Way Beyond Widgets: Delivering Integrated Lighting Design in Actionable Solutions

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ABSTRACT

Previously, energy-efficiency strategies for commercial spaces have focused on using efficient equipment without providing specific detailed instructions. Designs by experts in their fields are an energy-efficiency product in its own right. A new national program is developing interactive application-specific lighting designs for widespread use in four major commercial sectors. This paper will describe the technical basis for the design solutions, energy efficiency and cost-savings methodology, and proposed installations.

Lighting designs have been developed for five types of retail stores (big box, small box, grocery, specialty market, and pharmacy) and are planned for the office, healthcare, and education sectors as well. Nationally known sustainable lighting designers developed the designs using high-performance commercially available products, daylighting, and lighting controls. Input and peer review was received by stakeholders, including manufacturers, architects, utilities, energy-efficiency program sponsors (EEPS), and end-users (i.e., retailers). An interactive web tool delivers the lighting solutions and analyzes anticipated energy savings using project-specific inputs.

The lighting solutions were analyzed against a reference building using the space-by-space method as allowed in the Energy Standard for Buildings Except Low-Rise Residential Buildings (ASHRAE 2004) co-sponsored by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) and the Illuminating Engineering Society of North America (IESNA). Early results showed that the design vignettes ranged from a 9% to 28% reduction in the allowed lighting power density. Detailed control strategies are offered to further reduce the actual kilowatt-hour power consumption. When used together, the lighting design vignettes and control strategies show a modeled decrease in energy consumption (kWh) by 33% to 50% below the baseline design.

Introduction

Energy efficiency has moved from the periphery to a mainstream priority as demonstrated by the number of companies advertising how the company has “gone green.” Numerous programs globally and nation-wide (e.g., Architecture 2050, the Mayor’s Conference 2030, Leadership in Energy and Environmental Design [LEED], Kyoto Protocol) outline ambitious goals, but the methods for achieving those goals are not readily available. Utilities and Energy Efficiency Program Sponsors (EEPS) have long offered incentives and rebates for reducing demand ($/kW) and energy ($/kWh) as well as financial incentives for energy-efficient equipment. By providing complete energy-efficient design solutions design quality can be maintained while maximizing both demand and energy-savings. For a design to be actionable, it must integrate all the elements of the lighting system into a lighting layout with efficient equipment and control recommendations, plus application and installation information.

Lighting is the largest single-end use in commercial buildings, consuming no less than 25% of total primary energy, roughly equal to the total use of heating and cooling (Buildings Energy Databook 2007). The U.S. Department of Energy's (DOE) *Commercial Lighting Solutions* program (CLS) strives to provide integrated lighting designs that can reduce the lighting consumption of targeted spaces by 30-50% against the American Society of Heating, Refrigeration and Air conditioning/Illuminating Engineering Society of North America (ASHRAE/IESNA) Standard 90.1-2004 (Std. 90.1-04)[1] The target energy savings goal for the CLS program is 5.5-billion square feet of commercial space across four buildings sectors including retail, office, healthcare, education.

The *Lighting Solutions* can be applied to both new construction and existing buildings, but the use in existing buildings does require new lighting technologies, including replacement luminaires. In the context of existing buildings, this would be considered a redesign, rather than a simple retrofit (retrofit is typically replacing inefficient ballasts or reflectors and leaving the luminaires in the original locations). The value of the *Lighting Solutions* is the optimization of *all* elements of a lighting design for the greatest possible savings, including high-performance luminaires as well as the lighting layout. As with virtually all energy-efficiency measures, the usage of the *Lighting Solutions* will be more cost effective in new construction projects where demolition costs are not a factor. However, existing building renovations are certainly an essential target for the *Lighting Solutions*, and the factors of tenant relocation, frequent lease turnover in the retail market, aging lighting equipment, and escalating energy cost will provide opportunities for application of the *Lighting Solutions* into the existing buildings market.

To provide a context for the potential market penetration of the *Lighting Solutions*, one can estimate the percentage of total applicable area in the existing buildings market. The 2007 Buildings Energy Data Book provides data about the area of square footage for those sectors that will be able to use *Lighting Solutions*. The estimated total applicable area in these sectors is 61.0 billion square feet (see Table 1). The target energy savings goal of 5.5 billion square feet represents 9% of this applicable area.

