Statement of goals and rationales of the design that can be referenced by the installer in case unforeseen issues arise, making it inadvisable or impossible to install as designed. ■ At **Project Completion** it is feasible to measure key aspects of work quality by requiring: ▫ Relevant Acceptance Test forms (NRCA-LTI-##-A) signed by a certified Acceptance Test Technician (ATT). ▫ Commissioning documentation (for new construction only) For the upcoming High Opportunity Projects and Program (HOPP) implementation, these requirements are also consistent with the intent of AB802 requirements.

[24] A permit is required for any project that triggers Title 24 Part 6, which includes virtually all lighting controls installation projects. The other items listed under this bullet typically are part of the Commissioning process required for nonresidential new construction. For retrofits, these documents (except the permit) are not required by code, but are a crucial component of ensuring the design meets customer needs and that the design intent is communicated to the installation team.

Conclusions re: Work Quality	Related Recommendations

6) Work quality as described in this report has the potential to help ensure lighting control projects realize their energy-savings potential (continued)	**For incentive programs in which significant long-term energy savings is a major consideration, consider evaluating the "Persistence" element of work quality.**
	
	If it seems reasonable to measure "persistence" for selected lighting projects, methods of verifying performance in an evaluation study after six months or a year could include:
	
	■ Perform a walkthrough of the job site to:
	  ▫ Observe the operator interface to verify the control strategy is still in place and operating
	  ▫ Check a sample of sensors and controls to confirm they still are in place and functioning as intended
	  ▫ Survey occupants and operations personnel to determine their satisfaction with the system and identify any issues that may hinder ongoing performance per the design.
	  ▫ Analyze meter data to confirm energy savings and control system function
	
	These study activities can also be included in the evaluation activities to support the SCE and SDG&E Advanced Lighting Control Pilot initiatives.

Appendix A
Manufacturer Interview Selection Criteria Memo

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MEMO

To: Caroline Chen
From: Scott E. Bailey, Katherine Randazzo
Date: June 8, 2015
Re: Selection Criteria and Potential Manufacturers

Introduction

The CALCTP Contractor Training Assessment project will characterize the market in lighting controls training programs from both CALCTP and manufacturers of lighting controls. A central focus is to determine whether the CALCTP training offers something needed and unique in the field, or whether there are other options that are filling that need. We will also assess their instructional value as it pertains to adult learning principles.

One of the critical tasks of the project is to develop a list of manufacturers that provide lighting controls training that is potentially comparable to CALCTP training. This memo explains the selection criteria and recommends the top potential manufacturers for assessment.

Another critical task of the project is to suggest possible definitions and ways of measuring work quality as it pertains to lighting controls. This includes design quality and installation quality. Manufacturers will have valuable input towards these definitions.

Methodology

Development of Selection Criteria

For the task of selecting manufacturers who have training programs that are potentially comparable to CALCTP training, we established several criteria for the manufacturers that we will investigate further with in-depth interviews. The sample frame will include manufacturers which satisfy the criteria that we list here and justify:

1. Manufacturers with a significant market share. Manufacturers meeting this criterion would provide the highest likelihood that they would have a training program that was large and detailed enough to be comparable with CALCTP training. These manufacturers would also be the most likely to answer questions about what constitutes work quality and how it might be measured or observed.
2. Manufacturers with product lines that offer complete lighting control systems or that manufacture the "brains" of the control system. CALCTP training encompasses all the lighting control components that are required for a complete lighting control system. Since manufacturers' training typically focuses on their product line alone, having a complete lighting control system might translate to a complete training program. Manufacturers with product lines based solely on one or two individual components, not a complete system, are less likely to offer training that is comparable; these manufacturers will not be considered in the sample frame. Manufacturers of the lighting controls' "brains" would most likely have to coordinate with other products manufactured by other companies, and would thus be likely to provide

comprehensive training that could be comparable to CALCTP. They are also considered candidates for in-depth interviews.

3. Manufacturers that offer formal training. CALCTP training is presented in a classroom with an established curriculum and dedicated course material, which is indicative of formal training environments. Some manufacturers only offer informal training, or individual consulting/mentoring of their lighting control systems, these manufacturers will not be considered in the sample frame. Manufacturers that offer only technical assistance or consulting to installers, are not likely to have a training program that could be comparable with the CALCTP training. A major indicator of what we count as formal training is whether or not there is a classroom component.

Data Collection for Selection Criteria

The sample frame was developed using the internet to search for lighting controls manufacturers. This resulted in a master list of 36 manufacturers.

As we researched the manufacturers to add to our sample frame, we collected as much information about the manufacturer, its products and its training as was available on the internet. From this preliminary research, we could eliminate many manufacturers based on whether their product line offered a complete lighting control system or individual components that are not central to the lighting controls' whole system.

When sufficient manufacturer information was not available on the internet, we made informal calls to the manufacturer to supplement the selection criteria data; these informal calls only inquired about their product line and their available training. Based on this information, we could eliminate additional manufacturers that did not provide formal training.

Industry Experts Feedback

We reached out to two lighting experts, an IOU program manager and one third party program administrator to review our selection criteria. They all agreed that the selection criteria are good for the goals of this study. We also inquired as to who they thought were the big players in the lighting controls manufacturer market. This input provided the basis for criterion #1 above.

Top Potential Manufacturers

Table 1 below shows the list of all 36 lighting controls manufacturers that we have identified, ranked by the number of positive factors (based on selection criteria) for each manufacturer indicating their potential for having a training program that is comparable to CALCTP training.

When we are ready to begin interviewing the manufacturers, we will start from the top of the list and attempt to conduct in-depth interviews with at least three manufacturers assessing their training programs; three manufacturers being the minimum that was specified in the scope of this assessment. We anticipate gaining access to the top three so we don't have to go down the list to those less likely to be comparable to CALCTP.

Thank you.

This table is a reformat of the table that was in the preceding memo. Note that our initial assessment of which manufacturers offered formal classroom training for controls installers was updated as a result of the interviews. See endnotes for details.

#	Manufacturer	Complete Lighting Control Sys. or "Brains"?[A]	Formal Classroom Training?	Major Players? Lighting Expert A	Major Players? Lighting Expert B	Major Players? Program Admin.	Major Players? IOU Program Mgr.	# of Positive Factors	Interview Status[1]
1	Leviton	Yes	**Yes**	X	X	X	X	6	Completed
2	Lutron	Yes	**Yes**	X	X	X	X	6	Completed
3	WattStopper (Legrand)	Yes	**Yes**	X	X	X		5	Completed
4	Cooper Controls (Eaton)	Yes	**Yes**	X	X			4	Completed
5	Hubbell Building Automation	Yes	No [B]	X	X			4	Completed
6	Acuity Brands	Yes	**Yes**		X			3	Attempted
7	Daintree networks	Yes	No [C]	X		X		3	Completed
8	GE Lighting (Genesis Lighting Controls)	Yes	No	X	X			3	n/a
9	Philips Lighting Controls	Yes	**Yes**		X			3	Completed
10	Creston Electronics	Yes	No			X		2	n/a
11	Digital Lumens	Yes	No				X	2	n/a
12	Intermatic	Yes	No			X		2	n/a
13	Osram Sylvania	Yes	**Yes**					2	n/a
14	Synergy Lighting Controls (Acuity)	Yes	**Yes**					2	n/a
15	Redwood Systems	Yes	No					1	n/a
16	Delta Controls	Yes	No					1	n/a

[1] The "Status" column was added, to provide additional information in the report, after the memo was issued.

