CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Outdoor Lighting and Controls

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team October 2011

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1. Overview

<table>
<tr><td>a. Measure Title</td><td>Outdoor lighting LPD revisions and the introduction of mandatory lighting controls (beyond the basic photocell control).</td></tr>
<tr><td>b. Description</td><td>The revisions in this measure detail two distinct points of effort. The changing IESNA design guidelines for some exterior lighting situations provides an opportunity to reduce the LPD's associated with these conditions. The second revision involves the application of motion sensors in exterior lighting situations where the lighting equipment is mounted below 24'. This includes lighting equipment on poles and building mounted, including under canopies.</td></tr>
<tr><td>c. Type of Change</td><td>Both of these are mandatory measures.</td></tr>
<tr><td>d. Energy Benefits</td><td>The LPD reduction measure will reduce power density for a select group of outdoor lighting applications, including those in the highest power density categories; outdoor retail and vehicle service stations. While this does not reflect a wide-ranging large scale impact on the total outdoor lighting environment, it is the opportunity to reduce the highest consumption categories with the support of the new IESNA Handbook.

The reduction in power and energy consumption associated with this specific measure is reflected in the table below.
<table>
<tr><td></td><td>Electricity Savings (kwh/yr)</td><td>Demand Savings (w)</td><td>TDV Electricity Savings</td></tr>
<tr><td>Outdoor Retail (per sq. ft.)</td><td>1.78</td><td>.408</td><td>$ 2.56</td></tr>
<tr><td>Outdoor Retail Frontage (per lin. ft.)</td><td>26.3</td><td>6</td><td>$ 37.65</td></tr>
<tr><td>Service Station Hardscape (per sq. ft.)</td><td>1.0</td><td>.228</td><td>$ 1.43</td></tr>
<tr><td>Service Station Canopy (per sq. ft.)</td><td>3.3</td><td>.758</td><td>$ 4.76</td></tr>
</table>
(Values based on LZ3, will vary depending on the LZ. Based on 11 operating hours per night, from 1900 to 0600.)

The savings from this/these measures results in the following statewide first year savings for LZ3:
<table>
<tr><td>Total Electric Energy Savings (GWh)</td><td>Total TDV Savings ($)</td></tr>
<tr><td>8,427</td><td>$ 12,072,000</td></tr>
</table></td></tr>
<tr><td>e. Non-Energy Benefits</td><td>The LPD allowance reductions may result in a reduction of the installed cost of the lighting system, and is likely to at least have no negative cost implications. The controls measure will increase installed costs, but has a payback that justifies the measure. The controls measure will reduce light pollution and trespass after the regular operating hours of the facility.</td></tr>
</table>

f. Environmental Impacts

The introduction of mandatory lighting controls will require additional equipment. The equipment does contain elements that may have potential adverse environmental impacts. The table below shows the statewide material content (in pounds) for the measure.

Component	Mercury	Lead	Cooper	Steel	Plastic	Others (Identify)
Occupancy Sensor	1	3	184	123	306	0
Cat 5 Control Wiring 100'	0	0	20,951	0	0	0
Control System	1	0	10,659	123	306	0

g. Technology Measures

The mandatory controls measure requires the application of motion sensors in outdoor applications. There are a variety of suitable motion sensors on the market, but many are limited in detection distance, and have a variety of other limitations. Because of this, the measure has been limited to certain physical constraints, including the 24' mounting height, for example.

While there are many products available in the residential-grade market, there are fewer in the commercial market, but still sufficient options to meet the market demand. It is anticipated that the mandatory measure will stimulate the controls industry to accelerate development in the outdoor sensor realm, and encourage more vendors to enter the market as well.

h. Performance Verification of the Proposed Measure

Both portions of this measure have current verification mechanisms written in the language that directly apply, or can be modified for the specific circumstances in this measure.

i. Cost Effectiveness

The LPD reductions have instant payback; no cost effectiveness calculations are required.

The cost effectiveness of the mandatory controls measure is dependent on the loads controlled. The following provides information on the cost effectiveness of the measure.

Measure	Cost / Sq. Ft.	15 Year TDV Savings / Sq. Ft.	Benefit to Cost Ratio	Cost Effective?
Mandatory Outdoor Occupancy Sensors	$0.17	$0.20	1.18	**YES**

j. Analysis Tools

These measures are mandatory. N/A

k. Relationship to Other Measures	This measure does not have any known interrelationships with any other measures.

2. Methodology

The outdoor lighting analysis focused on Lighting Power Allowances (LPAs) and lighting controls requirements. There were six separate points of review in this revision cycle:

- Comparison analysis among the Lighting Zones assignments in Title 24, ASHRAE 90.1-2010 and the joint IES/IDA Model Lighting Ordinance to determine if there is a need for recalibration in Title 24 documents.
- Review the Illuminance Basis of Design that was established in the 2008 revision cycle to determine if any changes have occurred in the design community that would permit a reduction in the LPS allowances due to a reduction in the industry standard design recommendation documents.
- Compare the current Title 24 allowance values and the most-recently adopted ASHRAE 90.1 values, and reduce Title 24 requirements where possible to ensure that all cost-effective savings are being captured.
- Consider the addition of controls (beyond the currently-mandatory photocell and curfew control capabilities). This will involve the consideration of occupancy sensors and part-night systems for circumstances where the controls are viable.
- State-of-the-market surveys.
- Review of PIER and GATEWAY pilot Projects.

2.1 ASHRAE Standard 90.1 Implications

The ASHRAE Standard 90.1 document is an evolving document, similar to California's Title 24, Part 6. It is currently on a three-year cycle, with the most recent version being ASHRAE 90.1-2010, which was adopted at the end of 2010. The previous version was 90.1-2007.

The original ASHRAE 90.1-2007 version did not include Lighting Zones, so all exterior lighting power density allowances had a single value. In 2008 ASHRAE introduced 'Addendum i', in which Lighting Zones were introduced and along with this change, LPD values were created along with the Lighting Zones throughout the tables.

2.2 Comparison of Title 24, ASHRAE 90.1-2010 and MLO Lighting Zone Mapping

Since the concept of Lighting Zones is being adopted in a variety of versions in other lighting design and energy guidance documents, there is concern that the mapping may begin to make direct comparisons of these documents more difficult.

There are three relevant documents that must be compared in this process.

- California Title 24-2008 Building Energy Efficiency Standards
- ASHRAE 90.1-2010
- Joint IESNA/IDA Model Lighting Ordinance (development documents)

As a result, a review of the Lighting Zone mapping was performed to make characterizations about how the IESNA, ASHRAE, and Title 24 apply the concept, and determine if there are any specific adjustments necessary to keep the Title 24 mapping consistent with the other two as much as possible.

This was done by collecting the specific Zone mapping language for each document and attempting to characterize the mapping based on the language and other details of the mapping infrastructure within each document.

2.3 Review of the Basis of Design for the Title 24 Exterior LPA Values

In the 2005 Title 24 revision cycle, the Lighting Zones concept was introduced. To make this viable to establish LPA values, the team 'mapped' the then-current IES lighting design recommendations from a variety of sources, (mostly IES Recommended Practice documents (RP's), Design Guidelines (DG's), and the Security Lighting document (G-1)). As a result, a map of general lighting design targets was established. This map created the various levels of lighting power density that were calibrated to and correspond with the LPD's. Since this initial mapping, there have been some modifications to the various source documents that produced the target illumination levels, and consequently the LPD allowances can be reconsidered and adjusted.

Refer to Figure 1 and Figure 2 for the illuminance criteria mapping used in Title 24-2008, providing horizontal illuminance (hfc) and vertical illuminance (vfc) recommendations.

T-24 Lighting Application	Recommended Design Criteria per Lighting Zone			
	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Hardscape for automotive vehicular use, including parking lots, driveways, and site roads	RP-20 NO VERTICAL (0.2 hfc min)	RP-20 Basic (0.2 hfc min, 0.1 vfc)	RP-20 Enhanced (0.5 hfc min, 0.25 vfc)	RP-20 Enhanced Security/Retail (1.0 hfc min, 0.25 vfc)
Hardscape for pedestrian use, including plazas, sidewalks, walkways, and bikeways	DG-5 Sidewalk along Street - Residential (0.2 hfc avg. 10:1 avg:min)	DG-5 Sidewalk along Street - Intermediate (0.5 hfc avg. 4:1 avg:min)	DG-5 Sidewalk along Street - Commercial (1.0 hfc avg. 4:1 avg:min)	DG-5 Sidewalk along Street - Commercial Special Conditions (2.0 hfc avg. vertical 5:1 avg:min)
Hardscape for driveways, side roads, sidewalks, walkways, and bikeways	RP-8 Walkway/Bikeway Mixed use - Pedestrian Low Conflict (0.5 hfc)	RP-8 Walkway/Bikeway Mixed use - Pedestrian Medium Conflict (1 hfc)	RP-8 Walkway/Bikeway Mixed use - Pedestrian High Conflict (2 hfc)	DG-5 Sidewalk along Street - Commercial Special Conditions (2.0 hfc avg. vertical 5:1 avg:min)
Building Entrances (without canopy)	DG-5 Sidewalk along Street - Commercial (1.0 hfc avg. 4:1 avg:min)	RP-2 Seasonal Outdoor Merchandise Circulation Low (5 hfc)	RP-2 Seasonal Outdoor Merchandise Circulation Medium (7 hfc)	RP-2 Seasonal Outdoor Merchandise Circulation High (10 hfc)
Outdoor Sales Lot	RP-33 Secondary Business District General Display (5 hfc, 10:1 max:min)	RP-2 Auto Retail Lot Low Level (20 hfc)	RP-2 Auto Retail Lot Medium Level (30 hfc)	RP-2 Auto Retail Lot High Level (50 hfc)

Figure 1: Title 24-2008 Table 147-A Illuminance Design Basis Mapping

T24 Lighting Application	Recommended Design Criteria per Lighting Zone			
	Lighting Zone 1	**Lighting Zone 2**	**Lighting Zone 3**	**Lighting Zone 4**
Building Facades	NA	RP-33 Dark Surrounds and Medium Light Surface (3 fc)	RP-33 Bright Surrounds and Light Surface (5 fc)	RP-33 Bright Surrounds and Dark Surface (10 fc)
Outdoor Sales Frontage (in linear feet)	NA	RP-2 Auto Dealership Feature Display (35 hfc)	RP-2 Auto Dealership Feature Display (50 hfc)	RP-2 Auto Dealership Feature Display (75 hfc)
Vehicle Service Station with or without canopies	RP-33 Service Station Pump Island (10 hfc)	RP-2 Service Station Gas Islands (20 hfc)	RP-2 Service Station Gas Islands (30 hfc)	RP-2 Service Station Gas Islands (50 hfc)
Vehicle Service Station Hardscape	RP-20 Basic (0.2 hfc min, 0.1 vfc)	RP-2 Service Station Approach (5 hfc)	RP-2 Service Station Approach (10 hfc)	RP-2 Service Station Approach (15 hfc)
All other Sales Canopies	NA	RP-2 Seasonal Outdoor Merchandise Display Low (10 hfc)	RP-2 Seasonal Outdoor Merchandise Display Medium (20 hfc)	RP-2 Seasonal Outdoor Merchandise Display High (30 hfc)
Non-sales Canopies	DG-5 Sidewalk along Street - Commercial (1.0 hfc avg. 4:1 avg:min)	RP-2 Seasonal Outdoor Merchandise Circulation Low (5 hfc)	RP-2 Seasonal Outdoor Merchandise Circulation Medium (7 hfc)	RP-2 Seasonal Outdoor Merchandise Circulation High (10 hfc)
Ornamental Lighting	NA	NA	NA	NA
Drive-Up Windows	G-1 Fast Food Drive Up Window (6 hfc)	G-1 Fast Food Drive Up Window (6 hfc)	G-1 Fast Food Drive Up Window (6 hfc)	G-1 Fast Food Drive Up Window (6 hfc)
Guarded Facilities	G-1 Fast Food Drive Up Window (6 hfc)	RP-2 Seasonal Outdoor Merchandise Display Low (10 hfc)	RP-2 Seasonal Outdoor Merchandise Display Medium (20 hfc)	RP-2 Seasonal Outdoor Merchandise Display High (30 hfc)
Outdoor Dining	DG-5 Sidewalk along Street - Commercial (1.0 fc avg. 4:1 avg:min)	RP-2 Seasonal Outdoor Merchandise Circulation Low (5 hfc)	RP-2 Seasonal Outdoor Merchandise Circulation Medium (7 hfc)	RP-2 Seasonal Outdoor Merchandise Circulation High (10 hfc)

Figure 2: Title 24-2008 Table 147-B Illuminance Design Basis Mapping

To complete this review, the current IESNA Recommended Practice documents were collected. If the document had been updated, the guideline values were compared to determine if any changes had occurred.

Where IESNA design recommendation changes had occurred, the changes were noted so that those portions of the LPA tables in Title 24 would be reviewed to see whether the changes to the design documents would result in a corresponding change in the LPA values.

2.4 Comparison of Title 24 and ASHRAE 90.1-2010 LPA Values

Since the ASHRAE 90.1 document has become more aggressive over the past few revisions, there is the possibility that the ASHRAE document may be more aggressive than Title 24 in some circumstances. In particular, the exterior portions of ASHRAE 90.1 have many corresponding allowances that can be directly or approximately compared to items in Tables 147-A and 147-B in Title 24.

The ASHRAE 90.1 document has been vetted through a public process, and is being adopted nationwide by a variety of jurisdictions as the minimum energy code for all new construction projects. If a specific item in ASHRAE 90.1-2010 is more aggressive, the Title 24 values should be tightened to match that level of aggressiveness, as California should be at least as aggressive as the minimum performance energy code national standard.

It was possible to make some direct comparisons between the two documents, but the majority of values cannot be compared directly due to basic infrastructural differences in the two documents.

As a result, a sequence of comparisons and models were developed to test the allowance levels in the two documents. These tests include:

- Comparison of the General Area Allowance values
- Comparison of specific Line Item Allowance values
- Development of a Big Box model to test the interactions of each allowance system
- Development of a Café model to test the interactions of each allowance system
- Development, review, and comparison of an Outdoor Retail model
- Development, review, and comparison of a Service Station with Canopy model

The General Area Allowances were tested by developing nine different site profiles, varying the size and shape of both the site and the building contained within. These comparisons then applied the allowances from each document to determine which General allowance is more aggressive. In situations where the ASHRAE 90.1 document was more aggressive, the Title 24 allowances were modified to bring them in line.

The specific Line Item Allowances represent several items in Table 147-B that are applied on a case-by-case basis depending on the circumstances on the site. Some of these line items include "Building Façades" and "Entrances". Since these are discreet items, they can be compared without considering the interactions of other allowances to determine whether they are comparable, and which document may be more aggressive.

However, these items cannot be directly compared in some cases, so a basic application of each line item was developed to test them against each other. Again, the line items were compared and adjustment recommendations developed in circumstances where the ASHRAE 90.1 document was the more aggressive standard.

The Big Box and Café models were developed to test the entire system; how the various allowance line items and the General Hardscape Allowance interact within each system, and whether as a composite, one system or the other appeared to be more aggressive. These further informed the recommended changes to Tables 147-A and 147-B.

The Outdoor Retail and Service Station with Canopy models were developed because the design basis for these two categories had changed, and there were specific interaction questions between the ASHRAE 90.1 document and Title 24, so a detailed review of these specific applications was needed. Once again, the results of these specific applications were used to make adjustment recommendations to Table 147-B.

2.5 Technical Review of Occupancy-Based Lighting Controls for Exterior Conditions

Lighting controls offer a significant opportunity for energy savings in the exterior portions of a property, primarily because there is relatively little current implementation of controls beyond the basic photocell and curfew time switch mandated in Title 24-2008. Even with the time switch present, there is no enforcement mechanism to ensure that it is used, but the capability is present for the property owner to utilize at their discretion.

The introduction of exterior occupancy controls requires careful consideration due to the limitations of the controls equipment, limitations of the light source technology that the controls will be affecting, and a recognition by the design team and owner that such controls, if applied, require an extra level of both initial commissioning/tuning and maintenance . As a result, a sequence of fact-finding efforts were taken to ensure that a measure could be recommended within the limitations of the currently-available technology.

First, 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

This market review involved an assessment of currently-available luminaires and sensor technology, as well as discussions with manufacturers regarding the future of exterior occupancy sensors.

Further, a review of ten pilot projects that have implemented controls technologies in exterior and parking garage environments was made to understand what unanticipated implementation or other integration problems have occurred, and whether the stated technology limitations are actually proving to be accurate or somewhat optimistic.

2.6 PIER and GATEWAY 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 effort 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];
- Raley's Supermarket Parking Lot Lighting Retrofit [DOE GATEWAY];
- TJ Maxx Parking Lot Lighting Retrofit [DOE GATEWAY].

Most of these projects are considered 'interior' because they are located in parking garages. A detailed review of these projects is included in the CASE report titled "Parking Garage LPA and Controls."

Based on the results of the pilot programs, in combination with the current and future availability of appropriate products, a set of final recommendations regarding advanced exterior lighting controls were established. The recommendations were adjusted to work within the limitations of the sensor, control equipment and light source technology available and anticipated to be available by the time of code implementation.

2.7 State of the Industry Reviews

A variety of State of the Industry reviews were developed to understand the intricacies of the various lighting technologies, and especially how they interact. Further, interviews with manufacturers provided information on where they see the industry being in the near future. Specifiers provided insight into the success and failures that are occurring in the application of the various technologies available.

2.8 Energy Savings Analysis

Using the California Energy Commission's 2013 cost-effectiveness methodology, we calculated energy savings using time-dependent valuation (TDV) assuming a 15-year measure life and the proposed changes in the lighting schedules.

2.9 Cost Analysis

To develop cost estimates, we combined data from equipment manufacturers and distributors with equipment costs and labor rates provided by RS Means (2010).

2.10 Cost Effectiveness Analysis

We calculated the cost-effectiveness by comparing the calculated TDV savings with the calculated measure costs. We also estimated the resulting annual statewide savings. The cost-effectiveness calculation is a direct comparison between:

- Measure costs per square foot (for equipment and labor).
- Measure savings per square foot over the 15-year measure life, calculated using the 2013 TDV method.

2.11 Statewide Savings Analysis

The total energy and energy cost savings potential for the LPD reduction measure are 1.89 kWh/ft2 and 2.71 $/ft2.

Applying these unit estimates to the statewide estimate of new construction of 4,475,694 million square feet per year of impacted outdoor area results in first year statewide energy savings of 8,427 MWh, andTDV $ 12,072,000.

The total energy and energy cost savings potential for the mandatory controls measure are .123 kWh/ft2 and 0.2 $/ft2.

Applying these unit estimates to the statewide estimate of new construction per year of impacted outdoor area results in first year statewide energy savings of 1,621 MWh, and TDV $ 2,533,000.

The statewide estimate of savings is based on new construction square footage forecasts obtained from the California Energy Commission, together with estimates of the typical hours of use and lighting power densities, as obtained from our data analysis.

2.12 Stakeholder Meeting Process

All of the main approaches, assumptions and methods of analysis used in this proposal have been presented for review at one of three public Lighting Stakeholder Meetings. At each meeting, the utilities' CASE team invited feedback on the proposed language and analysis thus far, and sent out a summary of what was discussed at the meeting, along with a summary of outstanding questions and issues.

A record of the Stakeholder Meeting presentations, summaries and other supporting documents can be found at www.calcodes.com. Stakeholder meetings were held on the following dates and locations:

- First Lighting Stakeholder Meeting: March 18th, 2010, Pacific Energy Center, San Francisco, CA
- Second Lighting Stakeholder Meeting: September 29th 2010, Hyatt Regency, Huntington Beach, CA (at the IESNA Street and Area Lighting Conference)
- Third Lighting Stakeholder Meeting: February 24th, 2011, UC Davis Alumni Center, Davis CA

In addition to the Stakeholder Meetings, a Stakeholder Work Session was held on December 8th, 2010 to allow detailed review of this and other lighting topics.

2.13 Statewide Savings Estimates

The statewide energy savings associated with the proposed measures will be calculated by multiplying the energy savings per square foot with the statewide estimate of new construction in 2014. Details on the method and data source of the nonresidential construction forecast are in Section 5.

3. Analysis and Results

With the exception of the controls portions of the efforts, all of the measures affect primarily Tables 147-A and 147-B. The basic infrastructure of Section 147 remains the same otherwise. All of these individual focus points interact to result in a combined set of recommendations for Tables 147-A and 147-B that are provided at the end of the Analysis section in summary.

3.1 Comparison of Title 24, ASHRAE 90.1-2010 and MLO Lighting Zone Mapping

The lighting zone definitions in Title 24 were compared to those in ASHRAE 90.1-2010 and in the IES/IDA Model Lighting Ordinance (MLO) documents. Refer to Appendix B: Title 24 2008 Lighting Design Basis Mapping and Changes to Update to 2011 for more information.

The Title 24-2008 Lighting Zone Mapping descriptions are provided below:

> *"LZ1: Dark*
> *Government designated parks, recreation areas, and wildlife preserves. Those that are wholly contained within a higher lighting zone may be considered by the local government as part of that lighting zone.*
>
> *LZ2: Low*
> *Rural areas, as defined by the 2000 US Census..*
>
> *LZ3: Medium*
> *Urban areas, as defined by the 2000 US Census..*
>
> *LZ4: High*
> *High intensity nighttime use, such as entertainment or commercial districts or areas with special security considerations requiring very high light levels."*

The joint IES/IDA Model Lighting Ordinance Lighting Zone descriptions are provided below:

> *"LZ0: No ambient lighting*
> *Areas where the natural environment will be seriously and adversely affected by lighting. Impacts include disturbing the biological cycles of flora and fauna and/or detracting from human enjoyment and appreciation of the natural environment. Human activity is subordinate in importance to nature. The vision of human residents and users is adapted to the total darkness, and they expect to see little or no lighting. When not needed, lighting should be extinguished.*
>
> *LZ1: Low ambient lighting*
> *Areas where lighting might adversely affect flora and fauna or disturb the character of the area. The vision of human residents and users is adapted to low light levels. Lighting may be used for safety and convenience but it is not necessarily uniform or continuous. After curfew, most lighting should be extinguished or reduced as activity levels decline.*

LZ2: Moderate ambient lighting
Areas of human activity where the vision of human residents and users is adapted to moderate light levels. Lighting may typically be used for safety and convenience but it is not necessarily uniform or continuous. After curfew, lighting may be extinguished or reduced as activity levels decline.

LZ3: Moderately high ambient lighting
Areas of human activity where the vision of human residents and users is adapted to moderately high light levels. Lighting is generally desired for safety, security and/or convenience and it is often uniform and/or continuous. After curfew, lighting may be extinguished or reduced in most areas as activity levels decline.

LZ4: High ambient lighting
Areas of human activity where the vision of human residents and users is adapted to high light levels. Lighting is generally considered necessary for safety, security and/or convenience and it is mostly uniform and/or continuous. After curfew, lighting may be extinguished or reduced in some areas as activity levels decline."

The ASHRAE 90.1-2010 Lighting Zone descriptions are as follows:

"LZ0
Undeveloped areas within national parks, state parks, forest land, rural areas, and other undeveloped areas as defined by the authority having jurisdiction.

LZ1
Developed areas of national parks, state parks, forest land, rural areas.

LZ2
Areas predominately consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed use areas.

LZ3
All other areas.

LZ4
High activity commercial districts in major metropolitan areas as designated by the local jurisdiction."

As implemented, Title 24 LZ2 and LZ3 are the two most common categories in the Title 24 code. All areas are by default, designated either LZ2 or LZ3 based on census tract housing density, and an application to the CEC is required to move an area to a different zone (State and Federal Parks being the exception). LZ2 is used mostly for rural and small cities, and LZ3 is used in larger city centers. LZ1 is primarily designated for state and national parks and national forest land. LZ4 is implemented by special application only, and at this point has not been applied in any area in the state of California.

The default Lighting Zone intended for the MLO document is LZ2. This permits larger cities to move up to LZ3 for city centers, and the largest cities to implement a central city LZ4 zone under special circumstances. LZ1 is designated for developed portions of national and state parks and communities who desire an environment with greater concern for human impact on the night sky or ecosystem. LZ0 is designated for the undeveloped and natural portions of parks and forests.

ASHRAE 90.1-2010 has LZ3 as the default zone. It downgrades to LZ2 for primarily residential areas, and upgrades to LZ4 for major metropolitan areas. LZ0 is intended for undeveloped areas, and LZ1 for developed areas in national and state parks and forests.

It's clear that the mapping may not be identical in all cases. While the apparent default zone is different among the documents, this does not mean that implementation will result in largely different zoning for the same environmental conditions. This will need to be reevaluated once the ASHRAE and MLO documents are implemented to see if the descriptions create different mapping conditions. At this point, different mapping is possible, but not assured.

Two aspects of this mapping are clear. While LZ4 is available and can be applied through all three documents, there is specific language to discourage its application. However, the ASHRAE 90.1-2010 document seems to be the most permissive of its application. Title 24-2008 requires an application to the CEC, and the MLO has specific language to discourage LZ4 use. 90.1-2010 requires the local jurisdiction to establish the zone, but without specific guidance it is not clear whether the jurisdiction can make an appropriate decision on this issue. Whether this ultimately becomes a distinction in mapping implementation is not clear at this point.

Second, LZ0 is not included in Title 24-2008, whereas ASHRAE 90.1-2010 and the MLO documents do include this zone. It is clear that LZ1 in Title 24 essentially matches LZ1 in the other two documents, so LZ0 is essentially wholly included in Title 24's designation of LZ1.

Figure 3 provides an approximate lineup of the Lighting Zones between the two energy codes.

Model Lighting Ordinance & ASHRAE 90.1-2010		**Title 24-2008**	
Ambient Illumination	Zone	Zone	Ambient Illumination
None	**LZ0**	**LZ1**	Dark
Low	**LZ1**		
Mod	**LZ2**	**LZ2**	Low
Mod-high	**LZ3**	**LZ3**	Medium
High	**LZ4**	**LZ4**	High

Figure 3: Comparison of MLO and ASHRAE Lighting Zones to Title 24 Lighting Zones

The results of the comparison of the lighting zone definition demonstrated that ASHRAE 90.1-2010 takes a philosophically-different approach to lighting zones compared to Title 24. The zone definitions in Title 24 are based on the 2000 census results, and effectively place the majority of the state in LZ2 or LZ3. ASHRAE 90.1-2010 provides more broad definitions of zones that appear to be intended to be adopted on a finer scale than Title 24, likely resulting variations of lighting zone within one neighborhood or district. However, since Title 24 is generally more aggressive than 90.1 mapping, there is no need to make adjustments to the Lighting Zone infrastructure or current mapping for this reason.

While the addition of LZ0 to Title 24 would be advantageous, the impact on the State mapping is minimal, as the current LZ1 includes all the regions that would be considered for a new LZ0, and these regions are not subject to development in a manner where the distinctions between the two levels would be tested. However, the message that the addition of LZ0 sends to the lighting design and environmental communities is significant, and therefore, while the change is largely in definitions and labels, consideration of this addition is recommended.

3.2 Review of the Basis of Design for the Title 24 Exterior LPA Values

The illuminance basis-of-design from the 2008 code revision cycle was analyzed to determine if the limiting criteria had been adjusted. Many of the design guidelines have not changed, so few changes were considered for that reason alone. Figure 4 details the changes that did occur.

Lighting Application	Reference	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Sales Frontage	Title 24-2008 Basis	N/A	RP-2-01 Feature Display- Low Activity (35 hfc)	RP-2-01 Feature Display- Medium Activity (50 hfc)	RP-2-01 Feature Display- High Activity (75 hfc)
	New IES Handbook Tenth Edition	N/A	Front Row- High Activity / Medium age group (15 hfc, 15 vfc)	Front Row- High Activity / Medium age group (20 hfc, 20 vfc)	Front Row- High Activity / Medium age group (30 hfc, 30 vfc)
	Change	N/A	**Decreased by 20 hfc (57%)** Added vfc Recommendation	**Decreased by 30 hfc (60%)** Added vfc Recommendation	**Decreased by 45 hfc (64%)** Added vfc Recommendation
Sales Area	Title 24-2008 Basis	RP-33-99 Secondary Business District General Display (5 hfc)	RP-2-01 Auto Retail Lot- Low Activity (20 hfc)	RP-2-01 Auto Retail Lot- Medium Activity (30 hfc)	RP-2-01 Auto Retail Lot- High Activity (50 hfc)
	New IES Handbook Tenth Edition	Sales Area- High Activity / Medium age group (5 hfc)	Sales Area- High Activity / Medium age group (7.5 hfc)	Sales Area- High Activity / Medium age group (10 hfc)	Sales Area- High Activity / Medium age group (15 hfc)
	Change	No Change	**Decreased by 12.5 hfc (63%)**	**Decreased by 20 hfc (67%)**	**Decreased by 35 hfc (70%)**
Vehicle Service Station with or without canopies	Title 24-2008 Basis	RP-33 Service Station Pump Island (10 hfc)	RP-2 Service Station Gas Islands (20 hfc)	RP-2 Service Station Gas Islands (30 hfc)	RP-2 Service Station Gas Islands (50 hfc)
	New IES Handbook Tenth Edition	Fuel Islands- High Activity / Medium age group (7.5 hfc)	Fuel Islands- High Activity / Medium age group (10 hfc)	Fuel Islands- High Activity / Medium age group (15 hfc)	Fuel Islands- High Activity / Medium age group (20 hfc)
	Change	**Decreased by 2.5 hfc (25%)**	**Decreased by 10 hfc (50%)**	**Decreased by 15 hfc (50%)**	**Decreased by 30 hfc (60%)**
Vehicle Service Station Hardscape	Title 24-2008 Basis	RP-20 Basic (0.2 hfc min)	RP-2 Service Station Approach (5 hfc)	RP-2 Service Station Approach (10 hfc)	RP-2 Service Station Approach (15 hfc)
	New IES Handbook Tenth Edition	Approach Lanes- High Activity / Medium age group (0.8 hfc avg)	Approach Lanes- High Activity / Medium age group (1.0 hfc)	Approach Lanes- High Activity / Medium age group (1.5 hfc)	Approach Lanes- High Activity / Medium age group (2 hfc)
	Change	Approximately No Change	**Decreased by 4 hfc (80%)**	**Decreased by 8.5 hfc (85%)**	**Decreased by 13 hfc (87%)**

Figure 4: Title 24-2008 to 2013 Design Basis Changes

As of February 2011, some updated IESNA illuminance criteria are currently under committee review and have not been adopted yet, though "preview" values were provided to assist with this analysis. It

was determined that since the updated illuminance criteria has not yet made it through committee, the criteria used for the 2008 basis-of-design should continue to be used until the next revision cycle.

