ADVANCED LIGHTING SYSTEMS FOR RETROFITTING PARKING GARAGES

August 2014

A Pilot Study at the Palo Alto Civic Center's Underground Parking Garage

Program for Emerging Technologies
Resource Management Division, City of Palo Alto Utilities

CITY OF PALO ALTO UTILITIES

EXECUTIVE SUMMARY

In this report, we describe a pilot project demonstrating Enlighted Inc.'s[1] advanced lighting controls technology and NEXT Lighting Corp.'s[2] light-emitting diode (LED) lamp technology in the Palo Alto Civic Center's parking garage, a three-level underground garage with an existing fluorescent lighting system.

The pilot study focuses on the following three pathways for energy savings: 1) LED lamp efficiency, 2) occupancy-sensing, and 3) task-tuning. For the pilot project analysis, we evaluate the energy efficiency savings and simple payback period for five scenarios that represent different combinations of lamp types (LED or fluorescent) and advanced lighting controls savings modes (standard or aggressive savings modes).

The primary objectives of the pilot project are the following.

- Document the energy savings demonstrated in the twelve-fixture pilot project.
- Using the demonstrated energy savings and industry price quotes, estimate the simple payback period for implementing a full-garage retrofit of the existing lighting system.
- Collect, summarize, and address stakeholder feedback related to implementing advanced lighting controls. Stakeholder feedback includes both perceived safety and quality of the lighting system of parking garage users, and also maintenance considerations of facilities maintenance staff.

Results from the analysis using conservative assumptions indicate that all scenarios investigated in the pilot led to substantial energy savings (25-72%) and the majority of scenarios had a simple payback period of around a decade, which is a payback period that is typically considered viable for a municipal organization.

Parking garage users strongly supported the City's efforts to modernize the lighting system and increase efficiency in municipal buildings. The primary concern from parking garage users was the sensitivity of the occupancy sensors, whose performance depend upon the pedestrian approach pathway and the installation configuration. This concern can be addressed in multiple ways by using advanced lighting controls, including, for example, coordinating occupancy response between nearby fixtures.

The facilities maintenance staff feedback noted the benefits of increased lamp life using LED lamps, which will result in reduced maintenance needs. However, the facilities maintenance staff also noted that the number of components of the system make trouble-shooting and maintenance considerably more challenging.

In summary, results from the pilot project strongly support retrofitting the Civic Center underground parking garages with LED lamps and advanced lighting controls, contingent upon successfully addressing the facilities maintenance staffs' concerns regarding maintaining a comparatively complex lighting system.

[1] http://enlightedinc.com/
[2] http://www.nextlighting.com/

ABOUT THIS REPORT

This report is an independent assessment by the City of Palo Alto Utilities (CPAU) of Enlighted Inc.'s advanced lighting controls technology and NEXT Lighting Corp.'s light-emitting diode (LED) lamp technology through a pilot project under the Program for Emerging Technology[3]. CPAU launched the program in 2012 in order to assist individuals and organizations that want to evaluate, test, and implement innovative emerging technologies. The overarching goal of the program is to find and nurture creative products and services that will manage and better use electricity, gas, water and fiber optic services. The conclusions outlined in this report are intended to help inform decision-making related to retrofitting lighting systems at both City-owned facilities and also at other non-municipal facilities within the Palo Alto service territory and beyond.

ABOUT THE CITY OF PALO ALTO UTILITIES

The City of Palo Alto is the only municipality in California that operates a full suite of City-owned utility services. The City of Palo Alto Utilities' (CPAU) history began over one hundred years ago, in 1896, when the water supply system was first installed. Two years later, the wastewater or sewer collection system came on line in 1898. In 1900, the municipal electric power system began operation, followed in 1917 by a natural gas distribution system. Palo Alto is the only city in California to own and operate six essential utility services, including refuse and storm drain (operated out of Public Works). In 1996, Palo Alto ventured into a new endeavor with the construction of its dark fiber loop.

[3] http://www.cityofpaloalto.org/gov/depts/utl/projects/program_for_emerging_technologies/default.asp

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A PILOT STUDY AT THE PALO ALTO CIVIC CENTER'S UNDERGROUND PARKING GARAGE

CHAPTER 1: INTRODUCTION

The recent wave of national and state legislation aimed at increasing lighting efficiency[4] and the correlated plummeting costs of energy efficient lighting technologies[5] have helped spur a renaissance in advanced lighting systems. Notably, light-emitting diode (LED) lamp technologies are on track to achieve an 85% drop in price from 2010 to 2015[6]. The range of new lighting technologies emerging in the marketplace, however, extends well beyond LEDs. Integrated control and communication technologies, intelligent sensors, and software with advanced analytics capabilities intersect to provide deep energy savings opportunities as well as an enhanced user experience.

The ease and degree of control of emerging advanced lighting systems combined with high efficiency light sources offer significant opportunities to optimize energy savings and occupant comfort and productivity. A summary of potential benefits include:

- Reduced electricity consumption and corresponding energy costs,
- Real-time monitoring and recording of electricity usage and savings,
- Automated diagnostics, and
- Remote control.

Although previously hampered by prohibitively high upfront costs and resultant long payback periods, retrofit applications are becoming increasingly attractive. The City of Palo Alto partnered with Enlighted Inc. and NEXT Lighting Corp. to test their advanced lighting controls and LED lamps, respectively, at the Palo Alto Civic Center's underground parking garage, a three-level garage with an existing fluorescent lighting system. This report focuses on the following three pathways for energy savings: 1) LED lamp efficiency, 2) occupancy-sensing, and 3) task-tuning.

The primary objectives of the pilot project are the following.

