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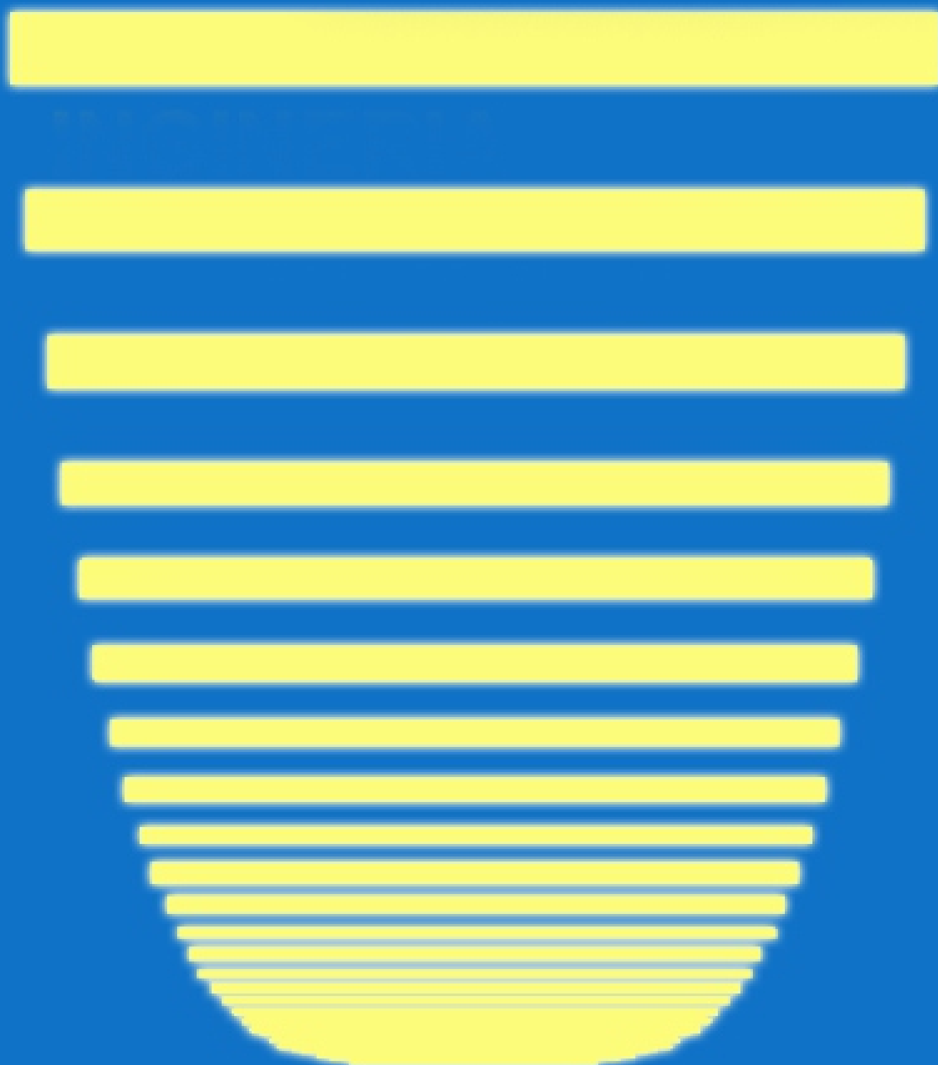

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INGINERIA ILUMINATULUI – Journal of Lighting Engineering - is a publishing media for valuable original scientific papers in the field of lighting engineering. The papers proposed for publication are considered based on their originality, meaningfullness and area of interest. In order to be accepted, the papers have to be remarquable in their field. The papers are evaluated by two independent reviewers. The contributions have to conform to the generally accepted practices for writing scientific papers, with respect to paper organization and style of writing.

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LIGHTING EDITORIAL 2.0

Since 1879, we have been so fascinated by the invention of incandescent lamp by Edison, that it still influences the way we treat daylight or new LED solutions. Until a few years ago, most of lighting books referred only to electric lighting (sometimes mentioned as artificial lighting, a subject of debate between specialists). In the last years situation has changed a lot and daylight has been greatly reconsidered. A presentation of Dean Hawkes on the way daylight was used by famous architects like Wren, Soane, Scarpa, Kahn and Zumthor showed that one the secrets lies in the way they shape the space with light. One of the common mistakes done nowadays is that we tend to consider architects more like architectural designers and not as a science. Cristopher Wren has started as a remarkable astronomer and mathematician and then he became an architect. In our days Zaha Hadid took a degree in mathematics before becoming architect. When people look at the Vortexx luminaire used in Puerta America hotel, they think more to a visual artist. Yes, there is magic about lighting but there is also a lot of mathematics and physics.