For outdoor sales and frontage areas, the illuminance criteria were shifted from RP-2-01 to a new 'Design Guide' document, DG-3-11. Upon review of the sales frontage criteria, it was found that the horizontal illuminance recommendations are typically reduced from the previous basis-of-design values, but now include a vertical illuminance requirement. Additionally, the new IES Lighting handbook Edition 10 was released this spring, which introduces another set of design criteria for these categories. The Tenth Edition of the Handbook also introduces new design recommendations for Service Station areas, including the pump areas, and service station hardscape.

The Handbook values were selected for the next T24 revision because the represent a comprehensive set of design criteria with substantial energy savings potential compared to the previously adopted criteria, and ultimately represent the most environmentally responsible approach for outdoor retail lighting design.

Modeling of reasonable typical conditions was performed to establish what the new LPA allowances may be, along with a comparison of the Title 24 allowances to analogous 90.1 allowances.

As a result of these design criteria changes, Figure 5 details the specific recommendations for changes in the outdoor LPA tables.

Lighting Application	Reference	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Sales Frontage	Title 24-2008	N/A	22.5 W/lin. ft.	36 W/lin. ft.	45 W/lin. ft.
	Proposed Title 24-2013	N/A	17.5 W/lin. ft.	30 W/lin. ft.	35 W/lin. ft.
	Change	N/A	**Decrease by 22%**	**Decrease by 17%**	**Decrease by 22%**
Sales Area	Title 24-2008	0.164 W/ft^2	0.555 W/ft^2	0.758 W/ft^2	1.285 W/ft^2
	Proposed Title 24-2013	0.164 W/ft^2	0.25 W/ft^2	0.35 W/ft^2	0.45 W/ft^2
	Change	**No Change**	**Decrease by 55%**	**Decrease by 54%**	**Decrease by 65%**
Vehicle Service Station Canopy	Title 24-2008	0.514 W/ft^2	1.005 W/ft^2	1.358 W/ft^2	2.285 W/ft^2
	Proposed Title 24-2013	0.4 W/ft^2	0.5W/ft^2	0.6 W/ft^2	0.7 W/ft^2
	Change	**Decrease by 22%**	**Decrease by 50%**	**Decrease by 56%**	**Decrease by 69%**
Vehicle Service Station Hardscape	Title 24-2008	0.014 W/ft^2	0.155 W/ft^2	0.308 W/ft^2	0.485 W/ft^2
	Proposed Title 24-2013	0.014 W/ft^2	0.06 W/ft^2	0.08 W/ft^2	0.1 W/ft^2
	Change	**No Change**	**Decrease by 61%**	**Decrease by 74%**	**Decrease by 79%**

Figure 5: Title 24-2008 to 2013 Table 147B Proposed Changes

3.3 Comparison of Title 24 and ASHRAE 90.1-2010 LPA Values

Specific line-item LPA's were reviewed to bring them in-line with ASHRAE 90.1-2010 in situations where the 90.1 document is more stringent. Most of the values within the comparison table indicate that the Title 24 documents are more stringent or approximately equal in stringency to the 90.1 document.

The structure of the ASHRAE 90.1-2010 allowances is such that with the exception of a few specific applications, all power allowances are tradable across the site. This makes direct comparison to Title 24 a challenge since Title 24 takes a more aggressive stance of providing allowances for specific task areas or applications that cannot be traded to other locations on the site.

Items that could be directly compared to ASHRAE 90.1-2010 were reviewed, including:

- "Primary Entrances to Senior Care Facilities, Police Stations, Hospitals, Fire Stations and Emergency Vehicles"
- "Drive-up Windows"
- "Hardscape Ornamental Lighting"

- "Sales Canopies"
- "Non-Sales Canopies"
- "Guard Stations"
- "Outdoor Dining"
- "Special Security Lighting for Retail Parking and Pedestrian Hardscape"

During this process, we identified that ASHRAE 90.1-2010 does not have an equivalent allowance for two specific applications included in Title 24: "Vehicle Service Station Uncovered Fuel Dispensers," and "Student Pick-Up/Drop-Off Zones." See Figure 6 for a line-by-line breakdown analysis of which code is more aggressive.

Title 24-2008 Allowance Type		ASHRAE 90.1-2010 Allowance Type	Who's Lower? Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
General Hardscape Allowance	Area Wattage Allowance (AWA)	Uncovered Parking	*90.1*	Nearly Equal	*90.1*	*90.1*
	Linear Wattage Allowance (LWA)					
	Initial Wattage Allowance (IWA)	Base Site	**T24**	Nearly Equal	Nearly Equal	**T24**
Wattage Allowance per Application	Building Entrances or Exits	Main Entries	**T24**	*90.1*	Nearly Equal	*90.1*
		Other Doors	**T24**	*90.1*	*90.1*	*90.1*
	Primary Entrances to Senior Care Facilities, Police Stations, Hospitals, Fire Stations, and Emergency Vehicle Facilities	Loading areas for law enforcement	**T24**	**T24**	Equal	Nearly Equal
	Drive Up Windows	Drive-up windows/doors	**T24**	**T24**	**T24**	Equal
	Vehicle Service Station Uncovered Fuel Dispenser	*No equivalent*	*No Equivalent Allowance*			
Wattage Allowance per Unit Length (W/lf). May be used for one or two frontage side(s) per site.	Outdoor Sales Frontage	Sales street frontage	See Detailed Outdoor Sales Analysis			
Wattage Allowance per Hardscape Area	Hardscape Ornamental Lighting	Landscape	**T24**	**T24**	**T24**	*90.1*
Wattage Allowance per Specific Area (W/sf). Use as appropriate provided that none of the following specific applications shall be used for the same area.	Building Facades	Facades	Equal	*90.1*	*90.1*	*90.1*
			Equal	**T24**	Nearly Equal	Equal
			Equal	*90.1*	*90.1*	*90.1*
	Outdoor Sales Lots	Outdoor sales open areas	See Detailed Outdoor Sales Analysis			
	Vehicle Service Station Hardscape	Uncovered Parking	See Detailed Service Station Analysis			
	Vehicle Service Station Canopies	Sales Canopies	See Detailed Service Station Analysis			
	Sales Canopies	Sales Canopies	**T24**	Nearly Equal	Nearly Equal	Nearly Equal
	Non-sales Canopies	Entry Canopies	**T24**	**T24**	**T24**	**T24**
	Guard Stations	Entrances and gate-house inspection stations at guarded facilities	**T24**	**T24**	*90.1*	*90.1*
	Student Pick-up/Drop-off zone	*No equivalent*	*No Equivalent Allowance*			
	Outdoor Dining	Feature Areas	**T24**	Nearly Equal	*90.1*	*90.1*
	Special Security Lighting for Retail Parking and Pedestrian Hardscape	Parking near 24 hour retail entrances	**T24**	**T24**	**T24**	**T24**

Figure 6: Comparison of Title 24 to ASHRAE 90.1-2010

The results of these individual line item analyses are discussed further in the conclusions and specific recommendations below in Sections 3.3.1 and 3.3.2.

3.3.1 General Hardscape Comparison of Title 24 and ASHRAE 90.1-2010 LPA Values

For the general hardscape allowances, a direct line item comparison was not possible as the two codes have significantly different structures. Both 90.1-2010 and Title 24-2008 provide an "Initial Wattage

Allowance" (IWA) (referred to as Base Site allowance in 90.1). ASHRAE 90.1-2010 provides only a tradable, non-layered uncovered parking allowance, while Title 24 provides a "Linear Wattage Allowance" (LWA) and an "Area Wattage Allowance" (AWA) for hardscape areas.

The IWA values were compared directly to the Base Site Allowances in 90.1. In order to assess the additional Title 24 area lighting allowances, a series of model site geometries were created to evaluate the effective overall LPA based on the combined LWA and AWA. These are prototypical site plans, and do not represent actual sites. The resultant effective LPDs were then compared to the ASHRAE 90.1-2010 uncovered parking allowances to establish equivalency.

The series of model sites considered in this review are shown in the drawing and site descriptions below, in Figure 7. Please see Appendix D: Outdoor Sales Allowance Detailed Analysis for complete information on the calibration process.

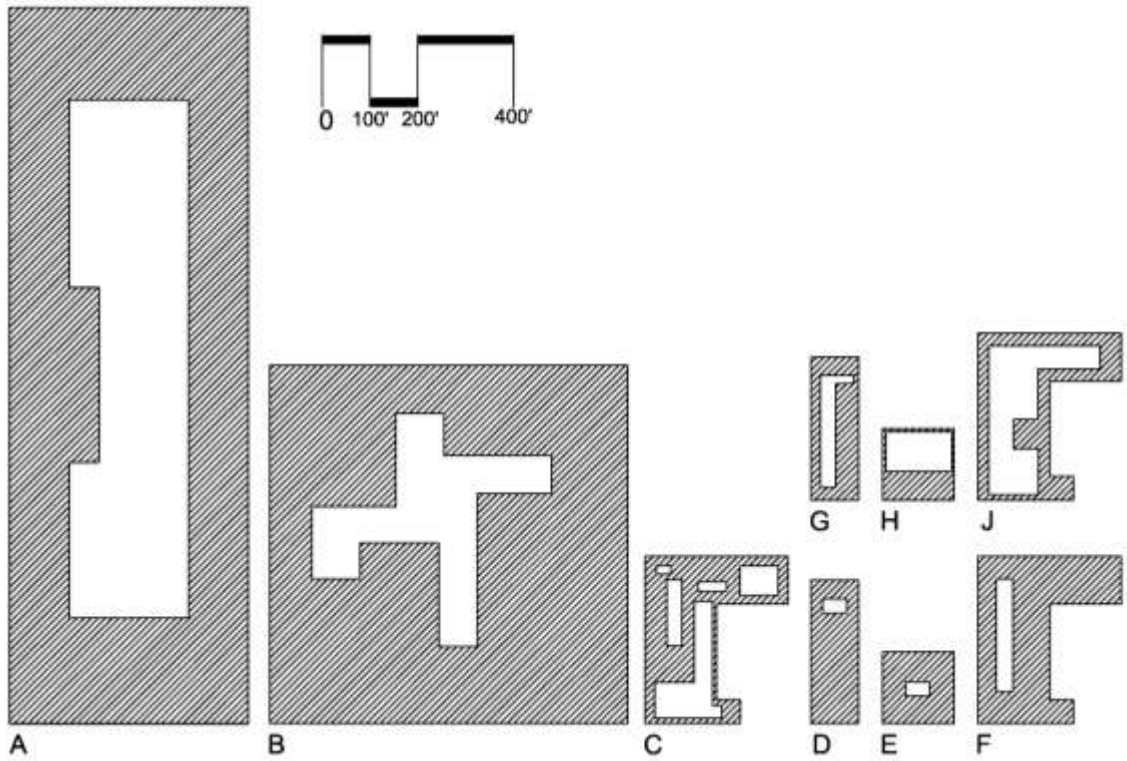

Figure 7: Model Site Geometries Considered for General Hardscape Allowance Analysis

- Area A - Long rectangular building on large, skinny property.
- Area B - Large building with irregular shape, square lot.
- Area C - Smaller odd shapes, multiple buildings.
- Area D - Small rectangular building on small, skinny lot.
- Area E - Small rectangular building on square lot.
- Area F - Long building on irregular lot.
- Area G - Long skinny building on long, skinny lot. Same lot dimensions as Area D.
- Area H - Larger rectangular building on square lot. Same lot dimensions as Area E.
- Areas J - Larger irregular building on irregular lot. Same lot dimensions as Area F.

These specific configurations were chosen to capture a range of possible perimeter-to-area ratios, as well as absolute site sizes.

The comparisons and subsequent adjustments calibrate the overall aggressiveness of the General Hardscape allowances of Title 24 so that collectively, Title 24 and ASHRAE 90.1-2010 have similar levels of performance, even though they have somewhat different methods of implementation. Figure 8 and Figure 9 provide a sample of the overall General Hardscape Allowance comparison for LZ3, and the comparison once the adjustments are made.

	LZ3				
	Title 24		**ASHRAE 90.1**		
	TOTAL	LPD	TOTAL	LPD	
	W	W/sf	W	W/sf	% of ASHRAE
A- Long Skinny, Big Building	53,170	0.106	50,913	0.101	104%
B-Square, Odd Building	48,889	0.104	47,923	0.102	102%
C- Odd, Campus Buildings	7,518	0.176	5,033	0.118	149%
D- Long Skinny, Small Square Building	4,275	0.150	3,600	0.126	119%
E- Square, Small Building	3,401	0.162	2,850	0.136	119%
F- Odd, Long Square Building	8,240	0.133	6,930	0.112	119%
G- Long Skinny, Odd Building	4,071	0.187	2,930	0.134	139%
H- Square, Large Square Building	2,744	0.249	1,854	0.168	148%
J- Odd, Large Odd Building	6,351	0.183	4,224	0.122	150%

Figure 8: LZ3 Total General Hardscape Allowance Values for Title 24-2008 Compared to ASHRAE 90.1-2010

	LZ3				
	Title 24		**ASHRAE 90.1**		
	TOTAL	LPD	TOTAL	LPD	
	W	W/sf	W	W/sf	% of ASHRAE
A- Long Skinny, Big Building	49,993	0.100	50,913	0.101	98%
B-Square, Odd Building	46,304	0.098	47,923	0.102	97%
C- Odd, Campus Buildings	6,456	0.151	5,033	0.118	128%
D- Long Skinny, Small Square Building	3,911	0.137	3,600	0.126	109%
E- Square, Small Building	3,116	0.148	2,850	0.136	109%
F- Odd, Long Square Building	7,496	0.121	6,930	0.112	108%
G- Long Skinny, Odd Building	3,577	0.164	2,930	0.134	122%
H- Square, Large Square Building	2,389	0.216	1,854	0.168	129%
J- Odd, Large Odd Building	5,452	0.157	4,224	0.122	129%

Figure 9: LZ3 Total General Hardscape Allowance Values for Title 24-2013 Compared to ASHRAE 90.1-2010 Showing Impact of Modified AWA and LWA Values

LZ3 is a zone where the ASHRAE allowances were more aggressive than Title 24-2008. This calibration shows that the overall allowances have shifted downward somewhat, but most importantly, the proposed Title 24 allowances are considerably more aggressive in the irregular site conditions compared to the 2008 allowances.

It is important that some accommodation for irregular site conditions be included in the basic infrastructure of the General Hardscape allowances, because these site conditions prove to be less 'efficient'; requiring more energy to meet the general design guidelines for parking lot design. The Title 24 General Hardscape Allowance infrastructure is designed to accommodate this, whereas the ASHRAE document is not.

As a result of the calibration, there are recommended changes to some of the General Hardscape allowance values. All of the Initial Wattage Allowance (IWA) values will remain unchanged. In Lighting Zones LZ1 and LZ3, the Area Wattage Allowance (AWA) will be reduced slightly, to 0.035 and 0.090 respectively.

The most significant proposed change is the reduction to the Linear Wattage Allowance (LWA), which was designed to provide useful additional watts above the baseline allowance when site geometry deviates from 'ideal' conditions (a small square building on a large square lot).

The changes reduce the LWA impact on the property allowance by approximately 30% in LZ1, LZ3, and LZ4. This has only a slight impact on the properties that are close to 'ideal', and a larger impact on the sites that are more complex. Figure 10 provides the complete recommended changes to the AWA and LWA.

Zone	AWA Reduction, [W/sf]	LWA Reduction, [W/sf]	Reduced AWA, [W/sf]	Reduced LWA, [W/lf]
LZ1	0.001	0.11	0.035	0.25
LZ2	0.000	0.00	0.045	0.45
LZ3	0.002	0.32	0.090	0.60
LZ4	0.000	0.30	0.115	0.85

Figure 10: Proposed Changes to AWA and LWA

3.3.2 Individual Line Item Comparison of Title 24 and ASHRAE 90.1-2010 LPA Values

Specific line-item LPA's were reviewed to bring them in-line with ASHRAE 90.1-2010 in situations where the ASHRAE document is more stringent. Most of the values within the comparison table indicate that the Title 24 documents are more stringent or approximately equal in stringency to the ASHRAE document.

For line-item allowances such as "Building Entrances" and "Building Facades", ASHRAE 90.1-2010 uses a different method for determining the allowances. For "Building Entrances," Title 24 provides a per-door non-tradable allowance, while 90.1 provides a per-foot, tradable allowance based on the width of the door and distinguishes between "Main Entries" and "Other Doors." To compare these, a typical entrance door width of 3feet was used, and the resulting effective 90.1 allowance per door was compared to the Title 24 values.

For "Building Facades," Title 24 provides wattage allowances based on the area of the illuminated façade. ASHRAE 90.1-2010 provides wattage allowances based either on the area of the illuminated façade or the perimeter length of the illuminated façade. For the analysis, the area-based allowances were directly compared and the linear-based allowances were compared assuming two different façade heights. Figure 11 provides the specific recommendations. Refer to Appendix C: Title 24 Power Density Allowance Comparisons to ASHRAE 90.1-2010 for further information on the comparisons and recommended adjustments.

Allowance Type:	Recommended Change?	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Building Entrances or Exits	Reduced LPAs in LZs 2, 3 & 4	N/A	60W (reduced from 75)	90W (reduced from 100)	90W (reduced from 100)
Outdoor Dining	Reduced LPAs in LZs 3 & 4	N/A	N/A	0.240 W/sf (reduced from 0.258)	0.400 W/sf (reduced from 0.435)

Figure 11: Recommended Line Item Revisions to Exterior LPAs

3.3.3 Comparison of Title 24 and ASHRAE 90.1 LPA Values for Outdoor Sales Lots

The CASE Team performed detailed studies for Outdoor Sales and Service Station applications. The analysis compared light level requirements between Title 24 and ASHRAE 90.1 and also considered the recommended IESNA values, which have changed recently.

The Outdoor Sales section was evaluated primarily due to the changes in illuminance recommended in the new DG-3 document mentioned earlier. Later, the Tenth Handbook was introduced with different values with supersede these calculations as the Handbook values have been established as the new basis for design.

Provided below is a diagram for a small outdoor sales lot. Larger facilities were evaluated as well, to ensure that the comparisons are valid through a range of possible design parameters. See Appendix D: Outdoor Sales Allowance Detailed Analysis for more information on the validation procedures.

These allowances were also analyzed based on the contribution of illumination provided for one specific area onto another; for example, the spill light that goes into the parking lot past the first row of cars contributes to achieving IESNA criteria in the parking lot and vice-versa, effectively ensuring that the specific applications are considered in concert. For this analysis, three different site configurations were established, a small corner lot with two frontages and a small sales area, a larger corner lot with two frontages and a larger sales area, and a large mid-block lot with one frontage and a large sales area. The analysis was based on typical equipment and lamp/ballast options and was conservative when developing light loss factors. The LPDs required to meet the illuminance criteria for each of the three sites in each of the lighting zones were then determined.

Figure 12 is a representative layout for a typical corner lot designed for outdoor sales, and was used as one of the sites for calculation purposes.

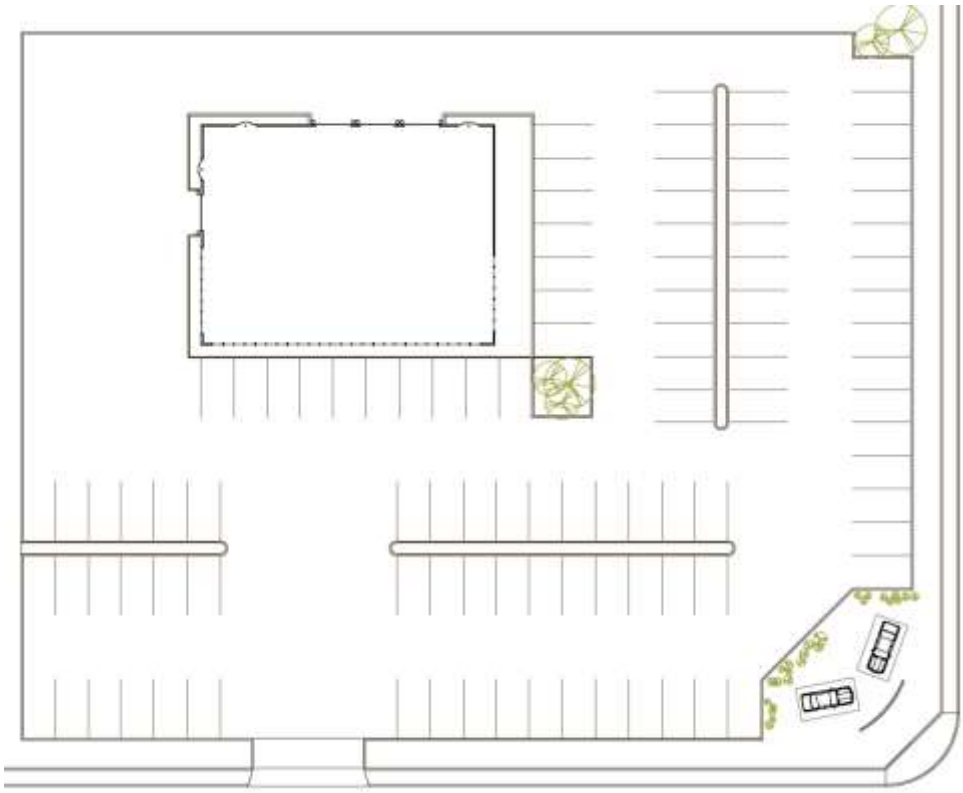

Figure 12: Geometry of Small Corner Lot for Outdoor Sales

Figure 13 provides information on the changes to the illuminance recommendations that are relevant for outdoor sales lots.

RP-2-01 Values				New RP-2 Values															
	Feature Display (hfc)	Merch. (hfc)	Circ. (hfc)	Front Row (Horizonta/Vertical) (fc)				Sales Area (hfc)				Customer Parking (hfc)				Preparation/Storage Area (hfc)			
				LZ1	LZ2	LZ3	LZ4	LZ1	LZ2	LZ3	LZ4	LZ1	LZ2	LZ3	LZ4	LZ1	LZ2	LZ3	LZ4
High	75	50	10	20/10	40/20	50/30	60/40	15	30	40	50	1	2	3	5	1	2	3	5
Medium	50	30	7	15/7.5	30/15	40/20	50/30	10	20	30	40	1	2	2.5	5	1	2	2.5	5
Low	35	20	3	10/0.5	20/10	30/15	40/20	7.5	15	20	30	0.5	1	1.5	3	0.5	1	1.5	3

Figure 13: IESNA Changes to Illuminance Recommendations for Outdoor Sales Lots

The values reflect a reduction in the horizontal illuminance guidelines, but the introduction of a vertical component that was previously not included in the guidelines introduces complexity to the analysis. This introduction may ultimately increase the overall amount of light compared to the previous recommendations, because adding a vertical performance metric begins to define the geometry of the propagating light. A traditional lighting design approach for a sales lot is not capable of delivering the recommended vertical light levels.

The information provided in Figure 14 allows us to judge the impact of the addition of the vertical light level requirements. NOTE: the location of the vertical illuminance grid may be somewhat open to interpretation at this time, as the final language of the revised RP-2 document is still pending.

Corner Small Lot

(Full Calculations- Includes Inter-reflections)

		Dropped Acrylic Lens Canopy Fixture			
		LZ1	LZ2	LZ3	LZ4
Light Levels (Average Illuminance)	Sales Frontage: Recommended (hfc/vfc)	7.5	30 / 15	40 / 20	50 / 30
	Sales Frontage: Achieved (hfc/vfc)	8.06	31.2 / 17.8	41.1 / 24.6	53.0 / 36.1
	Sales Area: Recommended (hfc)	7.5	20	30	40
	Sales Area: Achieved (hfc)	8.03	24.9	36.8	44.9
	Note: Sales Area & Sales Frontage (hfc) Calculation Plane Located at 0'-0" AFG.	*Notes: All pole luminaires mounted at 20'-0" AFG.*			
	Note: Sales Frontage (vfc) Calculation Points Located at Front Edge of Front Sales Row, facing toward Property Line at 3'-0" AFG.	*All floodlight luminaires mounted at 8'-0" AFG.*			
Luminaires	General Sales Area Pole-mounted Luminaire Quantity	16	10	10	10
	Total Input Watts per Luminaire (W)	465	820	1,080	1,080
	Sales Frontage Pole-mounted Luminaire Quantity	12	17	14	17
	Total Input Watts per Luminaire (W)	465	820	1,080	1,080
	Sales Frontage Floodlight Luminaire Quantity	0	34	28	34
	Total Input Watts per Luminaire (W)	0	62	94	118
	Total Watts	13,020	24,248	28,552	33,172
Geometry	Total Hardscape Area (sf)	23,261			
	Total Hardscape Perimeter Length (lf)	498			
	Sales Frontage (lf)	286			
	Outdoor Sales Lot (sf)	13,156			
Base Hardscape Allowance	LWA (W/lf)	0.45	0.45	0.92	1.15
	LWA (W)	224	224	458	573
	AWA (W/sf)	0.045	0.045	0.092	0.115
	AWA (W)	1,047	1,047	2,140	2,675
	Total Base Allowance (W)	1,271	1,271	2,598	3,248
	Effective Base Area Wattage Allowance (W/sf)	0.055	0.055	0.112	0.140
Proposed LPD & Determination of LPAs	Proposed Lighting Power Density (W/sf)	0.560	1.042	1.227	1.426
	LPD Over Base Hardscape Allowance (W/sf)	0.516	0.988	1.116	1.286
	% W at Frontage	42.9%	57.5%	53.0%	67.4%
	% W over Sales Area	57.1%	42.5%	47.0%	32.6%
	Effective Needed LPA at Frontage (W/lf)	18	46	48	71
	Effective Needed LPA over Sales Area (W/sf)	0.521	0.742	0.928	0.741
	If restrict Frontage LPA (W/lf)	0	22.5	36	45
	Effective Needed LPA over Sales Area	0.912	1.258	1.191	1.298

Figure 14: Impact of Vertical Light Level Requirements for Outdoor Sales

To achieve the new vertical illuminance guidelines (and still meet the horizontal guidelines), an increase in power allowance in the Sales Frontage category is required. Rather than make an increase in the allowance, the CASE team recommends that the Title 24 allowances for Outdoor Sales Frontage and Outdoor Sales Area remain the same. The recommendations in RP-2 are not dependent on factors of public safety and security and further do not sufficiently take into consideration the inherent contrast problems that light levels of these magnitudes can create on a public right of way.

As all of the lighting design decisions made in a project require some balancing, this particular issue should be considered one where the lighting designer may choose to meet the vertical illuminance guidelines in the frontage area, but it may require a slight reduction in the overall horizontal light

levels to meet that vertical number. Title 24 should not relax the current limits to enable this decision-making to occur without a compromise in the sales area horizontal light levels.

3.3.4 Comparison of Title 24 and ASHRAE 90.1 LPA Values for Service Stations

The Service Station section was evaluated because the ASHRAE requirement was apparently more aggressive, and there were concerns that the allowances provided in the ASHRAE document may not be sufficient to meet the light levels established as the basis of design. Later, the Tenth Handbook was introduced with different values with supersede these calculations as the Handbook values have been established as the new basis for design.

This analysis was based on two site sizes, a large and small site, both analyzed with and without canopies. The large site was analyzed with a small canopy that occupied a small area of the hardscape, as well as a large canopy that occupied more area. Similar to the approach for the Outdoor Sales, the lighting was allowed to "bleed" between applications, which allowed the LPAs to be examined in a more appropriate context as they will actually be used. Again, the analysis was based on typical equipment and lamp/ballast options, and was conservative when approaching light loss factors. The LPDs required to meet the illuminance criteria for the various site configurations in each of the lighting zones were then determined.

Figure 15 is a diagram for a small service station used in the calculations.

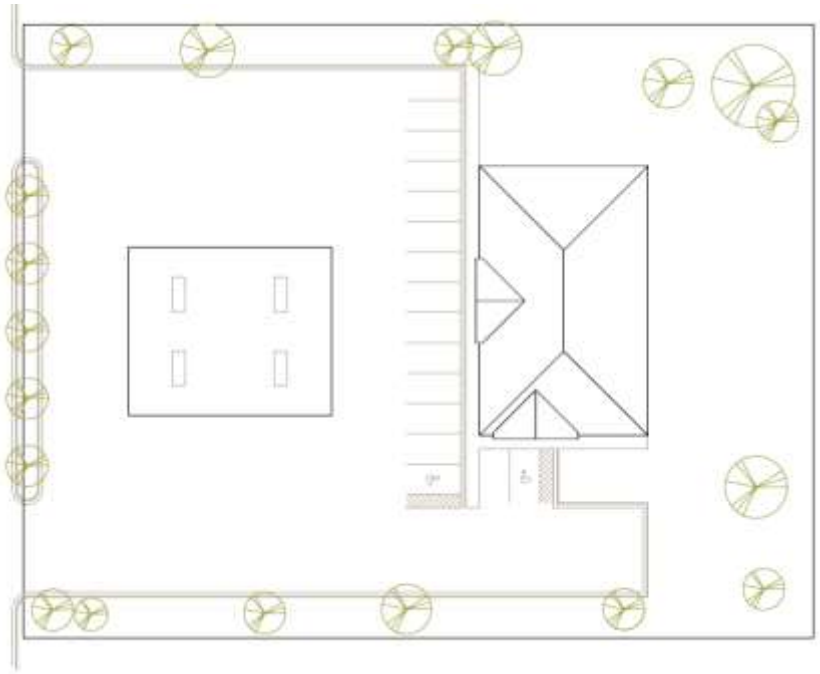

Figure 15: Geometry of Small Site for a Service Station with Canopy

One aspect of this analysis that has a seemingly significant difference is the Sales Canopy allowance. The Title 24-2008 and ASHRAE 90.1-2010 limits are detailed in Figure 16 below.

