CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Draft Measure Information Template – Parking Garage Lighting and Controls

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team, March 2011

This report was prepared by the California Statewide Utility Codes and Standards Program and funded by the California utility customers under the auspices of the California Public Utilities Commission.

Parking Garage LPA and Controls

2013 California Building Energy Efficiency Standards

February 15, 2011

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1. Methodology

Parking garage lighting is considered an interior space, even though in most cases, the structure is unconditioned. It therefore falls under Section 146 for lighting power allowances (LPAs) and Section 131 for controls requirements. However, the top deck of parking garages are considered exterior spaces and fall under Section 147 lighting power allowances and Section 132 controls requirements. As a result, parking garages straddle the line between the two in some respects.

It may be for this reason that an aggressive analysis and review of the LPA values and controls requirements have not been done as part of the regular code revision cycle. The LPA values currently are relatively low compared to most interior spaces, so there is a general consensus that there may not be much to be gained through such a review.

The code revision cycle for Title 24 has all but eliminated the easy gains over the years, so the review of lighting in parking garages is logical and there are opportunities within the current system.

The parking garage lighting analysis focused on LPA reduction and lighting controls requirements, including daylight- and occupancy-responsive controls. Several different points of review in this revision cycle include:

- Review the LPA values and determine if there is room to tighten the allowances.
- Review the current controls requirements for parking garages and determine whether controls are viable for mandatory measure implementation.
- Analyze daylighting controls to determine cost effectiveness and conditions of use.
- Analyze occupancy sensor controls to determine cost effectiveness and conditions of use in garage applications.

1.1 Review of LPA values in Title 24-2008

The lighting power allowances for parking garages were examined in relation to current market technology and IESNA illuminance criteria to determine whether or not the LPAs could feasibly be reduced.

This involved developing six different typical parking garage configurations and calculating the power density necessary to meet the IESNA design recommendations for parking garages (RP-20).

This review process considered a variety of light source technologies, including linear fluorescent, induction, metal halide, high-pressures sodium (HPS), and light-emitting diode (LED). In this analysis, no daylighting benefits were considered, so the electric lighting systems were required to meet the full design criteria values.

Once the various lighting design variables were collected, a review of the performance of the various approaches was completed to ensure that the recommended reductions in the LPA would not make any reasonable light source technology unusable.

1.2 Review Title 24-2008 Controls Requirements and Controls Viability

Parking garages are mostly exempt from lighting controls under Title 24-2008. Neither daylighting controls nor occupancy controls are required. Additionally, time switch curfew controls are not required.

Most parking garages are not secure facilities, and it is not possible to be certain that a vehicle or pedestrian will not enter the building. Because of this, parking garages are mostly operated in a 24/7 manner with the only controls in the spaces employed in the adaptation zone near the entry. Since stairwells and elevator lobbies are often considered paths of egress, those areas are typically operated without controls.

As part of this review, both light source technology limitations and controls limitations were considered to ensure that a mandatory measure would not be severely limited due to either of these factors.

1.3 State of Market and Pilot Project Review

In order to understand the feasibility and potential effectiveness, the current state of the market was examined with respect to sensors, lamp/ballast combinations and dimming equipment for outdoor lighting. This review of the market involved an assessment of currently-available luminaires and sensor technology, as well as discussions with manufacturers regarding the future of exterior occupancy sensors. This effort also included a review of pilot programs that demonstrated bi-level street and area lighting control, including:

- California Polytechnic State University, SLO, Parking Lot Lighting Retrofit [PIER Buildings Program];
- California Polytechnic State University, SLO, Street Lot Lighting Retrofit [PIER Buildings Program];
- California Department of Public Health Parking Lot Lighting Retrofit [California Lighting Technology Center];
- University of California, Davis, Parking Lot Lighting Retrofit [California Lighting Technology Center];
- University of California, San Francisco, Parking Lot Lighting Retrofit [California Lighting Technology Center];
- City of San Marcos Parking Garage Lighting Retrofit [California Lighting Technology Center];
- Los Angeles Trade Technical College Parking Lot Retrofit [California Lighting Technology Center];
- Irvine Parking Lot Phase 2 Lighting Retrofit [Southern California Edison];
- Raley's Supermarket Parking Lot Lighting Retrofit [DOE GATEWAY];
- TJ Maxx Parking Lot Lighting Retrofit [DOE GATEWAY].

Data logger files were provided by the CLTC for the CLTC and PIER demonstration projects, which allowed further in-depth analysis of the results of those studies. Since all of the demonstration projects were retrofits, significant energy savings were realized from the luminaire technology change alone, so this was discounted when the comparisons were made.

1.4 Analyze Daylighting Controls

Daylighting is prevalent in many parking garages, so the CASE team felt that a daylighting control measure could be readily implemented. Further, daylighting occurs at the best times of the day to take advantage of the highest Time Dependent Valuation (TDV) energy costs, so cost effectiveness is all but assured in most cases.

The following items were analyzed as part of this study:

- Determine wall cross-section and window requirements to ensure more than adequate daylighting penetration.
- Verify that the electric light sources are not able to mitigate the contrast introduced by daylighting (sidelighting) under typical conditions.
- Calculate the depth of penetration into a space for sidelighting situations where the lighting is still useful.
- Make cost effectiveness calculations based on the geometry limitations discovered above.

With these items finalized, the recommended code language was developed to accommodate the benefits and limitations of a basic sidelighting condition.

For toplighting situations, the same approach used in interior toplighting should be employed, because the conditions are similar, and no specific conditions could be devised that seemed to require a separate approach from the currently employed toplighting infrastructure.

1.5 Analyze Occupancy Sensor Controls

Occupancy sensors require another set of review steps to ensure that occupancy control is viable as a mandatory measure. A number of issues make this measure less clear-cut, so this review was as rigorous and extensive as was viable within the time constraints of this revision cycle.

The various steps in this review included:

- Determine the various methods of occupancy control that may be employed in a parking garage lighting system (discreet sensors, integral sensors, etc.).
- Create an energy model of a simple garage configuration to test the cost effectiveness and overall usefulness of an occupancy sensor control system.
  - Further, use this model to establish the conditions under which an occupancy control system will no longer maintain cost effectiveness (find the 'Bust' threshold).
  - Evaluate how extreme these conditions are to determine whether the cost effectiveness is likely to be assured for all reasonable use scenarios.
- Review the variety of PIER and DOE Gateway projects related to controls to determine if there are any unexpected problems with the implementation of lighting controls in parking garage spaces.

- Use data from the various PIER and GATEWAY studies to create a composite volume of traffic diagram that can be applied to the energy model.

With these research items completed, the recommendations for the code language changes were developed to ensure an effective implementation of the mandatory measure.

2. Analysis and Results

2.1 Review of LPA values in Title 24-2008

The process of reviewing the Title 24-2008 values included several different steps to produce all the information necessary:

- Determine typical parking garage configurations and dimensions.
- Verify IESNA design criteria for parking garages.
- Determine currently-available lighting and controls equipment options.
- Model lighting options for power density calculations.
- Analysis of results.
- Determine recommended LPA values.

2.1.1 Determine Typical Parking Garage Configurations and Dimensions

In order to examine the lighting power allowances for parking garages, six typical garage configurations were created. To determine what typical parking garage configurations to use in the simulations, various sources were reviewed, including local municipal codes, existing facilities, and design manuals, for reasonable configurations and dimensions.

The Los Angeles Department of Building and Safety (LADBS) parking design requirements (effective 10-1-99) were selected to assist in creating typical parking garage configurations, which includes required minimum dimensions for parking stalls and drive aisles that directly correlate to the overall parking garage dimensions.

Six different parking garage configurations were considered:

1. Single helix with two-way traffic;
2. Double helix with two-way traffic;
3. One-way flat floor with one-way ramps;
4. One-way flat floor with two-way ramps;
5. Single helix 'up' with circular dedicated 'down' ramp;
6. Flat floors with circular dedicated 'up' and 'down' ramps.

Figure 1 illustrates these six configurations.

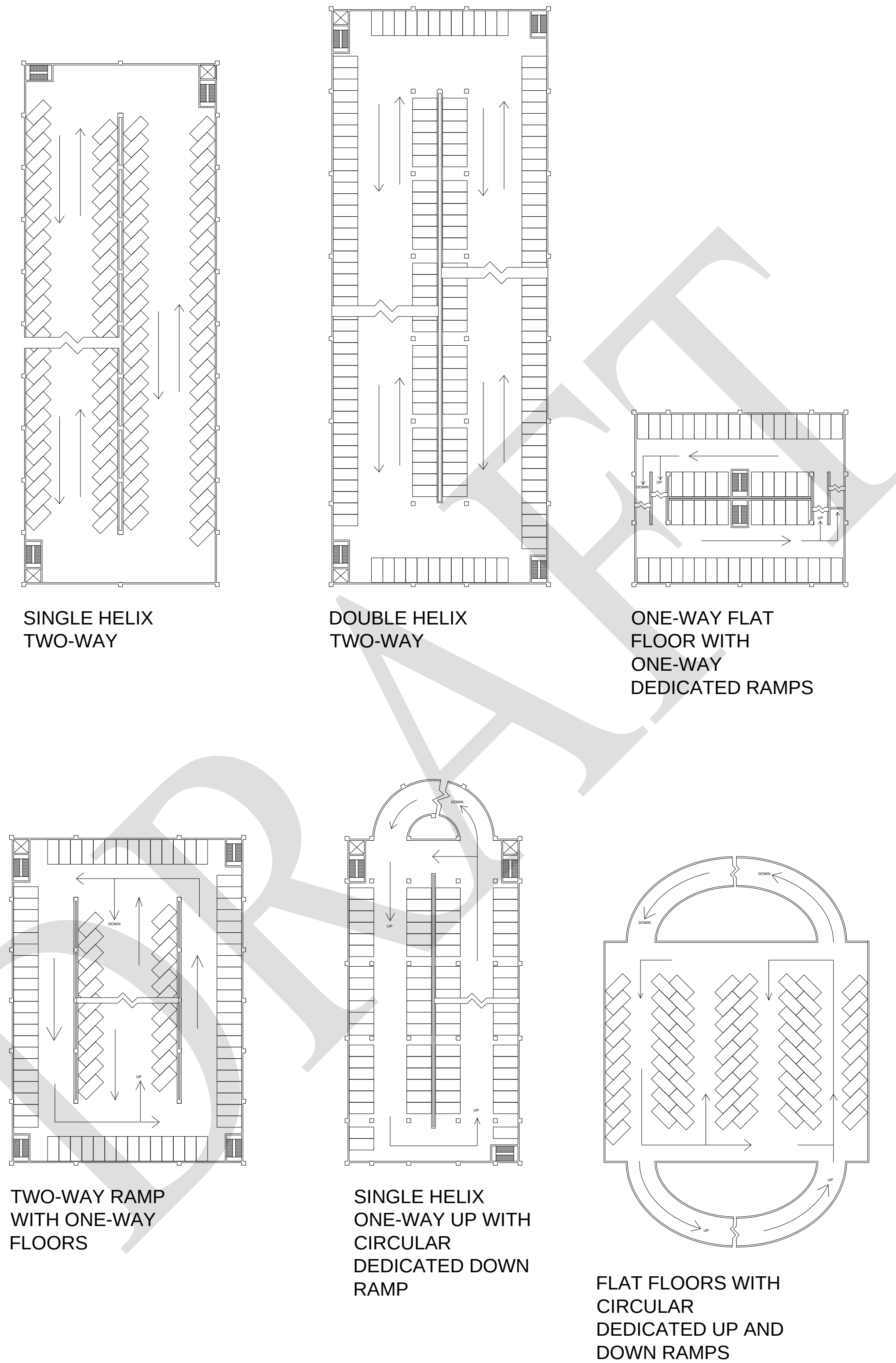

Figure 1: Typical Parking Garage Configurations

2.1.2 Verify IESNA Design Criteria for Parking Garages

IESNA criteria for parking garage interiors were examined. The recommended illuminance criteria for parking garages are included in Figure 2 below, per IESNA *Lighting for Parking Facilities* (RP-20-98 - Table 2).

Area	Minimum Horizontal Illuminance, [fc]	Maximum: Minimum Horizontal Uniformity Ratio
Basic	1.0	10:1
Ramps (Night)	2.0	10:1
Entrance Areas (Night)	1.0	10:1

Figure 2 : Parking Garage Lighting Design Criteria

Note that this does not include the 'rule of thumb' guideline that is stated in a note below the guideline table, which effectively states that the designer can use five foot-candles for preliminary design. This basic guideline is not part of the actual design criteria, and while the approach to apply more light than is necessary may have been viable at one time, this approach can no longer be reliably applied within the State of California with some light sources and garage configurations because it may not meet the LPA limits.

Only the specific lighting design criteria listed in Figure 2 above were applied when establishing the LPA values for the parking garage parking and drive aisle areas.

2.1.3 Determine Currently-Available Lighting and Controls Equipment Options

Currently available equipment options appropriate for parking garages were examined, and luminaire and control system manufacturers were engaged to discuss the future of parking garage lighting. It was determined that luminaires utilizing High-Intensity Discharge (HID) and linear fluorescent lamp technologies are both widely available and commonly used. LED and induction technologies provide alternatives, and are often used in retrofit scenarios.

The availability of luminaire-integrated controls was also reviewed, and it was shown that integral occupancy sensing in parking garage luminaires is still not widely available from multiple manufacturers. However, the availability of interior parking garage luminaires with integral occupancy sensors is increasing. In general, manufacturers are providing the option for an integral occupancy sensor on fluorescent, LED, and induction luminaires, all of which are capable of simple bi-level control. As of February 2011, no standard luminaire has been found that can be provided with integral occupancy sensing to control HID luminaires.

2.1.4 Model Lighting Options for Power Density Calculations

Based on the review of typical parking garage luminaires and the 'typical' parking garage configurations, a series of illuminance calculations were performed using the lighting calculation software AGI32 to establish the minimum power density required to meet the IESNA criteria. These calculations were performed on a series of four configurations:

1. Deep cross-section: perpendicular parking on both sides with two-way drive aisle.
2. Mid cross-section: perpendicular parking on exterior side only with two-way drive aisle.
3. Shallow cross-section: diagonal parking on exterior side only with one-way drive aisle.
4. Infinite parallel planes (theoretical minimum, not tied to a particular geometry).

Figure 3 shows the layouts for configurations 1 (Deep), 2 (Mid) and 3 (Shallow). While deeper configurations are likely to exist, as shown in Figure 1, the Deep cross-section configuration shown below was restricted to a depth more appropriate for quantifying the impact of sidelighting.

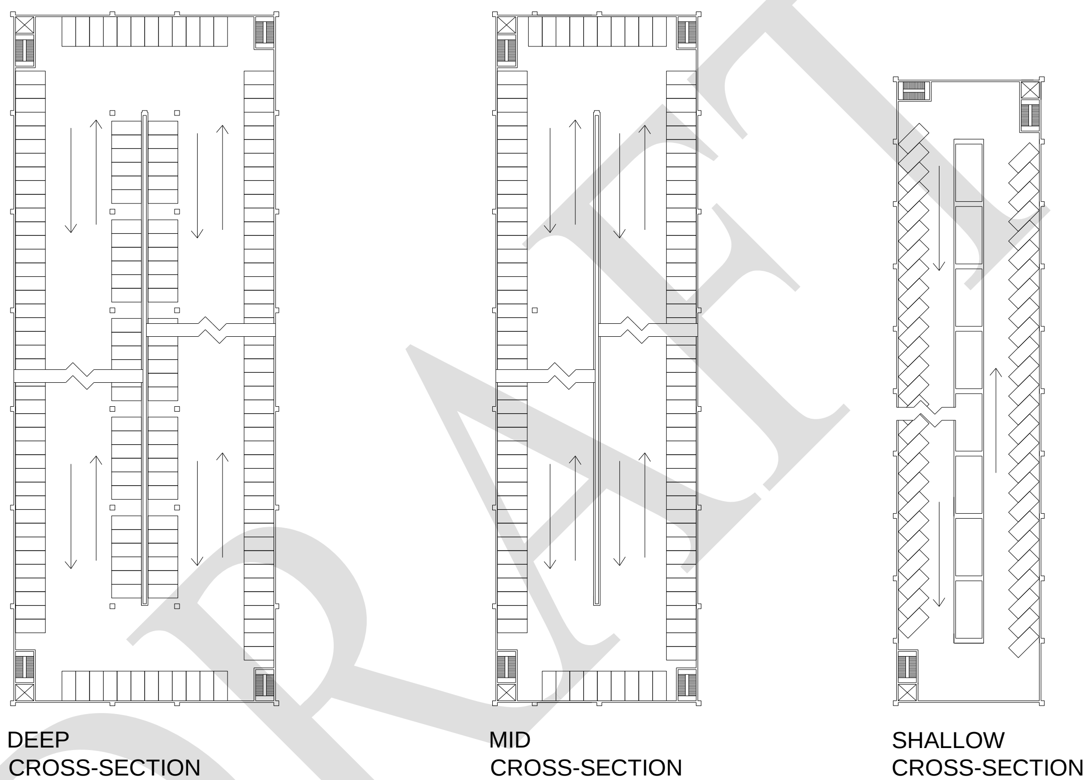

Figure 3: Garage Configurations for Lighting Power Density Calculations

This calculation effort was focused on the basic parking areas of the garage, which account for the majority of the typical floor plate through all of the 'typical' configurations reviewed. Illuminance calculations were conservative, using manufacturer-rated mean lamp lumens, a 70% Luminaire Dirt Depreciation (LDD), and low interior surface reflectances (15% Floor, 25% Ceiling, and 30% Walls).

This framework shifts the baseline technology from HID, which was the baseline technology for the 2008 and previous code revision cycles, to linear fluorescent, which is a very common and low-cost method of illuminating parking garages. Linear fluorescent appears to be the most prevalent light source technology employed in the State, especially in the warmer environments. While this shift was performed, the adjusted LPA values will still accommodate HID sources when the garage is designed using reasonable quality lighting equipment.

2.1.5 Analysis of Results

The results of the power density calculations indicate that there is room in the LPA values to lower the basic parking allowance considerably and still leave room for all lighting source technologies to meet or exceed the recommended design criteria. Refer to Figure 4 and Figure 5 below for the calculation results for a variety of different light sources and luminaire types based on the Deep cross-section configuration. Refer to Appendix B: Power Density Calculations for the full calculation results.

			Lamps			Deep			
Luminaire Type	Description	Luminaire Efficiency	Qty	Type	Luminaire Input Watts	LPD	E (min)	Max: Min	E (avg)
FL 1	Lamar Occu-Smart	85%	2	T8	55	0.072	1.0	7.20	3.69
FL 2	Columbia Gasketed	88%	2	T8	55	0.068	1.0	8.50	4.03
FL 3	Columbia Bare Strip	89%	2	T8	55	0.072	1.1	6.55	3.81
FL 4	Columbia Bare Strip	89%	1	T8	27	0.053	1.0	4.10	2.83
FL 5	Lithonia VAP, Wide	76%	2	T8	55	0.084	1.0	8.30	4.44
FL 6	Prudential White Wrap	61%	1	T8	27	0.048	1.1	2.27	1.67
FL 7	Prudential White Wrap	62%	2	T8	55	0.099	1.0	6.30	3.91
					Average:	**0.071**			
					Maximum:	**0.099**			
					Minimum:	**0.048**			

Figure 4: Fluorescent Illuminance and Power Calculation Results

			Lamps			Deep			
Luminaire Type	**Description**	**Luminaire Efficiency**	**Qty**	**Type**	**Luminaire Input Watts**	**LPD**	**E (min)**	**Max: Min**	**E (avg)**
MH 1	Gardco GP1	87%	1	PSMH	129	0.085	1.0	4.70	2.81
MH 2	Lithonia PGR	81%	1	MH	140	0.078	1.1	4.82	2.37
MH 3	McGraw-Edison EPL	81%	1	MH	151	0.071	1.0	7.50	3.17
MH 4	Widelite RSP	74%	1	MH	129	0.074	1.0	3.50	2.11
HPS 1	Gardco GP1	87%	1	HPS	130	0.076	1.1	3.45	2.61
HPS 2	KIM PGL4	86%	1	HPS	108	0.060	1.0	5.50	2.34
HPS 3	Lithonia PGR	82%	1	HPS	135	0.074	1.1	5.27	2.60
HPS 4	McGraw-Edison EPL	79%	1	HPS	150	0.068	1.0	7.40	3.46
HPS 5	RUUD F515-SCL	78%	1	HPS	170	0.112	1.4	9.07	4.85
LED 1	BetaLED 304	N/A	60	LED	110	0.060	1.0	5.10	2.58
LED 2	Gardco ELG 70LA	N/A	49	LED	68.7	0.048	1.0	3.70	2.62
LED 3	KIM PGL7	N/A	60	LED	73.1	0.042	1.0	2.00	1.62
LED 4	Widelite VIZOR 24"	N/A	60	LED	68	0.040	1.0	3.00	1.75
IND 1	Gardco GP1	83%	1	IF	85	0.068	1.0	4.70	2.18
IND 2	KIM PGL4	91%	1	IF	86.8	0.069	1.0	5.70	2.33
IND 3	Widelite RSP	88%	1	IF	85	0.072	1.0	5.10	2.27
IND 4	Everlast Bi-Level	not reported	1	IF	82.6	0.060	1.1	8.36	3.40
					Average:	**0.068**			
					Maximum:	**0.112**			
					Minimum:	**0.040**			

Figure 5: Other Sources Illuminance and Power Calculation Results

Based on the luminaire density needed to meet IESNA criteria, the resulting equipment cost density was evaluated to understand the cost impact of switching to fluorescent as the technology baseline. The equipment cost density divides the unit cost for a luminaire by area associated per luminaire, and provides a basic understanding of the cost to install a lighting system in a general lighting condition like this application. This information is provided in Figure 6 for two conditions. First, based on the illuminance calculations, the minimum equipment cost density needed to meet IESNA criteria was determined. Second, to normalize the comparison based on a desired power density of 0.14 WPF instead of illuminance criteria, the resultant equipment cost density was determined.

			Minimum Spacing To Meet Criteria				Spacing To Meet 0.14 W/sf			
Luminaire Description	Unit Cost	Input Power (High Mode)	E-W Spacing	N-S Spacing	LPD	Cost Density	E-W Spacing	N-S Spacing	LPD	Cost Density
4' (2) T8 Striplight with Wireguard, Standard Ballast	$ 60	55	28	28	0.072	$ 0.08	20	20	0.140	$ 0.15
4' (2) T8 Striplight with Wireguard, Bi-Level Ballast	$ 105	55	28	28	0.072	$ 0.14	20	20	0.140	$ 0.27
4' (2) T8 Washdown Striplight, Standard Ballast	$ 110	55	29	28	0.068	$ 0.14	20	20	0.140	$ 0.28
4' (2) T8 Washdown Striplight, Bi-Level Ballast	$ 120	55	29	28	0.068	$ 0.15	20	20	0.140	$ 0.31
Everlast Bi-Level Induction Luminaire, 70W	$ 406	83	38	37	0.060	$ 0.29	24	24	0.140	$ 0.68
Everlast Bi-Level Induction Luminaire, 70W, With Integral Occupancy Sensor	$ 491	83	40	46	0.045	$ 0.27	24	24	0.140	$ 0.83
Kim 100W HPS Luminaire, Standard Ballast	$ 326	108	42	43	0.060	$ 0.18	28	28	0.140	$ 0.42
Widelite LED, No Integral Controls	$ 1,502	68	40	43	0.040	$ 0.87	22	22	0.140	$ 3.09
Widelite LED with Integral Occ Sensor & Dimming Driver	$ 1,830	68	40	43	0.040	$ 1.06	22	22	0.140	$ 3.77
Beta LED (estimated cost)	$ 750	110	38	48	0.060	$ 0.41	28	28	0.140	$ 0.95
Kim LED	$ 736	73	40	43	0.042	$ 0.43	23	23	0.140	$ 1.41
Kim LED with integral Occ Sensor & Dimming Driver	$ 955	73	40	43	0.042	$ 0.56	23	23	0.140	$ 1.83
Kim 85W Induction Luminaire, Standard Electronics (Not Bi-Level)	$ 508	87	38	33	0.069	$ 0.41	25	25	0.140	$ 0.82

Figure 6: Equipment Cost Density Analysis

The results of this analysis indicate that the linear fluorescent systems can be substantially less expensive for a parking garage, which is a good indication why it is the most commonly employed design approach. Note that these values do not include installation, wiring or other associated costs, so the total installed costs will differ somewhat from those calculates above.

2.1.6 Determine Recommended LPA Values

From these calculations, the recommended LPA for parking areas was set at a level that allows all examined technologies to meet IESNA criteria in all evaluated configurations.

The analysis of the parking garage lighting power density illustrated the potential for reducing the current LPA. The results of the calculations show that the fluorescent baseline design is driven mostly by meeting the 1.0 fc minimum requirement, as the fluorescent system has much higher uniformity in general than other systems considered. In general, these alternate light source technologies are driven mostly by the uniformity design guideline.

These calculations support a reduction in the LPA from 0.20 WPF to 0.14 WPF. The overall delivered illuminance in the various designs is provided, and shows that even at the low power density necessary to meet the design criteria; there is often higher minimum illuminance values than are necessary. Figure 7 lists the recommended changes to the LPA values based on the Area Category method.

Allowance	Recommended Change?	Title 24-2008 LPA	Recommended LPA
Parking Garage - Parking Area	Reduce LPA by 0.06 WPF	0.20 WPF	0.14 WPF
Parking Garage – Ramps and Entries	Split 'Ramps' & 'Entries' into two separate categories.	0.60 WPF	-
Parking Garage – Dedicated Ramps	Reduce 'Ramps' LPA by 0.30 WPF	-	0.30 WPF
Parking Garage – Daylight Adaptation Zones	No changes	0.60 WPF	0.60 WPF

Figure 7: Recommended Changes to Parking Garage LPA Values found in Table 146-F; Area Category Method

The 'Ramps' LPA was adjusted based on the design criteria as well, but in this case, the 2008 allowance was excessively high because 'Ramps' was previously included with 'Entries', which has the very specific visual task requirement of adaptation from exterior light levels. The portion of the garage just inside the entry door must have enough light to provide a reasonable distance of vision into the space as the driver's visual system adapts from high exterior light levels to much darker interior light levels. For this reason, the LPA in this zone needs to be substantially higher than in the general garage.

The ramps do not require this adaptation lighting, and should be separated from the entry zone to permit a more appropriate LPA value. With the 'Ramps' separated from 'Entries', the LPA can be lowered substantially, from the original 0.60 WPF value to a much more appropriate 0.30 WPF. Because of the very specific visual task requirements, no changes are recommended to the new 'Entries' category.

Based on the LPA values for 'Parking Area' and 'Ramps and Entries', the Title 24-2008 whole-building allowance is comprised of approximately 13% 'Ramps and Entries' and 87% 'Parking Area'. Of that, 70% was assumed to be ramps and 30% entry areas. As a result, the recommended complete-building LPA was determined based on this distribution of areas in combination with the revised LPA recommendations, as shown in Figure 8.

Allowance	Recommended Change?	Title 24-2008 LPA	Recommended LPA
Parking Garages	Reduce LPA by 0.10 WPF	0.30 WPF	0.20 WPF

Figure 8: Recommended Changes to Parking Garage LPA Values found in Table 146-E; Complete Building Method

Cost-effectiveness of LPA reductions was not evaluated as the cost-effectiveness for reducing LPAs is implicit. As shown, the reduced LPA is achievable with all types of luminaires examined, and therefore makes to assumption that higher-cost equipment must be used. Energy cost savings are achieved by reducing the number of luminaires and therefore reduced energy consumption and maintenance costs are expected.

2.2 Review Title 24-2008 Controls Requirements and Controls Viability

Section 131 currently exempts parking garages from most controls, so the baseline for controls consideration is currently that none are required.

A state of the industry review was performed to assess the status and potential future capabilities for several aspects of this work, including:

- Sensor capabilities and limitations;
- Lamp/ballast interactions and limitations;
- Dimming limitations in various light source technologies; and
- Review existing PIER and GATEWAY projects to inform decision-making.

2.2.1 Sensor Capabilities and Limitations

Sensors have a limited range that results in some geometry problems when attempting to use the sensor in large area lighting conditions. This can result in 'dead zones' that can be quite extensive, especially when considering the potential shadowing associated with vehicles and other obstructions in a parking garage.

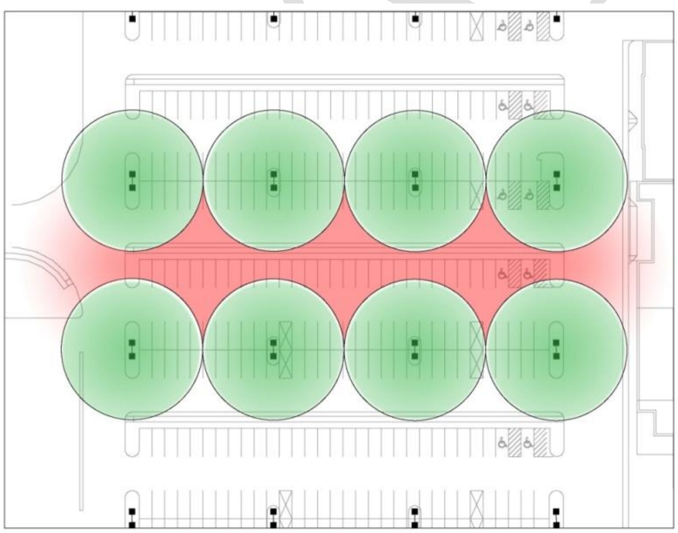

Figure 9: Illustration of PIR Sensor Range Limitations with Sensor Radius of 50 Feet

The example shown in Figure 9 uses a parking lot example where pole spacing, and thus sensor spacing, must be large, but the same problem can occur in parking garages. Because the mounting height of the sensor is limited by the ceiling height and on-center spacing are not limited to pole spacing, parking garages are generally conducive to appropriate sensor coverage. However, coverage that may be adequate in an empty garage could be obstructed by larger vehicles that cause 'shadows' of invisible areas, called 'dead zones'.

This particular issue has not been addressed adequately in design guidance documentation, and awareness of the problem is low. One retrofit study (SCE, 2009) tested the coverage patterns in the garage, and found the coverage insufficient. More details on this are found in Appendix C: Lighting Controls Limitations Survey. Other preliminary studies have shown that this is a concern, and more attention needs to be given to the potential problem. This is not an issue of viability, but of execution, so this does not reduce the potential for controls in parking garages.

Refer to Appendix C: Lighting Controls Limitations Survey for a discussion and review of sensors for lighting control in parking garages.

2.2.2 Lamp/Ballast Interactions and Limitations

There are some limitations associated with HID ballasts and lamps that limit the number of viable options for designers. However, research indicates that all lamp wattages are supported for bi-level capability, either through the lamp manufacturer, or through a third-party ballast manufacturer.

The largest issue with these interactions is the warranty support for the lamps when used on another manufacturer's ballast. There needs to be more clarity within the industry about warranty support before the implementation of this measure will be readily and fully supported by all aspects of the lighting industry, especially lighting designers, equipment installers, and end users/owners.

However, the technology is capable of supporting the mandate, and the time associated with actual adoption of this Title 24 revision will add additional time for manufacturers to develop capabilities beyond what is currently available.

LED light sources will likely revolutionize the exterior lighting industry as well, replacing most low and medium wattage light sources within 5 years. LED technology is much more readily dimmed, has few of the technical limitations of HID sources, and should also not have issues associated with warranty support, since the LED is ultimately part of the luminaire and must be supported by the luminaire manufacturer rather than by a separate lamp manufacturer.

Refer to Appendix D: Lamps and Ballasts for Bi-Level Control for more detailed information supporting this section.

2.2.3 Dimming Limitations of Various Light Sources

All of the light source technologies reviewed are capable of a 50% reduction in power input, though fluorescent, LED and induction sources can dim much farther. The National Electrical Manufacturers Association recommends that HID lamps be dimmed no further than a 50% reduction in power input (NEMA, 2002).

The current language in Section 131 for multi-level lighting controls calls for "at least one control step that is between 30 percent and 70 percent of design lighting power." It is clear that a light source technology that can dim further may achieve greater energy savings in unoccupied situations.

Many of the newer light sources, including LED, are capable of dimming beyond that range, and as far as 90 percent. Additionally, low-cost fluorescent dimming ballasts are available that are capable of dimming as far as 80 percent. While not a focus of this analysis, a change to the dimming range limitation to accommodate this greater dimming capability is worth consideration for future code revision cycles.

Refer Appendix D: Lamps and Ballasts for Bi-Level Control for more detailed information on this section.

2.3 Pilot Project Review

In reviewing the pilot projects listed in 1.3 State of Market and Pilot Project Review, the addition of occupancy-responsive controls provided additional energy savings by allowing the luminaires to operate in 'LOW' mode when vacancy was detected. The logger data files and additional information provided by the CLTC regarding sensor delay times and coverage patterns were analyzed to estimate the actual occupancy patterns in the garages that resulted in the energy savings reported in the submitted documents.

Review of the CLTC data and additional pilot programs demonstrated that occupancy-based lighting controls can lead to significant energy savings in parking garages. The savings of those projects are tied directly to their occupancy profiles and sensor delay times, and therefore the savings realized is likely not typical of parking garages in general because aggressive (short) delay times appear to have been used on many of the projects. Further information, including the analysis of the CLTC data, can be found in Appendix F: Pilot Project Review Documentation.

Based on the data files provided by the CLTC for four university parking garage demonstration projects and the delay times as reported by the CLTC, the approximate occupancy patterns within each garage were examined. Since the data logger files were based on illuminance measurements at the luminaire, they effectively include the impact of the sensor delay time, so it is unclear exactly how many occupancy "events" occurred within the periods of high mode operation. Therefore, estimates were made to determine approximately how many occupancy "events" would have been required to maintain the lighting in "HIGH" mode for the durations shown. The average number of occupancy "hits" that each sensor sees was determined for each data logger for each pilot study, and then those curves were combined to create the approximate activity profiles as shown in Figure 10.

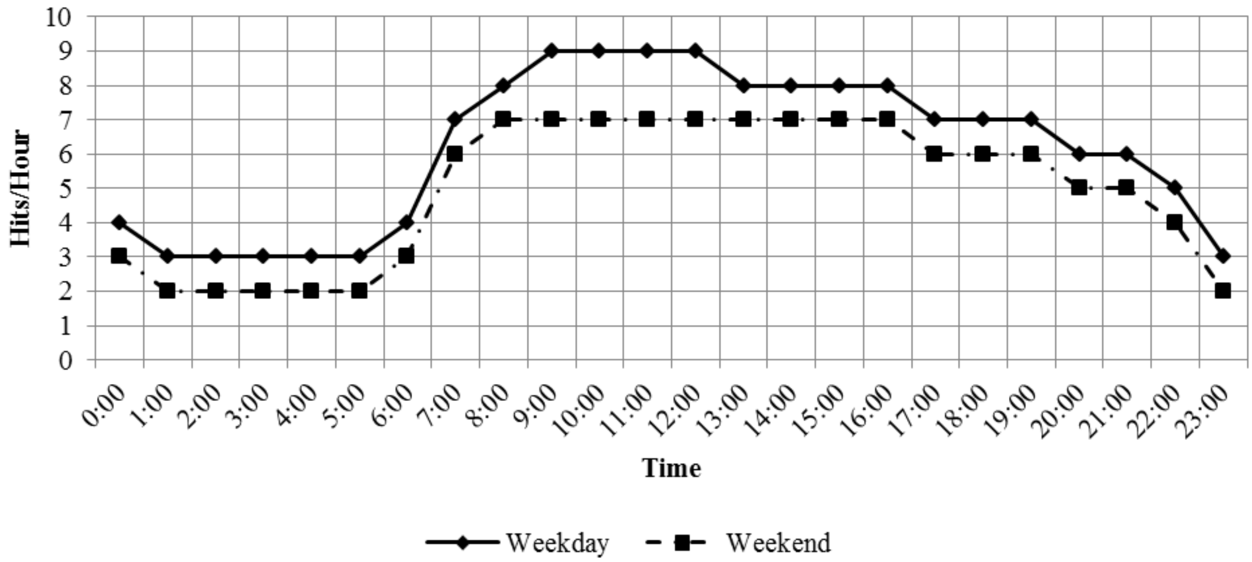

Figure 10: Activity Profile for University Parking Garages Determined based on CLTC Data Analysis

Since the specific test sites within the demonstration parking garages varied, the activity curve was assumed to apply to the mid-point of the garage. This activity curves was then applied to the advanced simulation model to evaluate the energy savings.

2.4 Daylighting Controls Analysis

The potential success of daylight-responsive controls as a mandatory measure was examined using the lighting calculation software AGI32. Five configurations were established, all with a length of 175 feet, a width of 175 feet and a height of 13 feet. The opening-to-wall height ratio was varied beginning at 35% up to 65% to determine the minimum threshold required for effective daylighting. Illustrations defining these opening ratios are shown in Figure 11 through Figure 15.

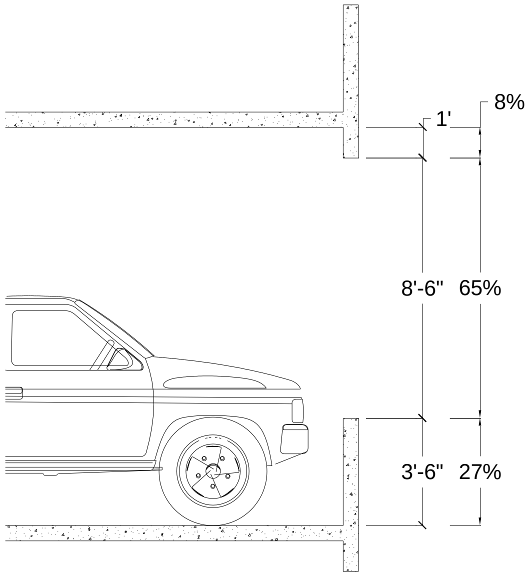

Figure 11: Cross-section of 65% Opening-to-Wall Height Ratio

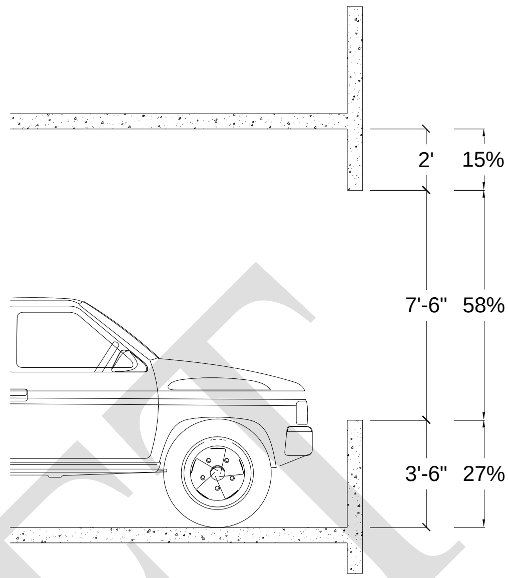

Figure 12: Cross-section of 58% Opening-to-Wall Height Ratio

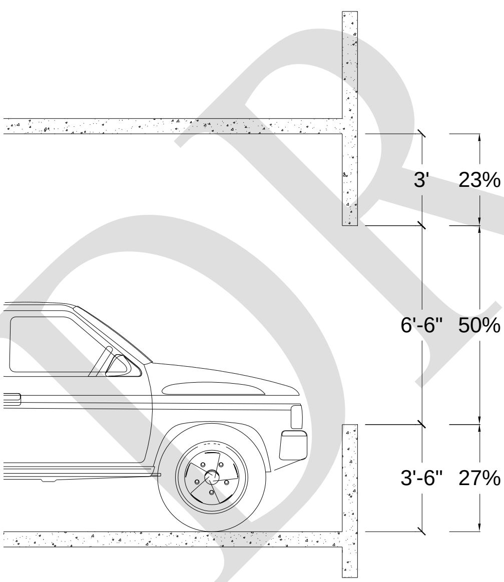

Figure 13: Cross-section of 50% Opening-to-Wall Height Ratio

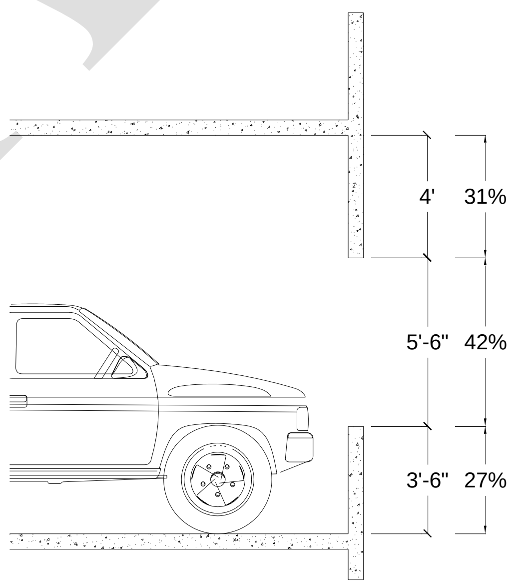

Figure 14: Cross-section of 42% Opening-to-Wall Height Ratio

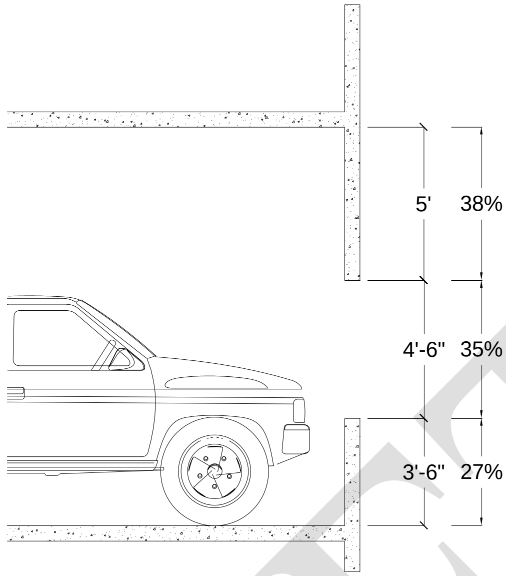

Figure 15: Cross-section of 35% Opening-to-Wall Height Ratio

Prior to the simulations, the availability of daylight-responsive control system equipment for parking garages was examined. Both integral and remote sensing technologies were reviewed and pilot studies including daylight-responsive controls were reviewed.

The daylight calculations were performed under the following conditions:

- Three days of the year: summer and winter solstice and equinox;
- Three times per day: 9AM, Noon, and 3PM;
- Two sky conditions: clear and overcast;
- Each simulation was performed with and without a row of cars parked directly in front of the window.

These calculation conditions were selected since they allow for a simplified analysis of the daylighting potential throughout the year and are typical daylighting calculation conditions.

The four cardinal directions were analyzed independently. The distance into the space at which the horizontal illuminance dropped below 25 fc was identified for each of the five models, as that illuminance level is five times the IESNA 'rule-of-thumb' guide of providing 5 fc average in parking garages. This level was selected because it is a point where the electric lighting (which often averages about half of the 'rule of thumb' value) will be 10% of the daylight delivered illuminance. Defining the lighting zone with this threshold permits several things to occur:

- The daylighting will be considerably higher than the electric lighting, so fluctuations in the daylighting will not necessitate cycling of the electric lighting system to ensure adequate light levels for design criteria.
- This level is high enough that the electric lighting will not be a substantial impact at the point of threshold, but beyond the daylighted zone boundary, the daylight contribution decreases rapidly, so electric lighting will be required to deliver full design illuminance.

- This is ultimately a conservative location, based on calculations that included vehicles in the spaces, so while a more aggressive approach may save more energy, this approach ensures that there is adequate light for less than ideal conditions.
- This threshold also makes it viable to ignore the orientation of each wall of the garage, simplifying design approaches for the design community.
- The geometry of typical parking garages makes this threshold a logical location once the analysis determined how far into the space this threshold would reliably be located.

The five models were then compared to determine the effective daylighted zone depth as well as the minimum window-to-wall ratio that will provide effective daylighting. The full results of this analysis are shown in Appendix G: Energy Modeling Documentation.

The results suggest that the daylighting is effective even in situations where the daylight availability is less than ideal, and in many cases, the effectiveness of defining a daylighting zone are not limited by general daylight availability for any orientation of the window, under all reasonable window cross-section conditions exceeding 40% of the wall height, and independent of the number of cars located directly at the window.

Based on the daylight autonomy calculations as shown in Appendix G: Energy Modeling Documentation, it was determined that the 'typical' anticipated time during which the daylighting is sufficient to extinguish the luminaires in the daylighted zone is approximately 30.7% of the total year. Incorporating that estimate with calculated luminaire layouts for three typical cross-sections, the anticipated percentage of annual energy savings was calculated, as shown in Figure 16:

		Number of Luminaires	Input Watts per Luminaire	Total Watts	Luminaires within Daylit Zone	% W in Daylit Zone	Annual % Time Daylit Zone is "OFF"	Annual % Savings	Average E	Minimum E	Max:Min Uniformity	Overall LPD
Fluor.	Shallow	30	53	1,590	14	47%	30.7%	14.3%	5.90	1.1	5.36	0.134
	Medium	59	53	3,127	17	29%	30.7%	8.9%	6.33	1.0	7.03	0.139
	Deep	78	53	4,134	18	23%	30.7%	7.1%	6.77	1.6	4.23	0.139
HID	Shallow	14	118	1,652	0	0%	30.7%	0.0%	6.79	2.2	5.41	0.134
	Medium	27	118	3,186	12	44%	30.7%	13.7%	7.02	3.1	3.16	0.136
	Deep	36	118	4,248	10	28%	30.7%	8.5%	7.41	4.6	2.30	0.138
LED	Shallow	14	124	1,736	0	0%	30.7%	0.0%	6.79	2.2	5.41	0.134
	Medium	27	124	3,348	12	44%	30.7%	13.7%	7.02	3.1	3.16	0.136
	Deep	36	124	4,464	10	28%	30.7%	8.5%	7.41	4.6	2.30	0.138
						Mean	**Shallow**	4.8%				
							Medium	12.1%				
							Deep	8.1%				

Figure 16: Summary of Impact of Daylight Calculations

This analysis does not make a value judgment on the 'usefulness' of the daylight that is penetrating the space. To assist this understanding, a glare analysis was performed to understand how the daylighting and electric lighting interact in a parking garage space.

2.4.1 Daylighting Glare Analysis

When considering daylight-responsive controls, it was important to understand the visual impact of electric lighting on interior daytime visibility. Using the five models from the daylight penetration calculations, a series of simulations were performed to determine the luminance contrast between the sky and the interior surfaces.

The simulations were performed both with and without the contribution from electric lighting, and the ratio of diffuse surface luminance directly adjacent to the window to the effective diffuse sky luminance was quantified for each model. Again, these simulations were performed on three days (both solstices and one equinox) at three times per day (9AM, 12PM and 3PM) and under both clear and overcast skies. Figure 17 presents a rendering from one model with the electric lighting 'ON', and the point values shown on all surfaces indicate the diffuse luminance. Figure 18 presents a rendering from the same model with the electric lighting 'OFF', and the diffuse luminance values are again shown.

Figure 17: Clear Sky: Electric Lighting 'ON'

Figure 18: Clear Sky: Electric Lighting 'OFF'

There is general belief in the industry that daylight from the windows will reduce visibility and create a contrast condition that is too great for human vision to handle without using the electric lighting to counteract that effect. This is the greatest argument against daylight dimming controls in parking garages. The results of these simulations are provided in Figure 19. They indicate that regardless of the electric light operation, the lighting conditions result in somewhat high contrast and the electric lighting is incapable of improving the contrast conditions. While electric lighting designed to meet the IESNA recommended criteria does not increase the contrast, it does little to improve the situation.

									Typical Change in Contrast due to Electric Lights	
Model #	Window Width	Window Height	Number of Windows per Wall	Wall Length	Wall Height	Window: Wall Ratio	Average Eelectric	Max:Min Eelectric	Overcast Day	Clear Day
1	27	8.5	4	117	13	60.4%	6.50	2.71	-0.61%	-0.16%
2	27	7.5	4	117	13	53.3%	6.51	2.71	-0.61%	-0.14%
3	27	6.5	4	117	13	46.2%	6.39	2.59	-0.60%	-0.12%
4	27	5.5	4	117	13	39.1%	6.45	2.54	-0.60%	-0.13%
5	27	4.5	4	117	13	32.0%	6.53	2.47	-0.59%	-0.14%

Figure 19: Summary of Contrast Calculation

As daylight penetrates into a parking garage space from a typical sidelit configuration, the angle of light propagation approaches horizontal. This is specifically the conditions where glare and decreased visibility are perceived, so this condition was considered in these modeling exercises. This is an additional reason that the 25 footcandle threshold was used for the daylighting analysis discussed above; when this threshold was used, the daylight zone was reliably calculated to be 20 feet or greater in the simulations.

The demarcation at 20 feet has a variety of lighting and physical benefits that support it as the selection of the penetration limit for daylighting, including:

- The geometry of typical parking garages essentially sets the daylight zone at slightly greater than a single parking space depth, but not as much as a parking space plus 1/2 of the drive lane width. This is significant because if a single luminaire is used in the design of the garage (in a typical 'space-drive lane-space' cross-section) it is possible to locate it at the center of the drive lane and not have it turned 'OFF' by the daylight sensor, which can potentially leave the opposite side of the space darker than desired.
- The 20 foot depth line will be deep enough that the benefit is substantial, but not too deep that the only source of light is a very low-angle daylight condition where glare and shadowing effects are a source of visibility problems. Beyond the 20 foot line, electric light sources will begin to take over the lighting requirements in the space, ensuring uniformity and design criteria are met for the remainder of the garage floor plate.
- The 20 foot line is typically going to capture a single row of luminaires along the window wall but will not capture a second row unless the spacing is tight. In a two-row across arrangement of luminaires, one half of the fixtures will be captured.

As a result, the limit of daylight zone calculations is recommended to be 20 feet in from the window. Other details and limitations included in the recommended Section 131 documentation are mostly a result of geometry conditions:

- The minimum window-to-wall height ratio of 40% of the wall height. This ensures adequate light levels even on cloudy days, and regardless of orientation.
- Parking garage side lit zones will be 20 feet deep, or to the first 5 foot high vertical obstruction. This maintains consistency with other sidlit definitions.
- The sidelit width will be the width of the window plus 2 feet on each side, or to the nearest wall, whichever is lesser. This allows for otherwise continuously daylighted zones with up to a 4 foot wide solid area between to be considered continuously daylighted, accounting for structural interruptions to the window or opening.

Additionally, it is recommended that the controls requirement state that the lighting in the sidelit zone must be 100% 'OFF' rather than mandating a bi-level approach. Since the lighting calculations have indicated that a full power lighting system does little to help the contrast in a parking garage, a dimmed system will be of no benefit at all, and more energy will be saved.

There are several exceptions that are recommended to the requirements:

- A skylit or sidelit area that totals less than 250 square feet is not required to be controlled, even if a luminaire is present in the daylight zone.
- Sidelit zones where an adjacent structure is twice as tall as the distance away. The obstruction must be at least as wide as the window for this to be applied.
- Any lighting required for egress or emergency lighting.
- Lighting specifically in the daylight adaptation zone or on dedicated ramps.

2.5 Occupancy Controls Analysis

Occupancy controls have different conditions than daylight controls that make a mandatory measure less clear-cut with respect to cost effectiveness and overall logical application. Some of these issues are:

- Occupancy sensors create energy savings during low activity periods, typically at night when the TDV costs are at their lowest.
- The effectiveness of occupancy sensors is strongly dependent on a variety of factors, including occupancy volume, occupancy patterns, and delay time. These all interact to make a clear picture of the benefit of occupancy sensors less clear.
- Because of the reduced LPA values, occupancy sensors may cut the light levels below the IESNA recommended light level design criterion. This will require that occupancy sensors be effective at sensing occupancy by either a car or pedestrian to ensure that the garage space is not below recommended design levels when occupied.
- There is very little knowledgebase available on use patterns or volumes of traffic in parking garages that can be employed to model the impact of sensors.
- Occupancy sensors will be more useful the further from the entry and exit points the control zones are located. Sensors near the entries and exits may not be cost effective, depending on traffic volumes.

However, occupancy sensors have a variety of benefits that make them appealing for a mandatory control requirement:

- Occupancy sensors can effectively work in tandem with daylight sensors to bring down the 24-hour energy consumption by targeting times when daylight sensors are ineffective.
- Occupancy sensors will be applied to the full parking area, not just on the perimeter near the windows, so the benefit is potentially greater depending on the design of the parking garage.
- Underground parking garages will be able to employ occupancy sensors, but are unlikely to be able to employ daylight sensors.
- In some cases, the setback light levels will increase lamp longevity, reducing maintenance costs.

To do a thorough analysis of the occupancy sensor energy benefits a series of tasks were performed:

- Develop a matrix of calculation variables.
- Develop a prototype parking garage model.
- Develop prototype occupancy use profiles.
- Run the model for simulated 'normal' conditions.
- Perform analysis of the results.

2.5.1 Develop a Matrix of Calculation Variables

To develop an energy calculation model that will represent the full range of conditions that may be found in parking garages, a matrix of input variables was developed to ensure that all reasonable conditions were simulated during the analysis process. Figure 20 below provides a list of the primary variables used in the simulations:

	USE TYPE	TRAFFIC VOLUME	DAYLIGHT AVAILABILITY	% ZONES DAYLIGHTED	ELECTRIC LIGHT SOURCE	SENSOR DELAY TIME
INPUT VARIABLES	OFFICE PARK / MIXED-USE / TRANSPORTATION	HIGH / MEDIUM / LOW	GOOD / MODERATE / POOR	80% / 50% / 20%	FLUORESCENT / HID / LED / INDUCTION	5 DIFFERENT DELAY SLOTS AVAILABLE

Figure 20: Matrix of Primary Calculation Variables

These variables are discussed in Section 2.5.3 Develop Prototype Occupancy Use Profiles below.

Figure 21 indicates the secondary calculation variables. These variables do not impact functionality of the system, and therefore can be applied post-hoc to examine the impact on cost-effectiveness. For example, all of the equipment and installation costs are calculated in present value and can be added to the TDV-weighted 15-year annual energy cost to understand the impact of various physical configurations that produce the same functionality.

	SENSOR CONFIGURATION	SENSOR COST	LIGHTING EQUIPMENT COST	SYSTEM MAINTENANCE
INPUT VARIABLES	INTERNAL / REMOTE	VARIABLE	VARIABLE	VARIABLE

Figure 21: Matrix of Secondary Calculation Variables

2.5.2 Develop a Prototype Parking Garage Model

Life-cycle cost analysis of both daylight- and occupancy-responsive controls as a mandatory measure was conducted. In order to perform the life-cycle cost analysis, a detailed simulation program was created using Visual Basic through Microsoft Excel. The simulation program requires various physical inputs, including the size of the garage, daylight availability, lighting system and number of zones. Two types of occupancy profiles are also input into the simulation. This is discussed in the section 2.5.3 Develop Prototype Occupancy Use Profiles below.

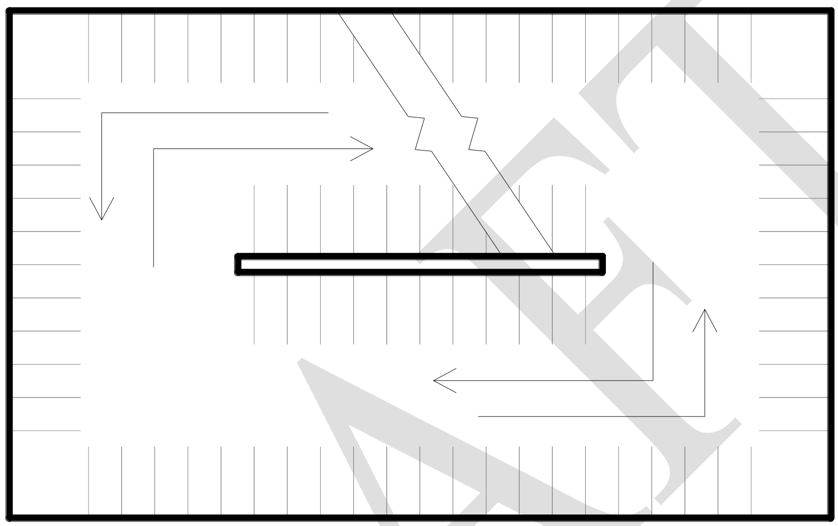

Figure 22: Prototype Parking Garage Model

The physical shape of the modeled parking garage is comparable to a single helix garage as shown in Figure 22. It was set to contain 320 parking spaces over 4 floors of parking. There is no top deck parking included in this design, so it represents most closely a garage within a larger building. However, the design also fairly represents a garage with a top deck, except the volume of the garage would be increased slightly to accommodate the higher total number of cars the garage can hold. This adjustment would decrease the energy savings slightly.

The single helix has the most straightforward geometry for modeling the impacts of a car entering and leaving the garage. It does not provide any 'shortcut' exit routes for a vehicle, so it may result in a higher prediction of traffic volume in the space compared to a double helix or other design.

In the model, each lighting control zone was given a number starting at the entry zone, and increased as the vehicle drives through the garage up to the top. The highest control zone number represented the furthest possible driving distance from the entry that a car can travel.

Based on the input occupancy profiles and physical information, a year of activity was simulated to estimate the impact of the control systems. For each hour of the year, the simulation randomly assigns all incoming traffic and cues cars in 15 second intervals to avoid simultaneous arrivals. It was assumed that the cars filed into the garage perfectly by parking in the first available space.

The hourly exits were then randomly assigned to times within the hour and queued to avoid having a negative garage population. The exiting was also assumed to be random in that any car in the garage can leave. The simulation then determines the hourly impact of the entrance and exit 'events' on the different lighting control systems that are simulated simultaneously for all of the individual control zones within the garage.

The twelve control systems include an 'UNCONTROLLED' scenario, which functions at full power independently of daylight and occupancy, a control system that responds only to daylight, and the ability to input five different occupancy sensor delay times and evaluate their impact both with and without daylight-responsive controls. One possible matrix of the twelve control system is listed below, but the delay time can be varied, so not every run used the same matrix:

CONTROL SYSTEM	OCCUPANCY SENSING?	TIME DELAY	DAYLIGHT CONTROL?
BASELINE	✗	N/A	✗
DAYLIGHT ONLY	✗	N/A	✓
1A	✓	1 Minute	✗
1B			✓
2A	✓	2.5 Minutes	✗
2B			✓
3A	✓	5 Minutes	✗
3B			✓
4A	✓	7.5 Minutes	✗
4B			✓
5A	✓	10 Minutes	✗
5B			✓

Figure 23: Simulated Control Systems

The hourly duration of 'HIGH', 'LOW' and 'OFF' operation for each control zone is then determined across the full year, and weighted by TDV to determine the present value of 15 years of energy use. The initial costs of the system, including the electrical and lighting installation costs, are included, as well as the on-going maintenance costs associated with lamp replacements, luminaire cleaning and sensor failures, to determine the 15-year present value of the system.

To quantify the impact of daylight availability, an input parameter was created within the simulation program to effectively adjust the daylight hours. This parameter varied from 'GOOD' daylight availability, which provides effective interior daylighting from a half hour after sunrise to a half hour before sunset. 'MODERATE' daylight availability has useable daylight hours 1 1/2 hour after sunrise to 1 1/2 hour before sunset. 'POOR' daylight availability shrinks the useable daylight hours to 3 hours after sunrise to 3 hours before sunset. The simulation also allows for the number of daylighted zones per floor to be varied to allow an analysis of the impact of the physical geometry with regard to daylighting.

Next, a series of run inputs was created which systematically varied the input parameters to provide a parametric analysis. These inputs included the analysis of various lighting technologies, including fluorescent, HID, LED and induction, all of which have varying associated equipment and electrical costs in addition to variations in the availability of integral occupancy sensing.

The results of the simulation provided an overall estimate of the cost-effectiveness of the lighting controls. The parametric analysis provided insight into the limiting conditions for cost-effectiveness.

2.5.3 Develop Prototype Occupancy Use Profiles

In order to use the simulation program, a series of occupancy profiles were created for analysis. Three archetypal profiles were created to understand the impact of different use types, based on an office park which has regular hours and little night-time activity, a mixed-use facility which has high daytime and evening activity, and a transportation facility which has a steady 24/7 occupancy. For each of these three archetypal profiles, three levels of occupancy were created as 'HIGH', 'MEDIUM' and 'LOW' occupancy. Additionally, based on the results of the CLTC data analysis, a university profile was created for analysis.

The baseline occupancy profile is first established as the percentage of the total garage that is occupied at the beginning of each hour, and can be thought of as effectively counting the percentage occupied the garage is at the beginning of each hour. This defines one aspect of the volume of traffic. Figure 24 below shows the three levels of occupancy for Weekdays for the Office Park Garage Profile, Figure 25 shows the profiles for Saturdays, and Figure 26 shows the profiles for Sundays.

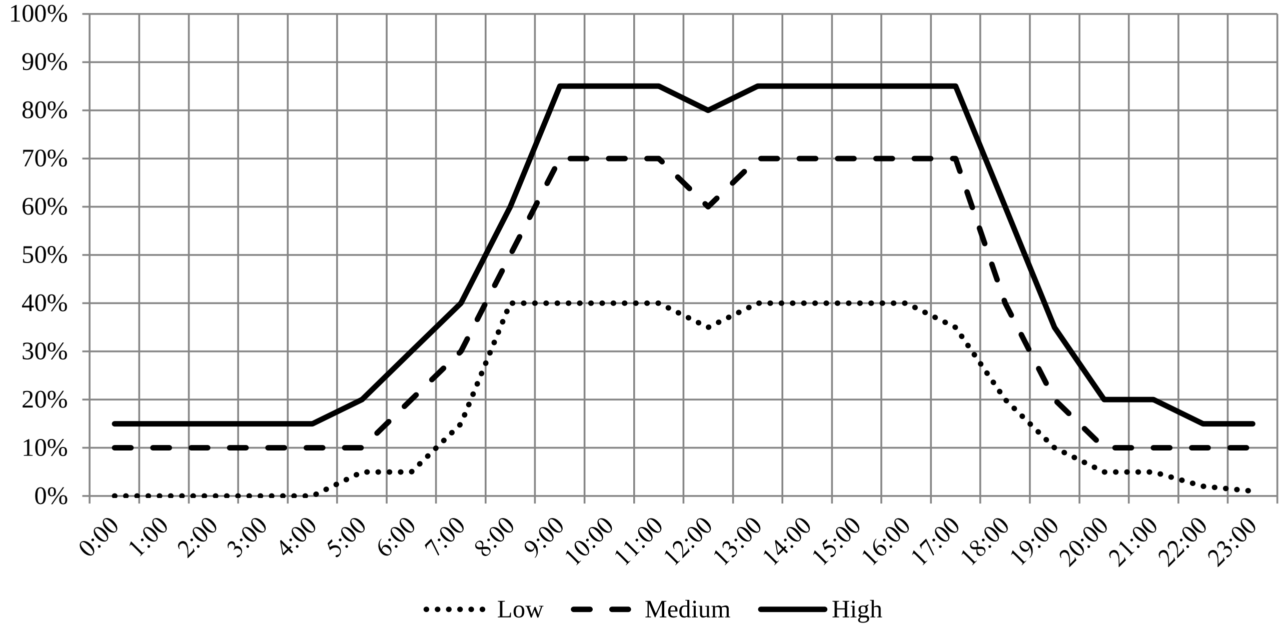

Figure 24: Office Park Garage Weekday Occupancy Profiles

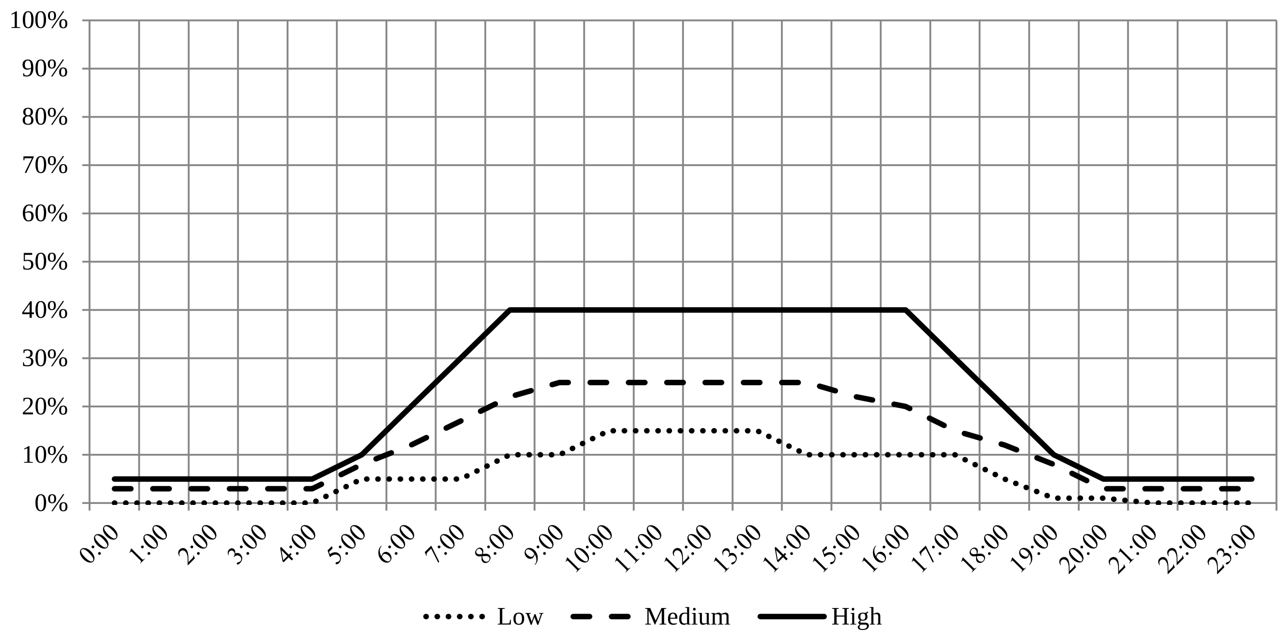

Figure 25: Office Park Saturday Occupancy Profiles

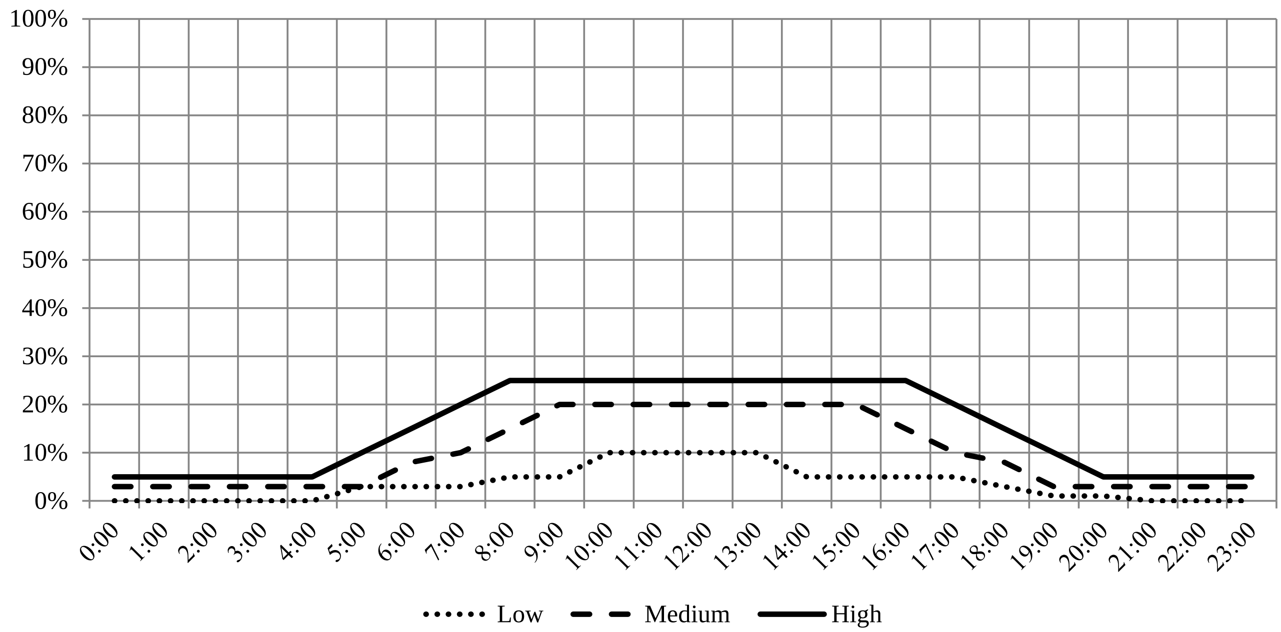

Figure 26: Office Park Sunday Occupancy Profiles

The second occupancy profile, referred to as transient profile, attempts to capture the in-and-out activity that occurs within each hour, and is input as a percentage of the total garage volume. Figure 27 below shows a sample of the transient profiles for the Office Park use type.

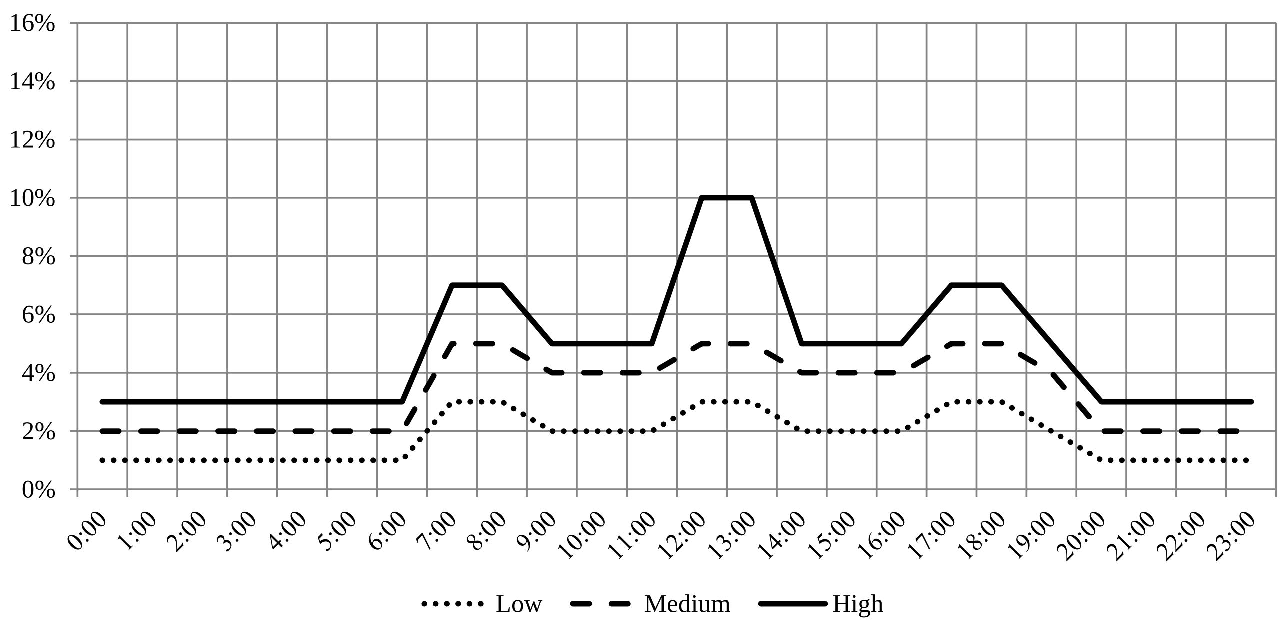

Figure 27: Office Park Transient Profiles

The two profiles individually do not produce a complete picture, and must be used in combination. The occupancy profile produces information on the net number of cars that are arriving or leaving in an hour, but does not account for cars that are offset in activity by another car that happens to do exactly the opposite in the same time period. The transient profile accounts for this hidden volume of traffic.

For example, suppose a car enters the garage in an hour, so the volume of the garage increases by one car. The next hour, a car leaves the garage, so the volume decreases by one car. The total amount of activity recorded in the occupancy profile in this two hour period is two cars, and the net gain/loss is zero cars. However, suppose five cars enter the garage, and four cars leave the garage in the first hour, for a net gain of one car. In the second hour, five cars leave the garage, and four cars enter, for a net loss of one car. In both of these examples, the occupancy profile (on an hourly basis) will look identical, recording one net gain, and one net loss, but there were only two activity 'hits' in the first example, and eighteen activity 'hits' in the second example.

As a result, sixteen of the eighteen cars were not counted in the occupancy profile, because it is only capable of measuring the net activity in the garage (percentage full), and is incapable of actually tracking the gross activity. Combined, these two profiles provide a reasonably accurate model of the volume of traffic experienced by a garage. Figure 28 demonstrates the impact of the transient profile on the hourly occupancy profile, showing how the transient profile serves to account for sub-hourly activity. Figure 29 shows, for this same example, the cumulative 'hits' seen based on the occupancy profile alone, and the occupancy profile modified by the transient profile.

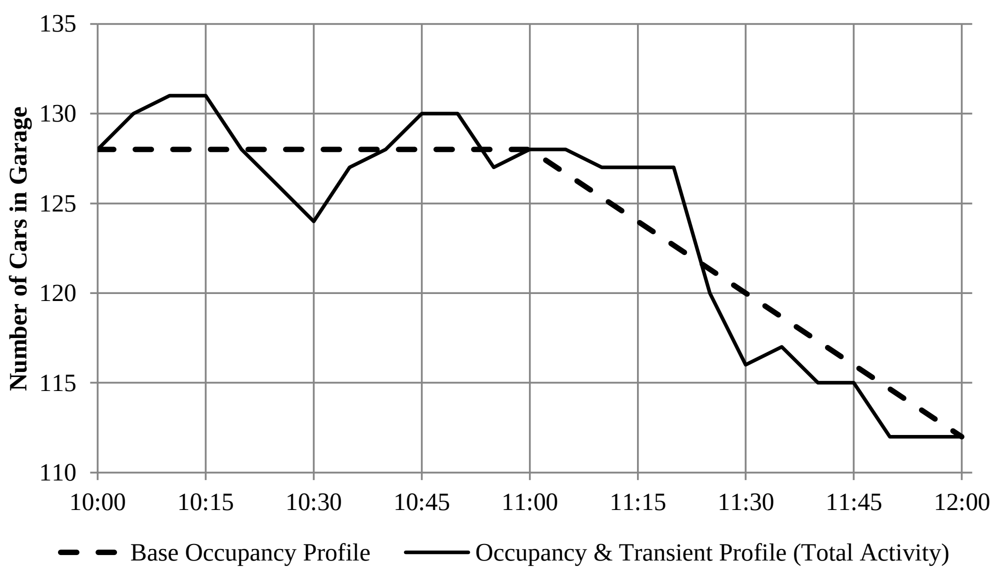

Figure 28: Example of Impact of Transient Profile on Occupancy Profile

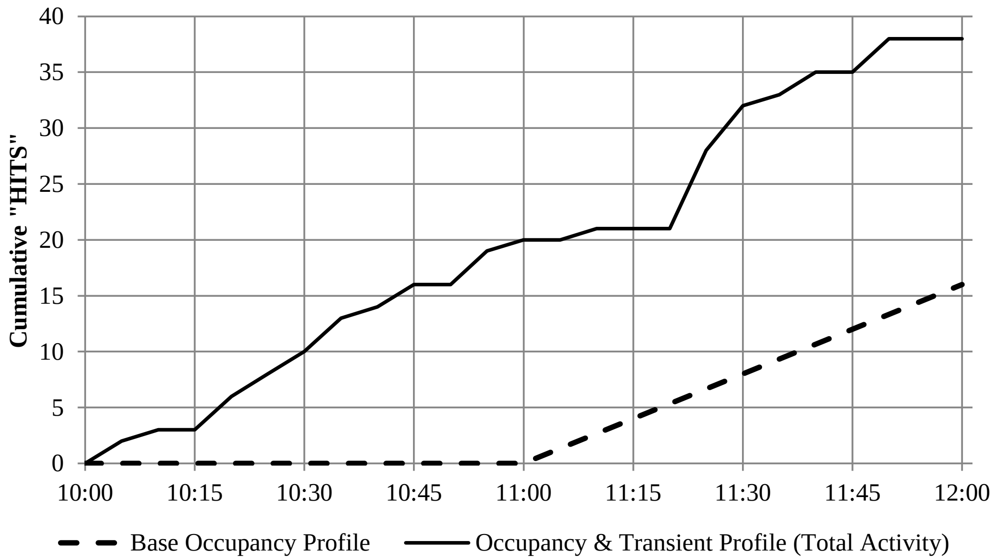

Figure 29: Example of Cumulative Activity based on Impact of Transient Profile on Occupancy Profile

Occupancy profiles and transient profiles were developed for each of the use type categories, and in three levels of traffic volume:

- Office park (High, Medium, Low)
- Mixed-use (High, Medium, Low)
- Transportation (High, Medium, Low)

Also included were deviations for Saturday, Sunday and Weekday adjustments.

Occupancy and transient profiles were also created for series of 'Bust' configurations, which were used to explore the limits of cost-effectiveness. Finally, a series of 'University' occupancy and transient profile configurations were created to evaluate the results of the model in comparison to the reported results from the pilot programs.

The complete profile information is included in Appendix H: Occupancy Profiles Documentation.

2.5.4 Run the Model for Simulated 'Normal' Conditions

The 'High' volume profiles for each Use Type are the most important because they reduce the opportunity for the sensors to turn the lights down to a setback level. Those are therefore the critical path in this analysis. Further, the Transportation Use Type has the highest volume of traffic on a 24/7 basis, so this particular run is likely to be the most difficult to show cost effectiveness.

The matrix of calculated energy runs is shown in Figure 30 below:

	INPUT VARIABLES					
	USE TYPE	**TRAFFIC VOLUME**	**DAYLIGHT AVAILABILITY**	**% ZONES DAYLIGHTED**	**ELECTRIC LIGHT SOURCE**	**SENSOR DELAY TIME**
RUN NUMBER	OFFICE PARK / MIXED-USE / TRANSPORTATION	HIGH / MEDIUM / LOW	GOOD / MODERATE / POOR	80% / 50% / 20%	FLUORESCENT / HID / LED / INDUCTION	5 DIFFERENT DELAY SLOTS AVAILABLE
1	Trans.	High	Poor	50%	Fluor.	1, 2.5, 5, 7.5, 10
2	Trans.	High	Poor	80%	Fluor.	1, 2.5, 5, 7.5, 10
3	Trans.	High	Poor	20%	Fluor.	1, 2.5, 5, 7.5, 10
4	Trans.	High	Moderate	50%	Fluor.	1, 2.5, 5, 7.5, 10
5	Trans.	High	Good	50%	Fluor.	1, 2.5, 5, 7.5, 10
6	Trans.	High	Poor	50%	LED	1, 2.5, 5, 7.5, 10
7	Trans.	High	Poor	50%	HPS	1, 2.5, 5, 7.5, 10
8	Trans.	High	Poor	50%	IND	1, 2.5, 5, 7.5, 10
9	Trans.	Medium	Poor	50%	Fluor.	1, 2.5, 5, 7.5, 10
10	Trans.	Low	Poor	50%	Fluor.	1, 2.5, 5, 7.5, 10
11	Office Park	High	Poor	50%	Fluor.	1, 2.5, 5, 7.5, 10
12	Office Park	Medium	Poor	50%	Fluor.	1, 2.5, 5, 7.5, 10
13	Office Park	Low	Poor	50%	Fluor.	1, 2.5, 5, 7.5, 10
14	Mixed Use	High	Poor	50%	Fluor.	1, 2.5, 5, 7.5, 10
15	Mixed Use	Medium	Poor	50%	Fluor.	1, 2.5, 5, 7.5, 10
16	Mixed Use	Low	Poor	50%	Fluor.	1, 2.5, 5, 7.5, 10
17	Trans.	High	Poor	50%	Fluor.	1, 2.5, 5, 7.5, 10
18	University	1 / 1	Poor	50%	Fluor.	1, 2.5, 5, 7.5, 10
19	Bust	-	Good	80%	Fluor.	1, 2.5, 5, 7.5, 10
20	Trans.	High	Poor	50%	Fluor.	1, 2.5, 5, 7.5, 10
21	Trans.	High	Poor	50%	Fluor.	10, 15, 20, 25, 30
22	Bust	-	Poor	20%	Fluor.	1, 2.5, 5, 7.5, 10
23	University	2 / 2	Poor	50%	Fluor.	1, 2.5, 5, 7.5, 10
24	Trans.	High	Poor	50%	LED	1, 2.5, 5, 7.5, 10
25	Trans.	High	Poor	50%	LED	10, 15, 20, 25, 30
26	Office Park	Medium	Poor	50%	Fluor.	5, 10, 15, 20, 30
27	Office Park	Medium	Poor	50%	LED	5, 10, 15, 20, 30
28	Office Park	High	Moderate	50%	Fluor.	5, 10, 15, 20, 30
29	Mixed Use	High	Moderate	50%	Fluor.	5, 10, 15, 20, 30
30	University	1 / 3	Poor	50%	Fluor.	5, 10, 15, 20, 30
31	University	1 / 4	Poor	50%	Fluor.	5, 10, 15, 20, 30
32	University	1 / 5	Poor	50%	Fluor.	5, 10, 15, 20, 30

Figure 30: Matrix of Simulation Runs

This set of runs provides enough information to define from the best-case to the worst case conditions that a garage is likely to experience. This set of runs also allows for the influence of specific variables to be determined; for example:

1. Comparing runs 1, 2 & 3 allows for the impact of the percentage of each floor that is daylighted to be determined.
2. Comparing runs 1, 4 & 5 allows for the impact of daylight availability to be determined.
3. Comparing runs 1, 6, 7 & 8 allows for the comparison of different electric light source technology.
4. Comparing runs 1, 9 & 10 allows for the impact of the traffic volume of the Transportation occupancy profile to be understood.
5. Comparing runs 11, 12 & 13 allows for the impact of the traffic volume on the Office Park occupancy profile to be understood.

6. Comparing runs 14, 15 & 16 allows for the impact of the traffic volume on the Mixed Use occupancy profile to be understood.
7. Comparing runs 20 & 21 allows for further in-depth analysis of the impact of occupancy sensor delay time on energy consumption.

2.6 Results Analysis

The impact of each of the primary control variables was examined first to understand the threshold for cost-effectiveness.

2.6.1 Impact of Occupancy Sensor Delay Time

Understanding impact of occupancy sensor delay time on potential energy savings was of key concern during this study. Figure 31 demonstrates the results of the baseline system analysis as a function of delay time. The main horizontal axis, labeled 'ZONE NUMBER,' indicates the depth into the garage, where zone 1 is at the main entry and zone 40 is the furthest zone into the parking garage. The vertical axis reports a zone-by-zone total 15-year cost relative to the uncontrolled baseline. This total cost includes initial equipment and installation costs, 15-year energy cost and 15-year maintenance cost. The depth axis reports these costs as a function of the occupancy sensor delay time, including delay times of 1, 2.5, 5, 7.5, 10, 15, 20, 25 and 30 minutes.

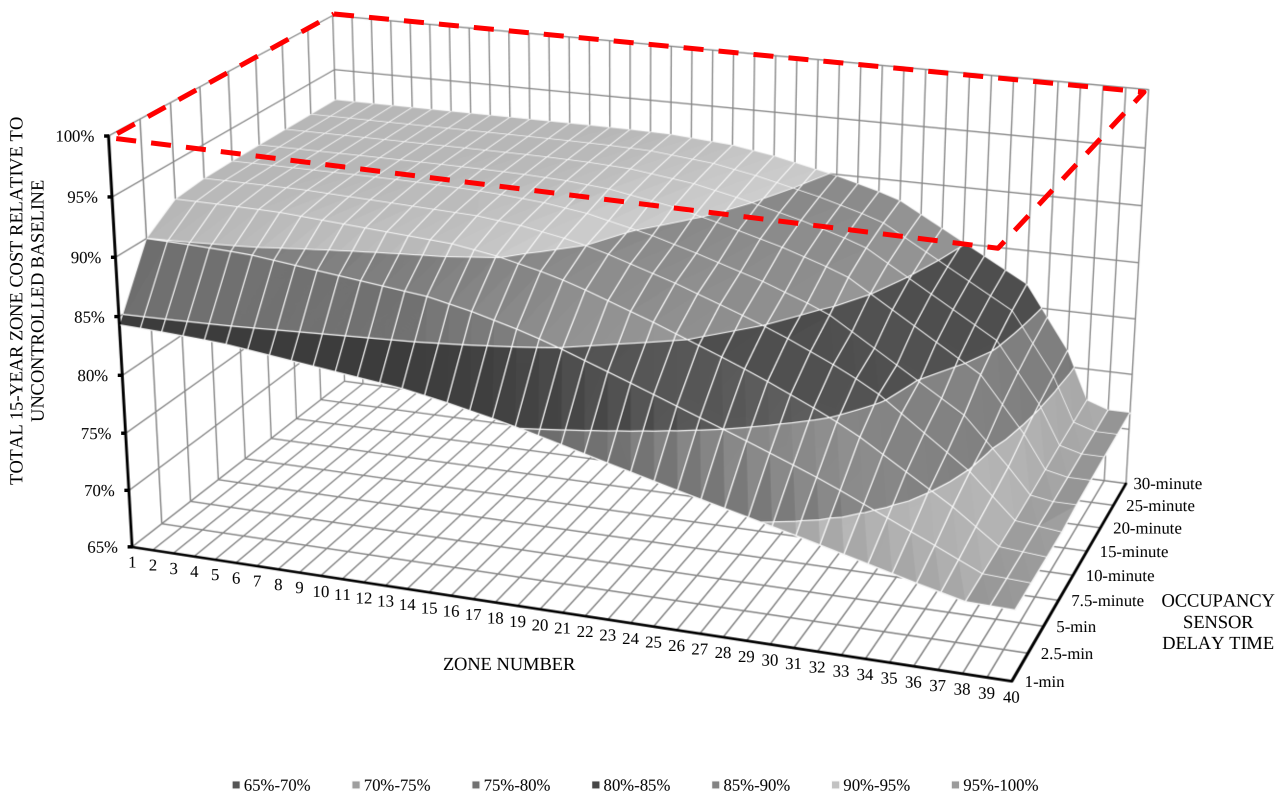

Figure 31: Zone-by-Zone Total Relative 15-Year Cost, Including Impact of Daylighting, Based On 'HIGH' Transportation Occupancy Profile

As shown in Figure 31, all of the lighting control zones in the design simulation fall below the red line, which represents the 'Uncontrolled' baseline cost, have cost effectiveness. As the zones get closer to the entry, the cost of the system gets closer to the 15 year benefit of the system, but never actually reaches the break-even point (which is the 100% level). The figure also shows that as the delay time increases, the benefits decrease, but again, all the control zones in the garage save money in the 15-year analysis. As a result, with the assumed volume of traffic and in the traffic pattern of a 24/7 style transportation hub garage, the whole garage will be cost effective regardless of the delay time used. This simulation includes the benefit of daylighting in the garage spaces. The daylighting is a significant benefit, as the simulation below will describe.

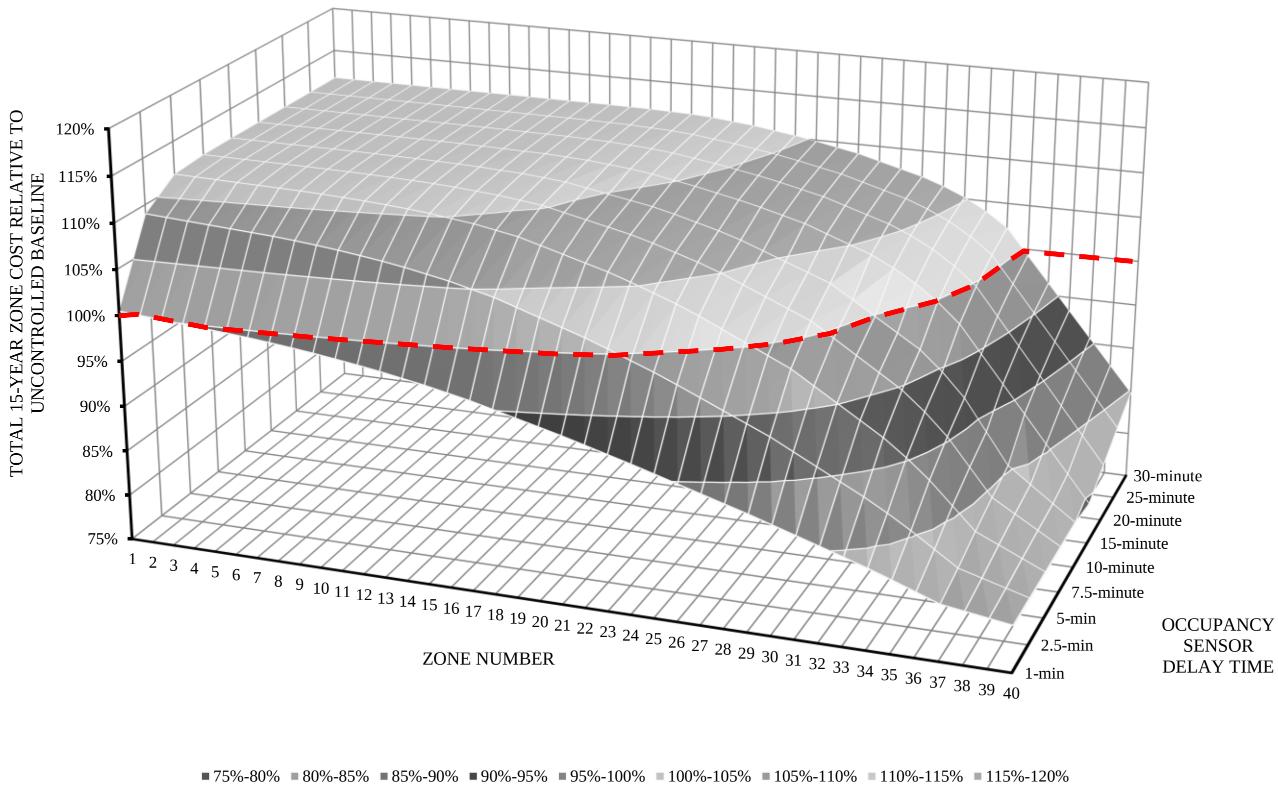

Figure 32: Zone-by-Zone Total Relative 15-Year Cost, Without Impact of Daylighting, Based on 'HIGH' Transportation Occupancy Profile

Figure 32 indicates the same relative zone-by-zone total cost but does not include the impact of daylighting. As shown, there are zones in the garage that no longer have cost effectiveness, even with the minimum time delay of 1 minute. By approximately 3.5 minutes, the occupancy sensor measure is not cost effective for the garage as a whole by itself.

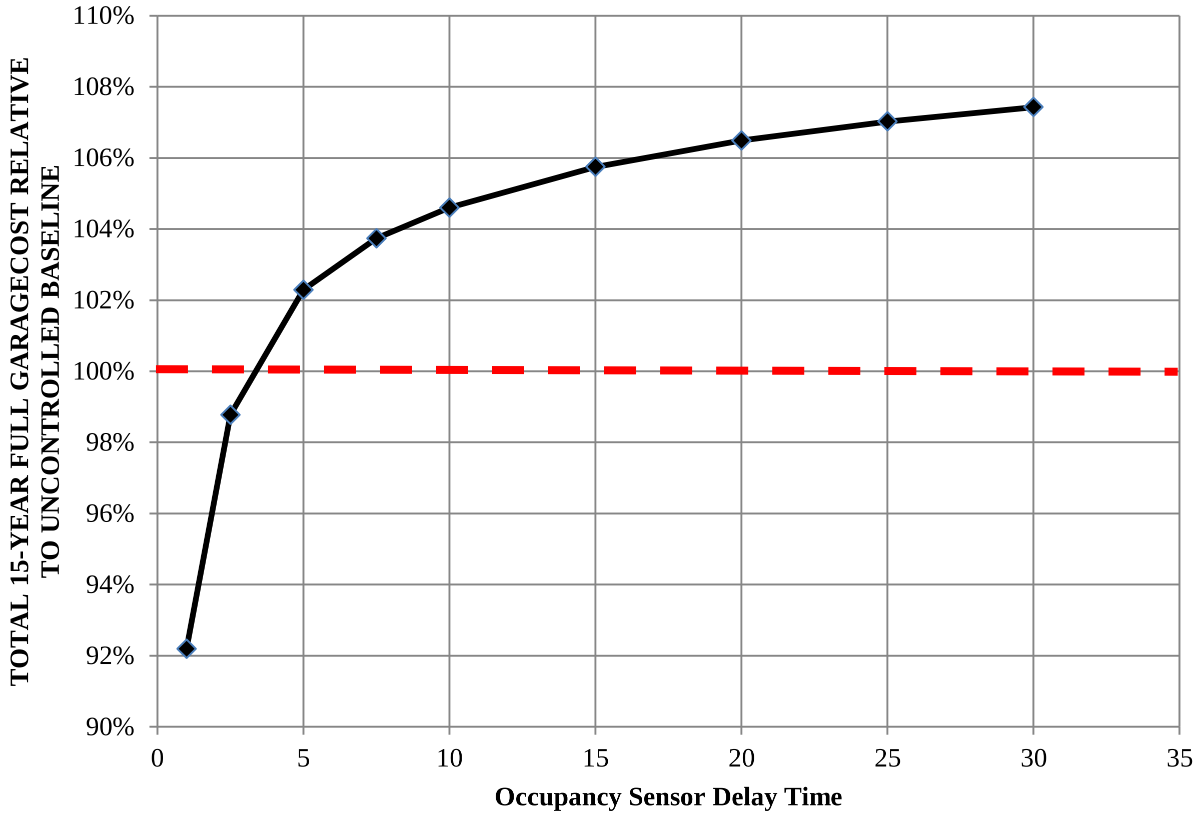

Figure 33: Complete Garage Relative 15-Year Cost, Without Impact of Daylighting, Based on 'HIGH' Transportation Occupancy Profile

Figure 33 provides the complete garage cost-effectiveness as a function of occupancy sensor delay time without the impact of daylighting relative to the 'Uncontrolled' baseline cost of 100%.

This garage is likely to be an outlier in use volume context for the state, especially with regular late-night traffic that many garages will not have. However, it is important to understand that there will be situations where specific control zones and possibly the entire garage may not meet the cost effectiveness measure. Also, this simulation represents a garage that has no daylighting, which is normally not the case, but does occur with city garages at times, and also represents the interior portions of a very deep, large garage, beyond the useful daylighting zones.

As the percentage of usefully-daylighted space in a garage decreases, the complete garage energy savings will decrease somewhat because daylighting is very cost-effective.