Despite that, more than two years have passed since the moment of incandescent lamp phase out. Still, many lighting experts are not happy about this decision, PLDA made a protest and some give the example of New Zeeland which changed its mind. Again, coming back to 1879, many are attached to the old incandescent lamp and to its unbeatable spectrum and color rendering.

But, for many others, the future lies in LED. I recently received some leaflets about Master LED Designer lamps and I was surprised by its innovative shape; if I were to bet on a LED retrofit lamp this it would be. I am not convinced yet by the QR 111 direct LED replacement lamps.

The LED potential is still not fully used: there are few luminaires where you can change the light distribution curve and the color temperature.

There is a slight change for the design of the our review cover, thanks to the help of an architecture student, Laura Grădişteanu.

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DAYLIGHT REQUIREMENTS IN SUSTAINABLE BUILDING RATING SYSTEMS

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Abstract: *Nowadays, daylighting criteria are included in some countries in building regulations with relation to occupant health safety. In this contribution exacting daylight rights in Slovakia are presented, as example of such practice. Slovak legislation requires architects to design all new occupied rooms for certain Daylight Factor (DF). DF 0.90% is required in reference points on working plane 0.85 m above the floor in half depth of living rooms and DF value of 1.5% in all working positions in side lit rooms. Daylight availability in all existing occupied interior spaces is guarantied by criterion "equivalent obstruction angle", which represents daylight access right. The Slovakian Hygienic Service has checked almost all urban and building plans from the viewpoints of the above outlined mandatory daylight access legislation. Planning permission does not override a legal right to daylight. Daylighting criteria are frequently expressed in voluntary national and international systems of sustainable construction evaluation, such as BREEAM, LEED, CASBEE, GREEN STAR. These criteria differentiate each other and are expressed in several ways. This article compares and contrasts several daylighting metrics, different in terms and structure, in several systems of sustainable construction evaluation. Moreover, some critical remarks are made with regards to present level of quantifying daylighting in some sustainable building rating systems. Generally, daylighting criteria in contemporary sustainable buildings rating systems are not balanced enough versus urban context and do not guarantee preservation in the future.*

Keywords: daylighting, sustainable buildings, criteria

1 Introduction

Protecting solar and daylight access in buildings is not a new concept. The Roman Empire had solar access laws, it was practised in the colonial cities of Greece, and the Doctrine of Ancient Lights protected landowners' rights to daylight in nineteenth-century Britain but there are problems with its application (roughly, the doctrine states that if in living memory no one has overshadowed your property, they cannot now do so; this doctrine has been repeatedly disavowed in U.S. courts). Access to solar radiation in the urban environment (direct and diffuse, including high intensities and natural dynamics) is an important health issue, from a hygienic, as well as from psycho-physiological and energy points of view. Architects through the ages have designed buildings to effectively introduce sunshine and daylight into internal environment. This effort is more than only provide task lighting. Unfortunately, the modern urban patterns and building forms often lead to reduced daylight and direct solar availability in interior spaces. This problem culminates in high-rise and dense cities.

Many rating systems of sustainable development attempt to stimulate developers to create built environment, in which shall be guaranteed adequate sunlighting and daylighting conditions. A review of daylighting requirements of many sustainable rating systems is the main aim of this article. Readers of this article can compare proposed new voluntary "sustainable" criteria with rights to daylight in Slovakia, which are introduced and practiced for many years.

2 Rights to daylight in Slovakia

The Ordinance of Ministry of Health of the Slovak Republic No. 259/2008 [1] ensures rights to enough daylight in all new and existing occupied spaces. Criteria of buildings daylighting are postulated in [2]. These rights are based on healthy principles and are strictly supervised by Hygienic Service.

2.1 Rights to daylighting

Slovak legislation requires architects to design all new occupied rooms for certain Daylight Factor (DF). DF 0.90% is required in two reference points on working plane 0.85 m above the floor in half depth of living rooms and DF value of 1.5% in all working positions in side lit rooms [2], for example. It means that from reference points is necessary to see part of free sky.