Vehicle Service Station Canopies				
Allowance Type	**Lighting Zone 1**	**Lighting Zone 2**	**Lighting Zone 3**	**Lighting Zone 4**
Title 24-2008	0.514 W/ft^2	1.005 W/ft^2	1.358 W/ft^2	2.285 W/ft^2
ASHRAE 90.1-2007	0.6 W/ft^2	0.6 W/ft^2	0.8 W/ft^2	1.0 W/ft^2
Who's Lower?	**T24**	**90.1**	**90.1**	**90.1**

Figure 16: Title 24-2008 and ASHRAE 90.1-2010 Limits for Sales Canopy Allowance

The ASHRAE 90.1-2010 limits appear to be lower than the Title 24-2008 limits prima fascia. When these values were developed in the previous code revision cycle, they were fairly aggressive, so there was concern within the CASE team that the 90.1values may not provide enough allowance to meet the design recommendations of RP-2, the Retail Lighting Recommended Practice.

Further analysis indicates that there are a few specific calculation idiosyncrasies in the ASHRAE 90.1-2010 document that make a direct comparison of the values between that two codes impossible. However, with detailed analysis, the results indicate that under no circumstances do the Title 24 values exceed the 90.1 values, and in particular, the Title 24 values are considerably lower than the 90.1 values when the canopy begins to get small. As a result, no changes to the Title 24 allowances for Service Station Canopies are recommended based on this comparison, but the new Handbook recommended values for illuminance do result in a change in LPA proposal. Figure 17 graphs some reasonable service station canopy sizes and shows that for the same sized canopy, the Title 24 allowance is more aggressive.

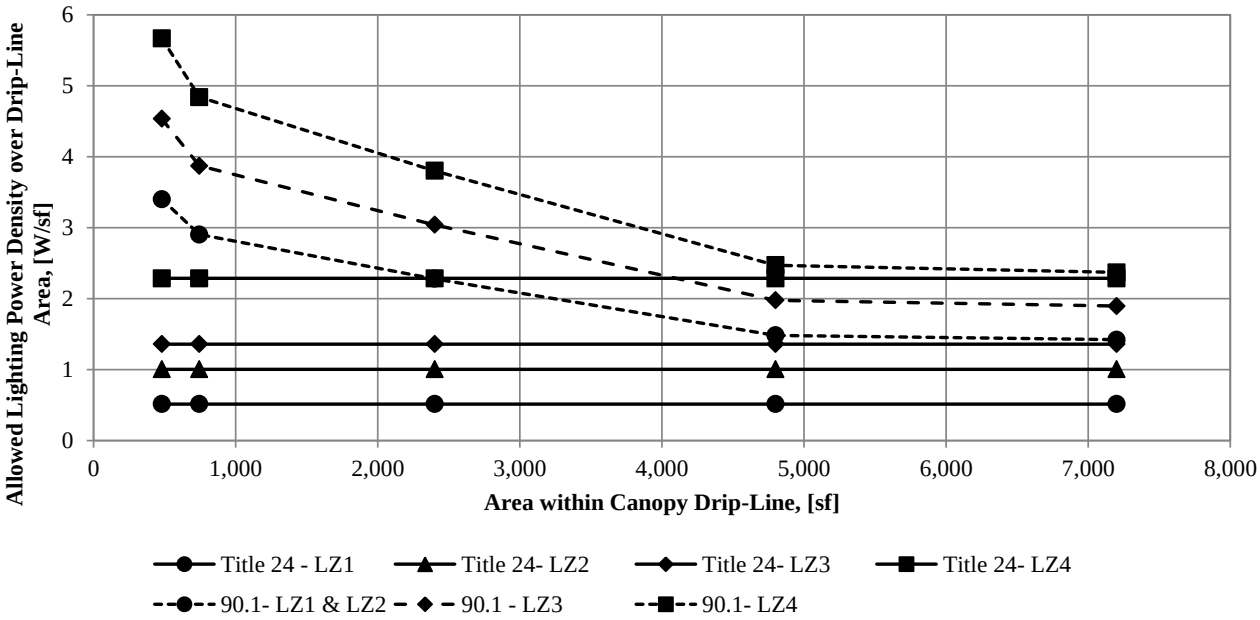

Figure 17: Comparison of Title 24-2008 and ASHRAE 90.1-2010 Allowances for Service Station Canopies

3.3.5 Collective Comparison of Title 24 and ASHRAE 90.1 LPA Values

To better understand and quantify the complete LPA allowance picture, two additional examples were created; a Big Box Retail site and a Café site. Based on the same physical geometries, the overall tradable and non-tradable allowances under Title 24 and ASHRAE 90.1-2010 were compared.

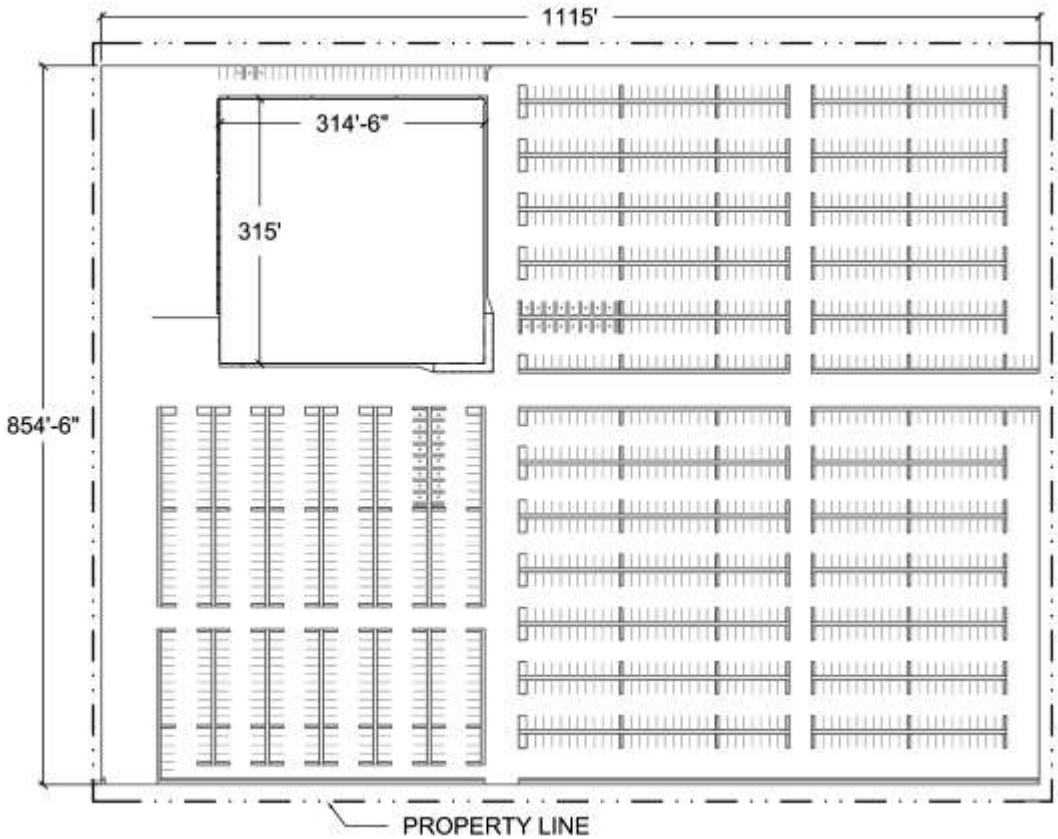

Figure 18: Layout of Big Box Prototype Example

Title 24-2008

Input Geometry	Hardscape Area	844,333	sf
	Hardscape Perimeter	2,922	lf
	Main Entry Doors	8	unit
	Other Entry Doors	8	unit
	Non-Sales Canopies	1,300	sf
	Special Security Area	59,285	sf

		LZ1	LZ2	LZ3	LZ4	Units
Summary	General Hardscape Allowance	31,788	39,820	81,137	101,489	W
	Entry Allowance	480	1200	1600	1920	W
	Non-Sales Canopy Allowance	109	267	530	761	W
	Special Security Area Allowance	415	534	1,126	0	W
	TOTAL	**32,792**	**41,820**	**84,394**	**104,169**	**W**

ASHRAE 90.1-2010

Uncovered Parking Area & Drives	842,622	sf
Walkways less than 10ft wide	832	lf
Walkways 10ft wide or greater	1,370	sf
Entry Canopy	1,300	sf
Main Entry Doors	48	lf
Other Doors	24	lf
24-Hour Entrances	4	unit

	LZ1	LZ2	LZ3	LZ4	Units
Total Tradable Allowance	36,744	53,697	88,337	114,387	W
Total Non-Tradable Allowance	3,200	3,200	3,200	3,200	W
TOTAL	**39,944**	**56,897**	**91,537**	**117,587**	**W**

Figure 19: Comparison of Total Site Power Allowance for Big Box Retail, Title 24-2008 and ASHRAE 90.1-2010

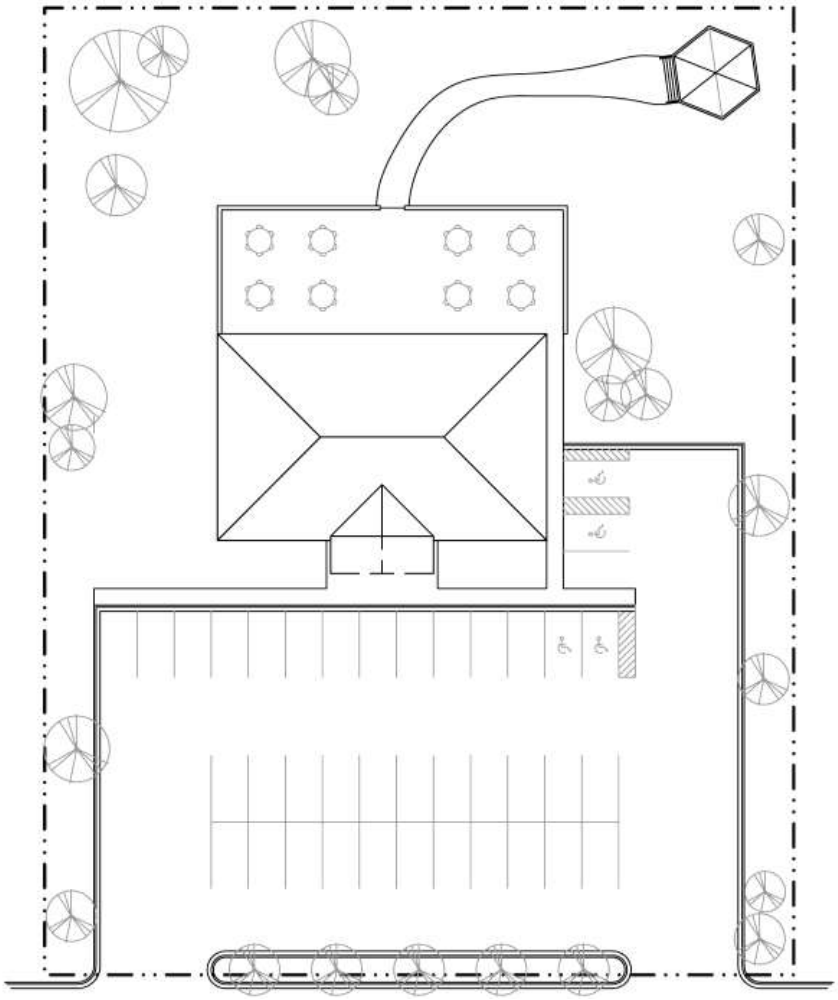

Figure 20: Layout of Café Prototype Example

Title 24-2008

Input Geometry	Hardscape Area	20,086	sf
	Hardscape Perimeter	1,103	ft
	Main Entry Doors	4	unit
	Other Entry Doors	4	unit
	Ornamental Lighting Area	971	sf
	Outdoor Dining Area	2,635	sf
	Non-Sales Canopy Area	225	sf
	South Façade Area	870	sf
	East Façade Area	578	sf

		LZ1	LZ2	LZ3	LZ4	Units
Summary	General Hardscape Allowance	1,460	1,910	3,633	4,608	W
	Entry Allowance	240	600	800	960	W
	Ornamental Lighting Allowance	0	19	39	58	W
	Outdoor Dining Allowance	40	356	680	1,146	W
	Non-Sales Canopy Allowance	19	46	92	132	W
	Façade Lighting Allowance	0	261	507	724	W
	TOTAL	**1,759**	**3,192**	**5,750**	**7,628**	**W**

ASHRAE 90.1-2010

Uncovered Parking Area	15,372	sf
Main Entry Door Width	12	lf
Other Door Width	12	lf
Entry Canopy	225	sf
Walkways less than 10ft wide	276	ft
Stairways	26	sf
Special Feature Areas	2,977	sf
South Façade Length	80	lf
East Façade Length	50	lf

	LZ1	LZ2	LZ3	LZ4	Units
Total Tradable Allowance	2,359	2,773	3,790	5,021	W
Total Non-Tradable Allowance	0	325	488	650	W
TOTAL	**2,359**	**3,098**	**4,278**	**5,671**	**W**

Figure 21: Comparison of Total Site Power Allowance for Cafe Retail, Title 24-2008 and ASHRAE 90.1-2010

The comparison shows that Title 24-2008 is in general, more aggressive, especially when considering the optional allowances that not all properties will include.

Based on this analysis procedure, recommendations were made to bring Title 24 to be at least as stringent as ASHRAE 90.1-2010 while allowing appropriate IESNA recommendations to be met for specific items where ASHRAE was found to be more stringent.

3.4 Technical Review of Occupancy-Based Lighting Controls for Exterior Conditions

The requirements for outdoor lighting controls were examined, because this is a specific opportunity for energy savings that is mostly untapped at this point, beyond the basic controls requirements. First, the current mandatory outdoor controls requirements in Title 24 were reviewed.

As written, there is no requirement for lighting controls beyond the basic photocell and curfew time switch requirements. Since the time switch is only required to be installed, and there is no mechanism to require the use of the curfew device, the savings associated with this approach are unclear. The implementation of an occupancy sensor measure will ensure energy savings.

First, 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

3.4.1 Sensor Capabilities and Limitations

The majority of exterior sensors have a limited range that results in some geometry problems when attempting to use the sensor in large area lighting conditions. The maximum detection range distance as stated in manufacturer's specifications is typically about 50 feet. This will result in 'dead zones' that can be quite extensive, especially when considering the potential shadowing associated with vehicles and other obstructions in a parking lot.

Figure 22 shows a diagram of a typical parking lot arrangement with 100' x 120' pole spacing. The sensors may just touch coverage down the parking aisle, but across the aisles, there will be coverage gaps, shown in red. Ideally, the coverage patterns should overlap by 30 to 50% to ensure that when cars are in the lot, the coverage pattern is a bit better than the absolute minimum to avoid large shadow dead zones.

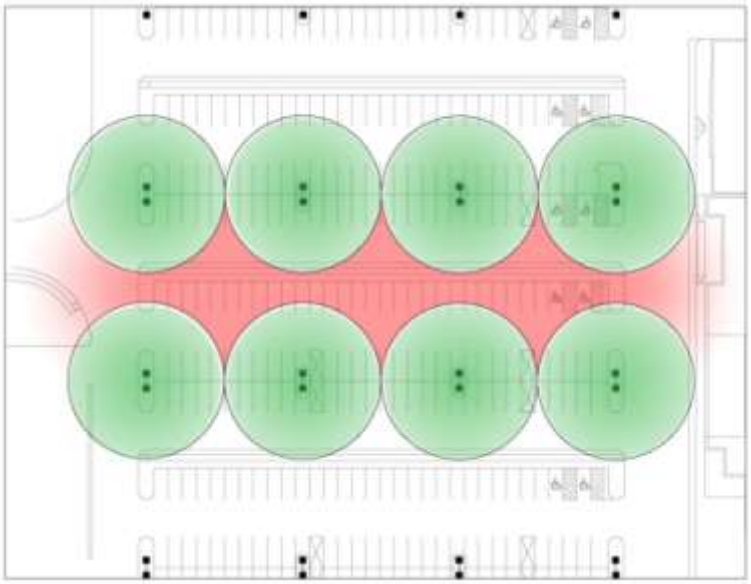

Figure 22: Illustration of PIR Sensor Range Limitations with Sensor Radius of 50 Feet

These range limitations result in very specific limitations in the luminaire mounting height that can be associated with sensors, as there is a common relationship between mounting height and pole spacing for an ideally-designed parking lot.

Since the sensor coverage limit is approximately 50 feet, in parking lot situations, the sensors can be used for single-row pole arrangements only (with an approximate row-to-row spacing of 60 feet). It is not viable to mandate sensors for pole spacing greater than 60 feet. The majority of parking lot poles that meet the criteria will utilize 20 foot poles, and may have a 3 or 4 foot concrete exposed foundation. This results in the maximum viable pole height for lighting controls set at 24 feet.

See Appendix F: Service Station Allowance Detailed Analysis for more detailed information on this section.

3.4.2 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, our research indicates that all lamp wattages are supported for bi-level capability, either through the lamp manufacturer, or through a third-party ballast manufacturer. There are some limitations in performance of some dimming ballasts that may be a source of concern for designers, so care should be taken to ensure that an appropriate specification with the desired operating characteristics becomes imperative to the success and safety of a design project.

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 capabilities beyond what is currently possible.

LED light sources will probably 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, because the LED is ultimately part of the luminaire, and must be supported by the luminaire manufacturer rather than by a separate lamp manufacturer.

See Appendix H: Exterior Dimming/Bi-Level Controls for more detailed information on this section.

3.4.3 Dimming Limitations of Various Light Sources

All of the light source technologies are capable of a 40% reduction in power input, but some HID sources are limited to that, whereas LED and induction sources can dim much farther.

The current language in Section 132 of Title 24-2008 for dimming setback calls for "50 percent to not exceeding 80 percent" dimming setback, or 40% for restricted range sources. It is clear that light source technologies that can dim more are capable of greater energy savings in unoccupied situations.

LED light sources are capable of dimming as low as a 10% power input, so a change to the dimming range limitation to accommodate this greater dimming capability is recommended.

See Appendix H: Exterior Dimming/Bi-Level Controls for more detailed information on this section.

3.4.4 Pilot Project Review

Based on the results of the pilot programs, in combination with the current and future availability of appropriate products, a set of final recommendations regarding advanced exterior lighting controls were established.

3.4.5 Code Language Rationale

The results of the state-of-the-market surveys indicated that the largest market gap preventing the wide-spread implementation of occupancy-based bi-level controls is based on sensor coverage issues. While there are lamp/ballast compatibility and warranty issues, those issues can be overcome with appropriate systems engineering. However, the sensor coverage issue presents a major hurdle for typical installations. In a typical parking lot (an 'every other row' arrangement), with poles spaces at 90 ft by 120 ft on center, all commercially-available outdoor-rated occupancy sensors were found to lack sufficient sensitivity to fully cover the parking lot, presenting a potential situation where the parking lot is occupied but operating in "LOW" mode. This demonstrates a gap in technology that prevents this control option from being feasible as a mandatory measure without placing limitations on the applicability of the measure.

3.5 Cost Analysis

The reduced LPA recommendations will normally result in a reduction in total lighting equipment or lamp wattage in an exterior lighting system, and therefore will reduce the cost of the system in most circumstances. As a result, the cost-effectiveness of these recommendations was not assessed.

The addition of controls requirements will increase the system cost in most applications. Figure 23 provides information on the added cost for a parking lot installation utilizing two 150W HPS heads on a single pole, with two sensors, added costs for a bi-level ballast, and added installation expenses.

	Sensor Cost	Added Installation	Ballast Adder	Added Cost of Assembly	Approximate Sq. Ft. per Assembly	Total Cost/Sq. Ft.
Outdoor Occupancy Sensors (Using two sensosr per pole, with two 150W HPS heads controlled)	$170	$100	$350	$620	3600	**$0.17**

Figure 23: Added Cost of Parking Lot Controls Installation

Some products do not require a substantial adder for bi-level controls, which will reduce the cost to install substantially. Integral sensors will reduce or eliminate the added installation (but not commissioning/tuning) labor required as well. Fluorescent luminaires will have substantially lower ballast adder costs, as well.

The part-night lighting controls technologies are similarly priced to sensor controls, and the primary adder to the system is the cost of bi-level ballasts. It is possible to have these systems turn 'OFF" lights, rather than use a bi-level system, which will reduce the cost of the approach considerably. How this technology (and all other controls technologies) is applied will determine the overall success of the design. It is imperative that a systematic approach to the application of these control systems is applied to ensure a successful project.

3.6 Cost Effectiveness Analysis

The reduced LPA recommendations will not result in a cost effectiveness calculation because the payback is instant.

Figure 24 provides a cost effectiveness calculation for a typical parking lot arrangement, using a 60' x 60' spacing, with twin heads and two sensors. The system is expected to reduce output for approximately 6 hours per night, from 2300 hours to 0500 hours. This results in a reduced energy consumption of approximately 13%.

Measure	Cost / Sq. Ft.	15 Year TDV Savings / Sq. Ft.	Benefit to Cost Ratio	Cost Effective?
Mandatory Outdoor Occupancy Sensors	$0.17	$0.20	1.18	**YES**

Figure 24: Cost Effectiveness of Exterior Controls Installation (Parking Lot Example)

The controls requirement measure calculation shows that this measure is cost effective. As outdoor sensors become part of the fixture options package, the added installation cost will decrease, improving the cost effectiveness.

The amount of time that the system is in 'low' mode has a significant impact on the savings. Since most of the time an exterior lighting system is operating is in the evening and night hours, the TDV cost is generally at its lowest during these times, so it takes more total time to have the same cost effectiveness as measures that are in effect during the day.

LED, Induction and Fluorescent lamp sources can be dimmed more than HID sources, so the differential in 'high' to 'low' energy consumption may be greater than HID. Ultimately the greater load that can be controlled by a single sensor, the more cost effective the measure will be.

A basic lighting control system is mandated for the top deck of parking garages, but this approach may be as simple as a part-night or motion sensor approach, which has proven cost effective with the above calculations.

3.7 Statewide Savings Estimates

The energy benefits were calculated using data from the PIER California Outdoor Lighting Baseline Assessment and the lower power allowances. Using 2008 Standards as the baseline, the proposed energy, first cost and maintenance savings were calculated for each change per unit basis per sq ft basis. These values were used to calculate a benefit cost ratio for each change. The energy cost savings methodology accounts for lower LPDs and lighting controls during curfew hours by using the Time Dependent Valuation (TDV) factors for electricity cost that vary by time of day and day of year.

The square footage by functional use area (FUA) from the PIER Outdoor Lighting Baseline Assessment report is presented in Figure 25. The current and proposed LPD values for the affected FUA categories is presented in Figure 26. The total kWh anticipated statewide as a result of the reduction in LPD values is presented in Figure 27.

2014 approx SF	LZ1	LZ2	LZ3	LZ4
Sales Frontage (linear feet)	85	8,526	60,832	608
Sales Area	3,411	341,058	2,433,268	24,333
Vehicle Service Station Canopy	130	13,015	92,858	929
Vehicle Service Station Hardscape	1,800	179,975	1,284,025	12,840

Figure 25: Anticipated first-year square footage of constructed outdoor space

Recommended change in LPD	LZ1 2008	LZ1 2013 Proposed	LZ2 2008	LZ2 2013 Proposed	LZ3 2008	LZ3 2013 Proposed	LZ4 2008	LZ4 2013 Proposed
Sales Frontage (linear feet)	NA	NA	22.5	17.5	36	30	45	35
Sales Area	0.164	0.164	0.555	0.25	0.758	0.35	1.285	0.45
Vehicle Service Station Canopy	0.514	0.4	1.005	0.5	1.358	0.6	2.285	0.7
Vehicle Service Station Hardscape	0.014	0.014	0.155	0.06	0.308	0.08	0.485	0.1

Figure 26: Current and Proposed LPD values for outdoor FUA's with recommended changes

Statewide 2014 kWh savings	LZ1	LZ2	LZ3	LZ4
Sales Frontage (linear feet)	NA	186,729	1,598,657	26,645
Sales Area	-	455,620	4,348,347	88,993
Vehicle Service Station Canopy	65	28,789	308,294	6,447
Vehicle Service Station Hardscape	-	74,888	1,282,278	21,653
			Total 2014 (First Year) kWh savings	8,427,403

Figure 27: kWh savings Statewide as a result of LPD recommended changes

The addition of a mandatory requirement for motion sensors in outdoor applications crosses across all FUA categories, and has technical limitations that limit it to certain specific application situation most notably, below 24' mounting height for the luminaire). The percentage of outdoor space that falls into this category is uncertain, but anticipated to be under 30% of total outdoor space. The total MWh savings anticipated statewide is provided in Figure 28.

	Without controls measure	With controls measure	MWh Savngs (First Year)
2014 statewide outdoor energy consumption (MWh)	41,557	39,936	1,621

Figure 28: MWh savings Statewide as a result of mandatory controls requirement

As the technology of outdoor sensor improves, the impact will increase as the limitation on the mandatory measure are lifted.

3.8 Material Impacts

The introduction of mandatory lighting controls will require additional equipment. The equipment does contain elements that may have potential adverse environmental impacts.

Occupancy sensors and lighting control systems, as well as the control wiring for the devices were considered in this analysis. The total 2014 square footage for exterior FUA categories was used to determine the statewide environmental material impacts for this measure. It was assumed that half of the total square footage would require occupancy sensors and half would require a lighting control system. Assuming an average occupancy sensor spacing of 100 by 100 feet, there are approximately 0.55 occupancy sensors per 1000 square feet, for a total 1,226 occupancy sensors statewide for this measure.

The number of lighting control systems was calculated assuming that one system would cover 50,000 square feet. It was also assumed that within those 50,000 square feet, 27.5 occupancy sensors were included (0.55 units per 1000 square feet) and 25,000 linear feet of control wire (5 units of 100 feet per 1000 square feet). There are a total of 22,288 lighting control systems statewide for this measure. It was assumed that control wiring would be required to connect the occupancy sensors throughout the total square footage.

Figure 29 below shows the assumptions for the quantity of equipment components and the statewide material content (in pounds) for the measure. See Appendix J: Data for Materials Impact for more information on how the material content for each component was calculated.

Component	Impacted SF	No. Components per 1000 SF	Total No. Components for Measure	Mercury	Lead	Cooper	Steel	Plastic	Others (Identify)
Occupancy Sensor	2,228,847	0.55	1,226	1	3	184	123	306	0
Cat 5 Control Wiring 100'	4,457,694	5	22,288	0	0	20,951	0	0	0
Control System	2,228,847	0.02	45	1	0	10,659	123	306	0

Figure 29: Summary of Statewide Material Impacts

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

4.1 Recommended Changes to Section 119

[The recommended language will be updated to include current proposed CEC language with proposed changes once the language is finalized.]

(i) **Outdoor Astronomical Time-switch Controls.** Outdoor astronomical time-switch controls used to control outdoor lighting as specified in Section 132(c) shall:

1. Contain at least 2 separately programmable steps per function area; and
2. Have the ability to independently offset the on and off times for each channel by 0 to 99 minutes before or after sunrise or sunset; and
3. Have sunrise and sunset prediction accuracy within +/- 15 minutes and timekeeping accuracy within 5 minutes per year; and
4. Store astronomical time parameters (used to develop longitude, latitude, time zone) for at least 7 days if power is interrupted; and
5. Display date/time, sunrise and sunset; and
6. Have an automatic daylight savings time adjustment; and
7. Have automatic time switch capabilities specified in Section 119(c); and
8. Have a default setback function that allows each controlled channel to be switched or dimmed to a lower level, or off, between 23:00 or one hour after close of business, whichever is later, and one hour before the open of business or 6:00 or dawn, whichever is earlier.

(j) **Distributed Part-night Automatic Controls.** Outdoor distributed part-night controls used to control outdoor lighting as specified in Section 132(c) shall:

1. Have sunrise and sunset prediction accuracy within +/- 15 minutes and timekeeping accuracy within 5 minutes per year; and
2. Have the ability to switch off or setback the lighting power based on a mid-night symmetry with an offset programmable at the device; and
3. Have the ability to setback or extinguish lighting power, or activate motion-sensing device, as required in Section 132(c); and
4. Have a default setback function that allows each controlled channel to be switched or dimmed to a lower level, or off, between 23:00 or one hour after close of business, whichever is later, and one hour before the open of business or 6:00 or dawn, whichever is earlier.

4.2 Recommended Changes to Section 132

(c) **Controls for Outdoor Lighting**

1. All permanently installed outdoor lighting shall be controlled by a photocontrol or astronomical time switch that automatically turns off the outdoor lighting when daylight is available.

   EXCEPTION to Section 132(c)1: Lighting in tunnels, and large permanently covered outdoor areas that require illumination during daylight hours.

~~2. For lighting of building facades, parking lots, sales and non-sales canopies, all outdoor sales areas, and student pick-up/drop-off zones where two or more luminaires are used, an automatic time switch shall be installed that is capable of:~~

~~(A) turning off the lighting when not needed; and~~

~~(B) reducing the lighting power (in watts) by at least 50 percent but not exceeding 80 percent or providing continuous dimming through a range that includes 50 percent through 80 percent reduction. This control shall meet the requirements of Section 119(c).~~

~~**EXCEPTION 1 to Section 132(c)2:** Lighting required by a health or life safety statute, ordinance, or regulation, including but not limited to, emergency lighting.~~

~~**EXCEPTION 2 to Section 132(c)2:** Lighting for steps or stairs that require illumination during daylight hours.~~

~~**EXCEPTION 3 to Section 132(c)2:** Lighting that is controlled by a motion sensor and photocontrol.~~

2. All permanently installed outdoor lighting equipment shall be circuited and/or switched to turn off the outdoor lighting independent of other electrical loads when not needed.

3. All permanently installed outdoor lighting equipment associated with Outdoor Sales Frontage, Outdoor Sales Lots, Outdoor Sales Canopies, Vehicle Service Station Canopies, Vehicle Service Station Hardscape, Uncovered Service Station Fuel Dispensers, and Special Security Lighting for Retail Parking and Pedestrian Hardscape lighting power allowances shall have an automatic lighting control system installed that is capable of turning off the lighting.

   All permanently installed outdoor lighting not associated with the Lighting Power Allowances listed above, where two or more luminaires are used, shall have an automatic lighting control system that is capable of reducing the lighting power (in watts) to between 20 percent and 50 percent of rated power.

   These lighting control systems shall meet at least one of these control descriptions:

   (A) A distributed part-night switching, step dimming, or dimming control system.

   (B) A centralized time-based zone switching, step dimming, or dimming control system, for Building Facades, Ornamental Hardscape, Outdoor Dining only.

   (C) A motion-sensor system capable of switching, step dimming, or dimming each luminaire based on human activity and employing an 'auto-on' functionality.

   EXCEPTION 1 to Section 132(c)3: Lighting required by a health or life safety statute, ordinance, or regulation, including but not limited to, emergency lighting.