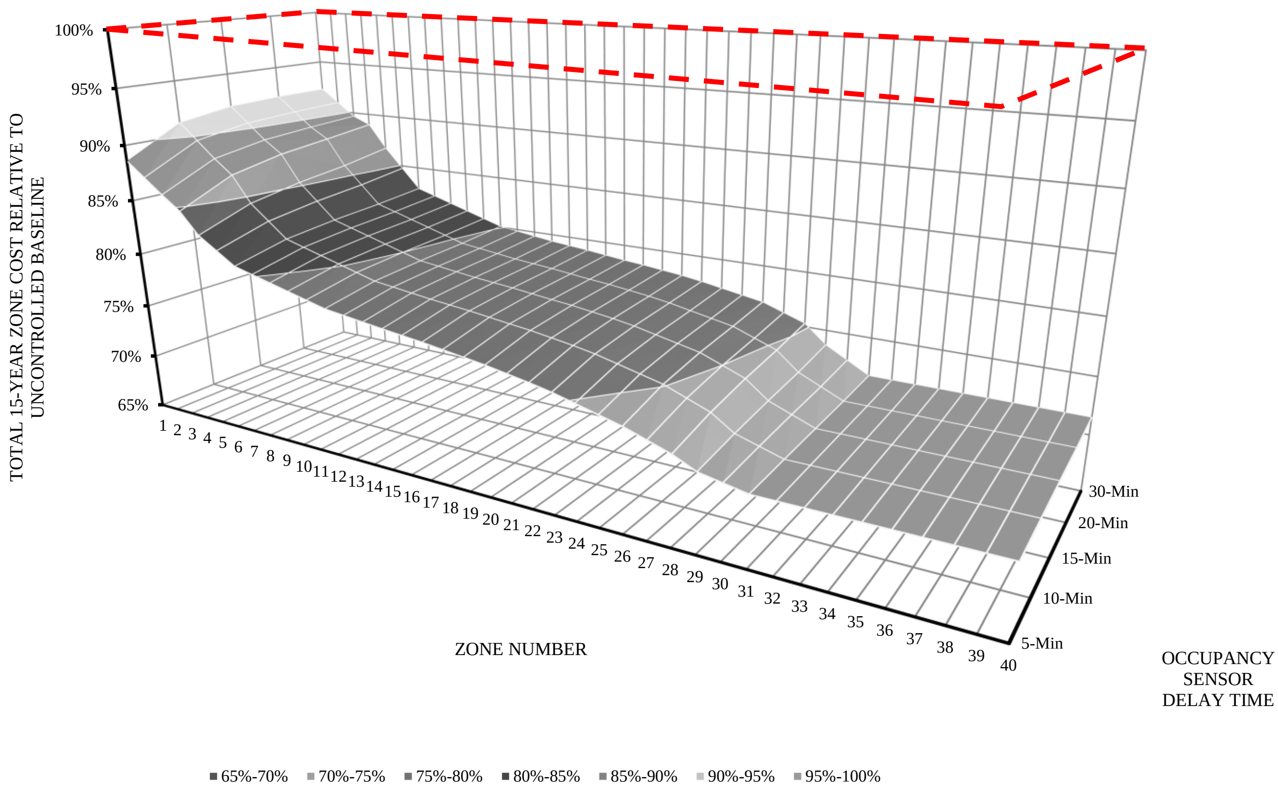

Figure 34: Zone-by-Zone Total Relative 15-Year Cost, With Impact of Daylighting, Based on 'MEDIUM' Office Park Occupancy Profile

Figure 34 shows the performance of a more typical parking garage, with medium occupancy volume, and an office park use profile. This simulation includes both daylighting and occupancy sensors. As can be seen, the entire garage has good payback regardless of the delay time setting. Since most of the volume of the garage happens during the day, the daylighting is beneficial, but ultimately the low volume at night produces a significant savings benefit.

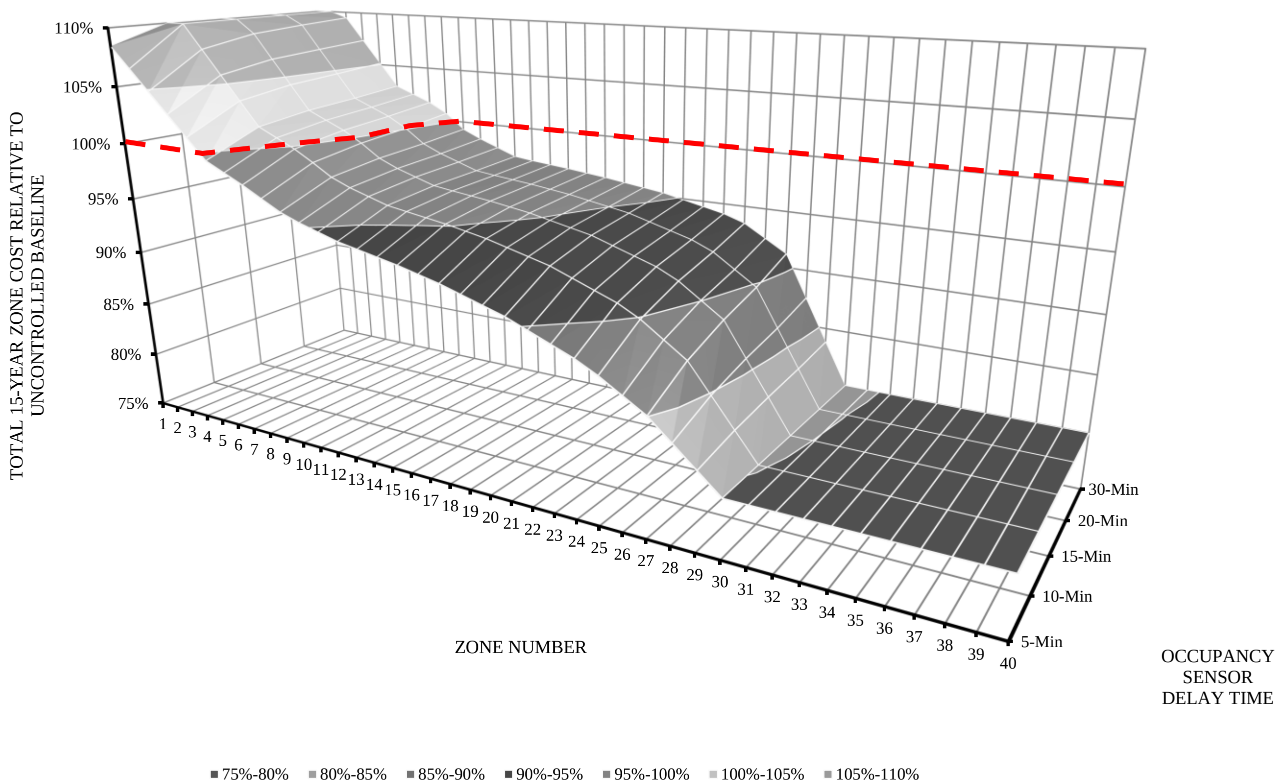

Figure 35: Zone-by-Zone Total Relative 15-Year Cost, Without Impact of Daylighting, Based on 'MEDIUM' Office Park Occupancy Profile

Figure 35 shows the same garage simulation with no daylighting contribution. The cost to benefit ratio decreases, and some zones now have become not cost effective. However, the entire garage remains cost effective, regardless of the occupancy sensor delay time, due to the relatively low nighttime activity.

2.6.2 Impact of Traffic Volume

The traffic volume is a variable that will impact the cost effectiveness, but it may not be as great a variable as one may think when daylighting is present. The traffic volume impacts the cost effectiveness deeper into the garage than near the entry, because once the entry zones reach 'saturation' (the point where more cars entering does not add any more energy consumption), the volume becomes hidden behind a 'full ON' lighting situation.

Further into the garage, the lighting systems do not reach that saturation point as quickly, if at all, so the differences in the volume of traffic become more apparent. Figure 36 shows this effect clearly; the difference in cost compared to the baseline is fairly small near the entry, but midway into the garage, the difference is substantial. By the furthest reaches of the garage, all volume levels have evened out to the baseline 'LOW' power consumption.

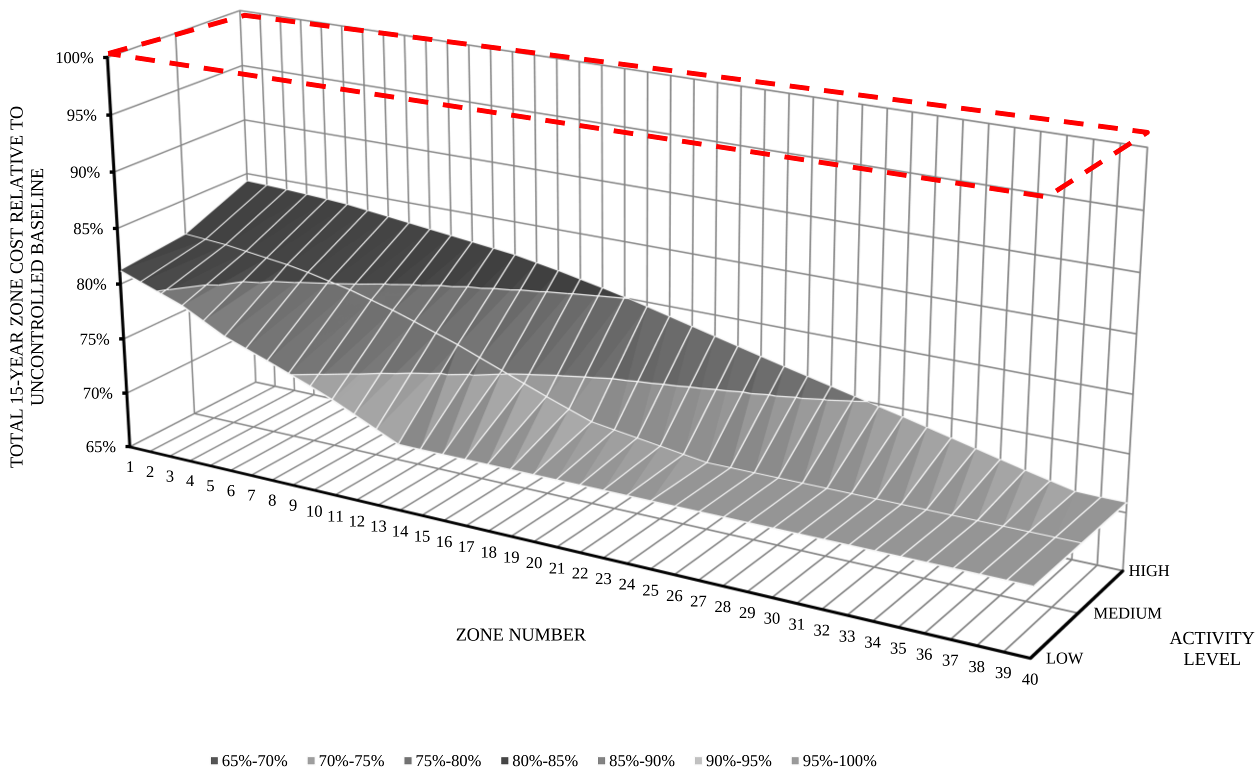

Figure 36: Zone-by-Zone Total Relative 15-Year Cost, With Impact of Daylighting, Based on Transportation 'High' Occupancy Profiles

The traffic volume becomes much more apparent when daylighting is not available. At that point, the daytime volume shows significant impacts from the volume of traffic during the day, which pushes the zone cost higher and closer to the 'Uncontrolled' baseline zone cost.

Figure 37 shows the impact of traffic volume on the garage when no daylighting is present. The range of values that the zones move through is much greater than the daylighted mode, and the hill of impact pushes further into the garage zones, both making the garage less cost effective. Note that this simulation shows that the 'High' activity level just breaks through the break even line so that a zone or two are not cost effective, although the entire garage is.

These simulations that test a single variable all use a 1 minute delay time so the interactions of the other variables are more easily seen (zones will hit saturation much less rapidly with longer delay times). While these figures appear to make a specific measure appear cost effective, or not, they are much more useful to understand the interactions of the variables rather than using them as a determination of overall system success. To understand that for a specific system, the model simulation must be run using a more reasonable delay time; which might be 5 minutes or 10 minutes. This will push all the curves up the scale, and portions that are shown as cost effective will no longer be so.

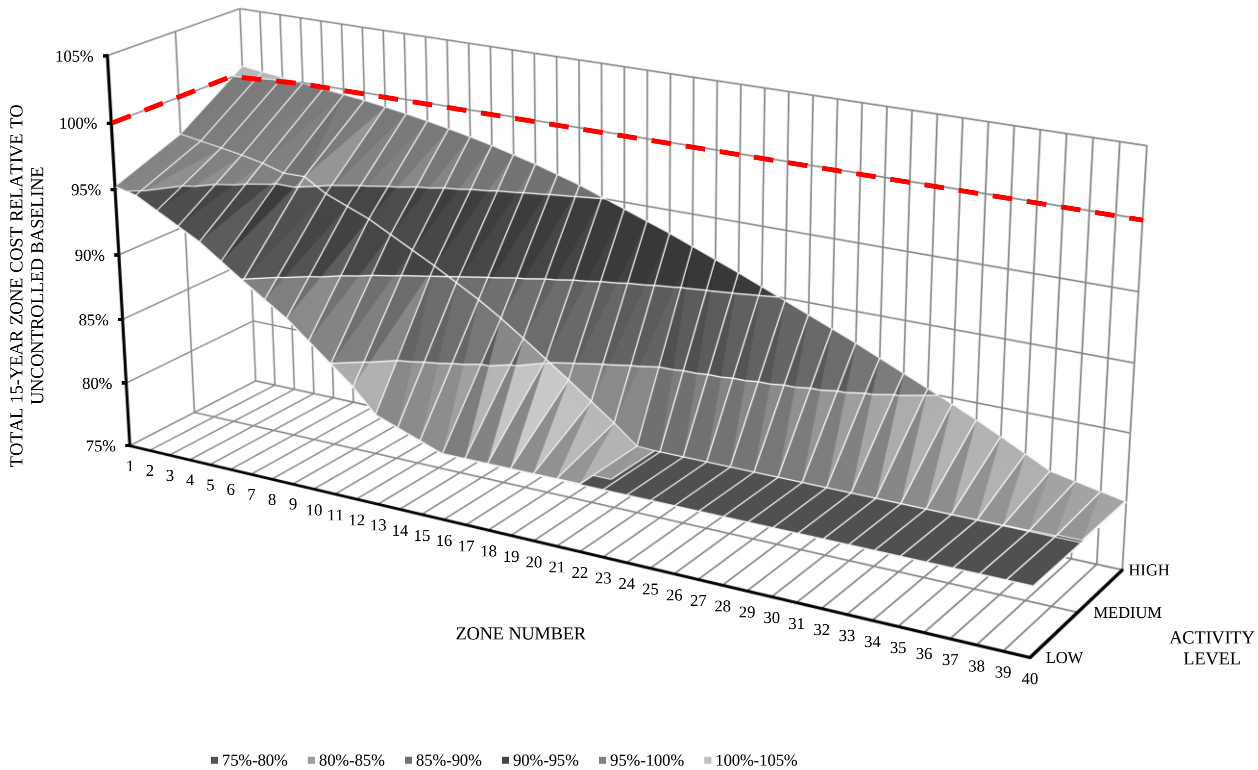

Figure 37: Zone-by-Zone Total Relative 15-Year Cost, Without Impact of Daylighting, Based on Transportation "High" Occupancy Profiles

2.6.3 Impact of Daylight Availability

The amount of daylight availability has relatively little impact on the cost effectiveness matrix. This may also appear counter intuitive because it creates such a substantial impact on the overall curve, but even a 'Poor' daylight availability situation has a substantial amount of useful light such that the daylighting zones are turned off regardless of their daylight availability most of the time.

This is partly due to the large amounts of daylight compared to the electric light design levels for a garage, and partially because the daylighting zone has to be set somewhat conservatively because of the issues of the quality of light in the space, which cannot be ignored.

Since a 'Poor' daylighted space still gets penetration into the 20 foot line of the daylighting zone most of the time, it is able to turn off lights as effectively as a 'Good' space. Figure 38 shows this effect in that the values from 'Poor' to 'Good' vary somewhat, but not in a real strong manner.

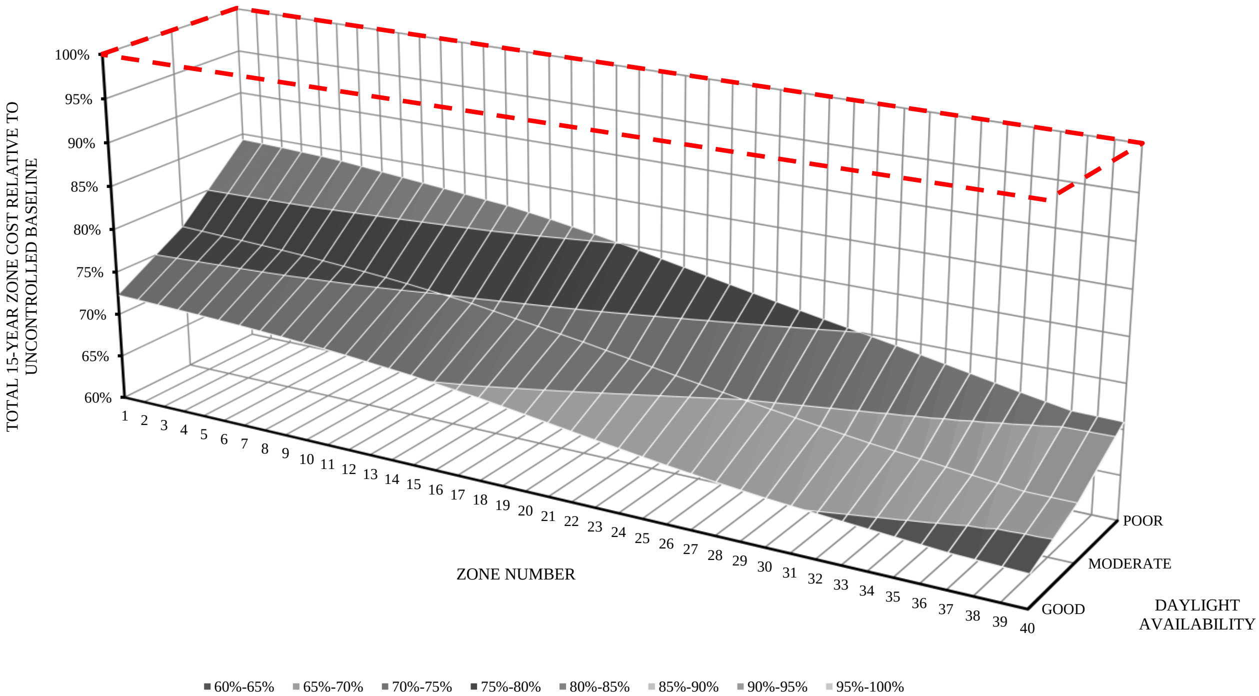

Figure 38: Zone-by-Zone Total Relative 15-Year Cost, Based on Transportation "High" Occupancy Profiles

The results of the control system simulation program illustrated that daylight availability has little impact on the overall cost-effectiveness of daylight-responsive controls. Peak TDV numbers occur at the peak of daylight, independent of the level of daylight availability, and therefore the daylight-responsive systems effectively shed load during peak hours.

2.6.4 Impact of Percentage of Floor Daylighted

The percentage of the floor plate that can be usefully daylighted has an impact on the cost effectiveness of the lighting system. As with the other variables, this impact improves cost effectiveness with increased access to daylighting, but the impact is not as large as might be expected because the benefit only occurs during the day, and does not occur through the night when the occupancy sensors control the system.

Figure 39 shows the impact on the average garage cost comparison rather than zone-by-zone, because the daylight availability is very geometry specific, impacting individual zones substantially, producing a graph that is difficult to interpret.

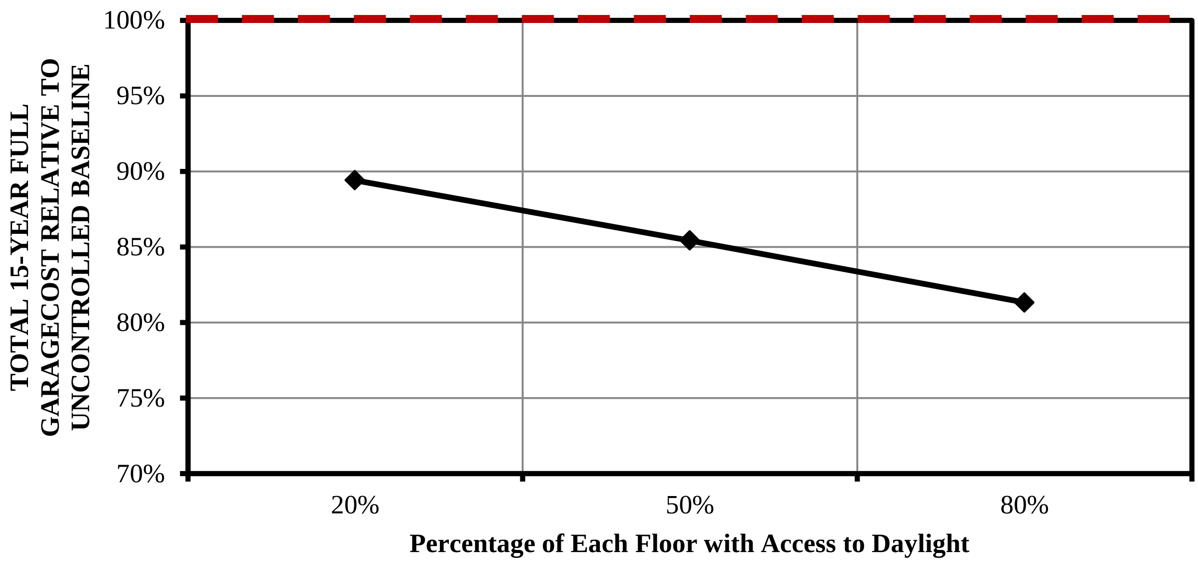

Figure 39: Impact of the Percentage of Each Floor with Access to Daylight

2.6.5 Comparing Electric Light Source Technologies

Figure 40 provides a comparison of four common light source technologies used in parking garage lighting designs. The 'Uncontrolled' Baseline bar represents the total 15-year cost density of each system applied to the same garage conditions. As is clear, there is a large variation in the total cost per square foot associated with the various light source technologies.

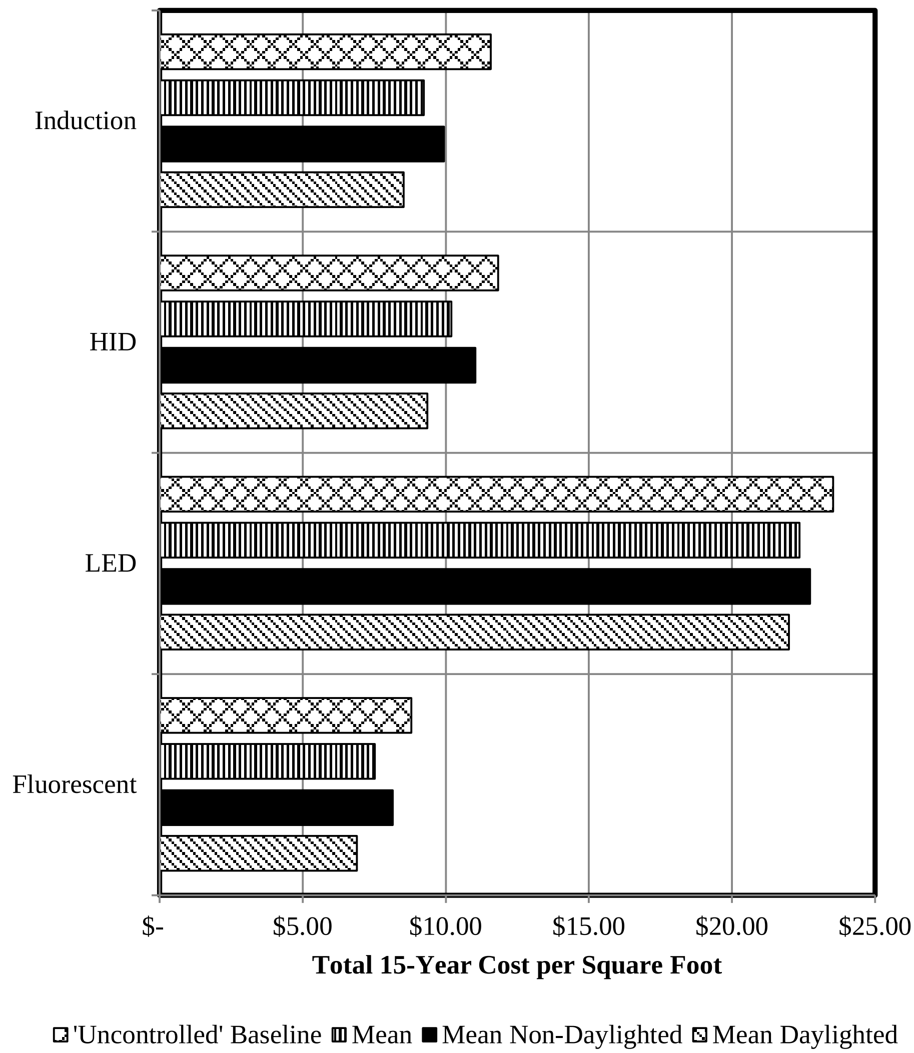

Figure 40: Electric Light Source Technology TDV Cost Comparison

In all cases, the controlled systems show lower cost density than the 'Uncontrolled' Baseline system options, indicating that mandatory controls can be applied to all light source technologies effectively.

2.6.6 Comparison to Pilot Projects

Based on the review of the pilot projects and the University profiles created, the simulation results were compared to the savings results as reported in the CLTC/PIER documents. Figure 41 includes this comparison.

TYPE OF RESULTS	PILOT PROJECT NAME	CLTC/PIER REPORTED RESULTS	SIMULATION RESULTS
Overall Energy Cost Savings	UC Davis Induction	30-50% energy savings anticipated	42% 15-year energy cost savings, without technology change
		32% energy savings per luminaire, including a technology change	
	UCSB Induction	53% total energy savings from retrofit, including technology change and controls	
	CSU Sacramento	68% energy savings, including technology change and controls	
Energy Cost Savings from Daylighting	UCSB Induction	12.2% energy cost savings from daylighting	16% savings from daylighting
Operational Characteristics	CSU Sacramento	60% of operating hours in "HIGH" mode	48% of operating hours in "HIGH" mode at mid-point of garage

Figure 41: Comparison Showing Results of Pilot Projects Compared to Results of Simulations

As shown, the overall energy cost savings from daylight- and occupancy-responsive controls found using the simulation program was determined to be in-line with the savings reported from the demonstration sites. The energy cost savings from daylighting alone were also verified, along with the reported operational characteristics.

This illustrates that the simulation program provides a reasonable method for determining the potential energy cost savings as it validates the simulation with real-world results. This also confirms that there is a high energy savings potential in these types of low-volume garages, both due to occupancy-based and daylight-responsive controls.

2.7 Overall Cost-Effectiveness

Based on the results of the simulation, the overall cost-effectiveness of daylight- and occupancy-responsive controls were determined.

2.7.1 Daylight-Responsive Lighting Controls

As shown in Figure 42, daylight-responsive lighting controls in parking garages are anticipated to be cost-effective, with a benefit-to-cost ratio of 17.

MEASURE	COST / Sq. Ft.	15-YEAR TDV SAVINGS / Sq. Ft.	BENEFIT-TO-COST RATIO	COST EFFECTIVE?
Daylight-Responsive Controls	$ 0.013	$ 0.229	17.0	YES

Figure 42: Overall Cost-Effectiveness of Daylight-Responsive Switching

2.7.2 Occupancy-Responsive Lighting Controls

Figure 43 illustrates the overall cost-effectiveness of occupancy-based controls. The 15-year energy cost savings used for this basis was determined by weighting the 15-year energy cost savings from the three 'HIGH' volume occupancy profiles, assuming that 5% of garages in the State follow the 'Transportation' profile, and the remaining 95% are split evenly between the 'Office Park' and 'Mixed Use' profiles. This calculation is also based on using a 15-minute time delay for occupancy sensing, which is recommended as the high limit for occupancy sensing time-out.

MEASURE	COST / Sq. Ft.	15-YEAR TDV SAVINGS / Sq. Ft.	BENEFIT-TO-COST RATIO	COST EFFECTIVE?
Occupancy-Responsive Controls	$ 0.26	$ 0.29	1.1	YES

Figure 43: Overall Cost-Effectiveness of Occupancy-Responsive Bi-Level Controls

Figure 44 shows the total 15-year cost relative to the 'Uncontrolled' Baseline for the three occupancy types as a function of occupancy sensor delay time. As shown, garages with the 'Office Park' profile should be cost-effective at any delay time. Garages with the 'Mixed Use' profile should be cost-effective when the sensor delay time is approximately 18 minutes or less. Finally, garages with a fairly high constant level of occupancy, as represented by the 'Transportation' profile, will struggle to be cost-effective when the delay time is 5 minutes or longer; however, it is also assumed that very few garages in the State will exhibit this type of occupancy profile.

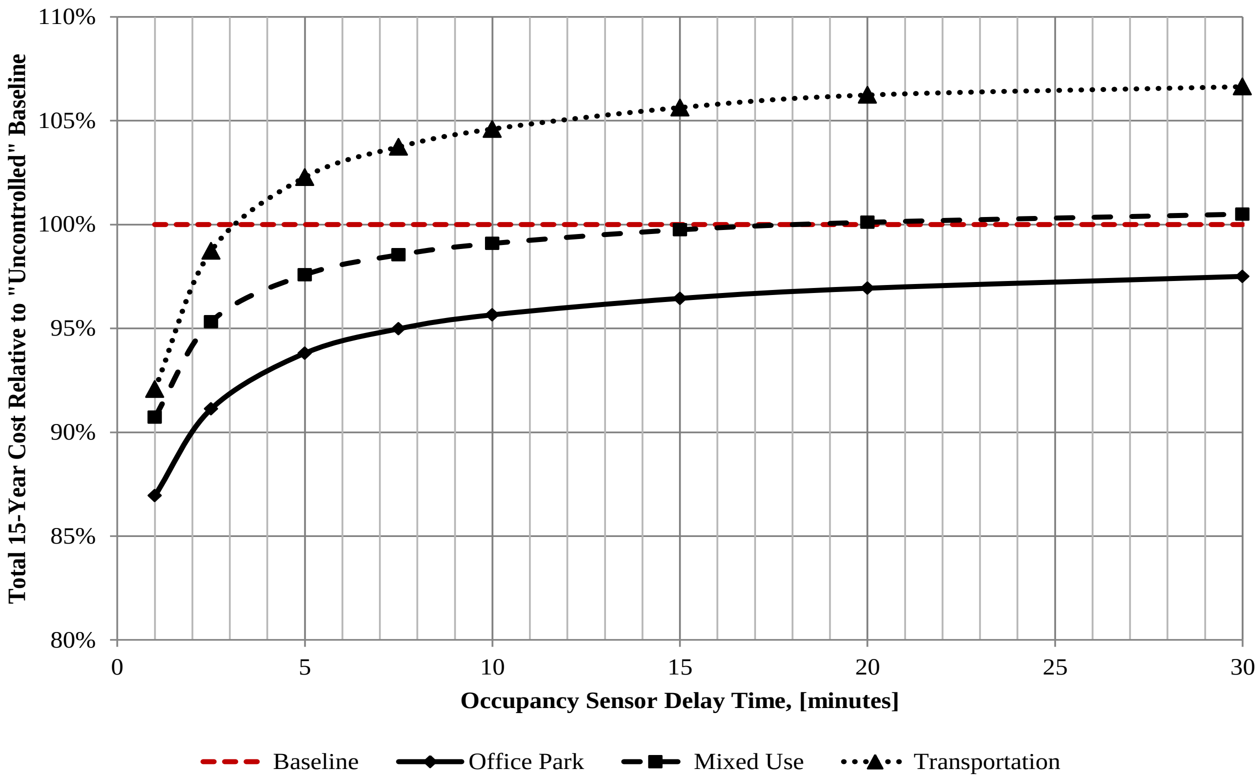

Figure 44: Total 15-Year Cost for Three 'HIGH' Occupancy Profiles as a Function of Occupancy Sensor Delay Time

2.8 Statewide Savings Analysis

Information will be provided as Statewide predictions are completed.

3. Recommended Language for the Standards Document, ACM Manuals, and the Reference Appendices

3.1 Recommended Changes to Section 131

SECTION 131 – INDOOR LIGHTING CONTROLS THAT SHALL BE INSTALLED

(a) **Area Controls.**

1. Each area enclosed by ceiling-height partitions shall have an independent switching or control device. This switching or control device shall be:

   A. Readily accessible; and

   B. Located so that a person using the device can see the lights or area controlled by that switch, or so that the area being lit is annunciated; and

   C. Manually operated, or automatically controlled by an occupant-sensor that meets the applicable requirements of Section 119.

2. Other devices may be installed in conjunction with the switching or control device provided that they:

   A. Permit the switching or control device to manually turn the lights off in each area enclosed by ceiling-height partitions; and

   B. Reset the mode of any automatic system to normal operation without further action.

EXCEPTION 1 to Section 131(a): Up to 0.3 watts per square foot of lighting in any area within a building that must be continuously illuminated for reasons of building security or emergency egress, if:

A. The area is designated a security or emergency egress area on the plans and specifications submitted to the enforcement agency under Section 10-103(a)2 of Title 24, Part 1; and

B. The security or egress lighting is controlled by switches accessible only to authorized personnel.

EXCEPTION 2 to Section 131(a): Public areas with switches that is accessible only to authorized personnel.

(b) **Multi-Level Lighting Controls**. The general lighting of any enclosed space 100 square feet or larger, and has a connected lighting load that exceeds 0.8 watts per square foot, shall have multi-level lighting controls. Multi-level controls shall have at least one control step that is between 30 percent and 70 percent of design lighting power and allow the power of all lights to be manually turned off. A reasonably uniform level of illuminance shall be achieved by any of the following:

1. Continuous or stepped dimming of all lamps or luminaires; or

2. Switching alternate lamps in luminaires, alternate luminaires, and alternate rows of luminaires.

EXCEPTIONS to Section 131(b):

1. Lights in corridors.

2. A space that has only one luminaire with no more than two lamps.

(c) **Parking Garage Areas.** The general lighting of any parking garage or loading/unloading space shall have lighting controls. Controls shall have at least one control step between 20 percent and 50 percent of design lighting power and allow the power of all lights to be manually turned off. A reasonably uniform level of illuminance shall be achieved by any of the following:

1. Continuous or stepped dimming of all lamps or luminaires; or
2. Switching alternate lamps in luminaires, alternate luminaires, and alternate rows of luminaires.

EXCEPTION to Section 131(c): Lighting specifically designated necessary for building emergency lighting systems if the specific area is designated as part of an egress path on the plans and specifications submitted to the enforcement agency under Section 10-103(a)2 of Title 24, Part 1.

(~~c~~d) **Daylight Area**s.

1. Daylight areas shall be defined as follows:

   A. **DAYLIGHT AREA** the total daylight area shall not double count overlapping areas with any primary sidelit daylight area, secondary sidelit daylight area, or skylit daylight area.

   B. **DAYLIGHT AREA, PRIMARY SIDELIT** is the combined primary sidelit area without double counting overlapping areas. The floor area for each primary sidelit area is directly adjacent to vertical glazing below the ceiling with an area equal to the product of the sidelit width and the primary sidelit depth.

   The primary sidelit width is the width of the window plus, on each side, the smallest of:

   i. 2 feet; or

   ii. The distance to any 5 feet or higher permanent vertical obstruction.

   The primary sidelit depth is the horizontal distance perpendicular to the glazing which is the smaller of:

   i. One window head height; or

   ii. The distance to any 5 feet or higher permanent vertical obstruction.

   C. **DAYLIGHT AREA. SECONDARY SIDELIT** is the combined secondary sidelit area without double counting overlapping areas. The floor area for each secondary sidelit area is directly adjacent to primary sidelit area with an area equal to the product of the sidelit width and the secondary sidelit depth.

   The secondary sidelit width is the width of the window plus, on each side, the smallest of:

   i. 2 feet; or

   ii. The distance to any 5 feet or higher permanent vertical obstruction; or

   iii. The distance to any skylit daylight area.

   The secondary sidelit depth is the horizontal distance perpendicular to the glazing which begins from one window head height, and ends at the smaller of:

   i. Two window head heights;

   ii. The distance to any 5 feet or higher permanent vertical obstruction; or

   iii. The distance to any skylit daylight area.

   D. **DAYLIGHT AREA, SKYLIT** is the combined daylight area under each skylight without double counting overlapping areas. The daylight area under each skylight is bounded by the rough opening of the skylight, plus horizontally in each direction the smallest of:

   i. 70 percent of the floor-to-ceiling height; or

   ii. The distance to any primary sidelit area, or the daylight area under rooftop monitors; or

   iii. The distance to any permanent partition or permanent rack which is farther away than 70 percent of the distance between the top of the permanent partition or permanent rack and the ceiling

   E. **DAYLIGHT AREA, PARKING GARAGE SIDELIT** is the combined sidelit area without double counting overlapping areas.

   The sidelit width is the width of the opening plus, on each side, the smallest of:

   i. 2 feet; or

   ii. The distance to any 5 feet or higher permanent vertical obstruction.

   The sidelit depth is the horizontal distance perpendicular to the opening which is the smaller of:

i. 20 feet; or

ii. The distance to any 5 feet or higher permanent vertical obstruction.

The area shall be considered daylighted when the following conditions are met:

i. A minimum of 40 percent of the floor-to-ceiling wall height is window or open.

ii. The minimum total length of sidelit opening in the affected space is 10 feet.

F. **DAYLIGHT AREA, PARKING GARAGE SKYLIT** is defined as **DAYLIGHT AREA, SKYLIT**.

2. Luminaires providing general lighting that are in or are partially in the skylit daylight area and/or the primary sidelit daylight area shall be controlled as follows:

A. Primary sidelit and skylit daylight areas shall have at least one lighting control that:

i. Controls at least 50 percent of the general lighting power in the primary sidelit and skylit daylight areas separately from other lighting in the enclosed space.

ii. Controls luminaires in primary sidelit areas separately from skylit areas.

EXCEPTION to Section 131(c) 2A: Primary sidelit and skylit daylight areas that have a combined area totaling less than or equal to 250 square feet within any enclosed space.

B. For all skylit daylight areas:

i. The skylit daylight area shall be shown on the plans.

ii. All of the general lighting in the skylit area shall be controlled independently by an automatic daylighting control device that meets the applicable requirements of Section 119.

iii. The automatic daylighting control shall be installed in accordance with Section 131(c)2D.

EXCEPTION 1 to Section 131(c)2B: Where the total skylit daylight area in any enclosed space is less than or equal to 2,500 square feet.

EXCEPTION 2 to Section 131(c)2B: Skylit daylight areas where existing adjacent structures obstruct direct beam sunlight for at least 6 hours per day during the equinox as calculated using computer or graphical methods.

EXCEPTION 3 to Section 131(c)2B: When the skylight effective aperture is greater than 4.0 percent, and all general lighting in the skylit area is controlled by a multi-level astronomical time switch that meets the requirements of Section 119(h) and that has an override switch that meets the requirements of Section 131(d)2.

EXCEPTION 4 to Section 131(c)2B: Skylit daylight areas where the effective aperture is less than 0.006. The effective aperture for skylit daylight areas is specified in Section 146(a)2E.

C. Luminaires providing parking garage lighting that are in or are partially in the **PARKING GARAGE** sidelit daylight area and/or the **PARKING GARAGE** skylit area shall have at least one lighting control that:

i. Controls 100 percent of the general lighting power in the sidelit and skylit daylight areas separately from other lighting in the enclosed space, in an ON/OFF manner.

ii. Controls luminaires in sidelit areas separately from skylit areas.

EXCEPTION 1 to Section 131(c) 2C: Sidelit and skylit daylight areas that have a combined area totaling less than or equal to 250 square feet within any enclosed space.

EXCEPTION 2 to Section 131(c) 2C: Sidelit daylight areas where existing adjacent structures are twice as tall as their distance away from the opening or window, and at least as wide as the opening or window.

EXCEPTION 3 to Section 131(c) 2C: Lighting specifically in the daylight adaptation (transition) zone, and lights on dedicated ramps (ramps without parking).

D~~C~~. The primary sidelit area(s) shall be shown on the plans, and the general lighting in the primary sidelit areas shall be controlled independently by an automatic daylighting control device that meets the applicable requirements of Section 119 and is installed in accordance with Section 131(c) 2E.

EXCEPTION 1 to Section 131(c) 2D: Where the total primary sidelit daylight area in any enclosed space has an area less than or equal to 2,500 square feet.

EXCEPTION 2 to Section 131(c) 2 D: Primary sidelit daylight areas where the effective aperture is less than 0.1. The effective aperture for primary sidelit daylight areas is specified in Section 146(a)2E.

EXCEPTION 3 to Section 131(c) 2 D: Primary sidelit daylight areas where existing adjacent structures are twice as tall as their distance away from the windows.

~~**EXCEPTION 4 to Section 131(c) 2C**: Parking garages.~~

E~~D~~. Automatic Daylighting Control Device Installation and Operation. Automatic daylighting control devices shall be installed and configured to operate according to all of the following requirements:

i. Automatic daylighting control devices shall have photosensors that are located so that they are not readily accessible in accordance with the designer's or manufacturer's instructions.

ii. The location where calibration adjustments are made to the automatic daylighting control device shall be readily accessible to authorized personnel, or located within 2 feet of a ceiling access panel that is no higher than 11 feet above floor level.

iii. Automatic daylighting controls shall be multi-level, including continuous dimming, and have at least one control step that is between 50 to 70 percent of rated power of the controlled lighting.

EXCEPTION 1 to Section 131(c) 2Eiii:

Controlled lighting having a lighting power density less than 0.3 W/ft^2.

EXCEPTION 2 to Section 131(c)2Eiii: When skylights are replaced or added to on an existing building with an existing general lighting system.

iv Under all daylight conditions in all areas served by the controlled lighting, the combined illuminance from the controlled lighting and daylight is not less than the illuminance from controlled lighting when no daylight is available.

v When all areas served by the controlled lighting are receiving daylight illuminance levels greater than 150 percent of the illuminance from controlled lighting when no daylight is available, the controlled lighting power consumption shall be no greater than 35 percent of the rated power of the controlled lighting.

3.2 Recommended Table 146-E and 146-F Changes

TABLE 146-E COMPLETE BUILDING METHOD LIGHTING POWER DENSITY VALUES (WATTS/FT²)

TYPE OF USE	**ALLOWED LIGHTING POWER**
Auditoriums	1.5
Classroom Building	1.1
Commercial and industrial storage buildings	0.6
Convention centers	1.2
Financial institutions	1.1
General commercial and industrial work buildings	
High bay	1.0
Low bay	1.0
Grocery Stores	1.5
Library	1.3
Medical buildings and clinics	1.1
Office buildings	0.85
Parking Garages	~~0.3~~ 0.2
Religious facilities	1.6
Restaurants	1.2
Schools	1.0
Theaters	1.3
All others	0.6

Figure 45: Recommended Changes to Table 146-E

TABLE 146-F AREA CATEGORY METHOD - LIGHTING POWER DENSITY VALUES (WATTS/FT²)

PRIMARY FUNCTION		ALLOWED LIGHTING POWER (W/ft²)	PRIMARY FUNCTION		ALLOWED LIGHTING POWER (W/ft²)
Auditorium		1.5 1	Laboratory, Scientific		1.4 4
Auto Repair		0.9 2	Laundry		0.9
Beauty Salon		1.7	Library	Reading areas	1.2
Civic Meeting Place		1.3 1		Stacks	1.5
Classrooms, lecture, training, vocational room		1.2	Lobbies	Hotel lobby	1.1 1
Commercial and industrial storage (conditioned and unconditioned)		0.6		Main entry lobby	1.5 1
Commercial and industrial storage (refrigerated)		0.7	Locker/dressing room		0.8
Convention, conference, multipurpose and meeting centers		1.4 1	Lounge/recreation		1.1
Corridors, restrooms, stairs, and support areas		0.6	Malls and atria		1.2 1
Dining		1.1 1	Medical and clinical care		1.2
Electrical, mechanical, telephone rooms		0.7 2	Offices	> 250 square feet	0.9
Exercise center, gymnasium		1.0		≤ 250 square feet	1.1
Exhibit, museum		2.0	Parking Garage	Parking Area	~~0.2~~ 0.14
				Dedicated Ramps	0.3
Financial transactions		1.2 1		~~Ramps and Entries~~ Daylight Adaptation Zones	0.6
General commercial and industrial work	Low bay	0.9 2	Religious Worship		1.5 1
	High bay	1.0 2	Retail merchandise sales, wholesale showrooms		1.6
	Precision	1.2 3	Tenant lease space		1.0
Grocery Sales		1.6	Theaters	Motion picture	0.9 1
Hotel function area		1.5 1		Performance	1.4 1
Housing, Public, and Commons Areas	Multi-family, Dormitory	1.0	Transportation Function		1.2
	Senior Housing	1.5	Waiting area		1.1 1
Kitchen, food preparation		1.6	All other		0.6

FOOTNOTES:

1. The smallest of the following values may be added to the allowed lighting power for ornamental chandeliers and sconces that are in addition to and switched or dimmed on circuits different from the circuits for general lighting:
   a. One watt per square foot times the area of the task space that the chandelier or sconce is in; or
   b. The actual design wattage of the chandelier or sconce.

2. The smallest of the following values may be added to the allowed lighting power for specialized task work:
   a. 0.5 watt per square foot times the area of the task space required for an art, craft assembly or manufacturing operation; or
   b. The actual design wattage of the luminaire(s) providing illuminance to the specialized task area.

For spaces employing this allowance, the plans shall clearly identify all task spaces using these tasks and the lighting equipment designed to illuminate these tasks. Tasks that are performed less than two hours per day or poor quality tasks that can be improved are not eligible for this specialized task work allowance.

3. The smallest of the following values may be added to the allowed power for precision commercial and industrial work:
   a. One watt per square foot times the area of the task space required for the precision work; or
   b. The actual design wattage of the luminaire(s) providing the illuminance to the precision task area.

For spaces employing this allowance, the plans shall clearly identify all task spaces using these tasks and the lighting equipment designed to illuminate these tasks. Tasks that are performed less than two hours per day or poor quality tasks that can be improved are not eligible for this precision task work allowance.

4. The smallest of the following values may be added to the allowed lighting power for specialized task work: a. 0.2 watt per square foot times the area of the task space required for a lab in a school; or b. The actual design wattage of the luminaire(s) providing illuminance to the specialized task area.

Figure 46: Recommended Changes to Table 146-F

4. References

NEMA. (2002). Guidelines on the Application of Dimming to High Intensity Discharge Lamps. National Electrical Manufacturers Association.

SCE. (2009). Emerging Technology Evaluation: LED Lighting for Covered Parking.

5. Appendix A: Parking Garage Light Source Technologies

Lighting for the interior of parking garages is currently regulated under Title 24 Section 146 "Prescriptive Requirements for Indoor Lighting," but the lighting controls are being examined in context with exterior lighting. Top deck levels, which are treated as exterior parking lots, are not addressed in this document.

5.1 State of the Market

Currently, parking garage lighting is commonly achieved using high-intensity discharge (HID) or linear fluorescent luminaires, both of which provide high light levels with reasonably low energy consumption. Recent trends are toward using light-emitting diode (LED) luminaires in garages, which provide low-energy white light alternatives that are inherently dimmable and controllable. The interior spaces of parking garages are treated more similarly to interior spaces than to exterior parking lots, and experience issues with visual adaptation when transitioning into and out of the interior space. To account for the high exterior light levels during the day, the typical parking garage interior lighting remains "on" at full power to provide high transition light levels.
Current control requirements for interior parking garages are included under the indoor lighting control requirements, essentially requiring automatic shut-off either via time switch or occupancy sensor, and daylight-responsive zoning.

5.2 Light Source Technologies

5.2.1 HID Lighting

High-intensity discharge luminaires provide a high-efficiency point-source option for lighting parking garage interiors. Both Metal Halide (MH) and High-Pressure Sodium (HPS) lamps are commonly used because of their long life and high efficiency. Since most HID lamps are essentially point sources, significant optical control is achievable. MH lamps provide a "whiter" white light than HPS lamps, and have a higher color rendering index (CRI). HID lamps are generally powered by core-and-coil, also known as magnetic, ballasts, but an industry-wide trend toward electronic ballasts seems to be emerging due to higher efficiencies, increased lamp performance and the potential for dimming.

5.2.2 Fluorescent Lighting

Fluorescent luminaires provide a low-cost and flexible alternative for parking garage lighting compared to HID luminaires. Fluorescent lamps, specifically T5 lamps, are the most efficacious light sources currently available, and therefore can provide sufficient light levels with lower energy consumption compared to HID lighting. Because of the extended diffuse nature of the fluorescent lamp envelope, tight optical control is much more difficult, and thus the luminous distributions are generally less precise than with a point source. Fluorescent luminaires are dimmable, lending themselves to applications requiring dimming or bi-level control, and the luminaires can be provided at a very low price point. Providing bi-level or dimming capabilities requires either a special dimming or bi-level ballast, or a two-lamp luminaire in which the two lamps can be switched separately to provide two levels of output. In colder climates, fluorescent lighting has posed an issue to due limited start-up capabilities at cold ambient temperatures. When used in conjunction with any type of sensing equipment, the negative impact of switching on lamp life expectancy should be considered.

Induction lamps, which are essentially electrodeless fluorescent lamps, have much longer lives than typical linear fluorescent lamps due to the lack of electrode degradation. Induction lamps provide white light at a reasonable efficacy, but are much larger than typical HID lamp configurations. The availability of induction lamps for exterior lighting, including street and parking garage lighting, is increasing due to the desirable benefits of white light for exterior spaces and the very long expected life of induction technology.

5.2.3 LED Lighting

LED luminaires are quickly becoming a viable alternative to other white-light sources for parking garage applications. LEDs have the potential for very precise optical control, and provide a low-energy alternative. Historically, the cost per lumen for LEDs has made them cost-prohibitive as a general solution, though the cost continues to decline. LEDs, which incorporate electronic drivers, are inherently capable of multi-level dimming control, and are not negatively impacted by on/off switching cycles or dimming. LED luminaires are less subject to low-end temperature operation issues as seen with HID and fluorescent sources.

5.3 Sensor Technology

5.3.1 Integral Occupancy Sensors

Occupancy sensors respond to trigger the luminaires "on" when occupancy is detected, and then extinguish the luminaires after no activity has been observed for a certain pre-determined period of time.

Luminaires with integral occupancy sensors are becoming more widely available for both interior and exterior applications. For specific low-use applications, such as stairwells, integral occupancy sensing has provided an energy-savings opportunity that has been proven through many installations. Control component manufacturers have trended toward creating occupancy sensors that can easily be integrated with luminaires by others, and generally rely on PIR technology for integral occupancy sensing. The sensor, however, must be integrated into the fixture in an appropriate way that allows the sensor to "see" the full coverage area and reduce the risk of false-"on" signals.

The availability of interior parking garage luminaires with integral occupancy sensors has been increasing. In general, manufacturers are providing the option for an integral occupancy sensor on fluorescent, LED and induction luminaires, all of which are capable of simple bi-level control. At this time, no standard luminaire has been found that can be provided with integral occupancy sensing to control an HID lamp source.

5.3.2 Remote Occupancy Sensors

Mounting the occupancy sensors remotely reduces the dependence on fixture selection when choosing to integrate occupancy-based control. Remotely-mounted occupancy sensors can be placed ideally to most accurately capture the occupancy, as they do not rely on specific luminaire locations. Remote-mounted occupancy sensors may also lead to a reduced quantity of sensors needed, since a single sensor could control an entire group of luminaires. Remote sensors can either be hard-wired with low- or line-voltage power, or can be wireless with battery power. Selecting the sensor apart from the luminaire also allows the specifier to determine the appropriate type of sensing technology.

5.3.3 Daylight Sensors

Daylight sensors, or photocells, can be provided either integral to luminaires or remote. Similar to occupancy sensors, if daylight sensors are provided integral with luminaire, then they must be placed and commissioned appropriately to reduce noise in the reading, and may not be oriented optimally depending on the luminaire location and orientation. Remotely-mounted daylight sensors can be used to control groups of luminaires, reducing the number of sensors necessary.

Daylight sensors can either be configured in an open-loop scenario, where they read only the ambient daylight, or in a closed-loop scenario, where they read the resultant interior light level due to both electric light and daylight. Closed-loop sensing also provides an opportunity for lumen maintenance dimming for lamps that are continuously dimmable, which may further serve to reduce energy consumption over the life of the system, though this configuration is rarely seen in parking garage systems.

5.4 Control Issues

In most parking garages, the typical approach is to leave all of the luminaires at full power at all times and to not provide sophisticated or “smart” control systems. During the daytime, the interior light levels at the entrances and exits is critical to providing smooth visual adaptation between the interior and exterior environments, and thus higher light levels are typically provided in those zones. At night, less lighting is necessary because the ambient environment is much darker, and therefore lower light levels are typically acceptable. However, since most garages are provided without sophistication in the control system, the potential reduction of energy use at night is generally not seen.

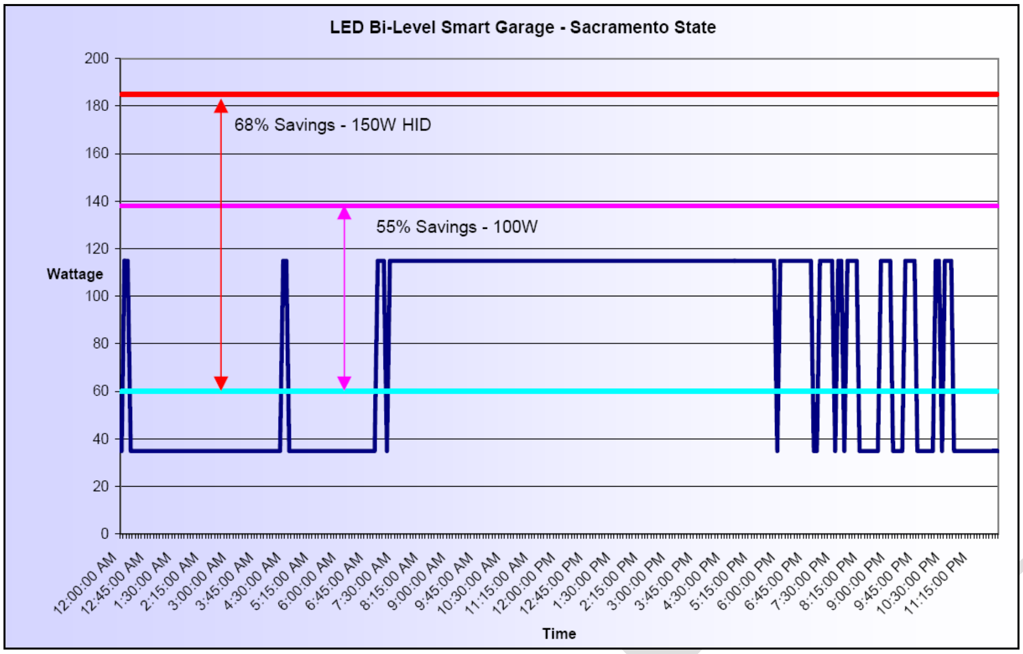

Figure 47: LED fixture activity (dark blue) when controlled using occupancy and daylight sensing, compared to baseline HID systems (red = 150W HID, pink = 100W HID). [PIER 2009]

5.5 Technical Issues

5.5.1 Visual Adaptation Issues

A major issue surrounding parking garage lighting design is based on the adaptation of the visual system. The human visual system is dynamic and able to accommodate a wide range of luminances, but adaptation between different luminances is not instantaneous. For parking garage applications, the typical interior light levels can approach 1/2000th of the daylight levels. In order to transition during the day from the very bright exterior to the interior spaces, most lighting designs provide significantly higher light levels at the entrances and exits than provided throughout the garage to allow for visual adaptation. This increased energy use during the day is counter to most energy-savings measures, but provides for increased safety and reduced risk of pedestrian conflict. During night hours, the typical exterior ambient light level is much closer to the level being provided in the garage, so adaptation is not an issue and most entry adaptation lighting systems are turned “off” at night.

5.5.2 Occupancy Sensing Issues

Occupancy sensing in parking garages is limited by the various types of technologies. Passive infrared (PIR) technology is the most common type of occupancy sensor found integral to luminaires and the most common type used outdoors. PIR occupancy sensors, though, are limited to a direct line-of-sight detection. PIR sensors must be selected and placed carefully to verify that full coverage of the required area is provided. Other sensor technologies, such as ultrasonic, are also used throughout lighting control, but are used less in noisy exterior environments because of the potential interference.

The specific placement and scope of controls for occupancy sensors in parking garages is also variable. Ideally, occupancy sensors would be placed according to function; they may turn the lights "on" down the drive aisle as a car enters, or they may turn "on" the luminaires as a pedestrian approaches the elevator. However, the cost-effectiveness of the various control configurations has not been reviewed.

5.5.3 Daylight Sensing Issues

Daylight sensing in parking garages provides an interesting opportunity to reduce daytime lighting energy consumption. Many above-grade parking garages are provided with open daylight apertures that are intended to provide natural ventilation of the space, but also allow daylight to penetrate into the space. Providing daylight sensors to control the luminaires in daylighted zones, either via switching or dimming, has been shown in previous demonstration projects (PIER 2009) to reduce lighting energy consumption in parking garages.
Again, the specific placement and scope of controls for daylight-responsive dimming or switching is variable. The approach can be very granular, with a sensor integrated into each individual luminaire, but that approach may be cost prohibitive for many projects. Since the guidelines for determining the extent of the daylighted zone used for Title 24-2008 interior control requirements is based on achieving a certain threshold illuminance at the workplane, the definitions may need to be re-examined for parking garages since they involve a different workplane, typically the floor level.

5.5.4 Control Issues

A previous demonstration project by the PIER program (2009) showed up to 80% energy savings in a parking garage when using occupancy and daylight-based bi-level switching. The results showed a 12.2% energy savings though daylight integration and a 21% annual energy saving through occupancy-based control. The remaining 53% energy savings was achieved through changing existing HPS luminaires out with new induction luminaires. This study was based on a retrofit using wireless control components, and therefore did not include any cost of rewiring the system.
Historically, little emphasis has been placed on the controls of parking garage lighting, and much of it remains on constantly, independent of occupancy or daylight availability. The introduction of substantial control requirements in parking garages would likely have a significant impact on the system first-costs. However, through reduced energy consumption and reduced maintenance-related costs, the additional premium of the control system might well be recovered quickly. For example, the PIER demonstration project of "smart" parking garage lighting (2009) showed a payback period of approximately 6 years for upgrading the luminaires and installing a new "smart" daylight- and occupancy-based control system.

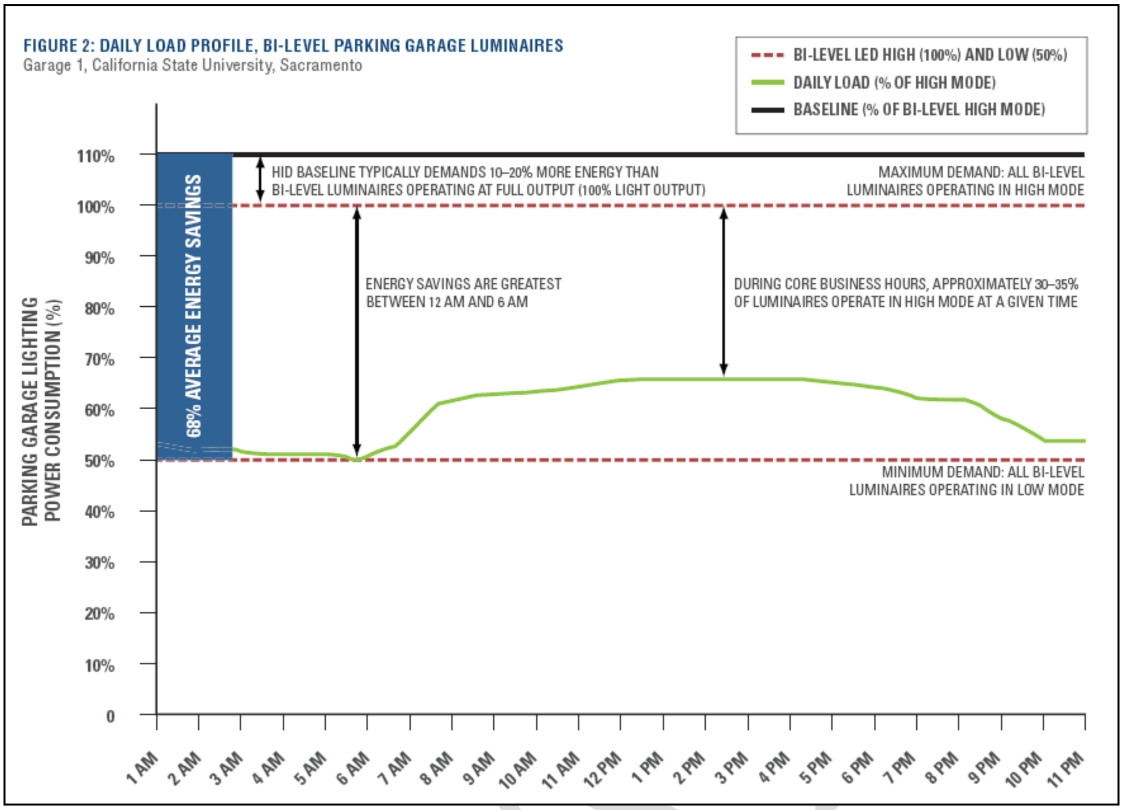

Figure 48: Daily Load Profile for Bi-Level Parking Garage Luminaires [PIER 2010]

5.6 Manufacturers

Current manufacturers of appropriate specification-grade luminaires with integral sensing equipment:

Gardco	Photocell, Occupancy Sensing (PIR)
Columbia Lighting	Photocell, Occupancy Sensing (PIR)
BetaLED	Photocell, Occupancy Sensing (PIR)
Widelite	Occupancy Sensing
Deco Lighting	Occupancy Sensing (Ultrasonic)
Alumen8	Photocell, Occupancy Sensing
Kim Lighting	Photocell, Occupancy Sensing
Lamar Lighting	Occupancy Sensing
Lithonia Lighting	Photocell, Occupancy Sensing (PIR)

Current manufacturers of specification-grade sensors that can be integrated with luminaires:

Leviton	Photocell, Occupancy Sensing (PIR)
Wattstopper	Photocell, Occupancy Sensing (PIR, Ultrasonic)
Lutron	Photocell

5.7 Future Technology Developments

The dimming of HID lamps through using electronic ballasts may present an opportunity to expand the applicability of bi-level control systems to a much broader selection of sources. Though current lamp/ballast and system compatibility issues make HID dimming difficult and fairly expensive, the benefits of electronic HID ballasts, such as increased lumen maintenance, make electronic HID very appealing from an energy-savings standpoint. Should the integration of dimming control with electronic HID become more commonplace and accepted, bi-level or dimmed control of HID luminaires in parking garages presents a large opportunity for energy savings.

As the availability of "smart" luminaires, ones with integral sensing, increases, the associated cost premiums are expected to decrease, making the equipment costs lower and thus the payback period for installing the upgraded system shorter.

5.8 References

2009. PIER Solutions for Parking Lots and Garages. California Energy Commission's Public Interest Energy Research Program.

2010. PIER Solutions for Parking Lots and Garages. California Energy Commission's Public Interest Energy Research Program.

2010. Bi-level LED Parking Garage Luminaires. California Energy Commission's Public Interest Energy Research Program.

2009. Wireless Integrated Photosensor and Motion Sensor. California Energy Commission's Public Interest Energy Research Program.

6. Appendix B: Power Density Calculations

			Lamps			Deep				Medium			
Type	**Description**	**Luminaire Efficiency**	**Qty**	**Type**	**Input Watts**	**LPD**	**E (min)**	**Max: Min**	**E (avg)**	**LPD**	**E (min)**	**Max: Min**	**E (avg)**
FL 1	Lamar Occu-Smart	85%	2	T8	55	0.072	1.0	7.20	3.69	0.073	1.0	7.10	3.73
FL 2	Columbia Gasketed	88%	2	T8	55	0.068	1.0	8.50	4.03	0.068	1.1	7.27	4.04
FL 3	Columbia Bare Strip	89%	2	T8	55	0.072	1.1	6.55	3.81	0.068	1.0	6.70	3.56
FL 4	Columbia Bare Strip	89%	1	T8	27	0.053	1.0	4.10	2.83	0.044	1.0	3.50	2.19
FL 5	Lithonia VAP, Wide	76%	2	T8	55	0.084	1.0	8.30	4.44	0.063	1.0	7.30	3.41
FL 6	Prudential White Wrap	61%	1	T8	27	0.048	1.1	2.27	1.67	0.054	1.0	2.60	1.83
FL 7	Prudential White Wrap	62%	2	T8	55	0.099	1.0	6.30	3.91	0.068	1.1	4.45	2.57
					Average:	**0.071**				**0.062**			

			Lamps			Shallow				Square			
Type	**Description**	**Luminaire Efficiency**	**Qty**	**Type**	**Input Watts**	**LPD**	**E (min)**	**Max: Min**	**E (avg)**	**LPD**	**E (min)**	**Max: Min**	**E (avg)**
FL 1	Lamar Occu-Smart	85%	2	T8	55	0.082	1.1	8.27	4.18	0.045	1.1	4.91	2.36
FL 2	Columbia Gasketed	88%	2	T8	55	0.063	1.2	8.42	3.63	0.042	1.1	5.82	2.57
FL 3	Columbia Bare Strip	89%	2	T8	55	0.074	1.1	8.00	3.79	0.042	1.0	5.30	2.39
FL 4	Columbia Bare Strip	89%	1	T8	27	0.053	1.0	5.00	2.51	0.032	1.0	2.90	1.79
FL 5	Lithonia VAP, Wide	76%	2	T8	55	0.074	1.0	9.90	3.97	0.054	1.1	5.64	2.87
FL 6	Prudential White Wrap	61%	1	T8	27	0.062	1.0	3.50	1.97	0.040	1.0	2.10	1.50
FL 7	Prudential White Wrap	62%	2	T8	55	0.091	1.0	7.50	3.50	0.054	1.0	4.30	2.16
					Average:	**0.071**				**0.044**			

Figure 49: Lighting Power Density Calculations for Fluorescent Sources

			Lamps			Deep			
Type	**Description**	**Luminaire Efficiency**	**Qty**	**Type**	**Input Watts**	**LPD**	**E (min)**	**Max: Min**	**E (avg)**
MH 1	Gardco GP1	87%	1	PSMH	129	0.085	1.0	4.70	2.81
MH 2	Lithonia PGR	81%	1	MH	140	0.078	1.1	4.82	2.37
MH 3	McGraw-Edison EPL	81%	1	MH	151	0.071	1.0	7.50	3.17
MH 4	Widelite RSP	74%	1	MH	129	0.074	1.0	3.50	2.11
HPS 1	Gardco GP1	87%	1	HPS	130	0.076	1.1	3.45	2.61
HPS 2	KIM PGL4	86%	1	HPS	108	0.060	1.0	5.50	2.34
HPS 3	Lithonia PGR	82%	1	HPS	135	0.074	1.1	5.27	2.60
HPS 4	McGraw-Edison EPL	79%	1	HPS	150	0.068	1.0	7.40	3.46
HPS 5	RUUD F515-SCL	78%	1	HPS	170	0.112	1.4	9.07	4.85
LED 1	BetaLED 304	N/A	60	LED	110	0.060	1.0	5.10	2.58
LED 2	Gardco ELG 70LA	N/A	49	LED	68.7	0.048	1.0	3.70	2.62
LED 3	KIM PGL7	N/A	60	LED	73.1	0.042	1.0	2.00	1.62
LED 4	Widelite VIZOR 24"	N/A	60	LED	68	0.040	1.0	3.00	1.75
IND 1	Gardco GP1	83%	1	IF	85	0.068	1.0	4.70	2.18
IND 2	KIM PGL4	91%	1	IF	86.8	0.069	1.0	5.70	2.33
IND 3	Widelite RSP	88%	1	IF	85	0.072	1.0	5.10	2.27
IND 4	Everlast Bi-Level	not reported	1	IF	82.6	0.060	1.1	8.36	3.40
					Average:	0.068			

Figure 50: Lighting Power Density Calculations for Other Sources

Note that the Fluorescent calculations were completed for more geometry conditions within the parking garage. Once completed, the Other Sources calculations were made only for the most difficult category as discovered in the Fluorescent calculations.

7. Appendix C: Lighting Controls Limitations Survey

7.1 Current Sensing Technology for Lighting Control

Currently, the majority of occupancy sensing equipment suitable for interior lighting control is based on one of two methods of detecting occupancy: passive infrared and ultrasonic. Though the terms "occupancy sensor" and "vacancy sensor" are often used interchangeably, a true vacancy sensor is actually a manual-on occupancy sensor that requires the user to turn the luminaires "on" and uses a lack of occupancy to determine when to extinguish the luminaires.

Passive infrared (PIR) technology is the most common, using sensors to track the heat of a person, large animal or object through angular cones that emanate from the sensor. The detector "senses" occupancy when a body of sufficient heat crosses the edge of the angular detection cones,

The second type of common sensing technology is based on ultrasonic detection. Ultrasonic detection is based on measuring the effects of the Doppler principle on moving bodies in the space based on an emitted frequency typically in the 32-40 kHz range.

Finally, some types of occupancy sensors use acoustic sensors, which rely on the noise generated by occupants, such as the noise of typing on a keyboard, to indicate that the space is occupied. This type of sensor has its roots in security applications, is rarely used for architectural lighting control applications.

Occupancy sensors that employ both PIR and ultrasonic detection methods, commonly referred to as dual-technology sensors, provide the most accurate and robust sensing of occupancy, and are becoming more commonplace.

For exterior occupancy sensing, the majority of the current equipment available is PIR-only, and do not use ultrasonic detection because of the possibility for noise generated by environmental factors.
Security-Based Occupancy Sensing

In other markets, such as security-based occupancy sensing and person-detection, there has been an increase in use of video detection systems. Such systems are capable of not only sensing whether or not a person is present, but identifying and tracking that person as well. Video detection systems are very robust, but are generally not seen in architectural control applications.

7.2 Luminaire-Integrated Occupancy Sensors

The availability of luminaire-integrated occupancy sensors for exterior environments is growing. Ultrasonic detection systems have been directly integrated into bollards and other exterior luminaires, and some pole-mounted luminaires are offered with an integral occupancy sensor. However, little research has been made available that describes the effectiveness of these solutions.

7.3 Technical Issues

The technical issues surrounding the use of exterior occupancy sensors can be broken into four major areas: Range, Environmental Interaction, Energy Draw and Luminaire Integration.

7.3.1 Range Limitations

The current sensors offered have range restrictions that may create issues when used in the target exterior environments. Since most PIR sensors use a segmented lens to create the angular cones of vision, the extent of those diverging cones continues to increase the further one is away from the sensor. Therefore, even though the sensor granularity may be appropriate when near the sensor, as one moves further away the control bands become larger and one must travel a longer distance before crossing a boundary and triggering the sensor, as shown in Figure 51. Also, because of the angular cone arrangement, it could be possible in a large application for someone to walk toward the sensor over a large distance and never cross a sensor boundary, as shown in Figure 52.

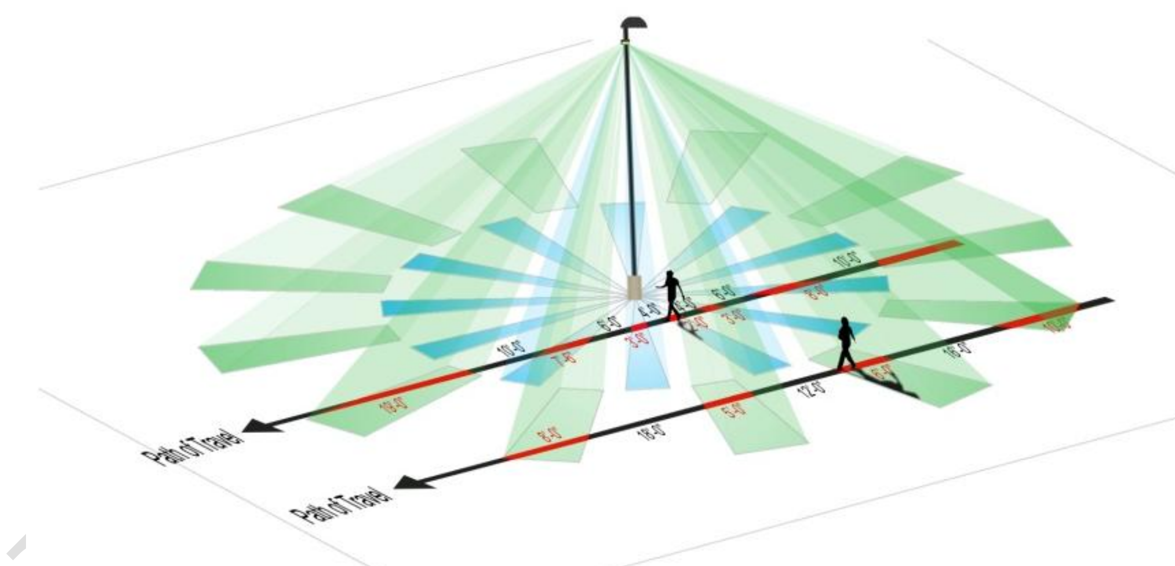

Figure 51: Illustration of PIR Sensor Limitations. A pedestrian near the edge of the radius of detection must travel much longer before triggering the sensor then a pedestrian near the center of the radius of detection.
[Based on Detection Pattern of Wattstopper LMPC-100 Outdoor PIR Occupancy Sensor] (Clanton 2010)

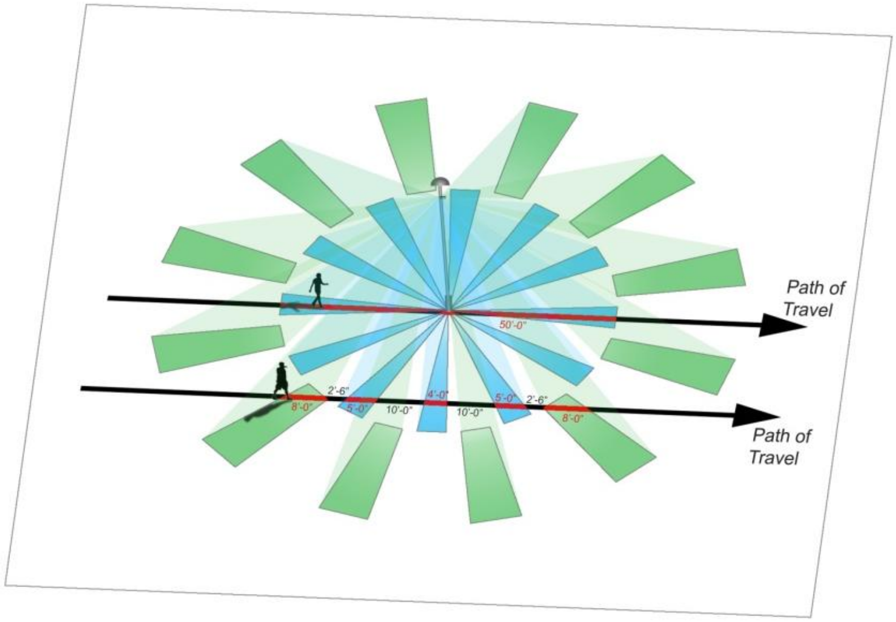

Figure 52: Illustration of PIR Sensor Limitations. A pedestrian moving directly toward the sensor can travel a long distance before triggering the sensor by crossing a boundary. A pedestrian moving parallel to that path but further from the sensor will trigger the sensor with much less distance traveled.
[Based on Detection Pattern of Wattstopper LMPC-100 Outdoor PIR Occupancy Sensor] (Clanton 2010)

Many current sensors are limited to ranges of mounting heights, and in the angular field-of-view. Finally, all PIR sensors are limited to a maximum range, in plan, over which they are effective. Of the sensors reviewed, the maximum available range was only 50 foot radius.

7.3.2 Environmental Interaction

Interaction with the environment for these types of PIR sensors may also be an issue. Because the sensor is detecting the presence of bodies hotter than the background, applications may be limited based on high ambient temperature considerations. Also, since water is highly refractive, increases in humidity and/or condensation may create sensor visibility issues. Finally, dirt and/or snow build-up on the lens could create sensor visibility issues in certain environments.

7.3.3 Energy Draw

The energy use of the various sensors must be understood. If the goal of the occupancy-based bi-level system is to conserve energy, then the energy consumption of the sensors themselves must be included when determining possible energy savings. The current maximum sensor range available for specification-grade exterior-rated occupancy sensors is approximately 50 feet. As shown in Figure 53 and Figure 54, this current radius is insufficient to provide complete coverage for typical parking lot pole spacings, resulting in "dead zones" where the motion of a pedestrian may not be captured.

For a typical pole spacing of 120 feet by 100 feet, Figure 55 shows the sensor radius that would be required to provide full coverage, defined as the minimum radius needed to verify that all locations in the parking lot are covered by at least one sensor. This increased radius also allows for the overlap of coverage area near the edges of the detection radius, where the sensor is less sensitive due to the diverging cones of sensitivity, which may serve to increase the likelihood of detection at these locations.

As shown in Figure 55, a sensor with a detection radius of approximately 78 feet would be necessary to provide full coverage of a parking lot with poles spaced approximately 120 feet by 100 feet. This results in a sensor area coverage increase of approximately 240%, from around 7,800 square feet to 19,100 square feet. The question of energy consumption as the range of the sensor increases is a valid area for study as the range, and thus power draw, of the sensors increase.

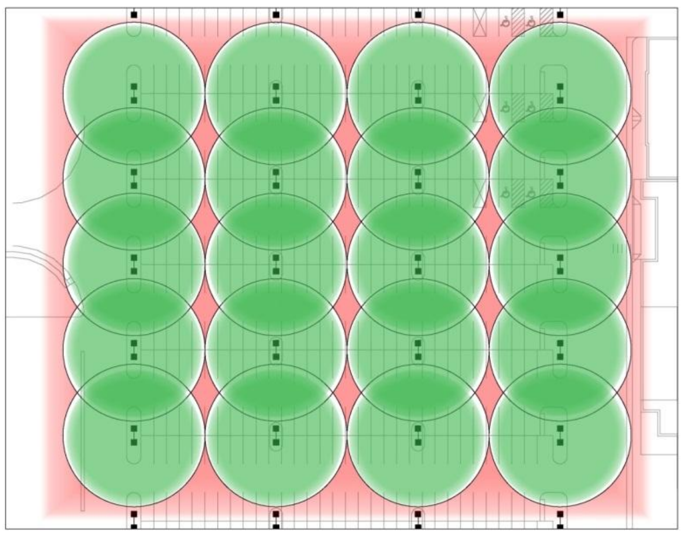

Figure 53: Illustration of PIR Sensor Range Limitations. With a tight parking lot pole spacing of 60 feet by 100 feet, the current maximum sensor radius of 50 feet, shown as the green circles surrounding each pole, does not provide full coverage of the parking lot, resulting in the potential "dead zones" shown in red.

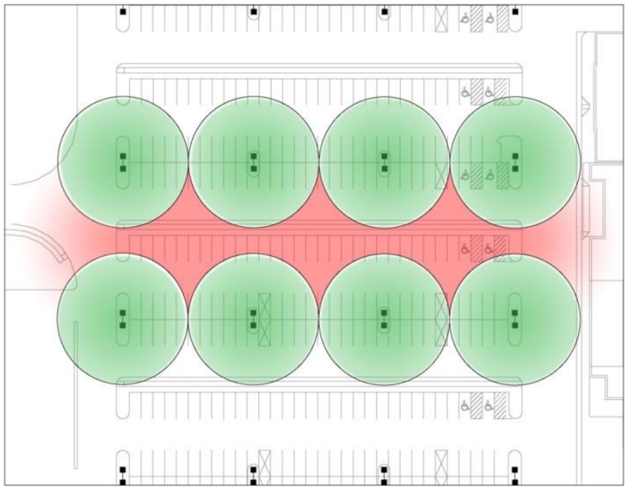

Figure 54: Illustration of PIR Sensor Range Limitations. With a more typical parking lot pole spacing of 120 feet by 100 feet, the current maximum sensor radius of 50 feet, shown as the green circles surrounding each pole, does not provide full coverage of the parking lot, resulting in the potential "dead zone" shown in red.

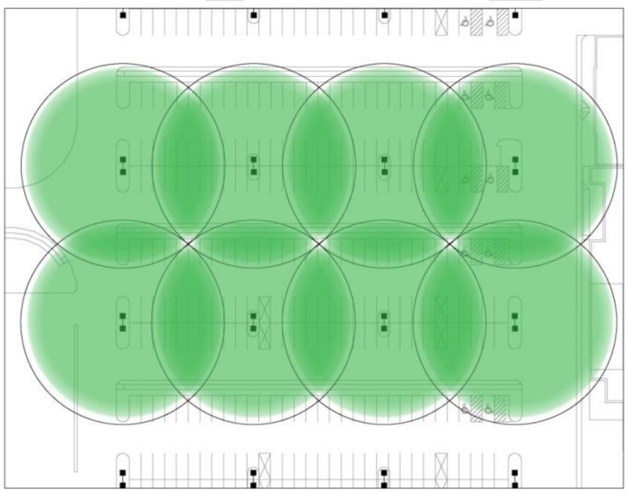

Figure 55: Illustration of PIR Sensor Range Limitations. With a typical parking lot pole spacing of 120 feet by 100 feet, the sensor detection radius needed to eliminate the "dead zones" is approximately 78 feet.

7.4 Luminaire Integration

The integration of sensing equipment into exterior-rated luminaires is becoming more common for off-the-shelf products, though there are both functional and aesthetic issues with many solutions. In general, the majority of exterior-rated PIR sensors available from non-luminaire manufacturers appear similar to large residential security-lighting motion sensors, and are generally placed onto the pole. While this meets the functional requirements of the sensors, the aesthetics may be compromised.

In a few luminaires from manufacturers who fully integrate the sensor, the motion sensor is provided directly adjacent to the luminous aperture. From experience with installed versions of these luminaires, the combination of the bug-attracting luminous aperture so close to the sensor can result in a permanent "on" situation, as the bugs are sufficient to trigger the sensor.
Future Technology Developments

7.5 Video Sensing

In general, the most promising current trend in sensor development is focused on using video technology to replace sensors. While only a limited number of manufacturers have created strictly video-based occupancy sensors, the technology to sense and track the presence of people is commonly used in surveillance and security applications. Video sensing could be used, not only for security purposes, but also to control both lighting and HVAC in a demand-responsive manner.

Video sensing, in general, can be accomplished with cameras that have built-in memory and therefore are capable of storing the collected data directly on the unit. More sophisticated systems tend to include those that are capable of detecting particular faces, tracking the presence of valuable items, tracking the eye movements of patrons in a retail store and other such high-level processing tasks. For the application of sensing occupancy for lighting and HVAC, the sensitivity and thus sophistication of the equipment need not be to the level needed for security, but the various systems may be able to be combined into one, eliminated additional control wiring and sensors.

One previous study (Sarkar et al 2008) was focused on the development of an integrated daylight and occupancy sensor based on digital image processing. Ultimately, the system used the pixel-by-pixel values to evaluate the luminance of various surfaces, and determined an occupancy event had occurred based on a change in the chromatic information in the scene. The general conclusion by the authors is that the technology is promising, but the largest hurdle to be overcome is the equipment cost, especially in comparison to standard occupancy sensors and photocells currently on the market.
PIR Sensing

Future developments in PIR sensing for exterior environments are promising. According to a major manufacturer who currently produces exterior PIR occupancy sensors, future developments focused around PIR detection include adding additional features, such as better weather-proofing and remote commissioning using a handled remote. Manufacturers are also looking into including multiple PIR elements to provide a wider range of coverage, and optimizing the design of the lens to enhance the coverage. According to this manufacturer, enhancing the coverage of PIR detection is done through using current technology PIR elements and creating new lenses, and therefore little additional power draw is anticipated as the detection capabilities are expanded. This same manufacturer also indicated that they are targeting a 90 foot detection radius with 180-degree coverage for large motion and a 60 foot detection radius with 360-degree coverage for small motion, which would provide sufficient coverage for most typical parking lot pole configurations.

7.6 Manufacturers

Current manufacturers of specification-grade indoor-rated occupancy sensors include:

Wattstopper	PIR, Combined Technologies
Leviton	Ultrasonic, PIR, Combined Technologies
SensorSwitch	Ultrasonic, PIR, Combined Technologies
NexLighting	PIR
GreenGate	Ultrasonic, PIR, Combined Technologies
Total Lighting Controls	Ultrasonic, PIR, Combined Technologies
Crestron	PIR, Combined Technologies

Current manufacturers of specification-grade outdoor-rated occupancy sensors include:

Wattstopper	PIR
Leviton	PIR

Current manufacturers of exterior-rated luminaires available with integral occupancy sensing include:

Gardco Lighting	Pole-Mounted Luminaires with PIR occupancy sensing
	Pathway Luminaires with Ultrasonic occupancy sensing
	Wall Sconces with PIR occupancy sensing
Everlast Induction Lighting	Pole-Mounted Luminaires with PIR occupancy sensing
	Parking Garage Luminaires with PIR occupancy sensing
BetaLED	Pole-Mounted Luminaires with PIR occupancy sensing
	Pathway Luminaires with Ultrasonic occupancy sensing
	Parking Garage Luminaires with PIR occupancy sensing
Cooper Lighting	Floodlight Luminaires with PIR occupancy sensing
	Decorate Wall Sconces with PIR occupancy sensing

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8. Appendix D: Lamps and Ballasts for Bi-Level Control

8.1 State of the Market

8.1.1 HID Lamps

The use of high-intensity discharge (HID) lamps for exterior environments is very common because of their high efficiency, long life, low temperature sensitivity and wide range of available lumen packages. In 2001, across the industrial, residential, commercial and stationary outdoor lighting sectors, HID lighting was estimated to consume 130 TWh/year nationally (DOE 2004).

High Pressure Sodium (HPS) lamps are very common throughout the market. HPS lamps offer long life, high efficiencies and acceptable lumen depreciation at a reasonable price point. HPS is generally used for street and area lighting in locations where color perception is of secondary concern, as the color rendering capabilities of HPS lamps are low. HPS lamps tend to cycle as they reach end of life, creating a burden on maintenance personnel, and have re-strike delay issues when trying to return to full power after a period of being “off”.

Metal Halide (MH) and Ceramic Metal Halide (CMH) lamps currently offer an alternative to HPS, delivering whiter light with better color rendering ability, but still with long life, reasonable lumen depreciation and acceptable efficiencies. Both MH and CMH have a slight premium when compared to standard HPS systems, which is likely why they are seen less often in outdoor environments, but sales of MH lamps continue to grow as HPS sales have essentially remain level (DOE 2004). Both MH and CMH have the same re-strike issues seen with HPS, a problem typical of most HID sources.

MH and CMH sources are often used in exterior environments where color rendering is of concern, such as retail parking lots and façade lighting, or where small physical lamp sizes are beneficial, such as interior recessed lighting.

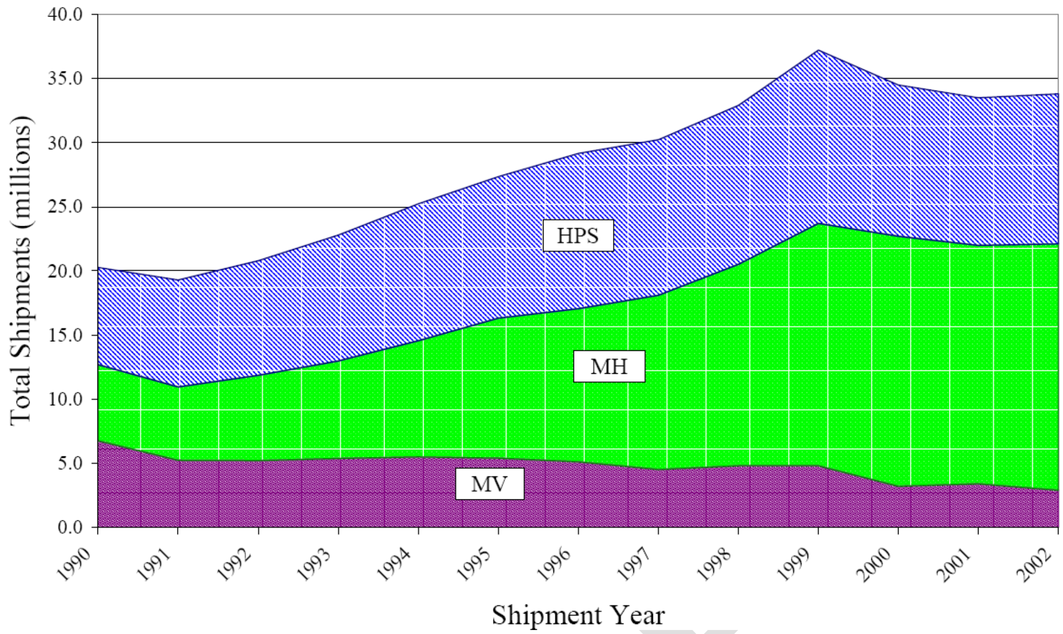

Figure 56: Total US HID Lamp Shipments by Type, 1990-2002 (DOE 2004)

8.1.2 HID Ballasts

Traditionally, HID sources use core-and-coil ballasts, commonly referred to as magnetic ballasts. These ballasts ultimately are rough on the lamp through start-up conditions leading to a foreshortened lamp life. Magnetic ballasts also tend to be large and heavy, due to the large iron cores included in the case and the need for sufficient heat dissipation. The efficiency of magnetic HID ballasts varies greatly across wattages, and tends to increase with increasing lamp wattage. Figure 57 shows the average efficiency of standard magnetic ballasts for MH and HPS sources based on the published information available from multiple manufacturers, defined as the ratio of lamp rated watts to total system input watts.

The introduction of new electronic HID (eHID) ballasts for both MH and HPS has created a wide range of possibilities, including promises of extended lamp life, increased lumen maintenance, and the ability to dim to reduce energy consumption. As shown in Figure 57, eHID ballasts are in general more efficient than the core-and-coil options, but are only available in limited wattage ratings, with few options available for lamps rated above 400W. eHID ballasts, because of the electronics, are temperature-sensitive, but are more concerned with restricting the high-end temperature to reduce the possibility of overheating the electronics and are less sensitive to cold-temperature conditions.

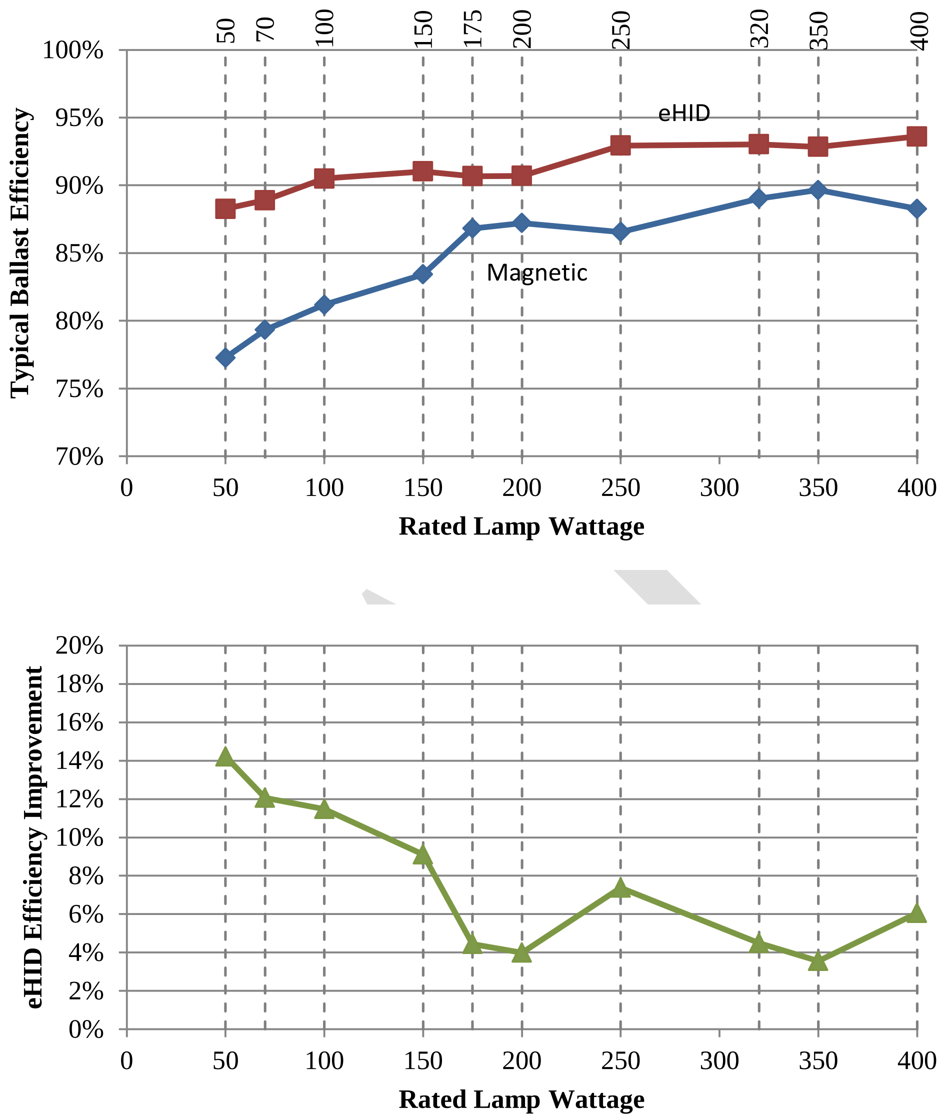

Figure 57: Typical Ballast Efficiencies and Estimated eHID Savings (Clanton 2010)

8.2 Legislation

Within the past few years, significant federal- and state-level legislation has been introduced to regulate HID light sources that effectively limit the types of lamp/ballast combinations available and regulating minimum efficiency requirements. Specifically, the Energy Independence and Security Act of 2007 (EISA 2007) identified probe-start HID ballasts as an inefficient technology and included regulation requiring that all luminaires rated 150W to 500W not be provided with probe-start technology as of January 1st, 2009. EISA 2007 also set minimum efficiency standards for HID ballasts, requiring magnetic pulse-start ballasts in the range of 150W to 500W must be at least 88% efficient, electronic ballasts below 250W must be at least 90% efficient, and electronic ballasts above 250W must be at least 92% efficient.

The American Clean Energy and Security Act of 2009 (ACESA 2009), also known as the HR 2454 Waxman-Markey Bill passed by the House on June 26, 2009, provides for additional phased provisions regulating the efficiency of HID luminaire systems. According to ACESA 2009, all HID luminaires manufactured on or after January 1st, 2016, must have a minimum luminaire efficacy of 50 lumens per watt, accounting for losses in the lamp, ballast and luminaire. That requirement is then tightened down, with a minimum luminaire efficacy of 70 lumens per watt required for luminaires manufactured on or after January 1st, 2018.

Assuming typical parking lot and area luminaire efficiency of 75.3% (McColgan & Derlofske 2004), the lamp ballast efficiency of an HID system including lamp and ballast would need to approach 67 lumens per watt, assuming no increases in the fixture efficiency, to meet the 2016 limit of 50 fixture lumens per watt (DOE 2010). In order to reach the 2018 limit, the lamp/ballast efficiency would need to be increased to around 94 lumens per watt (DOE 2010).

8.3 White Light Sources

Other white-light alternatives to HPS include induction, Light-Emitting Diode (LED), and Light-Emitting Plasma (LEP) technology, all of which are driven by electronic control gear, and are all capable of dimming or bi-level control. Induction lamps are essentially cathode-less fluorescent lamps, and have very long lives because of the lack of cathode degradation. They tend to be large, limiting the ability to incorporate them into luminaires designed for other, smaller light sources. But, induction lamps provide white light with high color-rendering capabilities, are dimmable, do not have the restrike issues seen with HID sources, and last three to four times longer than HPS lamps. Thermal management is again a concern of induction luminaire design, as the lamp's electronic components require careful management of the high-end thermal issues while considering the large size of the lamp assembly.

White-light LEDs are rapidly flooding the marketplace with lower-wattage alternatives to traditional HID sources. LEDs can be used to provide white or colored light, can be dimmed, have claims of very long expected life, and are available in a very small form factor, making them easy to integrate into a wide variety of fixtures. LEDs in general are less commonly seen because of the significant cost premium associated with the technology, but this cost premium is rapidly decreasing. Also fairly unique to LEDs as an exterior light source is that the pricing is generally a direct function of the quantity of light output, whereas with more traditional sources like HID, there is a much smaller premium associated with increasing light output. Thermal management, specifically managing the junction temperature of the diode, is of very high importance when using LEDs as increased junction temperature can result in reduced life.