- Document the energy savings demonstrated in the twelve-fixture pilot project.
- Using the demonstrated energy savings and industry price quotes, estimate the lifetime energy savings and simple payback period for implementing a complete, garage-wide retrofit of the existing lighting system.
- Collect, summarize, and address stakeholder feedback related to implementing advanced lighting controls. Stakeholder feedback includes both perceived safety and quality of the lighting system of parking garage users, and also maintenance considerations of facilities maintenance staff.

This report summarizes the findings from the pilot project. *Chapter 2: Methodology* describes the details of the pilot project, including the pilot site, scenarios, and data collection time periods. *Chapter 3: Results* documents the savings at the fixture level, for all twelve fixtures associated with the pilot. Demonstrated energy savings are extrapolated to estimate the energy savings and simple payback period of a full garage retrofit. The third section in Chapter 3 documents and addresses stakeholder feedback. *Chapter 4: Conclusions* summarizes the primary conclusions of the pilot project, while revisiting the study's limitations.

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[4] Energy Independence and Security Act of 2007 (EISA 2007); California's AB 1109 (Huffman) Lighting Efficiency & Toxics Reduction Act

[5] U.S. DOE, 2011, SSL Research and Development: Multi-Year Program Plan

[6] Bhandarkar, V., 2011, LED Lighting Market Trends, Strategies Unlimited, Presentation to Strategies in Light Conference, Santa Monica

CHAPTER 2: METHODOLOGY

Section 2.1: Pilot Site Description

The location of the pilot study is the City of Palo Alto Civic Center's three-level, underground parking garage. The pilot site lacks ambient lighting, except near the garage entrance at the street level (Level A). The existing lighting system uses fluorescent lamps that operate twenty-four hours a day, seven days a week. The garage has over 600 fixtures and a baseline power consumption of approximately 33 kilowatts. In a single day, the fluorescent lighting throughout the 3-level parking garage consumes approximately 800 kilowatt-hours of energy, which is approximately 25% more than the average monthly electricity consumption of a single-family home in Palo Alto[7]. The current installation does not incorporate occupancy sensors, but instead operates at 100% power at all hours of the day, irrespective of occupancy. Therefore, there is significant opportunity for energy savings during late night/early morning hours when the parking garage experiences very little traffic, particularly on the middle and lowest parking levels (Levels B and C, respectively).

Please see Appendix A for a reflective ceiling plan of Levels A and B the parking garage, which includes labels for all pilot fixtures.

Section 2.2: Technology Profiles

There are three lighting technologies discussed throughout this report: the existing fluorescent lamps, the LED retrofit lamps, and the Enlighted advanced lighting controls. Each technology is described in detail below.

Existing fluorescent lamps: The existing fluorescent lighting systems utilizes Sylvania-manufactured 32-Watt T8 lamps with a rated life expectancy of 25,000 operating hours. The vast majority of the fixtures installed throughout the garage are 2-lamp, 8 feet strip fixtures. An inventory table of all fixture types by level is outlined in Table 1.

The existing fluorescent lighting system utilizes Sylvania non-dimming ballasts with a ballast efficiency of approximately 0.85. All T8 fixtures incorporated into the pilot project were retrofitted with a Phillips dimmable ballast that is compatible with advanced lighting controls technology with dimming capability.

Garage Level	Fixture Type			Total Fixtures
	1- Lamp, 4 Ft Strip	2-Lamp, 8 Ft Strip	4-Lamp, 16 Ft Strip	
Level A	2	91	15	108
Level B	15	229	0	244
Level C	8	229	0	237
Total Fixtures	**25**	**549**	**15**	**589**

TABLE 1: INVENTORY BY GARAGE LEVEL AND FIXTURE TYPE

LED retrofit lamps: For the pilot project, we used NEXT Lighting's 22-Watt LED retrofit lamps with a life expectancy of 50,000 operating hours. The LED retrofit lamps have an integrated driver for dimming. To

[7] Average electricity consumption for single family homes in Palo Alto is 630 kWh.

install, the existing ballast was removed and the new LED retrofit lamp was installed within the existing fixture.

Enlighted advanced lighting controls: The Enlighted advanced lighting controls system incorporates both hardware and software components that, when combined, form the advanced lighting controls technology. Specifically, hardware components include: 1) a sensor unit installed at each fixture to monitor energy, temperature, occupancy and light levels; 2) a control unit installed at each fixture to control illumination levels; 3) gateways installed throughout the parking garage that enable two-way wireless communication to individual fixtures; and, 4) an energy manager server installed inside a nearby facilities room that connects to all gateways. The software component is the Enlighted Energy Manager platform for remote control, monitoring, tracking, and diagnostics. The Enlighted advanced lighting controls system offers three energy-saving functionalities:

- *Occupancy-sensing:* Dimming light levels when the lighting zone is unoccupied
- *Task-tuning*: Adjusting light levels so that the illuminance does not surpass the threshold of light deemed necessary for tasks in that region, based on building user comfort and safety
- *Daylight-harvesting*: Adjusting light levels to account for ambient light entering the lighting zone during daylight hours

The energy savings opportunities within the scope of this pilot project include only occupancy-sensing and task-tuning; the potential for daylight-harvesting at the underground parking garage is prohibitively small and therefore excluded from the scope of the study.

Section 2.3: Scenarios

The pilot project analysis includes five scenarios, which are evaluated against the parking garage's baseline energy usage. The baseline for this pilot project is the existing fluorescent fixtures operating twenty-four hours a day, seven days per week. As shown in Table 2, the baseline and Scenarios 1 & 2 are based on the existing fluorescent lamp technology, labeled as "FL" in the column labeled "Lamp". Scenarios 3-5 are based on the LED retrofit technology, labeled as "LED" in the column labeled "Lamp". For each lamp type, we analyze two energy savings modes offered through Enlighted's advanced lighting controls: *standard savings* and *aggressive savings*. Both standard savings mode and aggressive savings mode enable energy savings by dimming the lighting level during the occupied and unoccupied modes according to the settings shown in Table 3. Aggressive savings mode is configured to deliver higher savings compared to standard savings mode. In addition to these two energy savings mode, we also analyzed scenarios where there are no lighting controls, corresponding to the baseline and Scenario 3.

