CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

2008 California Energy Commission Title 24 Building Energy Efficiency Standards
February, 2007

Revised Report Indoor Lighting and Proposed Additions/Revisions to Tailored Method

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Overview

This proposal seeks to reduce both the Lighting Power Density (LPD) as well as total (annual accumulated) lighting power consumption for nonresidential buildings under provisions recommended for incorporation into the Title 24-2008 Energy Standards. Particular emphasis for LPD reductions has been placed on the Tailored Method of Title 24 compliance as it applies to Retail Lighting. Significant LPD reduction is warranted in this area since lighting technologies are now available which were not practical during development of the previous standards.

The primary drivers for LPD reductions under this proposal are: the use of Ceramic Metal Halide (CMH) versus Halogen as the light source for accent, display and feature lighting, increased use of other high efficacy sources and careful matching of display and ambient lighting levels to those recommended by IESNA-RP-2 "Recommended Practice for Lighting Merchandise Areas." Additional LPD reductions are also possible by fine tuning other light sources through ballast variables and improved lamp offerings such as the use of T-5 lamps driven by low or high power factor ballasts. Total electrical energy consumption will also be reduced by expanded requirements for daylight harvesting and the use of comprehensive lighting controls.

Description

Recommended proposed changes to Title 24 for improvements to the lighting component of building efficiency standards as applied to nonresidential buildings are:

1. Reduce the allowed LPD for accent display and feature lighting under the Tailored Compliance (Table 146D T24-2005 columns 4 and 6) based on increased use of Ceramic Metal Halide (CMH) and judicious use of other efficient light sources such as the latest infrared coated halogen lamps..
2. Reduce the allowed LPD for wall display lighting under the Tailored Compliance (Table 146D T24-2005 columns 3) based on increased use of CMH and other efficient sources for the accent/feature lighting component of this lighting category. Lower cost display lighting systems can still use halogen lighting and comply with both the RP-2 retail lighting recommendations and this revised proposal, but stores desiring higher light levels will need to use more efficient display lighting sources such as CMH.
3. Re-alignment of mounting height adjustment factor (TABLE 146-E T24-2005) to compensate for the difference between the lamp wattage range and optics of CMH versus halogen.
4. Relax criteria used to differentiate between luminaires qualifying as wall display versus floor display. Wall display luminaires can be as far away from the wall as 10 feet which allows for appropriate aiming angles for luminaires mounted up high and increases vertical footcandles on display. Floor display luminaires can be as close to the wall as 2 feet which allows for highlighting floor displays near wall. Thus luminaires in a band between 2 and 10 feet from walls can be allocated to either floor or wall display. These limited trade-offs helps provide design flexibility under more stringent lighting power density constraints.
5. Reduce allowed LPD for very valuable display power to account for use of CMH lamps for high ceiling heights while still allowing the use of halogen for lower ceiling heights. Very valuable display is intended to mean very valuable products in a display case. However this has been misapplied in the past to display lighting of valuable products. This confusion can be minimized by removing from Table 146-D and placing the allowance in the text of Section 146.
6. Mandate use of comprehensive lighting controls as a prerequisite to using the Tailored Lighting method of Title 24 compliance under the 2008 standards. Multi tier lighting zones, multi level

switching, demand responsive load shedding, and occupancy sensors are some of the control types that are applicable. Use of a comprehensive set of controls will assure that the added power (LPDs) allowed under the Tailored Method will be used only when required for the specific lighting application and will be appropriately monitored. The control mandate must include commissioning and verification.

7. Expand requirement for daylight harvesting to more space types and to smaller spaces when/where appropriate. As with use of controls as part of the Tailored Method, daylight harvesting must also employ a set of comprehensive controls to assure harvesting is maximized while maintaining appropriate lighting for merchandise sales.

Energy Benefits

LPDs will be calculated for various models under the current standard versus the proposed changed standard. Lighting will be compliant with appropriate IESNA standards while saving energy. We are proposing that the wall display be reduced by 5 Watts per linear foot and the floor display be reduced by 0.4 W/sf. In addition we are recommending that advanced lighting controls be installed as a condition of using the tailored lighting method. These controls will reduce full load operating hours by approximately 20%.

Energy savings are calculated in units of kWh/yr savings per square foot of floor area by store type in the table below.

Table 1 Weighted energy savings calculated by space type

Weighting factors	Space Type	Connected Load (W/sf)	Energy (kWh/yr-sf)	TDV kBtu/yr-sf	Dollars/yr-sf
10%	High End Retail	2.65	11.91	238.71	$1.69
50%	Medium Priced Retail	0.57	2.58	51.74	$0.37
40%	Strip Mall Small Business	0.39	1.76	35.24	$0.25
100%	**Area weighted total**	**0.71**	**3.2**	**63.8**	**$0.45**

Non-energy Benefits

Potential non-energy benefits include:

- Reduction in air emissions that results from any energy savings measure and the increase in electric system reliability that accompanies the reduction in peak electrical demand.
- Increased reliance on higher efficacy sources such as fluorescent and ceramic metal halide (CMH) which have longer lamp life and as a result lower maintenance costs.
- Improved lighting performance including better lumen maintenance (10-15% improvement) and color stability. (All environments)

The evaluation of non-energy benefits shall be based on recent (current) IES research studies as well as various individual industry publicly available testing and research.

Statewide Energy Impacts

Statewide energy impacts are based on building department surveys that found that 7% of all retail lighting permit applications used the tailored method for showing compliance. On average, this proposal reduces the allowable lighting power density by approximately17%. There is approximately 24 Million sf/yr of new retail spaces built each year in California. The 7% of these new retail spaces that use the tailored lighting approach is 1.7 Million/sf. per year.

According to the California Commercial End-Use Survey (CEUS) database (Itron 2006), the existing commercial retail floor space is approximately 702 Million sf. If retail lighting systems have an effective life span of 7 years, then 100 Million sf of retail lighting is remodeled each year. However a conservative estimate of permitted retail lighting retrofits is closer to 70 Million sf/yr. With 7% of retail lighting permits using the tailored method, 4.9 Million sf of retail lighting retrofits would be affected by changes to the tailored lighting method rules.

Thus the statewide impacts of changes to the tailored method requirements are based on a reduction in lighting power and operating hours of lighting in a total of 1.7 + 4.9 = 6.6 Million sf/yr of new or remodeled lighting systems.

Table 2: Statewide energy savings in the first and 10th year resulting from Tailored Method changes

	Million sf - 7% of retail permits	Demand (MW)	Energy (GWh/yr)	Million TDV kBtu/yr	Dollars (Millions/yr)
First Year Savings	6.6	4.7	21.1	422.7	$3.0
10th Year Savings	66.2	46.9	210.9	4,227.2	$29.9

Environmental Impact

The proposed changes/measures will not result in any adverse environmental impact. On the contrary several of the changes/measures will actually impact environmental issues in a positive vein. Such as use of the latest lamp/ballast technologies (required to meet the standards) will result in less mercury and other hazardous materials...

An additional positive environmental impact is the reduction in air emissions from power plants due to reduced electricity consumption. We will base these estimates of reduced emissions by multiplying the statewide energy savings by the emissions factor values generated by the California Energy Commission for evaluating the environmental impacts of the 2005 standards as shown in Table 3 below.[1]

Table 3: Emissions Factors used to calculate the air emissions reductions resulting from end-use reductions in electricity and natural gas consumption

Emissions Factors for Calculating Reduced Emissions from Energy Savings				
Emissions factors	**NOx**	**CO**	**CO2**	**PM10**
Natural Gas, California (lbs/MMBtu)	0.094	0.03	115	0.01
Electricity, Western States (lbs/MWh)	0.383	0.23	1200	0.06

Applying these emissions factors to the kWh/yr savings results in the annual statewide savings emissions calculated in Table 4

[1] Table 1, Appendix B page 2, Initial Study/Proposed Negative Declaration for the 2005 Building Energy Efficiency Standards for Residential and Nonresidential Buildings September 2003 P400-03-018 http://www.energy.ca.gov/reports/2003-09-12_400-03-018.PDF Values provided by the CEC System Assessment and Facilities Siting Division.

Table 4: The Statewide Emissions Reduction Estimate resulting from proposed Title 24-2008 Tailored Method

Air Emissions Reductions Resulting from Tailored Method Improvements				
	NOx	**CO**	**CO2**	**PM10**
First Year Savings (tons)	4.04	2.42	12,651	0.63
10th Year Savings (tons)	40.38	24.25	126,511	6.33

Type of Change

The types of changes anticipated and/or associated with the recommended measures are outlined as follows:

Table 5: Compliance Rath options for Code Chang

Mandatory Measure	The controls requirements that would be required if one chooses to use the tailored method for compliance would be mandatory. Mandatory measures must be satisfied with either the prescriptive or performance compliance methods.
Prescriptive Requirement	The change would add or modify prescriptive requirements in Section 147. Prescriptive requirements must be met for prescriptive compliance and define the Standards baseline building in performance calculations, but are not mandatory when the performance approach is used.
Compliance Option	Some of the controls requirements would be optional and would add a new means to comply with the standards by adding a new compliance option. This would likely be a simple Power Adjustment Factor applied of the controlled lighting or a different allowance for lighting that is dimmed.
Modeling	The ACM would only be changed to reflect the changes in the LPD and controls requirements. This proposal does not change the algorithms of how lighting and controls are modeled. The change would modify the calculation procedures or assumptions used in making performance calculations. This change would not add a compliance option or a new requirement, but would affect the way that tradeoffs are made.

The scope of the standards is not changed by this proposal. The standards have traditionally had the ability to limit the connected lighting power in spaces and to require or give credit for lighting controls. This proposal would result in modifications to the Standards, ACM, manuals, and the compliance forms. Changes to the standards language itself include:

- Section 146: Add and remove the types of lighting that are exempt. Add extra categories to the area category method for display lighting and case lighting, modify the lighting power densities, and require controls when the tailored method is used.

The ACM and the compliance forms would have to reflect these changes. The nonresidential manual would explain how these new changes are applied and include examples.

Technology Measures

The following technologies enable the increased stringency of the proposed lighting energy standards change:

- For aggressive energy reduction in directional lighting applications, promote use of CMH lamps as energy efficient alternative to IR halogen. Maturity of Ceramic Metal Halide (quality, performance and cost effectiveness) warrant use of CMH over Halogen where/when dimming of the directional lighting is not required. For dimming applications improved IR designs with 14% to 20% efficiency over previous IR lamps are available.
- Latest generation T8 fluorescent systems allow reduced general and ambient lighting connected load. The wide range of ballast factors and lamp lumen output options, with improved efficacy, results in lower LPD's while maintaining required illumination levels. Furthermore, encourage development of similar expanded ballast and lamp options for T5 lighting systems.
- Energy and electrical demand reduction during daylight hours is accomplished via introduction of daylight harvesting or daylight adaptation compensation into more space types where/when appropriate.
- Encourage use of LED lights versus fluorescent and neon for some signage, markers, visual effects, casework, under shelf and other specialty lighting applications
- Improved lighting design tools allow designers to more accurately model their spaces and fine tune their lighting designs to the need of the retailer to present their product within the lighting budget constraints of Title 24.

Measure Availability and Cost

IR halogen lamps are currently available from the three major lamp manufacturers and a second generation IR lamp with 10% efficiency improvement is currently available from two manufacturers (further efficiencies of 14% to 20% in IR lamps is expected by early 2007). CMH lamps and electronic ballasts are currently available from a wide range of manufacturers. All three major lamp manufactures offer a variety of lamps. There are at least a half dozen ballast manufactures and dozens of luminaire manufactures in the CMH market. Numerous LED systems are currently available and are effective for use as sign and specialty lighting. Improvements in LED color quality specifically in the area of better white light coupled with reduced power consumption have extended the range for LED usage. A wide variety of end use products are now available that can effectively be used to replace neon and some halogen light sources. There are also several recent and near future improvements to LED technology that suggests their role in lighting could be expanded.

The technology measures suggested are currently being employed by the "cutting –edge" market segment which in part demands (drives) their higher initial cost. All of them however offer potential for return on investment. Mainstreaming these measures through legislation may ultimately reduce their first cost and provide for greater product availability. Manufacturers and suppliers should have adequate lead-time between enactment and implementation of any new standard to prepare for the increased product demand created by the standards. However, the proposal offered is cost-effective in its entirety, and is based on products that are currently available. The prototype designs that meet the proposed standard have a lower life cycle cost than the prototypes that minimally comply with the 2005 standards. In some cases, the proposed designs solutions have lower first cost and lower operating cost with an immediate payback.

Title 24 – 2005 "Tailored Method" as applied to the retail models will serve as the baseline for the proposed 2008 retail lighting measures. Life cycle costing shall be determined comparing the base system to the proposed system. Life of the system shall be determined by the equipment's useful life, which may or may not equate to its actual life.

The proposed measures will most likely result in higher first cost for lighting equipment and addition of comprehensive lighting control. However, in addition to the lower operating cost due to energy savings the equipment associated with the proposed measure may require less routine maintenance.

Useful Life, Persistence and Maintenance

Life, frequency of replacement, and maintenance procedures related to the measure will be based on data gathered from the limited base of current users (where/ when available). Manufacturers' technical data and recommendations will also be used when/as available. Persistence energy savings related to the measure will be based on life of the equipment. Persistence is related to performance verification. Proper maintenance or lack of will have limited effect on persistence but may drastically affect the non-energy related issues such as lighting quality. Projected life and required maintenance is based upon manufacturer's information and feedback from clients who are using various lighting products. Persistence of savings from CMH products is higher than for their halogen counterparts in that CMH ballasts typically serve only one wattage level per lamp. Thus it is harder to increase lamp wattage without replacing the whole fixture

Performance Verification

Persistence is related to performance verification in that the installer must verify that the system is in compliance and working. A licensed electrical contractor or the electrical engineer of record can accomplish the required verification. Cost impact will be minimal as such functions are often, if not always in the contractor's and/or consultant's contract agreement as part of implementation.

Cost Effectiveness

The proposed changes for T24-2008, "Tailored" method includes 25% to 30% lower LPD allowances for retail spaces versus allowances under the T24-2005 tailored compliance. Reductions of 5% to 15% in allowed maximum LPDs can also occur for other "Tailored" method" spaces and several categories under the "Area Category" compliance method. Increased implementation cost (design, equipment, etc.) is anticipated for those projects which set lighting standards to IES recommended practice. However, reduced cost of operation (lower maintenance and utility costs) will more than off set increased first cost when analyzed on a "life cycle" basis.

Cost analysis modeling on 39W and higher Ceramic Metal Halide for feature lighting (accent, display, wall-wash, etc.) was one of the key drivers to proposed LPD reductions that demonstrated that cost effectiveness is feasible within a seven year period. The seven year cost effectiveness is well under luminaire life expectancy and conforms to the typical project space life where these systems are used. Furthermore; the seven year period is far more conservative than the 15 year cost effective period considered acceptable by the CEC for non residential non-envelope compliance measures.

Other sources (most recent fluorescent and halogen IR technologies) driving LPD reductions are anticipated to have significantly shorter payback periods than the CMH as demonstrated by the cost analysis conducted on the AGI-32 model spaces and other model comparisons. The expanded use of controls, as mandated under this proposal, is also cost effective and further reduces energy consumption.

Analysis Tools

The tools used to perform the analysis for this CASE report fall under three categories:

1. Spreadsheet to approximate what lighting power densities are used under different task categories. This will build on the spreadsheets used in the developing the 2005 standards.

2. AGi32 lighting software to evaluate the lighting conditions of various lighting designs, especially in terms of how changes to lighting technology or design affect compliance with the RP-2 retail lighting recommendations.
3. Spreadsheet to keep track of results from AGi32 runs the PV energy costs of operating the system, the life cycle maintenance costs and the incremental first cost. These figures are used to calculate the benefit/cost ratio of the system.
4. MS Access database software for processing designer surveys.

Relationship to Other Measures

Proposed lighting measures under this case study will not affect other non-lighting measures outside of reducing the cooling loads on HVAC measures in primarily retail occupancies.

Methodology

Careful consideration of the factors that affect the lighting of a complex retail space and maintaining the relative light levels (fc) of that space over time resulted in choosing the following six major areas of interest. Each of these six selections for study will contribute significant information that will enable needed change to occur in a positive orderly fashion. For each of the six study areas we used a variety of methods and technology to obtain the relevant information for application to this project.

The six are:

1. Interviews with Designers, Contractors, Manufacturers, and End Users
2. Life Cycle Cost Analysis of CMH Lamps
3. Visual Observation and Analysis of Existing Relevant Spaces
4. Computer Modeling of seven (7) uniquely different retail stores types
    A. Big Box Retail (Warehouse stores, building supply, membership)
    B. High Atrium Retail (Large atrium spaces with ceilings over 22')
    C. High End Jewelry (Marketing precious gems, metals, museum quality pieces)
    D. High End Retail (Furs, Designer Dresses, etc.)
    E. Strip Mall Small Business (Card Shops, Flower Shop, Hobby Store)
    F. Furniture & Home Accessories (Lifestyle and fashion furnishings)
    G. Kitchen Accessories &Tableware (Basic and lifestyle items for kitchen & dining)
5. New Technology and Design Comparison Computer Models
    A. Benya 2001 Study – Vertical Wall Accent Lighting
    B. Accent Lights – New vs. Rated Life Comparison Re-lamping
    C. Mounting Height vs. Throw Distance
    D. All MR16 Design vs. MR16 & Fluorescent Wall-washer solution
6. Comparative Studies of Title 24-2001 and Title 24-2005

Models 4F and 4G were prepared after the initial public hearings to address concerns that this early draft lacked a more in depth review of design conditions of mid-range retail store. To that end we chose 2 representative locations. Experimental design and methods similar to those used in the initial draft report

were also observed for this study. The data and conclusions will be presented in the same format and have be introduced in the appropriate sections for better understanding and comparison to earlier models and findings.

1. Interviews with Designers, Manufacturers, and End-users

We conducted a survey of designers, end users, and manufacturers with knowledge of the Title 24 Tailored Method and retail lighting expertise were surveyed. The sample was not intended to be a formal population-based sample with weights developed for each respondent but were based on our experience with the local and national lighting market to contact the key players. A list was prepared by Integrated Lighting Concepts (the technical lead for this CASE report) from their contact database. Interviews were conducted mostly by phone. Face to face interviews were done at several conventions as well as during a lighting design class. The approximate interview length was 30-45 minutes depending on the level of involvement of the interviewee. The survey questionnaire contained 14 questions with a section to record the interviewee type, interview date, interviewer, etc. A copy of the survey can be found in Appendix 5 – Survey Questions for Designers

Interviewees were asked questions in a numbered scale format so the results could be more easily quantified. The goal was to get a sense of the lighting community at large in order to be able to better judge the acceptance level of the improved technology affecting lighting design, controls, luminaires and/or lamps.

Data was analyzed using Microsoft Access database tools for maximum flexibility in understanding our results.

2. Life Cycle Cost Analysis of CMH Lamps

An excel spreadsheet was developed to determine the life cycle cost of CMH lamp technology as compared to Basic Halogen, Halogen IR, and Advanced Halogen Silver IR. Both 15 year and 7 year cost recovery periods were studied. Various cost factors were determined for small retail establishments (low volume purchasing) and large corporate high volume purchases. Analysis was run at a 3% real discount rate as defined by the CEC in the 2008 Life Cycle Costing Methodology Report (AEC 2005).

3. Visual Observation of New Relevant Spaces

Field observations were conducted of 68 newly constructed shops and 2 anchor stores at a local shopping mall completed in October, 2005. All 70 stores were visually inspected. For the purposes of this Title 24-2008 report a special emphasis was placed on retail locations. The goal was to determine the extent to which non-mandated new technology was being employed in current designs.

The stores that were visited had been permitted under Title 24-2001. The use of daylighting was another consideration in our observations. The survey was used as a real world check against the Title 24-2001 guidelines and actual implementation and compliance standards set forth in Title 24-2005.

4. Retail Store Computer Modeling

Six complete and several partial store models were constructed using the computer program AGi32 v1.92 from Lighting Analysts, Inc., Littleton, CO. The design input for each model was from existing CAD drawing files or from observation and measurement (i.e. High Center Atrium Store). Luminaires were matched to the current design specification by downloading the necessary IES file data from the manufacturer. When exact luminaire data was unavailable Photometric Toolbox, Professional Edition from Lighting Analysts was used to make modifications to existing similar IES files to obtain the suitable and correct luminaire file. Photometric analysis was run on each model.

Spaces were selected that best represented technology available prior to the implementation of Title 24-2005 and that would be good candidates for conversion to the most current lighting technology. Varied room cavity ratios (RCR, i.e. the ratio of the wall area to the floor area of the space) were an additional consideration in choosing the various stores to allow us to review the RCR effect on lighting power density and appropriate light levels retail stores.

After base (reference) models were constructed and analyzed each was subjected to lighting design changes. These changes incorporated the latest in fixture and lamp technology and were reanalyzed.

We concentrated on results for LPD, foot-candle levels on display cases and wall displays as well as the effect of ambient lighting on the overall model LPD. Light levels were measured to compare the older reference models with models using the newest technology available for commercial use.

Each model was designed to be RP-2 compliant as well as meet thorough economic analysis for costs or savings under T 24-2005 and proposed guidelines in T 24-2008. We were always aware of the visibility requirement that would translate into specific foot-candle levels for each model. Lamp color rendering index (CRI) became another component of the model design procedure because good color quality is a must if the retail community is to accept any major changes to the traditional lamp selection. We chose lamps that had good color quality over the life of the lamp as well as providing adequate light levels.

Luminaire Photometric File Data

All photometry used for store modeling and partial space models was downloaded from each manufacturer's IES file database. Total Light Loss Factors (LLFs) were calculated for each luminaire. Dust depreciation was kept at a constant 0.80 for purposes of this study unless otherwise noted. The following tables for each model describe the various luminaires and/or lamps along with fixture data and quantities used. Note that for each model there is a REFERENCE (Title 24-2005) MODEL and a NEW TECHNOLOGY MODEL which forms the basis for code change recommendations.

Table 6:Summary Description of Computer Models

Model	Space Description
Model A	Big Box Retail
Model B	Store with Atrium
Model C	Jewelry Store
Model D	Designer Shop Inside of Store
Model E	Small Store in Strip Mall
Model F	Furniture and Home Accessories
Model G	Kitchen Accessories

Model A represents the typical big box retail store. A big box retail space was chosen for our prototype because of their use of daylight harvesting to reduce LPD during daylight hours. The connected load that was measured for purposes of this study was only seen during evening hours during complete outside darkness. This is a good opportunity to look at a model that is currently running at a relatively low LPD. This model is also suitable for doing advanced daylight harvesting modeling, as would be found in stores such as Lowe's, Home Depot or Food 4 Less.

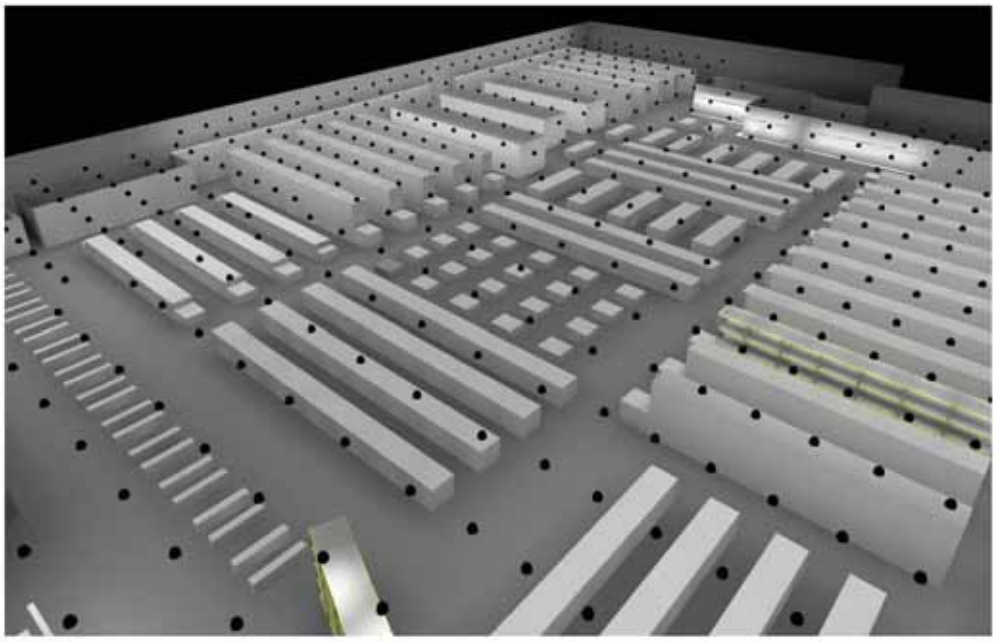


Figure 1 Model A Big Box Store

Table 7: Computer Model A – Big Box Store Under Title 24-2005

Luminaire Description	Watts/ Fixture	Fixture Lumens	LLF	Quantity	Reference Identifier
4 Ft 2 Lamp T8 Industrial Fluorescent Electronic Ballast	68	5,900	0.68	63	HEW SD13-4-232-127W
High Bay Fixture w/ Refractor - Pulse Start Magnetic Ballast	458	36,000	0.56	452	THR 400W 90121917

Table 8: Computer Model A1 – Big Box Store New Luminaire Technology

Luminaire Description	Watts/ Fixture	Fixture Lumens	LLF	Quantity	Reference Identifier
4 Ft 2 Lamp T5/HO Industrial Fluorescent Electronic Ballast	88	10,000	0.72	63	HEW SD13-4-232-127W
4 Ft 6 Lamp T5/HO Specular Reflector Electronic Ballast	324	30,000	0.72	452	Williams GL B11837

Model B represents a large store with a high center atrium. A prototype similar to Barnes and Nobel is used for this study which also includes a variety of sub-area lighting design opportunities. Many retail stores also fit into this category using a center light-well to enhance the daylighting effect in the store. Certain properties such as flagship locations of Saks, Macys or Neiman Marcus would be other good examples. These higher ceilings allow the designer to take advantage of the improved candle power of a 70W CMH that coupled with a narrow beam (5%) is very effective at ceiling heights between 15 to 20 feet.

Figure 2 Model B High Center Atrium Store

Table 9: Computer Model B – High Atrium Retail Under Title 24-2005

Luminaire Description	Watts/ Fixture	Fixture Lumens	LLF	Quantity	Reference Identifier
70W CMH w/8" Specular Can and Electronic Ballast	79	6600	0.68	157	A1-1 Lightolier C6T6VWCLW 70W T-6 Electronic Ballast
2 X 2 3 Lamp T8 Parabolic Troffer w/9 Cell Semi Specular Louvers Electronic Ballast	128	9,450	0.56	154	A2 Columbia 10354 P222-340TTG-LD44-TT
Single 4 Ft. T8 Louvered 9 Cell Wall Washer with Electronic Ballast	32	2800	0.68	139	A3 Cooper Paralux IV PGX-232SI9I-PAF
8" Specular Can w/. Metal Halide Downlight Electronic Ballast	77	5,700	0.68	24	A5 Lightolier C7E170VW C770MHOU
8" Dia. Single 42W Biax Vertical CFL Downlight	44	3200	0..64	149	B4 Prescolite CFT832-EB-WTF-805 42W
36" Dia. Chandelier 4 55W Biax & 3 39W Biax CFLs	237	27750	0.68	5	B5 Winona Lighting 492-36-F55 Deco Pendant

Table 10: Computer Model B1 – High Atrium Retail New Luminaire Technology

Luminaire Description	Watts/ Fixture	Fixture Lumens	LLF	Quantity	Reference Identifier
7" Clear Anodized Aluminum Reflector Ceramic Metal Halide Electronic Ballast	110	6,500	0.68	37	Lightolier C7E17OVW CLW-100W
2 X 2-Two Lamp Biax Parabolic Troffer w/9 Cell Semi Specular Louvers	70	6,300	0.56	154	Columbia 10354 P222-340TTG-LD44-TT
One T5 Asymmetrical Semi Specular Wall washer	34	2,900	0.72	139	Elliptipar F102-T128-S-02-A-000
Two 42W Triple Tube Horizontal CFL Downlight	88	6,400	0.64	29	Lithonia LT9582F8B3 (2-42WDTT)
8" Clear Anodized Aluminum Reflector Ceramic Metal Halide Electronic Ballast	172	14,000	0.68	68	Lightolier C7E170VW C715MHOU
One 42W Triple Tube Horizontal CFL Downlight	44	3,200	0.64	104	Prescolite CFT832-EB-WTF-805 42W
36" Dia. Chandelier 4 55W Biax & 3 39W Biax CFLs	237	27,750	0.68	5	Winona Lighting 492-36-F55 Deco Pendant

Model C is a stand alone high end jewelry store. A jewelry store similar to Zales Jewelers was the choice for this design. There is a high case to floor surface ratio, many wall displays and cove fluorescents are used extensively for ambient lighting.

Figure 3 Model C High End Jewelry Store

Table 11: Computer Model C – High End Jewelry under Title 24-2005

Luminaire Description	Watts/ Fixture	Fixture Lumens	LLF	Quantity	Reference Identifier
75W Recessed PAR30 HIR Accent Spot	75	1000	0.79	82	Indy Lighting 472R30NS
42W Single Triple Tube CFL Downlight	44	3200	0.64	21	Capri Lighting FAE1142U
4 Foot Field Staggered T8 Fluorescent Cove	37	2900	0.68	39	Lightolier T8 K88071

Table 12: Computer Model C1 – High End Jewelry New Luminaire Technology

Luminaire Description	Watts/ Fixture	Fixture Lumens	LLF	Quantity	Reference Identifier
Recessed PAR20 CMH Accent Light	39	2100	0..68	82	473R320S MH 73-4-254T5-E254T5
Single Tube Fluorescent Downlight	42	3200	0..64	21	Capri Lighting FAE1142U
Field Stagger High Lumen Fluorescent Cove	35	3100	0.68	39	GE F32T8XLSPX30HLEC

Model D is a typical designer shop that carries expensive gowns and/or furs. This model is within a larger department store like a Neiman Marcus, Saks or Bloomingdales. Some accent lighting is contributed from the general circulation area outside of the selling space.

Figure 4: Model D Designer Shop (furs, gowns, etc)

Table 13: Computer Model D – Designer Shop Under Title 24-2005

Luminaire Description	Watts/ Fixture	Fixture Lumens	LLF	Quantity	Reference Identifier
Semi-Recessed Adjustable Spot 60W PAR 38 Accent Light	60	1000	0..79	59	Indy 401R10SP
Field Staggered Fluorescent Cove T5	28	2900	0.68	14	Columbia T5 CN4-254-EB5-PAF
Triple Tube CFL Downlight	44	3200	0.64	12	Indy729R-42E-SATS-PGL-CB

Table 14: Computer Model D1 - Designer Shop New Luminaire Technology

Luminaire Description	Watts/ Fixture	Fixture Lumens	LLF	Quantity	Reference Identifier
20W T4 CMH Narrow Spot Reflector Adjustable Accent Light	25	1700	0.68	59	PB3T4MHT4R-20W CMH
Field Staggered Fluorescent Cove T5	28	2900	068	14	Columbia T5 CN4-254-EB5-PAF
42W Triple Tube CFL Downlight	44	3200	0.64	12	Indy729R-42E-SATS-PGL-CB

Models E and E1 are composites of some typical retail store types in a strip mall. The model was constructed to study the interplay of ambient lighting with accent lighting on floor displays or cases. Choices for luminaries were made after observation of over 40 small stores at 5 different strip malls. A specific location was not modeled because of the wide variation in store design. Model E used 42W compact fluorescent luminaries for ambient lighting and Model E1 uses 2x4 T8 fluorescent recessed luminaires. (See Appendix for luminaire details)

Figure 5: Model E Small strip mall retail business (card Shops, flower Shop, hobby store) using 42W recessed CFL luminaires for ambient lighting

Figure 6: Model E1 Small strip mall retail business (Card Shops, Flower Shop, Hobby Store) using 2x4 T8 recessed luminaries for ambient lighting

Table 10: Computer Models E and E1 – Fixtures used in strip mall composite space for sole proprietor

Model	Luminaire Description	Watts/ Fixture	Fixture Lumens	LLF	Quantity	Reference Identifier
E & E1	55W PAR 38 HIR Accent Light	55	1150	0.79	30	Indy Q155R60SP (Modified 55)
E	Triple Tube 42W CFL Downlight with Specular Reflector	48	3200	0.64	24	Lightolier LT 9815
E1	2x4 T8 Troffer	58	5900	0.60	12	U4G-X24-232-28S

Models F - Furniture and Home Accessories is typical of a high mid-range retail establishment. The **Furniture and Home Accessory Model** below has specific illumination requirements because of the large pieces contrasted by smaller accessory items. The model below is an upscale home accessory storn. Track lighting was used throughout the store in combination some puck lights in millwork. Narrow and wide MRC floods were in most locations with a minimum of spot accent lighting. Fluorescent fixtures were only used in the stock areas

Figure 7 Model F Furniture and Home Accessories

Luminaire Schedule					
Symbol	**Qty**	**Label**	**Lumens**	**LLF**	**Description**
	4	M Wall SconcelTL42204	860	1.000	Winona Ltg3202,3302,3402,3702,4101,4111,4420,4421
	63	R T8 Strip 32W Single	2900	0.640	Lightolier fluorescent single strip SN4S132HPF
	5	A Spot 10 Deg	800	0.784	ERCO MR16 37W (50W) 10 Deg Spot 74627023
	115	K 40Deg 37W (50W) MR16	800	0.784	Lightolier Calculite 4in 40Deg 37W (50W) C4MRDCLW
	56	E Narrow Flood 24 Deg	800	0.784	ERCO MR16 37W (50W) 24 Deg Narrow Flood 74627023
	532	H Flood 36 Deg	800	0.784	ERCO Parascan Flood 36 Deg 37W (50W) 72114023
	130	J Flood Double	800	0.784	ERCO Quadra 36 Deg 37W (50W) 88047023

Numeric Summary							
Label	**CalcType**	**Units**	**Avg**	**Max**	**Min**	**Avg/Min**	**Max/Min**
Stockroom_Floor_1	Illuminance	Fc	17.91	42.9	4.2	4.26	10.21
Sales Floor_Floor-WP_1	Illuminance	Fc	55.90	269	0.1	559.00	2690

LPD Area Summary				
Label	**Area**	**Perimeter**	**Total Watts**	**LPD**
Circulation	73.29	44.12	111	1.515
Office	68.54	34.09	36	0.525
Restrooms	137.55	49.86	276.8	2.012
Sales Floor LPD	7114	534.79	30710	4.317
Stock Room LPD	3715	495.41	2269	0.611

Model G: Kitchen Accessories and Tableware Store. The **Kitchen Accessories & Tableware Model** below uses a uniform illumination approach with little accent lighting. The two demonstration areas are highlighted using a combination of directed wall wash fluorescent and down lights. As with the Home Furnishing Model track lighting was used extensively for flexibility.