Light-Emitting Plasma is an emerging technology, with claims of reduced energy consumption, long life, full-spectrum white light, and dimmability. LEP units are composed of three primary components, a sealed bulb that is partially embedded in dielectric material, and radio frequency (RF) driver that creates an electric field around the bulb, and a power supply. The electric field generated by the RF driver is concentrated by the dielectric material around the bulb, which vaporizes the bulb contents, a mixture of gas and metal halides, into a plasma form. In the plasma state, the combined gas and metal halides emit broad-spectrum white light. Because of the nature of the light source itself and the lack of electrodes within the bulb walls, it is anticipated that LEP lamps will have a rated life at or beyond those seen with LEDs. The current efficacy of LEP units is also nearly as high as for high-pressure sodium lamps.

8.4 Technical Issues

8.4.1 HID Ballasts

The new generation of eHID ballasts being offered by various manufacturers claim to provided extended lamp life, increased lumen maintenance, and reduced energy consumption. Figure 58demonstrates the increased lumen maintenance claim from Universal Lighting Technologies, showing that eHID ballasts result in improved lumen maintenance when compared to core-and-coil ballasts. The improvement in lumen maintenance can lead to reduced maintenance costs by extending the time between relamping. Increased lumen maintenance can also help to reduce the quantity of luminaires needed, by increasing the maintained lumens used to determine design light levels. Increasing the lamp life can also contribute to reducing the environmental impact of the lighting equipment by extending the time between relamping, which serves to reduce the amount of mercury-containing lamps that must be properly disposed.

The new eHID ballasts are also generally more efficient than standard core-and-coil ballasts, resulting in lower ballasts losses and higher system efficiency. eHID ballasts also tend to have a Total Harmonic Distortion (THD) of less than 5% compared to core-and-coil ballasts, which typically have a THD between 15 and 30% (Capehart 2007). This can help reduce power distribution losses within the overall system.

Other benefits of eHID include reduced lamp blackening, which reduces the color shift of the lamp overtime. eHID ballasts are also more precise at determining when the lamp has been ignited. This allows the lamp to be exposed while “on” to less of the high start-up current, reducing the degradation of the electrodes and thus increasing lamp life.

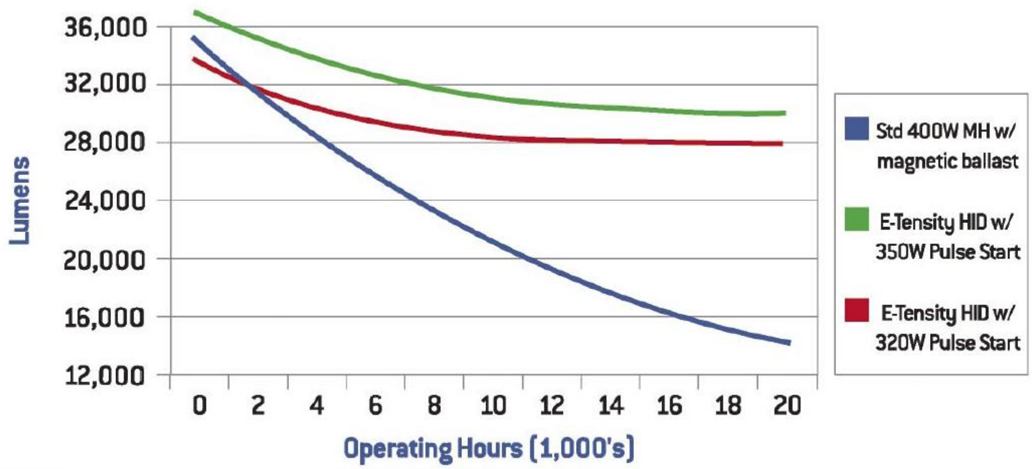

Figure 58: Claims of Increased Lumen Maintenance using eHID Ballast (Universal Lighting Technologies)

E-Tensity delivers greater energy savings than standard metal halide or magnetic pulse start ballasts.	Std 400W Metal Halide	Magnetic 400W Pulse Start	E-Tensity 400W Pulse Start
Input Power (Watts)	458	452	425
Utility Rate ($/KWH)	$0.08	$0.08	$0.08
Annual Operating Hours	4750	4750	4750
Annual Operating Costs	$174	$172	$162

Figure 59: Claims of Increased Lumen Maintenance, Reduced Wasted Energy and Extended Time Between Relamping (GE Lighting)

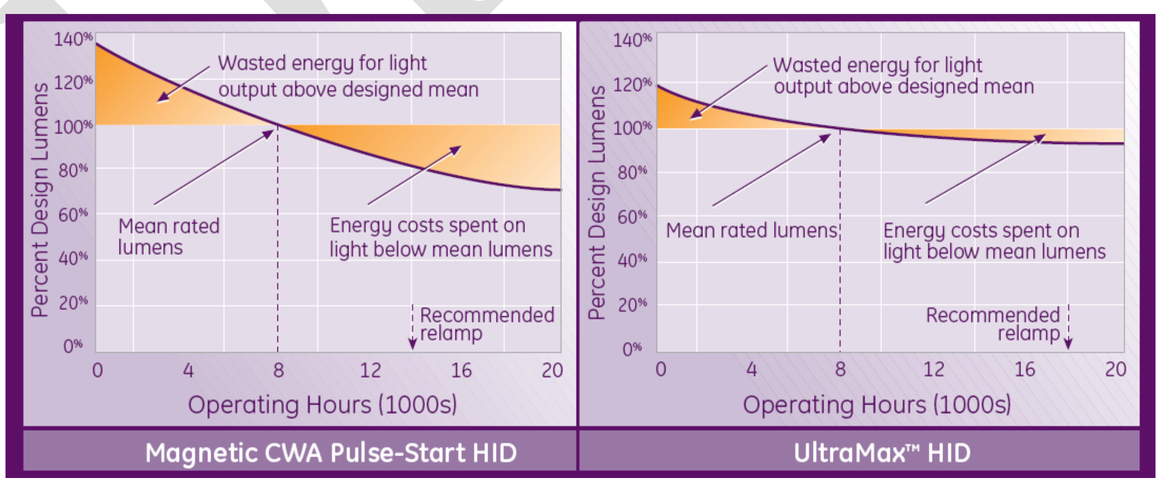

Figure 60: Claims of Reduced Energy Use with eHID Ballast (Universal Lighting Technologies)

8.4.2 HID Lamp/Ballast System Issues

There are concerns among the various HID lamp and eHID ballast manufacturers about the interoperability of such systems, as there is yet no National Electrical Manufacturer's Association (NEMA) standard for the operation of eHID ballasts. This leads to concerns regarding the warranty of the lamp/ballast system, and the potential for conflict should a problem exist.

Because eHID ballasts are much more sensitive to high temperatures then traditional magnetic ballasts, there currently is market resistance to adopting them, as the increased sensitivity to heat requires more careful design of thermal management within the luminaire. eHID ballasts are, in general, not considered a direct retrofit option by luminaire manufacturers because of the thermal management issues, with a maximum allowable case temperature of 75-90C.

Luminaires designed for use with magnetic ballasts, which have maximum case temperatures approaching 180C, tend to be designed to retain the heat which allows the ballast to operate at a higher temperature to avoid low-temperature start-up issues. eHID ballasts, which exhibit almost the opposite thermal sensitivity as standard magnetic ballasts, must be addressed through managing the high-end temperature concerns, posing a large challenge for a direct retrofit situation.

However, this focus on high-temperature thermal management has become more prevalent among luminaire manufacturers because of the industry-wide challenges with current trends toward direct LED retrofit options, which require the same type of high-temperature thermal control.

8.4.3 Alternate White Light Sources, Drivers and Generators

Induction lamps present an interesting alternative to traditional HID sources, as they provide dimmable white light with high color-rendering and long life. However, the traditional issue with induction lamps has been the large size of the lamps themselves, since they must contain the electronic igniter components.

LED provides a promising alternative to traditional white light sources for exterior environments, and has the added benefit of being able to provide truly monochromatic light or color-changing capabilities. The long predicted life the LEDs tends to be the selling point for many current applications, theoretically leading to reduced maintenance expenditures. White-light LEDs have been rapidly evolving over the past few years and are beginning to reach levels of efficiency that make them suitable for the replacement of other less-efficient white light technologies.

However, since the development of these high-performance LEDs is so recent, the cost premium associated with the increased light output is significant and oftentimes prohibitive. As the LED market continues to evolve, the price per lumen of LEDs should continue to decrease, as has been witnessed over the past decade with LEDs and longer with other traditional light sources.

LEP provides a new and promising alternative to traditional sources, and is seen as a complement to low-wattage LEDs to complete exterior lighting environments. However, there are currently few manufacturers using LEP sources in luminaires within the United States, though its popularity and integration is growing in Europe.

These alternate technologies are built around electronics rather than magnetic power sources, so they offer dimming capability and high efficiencies in their primary formats and with little or no added cost premium.

8.5 Manufacturers

Current manufacturers of specification-grade lamps include:

Osram/Sylvania	Metal Halide, HPS, Induction, LED
Philips	Metal Halide, HPS, Induction, LED
GE	Metal Halide, HPS, Induction, LED
Venture	Metal Halide, HPS

Current manufacturers of specification-grade HID ballasts include:

Osram/Sylvania	Magnetic (HPS, MH, pulse-start)
	Electronic (HPS, MH)
Philips/Advance	Magnetic (HPS, MH, pulse-start)
	Electronic (HPS, MH,dimmable)
Metrolight	Electronic (HPS, MH, dimmable)
Universal Lighting	Magnetic (HPS, MH, pulse-start)
	Electronic (HPS, MH, bi-level)

8.6 Future Technology Developments

The lack of NEMA standard for eHID ballasts seems to be the main driving factor behind the issues of interoperability and warranty. NEMA standards serve to regulate the general methodology of lighting equipment, leading to the type of system interoperability that we see today with fluorescent lamp/ballast systems and components.

Since no such standard currently exists, the various eHID manufacturers are addressing the function and properties of the ballasts differently, and thus the systems are not generally interoperable at this point. This leads to issues surrounding the lamp/ballast warranty when the two components are provided from different and independent manufacturers who may not be approaching the eHID ballast operation in the same manner. The development of a NEMA standard would serve to regulate the various approaches, such as starting and dimming methods.

8.7 References

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9. Appendix E: Dimming/Bi-Level Controls

9.1 State of the Market

Dimming controls for exterior applications are becoming more widespread. Dimming for exterior environments has not historically been widely used, most likely due to the cost premium associated with providing dimming system components. Dimming exterior lighting can provide significant energy savings by reducing illuminance levels and power consumption during non-use hours. Bi-level control is considered to be limited dimming, that provides a control “stop” at approximately 50% light or power output, depending on the dimming form of equipment.

9.2 Legislation

The American Clean Energy and Security Act of 2009 (ACESA 2009), also known as the HR 2454 Waxman-Markey Bill passed by the House on June 26, 2009, includes provisions requiring the ability of exterior high-intensity discharge (HID) luminaire systems to dim to 50% of output. According to ACESA 2009, all HID luminaires manufactured on or after January 1st, 2016, must be capable of providing two levels of output, 100% and 50% lamp output, in addition to meeting minimum efficiency requirements, but exempting roadway luminaires (DOE 2010).

Under California’s Title 20-2008, Appliance Efficiency Standards, outdoor HID luminaires manufactured on or after January 1st, 2010 must contain a ballast with “a minimum ballast efficiency of 88 percent and automatic daylight integral control… shipped with the factory default setting to reduce lamp power automatically through dimming by a minimum of 40 percent” (DOE 2010).

Under California’s Title 24-2008, Building Energy Efficiency Standards, outdoor lighting in areas with two or more luminaires must be controlled by an automatic time switch that is capable of either turning off the lighting during times of non-use or reducing the lighting power by at least 50%, but not more than 80%, through either dimming or switching (CEC 2008). The requirement for lighting power reduction can be met through dimming, or by using separate switching, such as in a “checkerboard” switching configuration.

The results of the regulation through both ACESA 2009 and Title 20-2008 require dimming or switching to 60% of power, which typically translates to 50% of light output, where Title 24-2008 regulates that the lighting power must be reduced by at least 50%, which would translate to a dimmed level of 40% of light output. The industry is trending toward dimming to 50% of power, driven by light levels, which essentially translates to 60% of power, and places the current regulation and industry trends in conflict with one another.

The overall result of the national and local legislation is essentially the requirement for all HID luminaires to be able to operate at a reduced power level and an increased minimum allowable lamp/ballast system efficacy. Both of these measures will likely push the industry toward nearly exclusive use of electronic HID (eHID) ballasts and require integration of controls.

9.3 Fluorescent Dimming

Fluorescent dimming has become a widespread approach for interior lighting control. With the cost of dimming equipment, including the necessary ballasts and control gear, steadily on the decline, dimming has become much more ubiquitous in interior environments, allowing occupancy- or daylight-based dimming to reduce energy consumption. Fluorescent dimming has been regulated by NEMA/ANSI to a point that allows wide-spread interoperability of systems. Fluorescent dimming continues to be encouraged through lighting energy code regulations for indoor environments.

There currently are multiple methods for dimming fluorescent lamps, including line-voltage (two-wire) dimming, analog signal dimming and digital signal dimming. Dimming fluorescent lamps does not result in any obvious color shift, as does occur with incandescent lamps. For fluorescent dimming, the relationship between dimmed light level and power consumption is typically non-linear. Ballasts designed specifically for bi-level operation are also now widely available, and can be provided at a cost premium lower than full-range dimming options. Fluorescent continuous dimming can be provided as full-range, dimming to 1% light output, but the majority of dimming ballasts limit the low-end light output to 10% at a slightly lower cost premium.

In low ambient temperature conditions, fluorescent dimming can be limited at the low end, and lamps may not be able to start when subject to extremely cold temperatures. Most fluorescent dimming ballasts are designed for interior spaces, and thus have high minimum case temperatures which are difficult to achieve in exterior luminaires.

9.4 LED Dimming

LED luminaires are becoming more prevalent in exterior environments, likely due to their long life, low wattage consumption and small form factor. LED dimming be achieved through multiple methods. Pulse width modulation (PWM) via digital control provides dimming with minimal color shift in the LED output, and is the most common dimming method used with LEDs. PWM dimming can be used with constant-current and constant-voltage LEDs. Dimming LEDs can also be achieved through forward-phase (incandescent) dimmers and reverse-phase (ELV) dimmers. Dimmable LED drivers are typically configured to follow the square-law luminance curve as is typical to incandescent dimming. LED dimming is typically considered infinitely continuous down to 1% of light output.

9.5 Induction Dimming

The dimming of induction lamps is becoming more available, but not yet widespread as up until a few years ago, most induction lamps were not considered dimmable. Dimming induction lamps provides similar results to dimming fluorescent, as they are essentially electrode-less fluorescent lamps. No color shift is anticipated when induction lamps are dimmed, and bi-level dimming options are becoming more prevalent in the market.

9.6 HID Dimming

Until recently, it was generally understood that HID sources, including metal halide (MH) and high pressure sodium (HPS) lamps, were challenging to dim in an acceptable manner. Using standard core-and-coil ballasts, step-dimming or bi-level dimming can be achieved by using a secondary capacitor within the circuit of the constant-wattage autotransformer (CWA) ballast during dimmed periods to modify the function of the ballast. Dimming HID lamps, and more specifically MH lamps, using these core-and-coil methods also results in significant color shift toward a cooler correlated color temperature (CCT) and a lower color rendering index (CRI), based on the decreased operating temperature within the arc tube at dimmed levels.

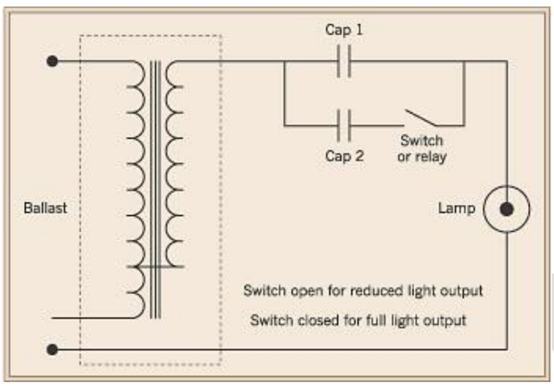

Figure 61- Example of HID Dimming Circuit using CWA Ballast (2007 EC&M)

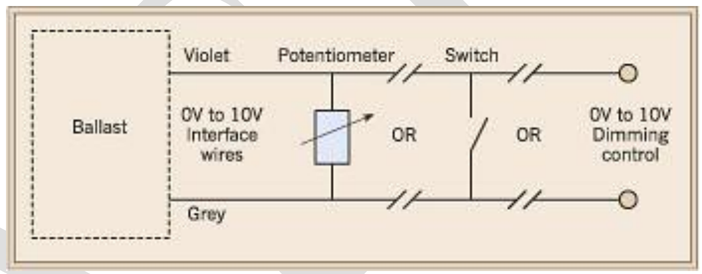

Figure 62- Example of HID Dimming Circuit using eHID Ballast (2007 EC&M)

With the recent advent of electronic eHID ballasts, dimming through solid-state electronics has become available in the general commercial market. However, there currently exists no NEMA standard for the design and operation of electronic ballasts, and the various ballast manufacturers are addressing the method of dimming, as well as start-up and operation, in different ways. There are concerns among manufacturers of the interoperability of the lamp/ballast system when using eHID, and therefore most manufacturers are recommending that a lamp/ballast system from a single source be used for all eHID applications.

Figure 63 and Figure 64 indicate the current availability of eHID dimming ballasts from multiple manufacturers, for both Metal Halide and HPS lamps, respectively.

	Metal Halide																		
Wattage:	20	39	60	50	70	90	100	140	150	175	250	320	350	360	400	450	750	1000	1500
Metrolight (Third-party ballast)	■	■		■	■		■		■										
Advance (Philips)			■			■		■				■	■		■				
GE Lighting										■	■	■	■	■	■		■	■	■
Universal	■	■		■	■		■		■										
Venture Lighting											■		■		■	■			
Osram/Sylvania											a	a							

a- Anticpated within next 12 months

Figure 63: Current eHID Dimming Ballast Availability for Metal Halide Lamps

	HPS																
Wattage:	35	50	70	95	100	110	125	150	200	215	250	310	360	400	750	1000	
Metrolight (Third-party ballast)					■			■			■			■			
Advance (Philips)																	
GE Lighting	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Universal	■	■	■		■			■									
Venture Lighting																	
Osram/Sylvania																	

Figure 64: Current eHID Dimming Ballast Availability for High-Pressure Sodium Lamps

It appears that CWA dimming, using a secondary capacitor in the ballast circuit, is possible with any wattage of ballast. However, many of the same issues, such as lamp drop-out and rise time limitations, are present with this type of bi-level dimming as well.

eHID ballasts can not only provide a dimming or bi-level capability, but also are claimed to extend lamp life, reduce energy consumption and increase lumen maintenance. Dimmable eHID ballasts typically operate using a high-frequency (above 100 kHz) sinusoidal wave, which helps to prevent noise and flicker in both full-power and dimmed states, in addition to the life and lumen maintenance benefits. Non-dimmable eHID ballasts tend to operate using a low-frequency (100-200 Hz) square wave.

Currently available eHID ballasts are capable of control integration using analog dimming (such as a 0-10V signal), digital dimming (such as DALI), or PWM. Some eHID ballasts that are currently available can store dimming schedules and programs internally, eliminating the need to provide additional control equipment for scheduling and control.

In general, it is recommended by NEMA and the lamp manufacturers that the lamp not be dimmed below 50% of rated power, based on limiting the amount of arc tube blackening caused by electrode sputtering. However, this low limit was determined based on how a magnetic ballast functions at dimmed power levels, and electronic ballasts may prevent some of the electrode sputtering seen with magnetic ballasts that causes the lamp walls to blacken.

9.7 Technical Issues - HID Dimming

Currently, the only published standard information regarding HID dimming is the "Guidelines on the Application of Dimming to High Intensity Discharge Lamps," published in 2002 by the National Electrical Manufacturers Association (NEMA). This document provides general guidance on dimming HID sources, including HPS, MH and mercury vapor lamps, and addresses step-dimming/bi-level dimming and line voltage dimming.

The recommendations for line-voltage dimming are based upon a system that modifies the incoming voltage to the lamp, which is typically not how eHID ballasts are dimming HID lamps. The document provides general statements, such as limiting the low-end of HPS and MH dimming to no less than 50% of the lamp's rated power, recommending a 15-minute burn-in before lamps are dimmed under all circumstances, and recommending that the lamp not be started in the dimmed mode. The document also warns that, using standard dimming methods, HPS lamps face potential drop-out when the dimming rate is faster than 1.5 minutes between full-power and minimum power. Many lamp warranty documents also expressly prohibit dimming lamps used in a horizontal-burn orientation.

For MH lamps, the document indicates that manufacturers are likely to restrict dimmed probe-start metal halide lamps to a base-up operating position, which allows the bi-metallic switch used with the starting probe to operate close to design temperature, reducing the chances of premature failure and lamp rupture.

Currently, the only standard requirement provided by NEMA and ANSI for dimming requires that the minimum ANSI open circuit voltage be provided to the lamp during dimmed mode.
In the 2005 US Lighting Market Characterization report issued to the US Department of Energy, dimming metal halide was identified as a potential technology to significantly reduce energy savings, estimating a potential 37 TWh nationally of energy savings through use of HID dimming in conjunction with occupancy and daylight sensing indoors, and off-peak dimming outdoors. According to that report, the perceived color shift when dimmed is one of the largest market barriers, but is more likely a barrier for interior applications where color is more critical then exterior applications. The report also indicates that, though the first-cost of dimmable HID ballasts is approximately 230% of the cost of non-dimmable standard HID ballasts, the life-cycle costs are comparable due to lifetime energy savings.

Previous studies (RPI 1994) had shown that the efficacy of HID lamps is reduced as the lamp is dimmed below full power. According to one of the major HID lamp/ballast manufacturers, dimming using an eHID ballast will result in approximately the same drop in efficacy as when using a magnetic HID ballast, but with the improved lumen maintenance expected when using eHID, the starting point is actually higher and so the net loss through dimming is minimized.

9.8 Manufacturers

HID Dimming Ballasts

Metrolight	eHID Dimming
GE Lighting	eHID Dimming, CWA Dimming
Philips/Advance	eHID Dimming, CWA Dimming
Venture	eHID Dimming, CWA Dimming
Universal Lighting Technologies	eHID Dimming, CWA Dimming
WideLite	CWA Dimming

9.9 Future Technology Developments - HID Dimming

The ability to dim HID lighting has been identified as a potential source for significant national energy savings. Dimming HID sources allows them to be used in conjunction with daylight sensors to provide intelligent lighting control, which is not commonly acceptable with standard switched HID systems because of warm-up and restrike delay times. Integration of HID sources with occupancy sensors may prove to be an issue indoors, where the occupancy sensor would likely be triggering on/off, though integration with occupancy sensors outdoor, where the luminaires are likely turned from high to low, is more plausible. However, there is a strong need for standardization throughout the lamp and ballast manufacturers in a way that leads to the type of interoperability that we see today with fluorescent systems.

A major barrier identified by the DOE for adoption of dimmable electronic ballasts for HID lighting is based on the high initial cost. As is the trend with new technologies in the past, it is expected that the price of electronic HID ballasts will continue to decrease as the products become offered by more manufacturers and as higher quantities are sold over time. The benefit of reduced energy consumption presents a strong impetus for the development and production of these ballasts, in addition to the dimming capabilities.

9.10 References

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10. Appendix F: Pilot Project Review Documentation

10.1 Summary of Available Data

10.1.1 Available Information

- CLTC/PIER Pilot Projects with Data Provided:
  1. California Polytechnic State University, SLO, Parking Lot Lighting Retrofit (1)
  2. California Polytechnic State University, SLO, Street Lighting Retrofit (2)
  3. California Department of Public Health Parking Lot Lighting Retrofit (3)
  4. University of California, Davis, Parking Garage Lighting Retrofit (4)
  5. University of California, Davis, Parking Lot Lighting Retrofit (1)
  6. California State University, Sacramento, Parking Garage Lighting Retrofit (4)
  7. University of California, San Francisco, Parking Lot Lighting Retrofit (1)
  8. University of California, Santa Barbara, Parking Garage Induction Lighting Retrofit (4)
  9. University of California, Santa Barbara, Parking Garage Roof Lighting Retrofit (1)
  10. University of California, Santa Barbara, Parking Garage Fluorescent Lighting Retrofit (4)
  11. Adura Garages AMAT Parking Garage Lighting (5)
  12. Adura Garages Wharf Parking Garage Lighting (5)

- CLTC/PIER Pilot Projects with Summaries:
  13. City of San Marcos Parking Garage Lighting Retrofit (6)
  14. Los Angeles Trade Technical College Parking Lot Retrofit (6)
  15. California Department of General Services Parking Garage Retrofits (6)

- Southern California Edison Pilot Projects with Summaries:
  16. Los Padrinos Parking Garage Lighting Retrofit (6)
  17. Irvine Parking Lot Phase 2 Lighting Retrofit (6)

- Department of Energy GATEWAY Program Demonstration Projects:
  18. Raley's Supermarket Parking Lot Lighting Retrofit (6)

- DOE GATEWAY / Pacific Gas & Electric Pilot Projects:
  19. TJ Maxx Parking Lot Lighting Retrofit (6)

- BetaLED Project Summaries:
  20. California State University, Fullerton, Parking Garage Lighting (6)

10.1.2 How Information will be Used

(1) Data will be used to support development of “typical” university parking lot occupancy profile:

1. California Polytechnic State University, SLO, Parking Lot Lighting Retrofit
5. University of California, Davis, Parking Lot Lighting Retrofit
7. University of California, San Francisco, Parking Lot Lighting Retrofit
9. University of California, Santa Barbara, Parking Garage Roof Lighting Retrofit

(2) Data will not be used; street lighting not currently under review:

2. California Polytechnic State University, SLO, Street Lighting Retrofit

(3) Data will be used to support development of “typical” office parking lot occupancy profile:

3. California Department of Public Health Parking Lot Lighting Retrofit

(4) Data will be used to support development of “typical” university parking garage occupancy profile:

4. University of California, Davis, Parking Garage Lighting Retrofit
6. California State University, Sacramento, Parking Garage Lighting Retrofit
8. University of California, Santa Barbara, Parking Garage Induction Lighting Retrofit
10. University of California, Santa Barbara, Parking Garage Fluorescent Lighting Retrofit

(5) Data will be used to support development of “typical” retail parking garage occupancy profile:

11. Adura Garages AMAT Parking Garage Lighting
12. Adura Garages Wharf Parking Garage Lighting

(6) Information will provide anecdotal evidence to assess energy savings potentials:

13. City of San Marcos Parking Garage Lighting Retrofit
14. Los Angeles Trade Technical College Parking Lot Retrofit
15. California Department of General Services Parking Garage Retrofits
16. Los Padrinos Parking Garage Lighting Retrofit
17. Irvine Parking Lot Phase 2 Lighting Retrofit
18. Raley’s Supermarket Parking Lot Lighting Retrofit
19. TJ Maxx Parking Lot Lighting Retrofit
20. California State University, Fullerton, Parking Garage Lighting

10.1.3 California Polytechnic State University, SLO, Parking Lot Lighting Retrofit

Materials Available:

- "Bi-level Street and Parking Area Lighting" [www.energy.ca.gov/research]
- "Parking Lot and Garage PIER Demonstrations Summary 9/23/2010" [via email]
- Bi-level_Exterior_Demos_Summary.xlsx [via email]
- (6) data logger files

Summary of Pilot Project

Bi-level induction luminaires were installed in a parking lot on the Cal Poly campus. This involved replacing four existing 280W (system power) HPS luminaires with 110W (in high mode, system power) induction luminaires. Light level loggers were used to record illuminance at one-minute increments over six weeks. Data files were provided for six luminaires for the entire Cal Poly SLO project, however it is not clear for which area (street or parking lot) the data files support.

The results showed a 74% energy savings, which includes savings both due to technology change and additional lighting controls, with the luminaires operating in "high" mode only 32% of the time and in low mode 68% of the time. Additional information provided by the CLTC indicates that the occupancy sensors were mounted at 25ft, spaced 80ft on center, with a sensor coverage pattern of 40ft and a time delay of 5.5 minutes. Photocell-based daylighting controls were also in place both pre- and post-retrofit.

How Results will Support Title 24 Development

The CLTC has provided data logger files, which will allow a proxy for parking lot occupancy to be extracted. Actual occupancy patterns cannot be determined from the data given that it includes the impact of the sensor delay time and thus does not capture multiple occupancy events that occur within durations less than the sensor delay time. However, as shown in Figure 65, the number of occupancy "events" per hour can be extracted and used to support the development of a composite "typical" occupancy profile for a parking lot supporting an academic institution.

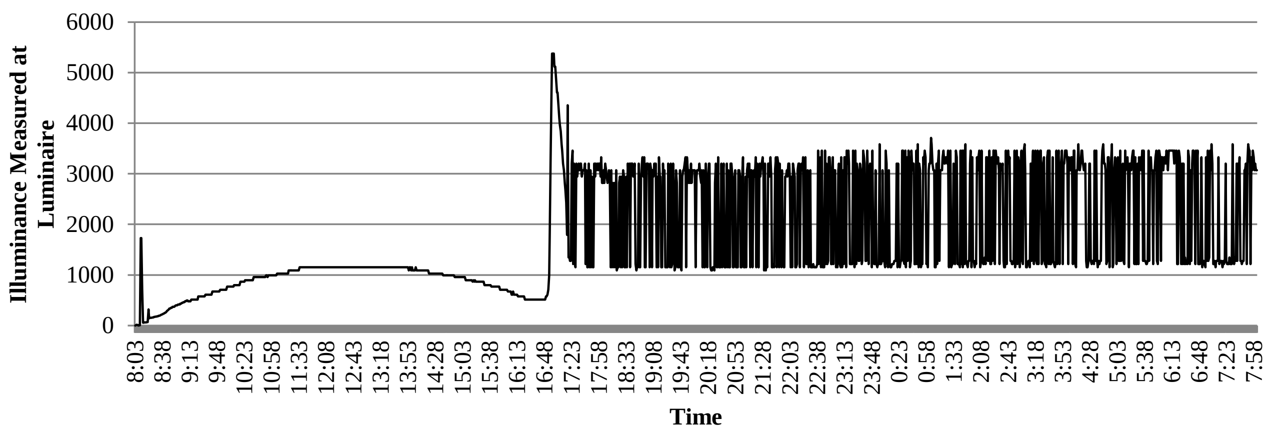

Figure 65: SLO Parking Lot Demonstration Single Day Profile

10.1.4 California Polytechnic State University, SLO, Street Lighting Retrofit

Materials Available:

- "Bi-level Street and Parking Area Lighting" [www.energy.ca.gov/research]
- "Parking Lot and Garage PIER Demonstrations Summary 9/23/2010" [via email]
- Bi-level_Exterior_Demos_Summary.xlsx [via email]
- (6) data logger files

Summary of Pilot Project

Four bi-level LED luminaires were installed along a small residential street adjacent to the Cal Poly campus. This involved replacing existing 128W (system power) HPS luminaires with 118W (in high mode, system power) LED luminaires. Light level loggers were used to record illuminance at one-minute increments over six weeks. Data files were provided for six luminaires for the entire Cal Poly SLO project, however it is not clear for which area (street or parking lot) the data files support.

The results showed a 32% energy savings, which includes savings both due to technology change and additional lighting controls, with the luminaires operating in "high" mode 60% of the time and in low mode 40% of the time. Additional information provided by the CLTC indicates that the occupancy sensors were mounted at 15ft, spaced 40ft on center, with a sensor coverage pattern of 40ft and a time delay of 15 minutes. Photocell-based daylighting controls were also in place both pre- and post-retrofit.

How Results will Support Title 24 Development

Occupancy-based bi-level control of street lighting is not currently under review.

10.1.5 California Department of Public Health Parking Lot Lighting Retrofit

Materials Available:

- "Parking Lot and Garage PIER Demonstrations Summary 9/23/2010" [via email]
- Bi-level_Exterior_Demos_Summary.xlsx [via email]
- (8) data logger files

Summary of Pilot Project

Bi-level induction parking lot luminaires were installed on the campus of the California Department of Public Health, replacing eight 188W (system watts) luminaires with bi-level induction luminaires that operating at 111W (high mode, system watts). Eight data files were provided by the CLTC, which include measured illuminance at the luminaire in one-minute increments over approximately four weeks.

The results showed an estimated annual energy savings of nearly 62%, which includes savings both due to technology change and additional lighting controls. Time switch control of the luminaires was used both pre- and post-retrofit. Additional information provided by the CLTC indicates that the occupancy sensors were mounted at 25ft, spaced 60ft on center, with a sensor coverage pattern of 40ft and a time delay of 5.5 minutes.

How Results will Support Title 24 Development

The CLTC has provided data logger files, which will allow a proxy for parking lot occupancy to be extracted. Actual occupancy patterns cannot be determined from the data given that the data includes the impact of the sensor delay time and thus does not capture multiple occupancy events that occur within durations less than the sensor delay time. However, as shown in Figure 66, the number of occupancy "events" per hour can be extracted and used to support the development of a composite "typical" occupancy profile for a parking lot supporting an office building.

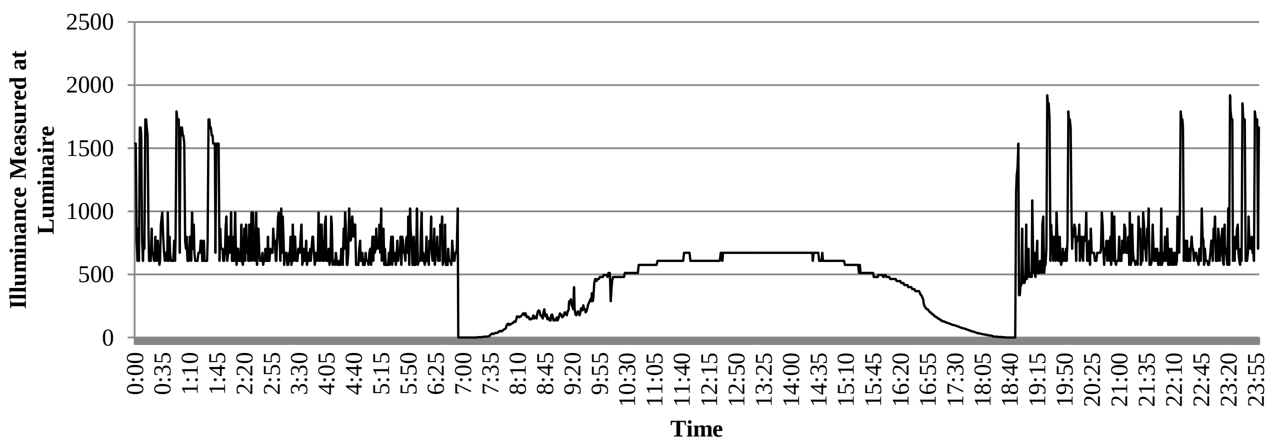

Figure 66: CDPH Demonstration Single Day Profile

10.1.6 University of California, Davis, Parking Garage Lighting Retrofit

Materials Available:

- "Bi-level Induction Parking Garage Luminaires" [www.energy.ca.gov/research]
- "Parking Lot and Garage PIER Demonstrations Summary 9/23/2010" [via email]
- Bi-level_Exterior_Demos_Summary.xlsx [via email]
- (2) data logger files

Summary of Pilot Project

Existing 189W (system watts) HPS parking lot luminaires replaced with bi-level 80.4W (high mode, system watts) induction luminaires on one third of the first floor of the Mondavi garage. Two data logger files were provided, which include illuminance data in one-minute increments.

The results showed an estimated annual energy savings of nearly 32%, which includes savings both due to technology change and additional lighting controls. Additional information provided by the CLTC indicates that the occupancy sensors were mounted at 10ft, spaced 35ft on center, with a sensor coverage pattern of 48ft and a time delay of 5.5 minutes. Photocell-based daylighting controls were also in place both pre- and post-retrofit.

How Results will Support Title 24 Development

The CLTC has provided data logger files, which will allow a proxy for parking garage occupancy to be extracted. Actual occupancy patterns cannot be determined from the data given that the data includes the impact of the sensor delay time and thus does not capture multiple occupancy events that occur within durations less than the sensor delay time. However, as shown in Figure 67, the number of occupancy "events" per hour can be extracted and used to support the development of a composite "typical" occupancy profile for a parking lot supporting an academic institution.

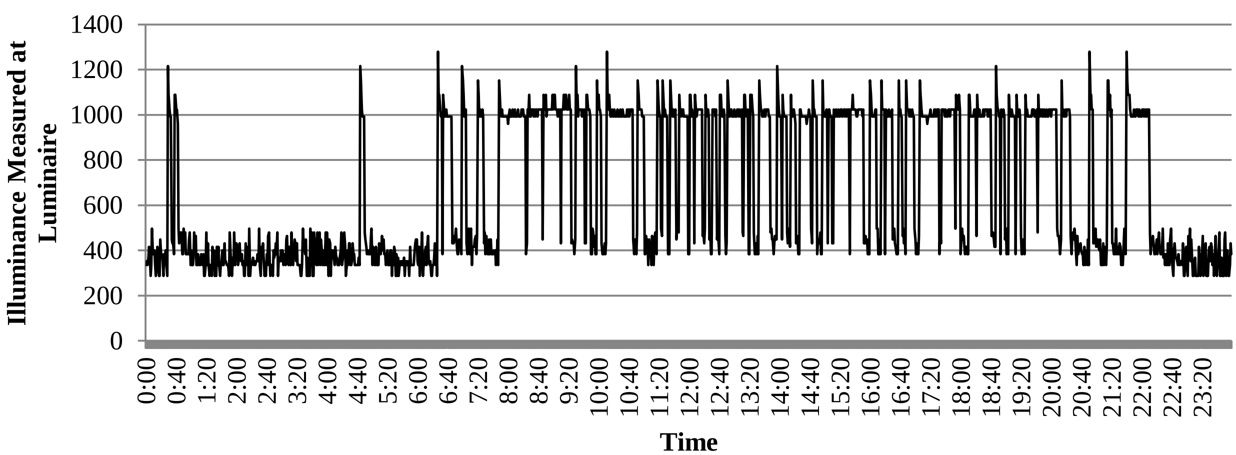

Figure 67: UC Davis Parking Garage Demonstration Single Day Profile

10.1.7 University of California, Davis, Parking Lot Lighting Retrofit

Materials Available:

- "Bi-level Induction Parking Garage Luminaires" [www.energy.ca.gov/research]
- "Parking Lot and Garage PIER Demonstrations Summary 9/23/2010" [via email]
- Bi-level_Exterior_Demos_Summary.xlsx [via email]
- (2) data logger files

Summary of Pilot Project

Existing 189W (system watts) HPS parking lot luminaires replaced with bi-level 80.4W (high mode, system watts) induction luminaires in the Mondavi parking lot. Two data logger files were provided that include illuminance data in one minute increments.

The results showed an estimated annual energy savings of nearly 74%, which includes savings both due to technology change and additional lighting controls. Additional information provided by the CLTC indicates that the occupancy sensors were mounted at 20ft, spaced 45ft on center, with a sensor coverage pattern of 40ft and a time delay of 5.5 minutes. Photocell-based daylighting controls were also in place both pre- and post-retrofit.

How Results will Support Title 24 Development

The CLTC has provided data logger files, which will allow a proxy for parking lot occupancy to be extracted. Actual occupancy patterns cannot be determined from the data given that the data includes the impact of the sensor delay time and thus does not capture multiple occupancy events that occur within durations less than the sensor delay time. However, as shown in Figure 68, the number of occupancy "events" per hour can be extracted and used to support the development of a composite "typical" occupancy profile for a parking lot supporting an academic institution.

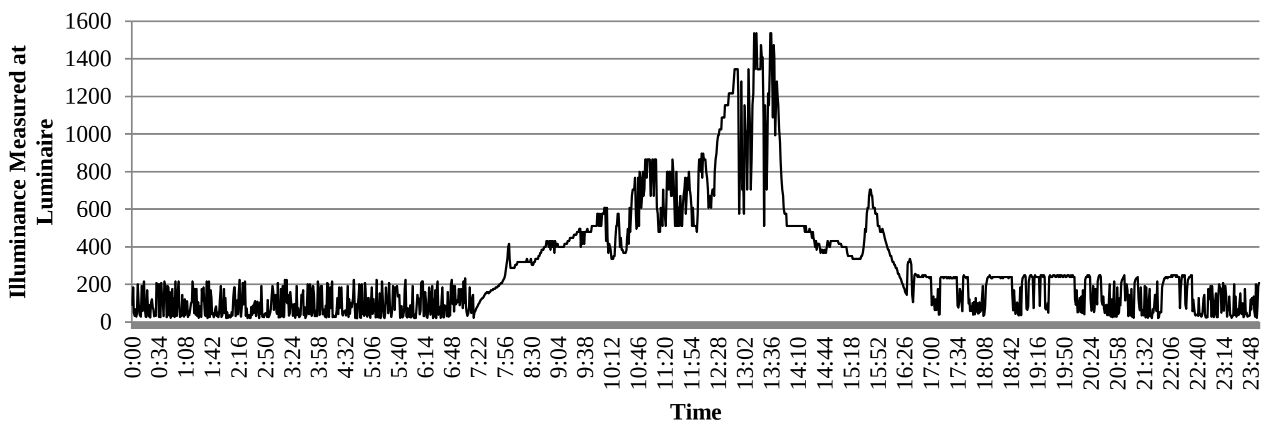

Figure 68: UC Davis Parking Lot Demonstration Single Day Profile

10.1.8 California State University, Sacramento, Parking Garage Lighting Retrofit

Materials Available:

- "Bi-level Induction Parking Garage Luminaires" [www.energy.ca.gov/research]
- "Parking Lot and Garage PIER Demonstrations Summary 9/23/2010" [via email]
- Bi-level_Exterior_Demos_Summary.xlsx [via email]
- (18) data logger files

Summary of Pilot Project

Thirty existing HPS luminaires were replaced in half of the third floor of a six-floor parking garage on the CSU Sacramento campus. Existing 189W (system watts) luminaires were replaced with bi-level 165W (high mode, system watts) bi-level LED luminaires. Multiple data file types were provided, including 18 data files that show relative power over each five-minute span.

The results showed an estimated annual energy savings of 68%, which includes savings both due to technology change and additional lighting controls. Additional information provided by the CLTC indicates that the occupancy sensors were mounted at around 10ft, spaced around 50ft on center, with a sensor coverage pattern of 48ft and a time delay of 15 minutes. Interior lighting was always "on" in spaces without daylight and photocell-controlled in spaces with daylight, both pre- and post-retrofit.

How Results will Support Title 24 Development

Note that the *.log data files provided by the CLTC cannot be read, so the "5-minute data" files are to be used for analysis. These data logger files present relative power in five-minute increments, which will allow a proxy for parking garage occupancy to be extracted. Actual occupancy patterns cannot be determined from the data given that the data includes the impact of the sensor delay time and thus does not capture multiple occupancy events that occur within durations less than the sensor delay time. Further clarification is required to understand these relative measurements, since the data files tend to show 0% power during late-night times, while the summary reports indicate they should likely be in "low" mode, or at approximately 50% power. However, as shown in Figure 69, the number of occupancy "events" per hour can be extracted and used to support the development of a composite "typical" occupancy profile for a parking garage supporting an academic institution.

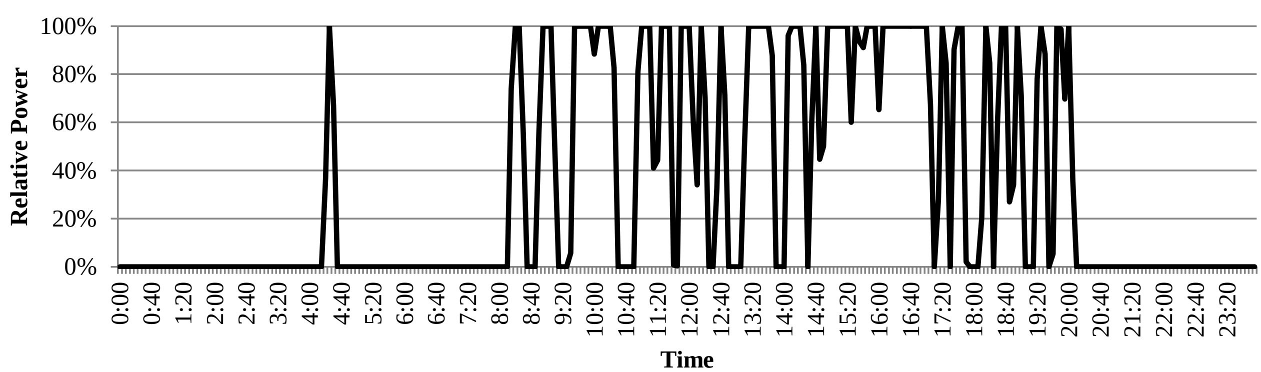

Figure 69: CSU Sacramento Parking Garage Demonstration Single Day Profile

10.1.9 University of California, San Francisco, Parking Lot Lighting Retrofit

Materials Available:

- "Parking Lot and Garage PIER Demonstrations Summary 9/23/2010" [via email]
- Bi-level_Exterior_Demos_Summary.xlsx [via email]
- (1) data logger file

Summary of Pilot Project

Thirty-five existing HID luminaires were replaced with bi-level induction luminaires in a parking lot on the UC San Francisco campus. Existing 188W (system watts) and 440W (system watts) HID luminaires were replaced with bi-level 111W (high mode, system watts) shoebox and cobrahead LED luminaires. A data file was provided by the CLTC, which includes illuminance measurements at one-minute intervals over nearly 22 days.

The results showed an estimated annual energy savings of 62% compared to the 188W incumbent technology, and nearly 84% savings compared to the 188W incumbent technology, which includes savings both due to technology change and additional lighting controls. Additional information provided by the CLTC indicates that the occupancy sensors were mounted on the shoebox luminaires at 30ft, spaced 30ft on center, with a sensor coverage pattern of 40ft and a time delay of 5.5 minutes. It was also indicated that the occupancy sensors were mounted on the cobrahead luminaires at 12ft, spaced 50ft on center, with a sensor coverage pattern of 40ft and a time delay of 5.5 minutes. Photocell-based daylighting controls were also in place both pre- and post-retrofit.

How Results will Support Title 24 Development

The CLTC has provided a data logger file, which will allow a proxy for parking lot occupancy to be extracted. Actual occupancy patterns cannot be determined from the data given that the data includes the impact of the sensor delay time and thus does not capture multiple occupancy events that occur within durations less than the sensor delay time. However, as shown in Figure 70, the number of occupancy "events" per hour can be extracted and used to support the development of a composite "typical" occupancy profile for a parking lot supporting an academic institution.

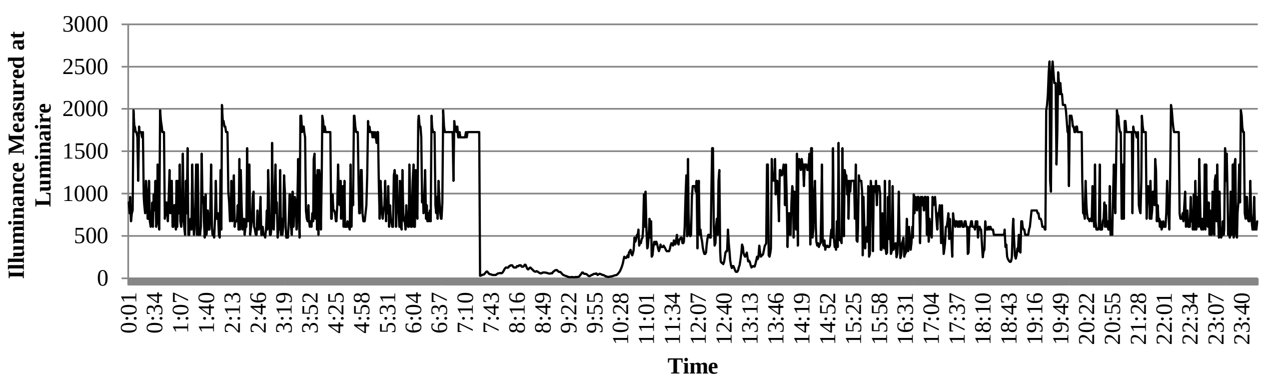

Figure 70: UC San Francisco Parking Lot Demonstration Single Day Profile

10.1.10 University of California, Santa Barbara, Parking Garage Induction Lighting Retrofit

Materials Available:

- "Wireless Integrated Photosensor and Motion Sensor" [www.energy.ca.gov/research]
- "Parking Lot and Garage PIER Demonstrations Summary 9/23/2010" [via email]
- Bi-level_Exterior_Demos_Summary.xlsx [via email]
- (10) data logger files

Summary of Pilot Project

Ten existing HPS luminaires were replaced with bi-level induction luminaires on half of the second floor of a parking garage on the UC Santa Barbara campus. Existing 170W (system watts) HPS luminaires were replaced with bi-level 70W (high mode, system watts) induction luminaires. Data files were provided by the CLTC, which include illuminance measurements at one-minute intervals over approximately six weeks.

The results showed an estimated total annual energy savings of 53% compared to the incumbent technology, 12.2% from daylight-responsive control, 21% from occupancy-based control and the remaining savings due to the technology change. Additional information provided by the CLTC indicates that the occupancy sensors were mounted at 12ft, spaced 35ft on center, with a sensor coverage pattern of 48ft and a time delay of 5.5 minutes.

How Results will Support Title 24 Development

Actual occupancy patterns cannot be determined from the data given that the data includes the impact of the sensor delay time and thus does not capture multiple occupancy events that occur within durations less than the sensor delay time. However, as shown in Figure 71, the number of occupancy "events" per hour can be extracted and used to support the development of a composite "typical" occupancy profile for a parking garage supporting an academic institution.

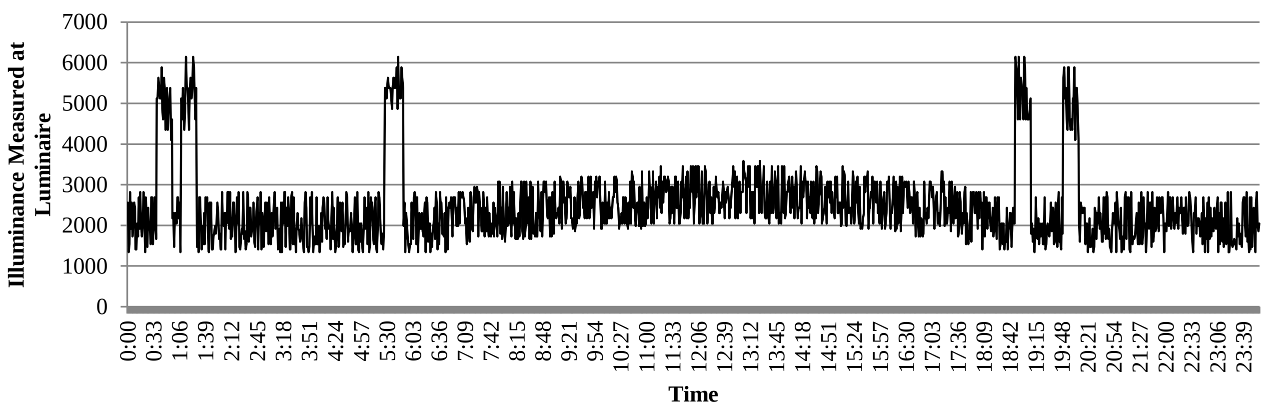

Figure 71: UC Santa Barbara Parking Garage Demonstration Single Day Profile

10.1.11 University of California, Santa Barbara, Parking Garage Roof Lighting Retrofit

Materials Available:

- "Parking Lot and Garage PIER Demonstrations Summary 9/23/2010" [via email]
- Bi-level_Exterior_Demos_Summary.xlsx [via email]
- (8) data logger files

Summary of Pilot Project

Ten existing HPS luminaires were replaced with bi-level induction luminaires on half of the second floor of a parking garage on the UC Santa Barbara campus. Existing 170W (system watts) HPS luminaires were replaced with bi-level 70W (high mode, system watts) induction luminaires. Data files were provided by the CLTC, which include illuminance measurements at one-minute intervals over approximately six weeks.

The results showed an estimated total annual energy savings of 53% compared to the incumbent technology, 12.2% from daylight-responsive control and 21% from occupancy-based control. Additional information provided by the CLTC indicates that the occupancy sensors were mounted at 25ft, spaced 18ft on center, with a sensor coverage pattern of 60ft and a time delay of 15 minutes.

How Results will Support Title 24 Development

Actual occupancy patterns cannot be determined from the data given that the data includes the impact of the sensor delay time and thus does not capture multiple occupancy events that occur within durations less than the sensor delay time. However, as shown in Figure 72, the number of occupancy "events" per hour can be extracted and used to support the development of a composite "typical" occupancy profile for a parking garage supporting an academic institution.

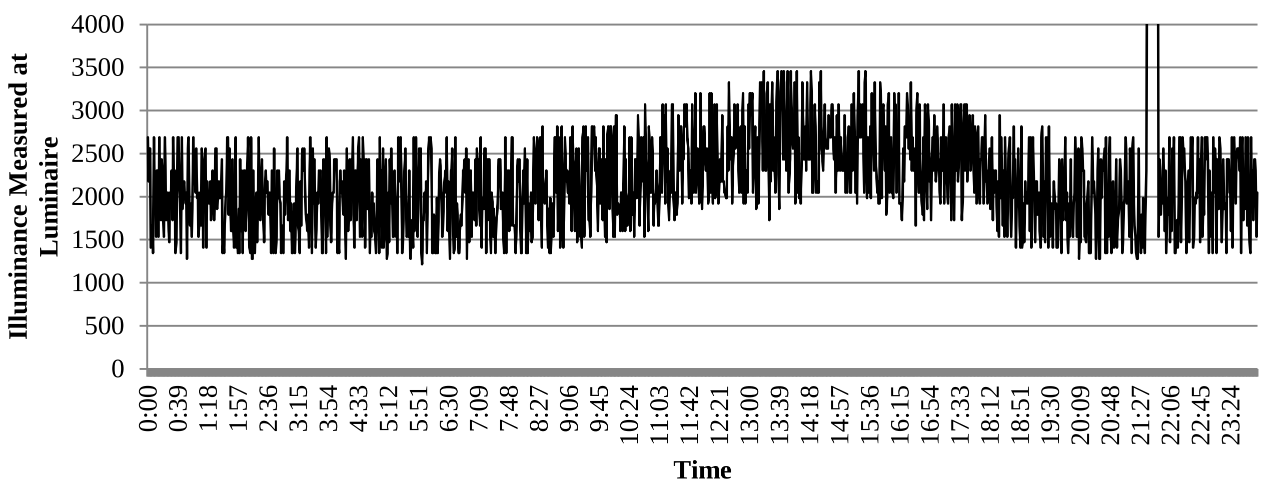

Figure 72: UC Santa Barbara Parking Garage Roof Demonstration Single Day Profile

10.1.12 University of California, Santa Barbara, Parking Garage Fluorescent Lighting Retrofit

Materials Available:

- "Parking Lot and Garage PIER Demonstrations Summary 9/23/2010" [via email]
- Bi-level_Exterior_Demos_Summary.xlsx [via email]
- (8) data logger files

Summary of Pilot Project

Thirty existing fluorescent luminaires were replaced upgraded to include bi-level occupancy-based control in a parking garage on the UC Santa Barbara campus. Existing 58W (system watts) fluorescent luminaires were replaced with bi-level 54W (high mode, system watts) fluorescent luminaires. Data files were provided by the CLTC, which include illuminance measurements at one-minute intervals over approximately six weeks.

The results showed an estimated total annual energy savings of 53% compared to the incumbent technology, 12.2% from daylight-responsive control and 21% from occupancy-based control. Additional information provided by the CLTC indicates that the occupancy sensors were mounted at 12ft, spaced 35ft on center, with a sensor coverage pattern of 48ft and a time delay between 30 seconds and 20 minutes.

How Results will Support Title 24 Development

Actual occupancy patterns cannot be determined from the data given that the data includes the impact of the sensor delay time and thus does not capture multiple occupancy events that occur within durations less than the sensor delay time. However, as shown in Figure 73, the number of occupancy "events" per hour can be extracted and used to support the development of a composite "typical" occupancy profile for a parking garage supporting an academic institution.

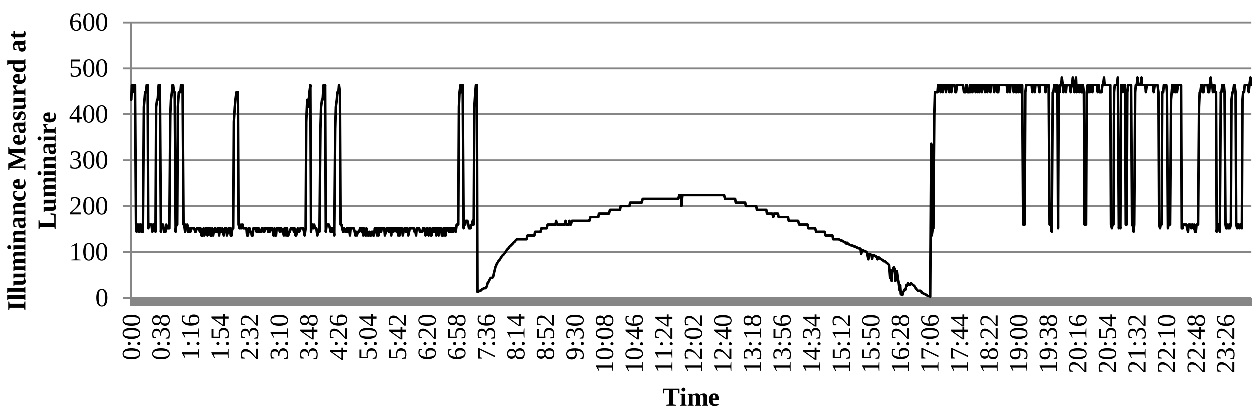

Figure 73: UC Santa Barbara Parking Garage Fluorescent Lighting Demonstration Single Day Profile

10.1.13 Adura Garages AMAT Parking Garage Lighting

Materials Available:

- AduraGarages_Weekly_kW_Profiles.xlsx

Summary of Pilot Project

Thirty existing T5HO fluorescent luminaires were upgraded to include bi-level occupancy-based control in a parking garage. Existing fluorescent luminaires were upgraded to include step-dimming ballasts. A data file was provided by the CLTC, which include power (demand) measurements at one-hour intervals. The results showed an estimated total annual energy savings of approximately 53% compared to the non-controlled system, which includes savings both due to technology change and additional lighting controls.

How Results will Support Title 24 Development

The data provided by the CLTC includes only demand measurements at one-hour intervals, and energy savings calculations were made assuming that those instantaneous hourly demand measurements are appropriately representative of the power consumption over the full hour. However, as shown Figure 74, this data can be used to shape the overall assumed occupancy profile for mixed-use retail areas.

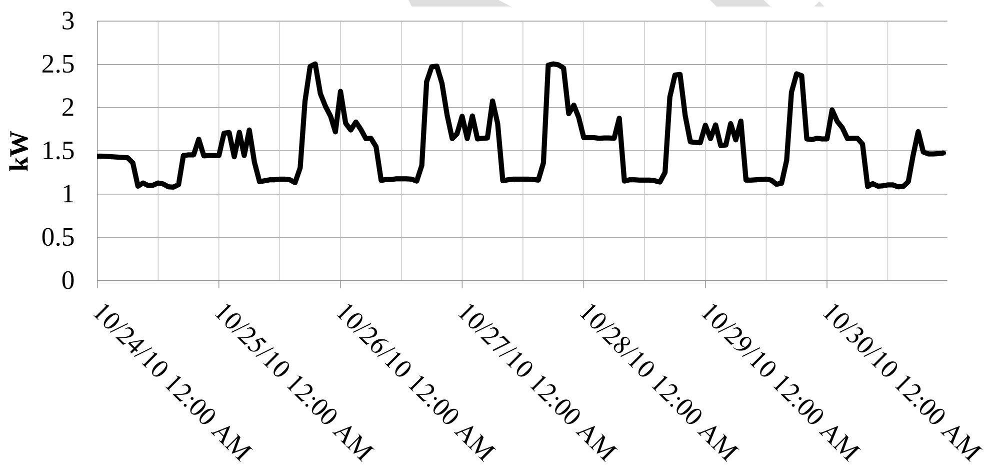

Figure 74: Adura AMAT Garage Multi-Day Profile

10.1.14 Adura Garages Wharf Parking Garage Lighting

Materials Available:
- AduraGarages_Weekly_kW_Profiles.xlsx

Summary of Pilot Project

One hundred and seventy-five existing T5HO fluorescent luminaires were upgraded to include bi-level occupancy-based control in a parking garage. Existing fluorescent luminaires were upgraded to include step-dimming ballasts. A data file was provided by the CLTC, which include power (demand) measurements at one-hour intervals. The results showed an estimated total annual energy savings of approximately 47% compared to the non-controlled system, which includes savings both due to technology change and additional lighting controls.

How Results will Support Title 24 Development

The data provided by the CLTC includes only demand measurements at one-hour intervals, and energy savings calculations were made assuming that those instantaneous hourly demand measurements are appropriately representative of the power consumption over the full hour. However, as shown in Figure 75, this data can be used to shape the overall assumed occupancy profile for mixed-use retail areas.

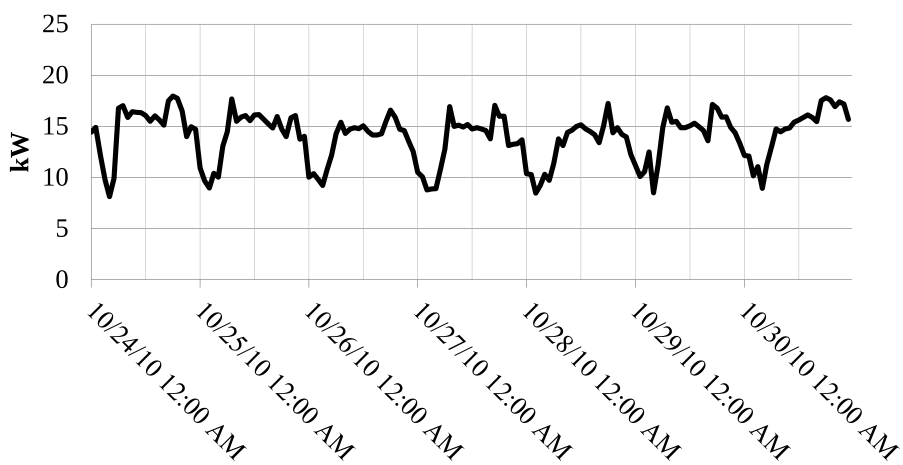

Figure 75: Adura Wharf Garage Multi-Day Profile

10.1.15 City of San Marcos Parking Garage Lighting Retrofit

Materials Available:
- "Parking Lot and Garage PIER Demonstrations Summary 9/23/2010" [via email]
- Bi-level_Exterior_Demos_Summary.xlsx [via email]

Summary of Pilot Project

The City Hall parking garage in the City of San Marcos was retrofit using 22 bi-level LED luminaires. No post-retrofit monitoring data is available. Information provided by the CLTC indicate that the sensors were mounted at 12ft, with an on-center spacing of 60ft, a sensor coverage of 28ft and a time-delay of 10 minutes. Summary reports indicate an expected energy savings of nearly 76%.

How Results will Support Title 24 Development

No results are yet available. Predictions of energy savings will be used as anecdotal evidence.

10.1.16 Los Angeles Trade Technical College Parking Lot Retrofit

Materials Available:
- "Parking Lot and Garage PIER Demonstrations Summary 9/23/2010" [via email]

Summary of Pilot Project

Twelve luminaires in a parking lot at the LA Trade Technical College were replaced with bi-level LED and induction luminaires as a part of the 2010 UC/CSU/CCC Sustainability conference. The LED luminaires are expected to produce savings of 84-91%, and the induction luminaires are expected to produce savings around 85%, based on an assumed 40% occupancy rate.

How Results will Support Title 24 Development

No results are available. Predictions of energy savings will be used as anecdotal evidence.

10.1.17 California Department of General Services Parking Garage Retrofits

Materials Available:
- "Parking Lot and Garage PIER Demonstrations Summary 9/23/2010" [via email]

Summary of Pilot Project

Retrofits, including the conversion of metal halide and HPS luminaires to bi-level induction luminaires, are currently underway. DGS expects to realize energy savings of at least 60%

How Results will Support Title 24 Development

No results are available and data collection has not begun. Predictions of energy savings will be used as anecdotal evidence.

10.1.18 Los Padrinos Parking Garage Lighting Retrofit

Materials Available:

- "Emerging Technology Evaluation LED Lighting for Covered Parking" [www.etcc-ca.com]

Summary of Pilot Project

A retrofit of covered parking lot lighting at the LA County Los Padrinos Juvenile Hall was performed, which included installing ten new bi-level LED luminaires and cleaning and replamping ten existing PSMH luminaires for comparison. Photometric, spectral and power measurements of the luminaires were performed by an independent testing lab. Illuminance measurements were taken both pre- and post-retrofit, and it was determined that neither the PSMH or LED systems met IESNA criteria for enhanced-security parking. Additionally, the response of the luminaires to the motion of cars and pedestrians was tested in the garage, and it was found that the sensors appropriately identified the presence of cars, but inadequately detected the movement of pedestrians, thus requiring that the system meet IESNA criteria in low mode.

The results of the study demonstrated a 72.6% energy savings compared to the current standard lighting. However, nearly 66% energy savings could be attributed solely to technology changes.

How Results will Support Title 24 Development

The results of this study, and in particular the results of the testing on sensor coverage, will be very valuable to assist with determining appropriate recommendations and requirements for sensor placement and spacing. The reported data, including the hourly fraction at high mode, will also be used to support the development of "typical" garage occupancy profiles.

10.1.19 Irvine Parking Lot Phase 2 Lighting Retrofit

Materials Available:

- "LED Lighting – Phase 2, Irvine Parking Lot" [www.etcc-ca.com]

Summary of Pilot Project

A retrofit of parking lot lighting at the Irvine City Hall was performed, which included installing six new bi-level LED luminaires and cleaning and replamping six existing HPS luminaires for comparison. Luminaire operation was monitored for one year. Illuminance measurements were taken in the field, both pre- and post-retrofit. Photometric, spectral and power measurements were performed at an independent testing facility.

The results of the study demonstrated a 29.5% energy savings compared to the current standard lighting.

How Results will Support Title 24 Development

The results can be used as anecdotal evidence to support claims of potential energy savings in parking lots.

10.1.20 Raley's Supermarket Parking Lot Lighting Retrofit

Materials Available:

- "Hi-Low Controls on Existing HID Lighting Fixtures in Ventura County" [apps1.eere.energy.gov]

Summary of Pilot Project

Sixteen pole-mounted 320W (rated power) MH luminaires in a parking lot were replaced with occupancy-based bi-level LED luminaires. Results of the study demonstrated that the LED luminaires were on high power for only 55% of the time, resulting in a time-averaged demand of 105W, compared to the 346W (system power) MH luminaires operating without occupancy control.

How Results will Support Title 24 Development

The results can be used as anecdotal evidence to support claims of potential energy savings in parking lots.

10.1.21 TJ Maxx Parking Lot Lighting Retrofit

Materials Available:

- "Demonstration Assessment of LED Parking Lot Lighting, Phase I" [apps1.eere.energy.gov]

Summary of Pilot Project

Twenty-two pole-mounted 400W (rated power) HPS luminaires and six 400W (rated power) MH luminaires in a parking lot of a retail center were replaced with twenty-five total ELD luminaires, each with its own integral occupancy sensor to provide bi-level control. The results of the study showed approximately 58% energy savings, which is stated to be largely attributable to the 47% reduction in provided illuminance levels under high power.

How Results will Support Title 24 Development

The results can be used as anecdotal evidence to support claims of potential energy savings in parking lots.

10.1.22 California State University, Fullerton, Parking Garage Lighting

Materials Available:

- "LED Application Project Overview" [BetaLED.com]

Summary of Pilot Project

A new parking garage for the CSU Fullerton campus was lit using 151 bi-level LED parking garage luminaires, achieving a lighting power density nearly 80% below Title-24. Fifty percent of the anticipated energy savings is due solely to technology change, while 30% is assumed to come from the bi-level operation.

How Results will Support Title 24 Development

The results can be used as anecdotal evidence to support claims of potential energy savings in parking garages.

10.2 CLTC Data Analysis Results

10.2.1 Summary of Process

Illuminance Data

Data files were provided by the CLTC that included logger information for the various pilot studies conducted to review the impact of parking garage lighting retrofits in combination with occupancy-based controls. The goal of this analysis was to distill the CLTC data logger information into an occupancy profile by determining the number of occupancy "events" or "hits" seen by each sensor as a proxy for actual dynamic occupancy.

Logger files were provided for four parking garage demonstrations on university campuses, two of which took place on the UC Santa Barbara campus, one on the CSU Sacramento campus, and one on the UC Davis campus. For the UCSB and UC Davis projects, the provided data files included illuminance logger information with the associated timestamps at regular intervals. An example of this data is shown in Figure 76:

Time/Date Stamp	Illuminance
11/6/2009 7:41	336
11/6/2009 7:42	288
11/6/2009 7:43	448
11/6/2009 7:44	1152
11/6/2009 7:45	1152
11/6/2009 7:46	1024
11/6/2009 7:47	1024
11/6/2009 7:48	992
11/6/2009 7:49	992

Figure 76: Example of Illuminance Data File

For the projects for which illuminance data was provided, an analysis was first done to determine the illuminance thresholds for each sensor that bins the status into "HIGH", "LOW", or "OFF" states. Next, changes from "LOW" status to "HIGH" status were identified and their associated timestamp recorded. Since the illuminance data provided effectively includes the time-impact of the sensor delay, it was also necessary to identify periods of "HIGH" times that exceeded the sensor delay time and thus must have been caused by additional occupancy events. The minimum events needed to trigger the luminaire to "HIGH" mode for each "HIGH" mode duration was determined based on the delay time reported by the CLTC.

The number of hourly occupancy events per sensor was then determined for each sensor across the study periods. The days were then separated into weekdays, Saturdays and Sundays, and each sensor's hourly events were averaged over their typical days. Finally, a composite profile for each study was created by determining the mean occupancy events per hour across the sensors for weekdays, Saturdays and Sundays.

It should be noted that this analysis provides a conservative estimate of hourly occupancy "events," as the calculation relied on the reported sensor delay times to determine the minimum number of events needed within each extended "HIGH" period to create that condition. This results in a conservative estimate of the level of activity.

Event Data

For the CSU Sacramento project, the provided data files included event descriptors with associated timestamps. An example of this data is shown in Figure 77:

Date	Time	Event Descriptors
3/13/2008	6:51:08 PM	Turned OFF
3/13/2008	6:51:18 PM	Turned ON
3/13/2008	6:57:35 PM	Turned OFF
3/13/2008	6:57:41 PM	Turned ON
3/13/2008	7:04:28 PM	Turned OFF
3/13/2008	7:06:02 PM	Turned ON

Figure 77: Example of Event Data File

It was assumed for this analysis that "Turned OFF" indicated a switch to "LOW" mode, and that "Turned ON" indicated a switch to "HIGH" mode. Based on the indicated "Turned ON" events, the hourly occupancy events per sensor were determined across the study period.

Again, since the data includes the impact of the sensor delay times, it was necessary to determine the minimum events needed to keep the luminaires in "HIGH" mode for the extended periods of time shown, typically mid-day. For this analysis, when the "HIGH" mode time exceeded the reported sensor delay time, the minimum events to maintain "HIGH" mode was estimated. Again, each sensor was analyzed to determine its mean weekday, Saturday and Sunday profiles, and then the sensors curves were averaged to determine a composite occupancy profile per hour across the sensors for weekdays, Saturdays and Sundays.

Compiled Data

Next, the results of the analysis of the four projects was compiled to determine the "typical" occupancy profile for a parking garage on a university campus. The profiles were separated, for each day type, into daylighted projects and non-daylighted projects. Finally, a composite, smoothed weekday and weekend set of occupancy profiles were determined by combining the mean volume during non-daylighted hours with the profile trend of the non-daylighted projects during the daylighted hours.

The final product of this analysis is an estimate of the traffic volume seen by individual occupancy sensors over the course of a day for weekdays and weekend days. This profile will be incorporated into the ongoing efforts to determine the threshold for parking garage advanced lighting control energy savings and provides a data-based estimate of parking garage use profiles for this specific application.

10.2.2 Analysis of UC Davis Data

For the UC Davis project, data was provided for two illuminance loggers, one located in the basement and one located on the first floor. As described previously, thresholds to determine "HIGH," "LOW," and "OFF" states were first established for each sensor, and then hourly events were determined based on transitions from "LOW" to "HIGH" status and "HIGH" mode durations exceeding the stated sensor delay time. Based on this analysis procedure, the occupancy profile shown in Figure 78was determined:

Figure 78: UC Davis Profile, 11/3/09 through 11/5/09

It was assumed that the data labeled for the basement indicated the response in a non-daylighted space, and that the data labeled for the first floor indicated the response in a daylighted space. Therefore, as shown in the profile, the daylighted space experiences zero occupancy events during daylighted times as the luminaires are on "OFF" mode for those durations; however, this is likely not representative of the actual occupancy during that time.

10.2.3 Analysis of UCSB Induction Data

For the UCSB project, a garage was retrofitted with bi-level induction luminaires controlled via occupancy sensors. Ten data logger files were provided by the CLTC for analysis that included illuminance measurements at one-minute increments, and the analysis as described above was performed. Based on the provided data, it was assumed that the tested space was non-daylighted. The results of the analysis procedure for these ten data loggers resulted in a site-specific occupancy profile, as shown in Figure 79:

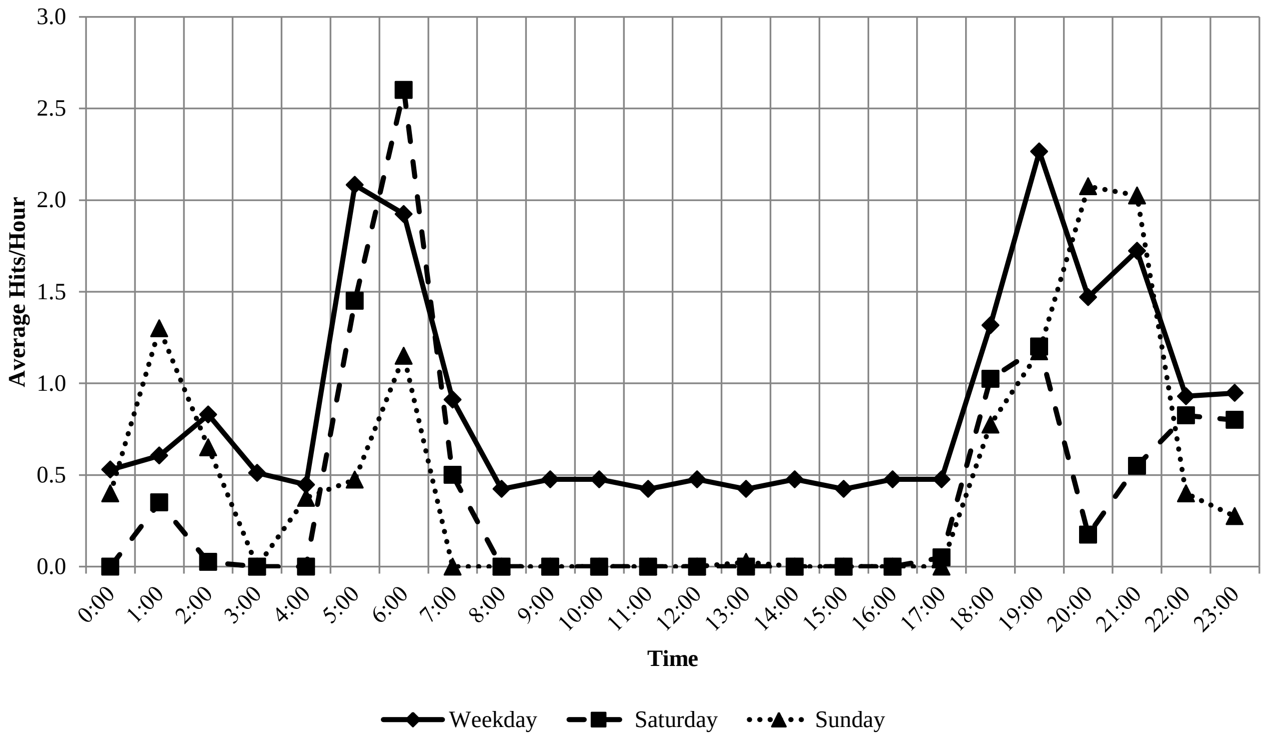

Figure 79: UCSB Induction Profile, 2/9/10 through 3/14/10

10.2.4 Analysis of UCSB Fluorescent Profile

As a second project on the UCSB campus, another parking garage was retrofitted to have bi-level fluorescent luminaires using occupancy- and daylight-sensing control systems. Eight data logger files were provided by the CLTC that included illuminance measurements at one-minute increments. Based on the reported occupancy-sensor delay time and the established thresholds for determining "HIGH," "LOW," and "OFF" operation, the process describe previously was followed to determine a composite occupancy profile. The results of that analysis are shown in Figure 80:

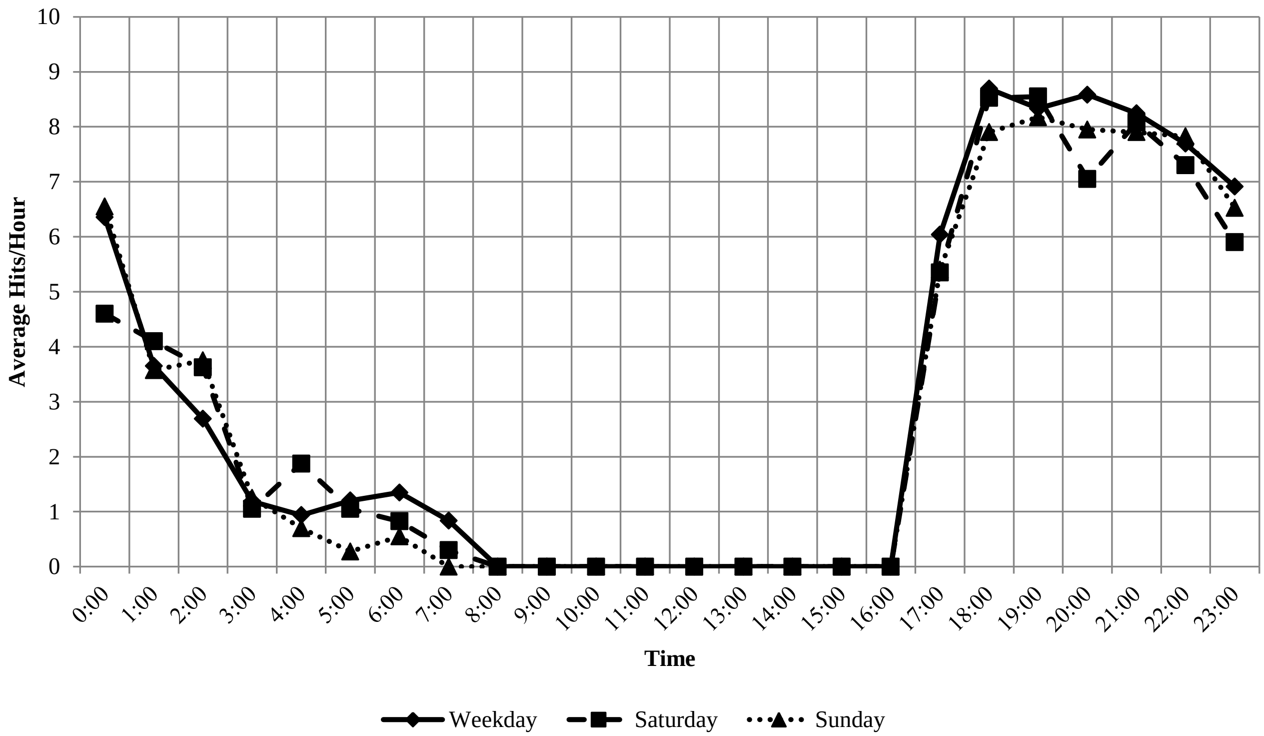

Figure 80: UCSB Fluorescent Profile, 2/9/10 through 3/14/10

It was assumed that the data loggers were located in a space that had access to daylight, which causes the measured occupancy events to drop to zero when daylight is present.

10.2.5 Analysis of CSU Sacramento Profile

On the CSU Sacramento campus, a parking garage was retrofitted with updated technology that included bi-level luminaires switched in response to occupancy. Effectively, eighteen data files were provided that recorded ON/OFF event times at unequal increments of time. The procedure described previously for this type of data was used to create the composite profiles, based on the reported sensor time-delay and seven of the provided data logger files, as shown in Figure 81:

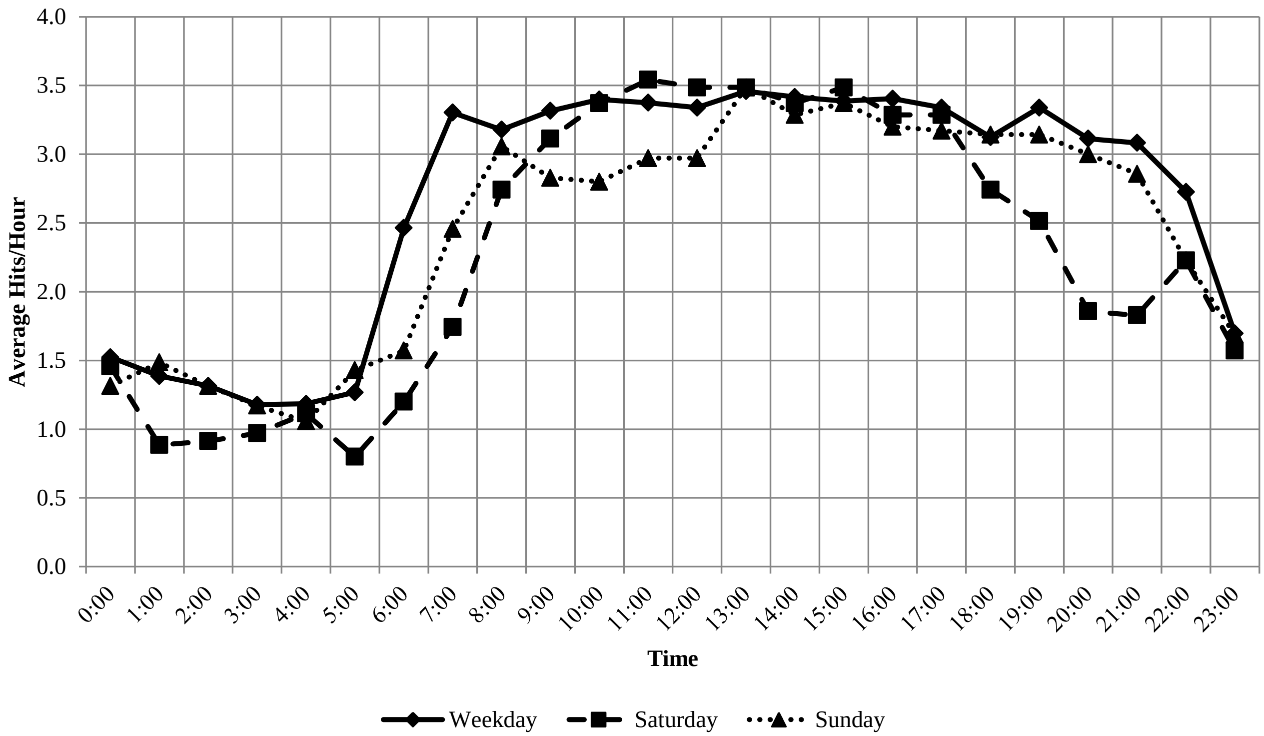

Figure 81: CSU Sacramento Profile, 3/13/08 through 4/15/08

The remaining data logger files were not analyzed due to inconsistency with the data. The reported sensor time-delay for this project according to the CLTC was 15 minutes, which was used to determine the minimum number of occupancy events needed across each hour to maintain a "HIGH" condition. However, there are multiple locations within the data that exhibit a "HIGH" condition that lasts less than the stated delay time, so the actual delay time is therefore unclear. Therefore, while the analysis caps out at four events per hour based on the stated delay time, the actual event number is likely higher.

10.2.6 Formation of Composite Profiles

Based on the analysis of the four university parking garage projects, it was desirable to come to a "typical" occupancy profile for this type of parking garage facility. First, the various weekday and weekend day profiles were examined, as shown in Figure 82 and Figure 83:

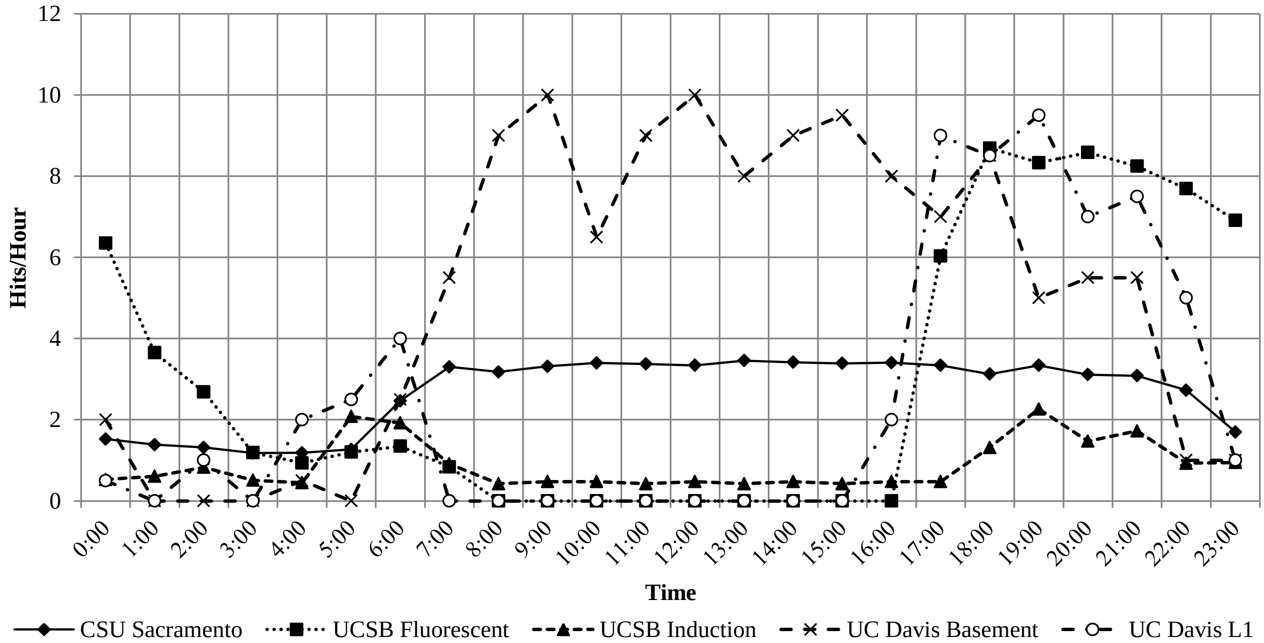

Figure 82: Weekday Profiles from Five Projects

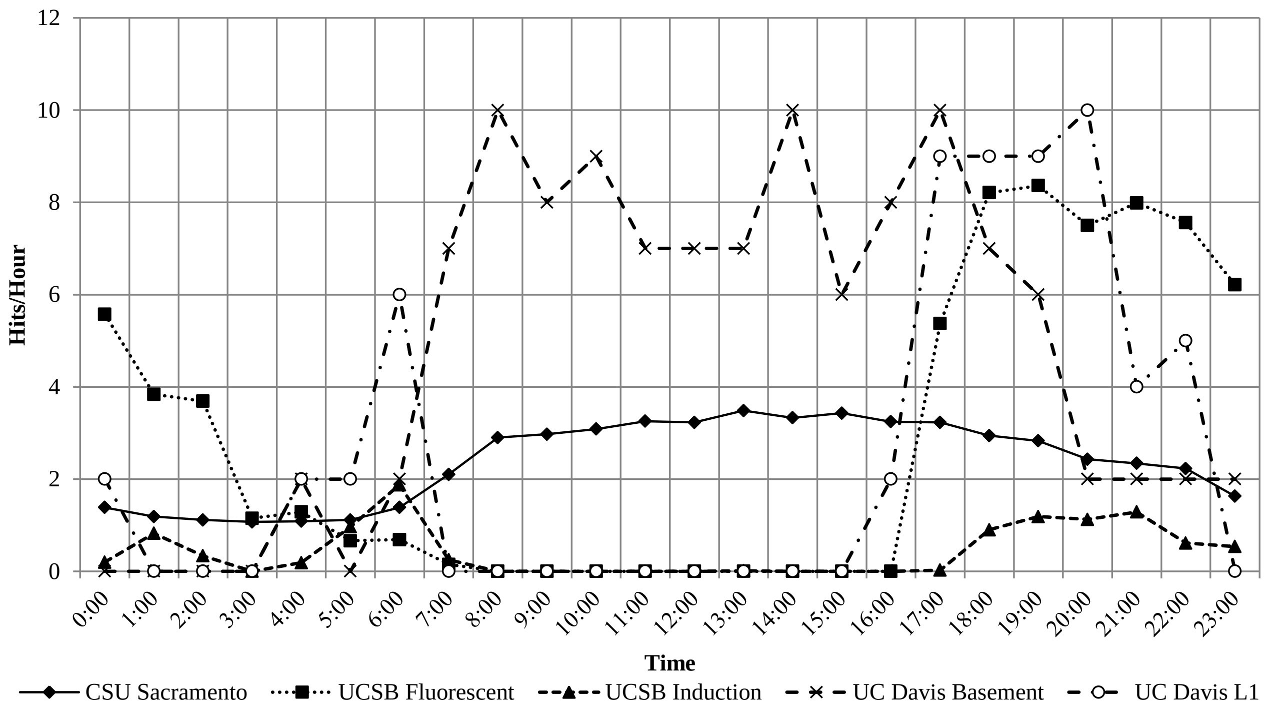

Figure 83: Weekend Day Profiles from Five Projects

The weekday and weekend day profiles were then averaged across the various studies, separating daylighted and non-daylighted projects, as shown in Figure 84 and Figure 85:

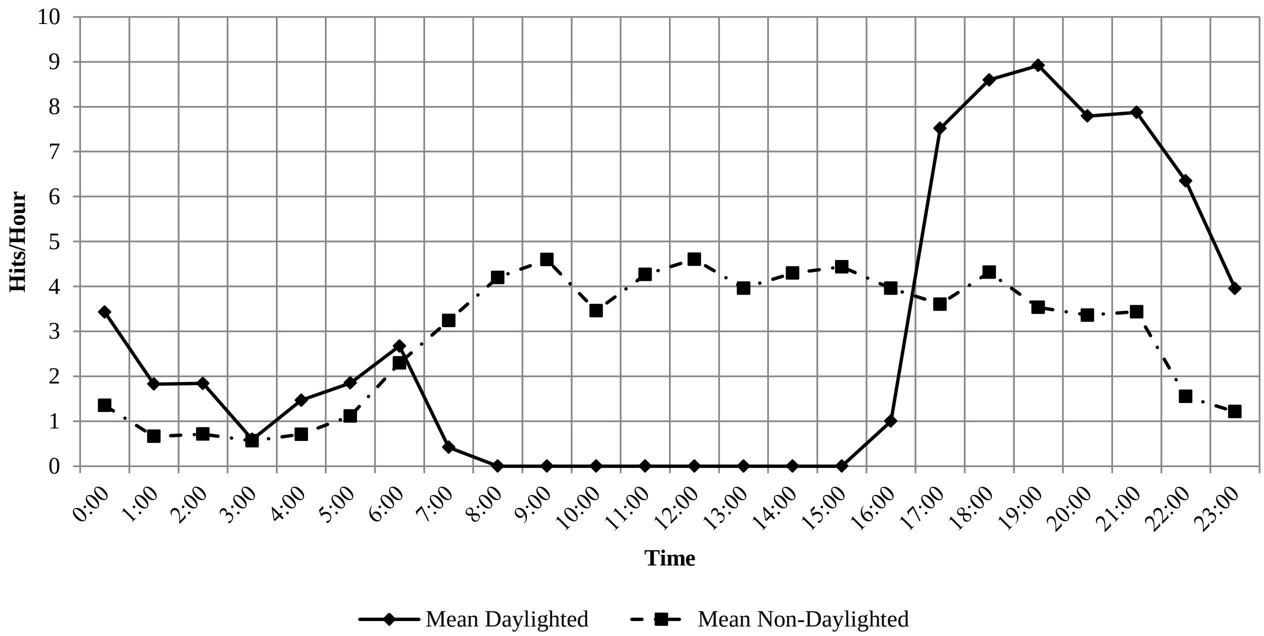

Figure 84: Composite Weekday Profile

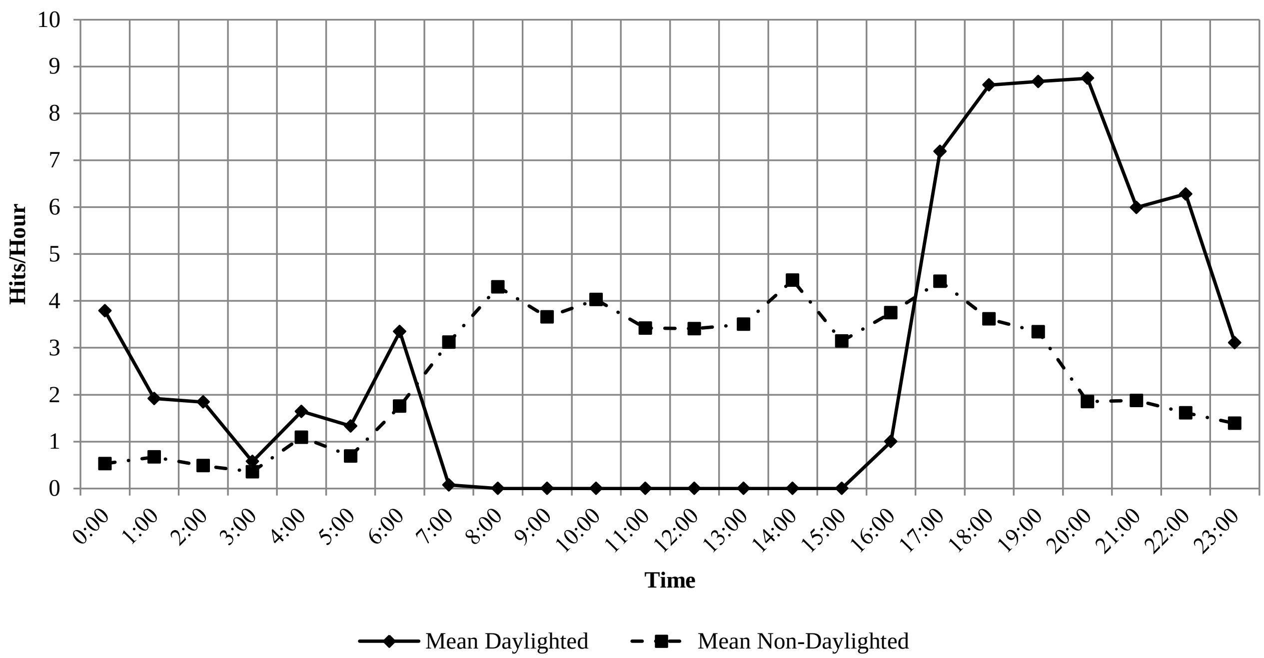

Figure 85: Composite Weekend Day Profile

Finally, the daylighted and non-daylighted profiles were combined. During non-daylighted hours, the mean events per hour between the daylighted and non-daylighted profiles were used. During daylighted hours, the general trend of the non-daylighted spaces was followed and applied to the curve. This analysis resulted in the occupancy profiles shown in Figure 86:

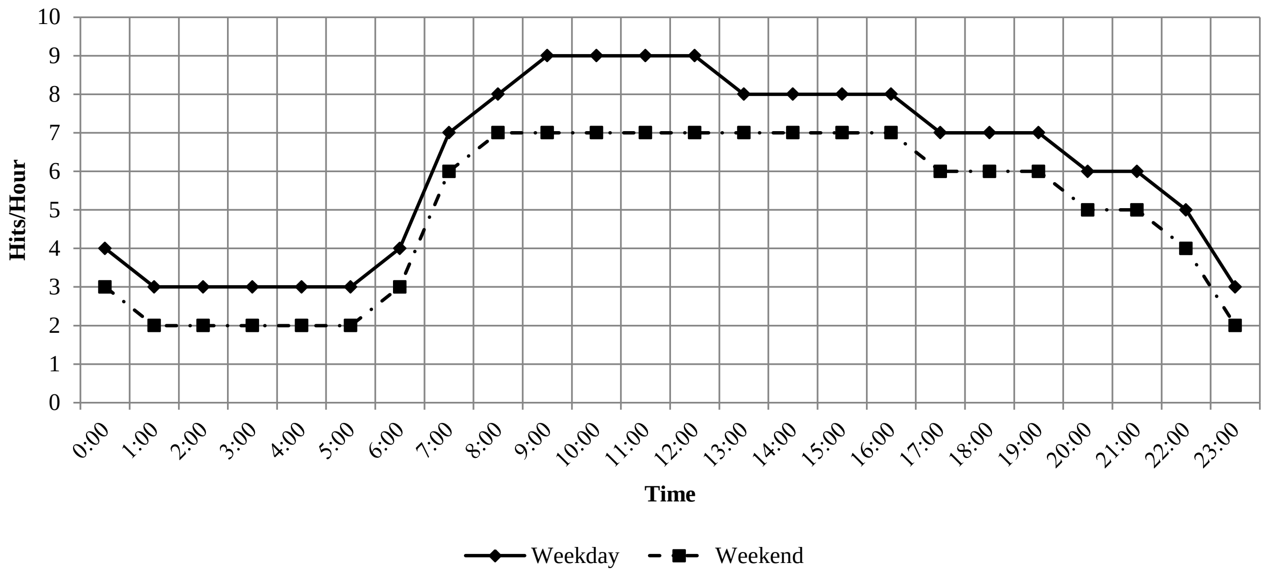

Figure 86: Final University Campus Parking Garage Occupancy Profile

This profile will be incorporated into the modeling efforts currently underway to quantify energy savings in a parking garage from occupancy- and daylight-responsive controls. The modeling program created allows the input of various occupancy schedules for analysis, and this occupancy profile will be used to examine energy savings potentials in university campus parking garages. The modeling results will then be compared to the reported energy savings from these various projects for analysis.

