A California NonResidential Lighting Logger Palooza!

Bob Ramirez, Itron, Inc., San Diego, Calif.
Rachel Harcharik, Itron, Inc., San Diego, Calif.
Tom Mayer, Itron, Inc., San Diego, Calif.
Christine Hungeling, Itron, Inc., San Diego, Calif.

ABSTRACT

This paper discusses key aspects and lessons learned from fielding a lollapalooza of a lighting logger study (7200+ loggers at 1250+ sites!), conducted by Itron as part of the CPUC evaluation of California's investor-owned utilities (IOU) 2006-2008 energy efficiency programs. The study focused on three non-residential lighting technology/configurations: linear fluorescents, high bay lighting, and CFLs. Results from this effort are used to develop lighting annual operating hours and 8760 shapes, and to enhance DEER building prototype lighting end use shapes at the building type and space use type (e.g. lobby, office) levels.

This study examined both downstream and upstream lighting measures. Upstream CFLs are important due to the assumption that a portion of the CFLs, intended for residences, end up in commercial establishments which have much higher annual operating hours that affect the overall CFL savings estimate. As expected, there were significant differences in the downstream versus upstream data collection approaches. Another special element of the study was a smaller subset of lighting projects for which both the pre- and post-retrofit configurations were inventoried and monitored, and spot watt fixture measurements obtained.

Key challenges in fielding the survey included creating a survey form to handle the diverse lighting applications, developing written procedures and training surveyors to understand and execute them correctly, adapting procedures to incorporate unanticipated situations encountered in the field, and creating an interactive tool to review logger data. The approach used and lessons learned from conducting this lighting study should be of great interest to others considering similar efforts.

Introduction

The Random House Dictionary of the English Language defines a "lollapalooza" as "*an extraordinary or unusual thing, person, or event; an exceptional example or instance*".[1] Often, lollapalooza is just shortened to "palooza" and added to the end of an existing word or group of words to not only mean exceptional, but also a grand-scale event. The California non-residential lighting logger study is the epitome of a palooza in the following ways:

- More than 7,200 lighting loggers were installed in over 1,250 commercial buildings.
- Over 14,500 phone surveys of program participants and non-participants were conducted.
- A total of 1,532 on-site surveys were conducted, 1,269 on-site surveys completed, and loggers were successfully installed at 1,020 sites.
- Measures from both downstream and upstream distribution methods and three lighting measure groups were covered.

- Pre-retrofit and post-retrofit fixture wattages were estimated using several methods. Baseline/pre-retrofit information was gathered via customer self-reports, and through a special pre-post lighting study that measured fixture input wattages for more than 750 unique ballast-lamp combinations. Lamp and ballast make/model information was also collected and used to look up fixture input watts.
- The study spanned the service areas of California's four IOUs and included nine energy-efficiency programs and 20 commercial building types.
- A sophisticated, multi-component system for generating survey forms, inputting data, tracking the field effort, and reviewing and dispositioning logger data was created by Itron.

This paper describes the lighting logger study, the system established to process and utilize the resulting data, and lessons learned from the effort.

Small Commercial Contract Group Lighting Logger Study Objective

This Small Commercial Contract Group was one of thirteen CPUC groups responsible for the evaluation of the 2006-2008 California IOU energy efficiency programs. The Small Commercial group was responsible for the evaluation of multiple IOU programs that rebated both lighting and non-lighting measures. The phase of the evaluation discussed within this paper is focused solely on three non-residential lighting "measure groups": linear fluorescents, high bay lighting, and screw-based CFLs. On-site surveys were conducted and lighting loggers installed at sites across the state and covering the service areas of the four California IOUs. The results from this effort were intended to be used to develop verification/installation rates, kW and kWh unit energy savings values, baseline and post fixture wattage values, baseline and post annual operating hours and 8760 shapes, and to enhance DEER building prototype lighting end use shapes at the building type and even the space use type (e.g. lobby, office) level.

