Final Report for

Energy Technology Assistance Program

Prime Contractor Name: Energy Solutions

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Project Manager: Tony Wong

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ARRA SEP contracts have not been granted confidentiality status for any contract deliverables, therefore, the Final Report is a public document and must be completed before the contract termination date of the contract. The contractor should use the outline below to complete the report. Each contractor should receive approval from their Commission Contract Manager to ensure the Final Report meets the needs of each individual contract.

Final meetings between the contractor and the Energy Commission will be at the discretion of each Commission Contract Manager.

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(1) EXECUTIVE SUMMARY

Program Background and Approach

Energy Solutions developed the Energy Technology Assistance Program (ETAP) to reduce energy consumption and stimulate the economy by accelerating the growth of the market for advanced building energy management technologies. While many Energy Commission stimulus programs targeted the commercial and residential sectors, ETAP exclusively targeted facilities in underserved public and nonprofit organizations. ETAP focused on facilitating the installation of advanced technologies with low market penetration but a demonstrated ability to deliver substantial cost and energy savings.

Leveraging the work of the Energy Commission's Public Interest Research Program (PIER) and other demonstration studies, ETAP concentrated on supporting three specific categories of state-of-the-art, advanced building energy management technologies:

- Bi-level lighting for parking lots, garages, stairwells, and walkways;
- Wireless lighting control systems; and
- Wireless HVAC control systems.

ETAP faced many significant challenges, including a compressed period of performance, time-consuming public approval processes, layoffs and budget cuts that reduced both capital and human resources within participating agencies, unfamiliar and sophisticated products, a limited portfolio of qualified technologies, and startup companies still optimizing their business processes.

Despite the challenges, ETAP facilitated the installation of 114 projects in 60 different agencies, achieving significant measure balance with 71 bi-level lighting, 16 wireless lighting, and 27 wireless HVAC projects. Together, these projects are delivering over 23,000,000 kWh of electricity savings, over 948,000 therms of natural gas savings, and over 1,300 kW of peak demand reduction annually, exceeding all contractual goals.

Program Design

ETAP implemented three major program activities to address market barriers to the adoption of bi-level lighting, wireless lighting controls, and wireless HVAC controls:

- **Technical Services & Rebates**: ETAP assisted participating organizations in identifying and implementing projects where qualified technologies were be likely to create cost-effective energy savings and paid rebates upon successful installation;
- **Marketing**: ETAP developed fact sheets and case studies describing the targeted categories of technologies and documenting successful installations of qualified products; and
- **Workforce Development**: ETAP produced a series of workshops and trainings on the targeted technologies to electricians, HVAC installers, participating organization staff, and other interested parties.

Organizational Structure

Energy Solutions, a private consulting company, served as prime contractor. To efficiently deliver program services, ETAP assigned an individual staff person to act as the program's primary point of contact (Agency Lead) for each participating organization (Agency). Agency Leads coordinated ETAP's outreach, technical services, and rebates for their designated participants. ETAP formed a separate Technical Services Team to perform product qualifications, energy audits, feasibility studies, and post-installation verification and monitoring activities. ETAP also assigned individual staff leads to manage the Marketing and Workforce Development activities. The Program Director provided overall program direction and oversight and the Program Manager managed day-to-day operations.

Organizations from the public, private, and nonprofit sectors collaborated with Energy Solutions to implement ETAP activities. Some manufacturers of qualified products, such as Adura Technologies, Lutron, Vigilent, and Cypress Envirosystems, also worked with ETAP staff to help participants identify and develop scopes of work for potential projects. Those organizations were not compensated by Energy Solutions or the Energy Commission for services provided to participating organizations. Subcontractors to Energy Solutions are listed below by the program activity for which they provided assistance.

TECHNICAL SERVICES

- California Lighting Technology Center (CLTC): Technical consulting services for selected lighting projects
- Lighting Wizards: Technical consulting services for selected lighting projects
- Integrity Electric: Installation and removal of monitoring equipment for lighting projects

MARKETING

- Linda Brandon Design: Graphic design services for case studies, fact sheets, and other program collateral
- William Porter Photography : Photography services for case studies
- Phoenix1: Printing services for fact sheets, case studies, and other program collateral
- Creative Slice: Website design services

WORKFORCE DEVELOPMENT

- Linda Brandon Design: Graphic design services for seminar and training announcements
- Vigilent: Curriculum license and staffing for wireless HVAC controls training curriculum
- California Lighting Technology Center (CLTC): Advanced lighting control curriculum development
- California Advanced Lighting Controls Training Program (CALCTP): Staffing, marketing, and curriculum for advanced lighting controls trainings

(2) GOALS

This section provides a high-level comparison of ETAP's contractual goals to actual accomplishments. For additional information about program activities and outcomes, please see *Section 3: Accomplishments* and *Section 5: Technology*. For information about specific contract deliverables, please see *Section 6: Deliverables*.

Primary Program Performance Metrics

Each of ETAP's major program activities (technical services, rebates, marketing, and workforce development) addressed a specific goal. To measure and track program performance, ETAP established quantitative objectives for each goal. ETAP met or exceeded all contractual program goals and objectives (see Table 1).

Table 1. Comparison of ETAP's Primary Contractual Goals to Actual Accomplishments

PROGRAM ACTIVITY	GOALS AND CONTRACTUAL OBJECTIVES		ACTUAL ACCOMPLISHMENTS	
	Goal	Objective	Achieved	% Objective
TECHNICAL SERVICES & REBATES	Annual Energy Savings			
	Electricity - kWh	13,200,000*	23,035,547	175%
	Nat. Gas - therms	46,275*	948,018	2,049%
	Peak Power Reduction			
	kW	1,275*	1,346	106%
MARKETING	Case Studies	7	8	114%
	Website	1	1	100%
	Other Materials			
	Brochure	1	1	100%
	Application	1	1	100%
	Fact Sheets	NA	3	NA
WORKFORCE DEVELOPMENT	Technology Seminars			
	# Seminars	6	6	100%
	# Participants	60	229	380%
	Electricians Trained	40	40	100%
	HVAC Installers Trained	20	26	130%
	Interns Trained	4	4	100%

*The objectives for annual energy savings and demand reduction were reduced from the original contractual amounts to those shown in the table following a Critical Performance Review on 3/4/2011 in which the Energy Commission requested an increase in rebate levels. It should be noted, however, that ETAP exceeded even the original contractual energy savings goals of 17.6 kWh and 61,700 therms. Due to high demand, ETAP requested and received additional rebate funding ($750,000 additional funding was added to the contract and $100,000 was re-allocated to rebates within the contract). Program participants installed a larger number of HVAC projects than envisioned during program design, which dramatically increased ETAP's total natural gas savings and decreased total peak electrical power demand reduction. The wireless HVAC measure produces little to no kW savings and thus the increase in these HVAC measures led to proportionally lower kW savings.

ETAP provided technical services and rebates to help program participants install cost-effective projects utilizing advanced energy management technologies that saved energy and reduced peak demand. Technical services objectives included quantitative annual electricity and natural gas savings and peak electrical power reduction targets for installed projects.

Through its marketing activities, ETAP sought to increase the availability of information about the targeted program technologies. Marketing objectives included specific quantities of program collateral to be developed and distributed.

ETAP's workforce development activities aimed to increase the number of workers and staff trained to install and operate the targeted program technologies. Workforce development objectives included specific quantities of events to be sponsored and minimum participation levels.

Although not officially established as contractual objectives, project data collected and tracked by ETAP staff provide several other insights into overall program performance.

Payback

The median payback of ETAP projects, including energy and maintenance cost savings, was 5.15 years, indicating that the program successfully targeted cost-effective projects. Net of ETAP rebates, the median payback dropped to 3.74 years. Total first year energy cost savings for the program were $3.37 million, which will continue to provide financial benefits to local cities, counties, universities, and nonprofit organizations for many years after the retrofits are fully paid, throughout the life of the installed measures.

Leverage Funding and Job Creation

ETAP rebates typically covered about 23% of project costs. As a program, ETAP used $3.4 million in rebate funding to leverage an additional $17.9 million into the state and national economies. The leveraged funding sources included utility incentives, participants' internal capital funds, revenue bonds, dedicated energy project funds, and federal block grants. The total impact of over $21.2 million of spending resulted in a net creation or retention of more than 350 jobs.[1]

Bi-Level Lighting Performance

ETAP's monitoring efforts provided crucial new empirical data on the performance of bi-level, or adaptive, lighting in parking garages. The data shows that bi-level light fixtures operated at the low output level 62% of the time in parking garages, which is a significantly higher percentage than previous industry assumptions. The measured data showing more time spent in low power mode means that actual savings for bi-level lighting were higher than originally estimated, and increasing the associated utility incentives could be justified if necessary to motivate more customers to install this measure.

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[1] The number of jobs created was estimated assuming $60,000/job, in the middle of the range inferred from several reports, including "Energy Efficiency, Innovation, and Job Creation in California," UC Berkeley (2008), "Redefining the Prospects for Sustainable Prosperity, Employment Expansion, and Environmental Quality in the US: An Assessment of the Economic Impact of the Initiatives Comprising the Apollo Project," Apollo Alliance (2003), and "ACEEE Energy Stimulus Job Impacts Calculator," ACEEE, (2009).

(3) ACCOMPLISHMENTS

This section provides information about ETAP's primary activities and outcomes. For a summary of key program performance metrics please see *Section 2: Goals*. For details about outcomes for each technology, see *Section 5: Technology*. For information about specific contract deliverables, please see *Section 6: Deliverables*.

ETAP implemented three primary activities: technical services and rebates, marketing, and workforce development. Additional administration and management activities supported, integrated, and directed all program operations. The sections below describe the primary activities and outcomes of each activity area.

Technical Services and Rebates

> "The ETAP staff was extremely helpful throughout the entire process – providing unbiased, high quality technical recommendations and a consistently fast response time. Particularly, I thought that the audit-level analysis and photometric modeling made compelling arguments for the project's feasibility and my team's overall comfort with the energy efficiency retrofit. My staff learned a lot about lighting efficiency in the course of working with the ETAP team, and I was very pleased with the entire program process."
>
> *– Mike Robertson, Deputy Director of Off-Street Parking,* ***San Francisco Municipal Transportation Agency (SF MTA)***

ETAP's technical services and rebates helped program participants (Agencies) install cost-effective, advanced energy management projects that saved energy and reduced operating costs. At the conclusion of the projects, ETAP provided a project rebate based on the installed savings.

In numerous cases, ETAP exposed agencies to advanced technologies that they would not have otherwise considered. As of this writing, the program has already received statements from many Agencies that based on the ability of the installed technologies to both perform their functions as designed and bring in the energy savings as projected, Agencies fully expect to continue implementing these technologies in additional facilities.

ETAP has therefore been successful in facilitating the establishment of these advanced energy efficiency technologies in the commercial and institutional market, which was one of the basic objectives of ETAP and the Energy Commission.

Technical Services Approach

Each Agency worked with an individual Agency Lead, who served as that organization's primary point of contact with ETAP throughout the Agency's participation in the program. Agency Leads coordinated with ETAP's Technical Team to help Agencies identify feasible projects and ensure that qualified products were installed. Once an Agency committed to installing a feasible project by signing an application form, ETAP reserved rebate funding for that project. To ensure that rebate funding was fully distributed within ETAP's period of performance, Agency Leads tracked each project's progress toward completion according to a schedule of milestones. The milestone schedule spanned all phases of implementation, from the initial project screening through post-installation verification. The Program Manager reallocated funding from projects that failed to comply with the milestone schedule to other projects on a waiting list.

ETAP issued one of two types of rebates: prescriptive rebates for qualified bi-level lighting fixtures ($200/LED fixture; $100/fluorescent and induction fixture; $40/lamp and ballast retrofit); and calculated rebates for qualified wireless lighting and HVAC control projects ($0.18/kWh). ETAP incentives coupled with utility incentives typically covered less than half the total measure cost.

Technical Services Provided

ETAP assigned each proposed project to a member of the Technical Team (Project Lead). The Project Lead worked with the Agency and Agency Lead to analyze the feasibility of the prospective project and to provide other technical services to support the Agency. Table 2 shows the ETAP services available to participating organizations at each phase of project implementation. In parallel with the services described in Table 2, the ETAP Technical Team evaluated products associated with proposed projects for rebate eligibility according to technology-specific criteria approved by the Energy Commission (See *Section 7: Technology, Technology Evaluation* for more details). The Energy Commission provided final approval for all product eligibility determinations.

SCREENING

Agency Leads worked with Agency representatives to collect basic information on lighting and HVAC equipment currently used at the Agency's facilities. Agency Leads also gathered information about funding, procurement, and overall level of interest by Agency decision makers in pursuing projects at facilities exhibiting high savings potential. Facilities that exhibited potential at this stage were selected for more in-depth screening. In some cases, a vendor of a qualified product would participate in follow-up calls to help scope opportunities and describe the technology.

The Project Lead used screening information and assumptions to calculate general estimates of baseline energy usage and savings opportunities and identify high priority buildings. For screening-level calculations as well as subsequent audit and verification-level calculations, ETAP developed a technology-specific spreadsheet model to calculate annual baseline and retrofit energy usage and energy costs and potential ETAP and utility incentives.

Table 2. Typical ETAP Services Available By Phase of Project Implementation

Phase of Project Implementation	ETAP Services
Screening	Determine rough savings potential
Audit	Collect more detailed equipment information, quantities, and other site-specific information, often through site visits
Feasibility Analysis	Complete savings analysis comparing existing equipment with available ETAP-supported retrofit options; reserve rebate if participant chooses to implement
Procurement Support	Provide resources and references to assist participant with specification and development of bid documents
Design Review	Review equipment order to confirm eligibility and refine estimated energy savings and rebate amounts
Installation Verification	Verify that installation of project was consist with original design, typically through site visits; issue rebate for properly installed projects
Data Monitoring	Collect actual equipment performance or electrical consumption data
Final Savings Report	Incorporate results from installation verification and data monitoring to calculate final savings reported to Energy Commission and DOE

AUDIT

For some buildings, sufficient information, up-to-date drawings and plans, and operating information were already available and an on-site audit was not necessary. Other buildings required on-site visits to better understand baseline controls, HVAC equipment, light fixture types, and building operating schedules. For “fast track” projects, vendors and their Agency counterparts often had already scoped a project at a facility and completed the auditing necessary to design a feasible project. In such cases, ETAP staff typically did not duplicate the audit activities, but instead spot-checked information provided by the vendor and/or Agency contact.

In a typical audit, the Project Lead walked through the facility and interviewed Agency staff to determine the make, model numbers, and quantities of relevant equipment, confirm hours of building operation, and identify other critical operational and design parameters.

During bi-level lighting audits, Project Leads measured light levels in several locations in order to gain a clear understanding of the existing light levels. Project leads noted the ratio of the maximum to minimum (or average to minimum) light, as this “uniformity” ratio is an important indicator of the overall lighting quality in an area.

For wireless lighting projects that were selected, approved, and funded by agencies, ETAP personnel recorded lighting operation over a two or more week period of normal facility operation prior to installation of wireless lighting controls. Monitoring data helped the Project Lead refine estimates of baseline lighting operating hours. Typically, ETAP deployed power loggers in electric service panels to record interval measurements of average lighting circuit power usage. In some cases, ETAP used light loggers to record interval measurements of relative illuminance at select fixtures to characterize when fixtures were switched on and off. The Project Lead used time-series data to calculate daily and weekly operating hours for lighting in various space types, and extrapolated these results to annual operating hours based on building schedules.

ETAP personnel collected any information not available at the time of the audit through subsequent email and phone communications with Agencies. In those few cases where ETAP staff could not obtain all information required, ETAP used standard assumptions based on previous experience with similar projects. ETAP designed assumptions to produce conservative estimates of energy savings and disclosed all assumptions to the Agencies.

FEASIBILITY ANALYSIS

Using data gathered during the audit phase and customized technology-specific calculator tools, Project Leads analyzed the feasibility of prospective projects. Agency Leads delivered results to the participating Agencies, typically in the form of an Audit Report or Audit Memo. Audit Reports and Memos included estimates of both energy savings and project financials, providing Agencies with the information needed to make a decision about whether or not to implement the project. ETAP reserved rebates for projects when the Agency committed to implementation by signing an ETAP rebate application and agreeing to an implementation schedule.

In analyzing the feasibility of a project on behalf of an Agency, ETAP estimated the total savings associated with a project, including savings both from equipment that was explicitly eligible for ETAP rebates (such as qualified bi-level light fixtures) as well as equipment that was part of the same overall project but was not eligible for ETAP rebates (such as fixed-output light fixtures that were more efficient than the previously installed fixtures). This approach allowed ETAP to accurately reflect the overall benefits and economics of the project in a single, cohesive report. ETAP disaggregated the sources of savings for each project in the Final Savings Report, as described in the relevant section below.

PROCUREMENT SUPPORT

ETAP staff provided as-needed assistance to participating Agencies to support the procurement of eligible equipment, including development and review of bid specifications. Wireless HVAC projects typically entailed more complicated procurement processes than did lighting projects. Depending on the measure installed and existing infrastructure at the installing Agency, Wireless HVAC Control Measure projects were likely to require a subset of the following types of contracts:

- Purchase and installation of variable frequency drives (VFD);
- Purchase and installation of wireless HVAC control equipment; and
- Controls integration with existing Building Automation System (BAS)

Agencies typically used existing contracts to purchase and install the VFDs that enabled the wireless HVAC control system to convert constant air volume (CAV) systems to variable air volume (VAV) systems. ETAP helped to ensure that the Agency understood which supply and return fans required VFDs and the size of the motors that the VFDs were to be applied to. The Agency itself then secured the contract for these services. Wireless pneumatic thermostat (WPT) projects typically did not require VFD installation.

Agencies used sole source contracts or Job Order Contracting (JOC) to purchase and install the wireless HVAC control equipment. When necessary, ETAP helped assemble sole source justifications and was available to answer questions from Agency procurement offices. In one instance, ETAP helped facilitate adding the WPT measure to a JOC instrument where the measure was not previously available.

Agencies sought control integration with existing BASs primarily in connection with WPT installations. While integration was not a specific ETAP requirement, many of the agencies saw this as a primary benefit of the system. The Agency's existing control contractor, if it had one, was the first choice to provide integration services as it would be the most familiar the existing BAS. In the event that the Agency did not have a controls contractor, the equipment manufacturer provided a short list of control contractors that were familiar with the WPT product.

DESIGN REVIEW

After securing authorization for project implementation, Agency representatives completed and submitted the project design or scope of work for ETAP review. ETAP staff used the design review process to confirm the eligibility of proposed equipment and control strategies and refine the estimate of energy and cost savings anticipated for the project. The Project Lead's review also acted as an additional level of overall quality control to help ensure the use of industry best practices. Vendors and installation contractors sometimes provided information affecting the design review as well. ETAP adjusted the reserved rebate amount according to the project information provided during this phase.