11. Appendix G: Energy Modeling Documentation

11.1 Simulation 1: Baseline Model

First, a baseline was established as the assumed critical path toward demonstrating cost-effectiveness. This baseline model, as shown in Figure 88, serves as the physical basis for the typical garage design for subsequent analysis. Figure 87 includes all input variables for the baseline run.

11.1.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Transportation HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Transportation HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 87 : Simulation 1 Input Variables

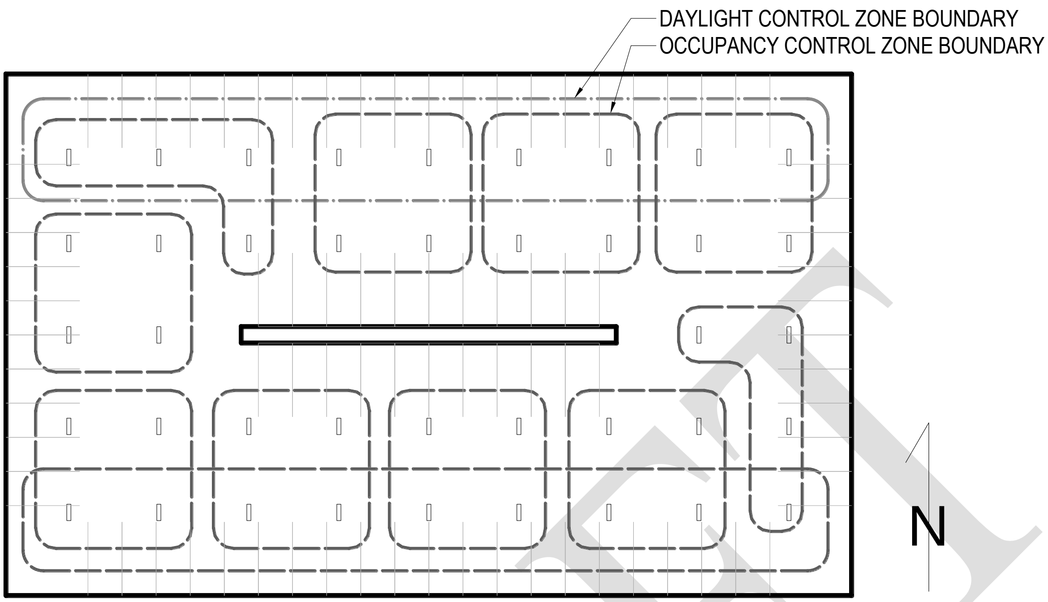

Figure 88: Configuration of Typical Floor for Baseline Fluorescent Lighting System

The critical path, where cost-effectiveness is less certain, was determined to be the 'HIGH' level of occupancy based on the Transportation profile, which maintains a high level of activity during all hours and was likely to return the least energy savings potential. The critical path also assumed 'POOR' daylight availability at which the daylight-responsive system was likely to produce significant energy savings.

The lighting system was assumed to use a linear fluorescent system, which has been established as the baseline configuration for all parking garage lighting analysis. For this analysis, the lighting power density was held to the proposed new lighting power densities, and thus when cost effectiveness is shown, it also implies cost-effectiveness at an increased power density. The luminaires were assumed to use remote occupancy sensing, and thus were grouped into control zones of four luminaire each, as shown by the dashed groupings in Figure 88.

The lighting system cost includes such initial 'present value' costs as the cost of the luminaire, installation cost, and associated wiring and conduit for power. The lighting system cost calculations also includes on-going costs such as annual luminaire cleanings as well as lamp replacements.

For the lighting control systems, each occupancy zone was assumed to use a single occupancy sensor mounted in the center of the zone. For the daylight-responsive control, it was assumed that five total daylight switching zones were used, one on each floor on the south side and one controlling all daylight groups on the north side. The control system costs include the "present value" costs such as equipment, installation and wiring, and also including on-going costs, such as replacement of failed sensors.

11.1.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:56	3230:50:20	2753:19:20	4998:12:14	4264:45:14	5964:39:36	5104:18:07	6365:47:00	5456:40:54	6602:17:25	5665:26:04
Average Zone Low Power Time:	0:00:00	0:00:00	5529:09:40	4880:29:25	3761:47:44	3369:03:30	2795:20:18	2529:30:35	2394:12:58	2177:07:48	2157:42:34	1968:22:41
Average Zone OFF Time:	0:00:00	1126:48:01	0:00:00	1126:11:16	0:00:00	1126:11:16	0:00:00	1126:11:16	0:00:00	1126:11:16	0:00:00	1126:11:16
Average % Time at High Power:	100.0%	87.1%	36.9%	31.4%	57.1%	48.7%	68.1%	58.3%	72.7%	62.3%	75.4%	64.7%
Average % Time at Low Power:	0.0%	0.0%	63.1%	55.7%	42.9%	38.5%	31.9%	28.9%	27.3%	24.9%	24.6%	22.5%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 147,152	$ 123,074	$ 101,858	$ 84,702	$ 117,092	$ 97,205	$ 125,238	$ 103,999	$ 128,572	$ 106,815	$ 130,519	$ 108,471
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 206,426	$ 210,946	$ 195,208	$ 226,180	$ 207,710	$ 234,326	$ 214,505	$ 237,660	$ 217,321	$ 239,607	$ 218,977
Total 15-year Cost Savings:	N/A	9.9%	7.9%	5.4%	1.3%	-0.6%	-2.3%	-3.9%	-3.7%	-5.3%	-4.6%	-6.1%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 16.98	$ 2.27	$ 2.92	$ 1.51	$ 2.34	$ 1.10	$ 2.02	$ 0.93	$ 1.89	$ 0.83	$ 1.81
Approximate Annual Energy Cost Savings:	N/A	$ 1,605	$ 3,020	$ 4,163	$ 2,004	$ 3,330	$ 1,461	$ 2,877	$ 1,239	$ 2,689	$ 1,109	$ 2,579

Figure 89: Simulation 1 Results

Figure 89 provides the simulation output results. As shown, the control system based on only daylight-responsive control provides approximately 10% total 15-year cost savings relative to the 'Uncontrolled' Baseline. This is a combination of the fact that the daylight-responsive systems effectively shed load during peak energy cost times and that the daylight-responsive systems are generally low cost based on simple switching.

In general, the occupancy-based control systems were shown to be cost-effective over 15 years when the occupancy sensor time delay was less than five minutes. Beyond five minutes, the high level of activity in this garage type leads to significant time operating in 'HIGH' power mode. For example, with a one-minute time delay, the typical zone operated in 'HIGH' power mode for only 37% of the year when daylighting was excluded. But, when that time delay was increased to 10 minutes, the average zone operated in 'HIGH' mode approximately 75% of the year. Though these results are based on a fairly high level of continuous occupancy, it demonstrates the need to understand the appropriate occupancy sensor time delay that will likely lead to energy savings and cost-effectiveness.

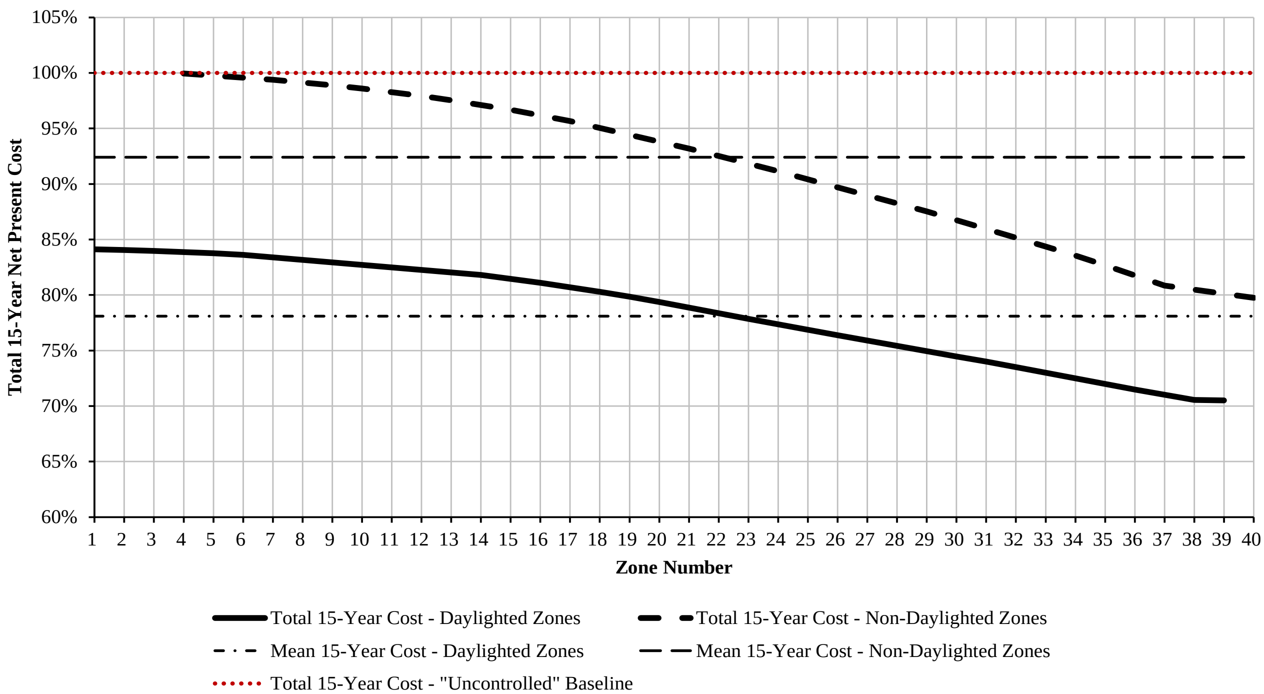

Figure 90: Simulation 1 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

Figure 90 shows the total 15-year costs, broken into zone-by-zone costs relative to an 'Uncontrolled' baseline. As shown, the zones nearest the entrance that are not daylighted show a total 15-year cost that is approximately equal to an 'Uncontrolled' baseline, essentially because the occupancy-based savings are small enough to be offset by the increased initial costs. Further into the garage, the occupancy levels essentially drop, and the occupancy-based control leads to increasing energy savings. This is also true of the daylighted zones, though the total cost of those zones never approaches the baseline because of the additional daytime savings.

11.2 Simulation 2: 80% Daylighted Model

As outline previously, it was desirable to understand the influence of certain parameters on the potential energy savings. The baseline model was adjusted to provide 80% daylighting per floor, increased from 50%. This represents a garage configuration where the floor plates are shallow and thus most of the floor plate can be effectively daylighted.

11.2.1 Simulation Inputs

Figure 91 lists the input values for this simulation run. The physical basis is the same for this run as it was for Simulation 1. Figure 88 illustrates this configuration.

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Transportation HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Transportation HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	8
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 91: Simulation 2 Input Variables

11.2.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	6957:07:07	3230:48:20	2467:27:34	5003:42:33	3824:21:17	5965:20:44	4576:48:23	6364:36:59	4894:23:32	6600:53:32	5083:59:46
Average Zone Low Power Time:	0:00:00	0:00:00	5529:11:40	4490:38:43	3756:17:27	3133:44:59	2794:39:17	2381:17:47	2395:23:00	2063:42:40	2159:06:30	1874:06:27
Average Zone OFF Time:	0:00:00	1802:52:46	0:00:00	1801:53:45	0:00:00	1801:53:45	0:00:00	1801:53:45	0:00:00	1801:53:45	0:00:00	1801:53:45
Average % Time at High Power:	100.0%	79.4%	36.9%	28.2%	57.1%	43.7%	68.1%	52.2%	72.7%	55.9%	75.4%	58.0%
Average % Time at Low Power:	0.0%	0.0%	63.1%	51.3%	42.9%	35.8%	31.9%	27.2%	27.3%	23.6%	24.6%	21.4%
Average % Time OFF:	0.0%	20.6%	0.0%	20.6%	0.0%	20.6%	0.0%	20.6%	0.0%	20.6%	0.0%	20.6%
15-yr Energy Cost:	$ 147,152	$ 108,628	$ 101,863	$ 74,418	$ 117,168	$ 85,273	$ 125,245	$ 91,153	$ 128,560	$ 93,610	$ 130,511	$ 95,068
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 191,979	$ 210,951	$ 184,924	$ 226,256	$ 195,779	$ 234,333	$ 201,659	$ 237,648	$ 204,116	$ 239,599	$ 205,573
Total 15-year Cost Savings:	N/A	16.2%	7.9%	3.7%	1.2%	-2.0%	-2.3%	-5.0%	-3.7%	-6.3%	-4.6%	-7.1%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 27.17	$ 2.27	$ 3.40	$ 1.50	$ 2.90	$ 1.10	$ 2.62	$ 0.93	$ 2.51	$ 0.83	$ 2.44
Approximate Annual Energy Cost Savings:	N/A	$ 2,568	$ 3,019	$ 4,849	$ 1,999	$ 4,125	$ 1,460	$ 3,733	$ 1,239	$ 3,569	$ 1,109	$ 3,472

Figure 92: Simulation 2 Results

Figure 92 provides the simulation output results. As shown, increasing the amount of floor plate that is effectively daylighted serves to increase the total 15-year cost savings to over 16% relative to the 'Uncontrolled' Baseline.

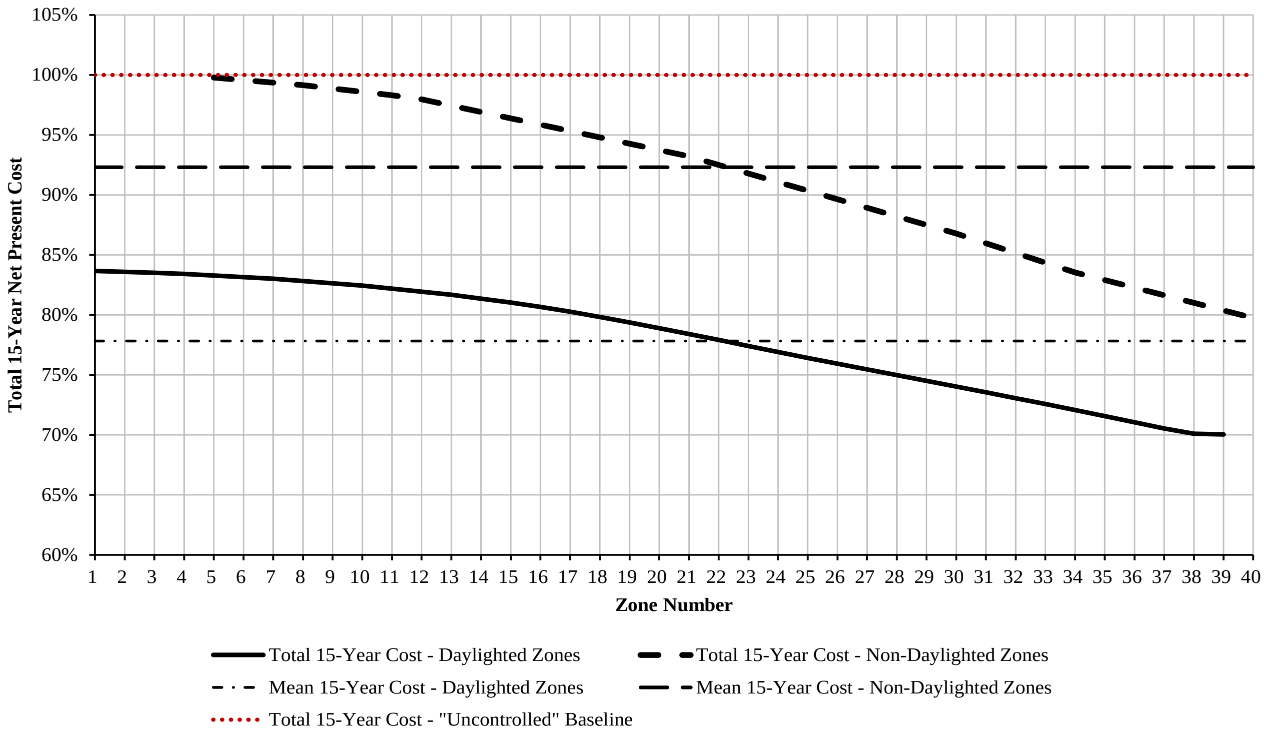

Figure 93: Simulation 2 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

Figure 93 shows the total 15-year costs, broken into zone-by-zone costs relative to an 'Uncontrolled' baseline. Typical to the results from Simulation 1, the zones nearest the entrance that are not daylighted show a total 15-year cost that is approximately equal to an 'Uncontrolled' baseline, essentially because the occupancy-based savings are small enough to be offset by the increased initial costs. Further into the garage, the occupancy levels essentially drop, and the occupancy-based control leads to increasing energy savings.

Figure 93 also illustrates the consistency in the simulation. For Simulation 1, with 50% daylighting per floor, the mean daylighted zone cost is nearly identical to Simulation 2 at 78% relative cost compared to the 'Uncontrolled' Baseline. However, the composite garage numbers show that the overall garage cost is reduced when more of the floor plate can be daylighted.

11.3 Simulation 3: 20% Daylighted Model

In order to fully understand the impact of daylighting on the overall energy picture, it was important to quantify the impact on a garage with reduced daylighting. For this simulation, the percentage of each floor plate with access to daylight was reduced to 20%, which would represent a garage with very limited exterior exposure.

11.3.1 Simulation Inputs

Figure 94 lists the input values for this simulation run. The physical basis is the same for this run as it was for Simulations 1 and 2. Figure 88 illustrates this configuration

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Transportation HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Transportation HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	2
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 94: Simulation 3 Input Variables

11.3.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	8309:16:48	3230:23:03	3029:25:58	5000:00:25	4693:29:03	5967:38:44	5612:43:56	6367:56:38	5997:07:15	6604:53:07	6226:15:04
Average Zone Low Power Time:	0:00:00	0:00:00	5529:36:57	5280:05:40	3759:59:34	3616:02:37	2792:21:16	2696:47:44	2392:03:22	2312:24:20	2155:06:57	2083:16:40
Average Zone OFF Time:	0:00:00	450:43:12	0:00:00	450:28:21	0:00:00	450:28:21	0:00:00	450:28:21	0:00:00	450:28:21	0:00:00	450:28:21
Average % Time at High Power:	100.0%	94.9%	36.9%	34.6%	57.1%	53.6%	68.1%	64.1%	72.7%	68.5%	75.4%	71.1%
Average % Time at Low Power:	0.0%	0.0%	63.1%	60.3%	42.9%	41.3%	31.9%	30.8%	27.3%	26.4%	24.6%	23.8%
Average % Time OFF:	0.0%	5.1%	0.0%	5.1%	0.0%	5.1%	0.0%	5.1%	0.0%	5.1%	0.0%	5.1%
15-yr Energy Cost:	$ 147,152	$ 137,521	$ 101,839	$ 94,866	$ 117,071	$ 108,972	$ 125,213	$ 116,602	$ 128,549	$ 119,770	$ 130,506	$ 121,647
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 220,873	$ 210,927	$ 205,372	$ 226,159	$ 219,477	$ 234,301	$ 227,108	$ 237,637	$ 230,276	$ 239,594	$ 232,153
Total 15-year Cost Savings:	N/A	3.6%	7.9%	7.0%	1.3%	0.6%	-2.3%	-2.8%	-3.7%	-4.3%	-4.6%	-5.1%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 6.79	$ 2.27	$ 2.45	$ 1.51	$ 1.79	$ 1.10	$ 1.43	$ 0.93	$ 1.28	$ 0.83	$ 1.19
Approximate Annual Energy Cost Savings:	N/A	$ 642	$ 3,021	$ 3,486	$ 2,005	$ 2,545	$ 1,463	$ 2,037	$ 1,240	$ 1,825	$ 1,110	$ 1,700

Figure 95: Simulation 3 Results

Figure 95 provides the simulation output results. As shown, decreasing the amount of floor plate that is effectively daylighted serves to decrease the total 15-year cost savings to around 4% relative to the 'Uncontrolled' Baseline.

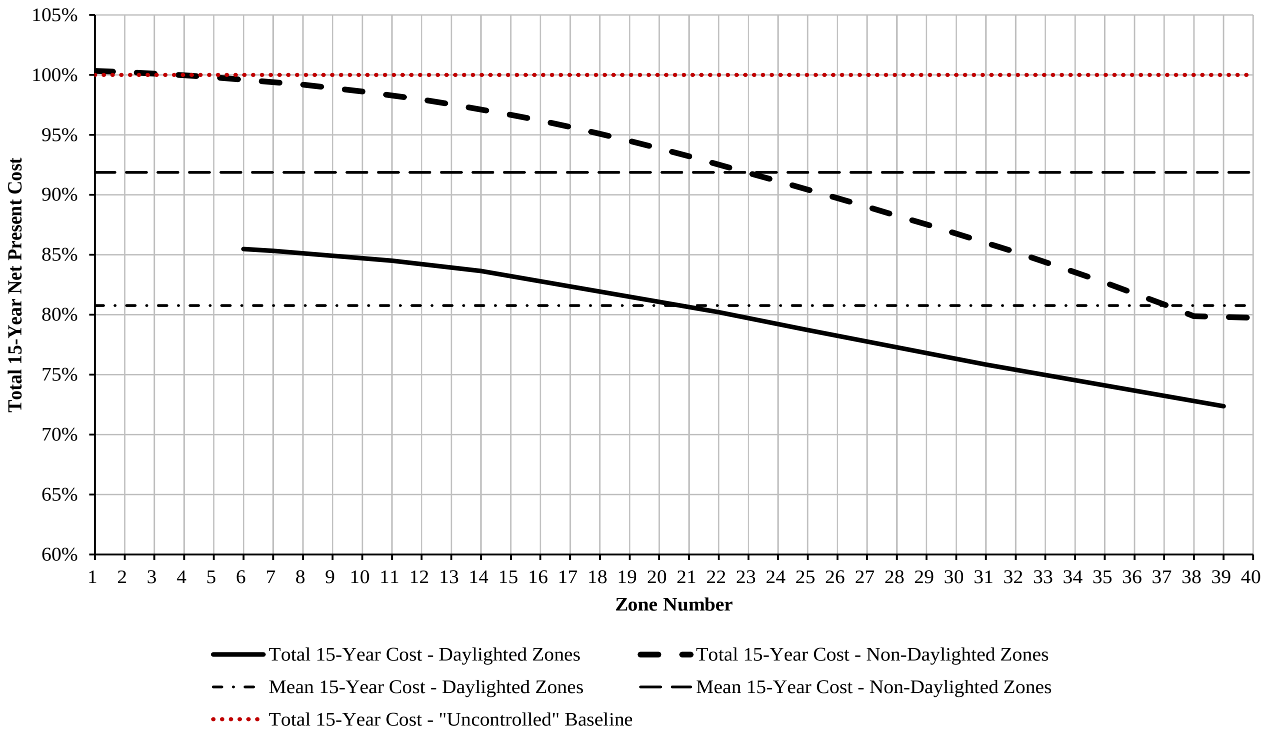

Figure 96: Simulation 3 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

Figure 96 shows the total 15-year costs, broken into zone-by-zone costs relative to an 'Uncontrolled' baseline. Typical to the results from Simulations 1 and 2, the zones nearest the entrance that are not daylighted show a total 15-year cost that is approximately equal to an 'Uncontrolled' baseline, essentially because the occupancy-based savings are small enough to be offset by the increased initial costs. Further into the garage, the occupancy levels essentially drop, and the occupancy-based control leads to increasing energy savings.

Figure 96 again illustrates the consistency in the simulation. For Simulation 1, with 50% daylighting per floor, the mean daylighted zone cost is nearly identical to Simulation 2 and 3 at 78% relative cost compared to the 'Uncontrolled' Baseline. However, the composite garage numbers show that the overall garage cost is increased when less of the floor plate can be daylighted.

11.4 Simulation 4: Moderate Daylight Availability Model

Simulation 4 was configured to understand the impact of daylight availability, as defined previously. The Simulation 1 Baseline was based on 'Poor' daylight availability. This simulation took the same parameters, but changed to 'Moderate' daylight availability.

11.4.1 Simulation Inputs

Figure 97 lists the input values for this simulation run. The physical basis is the same for this run as it was for previous runs; Figure 88 illustrates this configuration.

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Transportation HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Transportation HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Moderate
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 97: Simulation 4 Input Variables

11.4.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Moderate	0	Moderate	0	Moderate	0	Moderate	0	Moderate	0	Moderate
Average Zone High Power Time:	8760:00:00	7085:41:59	3223:15:59	2489:10:21	4992:29:21	3883:39:02	5960:24:57	4681:52:25	6362:58:49	5027:11:25	6601:03:04	5236:02:39
Average Zone Low Power Time:	0:00:00	0:00:00	5536:44:00	4597:10:48	3767:30:39	3202:42:05	2799:35:02	2404:28:43	2397:01:12	2059:09:43	2158:56:52	1850:18:26
Average Zone OFF Time:	0:00:00	1674:18:00	0:00:00	1673:38:53	0:00:00	1673:38:53	0:00:00	1673:38:53	0:00:00	1673:38:53	0:00:00	1673:38:53
Average % Time at High Power:	100.0%	80.9%	36.8%	28.4%	57.0%	44.3%	68.0%	53.4%	72.6%	57.4%	75.4%	59.8%
Average % Time at Low Power:	0.0%	0.0%	63.2%	52.5%	43.0%	36.6%	32.0%	27.4%	27.4%	23.5%	24.6%	21.1%
Average % Time OFF:	0.0%	19.1%	0.0%	19.1%	0.0%	19.1%	0.0%	19.1%	0.0%	19.1%	0.0%	19.1%
15-yr Energy Cost:	$ 147,152	$ 112,849	$ 101,785	$ 77,150	$ 117,032	$ 88,555	$ 125,174	$ 94,950	$ 128,531	$ 97,709	$ 130,504	$ 99,375
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 196,201	$ 210,873	$ 187,656	$ 226,120	$ 199,061	$ 234,262	$ 205,456	$ 237,619	$ 208,215	$ 239,592	$ 209,881
Total 15-year Cost Savings:	N/A	14.4%	8.0%	18.1%	1.3%	13.1%	-2.3%	10.3%	-3.7%	9.1%	-4.6%	8.4%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 24.19	$ 1.67	$ 2.45	$ 1.11	$ 2.05	$ 0.81	$ 1.83	$ 0.69	$ 1.73	$ 0.61	$ 1.67
Approximate Annual Energy Cost Savings:	N/A	$ 2,287	$ 3,024	$ 4,667	$ 2,008	$ 3,906	$ 1,465	$ 3,480	$ 1,241	$ 3,296	$ 1,110	$ 3,185

Figure 98: Simulation 4 Results

Figure 98 provides the simulation output results. As shown, increasing the daylight availability from 'Poor' to 'Moderate' served to increase the total 15-year cost savings by nearly 50%.

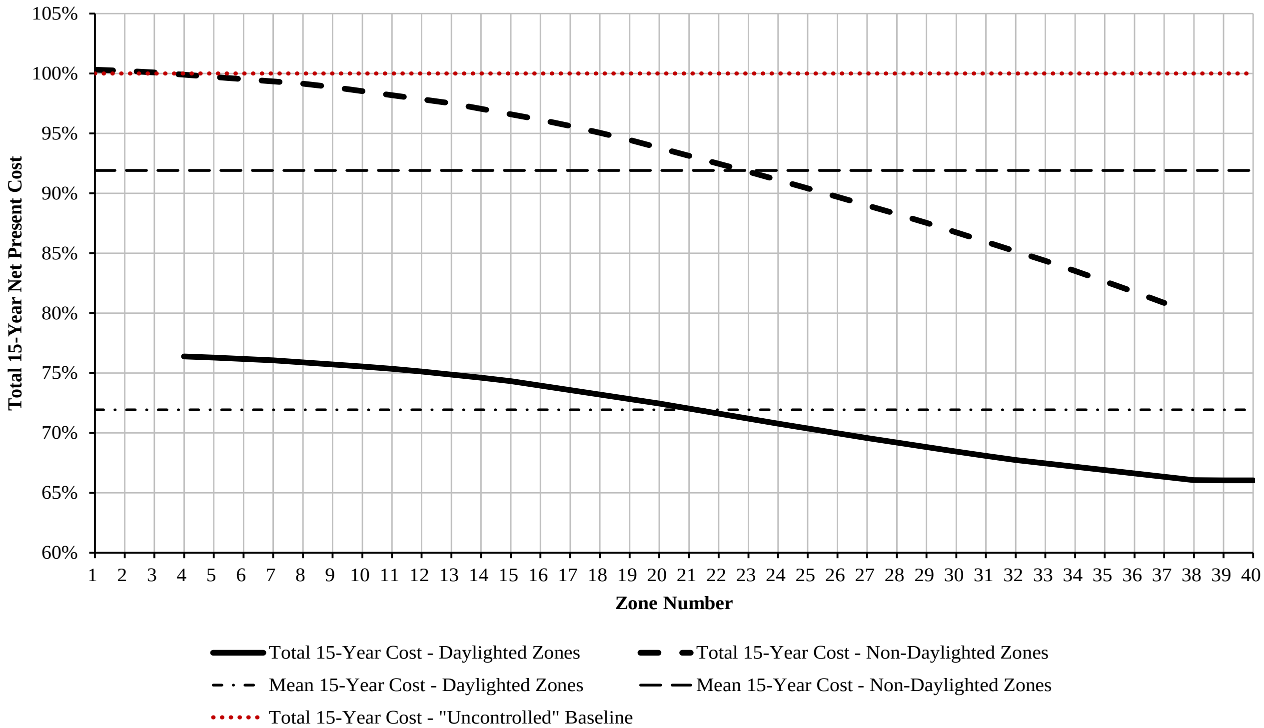

Figure 99: Simulation 4 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

Figure 99 shows the total 15-year costs, broken into zone-by-zone costs relative to an 'Uncontrolled' baseline. Typical to the results from previous simulations, the zones nearest the entrance that are not daylighted show a total 15-year cost that is approximately equal to an 'Uncontrolled' baseline, essentially because the occupancy-based savings are small enough to be offset by the increased initial costs. Further into the garage, the occupancy levels essentially drop, and the occupancy-based control leads to increasing energy savings.

Figure 96 also illustrates the impact of daylight availability. Per Simulation 1, the mean 15-year cost among daylighted zones was approximately 78% based on 'Poor' daylight availability. As shown in Figure 96, the mean 15-year cost of these same zones is reduced to 72%. This also illustrates that increasing the daylight availability serves to 'flatten' the daylighted zone-by-zone curve by allowing longer periods of 'OFF' time throughout that lead to increased energy savings.

11.5 Simulation 5: Good Daylight Availability

Simulation 5 again took the baseline configuration, but changed the daylight availability parameter to 'Good'. This simulation was performed to provide the high-end evaluation of the impact of daylighting.

11.5.1 Simulation Inputs

Figure 100 lists the input values for this simulation run. The physical basis is the same for this run as it was for previous runs; Figure 88 illustrates this configuration.

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Transportation HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Transportation HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Good
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 100: Simulation 5 Input Variables

11.5.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Good	0	Good	0	Good	0	Good	0	Good	0	Good
Average Zone High Power Time:	8760:00:00	6720:42:01	3234:43:12	2337:55:06	5009:00:56	3660:00:21	5973:26:39	4410:45:04	6373:53:39	4728:47:49	6610:40:22	4917:24:26
Average Zone Low Power Time:	0:00:00	0:00:00	5525:16:48	4383:20:18	3750:59:04	3061:15:00	2786:33:21	2310:30:19	2386:06:12	1992:27:32	2149:19:36	1803:50:59
Average Zone OFF Time:	0:00:00	2039:18:00	0:00:00	2038:44:37	0:00:00	2038:44:37	0:00:00	2038:44:37	0:00:00	2038:44:37	0:00:00	2038:44:37
Average % Time at High Power:	100.0%	76.7%	36.9%	26.7%	57.2%	41.8%	68.2%	50.4%	72.8%	54.0%	75.5%	56.1%
Average % Time at Low Power:	0.0%	0.0%	63.1%	50.0%	42.8%	34.9%	31.8%	26.4%	27.2%	22.7%	24.5%	20.6%
Average % Time OFF:	0.0%	23.3%	0.0%	23.3%	0.0%	23.3%	0.0%	23.3%	0.0%	23.3%	0.0%	23.3%
15-yr Energy Cost:	$ 147,152	$ 106,616	$ 101,911	$ 72,789	$ 117,178	$ 83,549	$ 125,280	$ 89,486	$ 128,614	$ 91,968	$ 130,579	$ 93,429
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 189,968	$ 210,999	$ 183,295	$ 226,266	$ 194,055	$ 234,368	$ 199,992	$ 237,702	$ 202,474	$ 239,667	$ 203,934
Total 15-year Cost Savings:	N/A	17.1%	7.9%	3.5%	1.2%	-2.2%	-2.3%	-5.3%	-3.8%	-6.6%	-4.6%	-7.4%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 28.59	$ 2.27	$ 3.48	$ 1.50	$ 2.98	$ 1.10	$ 2.70	$ 0.93	$ 2.58	$ 0.83	$ 2.51
Approximate Annual Energy Cost Savings:	N/A	$ 2,702	$ 3,016	$ 4,958	$ 1,998	$ 4,240	$ 1,458	$ 3,844	$ 1,236	$ 3,679	$ 1,105	$ 3,582

Figure 101: Simulation 5 Results

Figure 101 provides the simulation output results. As shown, increasing the daylight availability to 'Good' again serves to increase the 15-year cost savings.

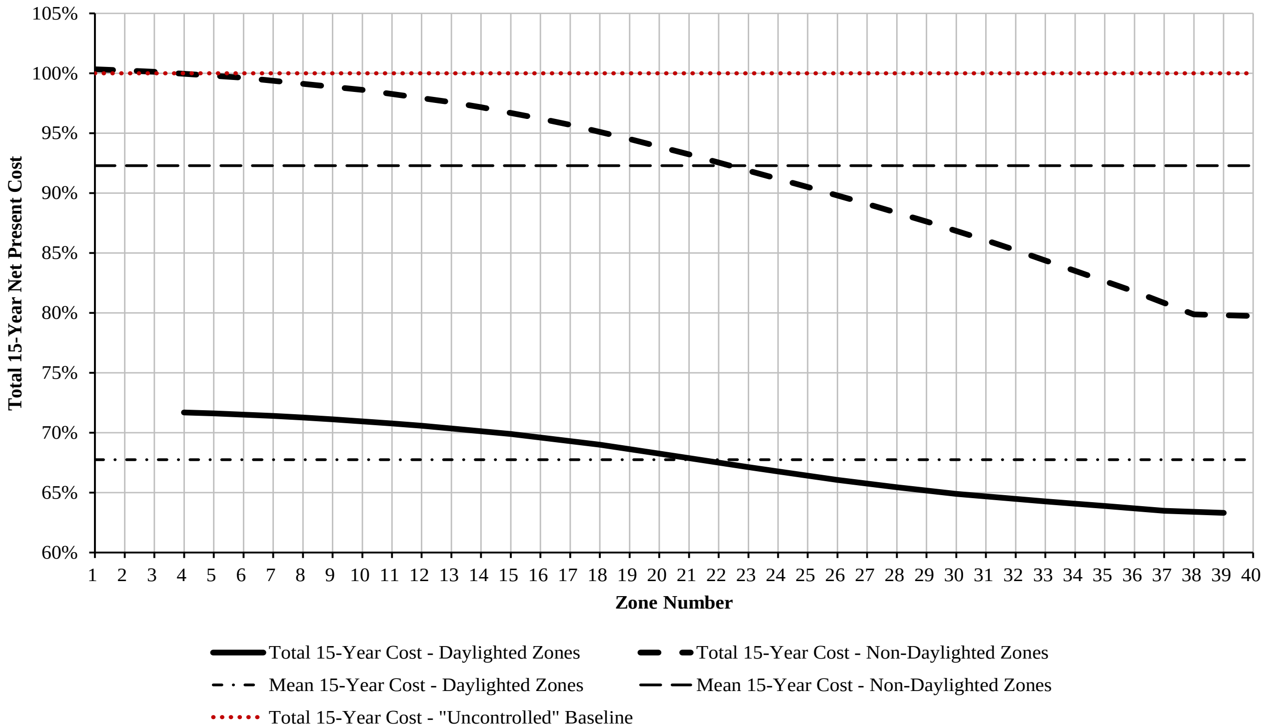

Figure 102: Simulation 5 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

Figure 102 shows the total 15-year costs, broken into zone-by-zone costs relative to an 'Uncontrolled' baseline. As shown, near the entrance to the garage, the zone unit cost exceeds that of the 'Uncontrolled' basline zones due to high traffic volume which negate energy savings.

11.6 Simulation 6: LED Lighting System

Simulation 6 took the basic garage configuration and occupancy patterns, but used an LED lighting system. The chosen luminaire is available with an integral occupancy sensor, which requires a bi-level ballast, in a 'master' configuration, with additional luminaires available with only the bi-level ballast for a 'slave' configuration.

11.6.1 Simulation Inputs

Figure 103 shows the input information used for this run. As shown, the cost for providing the integral occupancy sensor in the described Master/Slave condition was included as the 'Occupancy Sensing Cost', not within the 'Controlled Luminaire Cost.' It was assumed that the LEDs, in 'LOW' mode, were dimmed to 20% of rated power, in order to capture the potentially increased energy savings available from LEDs due to the wide range of dimming available.

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Transportation HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Transportation HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	28
	Daylight Availability	Poor
	# Daylighted Zones per Floor	14
Luminaire Information	Luminaire Description	LED with optional integral occupancy sensor
	Uncontrolled Luminaire Total Unit Cost	$4,373
	Controlled Luminaire Total Unit Cost	$4,373
	High Power	68
	Low Power	13.6
	OC Spacing E-W	32
	OC Spacing N-S	32
	# Luminaires per Control Zone	1
Control System Information	Occupancy Sensing Cost	$402
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$25
	Notes	Control system costs per controlled zone

Figure 103: Simulation 6 Input Variables

Figure 104 illustrates the physical basis for the LED lighting system. This physical geometry is the same as used for other lighting systems, but the required luminaire quantity using LEDs is reduced.

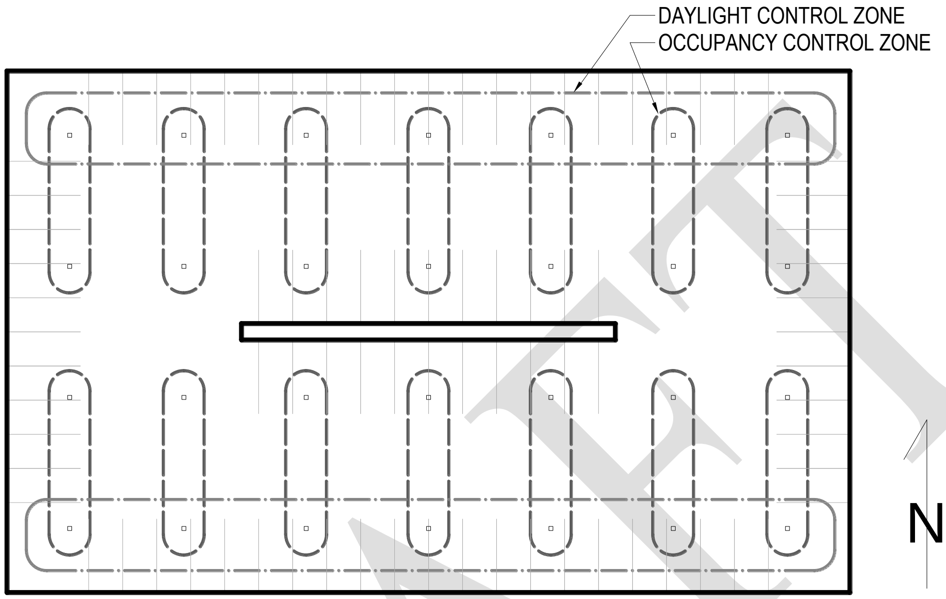

Figure 104: Configuration of Typical Floor for LED Lighting System

11.6.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:59	2989:57:01	2543:25:06	4639:54:30	3952:34:21	5555:24:10	4748:12:18	5944:47:36	5090:38:57	6181:21:26	5300:00:04
Average Zone Low Power Time:	0:00:00	0:00:00	5770:02:58	5090:24:04	4120:05:35	3681:14:50	3204:35:50	2885:36:57	2815:12:21	2543:10:11	2578:38:40	2333:49:05
Average Zone OFF Time:	0:00:00	1126:47:58	0:00:00	1126:10:51	0:00:00	1126:10:51	0:00:00	1126:10:51	0:00:00	1126:10:51	0:00:00	1126:10:51
Average % Time at High Power:	100.0%	87.1%	34.1%	29.0%	53.0%	45.1%	63.4%	54.2%	67.9%	58.1%	70.6%	60.5%
Average % Time at Low Power:	0.0%	0.0%	65.9%	58.1%	47.0%	42.0%	36.6%	32.9%	32.1%	29.0%	29.4%	26.6%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 129,712	$ 108,488	$ 63,396	$ 52,340	$ 83,349	$ 68,696	$ 94,125	$ 77,700	$ 98,637	$ 81,515	$ 101,346	$ 83,819
Lighting Equipment Cost:	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079
Total 15-yr Cost (Initial + NPV of Energy):	$ 619,527	$ 599,721	$ 598,290	$ 588,652	$ 618,244	$ 605,009	$ 629,019	$ 614,012	$ 633,532	$ 617,827	$ 636,241	$ 620,131
Total 15-year Cost Savings:	N/A	3.2%	3.4%	1.8%	0.2%	-0.9%	-1.5%	-2.4%	-2.3%	-3.0%	-2.7%	-3.4%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 14.97	$ 1.47	$ 1.66	$ 1.03	$ 1.31	$ 0.79	$ 1.12	$ 0.69	$ 1.04	$ 0.63	$ 0.99
Approximate Annual Energy Cost Savings:	N/A	$ 1,415	$ 4,421	$ 5,158	$ 3,091	$ 4,068	$ 2,372	$ 3,467	$ 2,072	$ 3,213	$ 1,891	$ 3,060

Figure 105: Simulation 6 Results

First, it should be noted that the LED equipment cost is much higher than the cost of fluorescent equipment for the same garage configuration, despite the fact that more fluorescent luminaires are required, accounting for all associated electrical and installation costs. Second, it should be noted that the cost of providing occupancy sensing for the entire garage when using an LED system is 166% of the cost of providing occupancy sensing for the entire garage when using a fluorescent system.

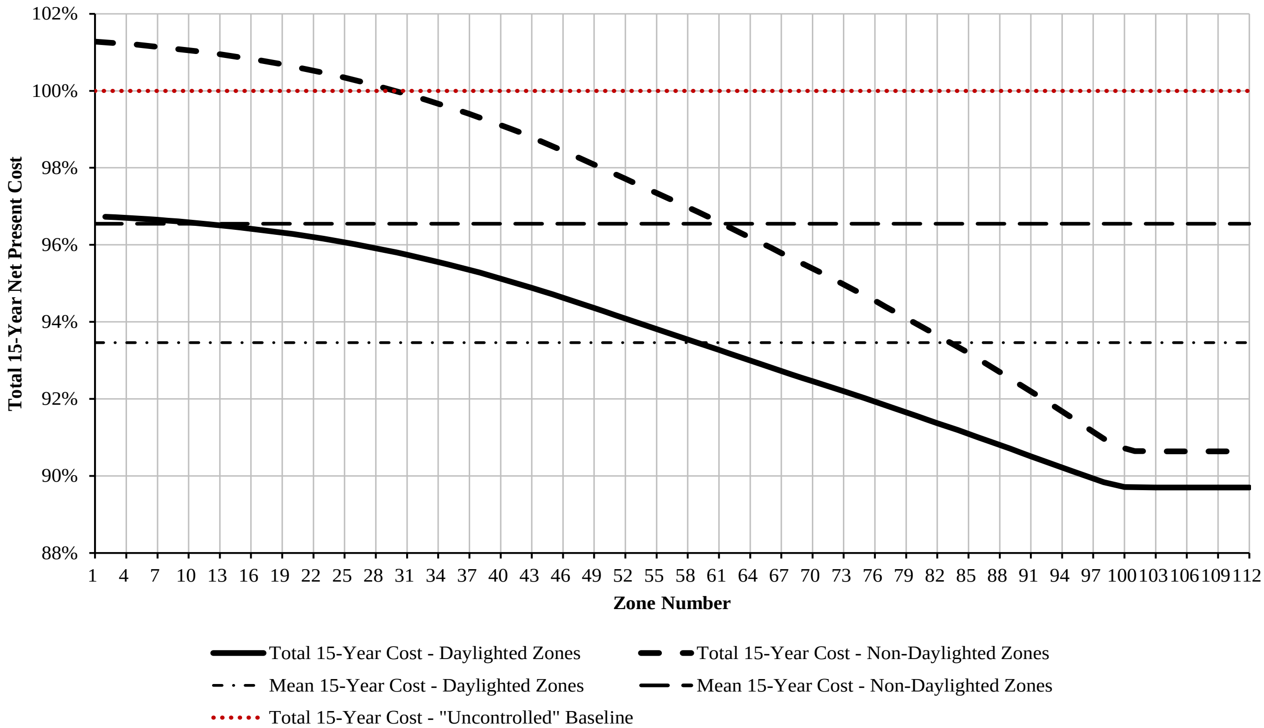

Figure 106: Simulation 6 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

As shown in Figure 106, with a one-minute sensor time delay, the non-daylighted zones nearest the entrance show a 15-year cost higher than the 'Uncontrolled' baseline. Again, this is due to the high volume rates near the entrance which effectively keep the lighting at 'HIGH' power for a significant amount of time.

However, with this one-minute time delay, the entire garage is found to be cost effective using occupancy controls and with or without daylighting controls. With delay times beyond one minute, the occupancy controls, for this use pattern and lighting system type, are not cost-effective both with and without daylighting controls.

11.7 Simulation 7: HID Lighting System

Simulation 7 again took the basic garage configuration and occupancy patterns, but used a High Pressure Sodium (HPS) lighting system. The chosen luminaire is available with an integral occupancy sensor, which requires a bi-level ballast, in a 'master' configuration, with additional luminaires available with only the bi-level ballast for a 'slave' configuration.

11.7.1 Simulation Inputs

Figure 107 shows the input information used for this run. To note, the manufacturer of this luminaire was unable to provide a specific adder amount for a bi-level capable ballast. Therefore, budget-level unit pricing of a bi-level ballast suitable for this lamp type was included to estimate the total cost of the 'Controlled' luminaires.

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Transportation HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Transportation HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	14
	Daylight Availability	Poor
	# Daylighted Zones per Floor	7
Luminaire Information	Luminaire Description	HPS Luminaire with eHID dimming ballast
	Uncontrolled Luminaire Total Unit Cost	$992
	Controlled Luminaire Total Unit Cost	$1,992
	High Power	108
	Low Power	54
	OC Spacing E-W	30
	OC Spacing N-S	30
	# Luminaires per Control Zone	2
Control System Information	Occupancy Sensing Cost	$327
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$51
	Notes	Control system costs per controlled zone

Figure 107: Simulation 7 Input Variables

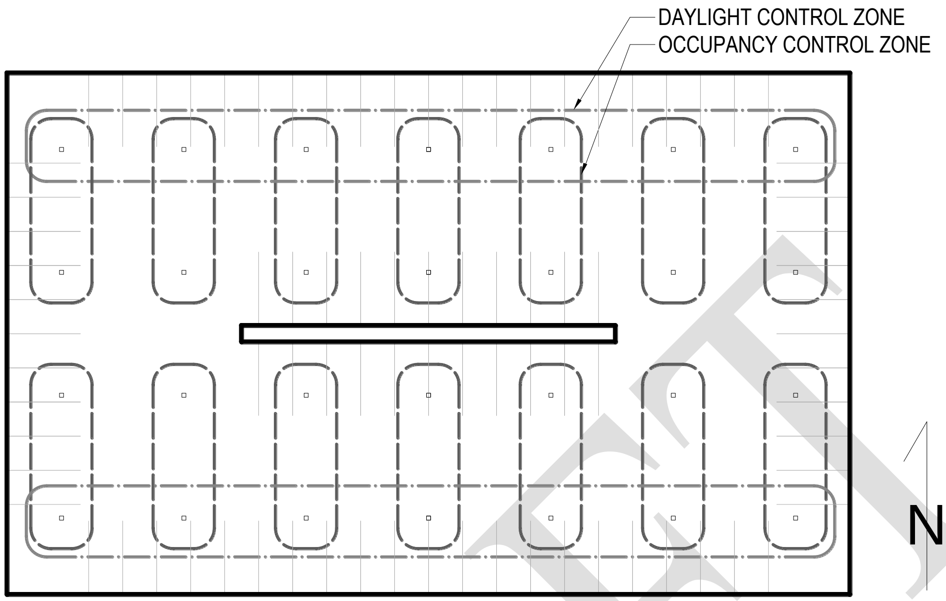

Figure 108: Configuration of Typical Floor for HID Lighting System

11.7.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:51	3052:17:34	2604:17:45	4727:34:29	4038:44:38	5646:00:04	4841:56:50	6031:46:56	5187:37:26	6261:04:29	5396:50:53
Average Zone Low Power Time:	0:00:00	0:00:00	5707:42:26	5029:31:02	4032:25:33	3595:04:14	3113:59:57	2791:51:54	2728:13:03	2446:11:21	2498:55:30	2236:57:52
Average Zone OFF Time:	0:00:00	1126:47:59	0:00:00	1126:11:15	0:00:00	1126:11:15	0:00:00	1126:11:15	0:00:00	1126:11:15	0:00:00	1126:11:15
Average % Time at High Power:	100.0%	87.1%	34.8%	29.7%	54.0%	46.1%	64.5%	55.3%	68.9%	59.2%	71.5%	61.6%
Average % Time at Low Power:	0.0%	0.0%	65.2%	57.4%	46.0%	41.0%	35.5%	31.9%	31.1%	27.9%	28.5%	25.5%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 206,013	$ 172,304	$ 140,405	$ 116,840	$ 160,628	$ 133,469	$ 171,469	$ 142,589	$ 175,961	$ 146,483	$ 178,603	$ 148,831
Lighting Equipment Cost:	$ 111,155	$ 111,155	$ 133,555	$ 133,555	$ 133,555	$ 133,555	$ 133,555	$ 133,555	$ 133,555	$ 133,555	$ 133,555	$ 133,555
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 18,339	$ 18,339	$ 18,339	$ 18,339	$ 18,339	$ 18,339	$ 18,339	$ 18,339	$ 18,339	$ 18,339
Total 15-yr Cost (Initial + NPV of Energy):	$ 317,168	$ 284,878	$ 292,299	$ 270,153	$ 312,522	$ 286,781	$ 323,364	$ 295,901	$ 327,855	$ 299,795	$ 330,497	$ 302,143
Total 15-year Cost Savings:	N/A	10.2%	7.8%	5.2%	1.5%	-0.7%	-2.0%	-3.9%	-3.4%	-5.2%	-4.2%	-6.1%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 23.77	$ 3.58	$ 4.51	$ 2.47	$ 3.67	$ 1.88	$ 3.21	$ 1.64	$ 3.01	$ 1.49	$ 2.89
Approximate Annual Energy Cost Savings:	N/A	$ 2,247	$ 4,374	$ 5,945	$ 3,026	$ 4,836	$ 2,303	$ 4,228	$ 2,003	$ 3,969	$ 1,827	$ 3,812

Figure 109: Simulation 7 Results

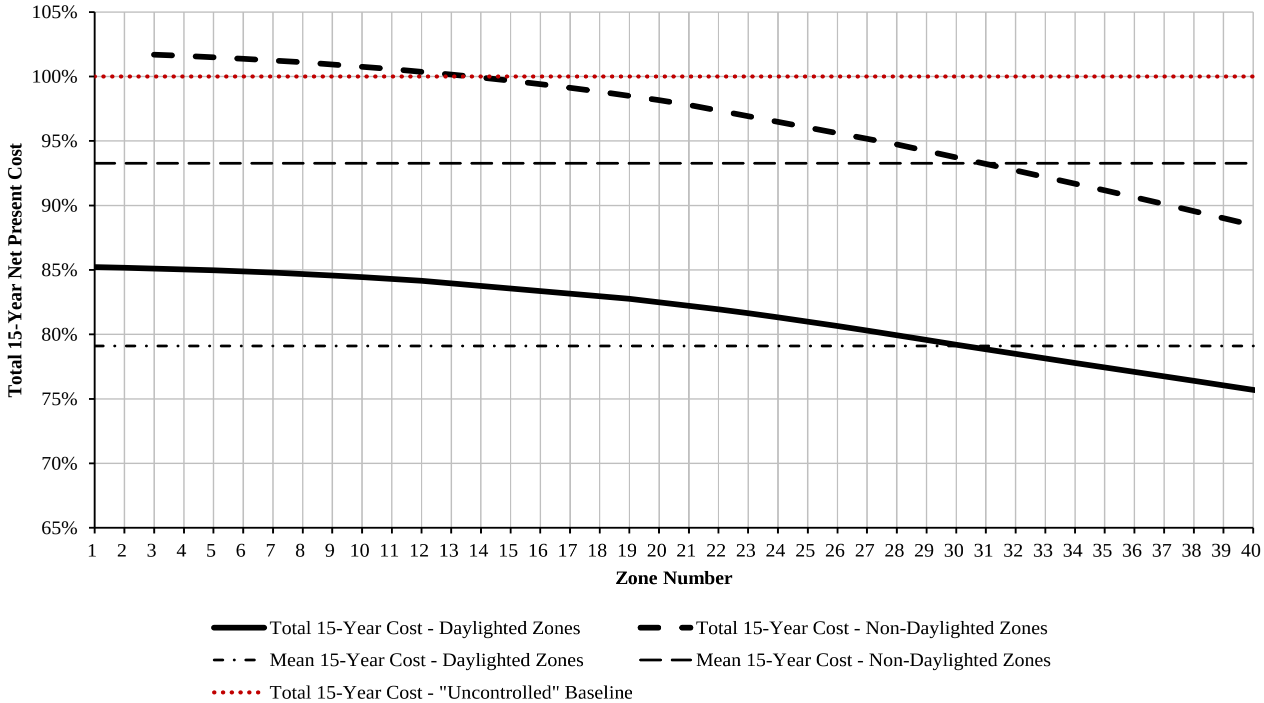

Figure 110: Simulation 7 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

11.8 Simulation 8: Induction Lighting System

11.8.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Transportation HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Transportation HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	16
	Daylight Availability	Poor
	# Daylighted Zones per Floor	8
Luminaire Information	Luminaire Description	Induction luminaire with optional integral occupancy sensor and master/slave configuration
	Uncontrolled Luminaire Total Unit Cost	$986
	Controlled Luminaire Total Unit Cost	$1,071
	High Power	82.6
	Low Power	36.9
	OC Spacing E-W	27
	OC Spacing N-S	27
	# Luminaires per Control Zone	2
Control System Information	Occupancy Sensing Cost	$32
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$44
	Notes	Control system costs per controlled zone

Figure 111: Simulation 8 Input Variables

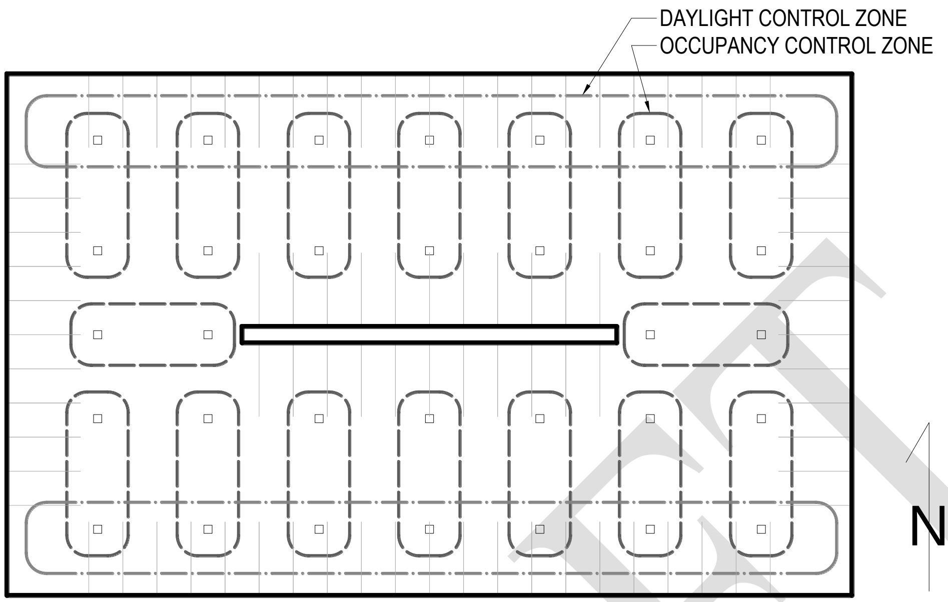

Figure 112: Configuration of Typical Floor for Induction Lighting System

11.8.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:54	3181:15:15	2709:35:37	4935:16:01	4210:07:47	5899:16:04	5049:45:55	6305:48:58	5408:36:43	6549:51:14	5625:19:02
Average Zone Low Power Time:	0:00:00	0:00:00	5578:44:45	4924:14:03	3824:43:58	3423:41:51	2860:43:59	2584:03:39	2454:11:04	2225:12:54	2210:08:44	2008:30:38
Average Zone OFF Time:	0:00:00	1126:47:59	0:00:00	1126:10:22	0:00:00	1126:10:22	0:00:00	1126:10:22	0:00:00	1126:10:22	0:00:00	1126:10:22
Average % Time at High Power:	100.0%	87.1%	36.3%	30.9%	56.3%	48.1%	67.3%	57.6%	72.0%	61.7%	74.8%	64.2%
Average % Time at Low Power:	0.0%	0.0%	63.7%	56.2%	43.7%	39.1%	32.7%	29.5%	28.0%	25.4%	25.2%	22.9%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 180,943	$ 151,336	$ 118,610	$ 98,531	$ 139,211	$ 115,462	$ 150,304	$ 124,742	$ 154,901	$ 128,646	$ 157,637	$ 130,987
Lighting Equipment Cost:	$ 126,206	$ 126,206	$ 137,086	$ 137,086	$ 137,086	$ 137,086	$ 137,086	$ 137,086	$ 137,086	$ 137,086	$ 137,086	$ 137,086
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 2,073	$ 2,073	$ 2,073	$ 2,073	$ 2,073	$ 2,073	$ 2,073	$ 2,073	$ 2,073	$ 2,073
Total 15-yr Cost (Initial + NPV of Energy):	$ 307,149	$ 278,960	$ 257,769	$ 239,109	$ 278,371	$ 256,040	$ 289,463	$ 265,319	$ 294,060	$ 269,224	$ 296,796	$ 271,565
Total 15-year Cost Savings:	N/A	9.2%	16.1%	14.3%	9.4%	8.2%	5.8%	4.9%	4.3%	3.5%	3.4%	2.7%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 20.88	$ 30.06	$ 23.60	$ 20.13	$ 18.75	$ 14.78	$ 16.10	$ 12.56	$ 14.98	$ 11.24	$ 14.31
Approximate Annual Energy Cost Savings:	N/A	$ 1,974	$ 4,156	$ 5,494	$ 2,782	$ 4,365	$ 2,043	$ 3,747	$ 1,736	$ 3,486	$ 1,554	$ 3,330

Figure 113: Simulation 8 Results

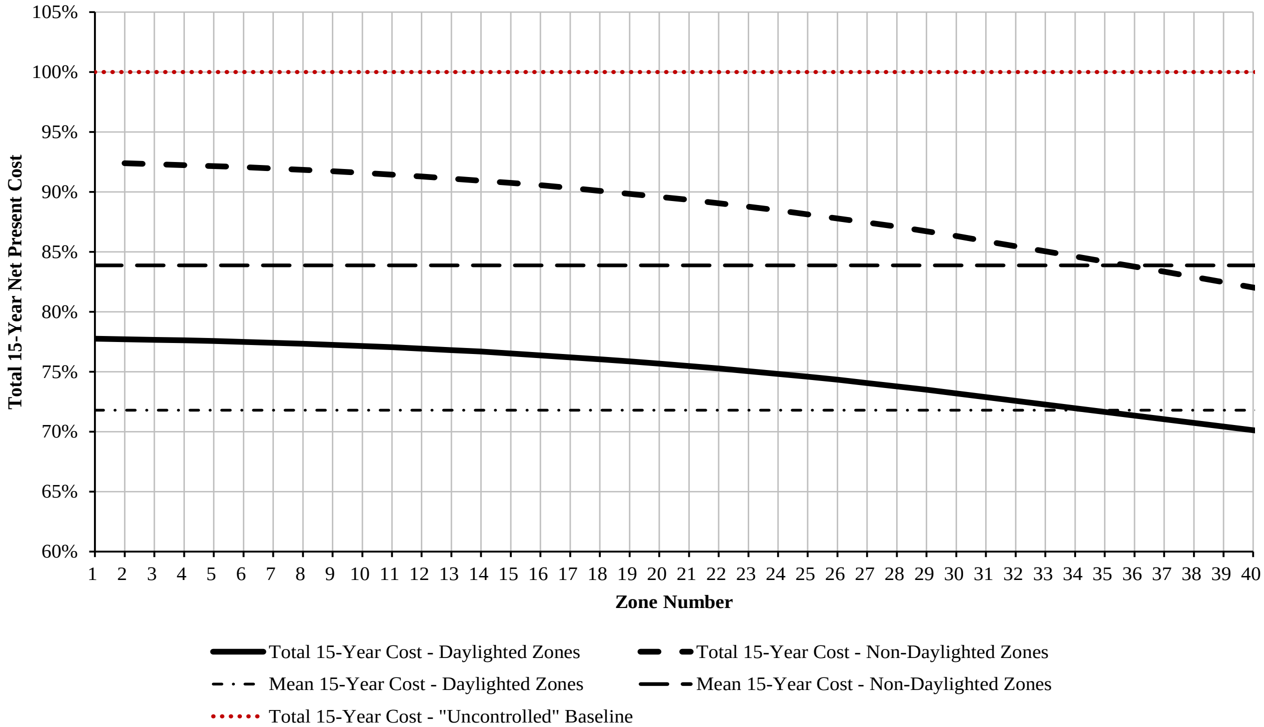

Figure 114: Simulation 8 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

11.9 Simulation 9: Transportation Profile with "MEDIUM" Activity

11.9.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Transportation MEDIUM
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Transportation MEDIUM
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 115: Simulation 9 Input Variables

11.9.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:54	1557:36:54	1317:20:09	2610:06:32	2220:45:28	3266:26:49	2800:07:29	3538:25:23	3047:36:28	3693:28:48	3191:04:19
Average Zone Low Power Time:	0:00:00	0:00:00	7202:23:05	6316:29:07	6149:53:27	5413:03:45	5493:33:11	4833:41:42	5221:34:38	4586:12:53	5066:31:13	4442:44:53
Average Zone OFF Time:	0:00:00	1126:48:01	0:00:00	1126:10:46	0:00:00	1126:10:46	0:00:00	1126:10:46	0:00:00	1126:10:46	0:00:00	1126:10:46
Average % Time at High Power:	100.0%	87.1%	17.8%	15.0%	29.8%	25.4%	37.3%	32.0%	40.4%	34.8%	42.2%	36.4%
Average % Time at Low Power:	0.0%	0.0%	82.2%	72.1%	70.2%	61.8%	62.7%	55.2%	59.6%	52.4%	57.8%	50.7%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 147,152	$ 123,074	$ 87,277	$ 72,679	$ 96,387	$ 80,199	$ 101,903	$ 84,900	$ 104,145	$ 86,885	$ 105,421	$ 88,041
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 206,426	$ 196,365	$ 183,184	$ 205,475	$ 190,705	$ 210,990	$ 195,406	$ 213,233	$ 197,391	$ 214,509	$ 198,547
Total 15-year Cost Savings:	N/A	9.9%	14.3%	11.3%	10.3%	7.6%	7.9%	5.3%	6.9%	4.4%	6.4%	3.8%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 16.98	$ 3.00	$ 3.48	$ 2.54	$ 3.13	$ 2.27	$ 2.91	$ 2.16	$ 2.82	$ 2.09	$ 2.77
Approximate Annual Energy Cost Savings:	N/A	$ 1,605	$ 3,992	$ 4,965	$ 3,384	$ 4,464	$ 3,017	$ 4,150	$ 2,867	$ 4,018	$ 2,782	$ 3,941

Figure 116: Simulation 9 Input Variables

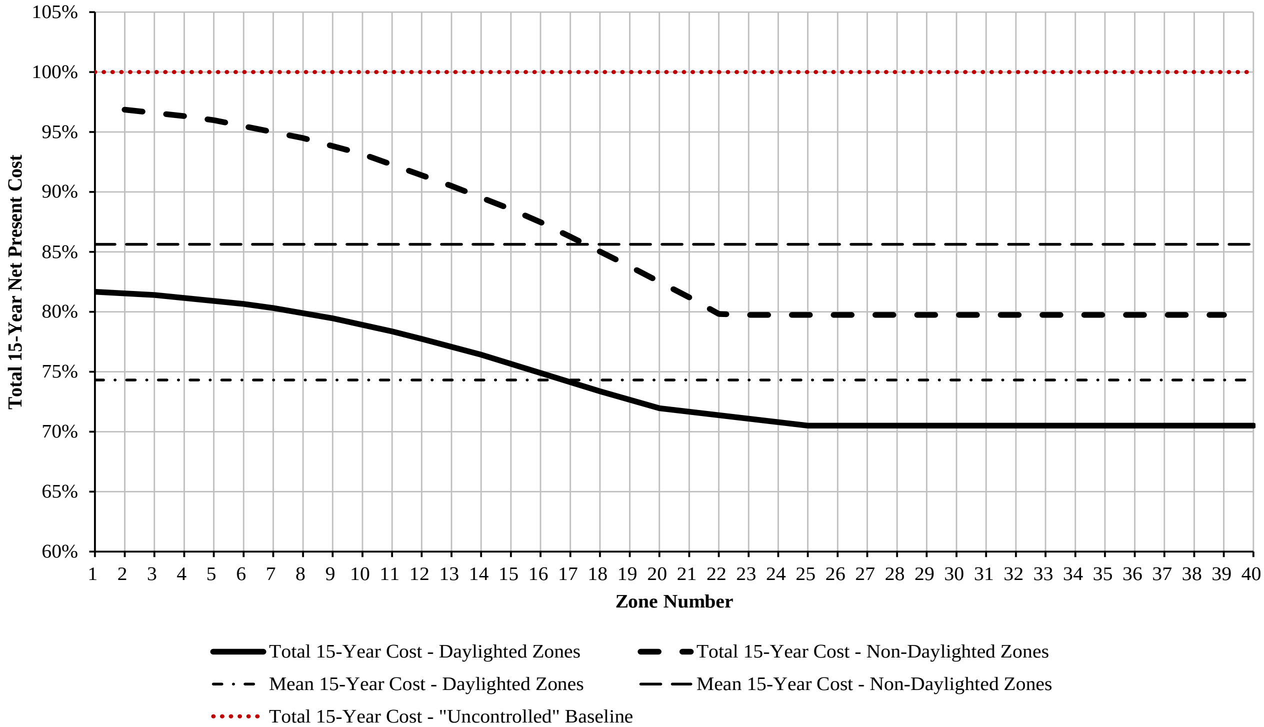

Figure 117: Simulation 9 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

11.10 Simulation 10: Transportation Garage with "LOW" Activity

11.10.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Transportation LOW
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Transportation LOW
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 118: Simulation 10 Input Variables

11.10.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:59	794:47:18	666:44:56	1367:41:44	1148:50:54	1746:30:13	1474:31:54	1907:28:55	1618:02:04	1997:52:50	1701:30:33
Average Zone Low Power Time:	0:00:00	0:00:00	7965:12:45	6967:03:51	7392:18:17	6484:57:49	7013:29:49	6159:16:58	6852:31:04	6015:46:42	6762:07:10	5932:18:17
Average Zone OFF Time:	0:00:00	1126:48:01	0:00:00	1126:11:16	0:00:00	1126:11:16	0:00:00	1126:11:16	0:00:00	1126:11:16	0:00:00	1126:11:16
Average % Time at High Power:	100.0%	87.1%	9.1%	7.6%	15.6%	13.1%	19.9%	16.8%	21.8%	18.5%	22.8%	19.4%
Average % Time at Low Power:	0.0%	0.0%	90.9%	79.5%	84.4%	74.0%	80.1%	70.3%	78.2%	68.7%	77.2%	67.7%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 147,152	$ 123,074	$ 80,794	$ 67,388	$ 85,962	$ 71,585	$ 89,292	$ 74,357	$ 90,673	$ 75,559	$ 91,442	$ 76,261
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 206,426	$ 189,882	$ 177,894	$ 195,050	$ 182,091	$ 198,380	$ 184,863	$ 199,760	$ 186,065	$ 200,530	$ 186,767
Total 15-year Cost Savings:	N/A	9.9%	17.1%	13.8%	14.9%	11.8%	13.4%	10.4%	12.8%	9.9%	12.5%	9.5%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 16.98	$ 3.33	$ 3.73	$ 3.07	$ 3.54	$ 2.90	$ 3.41	$ 2.83	$ 3.35	$ 2.79	$ 3.32
Approximate Annual Energy Cost Savings:	N/A	$ 1,605	$ 4,424	$ 5,318	$ 4,079	$ 5,038	$ 3,857	$ 4,853	$ 3,765	$ 4,773	$ 3,714	$ 4,726

Figure 119: Simulation 10 Results

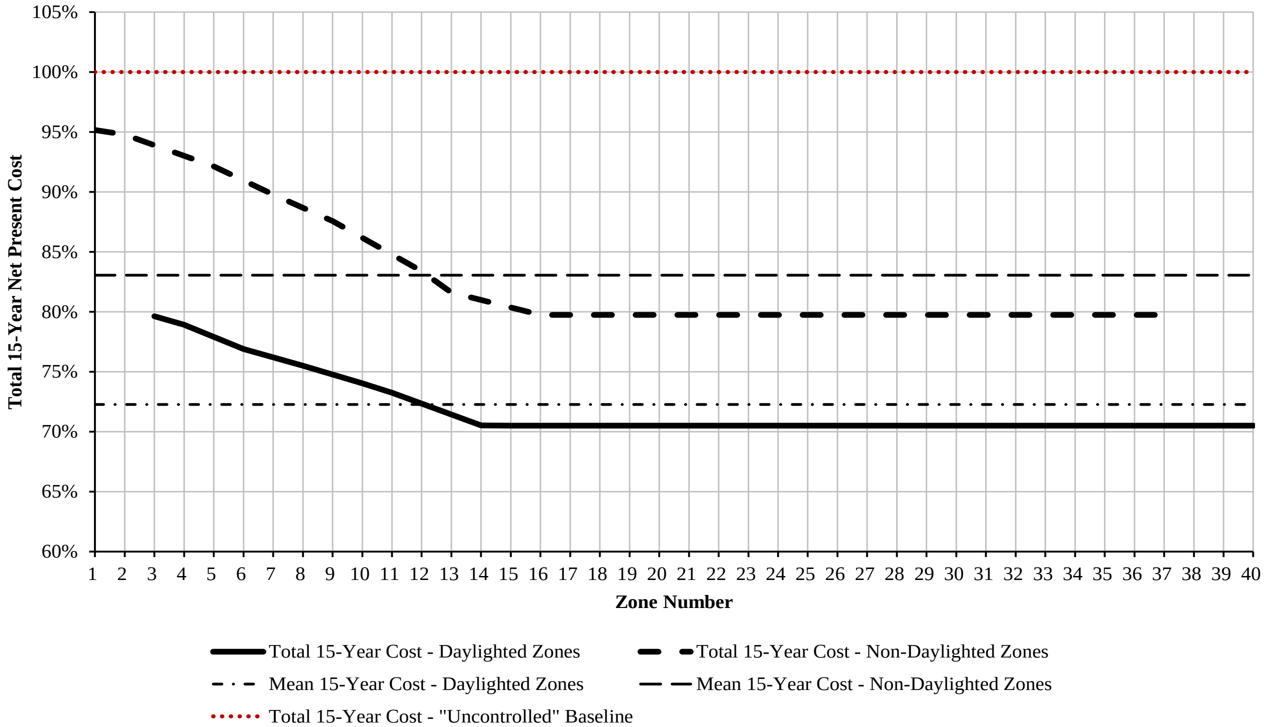

Figure 120: Simulation 10 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

11.11 Simulation 11: Office Park Garage with "HIGH" Activity

11.11.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Office Park HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Office Park HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 121: Simulation 11 Input Variables

11.11.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:56	1701:00:56	1396:03:37	2685:30:38	2181:57:49	3324:03:47	2695:33:40	3605:21:21	2926:33:30	3768:03:12	3062:13:22
Average Zone Low Power Time:	0:00:00	0:00:00	7058:59:02	6237:46:32	6074:29:22	5451:52:23	5435:56:11	4938:16:27	5154:38:40	4707:16:41	4991:56:50	4571:36:49
Average Zone OFF Time:	0:00:00	1126:48:01	0:00:00	1126:09:50	0:00:00	1126:09:50	0:00:00	1126:09:50	0:00:00	1126:09:50	0:00:00	1126:09:50
Average % Time at High Power:	100.0%	87.1%	19.4%	15.9%	30.7%	24.9%	37.9%	30.8%	41.2%	33.4%	43.0%	35.0%
Average % Time at Low Power:	0.0%	0.0%	80.6%	71.2%	69.3%	62.2%	62.1%	56.4%	58.8%	53.7%	57.0%	52.2%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 147,152	$ 123,074	$ 90,086	$ 74,622	$ 99,654	$ 81,935	$ 105,807	$ 86,653	$ 108,499	$ 88,758	$ 110,039	$ 89,981
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 206,426	$ 199,174	$ 185,128	$ 208,742	$ 192,441	$ 214,895	$ 197,159	$ 217,587	$ 199,264	$ 219,127	$ 200,487
Total 15-year Cost Savings:	N/A	9.9%	13.1%	10.3%	8.9%	6.8%	6.2%	4.5%	5.0%	3.5%	4.3%	2.9%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 16.98	$ 2.86	$ 3.39	$ 2.38	$ 3.05	$ 2.07	$ 2.83	$ 1.94	$ 2.73	$ 1.86	$ 2.68
Approximate Annual Energy Cost Savings:	N/A	$ 1,605	$ 3,804	$ 4,835	$ 3,167	$ 4,348	$ 2,756	$ 4,033	$ 2,577	$ 3,893	$ 2,474	$ 3,811

Figure 122: Simulation 11 Results

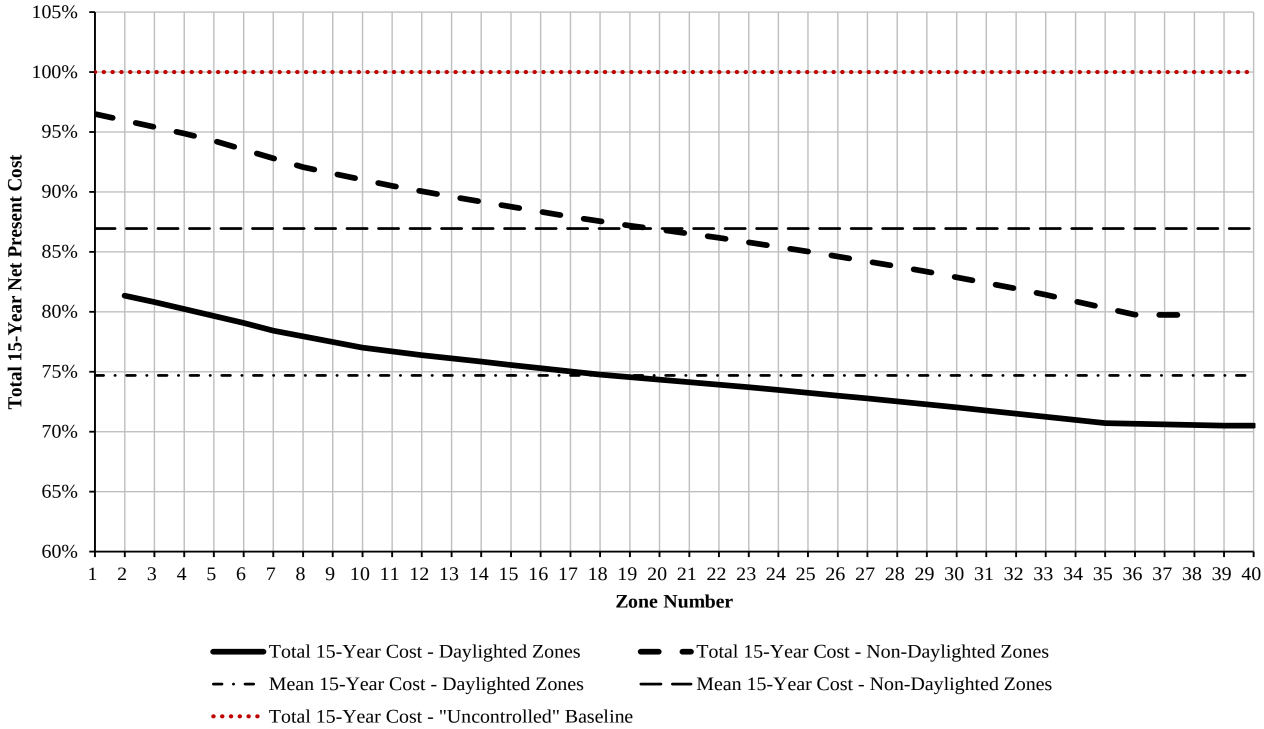

Figure 123: Simulation 11 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

11.12 Simulation 12: Office Park Garage with "MEDIUM" Activity

11.12.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Office Park MEDIUM
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Office Park MEDIUM
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 124: Simulation 12 Input Variables

11.12.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:59	1129:45:09	922:37:58	1861:50:47	1494:50:57	2386:00:04	1900:53:14	2630:47:23	2093:50:26	2773:11:10	2208:16:00
Average Zone Low Power Time:	0:00:00	0:00:00	7630:14:53	6711:11:04	6898:09:13	6138:58:04	6373:59:56	5732:55:51	6129:12:37	5539:58:39	5986:48:51	5425:33:06
Average Zone OFF Time:	0:00:00	1126:48:01	0:00:00	1126:10:58	0:00:00	1126:10:58	0:00:00	1126:10:58	0:00:00	1126:10:58	0:00:00	1126:10:58
Average % Time at High Power:	100.0%	87.1%	12.9%	10.5%	21.3%	17.1%	27.2%	21.7%	30.0%	23.9%	31.7%	25.2%
Average % Time at Low Power:	0.0%	0.0%	87.1%	76.6%	78.7%	70.1%	72.8%	65.4%	70.0%	63.2%	68.3%	61.9%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 147,152	$ 123,074	$ 84,764	$ 70,376	$ 92,083	$ 75,847	$ 97,313	$ 79,697	$ 99,698	$ 81,472	$ 101,067	$ 82,508
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 206,426	$ 193,852	$ 180,881	$ 201,171	$ 186,353	$ 206,401	$ 190,203	$ 208,786	$ 191,978	$ 210,155	$ 193,013
Total 15-year Cost Savings:	N/A	9.9%	15.4%	12.4%	12.2%	9.7%	9.9%	7.9%	8.9%	7.0%	8.3%	6.5%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 16.98	$ 3.13	$ 3.59	$ 2.76	$ 3.34	$ 2.50	$ 3.16	$ 2.38	$ 3.07	$ 2.31	$ 3.02
Approximate Annual Energy Cost Savings:	N/A	$ 1,605	$ 4,159	$ 5,118	$ 3,671	$ 4,754	$ 3,323	$ 4,497	$ 3,164	$ 4,379	$ 3,072	$ 4,310

Figure 125: Simulation 12 Results

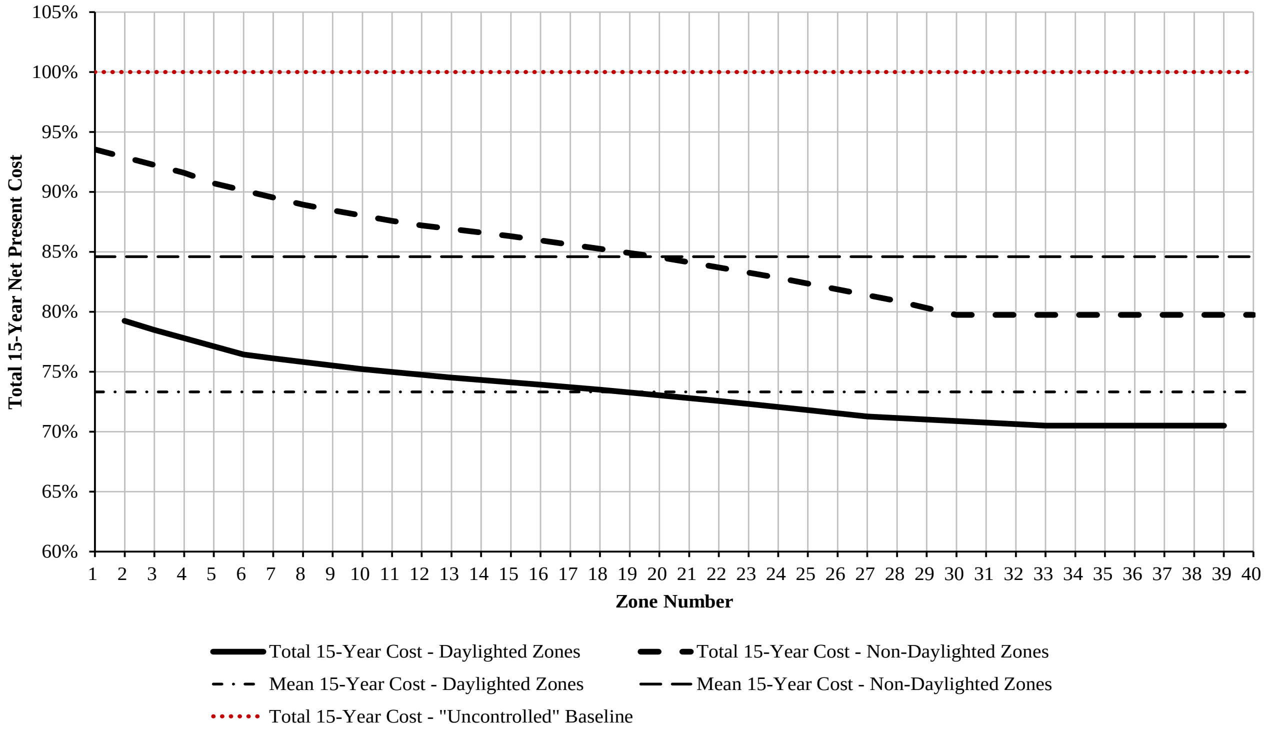

Figure 126: Simulation 12 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

11.13 Simulation 13: Office Park Garage with "LOW" Activity

11.13.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Office Park LOW
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Office Park LOW
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 127: Simulation 13 Input Variables

11.13.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:59	554:20:05	462:42:26	1039:10:10	855:40:41	1498:56:11	1228:17:18	1764:09:25	1447:57:26	1936:34:51	1594:45:40
Average Zone Low Power Time:	0:00:00	0:00:00	8205:39:57	7171:06:29	7720:49:49	6778:08:10	7261:03:49	6405:31:38	6995:50:36	6185:51:28	6823:25:10	6039:03:20
Average Zone OFF Time:	0:00:00	1126:48:01	0:00:00	1126:11:07	0:00:00	1126:11:07	0:00:00	1126:11:07	0:00:00	1126:11:07	0:00:00	1126:11:07
Average % Time at High Power:	100.0%	87.1%	6.3%	5.3%	11.9%	9.8%	17.1%	14.0%	20.1%	16.5%	22.1%	18.2%
Average % Time at Low Power:	0.0%	0.0%	93.7%	81.9%	88.1%	77.4%	82.9%	73.1%	79.9%	70.6%	77.9%	68.9%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 147,152	$ 123,074	$ 79,015	$ 65,927	$ 83,820	$ 69,671	$ 88,316	$ 73,156	$ 90,855	$ 75,166	$ 92,464	$ 76,480
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 206,426	$ 188,103	$ 176,433	$ 192,908	$ 180,177	$ 197,404	$ 183,662	$ 199,943	$ 185,672	$ 201,552	$ 186,986
Total 15-year Cost Savings:	N/A	9.9%	17.9%	14.5%	15.8%	12.7%	13.8%	11.0%	12.7%	10.1%	12.0%	9.4%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 16.98	$ 3.41	$ 3.80	$ 3.17	$ 3.63	$ 2.95	$ 3.46	$ 2.82	$ 3.37	$ 2.74	$ 3.31
Approximate Annual Energy Cost Savings:	N/A	$ 1,605	$ 4,543	$ 5,415	$ 4,222	$ 5,165	$ 3,922	$ 4,933	$ 3,753	$ 4,799	$ 3,646	$ 4,711

Figure 128: Simulation 13 Results

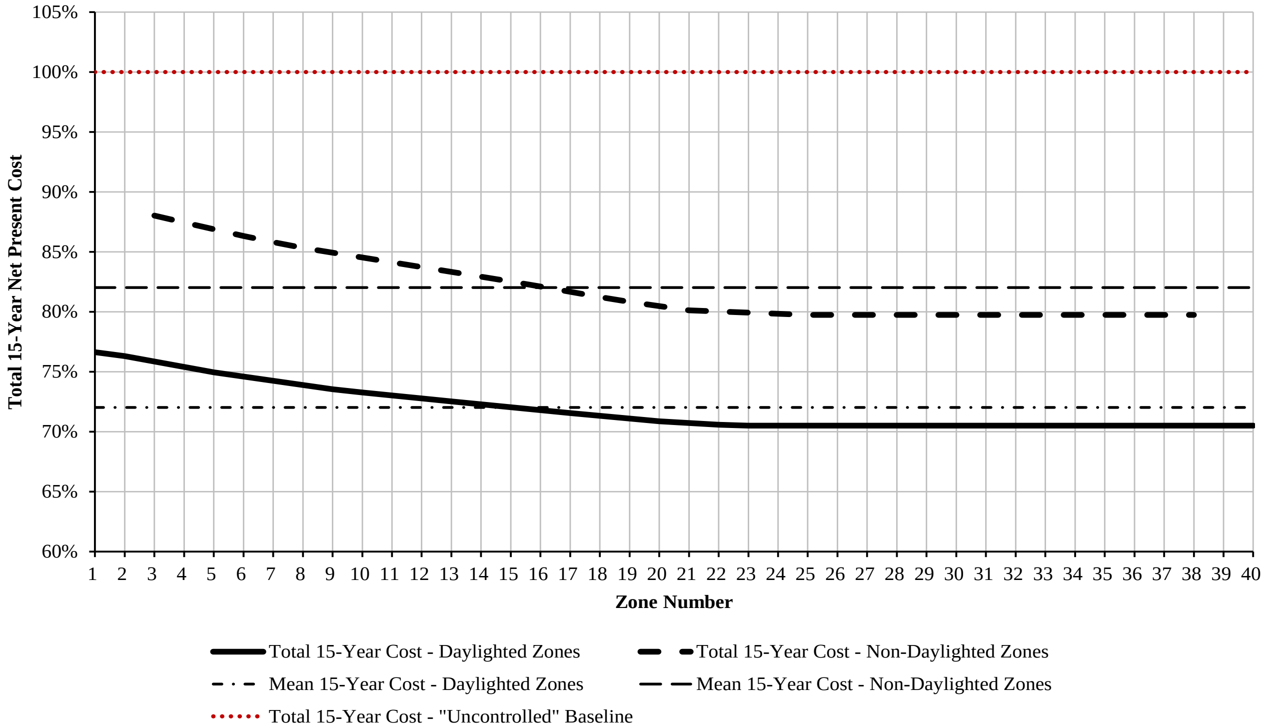

Figure 129: Simulation 13 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

11.14 Simulation 14: Mixed Use Garage with "HIGH" Activity

11.14.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Mixed Use HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Mixed Use HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 130: Simulation 14 Input Variables

11.14.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:59	2691:22:42	2284:00:00	3858:57:01	3278:09:25	4455:54:20	3795:01:43	4712:52:29	4020:56:14	4863:06:34	4154:38:52
Average Zone Low Power Time:	0:00:00	0:00:00	6068:37:17	5349:48:56	4901:02:56	4355:39:29	4304:05:41	3838:47:15	4047:07:32	3612:52:45	3896:53:23	3479:10:03
Average Zone OFF Time:	0:00:00	1126:48:01	0:00:00	1126:11:04	0:00:00	1126:11:04	0:00:00	1126:11:04	0:00:00	1126:11:04	0:00:00	1126:11:04
Average % Time at High Power:	100.0%	87.1%	30.7%	26.1%	44.1%	37.4%	50.9%	43.3%	53.8%	45.9%	55.5%	47.4%
Average % Time at Low Power:	0.0%	0.0%	69.3%	61.1%	55.9%	49.7%	49.1%	43.8%	46.2%	41.2%	44.5%	39.7%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 147,152	$ 123,074	$ 98,745	$ 81,989	$ 109,274	$ 90,589	$ 114,457	$ 94,888	$ 116,650	$ 96,735	$ 117,913	$ 97,815
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 206,426	$ 207,833	$ 192,495	$ 218,362	$ 201,095	$ 223,545	$ 205,394	$ 225,738	$ 207,240	$ 227,001	$ 208,321
Total 15-year Cost Savings:	N/A	9.9%	9.3%	6.7%	4.7%	2.6%	2.4%	0.5%	1.5%	-0.4%	0.9%	-0.9%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 16.98	$ 2.43	$ 3.05	$ 1.90	$ 2.65	$ 1.64	$ 2.45	$ 1.53	$ 2.36	$ 1.47	$ 2.31
Approximate Annual Energy Cost Savings:	N/A	$ 1,605	$ 3,227	$ 4,344	$ 2,525	$ 3,771	$ 2,180	$ 3,484	$ 2,033	$ 3,361	$ 1,949	$ 3,289

Figure 131: Simulation 14 Results

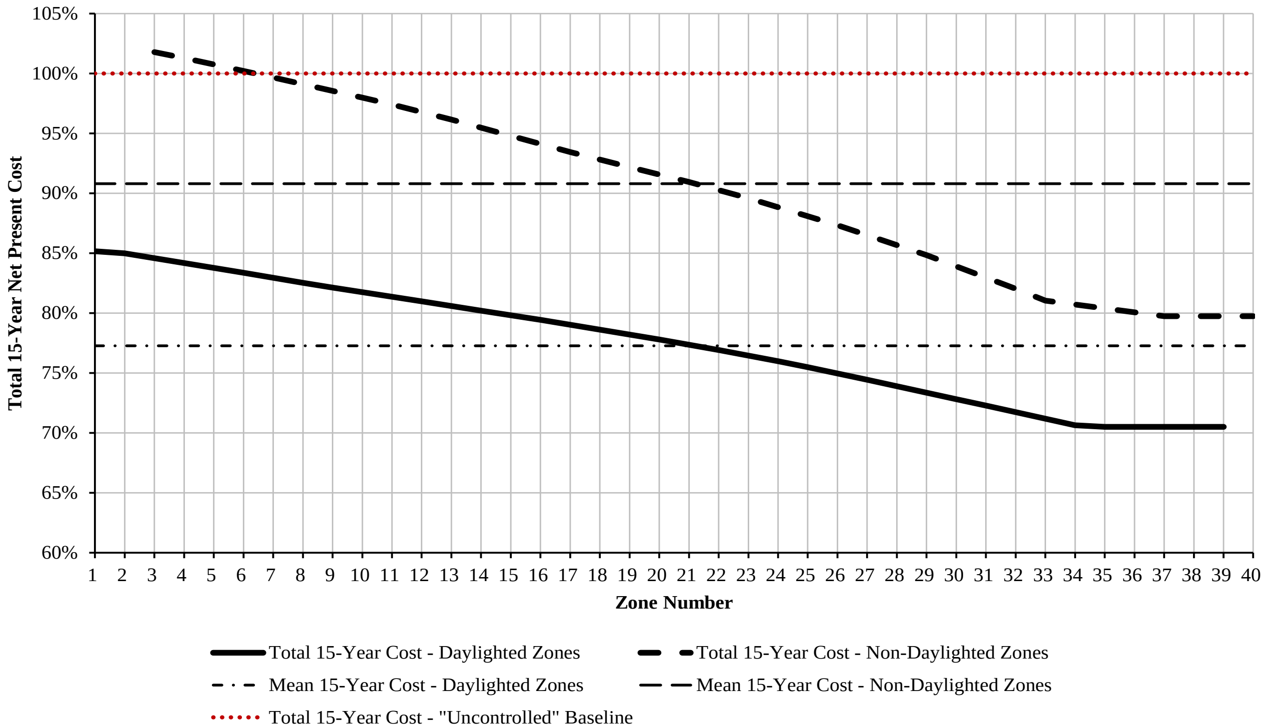

Figure 132: Simulation 14 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

11.15 Simulation 15: Mixed Use Garage with "MEDIUM" Activity

11.15.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Mixed Use MEDIUM
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Mixed Use MEDIUM
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 133: Simulation 15 Input Variables