#	Manufacturer	Complete Lighting Control Sys. or "Brains"?[A]	Formal Classroom Training?	Major Players? Lighting Expert A	Major Players? Lighting Expert B	Major Players? Program Admin.	Major Players? IOU Program Mgr.	# of Positive Factors	Interview Status[1]
17	Distech Controls	Yes	No					1	n/a
18	Douglas	Yes	No					1	n/a
19	Echoflex	Yes	No					1	n/a
20	Encelium / Traxon (Osram)	Yes	No					1	n/a
21	Enlighted	Yes	No					1	n/a
22	Eye Lighting	Yes	No					1	n/a
23	Hunt Dimming	Yes	No					1	n/a
24	PLC Multipoint	Yes	No					1	n/a
25	Schneider Electric	Yes	No					1	n/a
26	Sensorswitch	Yes	No					1	n/a
27	Universal Lighting Technologies	Yes	No					1	n/a
28	CREE	No	n/a					0	n/a
29	Enmetric Systems	No	n/a					0	n/a
30	Exergy	No	n/a					0	n/a
31	Harvard Engineering	No	n/a					0	n/a
32	Illumra	No	n/a					0	n/a
33	Innovative Lighting	No	n/a					0	n/a
34	Magnum Energy Solutions	No	n/a					0	n/a
35	Sensity	No	n/a					0	n/a
36	Tork (NSi Industries)	No	n/a					0	n/a

[A] If a manufacturer does not offer a complete lighting system or the "brains" for a complete lighting system, then it is a moot point as to whether they have formal classroom training, since their training will be incomplete.

[B] Although initial information gathering indicated that Hubbell provides installer training, our training contact at Hubbell indicated that they did not, although they were considering doing so in the future.

[C] Although initial information gathering indicated that Daintree does not provide installer training, a later SME said that they did. Our interview with Daintree indicates they do not offer installer training, but they do have certified "commissioning agents" who complete the programming and functional performance testing for Daintree installations.

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Appendix B
Background Characteristics of the Interviewed Sample of Installers

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Background Characteristics of the Interviewed Sample of Installers

The table below summarizes general characteristics of the individuals who participated in the in-depth installer interviews.

Description	Range	Number in CALCTP & MFR Group	Number in CALCTP-Only Group	Number in MFR-Only Group
Number of employees	1-3	2	0	1
	4-15	5	3	1
	16+	2	1	1
Number CALCTP certified	1	3	2	0
	2-3	4	2	0
	4+	2	0	0
Years of company experience in lighting controls	1-5	1	0	3
	6-15	2	1	0
	16-25	3	1	0
	26+	3	1	0
Education & training background	High School	1	1	0
	Some College	5	2	1
	BA/BS	2	1	2
Company training requirements	None	1	3	2
	Cert electrician or Lighting	4	0	0
	Relevant Mfr	2	0	1
	CALCTP	1	0	0
	Experience/Knowledge /In-house	3	1	0

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Appendix C
Lighting Controls Installer Training Evaluation Yardsticks

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Lighting Controls Installer Training "Yardsticks" — Evaluation Criteria and Data Points

This document summarizes the evaluation criteria ("yardsticks") that the evaluation team will use to compare manufacturer and CALCTP training for lighting controls installers. Telephone interviews with manufacturer and CALCTP representatives will yield the information we need to complete the "yardsticks." (See Append D: Interview Guide for Lighting Controls Installer Training for the questions we addressed in the telephone interviews.)

How the Yardsticks Are Used for Scoring

There are four yardsticks, each focusing on a specific area of evaluation:

1. Adult Learning Principles and Practices
2. Assessment (Certification)
3. Availability / Accessibility
4. Learning Focus and Objectives

Each of the yardsticks are divided into "dimensions" or major aspects of an evaluation area. For Example, "Adult Learning Principles and Practices," as used in this assessment, has four dimensions:

1. *Adult Learning Principles and Practices*
   - 1.1. *Performance-Based Objectives*
   - 1.2. *Practice and feedback opportunities*
   - 1.3. *Modalities engaged during the training*
   - 1.4. *Structure and organization*

Each of these dimensions is "scored" based on specific evaluation criteria. For each criterion, a course may score 1 (yes), 0 (no), or "na" (not applicable). If a criterion is not applicable to a given course, that criterion is not considered in the scoring. A course's overall score in a dimension is determined by actual score divided by the total possible score.

For example, let's consider the "Performance-based Objectives" dimension of the Adult Learning Principles and Practices yardstick. This dimension is evaluated on three criteria, as shown in Table C- 1 below. Let's say one review results in yes for all criteria, while another results on "yes" in two criteria and "no" on the third criterion. This means the first review results in a score of 100% (3/3) for that dimension, while the second review results in a score of 67% (2/3).

Table C- 1: Scoring the Performance-based Objectives Dimension of the Adult Learning Principles and Practices Yardstick.

1.1	Performance-based Objectives	100%	67%
	1.1.1 TPOs parallel to job requirements	1	1
	1.1.2 Apply level or higher	1	0
	1.1.3 EOs build to TPOs	1	1

Relationship between Interview Guide and Evaluation Yardsticks

This document will not be distributed to the interviewees before or during the telephone interviews. Rather we will use the accompanying Interview Guide to structure the conversation. We want to keep the interview guide fairly short, simple, and unimposing. The reason for this is two-fold:

- We're planning to send the interview guide prior to the actual interviews, so interviewees can prepare for the call—or let us know that someone else would be better positioned to answer our questions
- We don't want to make people feel uncomfortable or defensive. We don't want to scare them away with a big, detailed interview guide or evaluation criteria.

We'll address the evaluation criteria based on what we learn in the interviews. The interview guide is designed to open topics that we can follow up on as appropriate.

For example, if somebody says "no" to question 7, we know that the answer to evaluation criterion 2.1 is "0" and 2.2 is "not applicable." We would verify that by a follow-up question such as, "We know of some training where people get credit for completing training based on their attendance rather than a test of some sort... Do you track that or have any other way to say 'Yes, this person gets credit,' or 'No, this person doesn't get credit?"

The interviews will be conducted by a team of two instructional design experts with extensive experience in training evaluation and two engineers with expertise in the field of lighting controls. We will record the interviews, but will keep individuals' responses confidential. (That is, no comment or answer will be attributable to a person or a manufacturer.)

Purple italic text in a blue box in this document and in the Interview Guides show how specific interview questions relate to individual evaluation criteria.

1. Adult Learning Principles and Practices

1.1. Performance-based Objectives — Design reflects performance-based learning objectives (learning outcomes) that reflect relevant on-the-job requirements.

Indicators (below) have binary scoring (Yes = 1; No = 0). Score for item (above) is average (mean) score for indicators.

1.1.1. Terminal performance objectives (TPOs) directly parallel on-the-job requirements.

1.1.2. TPOs reflect Level Three (Apply) higher of Bloom's taxonomy for the cognitive domain (see "Reference: Bloom's Taxonomy for Cognitive Domain" on p. 12).

1.1.3. Enabling objectives (EOs) that collectively build to the TPOs.

1.1 addressed through Q6, Q7, Q8, and Q9 and their respective follow-up questions.

1.2. Practice and Feedback — Includes frequent and appropriate practice and feedback opportunities that directly support the learning objectives.