Daylight availability in all existing occupied interior spaces is guarantied by criterion "equivalent obstruction angle", which represents daylight access right. The main features of present rights to daylight access in Slovakia are: (1) only the sky light from CIE Standard Overcast Sky on vertical external surfaces of windows or on reference points is taken into consideration, (2) own obstructions of a window or a reference point are not taken into account in calculations of daylight/skylight right, (3) the shape and dimensions of new development are defined by equivalent obstruction angle α_e. For classrooms α_e=20º, max. 25º, for common interiors in housing estates α_e=25º, max. 30º are used.

The maximal equivalent obstruction angles in cities are α_e=36º and in historic city centres α_e=42º. The equivalent obstruction angles can be calculated graphically by the modified Waldram diagram (see Figure 1 left) and by diagram in Figure 1 right or by computer program. Only geometry data are needed for assessment of daylight rights.

3 Criteria of daylight access in buildings in sustainable rating systems

In essence, there are three layers of building regulation - central (international and national), regional and local. Worldwide it is not usual to keep rules for daylight/sunlight access on central level. Professionals through out the building industry use usually voluntary assessment

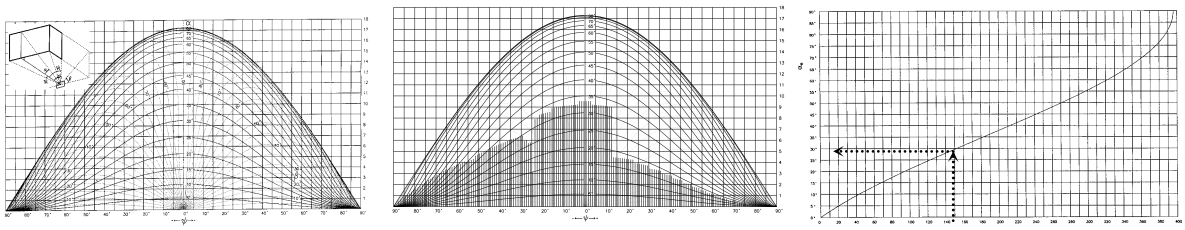

Figure 1 Modified Waldram diagram for assessment of daylight access rights (left), example of diagram application (in middle) and diagram for quantification of equivalent obstruction angle (right)

rating systems to evaluate and differentiate their product or design. In several sustainable rating systems exists criteria for sunlight access and into many systems are included criteria for daylighting. Non sustainable rating system guarantees preservation daylight and sunlight access in the future.

3.1 Criteria for daylighting in homes

Daylighting evaluation can be divided into two types: (1) prescriptive-based and (2) performance-based. Very simple geometrical, prescriptive-based criteria don't guarantee enough daylight in interior spaces of buildings. Window sizes prescribed as a percentage derived from external wall or floor area of the room have only a slight relation to real daylight environment, mainly in obstructed sites. Performance-based daylighting in buildings need to be based on a set of dedicated performance requirements and that can be evaluated on the basis of performance indicators. Beside dimensions of the room and widows man need to take into account shape of indoor space, glazing type and its slope, light climate, reflectance of the internal and external surfaces, own and external obstructions. Performance-based daylighting legislation is typically based on the well known DF method. Nowadays, simulation methods are preferred. Sometimes, simulation methods are used in very "creative" manner, mainly in the area of sustainable rating systems.

Criteria of living rooms daylighting of various sustainable building certification systems can be found in Table 1. Preferably rating systems were chosen, which daylighting criteria were based on DF method. In spite of common basis the methodologies differentiate each other in great amount. All information presented in Table 1 and Table 2 is available on Internet.

Table 1 Criteria of sustainable rating systems for daylighting in dwellings

Rating system	Country	Criteria
BREEAM EcoHomes	UK	Kitchen to achieve a minimum average DF of at least 2%. Living rooms, dining rooms and studies to achieve a minimum average DF of at least 1.5%.
BREEAM-NL	Netherlands	Guidelines for DF in home functions are: living room: 3.5%, kitchen: 2.5%, bedroom: 2.0%.