INSTALLATION VERIFICATION

After project installation, Project Leads verified that the project was installed in a manner consistent with the submitted design or scope of work. Verification procedures varied by technology area, but typically consisted of a site visit and inspection, review of invoices for equipment quantities and project costs, and review of any controls programming or commissioning documentation. For projects that were also enrolled in a utility incentive program, ETAP also considered utility post-installation audits for verification.

If the Project Lead identified any discrepancies between the installed project and the approved project design that were likely to impact the expected energy savings, ETAP adjusted the rebate adjusted accordingly.

DATA MONITORING

Project leads used monitoring data to determine the final project savings reported to the Energy Commission. Monitoring efforts varied significantly by technology type, as described below.

Bi-Level Lighting Controls

After the completion of a bi-level lighting project, the Project Lead coordinated with the ETAP's electrical subcontractor, Integrity Electric, to install light level loggers in six different fixtures throughout the facility. The loggers were placed in areas that were representative of the distinct traffic patterns of the garage (e.g., near entrance, in average area, and in low traffic area).

To determine the amount of time spent in high and low power modes, ETAP categorized light level readings (taken at 1 minute intervals) as either “high” or “low” power. ETAP determined the lumen values corresponding to high and low power separately for each logger using histograms to count the number of logs taken at various lumen levels.

The Project Lead used an ETAP-customized Excel-based analysis tool to convert the categorized light level readings into the fraction of time the logged spent in low-power mode. Project Leads also use to tool to determine the fraction of “Peak” time that the fixtures are in low-power mode.

Wireless Lighting Controls

Following the installation and commissioning of a wireless lighting controls project, the Project Lead worked with facility contacts, contractors, or controls vendors to trend lighting system data over a two week period of time (or more) to quantify actual operation and energy savings from the system. Because the controls systems included the ability to record lighting system demand and energy usage over time, ETAP did not install data loggers for post-installation monitoring. Before trending lighting data from the new controls system, ETAP typically allowed several weeks after system installation for all troubleshooting and system adjustments to be completed so that the new controls system was in a “steady state” for the ETAP evaluation.

In order to generate data for each space type to compare with pre-installation monitoring results, Project Leads selected representative fixtures or locations from the controls system diagrams within the same spaces originally monitored. Project Leads used time-series data polled from the controls system for the representative fixtures to compare baseline and retrofit operation.

Wireless HVAC Controls

Monitoring for HVAC control measures focused on collecting fan speed data and corresponding outside air temperatures. ETAP worked with the equipment manufacturer to collect performance data for each controlled supply fan as well as outdoor air temperatures. ETAP staff used this data used to determine if, on average, fan speeds for a given temperature bin performed as predicted by the bin analysis used in the ETAP savings model. ETAP calculated average air flow per fan and temperature bin and summed across all supply fans. ETAP used these air flow values used to override the predicted air flow in the bin analysis, producing calibrated fan, cooling, and heating savings for the project. Actual power usage for fans and cooling and heating plants was not monitored.

FINAL SAVINGS REPORT

After ETAP completed the data monitoring and analysis, the Project Lead updated the technology-specific calculator tool to include any changes found during the verification and the results of the data monitoring analysis. Changes in final (monitored) energy savings calculations typically did not affect the value of the rebate ETAP paid to the Agency, but did affect the total program savings reported to the Energy Commission.

The final estimate of energy savings was disaggregated by whether savings were specifically attributable to controls (rather than other sources of savings, such as more efficient light sources), and whether savings were specifically attributable to qualified ETAP products (rather than other energy-saving equipment that were installed as part of the same project).

Technical Services Outcomes

ETAP conducted audits or feasibility studies for over 300 projects in 99 different public and nonprofit organizations throughout the state. ETAP issued $3.4 million in rebates for 114 different installed projects. Table 3 and Table 4 show major technical service outcomes by the targeted technology type (bi-level lighting, wireless lighting controls, and wireless HVAC controls). In aggregate, bi-level lighting projects accounted for the largest number of projects and the largest share of total program savings, delivering 11,847,265 kWh of annual electricity savings and 970 kW of peak demand reduction. Wireless HVAC projects typically had the shortest payback periods and despite constituting less than a quarter of all ETAP retrofits, contributed almost 39% of the program's total electricity savings and 100% of total natural gas savings.

Table 3. ETAP Technical Services – Total Program Outcomes

	PRIMARY PROJECT TECHNOLOGY			
METRIC	**Bi-Level Lighting**	**Wireless Lighting Controls**	**Wireless HVAC Controls**	**PROGRAM TOTALS**
Number of Audits Completed	183	63	58	304
Number of Retrofits Completed	71	16	27	114
Number of Projects Monitored	38	10	6	54
Rebates Issued ($)	$1,851,860	$415,675	$1,126,557	$3,394,092
Annual Electricity Savings (kWh)	11,847,265	2,238,102	8,950,180	23,035,547
Annual Natural Gas Savings (therms)	0	0	948,018	948,018
Peak Demand Reduction (kW)	970	216	160	1,346

Table 4. ETAP Technical Services – Median Project Outcomes

	PRIMARY PROJECT TECHNOLOGY			
	Bi-Level Lighting	**Wireless Lighting Controls**	**Wireless HVAC Controls**	**PROGRAM MEDIAN**
Median Project Cost ($)*	$65,009	$156,446	$62,290	$70,072
Median Project Rebate ($)	$15,400	$20,377	$20,274	$17,000
Median Payback (years)	3.71	6.63	1.93	3.74
Estimated Measure Life (years)	9-10	8	12-15	>8
Median Peak Power Reduction (kW)	3.10	14.10	1.10	3.35
Median Annual Energy Savings				
Electricity Savings (kWh)	62,393	101,052	87,394	88,191
Natural Gas Savings (therms)	0	0	6,989	0

*Project cost before utility and ETAP rebates, but excluding internal costs

BENEFITS OF CONTROLS

ETAP focused its support on advanced control technologies. Every ETAP project included the installation of qualified products that provide facility managers with greater control over building energy consumption. In some cases projects also included the installation of non-control equipment that delivered energy savings. For example, some bi-level lighting projects also included the installation of more efficient light fixtures that facility managers did not wish to place under the control of an occupancy sensor. To better understand the effects of controls themselves on program savings, ETAP disaggregated the sources of savings in each project.

Table 5 shows the program savings and peak demand reduction for each technology that are attributable to controls. Controls accounted for 22% of the energy savings and 16% of the peak demand reduction associated with bi-level projects, with the balance attributable to the installation of more efficient light sources. For wireless lighting controls projects, nearly half of energy savings, but only a quarter of peak demand reduction, were due specifically to controls, with the remainder due to more efficient light sources. Nearly all of energy savings and peak demand reduction in wireless HVAC controls projects were due to controls.

Table 5. Total Energy Savings and Peak Demand Reduction Attributed to Controls

	PRIMARY PROJECT TECHNOLOGY						
	Bi-Level Lighting		Wireless Ltg Cntls		Wireless HVAC Controls		
Source of Savings	kW	kWh	kW	kWh	kW	kWh	therms
Controls	154.20	2,642,140	54.24	1,034,902	146.50	8,513,014	884,904
Other	815.56	9,205,125	162.42	1,203,200	13.53	437,166	63,114
Total	969.76	11,847,265	216.66	2,238,102	160.03	8,950,180	948,018
Controls %	16%	22%	25%	46%	92%	95%	93%

ADVANCED EQUIPMENT

ETAP evaluated twelve advanced wireless lighting and HVAC control products for eligibility for ETAP rebates. Of these, ETAP approved seven wireless lighting control products, and two wireless HVAC products. In some cases, equipment that did not qualify for targeted ETAP technical support nevertheless contributed to the total energy savings delivered by a project. Such equipment, such as photocell controls, did not qualify for ETAP technical support because it was not deemed sufficiently “advanced” to be consistent with ETAP’s focus on cutting-edge technologies with low market penetration. However, ETAP calculated rebates for wireless lighting and wireless HVAC controls projects based on the total energy savings captured by a project, including those savings resulting from the installation of a product not specifically targeted for ETAP technical support.

To better understand the role of the advanced products that qualified for ETAP technical services in delivering program savings, ETAP disaggregated the sources of savings for each project (see Table 6). Advanced equipment captured the vast majority of the project energy savings and peak demand reduction delivered by all technology types.

Table 6. Total Energy Savings and Peak Demand Reduction Attributed to Advanced Equipment

	PRIMARY PROJECT TECHNOLOGY						
	Bi-Level Lighting		Wireless Ltg Cntls		Wireless HVAC Controls		
Source of Savings	kW	kWh	kW	kWh	kW	kWh	therms
Advanced Equip.	837.79	10,597,651	216.66	2,215,633	150.27	8,493,038	876,401
Other Equipment	131.97	1,249,614	0.00	22,469	9.76	457,142	71,617
Total	969.76	11,847,265	216.66	2,238,102	160.03	8,950,180	948,018
Advanced %	86%	89%	100%	99%	94%	95%	92%

Marketing

ETAP’s high quality case studies, fact sheets, website, brochure, and press releases served to disseminate useful technical information about advanced lighting and HVAC technologies to the target market.

Marketing Activities

ETAP’s marketing activities consisted primarily of the production of program collateral, including case studies, fact sheets, a website, a brochure, and press releases.

Through its marketing activities, ETAP sought to increase the availability of information about the targeted program technologies as well as attract potential participants to the program. As a part of its marketing activities, ETAP developed a unique logo in compliance with the Energy Upgrade California brand usage and style guide and deployed it on most program materials. At the Energy Commission's request, a modified logo emphasizing the Energy Upgrade California brand was used on case studies.

Marketing Outcomes

Key outcomes of ETAP's marketing activities are described below. For a summary of marketing performance metrics, see *Section 2: Goals.* For additional details about marketing materials, please see *Section 5: Technology*. For information about specific contract deliverables, please see *Section 6: Deliverables*.

CASE STUDIES AND FACT SHEETS

ETAP designed and produced eight four-page case studies highlighting retrofit projects that were supported by ETAP technical and financial assistance. ETAP printed 500 hard copies of each case study. ETAP distributed both hard and electronic versions of the case study to a wide range of local government, utility, energy, educational, governmental and nonprofit organizations and contacts. ETAP posted all case studies to the program website.

ETAP also designed and produced a single page, double sided fact sheet on describing each of the three primary supported technologies (bi-level lighting, wireless lighting controls, and wireless HVAC controls). The fact sheets included sample energy savings and financial calculations as well as references to additional information. ETAP printed 485 copies of each and distributed them at kickoff meetings with participants, seminars, and other events. ETAP also posted the fact sheets to the ETAP website.

ETAP WEBSITE

A comprehensive program website provided program information, regular updates on accomplishments, downloadable resources including case studies and fact sheets, and links to third party resources and partners. For public reference, the program website will continue to be accessible after program closeout at: www.energy-solution.com/etap.

ETAP BROCHURE

ETAP designed a color, tri-fold brochure. The brochure was available for download from the program website and 515 copies were professionally printed and distributed at technology seminars, outreach presentations, kick-off meetings, and at other suitable events.

PRESS RELEASES

ETAP developed four press releases either independently or jointly with participating agencies or partners. ETAP distributed press releases in accordance with the preference and resources of its collaborating partners and posted them to the ETAP website. Qualified technology vendors produced and distributed two additional press releases that highlighted the ETAP rebates, for which minimal review was provided.

Workforce Development

ETAP's workforce development activities included developing and conducting technology seminars targeting public sector agencies throughout the State of California, supporting trainings on the ETAP technologies for lighting and HVAC contractors, and offering internships to students that were enrolled or recently graduated from energy efficiency training programs at Laney College and the Workforce Institute.

Workforce Development Activities

TECHNOLOGY SEMINARS

> "This was a great event! The presentations and case studies were both valuable. The case studies really clued me in to who my organization should network with."
>
> "Good cross-section of speakers and topics."
>
> "Case studies to support overall program show it can be done with good results."
>
> "The case studies relate to current projects my organization is working on."
>
> *-Sample written comments provided by attendees of ETAP Technology Seminars on feedback forms*

Energy Solutions hosted six Technology Seminars throughout the course of the program. The Seminars gave public sector staff an opportunity to learn about projects and programs other agencies in the region have completed. Participants also learned about financing options and technical services available to agencies who were implementing efficiency retrofits.

ETAP invited guest speakers from cities, counties, schools, non-profits, and utilities to present at seminars. Presentation topics included:

- Case studies on ETAP technologies, LED streetlighting, server virtualization, and renewable energy installations, and other topics;
- Renewable and energy efficiency financing options including power purchase agreements, on-bill financing, and bond financing;

- Collaborative procurements;
- Utility services;
- Demand response opportunities; and
- Achieving zero net energy buildings.

Presentations from the Technology Seminars are available on the ETAP website (http://energy-solution.com/etap/training/tech-seminar-presentations/) and will be provided to the Energy Commission at program closeout.

LIGHTING TRAININGS

The California Advance Lighting Controls Training Program (CALCTP) is a well-established program that offers 50 hour trainings to certified electricians on the installation and commissioning of advanced lighting systems. ETAP supported an update to the CALCTP curriculum to add relevant information about wireless lighting controls. The California Lighting Technology Center updated curriculum, which is now being taught to electricians throughout the state.

ETAP also funded 40 under-employed or unemployed electricians to complete the CALCTP training. To help increase the chances that the CALCTP training would lead to job opportunities, ETAP and its partners sponsored training events in regions where advanced lighting projects were known to be under development.

HVAC CONTROLS TRAININGS

ETAP hosted two courses focusing on Vigilent's wireless Discharge Air Regulation Technique (DART) system. The courses introduced participants to the fundamental concepts and skills needed to design and install Vigilent's DART system. Attendees learned the basic principles of wireless controls and how wireless sensors can be used to increase HVAC energy efficiency in buildings. Vigilent's technical experts developed the course material and taught the courses.

INTERNSHIP PROGRAM

> "Energy Solutions was a great follow-up to a green job training I received at Laney College. I have nothing but positive things to say about the experience, Thank you."
>
> *–ETAP Intern #1, from anonymous feedback form*
>
> "I like the Energy Solutions mentality: focus and action that is the way to improve energy efficiency and life. However, three months were a little bit short to me. It would be great to work a few more months."
>
> *– ETAP Intern #2, from anonymous feedback form*

ETAP developed and implemented an internship program for students enrolled or recently graduated from particular energy efficiency training programs at Laney College and the Workforce Institute.[2] The internship supplemented students' formal classroom education with on-job training. At the beginning of their internship, each student participated in one full-day training where they received an introduction

[2] The Workforce Institute is a division the San Jose Evergreen Community College District

to the energy efficiency market in California and Energy Solutions' role in the market. This training provided valuable background information on the market through the lens of a consulting firm. Interns also learned about ETAP, the technologies ETAP supports, and how Energy Solutions implements ETAP.

During the three-month long internship, participants worked closely with their Energy Solutions mentors to research a topic relevant to ETAP or Energy Solutions. On their last day, interns presented the findings from their capstone projects to Energy Solutions' staff. The capstone projects granted interns the opportunity to work closely with a mentor, hone their research skills, and practice presenting to a large group. The capstone topics included classifying financing options that can be used to implement efficiency projects, detecting agencies with buildings well suited for bi-level lighting retrofits, and identifying potential markets for upstream HVAC incentive programs. Interns also had the chance to participate in ETAP-related meetings and audits and helped staff the ETAP Technology Seminars.

Workforce Development Outcomes

Table 7 presents the date and location of each ETAP-sponsored workforce development event along with the number of people who participated in each event.

ETAP received positive feedback from participants at all of the workforce development events. In general, participants indicated the content of ETAP Technology Seminars and trainings valuable and relevant. Technology Seminar participants seemed to find the case studies and information about project financing most useful. Participants in the HVAC trainings found the hands-on learning opportunities most useful. The ETAP internship helped prepared interns for a career in energy efficiency. At least half of the ETAP interns went on to receive paid internships or jobs after their ETAP internship ended.

Table 7. ETAP Workforce Development Activities – Date, Location, Number Trained

Event	Date	Location	Trainees or Participants
ETAP Technology Seminars			
Seminar #1	Apr 26, 2011	Sacramento	10
Seminar #2	Jun 15, 2011	Oakland	49
Seminar #3	Jun 23, 2011	Statewide Call	53
Seminar #4	Jul 21, 2011	San Diego	46
Seminar #5	Aug 24, 2011	Los Angeles	23
Seminar #6	Feb 23, 2012	Oakland	48
		Subtotal:	**181**
Lighting Trainings			
CALCTP Training #1	Feb 2011	Sacramento Area	7
CALCTP Training #2	Apr 2011	Alameda County	11
CALCTP Training #3	May 2011	Tri-Counties Castroville	4
CALCTP Training #4	Jul 2011	Orange County	6
CALCTP Training #5	Jul 2011	Los Angeles	6
CALCTP Training #6	Oct 2011	Tri-Counties Castroville	1
CALCTP Training #7	Feb 2012	Sacramento Area	5
		Subtotal:	**40**
HVAC Controls Training			
HVAC Training #1	Aug 15-16, 2011	Oakland	14
HVAC Training #2	Aug 31, 2011	San Diego	12
		Subtotal:	**26**
ETAP Internship			
Cohort #1	Feb – Apr 2011	Oakland	3
Cohort #2	Jun – Aug 2011	Oakland	1
		Subtotal:	**4**
		TOTAL ALL TRAININGS:	**251**

Program Administration and Management

> "Participating in Energy Solutions' ETAP Program was a pleasure for the City of Anaheim. The ETAP program was effectively designed; and the Energy Solutions team communicated all the necessary steps in such an efficient manner that we were able to get our bi-level lighting project installed and rebated in 3 months. This is a very quick timeframe compared to the City's typical process and demonstrates the highly effective program design and service delivery offered by the Energy Solutions team."
>
> – *Wendy DeLeon, Business Expansion/Retention Specialist,* ***City of Anaheim***

ETAP performed the program administration and management activities necessary to ensure widespread and successful participation from Agencies, as well as effective service delivery from program staff. The program's effective management and organizational structure resulted in the successful achievement of all of the ETAP's goals.

General Activities and Outcomes

Administration and management activities included communicating with the Energy Commission Contract Manager, preparing and delivering regular monthly and ad-hoc program performance reports requested by the Energy Commission, the Department of Energy, and other organizations, developing and managing the program budget, developing and implementing program strategies and policies, developing and maintaining the program performance tracking database, coordinating with utility incentive programs, managing risks, and ensuring accomplishment of all program goals.

One major outcome of ETAP's administration and management activities apart from the overall program accomplishments was the development of a performance tracking database. The ETAP database provided detailed, phase-specific information at the measure, project, customer, and program levels, facilitating communications among program staff about project status as well as enabling reporting required by the Energy Commission and the Department of Energy. The database will be provided to the Energy Commission as a part of program closeout.