Scenario Number	Scenario Description	Lamp	Enlighted Advanced Lighting Controls Mode
-	Baseline	FL	None
1	Standard	FL	Standard Savings
2	Aggressive	FL	Aggressive Savings
3	LED Baseline	LED	None
4	LED Standard	LED	Standard Savings
5	LED Aggressive	LED	Aggressive Savings

TABLE 2. DESCRIPTIONS OF SCENARIOS INCLUDED WITHIN THE SCOPE OF THE ANALYSIS

Fixture Location	Lamp	Standard Savings Mode		Aggressive Savings Mode	
		Occupied	Unoccupied	Occupied	Unoccupied
Level A, Drive Path	FL	75%	50%	70%	50%
Level A, Drive Path	LED	60%	20%	60%	20%
Level B, Elevator Entrance	FL	75%	50%	75%	50%
Level B, Parking Stall & Drive Path	FL	75%	50%	75%	25%

TABLE 3. LIGHT LEVELS FOR STANDARD SAVINGS AND AGGRESSIVE SAVINGS MODES

Due to the limited nature of the pilot project, there are no pilot fixtures with LED lamps on Level B, and there are no pilot fixtures at all – either LED or fluorescent – on Level C. For each of the five scenarios shown in Table 2, we estimate the projected annual energy savings and simple payback period compared to the baseline.

Section 2.4: Data Collection Timeline

For each of the two energy savings modes, we collected approximately four weeks of data between January and March. The analysis is based on seven consecutive days of data within each data collection time period. We specifically chose a seven-day period for each savings mode that excluded holidays. The garage traffic during the data period used for the analysis is assumed to be representative of the overall garage traffic throughout the entire year.

Savings Mode	Data Collection Time Period	Data Period Used in Analysis
Standard	Jan. 1st-21st, 2014	Jan. 10th – 16th, 2014 (7 days)
Aggressive	Feb. 23th – March 9th, 2014	Feb. 28th – March 6th, 2014 (7 days)

TABLE 4: DATA COLLECTION TIME PERIODS BY SAVINGS MODE

CHAPTER 3: RESULTS

In this chapter, we first document the measured energy usage of all fixtures incorporated into the pilot study. We then estimate the energy savings and simple payback for a full-garage retrofit based on pilot measurements. And finally, we address stakeholder feedback, both from the garage users' perspective and from the facilities maintenance staffs' perspective.

Section 3.1: Measured Performance at Fixture Level

A. Analysis of Monitored Data

The data shown in Table 5 are observed fixture-level savings calculated from hourly energy usage data for the standard and aggressive savings modes, respectively, from the Enlighted Energy Manager portal. As described in Section 2.4, the analysis is based on monitored data from seven consecutive days within the data collection time period. A breakdown of energy savings attributed to occupancy and to task-tuning is included for reference. These results observed on a fixture-level will be used in Section 3.2 to project the performance of a full-garage retrofit.

Fixture ID	Lamp	Level	Area Description[8]	Observed Savings in Standard Savings Mode			Observed Savings in Aggressive Savings Mode		
				Occupancy	Task-Tuning	Total#	Occupancy	Task-Tuning	Total#
A1	FL	A	Drive path	5%	10%	**15%**	5%	10%	**14%**
A2	FL	A	Drive path	5%	12%	**18%**	6%	12%	**18%**
A3*	LED	A	Drive path	11%	36%	**47%**	12%	36%	**47%**
A4*	LED	A	Drive path	12%	36%	**48%**	12%	27%	**39%**
B1*	FL	B	Elevator Entrance	9%	11%	**19%**	10%	11%	**21%**
B2	FL	B	Parking Stall	9%	14%	**22%**	21%	16%	**37%**
B3	FL	B	Drive path	9%	14%	**22%**	21%	16%	**37%**
B4	FL	B	Drive path	9%	11%	**20%**	25%	15%	**40%**
B5	FL	B	Parking Stall	13%	13%	**26%**	34%	18%	**52%**
B6	FL	B	Parking Stall	17%	17%	**33%**	39%	20%	**59%**
B7	FL	B	Parking Stall	16%	16%	**32%**	38%	19%	**57%**
B8	FL	B	Drive path	12%	16%	**28%**	27%	18%	**46%**

TABLE 5. ANALYSIS OF MONITORED DATA FOR EACH PILOT FIXTURE FOR BOTH STANDARD SAVINGS MODE AND AGGRESSIVE SAVINGS MODE
***FIXTURES HAVE EQUIVALENT LIGHT LEVELS DURING STANDARD AND AGGRESSIVE SAVINGS MODES**
#OCCUPANCY PLUS TASK-TUNING MAY BE +/- 1% OF TOTAL DUE TO ROUNDING ERROR

[8] Please see Appendix B for a reflective floor plan of the parking garage that labels each pilot fixture.

Upon reviewing Table 5, there are two unexpected observations about the results. First, we measured nearly identical savings for each Fixture A1 and A2 between standard savings mode and aggressive savings mode, although the two savings modes had different settings for the light level during the occupied mode (70% and 75%, respectively, while unoccupied mode was 50% for both). We believe that the small difference in the light level settings during unoccupied mode between the two savings modes explains the lack of an observed difference in savings.

The second notable observation is that Fixture A4 exhibited significantly less savings during aggressive savings mode compared to standard savings mode, even though the occupied/unoccupied light levels were set to be equivalent during both savings modes (please see Table 3). Upon careful observation of the hourly data from that fixture, we discovered that the light level was reverting to 100% for long periods of time, apparently irrespective of occupancy. After significant efforts to trouble-shoot the anomalous behavior, the Enlighted engineering team eventually determined that it was a software issue. They reprogrammed the control unit of the fixture. All results from Fixture A4 were therefore excluded from the analysis.