Figure 8: Model G Kitchen Accessories and Tableware

Table 11: Kitchen Accessories and Tableware - Model Data Summary

Luminaire Schedule						
Symbol	Qty	Label	Lumens	LLF	Watts	Description
	124	A1 72114023_36deg	800	0.784	37	ERCO Parascan Flood 37W (50W) 72114023
	173	B 74627023_24deg	800	0.784	37	ERCO MR16 37W (50W) 24 Deg Narrow Flood 74627023
	36	D 74627023_10deg	800	0.784	37	ERCO MR16 37W (50W) 10 Deg Spot 74627023
	42	F P2GX132S113I	2800	0.680	25	Cooper Metalux 1 DaisyChain 25W (32W) T8 P2GX-132S113I
	16	J 89226023_24deg	800	0.784	37	ERCO Starpoint MR16 37W (50W) NFL 89226023
	10	K C3MRLCLW-37FL	840	0.640	37	Lightolier Lensed WallWash C3MRLCLW
	8	L C4MRGD-37FL	800	0.784	37	Lightolier 37W MR16 Downlight C4MRGD

Numeric Summary							
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min
Vertical South Wall	Illuminance	Fc	30.18	81.0	4.7	6.42	17.23
Marbel Top_Top	Illuminance	Fc	62.23	78.5	47.2	1.32	1.66
Marbel Top_1_Top	Illuminance	Fc	60.94	80.8	26.4	2.31	3.06
Sales Floor_Floor-WP	Illuminance	Fc	51.27	224	0.0	N.A.	N.A.
Stock Room_Floor-WP	Illuminance	Fc	22.17	30.3	4.6	4.82	6.59
Vertical North Wall Illuminance	Illuminance	Fc	34.52	103	5.2	6.64	19.75

LPD Area Summary				
Label	Area	Total Watts	LPD	Perimeter
WS Sales Floor LPD	3040	13579	4.467	234.37
WS Stock Room LPD	1329	950	0.715	179.9

5. New Technology and Design Comparison Computer Models

Partial computer models were also constructed using AGi32 to simulate various accent lighting situations that are encountered in most retail locations. Some of these models have been previously reviewed for Title 24-2005 standards development projects and represented the high efficiency fixtures and lamps used at that time. These include but are not limited to the following three studies:

A. Benya 2001 Study for T24-05 -Vertical Wall Accent Lighting Using CMH Lamps (Benya 2002a, 2002b)

B. Accent Downlight - New vs. Rated Life Comparison

C. Mounting Height vs. Throw Distance

D. All MR16 Design vs. Hybrid (MR16 & Fluorescent Wall-washer) solution

A format similar to Section 4 above was used for each analysis. Our goal was to examine each design model for the best application of the latest lamp technology and determine the strength and weakness of the currently available lamps and luminaires with respect to foot-candle levels as they relate to ceiling (or luminaire) height and/or throw distance.

Study A: Benya 2001 Study – Vertical Wall Accent Lighting Using CMH Lamps

This study duplicated the work done by Benya for T24-2005 standard recommendations. Lamps were placed at 10 feet from the floor with 3 foot spacing 3 feet form the wall and at a 30 degree angle. Foot-candle readings were taken of the vertical surfaces on 3 walls (in an area bounded by a box created by a space 3 feet

from the floor and 3 feet from the ceiling) as well as the floor area within 3 feet of the walls. Model E pictures this study.

Accent Lighting Study using 20W PAR20 CMH spaced at 3 foot intervals at a 30 degree angle

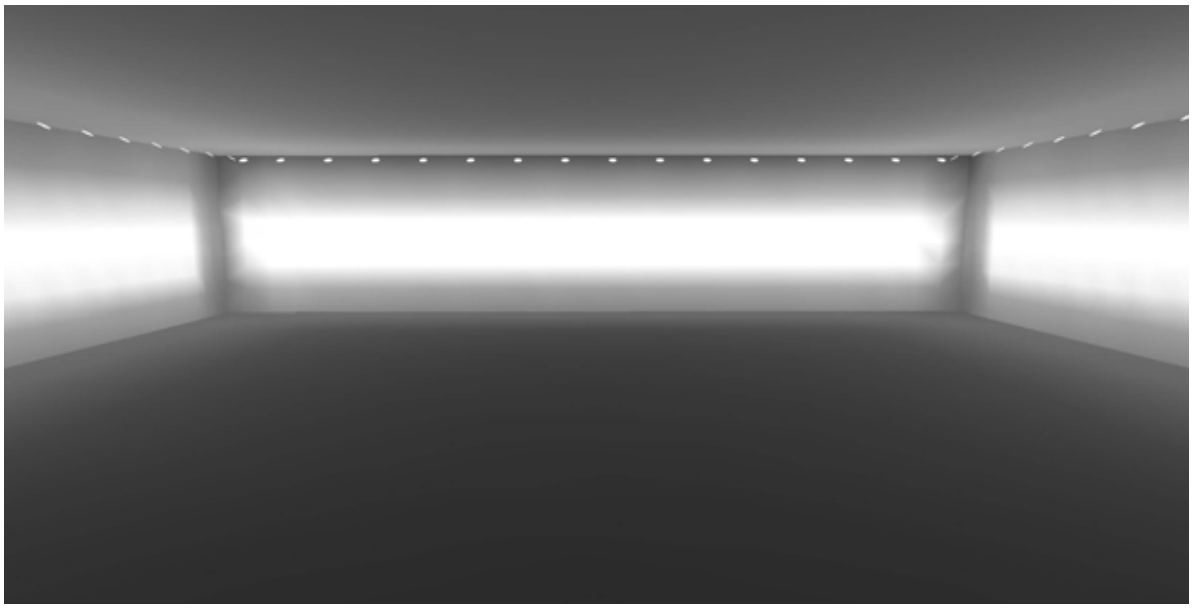


Figure 9: Model F Recreation of 2005 Benya protoype

Table 12: Computer Model F - Recreation of the Benya 2001 Study - Lamp Selection

Luminaire Description	Watts/ Fixture	Fixture Lumens	LLF *	Quantity	Reference Identifier
60W Semi-Recessed Adjustable Incandescent PAR 38 Spot Accent Light	60	1000	1.00	44	Indy 401R10SP
39W PAR30 CMH 10 Degree Spot	44	2000	0.85 *	44	444R-35-SP
20W PAR30 CMH 10 Degree Spot	25	1700	0.85 *	44	MHT 4RS-20W

* Note: Set at 0.85 to adjust for CMH light loss as compared to Halogen lamps.

Study B: Accent Lights - New vs. Rated Life Comparison Re-lamping Intervals

We chose to make a distinction between the re-lamping interval and the lamp manufacturer's term "design limit" (published lamp life) which usually means that point in time when 50% of the lamps are burned out. Re-lamping interval was defined as 80% of the manufacturer's design limit. At this point the burnout curve is just beginning to drop with increased burnout frequency.

Table 13: Computer Model G Accent Lights - Re-lamping Interval (LLF Assumptions)

Luminaire Description	Watts/ Fixture	Fixture Lumens	LLF **	Quantity	Reference Identifier
35W PAR20 CMH 10 Deg Spot	44	2000	0.98	3	440R 35W PAR20 MASTER COLOR
35W PAR20 CMH 10 Deg Spot	44	2000	0.68 **	3	440R 35W PAR20 MASTER COLOR

**Note: LLF represents re-lamping value which is different than Table 12 0.85 100 hour burn in value

Study C: Mounting Height vs. Throw Distance

Table14: Mounting Height vs. Throw Distance Study - Lamping

Luminaire Description	Watts/Fixture	Fixture Lumens	LLF	Quantity	Reference Identifier
CMH Spot Accent Light	44	2400	1.00	1	Lightolier 2500FR
CMH Spot Accent Light	25	1700	1.00	1	Lightolier PB3T4 MHTRS-20W CMH
CMH Spot Accent Light	75	4800	1.00	1	INDY 445R 70W PAR38 CMH 15SP
HIR PAR 38 Accent Light	60	1050	1.00	1	Q150R60CSP
HIR PAR38 Accent Light	80	1500	1.00	1	Q150R80CSP
HIR PAR38 Spot Accent Light	100	2000	1.00	1	

Table15: Mounting Height vs. Throw Distance Study – Layout Grid

Distance From the Wall	Ceiling Height
5 Feet	10 Feet
6 Feet	12 Feet
8 Feet	15 Feet
9 Feet	17 Feet

The ceiling height break points were picked to highlight the current problem of limited wattage offerings for CMH lamps. At the present time there are only 3 CMH lamps are available as substitutes (20W, 39W, 70W) to replace the wide variety of the popular PAR38 lamp for accent lighting. Based on the lumen output of the 39W and the 70W CMH we knew that there would be a gap at certain ceiling heights where the 39W wasn't enough and the 70W would be in excess of the desired foot-candle levels on various targets.

Study D: All MR16 Design vs. Hybrid Design (MR16 & Fluorescent Wall-washers)

This last model, the **Design Comparison** is a mock up of the shelving from the **Kitchen Accessories and Tableware Model**. On the right we recreated the current as built lighting setup. The shelving on the left illustrates the new design employing two fluorescent wall washer fixtures in place of wide floods. We also replaced two floods with spots for tighter center beam illumination.

New Lighting Design MR16 & CFL **As Built Lighting Design MR16 Only**

Total Watts = 218 Total Watts = 296

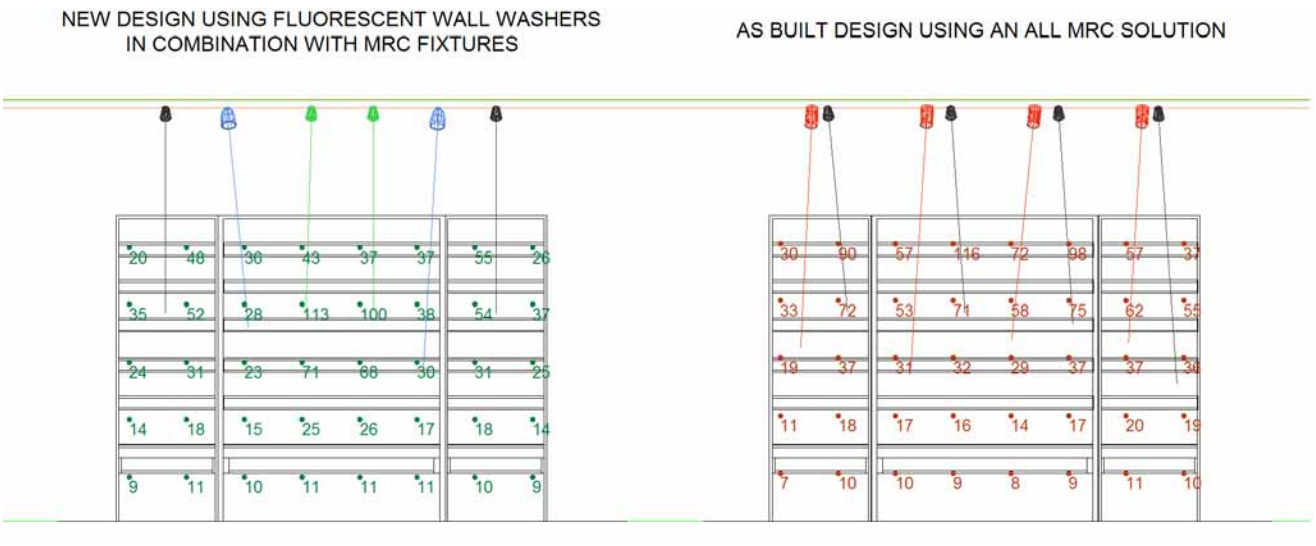
Figure 10: ***Design Comparison Model*** *- All MR16 Solution vs. Hybrid MR16 and Fluorescent Wall-washer Solution*

Table 16: Lighting Design Comparison - Model Data Summary

LPD Area Summary			
Label	**Area**	**Total Watts**	**LPD**
LPD New Design	112.48	218	1.938
LPD As Built WS Design	112.48	296	2.632

Numeric Summary							
Label	**CalcType**	**Units**	**Avg**	**Max**	**Min**	**Avg/Min**	**Max/Min**
As Built Lighting Design	Illuminance	Fc	37.50	116	7	5.36	16.57
New Lighting Design	Illuminance	Fc	32.28	113	9	3.59	12.56

Luminaire Schedule					
Symbol	**Qty**	**Label**	**Lumens**	**LLF**	**Description**
	4	A1 36Deg 37(50)W MRC Flood	800	0.784	ERCO Parascan Flood 37W (50W) 72114023
	6	B 24Deg 37(50)W MRC Narrow Flood	800	0.784	ERCO MR16 37W (50W) 24 Deg Narrow Flood 74627023
	2	W 35W SINGLE CFL	2400	0.680	Lightolier Triple Tube Scoop 32 W 8285WH
	2	V 10Deg Spot 74627023_10deg	800	0.784	ERCO 74627023



New Lighting Design
Total Watts = 218

As Built Lighting Design
Total Watts = 296

Figure 11: Footcandle Values for Lighting Design Comparison

6. Comparative Studies of Title 24-2001 and Title 24-2005

The LPD for challenging retail spaces (high LPD from accent lighting) from previously designed and built stores which met the ASHRAE or Title 24 compliance standards in force at the time was calculated and compared to the recalculated Allowed Lighting Power Density under ASHRAE 90.1 2004 as well as Title 24-2005. Particular emphasis was placed on the ability of 2001 models to pass T 24-2005 using more current technology. This information was then used to extrapolate the possible LPD level recommendations for T 24-2008. To gain further insight into the more rigorous ASHRAE 90.1 2004 standards we chose to use both a strict and loose interpretation of the somewhat ambiguous code dialogue. After T 24-2008 Tailored Method LPD allowances were determined we created an additional spreadsheet using these new criteria as compared to T 24-2005 data.

Controls Evaluation

Lighting controls are an effective way to save energy without impacting the appearance of a space. By its very nature the tailored lighting method is used when designers wish to install higher connected lighting loads. A code requirement for additional controls when the tailored lighting method is used helps minimize the energy impact of this method. In addition, since the lighting power densities are higher in tailored method space, there is more Wattage available to control and this helps accelerate the payback of control systems.

We have selected a prototypical control system for a relatively small 2,500 sf retail space to evaluate the cost-effectiveness of requiring controls that automatically reduce light levels after hours while still providing enough light for stocking and also automatically reduce lighting consumption in stockrooms based on occupancy. Cost savings are discussed in the Results Section.

There can be additional savings achieved by integrating demand response controls into the rest of the controls evaluated here. A demand responsive control is a control that uniformly reduces light levels in the space upon receiving a curtailment signal from the local utility. Most utilities offer a pricing incentive for those who

agree to demand response controls. The benefits and cost-effectiveness of demand response controls is described in the PG&E Demand Response Lighting Controls CASE proposal (PG&E 2006)

Ornamental Lighting Evaluation

Ornamental lighting allowances in both the area category method and the tailored method are based on incandescent light sources. This light source is often a small incandescent lamp. There are now halogen replacements for all of these small lamps. In some cases ornamental lighting includes fairly high wattage incandescent lamps in projectors. In recent years many of these lamps have been replaced with higher efficiency metal halide sources.

Results

1. Interviews with Designers, Contractors, Manufacturers, and End Users

This section summarizes the survey results from all respondents and, where appropriate, compares the responses of the different groups. A total of 50 people were contacted with 46 responding.

Table17: shows the number of completed surveys for each group.

Table17: Tailored Lighitng Survey Participants

Survey Group	No. of Respondents
Manufacturer	19
Designer	14
Agent/Rep/Distributor	5
End User	3
Engineer	3
Electrical/Lighting Maint./Contractor	1
Other	1
Total	46

The results of the survey were analyzed using multiple matrices to determine the central focus of the respondents. A major area of interest was operating and maintenance expenses.

Table18 Summarizes the responses to the survey question*: "What recommendations do you make to your client/customer who wants to reduce lighting operating and maintenance costs?*

Table 18: Frequency of lighting measures recommended to reduce O&M

Theme	ID	No. of Responses
Most/more efficient lamp/fixture	5	26
Use controls	3	16
Appropriate level & need	1	6
Metal halide	6	4
Did not reply to item on survey/said had not time to reply	13	4
Combo	4	3
Longer-life bulbs	7	3
Simplify lamps/fixture types	8	2
No further reductions	11	2
Off when not needed	2	1
Fiber optics	9	1
Use a professional	10	1
Education/training	12	1

Figure 12 represents the distribution of responses to the above question and clearly illustrates that most respondents feel that the best way to reduce operating costs (energy savings) and maintenance costs (lamp replacement) is to use more efficient lamps/fixtures that use less energy and last longer coupled with the use of controls and better design (the correct fixtures aimed properly**.**

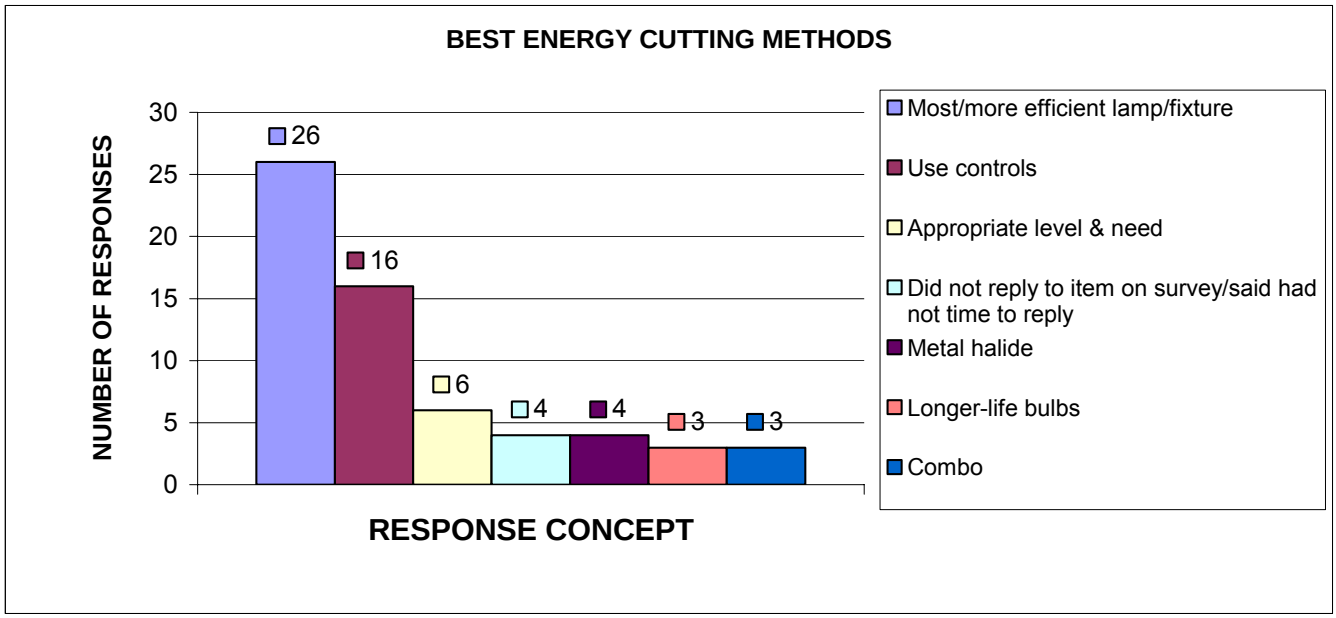


Figure 12: Summary of proposed lighting energy savings measures

Figure 13 through Figure 15 illustrate the analysis of the top three responses to the question, "Which measures offer the most practical/feasible means for achieving LPD reductions?" In Figure 13, 69% of the respondents thought using CMH as the basis for focal/feature display lighting was a good or better than good idea. In contrast in Figure 14, only 15% thought it was good or better to get rid of exceptions. The responses in Figure 15, illustrates that increasing control requirements has wide support, 51% thought this was an excellent idea.

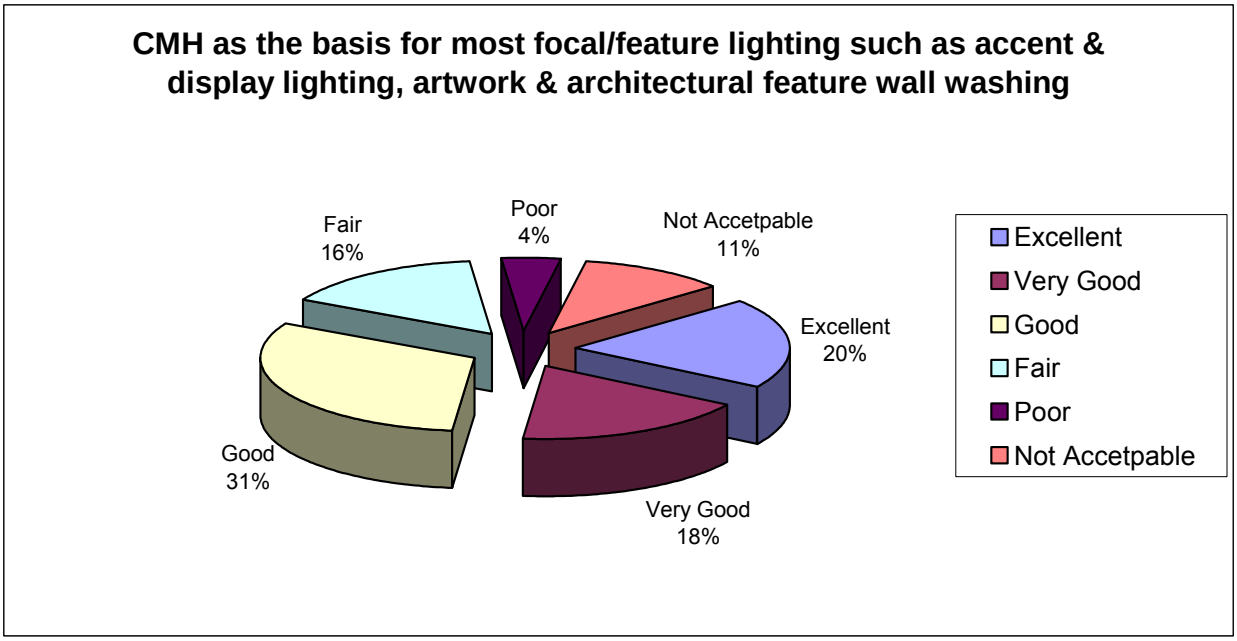


Figure 13 Acceptance of Ceramic Metal Halide (CMH) for focal/feature lighting

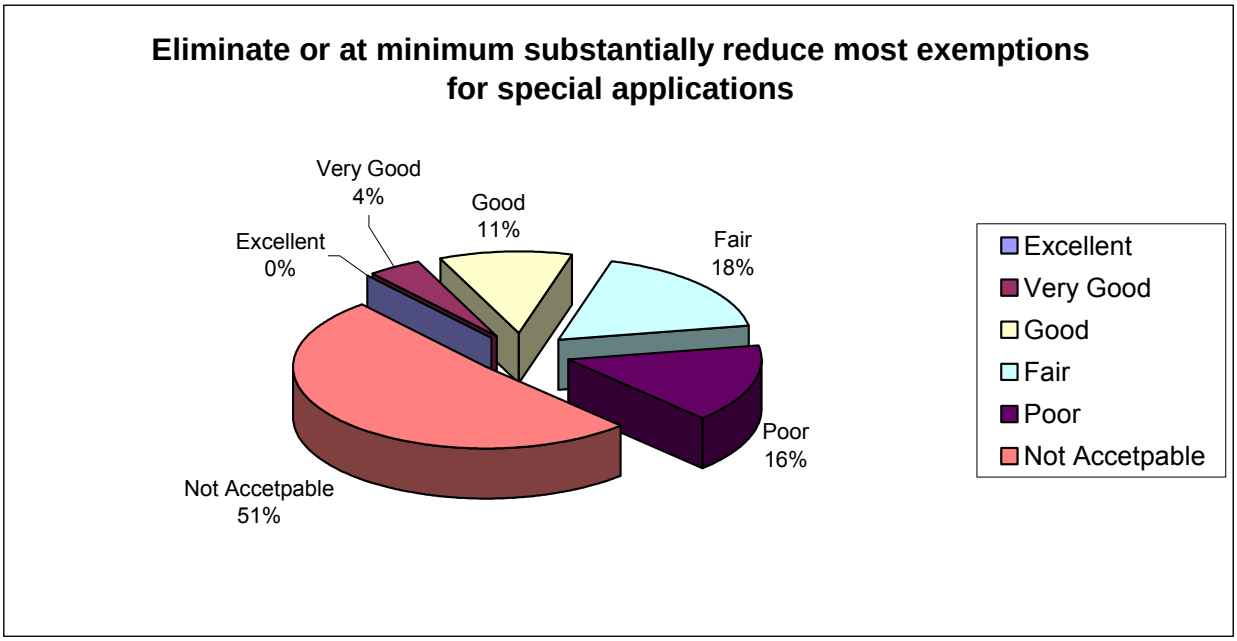


Figure 14 Survey response to substantially reducing exceptions

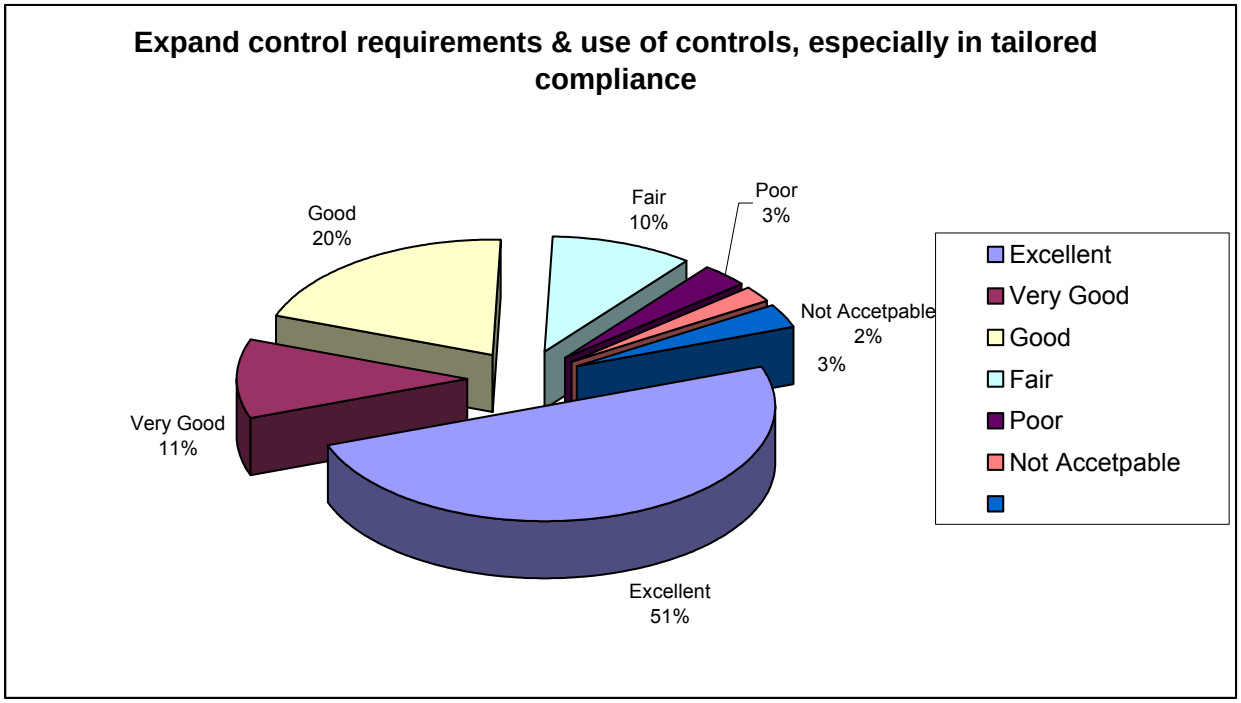


Figure 15: Survey acceptance of expanded control requirements

The need to retain the Tailored Method in Title 24-2008 was apparent from tabulating results from the interview respondents. It is clear from this survey that those questioned are willing to add more controls and move toward CMH as lighting source as long as they can maintain the flexibility of the Tailored Method including certain exemptions where appropriate. The complete survey questions can be found in Appendix 5 – Survey Questions for Designers.

2. Life Cycle Cost Analysis of CMH Lamps

The results of this analysis showed that even at a 7 year cost recovery interval using CMH technology will greatly reduce energy consumption while at the same time be a cost effective solution for the retail establishment. As more stores adopt these newer and currently more expensive technologies prices will drop as volume sales increase. This will further reduce the payback time as we have seen with the introduction of other new lamp technologies in the past. The CMH Cost Analysis Graphs below summarize the comparative cost for operating each lamp type over a 7 year cost recovery period. The three graphs represent comparisons made against a 75W, 120W, and 250W Halogen PAR38 reference lamps and their fixtures. The primary result is that all of the larger CMH lamps are cost-effective as compared to their halogen counterparts. Only the 20 W CMH has a higher life cycle cost than halogen infrared reflecting (HIR) lamps.

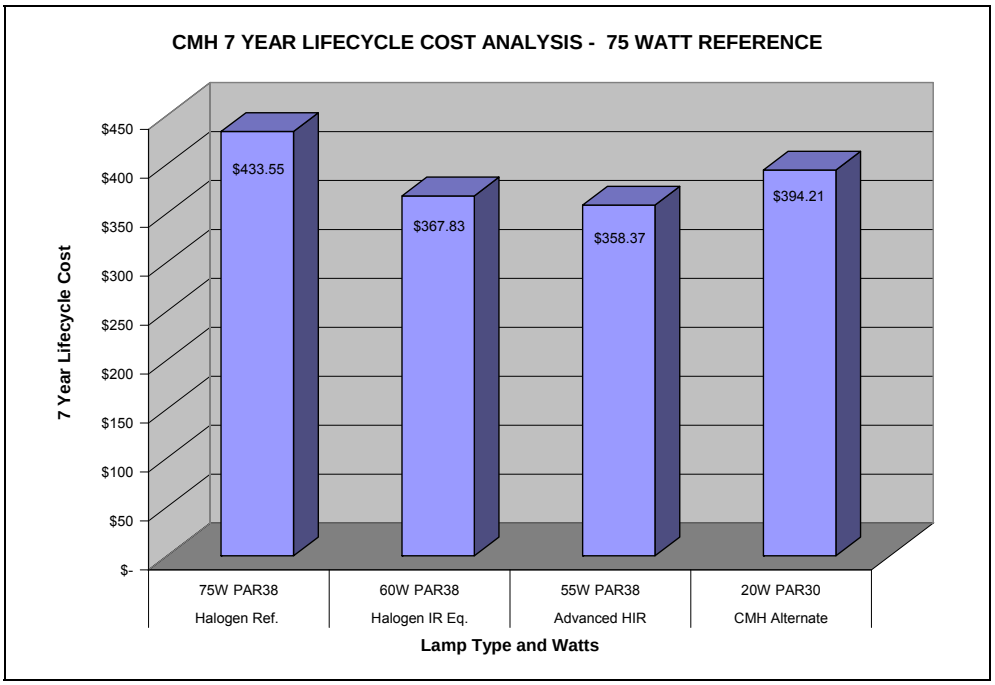


Figure 16 LCC 75 W standard halogen reference lamp to 20 W CMH

Typically a 15 year period of analysis is used for evaluating Title 24 proposals. If this 15 year period of analysis were used, the economics for CMH looks even better than the analysis conducted here over a 7 year time period. However, even with a 15 year period of analysis the 20 W CMH system was not cost effective.

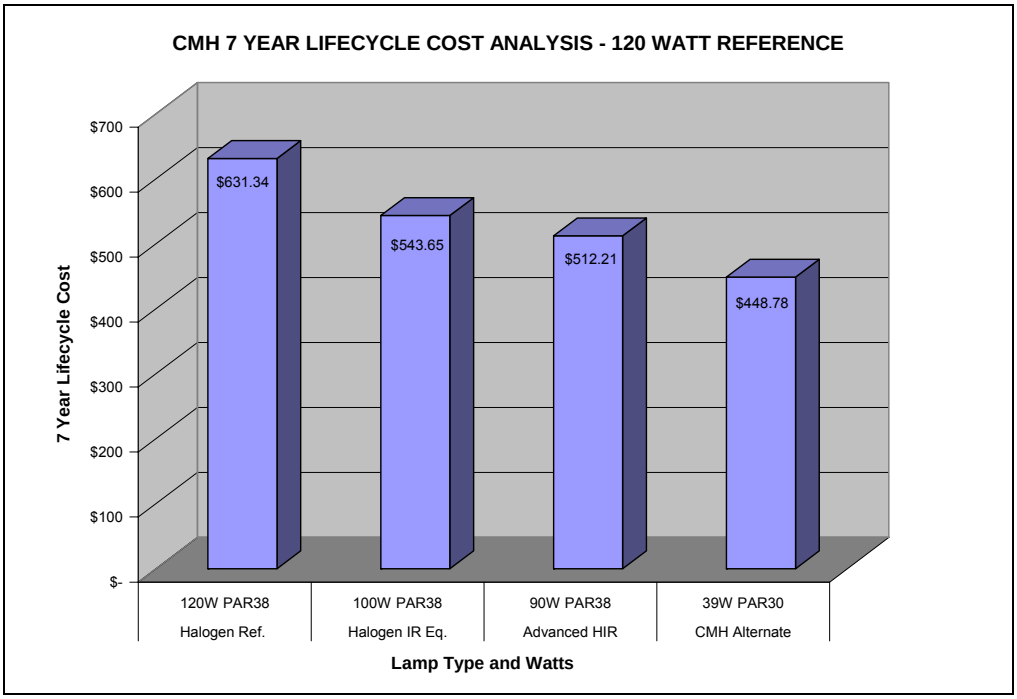


Figure 17 LCC 120 W standard halogen reference to 39 W CMH

It should be noted that 39 Watt CMH lamps used in this comparison have 10° beam spread so that they are comparable in terms of beam spread to the halogen spots with a 10° beam spread. The CMH lamps have similar center-beam candlepower and mean beam candlepower to their halogen equivalents. For more details of the illuminance comparison between these two sources, comparison please see Table 30.

It should be noted that as of 2006, there is less product availability of wattages and beam spreads in CMH than in comparable halogen lamps. Of the three major lamp producers, only one has a 39 W PAR lamp with a 10° beam spread. The other producers have a similar lamp but with a wider beam spread. Thus in the short term, there is less competition among manufacturers for comparable products.

As the wattages of lamps increase, the relative benefit of CMH increases relative to halogen lighting. The life cycle cost of a 70W CMH lighting system is less than half that of a 250 W halogen lighting system with comparable light output.

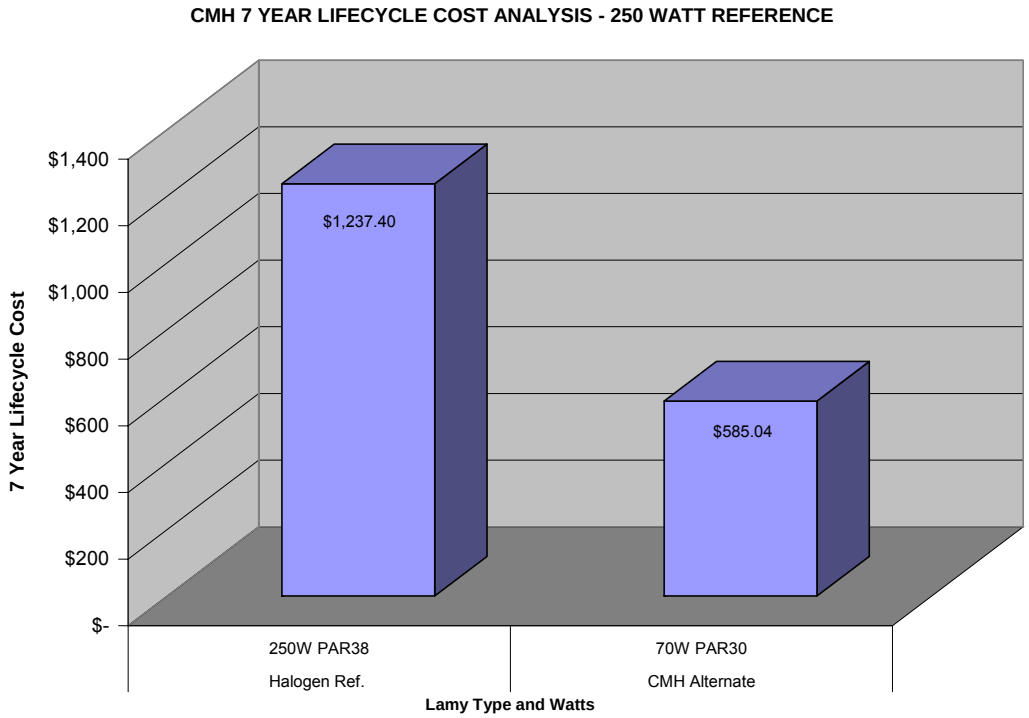


Figure 18 LCC 250 W Halogen reference to 70 W CMH

3. Visual Observation of New Relevant Spaces

A total of 68 retail stores were visually surveyed along with 2 anchor stores at a new mall in Simi Valley, California. A tally was kept of the lamp types in each space. Almost half (44.3%) of the stores observed were using either Ceramic Metal Halide (CMH) or Metal Halide (MH) technology as part of their lighting design. The extent of CMH usage varied between stores, from token lighting in front windows to 100% CMH accent lighting combined with triple tube fluorescent general lighting. This suggests that retail store designers and owners are willing to use this as a light source in place of the more traditional halogen or HIR technology. It further suggests that the high CRI produced by ceramic metal halide renders it acceptable as a light source.