Table 1. Commercial Space in the United States (2007)

Space Type		Area (in billions of sq. ft)[1]	Percentage of Total Area[1]	Primary Energy Consumption	
				Quads[2]	Consumption (10^3 BTU/SF)[2]
Commercial Floorspace as of 2005		74.3	100		
CLS Sector	**2007 DOE Energy Book Characterization**				
Office	Office	12.6	17	3.0	41.0
Retail	Mercantile (total)	11.9	16	2.9	38.6
Retail	Retail	4.5	6	1.1	14.5
Retail	Enclosed & Strip Malls	7.4	10	1.8	24.1

[1] The CLS program at DOE is part of a larger commercial buildings effort that is working towards 50% savings solutions for whole buildings within the context of end-user groups call the National Energy Alliances, including the Retailer Energy Alliance (REA), the Commercial Real Estate Energy Alliance (CREEA), and the Institutional Energy Alliance (IEA) will be formed. For the purposes of this paper, continued development and energy savings potential of *Lighting Solutions* will be discussed in terms of building sectors (e.g., retail, office, healthcare, education).

Education	Education	10.4	14	2.5	33.8
Retail	Warehouse and Storage	10.4	14	2.5	33.8
Retail	Lodging	5.2	7	1.3	16.9
Retail	Service	4.5	6	1.1	14.5
Healthcare	Health Care (total)	3.0	4	0.7	9.6
Healthcare	Inpatient	2.2	3	0.5	7.2
Healthcare	Outpatient	1.5	2	0.4	4.8
Retail	Food Sales	1.5	2	0.4	4.8
Retail	Food Service	1.5	2	0.4	4.8
Total Applicable CLS Area		61.0	82		

Data supplied by the Department of Energy 2007 Buildings Energy Data Book
1. Data from the DOE 2007 Buildings Energy Data Book Table 2.2.2 and for year 2003
2. Data from the DOE 2007 Buildings Energy Data Book Table 1.3.4 and for year 2005

Energy

Energy is power (kW) consumed over time (kWh), and there are three basic methods for its reduction:

- *Method 1.* Reduce the installed power—the traditional metric for energy as related to lighting is lighting power density (LPD), measured in Watts per unit area (W/ft^2 or W/m^2). LPD allowances are provided in Chapter 9 of Standard 90.1. Between the 2001 and 2004 iterations of Std. 90.1, LPDs as a weighted average US building stock basis were reduced by ASHRAE/IESNA by 24%. The LPDs for the Std. 90.1-04 and Std. 90.1-07 remained static, primarily because luminaire and lamp/ballast technology did not greatly improve in the interim.
- *Method 2.* Reduce consumption (either by decreasing the power of the lighting or curtailing the hours of operation) through the use of lighting controls—this method offers a greater potential energy savings than the first method. Std. 90.1 requires basic automatic scheduled shutoff control for building lighting and occupancy-based control in specific spaces. The lighting controls recommended in the *Lighting Solutions* go beyond the controls required in Std. 90.1, such as additional occupancy sensors, scheduled controls, timer switches or daylight switching or dimming.
- *Method 3.* A combination of methods 1 and 2: reducing both installed power and the actual consumption.

It is generally accepted in the codes and standards development community and the professional lighting community that further reductions in power density (method 1), need to be accomplished very carefully, on a case-by-case basis. Lighting design experts have been involved in the development of the *Lighting Solutions* for this reason.

However, the use of lighting controls represents a tremendous energy savings opportunity, without reducing the quality of the lighted environment (method 2). Measurement of energy savings from lighting controls (with or without combined reduced LPDs) requires the use of kWh as a metric. The use of kWh as a metric is more difficult than the simple kW approach, and consequently is far less common. However, utilities are increasingly offering incentives for reductions in kWh, so there is significant interest in working with this metric and measuring energy savings in addition to installed power.

The *Lighting Solutions* use a combination of reducing both input power and the actual energy consumption (method 3). The value of the *Lighting Solutions* is in the careful use of both strategies, and the built-in energy analysis using the kWh metric, which reduces the complexity for both users and utilities.

Lighting Design Process

The first set of *Lighting Solutions* was developed for retail box stores. The CLS program initially chose to focus on the retail sector for two reasons. First, these spaces tend to be prototypical and/or homogeneous. This allows easy replication across a great range of retail space and fits with the real estate business model for many national retailers. Second, the technical and programmatic challenges were considered more achievable for box retail as compared to other sectors, such as office or healthcare. For example, the primary daylighting strategy for box retail is toplighting, which can be generalized more readily than sidelighting or fenestration solutions in offices.