This study examined both downstream lighting measures and upstream screw-based CFLs. Downstream measures are those distributed either by direct installation or that received a rebate, while upstream screw-based CFLs refer to the IOU-subsidized CFLs sold at retail stores. Upstream CFLs, typically assumed to go into residential applications, are important for this nonresidential study because the IOUs assumed a portion of upstream CFLs are installed in commercial establishments. Because nonresidential operating hours are so much higher than residential operating hours (at least a factor of 10) this assumption has a significant impact on IOU portfolio savings. Another special element of the study focused on a smaller subset of lighting projects for which both the pre- and post-retrofit configurations were inventoried and monitored, and spot watt fixture measurements obtained.

Key challenges to fielding the survey included creating a survey form to handle the diverse lighting applications, developing written procedures and training surveyors to understand and execute them correctly, adapting procedures to incorporate unanticipated situations encountered in the field, and creating an interactive tool to review and disposition the massive amounts of logger data. The focus of this paper is on the effort related to gathering the logger data and other on-site survey data, and the process and tools needed to clean and prepare it for the 8760 analysis. Calculation of the annual operating hours and creation of the 8760 shapes are not discussed or addressed herein.

Key Concepts and Study Elements

A discussion of the process and results requires explanation of some key concepts and elements of the study.

IOU Program Tracking Database. In California, all of the IOUs are required to provide a program tracking "database" that contains key information on all programs, projects, customer sites, and measures. The information from the databases that were used to verify installation of rebated measures includes customer contact information, project and measure information, installation dates, quantity of *units* installed, and the *unit basis* (e.g. lamps, fixtures, sensors). A significant difficulty encountered by evaluators with IOU program tracking databases is the difference in measure names, measure codes, unit basis definitions, and building type categories used by each of the utilities. This required Itron to interpret the inconsistencies and reconcile the differences in order to create a standard dataset that could be used for the on-site verification effort. To illustrate the significance of this issue, a simple 4 foot, T12-to-T8 conversion measure was referred to as a "T-8 OR T-5 LAMP AND ELECTRONIC, 4-FOOT LAMP INSTALLED", a "PREMIUM T-8/T-5 LAMP&ELECT BALLAST-REPLCE OF T-12 LAMP&BALLAST-4 FT", and a "PREMIUM T8 WITH T12 40 WATT BASELINE" by the different IOUs.

Measure Groups. To deal with the non-standardized IOU measure names and enable verification and analysis at a higher level than the measure level, a variety of aggregated groups of IOU measures were used. The detailed IOU measures were mapped to three primary "measure groups": Linear Fluorescent, High Bay, and CFLs. Another type of measure grouping developed for the analysis was referred to as the "measure category". Measure categories were used for grouping measures together for the phone survey questions, since it is much easier to get a self-report response from a customer about a measure category than to ask about each individual measure by its IOU measure name. For example, some IOU measure names clearly referred to T8s, some covered both T5 and T8s, and others were clearly T5s, so the three measure categories used were T8, T5/T8, and T5HO.

Downstream and Upstream Measures. Downstream lighting measure information was taken directly from the IOU tracking database. These measures are predominantly prescriptive and come from both direct install and customer rebate distribution methods. For these sites, a "verification" approach was used by locating the measures on site and confirming their installation, operation, and eligibility with program specifications. The Upstream effort focused on screw-in CFLs and used an inventory approach. Because there are no records for who purchased CFLs from retail outlets, recruits for the upstream effort came from the IOU billing datasets with the downstream participants removed. The number of CFLs installed that was to be "verified" on site was taken from customer self-reports. Then for the on-site data effort, an inventory was made of <u>all</u> screw-in CFLs – both installed and spares – as well as incandescents that could be retrofitted with screw-in CFLs. Upstream CFLs are important for this nonresidential study because the IOUs assume 10% of residential upstream CFLs are installed in commercial establishments. An inventory was taken to help verify the proportion of the upstream CFLs installed and stored by commercial customers.