11.15.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:56	1912:27:42	1612:07:10	2885:57:46	2453:45:11	3426:24:47	2936:33:02	3660:48:40	3150:58:36	3799:34:10	3279:21:57
Average Zone Low Power Time:	0:00:00	0:00:00	6847:32:17	6021:41:36	5874:02:14	5180:03:30	5333:35:13	4697:15:40	5099:11:21	4482:50:14	4960:25:50	4354:26:48
Average Zone OFF Time:	0:00:00	1126:48:01	0:00:00	1126:11:16	0:00:00	1126:11:16	0:00:00	1126:11:16	0:00:00	1126:11:16	0:00:00	1126:11:16
Average % Time at High Power:	100.0%	87.1%	21.8%	18.4%	32.9%	28.0%	39.1%	33.5%	41.8%	36.0%	43.4%	37.4%
Average % Time at Low Power:	0.0%	0.0%	78.2%	68.7%	67.1%	59.1%	60.9%	53.6%	58.2%	51.2%	56.6%	49.7%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 147,152	$ 123,074	$ 91,922	$ 76,265	$ 100,778	$ 83,604	$ 105,401	$ 87,597	$ 107,333	$ 89,319	$ 108,458	$ 90,336
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 206,426	$ 201,010	$ 186,771	$ 209,866	$ 194,109	$ 214,489	$ 198,103	$ 216,421	$ 199,825	$ 217,546	$ 200,842
Total 15-year Cost Savings:	N/A	9.9%	12.3%	9.5%	8.4%	6.0%	6.4%	4.0%	5.5%	3.2%	5.0%	2.7%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 16.98	$ 2.77	$ 3.32	$ 2.32	$ 2.97	$ 2.09	$ 2.79	$ 2.00	$ 2.71	$ 1.94	$ 2.66
Approximate Annual Energy Cost Savings:	N/A	$ 1,605	$ 3,682	$ 4,726	$ 3,092	$ 4,237	$ 2,783	$ 3,970	$ 2,655	$ 3,856	$ 2,580	$ 3,788

Figure 134: Simulation 15 Results

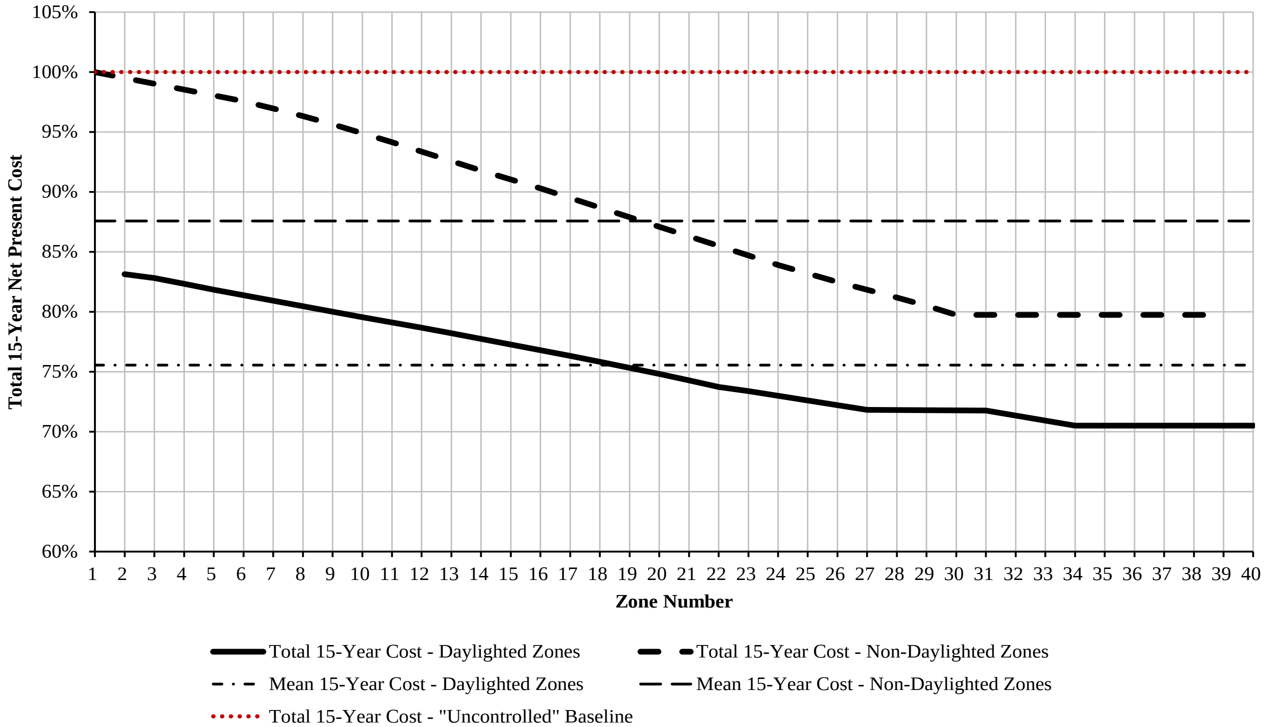

Figure 135: Simulation 15 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

11.16 Simulation 16: Mixed Use Garage with "LOW" Activity

11.16.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Mixed Use LOW
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Mixed Use LOW
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 136: Simulation 16 Input Variables

11.16.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:56	1257:49:52	1070:38:02	1989:10:39	1700:43:03	2430:55:30	2092:37:47	2628:12:48	2273:54:43	2746:45:12	2385:11:48
Average Zone Low Power Time:	0:00:00	0:00:00	7502:10:10	6563:11:13	6770:49:22	5933:06:09	6329:04:32	5541:11:30	6131:47:13	5359:54:33	6013:14:46	5248:37:27
Average Zone OFF Time:	0:00:00	1126:48:01	0:00:00	1126:10:47	0:00:00	1126:10:47	0:00:00	1126:10:47	0:00:00	1126:10:47	0:00:00	1126:10:47
Average % Time at High Power:	100.0%	87.1%	14.4%	12.2%	22.7%	19.4%	27.8%	23.9%	30.0%	26.0%	31.4%	27.2%
Average % Time at Low Power:	0.0%	0.0%	85.6%	74.9%	77.3%	67.7%	72.2%	63.3%	70.0%	61.2%	68.6%	59.9%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 147,152	$ 123,074	$ 85,603	$ 71,343	$ 92,278	$ 76,877	$ 96,108	$ 80,158	$ 97,755	$ 81,624	$ 98,727	$ 82,510
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 206,426	$ 194,691	$ 181,849	$ 201,366	$ 187,383	$ 205,196	$ 190,664	$ 206,843	$ 192,130	$ 207,814	$ 193,016
Total 15-year Cost Savings:	N/A	9.9%	15.0%	11.9%	12.1%	9.2%	10.4%	7.6%	9.7%	6.9%	9.3%	6.5%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 16.98	$ 3.08	$ 3.55	$ 2.75	$ 3.29	$ 2.56	$ 3.13	$ 2.48	$ 3.07	$ 2.43	$ 3.02
Approximate Annual Energy Cost Savings:	N/A	$ 1,605	$ 4,103	$ 5,054	$ 3,658	$ 4,685	$ 3,403	$ 4,466	$ 3,293	$ 4,369	$ 3,228	$ 4,309

Figure 137: Simulation 16 Results

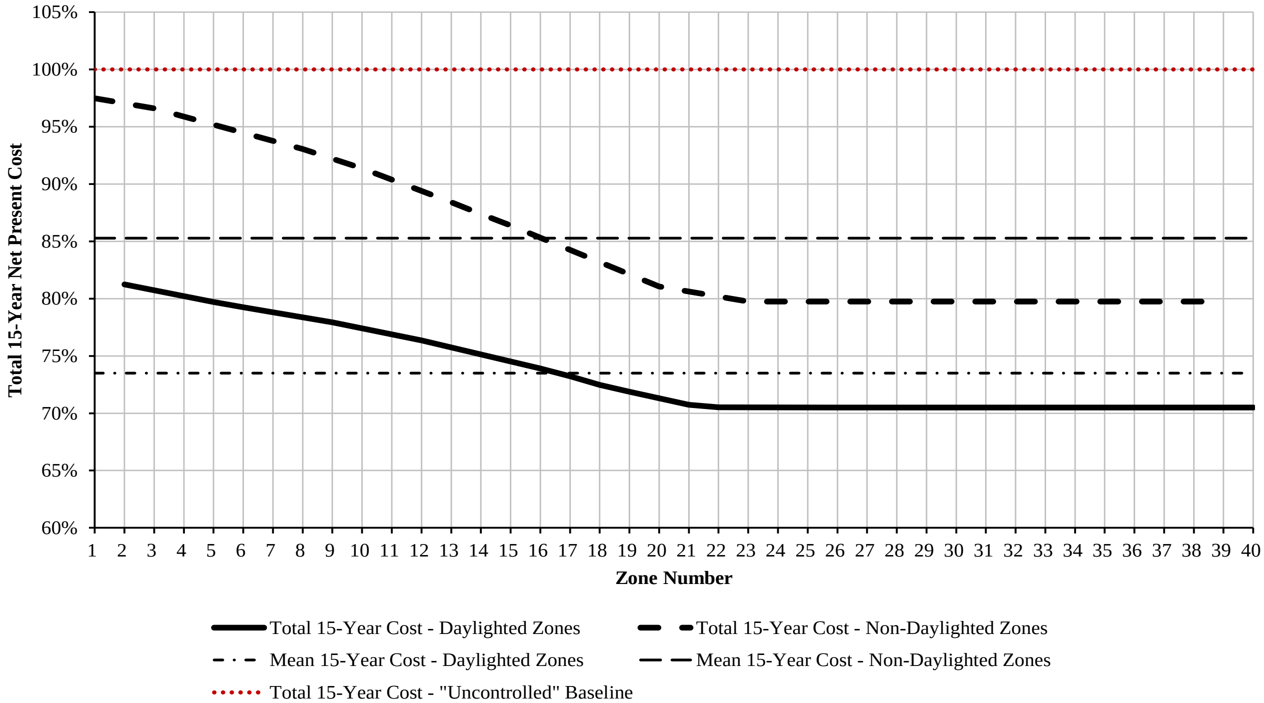

Figure 138: Simulation 16 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

11.17 Simulation 17: Baseline Configuration Adjusted to 0.2 WPF

11.17.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Transportation HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Transportation HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	16
	OC Spacing N-S	16
	# Luminaires per Control Zone	6
Control System Information	Occupancy Sensing Cost	$624
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$27
	Notes	Control system costs per controlled zone

Figure 139: Simulation 17 Input Variables

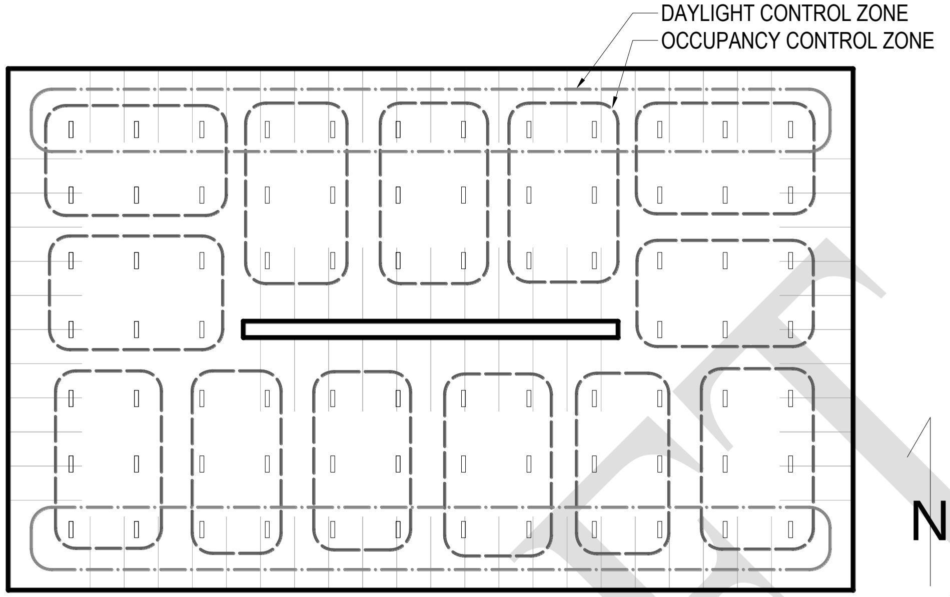

Figure 140: Configuration of Typical Floor for Fluorescent Lighting System at 0.2 WPF

11.17.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7719:52:31	3283:09:18	2817:11:39	5086:28:15	4372:09:04	6077:41:14	5244:40:52	6492:56:31	5617:32:36	6740:49:48	5842:27:24
Average Zone Low Power Time:	0:00:00	0:00:00	5476:50:38	4903:14:56	3673:31:44	3348:17:23	2682:18:47	2475:45:38	2267:03:34	2102:54:02	2019:10:12	1877:59:09
Average Zone OFF Time:	0:00:00	1040:07:23	0:00:00	1039:33:28	0:00:00	1039:33:28	0:00:00	1039:33:28	0:00:00	1039:33:28	0:00:00	1039:33:28
Average % Time at High Power:	100.0%	88.1%	37.5%	32.2%	58.1%	49.9%	69.4%	59.9%	74.1%	64.1%	77.0%	66.7%
Average % Time at Low Power:	0.0%	0.0%	62.5%	56.0%	41.9%	38.2%	30.6%	28.3%	25.9%	24.0%	23.0%	21.4%
Average % Time OFF:	0.0%	11.9%	0.0%	11.9%	0.0%	11.9%	0.0%	11.9%	0.0%	11.9%	0.0%	11.9%
15-yr Energy Cost:	$ 286,947	$ 243,607	$ 199,633	$ 168,195	$ 229,991	$ 193,369	$ 246,228	$ 207,165	$ 252,924	$ 212,994	$ 256,881	$ 216,485
Lighting Equipment Cost:	$ 159,771	$ 159,771	$ 173,811	$ 173,811	$ 173,811	$ 173,811	$ 173,811	$ 173,811	$ 173,811	$ 173,811	$ 173,811	$ 173,811
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 32,424	$ 32,424	$ 32,424	$ 32,424	$ 32,424	$ 32,424	$ 32,424	$ 32,424	$ 32,424	$ 32,424
Total 15-yr Cost (Initial + NPV of Energy):	$ 446,717	$ 404,795	$ 405,868	$ 375,847	$ 436,226	$ 401,022	$ 452,462	$ 414,818	$ 459,158	$ 420,646	$ 463,116	$ 424,138
Total 15-year Cost Savings:	N/A	9.4%	9.1%	7.2%	2.3%	0.9%	-1.3%	-2.5%	-2.8%	-3.9%	-3.7%	-4.8%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 30.56	$ 2.69	$ 3.51	$ 1.76	$ 2.77	$ 1.26	$ 2.36	$ 1.05	$ 2.19	$ 0.93	$ 2.08
Approximate Annual Energy Cost Savings:	N/A	$ 2,889	$ 5,821	$ 7,917	$ 3,797	$ 6,238	$ 2,715	$ 5,319	$ 2,268	$ 4,930	$ 2,004	$ 4,697

Figure 141: Simulation 17 Results

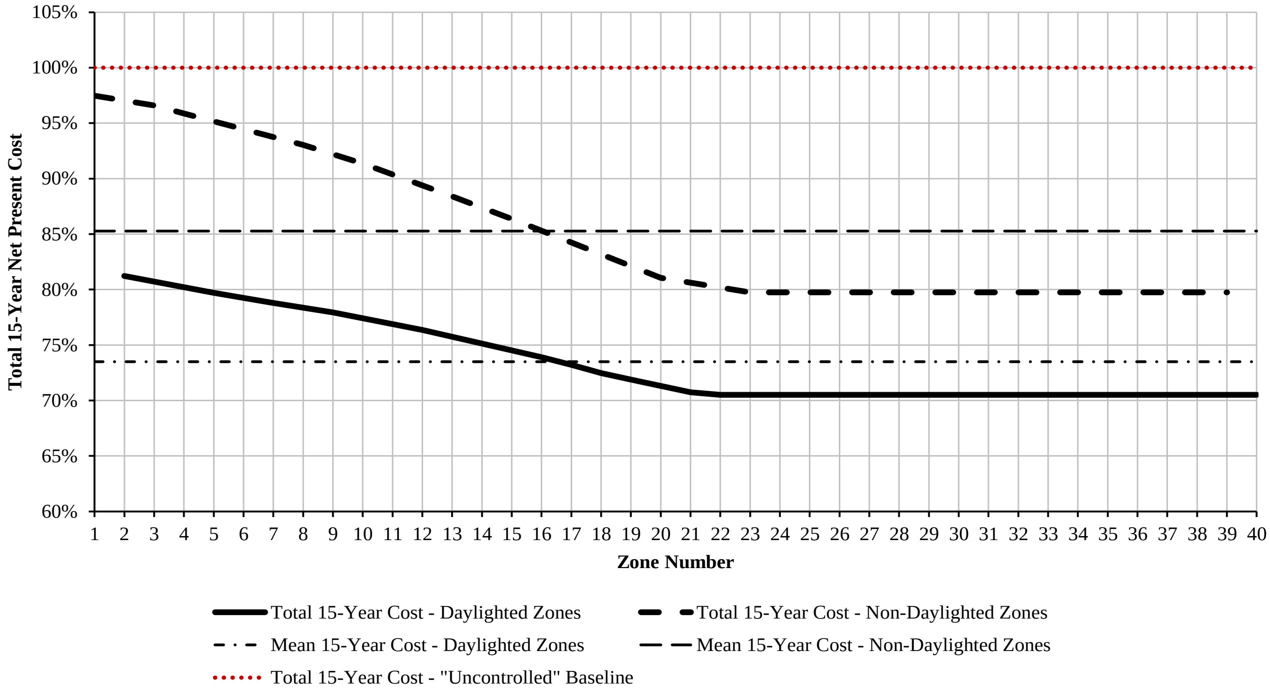

Figure 142: Simulation 17 Total Zone-by-Zone Costs 1-Minute Time Delay for Occupancy Sensing

11.18 Simulation 18: University Configuration 1

11.18.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	University 1
	Occupancy Schedule Variance	10%
	Transient Schedule Type	University 1
	Transient Schedule Variance	10%
Parking Garage Information	Total # Spaces	100
	Total # Floors	2
	# Occupancy Zones per Floor	6
	Daylight Availability	Poor
	# Daylighted Zones per Floor	3
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	16
	OC Spacing N-S	16
	# Luminaires per Control Zone	6
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$95
	Notes	Control system costs per controlled zone

Figure 143: Simulation 18 Input Variables

11.18.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:12:02	1143:46:23	967:55:36	2413:07:23	2051:23:37	3769:53:19	3222:12:26	4577:10:32	3927:46:26	5088:00:41	4377:57:49
Average Zone Low Power Time:	0:00:00	0:00:00	7616:13:38	6665:54:30	6346:52:38	5582:26:27	4990:06:43	4411:37:39	4182:49:28	3706:03:41	3671:59:19	3255:52:16
Average Zone OFF Time:	0:00:00	1126:48:00	0:00:00	1126:09:55	0:00:00	1126:09:55	0:00:00	1126:09:55	0:00:00	1126:09:55	0:00:00	1126:09:55
Average % Time at High Power:	100.0%	87.1%	13.1%	11.0%	27.5%	23.4%	43.0%	36.8%	52.3%	44.8%	58.1%	50.0%
Average % Time at Low Power:	0.0%	0.0%	86.9%	76.1%	72.5%	63.7%	57.0%	50.4%	47.7%	42.3%	41.9%	37.2%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 44,146	$ 36,922	$ 25,104	$ 20,926	$ 28,432	$ 23,653	$ 31,917	$ 26,541	$ 33,937	$ 28,238	$ 35,191	$ 29,300
Lighting Equipment Cost:	$ 24,580	$ 24,580	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740
Daylighting Control Equipment Cost:	$ -	$ 567	$ -	$ 567	$ -	$ 567	$ -	$ 567	$ -	$ 567	$ -	$ 567
Occupancy Control Equipment Cost:	$ -	$ -	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986
Total 15-yr Cost (Initial + NPV of Energy):	$ 68,726	$ 62,070	$ 57,831	$ 54,220	$ 61,158	$ 56,946	$ 64,643	$ 59,835	$ 66,663	$ 61,531	$ 67,917	$ 62,593
Total 15-year Cost Savings:	N/A	9.7%	15.9%	12.6%	11.0%	8.3%	5.9%	3.6%	3.0%	0.9%	1.2%	-0.8%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 12.74	$ 3.18	$ 3.54	$ 2.62	$ 3.13	$ 2.04	$ 2.69	$ 1.71	$ 2.43	$ 1.50	$ 2.27
Approximate Annual Energy Cost Savings:	N/A	$ 482	$ 1,269	$ 1,548	$ 1,048	$ 1,366	$ 815	$ 1,174	$ 681	$ 1,061	$ 597	$ 990

Figure 144: Simulation 18 Results

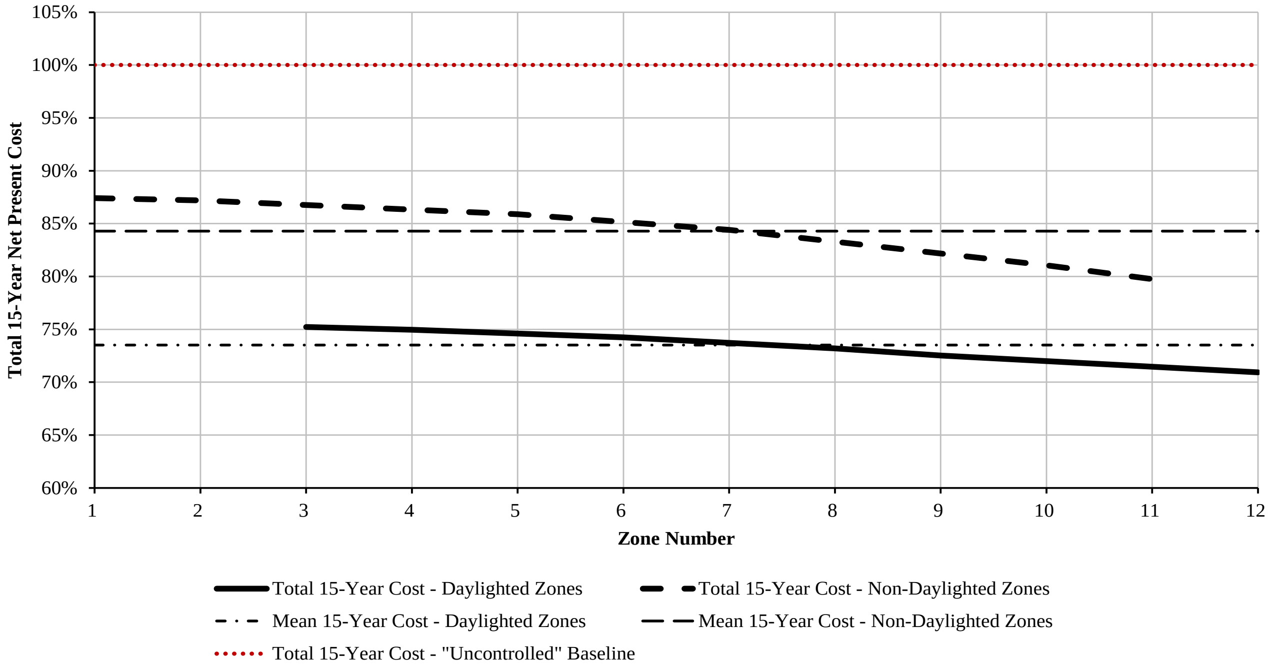

Figure 145: Simulation 18 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

11.19 Simulation 19: "Bust" Configuration 1

11.19.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Bust 1
	Occupancy Schedule Variance	5%
	Transient Schedule Type	Bust 1
	Transient Schedule Variance	5%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 146: Simulation 19 Input Variables

11.19.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Good	0	Good	0	Good	0	Good	0	Good	0	Good
Average Zone High Power Time:	8760:00:00	5497:07:09	3505:00:58	1918:27:10	5038:03:34	2803:05:30	5802:57:14	3271:34:32	6127:39:33	3479:34:32	6323:09:49	3608:33:04
Average Zone Low Power Time:	0:00:00	0:00:00	5254:59:00	3579:34:10	3721:56:26	2694:55:54	2957:02:45	2226:26:50	2632:20:25	2018:26:49	2436:50:10	1889:28:20
Average Zone OFF Time:	0:00:00	3262:52:51	0:00:00	3261:58:37	0:00:00	3261:58:37	0:00:00	3261:58:37	0:00:00	3261:58:37	0:00:00	3261:58:37
Average % Time at High Power:	100.0%	62.8%	40.0%	21.9%	57.5%	32.0%	66.2%	37.3%	70.0%	39.7%	72.2%	41.2%
Average % Time at Low Power:	0.0%	0.0%	60.0%	40.9%	42.5%	30.8%	33.8%	25.4%	30.0%	23.0%	27.8%	21.6%
Average % Time OFF:	0.0%	37.2%	0.0%	37.2%	0.0%	37.2%	0.0%	37.2%	0.0%	37.2%	0.0%	37.2%
15-yr Energy Cost:	$ 147,152	$ 82,295	$ 104,331	$ 56,288	$ 117,791	$ 63,159	$ 124,492	$ 66,774	$ 127,327	$ 68,365	$ 129,019	$ 69,336
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 165,646	$ 213,419	$ 166,794	$ 226,879	$ 173,665	$ 233,580	$ 177,280	$ 236,415	$ 178,871	$ 238,107	$ 179,842
Total 15-year Cost Savings:	N/A	27.7%	6.8%	-0.7%	1.0%	-4.8%	-2.0%	-7.0%	-3.2%	-8.0%	-3.9%	-8.6%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 45.74	$ 2.15	$ 4.25	$ 1.47	$ 3.93	$ 1.14	$ 3.76	$ 0.99	$ 3.69	$ 0.91	$ 3.64
Approximate Annual Energy Cost Savings:	N/A	$ 4,324	$ 2,855	$ 6,058	$ 1,957	$ 5,600	$ 1,511	$ 5,359	$ 1,322	$ 5,252	$ 1,209	$ 5,188

Figure 147: Simulation 19 Results

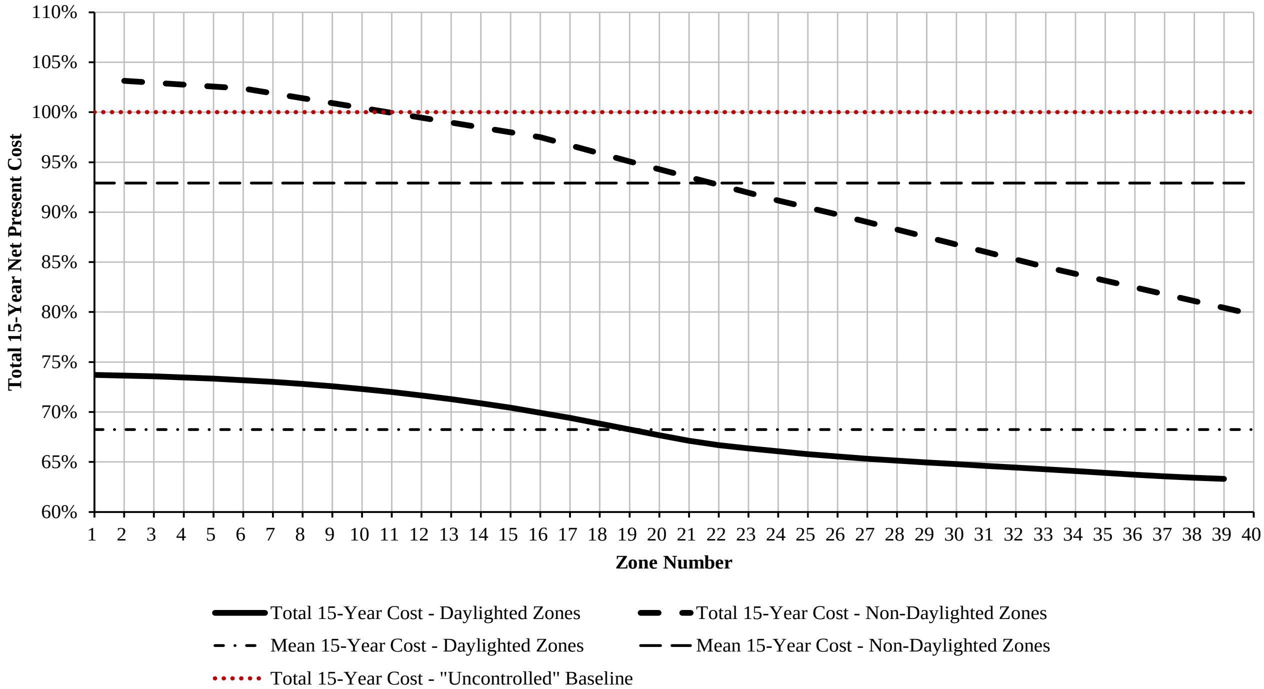

Figure 148: Simulation 19 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

11.20 Simulation 20: Baseline with Full Reporting & 1-10 Minute Delay Times

11.20.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Transportation HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Transportation HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 149: Simulation 20 Input Variables

11.20.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:54	3229:33:28	2762:50:45	5003:09:44	4282:25:15	5970:36:23	5119:53:27	6371:19:08	5469:44:14	6608:46:12	5678:06:02
Average Zone Low Power Time:	0:00:00	0:00:00	5530:26:32	4870:58:00	3756:50:16	3351:23:27	2789:23:38	2513:55:21	2388:40:48	2164:04:34	2151:13:47	1955:42:42
Average Zone OFF Time:	0:00:00	1126:48:01	0:00:00	1126:11:16	0:00:00	1126:11:16	0:00:00	1126:11:16	0:00:00	1126:11:16	0:00:00	1126:11:16
Average % Time at High Power:	100.0%	87.1%	36.9%	31.5%	57.1%	48.9%	68.2%	58.4%	72.7%	62.4%	75.4%	64.8%
Average % Time at Low Power:	0.0%	0.0%	63.1%	55.6%	42.9%	38.3%	31.8%	28.7%	27.3%	24.7%	24.6%	22.3%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 147,152	$ 123,074	$ 101,831	$ 84,783	$ 117,084	$ 97,331	$ 125,224	$ 104,093	$ 128,559	$ 106,887	$ 130,532	$ 108,548
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 206,426	$ 210,919	$ 195,289	$ 226,172	$ 207,837	$ 234,312	$ 214,599	$ 237,647	$ 217,393	$ 239,620	$ 219,054
Total 15-year Cost Savings:	N/A	9.9%	7.9%	5.4%	1.3%	-0.7%	-2.3%	-4.0%	-3.7%	-5.3%	-4.6%	-6.1%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 16.98	$ 2.27	$ 2.92	$ 1.51	$ 2.33	$ 1.10	$ 2.01	$ 0.93	$ 1.88	$ 0.83	$ 1.81
Approximate Annual Energy Cost Savings:	N/A	$ 1,605	$ 3,021	$ 4,158	$ 2,005	$ 3,321	$ 1,462	$ 2,871	$ 1,240	$ 2,684	$ 1,108	$ 2,574

Figure 150: Simulation 20 Results

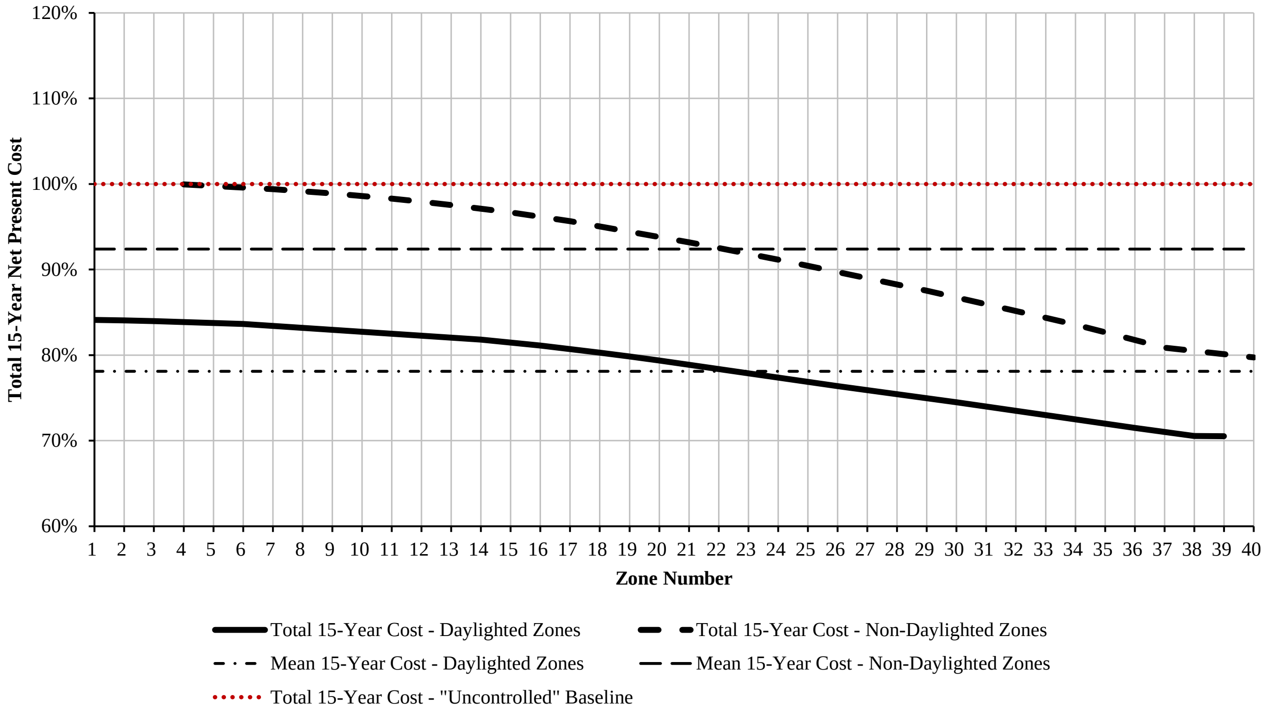

Figure 151: Simulation 20 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

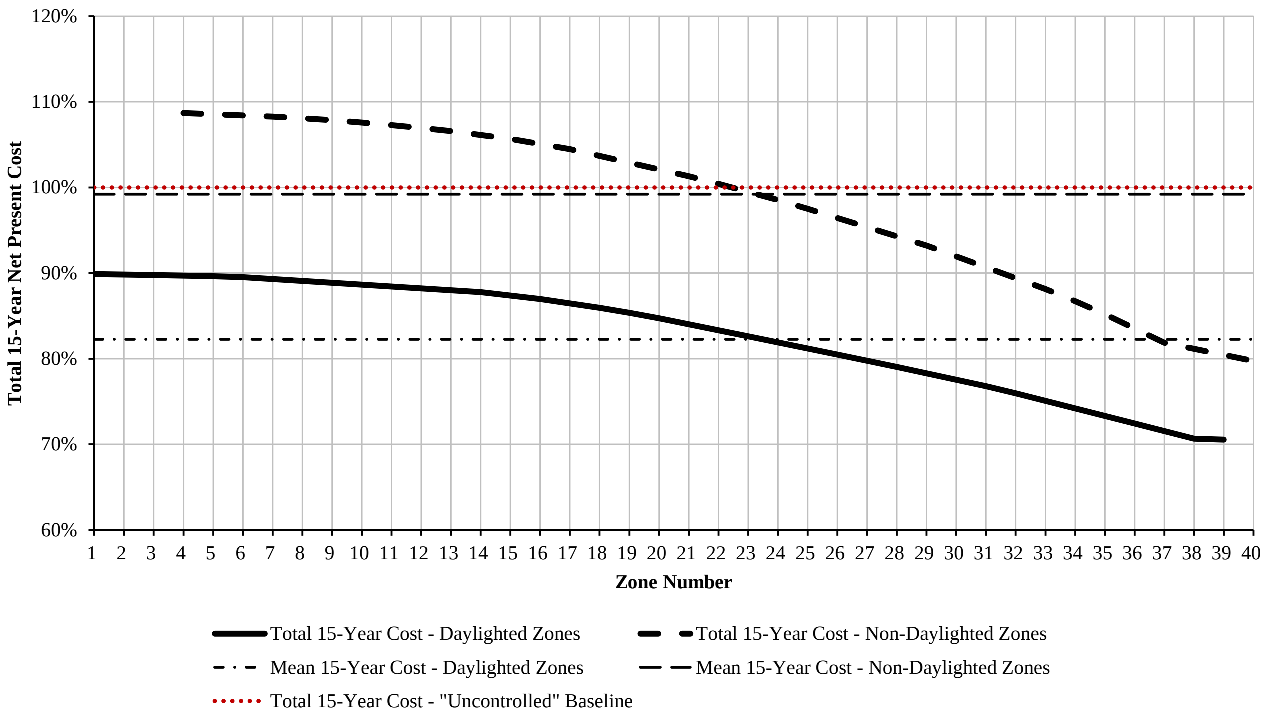

Figure 152: Simulation 20 Total Zone-by-Zone Costs
2 1/2-Minute Time Delay for Occupancy Sensing

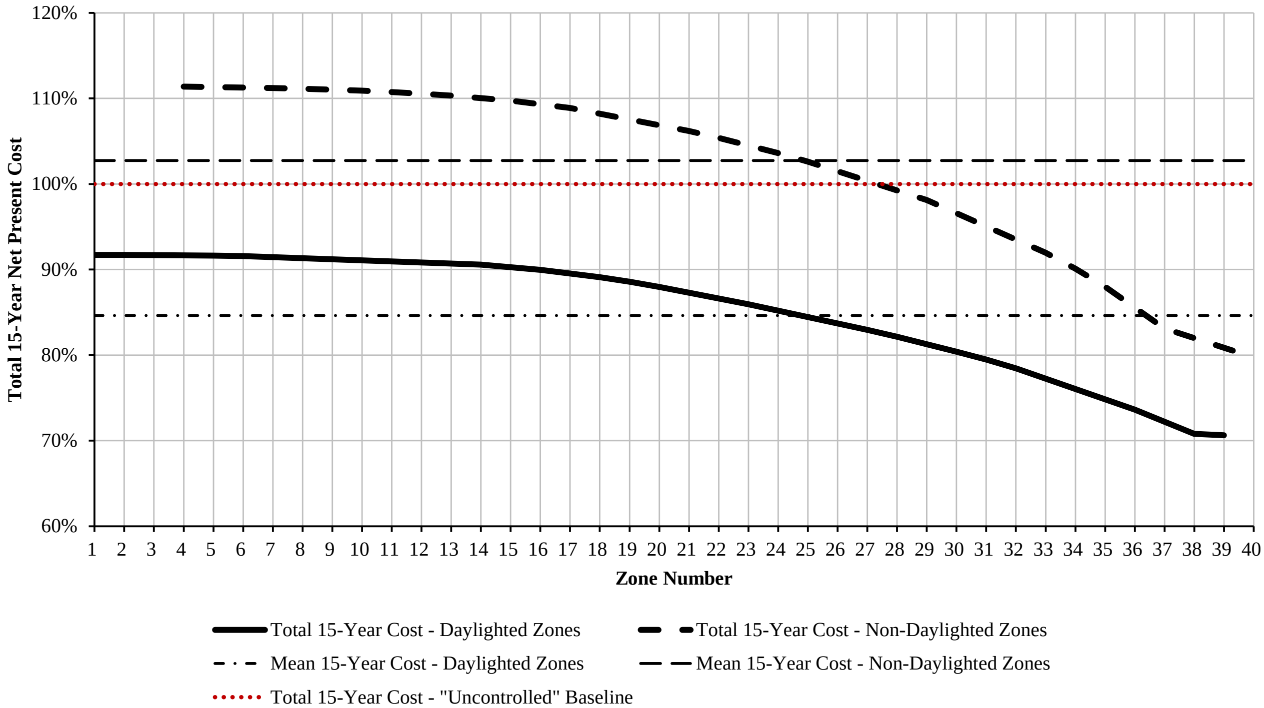

Figure 153: Simulation 20 Total Zone-by-Zone Costs
5-Minute Time Delay for Occupancy Sensing

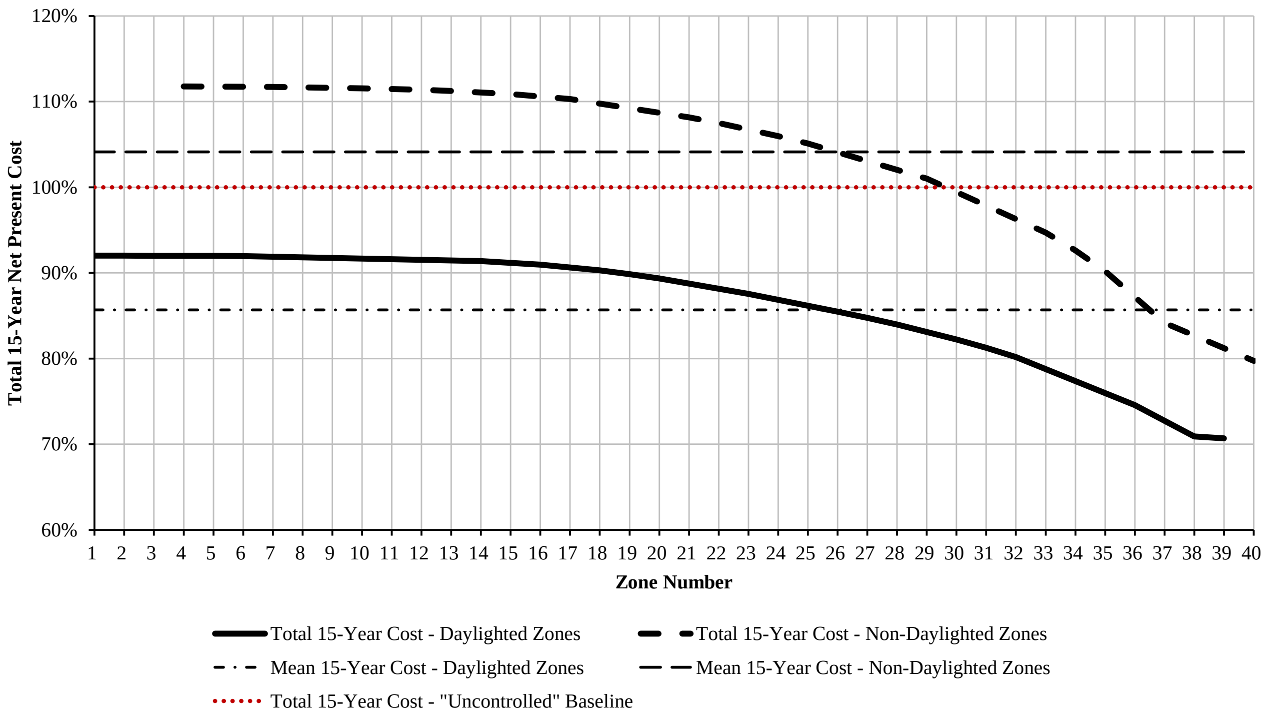

Figure 154: Simulation 20 Total Zone-by-Zone Costs
7 1/2-Minute Time Delay for Occupancy Sensing

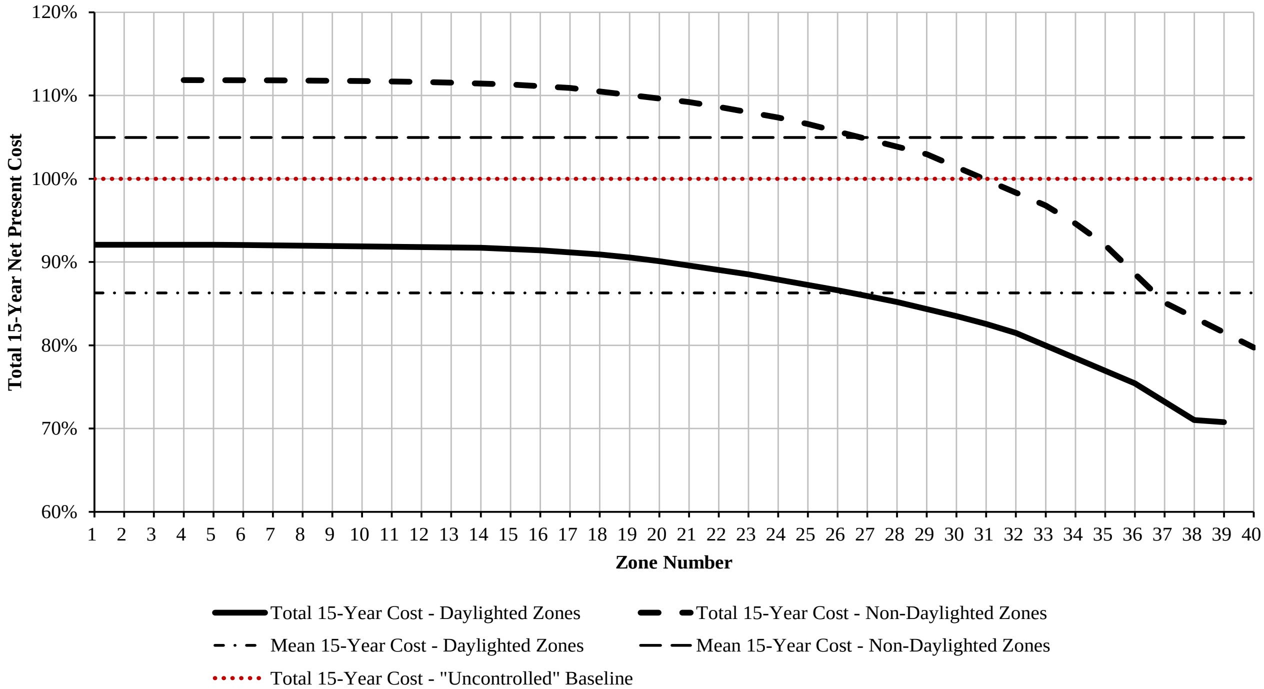

Figure 155: Simulation 20 Total Zone-by-Zone Costs
10-Minute Time Delay for Occupancy Sensing

11.21 Simulation 21: Baseline with Full Reporting & 10-30 Minute Delay Times

11.21.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Transportation HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Transportation HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	10
	Delay Time 2	15
	Delay Time 3	20
	Delay Time 4	25
	Delay Time 5	30
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 156: Simulation 21 Input Variables

11.21.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	10.00	10.00	15.00	15.00	20.00	20.00	25.00	25.00	30.00	30.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:56	6606:56:31	5738:13:40	6894:03:05	6003:41:46	7068:39:07	6166:37:28	7186:32:17	6277:17:39	7271:52:50	6357:42:14
Average Zone Low Power Time:	0:00:00	0:00:00	2153:03:28	1895:35:01	1865:56:57	1630:07:00	1691:20:52	1467:11:13	1573:27:39	1356:31:02	1488:07:11	1276:06:35
Average Zone OFF Time:	0:00:00	1126:48:01	0:00:00	1126:11:16	0:00:00	1126:11:16	0:00:00	1126:11:16	0:00:00	1126:11:16	0:00:00	1126:11:16
Average % Time at High Power:	100.0%	87.1%	75.4%	65.5%	78.7%	68.5%	80.7%	70.4%	82.0%	71.7%	83.0%	72.6%
Average % Time at Low Power:	0.0%	0.0%	24.6%	21.6%	21.3%	18.6%	19.3%	16.7%	18.0%	15.5%	17.0%	14.6%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 147,152	$ 123,074	$ 130,552	$ 109,241	$ 132,895	$ 111,355	$ 134,279	$ 112,617	$ 135,198	$ 113,463	$ 135,854	$ 114,069
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 206,426	$ 239,640	$ 219,747	$ 241,983	$ 221,860	$ 243,367	$ 223,123	$ 244,286	$ 223,969	$ 244,942	$ 224,575
Total 15-year Cost Savings:	N/A	9.9%	-4.6%	-6.5%	-5.6%	-7.5%	-6.2%	-8.1%	-6.6%	-8.5%	-6.9%	-8.8%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 16.98	$ 0.83	$ 1.77	$ 0.71	$ 1.67	$ 0.65	$ 1.62	$ 0.60	$ 1.58	$ 0.57	$ 1.55
Approximate Annual Energy Cost Savings:	N/A	$ 1,605	$ 1,107	$ 2,527	$ 950	$ 2,387	$ 858	$ 2,302	$ 797	$ 2,246	$ 753	$ 2,206

Figure 157: Simulation 21 Results

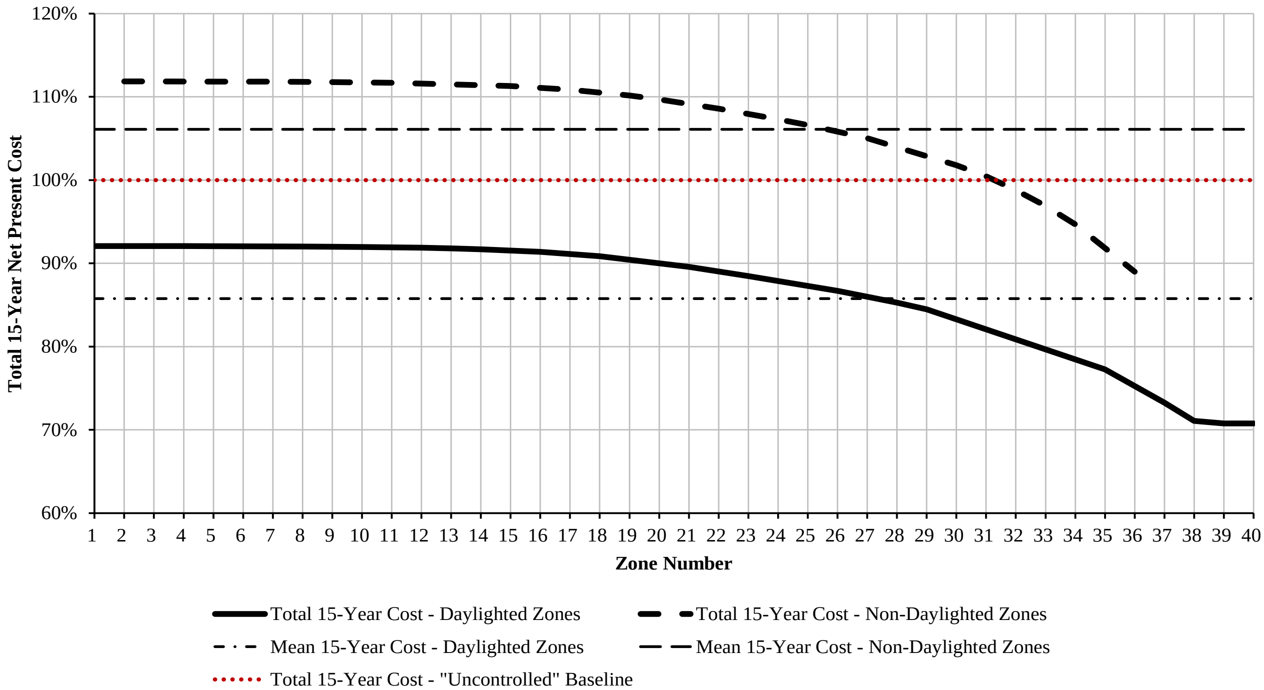

Figure 158: Simulation 21 Total Zone-by-Zone Costs
10-Minute Time Delay for Occupancy Sensing

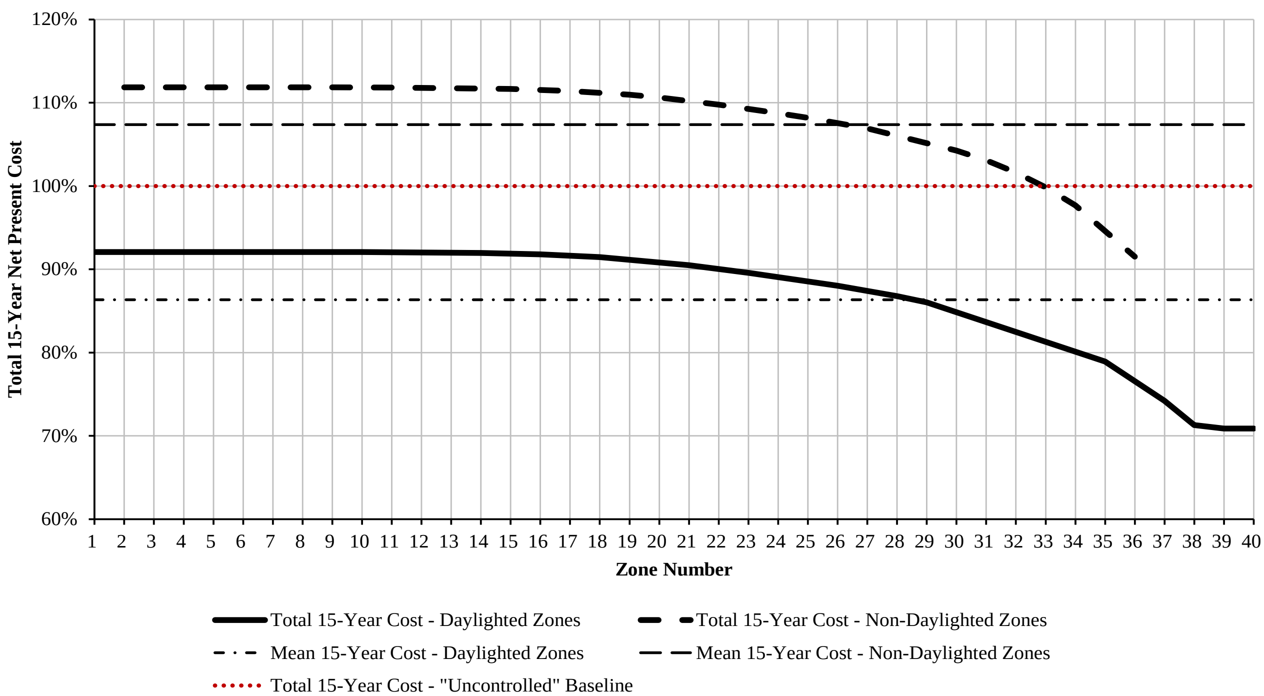

Figure 159: Simulation 21 Total Zone-by-Zone Costs
15-Minute Time Delay for Occupancy Sensing

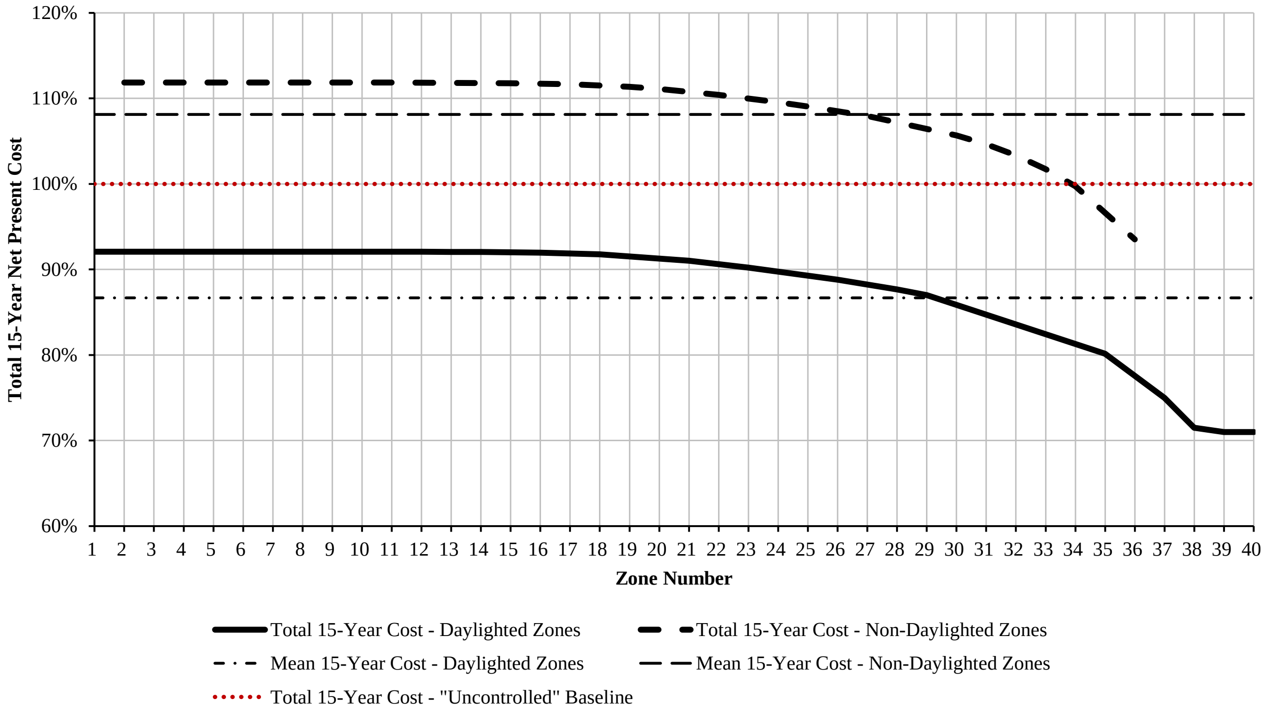

Figure 160: Simulation 21 Total Zone-by-Zone Costs 20-Minute Time Delay for Occupancy Sensing

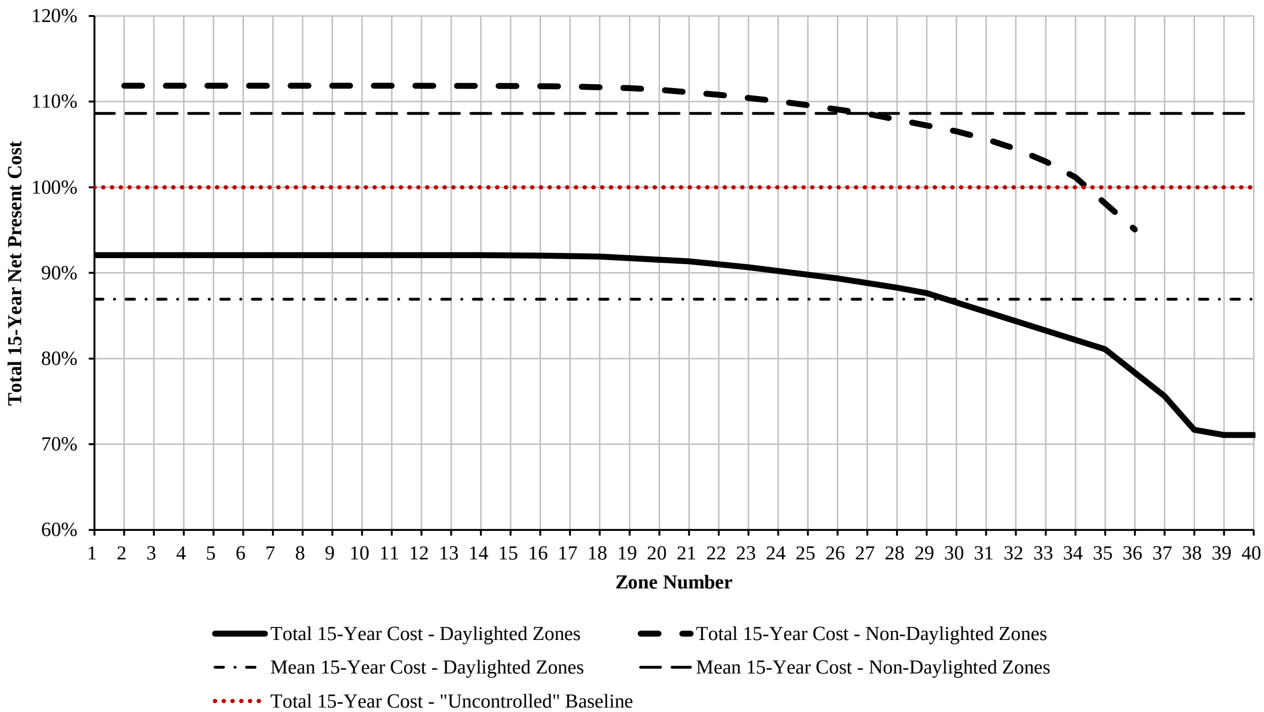

Figure 161: Simulation 21 Total Zone-by-Zone Costs 25-Minute Time Delay for Occupancy Sensing

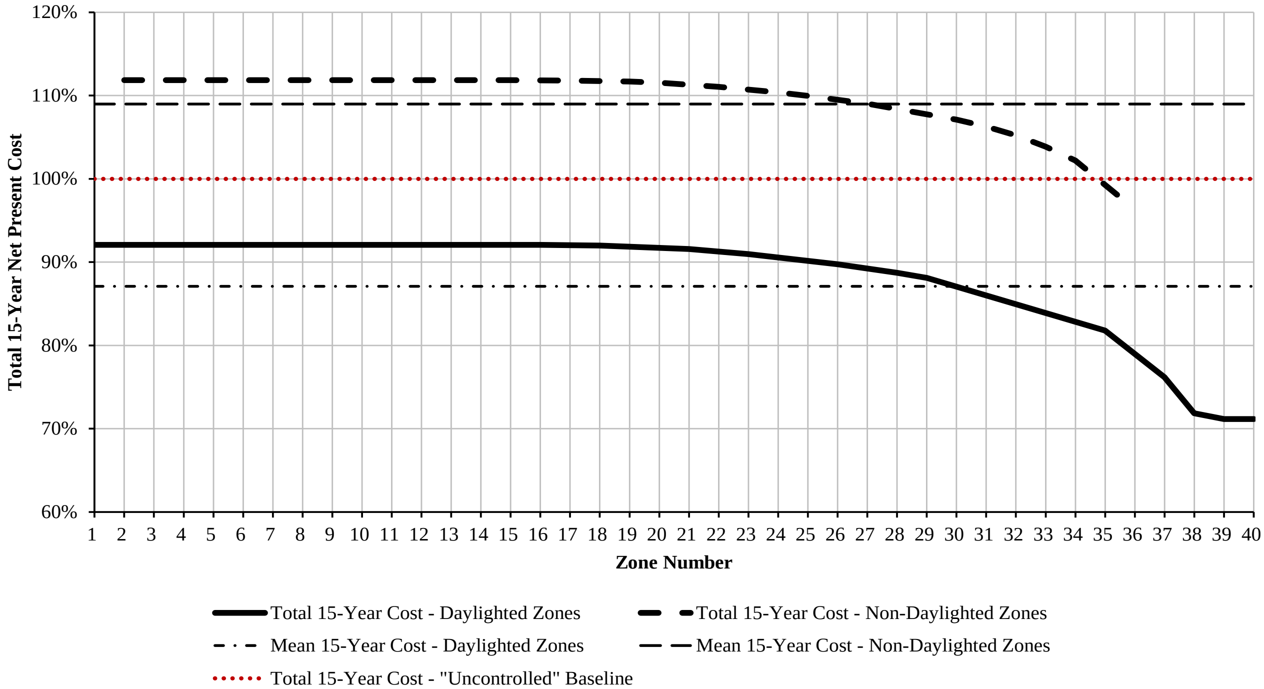

Figure 162: Simulation 21 Total Zone-by-Zone Costs 30-Minute Time Delay for Occupancy Sensing

11.22 Simulation 22: "Bust" Configuration 2

11.22.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Bust 2
	Occupancy Schedule Variance	5%
	Transient Schedule Type	Bust 2
	Transient Schedule Variance	5%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 163: Simulation 22 Input Variables

11.22.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	8309:16:45	3204:19:39	2989:58:04	4529:01:12	4224:25:41	5145:52:36	4802:54:40	5404:00:22	5045:49:02	5554:44:27	5187:41:33
Average Zone Low Power Time:	0:00:00	0:00:00	5555:40:21	5319:33:30	4230:58:47	4085:05:50	3614:07:24	3506:36:54	3355:59:41	3263:42:33	3205:15:33	3121:50:01
Average Zone OFF Time:	0:00:00	450:43:12	0:00:00	450:28:27	0:00:00	450:28:27	0:00:00	450:28:27	0:00:00	450:28:27	0:00:00	450:28:27
Average % Time at High Power:	100.0%	94.9%	36.6%	34.1%	51.7%	48.2%	58.7%	54.8%	61.7%	57.6%	63.4%	59.2%
Average % Time at Low Power:	0.0%	0.0%	63.4%	60.7%	48.3%	46.6%	41.3%	40.0%	38.3%	37.3%	36.6%	35.6%
Average % Time OFF:	0.0%	5.1%	0.0%	5.1%	0.0%	5.1%	0.0%	5.1%	0.0%	5.1%	0.0%	5.1%
15-yr Energy Cost:	$ 147,152	$ 137,521	$ 101,732	$ 94,635	$ 113,652	$ 105,580	$ 119,323	$ 110,816	$ 121,723	$ 113,035	$ 123,126	$ 114,329
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 220,873	$ 210,820	$ 205,140	$ 222,740	$ 216,086	$ 228,411	$ 221,322	$ 230,811	$ 223,541	$ 232,214	$ 224,835
Total 15-year Cost Savings:	N/A	3.6%	8.0%	7.1%	2.8%	2.2%	0.3%	-0.2%	-0.8%	-1.2%	-1.4%	-1.8%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 6.79	$ 2.28	$ 2.46	$ 1.68	$ 1.95	$ 1.39	$ 1.70	$ 1.27	$ 1.60	$ 1.20	$ 1.54
Approximate Annual Energy Cost Savings:	N/A	$ 642	$ 3,028	$ 3,501	$ 2,233	$ 2,771	$ 1,855	$ 2,422	$ 1,695	$ 2,274	$ 1,602	$ 2,188

Figure 164: Simulation 22 Results

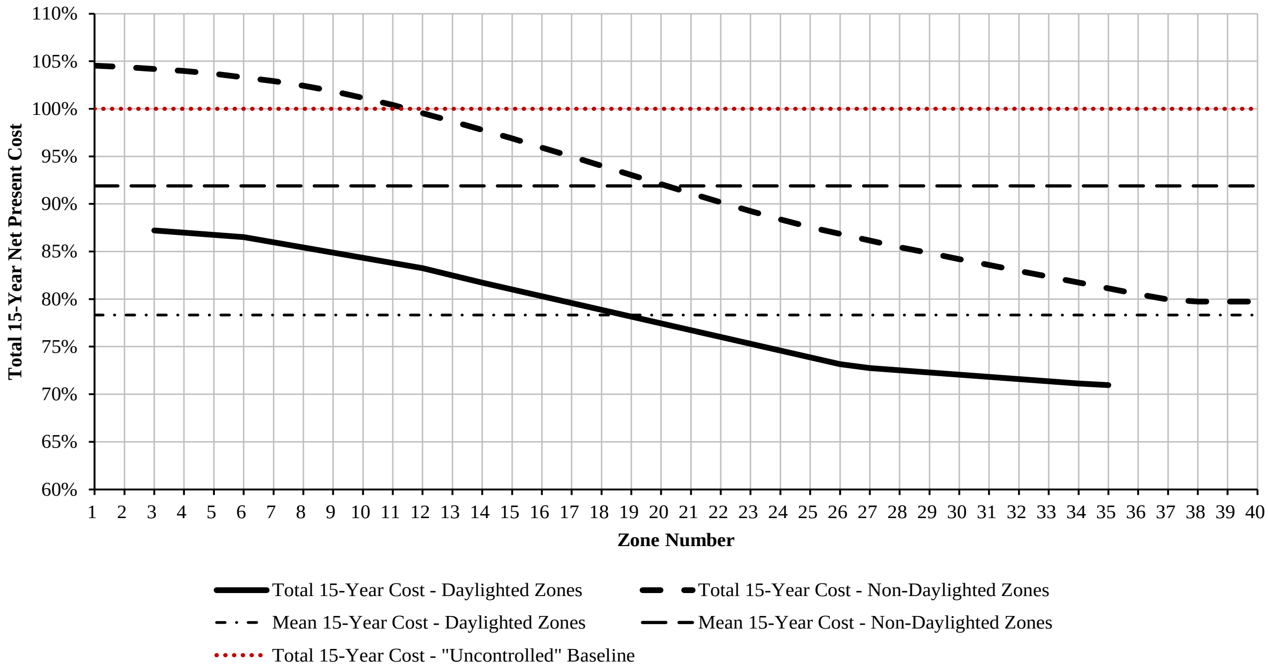

Figure 165: Simulation 22 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

11.23 Simulation 23: University Configuration 2

11.23.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	University 2
	Occupancy Schedule Variance	10%
	Transient Schedule Type	University 2
	Transient Schedule Variance	10%
Parking Garage Information	Total # Spaces	100
	Total # Floors	2
	# Occupancy Zones per Floor	6
	Daylight Availability	Poor
	# Daylighted Zones per Floor	3
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	10
	Delay Time 2	15
	Delay Time 3	20
	Delay Time 4	25
	Delay Time 5	30
	Daylight Switching Cost	$95
	Notes	Control system costs per controlled zone

Figure 166: Simulation 23 Input Variables

11.23.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:12:02	1066:26:32	922:38:47	2053:32:25	1788:49:17	2897:59:38	2542:00:37	3314:16:49	2916:59:38	3552:32:34	3131:02:02
Average Zone Low Power Time:	0:00:00	0:00:00	7693:33:28	6711:10:35	6706:27:35	5845:00:03	5862:00:22	5091:48:43	5445:43:11	4716:49:43	5207:27:28	4502:47:17
Average Zone OFF Time:	0:00:00	1126:48:00	0:00:00	1126:10:40	0:00:00	1126:10:40	0:00:00	1126:10:40	0:00:00	1126:10:40	0:00:00	1126:10:40
Average % Time at High Power:	100.0%	87.1%	12.2%	10.5%	23.4%	20.4%	33.1%	29.0%	37.8%	33.3%	40.6%	35.7%
Average % Time at Low Power:	0.0%	0.0%	87.8%	76.6%	76.6%	66.7%	66.9%	58.1%	62.2%	53.8%	59.4%	51.4%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 44,146	$ 36,922	$ 24,931	$ 20,858	$ 27,504	$ 23,042	$ 29,619	$ 24,867	$ 30,623	$ 25,740	$ 31,186	$ 26,225
Lighting Equipment Cost:	$ 24,580	$ 24,580	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740
Daylighting Control Equipment Cost:	$ -	$ 567	$ -	$ 567	$ -	$ 567	$ -	$ 567	$ -	$ 567	$ -	$ 567
Occupancy Control Equipment Cost:	$ -	$ -	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986
Total 15-yr Cost (Initial + NPV of Energy):	$ 68,726	$ 62,070	$ 57,658	$ 54,151	$ 60,230	$ 56,336	$ 62,345	$ 58,161	$ 63,349	$ 59,033	$ 63,913	$ 59,519
Total 15-year Cost Savings:	N/A	9.7%	16.1%	12.8%	12.4%	9.2%	9.3%	6.3%	7.8%	4.9%	7.0%	4.1%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 12.74	$ 3.21	$ 3.55	$ 2.78	$ 3.22	$ 2.43	$ 2.94	$ 2.26	$ 2.81	$ 2.16	$ 2.73
Approximate Annual Energy Cost Savings:	N/A	$ 482	$ 1,281	$ 1,553	$ 1,109	$ 1,407	$ 968	$ 1,285	$ 902	$ 1,227	$ 864	$ 1,195

Figure 167: Simulation 23 Results

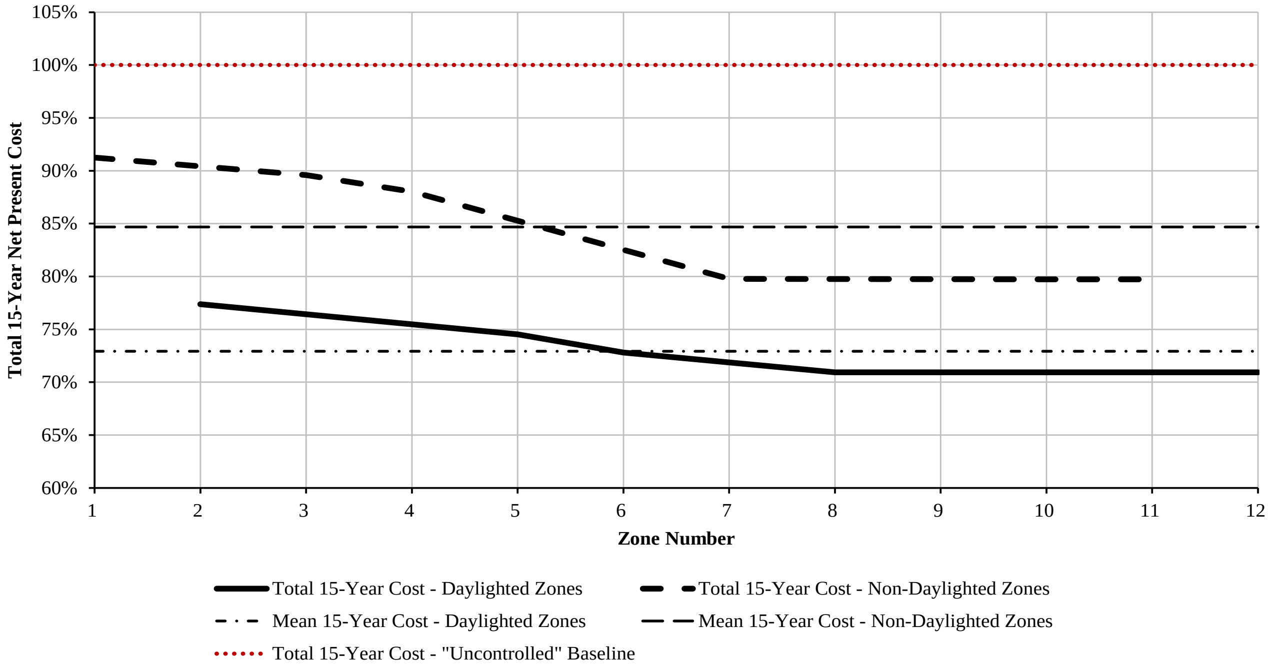

Figure 168: Simulation 23 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

11.24 Simulation 24: LED Lighting System with Full Reporting & 1-10 Minute Delay Times

11.24.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Transportation HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Transportation HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	28
	Daylight Availability	Poor
	# Daylighted Zones per Floor	14
Luminaire Information	Luminaire Description	LED with optional integral occupancy sensor
	Uncontrolled Luminaire Total Unit Cost	$4,373
	Controlled Luminaire Total Unit Cost	$4,373
	High Power	68
	Low Power	13.6
	OC Spacing E-W	32
	OC Spacing N-S	32
	# Luminaires per Control Zone	1
Control System Information	Occupancy Sensing Cost	$402
	Delay Time 1	1
	Delay Time 2	2.5
	Delay Time 3	5
	Delay Time 4	7.5
	Delay Time 5	10
	Daylight Switching Cost	$25
	Notes	Control system costs per controlled zone

Figure 169: Simulation 24 Input Variables

11.24.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	1.00	1.00	2.50	2.50	5.00	5.00	7.50	7.50	10.00	10.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:51	2989:15:45	2542:55:30	4638:58:19	3952:14:44	5554:30:11	4747:45:31	5947:02:35	5092:02:27	6184:45:02	5300:29:45
Average Zone Low Power Time:	0:00:00	0:00:00	5770:44:10	5090:53:51	4121:01:45	3681:34:46	3205:29:48	2886:03:54	2812:57:29	2541:46:58	2575:15:02	2333:19:41
Average Zone OFF Time:	0:00:00	1126:47:58	0:00:00	1126:10:37	0:00:00	1126:10:37	0:00:00	1126:10:37	0:00:00	1126:10:37	0:00:00	1126:10:37
Average % Time at High Power:	100.0%	87.1%	34.1%	29.0%	53.0%	45.1%	63.4%	54.2%	67.9%	58.1%	70.6%	60.5%
Average % Time at Low Power:	0.0%	0.0%	65.9%	58.1%	47.0%	42.0%	36.6%	32.9%	32.1%	29.0%	29.4%	26.6%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 129,712	$ 108,488	$ 63,377	$ 52,321	$ 83,313	$ 68,670	$ 94,120	$ 77,698	$ 98,682	$ 81,539	$ 101,421	$ 83,839
Lighting Equipment Cost:	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079
Total 15-yr Cost (Initial + NPV of Energy):	$ 619,527	$ 599,721	$ 598,271	$ 588,633	$ 618,208	$ 604,983	$ 629,015	$ 614,010	$ 633,577	$ 617,851	$ 636,315	$ 620,151
Total 15-year Cost Savings:	N/A	3.2%	3.4%	1.8%	0.2%	-0.9%	-1.5%	-2.4%	-2.3%	-3.0%	-2.7%	-3.4%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 14.97	$ 1.47	$ 1.66	$ 1.03	$ 1.31	$ 0.79	$ 1.12	$ 0.69	$ 1.04	$ 0.63	$ 0.99
Approximate Annual Energy Cost Savings:	N/A	$ 1,415	$ 4,422	$ 5,159	$ 3,093	$ 4,069	$ 2,373	$ 3,468	$ 2,069	$ 3,212	$ 1,886	$ 3,058

Figure 170: Simulation 24 Results

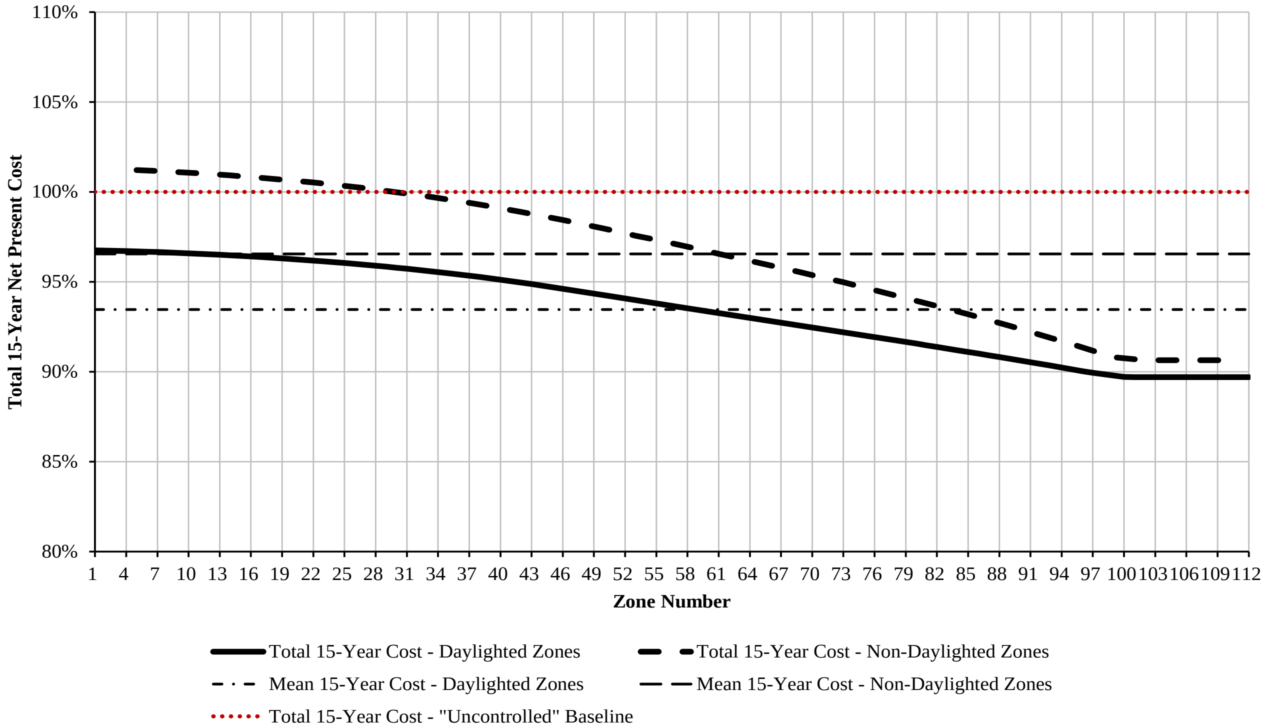

Figure 171: Simulation 24 Total Zone-by-Zone Costs
1-Minute Time Delay for Occupancy Sensing

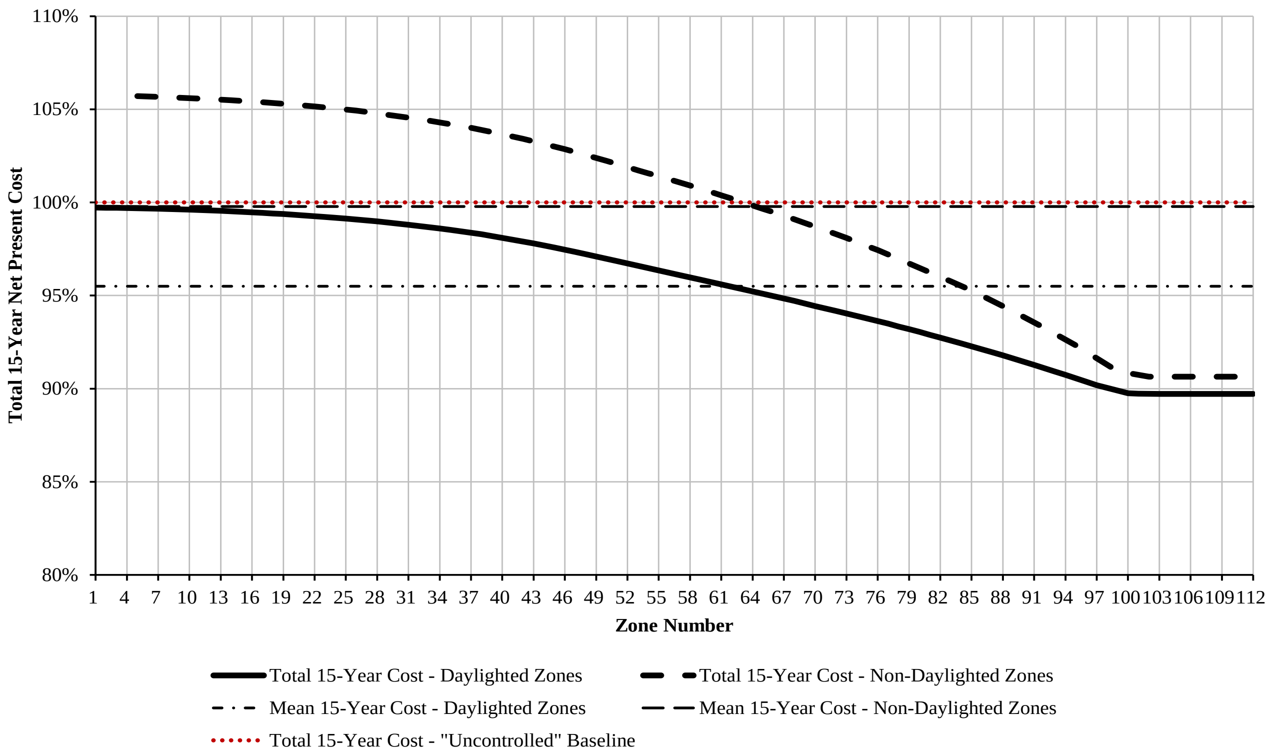

Figure 172: Simulation 24 Total Zone-by-Zone Costs
2 1/2-Minute Time Delay for Occupancy Sensing

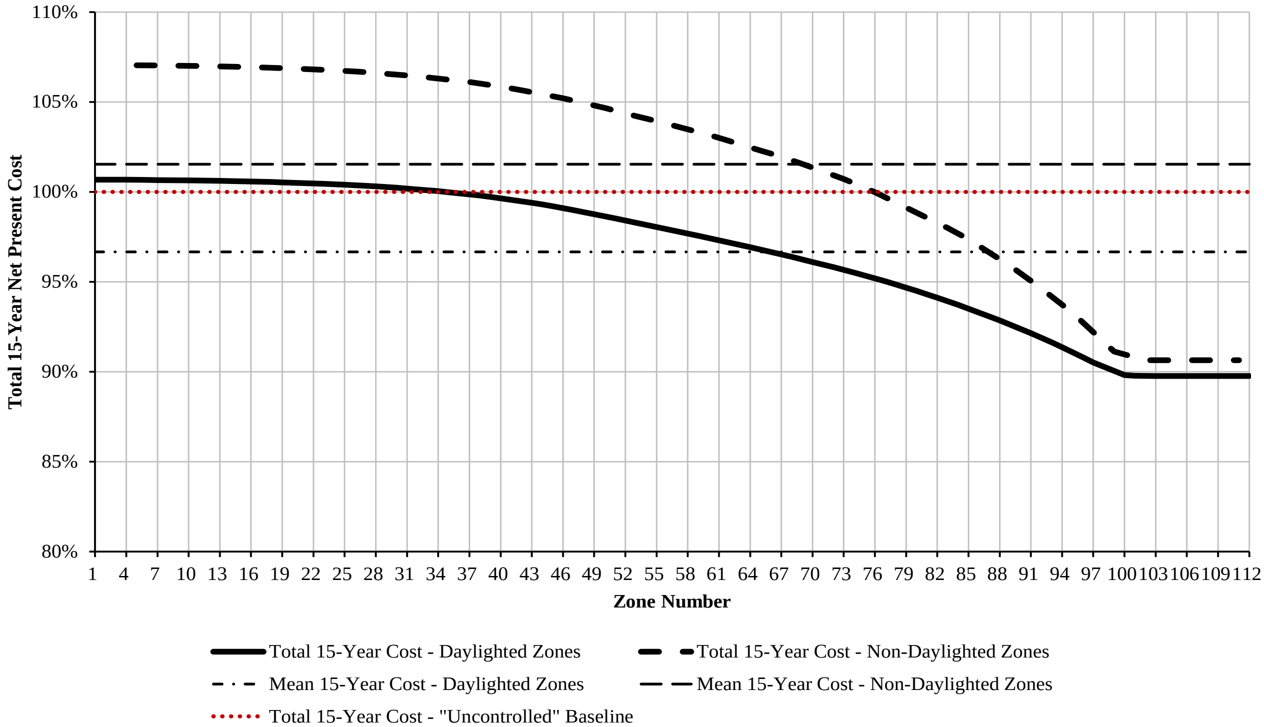

Figure 173: Simulation 24 Total Zone-by-Zone Costs
5-Minute Time Delay for Occupancy Sensing

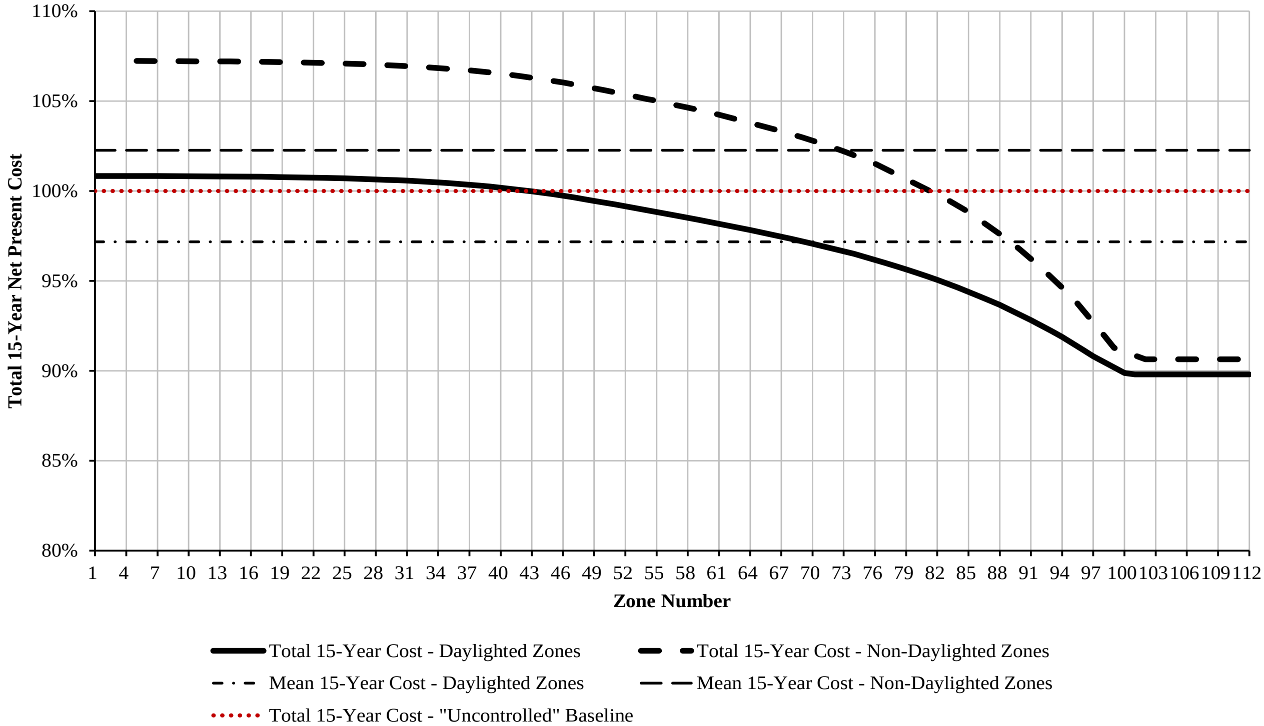

Figure 174: Simulation 24 Total Zone-by-Zone Costs
7 1/2-Minute Time Delay for Occupancy Sensing

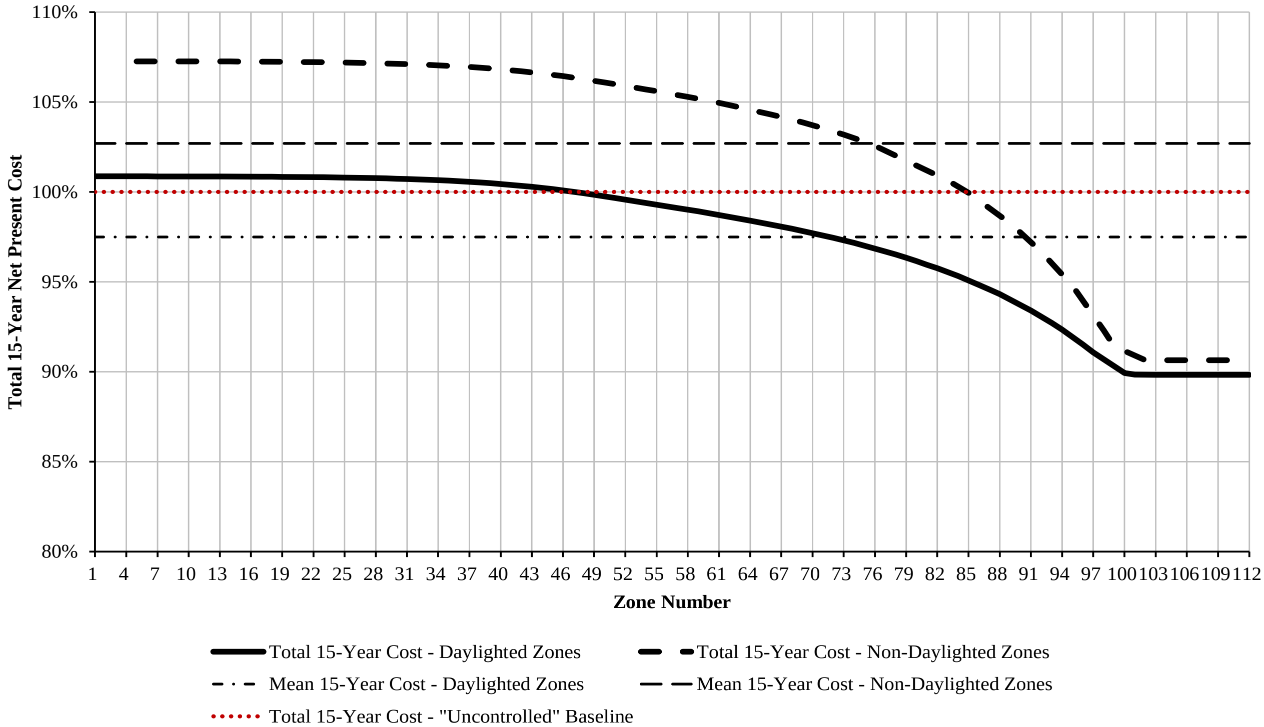

Figure 175: Simulation 24 Total Zone-by-Zone Costs
10-Minute Time Delay for Occupancy Sensing

11.25 Simulation 25: LED Lighting System with Full Reporting & 10-30 Minute Delay Times

11.25.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Transportation HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Transportation HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	28
	Daylight Availability	Poor
	# Daylighted Zones per Floor	14
Luminaire Information	Luminaire Description	LED with optional integral occupancy sensor
	Uncontrolled Luminaire Total Unit Cost	$4,373
	Controlled Luminaire Total Unit Cost	$4,373
	High Power	68
	Low Power	13.6
	OC Spacing E-W	32
	OC Spacing N-S	32
	# Luminaires per Control Zone	1
Control System Information	Occupancy Sensing Cost	$402
	Delay Time 1	10
	Delay Time 2	15
	Delay Time 3	20
	Delay Time 4	25
	Delay Time 5	30
	Daylight Switching Cost	$25
	Notes	Control system costs per controlled zone

Figure 176: Simulation 25 Input Variables

11.25.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	10.00	10.00	15.00	15.00	20.00	20.00	25.00	25.00	30.00	30.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:59	6189:23:02	5338:20:45	6483:40:55	5610:21:44	6666:45:58	5782:35:12	6793:10:11	5903:04:21	6884:56:05	5991:25:28
Average Zone Low Power Time:	0:00:00	0:00:00	2570:37:00	2295:28:24	2276:19:01	2023:27:08	2093:14:01	1851:13:45	1966:49:51	1730:44:37	1875:03:57	1642:23:32
Average Zone OFF Time:	0:00:00	1126:47:58	0:00:00	1126:11:03	0:00:00	1126:11:03	0:00:00	1126:11:03	0:00:00	1126:11:03	0:00:00	1126:11:03
Average % Time at High Power:	100.0%	87.1%	70.7%	60.9%	74.0%	64.0%	76.1%	66.0%	77.5%	67.4%	78.6%	68.4%
Average % Time at Low Power:	0.0%	0.0%	29.3%	26.2%	26.0%	23.1%	23.9%	21.1%	22.5%	19.8%	21.4%	18.7%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 129,712	$ 108,488	$ 101,465	$ 84,368	$ 104,777	$ 87,354	$ 106,793	$ 89,212	$ 108,163	$ 90,497	$ 109,142	$ 91,429
Lighting Equipment Cost:	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079
Total 15-yr Cost (Initial + NPV of Energy):	$ 619,527	$ 599,721	$ 636,359	$ 620,681	$ 639,671	$ 623,667	$ 641,687	$ 625,524	$ 643,057	$ 626,809	$ 644,036	$ 627,741
Total 15-year Cost Savings:	N/A	3.2%	-2.7%	-3.5%	-3.3%	-4.0%	-3.6%	-4.3%	-3.8%	-4.5%	-4.0%	-4.7%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 14.97	$ 0.63	$ 0.98	$ 0.55	$ 0.91	$ 0.51	$ 0.87	$ 0.48	$ 0.84	$ 0.46	$ 0.82
Approximate Annual Energy Cost Savings:	N/A	$ 1,415	$ 1,883	$ 3,023	$ 1,662	$ 2,824	$ 1,528	$ 2,700	$ 1,437	$ 2,614	$ 1,371	$ 2,552