The first step in developing *Lighting Solutions* was to develop and model lighting designs for a subset of typical retail buildings. Drawings (when possible) of actual stores were provided by members of the U.S. Department of Energy's Retailer Energy Alliance (REA). Five "standard" retail-building types were initially developed:

1. Big Box (i.e., Wal-Mart, Staples, Petco) stores where the floor plate is large, the ceiling is typically open-truss construction with a ceiling height of at least 18 ft, and the buildings are over 50,000 square feet.
2. Grocery (i.e., Albertsons, Safeway, Shaw's, Basha's, Eagle, Stop & Shop, Pathmark, Ralph's) stores where the floor plate is large but subdivided by merchandise sold in that area, the ceiling is typically open-truss construction with a ceiling height greater than 15 ft, and the buildings are typically between 40,000 to 70,000 square feet.
3. Pharmacy (i.e., Walgreens, CVS, Rite-Aid, Brooks, Osco/Jewell) stores where the store is small, the ceiling typically consists of dropped acoustical ceiling tile 14 to 16 ft high, and the buildings are typically 8,000 to 18,000 square feet.
4. Small Box (i.e., Kohls, L.L. Bean, REI) stores that are often freestanding, often multi-level, ceiling types/heights vary, and the buildings are typically 18,000 to 50,000 square feet.
5. Specialty Market (i.e., Whole Foods, AJ's, Sprouts) stores where customers pay for premium grocery products such as organic or specialty food not often carried in standard grocery stores and the positive shopping experience is a brand mission, ceiling types and heights vary by product area within the store, and the buildings are typically between 20,000 and 75,000 square feet.

For each of these building types energy-efficient lighting designs were developed based on IESNA lighting criteria. The designs were modeled using industry standard point-by-point lighting calculations. For each type of retail building, there are numerous distinct areas within the building requiring a different lighting design solution. For example, a grocery store design for the produce area would be different than the design for the point-of-sales or general merchandise area. These areas are called "vignettes" within the *Lighting Solutions*.

The criteria for dividing the stores into vignettes was primarily the task or function of the store area which called for different lighting design features such as color rendering, object highlighting or modeling, general lighting conditions, etc. Typically, two or three lighting design options were developed for each vignette. The vignette shows how the equipment should be spaced, includes important information about aiming or locating the luminaires, and provides an LPD for this store component. A vignette is differentiated by a different lighting design (e.g., vignette #1 could have the luminaires oriented parallel to the shelves, and vignette #2 could have the luminaires oriented perpendicular to the shelves).

Each vignette has an associated LPD, which is multiplied against the user-provided square footage to determine the projected power density for the store component. That power density then becomes the basis against which controls savings are calculated (see the Energy Analysis section below). The space-by-space method of Std. 90.1 provides the steps for determining the installed power density (Watts per square foot). The power is determined by summing the rated power of the lighting equipment in the design. The area is measured via the center of the walls. The LPDs for the CLS vignettes were developed the same manner, but with a slight modification. Where as Std. 90.1 typically defers to partitions to differentiate space types and thus different LPDs, CLS subdivides a typical Std. 90.1 space (in this case retail) into the different components of the store regardless of partitions. When a store component is adjacent to the building perimeter, the center of the wall is used. When two store components are adjacent, the borders are the same. Again, as provided by Std. 90.1, the installed power of the equipment designed for that store component is divided by area for the vignette LPD.

The vignettes only focus on the interiors of the store. The exterior lighting of the store was omitted from the *Lighting Solutions* for various reasons. Although this equipment consumes energy, it operates during a period of time when energy is considered less expensive (off-peak). Incentives for reducing energy or demand are greater (and some only apply) during peak-usage times. Another reason is that retailers do not always own the equipment lighting the site. Finally, interior commercial lighting represents a significantly larger portion of the installed power on a given site as well as the actual energy consumed.