Post-Only and Pre-Post Study Elements. There were two primary field elements of the lighting logger study. For the post-only study, as the name implies, measures were only inspected post-retrofit. This study encompassed the downstream measures from the IOU tracking databases, as well as the upstream measures. Lamp and ballast make/model information for the post-retrofit measures was obtained whenever possible. Field staff also gathered any and all available information on the pre-retrofit lighting systems, though this was difficult to obtain. The pre-post study recruited customers from both direct install and rebate program distribution methods, and <u>both</u> their pre- <u>and</u> post-retrofit configurations were inventoried and monitored. In addition, spot watt measurements were taken of each unique fixture (ballast-lamp) configuration and lamp and ballast make/model numbers were recorded, whenever possible. Lamp and ballast model numbers were used to lookup fixture input wattages from manufacturer specification sheets and compare them to spot watt measurements. They were then used for ex post fixture wattage estimates.

DEER. The Database for Energy Efficient Resources (www.deeresources.org) is the master repository and default source for prescriptive measure energy savings estimates and other relevant information (such as measure costs) in California. It contains annual impacts as well as 8760 whole-building and end use results. The energy and demand savings for many measures, such as lighting, are obtained from building simulations run on a set of building prototypes, which also allows HVAC interactive impacts to be simulated. The building prototypes use lighting operation schedules specified at the space usage type (e.g. office, kitchen, lobby) level. The IOU tracking databases use most of the DEER building prototype designations as-is, but also include some of their own, thereby complicating the evaluation further.

Key Study Aspects

Key aspects of the study including survey quotas, type of logger equipment used, and highlights of the system constructed for the lighting logger and verification effort are discussed below.

Logger/Site Quotas. A total of 1,400 monitored sites were initially targeted for this effort and allocated as follows:

- Upstream CFLs: Post-Only 600 sites
- Downstream CFLs: Post-Only 200 sites
- Linear Fluorescents: Post-Only 250 sites and Pre-Post 200 sites
- High Bay: Post-Only 50 sites and Pre-Post 100 sites

Furthermore, ideally, each of these quotas were to be distributed equally amongst the three electric IOUs. In addition, an average of 10 loggers installed per site was also targeted. At the time of this paper, 7,200 lighting loggers were installed in over 1,250 commercial buildings (the upstream effort was still underway), which is a bit less than 6 loggers per site. Because these were typically “small” commercial sites, there were many sites that could be represented with fewer than 10 loggers.

Logger Equipment Installed. Two types of time-of-use (TOU) *DENT Instruments* SMART*loggers* were used: the LIGHTING*logger,* which uses an internal photo-sensor, and the CT*logger*, which uses an external current transformer (CT). The pre-post effort relied upon an additional logger type: an *Onset* CTV-A/B/C split-core AC current transformer paired with an *Onset* HOBO 4-channel data logger. The loggers were installed between September 2008 through October 2009, with the majority of loggers installed during the second and third quarters of 2009. More than 75% of the loggers recorded lighting usage for more than eight weeks. The bulk of the remaining loggers recorded between six to eight weeks of monitored data.

Phone Surveys. CATI-conducted phone surveys were used to collect information used for a variety of evaluation objectives, including recruitment for the on-site verification site visits and participation in the lighting logger study. In addition, for the Upstream CFL effort, the phone survey was used to determine if screw-based CFLs were purchased by the site, and if so, how many were present on site. This data was critical for the upstream sites because it was essentially treated as the “verification” data, though of course the uncertainty around these customer estimates was much higher than that for the downstream measures from the IOU tracking databases.

The On-Site Survey Form. The on-site survey form used a number of MSWord document templates. Primary sections of the survey form included: site information, measure summary, business hours and equipment operation, activity area and site sketch, logger installation/extraction form, measure-specific verification and logger assignment forms, and finally the general comments and photo log forms. Data from the phone survey and the IOU tracking databases were automatically populated into the Word documents using bookmarks linked to the data in an MS Access database. This method was used to create a unique survey form for every surveyed site. For downstream sites, the site-specific measure information was a list of the measures from the IOU tracking database. This information was populated into a "Measure Summary" table at the front of the form and on to the measure-specific verification forms. For upstream sites, the site-specific information came from customer-reported screw-based CFL quantities reported during CATI phone surveys. Every survey form was reviewed for completeness before data entry in order to make sure any outstanding issues were resolved with the on-site surveyors who recorded the information. The completed survey forms were scanned to a pdf file and saved along with the on-site survey photos.