B. Illuminance Measurements

The Illuminating Engineering Society of North America (IESNA)'s *Lighting Handbook* sets application-dependent standards for illumination. For this pilot project, we measured the illuminance[9] on a fixture-by-fixture basis for all fixtures and compared the observed values to the IESNA standards for a parking garage. For each scenario included within the scope of the pilot project, the measured illuminance of each fixture significantly exceeded the IESNA illuminance standard in both the occupied and unoccupied lighting settings. To reiterate, the measured illuminance of absolutely all energy savings scenarios considered in this analysis exceeded the recommended illuminance standards for parking garages, in many cases by orders of magnitude.

Please see Appendix C for detailed IESNA standards and fixture-level illuminance measurements.

Section 3.2: Projected Performance of a Full-Garage Retrofit

Using the measured data from the twelve-fixture pilot project, we extrapolated energy savings for a full-garage retrofit. Given the limited number of fixtures involved in the pilot project, we incorporated a series of assumptions in order to project the full garage electricity consumption and corresponding savings. The itemized assumptions are described below.

- For each pilot fixture, we classify the lighting zone (referred to as "Zone Description" in Table 5) into four categories: 1) drive path, 2) parking stall, 3) stairwell entrance, and 4) elevator entrance. When possible, the average observed savings from all pilot fixtures with a specific zone description on a specific garage level were used to calculate expected savings of all fixtures in that zone description on that level for a full-garage retrofit.
- On Level A, all pilot fixtures were located along the drive path close to the garage and building entrances. We assumed that the observed savings from those pilot fixtures is equivalent to what we would observe across all of Level A for all area description categories upon a full-garage retrofit.

[9] Measurements were taken with an Omega light meter, Model HHLM112SF.

This is a conservative assumption since the lighting zone occupancy across the rest of Level A is most likely lower than that right by the garage and building entrance. Hence, we expect greater achievable savings.

- On Level B, all pilot fixtures used fluorescent lamps. In order to estimate the Level B energy savings for Scenarios 3-5, which all use LED lamps, we included an additive factor of 32% to the observed fluorescent T8 energy savings prior to extrapolating to all Level B fixtures. This factor is the approximate rated and observed difference in energy savings between the two lamp types at pilot fixtures.
- Because the pilot project only included fixtures on Levels A and B and not on Level C, we made the assumption that the traffic and resultant occupancy of Level C is equivalent to that on Level B. This is a conservative assumption, because the occupancy of Level C – the lowest level and furthest from the entrance – is in reality lower than Level B. Hence, we expect greater achievable energy savings.

Using these assumptions, the projected annual electricity savings for a full-garage retrofit is shown in Table 6. We project that with any of the five scenarios, the full-garage retrofit would enable at least 25%-72%, most likely more given our conservative assumptions.

Level	Projected Annual Electricity Savings by Scenario				
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
A	17%	16%	38%	49%	48%
B	27%	47%	38%	59%	78%
C	27%	47%	38%	59%	78%
Total	**25%**	**41%**	**38%**	**57%**	**72%**

TABLE 6: PROJECTED ANNUAL ELECTRICITY SAVINGS RELATIVE TO BASELINE FOR A FULL-GARAGE RETROFIT FOR EACH SCENARIO

As noted above, our assumptions leading to the projected savings shown in Table 6 are conservative assumptions. Therefore, we anticipate a higher achievable energy savings upon a garage-wide retrofit.

Section 3.3: Simple Payback Period

Using industry quotes, current utility incentive rates, and the projected annual electricity and maintenance savings, we calculated the simple payback period of the full-garage retrofit for every scenario, except Scenario 3[10]. The simple payback is number of years it will take to recoup all costs, which we calculate by taking the difference between the upfront costs and the utility incentives, and then dividing by the annual savings due to avoided electricity costs and O&M savings.

Each contribution to the simple payback calculation is as follow.

- ***Upfront Costs**:* The upfront costs include material costs, taxes, installation labor, and factory commissioning and training. The industry quotes were prepared by Enlighted and NEXT Lighting

[10] Given the specific details of the pilot project host site, a full garage retrofit would trigger the new Title 24 baseline, which mandates occupancy sensors. Scenario 3 would therefore not be Title 24 compliant.

specifically for the Palo Alto Civic Center's parking garage, and are based on the number of fixtures of the garage listed in Table 1.

- ***Utility Incentives****:* The Civic Center is eligible for a rebate of \$0.10/kWh applied to first-year's projected electricity savings relative to the Title 24 baseline[11].
- ***Annual Electricity Savings****:* There is annual savings due to avoided electricity costs using the projected full-garage energy savings calculated in Section 3.2. The Civic Center is currently operating under utility rate schedule E-18, the municipal electric service rate, which has a winter and summer rate (\$0.11479 and \$0.09249, respectively). We used an average between the summer and winter rates (\$0.10364) to calculate the avoided electricity costs.
- ***Annual Additional Operations and Maintenance (O&M) Costs****:* All assumptions used to calculate annual O&M costs compared to the baseline are itemized in Table 7, below. There are two contributions to the annual O&M costs.
    1. *Labor:* First, the annual O&M costs vary between scenarios. The fluorescent bulbs in our pilot study have a rated lifetime of 25,000 hours. LED lamps have a significantly higher rated lifetime of 50,000 hours. Additionally, dimming either the LED or fluorescent lamps may extend lamp lifetime for fluorescent and/or LED lamps, which we accounted for by extending the lamp lifetime by a factor of two for LEDs[12]. The labor costs of replacing lamps with extended lifetimes will be less than the baseline, since they do not need to be replaced as often. All scenarios incorporate these contributions to the lamp lifetime when calculating the labor contribution to O&M costs. We assumed that the O&M labor rate is \$83.18 per hour, which is the Davis-Bacon overall hourly rate (prevailing labor rate plus fringe benefits) for an electrician in Santa Clara County[13]. Furthermore, we assumed the lamp replacement rate to be 6 fixtures per hour.
    2. *Materials*: Second, the LED lamp replacement cost is estimated to be \$40, compared to \$4.50 for fluorescent lamps. We assume the lamp disposal cost is \$1.50 for both the LED and fluorescent lamps. These costs are incorporated into the materials contribution to the annual O&M costs.