Figure 177: Simulation 25 Results

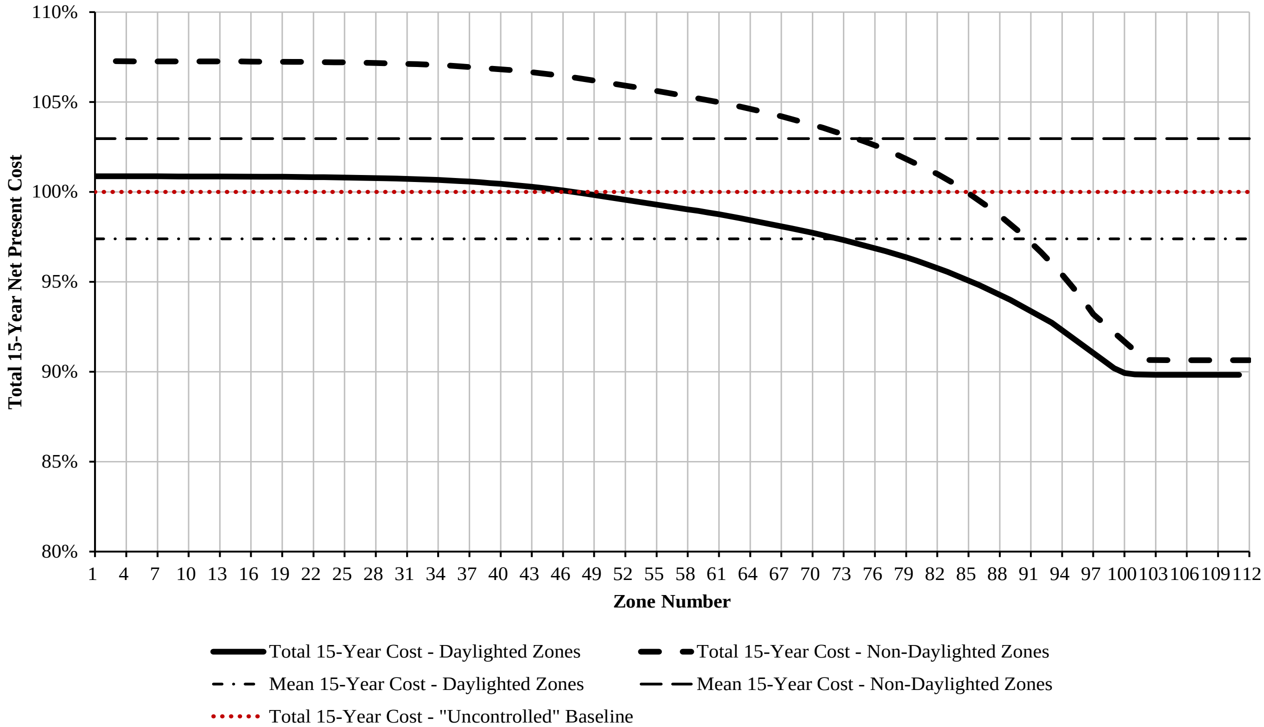

Figure 178: Simulation 25 Total Zone-by-Zone Costs
10-Minute Time Delay for Occupancy Sensing

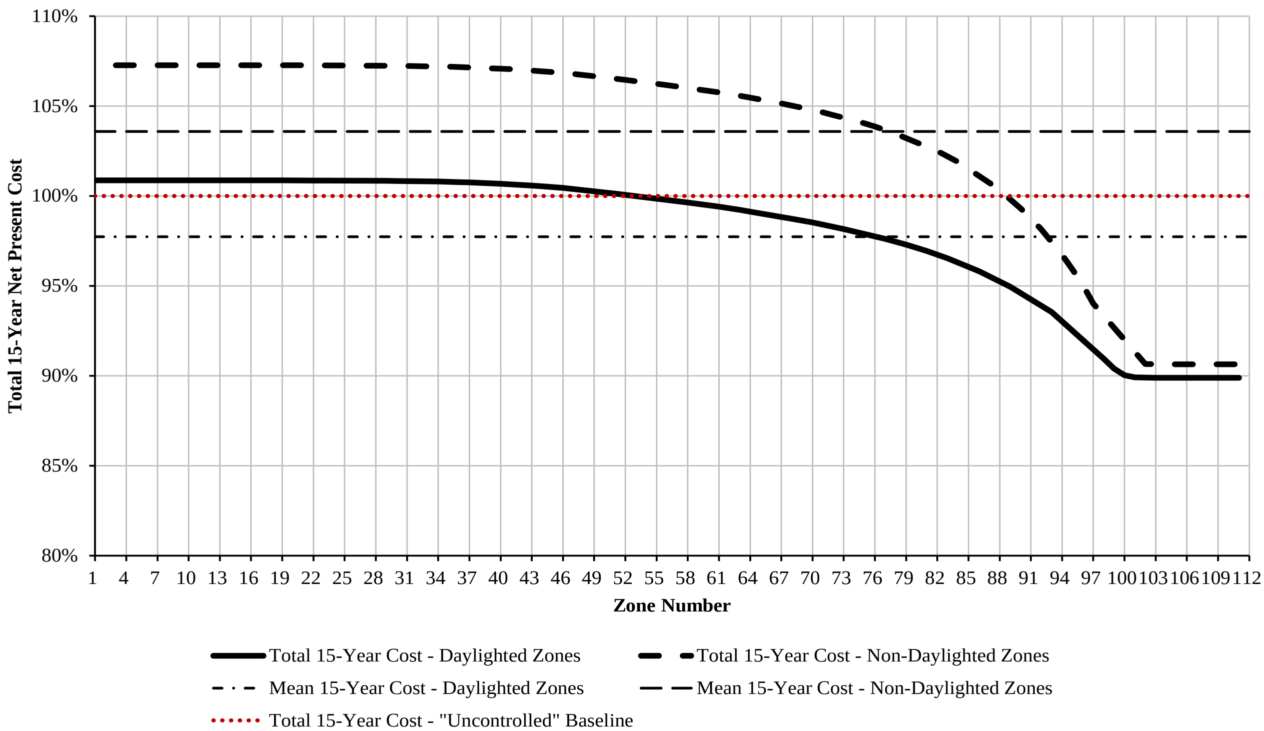

Figure 179: Simulation 25 Total Zone-by-Zone Costs
15-Minute Time Delay for Occupancy Sensing

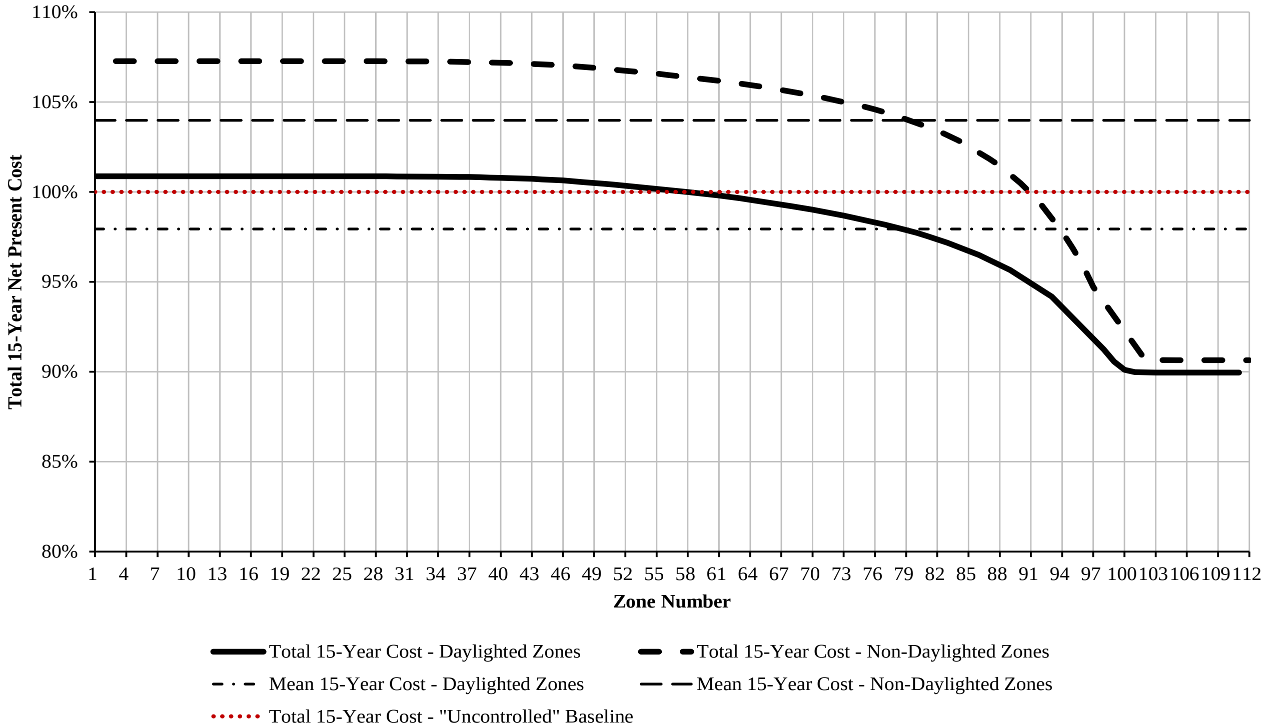

**Figure 180: Simulation 25 Total Zone-by-Zone Costs
20-Minute Time Delay for Occupancy Sensing**

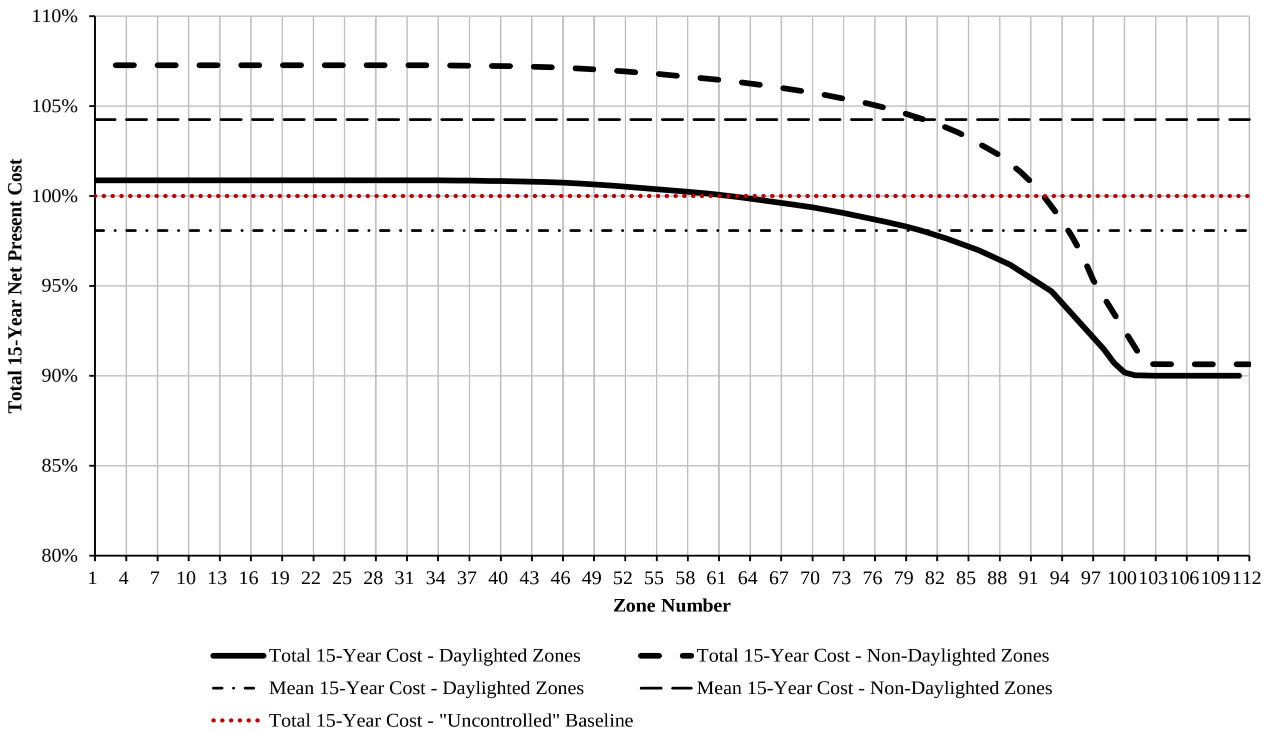

**Figure 181: Simulation 25 Total Zone-by-Zone Costs
25-Minute Time Delay for Occupancy Sensing**

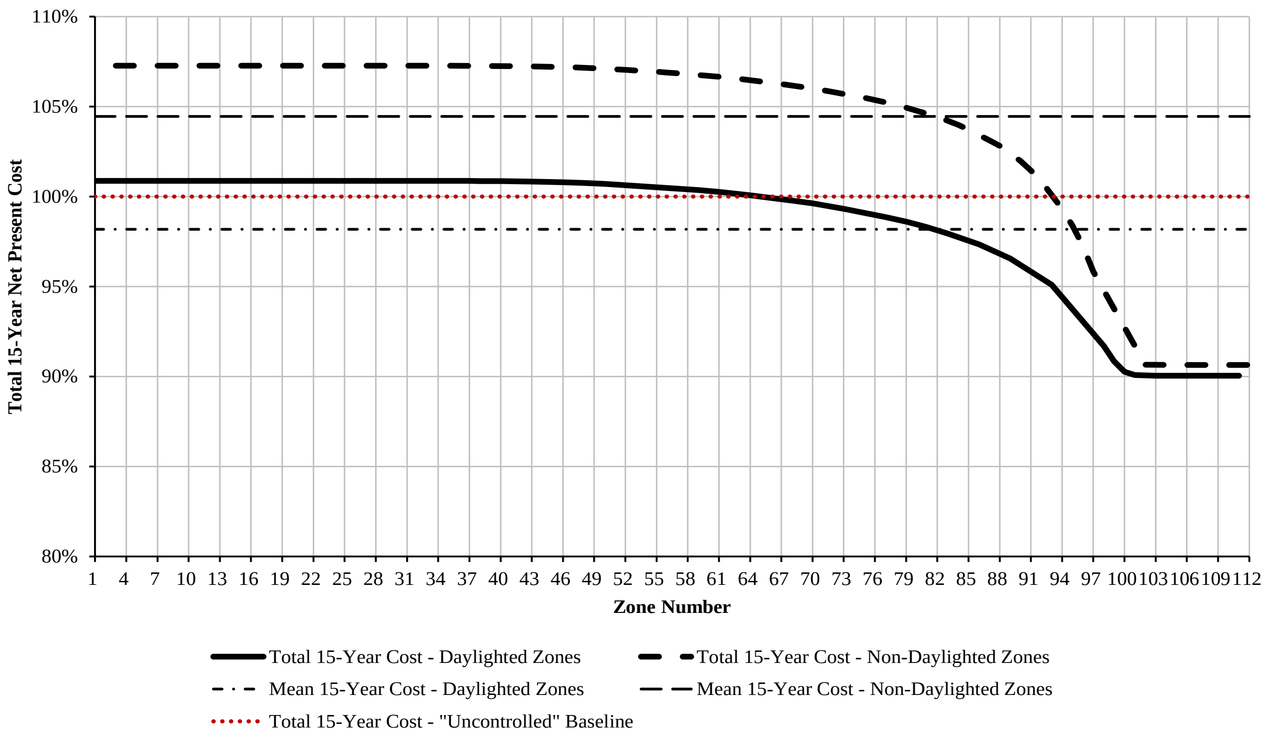

Figure 182: Simulation 25 Total Zone-by-Zone Costs
30-Minute Time Delay for Occupancy Sensing

11.26 Simulation 26: Office Park Garage with "MEDIUM" Activity, Fluorescent Lighting System & Full Reporting

11.26.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Office Park MEDIUM
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Office Park MEDIUM
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	5
	Delay Time 2	10
	Delay Time 3	15
	Delay Time 4	20
	Delay Time 5	30
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 183: Simulation 26 Input Variables

11.26.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	5.00	5.00	10.00	10.00	15.00	15.00	20.00	20.00	30.00	30.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:56	2383:15:19	1902:53:09	2771:24:10	2217:04:58	2934:59:58	2354:49:17	3031:03:06	2437:26:23	3143:47:21	2537:24:24
Average Zone Low Power Time:	0:00:00	0:00:00	6376:44:41	5730:56:07	5988:35:49	5416:44:17	5825:00:01	5278:59:49	5728:56:56	5196:22:45	5616:12:39	5096:24:48
Average Zone OFF Time:	0:00:00	1126:48:01	0:00:00	1126:10:51	0:00:00	1126:10:51	0:00:00	1126:10:51	0:00:00	1126:10:51	0:00:00	1126:10:51
Average % Time at High Power:	100.0%	87.1%	27.2%	21.7%	31.6%	25.3%	33.5%	26.9%	34.6%	27.8%	35.9%	29.0%
Average % Time at Low Power:	0.0%	0.0%	72.8%	65.4%	68.4%	61.8%	66.5%	60.3%	65.4%	59.3%	64.1%	58.2%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 147,152	$ 123,074	$ 97,169	$ 79,714	$ 100,925	$ 82,612	$ 102,484	$ 83,859	$ 103,388	$ 84,601	$ 104,440	$ 85,493
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 206,426	$ 206,257	$ 190,220	$ 210,013	$ 193,118	$ 211,572	$ 194,365	$ 212,476	$ 195,107	$ 213,528	$ 195,999
Total 15-year Cost Savings:	N/A	9.9%	10.0%	7.9%	8.3%	6.4%	7.6%	5.8%	7.3%	5.5%	6.8%	5.1%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 16.98	$ 2.50	$ 3.16	$ 2.32	$ 3.02	$ 2.24	$ 2.96	$ 2.19	$ 2.93	$ 2.14	$ 2.89
Approximate Annual Energy Cost Savings:	N/A	$ 1,605	$ 3,332	$ 4,496	$ 3,082	$ 4,303	$ 2,978	$ 4,220	$ 2,918	$ 4,170	$ 2,847	$ 4,111

Figure 184: Simulation 26 Results

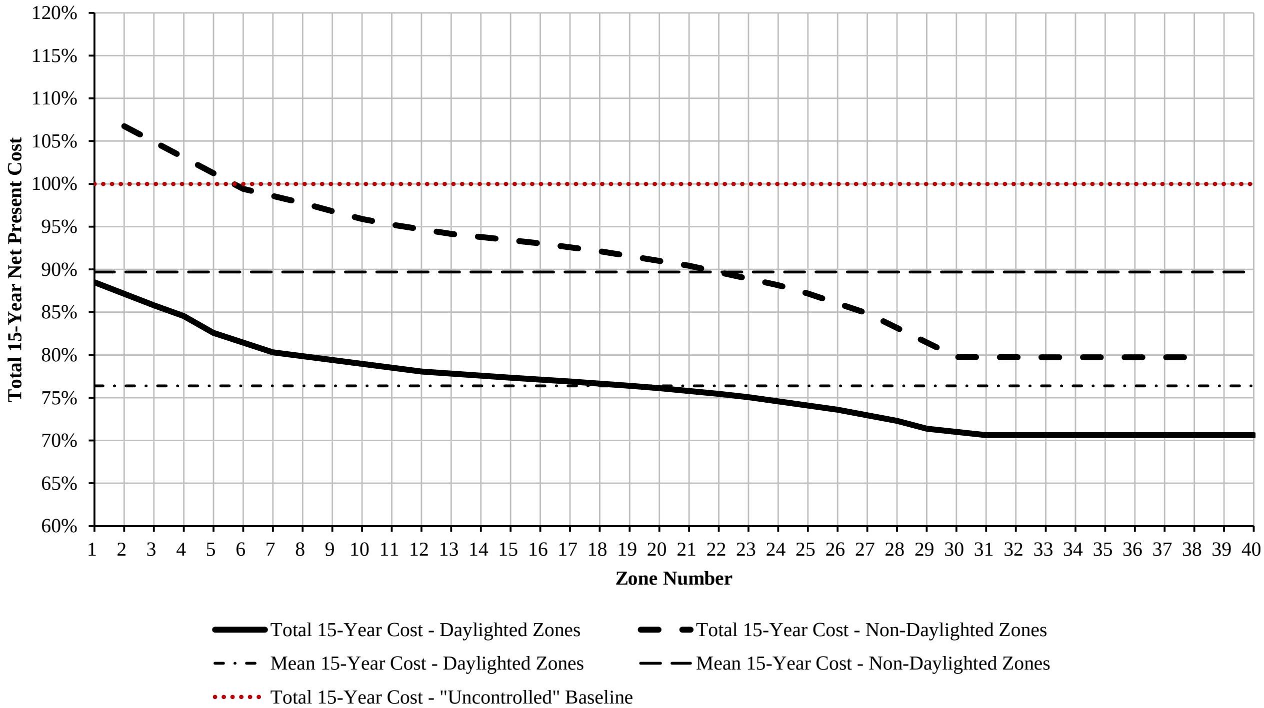

Figure 185: Simulation 26 Total Zone-by-Zone Costs 5-Minute Time Delay for Occupancy Sensing

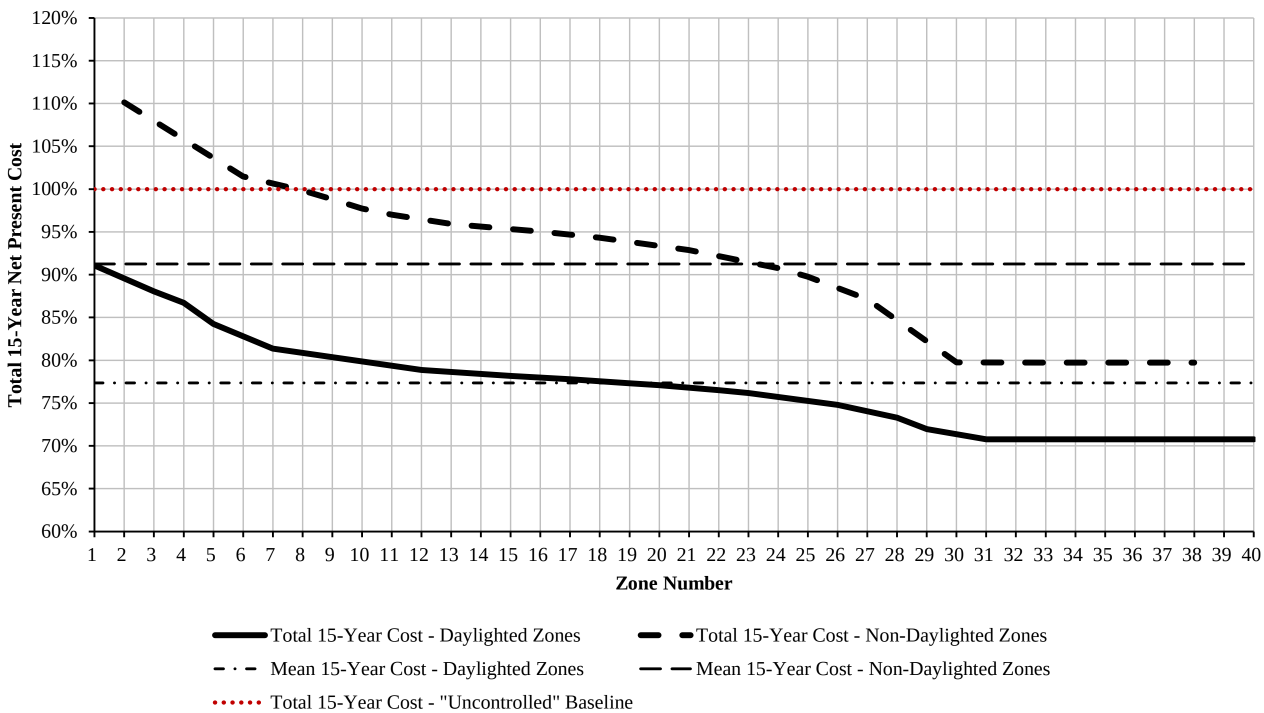

Figure 186: Simulation 26 Total Zone-by-Zone Costs 10-Minute Time Delay for Occupancy Sensing

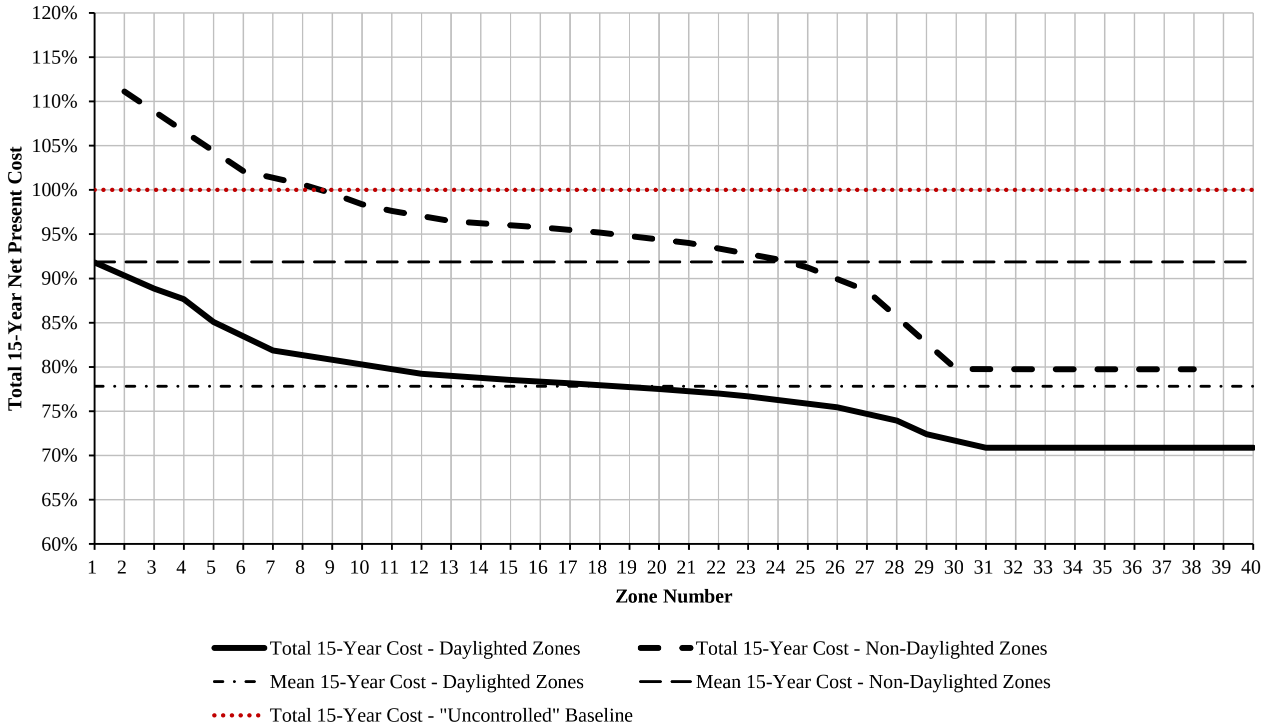

Figure 187: Simulation 26 Total Zone-by-Zone Costs
15-Minute Time Delay for Occupancy Sensing

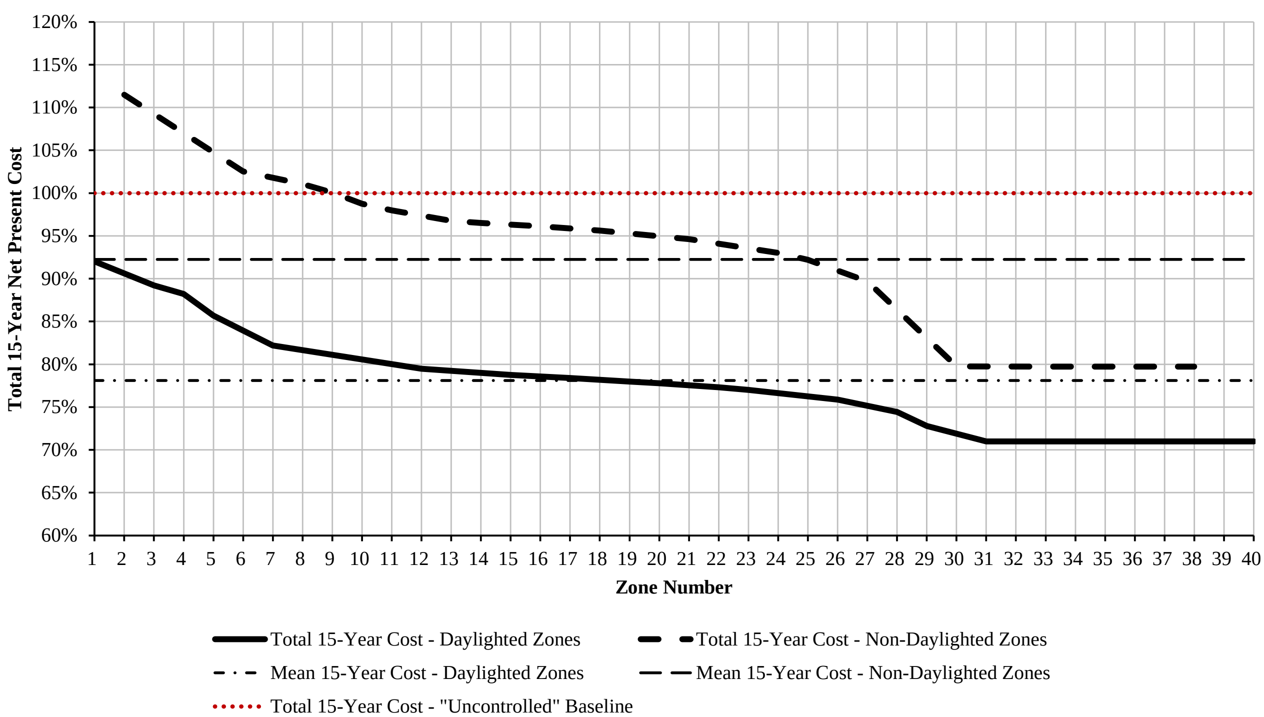

Figure 188: Simulation 26 Total Zone-by-Zone Costs
20-Minute Time Delay for Occupancy Sensing

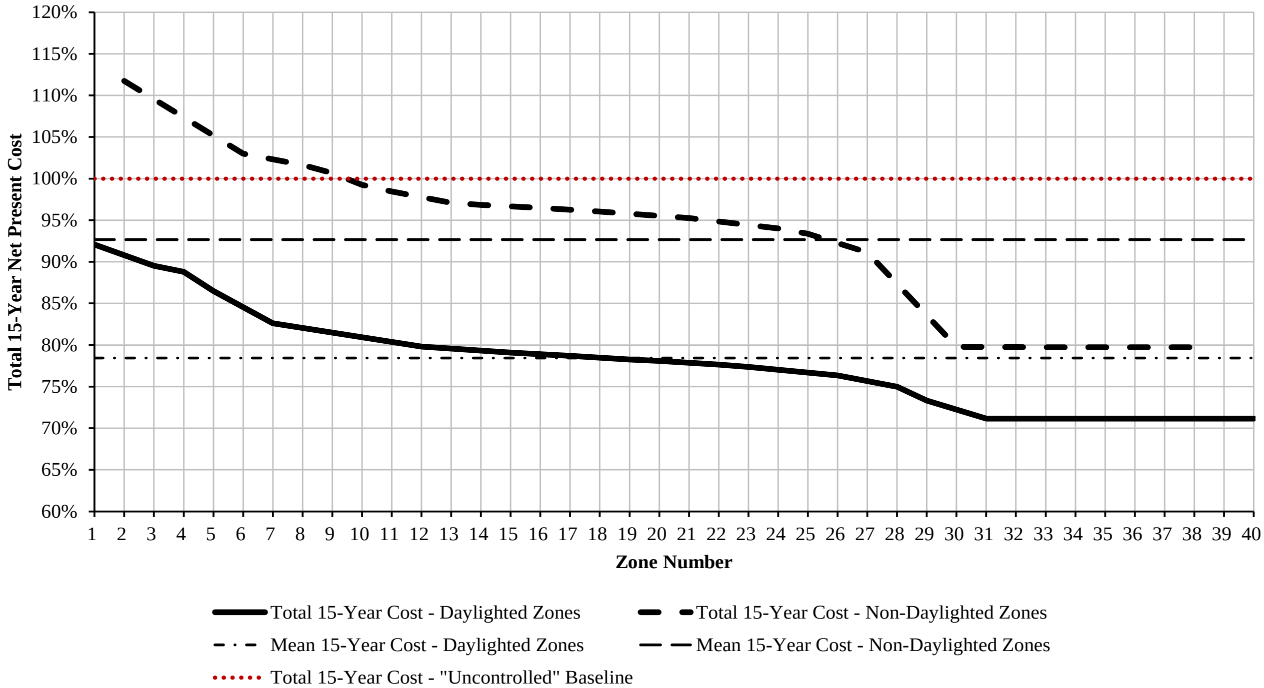

Figure 189: Simulation 26 Total Zone-by-Zone Costs
30-Minute Time Delay for Occupancy Sensing

11.27 Simulation 27: Office Park Garage with "MEDIUM" Activity, LED Lighting System & Full Reporting

11.27.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Office Park MEDIUM
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Office Park MEDIUM
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	28
	Daylight Availability	Poor
	# Daylighted Zones per Floor	14
Luminaire Information	Luminaire Description	LED with optional integral occupancy sensor
	Uncontrolled Luminaire Total Unit Cost	$4,373
	Controlled Luminaire Total Unit Cost	$4,373
	High Power	68
	Low Power	13.6
	OC Spacing E-W	32
	OC Spacing N-S	32
	# Luminaires per Control Zone	1
Control System Information	Occupancy Sensing Cost	$402
	Delay Time 1	5
	Delay Time 2	10
	Delay Time 3	15
	Delay Time 4	20
	Delay Time 5	30
	Daylight Switching Cost	$25
	Notes	Control system costs per controlled zone

Figure 190: Simulation 27 Input Variables

11.27.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	5.00	5.00	10.00	10.00	15.00	15.00	20.00	20.00	30.00	30.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:11:59	2232:23:33	1801:26:46	2622:57:30	2127:10:26	2801:22:45	2283:26:33	2912:09:40	2383:26:34	3050:47:11	2514:01:18
Average Zone Low Power Time:	0:00:00	0:00:00	6527:36:29	5832:23:50	6137:02:30	5506:40:10	5958:37:15	5350:24:04	5847:50:19	5250:23:46	5709:12:49	5119:49:20
Average Zone OFF Time:	0:00:00	1126:47:58	0:00:00	1126:09:29	0:00:00	1126:09:29	0:00:00	1126:09:29	0:00:00	1126:09:29	0:00:00	1126:09:29
Average % Time at High Power:	100.0%	87.1%	25.5%	20.6%	29.9%	24.3%	32.0%	26.1%	33.2%	27.2%	34.8%	28.7%
Average % Time at Low Power:	0.0%	0.0%	74.5%	66.6%	70.1%	62.9%	68.0%	61.1%	66.8%	59.9%	65.2%	58.4%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 129,712	$ 108,488	$ 57,649	$ 46,442	$ 62,906	$ 50,630	$ 65,217	$ 52,573	$ 66,633	$ 53,805	$ 68,354	$ 55,388
Lighting Equipment Cost:	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815	$ 489,815
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079	$ 45,079
Total 15-yr Cost (Initial + NPV of Energy):	$ 619,527	$ 599,721	$ 592,543	$ 582,754	$ 597,801	$ 586,943	$ 600,112	$ 588,885	$ 601,527	$ 590,118	$ 603,248	$ 591,700
Total 15-year Cost Savings:	N/A	3.2%	4.4%	2.8%	3.5%	2.1%	3.1%	1.8%	2.9%	1.6%	2.6%	1.3%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 14.97	$ 1.60	$ 1.79	$ 1.48	$ 1.70	$ 1.43	$ 1.66	$ 1.40	$ 1.63	$ 1.36	$ 1.60
Approximate Annual Energy Cost Savings:	N/A	$ 1,415	$ 4,804	$ 5,551	$ 4,454	$ 5,272	$ 4,300	$ 5,143	$ 4,205	$ 5,060	$ 4,091	$ 4,955

Figure 191: Simulation 27 Results

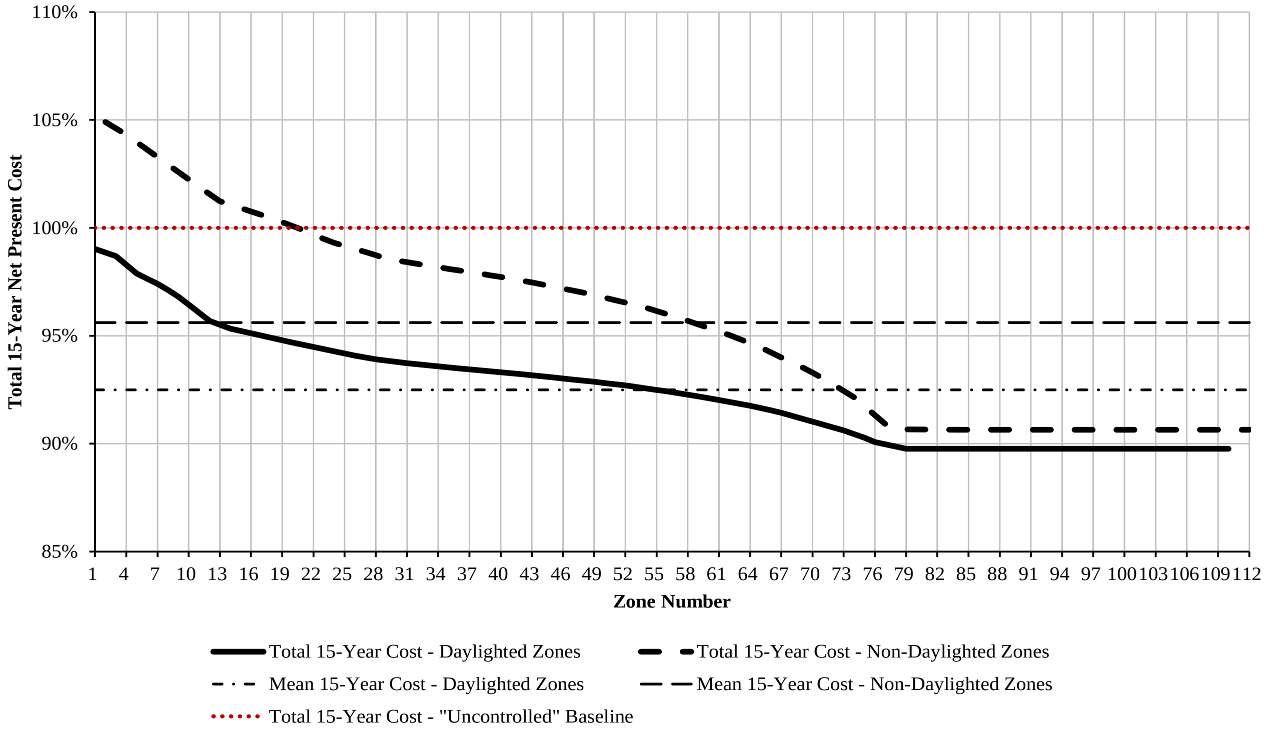

Figure 192: Simulation 27 Total Zone-by-Zone Costs
5-Minute Time Delay for Occupancy Sensing

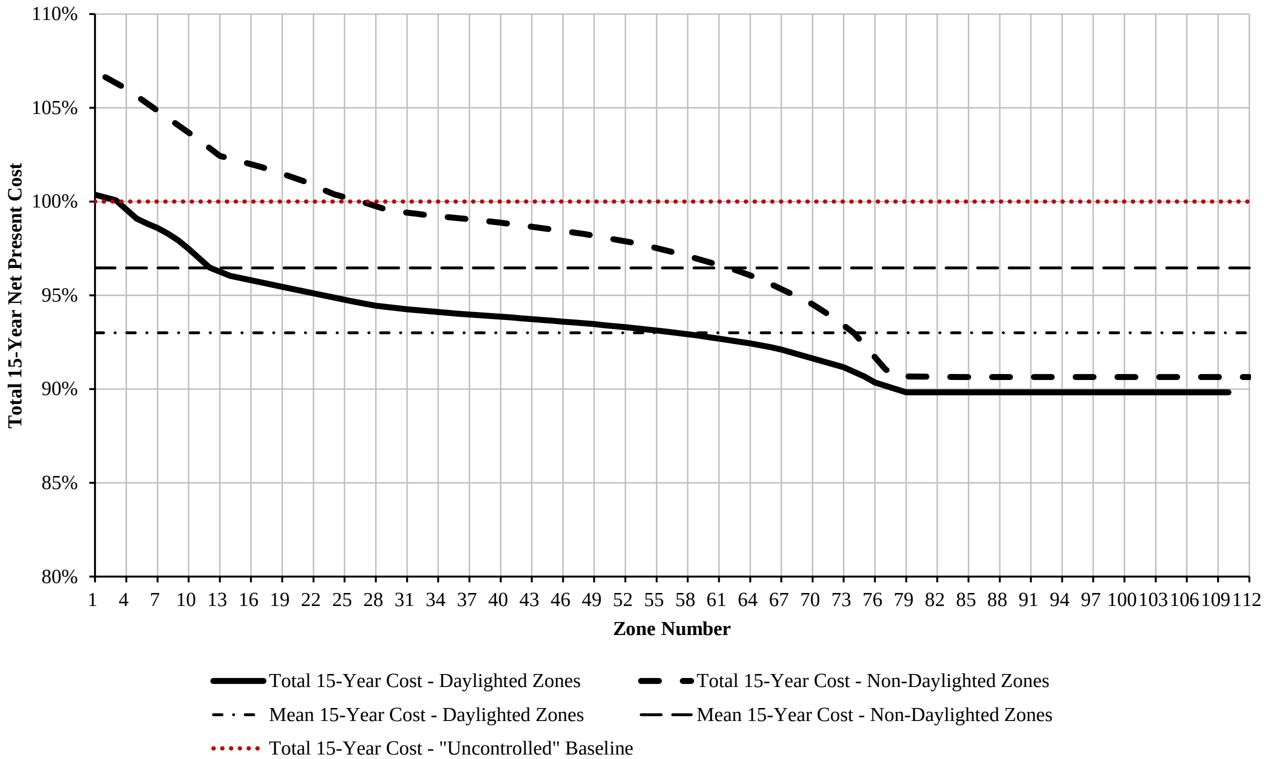

Figure 193: Simulation 27 Total Zone-by-Zone Costs
10-Minute Time Delay for Occupancy Sensing

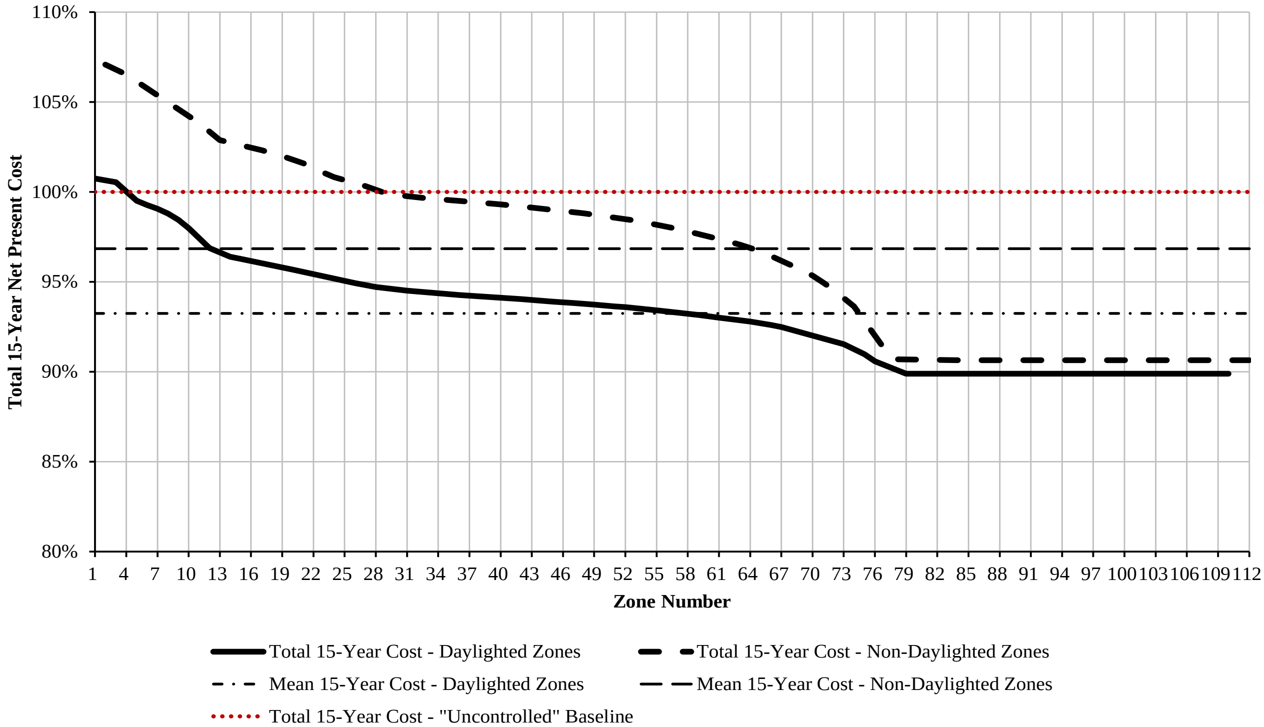

Figure 194: Simulation 27 Total Zone-by-Zone Costs 15-Minute Time Delay for Occupancy Sensing

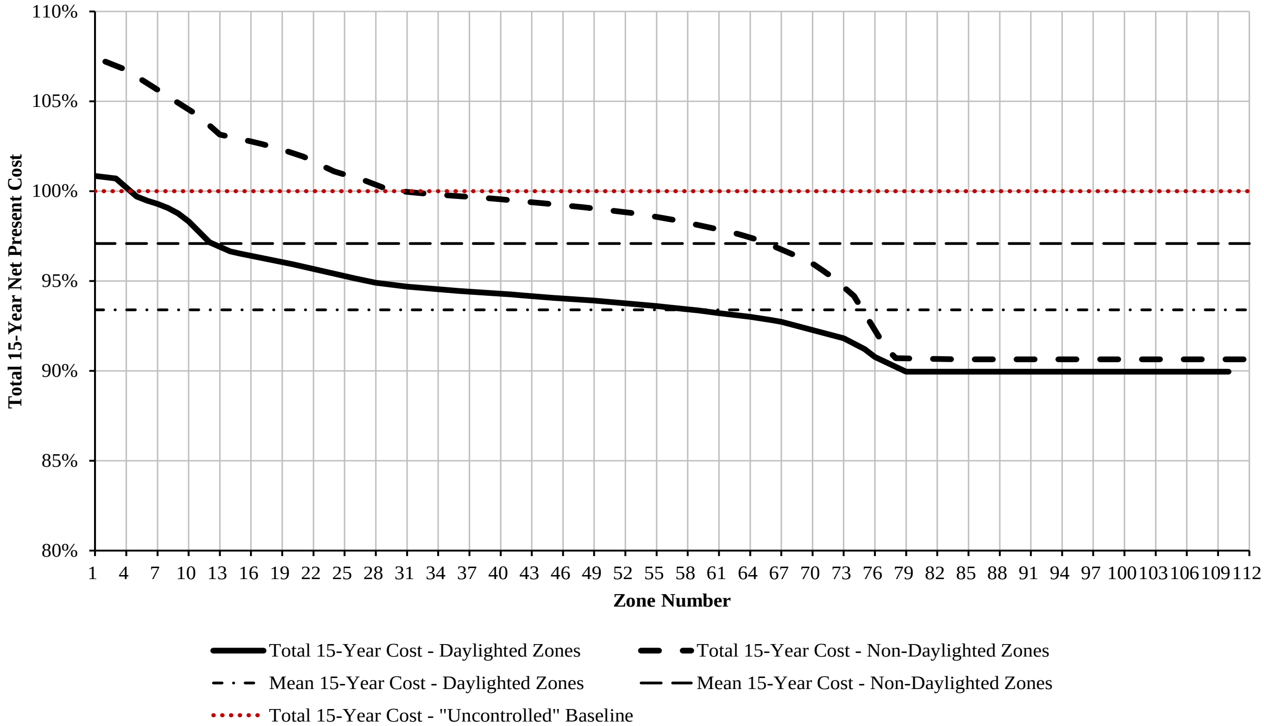

Figure 195: Simulation 27 Total Zone-by-Zone Costs 20-Minute Time Delay for Occupancy Sensing

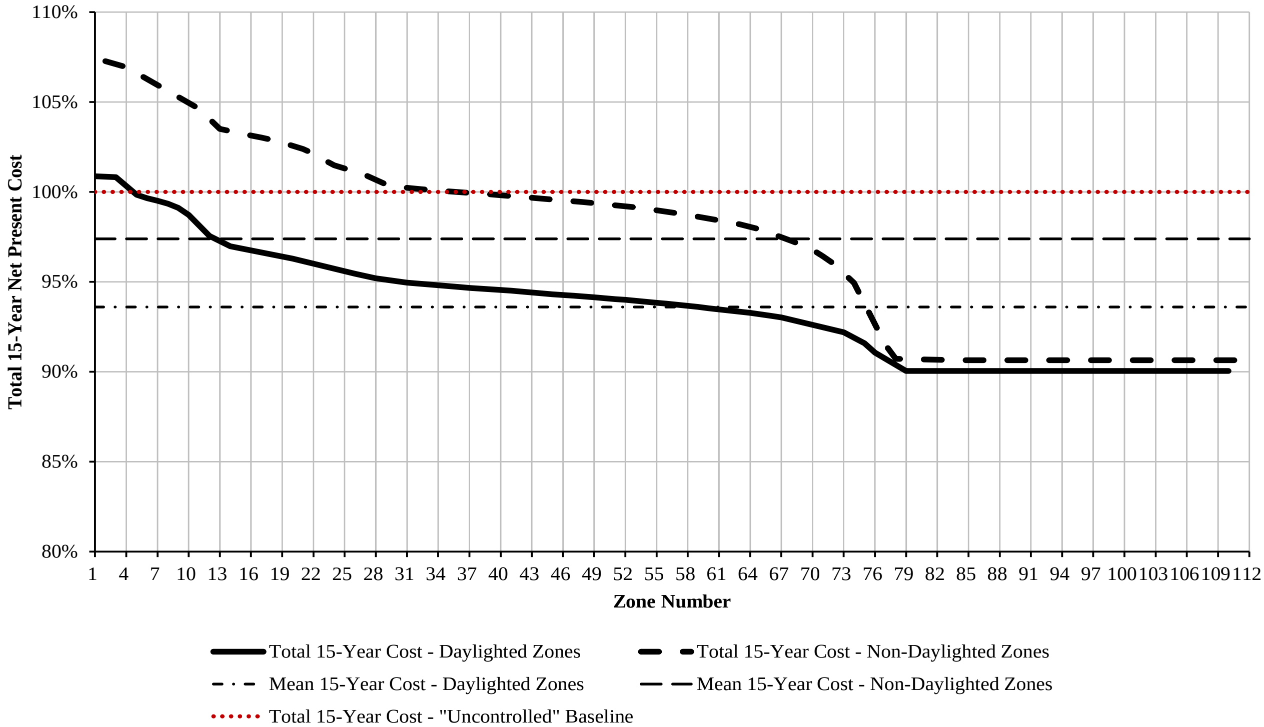

Figure 196: Simulation 27 Total Zone-by-Zone Costs
30-Minute Time Delay for Occupancy Sensing

11.28 Simulation 28: Office Park Garage with "HIGH" Activity & Full Reporting

11.28.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Office Park HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Office Park HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	5
	Delay Time 2	10
	Delay Time 3	15
	Delay Time 4	20
	Delay Time 5	30
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 197: Simulation 28 Input Variables

11.28.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	5.00	5.00	10.00	10.00	15.00	15.00	20.00	20.00	30.00	30.00
Daylight Availability:	0	Moderate	0	Moderate	0	Moderate	0	Moderate	0	Moderate	0	Moderate
Average Zone High Power Time:	8760:00:00	7085:41:59	3325:52:15	2373:06:03	3774:31:25	2709:28:04	3972:42:40	2861:48:19	4093:55:19	2956:55:00	4237:52:14	3073:56:04
Average Zone Low Power Time:	0:00:00	0:00:00	5434:07:45	4713:15:06	4985:28:39	4376:53:05	4787:17:20	4224:32:44	4666:04:44	4129:26:07	4522:07:45	4012:25:05
Average Zone OFF Time:	0:00:00	1674:18:00	0:00:00	1673:38:53	0:00:00	1673:38:53	0:00:00	1673:38:53	0:00:00	1673:38:53	0:00:00	1673:38:53
Average % Time at High Power:	100.0%	80.9%	38.0%	27.1%	43.1%	30.9%	45.4%	32.7%	46.7%	33.8%	48.4%	35.1%
Average % Time at Low Power:	0.0%	0.0%	62.0%	53.8%	56.9%	50.0%	54.6%	48.2%	53.3%	47.1%	51.6%	45.8%
Average % Time OFF:	0.0%	19.1%	0.0%	19.1%	0.0%	19.1%	0.0%	19.1%	0.0%	19.1%	0.0%	19.1%
15-yr Energy Cost:	$ 147,152	$ 112,849	$ 105,810	$ 78,320	$ 110,009	$ 81,280	$ 111,853	$ 82,605	$ 112,972	$ 83,423	$ 114,280	$ 84,408
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 196,201	$ 214,898	$ 188,826	$ 219,097	$ 191,786	$ 220,941	$ 193,111	$ 222,060	$ 193,929	$ 223,368	$ 194,914
Total 15-year Cost Savings:	N/A	14.4%	6.2%	3.8%	4.4%	2.3%	3.6%	1.6%	3.1%	1.2%	2.5%	0.7%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 24.19	$ 2.07	$ 3.22	$ 1.86	$ 3.08	$ 1.77	$ 3.02	$ 1.71	$ 2.98	$ 1.65	$ 2.94
Approximate Annual Energy Cost Savings:	N/A	$ 2,287	$ 2,756	$ 4,589	$ 2,476	$ 4,392	$ 2,353	$ 4,303	$ 2,279	$ 4,249	$ 2,191	$ 4,183

Figure 198: Simulation 28 Results

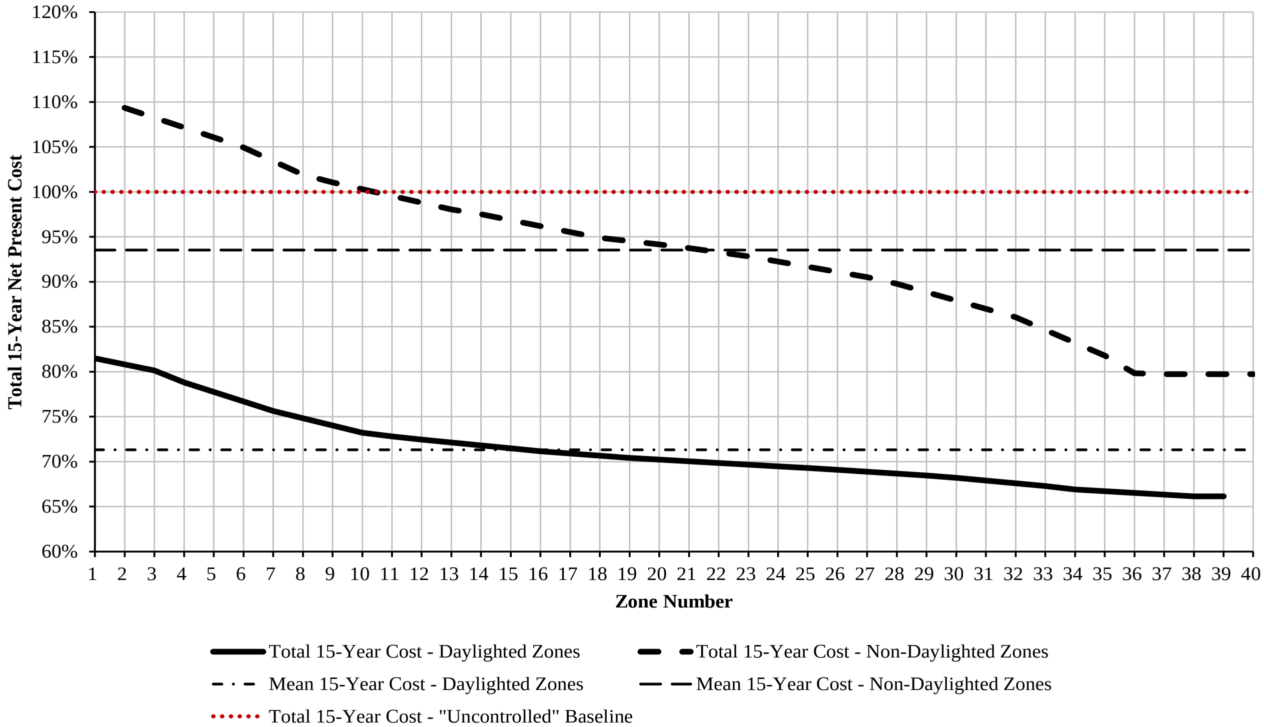

Figure 199: Simulation 28 Total Zone-by-Zone Costs
5-Minute Time Delay for Occupancy Sensing

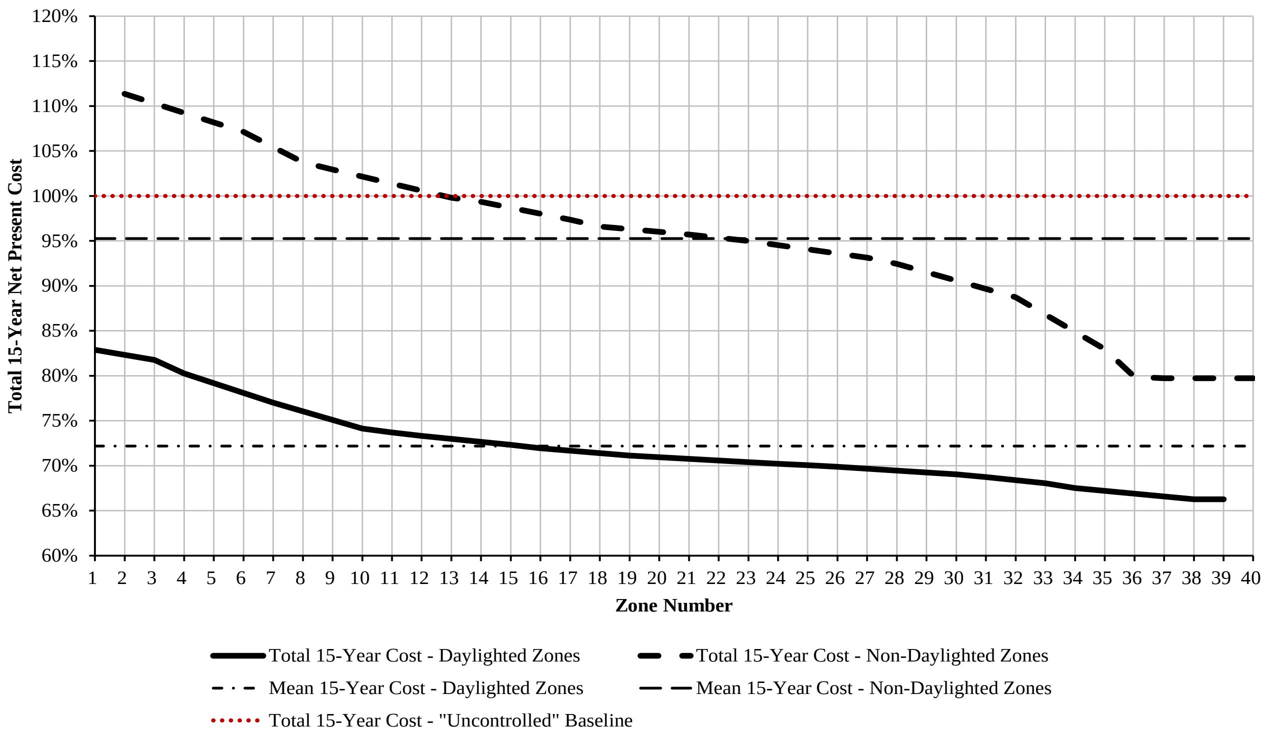

Figure 200: Simulation 28 Total Zone-by-Zone Costs
10-Minute Time Delay for Occupancy Sensing

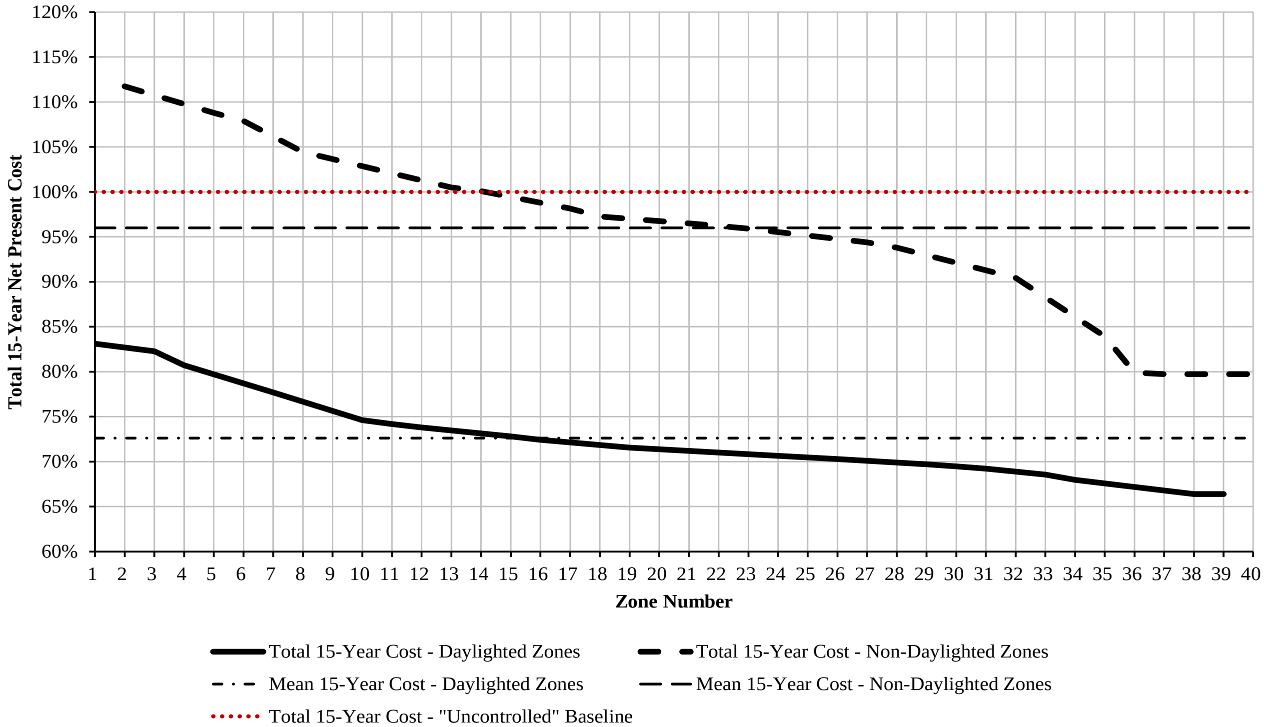

Figure 201: Simulation 28 Total Zone-by-Zone Costs
15-Minute Time Delay for Occupancy Sensing

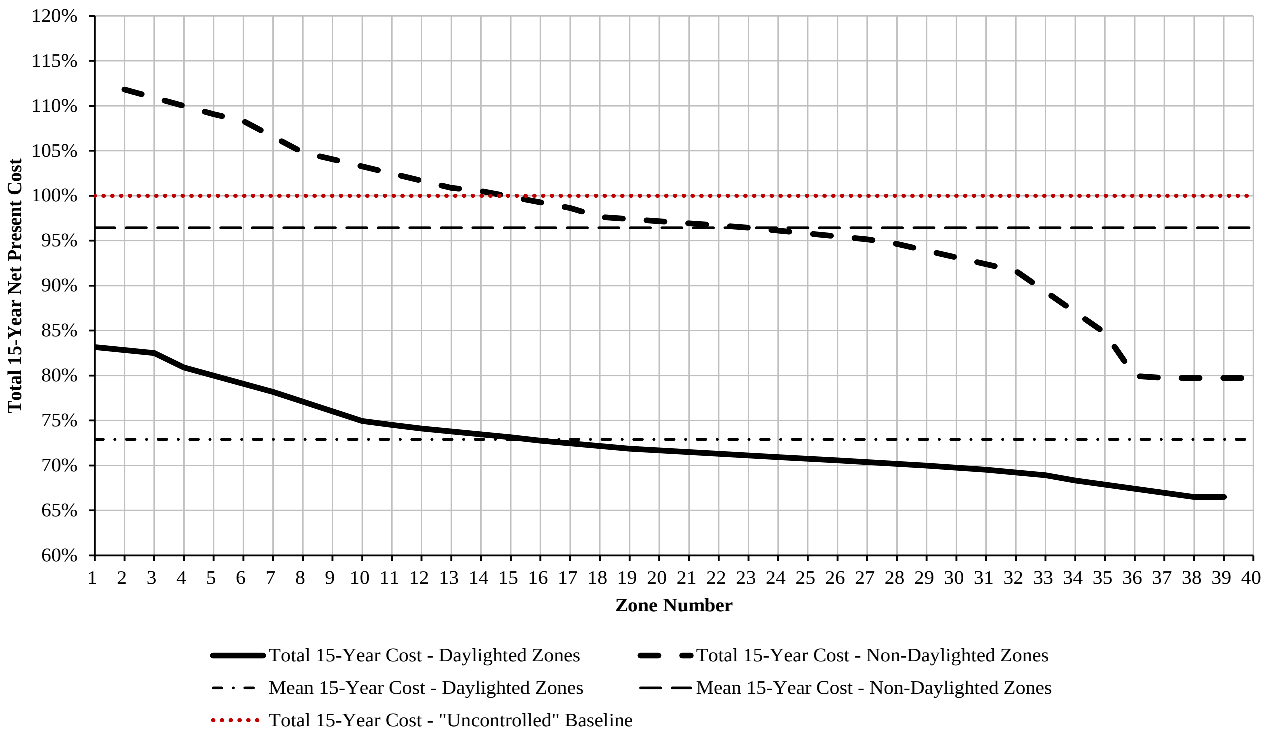

Figure 202: Simulation 28 Total Zone-by-Zone Costs
20-Minute Time Delay for Occupancy Sensing

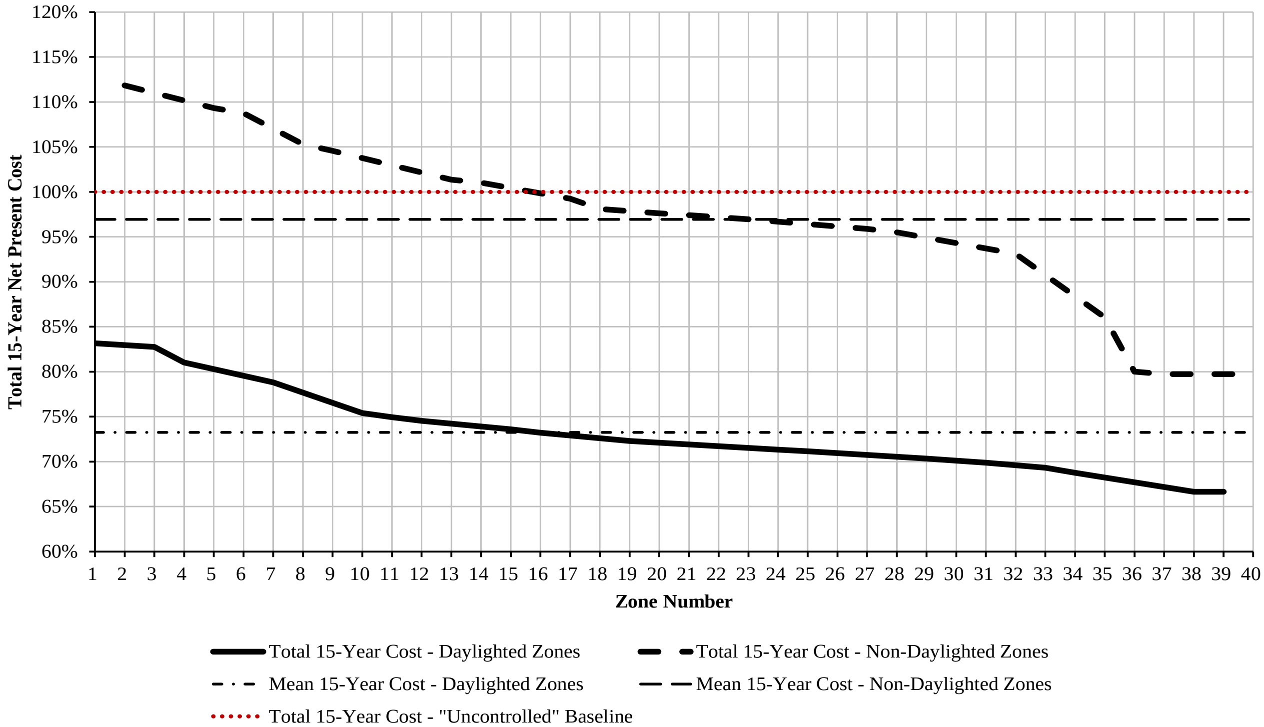

Figure 203: Simulation 28 Total Zone-by-Zone Costs
30-Minute Time Delay for Occupancy Sensing

11.29 Simulation 29: Mixed Use Garage with "HIGH" Activity & Full Reporting

11.29.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	Mixed Use HIGH
	Occupancy Schedule Variance	1%
	Transient Schedule Type	Mixed Use HIGH
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	320
	Total # Floors	4
	# Occupancy Zones per Floor	10
	Daylight Availability	Poor
	# Daylighted Zones per Floor	5
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	5
	Delay Time 2	10
	Delay Time 3	15
	Delay Time 4	20
	Delay Time 5	30
	Daylight Switching Cost	$71
	Notes	Control system costs per controlled zone

Figure 204: Simulation 29 Input Variables

11.29.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	5.00	5.00	10.00	10.00	15.00	15.00	20.00	20.00	30.00	30.00
Daylight Availability:	0	Moderate	0	Moderate	0	Moderate	0	Moderate	0	Moderate	0	Moderate
Average Zone High Power Time:	8760:00:00	7085:41:59	4459:49:41	3472:03:00	4868:19:09	3821:30:04	5043:17:49	3976:30:44	5144:45:07	4068:29:20	5259:21:56	4174:45:20
Average Zone Low Power Time:	0:00:00	0:00:00	4300:10:16	3614:18:07	3891:40:53	3264:51:01	3716:42:11	3109:50:23	3615:14:54	3017:51:48	3500:38:07	2911:35:45
Average Zone OFF Time:	0:00:00	1674:18:00	0:00:00	1673:38:53	0:00:00	1673:38:53	0:00:00	1673:38:53	0:00:00	1673:38:53	0:00:00	1673:38:53
Average % Time at High Power:	100.0%	80.9%	50.9%	39.6%	55.6%	43.6%	57.6%	45.4%	58.7%	46.4%	60.0%	47.7%
Average % Time at Low Power:	0.0%	0.0%	49.1%	41.3%	44.4%	37.3%	42.4%	35.5%	41.3%	34.5%	40.0%	33.2%
Average % Time OFF:	0.0%	19.1%	0.0%	19.1%	0.0%	19.1%	0.0%	19.1%	0.0%	19.1%	0.0%	19.1%
15-yr Energy Cost:	$ 147,152	$ 112,849	$ 114,503	$ 86,654	$ 117,966	$ 89,485	$ 119,420	$ 90,723	$ 120,242	$ 91,441	$ 121,145	$ 92,250
Lighting Equipment Cost:	$ 81,934	$ 81,934	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134	$ 89,134
Daylighting Control Equipment Cost:	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418	$ -	$ 1,418
Occupancy Control Equipment Cost:	$ -	$ -	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954	$ 19,954
Total 15-yr Cost (Initial + NPV of Energy):	$ 229,086	$ 196,201	$ 223,591	$ 197,160	$ 227,054	$ 199,991	$ 228,508	$ 201,229	$ 229,330	$ 201,947	$ 230,233	$ 202,756
Total 15-year Cost Savings:	N/A	14.4%	2.4%	-0.5%	0.9%	-1.9%	0.3%	-2.6%	-0.1%	-2.9%	-0.5%	-3.3%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 24.19	$ 1.64	$ 2.83	$ 1.46	$ 2.70	$ 1.39	$ 2.64	$ 1.35	$ 2.61	$ 1.30	$ 2.57
Approximate Annual Energy Cost Savings:	N/A	$ 2,287	$ 2,177	$ 4,033	$ 1,946	$ 3,844	$ 1,849	$ 3,762	$ 1,794	$ 3,714	$ 1,734	$ 3,660

Figure 205: Simulation 29 Results

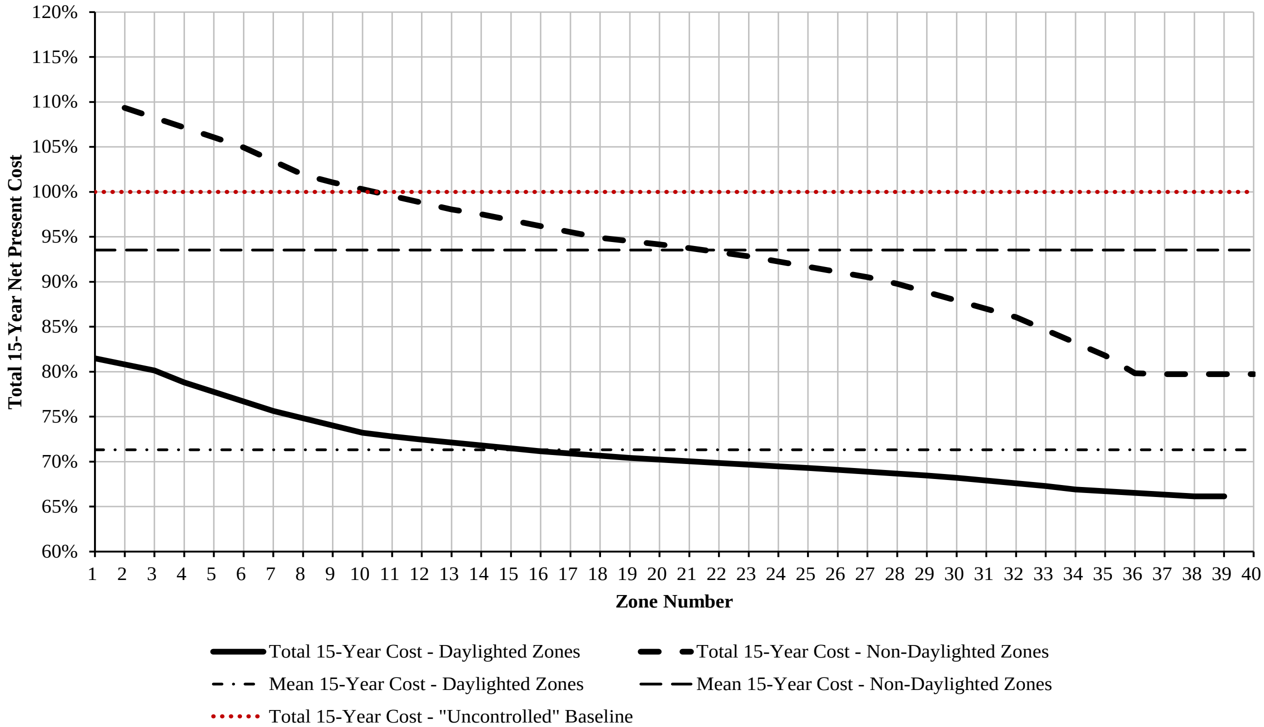

Figure 206: Simulation 29 Total Zone-by-Zone Costs 5-Minute Time Delay for Occupancy Sensing

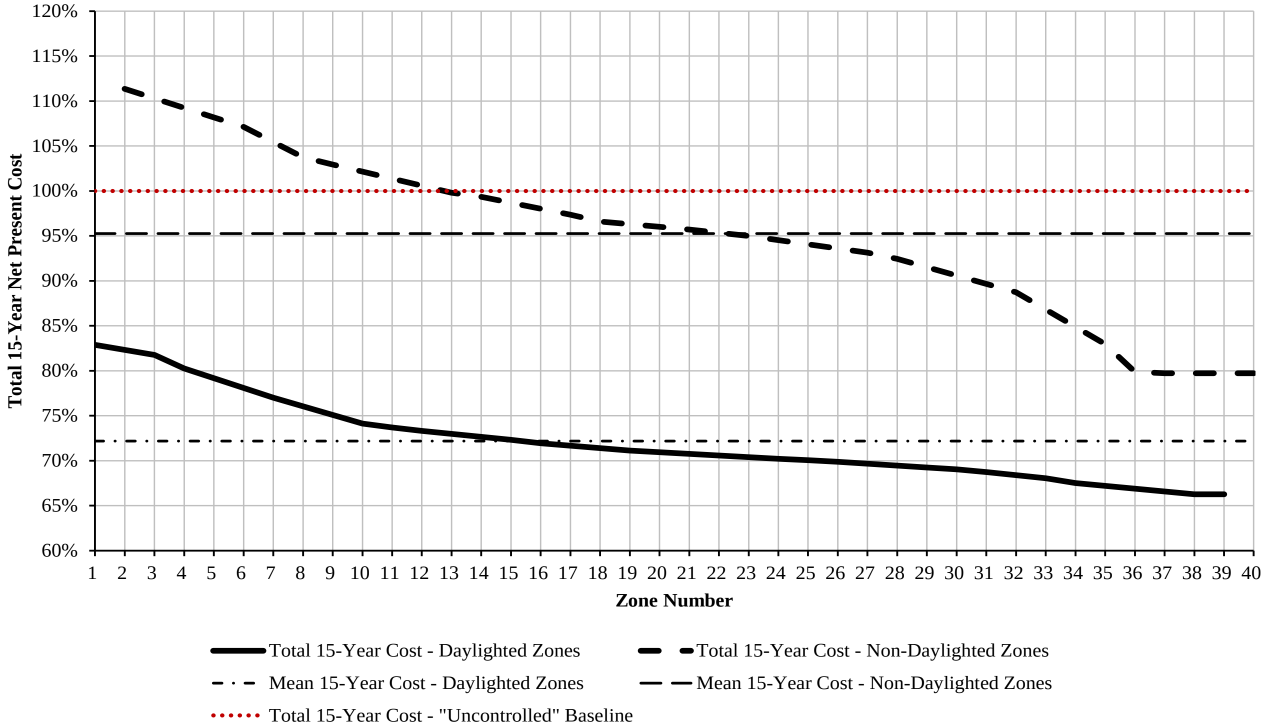

Figure 207: Simulation 29 Total Zone-by-Zone Costs 10-Minute Time Delay for Occupancy Sensing

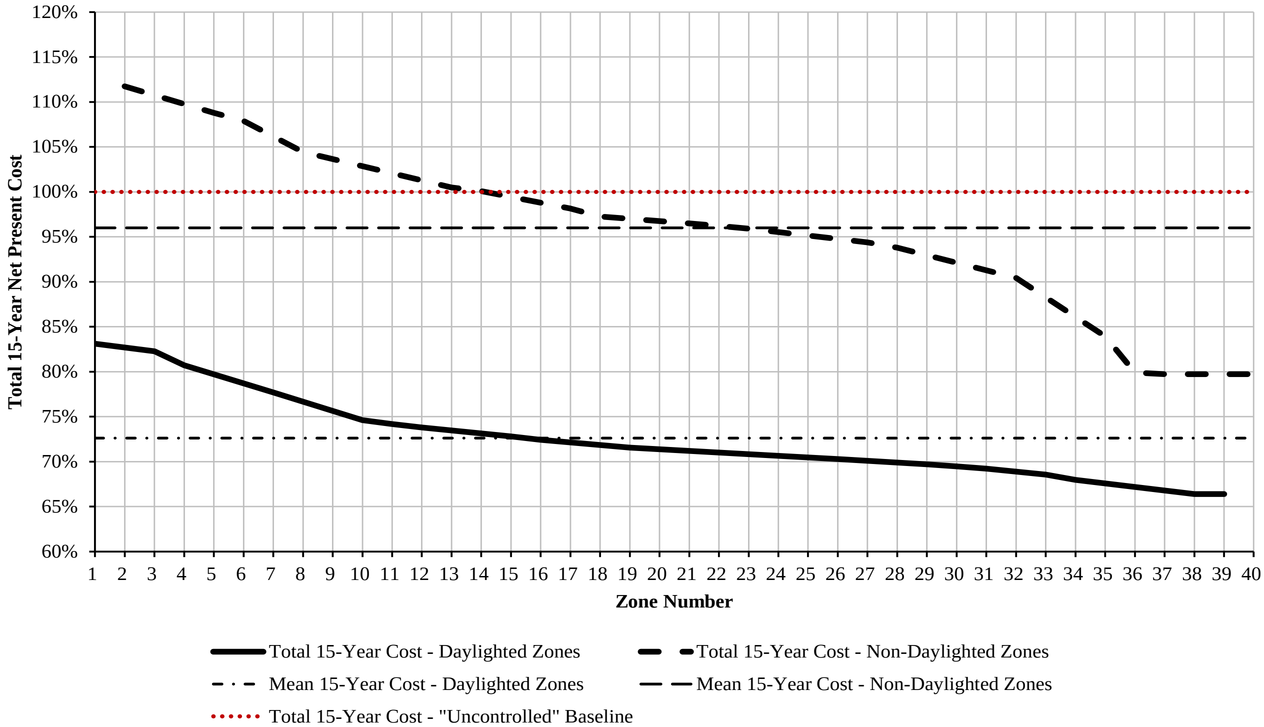

Figure 208: Simulation 29 Total Zone-by-Zone Costs
15-Minute Time Delay for Occupancy Sensing

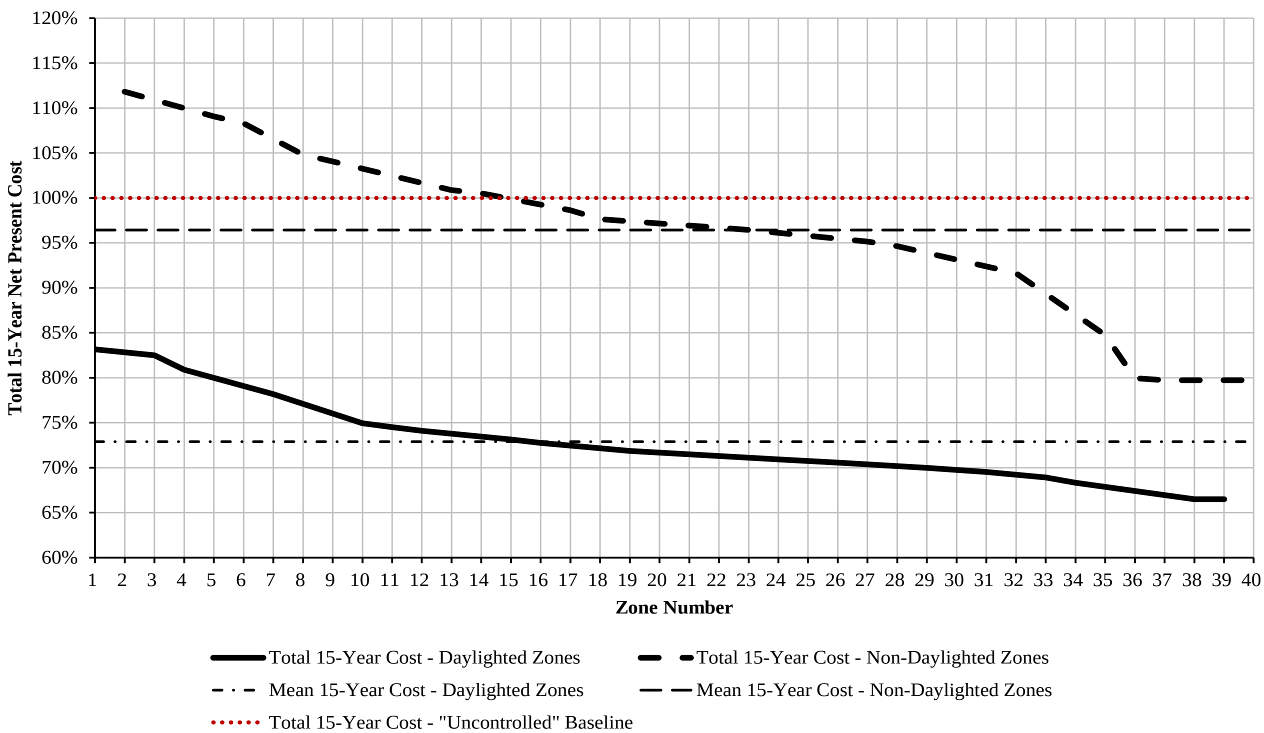

Figure 209: Simulation 29 Total Zone-by-Zone Costs
20-Minute Time Delay for Occupancy Sensing

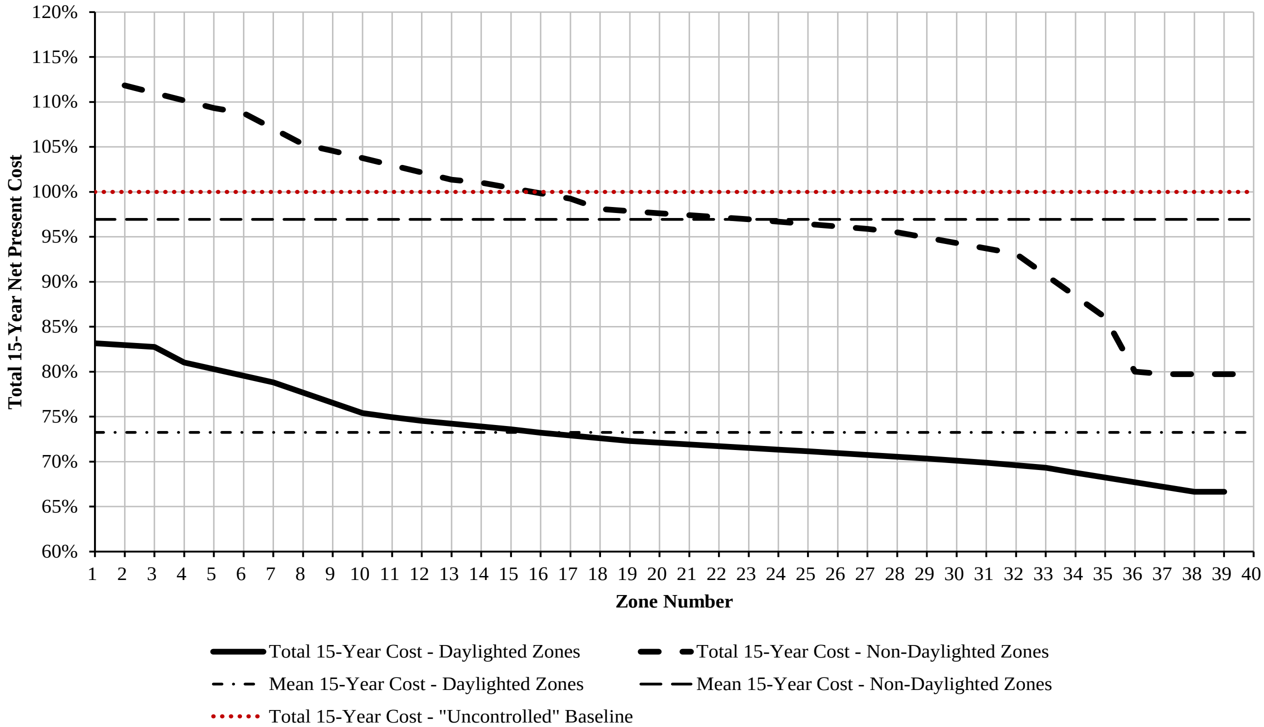

Figure 210: Simulation 29 Total Zone-by-Zone Costs
30-Minute Time Delay for Occupancy Sensing

11.30 Simulation 30: University Configuration 3

11.30.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	University 2
	Occupancy Schedule Variance	1%
	Transient Schedule Type	University 3
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	100
	Total # Floors	2
	# Occupancy Zones per Floor	6
	Daylight Availability	Poor
	# Daylighted Zones per Floor	3
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	10
	Delay Time 2	15
	Delay Time 3	20
	Delay Time 4	25
	Delay Time 5	30
	Daylight Switching Cost	$95
	Notes	Control system costs per controlled zone

Figure 211: Simulation 30 Input Variables

11.30.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	Daylighting Only	No Daylighting	With Daylighting	No Daylighting	With Daylighting	No Daylighting	With Daylighting	No Daylighting	With Daylighting	No Daylighting	With Daylighting
Occupancy Sensor Delay Time:	-	-	5.00	5.00	10.00	10.00	15.00	15.00	20.00	20.00	30.00	30.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:12:02	3665:48:07	3064:33:16	5023:49:00	4212:28:29	5600:39:48	4696:10:29	5898:07:27	4940:07:59	6208:56:30	5190:39:58
Average Zone Low Power Time:	0:00:00	0:00:00	5094:11:56	4569:16:59	3736:11:00	3421:21:46	3159:20:12	2937:39:46	2861:52:36	2693:42:17	2551:03:33	2443:10:18
Average Zone OFF Time:	0:00:00	1126:48:00	0:00:00	1126:09:45	0:00:00	1126:09:45	0:00:00	1126:09:45	0:00:00	1126:09:45	0:00:00	1126:09:45
Average % Time at High Power:	100.0%	87.1%	41.8%	35.0%	57.3%	48.1%	63.9%	53.6%	67.3%	56.4%	70.9%	59.3%
Average % Time at Low Power:	0.0%	0.0%	58.2%	52.2%	42.7%	39.1%	36.1%	33.5%	32.7%	30.8%	29.1%	27.9%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 44,146	$ 36,922	$ 31,502	$ 25,967	$ 34,886	$ 28,677	$ 36,304	$ 29,791	$ 37,036	$ 30,347	$ 37,806	$ 30,918
Lighting Equipment Cost:	$ 24,580	$ 24,580	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740
Daylighting Control Equipment Cost:	$ -	$ 567	$ -	$ 567	$ -	$ 567	$ -	$ 567	$ -	$ 567	$ -	$ 567
Occupancy Control Equipment Cost:	$ -	$ -	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986
Total 15-yr Cost (Initial + NPV of Energy):	$ 68,726	$ 62,070	$ 64,229	$ 59,261	$ 67,613	$ 61,970	$ 69,031	$ 63,084	$ 69,762	$ 63,641	$ 70,532	$ 64,211
Total 15-year Cost Savings:	N/A	9.7%	6.5%	4.5%	1.6%	0.2%	-0.4%	-1.6%	-1.5%	-2.5%	-2.6%	-3.5%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 12.74	$ 2.11	$ 2.77	$ 1.55	$ 2.36	$ 1.31	$ 2.19	$ 1.19	$ 2.11	$ 1.06	$ 2.02
Approximate Annual Energy Cost Savings:	N/A	$ 482	$ 843	$ 1,212	$ 617	$ 1,031	$ 523	$ 957	$ 474	$ 920	$ 423	$ 882

Figure 212: Simulation 30 Results

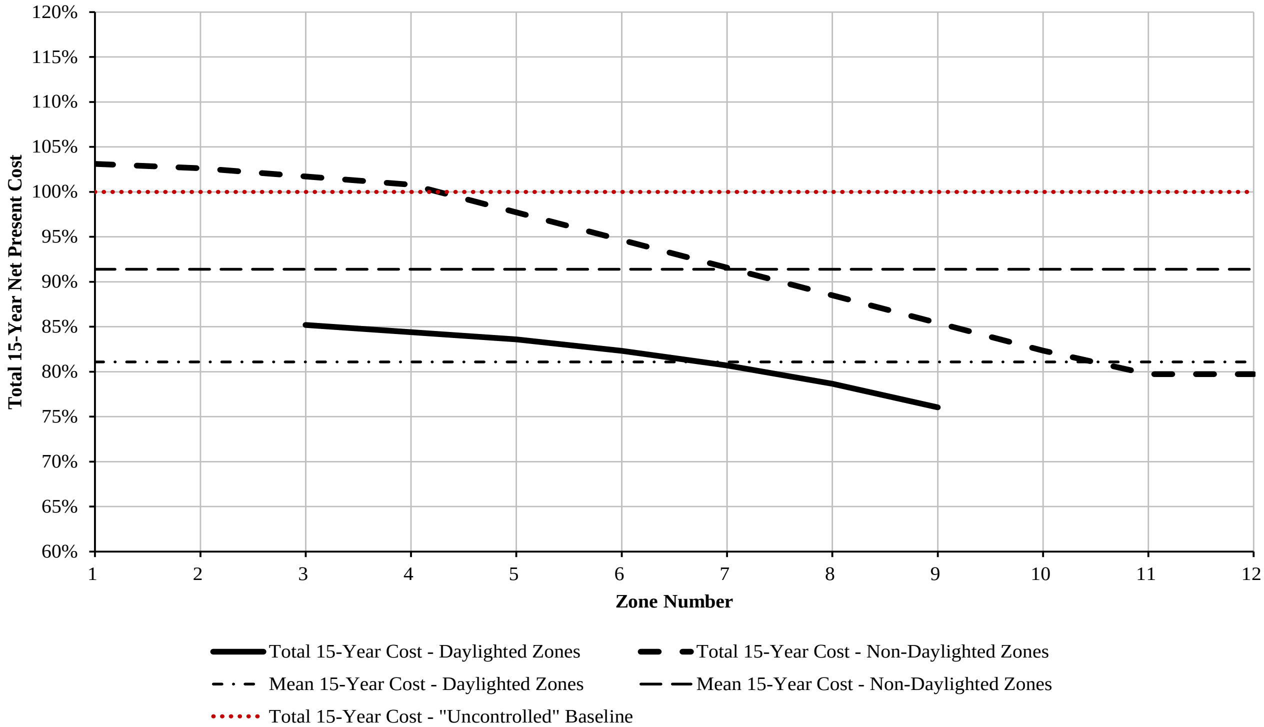

Figure 213: Simulation 30 Total Zone-by-Zone Costs
5-Minute Time Delay for Occupancy Sensing

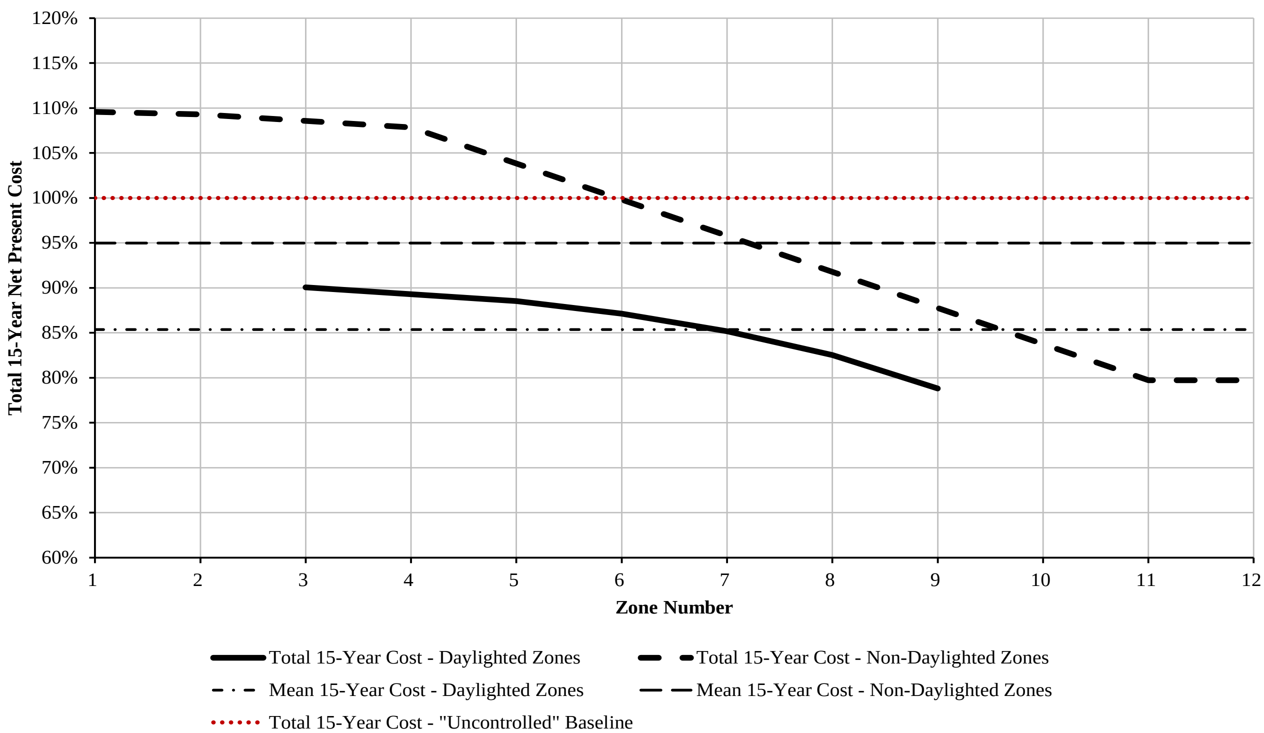

Figure 214: Simulation 30 Total Zone-by-Zone Costs
10-Minute Time Delay for Occupancy Sensing