From our observations, however, it was apparent that in some stores CMH was not being used to reduce power consumption but to boost light levels while maintaining the same LPD. When used properly stores that are already comfortable with the CMH lamp will be able to reduce their LPD to comply with this proposal for the Title 24-2008 standards. This assumes that additional lamp wattage categories are made available by the leading lamp manufacturers. Graph 22 below summarizes our observations by placing each store in a category (1 through 5) based on the extent of CMH penetration in the store. Categories1 and 2 have almost no high efficacy sources and would be unlikely to pass the current Title 24 tailored lighting standards,, are poorer than even currently acceptable, 3 is an average installation, and 4 and 5 are above average and should pass Title 24-2005. Level 5 would probably pass the proposed Title 24-2008 standards.

Figure 19 represents the distribution of HID utilization in the stores surveyed using the above grading system. Of the 70 stores surveyed 34 were at a level 4 or 5 which incorporate some level of metal halide or ceramic metal halide lighting. In all likelihood these locations would pass Title 24-2005 with the 7 stores ranked in category 5 probably able to pass the proposed Title 24-2008 standards. A more accurate breakdown of the 5 categories would put 1 at just able to pass T24-2001; 2 has less than 25% advanced T8 and HIR lighting; 3 approximately 50% HIR with a few Metal Halide lamps in windows; category 4 uses at least 60% Metal

Halide or Ceramic Metal Halide fixtures; and 5 is all Ceramic Metal Halide with advanced T8 or compact fluorescent general lighting.

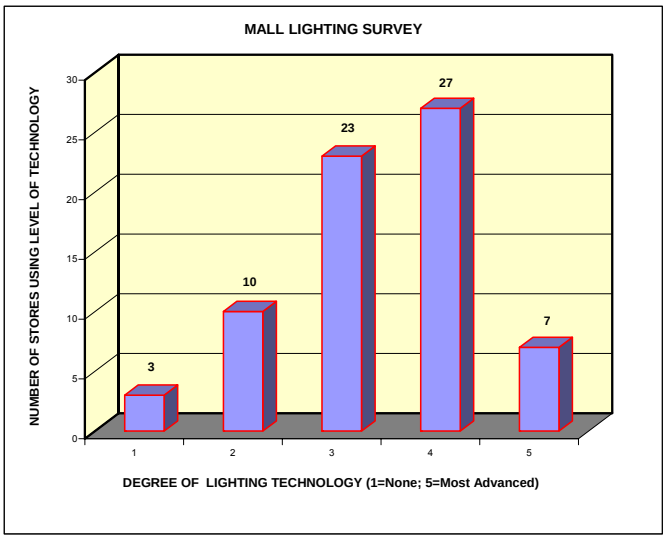


Figure 19 Mall lighting survey – level of efficient technologies

4. Computer Modeling

Table 15: and Table 16: below show the photometry results from the computer modeling of the four selected spaces detailed in the Methodology Section. Each space was studied using two lighting scenarios. The "under Title 24-2005" models (configured to pass the current standards) were compared with the best available "new luminaire technology" concepts in fixture and lamp design to determine if they would pass the proposed Title 24-2008 standards.

It would be helpful at this point to discuss and define the terms "average foot-candles" and "ambient lighting". An average foot-candle measurement is the average of a grid of data points on either vertical, horizontal, or counter top surfaces. Ambient lighting refers to the light in a space from "non accent lighting" and is the general lighting level needed in that space depending on the merchandise and purpose of that space. A high level of accent lighting is usually accompanied by a low level of ambient lighting. When there is little or no accent lighting then the ambient/general lighting serves the dual purpose of lighting the merchandise and the space at the same time.

Table 15: compares the "under Title 24-2005" and "new luminaire technology" foot-candle levels in each model. While the overall goal of reduced LPD was achieved in all cases it was accompanied by a small drop in average foot-candle levels also seen in Table 15: .

We compared the ambient (general) and accent lighting in two models. Both High End Jewelry and Designer Shops (High End Retail) used a high level of accent lighting with reduced general lighting. A similar comparison for Big Box and High Center Atrium stores was not done since these models typically use a high foot-candle level of general lighting (ambient) with little or no accent lighting.

Table 16: summarizes the LPD improvements for each model when "new luminaire technology" was used. Significant positive drops were seen in each of the four models as compared to the "under Title 24-2005" lighting. While achieving these reductions we did sacrifice some foot-candles in each model (Table 15:). This slightly reduced foot-candle level is still well within the RP2 suggested light levels for the modeled spaces. This would suggest that further analysis is needed to determine the foot-candle levels in the important selling spaces and on desired surfaces. It became apparent that an overall reduction in the "average" acceptable foot-candle levels without sacrificing accent lighting levels could be achieved if light was better

directed at the right targets using improved luminaires and/or lamps with narrower beam spread and minimal light loss.

Table 15: Average Foot-candles under existing and proposed Title 24 requirements

ILLUMINANCE IN STORE MODELS - 4 RETAIL SPACES - AGi32 SOFTWARE

	Sales Area (SqFt)	Average Foot-candles at Re-lamping Interval		Average Foot-candles			
				Ambient Only	Accent Only	Ambient Only	Accent Only
		Under Title 24-2005	New Luminaire Technology	Under Title 24-2005		Under Title 24-2008	
Big Box	124,222	62.1	60.8	N/A	N/A	N/A	N/A
High End Jewelry	3,940	79.0	83.7	6.6	72.2	13.9	71.8
High Center Atrium	22,733	52.7	51.2	N/A	N/A	N/A	N/A
Designer Shops	932	67.9	65.9	22.1	45.8	22.4	37.9
Small Retail Shops	1228	76.7	73.9	38.3	38.4	37.6	36.5

Table 16: Lighting Power Density under 2005 Title 24 and with New Technology

LIGHTING POWER DENSITY (LPD) IN STORE MODELS – 4 RETAIL SPACES – AGi32 SOFTWARE

Models	Total Watts		Lighting Power Density (LPD) (W/SqFt)		Percentage Change
	Under Title 24-2005	New Luminaire Technology	Under Title 24-2005	New Luminaire Technology	% Change
Big Box	218,134	150,039	1.76	1.21	-31.3%
High End Jewelry	20,301	7,995	5.15	2.03	-60.5%
High Center Atrium	51,121	48,675	1.69	1.61	-4.7%
Designer Shops	4,535	2,470	4.87	2.65	-45.6%
Small Retail Shops	2802	2322	2.28	1.89	-17.1%

Table 16 is a comparison of computer models of real designs designed specifically to pass Title 24-2005 and then upgraded to pass Title 24-2008. This comparison illustrates that modest changes in lighting technology can substantially reduce the LPD for a space while maintaining the necessary light levels for a selling environment.

Table 17 Comparison of LPD's from New Technology and Proposed 2008 LPD'

RETAIL STORE BASE MODELS USED TO ESTABLISH RECOMMENDED LPD FOR PROPOSED TITLE 24-2008 WHEN COMPARED TO TITLE 24-2005

MODEL	TITLE 24 CALCULATION METHOD	TITLE 24-2005 DESIGN LIGHTING POWER DENSITY			TITLE 24-2005 MAXIMUM ALLOWED POWER DENSITY FOR EACH MODEL GEOMETRY		TITLE 24-2008 DESIGN LIGHTING POWER DENSITY			TITLE 24-2008 (Proposed) MAXIMUM ALLOWED POWER DENSITY FOR EACH MODEL GEOMETRY	
		Watts	Square Feet	W/SqFt	Watts	W/SqFt	Watts	Square Feet	W/SqFt	Watts	W/SqFt
Big Box	AREA	218,134	124,222	*1.76*	186,333	*1.70*	150,039	124,222	*1.21*	186,333	*1.70*
High Center Atrium	AREA	50,759	30,227	*1.68*	51,386	*1.70*	48,675	30,227	*1.61*	51,386	*1.70*
High End Jewelry	TAILORED	20,301	3,940	*5.15*	25,556	*6.49*	7,995	3,940	*2.03*	17,826	*4.52*
Designer (High End Retail)	TAILORED	4,535	932	*4.87*	4,013	*4.31*	2,470	932	*2.65*	3,236	*3.47*
Location Average:		73,432	39,830	*3.36*	66,822	*3.55*	52,295	39,830	*1.87*	64,695	*2.85*

Specialty retail spaces representing the median size store were added to this study in response to stakeholder concerns about unique lighting needs. This data is summarized in the following tables. The results summary for Models F and G is twofold. First we compare the LPD of the various designs as they relate to Title 24-2005 and 2008 allowed LPD. Only one design meets the T 24-2005 or 2008 code requirements. We then modified the designs to meet the proposed 2008 LPD and the second table shows the resulting changes in the connected load.

Table 18 Model F: Kitchen Accessories & Tableware Store Title 24 Compliance Data

Store Area	Lighting Category	Title 24 Allowed Power W/SqFt		Area (SqFt)	LPD Allowed Under 2005	As Built Pre '05 Installed Power (Watts)	LPD Allowed Under Proposed T24-2008	Lighting Designed to Pass T24-2008
		2005 Current	2008 Proposed					
Sales Floor			PG&E				PG&E	
	General	0.9	0.9	3040	2,736		2,736	
	Wall Display (Perimeter Linear Feet)	21	16	234	4,914		3,744	
	Allowed Floor Display (1.10)	1.5	1.1	3040	4,560		3,344	
	Allowed Ornamental @ 30%	0.7	0.6	912	638		547	
	Display Case Lighting	1.3	0.9	0	0		0	
Back Area	Active Stock	0.9	0.9	1329	1,196		1,196	
	Office	1.3	1.3	75	98		98	
	Restrooms	0.7	0.7	120	84		84	
	Total Area (SqFt)			4564				
Summary	Totals Watts Allowed or Installed				14,226	14,529	11,749	10,546
	Lighting Power Density (W/SqFt)				**3.12**	**3.18**	**2.57**	**2.31**

Table 19: Fixture Modifications to Kitchen and Tableware Store Model

KITCHEN ACCESSORIES AND TABLEWARE STORE DESIGN MODIFICATIONS MADE TO PASS T24-2008 WHILE MAINTAINING RP2 LIGHTING STANDARDS			
StockRoom	Daisy Chain to reduce to 25W / Fixture	266	684
MRC16 Spot	Maintained same number of spots		1,332
Double Biax Wall Washer 39W	Replaced most floods with 64 32W wall washers		2,240
MRC 37W 24deg Flood	Reduced the numer of 24 degree floods to 120		4,440
MRC 37W 36deg Flood	Reduced the numer of 36 degree floods to 50		1,850
Current Power Consumption			14,529
NET ENERGY USAGE			10,546

Table 20: Model G: Furniture & Home Accessory Store Title 24 Compliance Data

Store Area	Lighting Category	Title 24 Allowed Power W/SqFt		Area (SqFt)	LPD Allowed Under 2005	As Built Pre '05 Installed Power (Watts)	LPD Allowed Under Proposed T24-2008	Lighting Designed to Pass T24-2008
		2005 Current	2008 Proposed					
Sales Floor			PG&E				PG&E	
	General	0.9	0.9	7,114	6,403		6,403	
	Wall Display (Perimeter Linear Feet)	21	16	958	20,118		15,929	
	Allowed Floor Display	1.5	1.1	7,114	10,671		7,825	
	Allowed Ornamental @ 30%	0.7	0.6	0	0		0	
	Display Case Lighting	1.3	0.9	0	0		0	
Back Area	Active Stock	0.9	0.9	3,715	3,344		3,344	
	Office	1.3	1.3	68	88		88	
	Restrooms	0.7	0.7	138	97		97	
	Circulation	0.9	0.9	73	66		66	
Summary	Totals:			11,108	40,720	34,363	33,686	32,706
	Lighting Power Density (W/SqFt)				**3.67**	**3.09**	**3.03**	**2.94**

Table 21: Furniture and Home Accessory Modifications Made to Model

FURNITURE & HOME ACCESSORY STORE DESIGN MODIFICATIONS MADE TO PASS T24-2008 WHILE MAINTAINING RP2 LIGHTING STANDARDS			
Fixture Type	**# Fixtures**	**Watts**	**Total Watts**
MRC 37W 24deg Flood	56	37	2,072
MRC 37W 36deg Flood	486	37	17,982
MRC 37W 40deg Flood 4in Fixture	245	37	9,065
21W Fluorescent Strip	52	21	1,092
T8 Fluorescent Strip 32W for Stock Room Daisy Chain	63	25	1,575
MRC 20W 36deg Flood	46	20	920
Store Total Watts			**32,706**

Computer Model Cost Analysis

The model cost analysis indicates that a new design which incorporates advanced technology into the project will not have any adverse effect on light levels and will impact annual operating cost with a reduction in annual energy expenses. For this scenario operating savings over the seven year period will offset any first cost increases and still provide the desired reduction in LPD and save money. New technology lighting was compared to the "under Title 24-2005" lighting comparing the various costs for the design and combining all luminaire first and operating costs for each design before the final cost comparison was made. In each case a savings was achieved in the seven year cost recovery period. A composite model of a strip mall store was also included in our analysis so we could analyze the effect of the proposed Title 24-2008 changes on small sole proprietor retail businesses. Using low cost current technology solutions will reduce energy usage and save the small business owner lighting dollars.

Table 22: Big Box LCC Analysis

BIG BOX STORE COST ANALYSIS FROM COMPUTER MODEL - HIGH VOLUME LAMP PURCHASE - 7 YEAR COST RECOVERY CYCLE

Computer Model	Big Box Store			
	Under Title 24-2005		Under Title 24-2008	
Lamp Type	Two 4 Foot T8 Fluorescent Electronic Ballast	Pulse Start HiBay MH Mag Ballast	1 T5/HO Fluorescent Electronic Ballast	6 Lamp T5/H0 Fluorescent SpecReflec
Lamp Watts	32	400	54	54
Fixture Lumens	2,950	36,000	5,000	30,000
Fixture Watts	80	439	54	324
Total Number of Luminaires	63	452	63	452
Total Watts	5,040	198,428	3,402	146,448
Operating Hours/yr	3,910	3,910	3,910	3,910
A/C interaction effect	0.15	0.15	0.15	0.15
Period of Analysis (Years)	7	7	7	7
Elec Consumption kWh/yr	22,662	892,232	15,297	658,503
Elec Consumption TDV kBtu	454,325	17,887,052	306,669	13,201,378
Annual Elec Costs	$ 3,210.62	$ 126,404.22	$ 2,167.17	$ 93,291.50
PV Electric Costs PV$	$ 20,003.08	$ 787,534	$ 13,502.08	$ 581,232
Avg elec cost $/kWh	$ 0.14	$ 0.14	$ 0.14	$ 0.14
Total Number of Luminaires	63	452	63	452
Fixture Cost	$ 55.00	$ 170.00	$ 55.00	$ 180.00
Lamp Cost Total for Luminaire	$ 12.00	$ 30.00	$ 8.00	$ 48.00
First Cost of Luminaires By Type	$ 4,221.00	$ 90,400.00	$ 3,969.00	$ 103,056.00
A/C tons	0.023	0.125	0.015	0.092
First Cost AC	$ 34.13	$ 187.29	$ 23.04	$ 138.23
Total First Cost PV$	$ 4,255.13	$ 90,587.29	$ 3,992.04	$ 103,194.23
Relamping labor	$ 1.60	$ 1.60	$ 1.60	$ 4.80
Total Lamp replacement cost including labor	$ 856.80	$ 14,283.20	$ 604.80	$ 23,865.60
Lamp Life (burning hr)	10,000	10,000	10,000	10,000
Maintenance Cost PV $	$ 1,501.65	$ 25,033.11	$ 1,059.99	$ 41,827.47
Life Cycle Cost (LCC) PV$	$ 25,760	$ 903,154	$ 18,554	$ 726,254
Design Life Cycle Cost (DLCC) PV$		**$ 928,914**		**$ 744,808**

Table 23: High Center Atrium Store Model LCC Analysis

HIGH CENTER ATRIUM RETAIL STORE COST ANALYSIS FROM COMPUTER MODEL
HIGH VOLUME LAMP PURCHASE - 7 YEAR COST RECOVERY CYCLE

Computer Model	High Center Atrium Store											
	Under Title 24-2005					Under Title 24-2008						
Lamp Type	Pulse Start Metal Halide w/ Specular Reflector	2x2 3 Lamp Triple Tube Fluorescent Parabolic 9 Cell	4 Ft. T8 w/ Electronic Ballast Wallwasher	Single Triple Tube Horizontal Fluorescent	Fluorescent Decorative Chandelier	Pulse Start Metal Halide w/ Specular Reflector	2 42W Triple Tube Compact Flourescent Horiz Mounting	CMH w/ Electronic Ballast 8" Reflector	2x2 TwoTube Fluorescent Parabolic 9 Cell	Single T5 Assymetrical Specular Reflec Wall Washer	1 42W Triple Tube Compact Flourescent Horiz Mounting	Fluorescent Decorative Chandelier
Lamp Watts	70	40	28	42	na.	100	42	150	40	28	42	na.
Fixture Lumens	5,700	9,450	2,800	3,200	27,750	6,600	6,400	14,000	6,300	2,900	3,200	27,750
Fixture Watts	79	102	32	44	237	110	88	172	88	34	44	237
Total Number of Luminaires	181	154	139	149	5	37	29	68	154	139	104	5
Total Watts	14,299	15,708	4,448	6,556	1,185	4,070	2,552	11,696	13,552	4,726	4,576	1,185
Operating Hours/yr	3,910	3,910	3,910	3,910	3,910	3,910	3,910	3,910	3,910	3,910	3,910	3,910
A/C interaction effect	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Period of Analysis (Years)	7	7	7	7	7	7	7	7	7	7	7	7
Elec Consumption kWh/yr	64,295	70,631	20,000	29,479	5,328	18,301	11,475	52,591	60,937	21,250	20,576	5,328
Elec Consumption TDV kBtu	1,288,966	1,415,979	400,960	590,983	106,820	366,885	230,047	1,054,322	1,221,629	426,020	412,498	106,820
Annual Elec Costs	$ 9,108.87	$ 10,006.44	$ 2,833.50	$ 4,176.36	$ 754.88	$ 2,592.70	$ 1,625.70	$ 7,450.68	$ 8,633.01	$ 3,010.60	$ 2,915.04	$ 754.88
PV Electric Costs PV$	$ 56,750.81	$ 62,343	$ 17,653.51	$ 26,019.88	$ 4,703.11	$ 16,153.28	$ 10,128.55	$ 46,419.85	$ 53,786.07	$ 18,756.86	$ 18,161.53	$ 4,703.11
Avg elec cost $/kWh	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14
Total Number of Luminaires	181	154	139	149	5	37	29	68	154	139	104	5
Fixture Cost	$ 170.00	$ 55.00	$ 55.00	$ 80.00	$ 2,000.00	$ 220.00	$ 80.00	$ 220.00	$ 55.00	$ 100.00	$ 55.00	$ 2,000.00
Lamp Cost Total for Luminaire	$ 30.00	$ 24.00	$ 5.00	$ 6.50	$ 45.50	$ 35.00	$ 13.00	$ 35.00	$ 16.00	$ 8.50	$ 6.50	$ 45.50
First Cost of Luminaires By Type	$ 36,200.00	$ 12,166.00	$ 8,340.00	$ 12,888.50	$ 10,227.50	$ 9,435.00	$ 2,697.00	$ 17,340.00	$ 10,934.00	$ 15,081.50	$ 6,396.00	$ 10,227.50
A/C tons	4.067	4.468	1.265	1.865	0.337	1.158	0.726	3.327	3.854	1.344	1.301	0.337
First Cost AC	$ 6,100.31	$ 6,701.43	$ 1,897.63	$ 2,796.95	$ 505.55	$ 1,736.36	$ 1,088.75	$ 4,989.81	$ 5,781.62	$ 2,016.23	$ 1,952.24	$ 505.55
Total First Cost PV$	$ 42,300.31	$ 18,867.43	$ 10,237.63	$ 15,685.45	$ 10,733.05	$ 11,171.36	$ 3,785.75	$ 22,329.81	$ 16,715.62	$ 17,097.73	$ 8,348.24	$ 10,733.05
Relamping labor	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60
Total Lamp replacement cost including labor	$ 5,719.60	$ 3,942.40	$ 917.40	$ 1,206.90	$ 235.50	$ 1,354.20	$ 423.40	$ 2,488.80	$ 2,710.40	$ 1,403.90	$ 842.40	$ 235.50
Lamp Life (burning hr)	10,000	10,000	10,000	10,000	10,000	12,000	10,000	12,000	10,000	10,000	10,000	10,000
Maintenance Cost PV $	$ 10,024.32	$ 6,909.55	$ 1,607.86	$ 2,115.24	$ 412.74	$ 2,304.28	$ 742.06	$ 4,234.89	$ 4,750.32	$ -	$ -	$ -
Life Cycle Cost (LCC) PV$	$ 109,075	$ 88,120	$ 29,499	$ 43,821	$ 15,849	$ 29,629	$ 14,656	$ 72,985	$ 75,252	$ 35,855	$ 26,510	$ 15,436
Design Life Cycle Cost (DLCC) PV$					$ 286,364							$ 270,322

Table 24: High End Jewelry Store Model LCC Analysi

HIGH END JEWELRY STORE COST ANALYSIS FROM COMPUTER MODEL - HIGH VOLUME LAMP PURCHASE - 7 YEAR COST RECOVERY CYCLE

Computer Model	High End Jewelry Store					
	Under Title 24-2005			Under Title 24-2008		
Lamp Type	PAR30 Halogen IR Accent Spot	T8 4 Foot Advanced Electronic Ballast	Triple Tube Biax Fluorescent Downlight	PAR20 CMH Accent Spot	Triple Tube Biax Fluorescent Downlight	T5 4 Foot Electronic Ballast Cove Light
Lamp Watts	75	32	42	39	42	28
Fixture Lumens	1,000	2,950	3,200	2,100	3,200	2950
Fixture Watts	75	37	44	39	44	28
Total Number of Luminaires	238	39	28	160	24	39
Total Watts	17850	1443	1232	6240	1056	1092
Operating Hours/yr	3910	3910	3910	3910	3910	3910
A/C interaction effect	0.15	0.15	0.15	0.15	0.15	0.15
Period of Analysis (Years)	7	7	7	7	7	7
Elec Consumption kWh/yr	80,263	6,488	5,540	28,058	4,748	4,910
Elec Consumption TDV kBtu	1,609,067	130,077	111,057	562,497	95,192	98,437
Annual Elec Costs	$ 11,370.95	$ 919.23	$ 784.82	$ 3,975.06	$ 672.70	$ 695.63
PV Electric Costs PV$	$ 70,844.25	$ 5,727.07	$ 4,889.64	$ 24,765.72	$ 4,191.12	$ 4,334.00
Avg elec cost $/kWh	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14
Total Number of Luminaires	238	39	28	160	24	39
Fixture Cost	$ 55.00	$ 30.00	$ 55.00	$ 170.00	$ 55.00	$ 55.00
Lamp Cost Total for Luminaire	$ 6.50	$ 6.00	$ 8.50	$ 30.00	$ 8.50	$ 8.50
First Cost of Luminaires By Type	$ 14,637.00	$ 1,404.00	$ 1,778.00	$ 32,000.00	$ 1,524.00	$ 2,476.50
A/C tons	0.021	0.011	0.013	0.011	0.013	0.008
First Cost AC	$ 32.00	$ 15.79	$ 18.77	$ 16.64	$ 18.77	$ 11.95
Total First Cost PV$	$ 14,669.00	$ 1,419.79	$ 1,796.77	$ 32,016.64	$ 1,542.77	$ 2,488.45
Relamping labor	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60
Total Lamp replacement cost including labor	$ 1,927.80	$ 296.40	$ 282.80	$ 5,056.00	$ 10.10	$ 10.10
Lamp Life (burning hr)	2,500	10,000	10,000	9,000	10,000	10,000
Maintenance Cost PV $	$ 17,155.20	$ 519.48	$ 495.64	$ 13,099.30	$ 17.70	$ 17.70
Life Cycle Cost (LCC) PV$	$ 102,668	$ 7,666	$ 7,182	$ 69,882	$ 5,752	$ 6,840
Design Life Cycle Cost (DLCC) PV$			**$ 117,517**			**$ 82,473**

Table 25: High end retail store model LCC analysis

HIGH END RETAIL (DESIGNER) STORE COST ANALYSIS FROM COMPUTER MODEL - HIGH VOLUME LAMP PURCHASE - 7 YEAR COST RECOVERY CYCLE

Computer Model	High End Retail (Designer) Shop					
	Under Title 24-2005			Under Title 24-2008		
Lamp Type	Halogen IR PAR38 ACCENT	4 Foot T5 Fluorescent w/ Electronic Ballast	8" Single Triple Tube Horizontal Fluorescent	20W CMH PAR30	8" Single Triple Tube Horizontal Fluorescent	4 Foot T5 Fluorescent w/ Electronic Ballast
Lamp Watts	60	28	42	20	44	28
Fixture Lumens	1,000	2,900	3,200	1,700	3,200	2,900
Fixture Watts	60	28	44	25	44	28
Total Number of Luminaires	59	14	14	59	14	14
Total Watts	3,540	392	616	1,475	616	392
Operating Hours/yr	3910	3910	3910	3910	3910	3910
A/C interaction effect	0.15	0.15	0.15	0.15	0.15	0.15
Period of Analysis (Years)	7	7	7	7	7	7
Elec Consumption kWh/yr	15,918	1,763	2,770	6,632	2,770	1,763
Elec Consumption TDV kBtu	319,109	35,336	55,529	132,962	55,529	35,336
Annual Elec Costs	$ 2,255.08	$ 249.72	$ 392.41	$ 939.62	$ 392.41	$ 249.72
PV Electric Costs PV$	$ 14,049.78	$ 1,556	$ 2,444.82	$ 5,854	$ 2,444.82	$ 1,555.80
Avg elec cost $/kWh	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14
Total Number of Luminaires	59	14	12	59	12	14
Fixture Cost	$ 55.00	$ 55.00	$ 55.00	$ 170.00	$ 55.00	$ 55.00
Lamp Cost Total for Luminaire	$ 6.50	$ 6.50	$ 8.50	$ 30.00	$ 8.50	$ 6.50
First Cost of Luminaires By Type	$ 3,628.50	$ 861.00	$ 762.00	$ 11,800.00	$ 762.00	$ 861.00
A/C tons	0.017	0.008	0.013	0.007	0.013	0.008
First Cost AC	$ 25.60	$ 11.95	$ 18.77	$ 10.67	$ 18.77	$ 11.95
Total First Cost PV$	$ 3,654.10	$ 872.95	$ 780.77	$ 11,810.67	$ 780.77	$ 872.95
Relamping labor	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60
Total Lamp replacement cost including labor	$ 477.90	$ 113.40	$ 121.20	$ 1,864.40	$ 121.20	$ 113.40
Lamp Life (burning hr)	2,500	10,000	10,000	9,000	10,000	10,000
Maintenance Cost PV $	$ 4,252.76	$ 198.75	$ 212.42	$ 4,830.37	$ 212.42	$ 198.75
Life Cycle Cost (LCC) PV$	$ 21,957	$ 2,627	$ 3,438	$ 22,495	$ 3,438	$ 2,627
Design Life Cycle Cost (DLCC) PV$			**$ 28,022**			**$ 28,561**

Table 26: Strip Mall composite model for sole proprietor small business

STRIP MALL STORE COST ANALYSIS FROM COMPUTER MODEL - LOW VOLUME LAMP PURCHASE - 7 YEAR COST RECOVERY CYCLE

Computer Model	STRIP MALL Store			
Lamp Type	Single Triple Tube 42W CFL		2X4 Double T8 Troffer	
	60W PAR38 Spot HIR	Single 42W Triple Tube CFL Vertical	60W PAR38 Spot HIR	2x4 Double Tube T8
Lamp Watts	60	42	60	32
Fixture Lumens	1,150	3,200	1,150	5,900
Fixture Watts	60	48	60	56
Total Number of Luminaires	23	24	23	12
Total Watts	1,380	1,152	1,380	672
Operating Hours/yr	3,910	3,910	3,910	3,910
A/C interaction effect	0.15	0.15	0.15	0.15
Period of Analysis (Years)	7	7	7	7
Elec Consumption kWh/yr	6,205	5,180	6,205	3,022
Elec Consumption TDV kBtu	124,398	103,846	124,398	60,577
Annual Elec Costs	$ 879.10	$ 733.86	$ 879.10	$ 428.08
PV Electric Costs PV$	$ 5,477.03	$ 4,572	$ 5,477.03	$ 2,667
Avg elec cost $/kWh	$ 0.14	$ 0.14	$ 0.14	$ 0.14
Total Number of Luminaires	23	24	23	12
Fixture Cost	$ 55.00	$ 55.00	$ 55.00	$ 72.00
Lamp Cost Total for Luminaire	$ 6.50	$ 8.50	$ 6.50	$ 10.00
First Cost of Luminaires By Type	$ 1,414.50	$ 1,524.00	$ 1,414.50	$ 984.00
A/C tons	0.017	0.014	0.017	0.016
First Cost AC	$ 25.60	$ 20.48	$ 25.60	$ 23.89
Total First Cost PV$	$ 1,440.10	$ 1,544.48	$ 1,440.10	$ 1,007.89
Relamping labor	$ 1.60	$ 1.60	$ 1.60	$ 4.80
Total Lamp replacement cost including labor	$ 186.30	$ 242.40	$ 186.30	$ 177.60
Lamp Life (burning hr)	3,000	6,000	3,000	12,000
Maintenance Cost PV $	$ 1,477.71	$ 850.04	$ 1,477.71	$ 302.20
Life Cycle Cost (LCC) PV$	$ 8,395	$ 6,967	$ 8,395	$ 3,977
Design Life Cycle Cost (DLCC) PV$		**$ 15,361**		**$ 12,372**

Table 27: Kitchen Accessories &Tableware Store Model Cost Analysis

KITCHEN ACCESSORIES & TABLEWARE STORE
COST ANALYSIS FROM COMPUTER MODEL - HIGH VOLUME LAMP PURCHASE - 7 YEAR COST RECOVERY CYCLE

Computer Model	Kitchen Accessories and Tableware Store									
	Current Design Under Title 24-2005			Alternate Designs Passing Under Title 24-2008						
Lamp Type	36deg Flood MRC 37W	24deg Flood MRC 37W	10deg Spot MRC 37W	MR16 CMH 36deg Flood	MR16 CMH 24deg Flood	MR16 CMH Spot	36deg Flood MRC 37W	24deg Flood MRC 37W	10deg Spot MRC 37W	32W Fluorescent Wall Washer
Lamp Watts	37	37	37	20	20	20	37	37	37	32
Fixture Lumens	800	800	800	1,000	1,000	1,000	800	800	800	2,900
Fixture Watts	37	37	37	25	25	25	37	37	37	35
Total Number of Luminaires	124	173	36	124	173	36	50	120	36	64
Total Watts	4588	6401	1332	3100	4325	900	1850	4440	1332	2240
Operating Hours/yr	3910	3910	3910	3910	3910	3910	3910	3910	3910	3910
A/C interaction effect	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Period of Analysis (Years)	7	7	7	7	7	7	7	7	7	7
Elec Consumption kWh/yr	20,630	28,782	5,989	13,939	19,447	4,047	8,319	19,964	5,989	10,072
Elec Consumption TDV kBtu	413,580	577,010	120,072	279,446	389,872	81,129	166,766	400,238	120,072	201,922
Annual Elec Costs	$ 2,922.69	$ 4,077.62	$ 848.52	$ 1,974.79	$ 2,755.15	$ 573.33	$ 1,178.50	$ 2,828.41	$ 848.52	$ 1,426.94
PV Electric Costs PV$	$ 18,209.16	$ 25,404.71	$ 5,286.53	$ 12,303.48	$ 17,165.34	$ 3,571.98	$ 7,342.40	$ 17,621.76	$ 5,286.53	$ 8,890.26
Avg elec cost $/kWh	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14
Total Number of Luminaires	124	173	36	124	173	36	50	120	36	64
Fixture Cost	$ 60.00	$ 60.00	$ 60.00	$ 125.00	$ 125.00	$ 125.00	$ 60.00	$ 60.00	$ 60.00	$ 95.00
Lamp Cost Total for Luminaire	$ 10.00	$ 10.00	$ 10.00	$ 25.00	$ 25.00	$ 25.00	$ 10.00	$ 10.00	$ 10.00	$ 20.00
First Cost of Luminaires By Type	$ 8,680.00	$ 12,110.00	$ 2,520.00	$ 18,600.00	$ 25,950.00	$ 5,400.00	$ 3,500.00	$ 8,400.00	$ 2,520.00	$ 7,360.00
Total Luminaire First Cost			**$ 23,310.00**			**$ 49,950.00**				**$ 21,780.00**
A/C tons	0.011	0.011	0.011	0.007	0.007	0.007	0.011	0.011	0.011	0.010
First Cost AC	$ 15.79	$ 15.79	$ 15.79	$ 10.67	$ 10.67	$ 10.67	$ 15.79	$ 15.79	$ 15.79	$ 14.93
Total First Cost PV$	$ 8,695.79	$ 12,125.79	$ 2,535.79	$ 18,610.67	$ 25,960.67	$ 5,410.67	$ 3,515.79	$ 8,415.79	$ 2,535.79	$ 7,374.93
Relamping labor	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60
Total Lamp replacement cost including labor	$ 1,438.40	$ 2,006.80	$ 417.60	$ 3,298.40	$ 4,601.80	$ 957.60	$ 580.00	$ 1,392.00	$ 417.60	$ 1,382.40
Lamp Life (burning hr)	4,000	4,000	4,000	9,000	9,000	9,000	4,000	4,000	4,000	12,000
Maintenance Cost PV $	$ 7,565.13	$ 10,554.58	$ 2,196.33	$ 8,545.63	$ 11,922.54	$ 2,480.99	$ 3,050.46	$ 7,321.10	$ 2,196.33	$ 2,352.26
Life Cycle Cost (LCC) PV$	$ 34,470	$ 48,085	$ 10,019	$ 39,460	$ 55,049	$ 11,464	$ 13,909	$ 33,359	$ 10,019	$ 18,617
Design Life Cycle Cost (DLCC) PV$			**$ 92,574**			**$ 105,972**				**$ 75,903.39**

Note that there is an immediate first cost savings for the lower priced fluorescent wall wash solution as well as a substantial savings after 7 years.