Indicators (below) have binary scoring (Yes = 1; No = 0). Score for item (above) is average (mean) score for indicators.

1.2.1. Has incremental practice that helps build relevant skills and knowledge (e.g., quizzes or "hands-on" or both) addressing enabling objectives.

1.2.2. Has "putting it together" practice that requires student to perform at a level indicated by the TPOs.

1.2.3. Provides specific feedback and guidance based on student's performance during the practice (specifically what's right and what's wrong, why it's wrong, and how to correct).

1.2 addressed through Q1, Q5, Q6, and Q9 and their respective follow-up questions.

1.3. Variety of Modalities — Actively engages the student in a variety of modalities throughout the training.

Indicators (below) have binary scoring (Yes = 1; No = 0). Score for item (above) is average (mean) score for indicators.

1.3.1. Listening

1.3.2. Speaking

1.3.3. Reading

1.3.4. Interpreting graphics

1.3.5. Hands-on (with physical objects)

1.3 addressed through Q1, Q5, and Q9 and their respective follow-up questions.

1.4. Structure Conforms to ID Principles — Structured in accordance with proven instructional design principles

Indicators (below) have binary scoring (Yes = 1; No = 0). Score for item (above) is average (mean) score for indicators.

1.4.1. Is organized into modules (sections) focused on logical topic areas or skills.

1.4.2. Clearly communicates to the student the training organization and current position in the training relative to the whole.

1.4.3. Builds knowledge and skills in an incremental and progressive manner (from simple to complex)

1.4.4. Reviews key teaching points (through practice, structured discussion, or verbal recap)

1.4 addressed through Q1 and Q5 and their respective follow-up questions.

2. Assessment

2.1. Documented Performance Standards — Has documented performance standards for successful completion

Indicators (below) have binary scoring (Yes = 1; No = 0). Score for item (above) is average (mean) score for indicators.

2.1.1. Performance standards and the assessment criteria supporting them are documented.

2.1.2. Performance standards directly relate to training objectives (targeted learning outcomes), specifying which objectives are to be assessed.

2.1.3. Assessment criteria are documented, specific, measurable, and directly support on-the-job requirements.

2.1.4. Pass/fail criteria are clearly communicated to the examinee.

2.1 addressed through Q7 and Q8 and their respective follow-up questions.

2.2. Fair Assessment Methods — Assessment methods are fair, consistent, and reflect on-the-job performance requirements

Indicators (below) have binary scoring (Yes = 1; No = 0). Score for item (above) is average (mean) score for indicators.

2.2.1. Assessment methods are appropriate to the assessment criteria (e.g., "Apply" level objectives are addressed via "Apply" level assessment questions or tasks).

2.2.2. Specific scoring guidelines are documented and applied consistently across examinees, locations, and over time.

2.2.3. Any scoring that requires rater judgment incorporates methods for minimizing the effect of rater bias.

2.2.4. Assessment process incorporates systematic and unbiased process for collecting, assessing, and acting on examinees challenges of items or rating or both.

2.2.5. Test conditions are clearly specified and are consistently applied and enforced for all examinees.

2.2.5.1. Physical characteristics of the environment

2.2.5.2. Allotted time in which to answer the questions or complete the tasks

2.2.5.3. Resources made available to examinee

2.2.5.4. Other resources the examinee may bring/use as desired

2.2 addressed through Q7 and its respective follow-up questions.

2.3. Assessment of Training Impact on Competence

Indicators (below) have binary scoring (Yes = 1; No = 0). Score for item (above) is average (mean) score for indicators.

2.3.1. Employs methods for measuring students' competence before and after training (e.g., pre-test/post-test configuration to measure knowledge swing)

2.3.2. Pre- and post-training assessments are temporally close to the learning event

2.3.3. Pre- and post-training assessments are parallel and comparable

- 2.3.3.1. Same skills and knowledge tested
- 2.3.3.2. Same assessment methods employed
- 2.3.3.3. Same Rater construct (Raters receive the same training and use the same methods for minimizing rater bias)
- 2.3.3.4. Same test conditions (environment, time, resources)

2.2 addressed through Q7 and its respective follow-up questions.

3. Availability / Accessibility

Note: we did not "score" the responses on this yardstick because we were unable to resolve a fair and consistent method. We did consider establishing a range.

For example, we considered the following rating scale for or the "Cost" dimension:

- *5 = Free ..... 100% (5/5)*
- *4 = $1 to $99 ..... 80%*
- *3 = $100 to $249 ..... 60%*
- *2 = $250 to $499 ..... 40%*
- *1 = $500 to $999 ..... 20%*
- *0 = $1,000 or more ..... 0% (0/5)*

However, we soon determined that this was not a feasible scoring method because the cost for a given course can vary widely for a given training provider.

For example, about 50% of the CALCTP deliveries are free to the participants; the other deliveries range in cost from $275 to $1,000.

As another example, two manufacturers indicated that the cost of installer training they provide will vary depending upon the installer's relationship with the manufacturer, and may range from free to $250. In addition, several manufacturers offer online self-study training as well as webinars targeted to installers, and they never charge for these deliveries, though they do sometimes charge for traditional classroom deliveries.

We encountered similar challenges scoring the other availability and accessibility dimensions, so concluded that simple qualitative reporting for these dimensions was appropriate.

3.1 through 3.4 addressed through Qs 1 through 4 (and their respective follow-up questions).

3.1. Frequency (number of times offered per year)

3.2. Geographies (deliveries in each location: Southern CA, Central CA, Northern CA)

3.3. Time of day; day of week

3.4. Costs to:

- Enroll in the course
- Sign up for and take final/certification exam
- Receive or participate in updates (technology, best practices, regulations)

In addition to Q1:

- *Second bullet will be addressed through follow-up to Q7 if the answer indicates they do have a "final exam."*
- *Third bullet will be addressed in follow-up to Q9.*

4. Learning Focus (Content)

Below are listed seven terminal performance objectives (4.1, 4.2, 4.3). All use binary scoring (1=yes, addressed; 0=no, not addressed). When there are subordinate items (4.1.1, 4.1.2, 4.1.3), each individual subordinate item is scored as 1 or 0, and the score for the terminal performance objective is the average (mean) of the subordinate scores.

4.1 through 4.7 addressed through Q 9 (and follow-up questions).

4.1. Determine appropriate type and placement of lighting control systems components based on design requirements, customer/application requirements, and physical characteristics of the space:

4.1.1. Photocells for primary and secondary daylit zones

4.1.2. Variety of occupancy/vacancy sensors (passive infrared, ultrasonic, dual)

4.1.3. Demand response sensor

4.1.4. Gateways, receivers, and relays

4.1.5. Lighting system controllers

4.1.6. Manual controls

4.2. Determine whether given components from different manufacturers can be configured to work together as an effective lighting system

4.3. Determine whether a given lighting product complies with Title 20 California Appliance Efficiency Regulations

4.3.1. Product types within the scope of Title 20 Appliance Efficiency Regulations

4.3.2. How to determine whether a within-scope product complies (search MAEDBS)

4.4. Given a nonresidential scenario, lighting plan, and associated lighting system documentation determine whether the project triggers Title 24 Part 6, California Building Energy Efficiency Standards, and if so, whether the design meets both Mandatory Measures and Prescriptive Requirements for:

4.4.1. Indoor lighting, new construction

4.4.2. Indoor lighting, additions and alterations (modifications, retrofits)

4.4.3. Outdoor lighting, new construction

4.4.4. Outdoor lighting, alteration

4.4.5. Sign lighting

4.5. Install (wire and program) a variety of lighting control systems to meet design requirements and customer/application requirements, making necessary adjustments for sensitivity, coverage, and special needs associated with area's occupancy type, patterns, and physical configuration

4.5.1. Line voltage switching controls
- Multilevel (e.g., three-level and four-level) switches
- Mechanical and astronomical interval timers
- Shunt relays and emergency lighting fixtures

4.5.2. Wire and program low voltage lighting control devices
- Low voltage relay
- Programmable relay panel

4.5.3. Dimming and switching controls (ballast, dimmer, integrated and modular controllers with multi-zone, multi-scene, and preset capabilities

4.5.4. Occupancy sensors

4.5.5. Photo sensors

4.5.6. Wireless systems

4.6. For all lighting system installations, use effective wiring methods and techniques

4.6.1. Lay and strap wires in an organized manner, so wires are not stressed and installation conforms with code

4.6.2. Correctly connect components of the system, including RJ45 plugs, "hard terminator" screw-in-plugs, and connections to ballasts

4.6.3. Properly ground all relevant components of the system (especially controls)

4.7. Conduct quality assurance on installations

In the following, "NRCA..." refers to the Nonresidential Lighting Acceptance forms used in Title 24 Part 6. "NA7..." refers to specific sections of the Nonresidential Appendices for Title 24 Part 6.

4.7.1. Identify Title 24 Part 6 lighting acceptance testing criteria and procedures for:

- (General) **Lighting Control Acceptance**
  [See NRCA-LTI-02-A and NA7.6.2.3 for details]
  Construction inspection and functional testing for:
  - Automatic time switch
  - Occupancy sensors
  - Partial-off occupancy sensors
  - Partial-on occupancy sensors
  - Occupancy sensors serving small zones in large open plan offices

- **Automatic Daylighting Control Acceptance**
  [See NRCA-LTI-03-A and NA7.6.1 and NA7.6.1.2 for details]
  - Construction inspection
  - Functional Performance Testing of Continuous Dimming Systems (by watt-meter or amp-meter, or by light meter power measurement and default look-up table)
  - Functional Performance Testing of Stepped Switching/ Stepped Dimming Systems (by watt-meter or amp-meter, or based on light output)

- **Demand Responsive Lighting Control Acceptance**
  [See NRCA-LTI-04-A and NA7.6.3.2 for details]
  - Construction inspection
  - Functional Test using Method 1 (illuminance measurement) or Method 2 (power input measurement)

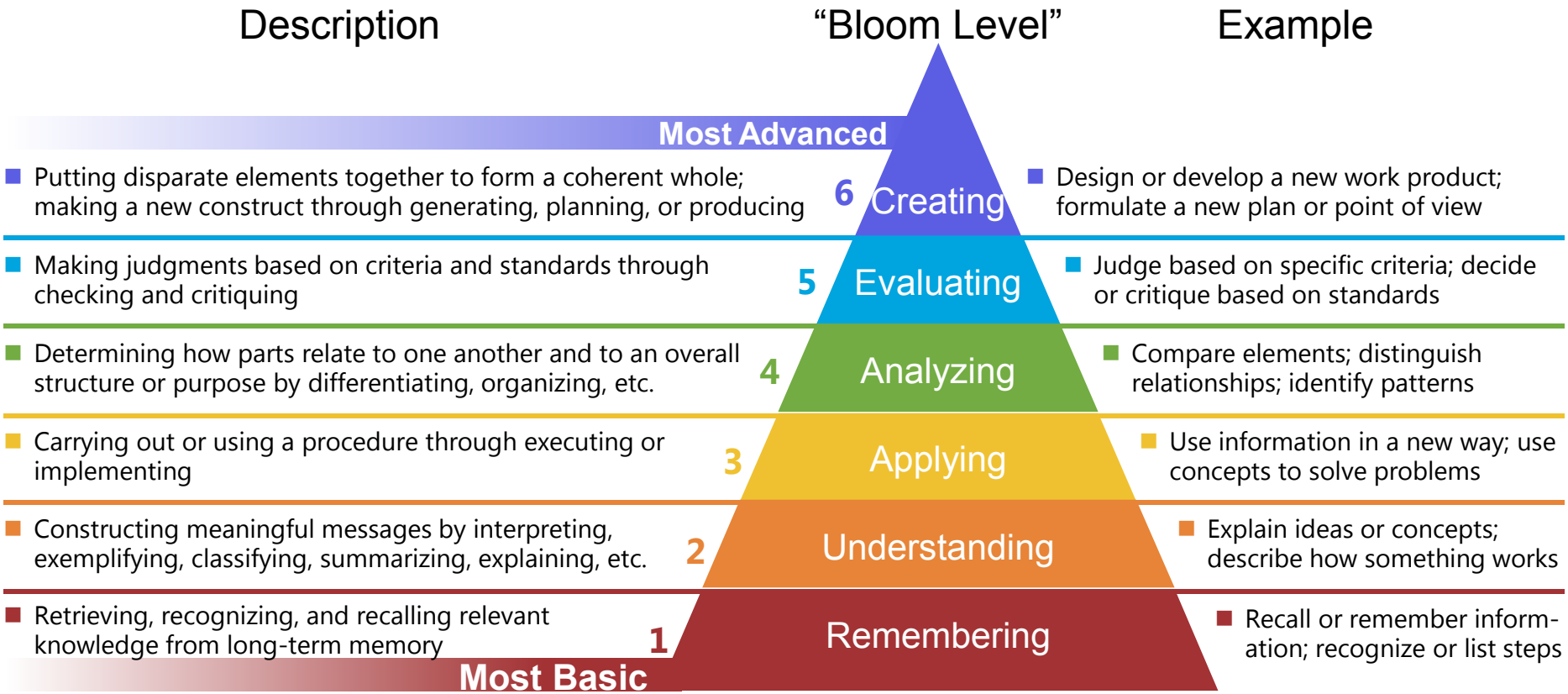
- **Outdoor Lighting Acceptance**
  [See NRCA-LTO-02-A and NA7.8 for details]
  - Outdoor Motion Sensor Acceptance — Construction inspection and functional testing
  - Outdoor Lighting Automatic Shut-off Controls Acceptance — Construction inspection and functional testing

4.7.2. Conduct testing (commissioning) of the following to ensure they are functioning according to requirements:

- Automatic Daylighting Controls
- Automatic Time Switch Controls
- Occupancy Sensors
- Outdoor Lighting Shut-off Controls
- Outdoor Motion Sensors
- Automated Demand Response Controls

Reference: Bloom's Taxonomy for Cognitive Domain

The cognitive domain involves knowledge and the development of intellectual skills. This includes the recall or recognition of specific facts, procedural patterns, and concepts that serve in the development of intellectual abilities and skills. There are six major levels, listed below.* The levels can be thought of as degrees of difficulties. That is, the first one must be mastered before the next one can take place.



* The original taxonomy, established by Bloom in 1956, defined the levels as Knowledge, Comprehension, Application, Analysis, Synthesis, Evaluation. This was refined in the 1990s to reflect the levels shown above. Anderson, L.W. & Krathwohl, D.R. (Eds.) (2001). *A taxonomy for Learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives.* New York: Addison Wesley Longman.