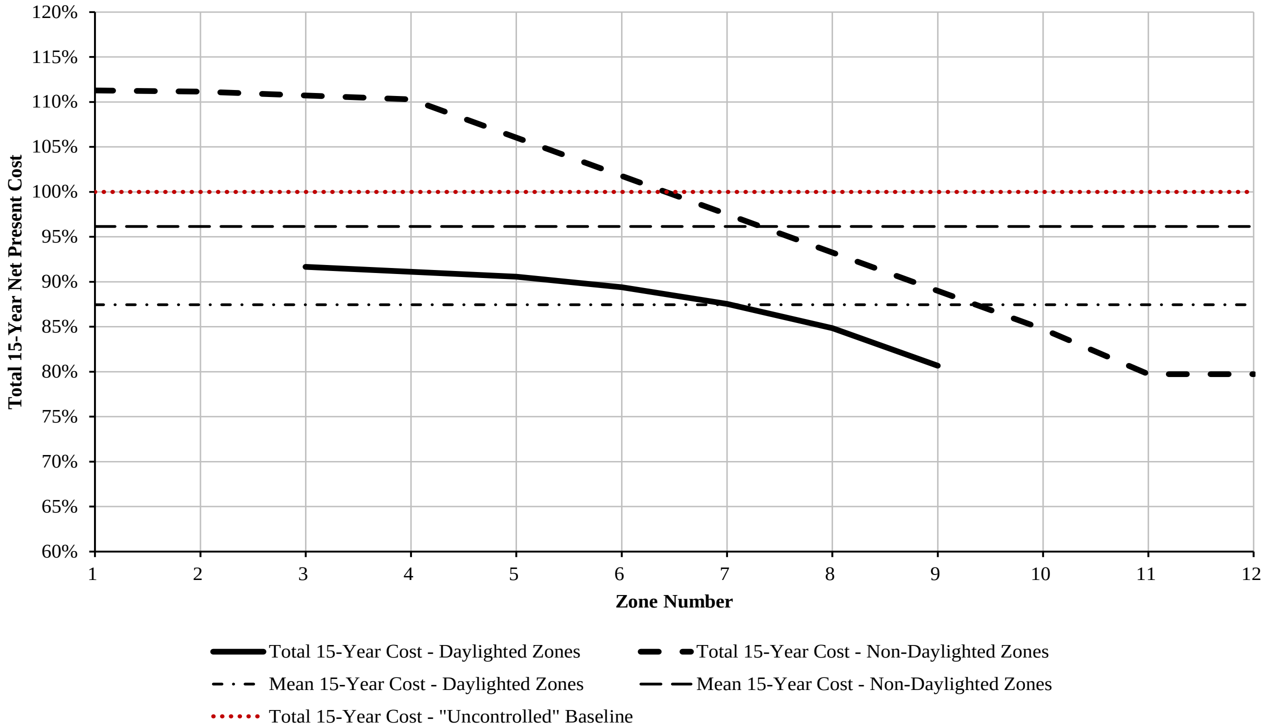

Figure 215: Simulation 30 Total Zone-by-Zone Costs
15-Minute Time Delay for Occupancy Sensing

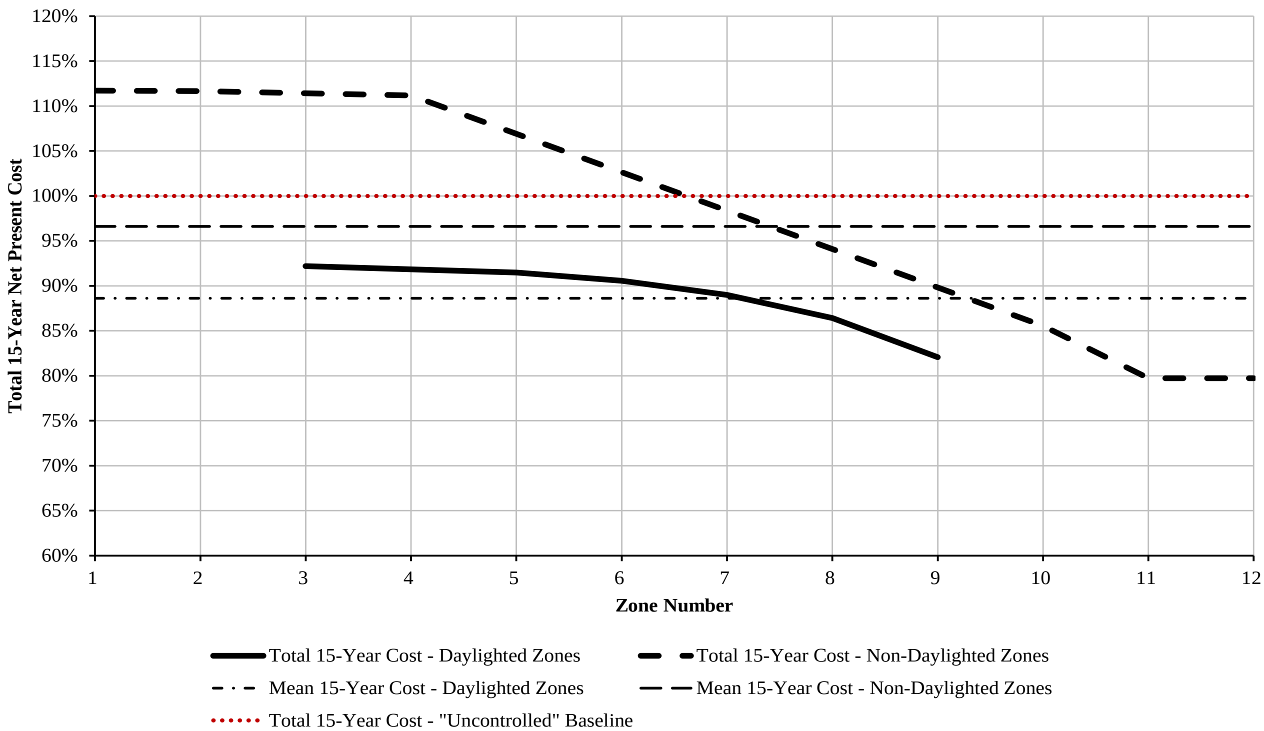

Figure 216: Simulation 30 Total Zone-by-Zone Costs
20-Minute Time Delay for Occupancy Sensing

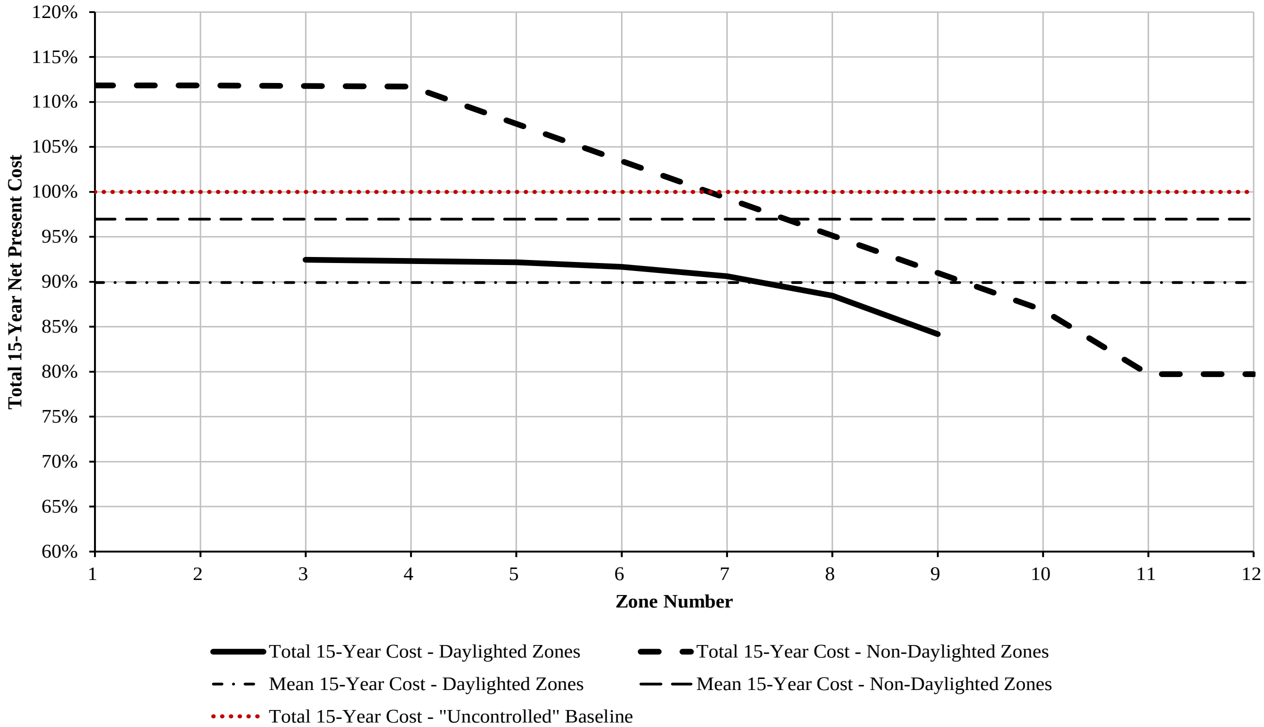

Figure 217: Simulation 30 Total Zone-by-Zone Costs 30-Minute Time Delay for Occupancy Sensing

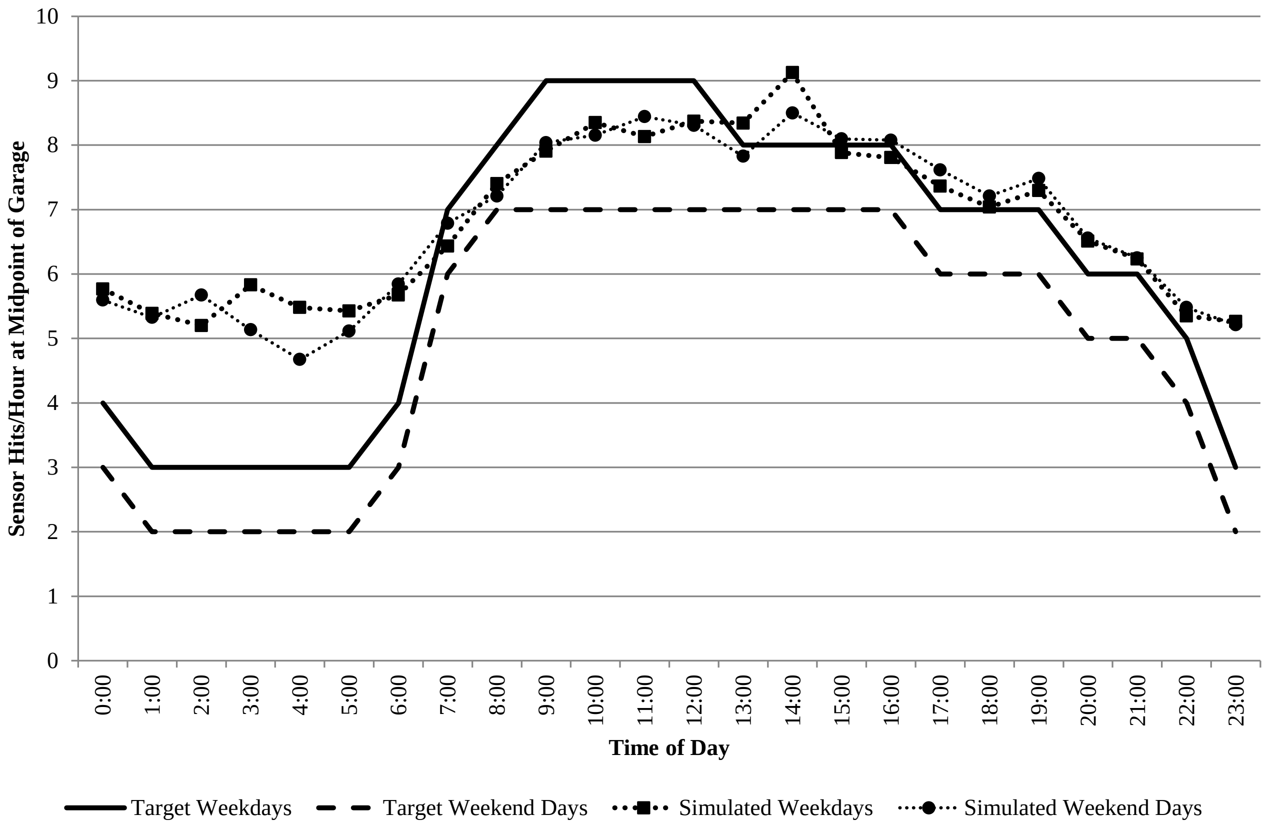

Figure 218: Simulation 30 Activity at Garage Mid-Point Compared to Activity Curve from Pilot Programs

11.31 Simulation 31: University Configuration 4

11.31.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	University 2
	Occupancy Schedule Variance	1%
	Transient Schedule Type	University 4
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	100
	Total # Floors	2
	# Occupancy Zones per Floor	6
	Daylight Availability	Poor
	# Daylighted Zones per Floor	3
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	10
	Delay Time 2	15
	Delay Time 3	20
	Delay Time 4	25
	Delay Time 5	30
	Daylight Switching Cost	$95
	Notes	Control system costs per controlled zone

Figure 219: Simulation 31 Input Variables

11.31.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	5.00	5.00	10.00	10.00	15.00	15.00	20.00	20.00	30.00	30.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:12:02	3053:40:08	2480:07:42	4375:36:53	3621:25:19	5039:42:36	4217:29:34	5422:24:58	4566:46:31	5836:56:10	4942:44:39
Average Zone Low Power Time:	0:00:00	0:00:00	5706:19:52	5153:42:03	4384:23:09	4012:24:25	3720:17:23	3416:20:12	3337:35:01	3067:03:15	2923:03:50	2691:05:07
Average Zone OFF Time:	0:00:00	1126:48:00	0:00:00	1126:10:15	0:00:00	1126:10:15	0:00:00	1126:10:15	0:00:00	1126:10:15	0:00:00	1126:10:15
Average % Time at High Power:	100.0%	87.1%	34.9%	28.3%	49.9%	41.3%	57.5%	48.1%	61.9%	52.1%	66.6%	56.4%
Average % Time at Low Power:	0.0%	0.0%	65.1%	58.8%	50.1%	45.8%	42.5%	39.0%	38.1%	35.0%	33.4%	30.7%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 44,146	$ 36,922	$ 30,279	$ 24,812	$ 33,611	$ 27,575	$ 35,206	$ 28,959	$ 36,101	$ 29,750	$ 37,064	$ 30,592
Lighting Equipment Cost:	$ 24,580	$ 24,580	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740
Daylighting Control Equipment Cost:	$ -	$ 567	$ -	$ 567	$ -	$ 567	$ -	$ 567	$ -	$ 567	$ -	$ 567
Occupancy Control Equipment Cost:	$ -	$ -	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986
Total 15-yr Cost (Initial + NPV of Energy):	$ 68,726	$ 62,070	$ 63,006	$ 58,106	$ 66,338	$ 60,869	$ 67,932	$ 62,253	$ 68,827	$ 63,044	$ 69,790	$ 63,885
Total 15-year Cost Savings:	N/A	9.7%	8.3%	6.4%	3.5%	1.9%	1.2%	-0.3%	-0.1%	-1.6%	-1.5%	-2.9%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 12.74	$ 2.32	$ 2.95	$ 1.76	$ 2.53	$ 1.49	$ 2.32	$ 1.34	$ 2.20	$ 1.18	$ 2.07
Approximate Annual Energy Cost Savings:	N/A	$ 482	$ 924	$ 1,289	$ 702	$ 1,105	$ 596	$ 1,012	$ 536	$ 960	$ 472	$ 904

Figure 220: Simulation 31 Results

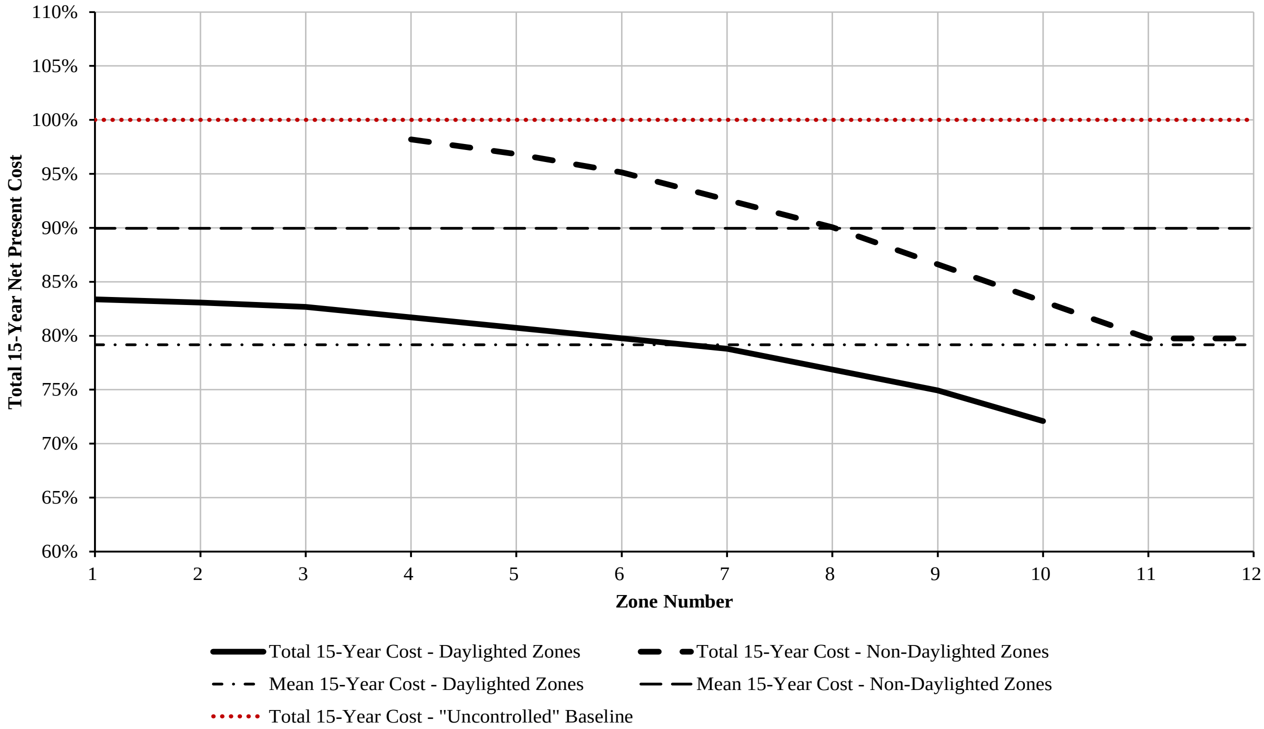

Figure 221: Simulation 31 Total Zone-by-Zone Costs
5-Minute Time Delay for Occupancy Sensing

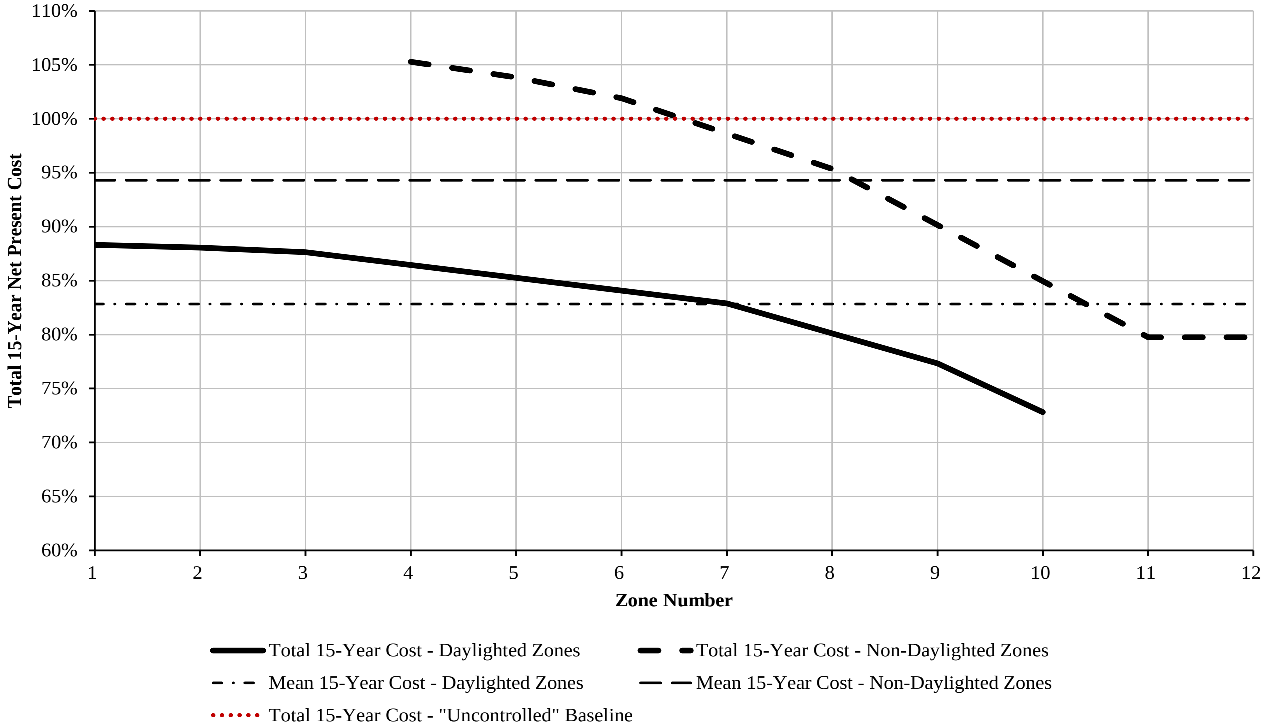

Figure 222: Simulation 31 Total Zone-by-Zone Costs
10-Minute Time Delay for Occupancy Sensing

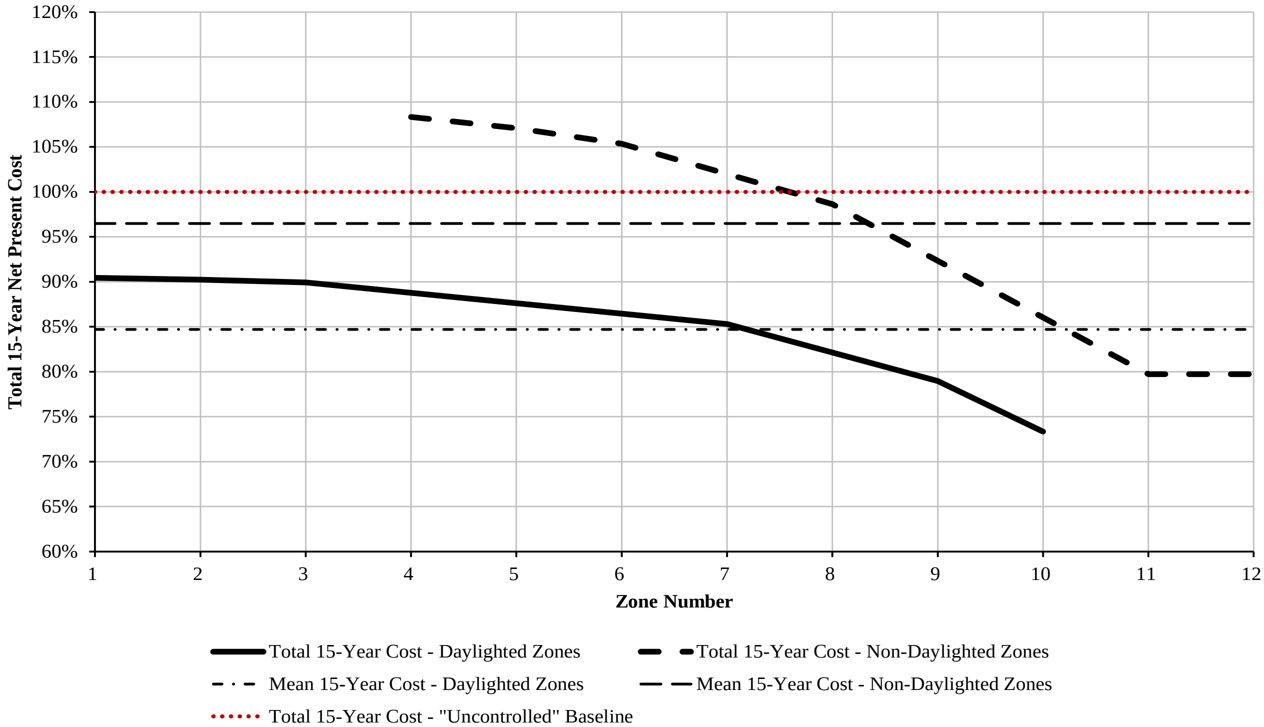

Figure 223: Simulation 31 Total Zone-by-Zone Costs
15-Minute Time Delay for Occupancy Sensing

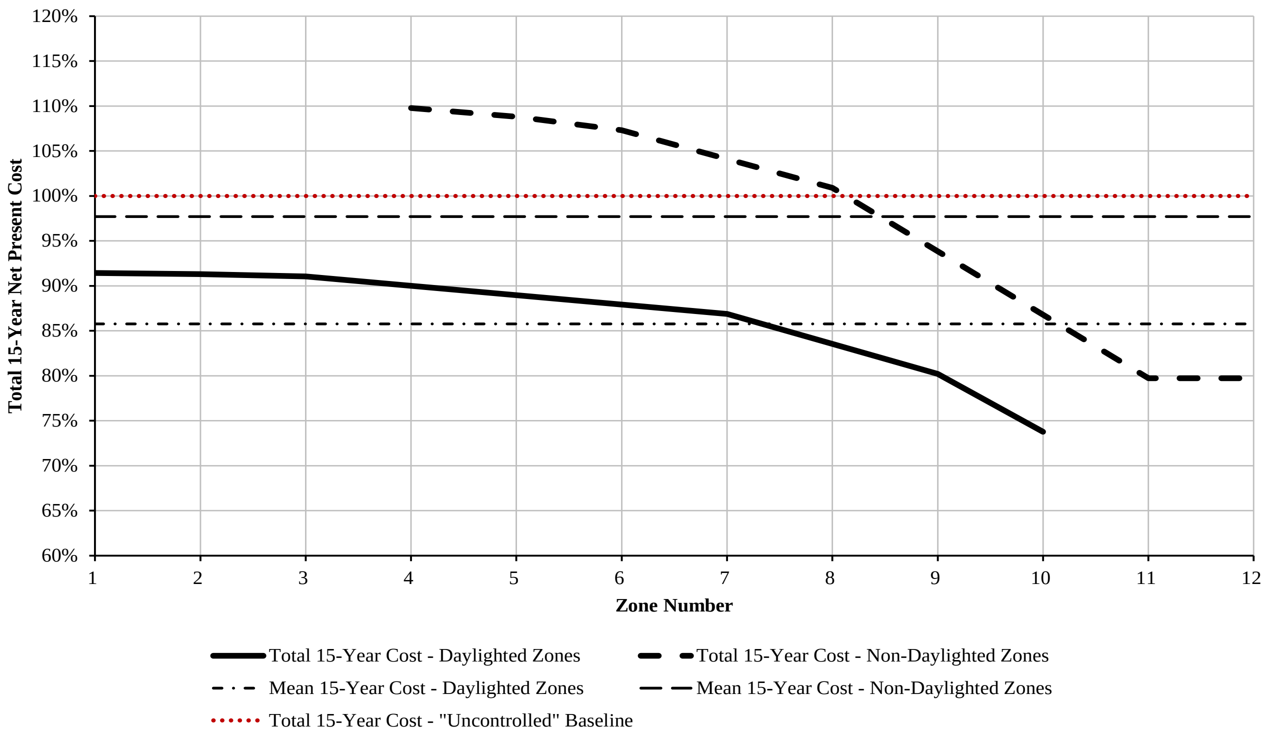

Figure 224: Simulation 31 Total Zone-by-Zone Costs
20-Minute Time Delay for Occupancy Sensing

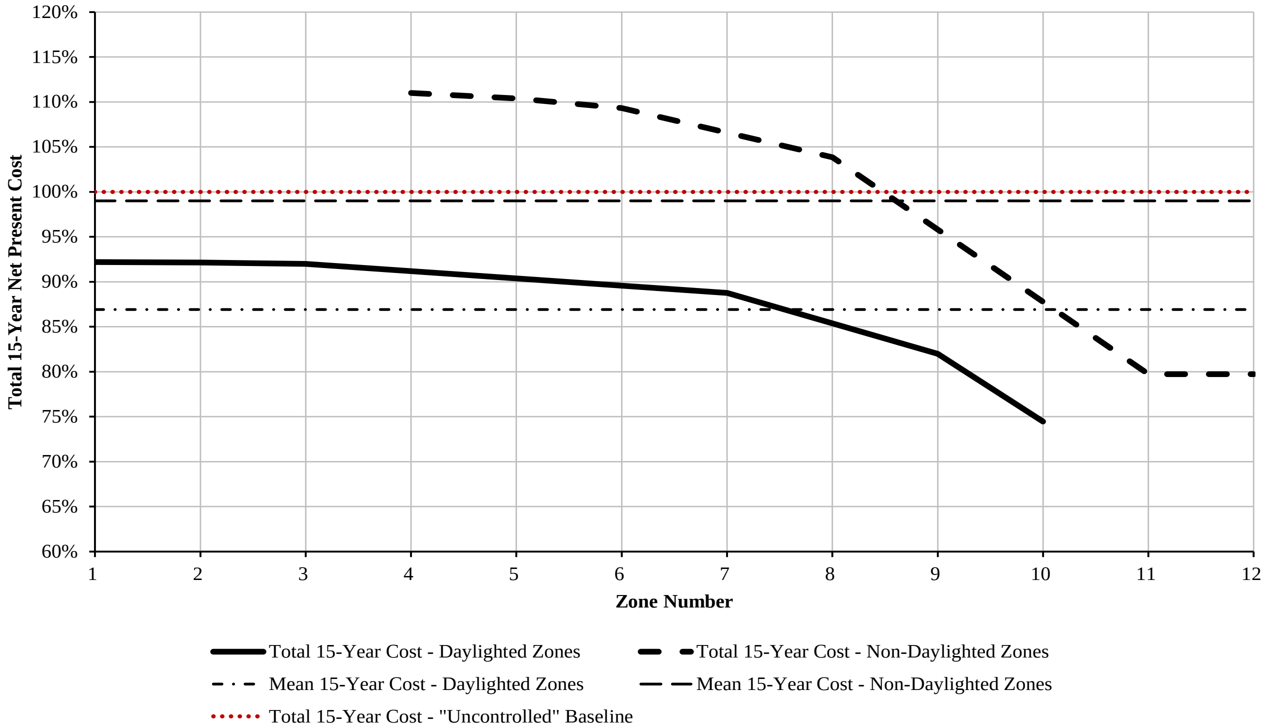

Figure 225: Simulation 31 Total Zone-by-Zone Costs
30-Minute Time Delay for Occupancy Sensing

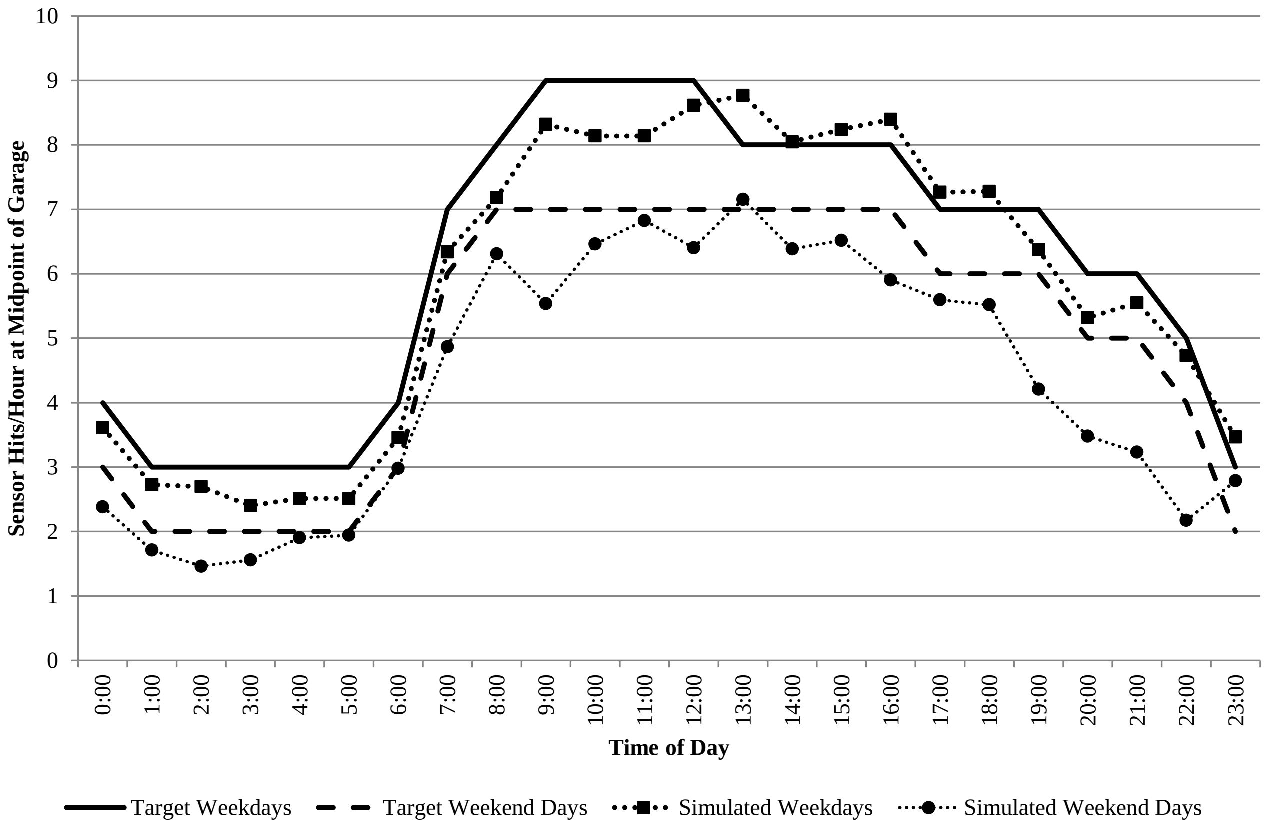

Figure 226: Simulation 31 Activity at Garage Mid-Point Compared to Activity Curve from Pilot Programs

11.32 Simulation 32: University Configuration 5

11.32.1 Simulation Inputs

PARAMETER		INPUT VALUE
Scheduling	Occupancy Schedule Type	University 2
	Occupancy Schedule Variance	1%
	Transient Schedule Type	University 5
	Transient Schedule Variance	1%
Parking Garage Information	Total # Spaces	100
	Total # Floors	2
	# Occupancy Zones per Floor	6
	Daylight Availability	Poor
	# Daylighted Zones per Floor	3
Luminaire Information	Luminaire Description	4' (2) T8 Striplight with Wireguard, Bi-Level Ballast
	Uncontrolled Luminaire Total Unit Cost	$512
	Controlled Luminaire Total Unit Cost	$557
	High Power	54
	Low Power	27
	OC Spacing E-W	22
	OC Spacing N-S	21
	# Luminaires per Control Zone	4
Control System Information	Occupancy Sensing Cost	$499
	Delay Time 1	10
	Delay Time 2	15
	Delay Time 3	20
	Delay Time 4	25
	Delay Time 5	30
	Daylight Switching Cost	$95
	Notes	Control system costs per controlled zone

Figure 227: Simulation 32 Input Variables

11.32.2 Simulation Results

			CS1		CS2		CS3		CS4		CS5	
	Baseline	**Daylighting Only**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**	**No Daylighting**	**With Daylighting**
Occupancy Sensor Delay Time:	-	-	5.00	5.00	10.00	10.00	15.00	15.00	20.00	20.00	30.00	30.00
Daylight Availability:	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor	0	Poor
Average Zone High Power Time:	8760:00:00	7633:12:02	3315:59:42	2752:47:41	4655:53:56	3910:14:44	5294:22:34	4474:29:44	5648:43:23	4789:37:28	6017:36:23	5114:44:15
Average Zone Low Power Time:	0:00:00	0:00:00	5444:00:19	4881:01:03	4104:06:04	3723:34:02	3465:37:28	3159:19:02	3111:16:37	2844:11:20	2742:23:37	2519:04:30
Average Zone OFF Time:	0:00:00	1126:48:00	0:00:00	1126:11:15	0:00:00	1126:11:15	0:00:00	1126:11:15	0:00:00	1126:11:15	0:00:00	1126:11:15
Average % Time at High Power:	100.0%	87.1%	37.9%	31.4%	53.1%	44.6%	60.4%	51.1%	64.5%	54.7%	68.7%	58.4%
Average % Time at Low Power:	0.0%	0.0%	62.1%	55.7%	46.9%	42.5%	39.6%	36.1%	35.5%	32.5%	31.3%	28.8%
Average % Time OFF:	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%	0.0%	12.9%
15-yr Energy Cost:	$ 44,146	$ 36,922	$ 30,857	$ 25,433	$ 34,211	$ 28,205	$ 35,740	$ 29,499	$ 36,574	$ 30,209	$ 37,445	$ 30,944
Lighting Equipment Cost:	$ 24,580	$ 24,580	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740	$ 26,740
Daylighting Control Equipment Cost:	$ -	$ 567	$ -	$ 567	$ -	$ 567	$ -	$ 567	$ -	$ 567	$ -	$ 567
Occupancy Control Equipment Cost:	$ -	$ -	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986	$ 5,986
Total 15-yr Cost (Initial + NPV of Energy):	$ 68,726	$ 62,070	$ 63,583	$ 58,727	$ 66,937	$ 61,499	$ 68,466	$ 62,793	$ 69,300	$ 63,503	$ 70,172	$ 64,237
Total 15-year Cost Savings:	N/A	9.7%	7.5%	5.4%	2.6%	0.9%	0.4%	-1.2%	-0.8%	-2.3%	-2.1%	-3.5%
Total 15-year Energy Cost Savings per Dollar of Investment:	N/A	$ 12.74	$ 2.22	$ 2.86	$ 1.66	$ 2.43	$ 1.40	$ 2.23	$ 1.26	$ 2.13	$ 1.12	$ 2.01
Approximate Annual Energy Cost Savings:	N/A	$ 482	$ 886	$ 1,247	$ 662	$ 1,063	$ 560	$ 976	$ 505	$ 929	$ 447	$ 880

Figure 228: Simulation 32 Results

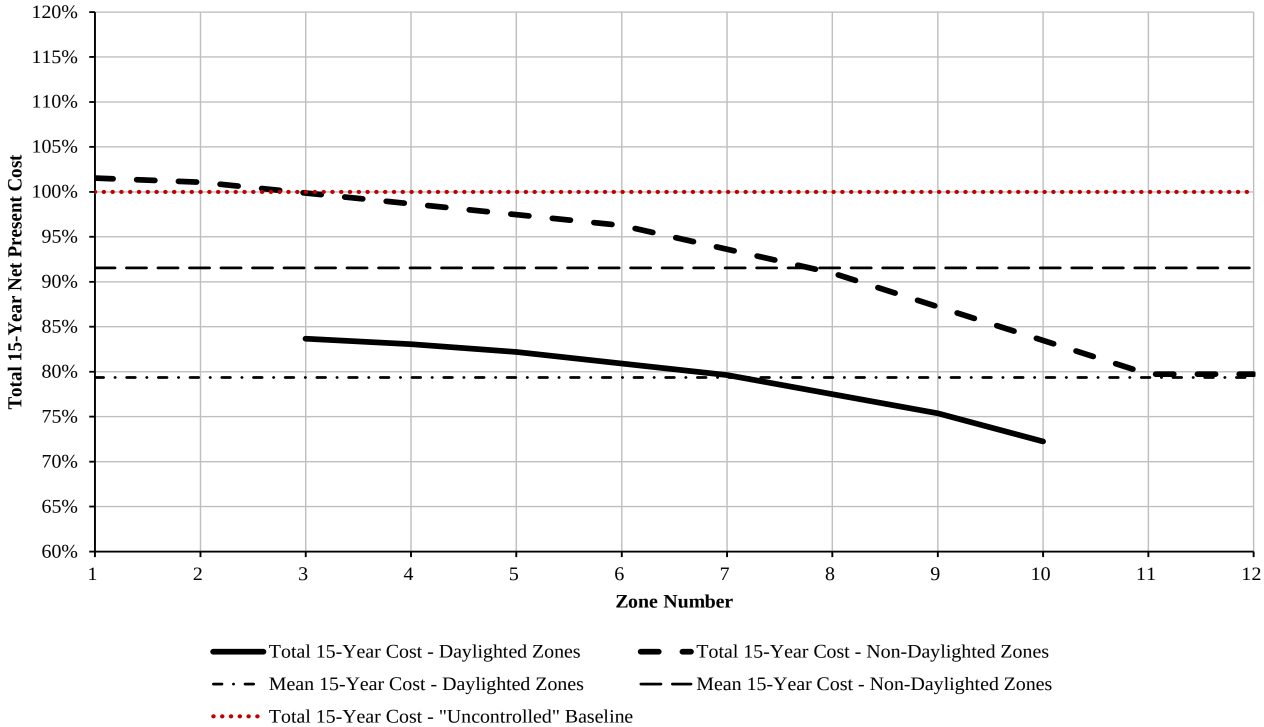

Figure 229: Simulation 32 Total Zone-by-Zone Costs
5-Minute Time Delay for Occupancy Sensing

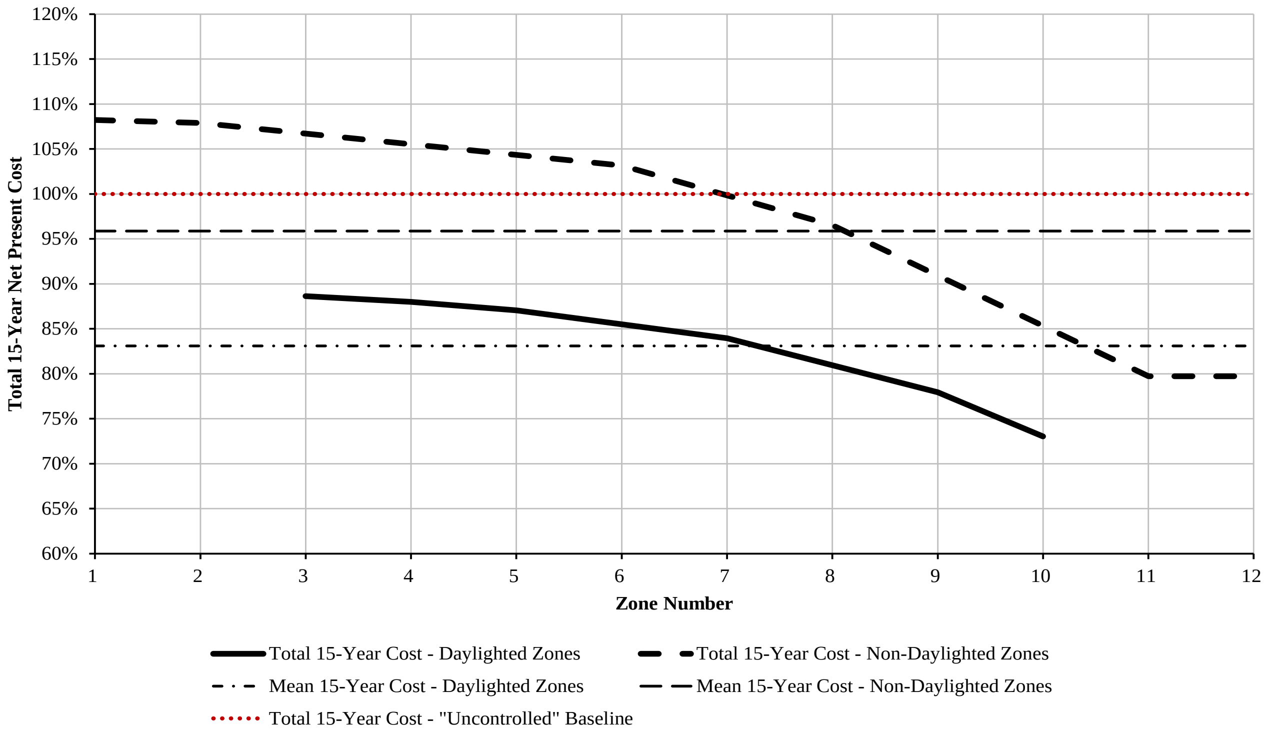

Figure 230: Simulation 32 Total Zone-by-Zone Costs
10-Minute Time Delay for Occupancy Sensing

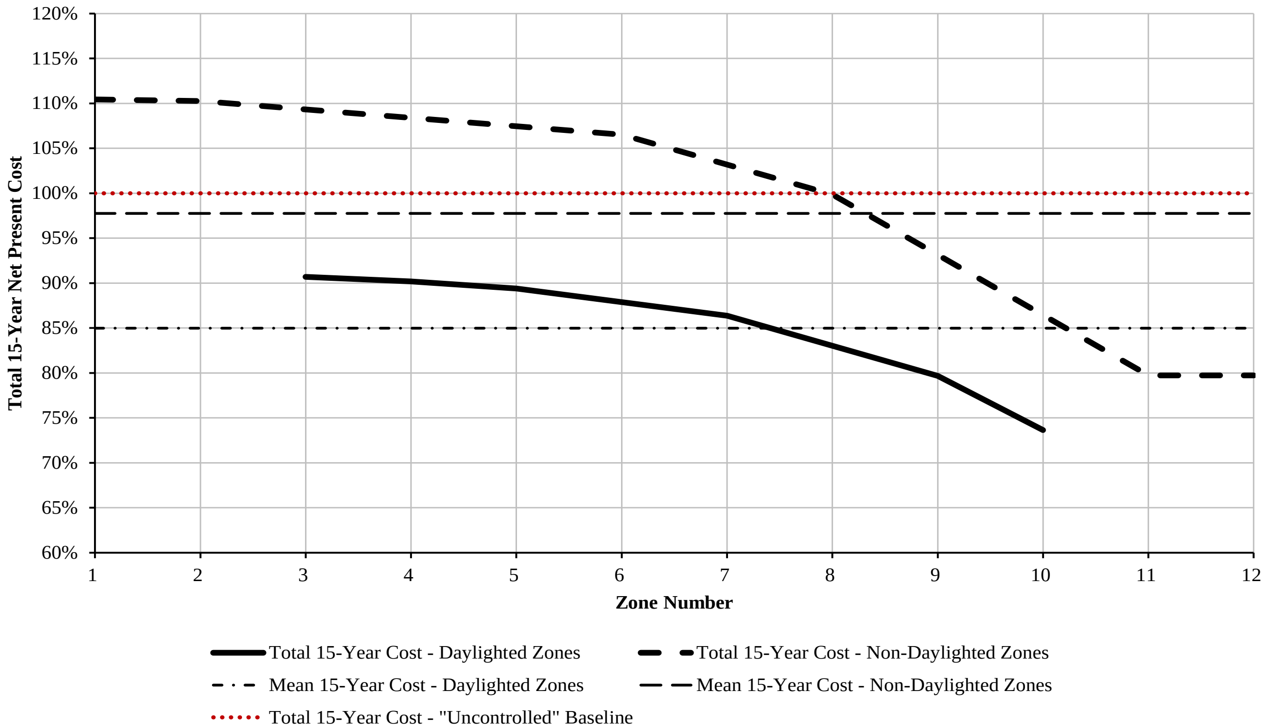

Figure 231: Simulation 32 Total Zone-by-Zone Costs
15-Minute Time Delay for Occupancy Sensing

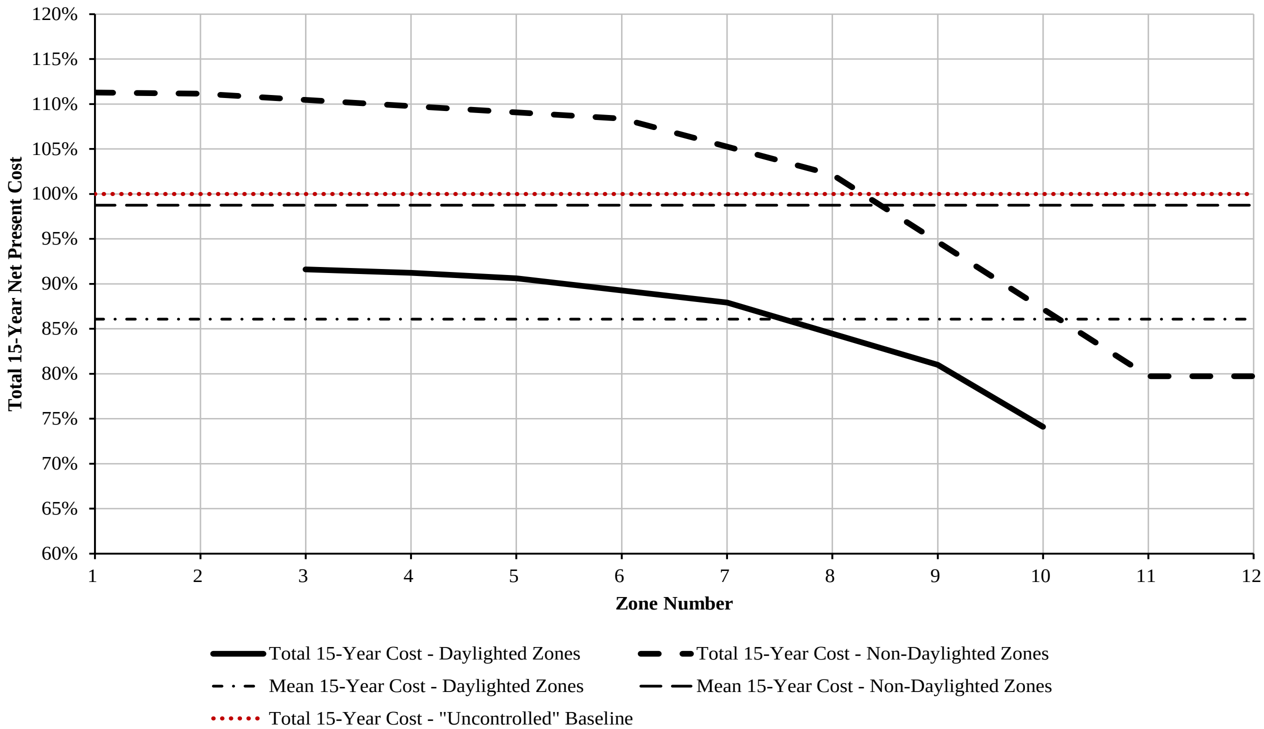

Figure 232: Simulation 32 Total Zone-by-Zone Costs
20-Minute Time Delay for Occupancy Sensing

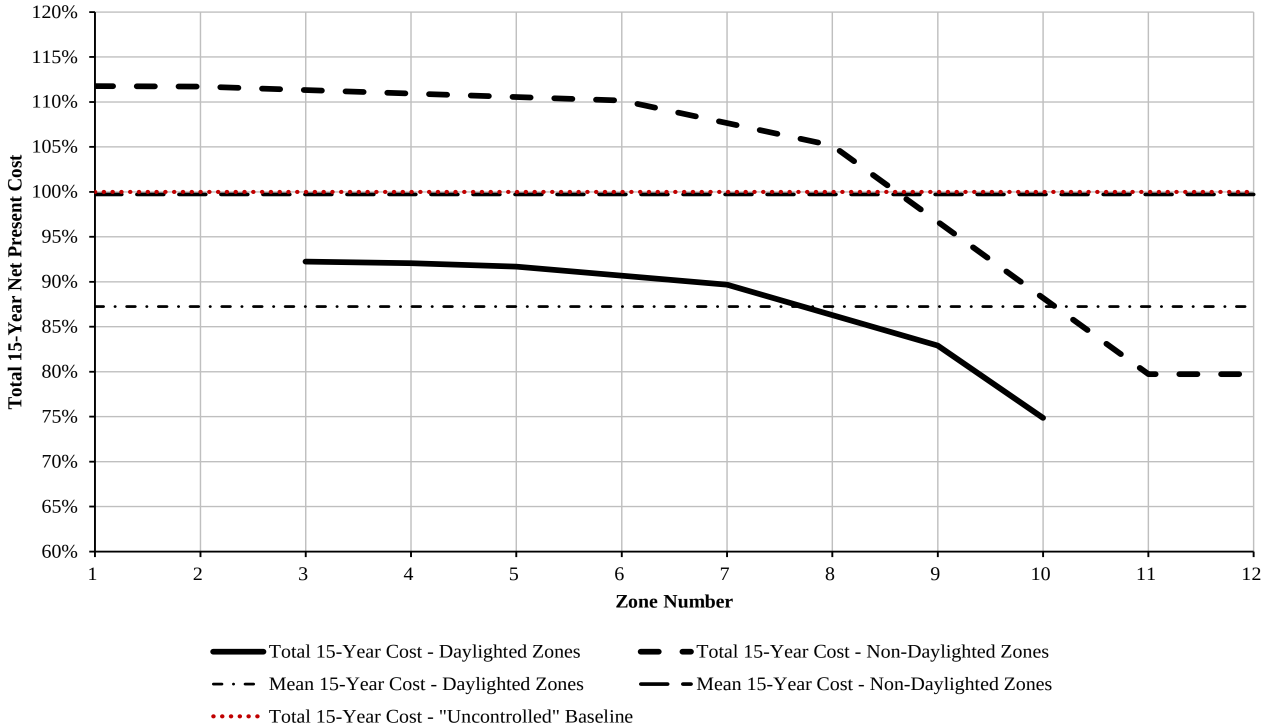

Figure 233: Simulation 32 Total Zone-by-Zone Costs
30-Minute Time Delay for Occupancy Sensing

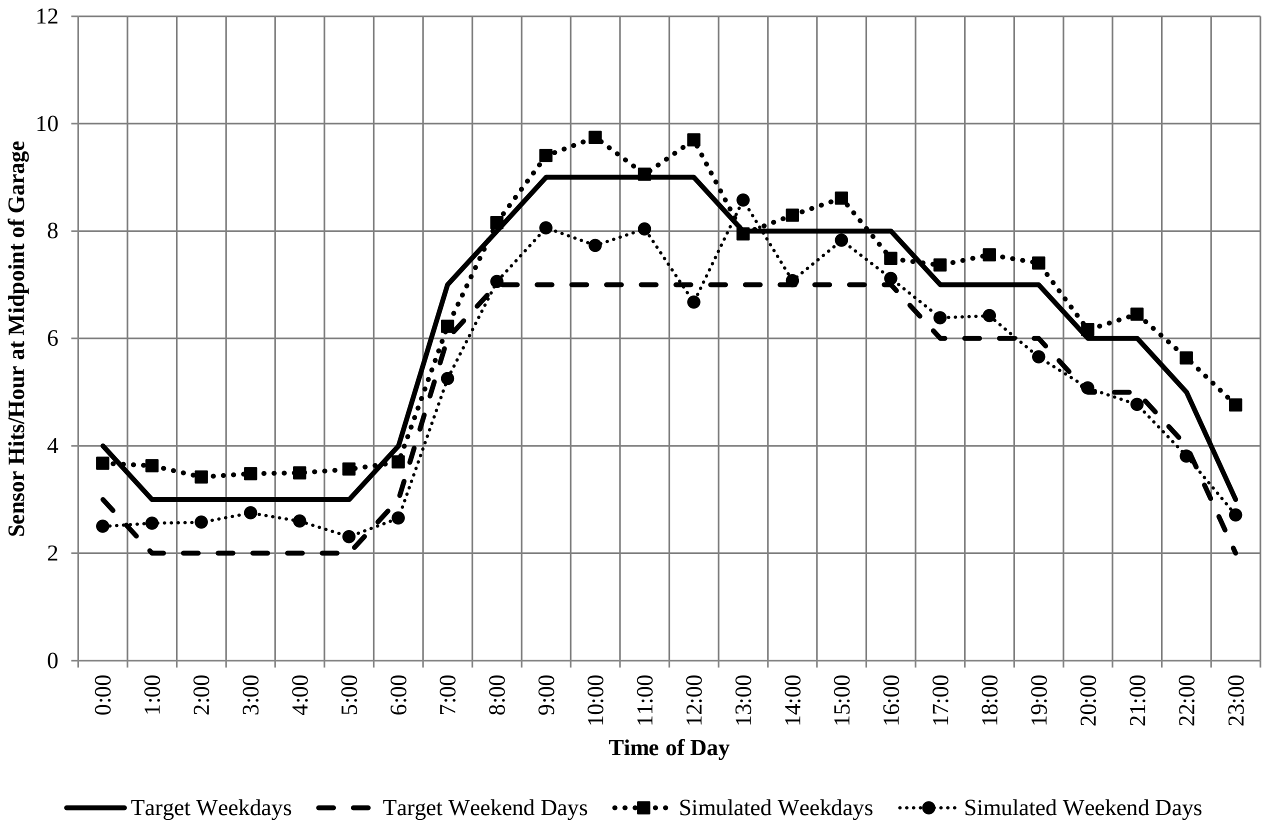

Figure 234: Simulation 32 Activity at Garage Mid-Point Compared to Activity Curve from Pilot Programs

11.33 Simulation Results Analysis: Fraction of Each Floor Daylighted

Comparing simulations 1, 2 and 3.

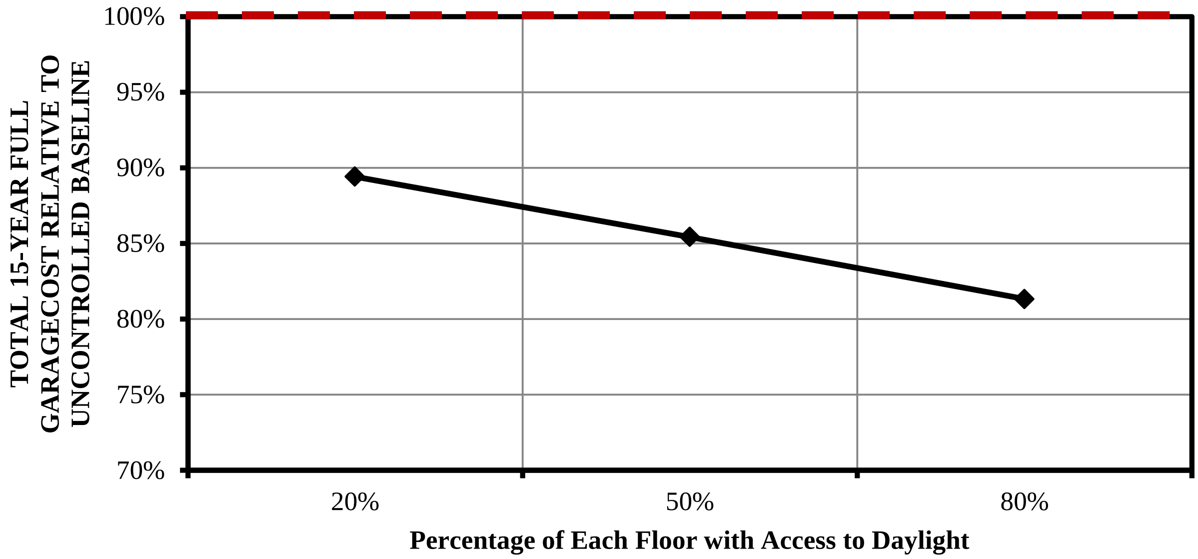

Figure 235: Impact of the Percentage of Each Floor with Access to Daylight Baseline Fluorescent Lighting System

11.34 Simulation Results Analysis: Daylight Availability

Comparing simulations 1, 4 and 5.

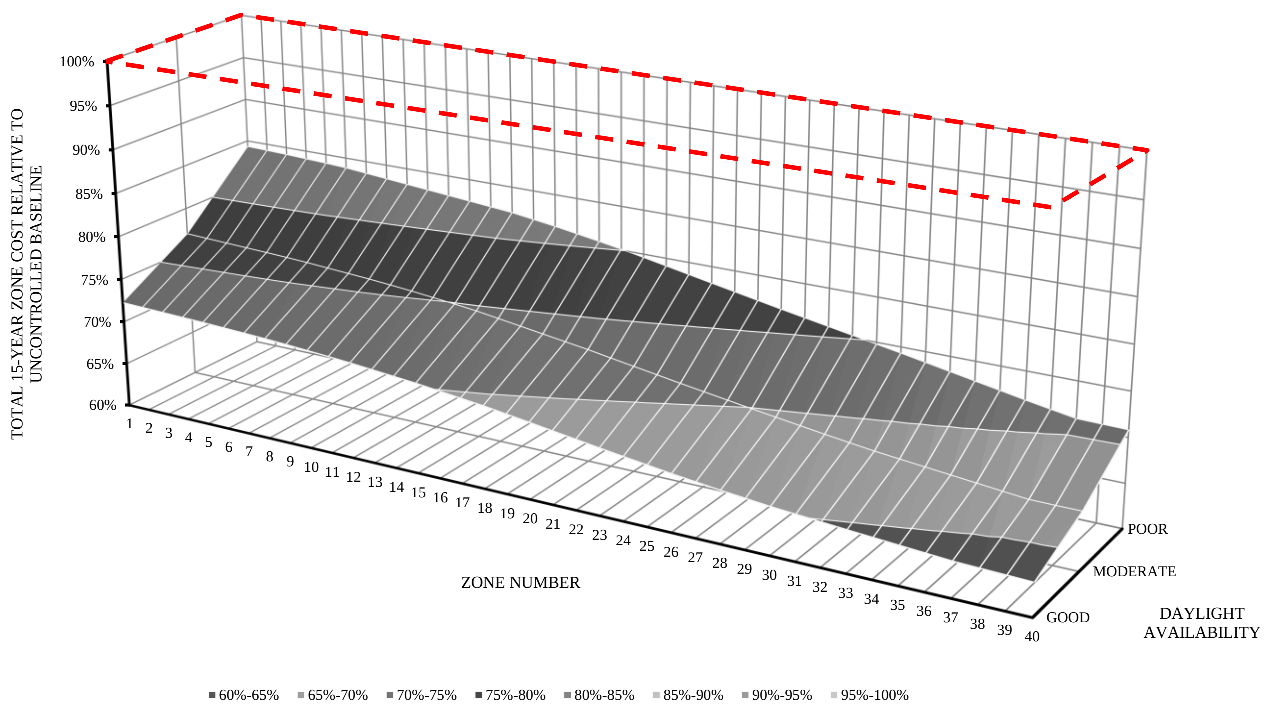

Figure 236 Zone-by-Zone Total Relative 15-Year Cost showing Impact of Daylight Availability 1-Minute Time Delay for Occupancy Sensing

% Daylighted	15-Year Relative Cost
Baseline	100%
20%	89%
50%	85%
80%	81%

Figure 237: Total Garage Relative 15-Year Cost showing Impact of Daylight Availability

11.35 Simulation Results Analysis: Source Type

Comparing simulations 1, 6, 7 and 8.

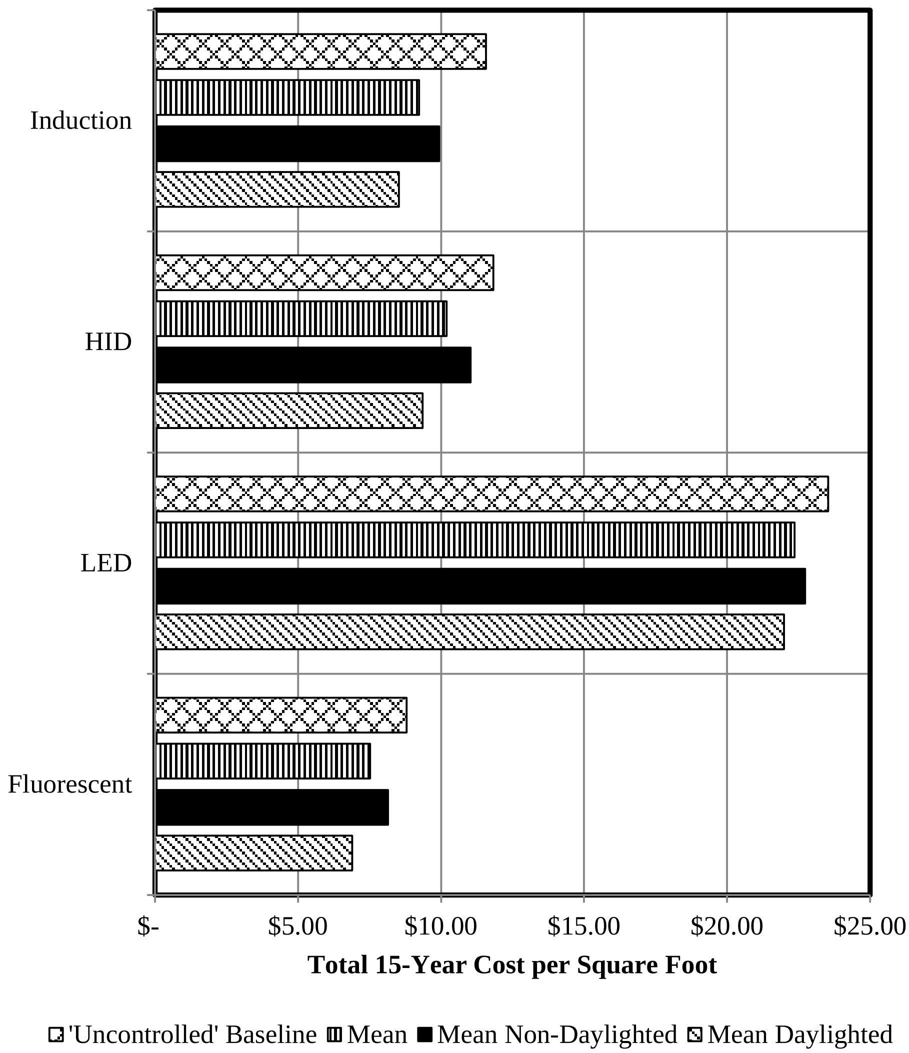

Figure 238: Electric Light Source Technology TDV Cost Comparison

11.36 Simulation Results Analysis: Transportation Garage Activity Levels

Comparing simulations 11, 12 and 13.

	Occupancy Sensor Delay Time				
Activity Level	**1**	**2.5**	**5**	**7.5**	**10**
High	85%	91%	94%	95%	96%
Medium	80%	83%	85%	86%	87%
Low	78%	79%	81%	81%	82%

Figure 239: Total Garage Relative 15-Year Cost showing Impact of Activity Level and Including Daylighting Control for Transportation Garage

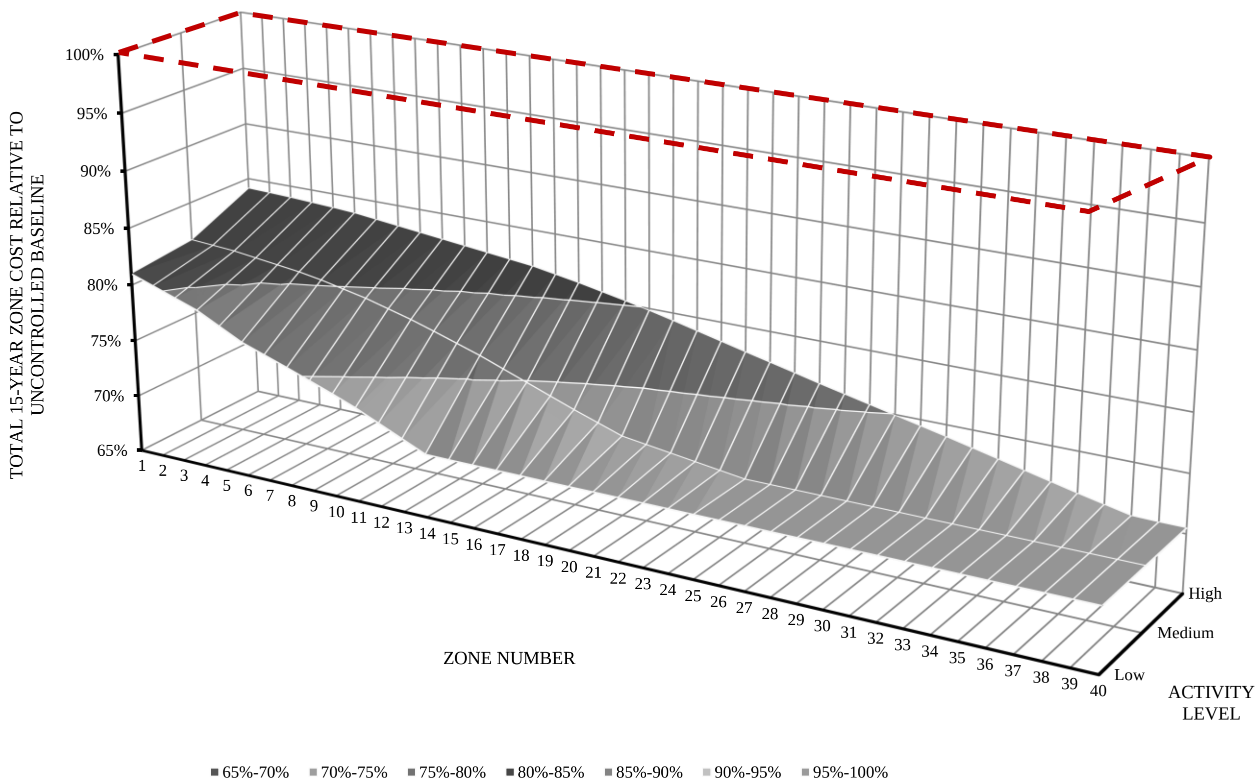

Figure 240: Zone-By-Zone Relative 15-Year Cost showing Impact of Activity Level on Daylighted Zones for Transportation Garage 1-Minute Time Delay for Occupancy Sensing

	Occupancy Sensor Delay Time				
Activity Level	**1**	**2.5**	**5**	**7.5**	**10**
High	92%	99%	102%	104%	105%
Medium	86%	90%	92%	93%	94%
Low	83%	85%	87%	87%	88%

Figure 241: Total Garage Relative 15-Year Cost showing Impact of Activity Level and Without Daylighting Control for Transportation Garage

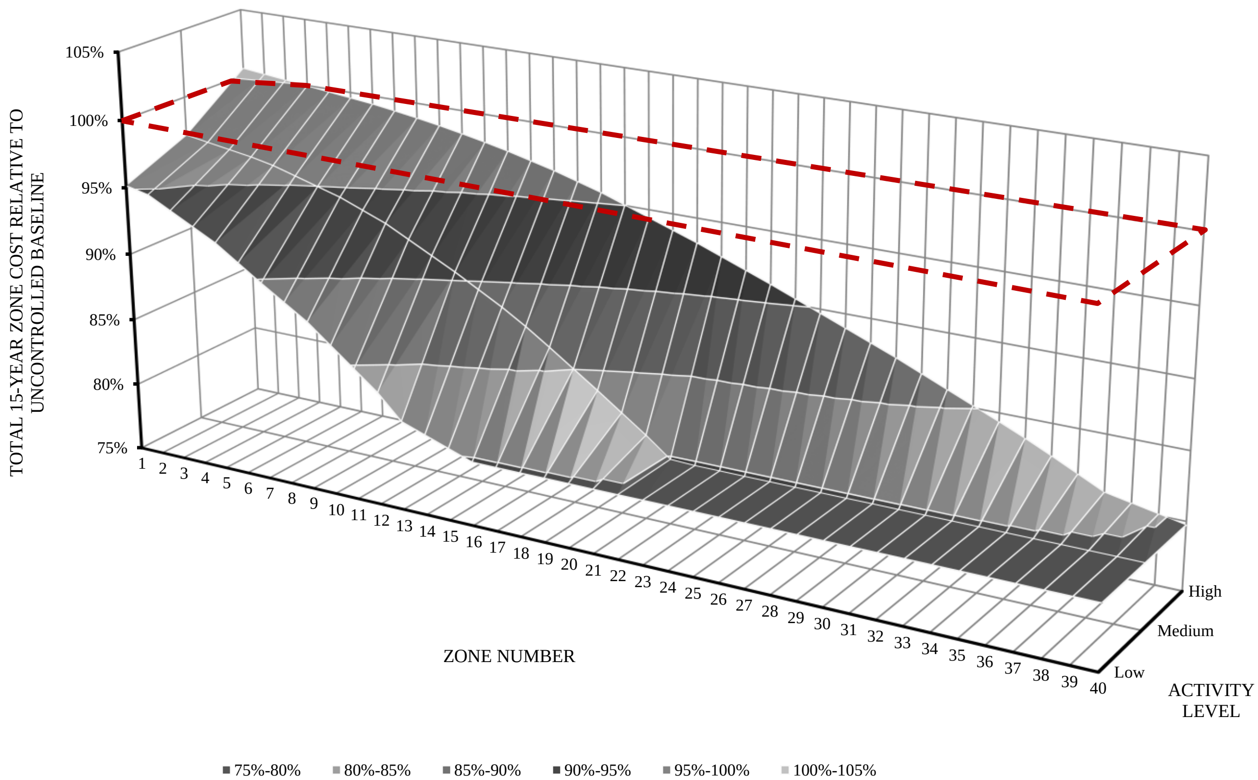

Figure 242: Zone-By-Zone Relative 15-Year Cost showing Impact of Activity Level on Non-Daylighted Zones for Transportation Garage 1-Minute Time Delay for Occupancy Sensing

11.37 Simulation Results Analysis: Office Park Garage Activity Levels

Comparing simulations 11, 12 and 13.

	Occupancy Sensor Delay Time				
Activity Level	**1**	**2.5**	**5**	**7.5**	**10**
High	81%	84%	86%	87%	88%
Medium	79%	81%	83%	84%	84%
Low	77%	79%	80%	81%	82%

Figure 243: Total Garage Relative 15-Year Cost showing Impact of Activity Level and With Daylighting Control for Office Park Garage

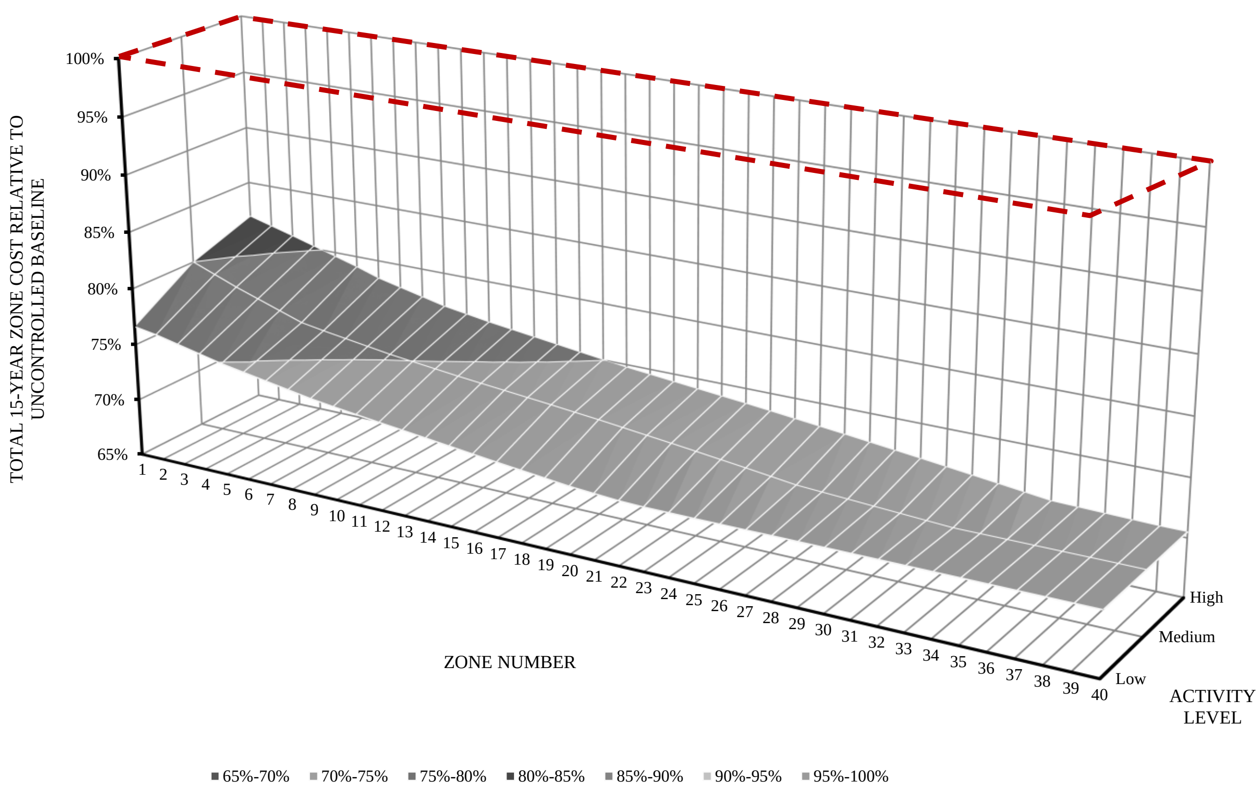

Figure 244: Zone-By-Zone Relative 15-Year Cost showing Impact of Activity Level on Daylighted Zones for Office Park Garage
1-Minute Time Delay for Occupancy Sensing

	Occupancy Sensor Delay Time				
Activity Level	**1**	**2.5**	**5**	**7.5**	**10**
High	87%	91%	94%	95%	96%
Medium	85%	88%	90%	91%	92%
Low	82%	84%	86%	87%	88%

Figure 245: Total Garage Relative 15-Year Cost showing Impact of Activity Level and Without Daylighting Control for Office Park Garage

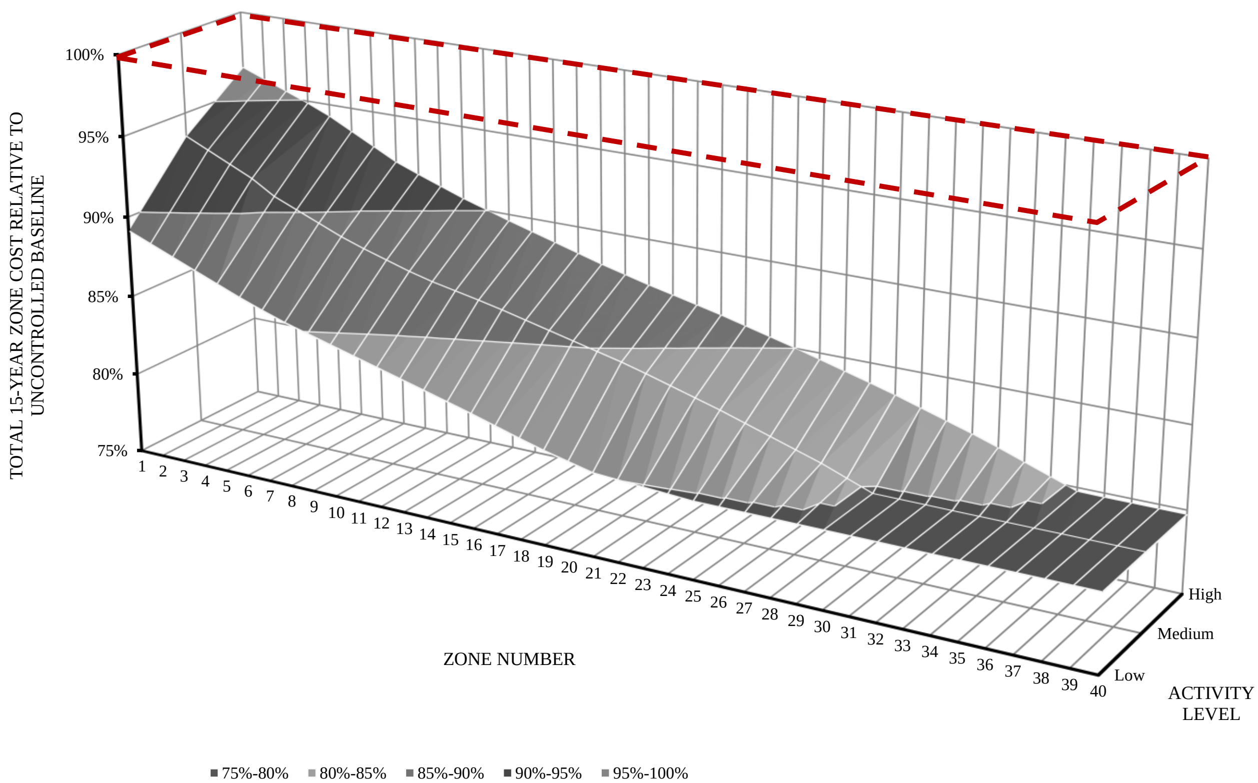

Figure 246: Zone-By-Zone Relative 15-Year Cost showing Impact of Activity Level on Non-Daylighted Zones for Office Park Garage
1-Minute Time Delay for Occupancy Sensing

11.38 Simulation Results Analysis: Mixed Use Garage Activity Levels

Comparing simulations 14, 15 and 16.

	Occupancy Sensor Delay Time				
Activity Level	**1**	**2.5**	**5**	**7.5**	**10**
High	84%	88%	90%	90%	91%
Medium	82%	85%	86%	87%	88%
Low	79%	82%	83%	84%	84%

Figure 247: Total Garage Relative 15-Year Cost showing Impact of Activity Level and With Daylighting Control for Mixed Use Garage

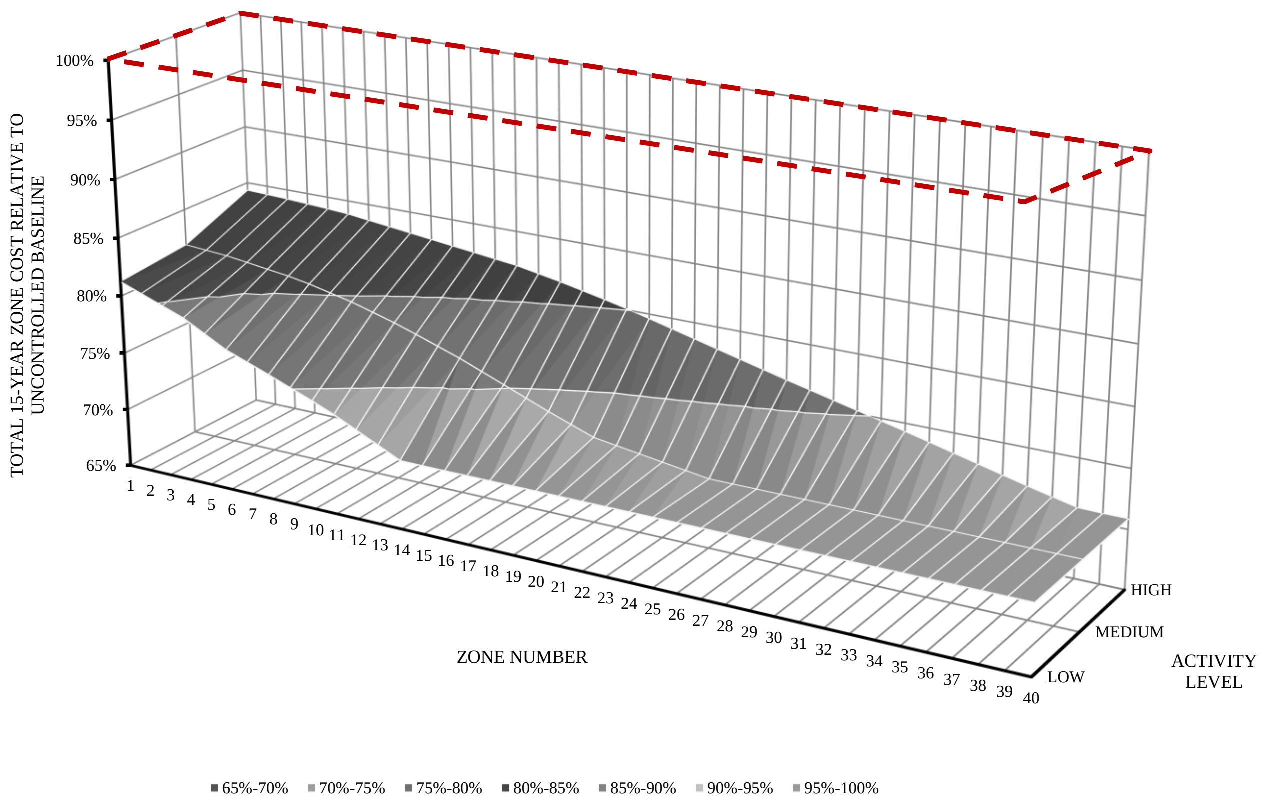

Figure 248: Zone-By-Zone Relative 15-Year Cost showing Impact of Activity Level on Daylighted Zones for Office Park Garage 1-Minute Time Delay for Occupancy Sensing

	Occupancy Sensor Delay Time				
Activity Level	**1**	**2.5**	**5**	**7.5**	**10**
High	91%	95%	98%	99%	99%
Medium	88%	92%	94%	94%	95%
Low	85%	88%	90%	90%	91%

Figure 249: Total Garage Relative 15-Year Cost showing Impact of Activity Level and Without Daylighting Control for Mixed Use Garage

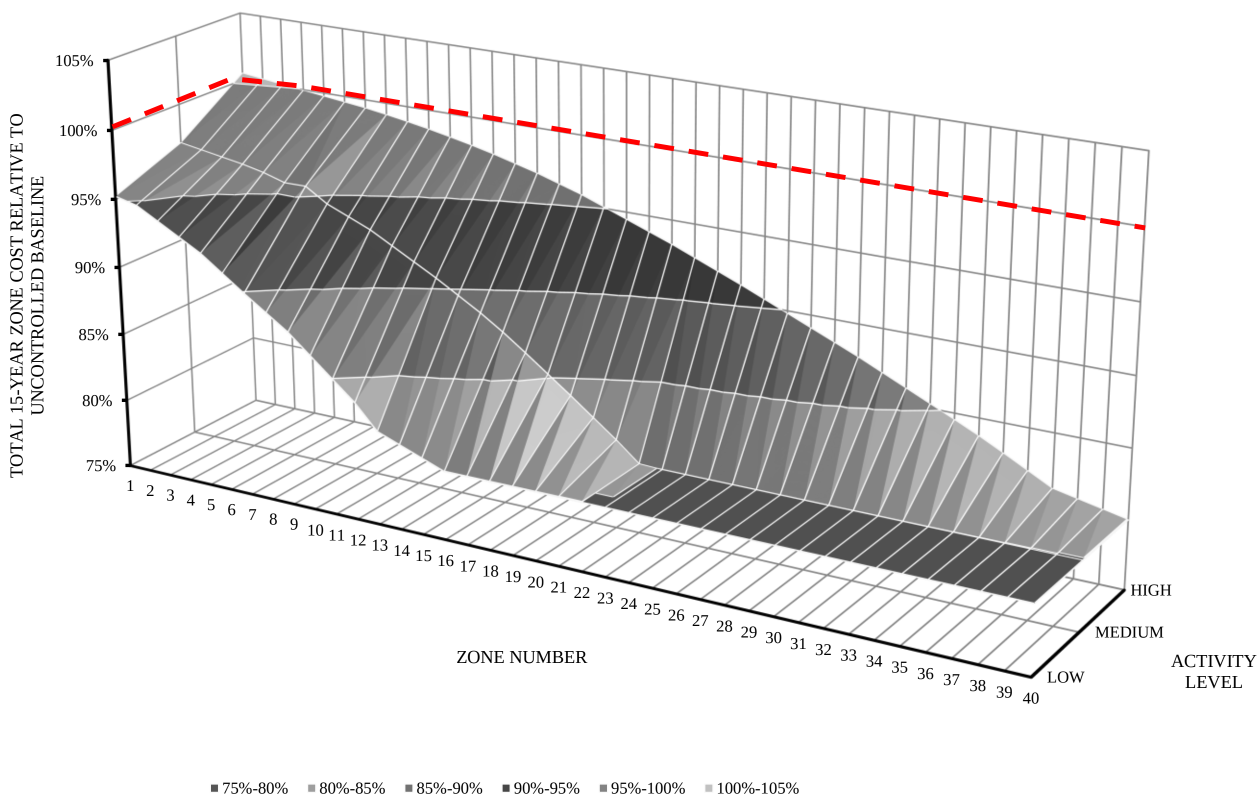

Figure 250: Zone-By-Zone Relative 15-Year Cost showing Impact of Activity Level on Non-Daylighted Zones for Mixed Garage 1-Minute Time Delay for Occupancy Sensing

11.39 Simulation Results Analysis: Occupancy Sensor Delay Time

Comparing simulations 11, 14, 20, 21, 28 and 29.