Table 28: Furniture & Home Accessories Store Model Cost Analysis

FURNITURE & HOME ACCESSORY STORE COST ANALYSIS FROM COMPUTER MODEL HIGH VOLUME LAMP PURCHASE - 7 YEAR COST RECOVERY CYCLE

Computer Model	Furniture and Decorating Accessories Store								
	Current Design Under Title 24-2005				Alternate Design Passing Under Proposed Title 24-2008				
Lamp Type	MRC 37W 24deg Flood	MRC 37W 36deg Flood	MRC 37W 40deg Flood 4in Fixture	T8 Fluorescent Strip 32W for Stock Room	MRC 37W 24deg Flood	MRC 37W 36deg Flood	MRC 37W 40deg Flood 4in Fixture	21W Fluorescent Strip	T8 Fluorescent Strip 32W for Stock Room Daisy Chain
Lamp Watts	37	37	37	32	37	37	37	21	28
Fixture Lumens	800	800	800	5,800	800	800	800	1,980	2,650
Fixture Watts	37	37	37	64	37	37	37	21	25
Total Number of Luminaires	56	662	115	63	56	620	11	52	63
Total Watts	2,072	24,494	4,255	4,032	2,072	22,940	407	1,092	1,575
Operating Hours/yr	3,910	3,910	3,910	3,910	3,910	3,910	3,910	3,910	3,910
A/C interaction effect	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Period of Analysis (Years)	7	7	7	7	7	7	7	7	7
Elec Consumption kWh/yr	9,317	110,137	19,133	18,130	9,317	103,150	1,830	4,910	7,082
Elec Consumption TDV kBtu	186,778	2,207,982	383,562	363,460	186,778	2,067,899	36,689	98,437	141,976
Annual Elec Costs	$ 1,319.92	$ 15,603.37	$ 2,710.55	$ 2,568.50	$ 1,319.92	$ 14,613.43	$ 259.27	$ 695.63	$ 1,003.32
PV Electric Costs PV$	$ 8,223.49	$ 97,213	$ 16,887.52	$ 16,002.47	$ 8,223.49	$ 91,045.78	$ 1,615.33	$ 4,334.00	$ 6,250.96
Avg elec cost $/kWh	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14
Total Number of Luminaires	56	662	115	63	56	620	11	52	63
Fixture Cost	$ 60.00	$ 60.00	$ 45.00	$ 50.00	$ 60.00	$ 60.00	$ 45.00	$ 70.00	$ 50.00
Lamp Cost Total for Luminaire	$ 10.00	$ 10.00	$ 10.00	$ 6.50	$ 10.00	$ 10.00	$ 10.00	$ 6.50	$ 6.50
First Cost of Luminaires By Type	$ 3,920.00	$ 46,340.00	$ 6,325.00	$ 3,559.50	$ 3,920.00	$ 43,400.00	$ 605.00	$ 3,978.00	$ 3,559.50
Total Luminaire First Cost				**$ 60,144.50**					**$ 55,462.50**
A/C tons	0.589	6.967	1.210	1.147	0.589	6.525	0.116	0.311	0.448
First Cost AC	$ 883.97	$ 10,449.75	$ 1,815.29	$ 1,720.15	$ 883.97	$ 9,786.78	$ 173.64	$ 465.87	$ 671.93
Total First Cost PV$	$ 4,803.97	$ 56,789.75	$ 8,140.29	$ 5,279.65	$ 4,803.97	$ 53,186.78	$ 778.64	$ 4,443.87	$ 4,231.43
Relamping labor	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60
Total Lamp replacement cost including labor	$ 649.60	$ 7,679.20	$ 1,334.00	$ 510.30	$ 649.60	$ 7,192.00	$ 127.60	$ 421.20	$ 510.30
Lamp Life (burning hr)	4,000	4,000	4,000	24,000	4,000	4,000	4,000	20,000	24,000
Maintenance Cost PV $	$ 3,416.51	$ 40,388.05	$ 7,016.05	$ 414.92	$ 3,416.51	$ 37,825.67	$ 671.10	$ 352.75	$ 414.92
Life Cycle Cost (LCC) PV$	$ 16,444	$ 194,391	$ 32,044	$ 21,697	$ 16,444	$ 182,058	$ 3,065	$ 9,131	$ 10,897
Design Life Cycle Cost (DLCC) PV$				**$ 264,576**					**$ 221,595**

Note that there is an immediate first cost savings for the suggested design solution as well as a substantial savings after 7 years.

The above data suggests that there are viable alternatives to the current lighting designs that we studied that will meet the proposed Title 24-2008 standards and that are cost effective.

Important to note in most cases even the luminaire first cost of the redesign is lower than the as built models, thus producing instant savings of both dollars for the business and lowering power density. In all but one case the new designs were cost effective. The more expensive design called for a complete CMH solution for the Kitchen Accessory. The design met the LPD requirements and although the cost recovery was better than the current design the first cost for CMH installation was double the current design. For those companies that want a socially responsible lighting design that maintains exactly the same look and feel of an all halogen solution they can use CMH lamps at a higher initial cost. It is our expectation that when these new standards are implemented in 2008 that the cost of CMH lighting will be much lower and this solution will be more attractive. Our experience is that as the code implementation deadline approaches, there will be more product availability which in turn will allow even more design alternatives than are currently available. However, this proposal is cost-effective with current availability and pricing.

There can be little doubt after this more extensive study into this middle market retail segment that there are several very favorable design solutions available now to meet current and future LPD guidelines as those suggested for 2008. While some of these changes may modestly alter the design intent of the retail establishment many promising technology improvements are already available to maintain design integrity and meet LPD requirements. Improvements and additions to these technologies will be needed before they are completely accepted by the consumer.

5. New Technology Lighting Models

The results of the several studies that were undertaken to look at the improved efficiency of CMH lamps coupled with all electronic ballast are presented in Table 29 and Table 30

The first study Table 25 and Table 26 looks at the Benya Model for vertical accent lighting. Previously as part of an evaluation for the 2005 Title 24 standards, Mr. Benya had used 60W halogen infrared reflecting PAR38 luminaires spaced at 3 foot intervals at a 30 degree angle to determine the LPD for a vertical surface combined with an expected average foot-candle level for that surface. Table 29compares the results from a PAR38 60W HIR with a CMH 20W PAR30 lamp each set at the same spacing of 3 feet at 10 feet in height and 3 feet from the vertical surface. Table 30 compares the same model using 35/39W PAR30 CMH lamps.

The resultant change is further proof that CMH luminaires as a replacement for HIR luminaires should be strongly considered. The 39W CMH more than doubled the light output of the 60W HIR while reducing the LPD by about 25%. The 20W CMH produced the same or slightly greater foot-candle levels than the 60W HIR while cutting LPD levels by over 50%. The first cost component may be reduced by using fewer 39W CMH fixtures as a replacement for 60W PAR HIR fixtures when manufacturers provide greater beam spread options for CMH luminaires or PAR lamps.

Table 29: Recreation of Benya study illuminances and LPDs as compared to 20 W CMH

BENYA STUDY 60W PAR38 HIR vs. 20W PAR30 CMH

	Average Foot-candles at Re-lamping Interval		Maximum		Minimum		Lighting Power Density (LPD) (W/Linear Foot)	
	60W HIR	20W CMH	60W HIR	20W CMH	60W HIR	20W CMH	60W HIR	20W CMH
Wall 1	49.4	48.9	70.2	74.9	37.5	27.2	18.60	7.75
Wall 2	52.8	50.1	76.4	83.4	41.6	35.9	18.60	7.75
Wall 3	50.0	49.0	70.8	75.0	37.8	32.7	18.60	7.75
Floor	46.6	35.1	63.3	50.1	31.2	18.7	n.a.	n.a.

Table 30: Re-creation of Benya study illuminances and LPDs as compared to 39 W CMH

BENYA STUDY 60W PAR38 HIR vs. 39W PAR30 CMH

	Average Foot-candles at Re-lamping Interval		Maximum		Minimum		Lighting Power Density (LPD) (W/Linear Foot)	
	60W HIR	35W CMH	60W HIR	35W CMH	60W HIR	35W CMH	60W HIR	35W CMH
Wall 1	49.4	93.7	70.2	139	37.5	54.4	18.60	13.63
Wall 2	52.8	98.2	76.4	155	41.6	66.8	18.60	13.63
Wall 3	50.0	93.7	70.8	138	37.8	53.9	18.60	13.63
Floor	46.6	81.7	63.3	124	31.2	38.2	n.a.	n.a.

Table 30and Table 51study the total lumens and power density of various halogen, halogen and CMH, or halogen with CFL against the Benya reference model used for Title 24-2005. These various scenarios demonstrate that wall LPD can be reduced to 16 watts per linear foot with any number of different design choices with or without CMH as a component. The reference data below was established using a model similar to the analysis performed James Benya in preparation for Title 24-2005 revision suggestions.

Table 31: Halogen and hybrid models used for wall accent lighting

LAMP SPACING AT 3 FEET AS IN ORIGINAL STUDY

Lamps	Benya 2005 Study REFERENCE	Silver IR 1 to 1 Exchange	60W PAR 38 HIR & 26W Quad CFL		60W PAR 38 HIR & 20W PAR30 CMH		55W PAR 38 SILVER HIR & 20W PAR30 CMH	
	60W PAR 38 HIR	55W SILVER IR	60W PAR 38 HIR	One 26W Quad CFL	60W PAR 38 HIR	PAR 30 20W CMH	55W SILVER IR	PAR 30 20W CMH
Fixture Watts	60	55	60	26	60	25	55	25
Lumens	1150	1150	1150	1850	1150	1200	1150	1200
Total Lamps	44	44	22	22	22	22	22	22
Total Watts Each Lamp	2640	2420	1320	572	1320	550	1210	550
Total Room Display Watts	2640	2420		1892		1870		1760
LPD	1.15	1.05		0.82		0.81		0.77
Lighted Perimeter Feet	132	132	132	132	132	132	132	132
Watts Per Linear Foot	**20.0**	**18.3**		**14.3**		**14.2**		**13.3**
Total Lamp Lumens	50600	50600	25300	40700	25300	26400	25300	26400
Total Room Display Lumens	**50600**	**50600**		**66000**		**51700**		**51700**

PASSES THE PROPOSED 2008 STANDARD OF 16 WATTS PER FOOT
MEETS RP-2 RECOMMENDED LEVELS FOR ACCENT LIGHTING

Table 32: Halogen and hybrid models with wall accent lighting spacing increased by on half foot

LAMP SPACING AT 3.5 FEET

	Benya 2005 Study	Silver IR 1 to 1 Exchange	60W PAR 38 HIR & 26W Quad CFL	
Lamps	60W PAR 38 HIR	55W SILVER IR	60W PAR 38 HIR	One 26W Quad CFL
Spacing	3.0 Feet	3.5 Feet	3.5 Feet	
Fixture Watts	60	55	60	26
Lumens	1150	1150	1150	1850
Total Lamps	44	38	19	19
Total Watts Each Lamp	2640	2090	1140	494
Total Room Display Watts	2640	2090		1634
LPD	1.15	0.91		0.71
Lighted Perimeter Feet	132	132	132	132
Watts Per Linear Foot	**20.0**	**15.8**		**12.4**
Total Lamp Lumens	50600	43700	21850	35150
Total Room Display Lumens	**50600**	**43700**		**57000**

The table below provides a Life Cycle Cost Comparison for the studies in Table 26 above. Of these options only the CFL wall washer paired with 60 W HIR spots resulted in a lower life cycle cost.

Table 33: Hybrid Model Life Cycle Cost Comparison

HALOGEN HYBRID MODELS - COMBINED WITH CFL, HID, SILVER IR - LOW VOLUME LAMP PURCHASE - 7 YEAR COST RECOVERY CYCLE

Computer Model	Hybrid Solutions							
Lamp Type	1 TO 1 Exchange		PAR38 w/ Quad CFL		PAR38 HIR w/ 20W PAR30 CMH		PAR38 SILVER IR w/ 20W PAR30 CMH	
	60W PAR38 Spot HIR	55W PAR38 Silver IR 1 to 1 Exchange	60W PAR38 Spot HIR	26W Quad CFL Wallwasher	60W PAR38 Spot HIR	20W PAR30 CMH	55W PAR38 Silver IR 1 to 1 Exchange	20W PAR30 CMH
Lamp Watts	60	55	60	26	60	25	55	25
Fixture Lumens	1,150	1,150	1,150	1,850	1,150	1,200	1,150	1,200
Fixture Watts	60	55	60	26	60	25	55	25
Total Number of Luminaires	44	44	22	22	22	22	22	22
Total Watts	2,640	2,420	1,320	572	1,320	550	1,210	550
Operating Hours/yr	3,910	3,910	3,910	3,910	3,910	3,910	3,910	3,910
A/C interaction effect	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Period of Analysis (Years)	7	7	7	7	7	7	7	7
Elec Consumption kWh/yr	11,871	10,882	5,935	2,572	5,935	2,473	5,441	2,473
Elec Consumption TDV kBtu	237,980	218,148	118,990	51,562	118,990	49,579	109,074	49,579
Annual Elec Costs	$ 1,681.75	$ 1,541.61	$ 840.88	$ 364.38	$ 840.88	$ 350.37	$ 770.80	$ 350.37
PV Electric Costs PV$	$ 10,477.81	$ 9,605	$ 5,238.90	$ 2,270	$ 5,238.90	$ 2,183	$ 4,802.33	$ 2,183
Avg elec cost $/kWh	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14
Total Number of Luminaires	44	44	22	22	22	22	22	22
Fixture Cost	$ 45.00	$ 45.00	$ 45.00	$ 98.00	$ 45.00	$ 168.00	$ 45.00	$ 168.00
Lamp Cost Total for Luminaire	$ 6.50	$ 10.00	$ 6.50	$ 10.00	$ 6.50	$ 45.00	$ 10.00	$ 45.00
First Cost of Luminaires By Type	$ 2,266.00	$ 2,420.00	$ 1,133.00	$ 2,376.00	$ 1,133.00	$ 4,686.00	$ 1,210.00	$ 4,686.00
A/C tons	0.017	0.016	0.017	0.007	0.017	0.007	0.016	0.007
First Cost AC	$ 25.60	$ 23.46	$ 25.60	$ 11.09	$ 25.60	$ 10.67	$ 23.46	$ 10.67
Total First Cost PV$	$ 2,291.60	$ 2,443.46	$ 1,158.60	$ 2,387.09	$ 1,158.60	$ 4,696.67	$ 1,233.46	$ 4,696.67
Relamping labor	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 4.80
Total Lamp replacement cost including labor	$ 356.40	$ 510.40	$ 178.20	$ 255.20	$ 178.20	$ 1,025.20	$ 255.20	$ 1,095.60
Lamp Life (burning hr)	3,000	4,000	3,000	12,000	3,000	6,000	4,000	9,000
Maintenance Cost PV $	$ 2,826.92	$ 2,684.40	$ 1,413.46	$ 434.24	$ 1,413.46	$ 3,595.15	$ 1,342.20	$ 2,838.53
Life Cycle Cost (LCC) PV$	$ 15,596	$ 14,733	$ 7,811	$ 5,092	$ 7,811	$ 10,475	$ 7,378	$ 9,718
Design Life Cycle Cost (DLCC) PV$	**$ 15,596**	**$ 14,733**		**$ 12,902**		**$ 18,286**		**$ 17,096**

7 year analysis at 3% real discount rate

NOTE: CMH Lamp Life was imput at 2/3 stated life to account for lamp LLF

The model below was constructed using alternating 60W PAR38 HIR Lamps (55W Silver IR could have been used in their place further reducing the energy load) alternating with 20W PAR30 CMH. This would reduce the cost of switching to CMH by half while providing additional brightness if desired for the same LPD.

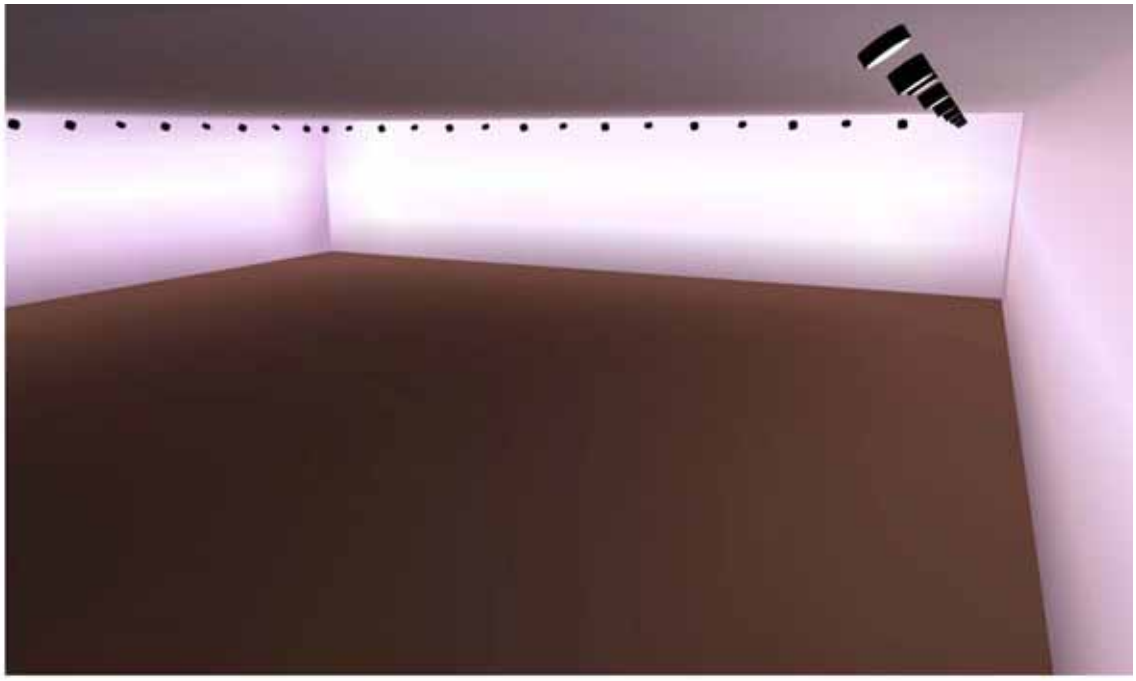


Figure 13 Figure 20: Rendering of hybrid wall display lighting system – halogen IR and CMH

Models E and E1 composites of some typical retail spaces in strip malls were constructed to study the LPD under a very basic lighting design consisting of PAR 38 55W accent lights with either 42W CFL triple tube or 2 lamp 32W T8 2x4 troffers. Table 28 compares the results for these two lighting designs.

Table 34: Comparing key parameters for strip mall retail space study

Concept - PAR38 55W Accent with...	Sales Area (SqFt)	LPD	Ambient Footcandles	Display Case Footcandles
Compact Fluorescent	1228	2.28	76.7	360
2 x 4 T8 Troffer	1228	1.89	73.9	365

Table 35: Cost comparison of Models E and E1, Strip Mall retail spaces

STRIP MALL STORE COST ANALYSIS FROM COMPUTER MODEL - LOW VOLUME LAMP PURCHASE - 7 YEAR COST RECOVERY CYCLE

Computer Model	STRIP MALL Store			
Lamp Type	Single Triple Tube 42W CFL		2X4 Double T8 Troffer	
	60W PAR38 Spot HIR	Single 42W Triple Tube CFL Vertical	60W PAR38 Spot HIR	2x4 Double Tube T8
Lamp Watts	60	42	60	32
Fixture Lumens	1,150	3,200	1,150	5,900
Fixture Watts	60	48	60	56
Total Number of Luminaires	23	24	23	12
Total Watts	1,380	1,152	1,380	672
Operating Hours/yr	3,910	3,910	3,910	3,910
A/C interaction effect	0.15	0.15	0.15	0.15
Period of Analysis (Years)	7	7	7	7
Elec Consumption kWh/yr	6,205	5,180	6,205	3,022
Elec Consumption TDV kBtu	124,398	103,846	124,398	60,577
Annual Elec Costs	$ 879.10	$ 733.86	$ 879.10	$ 428.08
PV Electric Costs PV$	$ 5,477.03	$ 4,572	$ 5,477.03	$ 2,667
Avg elec cost $/kWh	$ 0.14	$ 0.14	$ 0.14	$ 0.14
Total Number of Luminaires	23	24	23	12
Fixture Cost	$ 55.00	$ 55.00	$ 55.00	$ 72.00
Lamp Cost Total for Luminaire	$ 6.50	$ 8.50	$ 6.50	$ 10.00
First Cost of Luminaires By Type	$ 1,414.50	$ 1,524.00	$ 1,414.50	$ 984.00
A/C tons	0.017	0.014	0.017	0.016
First Cost AC	$ 25.60	$ 20.48	$ 25.60	$ 23.89
Total First Cost PV$	$ 1,440.10	$ 1,544.48	$ 1,440.10	$ 1,007.89
Relamping labor	$ 1.60	$ 1.60	$ 1.60	$ 4.80
Total Lamp replacement cost including labor	$ 186.30	$ 242.40	$ 186.30	$ 177.60
Lamp Life (burning hr)	3,000	6,000	3,000	12,000
Maintenance Cost PV $	$ 1,477.71	$ 850.04	$ 1,477.71	$ 302.20
Life Cycle Cost (LCC) PV$	$ 8,395	$ 6,967	$ 8,395	$ 3,977
Design Life Cycle Cost (DLCC) PV$		**$ 15,361**		**$ 12,372**

5A. Re-lamping Intervals

Early results from the modeling studies suggested that the re-lamping period for ceramic metal halide lamps would have to be set at a specific time frame and that this would be very different from a lamps design limit. Setting a specific re-lamping interval would allow a store to fully utilize the benefits of CMH technology. Using the design limit definition set at 50% of lamp failures would not produce enough foot-candles at lamp replacement unless there was a significant over design at first installation. This would be counter productive from an energy utilization standpoint as well as create some design challenges. We therefore set our re-lamping interval at 80% rated lamp life ("design limit") and adjusted the LLF accordingly for the various luminaires used in all of our studies.

Table 36 summarizes the light levels produced on casework from CMH accent lights on a 10 foot ceiling. Levels were measured for newly installed lamps and lamps that simulated replacement at an optimal re-lamping interval that is 80% of rated life. Readings were made at the surface of the case. Light levels dropped an average of 14% at the chosen interval for re-lamping for a 39W CMH lamp.

Table 36 Accent Light Re-Lamping Interval Foot-candle Loss Study (39 W PAR 20 CMH)

Lamps	Average	Maximum	Minimum	Avg/Min	Max/Min
Newly Installed	237	477	72	3.28	6.60
At Re-Lamping Interval	203	412	66	3.07	6.22

Table 37 illustrates the comparison of CMH and HIR at various ceiling heights and distances from the target (wall or case). The results would suggest that in every case a ceramic metal halide lamp is a suitable replacement for a halogen IR. The calculated "average" is the number obtained from 6 data points (3 evenly spaced down the middle long axis of the case and three just in front of the case). The "maximum" represents that point which would be center beam for each luminaire and is positioned in the middle center of the case surface. This study further highlights the need for the major lamp manufacturers to produce lamps with wattage between 39 and 70 and perhaps between 20 and 39 although this is not a critical. Further studies will pinpoint the best alternative lamp wattages to manufacture.

Table 37: Lamp height and throw distance CMH – Halogen IR illuminance comparison

			ILLUMINANCE IN FOOT-CANDLES (fc)				
Ceiling & Lamp Height (Feet)	**Throw Distance (Feet)**	**Lamp Type & Wattage**	**Average**	**Max**	**Min**	**Avg/Min**	**Max/Min**
10	5	20W CMH	51.5	238	7	7.36	34.0
		60W HIR	50.0	238	6	8.33	39.7
12	6	39W CMH	85.2	373	14	2.32	26.6
		80W HIR	60.5	232	9	6.72	25.8
15	8	39W CMH	39.5	98	17	2.32	5.8
		100W HIR	44.7	110	20	2.23	5.5
17	9	70 W CMH	82.0	182	38	2.16	4.8
		100W HIR	38.2	106	16	2.39	6.6

6. Comparative Studies of ASHRAE 90.1 1999 through 2004 versions and Title 24-2005

The results of the comparative study calculations using the more recent lighting (LPD) codes are summarized below. The results confirm the expectation that gradual reduction in allowed LPD over the past several years makes it impossible for older technology designs to pass the new more energy efficient requirements. The modeling results from Section 1 above suggest that by using a combination of CMH, T5/T5HO, and fixtures better suited to tasks (i.e. asymmetrical reflectors for cove lighting and/or valence lighting) that accent LPD can be reduced by as much as 50% in some cases without sacrificing illuminance (fc). The results of the comparison of Title 24-2005 and the proposed LPD in Title 24-2008 can be found in the second table below.

Table 38: ASHRAE 90.1 and Title 24 2005 Comparison

COMPARISON OF ASHRAE AND TITLE-24 LIGHTING CODES THRU 2005

WHEN APPLIED TO CURRENT AS BUILT DESIGN MODELS

LOCATION OF SURVEY SITE AT UPSCALE RETAILER STORE	ACTUAL DESIGNED LOAD (INSTALLED POWER) As Permitted Under ASHRAE 90.1-1999			ASHRAE 90.1-2001		ASHRAE 90.1-2004 LIBERAL INTERPRETATION APPROACH ##		ASHRAE 90.1-2004 STRICT INTERPRETATION APPROACH **		TITLE-24 2005	
	Watts	Square Feet	W/SqFt	Watts	W/SqFt	Watts	W/SqFt	Watts	W/SqFt	Watts	W/SqFt
A - Men's Shoes	5,514	1,376	4.01	5,555	4.04	3,769	2.74	3,141	2.28	4,982	3.62
B - Cosmetics	21,452	5,544	3.87	20,675	3.73	12,183	2.20	10,808	1.95	13,721	2.47
C - Contemporary	17,262	5,912	2.92	23,134	3.91	19,806	3.35	15,693	2.65	17,672	2.99
C - Women's Shoes	13,704	3,506	3.91	13,962	3.98	8,694	2.48	7,811	2.23	11,564	3.30
C - Designer	13,081	3,190	4.10	12,811	4.02	9,812	3.08	8,145	2.55	9,252	2.90
C - Men's Shoes	4,189	876	4.78	3,242	3.70	3,549	4.05	2,287	2.61	4,162	4.75
Average:	12,534	3,401	3.69	13,230	**3.89**	9,636	**2.83**	7,981	**2.35**	10,226	3.01

Liberal Approach considers all surface areas of the case including top, shelving, and glass sides since all are display surfaces. Both horizontal and vertical surfaces on free standing displays and wall displays were also included in the total surface area calculation.

** Strict Approach considers only the horizontal surfaces of the cases or free standing displays and the vertical surfaces on wall displays where the length x width of the wall display was used in these calculations.

Table 39: Comparison of 2005 Title 24with proposal for 200

COMPARISON TITLE 24-2005 and PROPOSED TITLE 24-2008 TAILORED METHOD

WHEN APPLIED TO CURRENT AS BUILT SALES DESIGN MODELS

LOCATION OF SURVEY SITE AT UPSCALE RETAILER STORE	ACTUAL DESIGNED LOAD (INSTALLED POWER)			TITLE 24-2005		TITLE 24-2008 (Proposed)	
	Watts	Square Feet	W/SqFt	Watts	W/SqFt	Watts	W/SqFt
Location A - Men's Shoes	5,514	1,376	4.01	4,982	3.62	3,958	2.88
Location B - Cosmetics	21,452	5,544	3.87	13,721	2.47	12,196	2.20
Location C - Contemporary	17,262	5,912	2.92	17,672	2.99	14,909	2.52
Location C - Women's Shoes	13,704	3,506	3.91	11,564	3.30	9,061	2.58
Location C - Designer	13,081	3,190	4.10	9,252	2.90	8,608	2.70
Location C - Men's Shoes	4,189	876	4.78	4,162	4.75	3,638	4.15
Location Average:	12,534	3,401	**3.69**	10,226	**3.01**	8,728	**2.57**

Controls evaluation

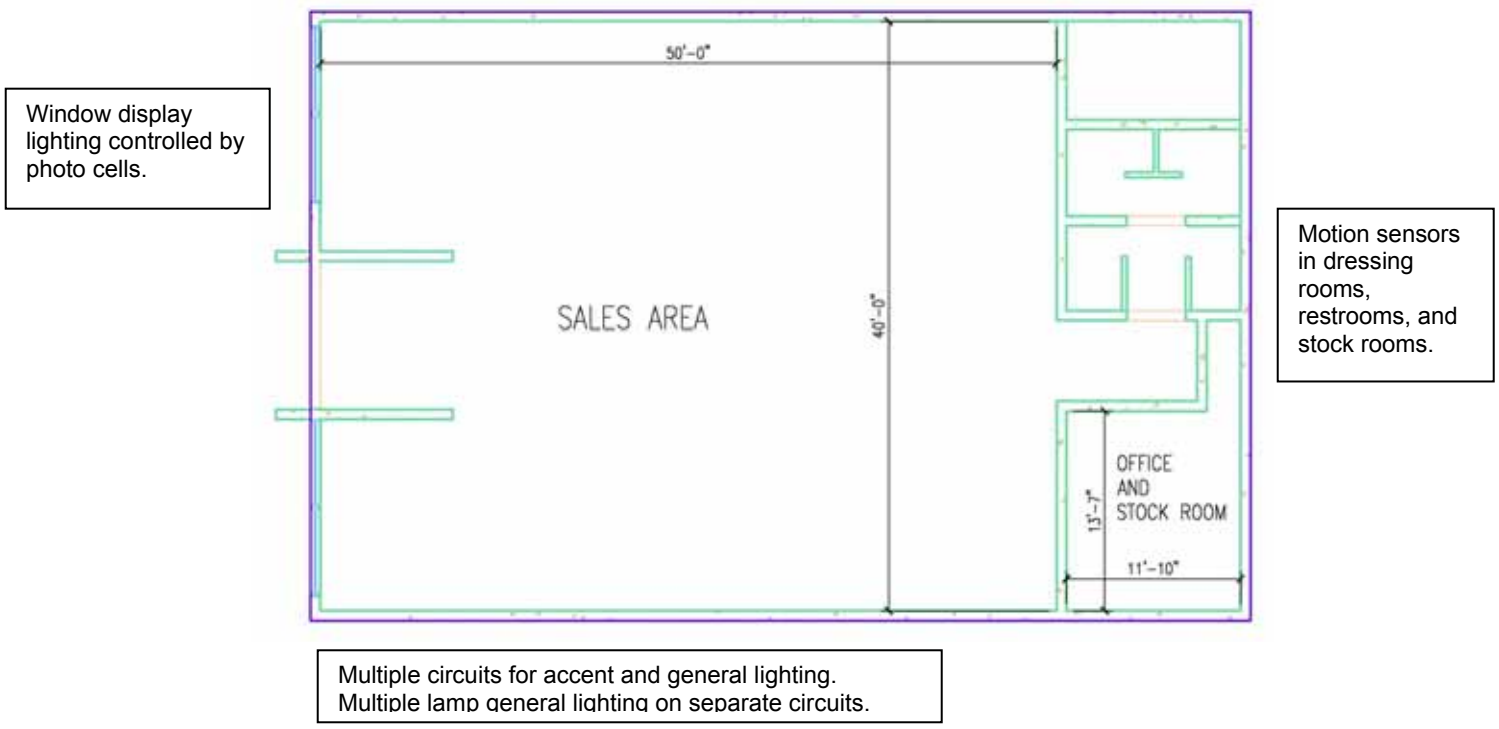
This evaluation of lighting controls that might be required of a space that makes use of the tailored lighting method for compliance itemizes the first costs, energy savings, maintenance effects and life cycle savings associated with installing lighting controls in a 2,500 sf small retail space. This evaluation is based on an annual energy cost of $0.14/kWh, which was the average cost of electricity for the other studies that made use of TDV analysis during typical retail hours of operation.

Use of more advanced control systems will produce an annual energy savings of approximately $2,000. The controls consist of multiple circuiting for general lighting (selling, stock, and circulation on separate circuits) and accent lighting (theme/deco, store front, wall, and floor two to three circuits) along with an appropriate digital timer. The cost to install the additional equipment and circuits is approximately $4,200. Therefore the cost recovery time for this upgrade is about 2 ¼ years. Below is the diagram for the space used for this study.

DIAGRAM FOR ADVANCED LIGHTING CONTROLS COST ANALYSIS MODEL

Store Type Assumption: 2500 Square Foot Soft Merchandising

Code Assumption: Title 24-2008



The costs and savings of these controls are explained by the following four tables. These savings are achieved by using some or all of the controls in the above diagram. In addition to general timing of the store lighting based on need these controls will give the store flexibility to have only necessary lights on at any given time. This will reduce energy usage and save money as less frequently used areas will use reduced or no lighting when not occupied.

Window displays in bright sun will automatically switch off at specified times or by photocell. In some cases illumination of window displays may require more lights during daylight hours to accommodate for higher ambient light levels. Most accent lighting is of little value when a showcase is directly illuminated by

sunlight. At those times photocells should turn off accent lighting. In the evening accent lighting can be reduced in the showcase since lower wattage will produce the same perceived effect.

Cleaning and stocking tasks will use the minimum wattage needed for safely to accomplish their jobs and those fixtures designated for these jobs should be on a separate circuit.

Table 40: Annual energy cost to operate base case 2,500 retail space with basic time clock control

	MINIMUM LIGHTING CONTROLS - TIMER ONLY					
	Location	Code Allowance W/SqFt	Area SqFt	Maximum Allowed Watts	Hours of Lighting Per Year	Kilowatts Per Year
General Lighting Component	Selling	0.9	2,000	1,800	4,600	8,280
	Office/Stock	1.1	250	275	4,600	1,265
	Dressing Room	0.9	200	180	4,600	828
	Misc/Circulation	1.0	50	50	4,600	230
					Sub-Total	10,603
Accent Lighting Component	Floor Display	1.0	2,000	2,000	4,600	9,200
	Wall Display	16	130	2,080	4,600	9,568
	Theme/Deco(Dressing)	n.a.	n.a.	500	4,600	2,300
	Store Front Display	n.a.	n.a.	500	4,600	2,300
					Sub-total	23,368
	Minimum Contol (Time Clock Only) Yearly kW TOTAL:					33,971
	Cost elec/kWHour:					$ 0.14
	Total Annual Cost of Electricity for Lighting:				A	$ 4,755.94

Table 41: Annual energy cost of operating 2,500 sf retail space with advanced control

	ADVANCED LIGHTING CONTROLS - MULTIPLE ZONES/CIRCUITS					
	Location	Code Allowance W/SqFt	Area SqFt	Maximum Allowed Watts	Hours of Lighting Per Year	Kilowatts Per Year
General Lighting Component	Selling	0.9	2,000	1,800	4,600	8,280
	Office/Stock	1.1	250	275	2,300	633
	Dressing Room	0.9	200	180	2,415	435
	Misc/Circulation	1.0	50	50	4,600	230
					Sub-Total	9,577
Accent Lighting Component	Floor Display	1.0	2,000	2,000	3,450	6,900
	Wall Display	16	130	2,080	3,833	7,973
	Theme/Deco(Dressing)	n.a.	n.a.	500	2,415	1,208
	Store Front Display	n.a.	n.a.	500	1,680	840
					Sub-Total	16,921
	Minimum Contol (Time Clock Only) Yearly kW TOTAL:					26,498
	Cost elec/kWHour:					$ 0.14
	Total Annual Cost of Electricity Using Advanced Controls:				B	$ 3,709.72

Table 42: Annual cost savings from using advanced lighting controls

ANNUAL SAVINGS USING ADVANCED CONTROLS	
Net Annual Savings by Switching to Advanced Lighting Control Systems **(A-B)**:	$ 1,046.22
HVAC Annual Cost Avoidance:	$ 250.00
Re-Lamping Annual Cost Avoidance:	$ 650.00
TOTAL POTENTIAL SAVINGS USING ADVANCED LIGHTING CONTROLS:	$ 1,946.22

Table 43: Incremental cost of advanced lighting controls

INCREMENTAL COST OVER MINIMUM CONTROLS (TIME CLOCK)	
DIGITAL MULTI-FUNCTION CONTROL SYSTEM:	$ 3,600.00
MOTION AND PHOTO SENSORS:	$ 600.00
INCREMENTAL ADDITIONAL COST FOR ADVANCED CONTROLS:	$ 4,200.00

The advanced lighting controls payback in three years and are therefore a justifiable addition to Title 24-2008.

Ornamental lighting evaluation

This analysis compares performance and life cycle cost (first cost and operating cost) of energy efficient newer technology light sources with their traditional incandescent and neon/cathode counterparts for ornamental lighting applications. Comparisons included in this evaluation are:

- Small incandescent lamps with small halogen lamps. This is the comparison for spaces where ornamental lighting needs dimming.
- Small incandescent lamps and a small wattage compact fluorescent (CFL) lamps. In spaces where dimming or exposed lamps, such as in crystal chandeliers, are not needed the compact fluorescent lamp is a viable energy efficient option.
- Low voltage (12V) halogen lamps with white LED lamps. Typical applications would include sign related lighting, picture (art) lighting under counter (shelf) and casework (cabinet) lighting.
- Neon/cathode with colored LEDs for decorative/theme illumination. Typical applications would include sign related lighting and other theme lighting where colored light is used.

As shown in Table 36, the halogen lamps and compact fluorescent lamps produce equivalent light output (maintained lumens); longer lamp life and have lower life cycle costs than do the incandescent lamps they replace.