Utility Coordination Activities and Outcomes

In order to best facilitate utility incentives for ETAP projects, ETAP staff worked with engineering and program management staff at the following utility companies:

- Pacific Gas and Electric (PG&E);
- Southern California Edison (SCE);
- Sacramento Municipal Utility District (SMUD);
- San Diego Gas & Electric (SDG&E); and
- Southern California Gas (SCG).

ETAP coordinated with these utilities to familiarize their staff with ETAP measures and methods for analyzing energy and cost savings. A notable outcome of this ETAP activity was that utility incentive programs and the engineering resources that support these incentive programs were given technical training and support on the advanced technologies and products approved for ETAP that in most cases were not vetted or approved for utility incentives prior to ETAP's involvement. This ETAP activity also helped to streamline the utilities' evaluation and approval of incentive applications that were submitted for projects that also received ETAP rebates.

ETAP's utility coordination efforts included:

- In-person meetings to review ETAP services, technologies, approved products, and program requirements;
- Phone conferences with utility engineering staff to discuss the details of ETAP calculation tools;
- Regular check-ins with utility program management staff regarding the progress of ETAP projects in each utility territory;
- Assistance with utility rebate application forms; and
- Follow up discussions on project-specific ETAP savings calculations.

(4) CONCLUSIONS

> "I give Energy Solutions and the ETAP program an 'A' for the university's overall experience working with them. I have worked with many rebate programs, and ETAP was by far one of the best rebate programs that we've participated in. The Energy Solutions team was very well organized and provided just the right amount of technical and administrative rigor to the project reviews and program processes to ensure that tax payer money was spent properly; yet did not burden us with unnecessary requirements that would have slowed down our project implementation. We simply couldn't have completed these projects without the ETAP program."
>
> *--Glen Brandenburg, Sustainability Advisor,* ***Associated Students of San Diego State University***

ETAP successfully demonstrated that advanced control technologies represent a significant energy savings opportunity for institutional and commercial buildings. The demand for advanced control products was extremely strong: an $850,000 increase in the program's rebate budget was easily absorbed by participating organizations wishing to installed qualified projects. Participating organizations captured a total of 23,035,547 kWh, 948,018 therms in annual energy savings, reducing peak demand by 1,346 kW and saving $3,370,000 per year in energy and maintenance costs. With measure lives of at least eight years and median payback of 3.74 years, the cost savings these projects deliver will continue to provide financial benefits to local cities, counties, universities, and nonprofit organizations long after the retrofits are fully paid. ETAP used rebates totaling $3.4 million to leverage an additional $17.9 million into the state and national economies. The leveraged funding sources included utility incentives, participants' internal capital funds, revenue bonds, dedicated energy project funds, and federal block grants. The total impact of over $21.2 million of spending resulted in a net creation or retention of at least 350 jobs.[1]

ETAP implemented four primary activities: technical services, rebates, marketing, and workforce development. Additional administration and management activities supported, integrated, and directed all program operations. The sections below describe the major findings, lessons learned, and best practices for each of ETAP's primary activities. Future programs targeting goals similar to ETAP's may benefit from these findings.

Technical Services

Specification, Vendor Coordination and Scope of Program Services

Major Finding: The complexity and novelty of controls technologies and nuanced variations in products and product combinations posed a challenge to many staff- and resource-limited program participants. Ensuring that the proper equipment was correctly specified, ordered, installed, and configured required greater effort from ETAP staff than originally planned. ETAP staff's combination of technical expertise and neutrality with respect to the implementation parties positioned them to understand and coordinate the actions of vendors or contractors. In this capacity, ETAP helped parties avoid miscommunications that could have caused costly delays or project cancellations.

Lesson Learned/Best Practice: Programs focused on promoting the installation of advanced control technologies should explicitly include owner's representative support including specification, procurement, and project management in the scope of services offered to participating organizations.

Neutral, Third-Party Product Certification Bodies

Major Finding: Using the qualified product list maintained by Design Lights Consortium[3] (DLC) in order to qualify bi-level LED products saved ETAP time and staff resources. In certain cases, however, delays in the DLC certification process posed a performance risk to ETAP and necessitated ETAP's independent review of product testing data.

Lesson Learned/Best Practice: Neutral certification bodies should be the default standard for product eligibility determinations, but a streamlined internal qualification procedure should also be used to avoid bottlenecks outside of the program's control.

Project Site Information

Major Finding: ETAP noticed significant variability in the quality of information provided by participating organizations that could significantly affect ETAP's estimates of energy savings and evaluations of project feasibility. Even within participating organizations, information about existing equipment, operating hours, and other site-specific data provided by project managers was sometimes different from that provided by end-users or building managers.

Lesson Learned/Best Practice: Program technical staff should visit each facility being evaluated for program inclusion, even if detailed facility information is available from customer staff or building documents.

Risks of Partnering With Startup Companies

Major Finding: The fast-paced market for "clean tech" and energy efficiency technologies requires that companies respond quickly to market needs and competitive pressures. Energy efficiency programs that partner with young technology companies are exposed to the risk that elements of the program design may become difficult to implement as a result of shifting business strategies.

Best Practice/Lesson Learned: Energy efficiency programs involving partnerships with startup companies should include in the program design a framework for adapting the program design and contractual deliverables to known or unforeseeable risks associated with the startup companies' business plans and market conditions.

Marketing

Co-Branding and Program Logo Development

Major Finding: One challenge during the development of marketing materials was the lack of well-defined branding guidelines for non-residential programs that fell under the Energy Upgrade California branding umbrella. When ETAP was developing its logo and brand at the outset of the program, only the Energy Upgrade California residential design guidelines were complete. ETAP was the first non-residential, non-commercial program that was to be co-branded with Energy Upgrade California. Due to

[3] Design Lights Consortium is collaboration of utility companies and regional energy efficiency organizations. For more information see: www.designlights.org.

ETAP's unique target market, there was some confusion as to how similar or unique the ETAP logo and brand should be from the residential Energy Upgrade California brand.

Lesson Learned/Best Practice: Co-branding guidelines would ideally be available at program commencement.

Project Sampling for Case Studies

Major Finding: The challenge of developing a balanced portfolio of case studies that reflected the geographic, institutional, and technological diversity of installed projects was amplified by protracted implementation schedules. The ETAP Marketing Team had to make project selections for the case studies as early as possible in order to complete them within the program's period of performance, but the scarcity of projects that finished early limited options.

Lesson Learned/Best Practice: If case study or project diversity is a primary program goal, programs should include project diversity targets and milestones early in the program period of performance. For example, the program could establish a goal of implementing a specific number of projects from each technology type within a specific number of months from program commencement.

Workforce Development

Benefits of Partnering with Successful Workforce Training Programs

Major Finding: Partnering with existing workforce training programs was an effective way to create a larger impact with ETAP's resources. ETAP's training partners (including community colleges and CALCTP) are well established and are proficient at providing training that enable people to find jobs. Partnering with well-established workforce training programs was an effective way to help confirm the effectiveness of existing training initiatives and to help promote the link between training programs and actual jobs. For example, ETAP sponsored CALCTP trainings in areas where ETAP projects were currently underway. This means that individuals trained through ETAP could potentially help install projects that received ETAP rebates.

Lesson Learned/Best Practice: Energy efficiency programs can achieve workforce training goals more efficiently and cost-effectively by partnering with existing training programs with a record of success rather than developing new training programs.

(5) TECHNOLOGY

Technology Evaluation

ETAP conducted two types of formal evaluations of the advanced technologies it supported: pre-installation product qualification and post-installation performance evaluation. ETAP conducted product qualification when products were submitted by Agencies as part of a proposed project. ETAP recommended that products meeting certain eligibility criteria be approved by the Energy Commission. The Energy Commission ultimately approved all products. After project installation, ETAP conducted monitoring activities to evaluate the actual performance of the installed equipment.

Through its communications with Agencies, ETAP also gained insights into technology-specific issues related to project implementation and equipment procurement.

The following section presents the technology evaluations ETAP performed. This section is organized by primarily technology (bi-level lighting, wireless lighting controls, and wireless HVAC controls) and secondarily by type of evaluation (product qualification, implementation and procurement, and performance evaluation).

The results of performance evaluations informed ETAP's official estimates of the energy savings and peak demand reduction delivered by the program. An overview of these results is provided in Table 1 of *Section 2: Goals* and additional technology-specific details are presented in S*ection 3: Accomplishments*. The performance evaluation data presented in this section is more granular than that presented in *Section 2* and *Section 3*.

Bi-Level Lighting

BI-LEVEL LIGHTING PRODUCT QUALIFICATION

ETAP provided financial incentives for LED, fluorescent, and induction lighting technologies as listed below. In order to qualify for ETAP incentives, all lighting technologies were controlled by occupancy sensors that allowed for bi-level operation. ETAP generally supported fixtures that achieved a minimum 50% power reduction during vacant periods, but exceptions were made to support fixtures achieving a lower power reduction percentage when project energy savings and cost considerations prevailed.

1. Linear fluorescent fixture and retrofits

High performance T8 lighting systems were equipped with 3rd generation high-lumen T8 lamps and extra efficient electronic ballasts. High performance lamps and ballasts are defined (below) and listed by the Consortium for Energy Efficiency at www.cee1.org.

High performance fluorescent lamps have a minimum color rendering index (CRI) of 80, minimum initial lumens of 3100 and minimum mean lumens of 2900. Ballasts were required to meet the performance standards outlined in Table 8.

T5 lamps had to meet a CRI of ≥82, and a minimum rated lamp life of 20,000 hours on 3 hour starts. Ballasts must have had less than 10% THD and a power factor greater than 98%.

In addition to meeting the qualifications maintained by the CEE, both T8 and T5 lighting systems also achieved a minimum 50% power reduction. This could be achieved with a dimming or step-dimming ballast, or other bi-level configuration using two or more ballasts.

For customers who needed a step-dimming, high ballast factor ballast, a 50% or greater power reduction was not possible because there are no such ballasts available. For these projects, the best solution is a step-dimming high ballast factor ballast which achieves a 40% power reduction during vacant periods. Using this ballast proved to be a more cost-effective option than purchasing two ballasts per fixture. Because of these factors, fixtures with this type of ballast were given an exception and deemed eligible for an ETAP rebate.

Table 8. Minimum Ballast Efficacy Factor (BEF) Required by ETAP

	Minimum Ballast Efficacy (BEF) By Ballast Factor (BF) Range* (Low, Normal, High)		
Ballast Type	**Low BF ≤0.85**	**Normal 0.85<BF≤1.0**	**High BF≥1.01**
Instant Start 1	≥3.08	≥3.11	≥3.03
Instant Start 2	≥1.60	≥1.58	≥1.55
Instant Start 3	≥1.04	≥1.05	≥1.04
Instant Start 4	≥0.79	≥0.80	≥0.77
Programmed Start 1	≥2.84	≥2.84	≥2.95
Programmed Start 2	≥1.48	≥1.47	≥1.51
Programmed Start 3	≥0.97	≥1.00	≥1.00
Programmed Start 4	≥0.76	≥0.75	≥0.75

***BEF = BF x 100 / ballast input watts. See CEE High Performance T8 Specification, http://www.cee1.org/com/com-lt/com-lt-specs.pdf

2. LED Fixtures

Initially, LED were required to meet the specifications for LED fixtures in Table 9. However, the Design Lights Consortium added new fixture categories and increased performance standards (version 1.6) in July of 2011. ETAP subsequently adopted the new performance standards, shown in Table 10, while continuing to allow fixtures qualified under the earlier standard. A list of products that met the LED specifications and were considered 'pre-approved' for ETAP incentives was maintained by ETAP, but was mainly populated by specific fixtures on the DesignLight Consortium's (DLC) Qualified Product List at www.designlights.org. These fixtures included parking garage, outdoor pole/arm mounted and all mounted area LED luminaires.

Table 11 shows the LED fixtures that were qualified by ETAP, independently of the DLC's list. ETAP qualified several additional fixtures that were later included in the DLC list, those fixtures are not included below. Independent ETAP qualification required documented results from three standard industry tests: LM-79, LM-80, ISTMT.

Every fixture was also capable of a minimum 50% power reduction in use with an occupancy sensor. In practice, bi-level power reduction was upwards of 66% or more for LED fixtures.

Additionally, unlike fluorescent fixtures, replacement of currently installed LED fixtures was not an eligible measure.

LED Driver Requirements:

- Drivers shall have a minimum efficiency of 85%
- Drivers shall have a power factor (PF) of ≥0.90
- Drivers shall have a Total Harmonic Distortion of ≤20%

Table 9. Performance Specification for LED Fixtures, Design Lights Consortium Requirements Version 1.5

.Application	Minimum Light Output	Zonal Lumen Density	Minimum Luminaire Efficacy	Allowable CCTs (ANSI C78.377-2008)	Minimum CRI	Minimum LED Lumen Maintenance at 6000hrs	Minimum Luminaire warranty
Outdoor Pole/Arm-Mounted Area and Roadway Luminaires	1,000 L	=100% 0–90º, <10% 80–90º	50 lm/W	<6500K	50	95.80%	50,000 hours and 5-year warranty
Outdoor Pole/Arm-Mounted Decorative Luminaires	1,000 L	95% 0–90º	40 lm/W	<6500K	50	95.80%	50,000 hours and 5-year warranty
Outdoor Wall-Mounted Area Luminaires	300 L	=100% 0–90º, <10% 80–90º	40 lm/W	<6500K	50	95.80%	50,000 hours and 5-year warranty
Parking Garage Luminaires	2,000 L	>=20% 60–70º, >=15% 70–80º	56 lm/W	<6500K	50	95.80%	50,000 hours and 5-year warranty

Table 10. Performance specification for LED fixtures, Design Lights Consortium Requirements Version 1.6

Application	Minimum Light Output	Zonal Lumen Density*	Minimum Luminaire Efficacy	Allowable CCTs	Minimum CRI	Minimum LED Lumen Maintenance at 6000 hrs	Minimum Luminaire warranty
1) Outdoor Pole/Arm-Mounted Area and Roadway Luminaires	1,000 lm	=100% 0–90º, <10% 80–90º	60 lm/W	≤5700K	50	95.80%	50,000 hours, 5-year warranty
2) Outdoor Pole/Arm-Mounted Decorative Luminaires	1,000 lm	≥65%: 0–90º	40 lm/W	≤5700K	50	95.80%	50,000 hours, 5-year warranty
3) Outdoor Wall-Mounted Area Luminaires	300 lm	=100% 0–90º, <10% 80–90º	60 lm/W	≤5700K	50	95.80%	50,000 hours, 5-year warranty
4) Bollards	500 lm	<15%: 90-110º 0%: >110º	35 lm/W	≤6500K	50	95.80%	50,000 hours, 5-year warranty
5) Wall-wash Luminaires	575 lm	≥50%: 20-40º	40 lm/W	≤5000K	50	95.80%	50,000 hours, 5-year warranty
6) Parking Garage Luminaires	2,000 lm	≥30% 60–80º, ≤25% 70-80°	60 lm/W	≤5700K	50	95.80%	50,000 hours, 5-year warranty

* Zonal lumen densities shown are ideal for fixtures in these applications, but there may be circumstances in which project considerations or preferences diminish the importance of meeting zonal lumen density target values

Table 11. LED Fixtures Qualified by Energy Solutions for ETAP Rebates

Manufacturer	Series	Model Number	Application	System Watts	Lumens	Lumens per Watt
LSI	XPG 3	XPG3 5 LED 68 350 CW UE	Parking Garage	79	4380	55
LSI	XPG 3	XPG3 5 LED 50 350 CW UE	Parking Garage	59	3775	64
Lunera	2200 2x2 Grid Lay-In	2200	Parking Garage	57	3569	63

3. Induction Product Qualifications

Induction technologies have been evaluated in ETAP on a case-by-case basis, with only a handful of fixtures pre-qualified (see Table 12). Like all other eligible ETAP technologies, induction equipment was capable of a minimum of 50% power reduction with bi-level controls. Replacing installed induction fixtures was not an eligible measure. ETAP requirements for induction fixtures were based on the draft performance standards of the Department of Energy's Commercial Building Energy Alliance (CBEA) for induction fixtures

Induction Lamp Requirements:

- Produce at least 3,500 lumens (initial) when measured on a reference generator
- A CCT between 3,000 – 5,000 K
- A CRI of ≥80
- Lamp Lumen Depreciation (LLD) shall be 80% or greater at 40,000 hours
- Induction Generator Requirements:
- Generators shall have a minimum efficiency of 85%
- Generators shall have a power factor (PF) of ≥0.90
- Generators shall have a Total Harmonic Distortion of ≤20%
- Input voltage: capable of 120 to 480 volts, single phase or as required by site
- Generators shall be Class A noise rated
- Generators shall comply with FCC 47 cfr part 18 non-consumer RFI/EMI standards
- Generators shall be Reduction of Hazardous Substances (RoHS) compliant. (see http://www.rohs.eu/english/index.html)
- Generators shall have a minimum starting temperature of -18˚ C (0˚ F)
- Fixture Requirements:
- The luminaire shall produce a minimum of 20% of total output in the 60˚ to 70˚ vertical zones
- Luminaires shall have a TER greater than 30
- The luminaire shall have an initial luminaire efficacy greater than 60 LPW
- Controls must be capable of reducing power by a minimum of 50%

Table 12. Induction Fixtures Eligible for ETAP Rebates

Manufacturer	Series	Model Number	Application	System Watts	Lumens	Lumens per Watt
Everlast	US Garage Srfc Mtd	EGFUS-EC-70W-BL	Garage Fixture	83	5674	69
Everlast	US Garage Srfc Mtd	EGFUS-EC-80W-BL	Garage Fixture	90	6840	76
Everlast	US Garage Srfc Mtd	EGFUS-EC-100W-BL	Garage Fixture	118	8047	68
Everlast	Smart Light Series	ECHUS-EC-70w-BL	Pole Mount Cobra Head	78	4928	63
Everlast	Smart Light Series	ECHUS-EC-100w-BL	Pole Mount Cobra Head	111	7743	70
Everlast	Smart Light Series	ECHUS-EC-120w-BL	Pole Mount Cobra Head	134	8673	65
DECO	D511ib	D511ib-95-50-UNI-DL	Garage Fixture	107	7096	66

BI-LEVEL LIGHTING – IMPLEMENTATION AND PROCUREMENT CHALLENGES

Market Acceptance of Bi-Level Technology

A key challenge to implementing bi-level projects was skepticism about the suitability of bi-level lighting in parking areas. Since bi-level lighting in parking areas is a relatively new concept, there were very few existing bi-level facilities to use as a reference for Agencies who had hoped to see a completed project prior to installing their own.

As the program progressed and more projects were installed, the Technical Team was able to direct Agencies to completed facilities to help inform their own project decisions.

Agency viewpoints on the safety implications of bi-level lighting fell into two broad camps. Some Agencies were concerned with the prospect of reducing a fixture's light output, but others saw the "signaling" feature of occupancy sensors as an advantage. These viewpoints are summarized below:

- **Decreases Safety -** This school of thought holds that the decrease in light levels when fixtures are in low-power mode may provide cover for increased criminal activity.