Operations & Maintenance Assumptions	
Description	**Assumption**
O&M labor cost (\$/h)	\$83.18
Fixtures replaced per hour (#/h)	6
FL rated lamp lifetime (h)	25,000
LED rated lamp lifetime (h)	50,000
Factor of extended LED lifetime due to dimming	2
FL lamp replacement cost (\$/lamp)	\$4.50
LED lamp replacement cost(\$/lamp)	\$40
FL/LED lamp disposal cost(\$/lamp)	\$1.50

TABLE 7: ASSUMPTIONS USED TO CALCULATE ANNUAL OPERATIONS AND MAINTENANCE COSTS

[11] The Title 24 baseline was calculated using a spreadsheet model by Energy & Resource Solutions (ERS Inc.).

[12] Please note that this assumption may be optimistic. We were not able to find a third party study quantifying extended lifetime to verify industry claims.

[13] http://www.wdol.gov/

We also assume that the lifetimes of the fixtures and all components of the advanced lighting control systems are beyond the timescales resulting from the simple payback analysis.

The resultant simple payback periods for each of the five scenarios are shown in Table 8. As expected, Scenario 5, which incorporates the LED lamp retrofit and the Enlighted advanced lighting controls system operating in aggressive savings mode, has the shortest payback period.

Scenario No.	Upfront Costs	Utility Incentives	Annual Electricity Savings	Annual Additional O&M Costs	Simple Payback
1	$182,952	$7,408	$7,792	$0	22.5 yrs.
2	$182,952	$12,149	$12,610	$0	13.5 yrs.
3	N/A	N/A	N/A	N/A	N/A
4	$226,281	$12,392	$17,544	$319	12.4 yrs.
5	$226,281	$16,903	$22,226	$319	9.6 yrs.

TABLE 8: UPFRONT COSTS, UTILITY INCENTIVES, ANNUAL ELECTRICITY SAVINGS, ANNUAL ADDITIONAL O&M COSTS COMPARED TO BASELINE, AND RESULTANT SIMPLE PAYBACK PERIOD

Section 3.4: Stakeholder Feedback

In addition to analyzing new prospective lighting systems with respect to energy savings and measured illuminance, we also sought stakeholder feedback. Specifically, we targeted two groups of stakeholders for feedback: 1) parking garage users and 2) facilities maintenance staff.

A. Parking Garage Users' Perspective

We sought qualitative feedback from parking garage users on the following three primary areas.

1. Quality of lighting
2. Sensitivity of motion sensors
3. Perception of safety

A number of circumstances limit our ability to implement an effective stakeholder survey of parking garage users for the pilot system. Most notably, due to cost considerations, the scale of the pilot project is very limited: 12 fixtures are included in the pilot project out of over 600 fixtures total across the entire 3-level parking garage.

In spite of this significant limitation, staff conducted a stakeholder walk-through of the parking garage to get qualitative feedback on the advanced lighting controls technology. During the walk-through, we led a group of 8 stakeholders to a series of small clusters of fixtures, each of which was included in the pilot. At each cluster, we asked the stakeholders for their feedback on the three areas outlined above, for both the occupied and unoccupied modes. Each fixture cluster was surrounded by the traditional T8 lighting. A copy of the survey is included as Appendix A.

Leaders from the following City departments and organizations participated in the stakeholder walk-through.

- Palo Alto's Downtown Business Group
- Planning & Community Environment Department, City of Palo Alto

- Police Department, City of Palo Alto
- Public Works Department - Traffic Operations, City of Palo Alto
- Public Works Department - Engineering, City of Palo Alto
- Public Works Department - Facilities, City of Palo Alto
- Utilities Department - Resource Management, City of Palo Alto

Qualitative trends in their feedback are summarized below.

- When asked "Does this lighting meet your expectations for quality?", stakeholders preferred the quality of the LED lighting compared to the T8 lighting.
- Stakeholders showed strong support for the City's efforts to increase efficiency and save energy in the Civic Center's Parking Garage.
- Stakeholders showed strong support for the modernizing the Civic Center's Parking Garage lighting system.
- A number of stakeholders were dissatisfied with the sensitivity of the occupancy sensors and their resultant perception of safety. The occupancy sensor response is highly dependent upon where the sensor is mounted on the light fixture relative to the direction of the pedestrian's approach.

Overall, stakeholder feedback from parking garage users was overwhelmingly positive. However, results indicate there is still room for improvement. One way to address the stakeholders' feedback related to the sensitivity levels of the occupancy sensors is by coordinating the occupancy-response between neighboring fixtures, which is a feature supported by the Enlighted advanced lighting controls system. For instance, when a specific fixture's occupancy sensor is triggered, that fixture and the fixtures immediately around it can be programmed to all concurrently switch to occupied mode. In this way, the area lit up during occupied mode would have a larger footprint. It is worth noting that only a lighting system with two-way communication would be able to implement this type of coordinated response. Fixtures with stand-alone sensors do not have the capability to coordinate their response.

Please note that in addition to the limitation of having a small number of pilot fixtures compared to the total number of fixtures in the garage, additional limitations of the stakeholder survey include the following.