4. All permanently installed outdoor area lighting mounted 24 feet, or lower, above grade or finished floor on the building façade, wall, canopy, or pole shall be controlled via motion sensor. The control system shall be capable of:

   (A) Reducing the lighting power (in watts) of each luminaire to between 20 percent and 50 percent of rated power; and

   (B) Operating with 'auto-on' functionality.

   EXCEPTION 1 to Section 132(c)4: Lighting required by a health or life safety statute, ordinance, or regulation, including but not limited to, emergency lighting.

   EXCEPTION 2 to Section 132(c)4: Pole mounted pedestrian lighting and decorative pedestrian poles mounted below 13 feet AND below 85 lamp watts per pole.

   EXCEPTION 3 to Section 132(c)4: Area lighting equipment mounted below 54 inches AND 26 lamp watts or lower OR less than 4 watts per linear foot.

   EXCEPTION 4 to Section 132(c)4: Lighting equipment intended for the building façade or other decorative lighting purposes that is not useful for human way-finding, navigation, or other activities.

EXCEPTION 5 to Section 132(c)4: Lighting equipment associated with Outdoor Sales Frontage, Outdoor Sales Lots, Outdoor Sales Canopies, Vehicle Service Station Canopies, Vehicle Service Station Hardscape, Uncovered Service Station Fuel Dispensers, and Special Security Lighting for Retail Parking and Pedestrian Hardscape allowances.

4.3 Recommended Changes to Section 147

(c) **Calculation of Actual Lighting Power.** The wattage of outdoor luminaires shall be determined in accordance with Section 130(d).

TABLE 147-A:

TABLE 147-A GENERAL HARDSCAPE LIGHTING POWER ALLOWANCE

Type of Power Allowance	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Area Wattage Allowance (AWA)	~~0.036~~ 0.035 W/ft²	0.045 W/ft²	~~0.092~~ 0.090 W/ft²	0.115 W/ft²
Linear Wattage Allowance (LWA)	~~0.36~~ 0.25 W/lf	0.45 W/lf	~~0.92~~ 0.60 W/lf	~~1.15~~ 0.85 W/lf
Initial Wattage Allowance (IWA)	340 W	510 W	770 W	1030 W

Figure 30: Recommended Changes to Table 147-A

TABLE 147-B:

TABLE 147-B ADDITIONAL LIGHTING POWER ALLOWANCE FOR SPECIFIC APPLICATIONS
All area and distance measurements in plan view unless otherwise noted.

	Lighting Application	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
WATTAGE ALLOWANCE PER APPLICATION. Use all that apply as appropriate.					
	Building Entrances or Exits. Allowance per door. Luminaires qualifying for this allowance shall be within 20 feet of the door.	30 watts	~~75~~ 60 watts	~~100~~ 90 watts	~~120~~ 90 watts
	Primary Entrances to Senior Care Facilities, Police Stations, Hospitals, Fire Stations, and Emergency Vehicle Facilities. Allowance per primary entrance(s) only. Primary entrances shall provide access for the general public and shall not be used exclusively for staff or service personnel. This allowance shall be in addition to the building entrance or exit allowance above. Luminaires qualifying for this allowance shall be within 100 feet of the primary entrance.	45 watts	80 watts	120 watts	130 watts
	Drive Up Windows. Allowance per customer service location. Luminaires qualifying for this allowance shall be within 2 mounting heights of the sill of the window.	40 watts	75 watts	125 watts	200 watts
	Vehicle Service Station Uncovered Fuel Dispenser. Allowance per fueling dispenser. Luminaires qualifying for this allowance shall be within 2 mounting heights of the dispenser.	120 watts	175 watts	185 watts	330 watts
WATTAGE ALLOWANCE PER UNIT LENGTH (w/linear ft). May be used for one or two frontage side(s) per site.					
	Outdoor Sales Frontage. Allowance for frontage immediately adjacent to the principal viewing location(s) and unobstructed for its viewing length. A corner sales lot may include two adjacent sides provided that a different principal viewing location exists for each side. Luminaires qualifying for this allowance shall be located between the principal viewing location and the frontage outdoor sales area.	No Allowance	22.5 W/linear ft	36 W/linear ft	45 W/linear ft
WATTAGE ALLOWANCE PER HARDSCAPE AREA (W/ft²). May be used for any illuminated hardscape area on the site.					
	Hardscape Ornamental Lighting. Allowance for the total site illuminated hardscape area. Luminaires qualifying for this allowance shall be rated for 100 watts or less as determined in accordance with Section 130(d), and shall be post-top luminaires, lanterns, pendant luminaires, or chandeliers.	No Allowance	0.02 W/ft²	0.04 W/ft²	0.06 W/ft²
WATTAGE ALLOWANCE PER SPECIFIC AREA (W/ft²). Use as appropriate provided that none of the following specific applications shall be used for the same area.					
	Building Facades. Only areas of building façade that are illuminated shall qualify for this allowance. Luminaires qualifying for this allowance shall be aimed at the façade and shall be capable of illuminating it without obstruction or interference by permanent building features or other objects.	No Allowance	0.18 W/ft²	0.35 W/ft²	0.50 W/ft²
	Outdoor Sales Lots. Allowance for uncovered sales lots used exclusively for the display of vehicles or other merchandise for sale. Driveways, parking lots or other non-sales areas shall be considered hardscape areas even if these areas are completely surrounded by sales lot on all sides. Luminaires qualifying for this allowance shall be within 5 mounting heights of the sales lot area.	0.164 W/ft²	0.555 W/ft²	0.758 W/ft²	1.285 W/ft²
	Vehicle Service Station Hardscape. Allowance for the total illuminated hardscape area less area of buildings, under canopies, off property, or obstructed by signs or structures. Luminaires qualifying for this allowance shall be illuminating the hardscape area and shall not be within a building, below a canopy, beyond property lines, or obstructed by a sign or other structure.	0.014 W/ft²	0.155 W/ft²	0.308 W/ft²	0.485 W/ft²
	Vehicle Service Station Canopies. Allowance for the total area within the drip line of the canopy. Luminaires qualifying for this allowance shall be located under the canopy.	0.514 W/ft²	1.005 W/ft²	~~1.358~~ 1.300 W/ft²	~~2.285~~ 2.200 W/ft²
	Sales Canopies. Allowance for the total area within the drip line of the canopy. Luminaires qualifying for this allowance shall be located under the canopy.	No Allowance	0.655 W/ft²	0.908 W/ft²	1.135 W/ft²

	Lighting Application	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
	Non-sales Canopies. Allowance for the total area within the drip line of the canopy. Luminaires qualifying for this allowance shall be located under the canopy.	0.084 W/ft²	0.205 W/ft²	0.408 W/ft²	0.585 W/ft²
	Guard Stations. Allowance up to 1,000 square feet per vehicle lane. Guard stations provide access to secure areas controlled by security personnel who stop and may inspect vehicles and vehicle occupants, including identification, documentation, vehicle license plates, and vehicle contents. Qualifying luminaires shall be within 2 mounting heights of a vehicle lane or the guardhouse.	0.154 W/ft²	0.355 W/ft²	0.708 W/ft²	0.985 W/ft²
	Student Pick-up/Drop-off zone. Allowance for the area of the student pick-up/drop-off zone, with or without canopy, for preschool through 12th grade school campuses. A student pick-up/drop off zone is a curbside, controlled traffic area on a school campus where students are picked-up and dropped off from vehicles. The allowed area shall be the smaller of the actual width or 25 feet, times the smaller of the actual length or 250 feet. Qualifying luminaires shall be within 2 mounting heights of the student pick-up/drop-off zone.	No Allowance	0.12 W/ft²	0.45 W/ft²	No Allowance
	Outdoor Dining. Allowance for the total illuminated hardscape of outdoor dining. Outdoor dining areas are hardscape areas used to serve and consume food and beverages. Qualifying luminaires shall be within 2 mounting heights of the hardscape area of outdoor dining.	0.014 W/ft²	0.135 W/ft²	~~0.258~~ 0.240 W/ft²	~~0.435~~ 0.400 W/ft²
	Special Security Lighting for Retail Parking and Pedestrian Hardscape. This additional allowance is for illuminated retail parking and pedestrian hardscape identified as having special security needs. This allowance shall be in addition to the building entrance or exit allowance.	0.007 W/ft²	0.009 W/ft²	0.019 W/ft²	No Allowance

Figure 31: Recommended Changes to Table 147-B

TABLE 147-C :

TABLE 147-C ~~*ADDITIONAL LIGHTING POWER ALLOWANCE FOR ORDINANCE REQUIREMENTS*~~

~~ADDITIONAL LIGHTING POWER ALLOWANCE (W/ft²) WHEN AVERAGE LIGHT LEVELS ARE REQUIRED BY LOCAL ORDINANCE~~				
~~Required (horizontal foot candles, AVERAGE)~~	~~Lighting Zone 1~~	~~Lighting Zone 2~~	~~Lighting Zone 3~~	~~Lighting Zone 4~~
~~0.5~~	~~0~~	~~0~~	~~0~~	~~0~~
~~1~~	~~0.004~~	~~0~~	~~0~~	~~0~~
~~1.5~~	~~0.024~~	~~0.015~~	~~0~~	~~0~~
~~2~~	~~0.044~~	~~0.035~~	~~0~~	~~0~~
~~3~~	~~0.084~~	~~0.075~~	~~0.028~~	~~0.005~~
~~4.0 or greater~~	~~0.124~~	~~0.115~~	~~0.068~~	~~0.045~~
~~ADDITIONAL LIGHTING POWER ALLOWANCE (W/ft²) WHEN MINIMUM LIGHT LEVELS ARE REQUIRED BY LOCAL ORDINANCE~~				
~~Required (horizontal foot candles, MINIMUM)~~	~~Lighting Zone 1~~	~~Lighting Zone 2~~	~~Lighting Zone 3~~	~~Lighting Zone 4~~
~~0.5~~	~~0.004~~	~~0~~	~~0~~	~~0~~
~~1~~	~~0.044~~	~~0.035~~	~~0~~	~~0~~
~~1.5~~	~~0.124~~	~~0.115~~	~~0.068~~	~~0.045~~
~~2~~	~~0.164~~	~~0.155~~	~~0.108~~	~~0.085~~
~~3~~	~~0.164~~	~~0.155~~	~~0.108~~	~~0.085~~
~~4.0 or greater~~	~~0.164~~	~~0.155~~	~~0.108~~	~~0.085~~

Figure 32: Recommended Changes to Table 147-C

5. Appendix A: Statewide Forecasts

5.1 Non-Residential Construction Forecast details

5.1.1 Summary

The Non-Residential construction forecast dataset is data that is published by the California Energy Commission's (CEC) demand forecast office. This demand forecast office is charged with calculating the required electricity and natural gas supply centers that need to be built in order to meet the new construction utility loads. Data is sourced from Dodge construction database, the demand forecast office future generation facility planning data, and building permit office data.

All CASE reports should use the statewide construction forecast for 2014. The TDV savings analysis is calculated on a 15 or 30 year net present value, so it is correct to use the 2014 construction forecast as the basis for CASE savings.

5.1.2 Additional Details

The demand generation office publishes this dataset and categorizes the data by demand forecast climate zones (FCZ) as well as building type (based on NAICS codes). The 16 climate zones are organized by the generation facility locations throughout California, and differ from the Title 24 building climate zones (BCZ). HMG has reorganized the demand forecast office data using 2000 Census data (population weighted by zip code) and mapped FCZ and BCZ to a given zip code. The construction forecast data is provided to CASE authors in BCZ in order to calculate Title 24 statewide energy savings impacts. Though the individual climate zone categories differ between the demand forecast published by the CEC and the construction forecast, the total construction estimates are consistent; in other words, HMG has not added to or subtracted from total construction area.

The demand forecast office provides two (2) independent data sets: total construction and additional construction. Total construction is the sum of all existing floor space in a given category (Small office, large office, restaurant, etc.). Additional construction is floor space area constructed in a given year (new construction); this data is derived from the sources mentioned above (Dodge, Demand forecast office, building permits).

Additional construction is an independent dataset from total construction. The difference between two consecutive years of total construction is not necessarily the additional construction for the year because this difference does not take into consideration floor space that was renovated, or repurposed. In order to further specify the construction forecast for the purpose of statewide energy savings calculation for Title 24 compliance, HMG has provided CASE authors with the ability to aggregate across multiple building types. This tool is useful for measures that apply to a portion of various building types' floor space (e.g. skylight requirements might apply to 20% of offices, 50% of warehouses and 25% of college floor space).

The main purpose of the CEC demand forecast is to estimate electricity and natural gas needs in 2022 (or 10-12 years in the future), and this dataset is much less concerned about the inaccuracy at 12 or 24 month timeframe.

It is appropriate to use the CEC demand forecast construction data as an estimate of future years construction (over the life of the measure). The CEC non-residential construction forecast is the best publicly available data to estimate statewide energy savings.

5.1.3 Citation

"NonRes Construction Forecast by BCZ v7"; Developed by Heschong Mahone Group with data sourced August, 2010 from Abrishami, Moshen at the California Energy Commission (CEC).

6. Appendix B: Title 24 2008 Lighting Design Basis Mapping and Changes to Update to 2011

Many of the Lighting Applications categories in Title 24 match closely with specific lighting recommendations in various IESNA Recommended Practice documents and other IESNA documents. However, several do not have a direct match in the current IESNA documents.

This document provides the rational for the selection of specific IESNA lighting criteria for each particular Title 24 Lighting Application category.

6.1 Table 147-A Lighting Power Densities for General Site Illumination

6.1.1 Hardscape for Vehicular Use

The IESNA Recommended Practice for Parking Facilities (RP-20-1998) addresses pedestrian and vehicular safety issues in parking lots and access roadways. The lighting recommendations are suitable for direct application in this Lighting Application category. Table 1 in RP-20 is identified as 'Recommended Maintained Illuminance Values for Parking Lots,' and is the primary source of criteria for this Lighting Application category.

LZ4
The highest recommended lighting levels in RP-20 are designated for high activity retail applications, which match appropriately with LZ4. The IESNA designates this highest level by identifying a level above the 'Enhanced Security' category through superscript #2 in the table. This indicates a specific minimum horizontal illuminance level of 1.0fc for retail applications, and is the basis for the LZ4 target criteria.

LZ3
The 'Enhanced Security' guideline from Table 1 in RP-20 is the source for the LZ3 target criteria.

LZ2
The 'Basic' guideline from Table 1 in RP-20 is the source for the LZ2 target criteria.

LZ1
The lowest recommended lighting levels in RP-20 are designated by Note #2 in the table, which indicates that vertical illuminance guidelines may not be possible to meet with full cutoff lighting equipment. For LZ1, the target criteria is the 'Basic' recommendation, but disregarding the vertical illuminance requirement.

6.1.2 Hardscape for Pedestrian Use

The IESNA document Recommended Lighting for Walkways and Class I Bikeways (DG-5-1994) addresses pedestrian and bicyclist safety on pedestrian and bicycle corridors. The lighting recommendations are suitable for direct application in this Lighting Application category.

LZ4
The target criteria selected for this Lighting Zone is the highest recommendation provided in DG-5; 'City Center Walkway; Mixed Vehicle and Pedestrian.' The selection of this category accommodates the additional lighting necessary for potential pedestrian and vehicle conflict zones, and represents a substantial increase in light level to address the increased safety concern. The recommendation indicates a light level of 2.5fc average.

LZ3
The second highest recommendation provided in DG-5 has been selected for application in LZ3; 'Suburban Shopping Street; Mixed Vehicle and Pedestrian'. It represents a reduction from LZ4 of 20%, to 2.0fc average. It also represents one step down in the hierarchy of the IESNA city designations (Village, Suburban, City). This selection also accommodates the vehicle and pedestrian safety concern.

LZ2
The target criteria selected for LZ2 is one further step down in the IESNA city designation hierarchy; 'Village Center Walkway; Mixed Vehicle and Pedestrian'. This selection also accommodates the vehicle and pedestrian safety concern. It represents a reduction from LZ3 of 50%, to 1.0fc average.

LZ1
The target criteria selected for LZ1 is 'Specialized Residential Area Walkways; Medium Usage'. It represents a reduction from LZ2 of 50%, to 0.5fc average.

6.1.3 Building Entrances

The IESNA does not have a specific Recommended Practice that addresses building entrances. However, it is logical that building entrances be suitably lighted for identification purposes, as well as safety reasons. The primary lighting model selected as the basis for entrance lighting levels is the general circulation recommendations built into the IESNA document Lighting Merchandising Areas (RP-2-2001).

LZ4
The target criteria selected for this Lighting Zone is the highest general circulation recommendation from RP-2; 'Seasonal Outdoor Merchandise; High.' This represents a substantial increase in light level above general walkway lighting levels in this LZ, which makes it possible for a building entrance to be a suitable visual focal point for wayfinding purposes. The recommendation indicates a light level of 10.0fc average.

LZ3
The target criteria selected for this for this Lighting Zone is the second highest general circulation recommendation from RP-2; 'Seasonal Outdoor Merchandise; Medium.' It represents one step down from the LZ4 value in the hierarchy of use categories defined by the IESNA (Low, Medium, High). This also reflects a substantial increase in light level above general walkway lighting levels in this LZ. It represents a reduction from LZ4 of 30%, to 7.0fc average.

LZ2
The target criteria selected for this Lighting Zone is the circulation recommendation from RP-2 'Seasonal Outdoor Merchandise; Medium.' It represents one step down from the LZ3 value in the hierarchy of use categories defined by the IESNA. This also reflects a substantial increase in light level above general walkway lighting levels in this LZ. It represents a reduction from LZ3 of approximately 29%, to 5.0fc average.

LZ1
The LZ1 target criteria were selected from the IESNA document Recommended Lighting for Walkways and Class 1 Bikeways (DG-5-1994); 'Village Center Walkway; Mixed Vehicle and Pedestrian.' It was selected as a hierarchical increase in light level for building entrances based on the Hardscape for Pedestrian Use; LZ1 Lighting Application target criteria. It represents a reduction from LZ2 of 80%, to 1.0fc average.

6.1.4 Outdoor Sales Lot

The IESNA makes specific recommendations for outdoor sales lots in the document Lighting Merchandising Areas (RP-2-2001). The basis for these recommendations is the merchandise area recommendations portion of the auto dealership recommendation section. The lighting target criteria for LZ1 are selected from the IESNA document Lighting for Exterior Environments (RP-33-1999).

Specific feature lighting allowances are considered as part of the 'Outdoor Sales Frontage' Lighting Application (Table 147-B) with an explanation of the additional feature allowances provided in that section.

LZ4
The target criteria selected for this Lighting Zone is the highest general merchandise recommendation in RP-2; 'Auto Dealerships, Merchandise; High Use.' The recommendation indicates a light level of 50.0fc average.

LZ3
The target criteria selected for this Lighting Zone is the middle general merchandise recommendation in RP-2; 'Auto Dealerships, Merchandise; Medium Use.' It represents one step down from the LZ4 value in the hierarchy of use categories defined by the IESNA (Low, Medium, High). It represents a reduction from LZ4 of 40%, to 30.0fc average.

LZ2
The target criteria selected for this Lighting Zone is the low general merchandise recommendation in RP-2; 'Auto Dealerships, Merchandise; Low Use.' It is one step down from the LZ3 value in the hierarchy of use categories defined by the IESNA. It represents a reduction from LZ3 of approximately 33%, to 20.0fc average.

LZ1
The target criteria selected for this Lighting Zone is located in RP-33, 'Secondary Business District, Other Rows.' It has been selected with the lighting target illuminance set to the top of the range

recommended in the document (2.5fc to 5fc). It represents a reduction from LZ2 of approximately 75%, to 5.0fc average.

6.2 Table 147-B Lighting Power Densities for Specific Applications

6.2.1 Building Facades

The IESNA makes specific recommendations for outdoor sales lots in the document Lighting for Exterior Environments (RP-33-1999). 'Table 2: Illuminance Levels for Floodlighting Buildings and Monuments' directly addresses these lighting situations and the recommendations can be applied directly for this Lighting Application. Note that a Building Façades lighting allowance is not permitted in LZ1.

LZ4
The target criteria selected for this Lighting Zone is the highest recommended in RP-33; 'Bright Surroundings and Dark Surfaces'. The recommendation indicates a light level of 10.0fc average.

LZ3
The target criteria selected for this Lighting Zone is 'Bright Surroundings and Light Surfaces.' It represents a reduction from LZ4 of approximately 50%, to 5.0fc average.

LZ2
The target criteria selected for this Lighting Zone is 'Dark Surroundings and Medium Light Surfaces.' It represents a reduction from LZ3 of approximately 40%, to 3.0fc average.

LZ1
No Building Façades lighting allowance is permitted in LZ1.

6.2.2 Outdoor Sales Frontage

The IESNA makes specific recommendations for outdoor sales lots in the document Lighting Merchandising Areas (RP-2-2001). The basis for these recommendations is the feature merchandise recommendations portion of the auto dealership recommendation section. Note that an Outdoor Sales Frontage lighting allowance is not permitted in LZ1.

LZ4
The target criteria selected for this Lighting Zone is the highest feature display recommendation in RP-2; 'Auto Dealerships, Feature Display; High Use.' It is the highest illuminance recommendation provided within the RP-2 document (75fc average).

LZ3
The target criteria selected for this Lighting Zone is the middle feature display recommendation in RP-2; 'Auto Dealerships, Feature Display; Medium Use.' It represents one step down from the LZ4 value in the hierarchy of use categories defined by the IESNA (Low, Medium, High). The recommendation represents a reduction from LZ4 of approximately 33%, to 50fc average.

LZ2
The target criteria selected for this Lighting Zone is the low feature display recommendation in RP-2; 'Auto Dealerships, Feature Display; Low Use.' It represents one step down from the LZ3 value in the hierarchy of use categories defined by the IESNA. The recommendation represents a reduction from LZ3 of approximately 30%, to 35fc average.

LZ1
No Outdoor Sales Frontage lighting allowance is permitted in LZ1.

6.2.3 Vehicle Service Station with or without Canopies

The IESNA makes specific recommendations for service station canopies in document Lighting Merchandising Areas (RP-2-2001). The basis for these recommendations is the 'Service Stations, Gas Islands' category. These can be applied directly for three of the LZ levels. The lighting target criteria for LZ1 are selected from the IESNA document Lighting for Exterior Environments (RP-33-1999).

LZ4
The target criteria selected for this Lighting Zone is the highest gas island recommendation in RP-2; 'Service Stations, Gas Islands; High Use.' It is the highest illuminance recommendation provided within the RP-2 document suitable for service stations (50fc average).

LZ3
The target criteria selected for this Lighting Zone is the middle gas island recommendation in RP-2; 'Service Stations, Gas Islands; Medium Use.' It represents one step down from the LZ4 value in the hierarchy of use categories defined by the IESNA (Low, Medium, High). The recommendation represents a reduction from LZ4 of approximately 40%, to 30fc average.

LZ2
The target criteria selected for this Lighting Zone is the low gas island recommendation in RP-2; 'Service Stations, Gas Islands; Low Use.' It represents one step down from the LZ3 value in the hierarchy of use categories defined by the IESNA. The recommendation represents a reduction from LZ3 of approximately 33%, to 20fc average.

LZ1
The target criteria selected for this Lighting Zone is located in Table 8 of RP-33, 'Service Stations or Gas Pump Area Average Illuminance Levels.' The guideline selected is 'Pump Island Area with Light Surrounds.' The recommendation represents a reduction from LZ2 of approximately 50%, to 10fc average.

6.2.4 Vehicle Service Station Hardscape

The IESNA makes specific recommendations for outdoor sales lots in document Lighting Merchandising Areas (RP-2-2001). The basis for these recommendations is the 'Service Stations, Approach Lanes' category. These can be applied directly for three of the LZ levels. The lighting

target criteria for LZ1 is selected from the IESNA document Lighting for Parking Facilities (RP-20-1998).

LZ4
The target criteria selected for this Lighting Zone is the highest approach lane recommendation in RP-2; 'Service Stations, Approach Lane; High Use.' It is the highest illuminance recommendation provided within the RP-2 document suitable for service station approach lanes (15fc average). More importantly, it represents a transition zone from the high light levels under the canopy for adaptation purposes. The illuminance recommendation is 30% of the Vehicle Service station with or without Canopies; LZ4 Lighting Application values.

LZ3
The target criteria selected for this Lighting Zone is the middle approach lane recommendation in RP-2; 'Service Stations, Approach Lane; Medium Use.' It represents one step down from the LZ4 value in the hierarchy of use categories defined by the IESNA (Low, Medium, High). The recommendation represents a reduction from LZ4 of approximately 33%, to 10fc average, and also represents 30% of the Vehicle Service Station with or without Canopies; LZ3 Lighting Application values.

LZ2
The target criteria selected for this Lighting Zone is the low approach lane recommendation in RP-2; 'Service Stations, Approach Lane; Low Use.' It represents one step down from the LZ3 value in the hierarchy of use categories defined by the IESNA. The recommendation represents a reduction from LZ3 of approximately 50%, to 5fc average, and also represents 25% of the Vehicle Service Station with or without Canopies; LZ2 Lighting Application values.

LZ1
The target criteria selected for this Lighting Zone is located in Table 1 of RP-20, 'Recommended Maintained Values for Parking Lots.' The guideline selected is the full 'Basic' level, including the vertical illuminance guideline. The recommendation represents a reduction from LZ2 of approximately 70%, to approximately 1.5fc average. The guideline represents approximately 15% or the Vehicle Service Station with or without Canopies; LZ1 Lighting Application values.

The intent of a lower allowance for this Lighting Application is to help minimize the impact of the service station canopy lighting on the surrounding dark environment. While the accounting for the lighting equipment is calculated in a strict area allowance method, the light from the canopy will encroach into the approach lanes, providing a reasonable transition zone for a low use application intended for LZ1 conditions. It is therefore the approach that the lighting levels permitted for the general area at a service station be only slightly higher than is permitted for general parking conditions at other (non- service station) facilities.

6.2.5 All Other Sales Canopies

The IESNA makes specific recommendations for outdoor sales lighting in document Lighting Merchandising Areas (RP-2-2001). The basis for these recommendations is the 'Seasonal Outdoor Merchandise' category. These can be applied directly for the LZ levels. Note that an All Other Sales Canopies lighting allowance is not permitted in LZ1.

LZ4
The target criteria selected for this Lighting Zone is the highest outdoor sales recommendation in RP-2; 'Seasonal Outdoor Merchandise, Merchandise Display; High Use.' It is the highest illuminance recommendation provided within the RP-2 document suitable for non-automotive outdoor sales (30fc average).

LZ3
The target criteria selected for this Lighting Zone is the middle outdoor sales recommendation in RP-2; 'Seasonal Outdoor Merchandise, Merchandise Display; Medium Use.' It represents one step down from the LZ4 value in the hierarchy of use categories defined by the IESNA (Low, Medium, High). The recommendation represents a reduction from LZ4 of approximately 33%, to 20fc average.

LZ2
The target criteria selected for this Lighting Zone is the low outdoor sales recommendation in RP-2; 'Seasonal Outdoor Merchandise, Merchandise Display; Low Use.' It represents one step down from the LZ3 value in the hierarchy of use categories defined by the IESNA. The recommendation represents a reduction from LZ3 of 50%, to 10fc average.

LZ1
No All Other Sales Canopies lighting allowance is permitted in LZ1.

6.2.6 Non-sales Canopies

The IESNA makes specific recommendations for non-merchandise portions of exterior environments that are related to pedestrian circulation in document Lighting Merchandising Areas (RP-2-2001). The basis for these recommendations is the 'Seasonal Outdoor Merchandise, Circulation' category. These can be applied directly for three of the LZ levels. LZ1 uses the IESNA document Recommended Lighting for Walkways and Class I Bikeways (DG-5-1994) to address canopies.

LZ4
The target criteria selected for this Lighting Zone is the highest circulation recommendation in RP-2; 'Seasonal Outdoor Merchandise, Circulation; High Use.' It is the highest illuminance recommendation provided within the RP-2 document suitable for non-automotive circulation areas (10fc average).

LZ3
The target criteria selected for this Lighting Zone is the middle circulation recommendation in RP-2; 'Seasonal Outdoor Merchandise, Circulation; Medium Use.' It represents one step down from the LZ4 value in the hierarchy of use categories defined by the IESNA (Low, Medium, High). The recommendation represents a reduction from LZ4 of 30%, to 7fc average.

LZ2
The target criteria selected for this Lighting Zone is the low circulation recommendation in RP-2; 'Seasonal Outdoor Merchandise, Circulation; Low Use.' It represents one step down from the LZ3

value in the hierarchy of use categories defined by the IESNA. The recommendation represents a reduction from LZ3 of approximately 29%, to 5fc average.

LZ1
The target criteria selected for LZ1 is located in DG-5; 'Village Center Walkway; Mixed Vehicle and Pedestrian'. This selection represents a lighting level higher than basic sidewalk levels, so a visual hierarchy can be established. This recommendation also matches the illuminance values in the Building Entrances (without canopy); LZ1 Lighting Application. It represents a reduction from LZ2 of 80% to 1fc average.

6.2.7 Ornamental Lighting

The IESNA makes no recommendations for ornamental lighting that will provide suitable average illuminance guidelines or watts per square foot (WPF) allowances. Ornamental lighting is not of a uniform nature, and it is therefore not possible to characterize suitable ornamental lighting with specific recommendations that use a measure of average illuminance. Note that no Ornamental Lighting allowance is permitted for LZ1.

6.2.8 Drive Up Windows

The IESNA makes specific recommendations for drive up window lighting in document Guideline on Security Lighting for People, Property, and Public Spaces (G-1-2003). The recommendation is 'Fast Food Restaurants; Drive Up Window.' This recommendation can be applied directly for the LZ levels. The recommendation (6fc average) is necessary for security associated with the threat of armed holdup by an assailant on foot or in a vehicle. The values also are necessary for security camera operation in the area. As such this recommendation is applied singularly to all LZ categories.

LZ4, LZ3, LZ2, LZ1
G-1 'Fast Food Restaurants; Drive Up Window' is the target criteria applied to all four Lighting Zones. The lighting power allowance varies for each LZ as an accommodation of the higher allowances permitted in the Hardscape for Vehicular Use Lighting Application, permitting higher illuminance values than the minimum stated in the G-1 recommendation in higher LZ's.

6.2.9 Guarded Facilities

The IESNA makes specific several recommendations for security lighting in various documents, but in no case is there a hierarchical arrangement of recommendations that take into account the context of the surrounding lighting environment.