Performance Analysis of Standard Decorative Lamps versus Halogen Decorative Lamps

Halogen decorative lamps can produce equivalent maintained lumens while consuming fewer watts (25% to 40% less) than their standard incandescent counterparts. The table below compares performance of a 40W incandescent decorative lamp and a 25W halogen decorative lamp of the same design and socket configuration. The halogen lamp provides equal or greater lumens over its operating life compared to the standard incandescent. The halogen however consumes 38% less energy than the standard lamp. An additional benefit of the halogen lamp is its longer lamp life.

Table 44: Compariosn of Halogen Flame and Incandescent Flame lamps

LAMP TYPE	WATTS	VOLTS	LIFE/HRS	INITIAL LUMENS	LLF (end lamp life)	END LIFE LUMENS
Halogen Flame *(Clear Lamp example – frosted lamp exhibits similar performance)*	25	120	3000	300	0.98 LLF	294
Incandescent Flame *(Clear Lamp example – frosted lamp exhibits similar performance)*	40	120	2000	370	0.80 LLF	296

Performance Analysis of Incandescent versus Compact Fluorescent (CFL) Decorative Lamps

CFL decorative lamps can produce equivalent maintained lumens while consuming significantly fewer watts (2/3 less) than their incandescent counterparts. The table below compares performance of a 25W incandescent decorative lamp and a 7W CFL decorative lamp of the same design and socket configuration. The CFL lamp provides equal or greater lumens over its operating life compared to the standard incandescent. The CFL however consumes 2/3 less (300%) energy than the standard lamp. An additional benefit of the halogen lamp is its significantly longer lamp life.

Table 45: Compariosn of CFL Flame and Incandescent Flame lamps

LAMP TYPE	WATTS	VOLTS	LIFE (HRS)	INITIAL LUMENS	LLF (end lamp life)	END LIFE LUMENS
CFL Flame *(Flame lamp example – other shapes exhibit similar performance)*	7	120	6000	280	0.70 LLF	196
Incandescent Flame *(Clear Lamp example – frosted lamp exhibits similar performance)*	40	120	1500	210	0.80 LLF	168

Performance Analysis of LED Luminaires versus Halogen & Neon/Cathode

LED (Light Emitting Diode) luminaires can sometimes provide an energy efficient alternative to incandescent, neon and cold cathode luminaires for decorative and theme (ornamental) illumination. The primary rationale for ornamental illumination is visual effect and ambiance. Therefore a comparison of lumens and quantity of illumination is not of primary importance. Although LED applications often produce fewer lumens or foot-candles than their incandescent or neon/cathode counterparts, desired visual effect and /or at least equivalent to other light sources and in some instances more effective. The following table provides the energy reduction that is possible for several typical LED versus incandescent and neon applications. Note that in the halogen example, maintaining equal lumen output while reducing LPD was also accomplished

Table 46: Comparion of Whitle LED and Hoalgen Strip Lights

LAMP TYPE	WATTS	VOLTS	LIFE (HRS)	INITIAL LUMENS	LLF (end lamp life)	END LIFE LUMENS
White LED Linear Strip *(One foot module of 5000K LED lamps, 3000K lamps have approximately 1/3 less raw lumens)*	15W linear foot	120	50,000	445	0.70 LLF	311
Halogen Lamp Strip *(5-5W mini halogen clear lamps in one foot module – frosted lamp exhibits similar performance)*	25W linear foot	120	2000	300	0.98 LLF	294

Table 47: Comapriosn of Colored LED Strip and Colored Neon Strip

LAMP TYPE	WATTS	VOLTS	LIFE (HRS)	Comments and Remarks
Colored LED Strip	4W-6W linear foot	120	50,000 (estimated)	Neon/cathode currently offers significantly higher lumens per watt than LED systems, but the ability to better control the LED source via a multitude of beam spreads and reflectors can offset this lumen disadvantage, and the increased color saturation adds to the visual impact for a given application. Visual impressions not measurable lumens are of key importance when making ornamental lighting decisions. Note: The estimates of watts per linear foot are based on field experience with currently-available systems.
Neon/Cathode Strip	7.5W linear foot	120	30,000 to 100,000	

Table 48: Cost effectiveness of energy efficient decorative and ornamental lighting

DECORATIVE LIGHTING COST COPMARISON- 7 YEAR COST RECOVERY CYCLE

Computer Model						
Lamp Type	Incandescent vs. Halogen Flame Lamps		Incandescent vs. Decorative CFL		LED vs. Halogen	
	40W Incancenscent	25W Halogen	25W Incandescent	7W CFL Decorative	5W Halogen Peanut Light 5/Foot	1 Ft LED Strip
Lamp Watts	40	25	25	7	5	15
Fixture Lumens	-	-	-	-	-	-
Fixture Watts	40	25	25	7	25	15
Total Number of Luminaires	34	34	34	34	12	12
Total Watts	1,360	850	850	238	300	180
Operating Hours/yr	3,910	3,910	3,910	3,910	3,910	3,910
A/C interaction effect	0.15	0.15	0.15	0.15	0.15	0.15
Period of Analysis (Years)	7	7	7	7	7	7
Elec Consumption kWh/yr	6,115	3,822	3,822	1,070	1,349	809
Elec Consumption TDV kBtu	122,596	76,622	76,622	21,454	27,043	16,226
Annual Elec Costs	$ 866.36	$ 541.47	$ 541.47	$ 151.61	$ 191.11	$ 114.67
PV Electric Costs PV$	$ 5,397.66	$ 3,374	$ 3,373.54	$ 945	$ 1,190.66	$ 714
Avg elec cost $/kWh	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14
Total Number of Luminaires	34	34	34	34	12	12
Fixture Cost	$ -	$ -	$ -	$ -	$ 50.00	$ 200.00
Lamp Cost Total for Luminaire	$ 1.29	$ 5.69	$ 1.29	$ 7.59	$ 24.95	$ -
First Cost of Luminaires By Type	$ 43.86	$ 193.46	$ 43.86	$ 258.06	$ 899.40	$ 2,400.00
A/C tons	0.011	0.007	0.007	0.002	0.007	0.004
First Cost AC	$ 17.07	$ 10.67	$ 10.67	$ 2.99	$ 10.67	$ 6.40
Total First Cost PV$	$ 60.93	$ 204.13	$ 54.53	$ 261.05	$ 910.07	$ 2,406.40
Relamping labor	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60
Total Lamp replacement cost including labor	$ 98.26	$ 247.86	$ 98.26	$ 312.46	$ 318.60	$ 19.20
Lamp Life (burning hr)	1,500	3,000	1,500	6,000	2,000	30,000
Maintenance Cost PV $	$ 1,568.95	$ 1,965.99	$ 1,568.95	$ 1,095.73	$ 3,660.62	$ -
Life Cycle Cost (LCC) PV$	**$ 7,028**	**$ 5,544**	**$ 4,997**	**$ 2,301**	**$ 5,761**	**$ 3,121**

Note that the total number of luminaires was determined by using the 2,500 sf Lighting Control Model containing 2 chandeliers (20 lamps) and 14 sconce lamps. The LED fixtures were used in 3 four foot cabinets for a total of 12 fixtures or lamps.

The net effect of the recommended changes to the Tailored Method are best understood by review of Table 49below that addresses the changes in LPD of the lighting zones (ambient, floor, wall) of models used throughout this report

Table 49: Lighting Power Density Summary by Zone Classification

COMPUTER MODEL - LIGHTING POWER DENSITY SUMMARY BY ZONE CLASSIFICATION														
Model*	Description	Floor Area SqFt	Wall Length Linear Ft	Mounting Height		Ambient lighting W/sf		Floor Display W/sf		Wall Display W/lin ft		Valuable Display Allowance	Total Lighting	
				Feet	Adjustment Factor	Allowed	Actual	Allowed	Actual	Allowed	Actual		Allowed	Actual
C	High End Jewelry	3,940	265	11	1.0	3,546	2,597	4,334	7,128	4,240	1,200	3,546	12,626	10,925
						0.9	0.7	1.1	1.8	16.0	4.5		3.20	2.77
D	High End Retail	932	83	10	1.0	839	528	1,025	725	1,328	1,142	0	3,006	2,395
						0.9	0.6	1.1	0.8	16.0	13.8		3.23	2.57
E	Strip Mall Small Business	1,228	111	10	1.0	1,105	672	1,351	550	1,776	1,829	0	4,232	3,051
						0.9	0.5	1.1	0.4	16.0	16.5		3.45	2.48
F	Furniture & Home Accessories	7,114	764	11	1.0	6,403	0	7,825	10,582	12,218	15,929	0	26,446	26,411
						0.9	0.0	1.1	1.5	16.0	20.8		3.72	3.71
G	Kitchen Accessories & Tableware	3,040	234	11	1.0	2,736	1,406	3,334	3,238	3,750	5,044	0	9,830	9,688
						0.9	0.5	1.1	1.1	16.0	21.6		3.23	3.19
*Model A - Big Box Retail & Model B High Atrium Retail Tailored Method not used - these spaces are better suited for compliance under "Area Method" calculations														

Display Case Lighting

The current PG & E case proposal to drop casework valuable merchandise accent lighting from the Title 24-05 20W per square foot of case top to 16W per square foot is predicated on more than halogen technology improvements. The PG & E proposal assumes that Ceramic Metal Halide may be required in some applications in addition to or in place of halogen. The 16W number was derived from analyzing the following scenarios using a typical four foot showcase with 8 square feet of top surface. It should be noted that this is just one example 5-foot and 6-foot cases as well as long case runs were also analyzed.

Table 50:Lighting Power Density of Various Display CaseLlighitng Configurations

Case Top Valuable Merchandise Display for 4-foot x 2-foot Showcase *(8 –square foot of case top)*				
Ceiling/Mounting Height	**Lamp**	**Lamp Type**	**Watts**	**W Sq. Ft.**
8 feet to 11 feet	2	20W CMH (with ballast)	50W	6.25
8 feet to 11 feet	2	50W IR MR16 or PAR38 IR	100W	12.5
8 feet to 11 feet	2	39W CMH (with ballast)	88W	11.0
8 feet to 11 feet	3	37W IR MR16	111W	13.88
8 feet to 11 feet	3	50W IR MR16 or PAR38 IR	150W	18.75
11 feet to 14 feet	2	39W CMH (with ballast)	88W	11.0
11 feet to 15 feet	3	39W CMH (with ballast)	88W	16.5
11 foot to 15 feet	2	67W PAR38 IR	134W	16.75
Over 15 feet	1	70W CMH (with ballast)	75W	9.38
Over 15 feet	2	70W CMH (with ballast)	150W	18.75

From comparisons in the above table it is evident that cases within lower ceilings can be accented with halogen and till conform to the lower proposed 15W bench mark. Cases in higher ceilings as well as when "very high illumination" is desired will need to use CMH. While we could see the casework number moving up to 16W per square foot, using only the 10% cut for halogen IR improvements (18W) is counter productive to encourage (promote) more use of CMH in appropriate applications.

It should be noted that even with high ceiling heights, the 16 W/sf number does not pose undue hardship in that this display case allowance is in addition to the 0.9 W/sf general lighting allowance and the 1.2 W/sf floor display allowance. The floor display allowance also has mounting height multipliers of 1.2 for display lighting over 11'6" and 1.4 for display lighting mounted above 16'. Thus the total lighting power allowance available is 18.1 W/sf for mounting heights less than 11'6", 18.34 W/sf for mounting heights greater than 11'6" and 18.53 W/sf for heights greater than 16'.

Thus dropping display case lighting power allowances from 20 W/sf to 16 W/sf, renders the standard more stringent while making it difficult to use halogen display lighting in high ceiling heights when a substantial amount of illumination (several hundred footcandles) is desired on the display cases. In these situations, 39 W and higher wattage CMH will provide the desired amount of light. As shown earlier in the report, 39 W and larger CMH are cost-effective as compared to halogen IR display lighting when evaluated over a 7 year time period.

Recommendations

Proposed changes to Title 24 building efficiency standards as applied to nonresidential buildings are:

1. Reduce the allowed LPD for accent display and feature lighting under the Tailored Compliance (Table 146D T24-2005 columns 4 and 6) based on use of Ceramic Metal Halide (CMH) as the light source for such lighting. The current standards are based on Halogen lighting. Use of CMH versus Halogen as the light source for this application will result in 30% to 50% LPD reductions for this category when applied to retail and spaces. Reduction within this category for other spaces is expected to be significantly less than for retail and may not be appropriate to all space types. However even spaces where use of CMH may not be applicable, because of the need to dim the accent display and feature lighting, using the latest generation of HIR lamping can produce 10% reductions
2. Re alignment of mounting height adjustment factor (TABLE 146-E T24-2005) to compensate for variables between the lamp wattage range and optics of CMH versus halogen. This adjustment will allow use of the lowest possible CMH lamps (20W application) in lower ceilings while allowing adequate increased power (35/39W and 70W applications) when and or where appropriate at higher ceilings.
3. Reduce the allowed LPD for wall power display lighting under the Tailored Compliance (Table 146D T24-2005 columns 3) based on use of Ceramic Metal Halide (CMH) as the light source for the accent/feature lighting component of this lighting category. The current standard is based on Halogen lighting. Use of CMH versus Halogen as the light source for the display/feature lighting component of this application will result in 20% to 30% LPD reductions for this category when applied to retail and museum/exhibit spaces. Reductions in the allowed LPD of approximately 10% for other areas while not as aggressive are possible through use of the latest generation T8 fluorescent technologies, T5 technologies and the next generation of HIR lamping..
4. Revise the criteria that defines acceptable wall and floor display equipment as; qualifying wall lighting systems shall be mounted within 72" of the wall and qualifying floor display lighting systems shall be mounted no closer than 72" to a wall. Replace this with wall display lighting no further away than 10 feet from walls and floor display lighting that is no closer than 2 feet from walls. This recommendation

has no inherent energy savings but will improve the usefulness and validity of this component of the tailored method.

5. Reduce the allowed LPD for ornamental chandeliers and sconces under the "Area Category Method" TABLE 146-C based on use of newer technology candelabra and medium socket based halogen decorative lamps and ability of increased compact fluorescent and low wattage CMH options for decorative lighting. Where/when dimming of decorative lighting is not required use of fluorescent and CMH sources can reduce LPD's by 40% to 60% or more. When dimming decorative chandelier and sconces a minimum of 10% is still possible by using the Halogen decorative lamps.
6. Reduce the allowed LPD for ornamental/special effect lighting under the Tailored Compliance (Table 146D T24-2005 column 5) based on use of newer technology candelabra and medium socket based halogen decorative lamps and ability of increased compact fluorescent and low wattage CMH options for decorative lighting and use of LED technology to replace neon/cold cathode lighting. Use of these improved efficacy fluorescent and halogen as well as CMH and LED sources can reduce LPD's in this category by 10% to 20%.
7. Reduce allowed LPD for very valuable display power to account for use of CMH lamps for high ceiling heights while still allowing the use of halogen for lower ceiling heights. Very valuable display is intended to mean very valuable products in a display case. Since this allowance applies only to three occupancies, remove these values from Table 146-D and place the allowance in the text of the section.
8. Mandate use of comprehensive lighting controls as a prerequisite to using the Tailored Lighting method of Title 24 compliance under the 2008 standards. Multi tier lighting zones, multi level switching, demand responsive load controls, and occupancy sensors are some of the control types that are applicable. Use of a comprehensive set of controls will assure that the added power (LPD'S) allowed under the Tailored Method will be used only when required for the specific lighting application and will be appropriately monitored. The control mandate must include commissioning and verification.
9. Expand requirement for daylight harvesting to more space types and to smaller spaces when/where appropriate. This measure while applicable to a number of space types is focused toward retail merchandizing space because of its inherent higher LPD requirement. The day lighting component in these spaces will significantly reduce the total power consumption (daily accumulative) while allowing the retail space a higher LPD for its "Night Time" sales illumination. As with use of controls as part of the Tailored Method, daylight harvesting must also employ a set of comprehensive controls to assure harvesting is maximized while maintaining appropriate lighting for merchandise sales. The controls also assure that electrical light is off when not needed.

Proposed Standards Language

Proposed language for the standards. The proposals here are based on the findings in the results section and detailed descriptions for LPD's can be found in Appendix 1. Original standards language is in black font, deleted text is ~~red text with hard strikeouts,~~ added language is blue font and underlined.

SECTION 146 – PRESCRIPTIVE REQUIREMENTS FOR INDOOR LIGHTING

A building complies with this section if the actual lighting power density calculated under Subsection (a) is no greater than the allowed indoor lighting power calculated under Subsection (b).

(a) **Calculation of Actual Indoor Lighting Power Density.** The actual indoor lighting power of the proposed building area is the total watts of all planned permanent and portable lighting systems (including but not limited to, track and flexible lighting systems, lighting that is integral with modular furniture, workstation task lights, portable freestanding lights, lights attached to workstation panels, movable displays and cabinets, and internally illuminated case work for task or display purposes), subject to the following specific requirements and adjustments under Subsections 1 through 6.

1. In office areas, if the actual watts of portable lighting are not known at the time of permitting, the actual lighting power for portable and integral lighting shall be determined using either A or B following. However, upon installation of the portable lighting systems the building official may require re-submittal of compliance documentation using installed lighting and equipment data.

   A. In office areas greater than 250 square feet with permanently installed lighting systems, a portable lighting power of 0.2 watts per square foot shall be included in calculation of actual lighting power density.

   B. In office areas of 250 square feet or less, no additional task lighting power will be required in the calculation of actual lighting power.

2. In office areas greater than 250 square feet with permanently installed lighting systems, if sufficient supporting evidence is submitted and accepted by the building official, the actual lighting power for portable lighting shall be included in the calculation of actual lighting power. The individual signing the lighting plans, pursuant to Division 3 of the California Business and Professions Code, shall clearly indicate on the plans the actual lighting power for the portable lighting systems in the area.

3. **Multiple interlocked lighting systems serving a space.** When multiple interlocked lighting systems serve a space, the watts of all systems except the system with the highest wattage may be excluded if:

   A. The lighting systems are interlocked to prevent simultaneous operation; or

   B. The lighting systems are controlled by a preset dimming system or other device that prevents simultaneous operation of more than one lighting system, except under the direct control of authorized personnel.

4. **Reduction of wattage through controls.** The controlled watts of any luminaire may be reduced by the number of controlled watts times the applicable factor from TABLE 146-A if:

   A. The control complies with Section 119; and

   B. At least 50 percent of the light output of the luminaire is within the applicable space listed in TABLE 146-A; and

   C. Except as noted in TABLE 146-A, only one power adjustment factor is used for the luminaire; and

   D. For occupant sensors used to qualify for the Power Adjustment Factor in small offices less than or equal to 250 square feet, the occupant sensor shall have an automatic OFF function that turns off all the lights, either an automatic or a manually controlled ON function, and have wiring capabilities so that each switch function activates a portion of the lights. The occupant sensor shall meet all the multi-level and uniformity requirements of Section 131 (b) for the controlled lighting. The first stage shall activate between 50-70% of the lights in a room either through an automatic or manual action. After that event occurs any of the following actions shall be assigned to occur when manually called to do so by the occupant.

      i. Activating the alternate set of lights.

ii. Activating 100% of the lights.

iii. Deactivating all lights.

E. For daylighting control credits, the luminaire is controlled by the daylighting control, and the luminaire is located within the day lit area. The power adjustment factor is a function of the lighting power density of the general lighting in the space and the effective aperture of the skylights determined using Equation 146-A.

EQUATION 146-A – EFFECTIVE APERTURES OF SKYLIGHTS

$$\text{Effective Aperture} = \frac{0.85 \text{ x Total Skylight Area x Glazing Visible Light Transmittance x Well Efficiency}}{\text{Daylit Area Under Skylights}}$$

Total skylight area is the sum of skylight areas above the space. The skylight area is defined as the rough opening of the skylight.

Glazing visible light transmitance is the ratio of visible light that is transmitted through a glazing material to the light that is incident on the material. This shall include all skylighting system accessories including diffusers, louvers and other attachments that impact the diffusion of skylight into the space. The visible light transmittance of movable accessories shall be rated in the full open position. When the visible light transmittance of glazing and accessories are rated separately, the overall glazing transmittance is the product of the visible light transmittances of the glazings and accessories.

Daylight area under skylights is as defined in Section 131(c).

Well Efficiency is the ratio of the amount of visible light leaving a skylight well to the amount of visible light entering the skylight well and shall be determined from the nomograph in FIGURE 146-A based on the weighted average reflectance of the walls of the well and the well cavity ratio (WCR), or other test method approved by the Commission.

The well cavity ratio (WCR) is determined by the geometry of the skylight well and shall be determined using either Equation 146-B or Equation 146-C.

EQUATION 146-B WELL CAVITY RATIO FOR RECTANGULAR WELLS

$$\text{WCR} = \left(\frac{5 \times \text{well height} \left(\text{well length} + \text{well width} \right)}{\text{well length} \times \text{well width}} \right)$$ ***; Or***

EQUATION 146-C WELL CAVITY RATIO FOR NON-RECTANGULAR-SHAPED WELLS:

$$\text{WCR} = \left(\frac{2.5 \times \text{well height} \times \text{well perimeter}}{\text{well area}} \right)$$

Where the length, width, perimeter, and area are measured at the bottom of the well.

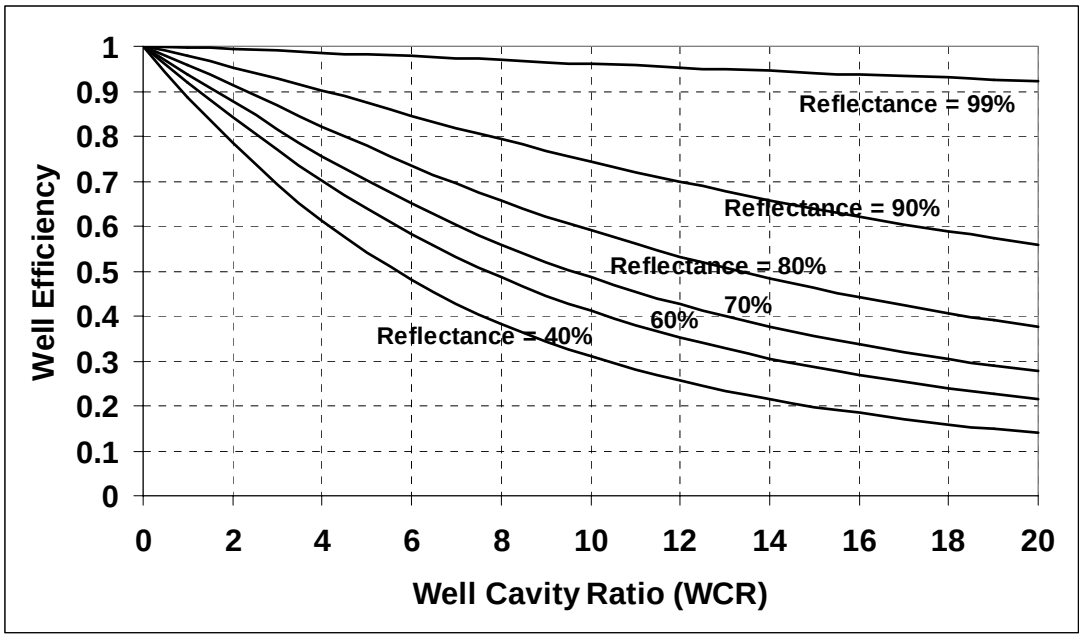


FIGURE 146-A WELL EFFICIENCY NOMOGRAPH

5. **Lighting wattage excluded**. The watts of the following lighting applications may be excluded from the actual lighting power of the building:

   A. In theme parks: lighting for themes and special effects;

   B. Lighting for film, video or photography studios;

   C. Lighting for dance floors and lighting for theatrical and other live performances, provided that these lighting systems are additions to a general lighting system and are controlled by a multiscene or theatrical cross-fade control station accessible only to authorized operators;

   D. In civic facilities, transportation facilities, convention centers, and hotel function areas: lighting for temporary exhibits, if the lighting is an addition to a general lighting system and is separately controlled from a panel accessible only to authorized operators;

   E. Lighting installed by the manufacturer in refrigerated cases, walk-in freezers, vending machines, food preparation equipment, and scientific and industrial equipment.;

   F. In medical and clinical buildings: examination and surgical lights, low-level night-lights, and lighting integral to medical equipment;

   G. Lighting for plant growth or maintenance, if it is equipped with an automatic 24-hour time switch that has program backup capabilities that prevent the loss of the switch's program and time setting for at least 10 hours if power is interrupted;

   H. Lighting equipment that is for sale;

   I. Lighting demonstration equipment in lighting education facilities;

   J. Lighting that is required for exit signs subject to the CBC if it has a maximum lamp input power rating of five watts per illuminated face;

   K. Exitway or egress illumination that is normally off and that is subject to the CBC;

L. In hotel/motel buildings: lighting in guestrooms;

M. In high-rise residential buildings: lighting in living quarters;

N. Temporary lighting systems;

O. Lighting in occupancy group U buildings less than 1000 square feet;

P. Lighting in unconditioned agricultural buildings less than 2500 square feet;

Q. Lighting systems in qualified historic buildings, as defined in the State Historic Building Code (Title 24, Part 8), are exempt from the lighting power allowances, if they consist solely of historic lighting components or replicas of historic lighting components. If lighting systems in qualified 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 lighting systems in qualified historic buildings shall comply with the lighting power allowances;

R. Parking garages for seven or less vehicles;

S. Internally illuminated, externally illuminated, and unfiltered signs.

6. **Lighting fixtures.** The watts of track and other lighting fixtures that allow the substitution of low efficacy sources for high efficacy sources without altering the wiring of the fixture shall be determined in accordance with Section 130 (c) or by a method approved by the commission.

(b) **Calculation of Allowed Indoor Lighting Power Density.** The allowed indoor lighting power density for each application for a building permit shall be calculated using one and only one of the methods in Subsection 1, 2, or 3, as applicable, except as noted in Section 146 (b) 3. The allowed indoor lighting power density for conditioned and unconditioned spaces shall be separate allotments, which shall be met separately without tradeoffs between the separate allotments. Spaces that use the tailored method (Subsection 3) shall have automatic controls as specified in Subsection 4.

1. **Complete Building Method.** The Complete Building Method shall be used only on projects involving entire buildings with one type of use occupancy or mixed occupancy buildings where one type of use occupancy makes up 90 percent of the entire building. This approach shall only be used when the applicant is applying for a lighting permit for, and submits plans and specifications for, the entire building. Under this approach, the allowed lighting power density is the lighting power density value in TABLE 146-B times the floor area of the entire building. Hotel/motel and high-rise residential buildings shall not use this method. The retail and wholesale store type of use lighting power allowance shall be used only for single tenant retail and wholesale buildings or for buildings with multiple tenants if it is known at the time of permit application that the buildings will be entirely made up of retail and wholesale stores. Retail and wholesale store buildings shall use this method only if the merchandise sales function area is 70% or greater of the building area.

2. **Area Category Method**. Under the Area Category Method, the total allowed lighting power for the building is the sum of all allowed lighting powers for all areas in the building. For purposes of the Area Category Method, an "area" shall be defined as all contiguous spaces which accommodate or are associated with a single one of the primary functions listed in TABLE 146-C. Where areas are bounded or separated by interior partitions, the floor space occupied by those interior partitions shall be included in any area. If at the time of permitting a tenant is not identified for a multi-tenant space, the tenant leased space allowance from TABLE 146-C shall be used. When the Area Category Method is used to calculate the allowed total lighting power for an entire building, main entry lobbies, corridors, restrooms, and support functions shall be treated as separate areas.

3. **Tailored Method**. The Tailored Method shall only be used for spaces whose combined area does not exceed 30 percent of the building that is otherwise using the Area Category Method. The Tailored Method and the Area Category method shall not be used for the same floor area. The floor area for calculations based on the Tailored Method shall be subtracted from the floor area for the remainder of the building lighting calculations. Trade-offs of lighting power between the Tailored Method and Area Category Methods are not allowed.

   EXCEPTION 1 TO 146 (b) 3. The Tailored Method may be used for up to 100% of the building area of Retail Merchandise Sales and Museums.

   EXCEPTION 2 TO 146 (b) 3. If a single function area within the building exceeds 30 percent of the floor area of the entire building, the Tailored Method may be used for that entire function area alone, with the remaining spaces using the Area Category Method.

   Under the Tailored Method, the allowed indoor lighting power shall be calculated according to primary function type as permitted in column 1 of TABLE 146-D.

   A. For all spaces, determine the general lighting allowance according to Sections 146 (b) 3 A i through vi.

      i. If a specific IESNA Illuminance Category is listed in Column 2 of TABLE 146-D, then such illuminance Category shall be used. Otherwise, determine the category for each lighting task according to categories specified in the IESNA Lighting Handbook (IESNA HB), using the "Design Guide" for illuminance. It is permissible to have more than one task type in a space. For spaces employing tasks E, F, or G, submit plans under Section 10-103 of Title 24, Part 1 clearly identifying all task spaces for such categories and the lighting equipment designed to illuminate them. Tasks that are performed less than two hours a day or poor quality tasks that can be improved shall not be employed to justify use of E, F, or G.

      ii. Determine the area of each task. Areas without tasks shall be identified as non-task. The total of all task areas and non-task areas shall be equal to the area of the space.

      iii. Determine the room cavity ratio (RCR) and area of each space. The RCR shall be calculated using either Equation 146-D or Equation 146-E.

EQUATION 146-D ROOM CAVITY RATIO FOR RECTANGULAR ROOMS,

$$RCR = \frac{5H(L + W)}{LW}$$

EQUATION 146-E ROOM CAVITY RATIO FOR IRREGULAR-SHAPED ROOMS

$$RCR = \frac{2.5H \times P}{A}$$

WHERE:

L = Length of room.

W = Width of room.

H = Vertical distance from the work plane to the centerline of the lighting fixture.

P = Perimeter of room.

A = Area of room.

iv. Multiply the area of each task by the allowed lighting power density for the task according to Table 146-F. The product, or the actual installed lighting power for the task, whichever is less, is the allowed lighting power for the task.

v. For non-task areas, the allowed lighting power density shall be 50% of the adjacent task area or that permitted for Category D, whichever is lower. Multiply the non-task area by the allowed lighting power density.

vi. Add the allowed lighting power of all tasks and non-task areas. This is the Allowed General Lighting Power for the Space.

B. Determine additional allowed power for display and decorative lighting according to Sections 146 (b) 3 B i through v.

i. Separate wall display lighting power is permitted if allowed by column 3 of TABLE 146-D. The allowed wall display lighting power is the smaller of:

a. The product of the room wall lengths and the listed allowed power density watts per linear foot (w/ft) in column 3 of TABLE 146-D, if applicable, or

b. The actual power of wall lighting systems.

The length of display walls shall include the length of the perimeter walls, including closable openings and permanent full height interior partitions. For mounting height of display ~~13'~~ 11'6"above the finished floor or higher, this amount may be increased by multiplying the product by the appropriate factor from TABLE 146E. Qualifying wall lighting systems shall be mounted ~~within 72" of the wall~~ within10 feet of the wall and shall be of a lighting system type appropriate for wall lighting including a lighting track, wallwasher, valance, cove, or adjustable accent light.

Additional lighting power is allowed for retail display walls if they have more than three rows of self-illuminated shelves. The allowable amount of additional lighting for illuminated shelving is the lesser of: the amount of lighting power installed for self-illuminated shelf lighting; or the product of the length of self-illuminated shelving units having more than three shelves and the appropriate Watt per linear foot values contained in Table 146-G..

.The added shelf lighting allocation shall be used for shelving and the scope of walls requiring the additional lighting must be documented on plan submittals prior to a permit being granted.

ii. Separate floor display lighting power is allowed if allowed by column 4 of TABLE 146-D. The allowed floor display lighting power is the smaller of:

a. The product of the area of the space and the allowed floor display lighting power density listed in column 4 of TABLE 146-D, if applicable, or

b. The actual power of floor display lighting systems.

For display lighting ~~13'~~ mounted greater than 11'6" above finished floor, this amount may be increased by multiplying the product by the appropriate factor from TABLE 146-E Qualifying floor display lighting systems shall be mounted ~~no closer than 72" to a wall~~ and no closer than 2 feet to a wall and shall be a lighting system type such as track lighting, adjustable or fixed luminaires with PAR, R, MR, AR, or other projector lamp types or employing optics providing directional display light from non-directional lamps. Except for lighting for very valuable

merchandise as defined below, lighting mounted inside of display cases shall also be considered floor display lighting.

iii. Separate ornamental/special effects lighting power is permitted if allowed by column 5 of TABLE 146-D. If so, the allowed ornamental/special effects lighting power is the smaller of:

a. The product of the area of the space and the allowed ornamental/special effects lighting power density specified in column 5 of TABLE 146-D, if applicable, or

b. The actual power of allowed ornamental/special effects lighting luminaires.

Qualifying ornamental luminaires include chandeliers, sconces, lanterns, neon and cold cathode, light emitting diodes, theatrical projectors, moving lights, and light color panels when used in a decorative manner that does not serve as display lighting. Ornamental/special effects lighting shall not be the only light source in the space.

iv. In retail, museum, and religious worship, the smallest of the following separate lighting power for ~~very valuable~~ display~~s~~ cases presenting very valuable merchandise is permitted ~~if allowed by column 6 of TABLE 146-D. The allowed lighting power for very valuable displays is the smallest of:~~

a. The product of the area of the space and 1.0 watts per square foot ~~the allowed very valuable lighting power density specified in column 6 of TABLE 146-D, if applicable~~, or

b. The product of the area of the display case and ~~20 watts~~ 16 watts per square foot, or

c. The actual power of lighting for very valuable displays.

Qualifying lighting includes internal display case lighting or external lighting employing highly directional luminaires specifically designed to illuminate the case or inspection area without spill light. To qualify for this allowance, cases shall contain jewelry, coins, fine china or crystal, precious stones, silver, small art objects and artifacts, and/or valuable collections the selling of which involves customer inspection of very fine detail from outside of a locked case.

v. Only the general portion of the lighting power determined in 146 (b) 3A above shall be used for tradeoffs among the various occupancy or task types of the permitted space. The allowed wall display lighting power, the allowed floor display lighting power, the allowed ornamental/special effect lighting power, and the allowed lighting power for very valuable displays are “use it or lose it” power allowances that shall not be traded off.

EXCEPTION 1 to 146 (b) 3: The Tailored Method may be used for up to 100% of the entire building area of Retail Merchandise Sales and Museums.

EXCEPTION 2 to 146 (b) 3: If a single function area within the building exceeds 30 percent of the floor area of the entire building, the Tailored Method may be used for that entire function area alone, with the remaining spaces using the Area Category Method.

4. Automatic Controls required for the Tailored Method Spaces. The following controls shall be used in spaces that use the tailored method for calculating allowed indoor lighting power density.

A. Egress and Security - an automatic time switch control device complying with Section 119(c) that turns off all lights except those used for egress and security as defined in Section 131(d)1 Exception 3.

B. Housekeeping controls - an automatic time switch control device complying with Section 119(c) that controls lighting so that uniform general lighting is produced throughout the space and consumes no greater Wattage than the general lighting allowance of the space.

C. Demand Response – a control that turns off lights automatically upon receiving a load curtailment signal from the local utility or Independent System Operator. Demand Response controls shall reduce lighting power consumption in the space while maintaining sufficient uniformity for occupied space activities albeit at lower illumination levels. Lighting power draw when the demand response control is enabled should be no greater than one half of the total installed wattage.

D. Display window lighting. Display window lighting shall be separately controlled by an automatic time switch control device complying with Section 119(c).