- **Increases Safety –** This school of thought suggests that since movements within a garage would cause a change in light levels, users would actually benefit from an increase in information about current or recent activity around them.

In most cases, low-power lighting quality was much better than expected, helping to further justify the case that bi-level lighting may actually improve safety. Even in low output operation, new bi-level fixtures often improve lighting uniformity, which is a key measure of lighting quality. The improvement in uniformity was particularly evident when new LED fixtures were installed.

Evolution of LED Technology and Lag in Qualification Process

LED technology continues to advance at a fast pace, and manufacturers are constantly creating new products to take advantage of the latest technology. While this is excellent for the technology as a whole, it does pose a challenge when it comes to the qualification of the new products.

As discussed earlier in this report, ETAP relies mainly on the Design Lights Consortium as a source for a qualified product list. Having one industry entity be responsible for maintaining a qualified products list allows programs such as ETAP to be more cost effective as they do not need to devote valuable resources to this task. However, the downside of having a single gateway for qualification is that it presents an opportunity for bottleneck.

The actual process of qualifying LED products is fairly complex and requires three separate tests to determine if the product meets the minimum performance standards. Often, manufactures have a lag in their product testing data due to the necessity for each chip and driver configuration to be tested separately.

Lack of Certification Body for Induction Fixtures

Unlike LED fixtures, there is not a central neutral entity responsible for the qualification of induction fixtures. ETAP adopted the draft performance standards of the Department of Energy's Commercial Building Energy Alliance (CBEA) for induction fixtures.

The lack of a reputable quality control process made it difficult for ETAP to qualify induction products in house as test reports were difficult to obtain and often not conducted by third party testing laboratories. ETAP was only able to qualify induction fixtures from two manufacturers.

Agencies often find it helpful to require that a product be listed as pre-qualified for utilityincentives (or other standard) in their bid documents. This gives the Agency an added level of certainty that they are selected a quality product. This is not currently possible for induction fixtures, and ETAP was only able to provide a limited list of options for induction fixtures.

Variability in Bi-level Project Costs

The variation in costs across projects with similar profiles presented a challenge. Variation in product costs for LEDs was the most prevalent throughout the program. It was not uncommon to see prices upwards of 50% higher or lower than the estimates used in ETAP's Audit Reports. Figure 1 below shows a scatter plot of price estimates used by ETAP for LED fixtures at various wattages overlaid with the actual per fixture costs taken from invoices after project completion. It should be noted the prices reflect material costs only.

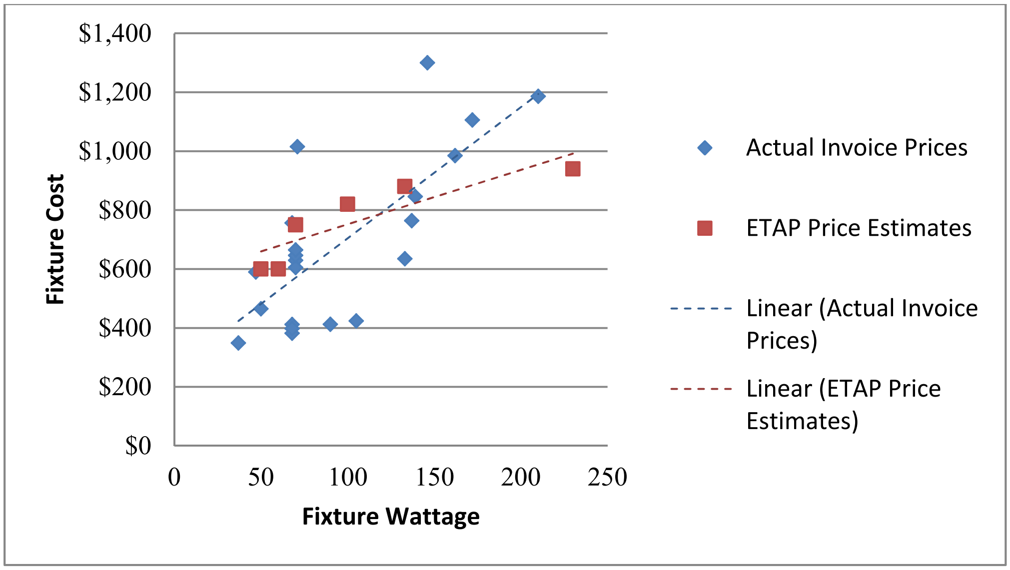

Figure 1. Estimated and Actual Material Costs of Bi-Level LED Fixtures in ETAP Projects.

While actual LED prices varied considerably, ETAP's estimates remained conservative on average, overestimating costs roughly 65% of the time. However, when looking at the lines of best fit (dotted lines) you can see that the slope of the line for the Actual Invoice Prices is larger than line slope the ETAP Price Estimates. This results in ETAP's prices for higher wattage LEDs to be underestimates in some cases.

The reasons for the price differences are poorly understood, but they are most likely due to differences in supply chain and markup practices. In some cases, participants purchased LEDs almost "direct" from the LED manufacturer (passing through distribution, but potentially with very little markup). In other cases participants purchased products through a contractor, who sourced the equipment from a distributor. The second case allowed for markup at two different points (distribution and the contractor).

Additional causes of LED price variability include:

- **Technology still relatively young** – many manufacturers are only on the first or second generation of the design. As the industry becomes more familiar and mature in the design and roll-out process for new LED fixtures you can expect manufactures to have less variability in their price models.
- **Variability in quality** –Construction, design and the extent to which an LED is "custom" ordered may impact price. Some manufacturers may offer many distribution types, color temperatures, and drive currents while others are limited to one or two options.
- **Variability in raw material requirements** – Components such as the LED chip that is used, internal circuitry, housing/heat-sink material, and controls specifications may impact fixture prices.

As a result of the variability in LED prices as well as installation costs, it was difficult to provide participants with an accurate financial picture of a proposed project without understanding the participant's procurement process and soliciting bids for a specific fixture type.

Specification and Installation Complexity

Bi-level fixtures must be specified and wired correctly to ensure reliable bi-level operation For example, in fluorescent fixtures, bi-level operation can be achieved through the use of a bi-level ballast, or multiple ballasts each controlling a some of the lamps in a fixture. In addition, factors such as operating temperature, ballast and lamp compatibility and the desired light output should all be considered. This added level of complexity in a bi-level fixture's specification creates additional opportunities for mistakes to be made throughout the procurement process.

Challenges with RFQ Procurements

A Request for Quote (RFQ) strategy was generally used by Agencies that were limited by resources and time. An RFQ procurement strategy has the least inclusive scope to be completed by the contractor and requires that the Agency self-specify the products to be ordered and installed.

Using an RFQ strategy could save time and costs, as Agencies are evaluating contractor proposals that include a consistent fixture and are not paying the contractor for the design and specification of that fixture. However, we found that in some cases, the RFQ process can add more challenges to a project than benefits. This is due to a number of factors, the first being that if contractors are only soliciting pricing for one manufacturer's product, the Agency is not realizing the savings from different fixture manufacturers competing on a low cost basis. The second factor is that Agency staff are often not well versed on sophisticated lighting technology and sometimes do not have the knowledge base to develop a complete and quality specification.

Some projects improved the procurement process by separating procurement of controls, fixtures, and labor into separate contracts and purchases. The challenge of that approach is that if the controls vendor is not involved in the installation of their equipment, so the contractor may have issues understanding and installing the controls unless they are well trained and the controls scope is well defined.

BI-LEVEL LIGHTING LESSONS LEARNED-TECHNOLOGY

Throughout the life of the ETAP program, the Bi-Level Technical Team became increasingly familiar with various considerations associated with the different technologies utilized in bi-level projects. Below are brief discussions of the lessons learned related to each technology type.

Induction

It was evident throughout the program that there was relatively low market interest in implementing induction lighting technology. In fact, there were no induction projects rebated under the program.

There are several factors leading to the lack of interest in this technology, some of which are listed below.

- Induction fixtures were found to be only marginally less costly than LEDs. Cost differences around 10% between comparable LED and induction fixtures were seen across contractor proposals.

- Negative buzz in the industry about existing induction fixtures likely lessened Agency interests in the technology. Some lighting industry experts view induction as mature technology that will probably soon be obsolete.
- Lack of industry standards surrounding manufacturer claims on lifetime and performance reduces market confidence in the technology (see earlier section on implementation challenges).
- There is a relatively small range of induction products (compared to LEDs). Inherently, this gives LED lighting an advantage as it can be used in an extremely wide range of applications.

Induction lighting may be reaching (or may have already reached) its technological limits and the industry at large is more focused on developing applications for LED technology. Although induction retrofits are still a proven energy saving strategy, as the LED industry continues to advance, the gap in technologies may widen to the point where this is no longer the case.

<u>T5</u>

Like induction fixtures, T5's were a lesser-utilized technology throughout the program, although there were a few ETAP-supported T5 projects installed. Some possible reasons for the low uptake of T5 technology are listed below.

- The market for T8 fixtures is larger, with more outdoor-appropriate fixtures and ordering options.
- For facilities managers, it is easiest to stock the same lamps for many facilities (most facilities are equipped with T8s.
- Energy savings from T5 fixtures are generally not as high as with T8s or LEDs.
- LEDs generally outperform linear fluorescent fixtures (T5 and T8) in pole mounted applications due to superior light distribution, and increased maintenance savings.

ETAP's experience with T5 technology remained fairly limited, as the majority of our bi-level projects were able to utilize a more financially attractive technology option.

<u>T8</u>

Extra efficient fluorescent T8 fixtures were one of the most common technologies installed in ETAP parking garage projects. This gave ETAP Technical staff considerable exposure to projects that used T8 products for exterior bi-level applications. Some key lessons learned regarding the technology are listed below:

- Some lamps and ballasts are not well-suited to lower temperatures common at parking facilities. Site temperatures and recommended operating temperature of the equipment should be reviewed carefully. In several instances, ETAP Project Leads reviewed proposals which did not consider the recommended operating temperature of the equipment, which could lead to premature failures if left uncorrected.
- There are limited bi-level ballast options on the market. For example, there are no single lamp bi-level ballasts on the market - which would make an excellent fit in a stairwell fixture. There are also fewer bi-level ballast choices at low or high ballast factors.

LED

Bi-Level LED fixtures were also among the most common type of fixtures installed in both parking garage project and parking lot ETAP projects.

- Customers were generally happy with reducing light levels to less than 50% power in low-mode. In assessing the installation of projects in which LED fixtures were dimmed to less than 50% (sometimes as low as 10%) ETAP recognized that light levels were often better than expected and not perceived as leaving the area too dark or unsafe. This is primarily because LED fixtures maintain light distribution and uniformity levels as the fixture is dimmed. Future programs may consider methods to further encourage the adoption of aggressive dimming practices.
- A concern that was often brought up with LED projects was potential for glare from the fixtures. Glare is sometimes a concern with LEDs because fixtures do not have lenses covering the individual light chips - each of which is quite bright. To help overcome this issue, many products are equipped with small hoods that cover the chips from view at certain distances. Being aware of this early on in the project can help prevent delay of the project.

BI-LEVEL LIGHTING LESSONS LEARNED-IMPLEMENTATION AND PROCUREMENT

In addition to knowledge gained on bi-level technology and products, there were also many best practices and lessons observed throughout the implementation of ETAP technical services, some of which are described below.

Benefits of Expanded Scope of Technical Services

The ETAP technical services described in the ETAP program Implementation plan generally assumed that Agency's and their chosen contractors would be primarily responsible for providing product selection and design specification.

In many cases, however, we found that participating Agencies required assistance in these areas in order to move their projects forward. Although it was outside the original scope of our services, ETAP technical staff provided advanced assistance including photometric modeling (which detailed the light distribution for a proposed fixture) and detailed product specifications. Future programs serving public agencies may want to consider including advanced lighting specification and bid document assistance as part of their standard offering.

Awareness of Impacts from Special Requirements

ETAP encountered a project that required that lighting fixtures maintain the architectural styling of Frank Lloyd Wright as it was used throughout the facility grounds. In order to satisfy this requirement, decorative fixtures were selected which necessitated custom painting. These factors resulted in higher than expected costs and implementation timelines when contractor proposals were submitted.

In conducting our financial analysis for the ETAP Audit Report, the technical team used standard price assumptions for the cost of the fixtures. It was not clear at that early stage of the project how the architectural requirements would impact the project cost, however marking up the total project cost by a nominal percentage would have helped lessen the discrepancy between our analysis and the eventual costs quoted to the Agency by contractors. The low quote for the fixtures came in at roughly 40% higher than ETAP estimated costs. Developing a standard approach to this issue would be difficult as it would vary greatly among projects, however, being aware of this type of consideration during early phases of the project can help mitigate the effect of any discrepancies seen later on.

Difficulties with Agencies Self-Specifying Fixtures

As discussed earlier in the Implementation Challenges section of this report, some agencies utilized an RFQ process in which they develop their own product specification. In the future, an Agency's knowledge base should be given close consideration. Members of the technical staff may find it useful to walk through a few specification examples with an Agency, discussing all of the inputs required and information needed in order to develop a quality specification. This may give the Agency added insight as to whether or not it would be best to pursue a procurement strategy in which they complete the design in-house.

Advantages of Aiding in Vendor Coordination

The ETAP Technical Team was in the unique position of having unbiased relationships with vendors involved in all phases of project implementation. These relationships include manufacturer sales representatives, fixture distributors, and contractors. In many instances when Agencies experienced issues with a product specifications or timing the ETAP Project Lead would be in a position to determine a what vendor level action needed to be taken. Having these relationships is an extremely valuable asset to a program as they can often help to avoid confusion between involved parties that can result in the delay or sometimes even cancellation of a project.

Importance of Site Information Quality Control

The project financials that an ETAP Project Lead develops for a site rely on several pieces of information that are collected during the screening and audit phases. Information such as operating hours and kWh rate paid are generally provided by Agency staff members who may not be closely familiar with accurate sources for the information. This can sometimes lead to the incorporation of erroneous data which can inaccurately skew the analysis of the project. Project Leads should be persistent in pinning down information where there may be a question concerning the accuracy of the data. In at least one project, the operating hours for a facility were assumed to be 24/7 based on initial screening level information. Later on during implementation, it was discovered that several fixtures in the facility utilized controls to turn off during the day. Luckily this piece of information was not a large enough factor to jeopardize the project, however, identifying Agency staff members who were closer to the management of the specific facilities would have allowed ETAP to uncover this piece of information sooner, enabling the Agency to make a more informed decision as to whether or not to move forward with the project.

BI-LEVEL LIGHTING PERFORMANCE EVALUATION

Overview of Results

ETAP collected bi-level monitoring data from 192 distinct fixtures in 38 different facilities. As shown in Table 13, sampled facilities included 30 parking garages, 5 stairwells, and 3 parking lots. On average, bi-level fixtures in garages were in low-power mode an average of 62% of the time (see Figure 2 and Table 14). During peak hours (Mon-Fri, 2-5pm), bi-level fixtures in garages were in low-power mode an average of 38% of the time. For 70% of monitored garages, the average time that sampled fixtures were in low-power mode was above 50%. The maximum that any garage's sampled fixtures spent in low-power mode was 87%, while the minimum was 25%.

Stairwell fixtures were in low-power mode an average of 81% of the time (see Table 15). During peak hours, stairwells were in low-power mode an average of 49% of the time. Parking lot fixtures spent, on average, 93% of the time in low-power mode. Parking lots do not have peak savings because they only operate at night. Monitoring results for stairwells showed less variability than garages, although there were also significantly fewer stairwells monitored than garages.

Table 13. Number of Facilities and Bi-Level Fixtures Monitored by ETAP

Facility Type	Facilities Monitored	Total Fixtures
Parking Garages	30	157
Stairwells	5	21
Parking Lots	3	14
Total	**38**	**192**

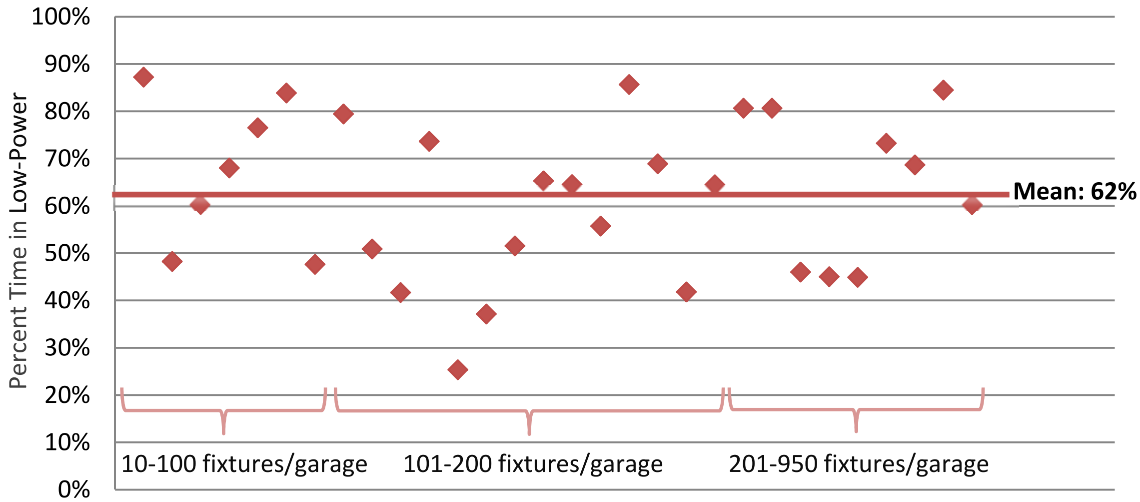

Figure 2. Bi-Level Fixture Performance in Parking Garages

Table 14. Bi-Level Fixture Performance in Parking Garages by Time of Day

	All Hours	**Peak** (Mon - Fri, 2-5 PM)	**Day Time** (7 AM - 7 PM)	**Night Time** (7 PM - 7 AM)
Mean	62%	38%	47%	74%
Max	87%	75%	84%	98%
Min	25%	2%	8%	30%
S.E. (% of mean)	4%	3%	3%	3%

Table 15. Bi-Level Fixture Performance in Stairwells by Time of Day

	All Hours	Peak (Mon - Fri, 2-5 PM)	Day Time (7 AM - 7 PM)	Night Time (7 PM - 7 AM)
Mean	81%	49%	66%	94%
Max	88%	63%	77%	98%
Min	71%	16%	46%	85%
S.E. (% of mean)	4%	9%	6%	2%

Discussion

Peak vs. Off-peak:

Unsurprisingly, across all building sites, fixtures spent more time in low-power mode during off-peak hours than during peak hours. However, the results suggest that on average, fixtures still spend an appreciable amount of the peak periods in low-power mode: 38% and 49% for garages and stairwells, respectively. While some projects will realize very little peak savings, bi-level controls can, in the aggregate, present an opportunity for peak demand savings.