Appendix D
Interview Guide for Lighting Controls Installer Training

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Interview Guide for Manufacturer Calls re Training for Lighting Controls Installers

NOTE: Purple text shown below is intended to assist reviewers in related interview questions to the evaluation criteria listed in the "yardstick items" provided in *Appendix C: Lighting Controls Installer Training Evaluation Yardsticks*

This cross-reference text was not included in the version of the Interview Guide sent to interviewees.

ASWB Engineering is partnering with Opinion Dynamics on a study funded by the California Public Utilities Commission and California's investor-owned utilities. One of the study goals is to better understand the training available to lighting controls installers—when and where it's offered, what is addressed, and what students are expected to do as a result of the training.

We're taking a look at California Advanced Lighting Controls Training Program (CALCTP) training for lighting control installers as well as training offered by top lighting controls manufacturers.

There are ten main questions (summarized below) we'd like to cover in our conversation with you.

We will keep your individual responses confidential. That is, we will not associate your comments with your name or your company. Rather, the information you share with us will be consolidated with information from other people at other companies to develop an overall description of the training available to lighting controls installers.

Please let us know if you have any question or comments.

1. **Please describe, at a high-level, the training opportunities your company offers to lighting installers.**

   "Delivery Methods" supports yardstick item 1.2 and 1.3
   "Cost to Enroll" supports yardstick item 3.4

   "Delivery Methods" might include things such as in-person instructor led, online instructor led (similar to a webinar), coached or facilitated labs, coached or mentored field experience, online on-demand (video or self-study modules), other on-demand

Title	Focus	Delivery Method(s)	Est. Duration	Cost to Enroll

2. How often is this training offered per year?

Supports yardstick item 3.1

3. In what locations is it offered?

3.1. Any in California? If so where and how often?

Supports yardstick item 3.2

4. Is "live" (instructor facilitated) training offered at times other than normal business hours (e.g., evenings or weekends)?

Supports yardstick item 3.3

5. What are the general design characteristics of these courses?

Supports yardstick item 1.2, 1.3, and 1.4

"Design characteristics" might include presentation of information, review questions, individual or group practice applying concepts and solving problems, hands-on practice with equipment, etc.

5.1. Could you please describe what the student experiences in a "typical training day"?

5.2. Would you make a copy of the training materials available to us?

6. Are there published performance objectives for the training?

Supports yardstick item 1.1, 1.2, and 2.1

By "performance objectives," we mean specific things you expect the student to DO as a result of the class.

6.1. If so, may we look at the objectives?

7. Does the training (or a follow-up test or "lab" or "field test") confirm whether a student has met the training objectives?

Supports yardstick item 1.1, 2.1, 2.2, and second bullet under 3.4

That is, does a student "pass or fail" a course — or simply participate in the course?

7.1. If pass/fail, what method(s) do you use to determine whether an individual has passed? (Multiple-choice test, short-answer or essay/diagram, hands-on performance, etc.)

7.2. For methods other than multiple-choice, how do you score an individual's answers? Who does the scoring?

8. Do you have any method to assess the impact of your training on the students?

Supports yardstick item 1.1 and 2.1

For example, do you have a pre-test and a post-test to measure knowledge swing, or ask students to "self-report" their level of expertise before and after the training?

9. Below are listed some objectives that might be appropriate for lighting installers.

Supports yardstick item 4.1 through 4.7 as well as third bullet under 3.4 (updates)

9.1. For each, please let us know whether your training addresses these objectives — and what kinds of training activities are associated with them.

9.2. Are there important objectives that you think we have missed? (If so, what are they and does your training address them?)

- **Determine appropriate type and placement of lighting control systems components based on design requirements, customer/application requirements, and physical characteristics of the space:**
  - Photocells for primary and secondary daylit zones
  - Variety of occupancy/vacancy sensors (passive infrared, ultrasonic, dual)
  - Demand response sensor
  - Gateways, receivers, and relays
  - Lighting system controllers
  - Manual controls
- **Determine whether given components from different manufacturers can be configured to work together as an effective lighting system**
- **Determine whether a given lighting product complies with Title 20 California Appliance Efficiency Regulations**
- **Given a nonresidential scenario, lighting plan, and associated lighting system documentation determine whether the project triggers Title 24 Part 6, California Building Energy Efficiency Standards, and if so, whether the design meets both Mandatory Measures and Prescriptive Requirements for:**
- **Install (wire and program) a variety of lighting control systems to meet design requirements and customer/application requirements, making necessary adjustments for sensitivity, coverage, and special needs associated with area's occupancy type, patterns, and physical configuration**
  - Line voltage switching controls
  - Wire and program low voltage lighting control devices
  - Dimming and switching controls (ballast, dimmer, integrated and modular controllers with multi-zone, multi-scene, and preset capabilities
  - Occupancy sensors
  - Photo sensors
  - Wireless systems

- **For all lighting system installations, use effective wiring methods and techniques**
  - Lay and strap wires in an organized manner, so wires are not stressed and installation conforms with code
  - Correctly connect components of the system, including RJ45 plugs, "hard terminator" screw-in-plugs, and connections to ballasts
  - Properly ground all relevant components of the system (especially controls)
- **Conduct quality assurance on installations**
  - Identify Title 24 Part 6 lighting acceptance testing criteria and procedures for:
    - (General) Lighting Control Acceptance
    - Automatic Daylighting Control Acceptance
    - Demand Responsive Lighting Control Acceptance
    - Outdoor Lighting Acceptance
- **Conduct testing (functional performance testing) of the following to ensure they are functioning according to requirements:**
    - Automatic Daylighting Controls
    - Automatic Time Switch Controls
    - Occupancy Sensors
    - Outdoor Lighting Shut-off Controls
    - Outdoor Motion Sensors
    - Automated Demand Response Controls

10. How would you define "quality work"? (What would indicate to you that a given installation is or is not a quality installation? What installation problems have you seen or heard about? How would you measure the quality of a lighting control installation?)

Supports non- yardstick item: Definition of and metrics for work quality

11. Is there something we should have asked you that we did not?

11.1. If so, what's the question and the answer?

11.2. If we find we need a bit of clarification as we review our notes, may be contact you again?

Appendix E
A Broader View of Lighting Controls Training

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Related Training Opportunities

As noted in the body of this report, there are numerous educational institutions and other sources that can and do teach their students about energy-efficient technologies, with lighting controls a relatively small piece of that. There also are other courses of study that are more specialized and that are offered at a multitude of different types of organizations, including community colleges, four-year colleges and universities, unions, IOU energy centers, and industry organizations (trade and professional).

A listing of these education and training sources, as they are available for both HVAC and lighting, can be found in, *PY2013-2014 California Statewide Workforce Education and Training Program: Contractor Training Market Characterization* (Opinion Dynamics, 2015), sponsored by the Energy Division of the CPUC. A selection of those programs that address lighting controls is provided here.