TABLE 146-A LIGHTING POWER ADJUSTMENT FACTORS

TYPE OF CONTROL	TYPE OF SPACE		FACTOR
Occupant sensor with "manual ON" or bi-level automatic ON combined with multi-level circuitry and switching	Any space ≤ 250 square feet enclosed by floor-to-ceiling partitions; any size classroom, corridor, conference or waiting room		0.20
Occupant sensor controlled multi-level switching or dimming system that reduces lighting power at least 50% when no persons are present	Hallways of hotels/motels		.25
	Commercial and Industrial Storage stack areas (max. 2 aisles per sensor)		.15
	Library Stacks (maximum 2 aisles per sensor)		.15
Dimming system			
Manual	Hotels/motels, restaurants, auditoriums, theaters		0.10
Multiscene programmable	Hotels/motels, restaurants, auditoriums, theaters		0.20
Manual dimming with automatic load control of dimmable electronic ballasts.	All building types		.25
Combined controls			
Occupant sensor With "manual ON" or bi-level automatic ON combined with multi-level circuitry and switching in conjunction with daylighting controls	Any space ≤ 250 square feet within a daylit area and enclosed by floor-to-ceiling partitions, any size classroom, corridor, conference or waiting room.		0.10 (may be added to daylighting control credit)
Manual Dimming with Dimmable Electronic Ballasts and Occupant sensor with "manual ON" or automatic ON to less than 50% power and switching	Any space ≤ 250 square feet enclosed by floor-to-ceiling partitions; any size classroom, corridor, conference or waiting room		0.25
Automatic Daylighting Controls with Windows (Stepped Switching or Stepped Dimming/Continuous Dimmed)			
	Window Wall Ratio		
Glazing Type - Windows	< 20%	20% to 40%	> 40%
VLT ≥ 60%	0.20/0.30	0.30/0.40	0.40/0.40
VLT ≥ 35 and < 60%	0/0	0.20/0.30	0.30/0.40
VLT < 35%	0/0	0/0	0.20/0.40
Automatic Multi-Level Daylighting Controls with Skylights			
Glazing Type - Skylights	Factor		
Glazing material or diffuser with ASTM D1003 haze measurement greater than 90%	$10 \times \text{Effective Aperture} - \frac{\text{Lighting Power Density}}{10} + 0.2$		
	WHERE		
	Effective Aperture is as calculated in the Equation 146-A.		
	Lighting Power Density is the lighting power density of general lighting		

TABLE 146-B COMPLETE BUILDING METHOD LIGHTING POWER DENSITY VALUES (Watts/ft²)

TYPE OF USE	ALLOWED LIGHTING POWER
Auditoriums	1.5
Convention centers	1.3
Financial institutions	1.1
General commercial and industrial work buildings	
High bay	~~1.1~~ 1.0
Low bay	1.0
Grocery stores	1.5
Hotel	1.4
Industrial and commercial storage buildings	~~0.7~~ 0.6
Medical buildings and clinics	1.1
Office buildings	1.1
Parking Garages	0.4
Religious facilities	1.6
Restaurants	1.2
Retail and wholesale stores*	1.5
Schools	1.2
Theaters	1.3
All others	0.6
* For retail and wholesale stores, the complete building method may only be used when the sales area is 70% or greater of the building space.	

TABLE 146-C AREA CATEGORY METHOD - LIGHTING POWER DENSITY VALUES (Watts/ft²)

PRIMARY FUNCTION	ALLOWED LIGHTING POWER
Auditorium	1.5*
Auto Repair	1.1**
Civic Meeting Place	1.3*
Classrooms, lecture, training, vocational room	1.2
Commercial and industrial storage	0.6
Convention, conference, multipurpose and meeting centers	1.4*
Corridors, restrooms, stairs and support areas	0.6
Dining	1.1*
Electrical, mechanical rooms	0.7**
Exercise center, gymnasium	1.0
Exhibit, museum	2.0
Financial transactions	1.2*
General commercial and industrial work	
High bay	1.1**
Low bay	1.0**
Precision	1.3***
Grocery sales	1.6
Hotel function area	1.5*
Industrial and commercial storage area	0.6

TABLE 146-C CATEGORY METHOD - Continued

PRIMARY FUNCTION	ALLOWED LIGHTING POWER
Housing, Public and Commons Areas	
Dormitory, Senior Housing	1.5
Multifamily	1.0
Kitchen, food preparation	1.6
Laundry	0.9
Library	
Reading areas	1.2
Stacks	1.5
Lobbies	
Hotel lobby	1.1*
Main entry lobby	1.5*
Locker/dressing room	0.8
Lounge/recreation	1.1
Malls and atria	1.2*
Medical and clinical care	1.2
Office	1.2
Parking garage	0.4
Religious worship	1.5*
Retail merchandise sales, wholesale showrooms	1.7*
Tenant lease space	1.0
Theaters	
Motion picture	0.9*
Performance	1.4*
Transportation Function	1.2
Waiting area	1.1*
All other	0.6

NOTES FOR TABLE 146-C

* The smallest of the following values may be added to the allowed lighting power for ornamental chandeliers and sconces that are switched or dimmed on circuits different from the circuits for general lighting:

a. ~~One watt per square foot~~ 0.9 Watt per square foot times the area of the task space that the chandelier or sconce is in; or

b. The actual design wattage of the chandelier or sconce.

** The smallest of the following values may be added to the allowed lighting power for specialized task work:

a. 0.5 watt per square foot times the area of the task space required for an art, craft assembly or manufacturing operation; or

b. The actual design wattage of the luminaire(s) providing illuminance to the specialized task area

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

*** The smallest of the following values may be added to the allowed power for precision commercial and industrial work:

a. One watt per square foot times the area of the task space required for the precision work; or

b. The actual design wattage of the luminaire(s) providing the illuminance to the precision task area.

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

TABLE 146-D TAILORED METHOD SPECIAL LIGHTING POWER ALLOWANCES

1	2	3	4	5	6
Primary Function	Horizontal Illumination Category	Wall Display Power (W/ft)	Allowed Floor Display Power (W/ft²)	Allowed Ornamental/ Special Effect Lighting	~~Allowed Display Case Power (W/ft²)~~
Auditorium	D	~~2.5~~ 2.25	0.3	0.5	~~0~~
Civic Meeting Place	D	~~3.5~~ 3.15	0.2	0.5	-
Classrooms, lecture, training, vocational room	D	~~7~~ 5.5	0	0	~~0~~
Commercial and industrial storage	~~IESNA HB~~	0	0	0	~~0~~
Inactive storage	B				
Active storage (bulk)	C				
Active storage (small items)	D				
Convention, conference, multipurpose and meeting centers	D	~~2.5~~ 2.0	0.4	0.5	~~0~~
~~Corridors, restrooms, stairs and support areas~~	~~IESNA HB~~	~~0~~	~~0~~	~~0~~	~~0~~
Corridors and stairs					
Active (primary	C	0	0	0	
Inactive (secondary)	B	0	0	0	
Dining	B	1.5	0.6	0.6	~~0~~
Exercise center, gymnasium		0	0	0	~~0~~
(general functions)	D				
Sporting events & Professional	IESNA HB				
Exhibit, museum	C	20.0	1.4	0.7	~~1.3~~
Financial Transactions	D	~~3.5~~ 3.15	0.2	0.6	~~0~~
Grocery store	D	~~11~~ 8.0	~~1.2~~ 0.8	0	~~0~~
Housing, Public and Commons Areas					
Multifamily	D	0	0	~~1.0~~ 0.9	~~0~~
Dormitory, Senior Housing	D	0	0	~~1.0~~ 0.9	~~0~~
Hotel function area	D	~~2.5~~ 2.25	0.2	0.5	~~0~~
Jail	~~IESNA HB~~ D	0	0	0	~~0~~
Kitchen, food preparation	~~IESNA HB~~ E	0	0	0	~~0~~
Laundry	~~IESNA HB~~ D	0	0	0	~~0~~
Library (Reading areas, stacks)					
~~Reading areas~~	~~D~~	~~0~~	~~0~~	~~0.7~~	~~0~~
~~Stacks~~	D	0	0	~~0.7~~ 0.6	~~0~~
Lobbies					
~~Hotel lobby~~	C	~~3.5~~ 2.8	0.2	~~0.7~~ 0.6	~~0~~
~~Main entry lobby~~	~~C~~	~~3.5~~	~~0.2~~	~~0~~	~~0~~
Locker/~~dressing room~~	~~IESNA HB~~ C	0	0	0	~~0~~
~~Locker/~~dressing room	~~IESNA HB~~ D	0	0	0	~~0~~
Lounge/recreation	C	~~7~~ 6	0	~~0.7~~ 0.6	~~0~~

1	2	3	4	5	6
Primary Function	Horizontal Illumination Category	Wall Display Power (W/ft)	Allowed Floor Display Power (W/ft²)	Allowed Ornamental/ Special Effect Lighting	~~Allowed Display Case Power (W/ft²)~~
Malls and atria	D	~~3.5~~ 2.8	0.5	~~0.7~~ 0.6	~~0~~
Medical and clinical care	IESNA HB	0	0	0	~~0~~
Office	~~IESNA HB~~	0	0	0	~~0~~
General Function	E				
Extensive VDT	D				
Police or fire stations	~~IESNA HB~~	0	0	0	~~0~~
Religious worship	D	1.5	0.5	0.5	~~0.3~~
Retail merchandise sales, wholesale showrooms	D	~~21.0~~ 17.0	~~1.5~~ 1.2	~~0.7~~ 0.6	~~1.3~~
Tenant lease space	C	0	0	0	~~0~~
Theaters					
Motion picture	C	3	0	0.6	~~0~~
Performance	D	6	0	0.6	~~0~~
Transportation Function	D	~~3.5~~ 3.15	0.3	~~0.7~~ 0.6	~~0~~
Waiting area	C	~~3.5~~ 3.15	0.2	~~0.7~~ 0.6	~~0~~

TABLE 146-E ADJUSTMENTS FOR MOUNTING HEIGHT ABOVE FLOOR

Height in feet above finished floor and bottom of luminaire(s)	Floor Display - Multiply by	Wall Display - Multiply by
~~12 or less~~ 11'-6" or less	1.0	1.0
~~13~~	~~1.05~~	
~~14~~	~~1.10~~	
~~15~~	~~1.15~~	
~~16~~ > 11'6"	~~1.21~~ 1.2	1.15
~~17~~	~~1.47~~	
~~18~~	~~1.65~~	
~~19~~ > 16'	~~1.84~~ 1.4	1.35
~~20 or more~~ > 20'	~~2.04~~ 2.0	1.75

TABLE 146-F ILLUMINANCE CATEGORIES A THROUGH G LIGHTING POWER DENSITY VALUES (WATTS/FT^2)

IESNA Illuminance Category	RCR<3.5	3.5<RCR<7.0	RCR>7.0
A	0.2	0.3	0.4
B	0.4	0.5	0.7
C	0.6	0.8	1.1
D	0.9	1.2	1.4
E	1.3	1.8	2.5
F	2.7	3.5	4.7
G	8.1	10.5	13.7

Technology Development and Enhancement Recommendations

As a result of developing this case study it is apparent that current lighting offerings from luminaire, ballast and lamp manufactures are limited with respect to technologies that have significant potential to reduce energy consumption. Technology areas and market/product segments which, in our opinion should be further developed and/or expanded are:

1. Expanded options for CMH (Ceramic Metal Halide).
   - Introduction of a 50W lamp both in PAR envelope and T4.5/T6 varieties
   - Greater number of beam angle offerings in both PAR lamps and reflector design (luminaires); especially introduction of beam angles of less than 10-degrees for high ceiling long throw applications.
   - Introduction of a lower (below 20W) lamp for miniature and special case work applications
   - General improvements with respect to extended (longer) lamp life and color quality (higher CRI), especially for lamp types most often used in retail lighting applications.
   - Special socket needed for self-ballasted CMH lamps. Currently credit for these lamps is hard to achieve unless they are on a circuit with a current limiter.
2. Introduce a wider range of T5 system options, both lamps and ballasts similar to systems now available in the latest generation T8 lighting.
   - Watt-miser T5 lamp and low power ballast combination (for under shelf applications)
   - Multi level step ballasts for increased light output and or light reduction options.
   - Low cost asymmetric distribution strip luminaire with T5 lamping for valances, soffits and coves.
3. Improved performance and color quality of LED lighting.
   - Improved “white light” options, especially in the 2800K to 3000K family
   - Longer life and higher LPW with less lumen depreciation
   - User/designer available tailored design options

Human Factors Research

Areas that have traditionally made use of the tailored lighting method for compliance such as retail spaces have typically not made much use of lighting controls as it relates to occupancy, demand reduction or adaptation compensation. All of these areas have potentially a large impact on energy consumption in retail lighting. In addition, from our interviews of designers, this was one area of the Title 24 standard which they were not opposed to greater regulation. Key research needs include:

- Better understanding of customer response to demand responsive controls that lower light levels during hot summer afternoons. If one is going to shed lighting load, which elements of retail lighting should one shed first?
- How people react to motion sensors in a retail environment. Research on how motion sensors could be used to save energy and attract attention simultaneously could set the stage for control credits for these devices. It is possible that such controls could even stimulate more sales for products that are “jumping out” at people as they pass by. The speed at which the system comes up to full brightness, how long a time delay should be set for such controls and whether certain lighting types and locations are more amenable for this type of control.
- Is less retail lighting at night desirable and does it improve security? When someone enters a store from the dark outdoors, the eye needs to accommodate to the vastly brighter light levels. Do people prefer to shop in areas that are less glaring in terms of lighting intensity and luminance contrast when entering from a darker environment? Retail stores that are open all night with during times of low

activity such as all night gas stations mini-markets etc. have greater visibility to the outside when it is darker inside.

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Appendix 1 - Rationale for proposed lower LPD's in Table 146-B THRU D

Overview

Rationale for proposed lower LPD'S under Table B – Complete Building

Recommended lower LPD'S numbers for title 24-2008 Table 146-B: General Commercial and Industrial Buildings and Industrial and Commercial Storage buildings are based on improved efficacy lamps and luminaires. These improvements result in approximately a 10% reduction potential. This recommendation can be achieved using the latest generation T5 and T8 fluorescent systems and electronic HID ballasts with pulse start and/or CMH lamps.

Rationale for proposed lower LPD'S under Table C – Area Category

Comments for 'asterisk item a', additional allowed power for chandelier and sconces are based on the following: The smaller proposed reduction to 0.9 is made feasible by the availability of decorative halogen lamp alternatives to conventional decorative incandescent lamps. This reduction is recommended when the need for dimming is required. A more aggressive reduction to 0.5 is possible because of the available compact fluorescent options that allow for substitution of traditional incandescent lamps when dimming is neither critical nor necessary. These improvements result in approximately a 10% reduction potential with dimming and up to a 50% reduction in non-dimming designs.

Rationale for proposed lower LPD's on floor, wall and valuable merchandise displays

Recommended lower LPD numbers for T24-2008 Table 146-D Grocery Store, and Retail Sales/Showrooms columns 3 (Wall Display) 4 (Floor Display) and 6 (Valuable Display Retail Spaces) are based on extensive detailed AGi-32 modeling, comparative space modeling and improved efficacy lamps and luminaires. Display functions where CMH is appropriate offer a 30% or greater reduction potential because the increased efficacy of ceramic metal halide over halogen. Other function/space areas with allowed LPD's in columns 3 and 4 were reviewed with recommended lower LPD's based primarily on improved efficacy lamps and luminaires. Some extrapolation of data gained from the models was also used when/where appropriate. While not as dramatic as the CMH effects, a 10% reduction potential is achieved through use of the latest generation of T5 and T8 with electronic ballast and halogen silver IR lamps.

Rationale for proposed lower LPD's on ornamental and special effect lighting

Recommended lower LPD's for T24-2008 Table 146-D column 5 "Ornamental/Special Effects Lighting is based primarily on improved efficacy lamps and luminaires. Even when incandescent used halogen replacements are available. These improvements result in approximately a 10% reduction potential. Impact of LED lighting technology to influence this category was also considered as compared to low wattage halogen in linear space applications.

Rationale for leaving certain allowed LPD's at the Title 24-2005 base

LPD numbers (T24-05 Table 146-D) under columns 3, 4 and 5 for certain functions/spaces are recommended as remaining unchanged for Title 24-2008 Table 146D because they either represent minimum impact and/or require traditional light sources and dimming capabilities. In most cases the function/space type allocations for T24-2005 were based on dimming needs and use of primarily decorative lighting equipment. This premise has not changed under proposed T24-2008 compliance. Furthermore in a number of applications such as "Religious Worship" and "Dinning" operating hours are limited and extensive use of programmed lighting controls are employed.

Functions/spaces not allowed additional LPD's under columns 3, 4, 5, and/or 6

Function/area spaces currently (T24-05) not allowed additional power under these columns is proposed to remain as under Title 24-2005. Our review and evaluation of the spaces/functions found no justification to change the status of these spaces with respect to additional LPD allowances.

Detail Tables

Individual functions/spaces were reviewed with respect to current Wall Display, Floor Display and Ornamental/effects lighting. Each of these categories has it own table with current and proposed watts for LPD's shown. Within the "Rationale – comments and remarks" a brief explanation if the rational is given. The rational is based on the more detailed explanations given in the above Overview section of this Appendix.

Table 51: Rationale for proposed changes to Wall Display Power under T24-2008 Table 146-D

Primary Function/Space	Current Wall Display Power (W/lf)	Proposed Wall Display Power (W/lf)	**Rationale – comments and remarks**
Auditorium	**2.5**	**2.25**	Proposed reduction based on improved lamping efficacy
Civic Meeting Place	**3.5**	**3.15**	Proposed reduction based on improved lamping efficacy
Classroom, lecture, training	**7.0**	**5.5**	Proposed reduction based on visual evaluation of classroom spaces and improved lamping efficacy
Commercial/Industrial storage	NA	NA	Not allowed T24-05, see no need under for T24-08
Convention, conference	**2.5**	**2.5**	No reduction proposed,
Corridors and stairs	NA	NA	Not allowed T24-05, see no need under for T24-08
Dining	**1.5**	**1.5**	No reduction proposed, significant requirement for dimming and standard decorative incandescent lamping
Exercise center/gymnasium	NA	NA	Not allowed T24-05, see no need under for T24-08
Exhibit, museum	**20.0**	**20.0**	No reduction proposed. Some issues with UV filtering of light for CMH; small statewide area. Redefine galleries as retail spaces.
Financial Transactions	**3.5**	**3.15**	Proposed reduction based on improved lamping efficacy
Grocery store	**11.0**	**8.0**	Proposed reduction based on AGi32 models
Housing; public and common area	NA	NA	Not allowed T24-05, see no need under for T24-08

Primary Function/Space	Current Wall Display Power (W/lf)	Proposed Wall Display Power (W/lf)	Rationale – comments and remarks
Hotel Function	**2.5**	**2.25**	Proposed reduction based on improved lamping efficacy
Jail	NA	NA	Not allowed T24-05, see no need under for T24-08
Kitchen, food preparation	NA	NA	Not allowed T24-05, see no need under for T24-08
Laundry	NA	NA	Not allowed T24-05, see no need under for T24-08
Library	NA	NA	Not allowed T24-05, see no need under for T24-08
Lobbies	**3.5**	**3.15**	Proposed reduction based on improved lamping efficacy
Locker rooms	NA	NA	Not allowed T24-05, see no need under for T24-08
Dressing rooms *(non retail)*	NA	NA	Not allowed T24-05, see no need under for T24-08
Lounge/recreation	**7.0**	**7.0**	No reduction proposed
Malls and Atria	**3.5**	**3.15**	Proposed reduction based on improved lamping efficacy
Medical and clinical care	NA	NA	Not allowed T24-05, see no need under for T24-08
Office *(general & VDT)*	NA	NA	Not allowed T24-05, see no need under for T24-08
Police and Fire stations	NA	NA	Not allowed T24-05, see no need under for T24-08
Religious worship	**1.5**	**1.5**	No reduction proposed, significant requirement for dimming and standard decorative incandescent lamping
Retail sales and showrooms	**21.0**	**17.0**	Proposed reduction based on AGi-32 models, with allowance for deep shelving
Tenant lease space	NA	NA	Not allowed T24-05, no need under T24-08
Theaters *(motion picture)*	**3.0**	**3.0**	No reduction proposed, significant requirement for dimming and standard decorative incandescent lamping
Theaters *(performance)*	**6.0**	**6.0**	No reduction proposed, significant requirement for dimming and standard decorative

Primary Function/Space	Current Wall Display Power (W/lf)	Proposed Wall Display Power (W/lf)	Rationale – comments and remarks
			incandescent lamping
Transportation Function	**3.5**	**3.15**	Proposed reduction based on improved lamping efficacy
Waiting Area	**3.5**	**3.15**	Proposed reduction based on improved lamping efficacy

Table 52 Rationale for proposed changes to Floor Display Power under T24-2008 Table 146-D

Primary Function/Space	Current Floor Display Power (W/sf)	Proposed Floor Display Power (W/sf)	Rationale – comments and remarks
Auditorium	**0.3**	**0.3**	No reduction proposed, minimal LPD allowance -2005
Civic Meeting Place	**0.2**	**0.2**	No reduction proposed, minimal LPD allowance -2005
Classroom, lecture, training	NA	NA	Not allowed T24-05, see no need under for T24-08
Commercial/Industrial storage	NA	NA	Not allowed T24-05, see no need under for T24-08
Convention, conference	**0.4**	**0.4**	No reduction proposed, minimal LPD allowance -2005
Corridors and stairs	NA	NA	Not allowed T24-05, see no need under for T24-08
Dining	**0.6**	**0.6**	No reduction proposed, significant requirement for dimming and standard decorative incandescent lamping
Exercise center/gymnasium	NA	NA	Not allowed T24-05, see no need under for T24-08
Exhibit, museum	**1.4**	**1.4**	No reduction proposed. Some issues with UV filtering of light for CMH; small statewide area. Redefine galleries as retail spaces.
Financial Transactions	**0.2**	**0.2**	No reduction proposed, minimal LPD allowance -2005
Grocery store	**1.2**	**0.85**	Proposed reduction based on AGi-32 models
Housing; public and common area	NA	NA	Not allowed T24-05, see no need under for T24-08
Hotel Function	**0.2**	**0.2**	No reduction proposed, minimal LPD allowance -2005
Jail	NA	NA	Not allowed T24-05, see no need under for T24-08
Kitchen, food preparation	NA	NA	Not allowed T24-05, see no need under for T24-08
Laundry	NA	NA	Not allowed T24-05, see no need under for

			T24-08
Library	NA	NA	Not allowed T24-05, see no need under for T24-08
Lobbies	**0.2**	**0.2**	No reduction proposed, minimal LPD allowance -2005
Locker rooms	NA	NA	Not allowed T24-05, see no need under for T24-08
Dressing rooms *(non retail)*	NA	NA	Not allowed T24-05, see no need under for T24-08
Lounge/recreation	NA	NA	Not allowed T24-05, see no need under for T24-08
Malls and Atria	**0.5**	**0.5**	No reduction proposed, minimal LPD allowance -2005
Medical and clinical care	NA	NA	Not allowed T24-05, see no need under for T24-08
Office *(general & VDT)*	NA	NA	Not allowed T24-05, see no need under for T24-08
Police and Fire stations	NA	NA	Not allowed T24-05, see no need under for T24-08
Religious worship	**0.6**	**0.6**	No reduction proposed, significant requirement for dimming and standard decorative incandescent lamping
Retail sales and showrooms	**1.5**	**1.1**	Proposed reduction based on AGi-32 models. With 1.2 W/sf, allows for use of halogen IR display lighting in low ceilings.
Tenant lease space	NA	NA	Not allowed T24-05, see no need under for T24-08
Theaters *(motion picture)*	NA	NA	Not allowed T24-05, see no need under for T24-08
Theaters *(performance)*	NA	NA	Not allowed T24-05, see no need under for T24-08
Transportation Function	**0.3**	**0.3**	No reduction proposed, minimal LPD allowance -2005
Waiting Area	**0.2**	**0.2**	No reduction proposed, minimal LPD allowance -2005

Table 53: Rationale for proposed changes to Special Effect Power allowances in Table 146-D

Primary Function/Space	Current Ornamental Special Effect	Current Ornamental Special Effect	Rationale – comments and remarks
Auditorium	**0.5**	**0.5**	No reduction proposed, minimal LPD allowance -2005
Civic Meeting Place	**0.5**	**0.5**	No reduction proposed, minimal LPD allowance -2005
Classroom, lecture, training	NA	NA	Not allowed T24-05, see no need under for T24-08
Commercial/Industrial storage	NA	NA	Not allowed T24-05, see no need under for T24-08
Convention, conference	**0.5**	**0.5**	No reduction proposed, minimal LPD allowance -2005
Corridors and stairs	NA	NA	Not allowed T24-05, see no need under for T24-08
Dining	**0.6**	**0.6**	No reduction proposed, significant requirement for dimming and standard decorative incandescent lamping
Exercise center/gymnasium	NA	NA	Not allowed T24-05, see no need under for T24-08
Exhibit, museum	**0.7**	**0.7**	No reduction proposed. Some issues with UV filtering of light for CMH; small statewide area. Redefine galleries as retail spaces.
Financial Transactions	**0.6**	**0.6**	No reduction proposed, minimal LPD allowance -2005
Grocery store	NA	NA	Not allowed T24-05, see no need under for T24-08
Housing; public and common area	**1.0**	**0.9**	Proposed reduction based on improved lamping efficacy
Hotel Function	**0.5**	**0.5**	No reduction proposed, significant requirement for dimming and standard decorative incandescent lamping
Jail	NA	NA	Not allowed T24-05, see no need under for T24-08
Kitchen, food preparation	NA	NA	Not allowed T24-05, see no need under for T24-08
Laundry	NA	NA	Not allowed T24-05, see no need under for T24-08
Library	**0.7**	**0.6**	Proposed reduction based on improved lamping efficacy
Lobbies	**0.7**	**0.6**	Proposed reduction based on improved

Primary Function/Space	Current Ornamental Special Effect	Current Ornamental Special Effect	Rationale – comments and remarks
			lamping efficacy
Locker rooms	NA	NA	Not allowed T24-05, see no need under for T24-08
Dressing rooms *(non retail)*	NA	NA	Not allowed T24-05, see no need under for T24-08
Lounge/recreation	**0.7**	**0.6**	Proposed reduction based on improved lamping efficacy and use of new technologies such as LED lighting
Malls and Atria	**0.7**	**0.6**	Proposed reduction based on improved lamping efficacy and use of new technologies such as LED lighting
Medical and clinical care	NA	NA	Not allowed T24-05, see no need under for T24-08
Office *(general & VDT)*	NA	NA	Not allowed T24-05, see no need under for T24-08
Police and Fire stations	NA	NA	Not allowed T24-05, see no need under for T24-08
Religious worship	**0.5**	**0.5**	No reduction proposed, significant requirement for dimming and standard decorative incandescent lamping
Retail sales and showrooms	**0.7**	**0.6**	Proposed reduction based on improved lamping efficacy and use of new technologies such as LED lighting
Tenant lease space	NA	NA	Not allowed T24-05, see no need under for T24-08
Theaters *(motion picture)*	**0.6**	**0.6**	No reduction proposed, significant requirement for dimming and standard decorative incandescent lamping
Theaters *(performance)*	**0.6**	**0.6**	No reduction proposed, significant requirement for dimming and standard decorative incandescent lamping
Transportation Function	**0.7**	**0.6**	Proposed reduction based on improved lamping efficacy and use of new technologies such as LED lighting
Waiting Area	**0.7**	**0.6**	Proposed reduction based on improved lamping efficacy and use of new technologies such as LED lighting

Appendix 2– Rationale for proposed Title 24 Table 146-E Adjustments for Mounting Heights

Overview of Philosophy and Rational

PG&E Version *(Exhibit A)*

Allowed display lighting LPD under proposed T24-08 standards is based on CMH design models. However, because of cost effective issues with some CMH lamps (20W CMH lamping) limited consideration is given to use of advanced generation "super IR' halogen technologies. The base Floor Display allowed LPD (1.1W per square foot) and base Wall Display LPD (16W per lineal foot) are skewed toward use of CMH while permitting some halogen, especially in lower ceilings.

Mounting height multipliers, as set in the PG&E version are designed to promote limited CMH use in lower ceilings and extensive use at higher ceilings. However, the newer halogen "Super IR" and 20W CMH lamps contain approximately 8% less maintained lumens than the 60W IR lamp used to set the 2005 standard. Therefore the PG&E proposal, allows height adjustments to kick in at a somewhat lower ceiling height than under the 05 standard. This lower ceiling threshold will compensate for the lower lumens used in the base case design models developed for spaces with 10-foot (and below) ceilings.

CEC Version *(Exhibit B)*

Note: CEC version accepted to allow the use of halogen lighting in lower ceiling heights.

Allowed display lighting LPD under the alternate (CEC counter proposal) proposed 2008 standards is based on advanced generation "super IR" halogen technologies for low and medium height environments. **CMH is considered by the CEC consultant to be Non Cost Effective except in higher wattages; therefore CMH is currently only appropriate at high ceilings.** The base Floor Display allowed LPD (1.2W per square foot) and base Wall Display LPD (16W per lineal foot) are skewed toward use of "Super IR" halogen, especially in lower ceilings.

Mounting height multipliers, as set in the CEC version are designed to promote CMH aggressively, but only at higher ceilings. "Super IR" halogen is the model for the LPD base of 1.2W per square foot and "Super IR" halogen is the expected source for low and medium ceiling applications. However, the newer halogen "Super IR" lamps contain approximately 8% less maintained lumens than the 60W IR lamp used to set the 2005 standard. Therefore the CEC proposal as was also stated in the PG&E proposal, allows height adjustments to kick in at a somewhat lower ceiling height than under the 05 standard. This lower ceiling threshold will compensate for the lower lumens used in the base case design (Title24-2005model 60E HIR) developed for spaces with 10-foot (and below) ceilings.

SPECIFIC DETAILS OF TABLE 146-E [PG&E as well as CEC Versions]

- New proposed table reduces the total adjustment factors from 9 to 4 divisions. This change will simplify the table; reducing compliance complexity while still allowing LPD increases to offset longer throw distances and greater luminaire mounting heights.
- Proposed new multipliers are weighted such that they should encourage greater use of CMH in higher ceilings while providing opportunity to use the additional range of advanced IR lamps along with lower wattage CMH lamps at medium heights.
- The latest proposed Title 24-2008 Table 146-E also separates the factors for floor display versus wall display with less allowance for wall displays. Floor display relies primarily on point source directional lighting (mostly halogen) while wall display has greater opportunity to employ fluorescent and CMH sources than the floor display.
- The following comparisons show proposed Table 146-E in the current PG&E Interior Lighting Draft, the revised proposed Table 146-E to be amended in the PG&E document, the current Title 24-2005 table 145-E and a comparison of the expected wattage reduction between the 2008 and 2005 tables:
  Table as submitted currently under PG&E T24-2008 Interior Lighting Draft Report *(Exhibit A)*

Based on PG&E Criteria of 1.1W Square Foot Floor Display and 16W Lineal Foot Wall Display

TABLE 146-E ADJUSTMENTS FOR MOUNTING HEIGHT ABOVE FLOOR

Height in feet above finished floor and bottom of luminaire(s)	Floor Display - Multiply by	Wall Display - Multiply by
~~12 or less~~ 11'6" or less	1.0	1.0
~~13~~	~~1.05~~	
~~14~~	~~1.10~~	
~~15~~	~~1.15~~	
~~16~~ > 11'6"	~~1.21~~ 1.3	1.15
~~17~~	~~1.47~~	
~~18~~	~~1.65~~	
~~19~~ > 16'	~~1.84~~ 1.5	1.35
~~20 or more~~ > 20'	~~2.04~~ 2.10	1.75

Alternate CEC Table proposed to replace above table - PG&E T24-2008 Interior Lighting Draft Report *(Exhibit B)*

Based on CEC Criteria of 1.2W Square Foot Floor Display and 16W Lineal Foot Wall Display

TABLE 146-E ADJUSTMENTS FOR MOUNTING HEIGHT ABOVE FLOOR

Height in feet above finished floor and bottom of luminaire(s)	Floor Display - Multiply by	Wall Display - Multiply by
~~12 or less~~ 11'-0" or less	1.0	1.0
~~13~~	~~1.05~~	
~~14~~	~~1.10~~	
~~15~~	~~1.15~~	
~~16~~ > 11'6"	~~1.21~~ 1.2	1.15
~~17~~	~~1.47~~	
~~18~~	~~1.65~~	
~~19~~ > 16'	~~1.84~~ 1.4	1.35
~~20 or more~~ > 20'	~~2.04~~ 2.0	1.75

TABLE 146-E ADJUSTMENTS FOR MOUNTING HEIGHT ABOVE FLOOR *(Floor Accent)*

Comparisons between current Title 24-2005 Table and Proposed Title 24-2008 Table *(Exhibit A)*

Title 24-05 Table – LPD Adjustments for Mounting Height				Proposed Title 24-08 Table – LPD Adjustments for Mounting Height				
Mount Height	Base Watts	Factor	Adjusted Watts	Mount Height	Base Watts	Factor	Adjusted Watts	% Reduction over 05
11-6 or less	1.5W	1.0	1.5W	**11-6 or less**	**1.1W**	**1.0**	**1.1W**	**26.7%**
Greater 11-6	1.5W		1.5W	**Greater 11-6**	**1.1W**	**1.3**	**1.43W**	**4.7%**
12 or less	1.5W	1.0	1.5W	12 or less	1.1W	1.3	1.43W	4.7%
13	1.5W	1.05	1.58W	13	1.1W	1.3	1.43W	9.5%
14	1.5W	1.10	1.65W	14	1.1W	1.3	1.43W	13.3%
15	1.5W	1.15	1.73W	15	1.1W	1.3	1.43W	17.3%
16	1.5W	1.21	1.82W	**16**	**1.1W**	**1.5**	**1.65W**	**9.3%**
17	1.5W	1.47	2.21W	17	1.1W	1.5	1.65W	25.3%
18	1.5W	1.65	2.48W	18	1.1W	1.5	1.65W	33.5%
19	1.5W	1.84	2.76W	19	1.1W	1.5	1.65W	40.2%
20 or more	1.5W	2.04	3.06W	**20 or more**	**1.1W**	**2.10**	**2.31W**	**24.5%**
							Average % Reduction	**19.0%**

TABLE 146-E ADJUSTMENTS FOR MOUNTING HEIGHT ABOVE FLOOR *(Wall Accent)*

Comparisons between current Title 24-2005 Table and Proposed Title 24-2008 Table *(Exhibit A)*

Title 24-05 Table – LPD Adjustments for Mounting Height				Proposed Title 24-08 Table – LPD Adjustments for Mounting Height				
Mount Height	Base Watts	Factor	Adjusted Watts	Mount Height	Base Watts	Factor	Adjusted Watts	% Reduction over 05
11-6 or less	21W	1.0	21W	**11-6 or less**	**16W**	**1.0**	**16W**	**23.8%**
Greater 11-6	21W	1.0	21W	**Greater 11-6**	**16W**	**1.15**	**18.4W**	**12.4%**
12 or less	21W	1.0	21W	12 or less	16W	1.15	18.4W	12.4%
13	21W	1.05	22.1W	13	16W	1.15	18.4W	16.7%
14	21W	1.10	23.1W	14	16W	1.15	18.4W	20.3%
15	21W	1.15	24.2W	15	16W	1.15	18.4W	24.0%
16	21W	1.21	25.4W	**16**	**16W**	**1.35**	**21.6W**	**15.0%**
17	21W	1.47	30.9W	17	16W	1.35	21.6W	30.1%
18	21W	1.65	34.7W	18	16W	1.35	21.6W	37.8%
19	21W	1.84	38.6W	19	16W	1.35	21.6W	44.0%
20 or more	21W	2.04	42.8W	**20 or more**	**16W**	**1.85**	**29.6W**	**30.8%**
							Average % Reduction	**24.3%**

TABLE 146-E ADJUSTMENTS FOR MOUNTING HEIGHT ABOVE FLOOR *(Floor Accent)*

Comparisons between current Title 24-2005 Table and Proposed Title 24-2008 Table *(Exhibit B)*

Title 24-05 Table – LPD Adjustments for Mounting Height				Proposed Title 24-08 Table – LPD Adjustments for Mounting Height				
Mount Height	Base Watts	Factor	Adjusted Watts	Mount Height	Base Watts	Factor	Adjusted Watts	% Reduction over 05
11 or less	1.5W	1.0	1.5W	**11 or less**	**1.2W**	**1.0**	**1.2W**	**20%**
Greater 11	1.5W		1.5W	**Greater 11**	**1.2W**	**1.2**	**1.44W**	**4%**
12 or less	1.5W	1.0	1.5W	12 or less	1.2W	1.2	1.44W	4%
13	1.5W	1.05	1.58W	13	1.2W	1.2	1.44W	9%
14	1.5W	1.10	1.65W	14	1.2W	1.2	1.44W	13%
15	1.5W	1.15	1.73W	15	1.2W	1.2	1.44W	17%
16	1.5W	1.21	1.82W	**16**	**1.2W**	**1.4**	**1.68W**	**8%**
17	1.5W	1.47	2.21W	17	1.2W	1.4	1.68W	24%
18	1.5W	1.65	2.48W	18	1.2W	1.4	1.68W	32%
19	1.5W	1.84	2.76W	19	1.2W	1.4	1.68W	39%
20 or more	1.5W	2.04	3.06W	**20 or more**	**1.2W**	**2.0**	**2.4W**	**21.5%**
							Average % Reduction	**17.4%**