Daytime vs. Nighttime:

While the majority of parking garage fixtures are on 24/7, some fixtures are photocell controlled and do not operate during daylight hours. There was a substantial difference in percent of time in low-power mode between day (7 AM – 7 PM) and night (7 PM – 7 AM).4 On average, garage fixtures were in low-power mode for 47% of the day and 74% of the night. This variation has implications for night-only fixtures, because they operate in low power mode roughly 12% more than a standard 24/7 fixture (74% vs 62%). When installing photocell-controlled night-only fixtures, it is recommended that decision makers assume a higher percent time in low-power mode than they would for a 24/7 fixture.

Stairwells saw moderate occupancy rates during the day and very low occupancy rates at night. The maximum that any stairwell spent in low-power mode site was 88%, while the minimum was 71%. Only three bi-level parking lot projects were monitoring as part of ETAP. Although the sample size is small, it is clear that bi-level parking lot fixtures spend a significant amount of time in low-power mode. Parking lots are generally only lit at night, when occupancy is very low. The maximum that any parking lot spent in low-power mode site was 95%, while the minimum was 88%.

Garage Size

ETAP assessed the impact of garage size on the fraction of time bi-level fixtures spent in low-power mode. ETAP categorized each garage by total fixture counts, and placed them into three categories: small (fewer than 100 fixtures), medium (100-200), or large (more than 200). Table 16 shows the fraction of time spent in low-power mode for small, medium, and large garages. Interestingly, little variability was evident across facility sizes. This suggests the results reported in this study may be broadly representative of bi-level garage lighting in general.

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[4] 7 PM – 7 AM reflects the average operating hours for a fixture with a photocell throughout the year.

Table 16. Comparison of Bi-Level Fixture Performance in Small, Medium, and Large Garages.

Garage Size	Sample Size	MEAN FRACTION OF TIME IN LOW-POWER MODE			
		All Hours	Peak (M-F 2-5 PM)	Day Time (7 AM - 7 PM)	Night Time (7 PM - 7 AM)
Small (0-100 fixtures)	7	67%	36%	50%	81%
Medium (100-200)	14	58%	39%	45%	68%
Large (>200)	9	65%	38%	47%	79%

Methods

ETAP used HOBO data loggers to determine whether fixtures were operating in high or low power mode. Samples were generally taken once per minute, for a period of at least two weeks. The loggers were installed close to the fixtures so that light from the fixtures could be clearly distinguished from day light. For LED fixtures, the loggers were generally attached to the fixture housing. For fluorescent and induction fixtures, loggers were placed inside the lens.

To determine the amount of time spent in high and low power modes, ETAP categorized individual light level readings as indicative of either "high" or "low" power-mode using histograms to count the number of logs taken at various lumen levels. ETAP determined the lumen values corresponding to high and low power bins separately for each logger

Exceeding Maximum Measureable Light Level

The data loggers first used for monitoring could measure light levels between zero and 3,000 foot-candles (fc). Unfortunately, light levels measured by some loggers on LED fixtures exceeded 3,000 fc. When this happens, the logger reports the measured value as 3,000 fc. Occasionally, these results were still useable because the low mode light levels were below 3,000 fc. Thus, all of the logs at 3000 fc attributed to periods of high mode operation. However, during some monitoring attempts, all of the logs were at or near 3000 fc. In these cases, the data did not produce any useful results.

Because mounting the loggers to the fixture housing is the only practical option for LED fixtures, ETAP researched data loggers that could measure light levels above 3,000 fc. HOBO Pendant loggers were ordered and used from that point forward for garage LED projects. The pendant loggers can measure light levels up to 30,000 fc.

Pole-Mounted Fixtures

While the new Pendant loggers could measure higher light levels, they seemed to have trouble measuring low light levels with accuracy. The loggers were used for a bi-level parking lot project, where pole-mounted LEDs were installed at height of 20-25 feet. ETAP could not mount the loggers on the fixture heads, so they were attached to the poles, about five feet below the fixtures. Although the fixtures were turning on at night, the data showed light levels near zero every night. While light levels exceeded zero occasionally, it was impossible to determine high and low modes in the data.

While the older HOBO loggers seem to be accurate at lower light levels, they are not rated for outdoor use. Ideally, data loggers that are rated for outdoor use, accurate at low light levels, and have high resolution at low light levels would be used for parking lot monitoring projects.

Recommendations for Occupancy Assumptions in Utility Incentive Programs

According to the Statewide Customized Offering Manual (Section 2.9.5.5)[5], occupancy sensors can be used to claim a 15% reduction in operating time for fixtures in parking garages. Presumably, this means that utilities can claim that bi-level fixtures spend 15% of the time in low power mode. However, our monitoring results show that, on average, bi-level parking garage fixtures spend approximately 62% of the time in low-power mode. Even the busiest garage spent, on average, over 25% of the time in low power mode. Moreover, the abnormally long timer delay observed in that particular garage suggests that it may provide overly conservative estimate of the savings potential for bi-level lighting.

Roughly 70% of monitored garage bi-level fixtures were in low-power mode at least 50% of the time. ETAP's monitoring results suggest that fixtures spend a larger percentage of nighttime hours in low power mode (about 12% more), suggesting that even higher savings can reasonably assumed for nighttime savings. Based on these results, ETAP recommends that utilities consider reducing assumed occupancy levels for bi-level garage lighting in customized incentive programs.

Utilities may also wish to revisit occupancy assumptions for bi-level stairwell projects (currently 25% of operating hours). While ETAP's monitoring data from stairwell projects is limited, initial results suggest that stairwell fixtures spend even more time in low-power mode than garage fixtures (on average, about 81%).

ETAP's research also suggests that some peak savings can be claimed for bi-level controls in stairwells and garages. In the past, it was generally not acceptable to claim peak savings from occupancy controls, since there is no guarantee that the fixture will actually be off (or in low-power mode) during peak periods. ETAP's monitoring results suggests that bi-level projects, in aggregate, can reasonably be assumed to deliver peak demand savings. A substantial number of monitored fixtures were in low power mode during the peak period: 38% for garage fixtures and 49% for stairwells fixtures

BI-LEVEL LIGHTING INTEGRATED SENSOR EVALUATION

Sensor Technology

Occupancy sensors are used to detect the presence of people or in some cases vehicles. In bi-level projects, sensors are either attached directly to fixtures (integrated occupancy sensors), or send signals wirelessly to a fixture or group of fixtures. Depending on how the fixture is wired, the signal from the sensor will turn the fixture on, off, or change its power level. This section focuses on occupancy sensors used to switch bi-level fixtures from low power to high power in parking garages and stairwells. There are three types of sensors that are can be used with bi-level parking lot, parking garage, pathway, and stairwell projects. These sensor types include Passive Infrared, High Frequency (Ultrasonic or Microwave), and Dual Technology sensors. A description of each technology is provided below.

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[5] Section 2 of the Statewide Customized Offering Manual can be found here; http://www.aesc-inc.com/download/spc/2011SPCDocs/UnifiedManual/Customized%202.0%20Energy%20Savings.pdf

PIR Sensors

Passive Infrared (PIR) sensors are the most common sensors used in parking garages, parking lots, pathways and stairwells. These sensors detect changes in infrared light. Humans and cars produce much different infrared signals than stationary objects and can easily be detected when passing through the sensors line of sight. PIR sensors come with different lenses that can be used to direct the sensors line of sight. In most applications only one sensor, which faces the same direction as the lamp(s), is mounted on the fixture. For example, in a parking garage the fixture and sensor face downwards. The lens would then create a circular radius in which motion can be detected. On a wall mounted stairwell fixture the sensor faces across the stairs and detects objects in front of the fixture. Because the lens is a point source the radius in which the sensor can read varies as the distance from the fixture increases. The coverage area of the same fixture with two different lenses can be seen in Figure 3 and Figure 4 below.

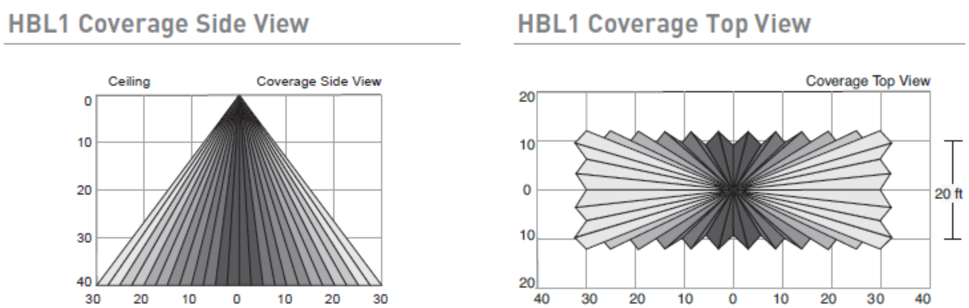

Figure 3. Sensor Coverage for WattStopper HB350 with HBL1 Lens (Source: WattStopper Pub No. 25703)

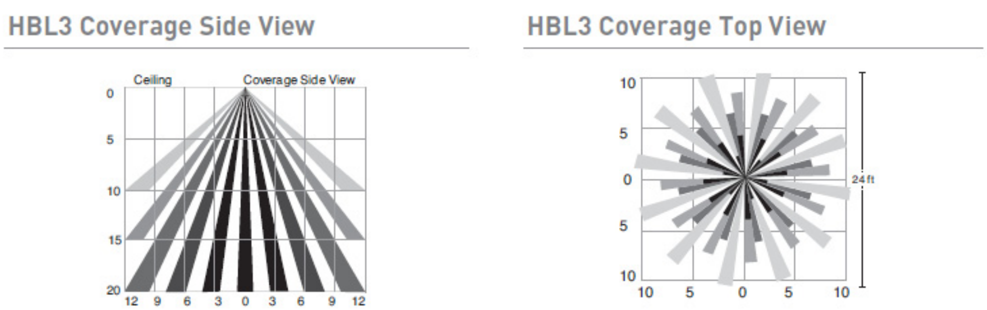

Figure 4. Sensor Coverage for WattStopper HB350 with HBL3 Lens (Source: WattStopper Pub No. 25703)

High Frequency Ultrasonic Sensors

High frequency sensors send out ultrasonic sound waves or microwaves and then detect the time it takes for the sound wave to return. Theses sensors rely on the presence of objects in the vicinity to reflect the sound waves. A change in the returned sound waves trigger the switch on the sensor, therefore the sensors are subject to false detection by air current or vibrations, making them an undesirable option for open air environments, or for use close to HVAC ducts. Ultrasonic sensors are often used as occupancy sensors for offices or bathrooms because they do not require direct line of sight in order to sense movement. The coverage area of an ultrasonic fixture can be seen in Figure 5 below.

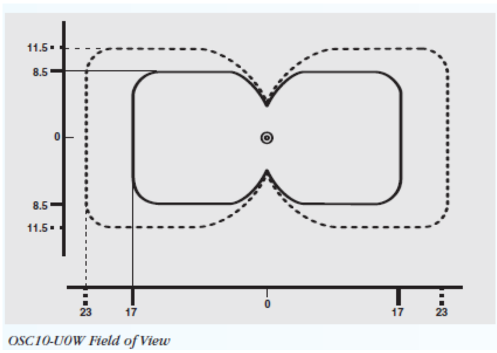

Figure 5. Coverage Area of Leviton OSC10-U0W Ultrasonic Ceiling-Mount Occupancy Sensor (Source: Leviton Occupancy Sensors)

Dual Technology Sensors

Dual technology sensors use both PIR and ultrasonic sensors to detect motion. These sensors have the advantages of both technologies. These sensors are not often used in bi-level projects because the advanced sensing capability is not as crucial when switching from low to high light. These technologies are usually reserved for indoor spaces where lights are switching off and on. The coverage area of a dual technology sensor can be seen in Figure 6 below.

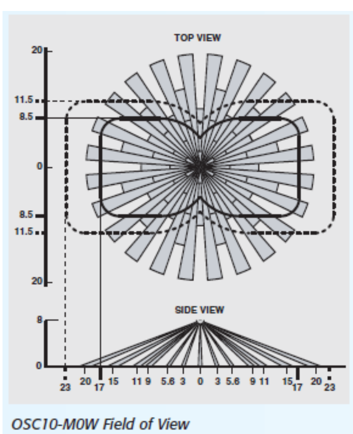

Figure 6. Coverage Area of Leviton OSC 10-M0W Multi-tech Ceiling Mounted Occupancy Sensor (Source Leviton Occupancy Sensors)

Sensor Performance Tests

ETAP Test Procedure

In order to show the effectiveness of occupancy sensors, field tests were performed to compare actual sensor performance to the performance shown on the sensor specifications sheet published by the manufacturer. Multiple field tests were performed in order to capture the average activation distances of different sensors in different field locations. The following instructions were given to testers to capture the average activation distance of each sensor:

1. The tester records the fixture mount height, sensor model number, and orientation.
2. The tester waits for light fixture to switch to low power mode.
3. The tester approaches the light fixture while walking directly toward the sensor.
4. The tester walks at a normal rate, until the light switches to high power mode.
5. The tester then stops walking and measures the distance from his or hers chest, to the sensor location using a digital laser distance measurer.
6. The tester then should repeat steps 1-4 while walking by the sensor at a multitude of different angles and positions, as seen in Figure 7 below.

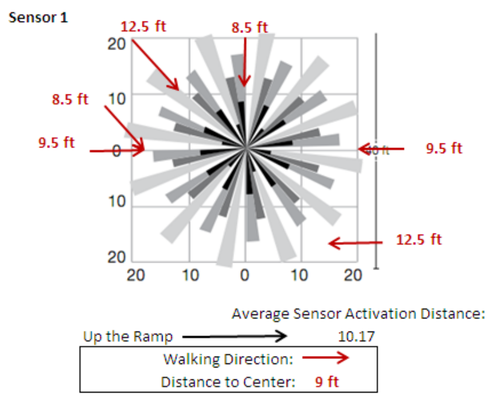

Figure 7. Sample Sensor Readings and Average Sensor Activation Distance

Knowing the fixture mount height, the height of the tester's chest, and the distance from the chest to the fixture, the horizontal distance from the person to fixture can be calculated. Figure 8 illustrates how the horizontal distance from the fixture was recorded. The average horizontal distance to the fixture was tabulated and compared to the horizontal distance specified by the sensor manufacturer's specifications sheet.

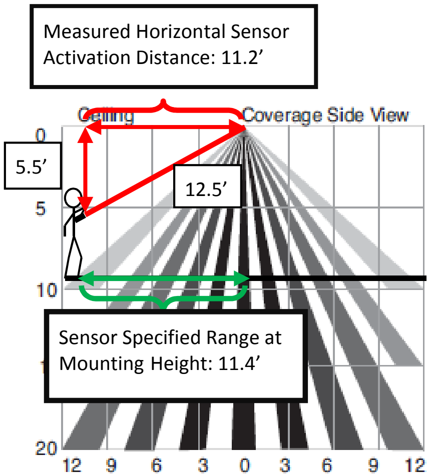

Figure 8. Calculation of Sensor Activation Distance

Test Results

Results of the field tests for garage mounted fixtures are compared to the sensors specification sheet in Table 17 below.

Analysis of Results

Field tests show that sensor ranges can vary greatly depending on the installation site’s ceiling height, bays, and fixture spacing. Because of the wide variation of sensor ranges and mounting heights, the above data is not statistically significant. The results do show that further investigation needs to be done to compare the field capabilities of sensors versus manufacturer claims for sensor detection. These preliminary results show that sensors underperform compared to manufacturer specifications 79% of the time and perform up to specifications or over perform only 21% of the time. On average PIR sensor underperform by approximately 66% of their stated activation range. Although some sensors boast a range of approximately 40 feet, no installation had a consistent activation range of more than 20.8 feet. The most popular sensor type tested was the Beta LED sensor for their 304 Series garage fixture. This sensor performed within 15% of the manufacturers projected claims at all 4 installations. It also had the highest average activation range of any sensor at approximately 16.6 feet.

Only one high frequency sensor was tested in the field. These sensors are not popular as popular in garages because of the possibility of false triggering. Although this one sensor did perform as the manufacturer projected, it had did have some false triggering due to vibrations in the garage.

Parking Garage Lighting Sensor Design Considerations

Timer delays in parking garages were set to an average of 14.75 minutes. Because a majority of garages had underperforming sensor designs, this is a reasonable time delay. The extra time at high power allows for more users to use the fixture that has been switched to high power. Shorter time delays of 5 minutes may be recommended for garages with high performing sensor designs in order to maximize energy savings. The determination of set delay should always be chosen by the owner and operator in order to balance both safety and energy efficiency.

Bi-Level Stairwell Lighting Sensor Design Considerations

Testing of stairwell projects was limited, but preliminary findings suggest that sensor capabilities are heavily affected by stairwell layout and logger positioning. It was found that all of wall mounted PIR sensors would activate before reaching the stairs to the landing below the fixture, but ceiling mounted sensors would often not meet this criterion when descending the stairs. Figure 9 and Figure 10 below illustrate why ceiling mounted sensors could underperform when people are descending stairwells. Ultrasonic sensors were found to have optimal performance in narrow stairwells, but sometimes lacked the necessary detection range for longer and taller stairwells.

Timer delays in stairwells were set to an average of 13 minutes. With occupants often spending less than a minute or two in a stairwell, this average set delay will typically be significantly longer than needed. In stairwells, a shorter time delay of one or five minutes may even greater energy savings. The determination of timer delays should always be chosen by the owner and operator in order to balance both safety and energy efficiency.