However, the document Lighting Merchandising Areas (RP-2-2001) does have a hierarchical arrangement, and the lighting recommendations in the 'Seasonal Outdoor Merchandise' category are a logical fit for this purpose. This set of recommendations are suitable for the general public to safely navigate an unfamiliar retail environment, so it is reasonable that an area where security is a concern and has a specific security detail or security-oriented activities would be well met by the lighting recommendations used for the retail portion of the RP-2 document.

These can be applied directly for the LZ levels. The recommendations also represent a light level somewhat higher than the typical sidewalk or parking lot, so there will be a suitable hierarchical capability when establishing light levels for different areas of a facility. The recommendation 'Fast Food Restaurants; Drive Up Window' is used for the LZ1 target criteria as this has the same safety and security visibility issues.

LZ4
The target criteria selected for this Lighting Zone is the highest outdoor sales recommendation in RP-2; 'Seasonal Outdoor Merchandise, Merchandise Display; High Use.' It is the highest illuminance recommendation provided within the RP-2 document suitable for non-automotive outdoor sales (30fc average).

LZ3
The target criteria selected for this Lighting Zone is the middle outdoor sales recommendation in RP-2; 'Seasonal Outdoor Merchandise, Merchandise Display; Medium Use.' It represents one step down from the LZ4 value in the hierarchy of use categories defined by the IESNA (Low, Medium, High). The recommendation represents a reduction from LZ4 of approximately 33%, to 20fc average.

LZ2
The target criteria selected for this Lighting Zone is the low outdoor sales recommendation in RP-2; 'Seasonal Outdoor Merchandise, Merchandise Display; Low Use.' It represents one step down from the LZ3 value in the hierarchy of use categories defined by the IESNA. The recommendation represents a reduction from LZ3 of 50%, to 10fc average.

LZ1
G-1 'Fast Food Restaurants; Drive Up Window' is the target criteria applied to this Lighting Zone. It represents a reduction from LZ2 of 40%, to 6fc average.

6.2.10 Outdoor Dining

The IESNA makes specific recommendations for non-merchandise portions of exterior environments that are related to pedestrian circulation in document Lighting Merchandising Areas (RP-2-2001). The basis for these recommendations is the 'Seasonal Outdoor Merchandise, Circulation' category. These can be applied directly for three of the LZ levels. LZ1 uses the IESNA document Recommended Lighting for Walkways and Class I Bikeways (DG-5-1994).

In an attempt to create ambiance, many dining facilities will use exceedingly low light levels, much below what is provided in these recommendations.

LZ4
The target criteria selected for this Lighting Zone is the highest circulation recommendation in RP-2; 'Seasonal Outdoor Merchandise, Circulation; High Use.' It is the highest illuminance recommendation provided within the RP-2 document suitable for non-automotive circulation areas (10fc average).

LZ3
The target criteria selected for this Lighting Zone is the middle circulation recommendation in RP-2; 'Seasonal Outdoor Merchandise, Circulation; Medium Use.' It represents one step down from the LZ4 value in the hierarchy of use categories defined by the IESNA (Low, Medium, High). The recommendation represents a reduction from LZ4 of 30%, to 7fc average.

LZ2
The target criteria selected for this Lighting Zone is the low circulation recommendation in RP-2; 'Seasonal Outdoor Merchandise, Circulation; Low Use.' It represents one step down from the LZ3 value in the hierarchy of use categories defined by the IESNA. The recommendation represents a reduction from LZ3 of approximately 29%, to 5fc average.

LZ1
The target criteria selected for LZ1 is located in DG-5; 'Village Center Walkway; Mixed Vehicle and Pedestrian'. This selection represents a lighting level higher than basic sidewalk levels, so a visual hierarchy can be established. It represents a reduction from LZ2 of 80% to 1fc average.

7. Appendix C: Title 24 Power Density Allowance Comparisons to ASHRAE 90.1-2010

7.1 General Hardscape Allowances

The General Hardscape analysis is detailed in Appendix E: General Hardscape Allowance LPD Comparisons and Recalibration.

7.2 Building Entrances or Exits

Title 24 provides an allowance on a per-door basis, and does not distinguish type of door. 90.1 provides an allowance on a per-foot of door width basis, with different allowances for main entries and other doors. Assuming a 3ft door width for the 90.1 allowance, a direct comparison was made. It was found that Title 24-2008 was more aggressive in Lighting Zone 1, but 90.1-2007 was more aggressive in Lighting Zones 2, 3 and 4.

Recommendation: Adjust the Lighting Power Densities in Lighting Zones 2, 3 and 4 to be as aggressive as (or more aggressive than) 90.1-2010 per Figure 33.

Allowance Type:	Recommended Change?	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Building Entrances or Exits.	Reduced LPA's in LZ2, 3 & 4	30 W (no change)	60W (reduced from 75W)	90W (reduced from 100W)	90W (reduced from 120W)

Figure 33: Summary of Recommendations for Building Entrances or Exits

7.3 Primary Entrances to Senior Care Facilities, Police Stations, Hospitals, Fire Stations, and Emergency Vehicle Facilities

ASHRAE 90.1-2010 does not provide an allowance for this exact type of application, so the allowances were compared to "Loading areas for law enforcement," which would have similar visibility issues. Title 24 provides this allowance on a per-entrance basis, while the 90.1 allowance is based on a per-area basis. For comparison, the area at which the two codes provide the same total allowance in LZ 3 was determined. Using that same area, it was shown that Title 24-2008 is more aggressive in LZ 1 and LZ 2. 90.1-2007 is slightly more aggressive in LZ 4.

Recommendation: No Change from Title 24-2008

7.4 Drive Up Windows

Title 24 provides an allowance per customer service location, whereas 90.1 provides an allowance per drive-thru, which is assumed to apply to the whole area independent of customer service location quantities. A comparison between the allowances was made assuming two customer service windows per drive-thru. Based on this approach, it was shown that 90.1-2007 and Title 24-2008 provide equal allowances in Zone 4, and that Title 24-2008 provides more aggressive allowances in LZ 1, LZ 2 and LZ 3.

Recommendation: No Change from Title 24-2008

7.5 Vehicle Service Station Uncovered Fuel Dispenser

There is no equivalent type of allowance in 90.1-2007, so no direct comparison to determine which code is more aggressive was appropriate.

Recommendation: No Change from Title 24-2008

7.6 Outdoor Sales Frontage

See detailed analysis of Outdoor Sales allowances in Appendix D: Outdoor Sales Allowance Detailed Analysis.

7.7 Hardscape Ornamental Lighting

This allowance under Title 24-2008 is provided as a tradable, layered allowance to allow decorative luminaires. For comparison, it was assumed that this type of allowance could be equated to 90.1-2007's Landscape Lighting allowance, since no such ornamental lighting allowance is included in 90.1. The values were then directly compared, and it was determined that Title 24-2008 is more aggressive than 90.1-2007 in LZ 1, LZ 2 and LZ 3. 90.1-2007 is more aggressive in Lighting Zone 4.

Recommendation: No Change from Title 24-2008

7.8 Building Facades

Title 24 provides façade lighting allowanced based on the area of illuminated façade. 90.1 provides an allowance based either on the area of illuminated façade, or on the length, in plan, of the illuminated façade. Three comparisons were performed in order to capture these various approaches. First, the values from Title 24-2008 were compared directly to the area-based allowances in 90.1-2007. Next, the values were compared assuming a 10ft tall wall and the distance-based 90.1-2007 allowances. Finally, the values were compared using a 30ft tall wall and the distance-based 90.1-2007 allowances. It was shown that neither code provides an allowance in Lighting Zone 1. Using the area-based method and the distance-based method with 30 ft walls, 90.1-2007 was shown to be more aggressive than Title 24-2008 in Lighting Zones 2, 3 and 4. Using the distance-based method

with 10ft walls, Title 24-2008 was shown to be more aggressive in Lighting Zones 2 and 3, while the codes provided equal allowances in Lighting Zone 4.

Though the Lighting Power Densities in Title 24-2008 are generally higher than ASHRAE 90.1-2007, it is not recommended to reduce the Lighting Power Densities during this revision cycle. This recommendation is based on feedback from the California Energy Commission regarding providing designers the ability to create decorative façade lighting, citing challenges under the 2008 values and recommending that those values not be reduced.

Recommendation: No Change from Title 24-2008

7.9 Outdoor Sales Lots

See detailed analysis of Outdoor Sales allowances in Appendix D: Outdoor Sales Allowance Detailed Analysis.

7.10 Vehicle Service Station Hardscape

See Service Station Canopy Allowance Analysis.

7.11 Vehicle Service Station Canopies

See Service Station Canopy Allowance Analysis.

7.12 Sales Canopies

A direct comparison of the seals canopy allowance between Title 24 and 90.1 was performed. Title 24-2008 does not provide an allowance in Lighting Zone 1, and is therefore more aggressive. For Lighting Zones 2, 3 and 4, 90.1-2007 provides slightly more aggressive allowances.

Recommendation: No Change from Title 24-2008

7.13 Non-Sales Canopies

Since 90.1 does not provide an allowance for this exact type of application, the Non-Sales Canopy allowance in Title 24 was compared to the Entry Canopy allowance in 90.1 The direct comparison showed that Title 24-2008 allowances are more aggressive than 90.1-2007 allowances in all four lighting zones.

Recommendation: No Change from Title 24-2008

7.14 Guard Stations

Since 90.1 does not provide an allowance for this exact application, the Guard Station allowance was compared to the "Entrances and Gate-House Inspections" allowance in 90.1. The direct comparison showed that Title 24-2008 provides more aggressive allowances in Lighting Zones 1 and 2, but 90.1-2007 provides more aggressive allowances in Lighting Zones 2 and 4. It should be noted that the 90.1-2007 allowances are essentially independent of Lighting Zones for this application.

Recommendation: No Change from Title 24-2008

7.15 Student Pick-Up/Drop-Off Zone

There is no equivalent type of allowance in 90.1-2007, so no direct comparison to determine which code is more aggressive was appropriate.

Recommendation: No Change from Title 24-2008

7.16 Outdoor Dining

ASHRAE 90.1-2010 does not provide an allowance for this exact type of application, so the allowed lighting power density was compared to the "Feature Areas" tradable allowance in 90.1. The comparison showed that Title 24-2008 provided more aggressive allowances in LZ1 and LZ2, but that ASHRAE 90.1-2010 provided more aggressive allowances in LZ3 and LZ4.

Recommendation: Adjust the Lighting Power Densities in LZ3 and LZ4 per Figure 34.

Allowance Type:	Recommended Change?	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Outdoor Dining	Reduced LPA's in LZ3 & 4	0.014 W/ft2 (no change)	0.135 W/ft2 (no change)	0.240 W/ft2 (reduced from 0.258)	0.400 W/ft2 (reduced from 0.435)

Figure 34: Summary of Recommendations for Outdoor Dining

7.17 Special Security Lighting for Retail Parking and Pedestrian Hardscape

The closest allowance to this in ASHRAE 90.1-2010 is given for parking near 24-hour retail entrances, and provided on a per-entry basis. Comparing the two codes, Title 24-2008 does not provide an allowance in Lighting Zone 4, and is therefore more aggressive in that zone. For Lighting Zones 1, 2 and 3, Title 24-2008 provides tight area-based allowances, which would need to be applied to areas of at least 114,285 square feet before 90.1 becomes more aggressive than Title 24-2008, assuming one main entry.

Recommendation: No Change from Title 24-2008

7.18 Two Whole-Site Reviews

Two whole-site LPD calculations were made to verify that the overall Title 24 infrastructure was working as intended. A Big Box retail property and a smaller café retail property were considered and designed to use for the simulations. These are prototypical sites, and are not intended to be actual development property examples.

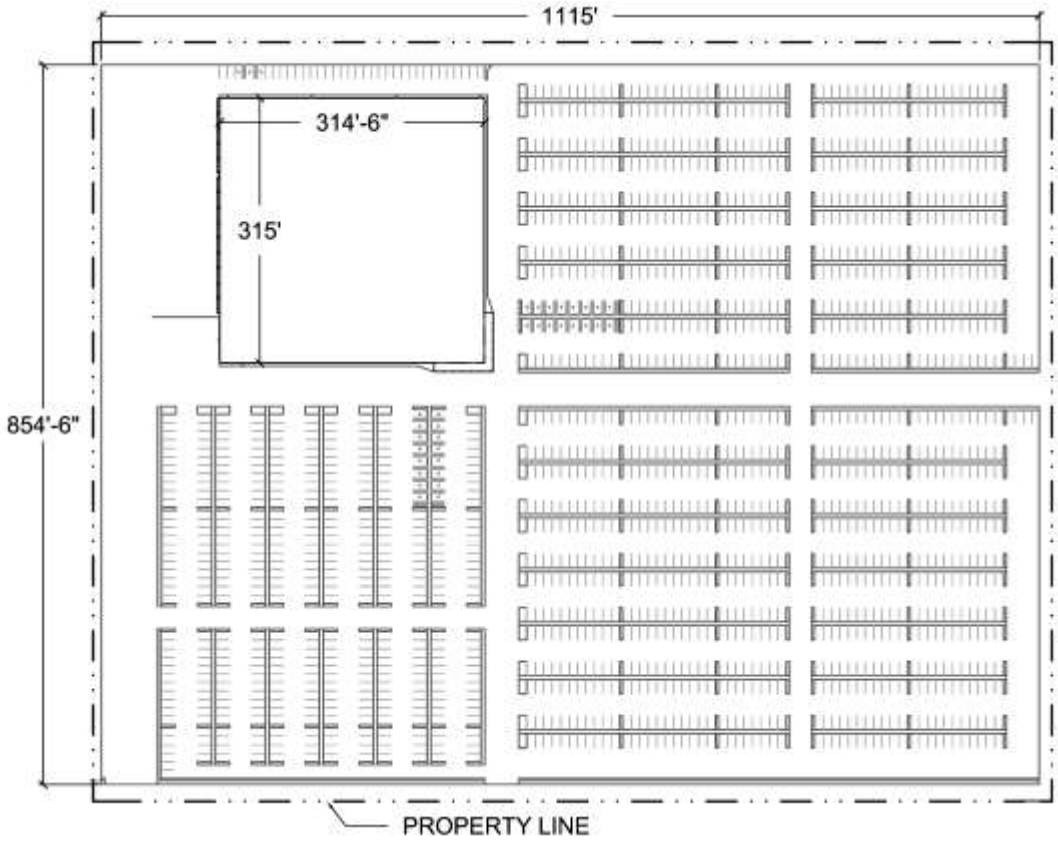

Figure 35: Layout of Big Box Prototype Example

Title 24-2008

Input Geometry	Hardscape Area	844,333	sf
	Hardscape Perimeter	2,922	lf
	Main Entry Doors	8	unit
	Other Entry Doors	8	unit
	Non-Sales Canopies	1,300	sf
	Special Security Area	59,285	sf

		LZ1	LZ2	LZ3	LZ4	Units
Tabulation	IWA	340	510	770	1030	W
	AWA	0.036	0.045	0.092	0.115	W/sf
		30,396	37,995	77,679	97,098	W
	LWA	0.36	0.45	0.92	1.15	W/lf
		1,052	1,315	2,688	3,360	W
	Building Entrances	30	75	100	120	W/door
		480	1200	1600	1920	W
	Non-Sales Canopy	0.084	0.205	0.408	0.585	W/sf
		109	267	530	761	W
	Special Security Area	0.007	0.009	0.019	0	W/sf
		415	534	1,126	0	W
Summary	General Hardscape Allowance	31,788	39,820	81,137	101,489	W
	Entry Allowance	480	1200	1600	1920	W
	Non-Sales Canopy Allowance	109	267	530	761	W
	Special Security Area Allowance	415	534	1,126	0	W
	TOTAL	32,792	41,820	84,394	104,169	W

ASHRAE 90.1-2010

Input Geometry	Uncovered Parking Area & Drives	842,622	sf
	Walkways less than 10ft wide	832	lf
	Walkways 10ft wide or greater	1,370	sf
	Entry Canopy	1,300	sf
	Main Entry Doors	48	lf
	Other Doors	24	lf
	24-Hour Entrances	4	unit

		LZ1	LZ2	LZ3	LZ4	Units
Tabulation	Base Site Allowance	500	600	750	1,300	W
	Uncovered Parking Areas	0.04	0.06	0.1	0.13	W/sf
		33,705	50,557	84,262	109,541	W
	Main Entries	20	20	30	30	W/lf
		960	960	1,440	1,440	W
	Other Doors	20	20	20	20	W/lf
		480	480	480	480	W
	Walkways less than 10ft wide	0.7	0.7	0.8	1.0	W/lf
		582	582	666	832	W
	Walkways 10ft wide or greater	0.14	0.14	0.16	0.20	W/sf
		192	192	219	274	W
	Entry Canopy	0.25	0.25	0.4	0.4	W/sf
		325	325	520	520	W
	Parking near 24-hour retail entrances	800	800	800	800	W/entry
		3,200	3,200	3,200	3,200	W
Summary	Total Tradable Allowance	36,744	53,697	88,337	114,387	W
	Total Non-Tradable Allowance	3,200	3,200	3,200	3,200	W

Title 24-2008

Canopy and Area Under Drip Line	Non-Sales Canopy Allowance	1,300	1,300	1,300	1,300	sf
		109	267	530	761	W
	Hardscape Area Allowance	47	59	120	150	W
	Entry Allowance	8	8	8	8	Unit
		240	600	800	960	W
	Total Allowance	396	925	1,450	1,870	W
		0.305	0.712	1.115	1.438	W/sf
Special Security Lighting	Special Security Area	0.007	0.009	0.019	0	W/sf
		415	534	1,126	0	W
Other Entries	Entry Allowance per Door	30	75	100	120	W/door
Remaining Hardscape Tradable	Hardscape Area Allowance	843,033	843,033	843,033	843,033	sf
		30,349	37,936	77,559	96,949	W
	Hardscape Perimeter Allowance	1,052	1,315	2,688	3,360	W
	Total Allowance	31,401	39,251	80,247	100,309	W
		0.037	0.047	0.095	0.119	W/sf

ASHRAE 90.1-2010

Canopy and Area Under Drip Line	Main Entry Allowance	48	48	48	48	lf
		960	960	1440	1440	W
	Walkways 10ft wide or greater Allowance	1,300	1,300	1,300	1,300	sf
		182	182	208	260	W
	Entry Canopy Allowance	325	325	520	520	W
	Total Allowance	1,467	1,467	2,168	2,220	W
		1.128	1.128	1.668	1.708	W/sf
Special Security Lighting	Parking near 24-hour retail entrances Allowance	3,200	3,200	3,200	3,200	W
	Allowance over T24 Special Security Area	0.054	0.054	0.054	0.054	W/sf
Other Entries	Other Doors Entry Allowance	480	480	480	480	W
		60	60	60	60	W/door
Remaining Hardscape Tradable	Uncovered Parking Allowance	842,622	842,622	842,622	842,622	sf
		33,705	50,557	84,262	109,541	W
	Walkways less than 10ft wide Allowance	582	582	666	832	W
	Walkways 10ft wide or greater Allowance	70	70	70	70	sf
		10	10	11	14	W
	Total Allowance	34,297	51,150	84,939	110,387	W
		0.041	0.061	0.101	0.131	W/sf

Figure 36: Summary of LPD Calculations for Big Box Prototype Example

These comparisons include all the viable allowances that a building of this type is likely to use, with the exception of façade allowances. Many of these are 'use it or lose it' in Title 24, but in ASHRAE 90.1 they are mostly tradable, so they go toward the whole site allowance more wholly in that code infrastructure. In the Title 24 infrastructure, the 'use it or lose it' system may force some watts to be left on the design table, which will lower the total watts that can are used.

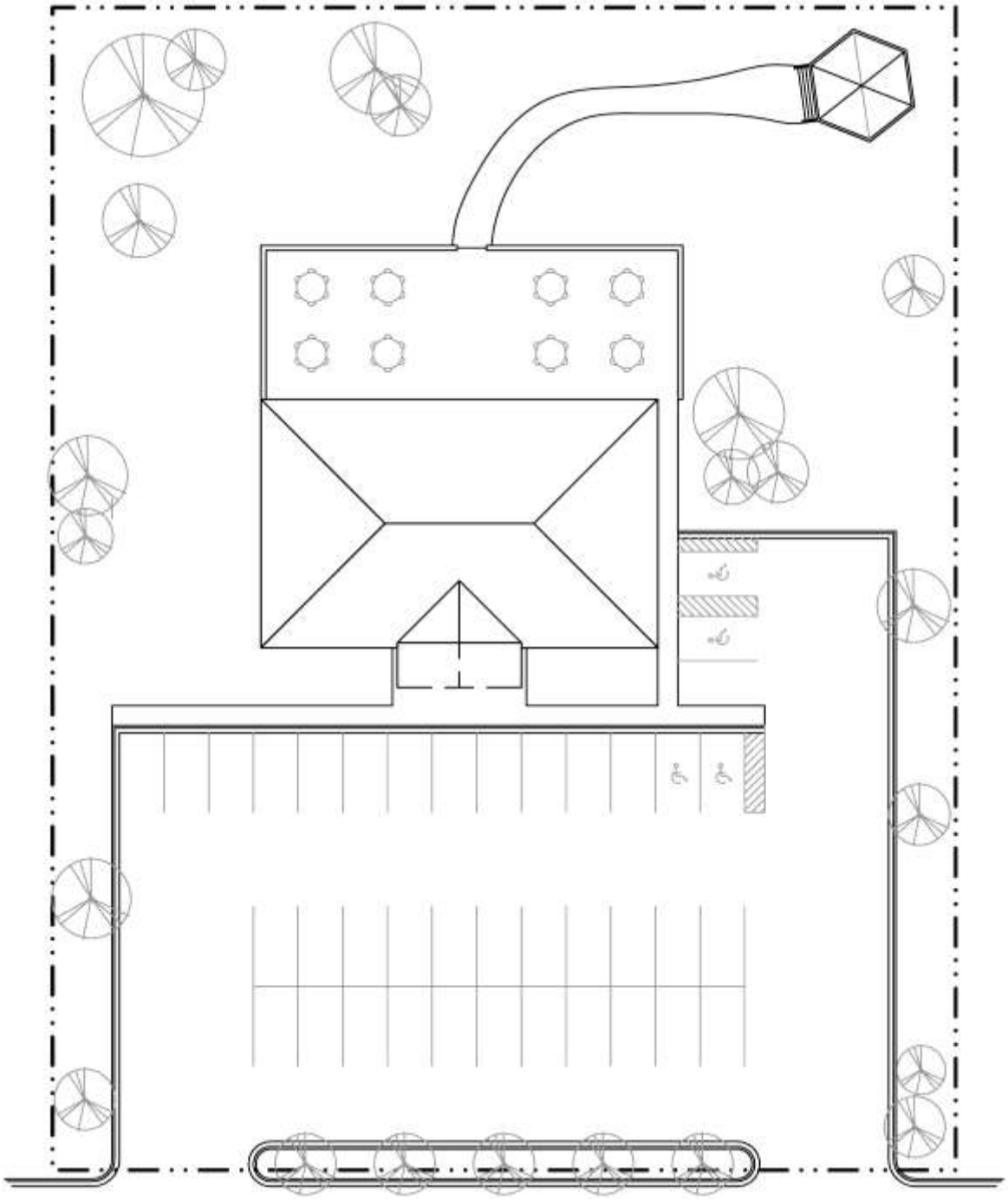

Figure 37: Layout of Café Prototype Example

	Title 24-2008						ASHRAE 90.1-2010					
Input Geometry	Hardscape Area	20,086	sf				Uncovered Parking Area	15,372	sf			
	Hardscape Perimeter	1,103	ft				Main Entry Door Width	12	lf			
	Main Entry Doors	4	unit				Other Door Width	12	lf			
	Other Entry Doors	4	unit				Entry Canopy	225	sf			
	Ornamental Lighting Area	971	sf				Walkways less than 10ft wide	276	ft			
	Outdoor Dining Area	2,635	sf				Stairways	26	sf			
	Non-Sales Canopy Area	225	sf				Special Feature Areas	2,977	sf			
	South Façade Area	870	sf				South Façade Length	80	lf			
	East Façade Area	578	sf				East Façade Length	50	lf			
Tabulation		LZ1	LZ2	LZ3	LZ4	Units		LZ1	LZ2	LZ3	LZ4	Units
	IWA	340	510	770	1030	W	Base Site Allowance	500	600	750	1,300	W
	AWA	0.036	0.045	0.092	0.115	W/sf	Uncovered Parking Areas	0.04	0.06	0.1	0.13	W/sf
		723	904	1,848	2,310	W		615	922	1,537	1,998	W
	LWA	0.36	0.45	0.92	1.15	W/lf	Main Entries	20	20	30	30	W/lf
		397	496	1,015	1,268	W		240	240	360	360	W
	Building Entrances	30	75	100	120	W/door	Other Doors	20	20	20	20	W/lf
		240	600	800	960	W		240	240	240	240	W
	Special Feature Area with Ornamental Lighting	0	0.02	0.04	0.06	W/sf	Walkways less than 10ft wide	0.7	0.7	0.8	1.0	W/lf
		0	19	39	58	W		193	193	221	276	W
	Outdoor Dining	0.015	0.135	0.258	0.435	W/sf	Stairways	0.75	1.0	1.0	1.0	W/sf
		40	356	680	1,146	W		20	26	26	26	W
	Non-Sales Canopy	0.084	0.205	0.408	0.585	W/sf	Special Feature Areas	0.14	0.14	0.16	0.20	W/sf
		19	46	92	132	W		417	417	476	595	W
	Façade Lighting	0	0.18	0.35	0.5	W/sf	Entry Canopy	0.6	0.6	0.8	1.0	W/sf
		0	261	507	724	W		135	135	180	225	W
							Building Facades	0	2.5	3.75	5	W/lf
								0	325	488	650	W
Summary	General Hardscape Allowance	1,460	1,910	3,633	4,608	W	Total Tradable Allowance	2,359	2,773	3,790	5,021	W
	Entry Allowance	240	600	800	960	W	Total Non-Tradable Allowance	0	325	488	650	W
	Ornamental Lighting Allowance	0	19	39	58	W						
	Outdoor Dining Allowance	40	356	680	1,146	W						
	Non-Sales Canopy Allowance	19	46	92	132	W						
	Façade Lighting Allowance	0	261	507	724	W						
	TOTAL	1,759	3,192	5,750	7,628	W	TOTAL	2,359	3,098	4,278	5,671	W

	Title 24-2008						ASHRAE 90.1-2010					
Entries							Entry Allowance	480	480	600	600	W
	Entry Allowance per Door	30	75	100	120	W	Effective Entry Allowance per Door	60	60	75	75	W
Outdoor Dining	Outdoor Dining Allowance	40	356	680	1,146	W	Special Feature Area Allowance	0.14	0.14	0.16	0.2	W/sf
	Hardscape Allowance over Outdoor Dining Area	95	119	242	303	W						
	Total Allowance	134	474	922	1,449	W						
		0.051	0.180	0.350	0.550	W/sf						
Entry Canopy	Non-Sales Canopy Allowance	0.084	0.205	0.408	0.585	W/sf	Entry Canopy Allowance	0.6	0.6	0.8	1.0	W/sf
Façade Lighting	Façade Lighting	0	261	507	724	W	Building Facades	0	325	488	650	W
Feature Area with Pathway and Gazebo	Hardscape Area	971	971	971	971	sf	Walkways less than 10ft wide Allowance	83.5	83.5	83.5	83.5	lf
	Hardscape Perimeter	237	237	237	237	lf		58	58	67	84	W
	Hardscape Allowance	120	150	307	384	W	Stairway Allowance	20	26	26	26	W
	Special Feature Area Allowance	0	19	39	58	W	Special Feature Area Allowance	342	342	342	342	sf
	Total Allowance	120	170	346	442	W		48	48	55	68	W
		0.124	0.175	0.357	0.456	W/sf	Total Allowance	126	132	148	178	W
							Total Divided by T24 Area	0.130	0.136	0.152	0.183	W/sf
Remaining Hardscape	Remaining Hardscape Area Allowance	593	742	1,516	1,895	W	Uncovered Parking Allowance	615	922	1,537	1,998	W
	Remaining Hardscape Perimeter Allowance	312	390	797	996	W	Walkways less than 10ft wide Remaining Allowance	135	135	154	193	W
	Total Remaining Allowance	905	1,131	2,313	2,891	W	Total Allowance	750	1,057	1,691	2,191	W
		0.055	0.069	0.140	0.175	W/sf	Total Divided by T24 Area	0.045	0.064	0.103	0.133	W/sf

Figure 38: Summary of LPD Calculations for Café Prototype Example

Title 24-2008

Input Geometry		
Hardscape Area	844,333	sf
Hardscape Perimeter	2,922	lf
Main Entry Doors	8	unit
Other Entry Doors	8	unit
Non-Sales Canopies	1,300	sf
Special Security Area	59,285	sf

Summary	LZ1	LZ2	LZ3	LZ4	Units
General Hardscape Allowance	31,788	39,820	81,137	101,489	W
Entry Allowance	480	1200	1600	1920	W
Non-Sales Canopy Allowance	109	267	530	761	W
Special Security Area Allowance	415	534	1,126	0	W
TOTAL	**32,792**	**41,820**	**84,394**	**104,169**	**W**

ASHRAE 90.1-2010

Uncovered Parking Area & Drives	842,622	sf
Walkways less than 10ft wide	832	lf
Walkways 10ft wide or greater	1,370	sf
Entry Canopy	1,300	sf
Main Entry Doors	48	lf
Other Doors	24	lf
24-Hour Entrances	4	unit

	LZ1	LZ2	LZ3	LZ4	Units
Total Tradable Allowance	36,744	53,697	88,337	114,387	W
Total Non-Tradable Allowance	3,200	3,200	3,200	3,200	W
TOTAL	**39,944**	**56,897**	**91,537**	**117,587**	**W**

Figure 39: Comparison of Total Site Power Allowance for Big Box Retail, Title 24-2008 and ASHRAE 90.1-2010

Title 24-2008

Input Geometry		
Hardscape Area	20,086	sf
Hardscape Perimeter	1,103	ft
Main Entry Doors	4	unit
Other Entry Doors	4	unit
Ornamental Lighting Area	971	sf
Outdoor Dining Area	2,635	sf
Non-Sales Canopy Area	225	sf
South Façade Area	870	sf
East Façade Area	578	sf

Summary	LZ1	LZ2	LZ3	LZ4	Units
General Hardscape Allowance	1,460	1,910	3,633	4,608	W
Entry Allowance	240	600	800	960	W
Ornamental Lighting Allowance	0	19	39	58	W
Outdoor Dining Allowance	40	356	680	1,146	W
Non-Sales Canopy Allowance	19	46	92	132	W
Façade Lighting Allowance	0	261	507	724	W
TOTAL	**1,759**	**3,192**	**5,750**	**7,628**	**W**

ASHRAE 90.1-2010

Uncovered Parking Area	15,372	sf
Main Entry Door Width	12	lf
Other Door Width	12	lf
Entry Canopy	225	sf
Walkways less than 10ft wide	276	ft
Stairways	26	sf
Special Feature Areas	2,977	sf
South Façade Length	80	lf
East Façade Length	50	lf

	LZ1	LZ2	LZ3	LZ4	Units
Total Tradable Allowance	2,359	2,773	3,790	5,021	W
Total Non-Tradable Allowance	0	325	488	650	W
TOTAL	**2,359**	**3,098**	**4,278**	**5,671**	**W**

Figure 40: Comparison of Total Site Power Allowance for Cafe Retail, Title 24-2008 and ASHRAE 90.1-2010

The comparison shows that Title 24-2008 is in general more aggressive, especially when considering the 'optional' allowances that not all properties will include.