Trainer/Certifier Type	Trainer/Certifier Name	Name of Training	Offered at a WE&T Center?	Level	Has EE Focus?	Geographical Scope	Equipment Targeted	Training Mode	Types of Tests
CA Community College	various CCCs	Electrical Construction and Maintenance	No	Certificate	No	California	Circuits, control systems, wiring, etc. Many other pieces of equipment can be covered by electives.	Classroom	Written
CA Community College	various CCCs	Electrical Construction and Maintenance	No	AA degree	No	California	Circuits, control systems, wiring, etc. Many other pieces of equipment can be covered by electives.	Classroom	Written
CA Community College	various CCCs	Green Building and Energy Management (Energy Management Technology)	No	Certificate	Yes	California	Electric motors, HVAC, lighting distribution systems, electric power systems, energy star products, solar thermal systems, EMS and controls	Classroom	Written
CA Community College	various CCCs	Green Building and Energy Management (Energy Management Technology)	No	AA degree	Yes	California	Electric motors, HVAC, lighting distribution systems, electric power systems, energy star products, solar thermal systems, EMS and controls	Classroom	Written
Government	Building Operator Certification (BOC)	BOC 1003 – Efficient Lighting Fundamentals	Yes	Certificate	Yes	National	Lighting fundamentals & principles of efficient lighting: evaluation of lighting levels; fixture and control technologies; retrofit and redesign options; & required maintenance to reduce energy use associated with lighting while maintaining recommended lighting levels needed for productivity and safety.	Classroom	Written, Field

Government	California Advanced Lighting Controls Training Program (CALCTP)/ California Energy Commission (CEC)	Certified Installer Electrician	Yes	Certification	Yes	California	Lighting Controls	Online, Field	Field
Government	California Advanced Lighting Controls Training Program (CALCTP)/ California Energy Commission (CEC)	Acceptance Technicians	Yes	Certification	Yes	California	Lighting Controls	Classroom	Written
Industry Organization	American Lighting Association (ALA)	Lighting Specialist	No	Certification	Yes	National	All aspects of the residential lighting industry, including industry trends, technology and technical developments.	Classroom, Online, Field	Written
Industry Organization	American Lighting Association (ALA)	Lighting Associate	No	Certification	Yes	National	Lighting and electricity, light sources, decorative lighting, recessed lighting, track lighting, ceiling fans, energy efficient lighting, outdoor and landscape lighting, dimming and lighting controls, kitchen and bath lighting.	Online	Written
Industry Organization	Association of Energy Engineers (AEE)	Certified Lighting Efficiency Professional (CLEP)	No	Certification	Yes	National	Lamps, fixture/luminaires, ballasts, controls	Classroom, Online, Field	Written
Industry Organization	Association of Energy Engineers (AEE)	Certified Lighting Efficiency Professional-in-Training (CLEPIT)	No	Certification	Yes	National	Lamps, fixtures/luminaires, ballasts, controls	Classroom, Online, Field	Written
Industry Organization	Illuminating Engineering Society (IES)	Offers a lighting fundamentals course (may be the SF chapter only)	Yes	Certification	No	California	Lights, lamps, controls, etc.	Classroom	Unknown
Industry Organization	International Association of Lighting Management Companies (NALMCO)	Certified Lighting Management Consultant (CLMC)	No	Certification	No	National	Luminaires, reflectors, lighting controls, lighting layout designs and applications, ballasts, lamps, energy conservation, lighting maintenance, recycling, disposal	Classroom, Online	Written
Industry Organization	International Association of Lighting Management Companies (NALMCO)	Certified Sustainable Lighting Consultant (CSLC)	No	Certification	Yes	National	Lighting systems, control systems, etc.	Classroom, Online	Written

Industry Organization	International Association of Lighting Management Companies (NALMCO)	Certified Apprentice Lighting Technician (CALT)	No	Certification	No	National	Lighting systems	Classroom, Online	Written
Industry Organization	International Association of Lighting Management Companies (NALMCO)	Certified Senior Lighting Technician (CSLT)	No	Certification	No	National	Lighting systems	Classroom, Online	Written
Industry Organization	National Council on Qualifications for the Lighting Professions (NCQLP)	Lighting Certified	Yes	Certification	No	National	Lighting systems, ballasts, lighting controls, others	Unknown	Written
Industry Organization	National Lighting Contractors Association of America (NLCAA)	Non-Residential Lighting Technician Certification	No	Certification	No	National	Lighting technology, lighting controls, safety	Classroom, Online, Field	Written, Field
Manufacturer	Leviton Manufacturing Co., Inc.	Regional Factory Training by Leviton Security & Automation	No	Training	No	National	Automation and controls	Classroom Online	Unknown
Manufacturer	Lighting Controls Association	Multiple trainings, all focused on lighting controls	No	Continuing education	Yes	National	Lighting controls	Online	Unknown
Manufacturer	Lutron Electronics	Light Control for Energy Savings	No	Continuing education	Yes	National	Lighting controls	Online	Unknown
Manufacturer	Lutron Electronics	Light Control and LEED	No	Continuing education	Yes	National	Lighting controls	Online	Unknown
Manufacturer	Philips Lighting Controls	TBD	No	Continuing education	Yes	National	Lighting controls	Classroom, Online	Unknown
Manufacturer	Universal Lighting Technologies	HID Ballast training and Fluorescent ballast basics I and II	No	Continuing education	Yes	National	Lighting controls and ballasts	Online	Unknown
Professional Organization	American Institute of Architects (AIA)	Multiple trainings, all focused on lighting	Yes	Industry training, continuing education	Yes	National	Lighting controls, LEDs,	Classroom, Online, Field	Written, Field
University of California and IOU	California Lighting Technology Center, UC Davis and IOU Statewide Codes and Standards, Compliance Improvement	Title 24 Part 6 Essentials – Standards & Technology for Retail Lighting	Yes	Industry training, continuing education	Yes	California	Title 24 Part 6 Requirements and Forms, lighting design considerations for retail, lamps, luminaires, lighting controls	Classroom	None

University of California and IOU	California Lighting Technology Center, UC Davis and IOU Statewide Codes and Standards, Compliance Improvement	Title 24 Part 6 Essentials – Standards & Technology for Office Lighting	Yes	Industry training, continuing education	Yes	California	Title 24 Part 6 Requirements and Forms, lighting design considerations for office buildings lamps, luminaires, lighting controls	Classroom	None
IOU	IOU Statewide Codes and Standards, Compliance Improvement	Title 24 Part 6 Essentials – Nonresidential Indoor Lighting Mandatory Measures	Yes	Industry training, continuing education	Yes	California	Title 24 Part 6 lighting compliance alternatives and forms, daylighting controls	Online	Written
IOU	IOU Statewide Codes and Standards, Compliance Improvement	Title 24 Part 6 Essentials – Nonresidential Indoor Lighting Prescriptive Requirements	Yes	Industry training, continuing education	Yes	California	Lighting efficiency strategies, Title 24 Part 6 lighting standards, forms, and triggers, indoor lighting controls, calculating daylit zones	Online	Written

Appendix F
Overview of CALCTP Installer Training

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Summary

The CALCTP lighting controls installer training is designed for California certified general electricians and focuses on how to install commercial lighting control systems. The course is about 50 hours of classroom training consisting of lecture, group discussion and structured practice as well as extensive hands-on labs.

In addition to the 50 hours of classroom training, participants are required to demonstrate successful completion online self-study training that is a prerequisite to the classroom training. Specifically, the prerequisite online self-study training is composed of four courses, representing approximately 12 hours of training:

- EE101: *Introduction to Lighting Control*
- EE102: *Switching Control Title*
- EE103: *Dimming Control Title*
- EE201: *Daylight Harvesting*

The classroom training is composed of seven modules summarized in the table below. The following pages present the training's Lesson Plan, which was provided by CALCTP.