Table 17. Occupancy Sensor Activation Distances in Selected Bi-Level Light Fixtures: Nominal and Measured Results

Installation Site	Model	Occupancy Sensor Technology	Manufacturer	Designed Mounting Height	Actual Mounting Height	Nominal Range at Designed Mounting Height	Expected Range at Actual Mounting Height	Measured Sensor Activation Distance (Average)	% of Expected Activation Distance Achieved
City of Cathedral Downtown Parking Garage	FM-105	Ultrasonic	Wattstopper	8'	11'	~12'	~12'	12.4'	103%
Ariosa HOA 989 Franklin Garage	On Q Fixture	PIR	On Q Fixture	N/A	N/A	N/A	N/A	14.1'	47%
Calif. Inst. of Technology Holliston Parking Garage	HB350 (HBL3 Lens)	PIR*	Watt Stopper	10'-20'	9.5'	12'	11.5'	10.1'	88%
Calif. Inst. of Technology Holliston Parking Garage	HB350 (HBL3 Lens)	PIR*	Watt Stopper	10'-20'	9.5'	12'	11.5'	8.6'	74%
City of Anaheim Convention Center Garage	PIR-10-P	PIR**	Hubbel	10'	9.75'	20'	25'	7.3'	29%
City of Concord Salvio Garage	FS-305RC	PIR	WattStopper	8'	8.5'	24'	25.5'	12.4'	49%
City of Concord Todos Santos Garage	FS-305RC	PIR	WattStopper	8'	8.5'	24'	25.5'	12.6'	49%
City of Mountain View City Hall Garage	304 Series-Parking Structure	PIR	Beta LED	10'	11.5	16' - 25'	18.4'	20.8'	113%
City of Sacramento Memorial Garage	304 Series-Parking Structure	PIR	Beta LED	10'	9.5	16' -25'	15.2'	15.5'	102%
City of Salinas Salinas St. Garage	FS-305RC	PIR	WattStopper	8'	10'	24'	30'	19.6'	65%
City of Santa Rosa Garage 3	304 Series-Parking Structure	PIR	Beta LED	10'	10'	16' - 25'	16'	14.2'	89%
CSU Long Beach Parking Structure 2	304 Series-Parking Structure	PIR	Beta LED	10'	11'	16' -25'	17.5'	16'	91%
SMUD Parking Garage Lower Level	XPG Occupancy Sensor	PIR	LSI	8-12'	8'	40'	40'	4'	10%
SMUD Parking Garage Upper Level	XPG Occupancy Sensor	PIR	LSI	8-12'	12'	40'	40'	20.3'	50%

*PIR Sensitivity=85%
** PIR Sensitivity=Medium

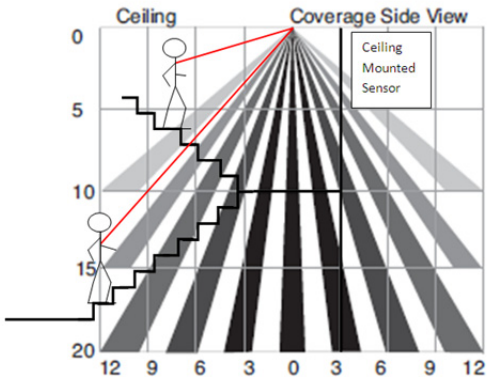

Figure 9. Ceiling Mounted PIR Sensor Range

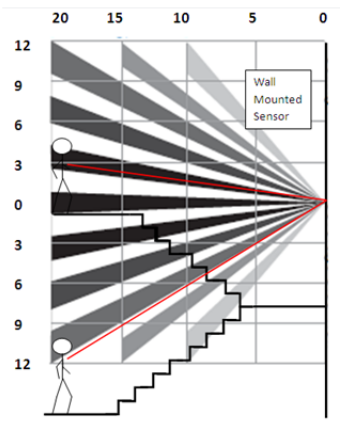

Figure 10. Wall Mounted PIR Sensor Range

Wireless Lighting Controls

WIRELESS LIGHTING CONTROLS PRODUCT QUALIFICATION

Through the course of the program, the ETAP Technical Team reviewed a variety of wireless lighting products to determine eligibility for ETAP rebates. The ETAP wireless lighting controls specification lists the requirements that technologies must meet to be approved for ETAP rebates. Product review typically included reviewing product literature, specification sheets, and case studies, and engaging with manufacturers to request any additional information required to determine product eligibility. The main requirements of the ETAP specification for wireless lighting controls were:

- Must include compatibility with occupancy sensors, photosensors, and occupant-controlled wireless switches to allow for on/off, stepped dimming, or continuous dimming functions based on detected occupancy, daylight harvesting, and/or individual control preference
- Must permit data transmission from an interface on the central processing system and from wireless field devices
- Must provide granular control of individual fixtures or groups of fixtures
- Must allow for robust, zonal scheduling of lighting loads
- Must be programmable and re-configurable such that controlled loads can be easily grouped to sensors and schedules based on each controlled space's changing lighting needs
- Must record and report fixture and system power and energy usage information
- Must have been previously demonstrated through a verifiable third-party evaluation or installed within a California local government municipal or government buildings in operation for at least one year
- Components must carry the appropriate safety and reliability designations
- All hardware must carry a minimum three year warranty
- Software must carry a warranty for a minimum of 90 days from the date of delivery
- Must be compliant with OpenADR
- Must not cause burdensome interference with other local RF bandwidths
- Must not add continuous load for controls power beyond 5% of maximum controlled load

Approved: Adura (Wireless Energy Management System)

Adura Technologies is a California-based manufacturer of networked lighting controls. Adura's primary focus is on the application of wireless control devices for the retrofit of existing commercial and industrial facilities and parking garages. By not requiring new control wiring, Adura's technology provides a cost effective method to retrofit existing facilities without requiring the costly installation of control wiring.

At the core of the Adura system is the light controller. This light controller communicates wirelessly through radio frequency with system components such as occupancy sensors, photosensors and individual fixtures. The light controller integrates the inputs of individual components and modifies the lighting environment to achieve desired light levels in the most energy-efficient manner.

Approved: Lutron Quantum (Quantum Total Light Management System)

Quantum manages both electric light and daylight, to not only save energy and simplify operations but also improve the comfort and productivity of building occupants. Quantum prevents wasted lighting energy by maximizing the efficient use of light in buildings. Quantum automatically dims or switches all electric lighting and controls daylight using automated window shades. Quantum manages, monitors, and reports on all the lighting usage in a building for optimal energy performance and productivity while minimizing maintenance and operating costs.

Approved: Exergy (Exergy Digital Lighting Controls)

Exergy's intelligent lighting management system allows users to:

- Streamline installation to reduce labor and material costs
- Give Users the power to select the appropriate light levels when and where needed
- Reduce lighting related energy costs by an average of 30% or more throughout the life of your facility
- Manage peak energy usage through load shedding and demand response

Approved: Daintree

Daintree Networks makes it easy to implement, automate and manage lighting controls, using a wide range of powerful wireless lighting control techniques. Lighting control strategies enabled by Daintree Networks include scheduling, occupancy control, task tuning and personal control, daylight harvesting, energy monitoring, and demand management.

Through Daintree Networks' web-based ControlScope Manager application, facility managers set automated and manual lighting control strategies that are applied wirelessly to individual fixtures and zones, or across the building or large enterprise.

Other Products Evaluated:

- Lumewave – Approved for Parking Lots and Garages
- Virticus – Approved for Parking Lots and Garages
- ROAM – Approved for Parking Lots and Garages
- Illumra – Evaluation inconclusive

WIRELESS LIGHTING CONTROLS IMPLEMENTATION CHALLENGES

Wireless Controller Integration / Ballast Compatibility

It was noted in more than one project that the reliability at startup of the fixture – level wireless lighting controller can be an issue. For some projects, several fixture-level controllers were non-functioning out of the box and needed to be replaced at additional cost and time. Ballast/controller compatibility may need to be better reviewed by controls vendors as well to ensure that specified equipment works well upon installation.

Coordination with Vendors

On new or potential projects, coordination with controls vendors can be a challenge initially. The motivations of the ETAP team, which is driven by data collection, accuracy, and conservatism, were not always perfectly aligned with those of the controls vendors, who are more sales driven. We found that the definition of roles between the ETAP team and the controls representatives is important. Also, the controls vendors are not always technically proficient in lighting design, which was a challenge in cases where projects were addressing new controls and lighting retrofits.

WIRELESS LIGHTING CONTROLS LESSONS LEARNED

High Project Costs

In general, costs for wireless lighting controls systems is still quite high on a per-fixture or per-square foot basis, resulting in longer paybacks than many agencies are comfortable with. Funding support through utility and other incentive programs is still important to spur adoption of this emerging technology.

Savings Estimates

Project energy use is best analyzed on per space type and fixture type basis, i.e. spreadsheet rows and unique assumptions for each room and fixture type. This type of finer scale analysis, as opposed to more generalized analysis, is harder to set-up initially but is more practical and accurate in the long term. At the program outset, ETAP analyzed spaces at a much broader level, assuming for example that all lighting in conference rooms behaved in one way, and all lighting in open offices behaved another way, etc.

Baseline monitoring of lighting operation was helpful, but does not directly show how often lights are on when space is unoccupied. An even more rigorous monitoring approach would be to use dual occupancy and lighting monitoring data to better characterize the savings opportunity. By and large, lighting controls savings opportunities simply involved turning lights off (or dimming) when no one is present.

Savings Strategies

Task – tuning, or “top trimming,” is an effective energy savings measure that was not expected to play as large a role as it did in some projects. This measure effectively reduces the connected wattage of the new lighting system, lowering light output to deliver only the maximum light levels necessary for a given space. Several agencies took advantage of this opportunity, enabled by wireless controls.

Implementation Players

The relationships between the controls vendor, the installation contractor, and the customer can be complex; roles and responsibilities should be clearly outlines as far as who is responsible for addressing issues and costs during and after installation.

Networked wireless systems can be built with a variety of topologies and communication architectures. The definition of wireless is relatively fluid, sometimes referring only to communication between sensors (occupancy, daylight) and switches, and sometimes referring to an all-wireless system where light controllers, switches, sensors, and gateways are all networked wirelessly.

Determining what communication strategies are acceptable at the outset of a wireless lighting project or program is important.

Data outputs, monitoring capabilities, trending options, etc. vary widely amongst wireless lighting controls vendors. Generally the level of data collected in a dedicated monitoring effort is not available from the controls system. For example, the shortest interval for hourly lighting kW averages from Adura's system is one hour.

Controls vendor assumptions on baseline conditions (lighting wattage and operating hours) must be scrutinized carefully, as vendors are in the business of selling controls and may overstate the energy savings potential of a project.

Some customers have very tight protocols around safety when working in their facilities, so thorough coordination on auditing and monitoring visits is essential to ensure success and to manage client relationships.

To ensure that a facility is a good opportunity for a wireless lighting controls investigation before sinking resources into a project, information on baseline controls and lighting is best collected from an end-user at the facility, such as on-site maintenance personnel or building managers, rather than Agency-level administrators or energy managers. Agency – level contacts are not always aware of past lighting and controls retrofits, and in one or more instance, screening information from agencies for individual buildings was contradicted by site walk-throughs.

Source change savings, such as lower wattage fixtures, lamps, or ballasts, can dominate overall project savings opportunities. Many wireless lighting projects will only be carried out in conjunction with lighting retrofits. On the other hand, the controls vendors are not always expert in lighting retrofit options.

WIRELESS LIGHTING CONTROLS PERFORMANCE EVALUATION

Table 18 summarizes the energy savings attributed to wireless lighting controls systems, as a fraction of annual baseline lighting energy usage.

Table 18. Wireless Lighting Controls Project Savings Summary

Location	% Savings from Controls	% Savings from Lighting Retrofit	Total Annual Energy Savings (kWh)	% Savings over Baseline System
Pleasanton Library	34.7%	10.6%	141,709 kWh	45.2%
Santa Clara Sheriffs Offices	15.1%	32.4%	229,130 kWh	47.5%
Contra Costa County 1275 Hall	21.7%	33.3%	89,264 kWh	55.0%
CSU Fullerton Pathway Lighting	24.8%	40.0%	83,398 kWh	64.8%
CSU Fullerton Gymnasium	18.2%	48.0%	93,170 kWh	66.2%
UC Irvine Student Center Parking Lot	29.1%	0%*	6,027 kWh	29.1%
CSU Long Beach Hallways	19.4%	37.3%	213,154 kWh	56.7%
San Diego Museums	6.0%	56.9%	106,461 kWh	62.9%
Citrus College	28.1%	11.7%	15,581 kWh	39.8%

*No light sources were changed as a part of the project

Variability in Energy Savings From Wireless Lighting Controls

Wireless lighting controls projects delivered energy savings of 29% to 66% of annual baseline electricity consumption, with 6% to 35% attributable to controls only (not including source change savings).

Variation is attributable to multiple factors, including the degree of sophistication of baseline lighting controls, the wattage of the controlled lights, whether or not efficient lighting retrofits were included in the project, and the wireless lighting controls measures implemented.

Some locations had long baseline operating hours and took advantage of simple scheduling benefits from centralized controls, such as the CSU Long Beach Hallways project, which took 24/7 operation of multiple hallways' lights to operating schedules based on building occupancy profiles. Other locations included dimming even during daytime hours, based on occupancy sensor feedback, such as the Pleasanton Library and the San Diego museums. Dimming or lighting shut-off due to daylight harvesting was an additional layer of energy savings achieved by other locations, such as UC Irvine Student Center Parking Facility, the Pleasanton Library, and the lobby of the San Diego Museum of Photographic Arts.

Task tuning, or "top trimming," was another effective measure enabled by dimming controls in some cases. The Pleasanton Library was able to trim 26% off the wattage of most of the facility's T-8 fixtures, using the new wireless controls system to reduce maximum fixture output while still maintaining adequate light levels. Still other locations included major lighting retrofits that reduced the total lighting load significantly, such as the CSU Fullerton Gymnasium and pathway lights and Contra Costa's administrative building, which increased overall project savings but reduced the energy savings impacts of the controls alone.

Some of the guidelines ETAP would recommend to sponsors of efficiency programs about structuring wireless lighting incentive programs include:

It seems that wireless lighting controls programs need to be highly customized, rather than prescriptive or "deemed" programs, as baseline and retrofit conditions are complex and involve many variables that are hard to quantify with standard assumptions. Each project is unique in terms of available data, so energy calculations need to be highly tailored to each project, rather than standardized for all projects.

More, and better, information on energy savings potential in commercial / office spaces from advanced controls measures is still necessary to build out more robust program assumptions. More published research on savings from dimming and shut off based on occupancy sensing and daylight harvesting would be very helpful. Additional case studies and data on these projects and projects involving task tuning opportunities for dimmable sources (advanced fluorescent ballasts, LEDs) will help planners design effective programs with realistic savings goals.

Also, wireless lighting controls solutions are still quite expensive, so high incentive levels may be necessary to drive adoption at this time. Paybacks were a challenge for many of the project opportunities reviewed. Allowing for incentives to extend to source change savings, such as fixture, lamp, or ballast retrofits, is helpful in improving the payback of projects and should be allowed. The best projects are often those that replace inefficient lighting equipment as well as installing advanced controls, as procurement and labor costs can be economized and savings greatly increased.

Wireless HVAC Controls

WIRELESS HVAC CONTROLS PRODUCT QUALIFICATION

ETAP provided financial incentives for wireless systems controlling heating, ventilation, and air conditioning equipment (Wireless HVAC). In order to qualify for ETAP incentives, all technologies had to provide wireless network communication between zone-level temperature sensors under one of the two following system classifications:

1. **Constant Volume Upgrades**: wireless, non-invasive retrofit solutions for Constant Air Volume (CAV) HVAC systems. These control systems are designed to allow existing CAV systems to function like Variable Air Volume (VAV) HVAC systems without incurring the cost of new ductwork and/or terminal boxes involved in a typical CAV-to-VAV retrofit.
2. **Wireless Pneumatic Thermostats**: wireless thermostat upgrades for pneumatic HVAC systems. These control systems will allow digital control of HVAC systems, including setpoint enforcement and savings strategies, without requiring modification to pneumatic control systems.

ETAP evaluated four and approved two Wireless HVAC products for ETAP rebates:

1. Vigilent’s Building Solution
2. Cypress Envirosystems’ Wireless Pneumatic Thermostat
3. Telkonet’s EcoSmart suite
4. Millennial Net’s Wireless Pneumatic Thermostat

<u>Approved: Vigilent’s Building Solution</u>

Vigilent was formerly known as Federspiel Controls, and the Building Solution is also known as DART. Vigilent’s Solution was familiar to ETAP from previous exposure and was evaluated at the start of the ETAP program. DART was qualified for ETAP Wireless HVAC rebates as a Constant Volume Upgrade, providing a comprehensive retrofit solution most applicable to buildings with Constant Air Volume HVAC systems.

Vigilent has been in business since 2004, and has been evaluated by PG&E's Emerging Techologies and the California Energy Commission's Public Interest Energy Research (PIER) programs. More information on the Vigilent Building Solution can be found at https://www.vigilent.com/buildings.php

Approved: Cypress Envirosystems' Wireless Pneumatic Thermostat

Cypress Envirosystems manufactures Wireless Pneumatic Thermostats (WPT) that replace existing pneumatic thermostats and send data and receive instructions over a wireless network. The WPT was new to the ETAP team and was evaluated at the beginning of the program. The WPT system was qualified for ETAP Wireless HVAC rebates as a Wireless Pneumatic Thermostat system, providing one-for-one replacement of existing pneumatic thermostats and offering integration into existing building management systems (BMSs).

Cypress Envirosystems is a subsidiary of a larger technology company, Cypress Semiconductor. Cypress WPTs had been installed and operational in the offices of the County of Santa Clara since 2008. More information on the WPT can be found at http://www.cypressenvirosystems.com/products/wireless-pneumatic-thermostat/

Telkonet's EcoSmart Suite

Telkonet manufactures the EcoSmart suite of energy management products. Telkonet products were ultimately not approved for ETAP rebates. The EcoSmart suite did not meet ETAP's requirement as either a specific fan-control algorithm or a pneumatic thermostat upgrade. ETAP began evaluating Telkonet products in March of 2011, and continued in February of 2012 when ETAP first heard of a Telkonet installation at a qualifying California agency. The EcoSmart products focus on hospitality and similar markets that typically use wired thermostats and package HVAC systems rather than the pneumatic thermostats and larger HVAC systems found in ETAP's Wireless HVAC projects.

Telkonet was formed in 1999, and provides solutions for energy management as well as high-speed internet to Hospitality, Education, and other market sectors. More information on Telkonet can be found at http://www.telkonet.com/

Millennial Net's Wireless Pneumatic Thermostat

Millennial Net manufactures the Wi-Stat IIIp Wireless Pneumatic Thermostat. ETAP evaluated the Millennial Net Wireless pneumatic thermostat first in April of 2011. The product was found to meet ETAP requirements under the Wireless Pneumatic Thermostat classification, but Millennial Net did not have a third-party evaluation report on the Wi-Stat IIIp, nor an installation in operation for over one year in California. In February 2012, ETAP verified that Millennial Net was still missing both these pieces. The Wi-Stat IIIp was reported to be under consideration for study in a California IOU-funded Emerging Technology report on wireless pneumatic thermostats that also included the Cypress Envirosystems' product, but a demonstration site had yet to be identified.

Millennial Net was founded in 2000 and provides wireless sensor networking systems for commercial and industrial markets. More information on Millennial Net can be found at http://www.millennial.net/

WIRELESS HVAC CONTROLS CHALLENGES-IMPLEMENTATION

Schedules and Timing

HVAC projects tended to include additional maintenance and retrofit items in the project scope. For example, for Vigilent DART™ projects it was sometimes necessary to replace fan motors or install VFDs (variable frequency drives) on air handler fans. For wireless pneumatic thermostat projects, it was sometimes necessary for the facility to fix leaks in the pneumatic system, verify actuator performance, and re-program set points and control sequences in the building management system. Such items increased project scope and cost, and extended the timeline.

Retrofit and maintenance projects tend to “cluster” at facilities. This increased the need for coordination between the wireless HVAC installation and other concurrent projects. For example, facilities often identified the need for wireless HVAC controls as part of a larger monitoring or retro-commissioning project. This resulted in other installations and maintenance at the facility concurrent with the wireless HVAC project installation, which also extended the timeline. While overall this is a desirable effect, more complex projects take longer to specify and implement creating distinct challenges with a program with a fixed implementation period.