7.19 Review of Outdoor Lighting Exemptions

Exemptions to Keep

- Temporary outdoor lighting
- Lighting required and regulated by the Federal Aviation Administration, and lighting for public streets, roadways, highways, and traffic signage lighting, entrances occurring in the public right-of-way. > This should remain exempt in the 2011 cycle.
- Lighting for sports and athletic fields, and children's playground.
- Lighting for industrial sites, including but not limited to, rail yards, maritime marinas, chemical and petroleum processing plants, and aviation facilities.

- Lighting specifically for Automated Teller Machines as required by California Financial Code Section 13040, or required by law through a local ordinance.
- Lighting of public monuments.
- Signs shall meet the requirements of Section 148.
- Lighting used in or around swimming pools, water features, or other locations subject to Article 680 of the California Electrical Code.
- Lighting of tunnels, bridges, stairs, wheelchair elevator lifts for American with Disabilities Act (ADA) compliance, and ramps that are other than parking garage ramps.
- In theme parks: outdoor lighting for themes and special effects.
- Lighting for outdoor theatrical and other outdoor live performances, provided that these lighting systems are additions to area lighting systems and are controlled by a multiscene or theatrical cross-fade control station accessible only to authorized operators.
- Outdoor lighting systems for qualified historic buildings, as defined in the California Historic Building Code (Title 24, Part 8), if they consist solely of historic lighting components or replicas of historic lighting components. If lighting systems for qualified historic buildings contain some historic lighting components or replicas of historic components, combined with other lighting components, only those historic or historic replica components are exempt. All other outdoor lighting systems for qualified historic buildings shall comply with Section 147.

Exemptions to be Re-Examined

- Landscape Lighting

Landscape lighting is currently regulated under ASHRAE 90.1-2010 as a tradable, layered allowance and not regulated under Title 24. However, ASHRAE's approach to allowing lighting power as a tradable, layered allowance does not directly require that allowance to be used toward landscape lighting.

If Title 24 were to limit landscape lighting power, it would likely be provided in the form of a non-tradable, non-layered "use-it-or-lose-it" allowance, but currently there is no basis of design criteria to determine an appropriate lighting power allowance.

8. Appendix D: Outdoor Sales Allowance Detailed Analysis

The outdoor sales allowances included in Title 24-2008 were based on IESNA illuminance recommendations included in RP-2-01 and RP-33-99. Outdoor sales lighting recommendations are currently being moved into the new DG-3-11 document, and the illuminance recommendations have been updated.

Lighting Application	Reference	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Sales Frontage	Title 24-2008 Basis	N/A	RP-2-01 Auto Dealership Feature Display- Low Activity (35 hfc)	RP-2-01 Auto Dealership Feature Display- Medium Activity (50 hfc)	RP-2-01 Auto Dealership Feature Display- High Activity (75 hfc)
	New DG-3-11 Values	N/A	DG-3-11 Automotive Sales Front Row- Low Activity (30 hfc, 15 hfc)	DG-3-11 Automotive Sales Front Row- Medium Activity (40 hfc, 20 hfc)	DG-3-11 Automotive Sales Front Row- High Activity (50 hfc, 30 vfc)
	Change	N/A	**Decreased by 5 hfc** Added vfc Recommendation	**Decreased by 10 hfc** Added vfc Recommendation	**Decreased by 25 hfc** Added vfc Recommendation
Sales Area	Title 24-2008 Basis	RP-33-99 Secondary Business District General Display (5 hfc)	RP-2-01 Auto Retail Lot- Low Activity (20 hfc)	RP-2-01 Auto Retail Lot- Medium Activity (30 hfc)	RP-2-01 Auto Retail Lot- High Activity (50 hfc)
	New DG-3-11 Values	DG-3-11 Automotive Sales Area- Low Activity (7.5 hfc)	DG-3-11 Automotive Sales Area- Low Activity (20 hfc)	DG-3-11 Automotive Sales Area- Medium Activity (30 hfc)	DG-3-11 Automotive Sales Area- Medium Activity (40 hfc)
	Change	**Increased by 2.5 hfc**	No Change	No Change	**Decreased by 10 hfc**

Figure 41: Title 24-2008 IESNA Basis of Design for Outdoor Sales

In general, the medium activity level target illuminance values are recommended as the basis of design for the Sales Frontage lighting power allowance in all zones, and for the Sales Area lighting power allowance in Lighting Zones 2, 3 and 4. For Lighting Zone 1, the low activity target illuminance value is recommended, though, as a basis of design, this increases the target by 2.5 hfc over the 2008 basis of design values. It is also still recommended that no Sales Frontage allowance be provided in Lighting Zone 1.

Similar to the service station allowance analysis, the sales frontage illuminance levels are likely to "bleed" onto the adjacent general sales area, contributing to the average illuminance in those areas. Therefore, this analysis examined the overall composite illuminance and lighting power in order to meet both the sales frontage and sales area illuminance recommendations. Three different sites were examined, a small corner lot with two frontages and a small sales area, a larger corner lot with two frontages and a larger sales area, and a large mid-block lot with one frontage and a large sales area. The analysis was based on typical equipment and lamp/ballast options.

Corner Small Lot

(Full Calculations- Includes Inter-reflections)

		LZ4	LZ3	LZ2	LZ1
Light Levels (Average Illuminance)	Sales Frontage: Recommended (hfc/vfc)	50 / 30	40 / 20	30 / 15	7.5
	Sales Frontage: Achieved (hfc/vfc)	53.0 / 36.1	41.1 / 24.6	31.2 / 17.8	8.06
	Sales Area: Recommended (hfc)	40	30	20	7.5
	Sales Area: Achieved (hfc)	44.9	36.8	24.9	8.03
	Note: Sales Area & Sales Frontage (hfc) Calculation Plane Located at 0'-0" AFG.	*Notes: All pole luminaires mounted at 20'-0" AFG. All floodlight luminaires mounted at 8'-0" AFG.*			
	Note: Sales Frontage (vfc) Calculation Points Located at Front Edge of Front Sales Row, facing toward Property Line at 3'-0" AFG.				
Luminaires	General Sales Area Pole-mounted Luminaire Quantity	10	10	10	16
	Total Input Watts per Luminaire (W)	1,080	1,080	820	465
	Sales Frontage Pole-mounted Luminaire Quantity	17	14	17	12
	Total Input Watts per Luminaire (W)	1,080	1,080	820	465
	Sales Frontage Floodlight Luminaire Quantity	34	28	34	0
	Total Input Watts per Luminaire (W)	118	94	62	0
	Total Watts	33,172	28,552	24,248	13,020
Geometry	Total Hardscape Area (sf)	23,261			
	Total Hardscape Perimeter Length (lf)	498			
	Sales Frontage (lf)	286			
	Oudoor Sales Lot (sf)	13,156			
Base Hardscape Allowance	LWA (W/lf)	1.15	0.92	0.45	0.36
	LWA (W)	573	458	224	179
	AWA (W/sf)	0.115	0.092	0.045	0.036
	AWA (W)	2,675	2,140	1,047	837
	Total Base Allowance (W)	3,248	2,598	1,271	1,017
	Effective Base Area Wattage Allowance (W/sf)	0.140	0.112	0.055	0.044
Proposed LPD & Determination of LPAs	Proposed Lighting Power Density (W/sf)	1.426	1.227	1.042	0.560
	LPD Over Base Hardscape Allowance (W/sf)	1.286	1.116	0.988	0.516
	% W at Frontage	67.4%	53.0%	57.5%	42.9%
	% W over Sales Area	32.6%	47.0%	42.5%	57.1%
	Effective Needed LPA at Frontage (W/lf)	71	48	46	18
	Effective Needed LPA over Sales Area (W/sf)	0.741	0.928	0.742	0.521
	If restrict Frontage LPA (W/lf)	45	36	22.5	0
	Effective Needed LPA over Sales Area	1.298	1.191	1.258	0.912
	Current Sales Area LPA	1.285	0.758	0.555	0.164

Figure 42: Title 24-2008 IESNA Power Density Required for Outdoor Sales Including Vertical Criteria

Based on the analysis, it was determined that no change should be made to the existing Lighting Power Densities. While the horizontal illuminance criteria, in general, have been reduced, the addition of the vertical illuminance criteria is actually now driving the calculation, requiring careful equipment selection and placement to meet those requirements. The full existing LPDs are required to meet these additional vertical requirements in LZ 2 through LZ 4. The horizontal illuminance criteria in LZ 1 have also increased, likely requiring the use of the full existing LPD to meet the criteria.

9. Appendix E: General Hardscape Allowance LPD Comparisons and Recalibration

Both 90.1 and Title 24 include base initial allowances, termed Initial Wattage Allowance in Title 24 and Base Site Allowance in 90.1 that are tradable, layered, and can be applied anywhere on the site. Title 24-2008's allowances in Lighting Zones 1, 2 and 4 are more aggressive than ASHRAE 90.1-2010's allowances. In Lighting Zone 3, the 90.1-2010 allowance is only 3% less than the Title 24-2008 allowance.

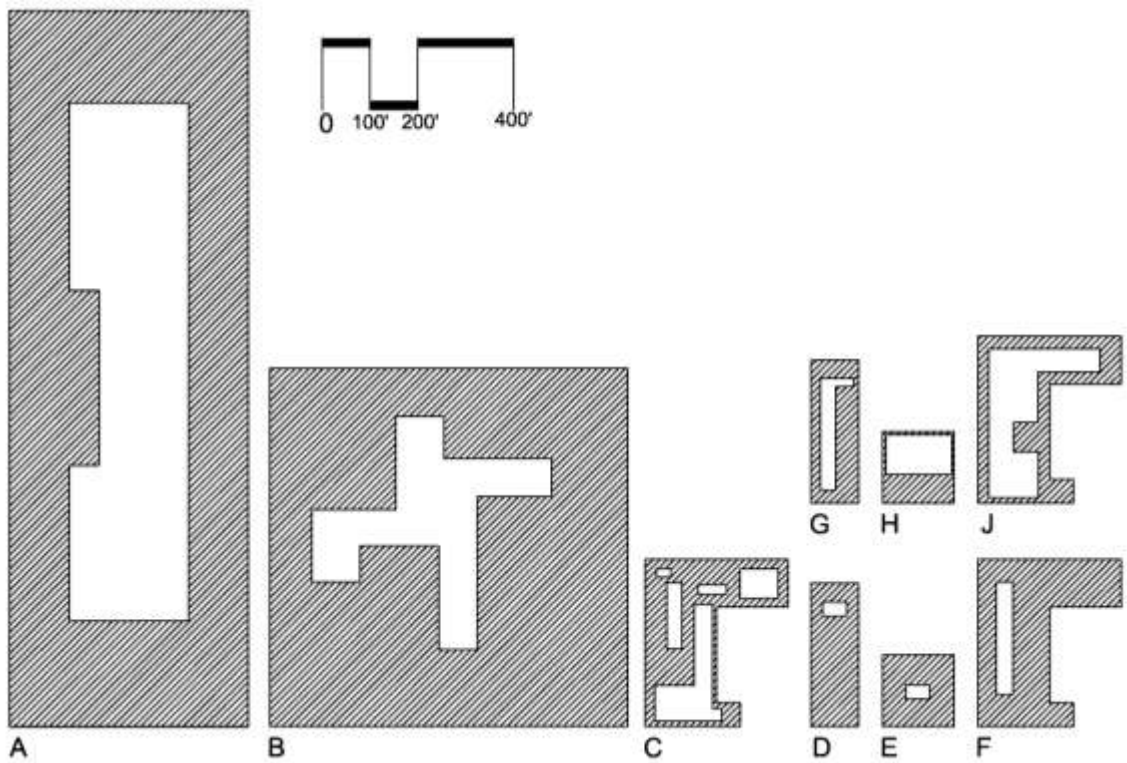

Figure 43: Geometry of Hardscape Areas Considered

Area A- Long rectangular building on large, skinny property.
Area B - Large building with irregular shape, square lot.
Area C - Smaller odd shapes, multiple buildings.
Area D- Small rectangular building on small, skinny lot.
Area E - Small rectangular building on square lot.
Area F - Long building on irregular lot.
Area G- Long skinny building on long, skinny lot. Same lot dimensions as Area D.
Area H- Larger rectangular building on square lot. Same lot dimensions as Area E.
Areas J- Larger irregular building on irregular lot. Same lot dimensions as Area F.

Title 24 approaches the remaining site allowance in a way that captures site geometry, through using the combination of an Area Wattage Allowance, based on the area of the hardscape, and a Linear Wattage Allowance, based on the perimeter length of the hardscape. ASHRAE 90.1-2010 provides

allowances based on the area or length of the hardscape type, including uncovered parking, plazas and walkways.

Site Description	A- Long Skinny, Big Building	B-Square, Odd Building	C- Odd, Campus Buildings	D- Long Skinny, Small Square Building	E- Square, Small Building	F- Odd, Long Square Building	G- Long Skinny, Odd Building	H- Square, Large Square Building	J- Odd, Large Odd Building
Area, [sf]	501,626	471,726	42,828	28,500	21,000	61,798	21,797	11,040	34,735
Perimeter, [sf]	6,794	5,131	3,052	960	760	1,940	1,408	1,042	2,593
P to A Ratio	1.4%	1.1%	7.1%	3.4%	3.6%	3.1%	6.5%	9.4%	7.5%

Title 24 - 2008

LZ1	IWA	W	340	340	340	340	340	340	340	340	340	
	AWA	W/sf	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	
		W	18,059	16,982	1,542	1,026	756	2,225	785	397	1,250	
	LWA	W/lf	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	
		W	2,446	1,847	1,099	346	274	698	507	375	933	
	TOTAL	W	20,844	19,169	2,981	1,712	1,370	3,263	1,632	1,113	2,524	**Mean**
	LPD	W/sf	0.042	0.041	0.070	0.060	0.065	0.053	0.075	0.101	0.073	**0.064**
LZ2	IWA	W	510	510	510	510	510	510	510	510	510	
	AWA	W/sf	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	
		W	22,573	21,228	1,927	1,283	945	2,781	981	497	1,563	
	LWA	W/lf	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	
		W	3,057	2,309	1,373	432	342	873	634	469	1,167	
	TOTAL	W	26,140	24,047	3,811	2,225	1,797	4,164	2,124	1,476	3,240	**Mean**
	LPD	W/sf	0.052	0.051	0.089	0.078	0.086	0.067	0.097	0.134	0.093	**0.083**
LZ3	IWA	W	770	770	770	770	770	770	770	770	770	
	AWA	W/sf	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	
		W	46,150	43,399	3,940	2,622	1,932	5,685	2,005	1,016	3,196	
	LWA	W/lf	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	
		W	6,250	4,721	2,808	883	699	1,785	1,295	959	2,386	
	TOTAL	W	53,170	48,889	7,518	4,275	3,401	8,240	4,071	2,744	6,351	**Mean**
	LPD	W/sf	0.106	0.104	0.176	0.150	0.162	0.133	0.187	0.249	0.183	**0.161**
LZ4	IWA	W	1030	1030	1030	1030	1030	1030	1030	1030	1030	
	AWA	W/sf	0.115	0.115	0.115	0.115	0.115	0.115	0.115	0.115	0.115	
		W	57,687	54,248	4,925	3,278	2,415	7,107	2,507	1,270	3,995	
	LWA	W/lf	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	
		W	7,813	5,901	3,510	1,104	874	2,231	1,619	1,198	2,982	
	TOTAL	W	66,530	61,179	9,465	5,412	4,319	10,368	5,156	3,498	8,006	**Mean**
	LPD	W/sf	0.133	0.130	0.221	0.190	0.206	0.168	0.237	0.317	0.231	**0.203**

Figure 44: Title 24-2008 Values for General Hardscape Lighting Analysis

Site Description	A- Long Skinny, Big Building	B-Square, Odd Building	C- Odd, Campus Buildings	D- Long Skinny, Small Square Building	E- Square, Small Building	F- Odd, Long Square Building	G- Long Skinny, Odd Building	H- Square, Large Square Building	J- Odd, Large Odd Building
Area, [sf]	501,626	471,726	42,828	28,500	21,000	61,798	21,797	11,040	34,735
Perimeter, [sf]	6,794	5,131	3,052	960	760	1,940	1,408	1,042	2,593
P to A Ratio	1.4%	1.1%	7.1%	3.4%	3.6%	3.1%	6.5%	9.4%	7.5%

ASHRAE 90.1-2007

LZ1	Base Allow.	W	500	500	500	500	500	500	500	500	500	
	Uncovered	W/sf	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	
	Parking	W	20,065	18,869	1,713	1,140	840	2,472	872	442	1,389	
	TOTAL	W	20,565	19,369	2,213	1,640	1,340	2,972	1,372	942	1,889	Mean
	LPD	W/sf	0.041	0.041	0.052	0.058	0.064	0.048	0.063	0.085	0.054	0.056

LZ2	Base Allow.	W	600	600	600	600	600	600	600	600	600	
	Uncovered	W/sf	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	
	Parking	W	30,098	28,304	2,570	1,710	1,260	3,708	1,308	662	2,084	
	TOTAL	W	30,698	28,904	3,170	2,310	1,860	4,308	1,908	1,262	2,684	Mean
	LPD	W/sf	0.061	0.061	0.074	0.081	0.089	0.070	0.088	0.114	0.077	0.079

LZ3	Base Allow.	W	750	750	750	750	750	750	750	750	750	
	Uncovered	W/sf	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
	Parking	W	50,163	47,173	4,283	2,850	2,100	6,180	2,180	1,104	3,474	
	TOTAL	W	50,913	47,923	5,033	3,600	2,850	6,930	2,930	1,854	4,224	Mean
	LPD	W/sf	0.101	0.102	0.118	0.126	0.136	0.112	0.134	0.168	0.122	0.124

LZ4	Base Allow.	W	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	
	Uncovered	W/sf	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	
	Parking	W	65,211	61,324	5,568	3,705	2,730	8,034	2,834	1,435	4,516	
	TOTAL	W	66,511	62,624	6,868	5,005	4,030	9,334	4,134	2,735	5,816	Mean
	LPD	W/sf	0.133	0.133	0.160	0.176	0.192	0.151	0.190	0.248	0.167	0.172

Figure 45: ASHRAE 90.1-2010 Values for General Hardscape Lighting Analysis

	LZ1				
	Title 24		ASHRAE 90.1		
	TOTAL	LPD	TOTAL	LPD	
	W	W/sf	W	W/sf	% of ASHRAE
A- Long Skinny, Big Building	20,844	0.042	20,565	0.041	101%
B-Square, Odd Building	19,169	0.041	19,369	0.041	99%
C- Odd, Campus Buildings	2,981	0.070	2,213	0.052	**135%**
D- Long Skinny, Small Square Building	1,712	0.060	1,640	0.058	104%
E- Square, Small Building	1,370	0.065	1,340	0.064	102%
F- Odd, Long Square Building	3,263	0.053	2,972	0.048	110%
G- Long Skinny, Odd Building	1,632	0.075	1,372	0.063	**119%**
H- Square, Large Square Building	1,113	0.101	942	0.085	**118%**
J- Odd, Large Odd Building	2,524	0.073	1,889	0.054	**134%**

Figure 46: Comparison of Title 24-2008 and ASHRAE 90.1-2010 Results for LZ1

	LZ2				
	Title 24		ASHRAE 90.1		
	TOTAL	LPD	TOTAL	LPD	
	W	W/sf	W	W/sf	% of ASHRAE
A- Long Skinny, Big Building	26,140	0.052	30,698	0.061	85%
B-Square, Odd Building	24,047	0.051	28,904	0.061	83%
C- Odd, Campus Buildings	3,811	0.089	3,170	0.074	**120%**
D- Long Skinny, Small Square Building	2,225	0.078	2,310	0.081	96%
E- Square, Small Building	1,797	0.086	1,860	0.089	97%
F- Odd, Long Square Building	4,164	0.067	4,308	0.070	97%
G- Long Skinny, Odd Building	2,124	0.097	1,908	0.088	**111%**
H- Square, Large Square Building	1,476	0.134	1,262	0.114	**117%**
J- Odd, Large Odd Building	3,240	0.093	2,684	0.077	**121%**

Figure 47: Comparison of Title 24-2008 and ASHRAE 90.1-2010 Results for LZ2

	LZ3				
	Title 24		ASHRAE 90.1		
	TOTAL	LPD	TOTAL	LPD	
	W	W/sf	W	W/sf	% of ASHRAE
A- Long Skinny, Big Building	53,170	0.106	50,913	0.101	104%
B-Square, Odd Building	48,889	0.104	47,923	0.102	102%
C- Odd, Campus Buildings	7,518	0.176	5,033	0.118	**149%**
D- Long Skinny, Small Square Building	4,275	0.150	3,600	0.126	**119%**
E- Square, Small Building	3,401	0.162	2,850	0.136	**119%**
F- Odd, Long Square Building	8,240	0.133	6,930	0.112	**119%**
G- Long Skinny, Odd Building	4,071	0.187	2,930	0.134	**139%**
H- Square, Large Square Building	2,744	0.249	1,854	0.168	**148%**
J- Odd, Large Odd Building	6,351	0.183	4,224	0.122	**150%**

Figure 48: Comparison of Title 24-2008 and ASHRAE 90.1-2010 Results for LZ3

	LZ4				
	Title 24		ASHRAE 90.1		
	TOTAL	LPD	TOTAL	LPD	
	W	W/sf	W	W/sf	% of ASHRAE
A- Long Skinny, Big Building	66,530	0.133	66,511	0.133	100%
B-Square, Odd Building	61,179	0.130	62,624	0.133	98%
C- Odd, Campus Buildings	9,465	0.221	6,868	0.160	**138%**
D- Long Skinny, Small Square Building	5,412	0.190	5,005	0.176	108%
E- Square, Small Building	4,319	0.206	4,030	0.192	107%
F- Odd, Long Square Building	10,368	0.168	9,334	0.151	**111%**
G- Long Skinny, Odd Building	5,156	0.237	4,134	0.190	**125%**
H- Square, Large Square Building	3,498	0.317	2,735	0.248	**128%**
J- Odd, Large Odd Building	8,006	0.231	5,816	0.167	**138%**

Figure 49: Comparison of Title 24-2008 and ASHRAE 90.1-2010 Results for LZ4

The figures above show the general aggressiveness of the two codes compared to each other, and the percentage of ASHRAE 90.1 that the Title 24 represents. A value within 10% of equal is considered functionally equal in this comparison. When 90.1 is more aggressive by more than 10%, the values are colored red. The less ideal sites are expected to have a higher allowance than the more ideal sites, so some of the sites that are showing higher allowances than 90.1 are logical and intended through the design of the LWA and AWA interactions.

As a result of this analysis, the following changes to the General Allowances in Table 147-A are recommended:

Zone	AWA Reduction, [W/sf]	LWA Reduction, [W/sf]	Reduced AWA, [W/sf]	Reduced LWA, [W/lf]
LZ1	0.001	0.11	0.035	0.25
LZ2	0.000	0.00	0.045	0.45
LZ3	0.002	0.32	0.090	0.60
LZ4	0.000	0.30	0.115	0.85

Figure 50: Recommended Changes to General Allowances in Table 147-A

This set of reductions accomplishes two different results; the first is that some of the AWA values are reduced slightly to more natural values for ease of implementation. The second is that the LWA values are reduced considerably, which reduces the overall impact of the site geometry in the calculation of total wattage allowance.

Note that the IWA values have not been modified. Also note that the LZ2 values for AWA and LWA have not been modified. Further, the AWA for LZ4 has not been modified.

The LWA is a fundamental part of the general wattage allowances because it is clearly understood that a more complex site will result in more watts needed to meet the lighting design guidelines. As a result, the LWA must remain an effective device to increase the LPD slightly when site geometry warrants a boost. This change reduces the boost amount by approximately 30% for LZ1, LZ3, and LZ4. The value remains the same for LZ2, because the overall LPD in that zone is aggressive.

The previous building scenarios have been recalculated with the recommended reduced values to the following results:

	LZ1				
	Title 24		ASHRAE 90.1		
	TOTAL	LPD	TOTAL	LPD	
	W	W/sf	W	W/sf	% of ASHRAE
A- Long Skinny, Big Building	19,595	0.039	20,565	0.041	95%
B-Square, Odd Building	18,133	0.038	19,369	0.041	94%
C- Odd, Campus Buildings	2,602	0.061	2,213	0.052	**118%**
D- Long Skinny, Small Square Building	1,578	0.055	1,640	0.058	96%
E- Square, Small Building	1,265	0.060	1,340	0.064	94%
F- Odd, Long Square Building	2,988	0.048	2,972	0.048	101%
G- Long Skinny, Odd Building	1,455	0.067	1,372	0.063	106%
H- Square, Large Square Building	987	0.089	942	0.085	105%
J- Odd, Large Odd Building	2,204	0.063	1,889	0.054	**117%**

Figure 51: Comparison of Title 24 (Recommended) and ASHRAE 90.1-2010 Results for LZ1

	LZ2				
	Title 24		ASHRAE 90.1		
	TOTAL	LPD	TOTAL	LPD	
	W	W/sf	W	W/sf	% of ASHRAE
A- Long Skinny, Big Building	26,140	0.052	30,698	0.061	85%
B-Square, Odd Building	24,047	0.051	28,904	0.061	83%
C- Odd, Campus Buildings	3,811	0.089	3,170	0.074	**120%**
D- Long Skinny, Small Square Building	2,225	0.078	2,310	0.081	96%
E- Square, Small Building	1,797	0.086	1,860	0.089	97%
F- Odd, Long Square Building	4,164	0.067	4,308	0.070	97%
G- Long Skinny, Odd Building	2,124	0.097	1,908	0.088	**111%**
H- Square, Large Square Building	1,476	0.134	1,262	0.114	**117%**
J- Odd, Large Odd Building	3,240	0.093	2,684	0.077	**121%**

Figure 52: Comparison of Title 24 (Recommended) and ASHRAE 90.1-2010 Results for LZ2

	LZ3				
	Title 24		ASHRAE 90.1		
	TOTAL	LPD	TOTAL	LPD	
	W	W/sf	W	W/sf	% of ASHRAE
A- Long Skinny, Big Building	49,993	0.100	50,913	0.101	98%
B-Square, Odd Building	46,304	0.098	47,923	0.102	97%
C- Odd, Campus Buildings	6,456	0.151	5,033	0.118	**128%**
D- Long Skinny, Small Square Building	3,911	0.137	3,600	0.126	109%
E- Square, Small Building	3,116	0.148	2,850	0.136	109%
F- Odd, Long Square Building	7,496	0.121	6,930	0.112	108%
G- Long Skinny, Odd Building	3,577	0.164	2,930	0.134	**122%**
H- Square, Large Square Building	2,389	0.216	1,854	0.168	**129%**
J- Odd, Large Odd Building	5,452	0.157	4,224	0.122	**129%**

Figure 53: Comparison of Title 24 (Recommended) and ASHRAE 90.1-2010 Results for LZ3

	LZ4				
	Title 24		ASHRAE 90.1		
	TOTAL	LPD	TOTAL	LPD	
	W	W/sf	W	W/sf	% of ASHRAE
A- Long Skinny, Big Building	64,492	0.129	66,511	0.133	97%
B-Square, Odd Building	59,640	0.126	62,624	0.133	95%
C- Odd, Campus Buildings	8,549	0.200	6,868	0.160	**124%**
D- Long Skinny, Small Square Building	5,124	0.180	5,005	0.176	102%
E- Square, Small Building	4,091	0.195	4,030	0.192	102%
F- Odd, Long Square Building	9,786	0.158	9,334	0.151	105%
G- Long Skinny, Odd Building	4,733	0.217	4,134	0.190	**115%**
H- Square, Large Square Building	3,185	0.289	2,735	0.248	**116%**
J- Odd, Large Odd Building	7,229	0.208	5,816	0.167	**124%**

Figure 54: Comparison of Title 24 (Recommended) and ASHRAE 90.1-2010 Results for LZ4

The proposed 2011 AWA and LWA values adjust the overall General Site Allowance downward slightly in LZ1, somewhat more in LZ3 and LZ4, to bring them in line with the current ASHRAE 90.1 allowances.

Due to the different methods of implementation between these two codes, it is impossible to directly compare singular values individually, so in the examples provided, there are examples of simpler sites where Title 24-2011 appears to be more aggressive, and sites where ASHRAE 90.1-2007 appears to be more aggressive. However, when taking into account the inefficiency of irregular and non-ideal site conditions (that is, sites that deviate from the prototypical 'ideal' site; a square site with a small square building in the center), the less aggressive allowance values in the Title 24-2011 document are warranted to enable the developer to design to meet the basis of design documents.

It is important to recall that the Title 24 document is somewhat more aggressive in that it does not permit as much trading of watts throughout the site as the ASHRAE document, so there is more opportunity for some wattage allowances to be left unused or not completely used because of the stipulations placed on the more stringent "use it or lose it" nature of these allowances.

10. Appendix F: Service Station Allowance Detailed Analysis

The service station allowances included in Title 24-2008 were based on IESNA illuminance recommendations included in RP-2-01 and RP-33-99.