- The stakeholder group included only eight people.
- The stakeholder group was comprised solely of men.
- The stakeholder group did not include any senior citizens, youth, children, or those with special needs.
- The survey took place at 3:30 pm in the afternoon, when ambient lighting near certain clusters of pilot fixtures was significant.

We believe the qualitative trends in feedback outlined above would remain unchanged upon correcting for these limiting factors.

B. Facilities Maintenance Staff's Perspective

In addition to stakeholder feedback representing parking garage *users*, we also solicited feedback from the City's facilities maintenance staff on maintenance-related concerns. The feedback we received is as follows.

- The more complex the lighting system is, the more difficult it will be for staff to maintain. An advanced lighting controls system has a number of components, including sensors, fixtures/lamps, gateways, and software. Therefore, when a component fails, trouble-shooting and repairing the system could be significantly more complicated and time-consuming.

- The interior of the parking garage is power-washed approximately once per year. Any advanced lighting controls components should be certified to withstand exposure to moisture, at least as well as the traditional T8 lighting system.[14]
- The longer lamp life of the LED lamps would serve to reduce maintenance time.

The Enlighted advanced lighting controls system incorporates a number of features that are designed to address facilities maintenance staff concerns, including those concerns listed above. For instance, although the advanced lighting controls system does have more components than the existing lighting system, if either the control unit or the sensor unit that are installed at the fixture-level fail, the fixture light level will revert to 100%. Furthermore, the Energy Manager interface includes fixture outage reports that list the locations of failed fixtures, which could eliminate labor associated with manual floor surveys to locate fixture and lamp failures. Maintenance staff training would be required upon installing advanced lighting controls and is already incorporated into the project cost estimates included in this report.

Enlighted offers and recommends an IP65-rated sensor that can withstand exposure to moisture from power-washing the garage interior. The IP65-rated sensor was not used in this pilot project because of limited inventory at the time of the pilot project installation. We do not expect that using the IP65-rated sensor would have impacted the observed results of this pilot.

One additional feature of Enlighted products that could also help facilities maintenance staff is the temperature readings from the sensor units. Sensor units, which are connected to every single fixture, also read and communicate temperature readings, along with other lighting system data. The Enlighted product therefore could help facilities maintenance staff to more easily trouble-shoot HVAC systems by allowing them to inspect a facility's heat map for local hot spots.

CHAPTER 4: CONCLUSIONS

Through the parking garage users stakeholder survey, we found overwhelming support for modernizing the lighting system, for reasons of perceived lighting quality in addition to enhanced energy and operational efficiency. The primary issue that emerged from the pilot project is sufficiently addressing facilities maintenance staff concerns about the complexity of the system and the associated barriers to proper trouble-shooting and maintenance. Given that proper understanding and use is key for realizing the full energy savings potential of advanced lighting controls, we recommend that these concerns be sufficiently addressed prior to embarking on a full retrofit.

The simple payback periods for the five scenarios investigated in this report ranged from 22.5 to 9.6 years, and our calculations were based on conservative assumptions. The most energy efficient scenarios – Scenarios 2, 4, and 5 – had the lowest payback periods, ranging between 9.6 - 13.5 years. This payback period is well within the range of what is generally considered an acceptable payback period for a municipal

[14] The current T8 lighting system complies with the IP65 standard.

organization. Through a similar pilot project investigating LED streetlamp retrofits in Palo Alto conducted through the U.S. DOE Solid-State Lighting Technology Demonstration GATEWAY Program, the projected payback periods were estimated to be 9-13 years[15]. That study was published in June 2010. Immediately after the completion of the pilot project, in part due to positive public feedback and the dual economic and environmental benefits[16], the City embarked on a multi-year streetlight retrofit project to convert all City streetlamps in a series of five phases planned through the 2015 calendar year[17]. The City is currently underway with Phase III, after which, approximately 85% of the City's streetlamps in Palo Alto will be LEDs.

Like the LED streetlight retrofit project, this pilot project demonstrated strong stakeholder support and payback periods of around a decade. Retrofitting the Palo Alto Civic Center underground parking garage – and other similar municipally-owned parking garages – would therefore be consistent with the City's prior and ongoing policies and supporting activities to increase energy and operational efficiency, such as was the case with the LED streetlight retrofit project.

[15] http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/gateway_palo-alto.pdf
[16] The LED streetlight retrofit was listed in Palo Alto's 2007 Climate Action Plan
[17] https://www.cityofpaloalto.org/ledstreetlights/