Table F- 1: Overview of CALTCPT Installer Training Modules

Module	Sections	Delivery Methods and Duration
1: Introduction	■ Introduction to CALCTP	(lecture: 45 min)
	■ Lighting Control Strategies	(lecture: 15 min)
	■ Fluorescent Lamps and Ballasts	(lecture, activities, and quiz: 90 min)
	■ Fluorescent Ballasts Lab	(lecture: 30 min; hands-on lab: 120 min)
2: Line Voltage Switching Controls	■ Line Voltage Switching Controls	(lecture: 45 min)
	■ Line Voltage Switching Controls Lab	(lecture: 30 min; hands-on lab: 180 min)
3: Low Voltage Switching Controls	■ Low Voltage Switching Controls	(lecture, activities, and quiz: 90 min)
	■ Low Voltage Switching Controls Lab	(lecture: 30 min; hands-on lab: 180 min)
4: Dimming Controls	■ Dimming Controls	(lecture, activities, and quiz: 75 min)
	■ Dimming Controls Lab	(lecture: 30 min; hands-on lab: 360 min)
5: Occupancy Sensors	■ Occupancy Sensors	(lecture, activities, and quiz: 75 min)
	■ Occupancy Sensors Lab	(lecture: 30 min; hands-on lab: 300 min)
6: Photosensors	■ Photosensors	(lecture, activities, and quiz: 75 min)
	■ Photosensors Lab	(lecture: 30 min; hands-on lab: 480 min)
7: Advanced Lighting Control Systems	■ Advanced Lighting Control Systems	(lecture, activities, and quiz: 75 min)
	■ Advanced Lighting Control Sys. Lab	(lecture: 30 min; hands-on lab: 360 min)
Wrap Up	■ Question and Answer Period	(discussion: 60 min)
	■ Examination	(written exam: 120 min)
	■ Course evaluation	(feedback session: 30 min)

Lesson Plan: CALCTP Lighting Controls Training (v. 4.0)

This lesson plan was provided to the evaluation team by ICF, the CALCTP program implementer.

TARGET AUDIENCE & QUALIFICATIONS: CALCTP requires that all participants be California State certified general electricians. Training will be offered at select California Joint Apprenticeship Training Committee training centers and several California Community Colleges.

INSTRUCTORS: Instructors must complete the Train-the-Trainer course and be CALCTP certified. The required Instructor/Participant Ratio is 1: 10 for Lecture and 1: 5 for Labs.

PREREQUISITE STUDIES: Lighting Controls Association - online program; modules EE101, EE102, EE103, EE201 (Approximately 12 hours). Prerequisite study hours are **NOT** included in the required 50 hours required for the CALCTP curriculum. Participants must present a certificate of completion for online study before beginning the CALCTP course.

DURATION: Onsite lectures, onsite lab introduction, onsite lab, Q & A, examination, evaluations. Total of 50 hours.

COURSE GOAL: To make significant, expeditious gains in conserving energy used for lighting in California through the widespread deployment and effective long term operation of advanced, high efficiency lighting control systems. CALCTP will train State certified general electricians and qualified contractors in the best practices and most effective techniques to install, tune, commission and maintain advanced lighting control systems.

COURSE DESCRIPTION: This Community College level CALCTP program provides a step-by-step approach to understand, apply and install commercial lighting control systems. The subjects presented in this course include lighting terminology, lighting control strategies, fluorescent lamps & ballasts, line and low voltage controls, dimming systems, occupancy sensors, photosensors, advanced lighting control systems, installation/wiring requirements, acceptance testing, codes and standards, commissioning requirements, and California Title 24 requirements.

COURSE OUTLINE OVERVIEW: This course is divided into seven modules consisting of lecture and lab activities. The module content is organized to answer the following questions about lighting controls. What are lighting controls? What do they do? Where are they used? How are they installed? Each "lecture" contains one or more interactive components, including group discussions, device demonstrations and/ or calculation exercises. There are outlines for each of the seven modules.

The corresponding lab period, following the lecture, allows the attendee to directly apply what has been learned by installing the devices on electrical lab board, under the supervision of the instructor.

The instructor will receive a CD with electronic copies of all the course materials, including content for participant lecture binders and lab binders, plus support materials. Speaker notes are also provided.

The duration times listed below are established by the CALCTP Board. They represent the results of a survey based on the collective experience of a number of trainers who have taught the class, and from experience gained from Train-the-Trainer classes. The lab duration periods reflect the maximum amount of time needed, as reported in the trainer survey. Lab duration will vary based on participant knowledge and performance level, the amount of interactivity with the participants, and the number of participants in the class. Participants should be encouraged to use the full amount of lab time to become thoroughly familiar with installation of controls components and programming logic.

Introduction to the CALCTP

Purpose: The participants will become aware of legislation and other drivers that mandate and/or promote the increased use of lighting controls in California. Additionally, the trainer will conduct a brief overview of the course.

Methods & Duration: Lecture (45 minutes)

Module 1a: Lighting Control Strategies

Lighting Control Strategies Lecture

Purpose: The participants will be able to identify opportunities for the use of advanced lighting technologies in commercial buildings.

Methods & Duration: Lecture (15 minutes)

Learning objectives:

- To identify the lighting control strategies used in commercial buildings.
- To explore how and where these strategies are used.

Module 1b: Fluorescent Lamps and Ballasts

Fluorescent Lamp and Ballast Lecture

Purpose: The participants will be able to identify the latest energy efficient fluorescent technologies and install them correctly to realize energy savings. The participants will also be able to measure illuminance in order to locate photosensors correctly.

Methods & Duration:

- Lecture, demonstration, group discussions, action plan (75 minutes).
- Written participant quiz/exercise and class review (15 minutes)

Learning Objectives:

- To identify and explain the latest generation of energy efficient lamps & ballasts.
- To define and explore the commonly used protocols for dimming systems.
- To practice the installation of various lamp & ballast systems.

Group Discussions:

- Understanding the difference between illuminance and luminance.
- Applications for various color temperature lamps
- Application of fluorescent technology based on temperature sensitivity.

Demonstration: The group will take illuminance measurements in the classroom.

Written participant quiz/exercise and class review: The trainer may elect to use this quiz for testing or for group discussion.

Action Plan: The trainer will help the participants to develop their own action plan.

Fluorescent Ballasts Lab (See the corresponding Lab Manual.)

Purpose: The participants will learn how to successfully install multiple types of fluorescent ballasts covered in this module.

Methods & Duration:

- Lecture: Lab Introduction (30 minutes).
- Lab: (120) minutes)

The participants will engage in hands-on wiring exercises, following the directions in the LAB MANUAL, on a pre-constructed lab board. The trainer supervises all exercises and must sign off on their successful completion.

Module 2: Line Voltage Switching Controls

Line Voltage Switching Controls Lecture

Purpose: The participants will learn to correctly Identify and install line voltage switching devices, including wall box, cabinet and emergency switching devices. Participants will explore the California code requirements associated with switching in commercial applications.

Methods & Duration:

- Lecture, group discussions, action plan (60 minutes).
- Written participant quiz/exercise and class review (15 minutes)

Learning Objectives:

- To describe the operation of line voltage switching devices
- To identify the types of line voltage switches
- To understand the application & wiring requirements of UL924 shunt relays
- To practice the installation of line voltage switching devices

Written participant quiz/exercise and class review: The trainer may elect to use this exam for testing or for group discussion.

Action Plan: The trainer will help the participants to develop their own action plan.

Line Voltage Switching Controls Lab (See the corresponding Lab Manual.)