On-Site Survey Verification and Logger Installation Procedures. A detailed written logger installation procedure and general field survey handbook were created to provide guidelines for conducting the on-site surveys and filling out the survey form. These resources were used not only as a training reference, but also as a *living document* to record any changes to the procedures and survey forms as the survey progressed and new issues were encountered and addressed. The *logger installation procedure* included background information on DEER space usage areas, information about the type of loggers used, how these loggers should be initialized and placed, and procedures for logger extraction. The *field survey handbook* contains project background information, general instructions, required tools and materials, suggested contact interview techniques, and, most importantly, a section on how to fill out the on-site survey form, including detailed instructions for each page and field of the form.

Extensive guidelines for selecting where and how to install lighting loggers were also provided in the lighting logger field installation procedure. These procedures include guidance on determining lighting schedule groups, the minimum and maximum number of loggers to install, placement of the logger within a fixture, single rooms served by multiple switches, difficult locations, etc. An engineering approach rather than a strict sampling approach was used to guide logger placement, with the prime objective being a representation of the complete range of operation of each rebated measure. Under this approach, the first step in deciding which fixtures to log was to assess the site's space use areas and distinct lighting operation schedules and points of control for the rebated lighting measures. Once the site assessment was made, the loggers were placed in all activity areas that had a different operation schedule, including those that were on 7/24 and those reported as never used. Primary and back-up loggers were installed on the largest representative clusters of rebated measures, and then a single logger used for each of the remaining fixtures. Back-up loggers were installed on the same switch or point-of-control (POC) as the primary logger, but in a different fixture. In some cases, loggers could not be installed, and surveyors were instructed to provide an explanation. Loggers were not to be installed on outside lighting fixtures for this study, though some were installed on covered patios and protected walkways.

On-Site Survey Tracking System. A spreadsheet and interlinked GPS map were used to track and assign the sites to on-site surveys. The surveyors were asked to report their status on a daily basis in order to keep the spreadsheet up to date. This daily routine allowed the small commercial team to determine whether a strata should be closed based on established quotas. As new sites were recruited, they were also added to the spreadsheet and assigned to surveyors. Once all field reports were in and new sites assigned, the spreadsheet was used to generate a corresponding GPS map that was sent out to surveyors and used by them to update their schedules. This system was set up so that assignments made in either the spreadsheet or the GPS mapping software could be propagated back to the other one. The system was used to track the entire field effort, including installations, extractions, verification-only sites, as well as "lost" sites. The dispositions for lost and verification sites – why they were lost or why loggers were not installed - were also tracked in the spreadsheet. The disposition of upstream sites was especially important, since customers often incorrectly reported the presence of screw-based CFLs. This was a critical issue for the upstream analysis effort.

On-Site Survey Master Database. An MS Access database was used for the on-site survey data, data entry system, and macros used to populate and generate the on-site survey form templates mentioned previously. As soon as new sites were recruited via the phone survey, key phone survey data and IOU tracking database data were added to the master database. An Access macro was then run to generate the electronic on-site survey forms for new sites. The data entry system resided in a separate Access database that was linked to the master database. The data entry system used a tabbed interface that reflected the format and order of the on-site survey form. A "coded" version of the on-site survey form was created and used as a "data dictionary" for data analysis. It was encoded by writing the Access database table and field names on to the corresponding pages and records of the survey form. Typically, each page will correspond to a table and each record will be a field in that table.