HVAC Data Collection

Large campuses with central plants that provide heating and cooling to other facilities did not always have easily-obtained, accurate information on the state of the plant. Different facility staff typically operated the campus buildings and plant, necessitating multiple points of contact to get information about chilled water, hot water, and steam consumption.

Large campuses tend to not have sub-metering of energy consumption for individual buildings, making benchmarking and usage assessment of projected savings against historical usage difficult. This process was a usual quality control step that was not available at master metered campuses.

It was often difficult to physically access HVAC related data during audits. Equipment was sometimes located in hard to reach places, nameplates were worn and unreadable, and sensors were unreliable or out of calibration. Some of this data could be checked against mechanical schedules, but those were not always readily available or up-to-date. It was also difficult to thoroughly survey a large and complicated facility in a limited period of time.

It was sometimes difficult to get clear information about facility operation (hours, set points, problems), particularly if that facility was old and was served by multiple facility staff. Facility staff sometimes varied in their understanding of building operation and equipment, or were mis- or under-informed about recent building changes and upgrades.

Building plans, mechanical schedules, and other building documents were often unavailable, undocumented, or out of date. Building documents were not a reliable alternative to obtaining information first-hand through an audit. For example, while fan motor horsepower could be compared between mechanical schedules and nameplate information, supply CFM was completely reliant on mechanical schedules that were sometimes unavailable.

Data collection was sometimes hindered by the need to also market the measure at the same time. Initial visits varied wildly as to how much time was spent in sales mode as compared to data collection mode. For projects that required longer measure discussion, customer contacts would sometimes rush the data collection process or indicate that they would collect and provide the information at a later date. This often resulted in unreliable data.

HVAC Savings Calculations – Predictive Modeling

Approaches to modeling the savings benefits from wireless thermostats were highly specific to a facility or savings approach, making it difficult to use one standardized calculation tool. It was often necessary to customize the calculation tool to particular projects (e.g. modeling systems with multiple operating schedules, with unusual duct structures, or with no mechanical cooling onsite). Even small projects required a great deal of data and assumptions to accurately characterize the HVAC system and develop reliable savings estimates.

It was difficult to accurately characterize baseline and post-installation facility operation without measured and monitored data. Examples of data that benefits from monitoring over a period of time include zone temperatures and set points, fan speeds, facility hours, and supply air or water temperatures. Such data is difficult to collect in a time-limited program like ETAP. This was particularly true for modeling energy savings from a CAV to VAV retrofit (variable fan speed operation). There is no way to reliably model VAV savings without information about post-installation fan speed operation and airflow over an extended period of time. Such information was difficult, if not impossible, to estimate pre-installation.

WIRELESS HVAC CONTROLS CHALLENGES-PROCUREMENT

HVAC Contracting and Financing

Agencies sometimes must put projects out to a public bid process when the project cost and scope are above a particular limit. HVAC projects may be more likely to exceed these limits, particularly if they involve significant equipment replacement or upgrades (motors, VFDs, sensors, etc.). This may necessitate making sure that a particular wireless HVAC product and installation is not limited to sole-sourcing. It also lengthens the project timeline and adds complexity.

WIRELESS HVAC CONTROLS LESSONS LEARNED

Schedules and Timing

If a project requires installation or repair of other equipment unrelated to the ETAP specific retrofit, obtain information about all project costs and schedules as early as possible. This allows ETAP to deal with potential holdups.

Contracting and Financing

Investigate partner and customer contracting and procurement processes prior to starting a program. Prepare options for customers to be able to procure no matter what the project.

If a project requires installation or repair of other equipment unrelated to the program specific retrofit, request information about the whole project scope and cost as early as possible.

HVAC Data Collection

There is no good substitute to visiting the facility oneself, rather than relying on third-party information. It is highly recommended that program technical staff visit each facility being evaluated for rebates, even if detailed facility information is available from customer staff or building documents.

Clearly state the dual objectives of the onsite meeting to both inform potential customer about functionality of the new system, and to collect data on existing system. Detail estimated times for each component of the meeting. Express willingness to discuss measure, but also provide distinct time estimate for data collection. This will help to distinguish the sales and marketing portion of the visit, from the data collection portion.

WIRELESS HVAC CONTROLS PERFORMANCE EVALUATION

ETAP gathered fan speed monitoring data was gathered from wireless HVAC projects that included fan control measures and for which ETAP was doing the primary energy savings analysis. In practice, this meant data was gathered by ETAP for each installation of the Vigilent Building Solution, and for the Cypress Envirosystems' WPT installations at UCLA Young Research Library, UCLA Law, and Sacramento County DGS and Sheriff's Admin. Of the projects where fan control data was collected, six sites yielded enough monitoring data to provide a conclusive energy savings result, and these are analyzed below.

Electricity Savings

As shown in Figure 11, monitored data indicated electricity savings 29% above the modeled estimates, in aggregate.

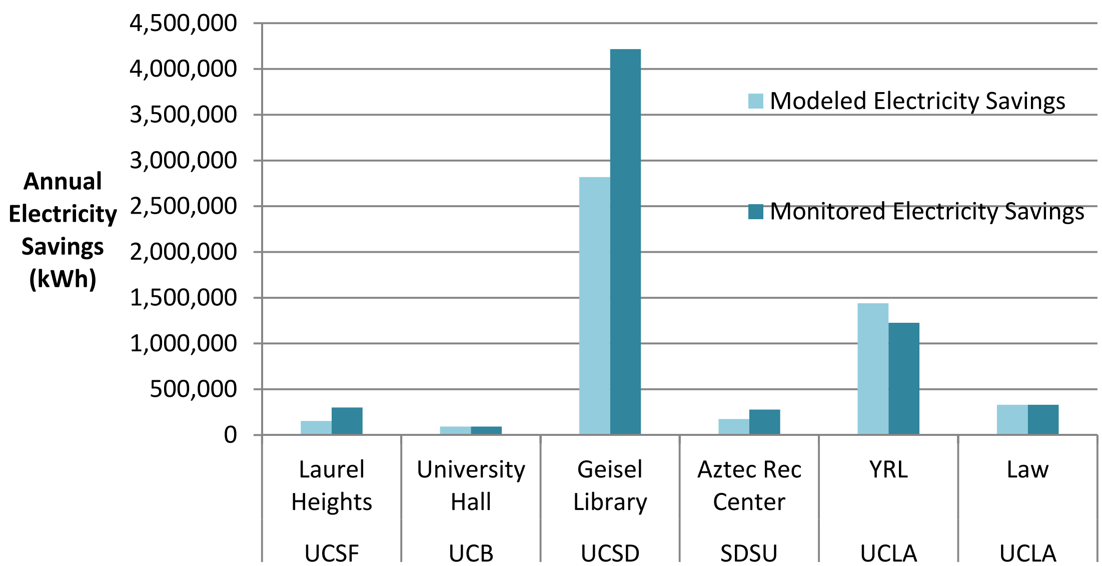

Figure 11. Modeled vs. Monitored Electricity Savings in Wireless HVAC Controls Projects

Natural Gas Savings

As shown in Figure 12, monitoring data for the six analyzed wireless HVAC projects indicated natural gas savings 29% above modeled estimates in aggregate.

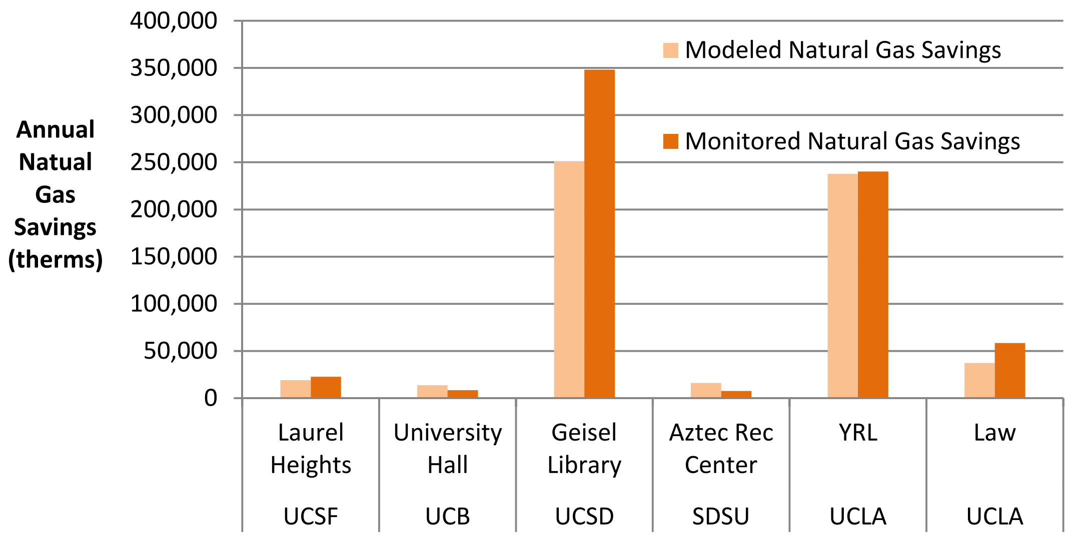

Figure 12. Modeled vs. Monitored Natural Gas Savings in Wireless HVAC Controls Projects

Energy Savings Models

The wireless HVAC energy savings calculators for both controls technologies performed their main task well: providing a conservative estimate of energy savings achievable with wireless controls retrofits. Across all 28 ETAP wireless HVAC projects, ETAP staff were able to predict quite well the feasible energy savings during the audit stage and effectively focused program resources on projects that contributed significantly to energy savings goals.

There are inherent limitations in the creation of a savings model. Interpreting the calculations literally, they assume only a single driver of HVAC demand: outdoor air temperature (OAT). For a big building with relatively high volume to surface area ratio, such as the UCSF Laurel Heights campus, outdoor temperatures are not the biggest driver of demand and the monitored fan speeds show poor correlation with outdoor air temperature. It is more accurate to say that the calculation methodology was built on the understanding that one variable (OAT) can stand in for all the multivariate factors that affect HVAC demand, each of which could not be represented in a calculation tool that would ETAP needs for ease of use. OAT is thus a stand-in for occupant load, plug loads and other electric loads, and various heat exchanges through the building envelope (conduction, convection & solar heat gain).

ETAPs involvement with each of these wireless HVAC controls technologies provided the first opportunity to have an independent party examine both modeling and monitoring results for so many separate projects. The feedback from ETAP has helped these manufacturers improve their own savings estimation tools and understand the needs of both customers and utility rebate programs.

Public Releases of Information

Outreach Materials

Various marketing materials were developed to support the outreach to and engagement with potential ETAP participants. The materials developed for use and release into the public domain included: a tri-fold brochure, three technology fact sheets, a program website, a rebate reservation application form, and a design review form.

The tri-fold brochure was designed to describe the program services, benefits, and eligibility requirements and includes information on the following topics:

- Program goals
- Program funding source
- Descriptions of targeted measures, including: technology introduction, and retrofit applicability
- Program services, including: feasibility audits, energy savings calculations and documentation, coordination with other funding sources and financing, and project implementation support.
- Program incentives
- Financing and funding options
- Program eligibility requirements

The tri-fold brochure was professionally designed in full color. The brochure was available for download from the program website and 515 copies were professionally printed and made available at the various technology seminars, outreach presentations, kick-off meetings, and at other suitable events.

Three fact sheets were developed, one for each of the target measures – wireless HVAC, wireless lighting controls, and bi-level lighting. The fact sheets were each a single double-sided page and included similar information as the brochure, but with more detail on the description of the targeted measure including energy savings calculations, retrofit applicability, estimates of potential energy savings and program eligibility requirements. Each of the fact sheets were available for download from the program website and 485 copies of each were professionally printed and made available at the various technology seminars, outreach presentations, kick-off meetings, etcetera.

Other outreach materials developed included the program website, rebate reservation application form and design review form. Both the program application form and design review form were designed as editable adobe PDF documents that the Agency Leads filled-out in coordination with the participating agencies. The application form was a two page form that both the Agency Lead and the participating Agency contact signed and included information such as project facilities, rebate reservation amounts, payment information, and program terms and conditions. The design review form was a single page form that was signed by the Agency Lead and project tech lead and provided to the Agency contact that finalized the ETAP rebate amount, based on the project details confirmed during the project design review, which typically occurred right before project installation.

In an effort to support environmentally friendly printing practices, the program had planned to print all marketing materials using soy-based rather than petroleum-based inks. It turned out that this goal was not practical, nor entirely feasible for the printing of all materials, due to the small number of printed copies required. It was more economical to print batches of less than 2,000 copies with digital methods for which soy inks could not be used. To use soy inks, lithographic printing is ideal. However, lithographic printing for batches of 500 is considerably more expensive and more time consuming. Thus, the first round of printing of the fact sheets and brochures were printed digitally. The remaining materials were printed lithographically using soy-based inks.

Press Releases

The program allocated a small portion of the budget for working with agencies to prepare and distribute press releases to raise awareness of the program and of the advanced technologies. The budget was sufficient to support the preparation of the press releases; however, no budget was reserved to support the considerable effort necessary to gain traction in the media using the press releases. In the future, if it is a program goal to garner media attention to highlight program accomplishments and technologies, it would likely be in the program's best interest to engage a public relations firm and allocate additional resources to this area.

As part of the programs on-going public relations effort, the program prepared or assisted in the preparation and distribution of four press releases.

3/29/11: AC TRANSIT CUTS LIGHTING USE IN HALF WITH BI-LEVEL LED LIGHTING RETROFITS

This press release was a joint press release with AC Transit, highlighting AC Transit's LED bi-level lighting parking area projects. This project was the first ETAP project to begin installation. The press release highlighted the estimated project savings anticipated from the project, AC Transit's commitment to reducing environmental impacts, as well as provided information on ETAP for potential participants.

8/18/2011: SACRAMENTO SHEDS LIGHT ON NEW FIXTURES USING LESS THAN HALF THE POWER

This press release was sent out by the City of Sacramento. ETAP assisted in writing the press release with the City of Sacramento PR team. The press release highlighted the City's multi-facility LED bi-level parking garage lighting retrofits and included a quote from U.S. Energy Secretary Steven Chu. It also included information on the ETAP program, rebates provided, and anticipated energy savings.

Press: Sacramento Press Article: http://www.sacramentopress.com/headline/55454/

9/13/11: ENERGY TECHNOLOGY ASSISTANCE PROGRAM TO SAVE CALIFORNIA CITIES AND PUBLIC UNIVERSITIES OVER $1.8 MILLION ANNUALLY AND SPUR GREEN JOB DEVELOPMENT

This press release was prepared by the ETAP team to highlight the successes to date of the program, as well as highlight that additional funding is still available for potential participants. The press release provided information on the program's accomplishments, highlighting productive use of ARRA funding for green job growth, the variety of participants eligibility, and participant savings.

Press: LGC Currents Energy Newsletter:
http://www.lgc.org/freepub/energy/newsletter/fall2011/page08.html

12/6/2011: PLEASANTON LIBRARY CUTS ENERGY USE BY 46% WITH ADURA TECHNOLOGIES WIRELESS LIGHTING CONTROLS

This press release was a joint press release with Adura Technologies, highlighting the City of Pleasanton's wireless lighting project completed at their public library. The press release was timed to coincide with the release of the program's first case study, prepared on the Pleasanton Library project.

The press release highlighted the energy and cost savings of the project, as well as describing the Adura wireless lighting technology.

Press: Online article on KCTV 5 News: http://www.kctv5.com/story/16198013/pleasanton-library-cuts-energy-use-by-46-with-adura-technologies-wireless-lighting-controls

Pleasanton Weekly.com article:
http://www.pleasantonweekly.com/news/show_story.php?story_id=8292

Additionally ETAP provided limited review of two additional press releases that were prepared and release by technology vendors participating in the program that highlighted the ETAP rebates.

- **7/12/11**: Lutron® Products Qualify for California Energy Technology Assistance Program (ETAP)
- **12/6/11**: Vigilent Systems Dramatically Reduce Energy Consumption at San Diego State University

  Press: MarketWatch article: http://www.marketwatch.com/story/vigilent-systems-dramatically-reduce-energy-consumption-at-san-diego-state-university-2011-12-06

Other media attention that ETAP has received is listed below.

- **8/2011**: CLTC Lighting Link Newsletter highlighted CSU Long Beach's best practice award for an ETAP-supported lighting project: https://app.e2ma.net/app/view:CampaignPublic/id:25667.10668527098/rid:68ea7d2cbbb2cdd643bc7e259b92db45
- **10/6/11**: California State University Public Affairs online post, Federal Funding Fuels Efficiency at Six CSUs. http://www.calstate.edu/pa/News/2011/Story/etap.shtml
- **10/9/11**: Transition South Bay LA Blog Post: http://transitionsouthbayla.blogspot.com/2011_10_01_archive.html

Case Studies

Seven case studies documenting ETAP projects in participant facilities were developed. Each case study highlights technologies utilized, savings, challenges, and accomplishments. In selecting projects for case studies, the team chose projects that illustrated a variety of circumstances, potential challenges, target measures, financing, climate zones, regional factors and project partners in order to show the breadth of the program and application of the three target measures. Additionally, timing of installation was also a large factor in selecting case study projects as each case study took a number of months to develop and the development of all seven needed to be spread out across the latter half of the program. The case studies include the following elements.

- Project overview, location and site information
- Energy use and equipment prior to project
- Technical specifications of retrofit
- Estimated energy savings, GHG emissions reductions, and cost savings
- Total project cost and payback period
- Information on challenges and solutions employed
- Financing and leveraged funding utilized

- Non-energy benefits
- Participant and stakeholder testimonials
- Photos

The printing and distribution of case studies was done in two batches. Once the first four case studies were completed, an announcement of their availability was emailed out to contacts at a wide variety of local government, utility, governmental, and energy affiliate organizations. The case study announcement was sent to the following organizations along with a request that they pass on the case studies to their constituents, members, colleagues, etc: Association of Bay Area Governments, Association of Energy Engineers, California Center for Sustainable Energy, California League of Cities, the California Energy Commission, Clean Tech San Diego, Coachella Valley Association of Governments, Ecology Action, California Local Government Commission, San Bernardino Associated Governments, Southern California Association of Governments, San Diego Association of Governments, Western Riverside Council of Governments, PG&E, SDG&E, SCE, and SMUD.

Additionally, emails announcing each batch of case studies were emailed to a larger group of recipients, including: a variety of utility contacts, ETAP participating agencies and partners, utility local government partner contacts, and other energy, educational, nonprofit and utility organizations. The case studies were all made available for download from the program website and 500 copies of each case study were professionally printed and copies distributed to organizations that requested them. A short synopsis of each of the seven case studies is presented below.

CASE STUDY 1: DRAMATIC ENERGY SAVING FOR SACRAMENTO WITH BI-LEVEL LED PARKING GARAGE RETROFITS

The first case study highlights one of the eight City of Sacramento bi-level parking garage projects completed through ETAP. This case study narrates the process that City staff undertook over a number of years to identify a fixture type and control option that meet their priority needs, as they were interested in retrofitting to fixtures with long useful lives, good color rendering, and low energy use. With their new bi-level LED fixtures the City has reduced electricity use by approximately 88%, compared to their previous metal halide fixtures in the Downtown Central Garage. Including all 8 parking garages, the City estimates it will save more than 4 GWh annually and reduce annual electricity expenditures by just under a half a million dollars.