	Lighting Application	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Title 24-2008 Basis of Design	Gas Island	RP-33-99 Service Station Pump Island (10 hfc)	RP-2-01 Service Station Gas Islands-Low Activity (20 hfc)	RP-2-01 Service Station Gas Islands-Medium Activity (30 hfc)	RP-2-01 Service Station Gas Islands-High Activity (50 hfc)
	Approach	RP-20-98 Basic (0.2 hfc)	RP-2-01 Service Station Approach-Low Activity (5 hfc)	RP-2-01 Service Station Approach-Medium Activity (10 hfc)	RP-2-01 Service Station Approach-High Activity (15 hfc)

Figure 55: Title 24-2008 Basis of Design for Service Stations

Previous allowances were determined independently of the adjacent allowances. For example, allowances under the service station canopy were determined independently of the allowance over the service station hardscape. However, in actual application, the lighting provided in each of these discrete areas will bleed into adjacent areas, therefore essentially combining the power of both allowances to meet the illuminance recommendations. Therefore, it was reasonable that the allowances should be revised to reflect the interaction of these adjacent allowances, and is particularly suited to service station applications due to the high illuminance criteria.

A series of calculations for two different sizes of service station properties and for several different canopy sizes within each were used to calculate the total power requirements. Largely, the canopy size determined the power required to meet the basis of design. Because the amount of light prescribed under the canopy is greater than the amount on the approach lanes (by a factor of about 3.5x), the spill light out from the canopy lights contribute to the overall illumination on the approach lanes, resulting in a lower power density required in the approach lanes. Conversely, the approach lane lighting also contributes to the light levels under the canopy, but at a somewhat lower magnitude.

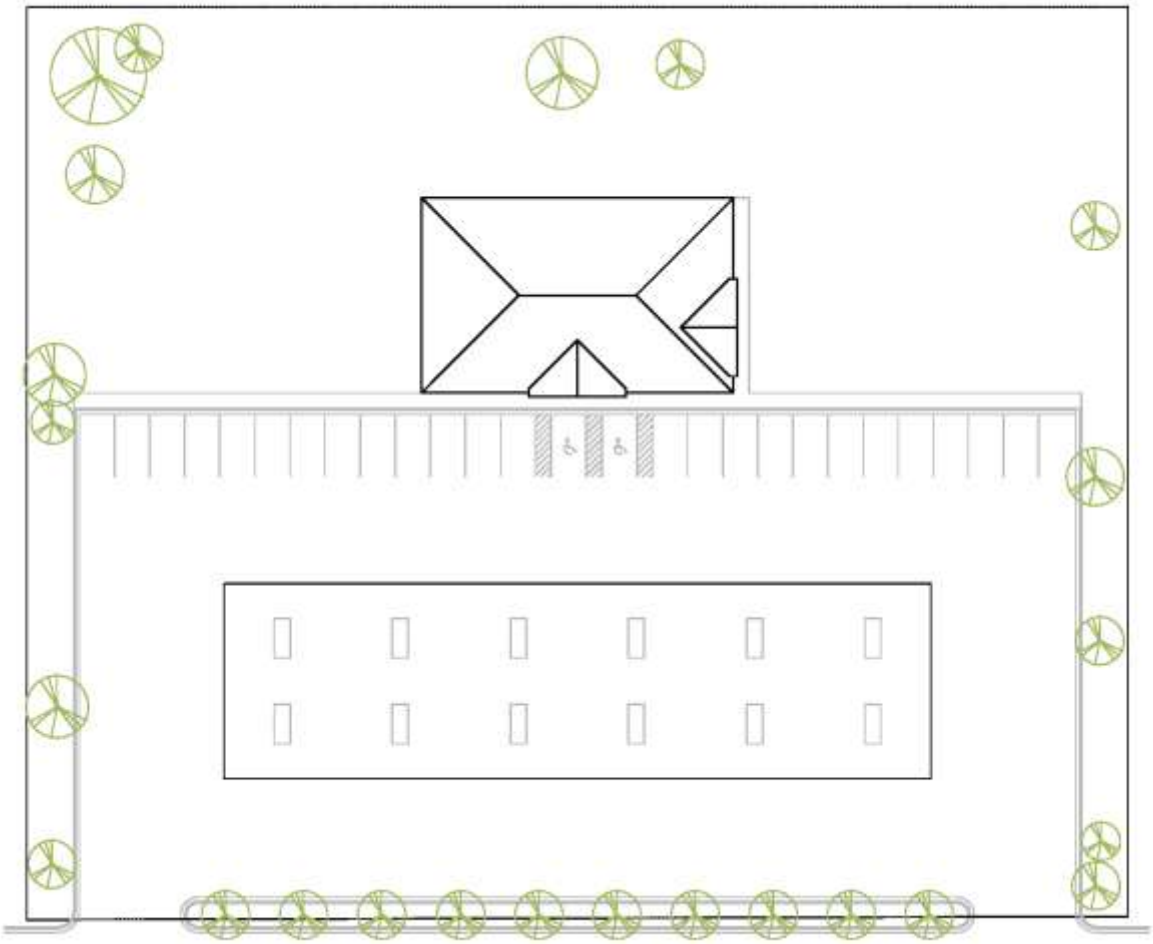

Figure 56: Site Design for Service Station Canopies and Hardscape - Large Site, Large Canopy

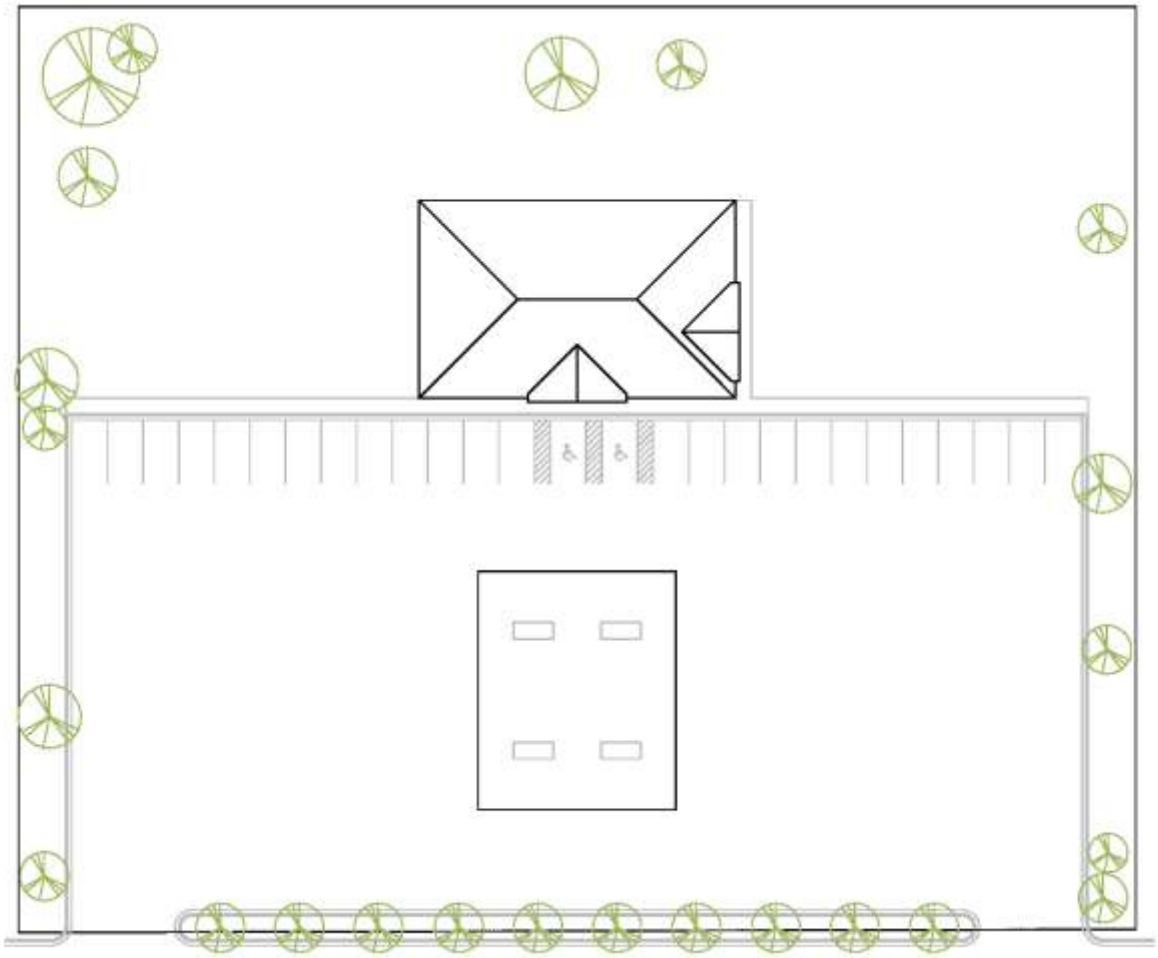

Figure 57: Site Design for Service Station Canopies and Hardscape - Large Site, Small Canopy

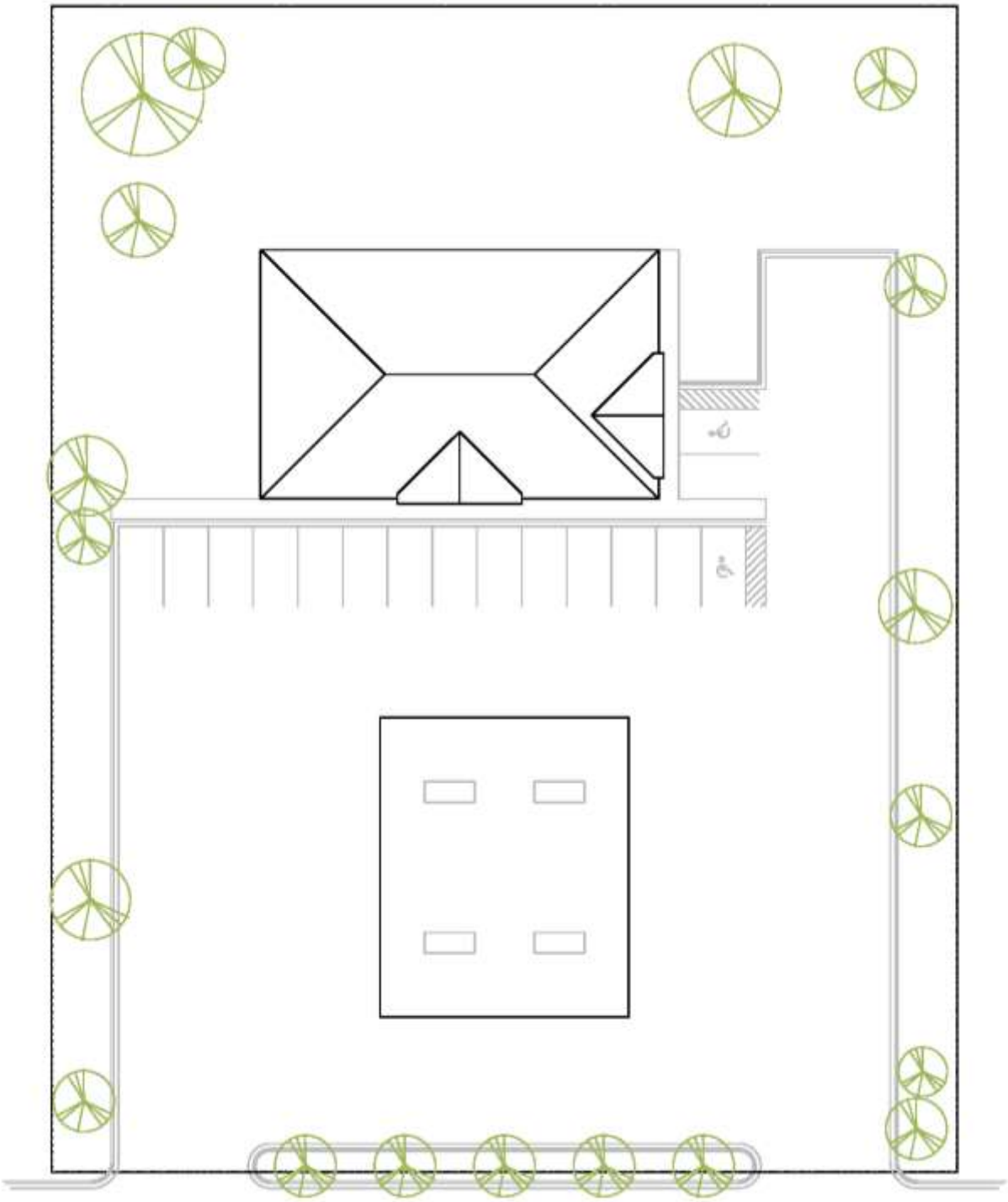

Figure 58: Site Design for Service Station Canopies and Hardscape - Large Site, Small Canopy

AGI32 was used to make illuminance calculations to meet the prescribed light levels, and the amount of lighting equipment was modified until the light levels were met. The analysis to determine the recommended reduced Lighting Power Densities was then performed based on two site sizes, a large site and a small site, both analyzed with and without canopies. The large site was analyzed with a small canopy that occupied a small area of the hardscape, and with a large canopy that occupied more area.

The analysis was also performed with a variety of typical equipment to accommodate the range of possible solutions. The results were then combined to determine appropriate revised Lighting Power Densities based on these geometries. Calculations indicate that no change would be made to the uncovered fuel dispenser allowance.

Large Site with Large Canopy

(Direct Calcs Only- No Inter-reflections)		With Canopy			
		Flat Clear Lens Canopy Fixture			
		LZ4	LZ3	LZ2	LZ1
Light Levels (Average Illuminance)	Approach: Recommended (hfc)	15	10	5	0.2
	Approach: Achieved (hfc)	16.71	11.35	6.18	1.38
	Gas Island: Recommended (hfc)	50	40	30	20
	Gas Island: Achieved (hfc)	55.76	44.23	33.45	20.97
	Note: Approach Calculation Plane Located at 0'-0" AFG.				
	Note: Gas Island Calculation Plane Located at 2'-6" AFG.				
Luminaires	Pole-mounted Luminaire Quantity	12	9	4	0
	Total Input Watts per Luminaire (W)	1,080	1,080	198	0
	Canopy-mounted Luminaire Quantity	48	48	36	48
	Total Input Watts per Luminaire (W)	465	295	465	173
	Total Watts	35,280	23,880	17,532	8,304
Geometry	Total Hardscape Area (sf)				31,682
	Total Hardscape Perimeter Length (lf)				776
	Canopy Drip-line Area (sf)				8,682
	Service Station Hardscape Area (sf)				23,000
Base Hardscape Allowance	LWA (W/lf)	1.15	0.92	0.45	0.36
	LWA (W)	892	714	349	279
	AWA (W/sf)	0.115	0.092	0.045	0.036
	AWA (W)	3,643	2,915	1,426	1,141
	Total Base Allowance (W)	4,535	3,628	1,775	1,420
	Effective Base Area Wattage Allowance (W/sf)	0.143	0.115	0.056	0.045
Proposed LPD & Determination of LPAs	Proposed Lighting Power Density (W/sf)	1.114	0.754	0.553	0.262
	LPD Over Base Hardscape Allowance (W/sf)	0.970	0.639	0.497	0.217
	% W under Canopy	63.3%	59.3%	95.5%	100.0%
	% W over Hardscape	36.7%	40.7%	4.5%	0.0%
	Effective Needed LPA Under Canopy (W/sf)	2.240	1.383	1.733	0.793
	Effective Needed LPA over Hardscape (W/sf)	0.491	0.000	0.000	0.000

Figure 59: Required LPD to Meet Basis of Design for Service Station Canopies and Hardscape - Large Site, Large Canopy

Large Site with Small Canopy/Service Area

(Direct Calcs Only- No Inter-reflections)		With Canopy			
		Flat Clear Lens Canopy Fixture			
		LZ4	LZ3	LZ2	LZ1
Light Levels (Average Illuminance)	Approach: Recommended (hfc)	15	10	5	0.2
	Approach: Achieved (hfc)	15.65	11.55	6.52	0.74
	Gas Island: Recommended (hfc)	50	40	30	20
	Gas Island: Achieved (hfc)	56.17	40.64	30.56	23.98
	Note: Approach Calculation Plane Located at 0'-0" AFG.				
	Note: Gas Island Calculation Plane Located at 2'-6" AFG.				
Luminaires	Pole-mounted Luminaire Quantity	16	12	6	2
	Total Input Watts per Luminaire (W)	1,080	1,080	1,080	118
	Canopy-mounted Luminaire Quantity	12	16	20	16
	Total Input Watts per Luminaire (W)	465	295	210	210
	Total Watts	22,860	17,680	10,680	3,596
Geometry	Total Hardscape Area (sf)				31,682
	Total Hardscape Perimeter Length (lf)				776
	Canopy Drip-line Area (sf)				3,006
	Service Station Hardscape Area (sf)				28,676
Base Hardscape Allowance	LWA (W/lf)	1.15	0.92	0.45	0.36
	LWA (W)	892	714	349	279
	AWA (W/sf)	0.115	0.092	0.045	0.036
	AWA (W)	3,643	2,915	1,426	1,141
	Total Base Allowance (W)	4,535	3,628	1,775	1,420
	Effective Base Area Wattage Allowance (W/sf)	0.143	0.115	0.056	0.045
Proposed LPD & Determination of LPAs	Proposed Lighting Power Density (W/sf)	0.722	0.558	0.337	0.114
	LPD Over Base Hardscape Allowance (W/sf)	0.578	0.444	0.281	0.069
	% W under Canopy	24.4%	26.7%	39.3%	93.4%
	% W over Hardscape	75.6%	73.3%	60.7%	6.6%
	Effective Needed LPA Under Canopy (W/sf)	1.488	1.248	1.165	0.676
	Effective Needed LPA over Hardscape (W/sf)	0.483	0.000	0.000	0.000

Figure 60: Required LPD to Meet Basis of Design for Service Station Canopies and Hardscape - Large Site, Small Canopy

Large Site with NO Canopy/Service Area

(Direct Calcs Only- No Inter-reflections)		No Canopy			
		LZ4	LZ3	LZ2	LZ1
Light Levels (Average Illuminance)	Approach: Recommended (hfc)	15	10	5	0.2
	Approach: Achieved (hfc)	15.71	10.37	6.73	2.07
	Gas Island: Recommended (hfc)	50	40	30	20
	Gas Island: Achieved (hfc)	50.8	46.02	31.71	20.93
	Note: Approach Calculation Plane Located at 0'-0" AFG.	*Note: All Pole Luminaires mounted at 20'-0" AFG.*			
	Note: Gas Island Calculation Plane Located at 2'-6" AFG.				
Luminaires	Pole-mounted Luminaires (Area Lighting) Quantity	12	8	16	2
	Total Input Watts per Luminaire	1,080	1,080	465	118
	Pole-mounted Luminaires (Pump Lighting) Quantity	6	4	4	8
	Total Input Watts per Luminaire	1,080	1,080	1,080	465
	Total Watts	19,440	12,960	11,760	3,956
Geometry	Total Hardscape Area (sf)	31,682			
	Total Hardscape Perimeter Length (lf)	776			
	Service Station Hardscape Area (sf)	31,682			
	Number of Uncovered Fuel Dispensers	4	4	4	4
Base Hardscape Allowance	LWA (W/lf)	1.15	0.92	0.45	0.36
	LWA (W)	892	714	349	279
	AWA (W/sf)	0.115	0.092	0.045	0.036
	AWA (W)	3,643	2,915	1,426	1,141
	Total Base Allowance (W)	4,535	3,628	1,775	1,420
	Effective Base Area Wattage Allowance (W/sf)	0.143	0.115	0.056	0.045
Proposed LPD & Determination of LPAs	Proposed Lighting Power Density (W/sf)	0.614	0.409	0.371	0.125
	Proposed Density Over Effective Base Allowance (W/sf)	0.470	0.295	0.315	0.080
	Allowed Power per Uncovered Fuel Dispenser (W)	330	185	175	120
	Uncovered Fuel Dispenser Total Allowance (W)	1,320	740	700	480
	Effective Needed LPA Over Hardscape (W/sf)	0.429	0.271	0.293	0.065

Figure 61: Required LPD to Meet Basis of Design for Service Station Canopies and Hardscape - Large Site, NO Canopy

Small Site with Small Canopy/Service Area

(Direct Calcs Only- No Inter-reflections)		With Canopy			
		Flat Clear Lens Canopy Fixture			
		LZ4	LZ3	LZ2	LZ1
Light Levels (Average Illuminance)	Approach: Recommended (hfc)	15	10	5	0.2
	Approach: Achieved (hfc)	15.67	11.21	5.12	1.53
	Gas Island: Recommended (hfc)	50	40	30	20
	Gas Island: Achieved (hfc)	53.90	42.41	31.84	24.29
	Note: Approach Calculation Plane Located at 0'-0" AFG.				
	Note: Gas Island Calculation Plane Located at 2'-6" AFG.				
Luminaires	Pole-mounted Luminaire Quantity	8	6	10	4
	Total Input Watts per Luminaire (W)	1,080	1,080	465	118
	Canopy-mounted Luminaire Quantity	16	12	20	16
	Total Input Watts per Luminaire (W)	465	465	210	210
	Total Watts	16,080	12,060	8,850	3,832
Geometry	Total Hardscape Area (sf)				19,413
	Total Hardscape Perimeter Length (lf)				568
	Canopy Drip-line Area (sf)				3,006
	Service Station Hardscape Area (sf)				16,407
Base Hardscape Allowance	LWA (W/lf)	1.15	0.92	0.45	0.36
	LWA (W)	653	523	256	204
	AWA (W/sf)	0.115	0.092	0.045	0.036
	AWA (W)	2,232	1,786	874	699
	Total Base Allowance (W)	2,886	2,309	1,129	903
	Effective Base Area Wattage Allowance (W/sf)	0.149	0.119	0.058	0.047
Proposed LPD & Determination of LPAs	Proposed Lighting Power Density (W/sf)	0.828	0.621	0.456	0.197
	LPD Over Base Hardscape Allowance (W/sf)	0.680	0.502	0.398	0.151
	% W under Canopy	46.3%	46.3%	47.5%	87.7%
	% W over Hardscape	53.7%	53.7%	52.5%	12.3%
	Effective Needed LPA Under Canopy (W/sf)	2.031	1.501	1.219	0.854
	Effective Needed LPA over Hardscape (W/sf)	0.432	0.319	0.247	0.022

Figure 62: Required LPD to Meet Basis of Design for Service Station Canopies and Hardscape - Small Site, Small Canopy

Small Site with NO Canopy/Service Area

(Direct Calcs Only- No Inter-reflections)		No Canopy			
		LZ4	LZ3	LZ2	LZ1
Light Levels (Average Illuminance)	Approach: Recommended (hfc)	15	10	5	0.2
	Approach: Achieved (hfc)	15.33	11.13	6.4	3.52
	Gas Island: Recommended (hfc)	50	40	30	20
	Gas Island: Achieved (hfc)	53.27	46.53	30.96	20.22
	Note: Approach Calculation Plane Located at 0'-0" AFG.	*Note: All Pole Luminaires mounted at 20'-0" AFG.*			
	Note: Gas Island Calculation Plane Located at 2'-6" AFG.				
Luminaires	Pole-mounted Luminaires (Area Lighting) Quantity	4	4	4	4
	Total Input Watts per Luminaire	1,080	1,080	118	118
	Pole-mounted Luminaires (Pump Lighting) Quantity	6	4	4	8
	Total Input Watts per Luminaire	1,080	1,080	1,080	465
	Total Watts	10,800	8,640	4,792	4,192
Geometry	Total Hardscape Area (sf)	19,413			
	Total Hardscape Perimeter Length (lf)	568			
	Service Station Hardscape Area (sf)	19,413			
	Number of Uncovered Fuel Dispensers	4	4	4	4
Base Hardscape Allowance	LWA (W/lf)	1.15	0.92	0.45	0.36
	LWA (W)	653	523	256	204
	AWA (W/sf)	0.115	0.092	0.045	0.036
	AWA (W)	2,232	1,786	874	699
	Total Base Allowance (W)	2,886	2,309	1,129	903
	Effective Base Area Wattage Allowance (W/sf)	0.149	0.119	0.058	0.047
Proposed LPD & Determination of LPAs	Proposed Lighting Power Density (W/sf)	0.556	0.445	0.247	0.216
	Proposed Density Over Effective Base Allowance (W/sf)	0.408	0.326	0.189	0.169
	Allowed Power per Uncovered Fuel Dispenser (W)	330	185	175	120
	Uncovered Fuel Dispenser Total Allowance (W)	1,320	740	700	480
	Effective Needed LPA Over Hardscape (W/sf)	0.340	0.288	0.153	0.145

Figure 63: Required LPD to Meet Basis of Design for Service Station Canopies and Hardscape - Small Site, NO Canopy

Scenario	Required Design Service Canopy LPD				Required Design Service Station Hardscape LPD			
	LZ4	LZ3	LZ2	LZ1	LZ4	LZ3	LZ2	LZ1
Small Site, Small Canopy, Flat Lens	2.031	1.501	1.219	0.854	0.432	0.319	0.247	0.022
Small Site, No Canopy	n/a	n/a	n/a	n/a	0.340	0.288	0.153	0.145
Large Site, Small Canopy, Flat Lens	1.488	1.248	1.165	0.676	0.483	0.000	0.000	0.000
Large Site, No Canopy	n/a	n/a	n/a	n/a	0.429	0.271	0.293	0.065
Large Site, Large Canopy, Flat Lens	2.240	1.383	1.733	0.793	0.491	0.000	0.000	0.000
Maximum	2.240	1.501	1.733	0.854	0.491	0.319	0.293	0.145
Minimum	1.488	1.248	1.165	0.676	0.340	0.000	0.000	0.000
Mean	**1.920**	**1.377**	**1.372**	**0.775**	**0.435**	**0.176**	**0.139**	**0.046**
Title 24-2008 Allowances	**2.285**	**1.358**	**1.005**	**0.514**	**0.458**	**0.308**	**0.155**	**0.014**

Figure 64: Required LPD to Meet Basis of Design for Service Station Canopies and Hardscape

The results showed that the current Lighting Power Densities for Service Station Canopies in Lighting Zones 1 and 2 are appropriate and needed to meet current IESNA illuminance recommendations. For Lighting Zones 3 and 4, the lighting power allowance should be reduced. The analysis also showed that the current Lighting Power Densities for Service Station Hardscape, in all four lighting zones, are appropriate and needed to meet current illuminance criteria.

Recommendation: Adjust the Lighting Power Densities for Service Station Canopies in Lighting Zones 3 and 4. Keep Title 24-2008 Lighting Power Densities for Service Station Hardscape with no changes:

Allowance Type:	Recommended Change?	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Vehicle Service Station Canopies	Reduced LPAs in LZs 2, 3 & 4	0.514 W/ft2 (no change)	1.005 W/ft2 (no change)	1.300 W/ft2 (reduced from 1.358)	2.200 W/ft2 (reduced from 2.285)
Vehicle Service Station Hardscape	No Change	0.014 W/ft2 (no change)	0.155 W/ft2 (no change)	0.308 W/ft2 (no change)	0.485 W/ft2 (no change)

Figure 65: Summary of Recommendations for Vehicle Service Station Canopies and Hardscape

10.1 Service Station Canopy Allowance Analysis

One aspect of the service station comparisons that has a seemingly significant difference between the Title 24-2008 and ASHRAE 90.1-2010 values is the Sales Canopy allowance. The Title 24-2008 and ASHRAE 90.1-2010 limits are detailed below.

Vehicle Service Station Canopies				
Allowance Type	**Lighting Zone 1**	**Lighting Zone 2**	**Lighting Zone 3**	**Lighting Zone 4**
Title 24-2008	0.514 W/ft2	1.005 W/ft2	1.358 W/ft2	2.285 W/ft2
ASHRAE 90.1-2010	0.6 W/ft2	0.6 W/ft2	0.8 W/ft2	1.0 W/ft2
Who's Lower?	**T24**	**90.1**	**90.1**	**90.1**

Figure 66: Title 24-2008 and ASHRAE 90.1-2010 Limits for Service Station Allowance

The ASHRAE 90.1 limits appear to be lower than the Title 24 limits prima fascia. When these values were developed in the 2008 code revision cycle, they were fairly aggressive, so there was concern among the CASE team that the ASHRAE 90.1 values may not provide enough allowance to meet the design recommendations of RP-2, the Retail Lighting Recommended Practice.

Further analysis indicates that there are a few specific calculation idiosyncrasies in the ASHRAE document that make a direct comparison of the values between that two codes impossible.

First, the Title 24 method uses the drip line of the canopy as the basis for calculation the area under the canopy, and also to define the region in which the lighting design guidelines must be met. This is a logical boundary condition selection, because the canopy is detailed in the architectural and site plans, and is easily verified in the field as well.

ASHRAE 90.1-2010 calls for separate definitions of both the 'canopy area' and the calculation grid. The 'canopy area' is defined as the area of the light fixtures mounted on the canopy, plus a 14 foot buffer zone around the light fixtures. This is a reasonable interpretation of the area of the canopy as well, but it is not as easily established on the plans, and special effort will be required to produce a submittal that documents where this 'canopy area' line actually is located, and what the actual area is within this defined region.

The result of this difference in interpretation impacts the total area that the Service Station Canopy allowance may be applied, and as a result, the total watts that a canopy will be permitted.