Field Staff Training Procedure and Pilot Test. To ensure valid and reliable results from the on-site survey and lighting logger data, Itron conducted a series of "pilot tests." Prior to full-scale implementation of the logger study, a series of general and individual surveyor pilot tests were conducted to test the equipment, the survey form, the procedures, and the field staff. The pilot test began with field staff receiving training in a multiple day training session, consisting of both office and field sessions (on-site surveys conducted in teams). After the training session, field staff were sent out to conduct several on-sites on their own, including logger installation. Their survey forms were thoroughly reviewed and discussed with them. A week or two later, they returned to those sites to do an interim download of the logger data, as well as to obtain any information that was missed on the first visit. The interim logger data were then reviewed and once again discussed with each surveyor. Any issues with logger installation techniques were discussed at that time. Once surveyors passed their pilot test, they were approved to perform full-scale installations. As a final note, separate pilot tests were conducted for the downstream and upstream efforts, since the downstream measures and procedures were fairly well established, but the materials and approach for the upstream effort were completely new and untested.

Quality Control Process and Feedback Loop. Even after the pilot tests were completed, the review-and-feedback process was maintained throughout the study, and the survey form and procedures were continually revised and enhanced. Every survey form was QCed and feedback from the lighting logger staff, the survey form QC/review staff, and the data entry staff was continuously incorporated into procedures and survey form changes. Furthermore, to keep field staff on the same page, weekly team meetings were held to discuss issues discovered in the field and the recommended approach to address the issue. Any changes to the process and survey form, as well as overall project schedule status were also discussed at these meetings.

Logger Data Review: The viewLoggers Interface. The data for every logger was manually reviewed and dispositioned by an analyst. This gargantuan effort was accomplished with the *viewLoggers* interface, an interactive program/tool developed by Itron that gathered together contextual survey information (building type, space use type, lighting control, photos, etc.) and logger data in graphical and tabular formats in a single interface. The logger data were reviewed versus the contextual data for that individual logger, and it was also compared to other loggers at the site, and then finally a series of standard dispositions are applied to the logger. The standard dispositions characterize the type of operation (e.g. always on, always off), data quality issues (e.g. flickering, lamp failed, logger fell), and final data usability (e.g. good, bad, undetermined). Comments about the disposition selections and any other issues were also recorded via the interface. In addition to being a quality control (QC) interface, *viewLoggers* also corrects data from loggers that span a daylight savings time (DST) event and that have time-drift or incorrect reset issues; the internal clock for some loggers appeared to lose time. Once the data are reviewed and dispositioned, viewLoggers also converts the data to the final hourly data format, using all data in between (and excluding) the installed date and extraction date.

Lessons Learned

As has been demonstrated, this was truly a multifaceted and complex study. Although many lessons were learned in the execution of this study, the primary ideas that would be useful to anyone else contemplating such an effort are summarized below.

- **Know your data.** Spend the time reviewing the verification data in depth and setting up a system to use them in as raw a format as possible. This ensures traceability back to the source. Also, if dealing with disparate data sources, create a single data structure and associated mapping routines and/or tables to map the source data into the common data structure. This was the approach used with the IOU tracking database data.
- **Design a system for the process.** A study of this size and complexity requires a "system", that is, a variety of semi-automated components and applications that can be used to attack the effort systematically and that work together to streamline the process, rather than using a custom, one-off, manually modified approach. Designing, creating, and refining the system requires an investment of time to set-up, but it is worth the effort in the end as <u>changes in the data and process are inevitable</u>. Without a good system, re-processing data when an issue is discovered can be a painful process. The time investment can also be further justified if there is a good probability that the system can be used again. The trick is in only spending as much effort as is required to make the system functional. It just has to function and does not necessarily need to be polished like shrink-wrapped software.
- **Consider using aggregated measure groups and mapping tables.** Think about the process and consider all of the various groupings that are needed and create a master mapping table, or a series of mapping tables that can be used to aggregate records at the lowest level to a higher level. For example, Itron grouped linear fluorescent IOU measure names into "measure categories" of "T5", "T5/T8", and "T5HO" in order to simplify the phone survey questions. Asking customer about the individual IOU measure names would not have worked!
- **Do a pilot test or pre-test shakedown.** Spend time up-front to make sure that the study will produce the data that is needed for the evaluation, but then field test and revise the documents and procedures. Also, be prepared to make additional adjustments as the study continues to address significant issues as they are encountered. For example, the field staff for this study

were frequently unable to remove all of the loggers at the same time at lodging sites. As a result, a "pending" code was added to the logger installation form, as well as to the tracking system, to allow field staff to continue to the next site instead of waiting indefinitely to access the occupied rooms. Pending loggers were then picked up the next time another field surveyor was in the area.