Purpose: The participants will learn how to successfully install the line voltage switching controls covered in this module.

Methods & Duration:

- Lecture: Lab Introduction (30 minutes).
- Lab: (180 minutes)

The participants will engage in hands-on wiring exercises, following the directions in the LAB MANUAL, on a pre-constructed lab board. The trainer supervises all exercises and must sign off on their successful completion.

Module 3: Low Voltage Switching Controls

Low Voltage Switching Controls Lecture

Purpose: The participants will learn to identify, select, and safely install low voltage switching devices as part of a lighting control strategy to save energy.

Methods & Duration:

- Lecture, demonstration, group discussions, exercise, action plan (60 minutes).
- Written participant quiz/exercise and class review (15 minutes).

Learning Objectives:

- To define the types of low voltage switching controls
- To review their operation
- To practice the installation of low voltage switching controls
- **Exercise:** Attendees will perform a transformer loading calculation.

Written participant quiz/exercise and class review: The trainer may elect to use this exam for testing or for group discussion.

Action Plan: The trainer will help the participants to develop their own action plan.

Low Voltage Switching Controls Lab (See the corresponding Lab Manual.)

Purpose: The participants will learn how to successfully install the low voltage switching controls covered in this module.

Methods & Duration:

- Lecture: Lab Introduction (30 minutes).
- Lab: (180 minutes)

  The participants will engage in hands-on wiring exercises, following the directions in the LAB MANUAL, on a pre-constructed lab board. The trainer supervises all exercises and must sign off on their successful completion.

Module 4: Dimming Controls

Dimming Controls Lecture

Purpose: The participants will understand the necessity of installing compatible lamps, ballasts and controls to ensure their proper operation and realize energy savings.

Methods & Duration:

- Lecture, demonstration, group discussions, action plan (60 minutes).
- Written participant quiz/exercise and class review (15 minutes)

Learning Objectives:

- To examine the reasons for dimming
- To define the types of dimming controls
- To explain their operation
- To explore where they are used
- To practice the installation of dimming controls

Group Discussion: What lighting control system would be suitable for a conference room in an office building? What power adjustment factor should be applied when calculating the lighting power density of a 400 sq. ft. conference room with luminaires controlled by a manual dimmer?

Written participant quiz/exercise and class review: The trainer may elect to use this exam for testing or for group discussion.

Action Plan: The trainer will help the participants to develop their own action plan.

Dimming Controls Lab (See the corresponding Lab Manual.)

Purpose: The participants will learn how to successfully install the dimming controls covered in this module.

Methods & Duration:

- Lecture: Lab Introduction (30 minutes).
- Lab: (360 minutes)

The participants will participate in hands-on wiring exercises, following the directions in the LAB MANUAL, on a pre-constructed lab board. The trainer supervises all exercises and must sign off on their successful completion.

Module 5: Occupancy Sensors

Occupancy Sensors Lecture

Purpose: The participants will learn to correctly select and install occupancy sensors for common commercial applications. This knowledge will help to maximize the success and subsequent energy savings realized through the use of line or low voltage occupancy sensors. Participants will explore the California code requirements associated with the use of occupancy sensors in commercial applications.

Methods & Duration:

- Lecture, demonstration, group discussions, action plan (60 minutes).
- Written participant quiz/exercise and class review (15 minutes)

Learning Objectives:

- To define and describe the types of occupancy sensor technologies
- To explain their operation and coverage
- To identify the applications for each type
- To practice the installation and startup of the occupancy sensors

Group Discussion: Why do you think all classrooms are required by code to have occupancy sensors? Do you think an occupancy or vacancy sensor would save more energy in a commercial office application?

Written participant quiz/exercise and class review: The trainer may elect to use this exam for testing or for group discussion.

Action Plan: The trainer will help the participants to develop their own action plan.

Occupancy Sensors Lab (See the corresponding Lab Manual.)

Purpose: The participants will learn how to successfully install the occupancy sensors covered in this module.

Methods & Duration:

- Lecture: Lab Introduction (30 minutes).
- Lab: (300 minutes)

The participants will engage in hands-on wiring exercises, following the directions in the LAB MANUAL, on a pre-constructed lab board. The trainer supervises all exercises and must sign off on their successful completion.

Module 6: Photosensors

Photosensors Lecture

Purpose: The participants will learn to maximize energy savings from daylight harvesting through the proper selection, placement, installation, and commissioning of photosensors. Participants will explore the California code requirements for use of photosensors.

Methods & Duration:

- Lecture, demonstration, action plan (60 minutes).
- Written participant quiz/exercise and class review (15 minutes)

Learning Objectives:

- To define and describe photosensor technology
- To explain photosensor operation
- To identify the applications for each type
- To practice the installation and startup of photosensors

Group Discussion: Why do you think wall switch photosensors are not a qualifying photosensor device under Title 24?

Written participant quiz/exercise and class review: The trainer may elect to use this exam for testing or for group discussion.

Action Plan: The trainer will help the participants to develop their own action plan.

Photosensors Lab (See the corresponding Lab Manual.)

Purpose: The participants will learn how to successfully install the photosensors covered in this module.

Methods & Duration:

- Lecture: Lab Introduction (30 minutes).
- Lab: (480 minutes)

The participants will participate in hands-on wiring exercises, following the directions in the LAB MANUAL, on a pre-constructed lab board. The trainer supervises all exercises and must sign off on their successful completion.

Module 7: Advanced Lighting Control Systems

Advanced Lighting Control Systems Lecture

Purpose: The participants will understand the application and installation of advanced lighting controls to realize significant energy savings in existing buildings.

Methods & Duration:

- Lecture, demonstration, group discussions, action plan (60 minutes).
- Written participant quiz/exercise and class review (15 minutes).

Learning Objectives:

- To introduce four additional lighting control systems
- To explain how these systems operate
- To describe their typical applications
- To practice the installation lighting control systems

Group Discussion: Are wireless lighting controls a benefit or a detriment to the electrical industry?

Written participant quiz/exercise and class review: The trainer may elect to use this exam for testing or for group discussion.

Action Plan: The trainer will help the participants to develop their own action plan.

Advanced Lighting Control Systems Lab (See the corresponding Lab Manual.)

Purpose: The participants will learn how to successfully install the advanced lighting control systems covered in this module.

Methods & Duration:

- Lecture: Lab Introduction (30 minutes).
- Lab: (360 minutes)

The participants will participate in hands-on wiring exercises, following the directions in the LAB MANUAL, on a pre-constructed lab board. The trainer supervises all exercises and must sign off on their successful completion.

Question & Answer Period

Purpose: Previous to the final examination, participants have the opportunity to ask the trainer questions to eliminate any confusion they may have from both the lecture and lab portions of this course.

Duration: (60 minutes)

Examination

A written Final Exam will be given after all the modules have been presented and the question and answer period has been conducted.

Duration: (120 minutes)

Grading Policy: Passing grade for the written Final Exam is 70% (correct answers). A participant who does not pass the exam must repeat the exam, for a maximum of three times. All participants must install the lighting control equipment in the lab exercises correctly (100%). They may not proceed to the next module until they do so. The trainer must verify and document (sign off) the correct installation of all devices. The average of the two grades for both the lecture and lab (70% and 100%) equals the CALCTP passing score of 85%.

Evaluations

The participants have an opportunity to evaluate the course and render feedback to the instructors.

Duration: (30 minutes)

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