TABLE 146-E ADJUSTMENTS FOR MOUNTING HEIGHT ABOVE FLOOR *(Wall Accent)*

Comparisons between current Title 24-2005 Table and Proposed Title 24-2008 Table *(Exhibit B)*

Title 24-05 Table – LPD Adjustments for Mounting Height				Proposed Title 24-08 Table – LPD Adjustments for Mounting Height				
Mount Height	Base Watts	Factor	Adjusted Watts	Mount Height	Base Watts	Factor	Adjusted Watts	% Reduction over 05
11 or less	21W	1.0	21W	**11 or less**	**17W**	**1.0**	**17W**	**19.0%**
Greater 11	21W	1.0	21W	**Greater 11**	**17W**	**1.15**	**19.55W**	**7.0%**
12 or less	21W	1.0	21W	12 or less	**17W**	1.15	**19.55W**	6.9%
13	21W	1.05	22.1W	13	**17W**	1.15	**19.55W**	11.5%
14	21W	1.10	23.1W	14	**17W**	1.15	**19.55W**	15.4%
15	21W	1.15	24.2W	15	**17W**	1.15	**19.55W**	19.2%
16	21W	1.21	25.4W	**16**	**17W**	**1.35**	**22.95W**	**9.6%**
17	21W	1.47	30.9W	17	**17W**	1.35	**22.95W**	25.1 %
18	21W	1.65	34.7W	18	**17W**	1.35	**22.95W**	33.9%
19	21W	1.84	38.6W	19	**17W**	1.35	**22.95W**	40.5%
20 or more	21W	2.04	42.8W	**20 or more**	**17W**	**1.85**	**31.45W**	**26.5 %**
							Average % Reduction	**19.6%**

Appendix 3 – Ceramic Metal Halide Life Cycle Cost Analysis

CMH COST ANALYSIS - HIGH VOLUME PURCHASE - 7 YEAR COST RECOVERY CYCLE

	Halogen Ref.	Halogen IR Eq.	Advanced HIR	CMH Alternate	Halogen Ref.	Halogen IR Eq.	Advanced HIR	CMH Alternate	Halogen Ref.	CMH Alternate
Lamp Watts	75W PAR38	60W PAR38	55W PAR38	20W PAR30	120W PAR38	100W PAR38	90W PAR38	39W PAR30	250W PAR38	70W PAR30
Mean Lumens	1050 *1	1100 *1	1050 *1	1030 *2	1800 *1	2030 *1	2030 *1	2160 *2	3600 *1	4230 *2
Input Watts	75 *3	60 *3	55 *3	25 *4	120 *3	100 *3	90 *3	44 *4	250 *3	75 *4
Watts	75	60	55	25	120	100	90	44	250	75
Operating Hours/yr	3910	3910	3910	3910	3910	3910	3910	3910	3910	3910
A/C interaction effect	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Period of Analysis (Years)	7	7	7	7	7	7	7	7	7	7
Elec Consumption kWh/yr	337	270	247	112	540	450	405	198	1,124	337
Elec Consumption TDV kBtu	6,761	5,409	4,958	2,254	10,817	9,014	8,113	3,966	22,536	6,761
Annual Elec Costs	$ 47.78	$ 38.22	$ 35.04	$ 15.93	$ 76.44	$ 63.70	$ 57.33	$ 28.03	$ 159.26	$ 47.78
PV Electric Costs PV$	$ 297.66	$ 238.13	$ 218.29	$ 99.22	$ 476.26	$ 396.89	$ 357.20	$ 174.63	$ 992.22	$ 297.66
Avg elec cost $/kWh	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14
Luminaire Cost	$ 55.00	$ 55.00	$ 55.00	$ 170.00	$ 55.00	$ 55.00	$ 55.00	$ 170.00	$ 55.00	$ 170.00
Lamp Cost	$ 3.50	$ 6.50	$ 8.50	$ 30.00	$ 3.50	$ 6.50	$ 8.50	$ 30.00	$ 12.00	$ 30.00
First Cost Lamp and Luminaire	$ 58.50	$ 61.50	$ 63.50	$ 200.00	$ 58.50	$ 61.50	$ 63.50	$ 200.00	$ 67.00	$ 200.00
A/C tons	0.021	0.017	0.016	0.007	0.034	0.028	0.026	0.013	0.071	0.021
First Cost AC	$ 32.00	$ 25.60	$ 23.46	$ 10.67	$ 51.20	$ 42.66	$ 38.40	$ 18.77	$ 106.66	$ 32.00
Total First Cost PV$	$ 90.50	$ 87.10	$ 86.96	$ 210.67	$ 109.70	$ 104.16	$ 101.90	$ 218.77	$ 173.66	$ 232.00
Relamping labor	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60
Lamp replacement cost including labor	$ 5.10	$ 8.10	$ 10.10	$ 31.60	$ 5.10	$ 8.10	$ 10.10	$ 31.60	$ 13.60	$ 31.60
Lamp Life (burning hr)	2,500	4,000	4,000	7,500	2,500	4,000	4,000	10,000	4,200	10,000
Maintenance Cost PV $	$ 45.38	$ 42.60	$ 53.12	$ 84.33	$ 45.38	$ 42.60	$ 53.12	$ 55.38	$ 71.53	$ 55.38
Life Cycle Cost (LCC) PV$	$ 433.55	**$ 367.83**	**$ 358.37**	**$ 394.21**	$ 631.34	**$ 543.65**	**$ 512.21**	**$ 448.78**	$ 1,237.40	**$ 585.04**

CMH COST ANALYSIS - LOW VOLUME PURCHASE - 7 YEAR COST RECOVERY CYCLE

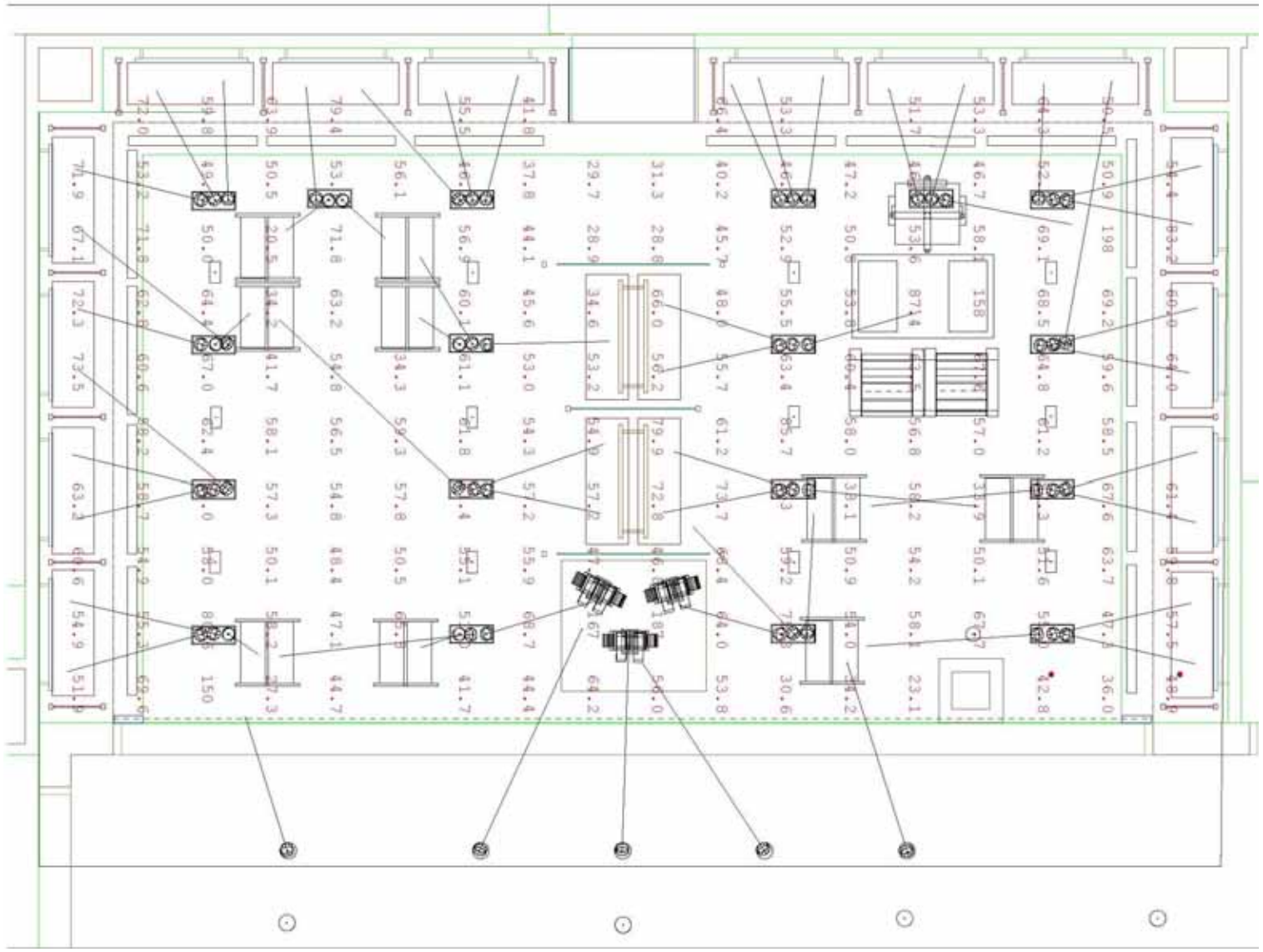
	Halogen Ref.	Halogen IR Eq.	Advanced HIR	CMH Alternate	Halogen Ref.	Halogen IR Eq.	Advanced HIR	CMH Alternate	Halogen Ref.	CMH Alternate
Lamp Watts	75W PAR38	60W PAR38	55W PAR38	20W PAR30	120W PAR38	100W PAR38	90W PAR38	39W PAR30	250W PAR38	70W PAR30
Mean Lumens	1050 *[1]	1100 *[1]	1050 *[1]	1030 *[2]	1800 *[1]	2030 *[1]	2030 *[1]	2160 *[2]	3600 *[1]	4230 *[2]
Input Watts	75 *[3]	60 *[3]	55 *[3]	25 *[4]	120 *[3]	100 *[3]	90 *[3]	44 *[4]	250 *[3]	75 *[4]
Watts	75	60	55	25	120	100	90	44	250	75
Operating Hours/yr	3910	3910	3910	3910	3910	3910	3910	3910	3910	3910
A/C interaction effect	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Period of Analysis (Years)	7	7	7	7	7	7	7	7	7	7
Elec Consumption kWh/yr	337	270	247	112	540	450	405	198	1,124	337
Elec Consumption TDV kBtu	6,761	5,409	4,958	2,254	10,817	9,014	8,113	3,966	22,536	6,761
Annual Elec Costs	$ 47.78	$ 38.22	$ 35.04	$ 15.93	$ 76.44	$ 63.70	$ 57.33	$ 28.03	$ 159.26	$ 47.78
PV Electric Costs PV$	$ 297.66	$ 238.13	$ 218.29	$ 99.22	$ 476.26	$ 396.89	$ 357.20	$ 174.63	$ 992.22	$ 297.66
Avg elec cost $/kWh	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14
Luminaire Cost	$ 55.00	$ 55.00	$ 55.00	$ 170.00	$ 55.00	$ 55.00	$ 55.00	$ 170.00	$ 55.00	$ 170.00
Lamp Cost	$ 5.00	$ 10.00	$ 13.00	$ 45.00	$ 5.00	$ 10.00	$ 13.00	$ 45.00	$ 15.00	$ 45.00
First Cost Lamp and Luminaire	$ 60.00	$ 65.00	$ 68.00	$ 215.00	$ 60.00	$ 65.00	$ 68.00	$ 215.00	$ 70.00	$ 215.00
A/C tons	0.021	0.017	0.016	0.007	0.034	0.028	0.026	0.013	0.071	0.021
First Cost AC	$ 32.00	$ 25.60	$ 23.46	$ 10.67	$ 51.20	$ 42.66	$ 38.40	$ 18.77	$ 106.66	$ 32.00
Total First Cost PV$	$ 92.00	$ 90.60	$ 91.46	$ 225.67	$ 111.20	$ 107.66	$ 106.40	$ 233.77	$ 176.66	$ 247.00
Relamping labor	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60
Lamp replacement cost including labor	$ 6.60	$ 11.60	$ 14.60	$ 46.60	$ 6.60	$ 11.60	$ 14.60	$ 46.60	$ 16.60	$ 46.60
Lamp Life (burning hr)	2,500	4,000	4,000	7,500	2,500	4,000	4,000	10,000	4,200	10,000
Maintenance Cost PV $	$ 58.73	$ 61.01	$ 76.79	$ 124.36	$ 58.73	$ 61.01	$ 76.79	$ 81.67	$ 87.31	$ 81.67
Life Cycle Cost (LCC) PV$	$ 448.39	**$ 389.74**	**$ 386.54**	$ 449.24	$ 646.19	**$ 565.56**	**$ 540.38**	**$ 490.07**	$ 1,256.18	**$ 626.33**

CMH COST ANALYSIS - HIGH VOLUME PURCHASE - 15 YEAR COST RECOVERY CYCLE

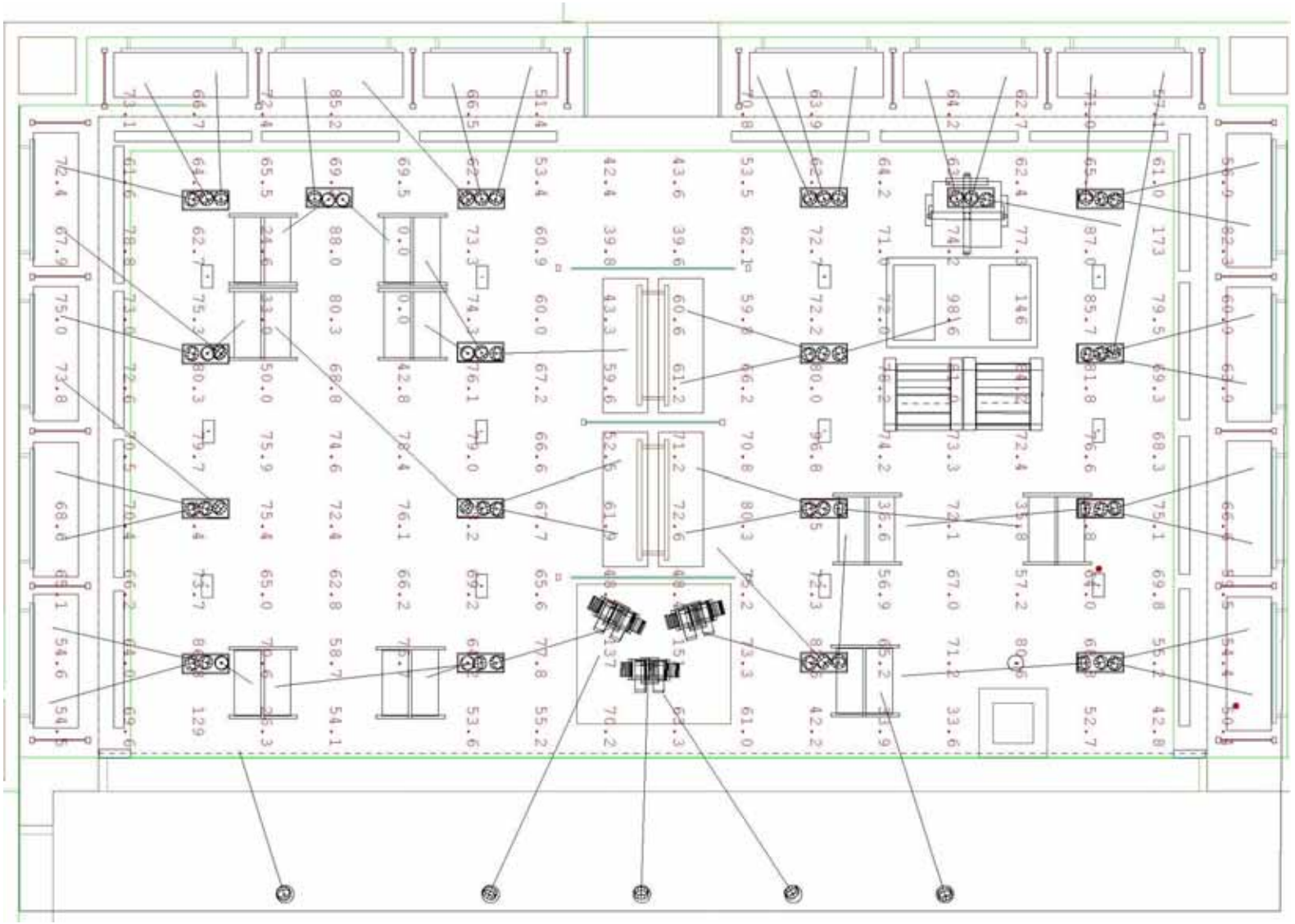
	Halogen Ref.	Halogen IR Eq.	Advanced HIR	CMH Alternate	Halogen Ref.	Halogen IR Eq.	Advanced HIR	CMH Alternate	Halogen Ref.	CMH Alternate
Lamp Watts	75W PAR38	60W PAR38	55W PAR38	20W PAR30	120W PAR38	100W PAR38	90W PAR38	39W PAR30	250W PAR38	70W PAR30
Mean Lumens	1050 *1	1100 *1	1050 *1	1030 *2	1800 *1	2030 *1	2030 *1	2160 *2	3600 *1	4230 *2
Input Watts	75 *3	60 *3	55 *3	25 *4	120 *3	100 *3	90 *3	44 *4	250 *3	75 *4
Watts	75	60	55	25	120	100	90	44	250	75
Operating Hours/yr	3910	3910	3910	3910	3910	3910	3910	3910	3910	3910
A/C interaction effect	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Period of Analysis (Years)	15	15	15	15	15	15	15	15	15	15
Elec Consumption kWh/yr	337	270	247	112	540	450	405	198	1,124	337
Elec Consumption TDV kBtu	6,761	5,409	4,958	2,254	10,817	9,014	8,113	3,966	22,536	6,761
Annual Elec Costs	$ 47.78	$ 38.22	$ 35.04	$ 15.93	$ 76.44	$ 63.70	$ 57.33	$ 28.03	$ 159.26	$ 47.78
PV Electric Costs PV$	$ 570.36	$ 456.29	$ 418.26	$ 190.12	$ 912.58	$ 760.48	$ 684.43	$ 334.61	$ 1,901.20	$ 570.36
Avg elec cost $/kWh	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14
Luminaire Cost	$ 55.00	$ 55.00	$ 55.00	$ 170.00	$ 55.00	$ 55.00	$ 55.00	$ 170.00	$ 55.00	$ 170.00
Lamp Cost	$ 3.50	$ 6.50	$ 8.50	$ 30.00	$ 3.50	$ 6.50	$ 8.50	$ 30.00	$ 12.00	$ 30.00
First Cost Lamp and Luminaire	$ 58.50	$ 61.50	$ 63.50	$ 200.00	$ 58.50	$ 61.50	$ 63.50	$ 200.00	$ 67.00	$ 200.00
A/C tons	0.021	0.017	0.016	0.007	0.034	0.028	0.026	0.013	0.071	0.021
First Cost AC	$ 32.00	$ 25.60	$ 23.46	$ 10.67	$ 51.20	$ 42.66	$ 38.40	$ 18.77	$ 106.66	$ 32.00
Total First Cost PV$	$ 90.50	$ 87.10	$ 86.96	$ 210.67	$ 109.70	$ 104.16	$ 101.90	$ 218.77	$ 173.66	$ 232.00
Relamping labor	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60
Lamp replacement cost including labor	$ 5.10	$ 8.10	$ 10.10	$ 31.60	$ 5.10	$ 8.10	$ 10.10	$ 31.60	$ 13.60	$ 31.60
Lamp Life (burning hr)	2,500	4,000	4,000	7,500	2,500	4,000	4,000	10,000	4,200	10,000
Maintenance Cost PV $	$ 92.86	$ 88.83	$ 110.77	$ 175.84	$ 92.86	$ 88.83	$ 110.77	$ 124.67	$ 140.42	$ 124.67
Life Cycle Cost (LCC) PV$	$ 753.72	**$ 632.22**	**$ 616.00**	**$ 576.63**	$ 1,115.13	$ 953.48	$ 897.10	**$ 678.06**	$ 2,215.28	**$ 927.03**

CMH COST ANALYSIS - LOW VOLUME PURCHASE - 15 YEAR COST RECOVERY CYCLE

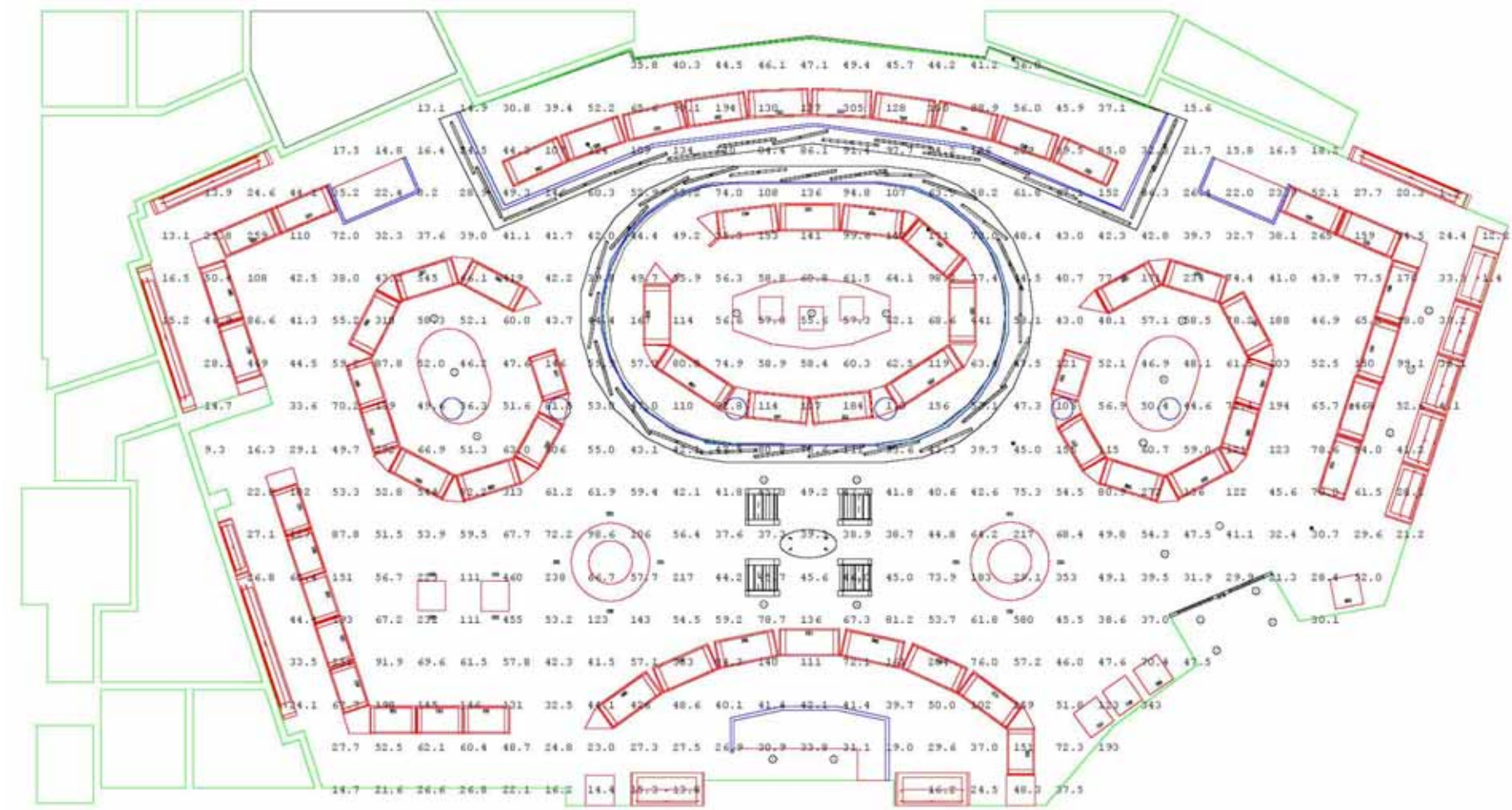
	Halogen Ref.	Halogen IR Eq.	Advanced HIR	CMH Alternate	Halogen Ref.	Halogen IR Eq.	Advanced HIR	CMH Alternate	Halogen Ref.	CMH Alternate
Lamp Watts	75W PAR38	60W PAR38	55W PAR38	20W PAR30	120W PAR38	100W PAR38	90W PAR38	39W PAR30	250W PAR38	70W PAR30
Mean Lumens	1050 *[1]	1100 *[1]	1050 *[1]	1030 *[2]	1800 *[1]	2030 *[1]	2030 *[1]	2160 *[2]	3600 *[1]	4230 *[2]
Input Watts	75 *[3]	60 *[3]	55 *[3]	25 *[4]	120 *[3]	100 *[3]	90 *[3]	44 *[4]	250 *[3]	75 *[4]
Watts	75	60	55	25	120	100	90	44	250	75
Operating Hours/yr	3910	3910	3910	3910	3910	3910	3910	3910	3910	3910
A/C interaction effect	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Period of Analysis (Years)	15	15	15	15	15	15	15	15	15	15
Elec Consumption kWh/yr	337	270	247	112	540	450	405	198	1,124	337
Elec Consumption TDV kBtu	6,761	5,409	4,958	2,254	10,817	9,014	8,113	3,966	22,536	6,761
Annual Elec Costs	$ 47.78	$ 38.22	$ 35.04	$ 15.93	$ 76.44	$ 63.70	$ 57.33	$ 28.03	$ 159.26	$ 47.78
PV Electric Costs PV$	$ 570.36	$ 456.29	$ 418.26	$ 190.12	$ 912.58	$ 760.48	$ 684.43	$ 334.61	$ 1,901.20	$ 570.36
Avg elec cost $/kWh	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14	$ 0.14
Luminaire Cost	$ 55.00	$ 55.00	$ 55.00	$ 170.00	$ 55.00	$ 55.00	$ 55.00	$ 170.00	$ 55.00	$ 170.00
Lamp Cost	$ 5.00	$ 10.00	$ 13.00	$ 45.00	$ 5.00	$ 10.00	$ 13.00	$ 45.00	$ 15.00	$ 45.00
First Cost Lamp and Luminaire	$ 60.00	$ 65.00	$ 68.00	$ 215.00	$ 60.00	$ 65.00	$ 68.00	$ 215.00	$ 70.00	$ 215.00
A/C tons	0.021	0.017	0.016	0.007	0.034	0.028	0.026	0.013	0.071	0.021
First Cost AC	$ 32.00	$ 25.60	$ 23.46	$ 10.67	$ 51.20	$ 42.66	$ 38.40	$ 18.77	$ 106.66	$ 32.00
Total First Cost PV$	$ 92.00	$ 90.60	$ 91.46	$ 225.67	$ 111.20	$ 107.66	$ 106.40	$ 233.77	$ 176.66	$ 247.00
Relamping labor	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60	$ 1.60
Lamp replacement cost including labor	$ 6.60	$ 11.60	$ 14.60	$ 46.60	$ 6.60	$ 11.60	$ 14.60	$ 46.60	$ 16.60	$ 46.60
Lamp Life (burning hr)	2,500	4,000	4,000	7,500	2,500	4,000	4,000	10,000	4,200	10,000
Maintenance Cost PV $	$ 120.17	$ 127.22	$ 160.12	$ 259.31	$ 120.17	$ 127.22	$ 160.12	$ 183.86	$ 171.40	$ 183.86
Life Cycle Cost (LCC) PV$	$ 782.53	**$ 674.10**	**$ 669.85**	**$ 675.09**	$ 1,143.94	**$ 995.36**	**$ 950.95**	**$ 752.24**	$ 2,249.25	**$ 1,001.21**



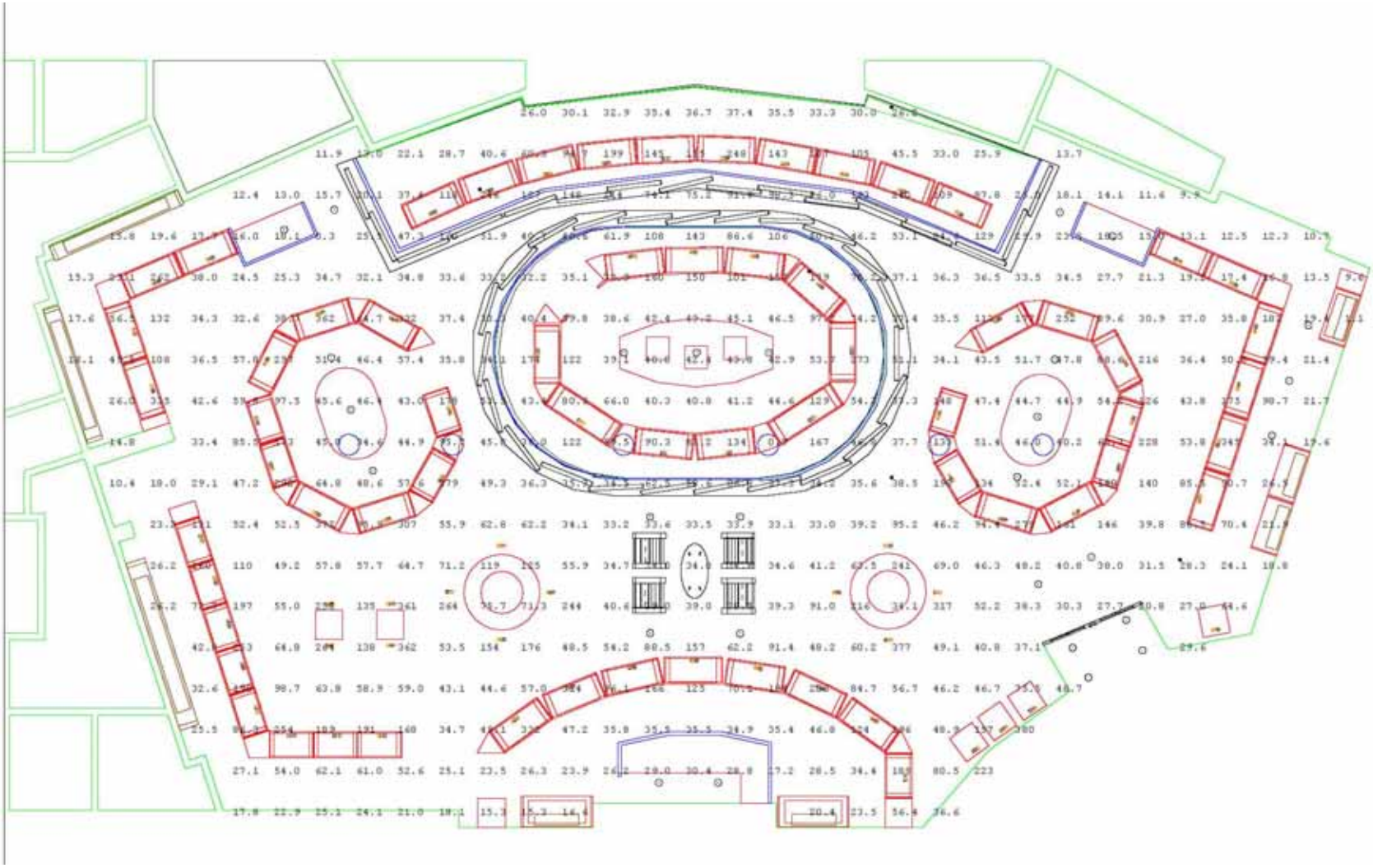
High End Retail 20W CMH



High End Retail 60W PAR38 HIR



High End Jewelry 39W PAR30 CMH



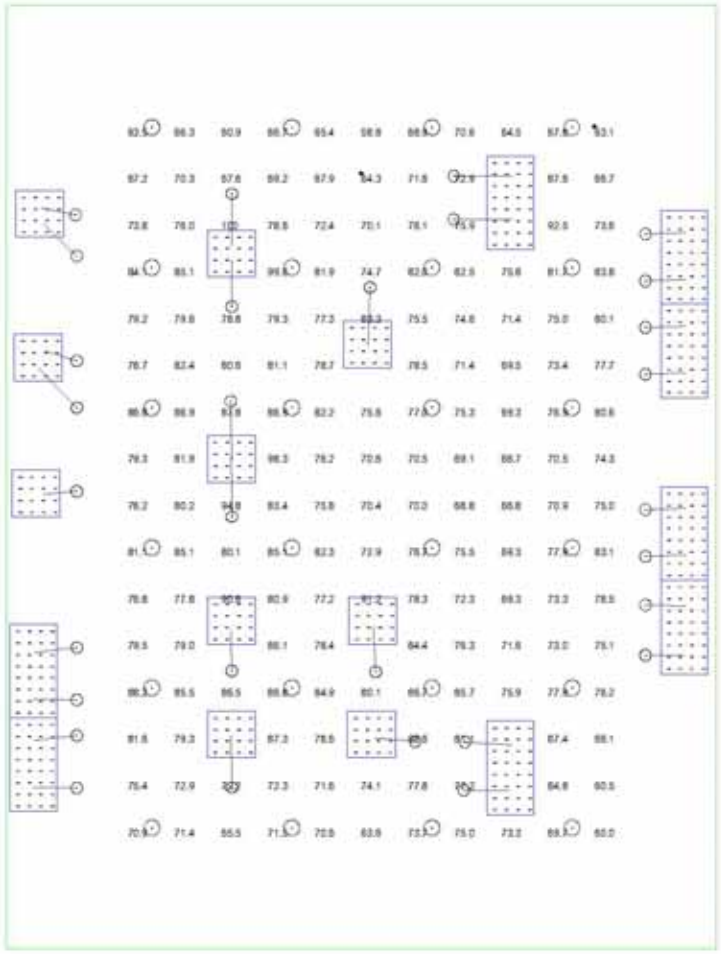
High End Jewelry 75W PAR30 HIR

42W Triple Tube CFL General Lighting w/ 55W PAR38 Silver HIR

Troffer Model: 2x4 Double T8 Design										
Symbol	Qty	Label	Lumens	LLF	LDD	LLD	BF	Watts	No. Lamps	Total Lumens
⊙	23	55W PAR38 Indy Q155R60SP	1150	0.776	0.8	0.97	1	55	1	1150
⊙	24	Ltl9815 TTube 42W SpecReflector	3200	0.627	0.8	0.8	0.98	48	1	3200

LPD Area Summary				
Label	Area	Total Watts	LPD	Perimeter
Strip Mall Retail LPD	1228	2417	1.968	141.62

Troffer Model: 2x4 Double T8 with 60W PAR38 HIR Accents							
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min
Strip Mall General Lighting	Illuminance	Fc	65.37	87.8	45.1	1.45	1.95
Display top-1	Illuminance	Fc	153.15	271	93.2	1.64	2.90
Display top-_2	Illuminance	Fc	152.61	288	89.1	1.71	3.24
Display top-_3	Illuminance	Fc	166.94	338	90.7	1.84	3.72
Display top-_4	Illuminance	Fc	176.25	385	103	1.72	3.75
Display top-_5	Illuminance	Fc	133.29	262	68.6	1.94	3.81
Display top-_6	Illuminance	Fc	137.81	266	71.0	1.94	3.75
Display top-_7	Illuminance	Fc	136.32	287	70.7	1.93	4.07
Display top-_8	Illuminance	Fc	153.78	285	89.5	1.72	3.19
Display top-_9	Illuminance	Fc	158.51	303	91.9	1.72	3.30
Display top-_10	Illuminance	Fc	160.09	300	95.4	1.68	3.14
Display top-_11	Illuminance	Fc	167.19	319	96.0	1.74	3.32
Display top-_12	Illuminance	Fc	165.97	413	89.7	1.85	4.60
Display top-_13	Illuminance	Fc	160.06	278	95.3	1.68	2.92
Display top-_14	Illuminance	Fc	164.01	346	99.8	1.64	3.47
Display top-_15	Illuminance	Fc	143.78	274	73.4	1.96	3.73