Web-Delivery Mechanism

Information for good energy-efficient lighting designs are available from numerous resources and many can be accessed via the internet. For instance, the Advanced Lighting Guidelines (NBI) from the New Buildings Institute or the Knowhow Series Guides from the DesignLights Consortium (NEEP) have PDFs for download of space-specific lighting designs. These PDFs provide between 2-4 pages of information about lighting spaces such as a classroom, a grocery store, or an office. At the time that they were developed these resources represented the state-of-the-art in technical advice. However, PDF files are in essence hard copy products made widely accessible in electronic form. Hyperlinks within PDF's create a dynamic element, but still these informational tools remain primarily static in nature.[2]

The *Lighting Solutions* are delivered to the users via a web tool using a novel approach that takes pattern tools to the next level. The web tool has been designed to walk the users

[2] The New Buildings Institute is partnered with the CLS project, so that the next update for the Applications Chapter of the ALG will be synergized with the Lighting Solutions. Similarly, NEEP (DesignLights Consortium) has made the content of the Knowhow Series available for use by CLS. In this way the web tool mechanism is leveraging existing products and market channels.

through an interactive decision process whereby they select only the information that they are interested in, assembling a self-selected custom package of information. This flexibility and dynamic relationship between user and the information allows for the patterns to be far more specific without overwhelming the user with information that they don't need.

The web tool process follows these simple steps: (1) register and provide project background including hours of operation and location, (2) pick store components of interest, (3) pick one vignette per store component, (4) after choosing vignettes, choose controls strategies for the store, (5) download documents to use for the project design process (including: sample lighting drawings, luminaire schedule, controls information, estimated energy analysis, implementation guidance), (6) return to website to provide inputs about project energy use per the design documents, (7) get final documentation about savings based on project design data vs. baseline.

The audience for the web tool will have at least a moderate/medium level of lighting knowledge. The users of the decision tool need to know enough about lighting to make reasonable choices, at least at a conceptual level. The implementation documentation assumes a deeper level of knowledge to be used by an architect, engineer, or lighting designer. The target user audience is a combination of owner-development teams, facility managers, energy managers, architects and engineers, lighting designers. Store personnel can view the different options and easily participate in design discussions with the Architecture and Engineering (A&E) team. Ultimately, the A&E team will implement the *Lighting Solutions*. Although the CLS designs are comprehensive, professionals with the appropriate credentials should prepare the documentation and manage the construction of the retail space.

Lighting Equipment

The retail vignettes use three possible light sources: linear fluorescent, compact fluorescent (CFL), or ceramic metal halide (CMH). These sources are included because of their high color-rendering index (CRI), high system efficacy, and current role in the marketplace. Incandescent/halogen sources have niche applications in some energy-efficient designs, but are not part of the *Lighting Solutions*. Solid-state lighting (SSL) has the potential to be an extremely efficacious light source, but at this time, few manufacturers produce reliable high-lumen luminaires. CLS focuses on technology already commercialized; therefore SSL luminaires are not currently part of the luminaire schedules, in the future this will change.

Of all the fluorescent lamp options, the T8 and T5 fluorescent lamps are the most prevalent lamp types used in these applications because of their longevity, excellent CRI, and the availability and variety of fixtures for these sources. Linear fluorescent lamps represent a bulk of the lighting solutions because the lamps are easily dimmed, the products are readily available in the marketplace, the source has superior lamp lumen depreciation (LLD) (greater than 0.88), and the reflectors can be designed around the source. Lamp lumen depreciation (LLD) measures the decline of lumen output from a light source over its rated life. Light sources begin their life with the greatest amount of light output (initial lumens) and output gradually declines until around half-life, which is when the light loss has mostly stabilized. These reduced lumens are known as mean lumens. LLD characterizes the difference between initial and mean lumens.

CMH sources were used sparingly in the lighting packages. Although these sources are common to some "big box" applications, they are not always an efficient option for saving energy. The sources are short lived (typically 10,000 hours) and have an LLD of 0.68. Unlike fluorescent lamps, CMH lamps have a greater LLD and it occurs earlier in the lamp's rated life (at 40% of rated life, the lamp is only producing 68% of the initial light). Lamp manufacturers specifically developed energy-efficient and good color-rendering directional (PAR and MR-16) CMH sources to replace the comparatively inefficient incandescent and halogen sources for retail applications. However, one major drawback to CMH sources is that they are not easily, efficiently, or effectively dimmed. Nevertheless, some lighting solutions will include CMH sources because they are the best and most efficient source for the specific application.