GREEN GLOBES	USA	Achieve minimum DF of 0.2% for living/dining areas.
HQE	France	Simplified criteria are based on the window area/floor area ratio (parameter Io). For living room is required Io≥15%, for example. Some versions of system works with DF. If 1%>DF>0.5% is in the middle of the living room, than 1 point is awarded for daylighting. If DF is under 0.5%, than the design acquires no credit. The lower limit DF=0.6% is in daylighting of kitchens. In cases: 2%>DF>1%, 1.5 points are granted for living rooms or kitchens, DF>2% - 2 points are granted.
DNGB	Germany	Daylighting of a building is qualified as "insufficient" if DF<1% is on more than 50% of whole utilizable floor space (zero points). 8 points are awarded when DF>1% is on more than 50% of whole utilizable floor space, than daylighting of a building is qualified as "low level". Daylighting of building is qualified as "good" if DF>1.5% is on more than 50% of whole utilizable floor space (12 points) and "very good" if DF>2.0% (16 points are granted). Points are weighted in further stages of certification process.
GRIHA	India	Daylighted area of the proposed dwellings shall be greater than 25% of the total "living area" and achieve the recommended DF=2.5% for kitchen, 0.625% for living room and 1.9% for study room at the centre of daylighted area in the design sky conditions to fetch 2 mandatory points. In case the total daylighted area is over 50% and/or 75% of total "living area" it shall fetch 1 additional point on each. This shall, however, be non-mandatory.
GREEN STAR	Australia	DF of >2.0%, or a Daylight Illuminance (DI) of at least 200 lux in kitchens, and DF of >1.5% and DI of at least 150 lx for living areas in accordance with prescribed requirements. Credit points achieved are determined by the percentage (60% and 90%) of the nominated area with the above defined DF or DI.
IBO ÖKOPASS	Austria	DF=2% in two points 2 m apart from window wall and 1 m from side walls of main living room. Daylighting in residential complex is qualified as "satisfactory" if more than 25% of main living rooms of flats meet DF criterion, as "good" when more than 40% of main living rooms has DF over 2%, rating "very good" is for more than 55% rooms and "excellent", when more than 85% of main living rooms in residential building is over above mentioned daylighting criterion [3].
SBTool.CZ	Czech Republic	As a first step criteria of code ČSN 73 0580 for daylighting of living rooms are checked (for one side lit rooms DF=0.9% is required in two points in the middle of the room, points are 1 m from side walls). Then is calculated visibility of free sky from the plane in level +1.1 m over the floor of living rooms. Resultant points are affected by area from which is visible sky and by orientation of windows towards cardinal points. [4]
HK – BEAM V 4/04	Hong Kong	Minimum window to floor ratio 10%, maximum obstruction angle 71.5 for habitable rooms. Vertical Daylight Factor (VDF) on the centre of the window pane for habitable room 8% and for kitchen 4%.

Table 2 Criteria of sustainable rating systems for daylighting in offices

Rating system	Country	Criteria
BREEAM	UK	One credit is awarded where evidence provided demonstrates that at least 80% of net lettable office floor area is adequately daylit. It means an average DF of 2% or more. One credit is awarded where evidence provided demonstrates that an occupant controlled glare control system (e.g. internal or external blinds) is fitted.
LEED	USA	75% of all occupied spaces achieve 2% Glazing Factor or 25 foot-candles (equivalent to 250 lx) - measured or modelled under clear sky (excluding all direct sunlight penetration). The Glazing Factor is specific criterion, which is not compatible with Daylight Factor and equivalence of measured and modelled daylighting under clear sky is questionable.
GREEN GLOBES	USA CANADA	Provide ambient daylighting to 80% of the primary spaces. Achieve minimum DF of 0.2% for work places and 0.5% for work areas requiring good lighting.
CASBEE	Japan	Evaluation is based on amount of daylighting and antiglare measures. DF is required in range from 1% to 2.5%. Daylight glare control - credits are awarded for provision of blinds and eaves.
DNGB	Germany	Daylight availability for the permanent workplaces (quantitative) is based on daylight saturation percentage according DIN V 18599-4. If daylighting is under required level for 45% of working time annually no points are granted. If required daylighting is fulfil for 45-60% of working time, than 7 points are awarded, for range of 60-80% of working time 10 points are granted and for over 80% of working time 14 points are assigned.
GREEN STAR GREEN STAR NZ	Australia New Zealand	Up to three points are awarded where it is demonstrated that a nominated percentage of the net lettable area (NLA) has a DF not less than 2.5% as measured at the floor level under a uniform design sky, as follows: 1 point=30% of the NLA; 2 points=60% of the NLA; 3 points=90% of the NLA. Credits are also awarded where fixed shading devices shade the working plane from at least 80% of the sunlight or where occupant controlled devices transmit <10% sunlight.
HQE	France	For each interior space, a zone is identified covering a surface from the facades to a given limit distance in the interior space. Inside that zone, daylight factors must reach defined levels. Basic label - DF≥1.5% in 80% inside the zone for 80% of all spaces. Good label - DF≥2% in 80% inside the zone for 80% of all spaces and DF≥1.5% in 80% of the remaining 20% of the spaces. Very good - DF≥2.5% in 80% inside the zone for 80% of all spaces and DF≥1.5% in 80% of the remaining 20% of the spaces and DF≥0.7% in 90% of the spaces. [5]
GRIHA	India	Daylighted area of the proposed office building shall be greater than 25% of the total "living area" and achieve the recommended DF=1.9% (general) at the centre of daylighted area in the design sky conditions to fetch 2 mandatory points. In case the total daylighted area is over 50% and/or 75% of total "living area" it shall fetch 1 additional point on each. This shall, however, be non-mandatory. DF is assumed 80 lx. The recommended design sky illuminances for cold climate is 6800 lx, for composite climate 8000 lx, and for warm-humid and temperate climates 9000 lx.