The graph below provides a plot of the effect this difference has on the total watts permitted when applying these two codes to the same canopy:

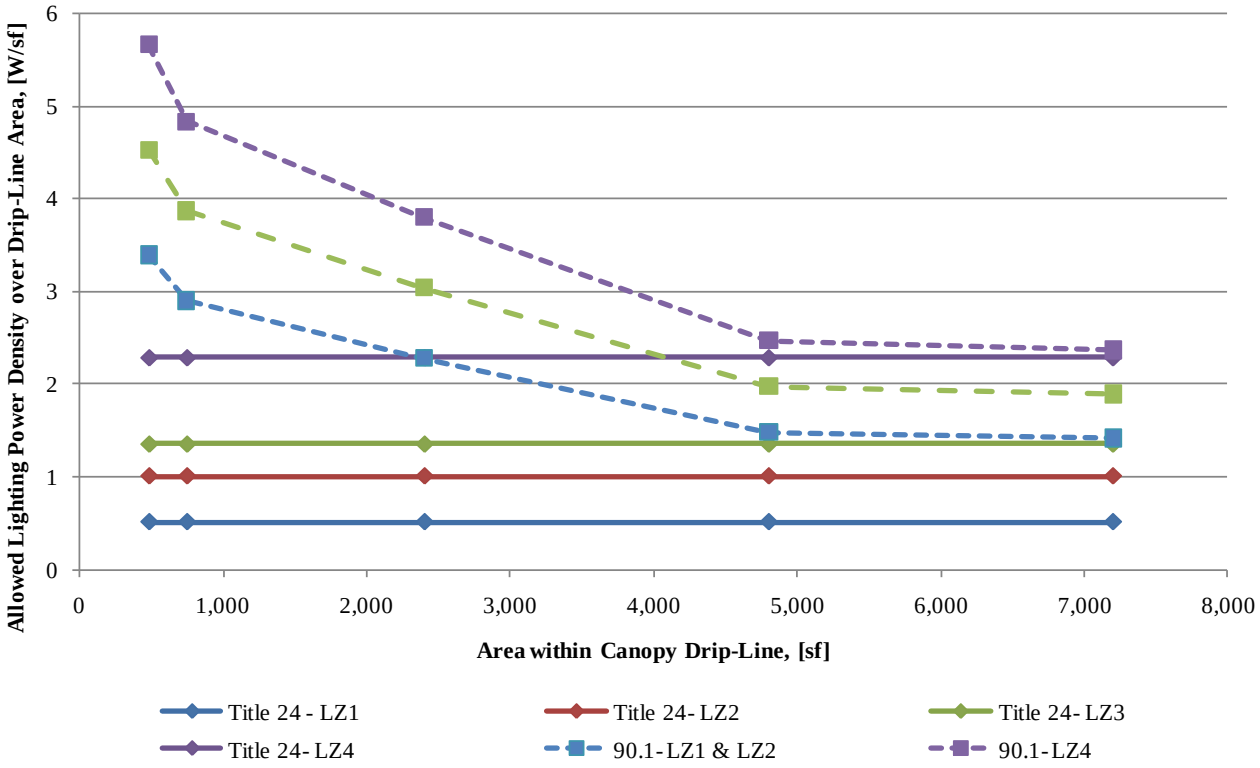

Figure 67: Summary of Title 24-2008 to ASHRAE 90.1-2010 Allowances for Service Stations

Under no circumstances do the Title 24 values exceed the ASHRAE values, and in particular, the Title 24 values are considerably lower than the ASHRAE values when the canopy begins to get small. As a result, no changes to the Title 24 allowances for Service Station Canopies are recommended.

11. Appendix G: Lighting Controls Limitations Survey

11.1 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.

11.2 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.

11.3 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.

11.3.1 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 68. 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 69.

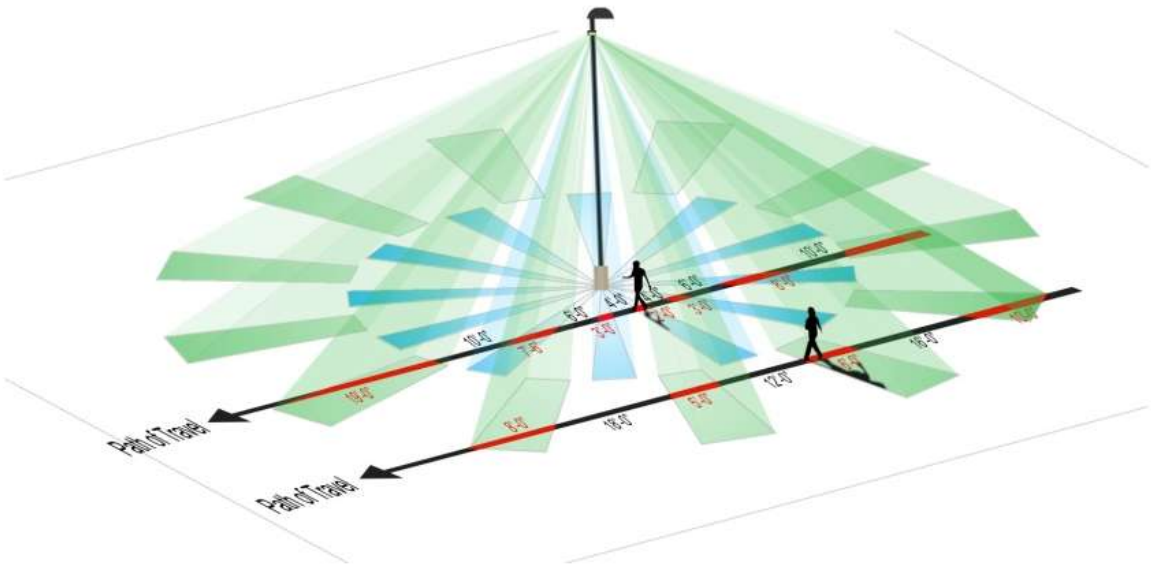

Figure 68: Illustration of PIR Sensor Limitations
A pedestrian near the edge of the radius of detection must travel much longer before triggering the sensor then a pedestrian near the center of the radius of detection.
[Based on Detection Pattern of Wattstopper LMPC-100 Outdoor PIR Occupancy Sensor]
(Clanton 2010)

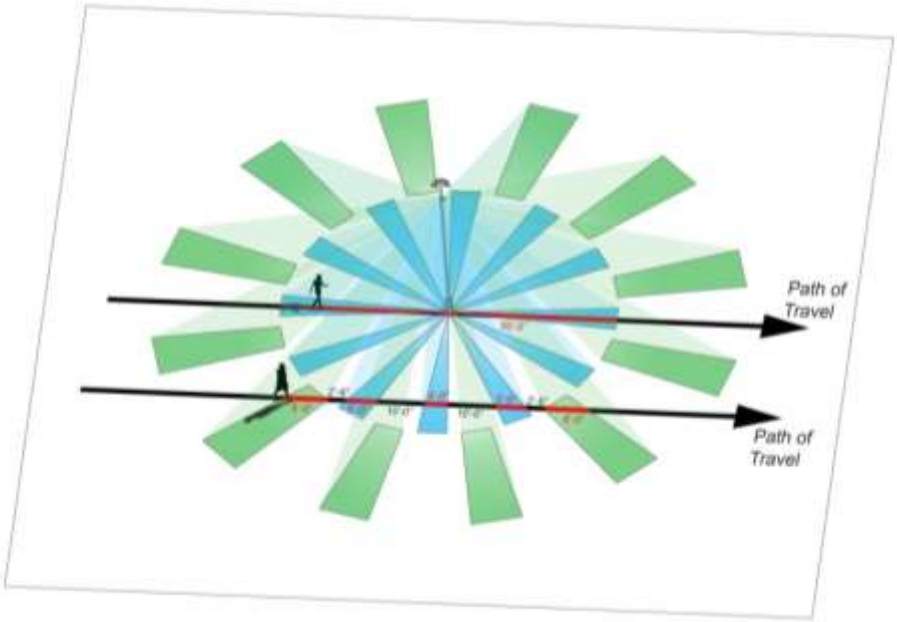

Figure 69: Illustration of PIR Sensor Limitations
A pedestrian moving directly toward the sensor can travel a long distance before triggering the sensor by crossing a boundary. A pedestrian moving parallel to that path but further from the sensor will trigger the sensor with much less distance traveled.
[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.

11.3.2 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.

11.3.3 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 70 and Figure 71, 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.

11.3.4 Coverage Limitations

For a typical pole spacing of 120 feet by 100 feet,
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 70, 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.

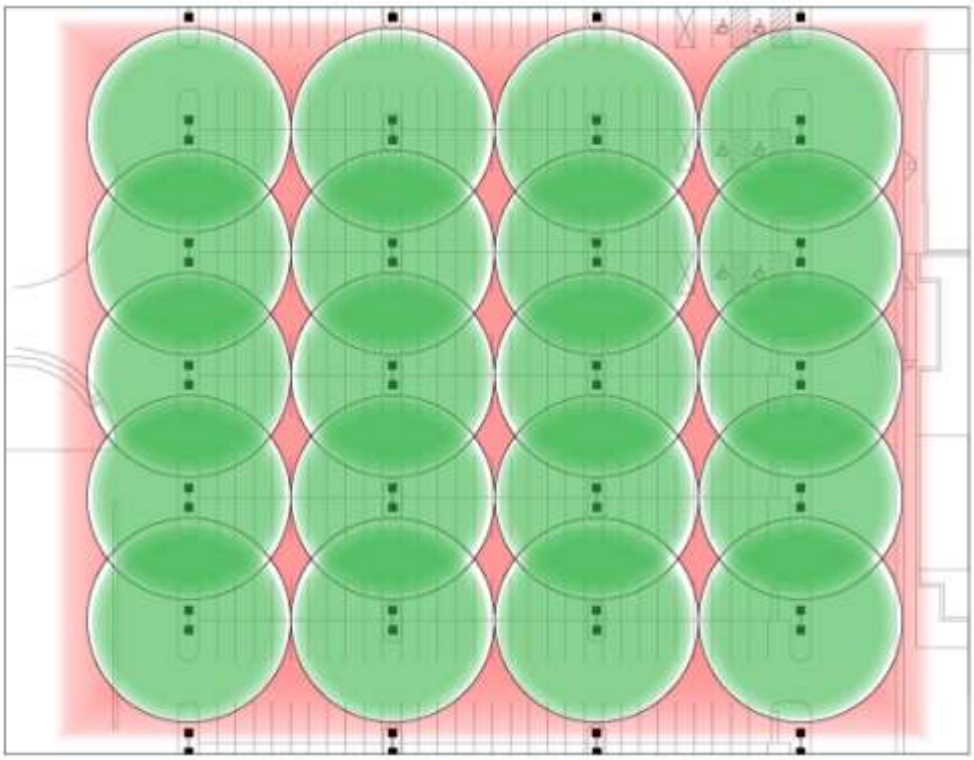

Figure 70: Illustration of PIR Sensor Range Limitations

With a tight parking lot pole spacing of 60 feet by 100 feet (every row arrangement0, 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.

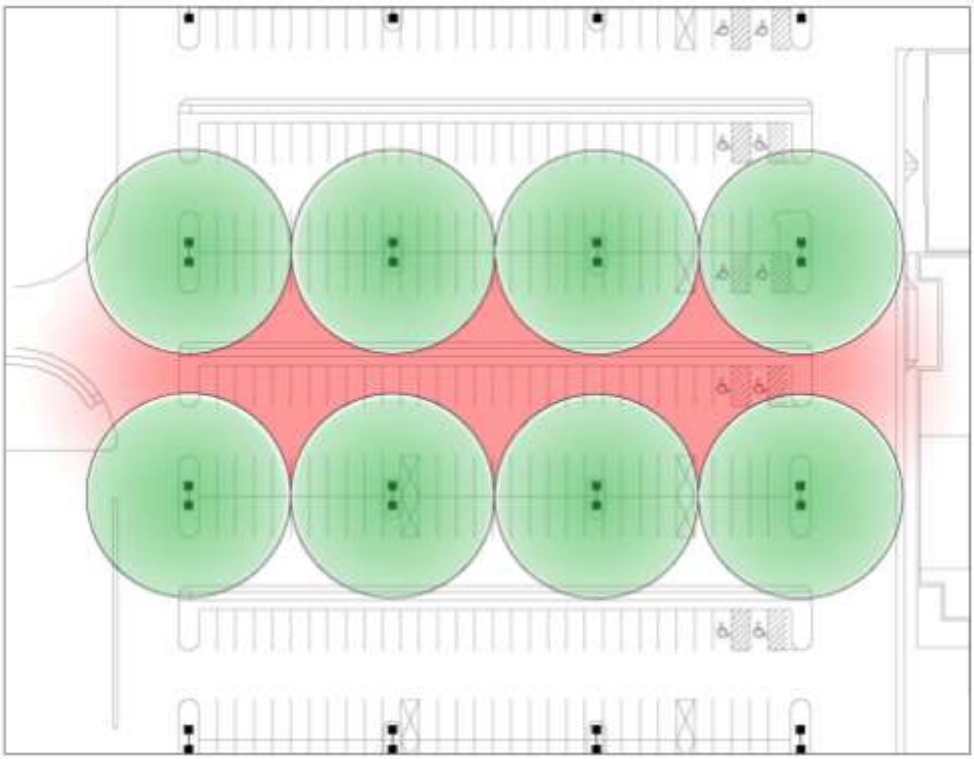

Figure 71: Illustration of PIR Sensor Range Limitations

With a more typical parking lot pole spacing of 120 feet by 100 feet (every other row arrangement), 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.

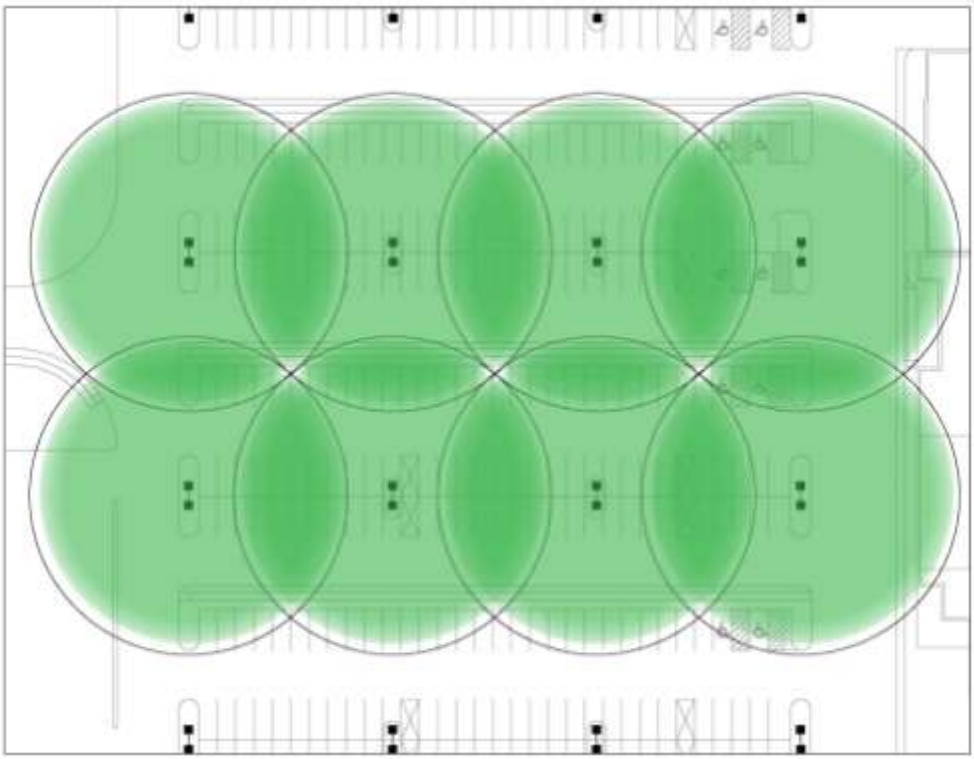

Figure 72- Illustration of PIR Sensor Range Limitations

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.

11.4 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.

11.5 Future Technology Developments

11.5.1 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.

11.5.2 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.

11.6 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
	Decorative Wall Sconces with PIR occupancy sensing

11.7 References

Sarkar, A., Fairchild, M.D. and Salvaggio, C. (2008) Integrated Daylight Harvesting and Occupancy Detection Using Digital Imaging, Electronic Imaging Conference, San Jose, CA, USA

Public Interest Energy Research Program. (2009) PIER Solutions for Parking Lots and Garages.

12. Appendix H: Exterior Dimming/Bi-Level Controls

12.1 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.

12.2 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.

12.3 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.

12.4 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.

12.5 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.

12.6 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.

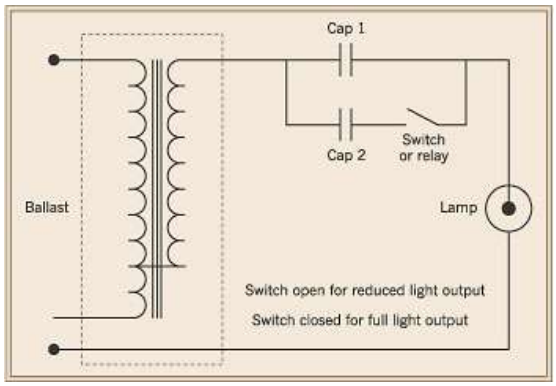

Figure 74- Example of HID Dimming Circuit using CWA Ballast (2007 EC&M)

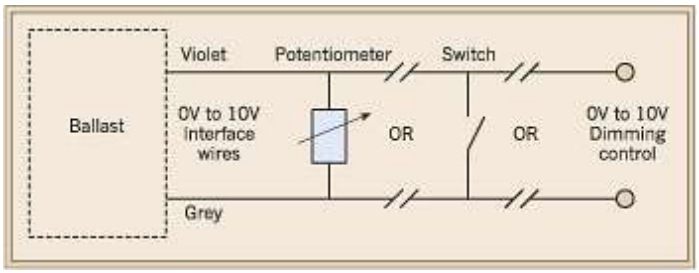

Figure 73- Example of HID Dimming Circuit using eHID Ballast (2007 EC&M)

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 75 and Figure 76 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 75: 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 76: 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.

12.7 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.

12.8 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

12.9 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.

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13. Appendix I: Lamps and Ballasts for Exterior Bi-Level Control

13.1 State of the Market

13.1.1 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.

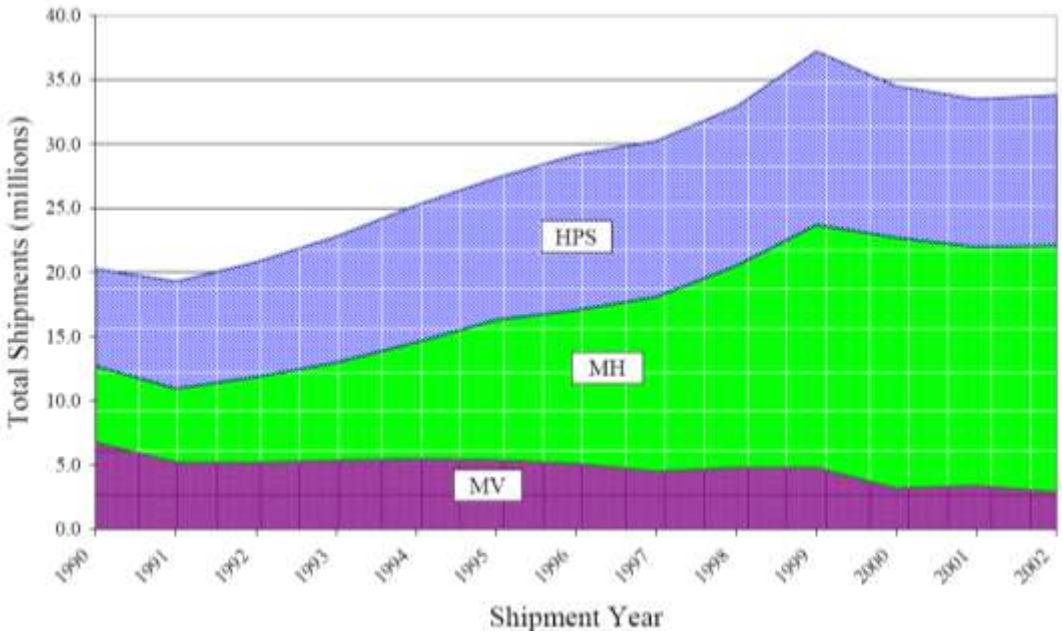

Figure 77: Total US HID Lamp Shipments by Type, 1990-2002 (DOE 2004)

13.1.2 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 78 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 78, 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.

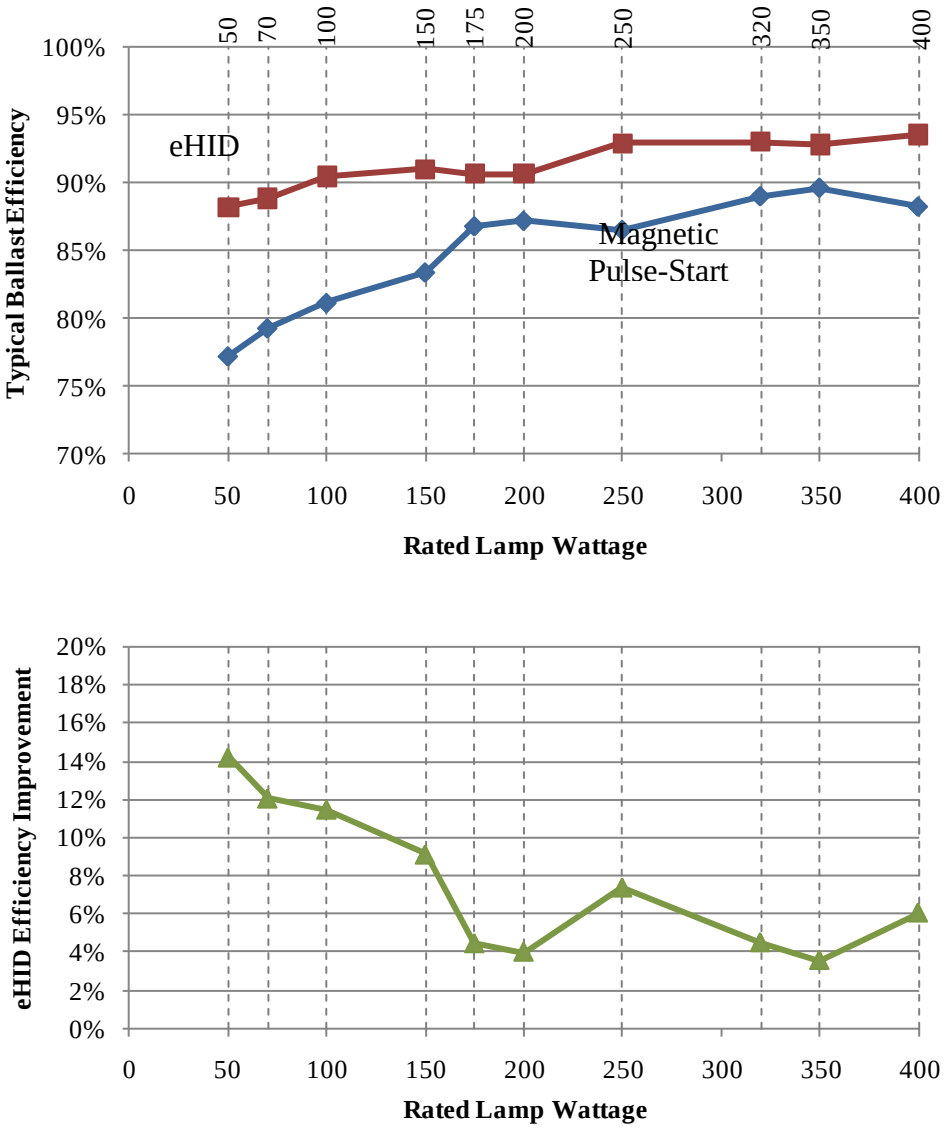

Figure 78: Typical Ballast Efficiencies and Estimated eHID Savings (Clanton 2010)

13.2 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).

13.3 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.

13.4 Technical Issues

13.4.1 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 79 demonstrates 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.

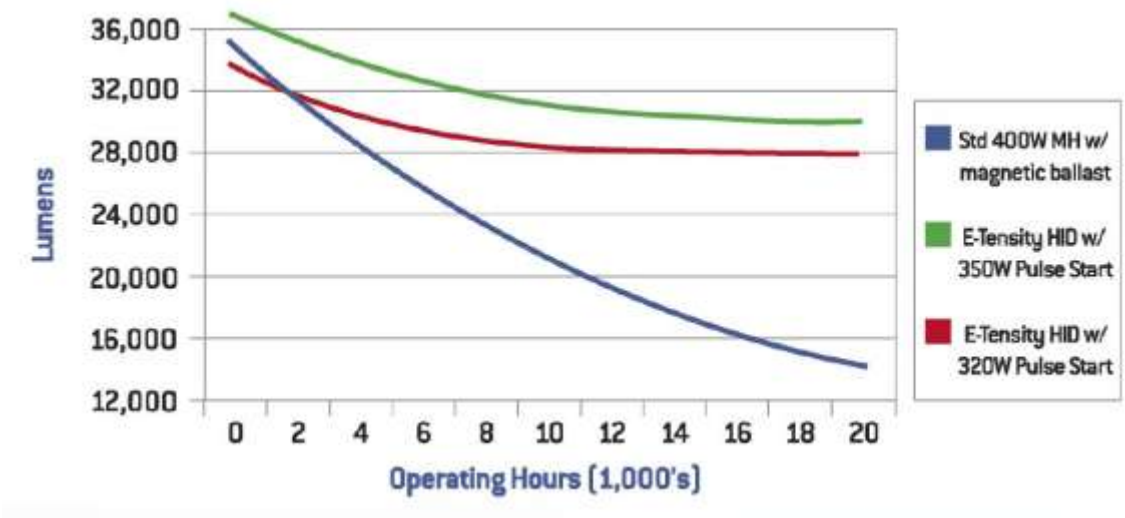

Figure 79: Claims of Increased Lumen Maintenance using eHID Ballast (Universal Lighting Technologies)

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

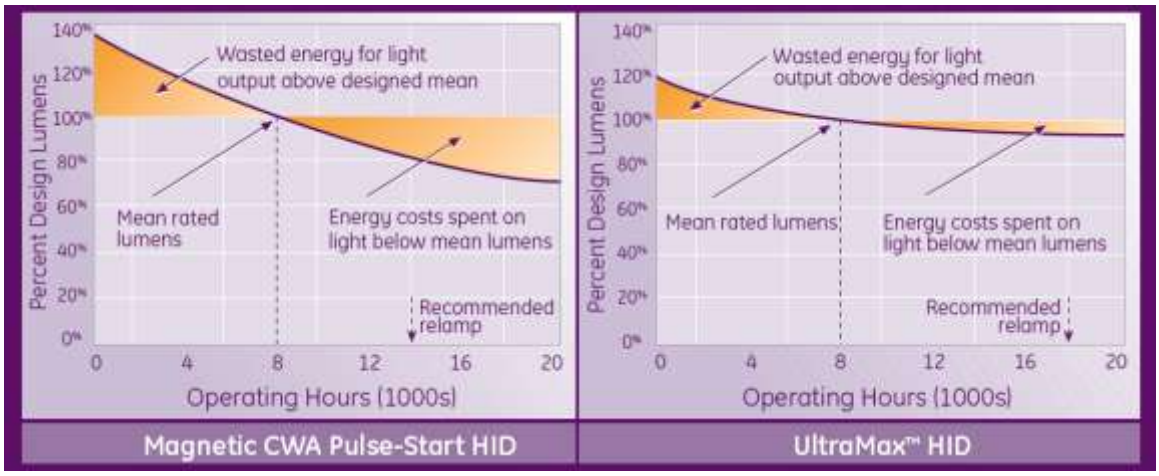

Figure 81: Claims of Reduced Energy Use with eHID Ballast (Universal Lighting Technologies)

13.4.2 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.

13.4.3 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.

13.5 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)

13.6 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.

13.7 References

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14. Appendix J: Data for Materials Impact

This section sets out the raw data used to calculate the materials impacts of the proposed measure (see Overview: Section F), and the underlying data and assumptions.

Component	Weight per component (lbs)					
	Mercury	Lead	Copper	Steel	Plastic	Others (Identify)
3-lamp magnetic ballast for linear fluorescent, steel case	0.0080	0.0080	0.50	7.5	0	0
3-lamp electronic ballast for linear fluorescent, steel case	0.0025	0.0025	0.15	2.35	0	0
3-lamp electronic ballast linear fluorescent, plastic case	0.0005	0.0005	0.15	0.1	0.25	0
occupancy sensor	0.0005	0.0025	0.15	0.1	0.25	0
#12 power wiring, 100'	0	0	2	0	0	0
Cat 5 control wire, 100'	0	0	0.94	0	0	0
Linear fluorescent or compact fluorescent lamp	0.00001	0	0	0	0	0
35W PAR30 CMH lamp	0.0055	0	0	0	0	0
70W PAR30 CMH lamp	0.022	0	0	0	0	0
150W T6 CMH lamp	0.031	0	0	0	0	0

Figure 82. Materials Content of Typical Lighting Components, by Weight

Note that in Figure 82 the materials weights for an occupancy sensor are the same as those for an electronic ballast with a plastic case. This assumption was made because these two components are very close to the same size, and both contain electronics that control electrical power, within an insulated plastic case. The material content within a daylight sensor was assumed to be the same as the material content within an occupancy sensor.

14.1 Mercury and Lead

The figures for mercury and lead were calculated in one of two ways. For electrical components (ballasts and occupancy sensors) they were calculated by using the maximum allowed percentages, by weight, under the European RoHS[1] requirements, which were incorporated into California state law effective January 1, 2010. The California Lighting Efficiency and Toxics Reduction Act applies RoHS to general purpose lights, i.e. "lamps, bulbs, tubes, or other electric devices that provide functional illumination for indoor residential, indoor commercial, and outdoor use." RoHS allows a

[1] http://ec.europa.eu/environment/waste/weee/index_en.htm

maximum of 0.1% by total product weight for both mercury and lead. In practice the actual percentage of mercury and lead in these components may be very much *less* than these values, so the values in the table are conservative overestimates. Values for the total weight of these components (from which the lead and mercury values are calculated) were obtained from the online retailer www.ballastshop.com, and corroborated by the Lighting Research Center's Specifier Report on electronic ballasts[2].

For lamps, the mercury content of the lamp is almost always given by the lamp manufacturer in product cut sheets. The figures in the table are all based on high-volume products from the online catalog for Philips lighting. The amount of lead in a lamp is assumed to be negligible; no information on the presence of these substances in lamps could be found either from product manufacturers or from online sources.

14.2 Copper, Steel and Plastics

For ballasts, the amount of copper and steel was estimated by comparing the weight of the electronic plastic-cased ballast with the electronic steel-cased ballast, and assuming that the difference in weight was due to the steel case (i.e., that the electronics inside the two ballasts were the same). For the plastic ballast, a little more than half the weight of the component was assumed to come from the case, with the remaining weight being made up by copper and steel. For the magnetic ballast, the weights for copper and steel were scaled up from the electronic ballast, in proportion to the increase in total component weight (from 2.5lbs up to 8lbs).
For wiring, the weight of copper was calculated using the cross-sectional area of the conductor wires, and multiplying this by the nominal length (100') and by the density of copper (8.94 g/cm^3). The area of the conductor wires was obtained from online sources[3].
For lamps, the amount of copper, steel and plastic in a lamp is assumed to be negligible; no information on the presence of these substances in lamps could be found either from product manufacturers or from online sources.

[2] http://www.lrc.rpi.edu/programs/NLPIP/PDF/VIEW/SREB2.pdf
[3] http://en.wikipedia.org/wiki/American_wire_gauge, and http://en.wikipedia.org/wiki/Cat_5