APPENDIX A: REFLECTIVE CEILING PLAN OF THE PILOT SITE

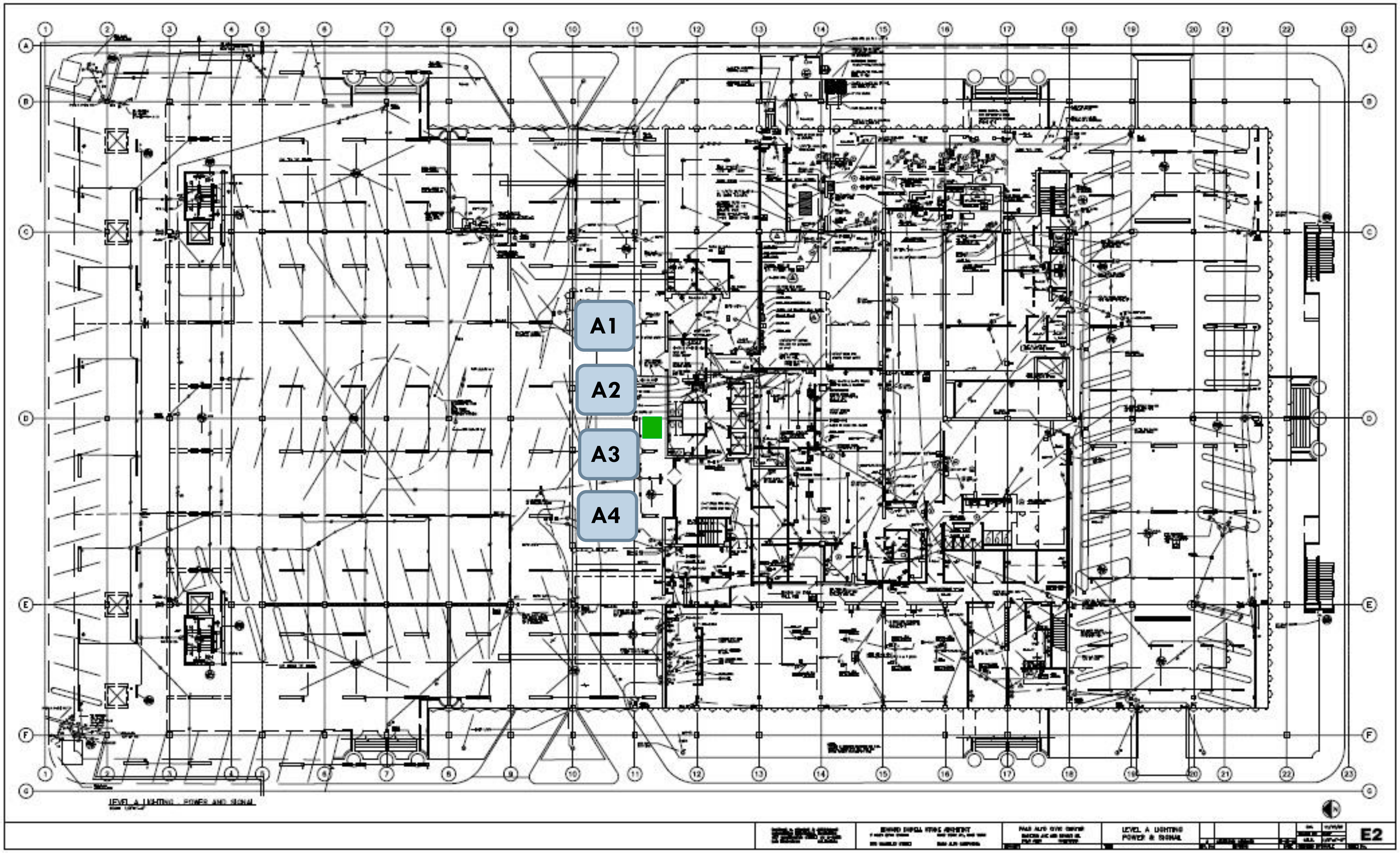

FIGURE 1: REFLECTIVE CEILING PLAN OF PALO ALTO CIVIC CENTER PARKING GARAGE, LEVEL A, SHOWING THE LOCATION OF THE GATEWAY (GREEN RECTANGLE) AND PILOT FIXTURES (LABELED BLUE RECTANGLES)