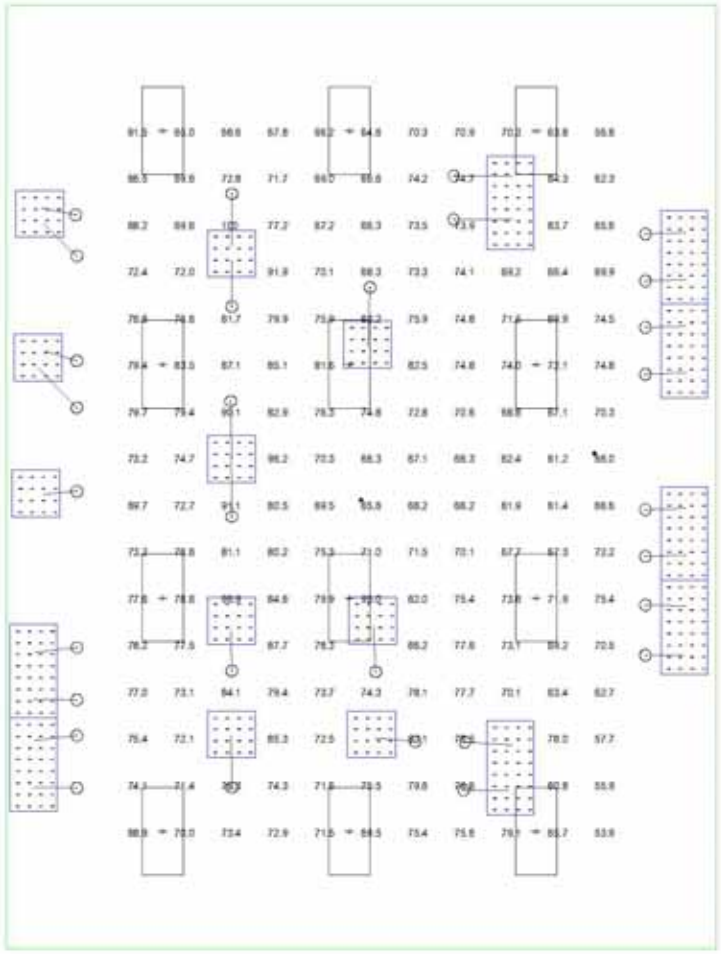
STRIP MALL STORE w/ 42W CFL General Lighting and 55W PAR38 Accent

2X4 Double T8 Troffer General Lighting w/ 55W PAR38 Silver HIR

Troffer Model: 2x4 Double T8 Design										
Symbol	Qty	Label	Lumens	LLF	LDD	LLD	BF	Watts	No. Lamps	Total Lumens
	23	55W PAR38 Indy Q155R60SP	1150	0.776	0.8	0.97	1	55	1	1150
	12	2x4 Double Tube T8 Troffer	2950	0.544	0.8	0.85	0.8	56	2	5900

LPD Area Summary				
Label	Area	Total Watts	LPD	Perimeter
Strip Mall Retail LPD	1228	1937	1.577	141.62

Troffer Model: 2x4 Double T8 with 60W PAR38 HIR Accents							
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min
Strip Mall General Lighting	Illuminance	Fc	61.21	82.1	45.6	1.34	1.80
Display top-1	Illuminance	Fc	149.66	267	87.2	1.72	3.06
Display top-_2	Illuminance	Fc	154.34	291	88.8	1.74	3.27
Display top-_3	Illuminance	Fc	167.75	339	91.2	1.84	3.71
Display top-_4	Illuminance	Fc	175.85	385	102	1.73	3.79
Display top-_5	Illuminance	Fc	141.09	270	76.5	1.84	3.53
Display top-_6	Illuminance	Fc	147.39	276	80.7	1.83	3.42
Display top-_7	Illuminance	Fc	143.38	295	77.6	1.85	3.80
Display top-_8	Illuminance	Fc	151.79	284	85.9	1.77	3.31
Display top-_9	Illuminance	Fc	162.36	308	94.2	1.72	3.27
Display top-_10	Illuminance	Fc	161.78	303	94.7	1.71	3.19
Display top-_11	Illuminance	Fc	163.68	313	92.4	1.77	3.38
Display top-_12	Illuminance	Fc	160.54	408	81.3	1.97	5.02
Display top-_13	Illuminance	Fc	158.09	275	94.0	1.68	2.93
Display top-_14	Illuminance	Fc	164.66	348	101	1.63	3.45
Display top-_15	Illuminance	Fc	151.91	283	82.4	1.84	3.44



STRIP MALL STORE w/ 2x4 T8 General Lighting and 55W PAR38 Accent

Appendix 4 – Building Department Surveys

Introduction

When a lighting design cannot comply with the Title 24 building efficiency standards though either the whole building method or the area category method of lighting power allowances, the tailored method may provide sufficient power allowances to comply without changing the lighting design. The tailored method is the most detailed method of calculation for the lighting power allowance and allows one to account difficult space geometries (high room cavity ratios), large areas requiring display lighting, casework lighting or ornamental lighting.. This method is appropriate for buildings that have unusual lighting needs and in many cases, may increase the lighting power allowance to meet those needs.

Most of the area category lighting power densities are currently low enough so that inefficient sources and excessive lighting quantities are not used in spaces complying with this method. Many of the most persistent questions relating to nonresidential lighting requirements have to do with the tailored method as it can allow lighting power densities that are three times higher than the area category limitations.. It has been an ongoing debate on whether this method is a necessary escape valve for users with unusual lighting needs or does it provide an unnecessary set of loopholes that allow excessive power allowances. The purpose of this study is to conduct phone and onsite surveys to answer some of these questions:

- When is tailored lighting used and for what reasons (frequency of tailored method and types of projects to which it is applied)?
- What fraction of buildings use tailored method and what types of buildings does it apply to?
- What lighting power densities are being used by the designers and what type of lighting allowances are being claimed?
- In spaces where IESNA categories are specified, how often are these categories misapplied?

Methodology

Selection Criteria for Building Departments

The following criteria used for selecting building departments for phone surveys to identify buildings with Tailored Method:

1. Square Feet of Area for retail buildings: The counties with the largest square feet of are for retail and warehouses were chosen for building department survey. This information is based on the Dodge Construction Database[2]

2. Number of Nonresidential Permits: The cities that have maximum number of nonresidential permits within the selected counties were short listed .This information on nonresidential permits is based on a phone survey conducted by HMG for Doug Beaman and Associates for the PG&E Codes enhancement study.

[2] RLW, 1999. "Final Report – Nonresidential New Construction Baseline Study." RLW Analytics. California State-Level Market Assessment and Evaluation Study. This database contains nonresidential construction activity by occupancy type for each of the counties in California.

3. Accessibility: Cities within the chosen counties that are easily accessible for on-site visits were selected for the phone surveys

4. Population density/size of City: Some cities within the chosen counties (counties with largest area) were selected based on their size and density (Example: City of LA doesn't have the highest number of permits, but is the largest city in the LA county that has maximum square feet of retail area)

5. Referred by other departments: While conducting phone surveys, some building departments suggested additional departments to contact. About 15 of these building departments were added later in the survey.

The final building department phone survey list had a total of 60 building departments out of which 57 completed the survey. There were 24 building departments surveyed from Southern California and 33 from Northern California.

Phone Survey

The phone survey was developed for the purpose of short listing about 10 building departments to visit and physically view the plans and Title 24 documents of those permits that have used tailored lighting for compliance with the 2005 energy standards. A total of 60 building departments were interviewed on the phone to retrieve the following information (either based on actual figures or estimates based on plan checker's experience). Out of these, 57 departments completed the survey. The four questions in the phone survey are listed below (For detailed survey questions, refer to Appendix 2):

1. Total number of building permit applications submitted after October 1st 2005 that have included interior lighting as part of the permit

2. Number of those building permits that have used tailored lighting

3. Type of building that use tailored lighting, like retail, restaurant etc, Percentage and area of that building type

4. Percent of tailored lighting permits that are tenant improvement or complete building permits

On-site Data Collection

Out of the 24 building departments that had tailored lighting permits, we short listed 12 building departments for onsite surveys. We requested building departments to provide us with plans and Title 24 documents of permits that had applied for tailored lighting under 2005 compliance. In most case, they were able to identify two or three building plan sets with energy compliance documents for HMG review.

The selection criteria for site surveys were based on:

- Willingness of building departments to spend time providing the plans
- Ease with which plans can be retrieved. Most building departments don't track tailored lighting as part of their tracking system and are unable to trace documentation of permits that have had tailored lighting since October 1, 2005.
- Availability of plans. Most permits are either under plan review through outside consultants, or are with owners for revision, or sent for imaging after they are issued. We selected departments that had plans available in their department at the time of our survey.

Tailored lighting has several components. There is a lighting power associated with each of these components. In order to understand how designers calculate tailored lighting for spaces, we collected the following information for general lighting and display lighting (includes walls, floors, ornamental displays

and very valuable displays). We referred to building plans to check the space dimensions and task functions. We retrieved the rest of the information from the energy compliance form LTG 6-C, the tailored method worksheet:

General Lighting (for illuminance categories A through G):

- *Project details* like building name, address, total area and climate zone
- *Task or activity* that will occur in the room or space
- *Illuminance category* for the space. This category assigns a horizontal illuminance based on type of space and function and helps define the LPD of a space
- *Space dimensions* (room length, width and height-this area is determined by measuring from the inside of the partitions that bound the task area)
- *Room Cavity ratio (RCR*), calculated based on the room dimensions
- *Allowed Lighting Power Density* (LPD), based on Table 146-F of Title 24 standards, the illuminance category and RCR
- *Allowed watts*, is the allowed lighting power allowance using tailored method and is a product of floor area and allowed LPD

Display Lighting (walls, floors, ornamental lighting and very valuable display):

- *Mounting Height*: height at which display luminaires are displayed.
- *Wall Display*, length in linear feet for walls
- *Display Area* , area of display for floors , ornamental and very valuable displays
- *Watts/linear feet:* Lighting power allowance from standards Table 146-D
- *Allotted watts:* Product of mounting height adjustment factor, times lighted display wall length (or area if it is a floor/ornamental/very valuable display) times lighting power density
- *Design watts*: product of quantity of luminaires times watts per luminaire.
- *Allowed Watts*: is the lesser of either the allotted watts or design watts and is what is allowed to be used in the space

Results

Phone Survey Results

- Out of 57 surveys, 22 building departments had tailored lighting permits submitted after October 1st 2005. Out of a total of 14852 permits submitted post October 1, 2005 (based on estimates of 57 building department submittals), 365 permits had tailored lighting. This translates into 2.4% of the total number of permits.

- Type of buildings that had tailored lighting:

    - 22 building departments listed “retail” as building types that applied for Tailored Method for compliance, 6 listed restaurants, and 2 as grocery stores, 7 as “other” like offices and 2 each for museum, religious facility, and financial institute. Figure 14 shows the fraction of building types that have used the Tailored Method based on percentages. Out of all the building types, retail buildings use tailored lighting the most and represent 86.6% of the building types that were listed in our survey.

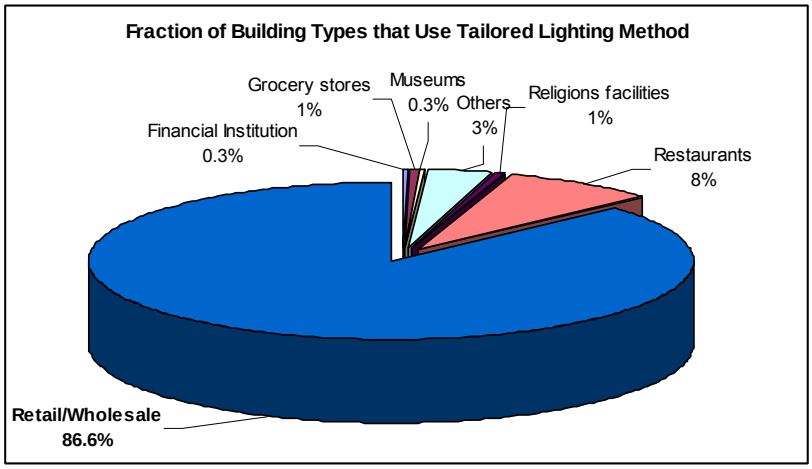


Figure 14: Fraction of Building Types that have used Tailored Method for Compliance with 2005 Standards

- Out of the total "retail" permits, about 7% are those that have applied for tailored lighting for compliance. In terms of square feet of area, this translates into approximately 1,756,800 SF. This is based on estimates of total nonresidential new construction activities under "retail" as an average of four years' (2000-2003) nonresidential construction data from the Dodge construction database (total of 24,400,000 SF).[3]

- Type of building permits that were tailored: 87% of the total tailored lighting permits were tenant improvements and about 13% were whole building permits (see Figure 15).

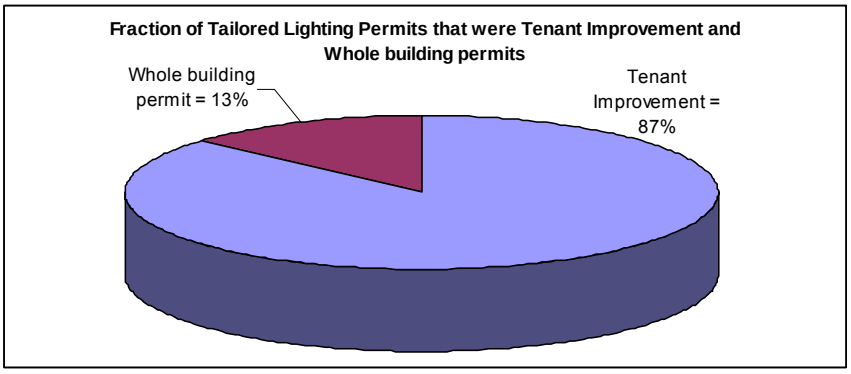


Figure 15: Fraction of Tailored Lighting Permits that are "Tenant Improvement" and "whole Building"permits under 2005 Compliance

[3] RLW, 1999. "Final Report – Nonresidential New Construction Baseline Study." RLW Analytics. California State-Level Market Assessment and Evaluation Study. This database contains nonresidential construction activity by occupancy type for each of the counties in California.

Onsite Survey Results

- Out of the 12 building departments surveyed, 10 building departments qualified under our criteria (tailored lighting permit submitted after October 1st 2005, and applied under the 2005 compliance code)
- The remaining two had tailored lighting applied under 2001 compliance code
- Total Tailored lighting plans surveyed = 53
- Total Tailored lighting plans that qualify under our criteria = 17
- Total Tailored lighting plans disqualified = 36
- Reasons for disqualification:
    - Complied by 2001 standards = 15
    - Used area category method = 21
- Discrepancy between the numbers that plan checkers indicate in the survey versus the numbers HMG staff estimates when on site is typically because plan checkers are giving these estimates based on their memory of last 6 months and sometimes they include the 2001 permits with the 2005 compliance permits. Building departments don't track permits based on "how many have applied for interior lighting" and "how many have tailored lighting". Hence these numbers are all rough estimates based on their memory and experience.
- Out of the surveyed tailored lighting permits, 77% had applied for Tailored Method in 100% of their building areas. The remaining 23% had applied for a combination of Area category Method and Tailored Method for their building areas.

Analysis

The analysis of the tailored lighting calculations is based on 17 Retail building plans that were surveyed. Tailored lighting was used in eight different category of spaces: Retail, Corridors/Restrooms, Offices, Dining, Kitchen, Lounge Lobby and Other (this included spaces like electrical rooms, waxing and facial areas, back bar, workroom, fitting room and stock room). Each of the collected data like LPD, design/allotted/allowed watts, was then compared with the LPD and design/allotted/allowed watts as per Title 24 standards. The following Figure 16 summarizes the average Watts/SF for each space as per the "Designer" (values as indicated in the permit documents by the lighting designer) and how it compares to the "Title 24 Standards" (calculation based on the Title 24 energy standards).

	Retail	Corridor/ Restroom	Office	Dining	Kitchen	Lounge	Lobby	Other
Calculated Values by Designer								
Area sf	3012.95	147.75	179.00	632.50	156.00	75.00	380.00	197.73
Allowed General lighting LPD (W/SF)	1.68	0.98	1.30	1.20	2.50	1.10	1.20	1.65
Allotted Wall W/sf	1.27			0.95				3.91
Design Wall W/sf	0.94			0.99				2.24
Allotted Floor W/sf	1.09			0.98				
Design Floor W/sf	0.97			0.56				
Allotted Ornamental W/sf				0.30				0.67
Design Ornamental W/sf				0.17				0.11
Allotted V Valuable W/sf	2.70							
Design V valuable W/sf	0.92							
Total alloted displays + ornamental	2.11			2.23				4.58
Total design displays + ornamental	1.63			1.72				1.23
Ratio of design W/sf to Alloted W/sf	0.83			0.79				0.33
Total allotted W/sf	3.39	0.98	1.30	3.43	2.50	1.10	1.20	2.13
Title 24 Energy Standard Calculation								
Area	2960.73	149.50	177.40	655.00	156.00	76.50	360.00	208.84
Allowed General lighting LPD (W/SF)	1.46	0.94	1.30	0.50	2.50	1.10	1.10	1.35
Allotted Wall W/sf	1.28			0.82				4.09
Design Wall W/sf	0.94			0.96				2.34
Allotted Floor W/sf	1.43			0.59				
Design Floor W/sf	0.98			0.54				
Allotted Ornamental W/sf				0.30				0.71
Design Ornamental W/sf				0.16				0.11
Allotted V Valuable W/sf	0.18							
Design V valuable W/sf	0.95							
Total alloted displays + ornamental	2.15		1.30	1.71				2.76
Total design displays + ornamental	1.60			1.66				1.28
Ratio of design W/sf to Alloted W/sf	0.79							0.33
Total allotted W/sf	3.29	0.94	1.30	2.21	2.50	1.10	1.10	1.86
Ratio of Designer/Energy Standard								
Area	104%	98%	102%	96%	100%	98%	106%	90%
Allowed General lighting LPD (W/SF)	117%	108%	100%	240%	100%	100%	109%	141%
Allotted Wall W/sf	100%			111%				96%
Allotted Floor W/sf	67%			166%				
Allotted Ornamental W/sf				185%				94%
Allotted V Valuable W/sf	285%							
Total allotted W/sf	104%	108%	100%	150%	100%	100%	109%	130%

Figure 16: Summary of Lighting Power Densities/SF of All Surveyed Spaces

Retail Spaces:

- On an average (based on 20 retail and display spaces surveyed), the general lighting LPD assigned by the "designer" is higher than "Title 24 standards" by 17% (refer to row 2 under heading 'Ratio of Designer/Energy Standards' in Figure 16). This may be because of the following reasons:
    - The illuminance category assigned by the designer may differ from the Title 24 assigned category.
    - In some instances, the illuminance category of the designer matched the Title 24 standard, but the LPD assigned by the designer was higher than the standards LPD.
    - The surveyor collected information on space dimensions based on the floor plan and applied this for the T-24 Standards calculation of RCR (Room Cavity Ratio). This may differ from what the designer may have assigned as the space dimensions and used for their calculation of RCR
- Wall display: The design and allotted Watts/SF were accurately calculated by the designers when compared to the Title 24 standards calculation.

- Floor display: More than 50% of the spaces with floor display tailored lighting, had assigned floor display areas much lower than the total area of their entire retail/display space. This could be because the definition of 'floor display area' as per the standards is not clear to designers. These designers calculated the allotted watts based on only a portion of the floor that needs the special display. However, the Title 24 Standards calculate the allotted watts based on the area of the entire retail space. As a result, on an average, the allotted Watts/SF as per the designer was 33% less than the allotted Watts/SF as per the Standards. There was one space that was assigned a very high LPD of 21 W/SF for allotted watts. As a result, the designed was claiming allowed watts of 800 while the standards calculation result in 80 W/SF. This was removed from the analysis as it was either an outlier or was just a typo.
- There was only one retail space with very valuable display lighting, a jewelry store. This project had used wrong values for display area and allotted watts. The assigned wattage for 'very valuable display' was also assigned too high. As a result, the allotted Watts/SF for very valuable display used by the designer was much higher than the Standards allotted Watts/SF.
- In all retail spaces surveyed, the "Design watts" (product of quantity of luminaires times watts per luminaire) were consistently less than their "allotted watts/SF" (product of mounting height adjustment factor, times area of display times lighting power density). [See row 13 under heading "Calculated Values by Designer in Figure 16]. This indicates that designers are using less watts/SF for their lighting designs than what is allotted to them as per the tailored lighting requirements.
- Out of all retail spaces surveyed, 15% of them had their total allotted watts/SF less than 1.7, which is the LPD (Lighting Power Density) required if they were to use Area Category Method. This implies that the remaining 85% of the "retail" spaces that had applied for tailored lighting made use of tailored Method instead of the Area category Method in order to get an LPD higher than the 1.7.
- The overall total allotted Watts/SF assigned by the designer was slightly higher (4%) than the total allotted Watts/SF as per the standards. Figure 4 shows that in most cases the designers calculate their allotted watts/SF as per the Standards. This figure also shows that the design watts/SF are less than the allotted watts/SF for display lighting.

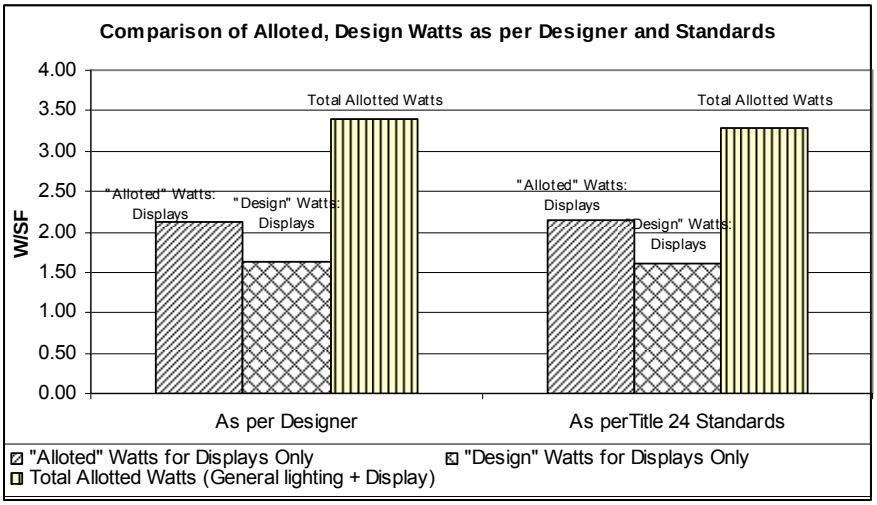


Figure 17: Comparison of Design and Alloted Watts/SF based on the Designer and Title 24 Standards for Retail Spaces

"Corridors/Restrooms", "Offices", "Kitchen" and "Lounge":

In most cases (out of a total of 11 spaces), corridors and restroom spaces were calculated correctly by the designers. The only difference between the Designer calculated and Standards calculation was in the RCR that is based on space dimensions like height, length and width. This resulted in an 8% difference between the designer assigned total allotted watts/SF and the Standards total allotted watts/SF. About 77% of the corridor/restroom spaces as per Designers had allotted a total allotted watt/SF of 1.1 or less. As per the Area Category Method, the maximum allowed Lighting Power Density for corridor/restroom spaces is 1.1. This indicates that these spaces don't particularly need a higher LPD than what is provided in the Area Category Method.
The office spaces (based on 5 spaces in the survey), Kitchen and Lobby/lounges (one of each space surveyed) areas were calculated correctly by the designers.

Dining:
There were 2 surveyed spaces that had designated dining spaces. The LPD assigned by the designer in both cases was higher than the Standards even though the illuminance category was correctly input. The designers used the higher of the two watts (Design and Allotted) as "allowed watts", while according to the Title 24 Standards, the lower of the two values should be the assigned "allowed watts". This makes the difference between by a factor of 1.6.

Other Spaces:
There were 11 spaces surveyed that belong to this primary function.

- Majority of these spaces fall under the IESNA category, where the IESNA handbook has to be referred to get the LPD values. Sixty percent of the designers have used the correct IESNA category and LPD as per the IESNA handbook. Forty percent of the spaces had assigned a wrong IESNA category or a higher LPD than what the standards indicate. There are some spaces like "waxing and facial", "back bar", and "music instrument displays", where the surveyor has used the designer's assumption of illuminance category.
- There were two spaces that have used wall and ornamental displays. Both these spaces have used a higher LPD than the Standards.
- The overall allotted Watts/SF based on designer calculation is 30% higher than the Standards Watts/SF. This can be attributed primarily to designers assigning wrong IESNA categories and higher LPD. Among all other space types, this category has second largest difference between designer calculations and Title 24 Standards, second only to the 'Dining" spaces.

Conclusion

This study is based on 57 phone surveys and 10 building department plan checks. The following points summarize the study based on non residential permits submitted after October 1, 2005:

- Tailored lighting method is a very small fraction of the overall lighting compliance for non residential buildings, approximately **2.4% of all non residential buildings**.

- However, for retail lighting, tailored lighting is approximately **7% of all retail lighting** submissions. For new construction, this translates into approximately **1.7 Million sf per year**. Renovations are likely three times this amount, to the total of new plus renovations that use tailored lighting method is approximately **6.8 Million/sf per year**.

- With a total allowable display LPD of 2.26 W/sf and the 0.9 General lighting allowance, tailored lighting allows for on average approximately 3.16 W/sf. When compared with the 1.7 W/sf for the area category method, this is an additional 1.46 W/sf allowed by the tailored method. When multiplied by 6.8 Million/sf per year, this accounts for a lighting load increase of approximately 10 MW per year as compared to what would be allowed under an area category only scenario.

- Most non residential building use Area Category Method and a small number use Complete Building Method for compliance with the lighting standards.

- Out of those that use Tailored Method for compliance with the energy standards, 80% of them were "Retail" buildings, and that constitutes 7% of the overall Retail buildings.

- Most tailored lighting buildings have used 100% of the building area for "Retail Merchandise Sales".

- Spaces that typically use Tailored Method in Retail buildings include: Sales areas (Retail areas), offices, corridor/restrooms, lounge/lobby and "all others".

- In most cases, "Sales areas" (retail), "dining" and "others" were the three categories that used Tailored Method for wall, floor and ornamental displays. All other spaces used tailored method only for general lighting.

- Overall, the Total allotted Watts/SF calculated by the designer is slightly (17%) higher than the allotted Watts/SF as calculated by the Title 24 Standards,.

- The IESNA category is not a very accurate system for assigning LPD to spaces. Designers who refer to IESNA handbook may face difficulty in assigning the correct watts/SF for the space. 40% of spaces that required IESNA handbook had assigned the category and LPD incorrectly. Most plan checkers don't have access to IESNA handbook and may not have a source to check some of the illuminance categories set by the designers.

- The display areas under Tailored Method should clearly be marked by designers in the floor plans. Currently, the areas for general lighting, and display lighting for walls, floors, ornamental and very valuable are not marked in floor plans. That leave the plan checker to make assumption based on their plan check and that may not match the areas assigned by the designer while calculating the Lighting Power Densities.

Phone Survey Script

PHONE SURVEYS FOR BUILDING DEPARTMENTS:

TAILORED METHOD LIGHTING IN NON RESIDENTIAL BUILDINGS

PART 1: GENERAL QUESTIONS

Building Department Name:_____

This survey is on behalf of the California Energy Commission, for a study that will help develop a better understanding of the building codes and standards related to non residential lighting and skylighting code requirements. These questions relate to the total number and type of non residential building permits [whole building, shell, tenant improvement] submitted after October 1, 2005, number of those buildings that use tailored lighting, and their total areas.

1. How many non residential building permit applications, that include lighting, [whole building, shell and tenant improvement] have been submitted since October 1st, 2005?

   _____(Actual number)

   _____(estimated number)

2. How many of these non residential permit applications have used the tailored lighting for compliance with the energy standards?

_____(Actual number)

_____(estimated number)

3. How many building permit applications are for warehouses and big box retail stores (or any buildings with spaces > 25,000 sqft and ceiling ht >15ft)?

   _____(Actual number)

   _____(estimated number)

4. Of those, how many have skylights?

   _____(Actual number)

   _____(estimated number)

PART 2: TAILORED LIGHTING

Please Fill data for only those building types that have tailored lighting

Notes for the table: 1) In first column, check if the building type has used the Tailored Lighting approach.

2) Fill out information only in those rows with building types that use the Tailored Method (those checked Yes). Which building types are covered is based on the estimates of your plan checkers

3) Indicate in middle column if information for total permits is an actual figure from a database (A), or ballpark estimate (E).

4) Estimates of Tailored Lighting Permits – this is based on a ballpark estimate from the plans checkers for the applicable building types.

Check if Tailored Lighting	Building Type	Total Permits Containing Lighting		Source for data: Actual/ Estimate	Estimate of Tailored Lighting Permits	
		No. of Permits	Total Area (Sqft)		No. of Permits	Total Area (Sqft)
❑	Retail/ Wholesale					
❑	Grocery stores					
❑	Museums					
❑	Libraries					
❑	Restaurants					
❑	Hotel					
❑	Financial Institution					
❑	Religious facilities					
❑	Schools					
❑	Others, specify					

For retail tailored lighting permits, how many of them (% or number) are applicable to tenant improvements (TIs), shell or whole building?

TI: % OR Number_____(actual/estimate)

Shell: % OR Number_____(actual/estimate)

Whole: % OR Number_____(actual/estimate)

Appendix 5 – Survey Questions for Designers

PG & E CASE STUDY
TITLE 24-2008 TAILORED METHOD
UPDATE & REVISIONS

Designer, End User and Manufacturer Survey Form

Prepared by Integrated Lighting Concepts August 29, 2005

INTERVIEW DOCUMENTATION

Interview Profile: ☐ End User ☐ Designer* ☐ Manufacturer ☐ Agent/Rep/Distributor

☐ Engineer ☐ Code Consultant ☐ Electrical/Lighting Maint. (Contractor)

Name & Organization Person Interviewed: _____

_____

Date Interview Conducted: _____ ID/ILC Interviewer: _____

* Architect, Lighting Designer, Interior Designer & Store Planner/Designer

Introduction

I am interviewing people to understand ways that the California Title 24 building energy code can be improved so that it saves more energy and is easier to use. This project is funded by PG&E in support of their Codes and Standards program.

INTERVIEW QUESTIONS

1. When you have a client/customer who wants to reduce the operating and maintenance costs of their lighting, what are the top three (3) recommendations you make?

   (1): _____

   (2): _____

   (3): _____

2. Are you familiar with the lighting requirement s in the California Title 24 building energy code?

   ☐ Yes ☐ No

3. Do you find any parts of the lighting requirements in Title 24 confusing or contradictory? **If yes** please explain what aspects.

   ☐ Yes ☐ No

   What aspects? Please provide details:

   Please explain how this could be improved?

4: Do you have any recommendations or suggestions that if included as part of Title 24 – 2008 could lower power consumption and result in energy savings? Please include comments below:

_____

_____

_____

_____

_____

_____

(add attachments as needed)

5. Accepting the premise that reduction in allowed power densities under the 2008 code version must (will) occur which measures offer the most practical or feasible means for achieving LPD reductions.
(please rate practicability feasibility as follows: 5 = Excellent 4 = Very Good 3 = Good 2 = Fair 1 = Poor 0 = Not Acceptable)

- ☐ Use Ceramic Metal Halide as the basis for most focal/feature lighting such as accent and display lighting artwork and architectural feature wall washing.
- ☐ Eliminate or minimize substantially reduce most exemptions for special applications
- ☐ Expand control requirements and use of controls, especially in tailored compliance
- ☐ Totally eliminate (do away with) Tailored Method under 2008 standards and replace with limited power add-ons (similar to ASHRAE/IES 90.1) - specialized spaces and or needs only
- ☐ Base new Tailored Method lighting wattage limitations (LPD's) on excusive use of advanced (latest technologies) electronic ballasts for fluorescent and Metal Halide light sources.
- ☐ Base new Tailored Method lighting wattage limitations (LPD's) on Metal Halide equipment on electronic ballasts and Pulse Start or Ceramic Metal Halide lamps
- ☐ Base new Tailored Method lighting wattage limitations (LPD's) on fluorescent equipment with electronic ballasts and latest generation of T8 and or T5 lamps
- ☐ Base new Tailored Method lighting wattage limitations (LPD's) on incandescent equipment with IRC MR16 lamps and electronic transformers (low voltage incandescent) and next generation Halogen IR lamps for all other incandescent lamps.
- ☐ Expand the mandate for uses of "Day-lighting" to more application types

☐ Increase stringency of new lighting wattage limitations (LPD's) but add more control credits to encourage more automatic control of lighting.

☐ Reduce ambient lighting in spaces using a heavy display lighting components. (lots of display and accent lights)

☐ Reduce the allocation of allowed area and or frequency of display and accent lighting (avoid syndrome that everything in the space will/must be accent lighted)

☐ Lower light levels throughout (general, accent & display) and compensate of lower levels by using "color and motion" to attract customers.

☐ Mandate use of automatic controls to reduce light levels at display window and store interiors during evening hours (night time) Including "full off" of non essential lighting after store closing.

6. Have you used the tailored method within the last year? ☐ Yes ☐ No
<skip questions 7-8 & 9 if they answer NO>

<Use questions 7, 8 & 9 to fill out table - see below>

7: For which space types and/or applications do you find that you routinely use the "Tailored Method" approach for code compliance?

☐ Retail ☐ Hospitality ☐ Museum ☐ Worship ☐ Offices (specialty)

☐ Other (Explain space type & application) _____

8: What percentage of time do you currently use the Tailored method of compliance for the project (% for each of the various space types).

9. Why is the tailored lighting method needed? <this should be somewhat open-ended at first, if respondent needs clarification of question use prompt list – see below>

a) Tall narrow rooms have high RCR – lot of losses in space

b) Low reflectance surfaces in space or cavities that are hard to light

c) Need for display lighting with high contrast

d) Need high light levels for design

e) Need to use incandescent or halogen lighting

f) Specialized high-resolution task

g) Need high light levels for space to stand out

g) Other (explain)

Space Type	Used Y/N	% of time	Why tailored?
Retail			
Hospitality			
Museum			
Worship			
Offices			
Other(s) describe below			
1.			
2.			
3.			
4.			

10: On a scale of 1 to 5, where 1 is strongly agree and 5 is strongly disagree please rate your opinion of the following statement: Ceramic Metal Halide lighting will become a feasible alternative to incandescent and halogen lighting for commercial and retail applications by 2008.

☐ Strongly Agree (1) ☐ Somewhat Agree (2) ☐ Not Sure/Don't Know (3)

☐ Somewhat Disagree (4) ☐ Strongly Disagree (5)

11. What if any are current limitations to the feasibility of replacing incandescent or halogen lighting with ceramic metal halide? <check all that apply>

☐ a) Color quality

☐ b) Beam control

☐ c) Variety of wattages and beam spreads

☐ d) First cost

☐

e) Maintenance cost

☐ f) other (please explain) _____

12: If California were to set compliance standards which resulted in increased use of CMH lamps and luminaires, how soon could luminaire and lamp manufactures respond to increased demand (equivalent to ½ of the current halogen luminaire market) for these products in California?

☐ Immediately to six (6) months
☐ Six (6) to Nine (9) Months
☐ Nine (9) months to One (1) year
☐ One (1) year to Eighteen (18) Months
☐ Eighteen (18) Months to Two (2) years
☐ More than Two (2) years
☐ More than Three (3) years
☐ Possibly never

13. What is the typical lifespan of lighting equipment used in retail? _____ Years

14: What are/is the greatest challenges/challenge and/or barriers to potential changes in the energy code for 2008?

_____

_____

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