GBI	Malaysia	If ≥ 30% of the NLA has a DF in the range of 1.0 - 3.5% as measured at the working plane (800 mm from floor level) 1 point is awarded and for≥ 50% of the NLA 2 points are given.
HK - BEAM	Hong Kong	Average DF at least 0.5% for all normally occupied spaces (1 credit), 2 credits are for average DF at least 1% and 3 credits for average DF over 2%.
VERDE	Spain	DF ≥ 1% of general value.

3.2 Criteria of offices daylighting

A comparison of North American - United States and Canada -, European - United Kingdom, Germany, Netherlands, Austria, France, Spain -, and Asian - China, India, Malaysia, Japan, Hong Kong -, Australian sustainable rating systems highlights the some similarities between different regions, as well as the differences in design recommendations for daylighting of buildings that are a reflection of unique local conditions and traditions in creation of built environment. Generally, sustainable rating systems prioritize daylighting. Unfortunately, this prioritization is often only formally declared, the criteria are oftentimes very low (e.g. LEED, GREEN GLOBES, HK-BEAM). Criteria are not stable; they are often less or more changed with each new version of many rating systems. So, some information in Table 1 and Table 2 doesn't have to be up-to-date. It is impossible to compare daylighting criteria, even if they are based on Daylight Factor method. Average DF is something else than DF prescribed in a point. Value of DF depends in great range on quantification method. Simplified physical models, computer simulations, or on-site measurements of the completed building are also allowed as methods to document DF requirements, but these procedures are hardly comparable, distinctively in system LEED, which introduced daylighting evaluation in clear sky conditions and criterion of Glazing Factor.

In sustainable building rating systems priority should be given to the unity of the criteria and computational methods prior to their "accuracy".

4 Conclusion

Sustainable rating systems are still in their infancy and further development and testing is needed to establish concrete methods and benchmarks even in area of daylighting evaluation and certification. Generally, daylighting criteria are not balanced enough versus urban context and don't guarantee preservation in the future. Whether for energy or for life quality daylighting of buildings remains a legitimate area of public policy in which the aim is to regulate buildings design and how and when neighbours may shade one another. When we contrast Slovakian ordinances and codes and everyday practice in given area with contemporary sustainable buildings rating systems we see that almost all "sustainable" daylighting criteria are much less ambitious.

Acknowledgement

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CASE STUDIES FOR ADOPTING LED TECHNOLOGY IN BRITISH COLUMBIA

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Abstract: *The awareness of limited resources as well as the increasing political interest in energy-efficiency, demands that we look beyond buildings for lighting upgrades. With approximately 70 million streetlights in North America and 250 million worldwide, street lighting has the potential for significant savings. LED-based street lighting is rapidly gaining market acceptance due to its greater energy efficiency, low maintenance, and long lifespan. Although energy savings of 30 to 40% can be expected by switching the existing HID light sources to LED, there are many technical and economical hurdles that will affect market transformation. Another 30% savings could be attributed to upgrades in lighting control. The Adaptive Lighting Control strategies are getting acceptance and more systems are now deployed.*

This paper outlines multiple field case studies that BC Hydro, the British Columbia provincial electrical utility, has performed in view of adopting LED technology for street lighting. The paper introduces some of the benefits and limitations of LED technology, presents the various field tests, and summarises the collected data, calculations, and results. In some of the case studies, LEDs and dimming control are combined to further increase energy savings. Conclusions cover economic feasibility and social impact analysis. Next steps are also mentioned mostly with regards to potential and doable "on situ" laboratory testing. Poised to advance both LED technology and Adaptive Street Lighting, municipalities, utilities and government transportation authorities are joining forces to develop specifications and product performance criteria.