CASE STUDY 2: PLEASANTON LIBRARY CUTS LIGHTING ENERGY USE 46% WITH WIRELESS LIGHTING CONTROLS AND FIXTURE RETROFITS

This case study highlights the installation of Adura wireless lighting controls and a light fixture retrofit project at the Pleasanton Public Library. Before the project, the library’s 661 fixtures (predominantly T8s, with some T5HO and CFLs) were on an average of 13 hours per day, seven days a week, and cost the City approximately $46,000 per year in electricity consumption. Retrofitting the buildings T8 lamps and ballasts to more efficient models reduced the lighting electricity use by about 10%. The installation of wireless lighting controls, which reduced the operating hours and light output of the fixtures depending on available daylight and occupancy, reduced the lighting electricity use by an additional 36%.

The City was able to take advantage of rebates offered by ETAP in addition to PG&E rebates for an estimated total project payback period of 6.2 years. In addition to the energy and cost savings, one very valuable benefit of this project to the Library facilities staff is the ability to now manage their lighting use via the flexible online control system. Before the project the library’s lights were all either on or off.

Now with the new controls system, they have a flexible control system that responds to occupancy, available daylight, and programmed scheduling.

CASE STUDY 3: WIRELESS PNEUMATIC THERMOSTATS HELP UCSD REACH SUSTAINABILITY GOALS BY REDUCING GREENHOUSE GAS EMISSIONS BY 538 TONS/YEAR

This case study highlights the installation of Cypress Envirosystems' Wireless Pneumatic Thermostats (WPTs) at U.C. San Diego's (UCSD) McGill-Mandler Hall. UCSD replaced McGill-Mandler Hall's 250 existing pneumatic thermostats one-for-one with WPTs, which were connected to the existing pneumatic piping, calibrated and programmed. The new system was connected to the building's existing Building Automation System (BAS). To complement utilization of the new WPTs, a number of other upgrades were implemented, including but not limited to installation of variable frequency drives (VFDs) on the air handler fans and three new outside air economizer dampers. The retrofit is projected to reduce annual electricity use at McGill-Mandler Hall by 27% and annual natural gas use by 51%, resulting in an estimated annual utility bill savings of $94,900.

UCSD was able to take advantage of rebates offered by ETAP in addition to SDG&E rebates for an estimated total project payback period of 0.2 years. In addition to the energy and cost savings, one very valuable benefit of this project is that WPTs allow both manual occupant control and centralized control of temperature set points. Facility managers can remotely monitor thermostat settings and zone temperatures, make changes, establish automated schedules, and diagnose problems through the BAS.

CASE STUDY 4: UC BERKELEY'S UNIVERSITY HALL WIRELESS HVAC RETROFIT BRINGS THE CAMPUS ONE STEP CLOSER TO ITS CLIMATE NEUTRALITY GOAL

The UC Berkeley University Hall case study highlights a Vigilent Intelligent Energy Management System retrofit that was installed to modify their previous constant air volume HVAC system to approximate a variable air volume system. The Vigilent System, coupled with the installation of variable frequency drives (VFDs) and new motors on the buildings air handling units allows the facility managers to dial back fan speeds in the building to better match demand and minimize energy use. The project is estimated to reduce the building's annual natural gas use by 9% and electricity use by 6%. An added benefit from this project for UC Berkeley has been that the Vigilent wireless control system also allows them to view and remotely operate the system through their existing Barrington Energy Management System.

CASE STUDY 5: WIRELESS HVAC CONTROLS RETROFIT SAVES MONEY AND ENERGY FOR STUDENTS AT SAN DIEGO STATE UNIVERSITY

The San Diego State University case study provides an in depth look at another Vigilent Intelligent Energy Management System retrofit project at a large recreation and exercise facility. The installation of the Vigilent System, again coupled with the installation of VFDs on the buildings four air handling units, set the building up for a payback period of less than a single day, taking into account both ETAP and SDG&E rebates. The estimated annual project energy savings, 18% reduction in electricity use and 55% reduction natural gas use, are significant. The case study illustrates that in similar buildings with constant air volume ventilation systems and long operating hours, a retrofit technology such as the Vigilent System can offer large energy savings with a short payback period.

CASE STUDY 6: LEDS AND BI-LEVEL CONTROLS DELIVER HEALTHY 87% ENERGY SAVINGS AT THE CONTRA COSTA COUNTY PITTSBURG HEALTH CENTER

This case study highlights the installation of a bi-level LED lighting fixture retrofit project at Contra Costa County's Pittsburg Health Center. Before the project, the parking lot was illuminated by 157 250-watt high pressure sodium (HPS) fixtures controlled by photocells that turned lights on in the evening and turned them off at dawn, costing the City approximately $29,000 per year in electricity consumption. Retrofitting the parking lot from HPS fixtures to more efficient LEDs improved light quality while drastically reducing the per-fixture electricity use, and the addition of bi-level controls and occupancy sensing reduced run time. In addition, the improved color rendering and light distribution of the LEDs, relative to the HPS lamps, allowed for significant de-lamping. These combined benefits have reduced lighting electricity use in the parking lot by 87%.

The County was able to take advantage of rebates offered by ETAP in addition to PG&E rebates for an estimated total project payback period of 2.2 years. The County used PG&E's On-Bill Financing program to cover the balance of upfront project costs. Under on-bill financing, PG&E financed the project with 0% interest and the County will pay back the loan through its monthly utility bills.

CASE STUDY 7: SAN MATEO COUNTY DRIVES DOWN ELECTRICITY COSTS IN PARKING GARAGE BY 67% WITH EFFICIENT T8 LAMPS AND WIRELESS LIGHTING CONTROLS

This case study highlights the installation of Adura Technologies' wireless lighting controls and high efficiency T8 fluorescent fixtures at San Mateo County's County Center Parking Garage. Prior to the retrofit, the parking garage utilized 297 150-watt high pressure sodium (HPS) fixtures, most of which operated 20-24 hours per day, resulting in an annual lighting electric bill of $46,000 for this six-level garage. The lighting upgrade included a bi-level lamp and ballast retrofit and the installation of a wireless lighting control system. The system maximizes energy savings in individually controlled zones by utilizing day lighting control, occupancy control, and an astronomical timeclock that adjusts daily for longer summer days and shorter winter days. The project is anticipated to reduce parking garage lighting energy use by 67%.

The County was able to take advantage of rebates offered by ETAP in addition to PG&E rebates for an estimated total project payback period of 3.8 years. In addition to the energy and cost savings, the County was able to meet its aim of maximizing savings without compromising occupant safety in the garage. In addition, the Adura Technologies Wireless Lighting Control System provides energy tracking and monitoring, automated maintenance notifications, and load shedding capability.

CASE STUDY 8: CSU FULLERTON'S TITAN GYM CUTS LIGHTING ENERGY USE 66% AND ADVANCES CLIMATE GOALS WITH WIRELESS LIGHTING CONTROLS AND FIXTURE RETROFITS

This case study highlights the installation of Lutron wireless lighting controls and a light fixture retrofit project at California State University Fullerton's Titan Gym. Prior to the lighting retrofit, the gym's 68 400-watt metal halide light fixtures were on an average of almost 16 hours per day, 7 days per week during the academic year. With additional hours of operation during summer and winter breaks, the University was paying approximately $17,500 annually in electricity costs. Retrofitting the metal halide fixtures with 4-lamp T5HO F54 216-watt XtraLight fixtures with Lutron EcoSystem H Series dimming ballasts reduced lighting electricity use by 48%. The installation of the wireless lighting controls is expected to reduce electricity use by an additional 18%.

The University was able to take advantage of rebates offered by ETAP in addition to SCE rebates for an estimated total project payback period of 2.6 years. By replacing light sources and installing a Lutron wireless control system, Cal State Fullerton was able to reduce the gym's lighting energy use by 66%, cutting energy costs and greenhouse gas emissions while improving light quality and controllability.

Technology Seminar

- Videos and Powerpoint presentations given during ETAP Technology Seminars are available on the ETAP website and will provided in electronic format to the Energy Commission Contract Manager as a part of the program closeout activities.

Other Presentations

- **7/11/11-7/12/11**: California Higher Education Sustainability Conference, California State University Long Beach. Staffed booth in the exhibitor section of the conference. ETAP promotional materials were distributed and attendees were presented overview of ETAP. Receptive agencies were engaged following the event.
- **5/26/11**: San Diego Association of Governments Energy Working Group meeting, SANDAG main office, downtown San Diego
- **6/13/11**: San Luis Obispo County Energy Watch Partnership Monthly Meeting
- **6/2/11**: San Diego Association of Governments Transportation Advisory Committee meeting, SANDAG main office, downtown San Diego
- **4/26/11**: Southern California Association of Governments Toolbox Tuesday Seminar, Energy Efficiency Retrofit Incentive Programs, SCAG main office in downtown Los Angeles
- **7/13/11**: UC/CSU/IOU Energy Efficiency Partnership Joint Energy Managers Meeting, California State University, Long Beach
- **9/14/11**: South Bay Environmental Services Center Monthly Partners Meeting, South Bay Cities Council of Governments, Lawndale
- **7/27/11**: Statewide Energy Efficiency Collaborative Energy Efficiency Best Practices Forum, San Jose

Website

The ETAP program website, www.energy-solution.com/etap was developed using HTML 4.0 and CSS 3.0, to meet WCAG (Web Content Accessibility Guidelines), Version 2, Level A. The website has served as a comprehensive program information source for the general public, program participants, potential participants, press, and partner agencies. The website provides extensive detail on the program technologies, and requirements and has been a dynamic resource, providing regular updates on program accomplishments. The site has also served as a repository for public program documents and supporting third party documents.

The website was developed with the assistance of a sub-contracted web design firm, Creative Slice. The ETAP site was developed using Word Press software and the majority of site content can be easily updated through the Word Press content management system. The website design utilizes the ETAP branding and logo to highlight its relationship with Energy Upgrade California.

The following information and features are included in the website:

- Program goals and funding source
- Descriptions of targeted measures, including: technology details, retrofit applicability, estimates of potential energy savings and payback rates
- Program services, including: feasibility audits, energy savings calculations and documentation, coordination with other funding and financing, and project implementation support.
- Program incentives
- Financing and funding options
- Program eligibility requirements
- List of participating agencies and program partners
- Resources, including downloadable program materials (brochure, press releases, case studies, technology fact sheets, application forms), links to partner and third party case studies, websites and technology information, as well as utility rebate programs, ARRA documentation and requirements, and other governmental energy resources
- Contact information
- Training information and technology seminar dates, announcements, and seminar presentations/materials
- Links to contractor bid opportunities for ETAP-supported projects
- Accomplishment updates: provided approximately once a month and including information such as - new participants, funding availability, number of projects installed, and energy savings identified
- Frequently asked questions

Networks or Collaborations Fostered

Regional LED Streetlights Procurement Initiative

ETAP offered technical support and rebates for bi-level LEDs in parking lots and parking garages. Many agencies who were interested in the ETAP measure were also pursuing projects to replace their existing streetlights with LED streetlights. While there are differences between parking lot, garage, and streetlighting projects, there is also significant overlap in the LED and controls technologies used in each application. Recognizing that there was a demand for LED streetlighting services, ETAP was receptive to contributing to efforts to promote LED streetlighting projects, and more specifically the use of controls in LED streetlight projects.

The Bay Area Next Generation Streetlight Initiative was convened after the ETAP Technology Seminar in Oakland on June 15, 2011. During the Seminar a representative from the City of San Jose spoke about their LED streetlight projects and a representative from the Association of Bay Area Governments (ABAG) spoke about financing efficiency projects. An audience member from the Bay Area Climate Collaborative saw an opportunity integrate financing for LED streetlighting projects with region-wide bulk fixture procurement. By fall 2011 a partnership between the Metropolitan Transportation Commission, ABAG, the City of San Jose, and the Bay Area Climate Collaborative had formed and the team was meeting regularly to develop a procurement and financing opportunity for cities and counties in the Bay Area. ETAP offered technical assistance in support of the effort.

The Bay Area Next Generation Streetlight Initiative aims to pool Bay Area-wide interest in LED conversions, providing a bulk procurement option to secure improved purchase and financing terms for streetlight upgrades to LEDs. The overarching aim is to use the Department of Energy Municipal Solid-State Lighting Consortium's technical specifications to catalyze the conversion of 200,000 streetlights in Northern California by the end of 2013 which could yield $15 million or more in annual energy savings.

In December, the Initiative issued an initial survey to gauge regional interest in the initiative. Fifty-four Bay Area cities and counties responded that they might be interested in participating. In light of the positive responses, the Team continuing its exploration into the feasibility of a regional procurement by reaching out to LED fixture and controls manufactures, distributors, and sales representatives to try and identifying potential barriers a successful large-scale procurement.

After performing outreach calls, the Team concluded that a bulk procurement of tens-of-thousands of fixtures could lead to significant cost savings. Some manufactures said that ordering tens of thousands of fixtures as opposed to hundreds of fixtures could result in as much as 50% cost savings. From the manufacturers' perspective, it would be much easier to respond to one request for proposals (RPFs) that would provide fixtures to dozens of agencies as opposed to responding to a dozen or more separate RFPs.

Another advantage of a joint procurement that is supported by ETAP or another third party organization is that the technical specifications that went into the joint RFP would be thorough and technically sound. Manufactures noted that oftentimes the technical specifications included in RFPs are not well envisioned. Since the bidder responds to the technical specifications included in the RFP, the agencies who have an inadequate specification in the RFP will receive fixtures that are not best suited for their applications. This information validates the need for a rigorous preparation of technical specifications – whether that specification is included in a joint procurement or in a procurement for an individual Agency.

ETAP got involved in the Initiative thinking we would provide technical assistance, as needed. In the end, ETAP played a central role in technical and non-technical aspects of the effort. ETAP assisted in the following ways:

- Developed and distributing the initial survey to Bay Area agencies to gauge interest in the Initiative;
- Analyzed survey results and developed an estimate of costs and impacts (energy savings, GHG reductions, jobs created, cost savings) of the Initiative;
- Conducted outreach effort to manufacturers, distributors, and sales representatives to identify potential barriers and benefits of the Initiative;
- Reviewed the MSSLC fixture and controls specification and helped tailor the specification to accommodate local performance and quality;
- Spearheaded outreach to interested agencies to encourage them to participate and to help them determine if the tailored MSSLC specification would be appropriate for their specific streetlighting applications;
- Authored a whitepaper to summarize the findings of the initial phases of the Initiative and offer input on how to proceed beyond the ETAP funding period.

Databases, Videos, Models, and Curricula

ETAP DATABASE

The ETAP performance tracking database will be provided to the Energy Commission contract manager as part of program closeout.

VIDEOS

Presentations from the Technology Seminars are available on the ETAP website (http://energy-solution.com/etap/training/tech-seminar-presentations/) and will be provided to the Energy Commission in electronic form at program closeout.

HVAC TRAINING CURRICULUM

Vigilent prepared the curriculum for the HVAC trainings. ETAP assisted by developing the course agenda and an outline for the curriculum. ETAP reviewed and provided substantive feedback on a draft version of the presentation material. Finally, ETAP formatted the final version of the presentation and printed hard copies that were distributed to course participants. The curriculum included the following training modules:

- Introduction to Controls
- How to Build a Wireless Sensor Solution
- Applying Wireless Technology to Make Smarter Buildings and Data Centers:
    - Installation Module Part 1 – Wireless Sensors and Gateway
    - Installation Module Part 2 – DART
- Student Hands-on Installation Exercise
- Building Management Integration
- Testing/Troubleshooting Module

The curriculum that was developed for the ETAP trainings belongs to Vigilent. By purchasing a license to use the materials, ETAP was able to utilize the course curriculum for the HVAC trainings and provide hard copies of the presentation materials to course participants. However, the license agreement does not allow ETAP to distribute the curriculum in any way.

(6) DELIVERABLES

Table 19 lists ETAP's contractual deliverables and the date they were transmitted to the Energy Commission.

Table 19. ETAP Contractual Deliverables

Deliverable	Brief Description	Due Date in Agreement	Date Delivered to CEC
Program Implementation Plan (PIP)	Description of Program Policies	12/15/2010	11/1/2010
Participation Agreement	Used to Enroll Participants	4/30/2012	In PIP
Program Rebate Application	Used to Reserve ETAP Rebate	4/30/2012	In PIP
Project Monitoring Plan	Monitoring Methods	12/15/2012	In PIP
Measure Development Plan	New Product Evaluation Process	12/15/2012	In PIP
Marketing Plan	Approach for Marketing Tasks	12/15/2012	In PIP
Monthly Progress Reports	Program Performance Update	4/30/2012	Continuous
An Updated List of Leverage Funds	Project Funding Form	4/1/2012	In Mnth Rpts.
Summary of Program Mgt. Meetings	Agendas, Participants	4/30/2012	In Mnth Rpts.
Program Database Reports	Snapshots of Prog. Performance	4/30/2012	In Mnth Rpts.
Technical/Econ. Feasibility Reports	Audit Memos, Audit Reports	4/30/2012	In Mnth Rpts.
Completed Rebate Applications	Used to Reserve ETAP Rebate	4/30/2012	In Mnth Rpts.
Lighting Distribution Reports	Monitoring Data and Results	4/30/2012	In Mnth Rpts.
CPR Report	Mid-Program Review	4/30/2012	3/4/2011
Closeout Activity Schedule	Steps for Program Closeout	4/9/2012	4/25/2012
Final Report	This Document	4/30/2012	4/30/2012
Program Database	Performance Tracking Database	4/30/2012	4/30/2012
Program Website	ETAP Website	4/30/2012	4/8/2011
Program Brochure	Overview of Program	4/30/2012	4/27/2011
Case Studies	Descriptions of ETAP Projects	4/30/2012	4/30/2011
Lighting Trainings	Training in advanced lighting	4/30/2012	Various
HVAC Trainings	Training in HVAC controls	4/30/2012	Various
Technology Seminars	Info. on Advanced Dnergy Tech.	4/30/2012	Various
ETAP Internship Program	Intro to Energy Effic. Industry	4/30/2012	Various

(7) BUDGET

Table 20 summarizes ETAP's total budget per task and the actual expenditure.

Table 20. ETAP Budget By Task

Budget Category	Brief Description	Budgeted	Actual Expenditure
1.0	Administration	$89,671	See invoice
2.1	Program Implementation Plan	$30,120	See invoice
2.2	Program Management	$828,198	See invoice
2.3	Marketing	$249,625	See invoice
2.4	Program Implementation	$1,847,170	See invoice
2.5	Workforce Development	$230,987	See invoice
2.6	Project Financing	$3,417,116	See invoice
2.7	Quality Assurance	$6,851	See invoice
	TOTAL	$6,699,738	See invoice