Luminaire specifications include information about the luminaire construction and general information about the distribution, as well as performance metrics. These metrics include:

1. Mean Lumens Per Watt (MLPW)—The lamp/ballast system produces the light emitted by the luminaire. Most sources will produce mean lumens, rather than initial lumens for a majority of the source's rated life. The specification will include information about the MLPW of the lamp/ballast. MLPW is calculated as Initial Lumens x Lamp Lumen Depreciation x # of lamps x ballast factor / input wattage of the ballast.
2. Efficiency—the ratio of lumens generated by the luminaire divided by the lumens generated by light source(s). Efficiency is a good metric because it accounts for the difficulty in using the lumens generated, regardless of the system efficacy. The product of efficiency and MLPW yields a very similar value to either Luminaire Efficacy Rating (LER) or Luminaire Efficacy (LE). LER or LE focus on initial lumens rather than mean lumens.
3. Photometric Distribution—characterization of how the light leaves the luminaire. Energy is saved through using a luminaire with the correct distribution; in contrast, the efficiency with which lumens are produced and the total percentage of lumens that the luminaire is immaterial if those lumens are directed to the right place. Lumens are the basic unit of light. Intensity (lumens per solid angle) are measured in candelas (cd). Photometric distribution characterizes the how the intensity of the luminaire is directed both vertically and horizontally out of the luminaire. Two luminaires could have virtually identical zonal lumens (total amount of light emitted in a given range) and yet different photometric curves. Therefore, ratios of maximum intensity of the luminaire per luminaire type of each vignette will be specified.

CLS, with input from the National Electrical Manufacturer's Association (NEMA), will develop the criteria for the luminaires. The photometric performance will be described for those luminaires which are most dominant in the vignettes, and where distribution is critical to the success of the design.

To allow manufacturers to participate in the program and to guarantee quality control for luminaire incentives, an online tool that analyzes and verifies photometric performance of luminaires using industry standard IES files will be developed. To determine if a product meets the photometric specifications for a particular luminaire type, the manufacturer will upload the IES files (digital photometric performance of the luminaire in LM-63 format) and the tool will indicate whether the product meets the photometric performance for that luminaire. Equipment that qualifies will be included in a database accessible to users to support their specification process. This will help users find products that meet the intent of the vignettes, and will bridge the gap between performance specifications and implementation of the solutions.

Lighting Controls

Lighting controls fall into four main categories: time based, occupancy based, need based, and daylighting. Multiple control strategies will be applicable to the retail sector. Each control strategy will have control factors that apply to appropriate luminaires within each vignette. These factors are multiplied against the controlled luminaire power to determine the actual consumption of the vignette. For example:

1. *Control Strategy 1— Daylight Harvesting*. Photosensors will dim the fluorescent lighting under a toplighting design. CLS acquired hourly energy meter readings for a 6-month period from a participating 24-hour retailer with daylighting capability (skylights). The building reviewed had a skylight-to-floor ratio (SFR) of 3%. Assuming that the available daylight is relatively symmetrical about the year and using the middle of the night as a constant baseline, the average lighting loads were found to be dimmed by 24% across the course of the day throughout a year. This 24% is an average, in the afternoon, the luminaires dimmed by more than 24%, but the average for the course of the day is 24%. These data were compared to other national and regional daylight dimming data and modeling estimates and found to be conservatively on the low end of known and expected effects. Therefore, these data were chosen as a representative effect for the CLS solutions. On average across the year, across the country, there are 12-hours of daylight available (amount of hours between sunrise and sunset). Most retail stores will open after the sun has risen on average and close after the sun has set. Therefore, although the CF is conservative, the CF is applicable to all buildings across the country. These data equate to a control-strategy factor of 0.76.
2. *Control Strategy 2— Non-daylight Dimming*. Electric lighting in stores tends to be static. The store has the same illuminance during the day and night – which is actually not needed because eye adaptation is vastly different in the day compared to the night. Lighting could be reduced at night to account for the different adaptation. Although this sounds like a radical idea, some retailers already use this strategy. The ALG recommends this strategy as well and refers to as Adaptive Compensation (NBI 2003). The Square Law of Curve (Rea 2000) states that the perceived reduction in illuminance is roughly half the actual reduction in measured illumination. Therefore, the nighttime lighting could be dimmed by 30% (producing 70% of the daytime illuminance), and the occupants in the space would only perceive a 15% (the perceived reduction value is roughly half of the actual reduction) reduction in illuminance. The control factor for this strategy is 0.7.
3. *Control Strategy 3— Time-based Switching*. Stores are lighted for customers who need to read product labels and intensely scrutinize products, but employees often do not need the same amount of illumination. During stocking-hours, half or a third of the lighting could be switched off, reasoning that if the store is illuminated to 50 fc per the IESNA recommendations, then 25 fc are really only needed when items are being stocked by an employee familiar with the store. The control factor for this strategy is 0.5 (half the lighting is being turned off).
4. *Control Strategy 4— Occupancy Sensors*. In very large stores (over 50,000 square feet), the cleaning crews will only occupy small sections of the store at any given time. Occupancy sensors could be used to turn off the lighting in portions of the store when no one is there cleaning the store. The control factor for this strategy is 0.5.