PROFILE TYPE	OCCUPANCY SENSOR DELAY TIME							
	1	2.5	5	7.5	10	15	20	30
Office Park	87%	91%	94%	95%	96%	96%	97%	98%
Mixed Use	91%	95%	98%	99%	99%	100%	100%	101%
Transportation	92%	99%	102%	104%	105%	106%	106%	107%

Figure 251: Total Garage Relative 15-Year Cost for Three Profile Types at 'HIGH' Activity Level as a Function of Occupancy Sensor Delay Time

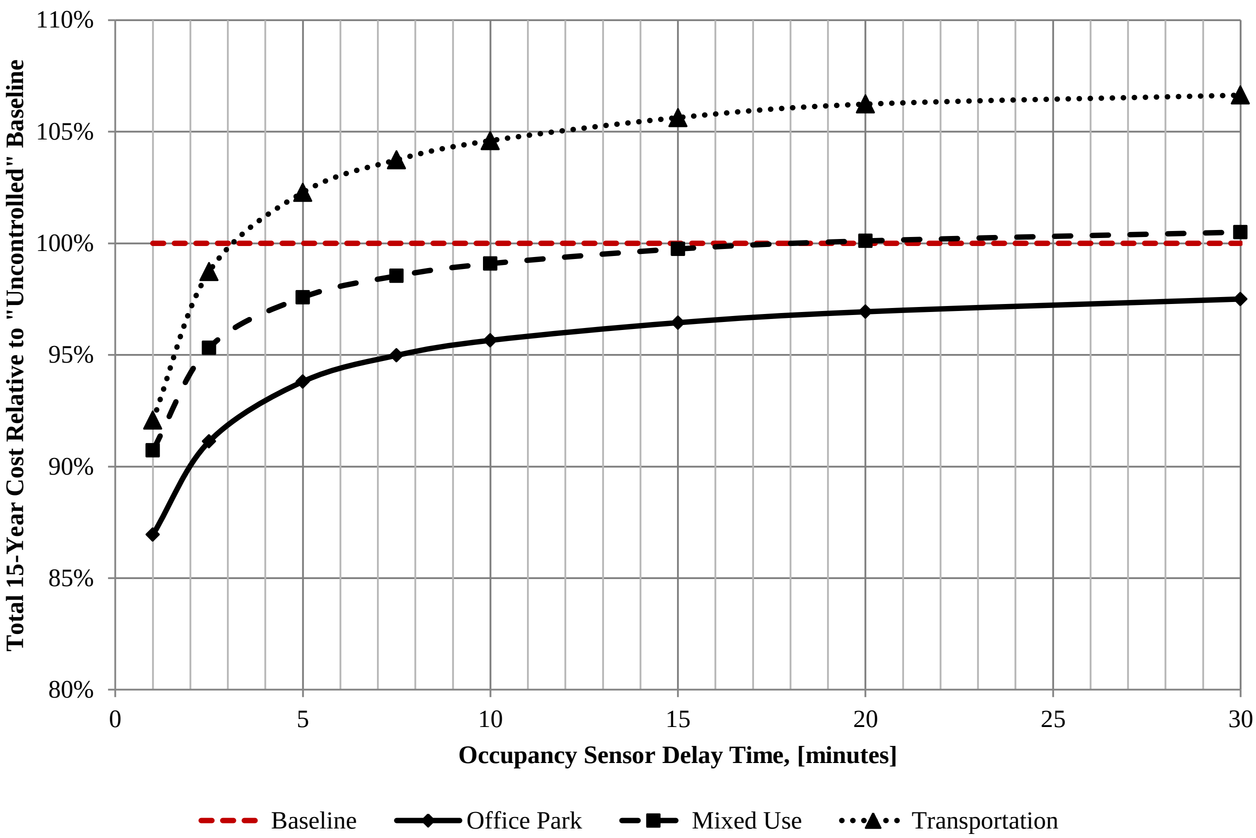

Figure 252: Total Garage Relative 15-Year Cost for Three Profile Types at 'HIGH' Activity Level as a Function of Occupancy Sensor Delay Time

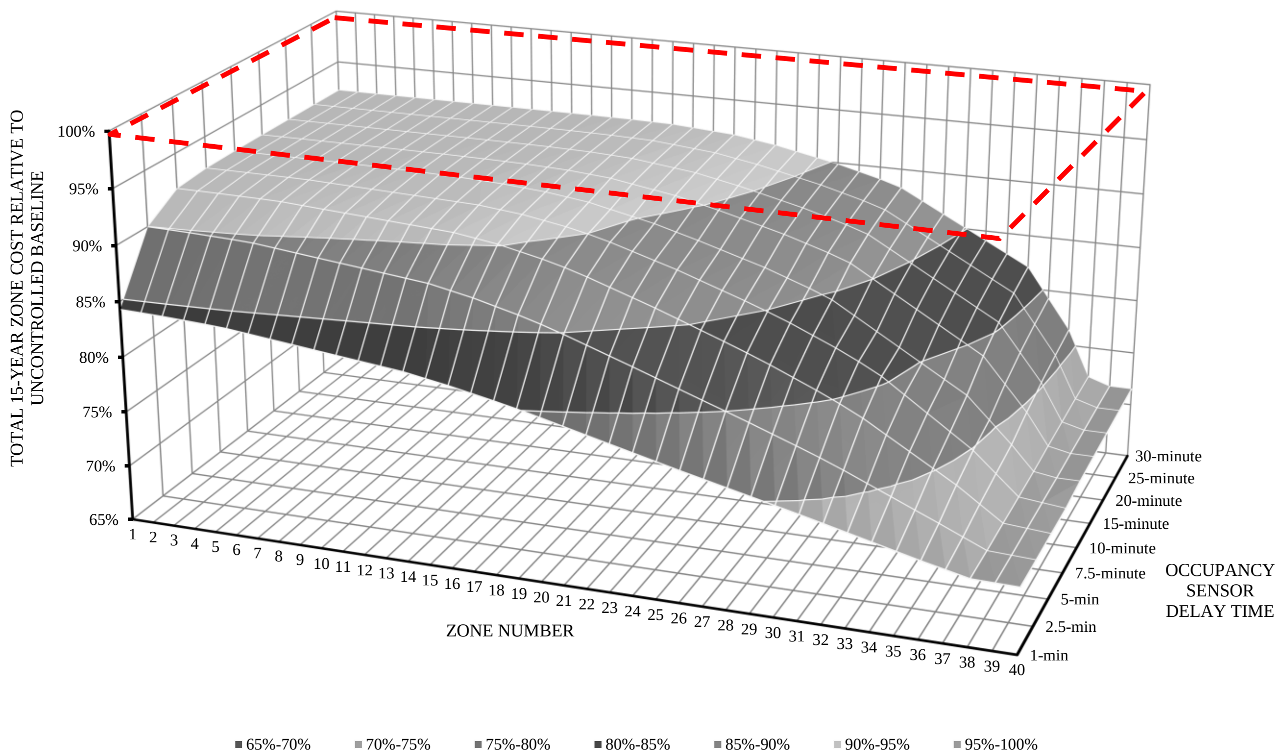

Figure 253: Zone-by-Zone Total Relative 15-Year Cost Including Impact of Daylighting based on 'HIGH' Transportation Occupancy Profile and Fluorescent Lighting System

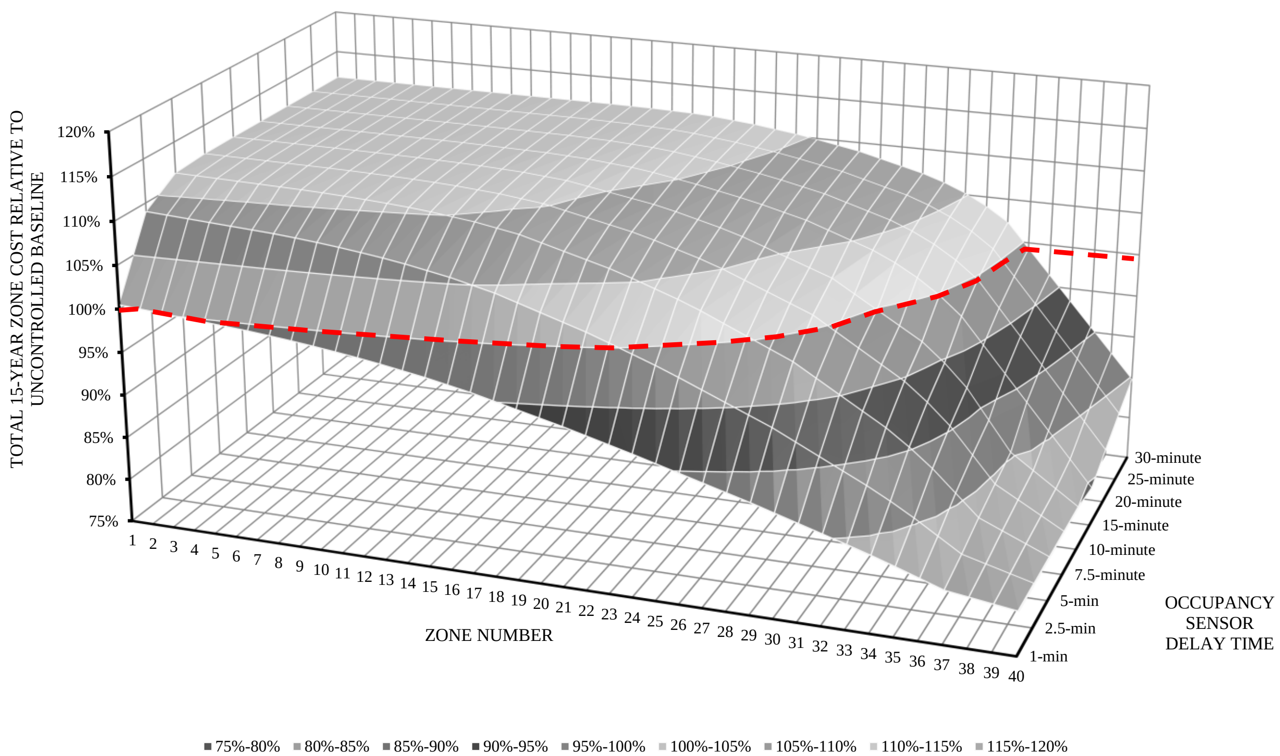

Figure 254: Zone-by-Zone Total Relative 15-Year Cost Without Impact of Daylighting based on 'HIGH' Transportation Occupancy Profile and Fluorescent Lighting System

Occupancy Sensor Delay Time	With Daylighting	Without Daylighting
Daylighting Only	90%	N/A
1	85%	92%
2.5	91%	99%
5	94%	102%
7.5	95%	104%
10	96%	105%
15	97%	106%
20	97%	106%
25	98%	107%
30	98%	107%

Figure 255: Total Garage Relative 15-Year Cost based on 'HIGH' Transportation Occupancy Profile and Fluorescent Lighting System

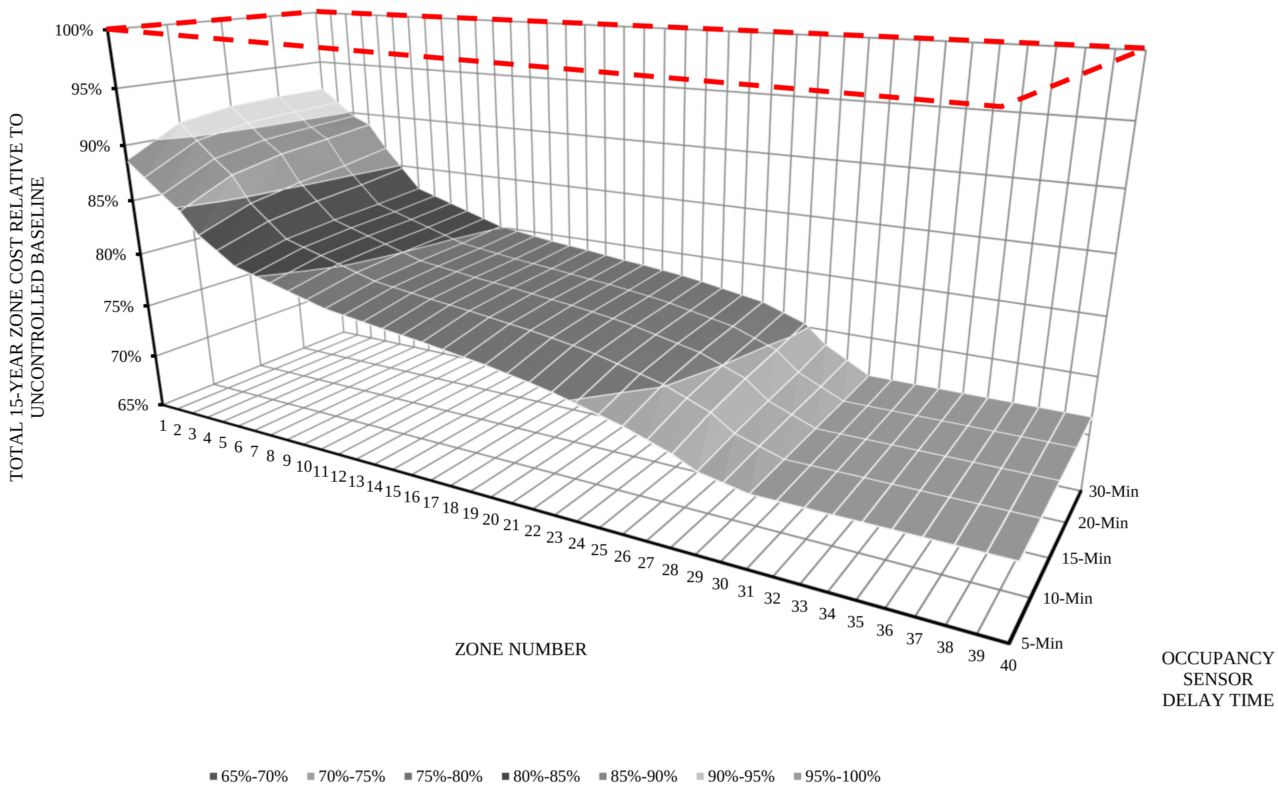

Figure 256: Zone-by-Zone Total Relative 15-Year Cost Including Impact of Daylighting based on 'HIGH' Office Park Occupancy Profile and Fluorescent Lighting System

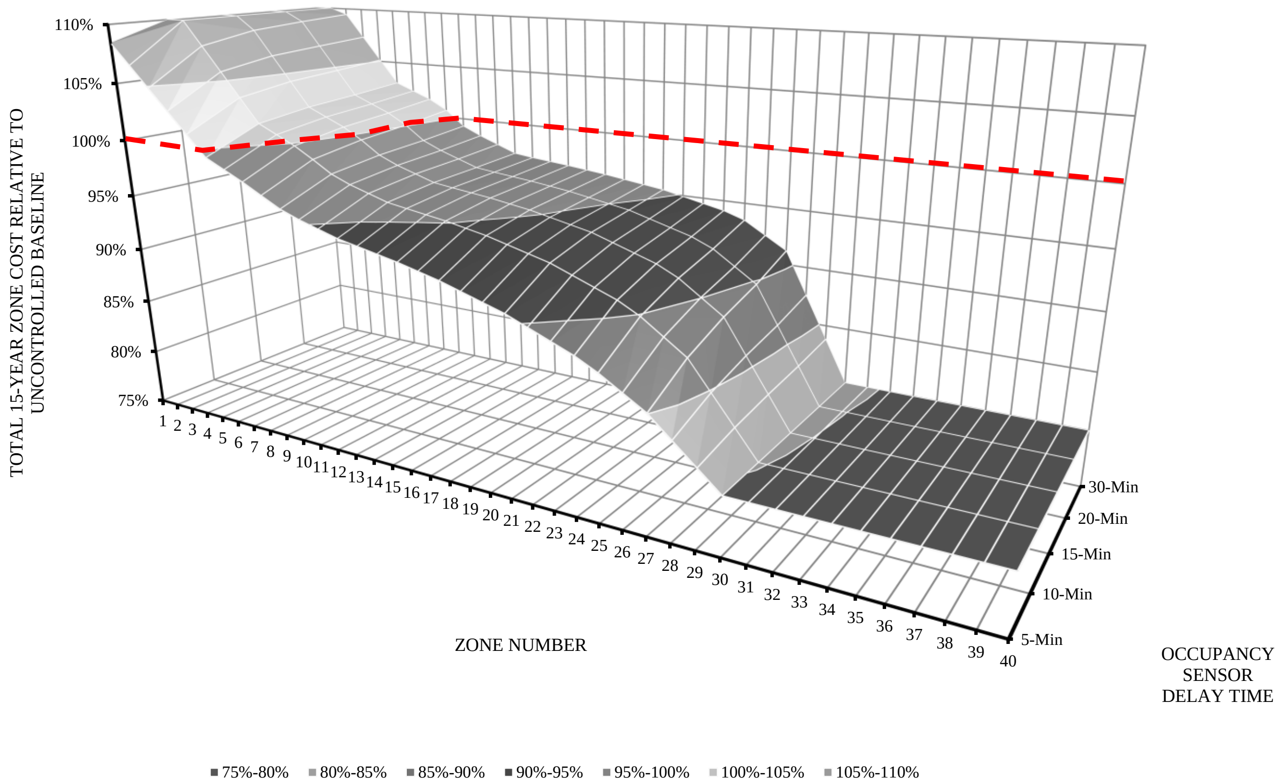

Figure 257: Zone-by-Zone Total Relative 15-Year Cost Without Impact of Daylighting based on 'HIGH' Office Park Occupancy Profile and Fluorescent Lighting System

Occupancy Sensor Delay Time	With Daylighting	Without Daylighting
Daylighting Only	86%	N/A
5	82%	94%
10	84%	96%
15	84%	96%
20	85%	97%
30	85%	98%

Figure 258: Total Garage Relative 15-Year Cost based on 'HIGH' Office Park Occupancy Profile and Fluorescent Lighting System

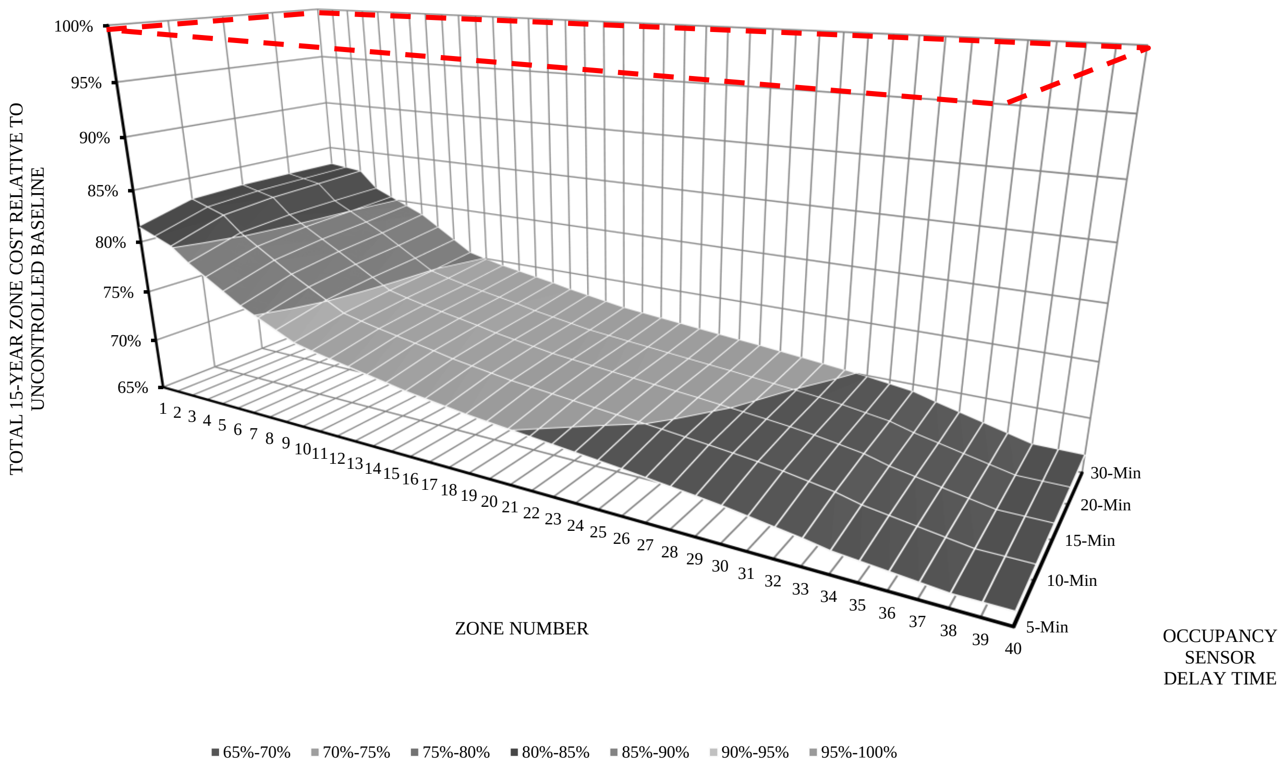

Figure 259: Zone-by-Zone Total Relative 15-Year Cost Including Impact of Daylighting based on 'HIGH' Mixed Use Occupancy Profile and Fluorescent Lighting System

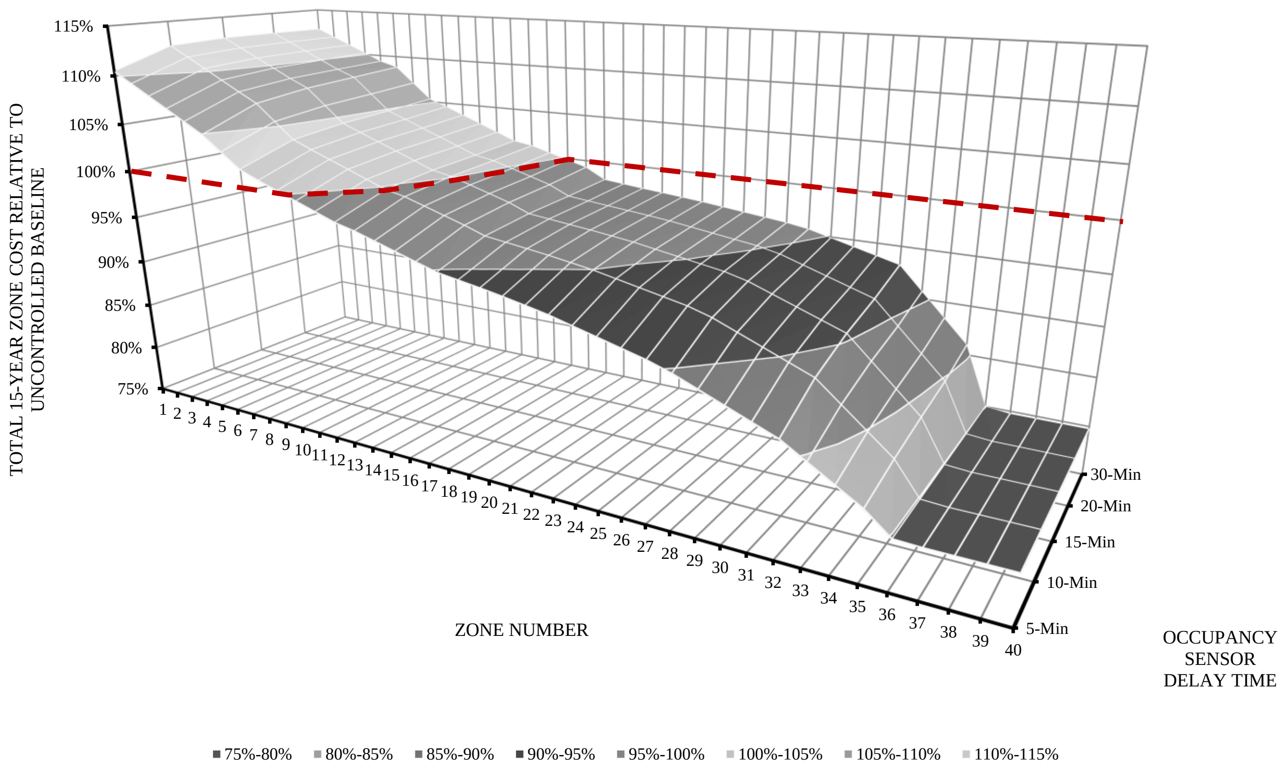

Figure 260: Zone-by-Zone Total Relative 15-Year Cost Without Impact of Daylighting based on 'HIGH' Mixed Use Occupancy Profile and Fluorescent Lighting System

Occupancy Sensor Delay Time	With Daylighting	Without Daylighting
Daylighting Only	86%	N/A
5	86%	98%
10	87%	99%
15	88%	100%
20	88%	100%
30	89%	101%

Figure 261: Total Garage Relative 15-Year Cost based on 'HIGH' Mixed Use Occupancy Profile and Fluorescent Lighting System

12. Appendix H: Occupancy Profiles Documentation

12.1 Office Park Parking Garage Profiles

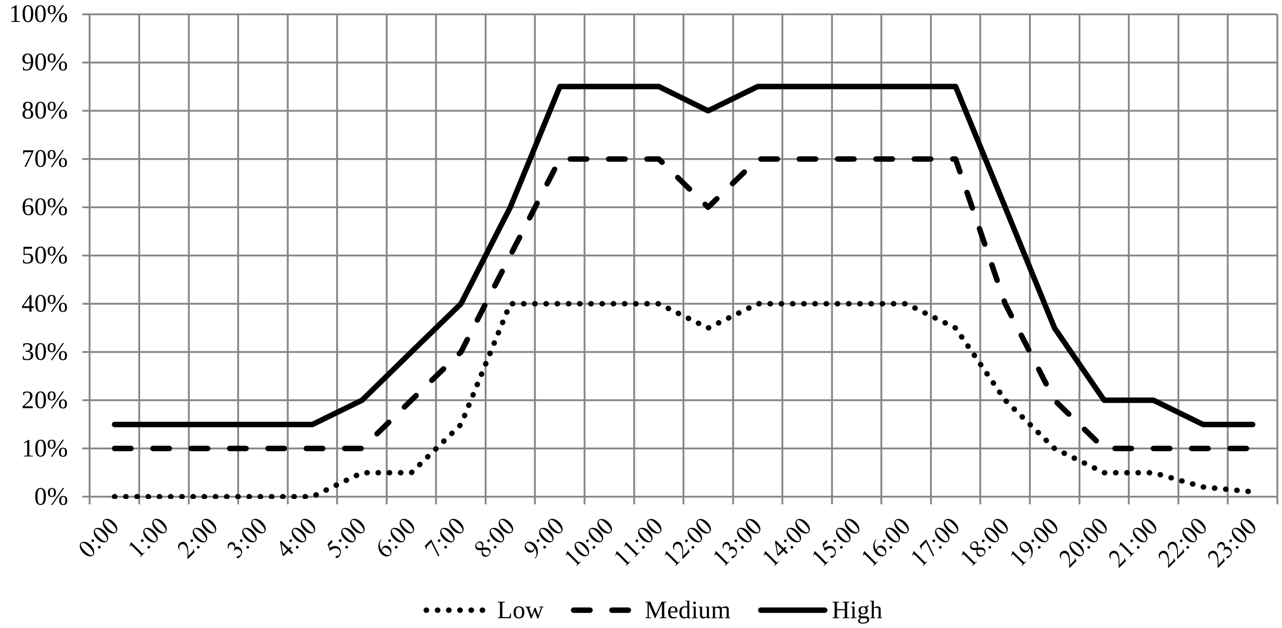

Figure 262: Office Park Garage Weekday Occupancy Profiles

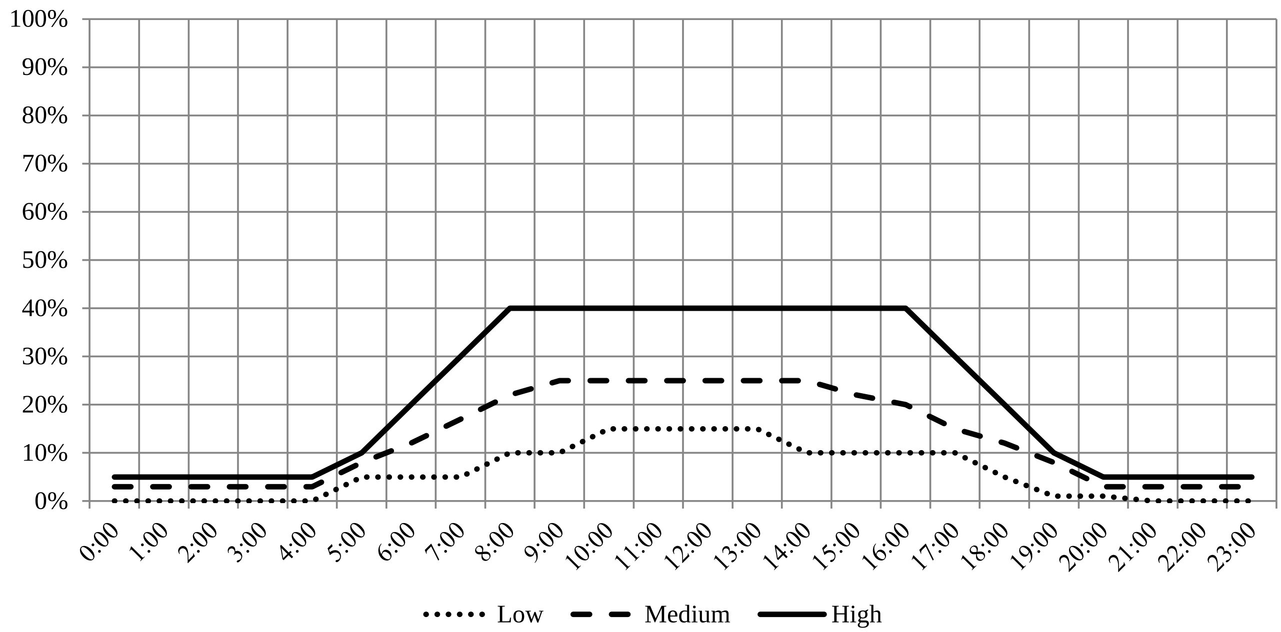

Figure 263: Office Park Garage Saturday Occupancy Profiles

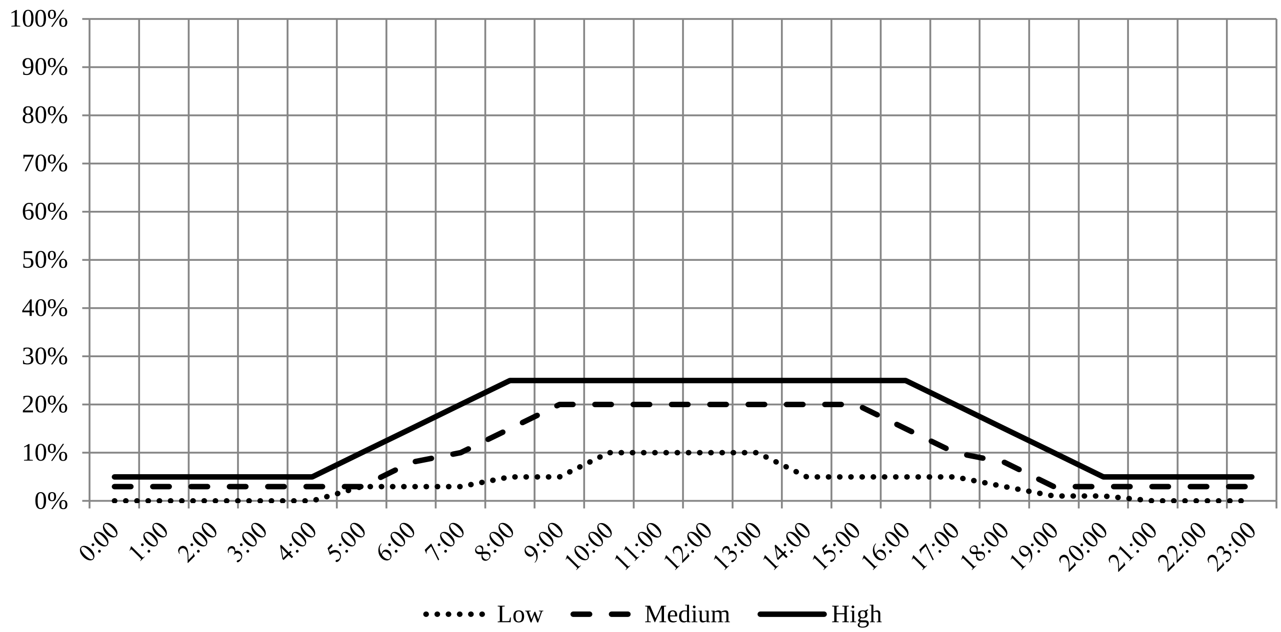

Figure 264: Office Park Garage Sunday Occupancy Profiles

	WEEKDAYS			SATURDAY			SUNDAY		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
0:00	0%	10%	15%	0%	3%	5%	0%	3%	5%
1:00	0%	10%	15%	0%	3%	5%	0%	3%	5%
2:00	0%	10%	15%	0%	3%	5%	0%	3%	5%
3:00	0%	10%	15%	0%	3%	5%	0%	3%	5%
4:00	0%	10%	15%	0%	3%	5%	0%	3%	5%
5:00	5%	10%	20%	5%	8%	10%	3%	3%	10%
6:00	5%	20%	30%	5%	12%	20%	3%	8%	15%
7:00	15%	30%	40%	5%	17%	30%	3%	10%	20%
8:00	40%	50%	60%	10%	22%	40%	5%	15%	25%
9:00	40%	70%	85%	10%	25%	40%	5%	20%	25%
10:00	40%	70%	85%	15%	25%	40%	10%	20%	25%
11:00	40%	70%	85%	15%	25%	40%	10%	20%	25%
12:00	35%	60%	80%	15%	25%	40%	10%	20%	25%
13:00	40%	70%	85%	15%	25%	40%	10%	20%	25%
14:00	40%	70%	85%	10%	25%	40%	5%	20%	25%
15:00	40%	70%	85%	10%	22%	40%	5%	20%	25%
16:00	40%	70%	85%	10%	20%	40%	5%	15%	25%
17:00	35%	70%	85%	10%	15%	30%	5%	10%	20%
18:00	20%	40%	60%	5%	12%	20%	3%	8%	15%
19:00	10%	20%	35%	1%	8%	10%	1%	3%	10%
20:00	5%	10%	20%	1%	3%	5%	1%	3%	5%
21:00	5%	10%	20%	0%	3%	5%	0%	3%	5%
22:00	2%	10%	15%	0%	3%	5%	0%	3%	5%
23:00	1%	10%	15%	0%	3%	5%	0%	3%	5%

Figure 265: Hourly Occupancy Level as a Percentage of Garage Capacity for Office Park Garages Based on Activity Level

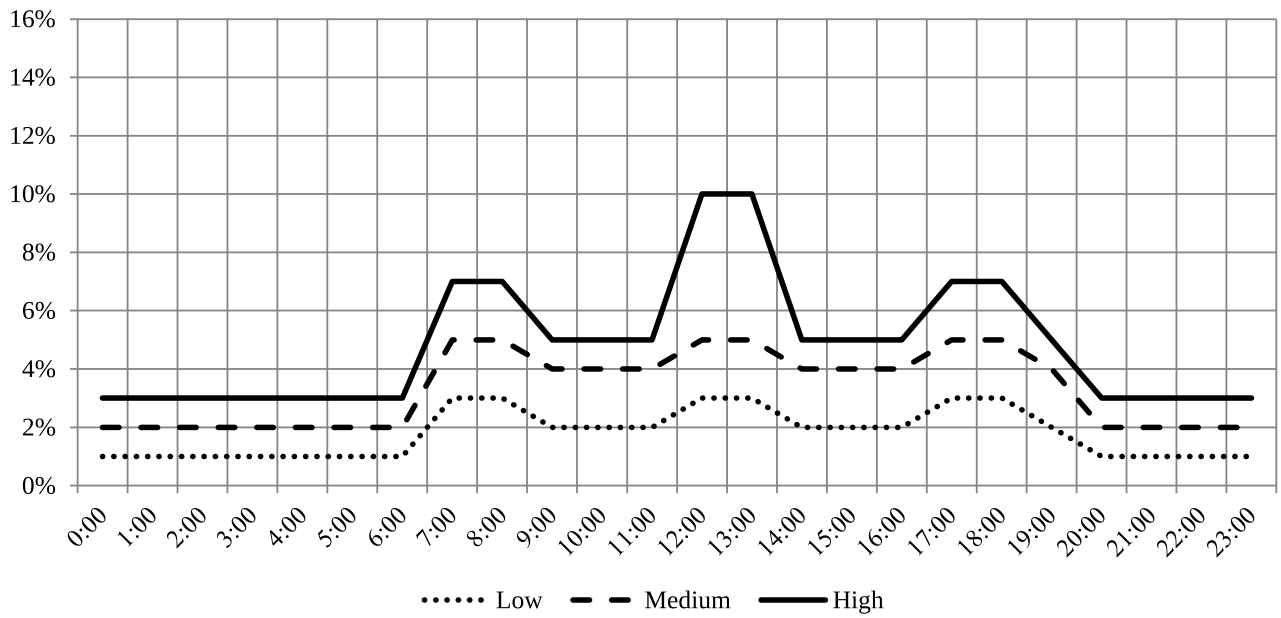

Figure 266: Office Park Garage Transient Profiles

	Low	Medium	High
0:00	1%	2%	3%
1:00	1%	2%	3%
2:00	1%	2%	3%
3:00	1%	2%	3%
4:00	1%	2%	3%
5:00	1%	2%	3%
6:00	1%	2%	3%
7:00	3%	5%	7%
8:00	3%	5%	7%
9:00	2%	4%	5%
10:00	2%	4%	5%
11:00	2%	4%	5%
12:00	3%	5%	10%
13:00	3%	5%	10%
14:00	2%	4%	5%
15:00	2%	4%	5%
16:00	2%	4%	5%
17:00	3%	5%	7%
18:00	3%	5%	7%
19:00	2%	4%	5%
20:00	1%	2%	3%
21:00	1%	2%	3%
22:00	1%	2%	3%
23:00	1%	2%	3%

Figure 267: Hourly Transient Activity as a Percentage of Garage Capacity for Office Park Garages Based on Activity Level

12.2 Mixed-Use Garage Profiles

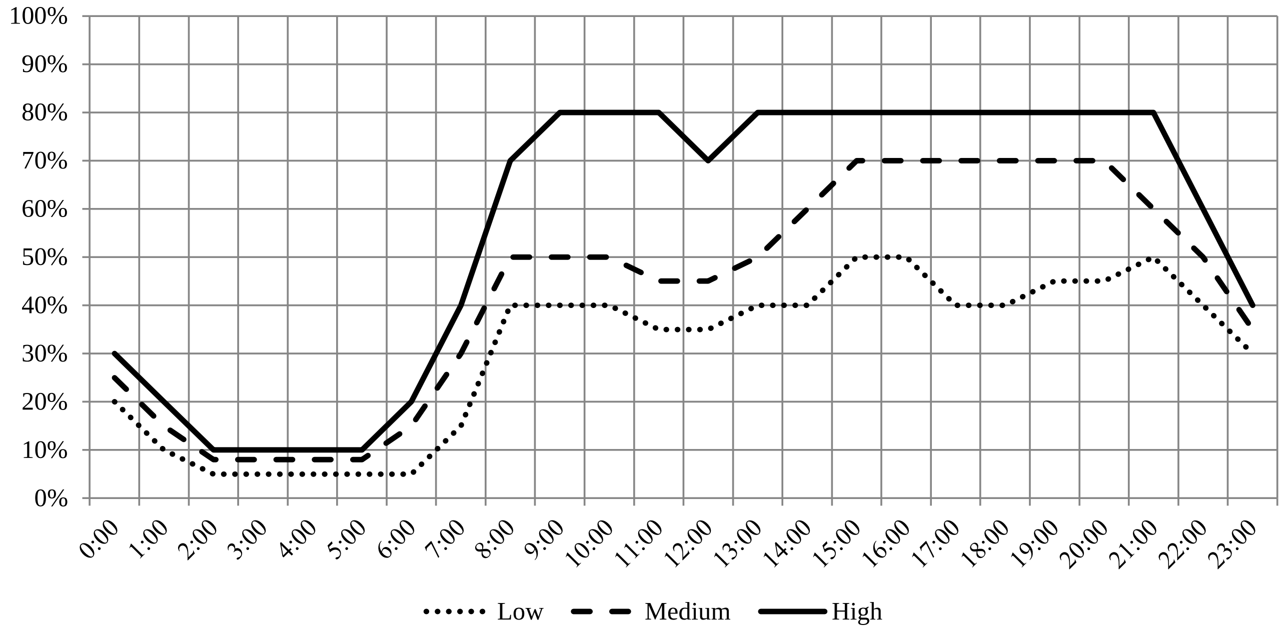

Figure 268: Mixed Use Garage Weekday Occupancy Profiles

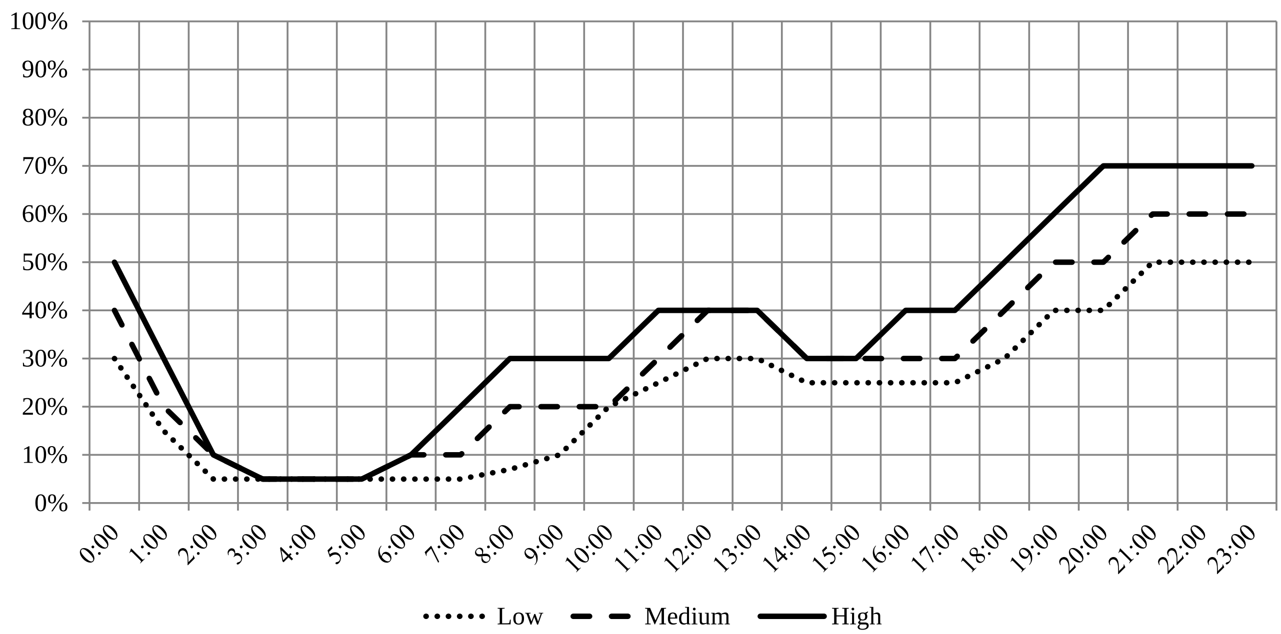

Figure 269: Mixed Use Garage Saturday Occupancy Profiles

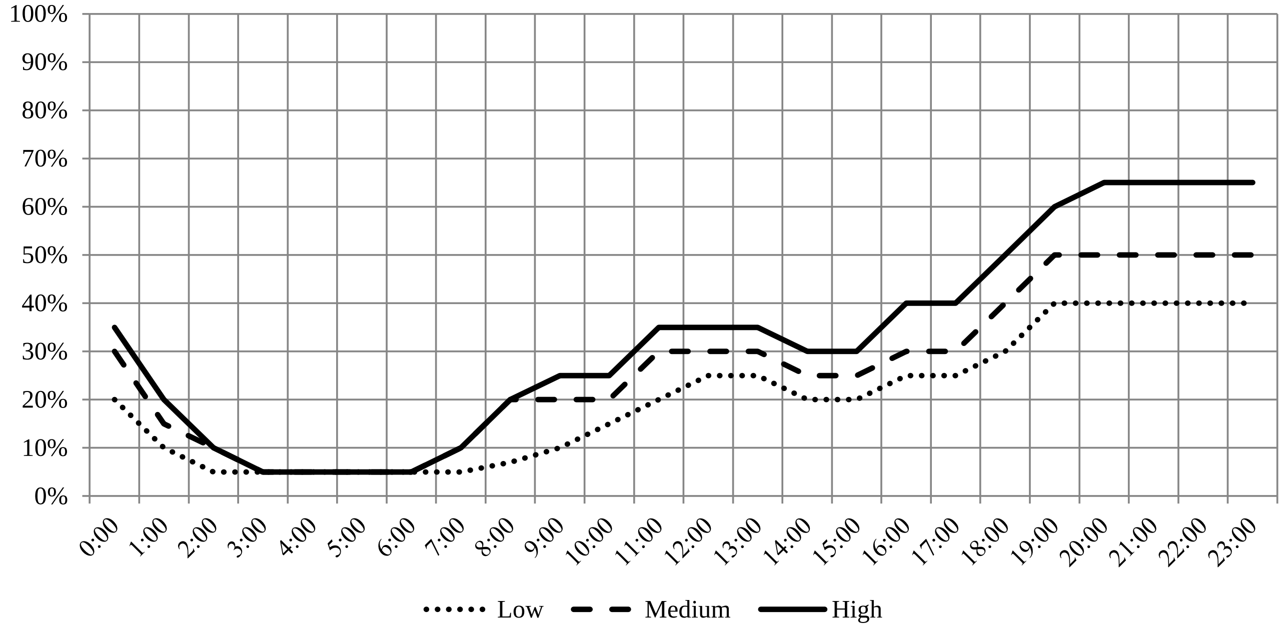

Figure 270: Mixed Use Sunday Occupancy Profiles

	WEEKDAYS			SATURDAY			SUNDAY		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
0:00	20%	25%	30%	30%	40%	50%	20%	30%	35%
1:00	10%	15%	20%	15%	20%	30%	10%	15%	20%
2:00	5%	8%	10%	5%	10%	10%	5%	10%	10%
3:00	5%	8%	10%	5%	5%	5%	5%	5%	5%
4:00	5%	8%	10%	5%	5%	5%	5%	5%	5%
5:00	5%	8%	10%	5%	5%	5%	5%	5%	5%
6:00	5%	15%	20%	5%	10%	10%	5%	5%	5%
7:00	15%	30%	40%	5%	10%	20%	5%	10%	10%
8:00	40%	50%	70%	7%	20%	30%	7%	20%	20%
9:00	40%	50%	80%	10%	20%	30%	10%	20%	25%
10:00	40%	50%	80%	20%	20%	30%	15%	20%	25%
11:00	35%	45%	80%	25%	30%	40%	20%	30%	35%
12:00	35%	45%	70%	30%	40%	40%	25%	30%	35%
13:00	40%	50%	80%	30%	40%	40%	25%	30%	35%
14:00	40%	60%	80%	25%	30%	30%	20%	25%	30%
15:00	50%	70%	80%	25%	30%	30%	20%	25%	30%
16:00	50%	70%	80%	25%	30%	40%	25%	30%	40%
17:00	40%	70%	80%	25%	30%	40%	25%	30%	40%
18:00	40%	70%	80%	30%	40%	50%	30%	40%	50%
19:00	45%	70%	80%	40%	50%	60%	40%	50%	60%
20:00	45%	70%	80%	40%	50%	70%	40%	50%	65%
21:00	50%	60%	80%	50%	60%	70%	40%	50%	65%
22:00	40%	50%	60%	50%	60%	70%	40%	50%	65%
23:00	30%	35%	40%	50%	60%	70%	40%	50%	65%

Figure 271: Hourly Occupancy Level as a Percentage of Garage Capacity for Mixed Use Garages Based on Activity Level

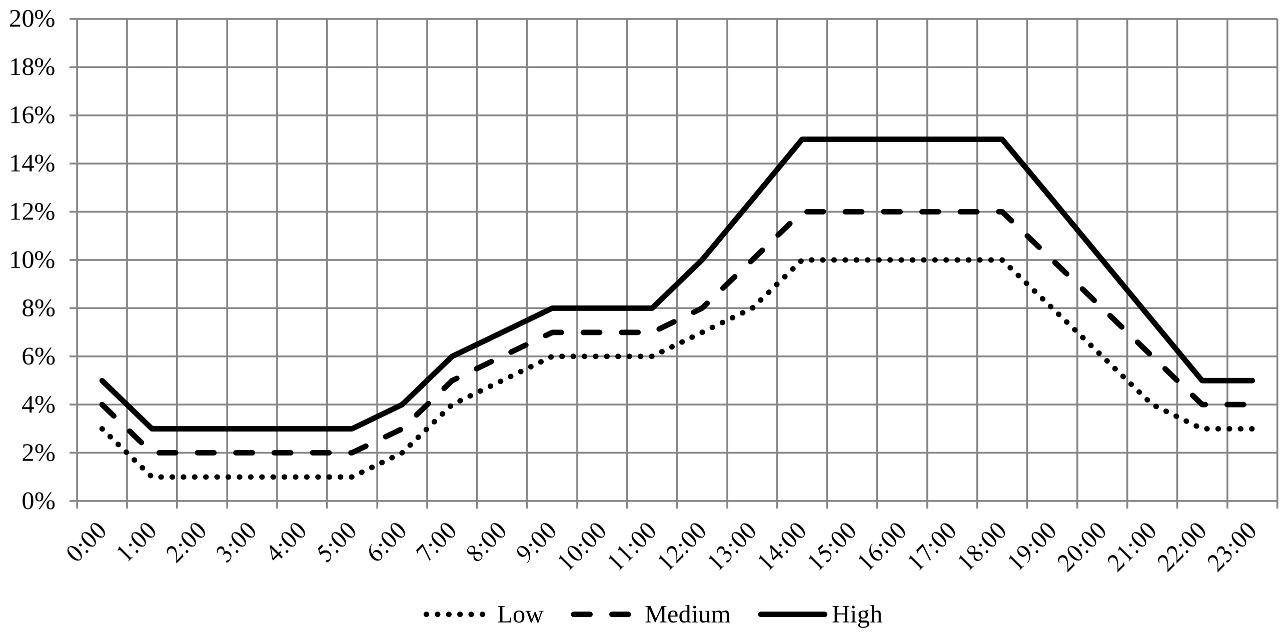

Figure 272: Mixed Use Garage Transient Profiles

	Low	Medium	High
0:00	3%	4%	5%
1:00	1%	2%	3%
2:00	1%	2%	3%
3:00	1%	2%	3%
4:00	1%	2%	3%
5:00	1%	2%	3%
6:00	2%	3%	4%
7:00	4%	5%	6%
8:00	5%	6%	7%
9:00	6%	7%	8%
10:00	6%	7%	8%
11:00	6%	7%	8%
12:00	7%	8%	10%
13:00	8%	10%	13%
14:00	10%	12%	15%
15:00	10%	12%	15%
16:00	10%	12%	15%
17:00	10%	12%	15%
18:00	10%	12%	15%
19:00	8%	10%	13%
20:00	6%	8%	10%
21:00	4%	6%	8%
22:00	3%	4%	5%
23:00	3%	4%	5%

Figure 273: Hourly Transient Activity as a Percentage of Garage Capacity for Mixed Use Garages Based on Activity Level

12.3 Transportation Garage Profiles

Note that for the Transportation facility type, a single occupancy profile was applied to all days.

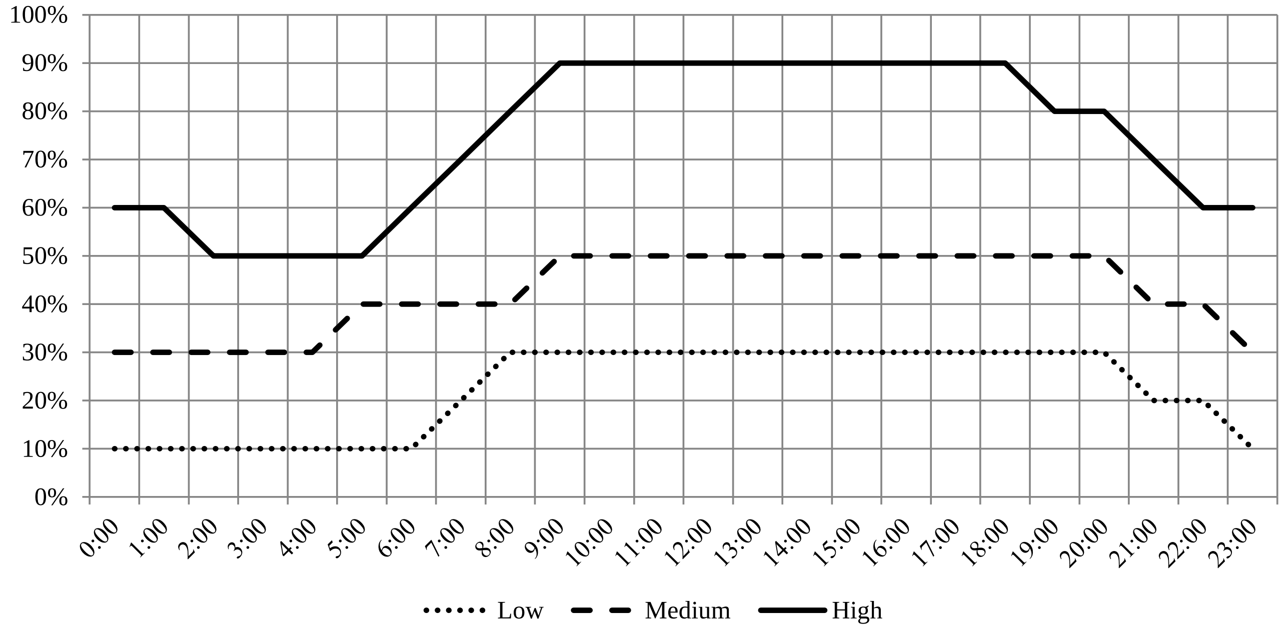

Figure 274: Transportation Garage Daily Occupancy Profiles

	Low	Medium	High
0:00	10%	30%	60%
1:00	10%	30%	60%
2:00	10%	30%	50%
3:00	10%	30%	50%
4:00	10%	30%	50%
5:00	10%	40%	50%
6:00	10%	40%	60%
7:00	20%	40%	70%
8:00	30%	40%	80%
9:00	30%	50%	90%
10:00	30%	50%	90%
11:00	30%	50%	90%
12:00	30%	50%	90%
13:00	30%	50%	90%
14:00	30%	50%	90%
15:00	30%	50%	90%
16:00	30%	50%	90%
17:00	30%	50%	90%
18:00	30%	50%	90%
19:00	30%	50%	80%
20:00	30%	50%	80%
21:00	20%	40%	70%
22:00	20%	40%	60%
23:00	10%	30%	60%

Figure 275: Hourly Occupancy Level as a Percentage of Garage Capacity for Transportation Garages Based on Activity Level

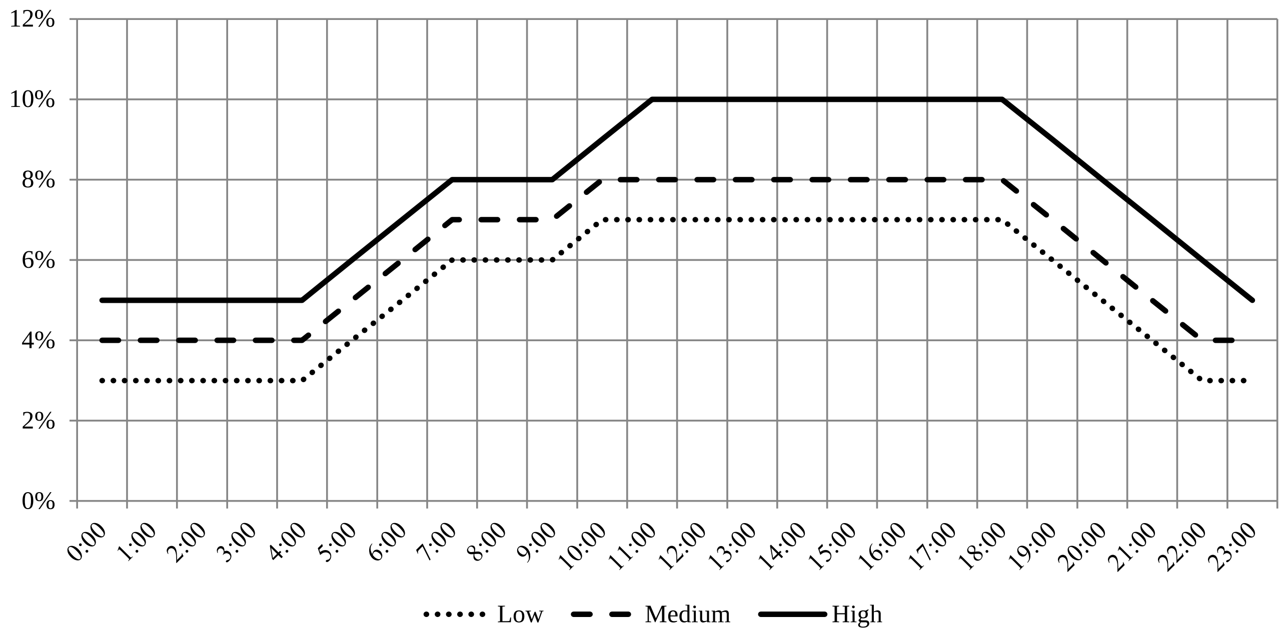

Figure 276: Transportation Garage Transient Profiles

	Low	Medium	High
0:00	3%	4%	5%
1:00	3%	4%	5%
2:00	3%	4%	5%
3:00	3%	4%	5%
4:00	3%	4%	5%
5:00	4%	5%	6%
6:00	5%	6%	7%
7:00	6%	7%	8%
8:00	6%	7%	8%
9:00	6%	7%	8%
10:00	7%	8%	9%
11:00	7%	8%	10%
12:00	7%	8%	10%
13:00	7%	8%	10%
14:00	7%	8%	10%
15:00	7%	8%	10%
16:00	7%	8%	10%
17:00	7%	8%	10%
18:00	7%	8%	10%
19:00	6%	7%	9%
20:00	5%	6%	8%
21:00	4%	5%	7%
22:00	3%	4%	6%
23:00	3%	4%	5%

Figure 277: Hourly Transient Activity as a Percentage of Garage Capacity for Transportation Garages Based on Activity Level

12.4 "Bust" Configuration Profiles

The "Bust" garage profiles were created to demonstrate a very high level of activity throughout the day as an attempt to determine the limits of cost-effectiveness of occupancy-based lighting controls.

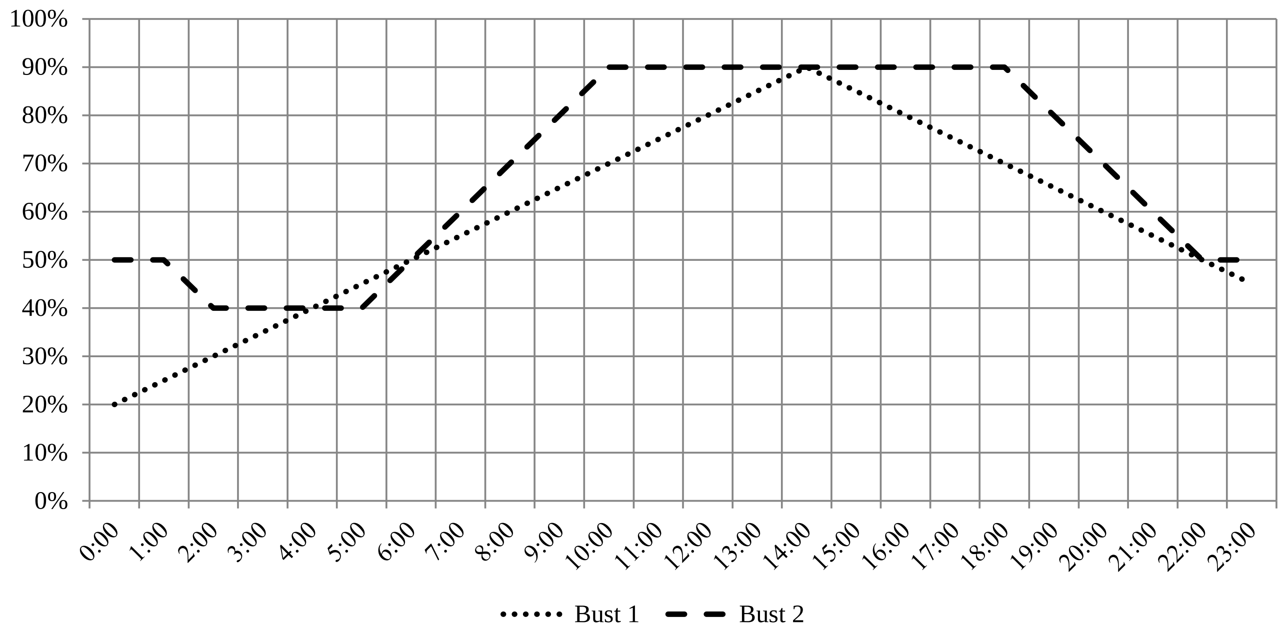

Figure 278: "Bust" Analysis Occupancy Profiles

	Bust 1	Bust 2
0:00	20%	50%
1:00	25%	50%
2:00	30%	40%
3:00	35%	40%
4:00	40%	40%
5:00	45%	40%
6:00	50%	50%
7:00	55%	60%
8:00	60%	70%
9:00	65%	80%
10:00	70%	90%
11:00	75%	90%
12:00	80%	90%
13:00	85%	90%
14:00	90%	90%
15:00	85%	90%
16:00	80%	90%
17:00	75%	90%
18:00	70%	90%
19:00	65%	80%
20:00	60%	70%
21:00	55%	60%
22:00	50%	50%
23:00	45%	50%

Figure 279: Hourly Occupancy Level as a Percentage of Garage Capacity for "Bust" Profiles

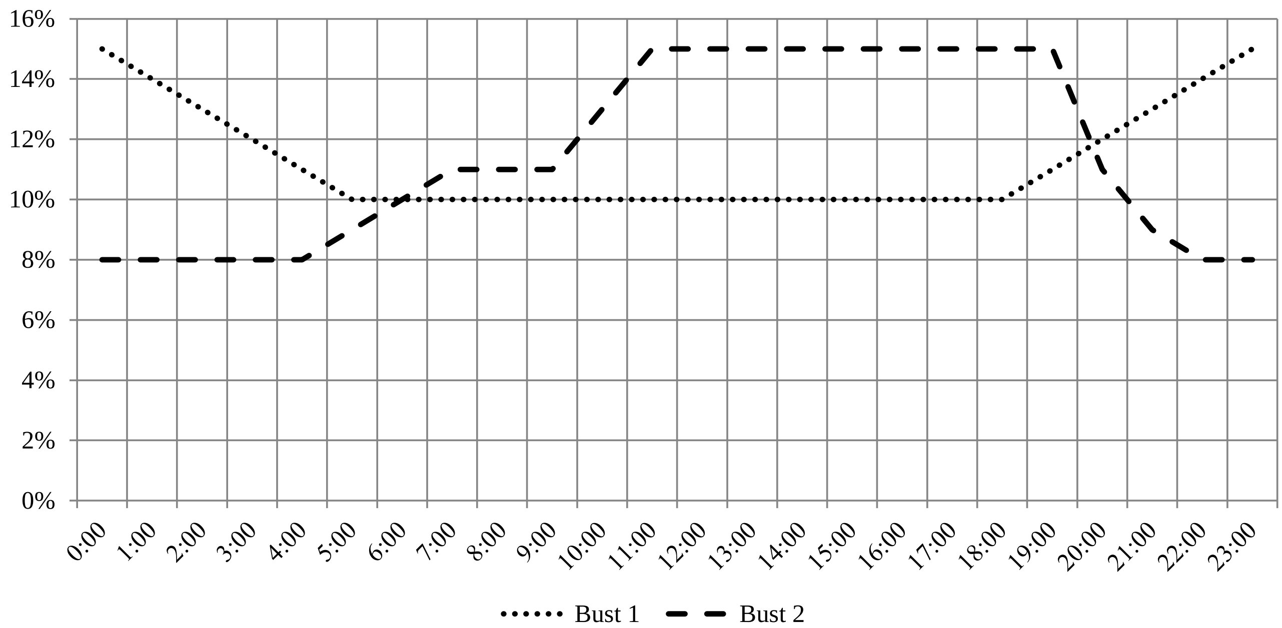

Figure 280: "Bust" Analysis Transient Profiles

	Bust 1	Bust 2
0:00	15%	8%
1:00	14%	8%
2:00	13%	8%
3:00	12%	8%
4:00	11%	8%
5:00	10%	9%
6:00	10%	10%
7:00	10%	11%
8:00	10%	11%
9:00	10%	11%
10:00	10%	13%
11:00	10%	15%
12:00	10%	15%
13:00	10%	15%
14:00	10%	15%
15:00	10%	15%
16:00	10%	15%
17:00	10%	15%
18:00	10%	15%
19:00	11%	15%
20:00	12%	11%
21:00	13%	9%
22:00	14%	8%
23:00	15%	8%

Figure 281: Hourly Transient Activity as a Percentage of Garage Capacity for "Bust" Profiles

12.5 University Garage Profiles

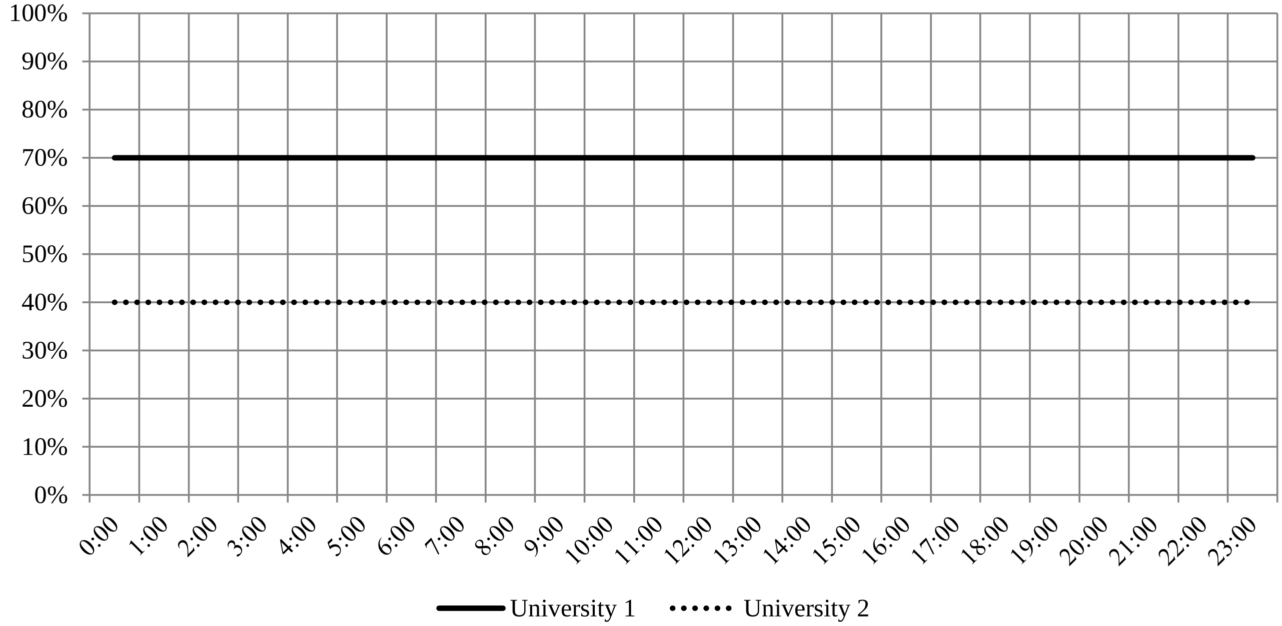

Figure 282: University Analysis Occupancy Profiles

	University 1	University 2
0:00	70%	40%
1:00	70%	40%
2:00	70%	40%
3:00	70%	40%
4:00	70%	40%
5:00	70%	40%
6:00	70%	40%
7:00	70%	40%
8:00	70%	40%
9:00	70%	40%
10:00	70%	40%
11:00	70%	40%
12:00	70%	40%
13:00	70%	40%
14:00	70%	40%
15:00	70%	40%
16:00	70%	40%
17:00	70%	40%
18:00	70%	40%
19:00	70%	40%
20:00	70%	40%
21:00	70%	40%
22:00	70%	40%
23:00	70%	40%

Figure 283: Hourly Occupancy Level as a Percentage of Garage Capacity for University Occupancy Profiles

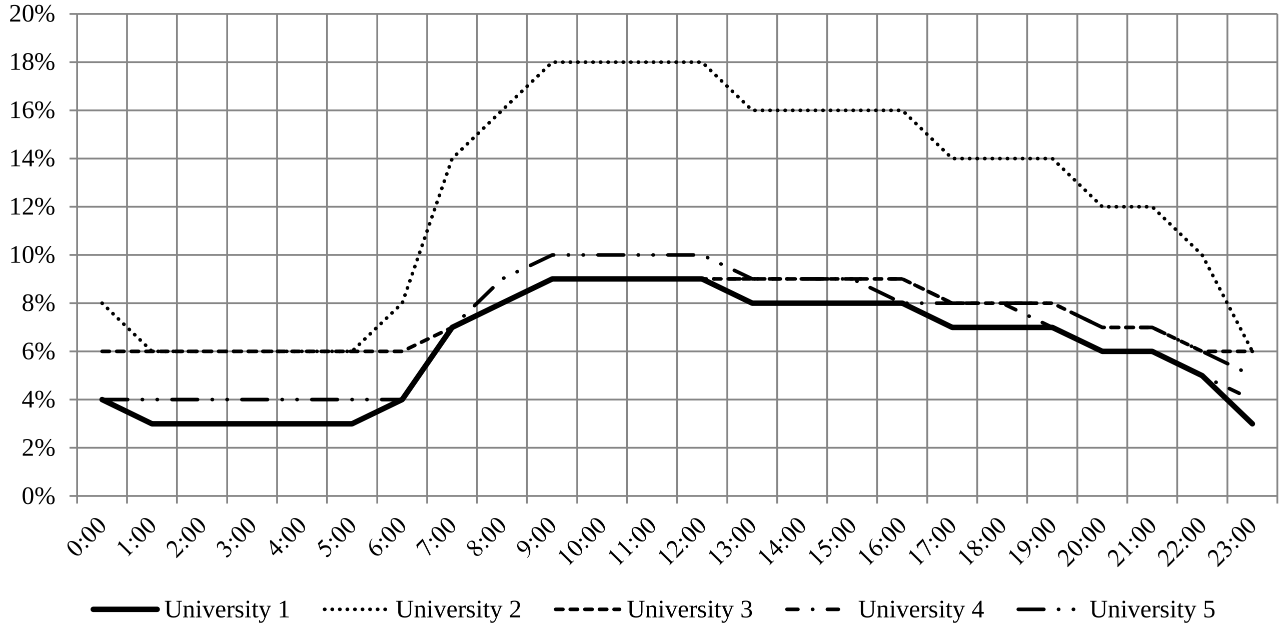

Figure 284: University Analysis Weekday Transient Profiles

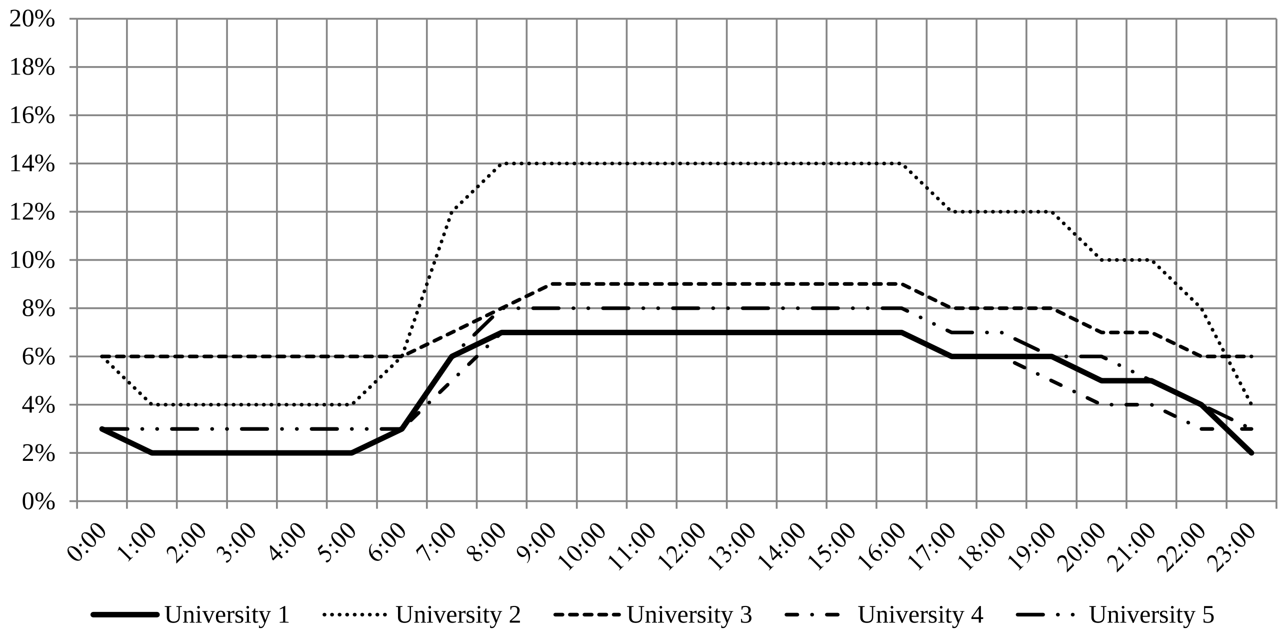

Figure 285: University Analysis Weekend Day Transient Profiles

	WEEKDAYS					WEEKDEND DAYS				
	University 1	University 2	University 3	University 4	University 5	University 1	University 2	University 3	University 4	University 5
0:00	4%	8%	6%	4%	4%	3%	6%	6%	3%	3%
1:00	3%	6%	6%	3%	4%	2%	4%	6%	2%	3%
2:00	3%	6%	6%	3%	4%	2%	4%	6%	2%	3%
3:00	3%	6%	6%	3%	4%	2%	4%	6%	2%	3%
4:00	3%	6%	6%	3%	4%	2%	4%	6%	2%	3%
5:00	3%	6%	6%	3%	4%	2%	4%	6%	2%	3%
6:00	4%	8%	6%	4%	4%	3%	6%	6%	3%	3%
7:00	7%	14%	7%	7%	7%	6%	12%	7%	5%	6%
8:00	8%	16%	8%	8%	9%	7%	14%	8%	7%	8%
9:00	9%	18%	9%	9%	10%	7%	14%	9%	7%	8%
10:00	9%	18%	9%	9%	10%	7%	14%	9%	7%	8%
11:00	9%	18%	9%	9%	10%	7%	14%	9%	7%	8%
12:00	9%	18%	9%	9%	10%	7%	14%	9%	7%	8%
13:00	8%	16%	9%	9%	9%	7%	14%	9%	7%	8%
14:00	8%	16%	9%	9%	9%	7%	14%	9%	7%	8%
15:00	8%	16%	9%	9%	9%	7%	14%	9%	7%	8%
16:00	8%	16%	9%	9%	8%	7%	14%	9%	7%	8%
17:00	7%	14%	8%	8%	8%	6%	12%	8%	6%	7%
18:00	7%	14%	8%	8%	8%	6%	12%	8%	6%	7%
19:00	7%	14%	8%	7%	8%	6%	12%	8%	5%	6%
20:00	6%	12%	7%	6%	7%	5%	10%	7%	4%	6%
21:00	6%	12%	7%	6%	7%	5%	10%	7%	4%	5%
22:00	5%	10%	6%	5%	6%	4%	8%	6%	3%	4%
23:00	3%	6%	6%	4%	5%	2%	4%	6%	3%	3%

Figure 286: Hourly Transient Activity as Percentage of Garage Capacity for University Profiles

13. Appendix I: Electrical Cost Estimating

13.1 Initial Costs

		Luminaire Installation Costs						
Run Number	**Run Name**	**Luminaires per Zone**	**Luminaire Unit Cost**	**Luminaire Installation Cost**	**Total Length of Conduit & Wiring**	**Power Conduit & Wiring Cost**	**TOTAL COST PER ZONE**	**Notes**
1	BASELINE	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
2	80% Daylighted	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
3	20% Daylighted	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
4	Moderate Daylight	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
5	Good Daylight	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
6	LED	1	$ 1,502	$ 100	46	$ 501	$ 2,103	Does not include adder for integral sensor - Included under "Occupancy Sensor Costs"
7	HID	2	$ 526	$ 100	43	$ 469	$ 1,721	Includes adder for bi-level ballast
8	Induction	2	$ 510	$ 100	46	$ 501	$ 1,721	Includes adder for bi-level driver
9	Medium Occupancy 24/7	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
10	Low Occupancy 24/7	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
11	Office High Occupancy	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
12	Office Medium Occupancy	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
13	Office Low Occupancy	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
14	Mixed Use High Occupancy	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
15	Mixed Use Medium Occupancy	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
16	Mixed Use Low Occupancy	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
17	Baseline @ 0.2 W/sf	6	$ 105	$ 100	125	$ 1,363	$ 2,593	Includes adder for bi-level ballast
18	University	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
19	Bust	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
20	Baseline 2 (With Reporting)	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
21	Baseline 3 (With Reporting)	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
22	Bust 2	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
23	University 2	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
24	LED 2	1	$ 1,502	$ 100	46	$ 501	$ 2,103	Does not include adder for integral sensor - Included under "Occupancy Sensor Costs"
25	LED 3	1	$ 1,502	$ 100	46	$ 501	$ 2,103	Does not include adder for integral sensor - Included under "Occupancy Sensor Costs"
26	Office Medium Bracket FL	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
27	Office Medium Bracket LED	1	$ 1,502	$ 100	46	$ 501	$ 2,103	Does not include adder for integral sensor - Included under "Occupancy Sensor Costs"
28	Office High Bracket FL	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
29	Mixed Use High Bracket FL	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
30	University 3	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
31	University 3	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast
32	University 3	4	$ 105	$ 100	83	$ 908	$ 1,728	Includes adder for bi-level ballast

Figure 287: Initial Costs for 'Controlled' Lighting Equipment

		Luminaire Installation Costs						
Run Number	**Run Name**	**Luminaires per Zone**	**Luminaire Unit Cost**	**Luminaire Installation Cost**	**Total Length of Conduit & Wiring**	**Power Conduit & Wiring Cost**	**TOTAL COST PER ZONE**	**Notes**
1	BASELINE	4	$ 60	$ 100	83	$ 908	$ 1,548	
2	80% Daylighted	4	$ 60	$ 100	83	$ 908	$ 1,548	
3	20% Daylighted	4	$ 60	$ 100	83	$ 908	$ 1,548	
4	Moderate Daylight	4	$ 60	$ 100	83	$ 908	$ 1,548	
5	Good Daylight	4	$ 60	$ 100	83	$ 908	$ 1,548	
6	LED	1	$ 1,502	$ 100	46	$ 501	$ 2,103	
7	HID	2	$ 326	$ 100	43	$ 469	$ 1,321	
8	Induction	2	$ 425	$ 100	46	$ 501	$ 1,551	
9	Medium Occupancy 24/7	4	$ 60	$ 100	83	$ 908	$ 1,548	
10	Low Occupancy 24/7	4	$ 60	$ 100	83	$ 908	$ 1,548	
11	Office High Occupancy	4	$ 60	$ 100	83	$ 908	$ 1,548	
12	Office Medium Occupancy	4	$ 60	$ 100	83	$ 908	$ 1,548	
13	Office Low Occupancy	4	$ 60	$ 100	83	$ 908	$ 1,548	
14	Mixed Use High Occupancy	4	$ 60	$ 100	83	$ 908	$ 1,548	
15	Mixed Use Medium Occupancy	4	$ 60	$ 100	83	$ 908	$ 1,548	
16	Mixed Use Low Occupancy	4	$ 60	$ 100	83	$ 908	$ 1,548	
17	Baseline @ 0.2 W/sf	6	$ 60	$ 100	125	$ 1,363	$ 2,323	
18	University	4	$ 60	$ 100	83	$ 908	$ 1,548	
19	Bust	4	$ 60	$ 100	83	$ 908	$ 1,548	
20	Baseline 2 (With Reporting)	4	$ 60	$ 100	83	$ 908	$ 1,548	
21	Baseline 3 (With Reporting)	4	$ 60	$ 100	83	$ 908	$ 1,548	
22	Bust 2	4	$ 60	$ 100	83	$ 908	$ 1,548	
23	University 2	4	$ 60	$ 100	83	$ 908	$ 1,548	
24	LED 2	1	$ 1,502	$ 100	46	$ 501	$ 2,103	
25	LED 3	1	$ 1,502	$ 100	46	$ 501	$ 2,103	
26	Office Medium Bracket FL	4	$ 60	$ 100	83	$ 908	$ 1,548	
27	Office Medium Bracket LED	1	$ 1,502	$ 100	46	$ 501	$ 2,103	
28	Office High Bracket FL	4	$ 60	$ 100	83	$ 908	$ 1,548	
29	Mixed Use High Bracket FL	4	$ 60	$ 100	83	$ 908	$ 1,548	
30	University 3	4	$ 60	$ 100	83	$ 908	$ 1,548	
31	University 3	4	$ 60	$ 100	83	$ 908	$ 1,548	
32	University 3	4	$ 60	$ 100	83	$ 908	$ 1,548	

Figure 288: Initial Costs for 'Uncontrolled' Lighting Equipment

		Occupancy Sensors Installation Costs						
Run Number	Run Name	Occupancy Sensor Unit Cost	Occupancy Sensor Installation Cost	Total Length of Power Conduit & Wiring	Total Length of Sensor Conduit & Wiring	Sensor Conduit & Wiring Cost	TOTAL COST PER ZONE	Notes
1	BASELINE	$ 128	$ 100	11	76	$ 238	$ 466	
2	80% Daylighted	$ 128	$ 100	11	76	$ 238	$ 466	
3	20% Daylighted	$ 128	$ 100	11	76	$ 238	$ 466	
4	Moderate Daylight	$ 128	$ 100	11	76	$ 238	$ 466	
5	Good Daylight	$ 128	$ 100	11	76	$ 238	$ 466	
6	LED	$ 328	$ -	0	32	$ 50	$ 378	Integral
7	HID	$ 128	$ 100	0	43	$ 67	$ 295	
8	Induction	$ -	$ -	0	0	$ -	$ -	Cost included in 'Controlled' Luminaire cost
9	Medium Occupancy 24/7	$ 128	$ 100	11	76	$ 238	$ 466	
10	Low Occupancy 24/7	$ 128	$ 100	11	76	$ 238	$ 466	
11	Office High Occupancy	$ 128	$ 100	11	76	$ 238	$ 466	
12	Office Medium Occupancy	$ 128	$ 100	11	76	$ 238	$ 466	
13	Office Low Occupancy	$ 128	$ 100	11	76	$ 238	$ 466	
14	Mixed Use High Occupancy	$ 128	$ 100	11	76	$ 238	$ 466	
15	Mixed Use Medium Occupancy	$ 128	$ 100	11	76	$ 238	$ 466	
16	Mixed Use Low Occupancy	$ 128	$ 100	11	76	$ 238	$ 466	
17	Baseline @ 0.2 W/sf	$ 128	$ 100	17	114	$ 363	$ 591	
18	University	$ 128	$ 100	11	76	$ 238	$ 466	
19	Bust	$ 128	$ 100	11	76	$ 238	$ 466	
20	Baseline 2 (With Reporting)	$ 128	$ 100	11	76	$ 238	$ 466	
21	Baseline 3 (With Reporting)	$ 128	$ 100	11	76	$ 238	$ 466	
22	Bust 2	$ 128	$ 100	11	76	$ 238	$ 466	
23	University 2	$ 128	$ 100	11	76	$ 238	$ 466	
24	LED 2	$ 328	$ -	0	32	$ 50	$ 378	Integral
25	LED 3	$ 328	$ -	0	32	$ 50	$ 378	Integral
26	Office Medium Bracket FL	$ 128	$ 100	11	76	$ 238	$ 466	
27	Office Medium Bracket LED	$ 328	$ -	0	32	$ 50	$ 378	Integral
28	Office High Bracket FL	$ 128	$ 100	11	76	$ 238	$ 466	
29	Mixed Use High Bracket FL	$ 128	$ 100	11	76	$ 238	$ 466	
30	University 3	$ 128	$ 100	11	76	$ 238	$ 466	
31	University 3	$ 128	$ 100	11	76	$ 238	$ 466	
32	University 3	$ 128	$ 100	11	76	$ 238	$ 466	

Figure 289: Initial Costs for Occupancy Sensor Equipment

		Photocell Installation Costs					
Run Number	**Run Name**	**Photocell Total Unit Cost**	**Total Length of Power Conduit & Wiring**	**Total Length of Sensor Conduit & Wiring**	**Associated Wiring and Conduit per Zone**	**TOTAL COST CONTROL PER ZONE**	**Notes**
1	BASELINE	$ 190	0	60	$ 94	$ 284	
2	80% Daylighted	$ 190	0	60	$ 94	$ 284	
3	20% Daylighted	$ 190	0	60	$ 94	$ 284	
4	Moderate Daylight	$ 190	0	60	$ 94	$ 284	
5	Good Daylight	$ 190	0	60	$ 94	$ 284	
6	LED	$ 190	0	60	$ 94	$ 284	
7	HID	$ 190	0	60	$ 94	$ 284	
8	Induction	$ 190	0	60	$ 94	$ 284	Per controlled zone, one zone total on North side, one zone per floor on South side
9	Medium Occupancy 24/7	$ 190	0	60	$ 94	$ 284	
10	Low Occupancy 24/7	$ 190	0	60	$ 94	$ 284	
11	Office High Occupancy	$ 190	0	60	$ 94	$ 284	
12	Office Medium Occupancy	$ 190	0	60	$ 94	$ 284	
13	Office Low Occupancy	$ 190	0	60	$ 94	$ 284	
14	Mixed Use High Occupancy	$ 190	0	60	$ 94	$ 284	
15	Mixed Use Medium Occupancy	$ 190	0	60	$ 94	$ 284	
16	Mixed Use Low Occupancy	$ 190	0	60	$ 94	$ 284	
17	Baseline @ 0.2 W/sf	$ 190	0	60	$ 94	$ 284	
18	University	$ 190	0	60	$ 94	$ 284	Per controlled zone, one zone total on North side, one zone total on South side
19	Bust	$ 190	0	60	$ 94	$ 284	
20	Baseline 2 (With Reporting)	$ 190	0	60	$ 94	$ 284	Per controlled zone, one zone total on North side, one zone per floor on South side
21	Baseline 3 (With Reporting)	$ 190	0	60	$ 94	$ 284	
22	Bust 2	$ 190	0	60	$ 94	$ 284	
23	University 2	$ 190	0	60	$ 94	$ 284	Per controlled zone, one zone total on North side, one zone total on South side
24	LED 2	$ 190	0	60	$ 94	$ 284	
25	LED 3	$ 190	0	60	$ 94	$ 284	
26	Office Medium Bracket FL	$ 190	0	60	$ 94	$ 284	Per controlled zone, one zone total on North side, one zone per floor on South side
27	Office Medium Bracket LED	$ 190	0	60	$ 94	$ 284	
28	Office High Bracket FL	$ 190	0	60	$ 94	$ 284	
29	Mixed Use High Bracket FL	$ 190	0	60	$ 94	$ 284	
30	University 3	$ 190	0	60	$ 94	$ 284	Per controlled zone, one zone total on North side, one zone total on South side
31	University 3	$ 190	0	60	$ 94	$ 284	
32	University 3	$ 190	0	60	$ 94	$ 284	

Figure 290: Initial Costs for Photocell Equipment

13.2 Ongoing Maintenance Costs

		Lamp Replacement Costs							
Run Number	**Run Name**	**Rated Lamp Life, [hrs]**	**70% of Rated Life**	**Expected Years per Lamp**	**Total Lamp Changes**	**Escalation Rate**	**Present Cost per Luminaire (Labor & Materials)**	**Total 15-Year Lamp Replacement Cost per Zone**	**Notes**
1	BASELINE	42,000	29,400	4	4	3%	$ 14	$ 70	
2	80% Daylighted	42,000	29,400	4	4	3%	$ 14	$ 70	
3	20% Daylighted	42,000	29,400	4	4	3%	$ 14	$ 70	
4	Moderate Daylight	42,000	29,400	4	4	3%	$ 14	$ 70	
5	Good Daylight	42,000	29,400	4	4	3%	$ 14	$ 70	
6	LED	60,000	42,000	5	3	3%	$ 1,502	$ 2,163	Must replace luminaire, cost is reduced by 7% per year (net)
7	HID	30,000	21,000	3	5	3%	$ 75	$ 449	
8	Induction	100,000	70,000	8	2	3%	$ 75	$ 206	
9	Medium Occupancy 24/7	42,000	29,400	4	4	3%	$ 14	$ 70	
10	Low Occupancy 24/7	42,000	29,400	4	4	3%	$ 14	$ 70	
11	Office High Occupancy	42,000	29,400	4	4	3%	$ 14	$ 70	
12	Office Medium Occupancy	42,000	29,400	4	4	3%	$ 14	$ 70	
13	Office Low Occupancy	42,000	29,400	4	4	3%	$ 14	$ 70	
14	Mixed Use High Occupancy	42,000	29,400	4	4	3%	$ 14	$ 70	
15	Mixed Use Medium Occupancy	42,000	29,400	4	4	3%	$ 14	$ 70	
16	Mixed Use Low Occupancy	42,000	29,400	4	4	3%	$ 14	$ 70	
17	Baseline @ 0.2 W/sf	42,000	29,400	4	4	3%	$ 21	$ 105	
18	University	42,000	29,400	4	4	3%	$ 14	$ 70	
19	Bust	42,000	29,400	4	4	3%	$ 14	$ 70	
20	Baseline 2 (With Reporting)	42,000	29,400	4	4	3%	$ 14	$ 70	
21	Baseline 3 (With Reporting)	42,000	29,400	4	4	3%	$ 14	$ 70	
22	Bust 2	42,000	29,400	4	4	3%	$ 14	$ 70	
23	University 2	42,000	29,400	4	4	3%	$ 14	$ 70	
24	LED 2	60,000	42,000	5	3	3%	$ 1,502	$ 2,163	Must replace luminaire, cost is reduced by 7% per year (net)
25	LED 3	60,000	42,000	5	3	3%	$ 1,502	$ 2,163	Must replace luminaire, cost is reduced by 7% per year (net)
26	Office Medium Bracket FL	42,000	29,400	4	4	3%	$ 14	$ 70	
27	Office Medium Bracket LED	60,000	42,000	5	3	3%	$ 1,502	$ 2,163	Must replace luminaire, cost is reduced by 7% per year (net)
28	Office High Bracket FL	42,000	29,400	4	4	3%	$ 14	$ 70	
29	Mixed Use High Bracket FL	42,000	29,400	4	4	3%	$ 14	$ 70	
30	University 3	42,000	29,400	4	4	3%	$ 14	$ 70	
31	University 3	42,000	29,400	4	4	3%	$ 14	$ 70	
32	University 3	42,000	29,400	4	4	3%	$ 14	$ 70	

Figure 291: Present Value of Lamp Replacement Costs

		Luminaire Cleaning Costs		
Run Number	**Run Name**	**Present Cost of Luminaire Cleaning**	**Present Value of 15-Year Cleaning Cost per Luminaire**	**Present Value of 15-Year Cleaning Cost per Zone**
1	BASELINE	$ 9	$ 107	$ 430
2	80% Daylighted	$ 9	$ 107	$ 430
3	20% Daylighted	$ 9	$ 107	$ 430
4	Moderate Daylight	$ 9	$ 107	$ 430
5	Good Daylight	$ 9	$ 107	$ 430
6	LED	$ 9	$ 107	$ 107
7	HID	$ 9	$ 107	$ 215
8	Induction	$ 9	$ 107	$ 215
9	Medium Occupancy 24/7	$ 9	$ 107	$ 430
10	Low Occupancy 24/7	$ 9	$ 107	$ 430
11	Office High Occupancy	$ 9	$ 107	$ 430
12	Office Medium Occupancy	$ 9	$ 107	$ 430
13	Office Low Occupancy	$ 9	$ 107	$ 430
14	Mixed Use High Occupancy	$ 9	$ 107	$ 430
15	Mixed Use Medium Occupancy	$ 9	$ 107	$ 430
16	Mixed Use Low Occupancy	$ 9	$ 107	$ 430
17	Baseline @ 0.2 W/sf	$ 9	$ 107	$ 645
18	University	$ 9	$ 107	$ 430
19	Bust	$ 9	$ 107	$ 430
20	Baseline 2 (With Reporting)	$ 9	$ 107	$ 430
21	Baseline 3 (With Reporting)	$ 9	$ 107	$ 430
22	Bust 2	$ 9	$ 107	$ 430
23	University 2	$ 9	$ 107	$ 430
24	LED 2	$ 9	$ 107	$ 107
25	LED 3	$ 9	$ 107	$ 107
26	Office Medium Bracket FL	$ 9	$ 107	$ 430
27	Office Medium Bracket LED	$ 9	$ 107	$ 107
28	Office High Bracket FL	$ 9	$ 107	$ 430
29	Mixed Use High Bracket FL	$ 9	$ 107	$ 430
30	University 3	$ 9	$ 107	$ 430
31	University 3	$ 9	$ 107	$ 430
32	University 3	$ 9	$ 107	$ 430

Figure 292: Present Value of Luminaire Cleaning Costs

		Occ Sensor Replacement Costs			
Run Number	**Run Name**	**Sensor Cost**	**Labor**	**Total Cost per Replacement**	**Total 15-Year Sensor Replacement Cost per Zone**
1	BASELINE	$ 128	50	$ 178	$ 32
2	80% Daylighted	$ 128	50	$ 178	$ 32
3	20% Daylighted	$ 128	50	$ 178	$ 32
4	Moderate Daylight	$ 128	50	$ 178	$ 32
5	Good Daylight	$ 128	50	$ 178	$ 32
6	LED	$ 328	50	$ 378	$ 25
7	HID	$ 128	50	$ 178	$ 32
8	Induction	$ 128	50	$ 178	$ 32
9	Medium Occupancy 24/7	$ 128	50	$ 178	$ 32
10	Low Occupancy 24/7	$ 128	50	$ 178	$ 32
11	Office High Occupancy	$ 128	50	$ 178	$ 32
12	Office Medium Occupancy	$ 128	50	$ 178	$ 32
13	Office Low Occupancy	$ 128	50	$ 178	$ 32
14	Mixed Use High Occupancy	$ 128	50	$ 178	$ 32
15	Mixed Use Medium Occupancy	$ 128	50	$ 178	$ 32
16	Mixed Use Low Occupancy	$ 128	50	$ 178	$ 32
17	Baseline @ 0.2 W/sf	$ 128	50	$ 178	$ 32
18	University	$ 128	50	$ 178	$ 32
19	Bust	$ 128	50	$ 178	$ 32
20	Baseline 2 (With Reporting)	$ 128	50	$ 178	$ 32
21	Baseline 3 (With Reporting)	$ 128	50	$ 178	$ 32
22	Bust 2	$ 128	50	$ 178	$ 32
23	University 2	$ 128	50	$ 178	$ 32
24	LED 2	$ 328	50	$ 378	$ 25
25	LED 3	$ 328	50	$ 378	$ 25
26	Office Medium Bracket FL	$ 128	50	$ 178	$ 32
27	Office Medium Bracket LED	$ 328	50	$ 378	$ 25
28	Office High Bracket FL	$ 128	50	$ 178	$ 32
29	Mixed Use High Bracket FL	$ 128	50	$ 178	$ 32
30	University 3	$ 128	50	$ 178	$ 32
31	University 3	$ 128	50	$ 178	$ 32
32	University 3	$ 128	50	$ 178	$ 32

Figure 293: Present Value of Occupancy Sensor Replacement Costs

13.3 Total Costs

			TOTAL GARAGE 15-YEAR EQUIPMENT AND MAINTENANCE COSTS			
Run Number	**Run Name**	**NUMBER OF ZONES**	**BASELINE**	**DAYLIGHT ONLY**	**OCCUPANCY, NON-DAYLIGHTED**	**OCCUPANCY, DAYLIGHTED**
1	BASELINE	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
2	80% Daylighted	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
3	20% Daylighted	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
4	Moderate Daylight	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
5	Good Daylight	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
6	LED	112	$ 489,815	$ 491,233	$ 534,894	$ 536,312
7	HID	56	$ 111,155	$ 112,573	$ 151,894	$ 153,312
8	Induction	64	$ 126,206	$ 127,624	$ 139,159	$ 140,577
9	Medium Occupancy 24/7	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
10	Low Occupancy 24/7	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
11	Office High Occupancy	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
12	Office Medium Occupancy	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
13	Office Low Occupancy	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
14	Mixed Use High Occupancy	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
15	Mixed Use Medium Occupancy	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
16	Mixed Use Low Occupancy	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
17	Baseline @ 0.2 W/sf	52	$ 159,771	$ 161,189	$ 206,235	$ 207,653
18	University	12	$ 24,580	$ 25,147	$ 32,726	$ 33,294
19	Bust	40	$ 81,934	$ 84,202	$ 109,088	$ 111,357
20	Baseline 2 (With Reporting)	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
21	Baseline 3 (With Reporting)	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
22	Bust 2	40	$ 81,934	$ 82,501	$ 109,088	$ 109,655
23	University 2	12	$ 24,580	$ 25,147	$ 32,726	$ 33,294
24	LED 2	112	$ 489,815	$ 491,233	$ 534,894	$ 536,312
25	LED 3	112	$ 489,815	$ 491,233	$ 534,894	$ 536,312
26	Office Medium Bracket FL	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
27	Office Medium Bracket LED	112	$ 489,815	$ 491,233	$ 534,894	$ 536,312
28	Office High Bracket FL	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
29	Mixed Use High Bracket FL	40	$ 81,934	$ 83,352	$ 109,088	$ 110,506
30	University 3	12	$ 24,580	$ 25,147	$ 32,726	$ 33,294
31	University 3	12	$ 24,580	$ 25,147	$ 32,726	$ 33,294
32	University 3	12	$ 24,580	$ 25,147	$ 32,726	$ 33,294

Figure 294: Total Garage Present Value of All Equipment and Maintenance Costs per Scenario

						TOTAL ZONE-BY-ZONE COSTS			
Run Number	**Run Name**	**Total # Floors**	**# Occupancy Zones per Floor**	**# Daylighted Zones per Floor**	**NUMBER OF ZONES**	**UNCONTROLLED LUMINAIRE ZONE COST**	**CONTROLLED LUMINAIRE ZONE COST**	**OCCUPANCY SENSING ZONE COST**	**EFFECTIVE DAYLIGHTING ZONE COST**
1	BASELINE	4	10	5	40	$ 2,048	$ 2,228	$ 499	$ 71
2	80% Daylighted	4	10	8	40	$ 2,048	$ 2,228	$ 499	$ 44
3	20% Daylighted	4	10	2	40	$ 2,048	$ 2,228	$ 499	$ 177
4	Moderate Daylight	4	10	5	40	$ 2,048	$ 2,228	$ 499	$ 71
5	Good Daylight	4	10	5	40	$ 2,048	$ 2,228	$ 499	$ 71
6	LED	4	28	14	112	$ 4,373	$ 4,373	$ 402	$ 25
7	HID	4	14	7	56	$ 1,985	$ 2,385	$ 327	$ 51
8	Induction	4	16	8	64	$ 1,972	$ 2,142	$ 32	$ 44
9	Medium Occupancy 24/7	4	10	5	40	$ 2,048	$ 2,228	$ 499	$ 71
10	Low Occupancy 24/7	4	10	5	40	$ 2,048	$ 2,228	$ 499	$ 71
11	Office High Occupancy	4	10	5	40	$ 2,048	$ 2,228	$ 499	$ 71
12	Office Medium Occupancy	4	10	5	40	$ 2,048	$ 2,228	$ 499	$ 71
13	Office Low Occupancy	4	10	5	40	$ 2,048	$ 2,228	$ 499	$ 71
14	Mixed Use High Occupancy	4	10	5	40	$ 2,048	$ 2,228	$ 499	$ 71
15	Mixed Use Medium Occupancy	4	10	5	40	$ 2,048	$ 2,228	$ 499	$ 71
16	Mixed Use Low Occupancy	4	10	5	40	$ 2,048	$ 2,228	$ 499	$ 71
17	Baseline @ 0.2 W/sf	4	13	6	52	$ 3,073	$ 3,343	$ 624	$ 59
18	University	2	6	3	12	$ 2,048	$ 2,228	$ 499	$ 95
19	Bust	4	10	8	40	$ 2,048	$ 2,228	$ 499	$ 71
20	Baseline 2 (With Reporting)	4	10	5	40	$ 2,048	$ 2,228	$ 499	$ 71
21	Baseline 3 (With Reporting)	4	10	5	40	$ 2,048	$ 2,228	$ 499	$ 71
22	Bust 2	4	10	2	40	$ 2,048	$ 2,228	$ 499	$ 71
23	University 2	2	6	3	12	$ 2,048	$ 2,228	$ 499	$ 95
24	LED 2	4	28	14	112	$ 4,373	$ 4,373	$ 402	$ 25
25	LED 3	4	28	14	112	$ 4,373	$ 4,373	$ 402	$ 25
26	Office Medium Bracket FL	4	10	5	40	$ 2,048	$ 2,228	$ 499	$ 71
27	Office Medium Bracket LED	4	28	14	112	$ 4,373	$ 4,373	$ 402	$ 25
28	Office High Bracket FL	4	10	5	40	$ 2,048	$ 2,228	$ 499	$ 71
29	Mixed Use High Bracket FL	4	10	5	40	$ 2,048	$ 2,228	$ 499	$ 71
30	University 3	2	6	3	12	$ 2,048	$ 2,228	$ 499	$ 95
31	University 3	2	6	3	12	$ 2,048	$ 2,228	$ 499	$ 95
32	University 3	2	6	3	12	$ 2,048	$ 2,228	$ 499	$ 95

Figure 295: Total Effective Zone-by-Zone Present Value of All Equipment and Maintence Costs per Scenario