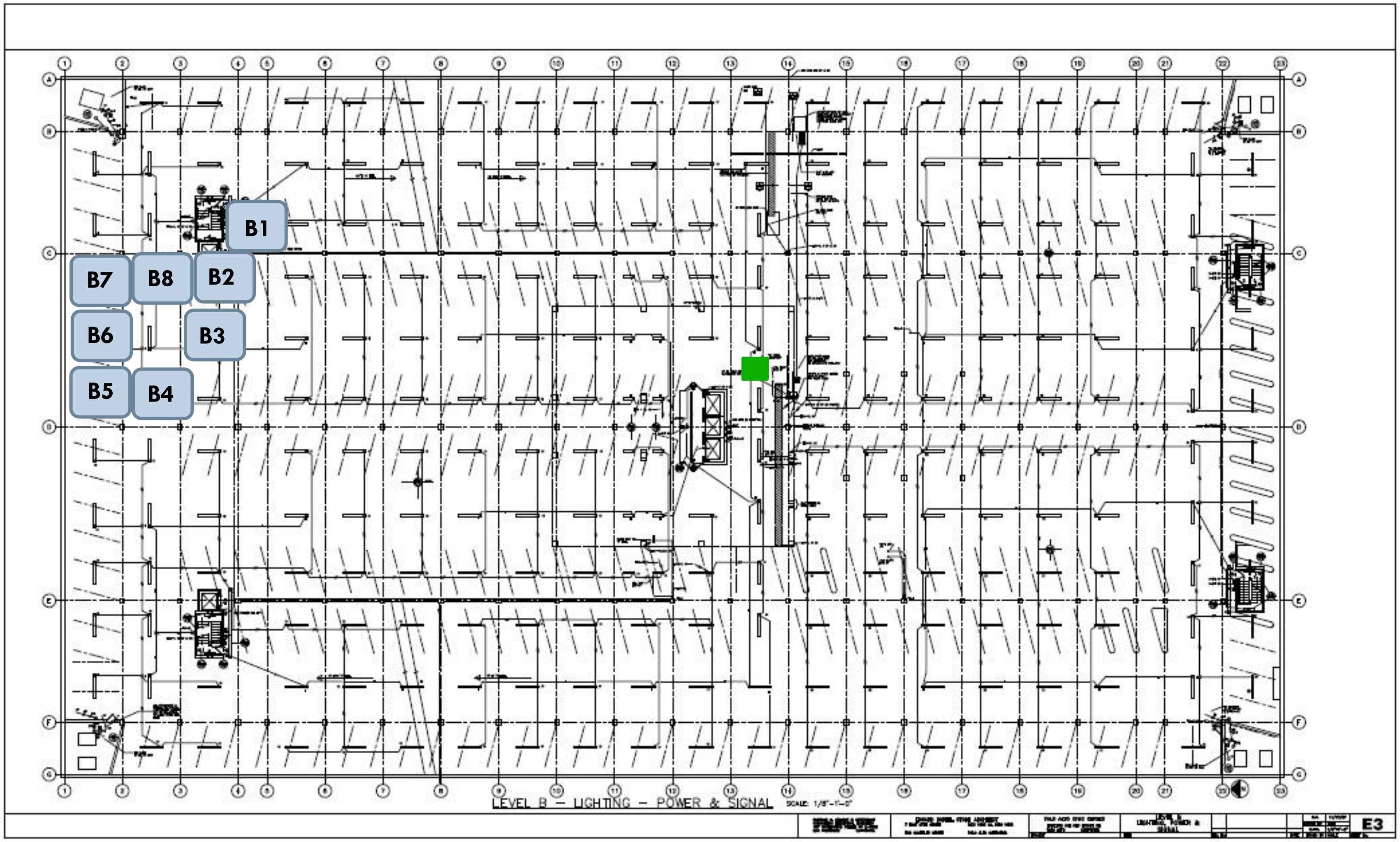

FIGURE 2: REFLECTIVE CEILING PLAN OF PALO ALTO CIVIC CENTER PARKING GARAGE, LEVEL B, SHOWING THE LOCATION OF THE GATEWAY (GREEN RECTANGLE) AND THE PILOT FIXTURES (LABELED BLUE RECTANGLES)

APPENDIX B: STAKEHOLDER SURVEY

City Hall Parking Garage Stakeholder Walk-through
CPAU Facilitators: Christine Tam, Bruce Lesch, Aimee Bailey
March 10th, 2014

Stop #1, Parking Garage, Level A

T8 lighting		
	Is this lighting level adequate in unoccupied mode? (Y/N)	**Is this lighting level adequate in occupied mode? (Y/N)**
Setting 1		
Setting 2		
Setting 3		
Setting 4		
Setting 5		

1. *Does this lighting meet your expectations for quality? (Circle one)*

1	2	3	4	5
Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree

Additional comments:

1

Stop #2, Parking Garage, Level A

LED lighting		
	Is this lighting level adequate in unoccupied mode? (Y/N)	Is this lighting level adequate in occupied mode? (Y/N)
Setting 1		
Setting 2		
Setting 3		
Setting 4		

1. *Does this lighting meet your expectations for quality? (Circle one)*

1	2	3	4	5
Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree

Additional comments:

2

Stop #3, Parking Garage, Level B

T8 lighting		
	Is this lighting level adequate in unoccupied mode?	Is this lighting level adequate in occupied mode?
Setting 1		
Setting 2		
Setting 3		
Setting 4		
Setting 5		
Setting 6		

1. *Does this lighting meet your expectations for quality? (Circle one)*

1	2	3	4	5
Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree

2. *Are the motion sensors sensitive enough? (Y/N)*

Additional comments:

3

Stop #4, Parking Garage, Level B

LED lighting	
Are the motion sensors sensitive enough? (Y/N)	
Relative to the T8 lamps, does this lighting meet your expectations for quality? (Y/N)	
Do you feel that this lighting level is adequate? (Y/N)	

Additional Questions

1. *Do you support the City's efforts to increase efficiency and save energy in the City Hall Parking Garage?*

   1 2 3 4 5

2. *Do you support the City's efforts to modernize the City Hall Parking Garage lighting system?*

   1 2 3 4 5

Please provide any additional feedback here:

*** *Thank you for your participation!* ***

4

APPENDIX C: ILLUMINANCE MEASUREMENTS AND STANDARDS

Table 8 shows the measured illuminance of each individual fixture for five distinct settings using the Enlighted advanced lighting controls system: 100%, 75%, 65%, 50%, and 25%. The illuminance was measured vertically at 60”. Measurements were taken directly below the center of the fixture and five feet in either direction perpendicular to the fixture’s primary axis.

ID	Lamp	Garage Level	Area Description	Illuminance Measurement (foot-candles) Vertical FC at 60”				
				100%	75%	65%	50%	25%
A1	FL	A	Drive path	38	29	26	16	8
A2	FL	A	Drive path	16	12.5	10	9.5	6.5
A3	LED	A	Drive path	21	13.5	10.5	7.5	5
A4	LED	A	Drive path	40	31	28	19	7.5
B1	FL	B	Elevator	15	11	9	5	3
B2	FL	B	Stall	14	12	10	8	5
B3	FL	B	Drive path	15	10	9	7.5	4
B4	FL	B	Drive path	20	13	12	9.5	5
B5	FL	B	Stall	14	10.5	8	6.5	4
B6	FL	B	Stall	12	10	7	5.5	3.5
B7	FL	B	Stall	13	11.5	8	6	2
B8	FL	B	Drive path	18.5	12	11	9	6

TABLE 9: ILLUMINANCE MEASUREMENTS OF EACH OF THE TWELVE PILOT PROJECT FIXTURES

Please note that fixture A1 and fixture A4 have a significantly higher illuminance. This is due to the fact that they are located on the ground level close to the parking garage entrance; therefore, the illuminance incorporates significant ambient light.

Illumination standards from the Illuminating Engineering Society of North America for parking garages are shown in Table 10[18]. As seen by comparing Table 9 with Table 10, for each fixture, all light levels investigated – 100% down to 25% – meet the minimum IESNA requirements for all areas of the parking garage.

Parking Garage Area Description	Foot-candle Measurement Vertical FC at 60”
Basic	0.5
Entrance, Day	25
Entrance, Night	0.5
Ramps, Day	1
Ramps, Night	0.5
Stairways	1

TABLE 10: IESNA STANDARDS FOR LIGHTING IN PARKING GARAGES

[18] *The IESNA Lighting Handbook, Ninth Edition,* Figure 22-22.