5. *Demand Response (DR)*. This strategy does not save significant energy, but reduces peak power load and typically utility cost. If any of control strategies 1 to 2 are already being implemented, the DR can quite easily be used because the infrastructure is already being purchased. Currently, demand effects will be captured with the use of average utility rate values for the analysis, which incorporate demand costs.

Roughly 65% of the buildings in U.S. are one- or two-story spaces (Table 2). Spaces with few floors can be lighted more effectively from skylights rather than through façade fenestration. Through shafts and wells, light can be re-directed from skylights to levels not at the top of the building, but the farther the light has to go, the less efficient the redirection. Toplighting was selected as the daylighting strategy because energy savings are typically greater from toplighting than from sidelighting. Furthermore, sidelighting is severely dependent on location and the manner in which the building is oriented on the site. Since 2005, California's Title 24 (state energy code) has mandated toplighting in low rise condition and unconditioned spaces 25,000 ft^2 with a ceiling height greater than 15' (CEC 2006); recently, the Std. 90.1 Lighting Subcommittee introduced a similar requirement to the full ASHRAE committee.

Table 2. Number of Floors of Buildings in the United States

Floors	**Percentage of Total Area**
One	40
Two	25
Three	12
Four to Nine	6
Ten or More	8
Total	100

Data supplied by the Department of Energy 2007 Buildings Energy Data Book

Energy Analysis

The CLS program baseline is Std. 90.1-2004, but there are many different potential baselines. CLS users will be able to compare their building to a baseline of their choice. It is possible for the user to select a combination of vignettes and controls that do not save 30% below Std. 90.1-04. When that happens, the user will be notified in the web tool, but they will not be restricted from using the tool.

The baseline energy usage will be determined by taking the allowed power density of the space and multiplying this area by the power density and the operating hours (based on the inputs of the user). The expected space energy consumption using the chosen design vignette and control strategies will be determined by taking the power density of the user-selected vignette, multiplied by the area of the vignette, multiplied by the applicable control strategy factor, and finally multiplied by the period of time that the control strategy is applicable. For example:

Table 3. Sample Vignette Energy Analysis

	LPD W/SF	Selected Control Strategy	Applicable Control Factor[1]	Applicable % of LPD[2]	Area (SF)	Time	# of Hours	Energy kWh
CLS Baseline Energy Consumption								
Baseline	1.7		1.0	100%	5600	7:00 am - 10:00 pm	15	142.8
Total								142.8
CLS Projected Energy Consumption								
Pre-Open	1.4	CS4	0.50	0%	5600	7:00 am – 9:00 am	2	15.7
Open (daylight)	1.4	CS1	0.76	69%	5600	9:00 am – 7:00 pm	10	41.1
Open (daylight)	1.4	CS1	1.00	31%	5600	9:00 am – 7:00 pm	10	24.3
Open (no-daylight available)	1.4	CS2	0.70	69%	5600	7:00 pm – 10:00 pm	3	11.4
Open (no-daylight available)	1.4	CS2	1.00	31%	5600	7:00 pm – 10:00 pm	3	7.3
Total								99.7
Energy saved compared to Std. 90.1-04								30.1%

1. Control Factor – A control strategy helps curb consumption. This factor is the percentage that power of the vignette is reduced for that period of time when the control strategy is in use. For example, CS 4 switches half of the lighting off during pre and post stocking. Therefore, the LPD is reduced by 50%.
2. Applicable % of LPD – Not all of the luminaires in a given vignette should or could be controlled the same way (e.g., fluorescent lamps can dim and CMH do not). The Applicable % of LPD is a ratio of the installed power of the luminaires in that vignette that should be controlled to the total vignette power. Since control strategies are selected on an overall store wide basis, some Applicable % of LPD values could be 0 for certain time periods. This simply means that the strategy is not applicable to the vignette at that time and the combined Applicable Control Factor and Applicable % of LPD becomes a default to 1.0 (i.e., the vignette LPD thus is unaffected).