- **Treat procedures as living documents until the end of the project.** A recurrent lesson learned during this evaluation is that you cannot anticipate everything. As such, the system and procedures need to be designed with the flexibility to be changed. First, a written procedure – even if not complete, even if just highlights, even if just written as a field-manual rather than a formal procedure – should be created before starting the project and then maintained and updated throughout the study. This functions as a reference for field staff so that they receive consistent instruction, and can also be used by those reviewing the final results to understand the approaches used in conducting the survey.
- **Expect equipment anomalies.** In a study this size, equipment anomalies will be encountered, even manufacturing issues that are normally statistically small. So be prepared to either do special testing/screening before sending loggers in to the field, or to add procedures to deal with those anomalies as they are retrieved from the field. The most significant example from this study is recording/comparing the logger internal clock versus computer date-time when the logger data was downloaded. This allowed us to save logger data that might have otherwise been unusable, and also to correct the time-slip issue.
- **Propagate changes quickly.** Every project has nuances and abnormalities that need to be dealt with. If a change to the system is needed (i.e. whatever happened is not an outlier/anomaly but can be expected to happen again and more than a few more times) then you need to make that change systematic, and propagate it through the system and to the field staff as fast as possible. Feedback and communication throughout the team is imperative for detecting and attacking major issues and quickly propagating any required changes.
- **Estimate your data storage needs.** The data, results, and components of such a system can take up a lot of disk space. To avoid having to scramble midway through the project to get more space, or to have to scatter bits and pieces of the project across numerous servers and drives, try to anticipate how much data will be produced and then double or triple that estimate.
- **Photos and site plan sketches are worth the extra time!** Field staff are typically powering through the surveys, sometimes different cities different days. As a result, they can sometimes miss or jumble information on the form, especially on a complicated survey form. In other situations, the rebated measures cannot be clearly identified, so they will take down all information and install loggers everywhere. Fortunately, with sketches, photos, the surveyors' comments, and additional feedback from the surveyor, survey form QC staff are able to sort things out and salvage the site.
- **Start with more field staff then you think you need.** Especially with a complex survey form, there will be some field staff that just will not be able to grasp what is needed. Those people need to be released to work on other projects, for your benefit as well as theirs. Also, field staff need to be provided with real-time feedback as soon after the survey is complete as possible. To make this real-time feedback happen, you also need to ensure that there is a team of people available and working in concert to QC the survey forms and provide feedback. In addition, an individual surveyor should not be allowed to have more than 5 to 10 uncompleted surveys out at any one time, especially in the beginning of the project. This will limit the loss if the surveyor decides to call it quits without turning in completed survey forms.

- **“Provide the black & white, but put the gray in comments”.** This is an instruction given repeatedly to field staff throughout the survey effort. It means, fill out the survey form completely (the black and white), even in a situation where doing so is not quite right, and then use comments, sketches, and photos if needed to explain the real situation (the gray). This will provide the closest-fit data for data entry folks and analysts, but also allow the QC staff to make any corrections that are needed, or adapt the process to systematically account for this situation by adding a new field or code, or additional procedures needed to explain this situation to other field staff.

Conclusion

The Small Commercial lighting logger study is a truly a multi-faceted study, unique in many ways. The data, results, and systematic approach toward obtaining the data needed for this study will be invaluable to the CPUC and California utilities in developing verification/installation rates, kW and kWh unit energy savings values, baseline and post fixture wattage values, baseline and post annual operating hours and 8760 shapes, and in enhancing DEER building prototype lighting end use shapes at the building type and even the space use type (e.g. lobby, office) level. Although the key features of the Small Commercial lighting logger study have been explained herein, there is much more that could – and likely will - be written about this lighting logger palooza.