Table 3 shows a sample energy analysis similar to what would occur for every vignette selected in a given building. The baseline energy is the prescribed LPD times the total applicable area. The estimated energy for each vignette is the sum of the savings across the different operating time periods of the business. In the example above, the energy savings are derived first from the LPD of the vignette being 18% below baseline code. Additional significant savings are derived from the daylight dimming. To achieve 30% below code solely through installed power, the vignette LPD would have to be 1.2 (1.7 * 0.7 = 1.19). The selection of controls allows for a slightly higher LPD to achieve the desired savings. In this example, the most significant amount of control savings stemmed from daylight harvesting (CS1).

Return on Investment

Retailers operate on razor thin margins. Before making any changes to standard operating procedures, an economic analysis of the benefits is needed. Most retailers feel that a 2-year payback is an automatic "go" for the project. The CLS web tool will have an economic analysis portion based on some defaults and will allow the user to input some variables. Retailers will want an understanding of the financial risk involved with participating in CLS.

In 2005, the Energy Policy Act (EPAct) was revised to include property tax credits for energy-efficient spaces. Spaces with installed lighting below the values prescribed in Std. 90.1-2001 are eligible for property tax credits. For most spaces, Std. 90.1-04 is more restrictive than Std. 90.1-01. Therefore, most CLS users should qualify for these credits.

Baseline costs for a standard design will developed per building type on a square footage basis (e.g., $4/SF) using acquired pricing data. Each luminaire in the luminaire schedule will have a price developed on a unit basis that is applied to the ratio of luminaire type per square foot for the vignette space. For example, a vignette might use 0.015 luminaires per square foot, and the default equipment price per luminaire is $300. If the applicable area of the space of the vignette is 7500 square feet, then a total of 113 luminaires are needed (0.015 * 7500 = 112.5, but luminaries are rounded to the nearest whole number). The equipment costs $33,900. The price of the equipment, coupled with the energy savings, will allow the ROI to be calculated.

The price of energy, energy savings, and possible EPAct savings will all factor into the ROI calculation. A number of factors (region of the country, quantity of equipment, relationship to manufacturer and national accounts) affect the price of equipment. Generalized pricing estimates for lighting equipment will have a wide margin of error as compared to project-specific pricing. For this reason, users will be able to enter their own project-specific equipment pricing in place of default values to determine a more realistic ROI.

Project Escalation

As of the writing of this paper, pilot installations of *Lighting Solutions* are in the planning stages. The protocol for pilot projects will typically include a retailer with a utility or energy efficiency program sponsor. Detailed measurement and verification of the energy savings is required for pilot projects and the findings will be published in case study reports. These pilot projects will serve as a demonstration of the program and allow CLS to continue to improve the tool. Finally, the visibility of the demonstrations will be used to leverage the adoption of CLS *Lighting Solutions* into more utilities and EEPS programs.

Through a working group with utilities and EEPS, CLS plans to develop compliance methods. CLS will request the users to input information into the tool about the design of their store. EEPS and utilities will most likely request plans, proof of purchase of equipment, and ultimately on-site review the energy consumption to verify compliance. These are already current methods to documenting compliance for EEPS and utilities. Since these organizations will be providing the actual financial incentives to the companies and these organizations have a closer relationship with properties located in their jurisdiction, the onus of final compliance will be with the EEPS and utilities.

Conclusion

CLS represents progress by providing an interactive mechanism that allows users to select from different design options for a given space, receive detailed equipment specifications, instantly analyze their proposed energy usage, and to interface directly with EEPS and utilities providing incentives to interested in saving kW or kWh through good lighting designs. The CLS method for saving energy is to reduce the installed power of the design, while maintaining design quality, and the use of lighting controls to curb consumption of the installed power. This will yield the largest amount of energy savings.

Currently, *Lighting Solutions* have been developed for the Retail Sector because retail companies have prototypical and homogenous spaces that can be easily reproduced regardless of the location. Additional sectors are being modeled and incorporated into CLS including: office, healthcare, and education with the overall goal of the *Lighting Solutions* reducing energy consumption by 30% below Std. 90.1-04 in 5.5 billion square feet of commercial space. Progress will be reported by DOE and its partners, and published in journals, trade press and other partner communication venues to maximum usage and impact.

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