Keywords: street lighting, LED, dimming controls strategies

1 Introduction

A typical North American municipality spends about 20-30% of its electricity bill on street lighting. While British Columbia alone has about 300,000 streetlights there are approximately 4.5 million street lights in operation in Canada and about 70 million street lights in North America [1]. If one considers an average 30% reduction in energy consumption due to more efficient emerging technologies, British Columbia could save approximately 100 GWh annually, and savings in North America could exceed 5000 GW and 23 TWh. This would be enough to power 800,000 houses (a large city like Toronto). Additionally, greenhouse gas emissions could be reduced by over 7000 thousand metric tonnes. Considering that there are over 250 million street lights worldwide, the potential benefits are staggering.

Over 90% of street lighting today utilizes high-intensity discharge (HID) lighting – the most common being high pressure sodium (HPS) lamps [1]. However, LED applications in street lighting are increasingly of interest due to the potential advantages over conventional metal halide (MH) and HPS sources. LED lighting sources are still relatively new in development and have no long-term operating history. They are also relatively costly. Thus, due to the uncertainty in how well they perform in a real-world environment, large-scale construction, retrofits, or replacements of current MH and HPS sources are a substantial risk.

Adoption in North America lags behind that of Europe and parts of Asia. In response to this, unique alliances have been forged. The U.S. Department of Energy (DOE) has partnered with several notable organizations. Part of their goal was to explore the potential for savings and to create awareness within the industry as it relates to LED street lighting products.

In 2005, the first to commit was the Next Generation Lighting Industry Alliance.

In 2006, the Illuminating Engineering Society of North America (IESNA) also joined the force. As a major guiding force for lighting standards in North America, the IESNA is an essential stakeholder when it comes to adapting new lighting technologies.

In 2008, the International Association of Lighting Designers (IALD) joined as well.

Since then, the groups have organized a number of activities – hosting seminars, demonstrations, competitions, and much more.

In 2009 the DOE formed the Municipal Solid-State Street Lighting Consortium. The consortium is comprised of municipalities, power providers, building owners, energy efficiency organizations, and other decision-makers who invest in street and area lighting to share valuable field experience and data on their investments in LED street lighting. The consortium was also formed to minimize the duplication of effort and to also provide coordination among projects to help ensure consistency in evaluation methodology [2]. Many utilities, such as BC Hydro, Pacific Gas and Electric (PG&E), and Seattle City Lights also share resources, information, and perform independence testing to develop regional and North American databases.

2 LED Street Lighting Systems

2.1 Benefits and Limitations

From a technical standpoint, LED street lighting systems offer many benefits over existing street lighting technology. At the same time, the uncertainty and risk associated with this new technology prevent municipalities from leaping into the market and pursuing an LED based solution.

Table 1 and 2 summarize the benefits and disadvantages/issues of the LED street lighting systems compared with conventional HPS/MH ones.

Table 1 The benefits of the LED street lighting systems

Benefits	**Why it is Beneficial**
Street Lighting Design	
Higher Colour Rendering Index (CRI)	• Improved night visibility • Improved colour rendering perceived by the eye
Higher Correlated Colour Temperature (CCT)	• Improved night visibility • Improved perceived lighting quality and "seems" brighter • Recommended by Police Departments, as it is believed to discourage crime
Increased Illuminance Uniformity	• Eliminates "hotspot" effects, reducing the chance of over lighting design • Eliminates dark spots between poles • Increased pole spacing in some applications (uses fewer poles)
Minimal Glare	• If designed correctly, a non-issue when comparing existing street lighting and new LED street lighting
Easy to Control Optics	• LEDs are a point source, making the optics very controllable (depends on luminaire fitting) • Significant reduction of light pollution • Easier to control road/house light distribution
Adaptive/Dynamic Control Potential	• Can be combined with adaptive/dynamic lighting controls to dim lighting levels
Economics	
Lower Energy Consumption	• Energy savings vary widely depending on luminaire type but can average 25%-50% and could increase up to 70% when including controls
Longer life	• Expected life is 2-4 times the life of existing street lighting technologies
Lower maintenance	• Maintenance savings vary, but are significant. Savings appear to be primarily associated with longer luminaire life
Increased Pole Spacing	• Increased lighting uniformity and better efficacies from LEDs, may allow pole spacing (new construction scenarios) to be increased
Adaptive/Dynamic Control Potential	• Lower light levels at different times of the night (depending on pedestrian traffic level) increases energy savings potential
Operation	
Instant-on	• Instantly turns on with no run-up or re-strike delays • No cycling issues as HPS lamps
No Mercury	• Operation requires no mercury resulting in lower environmental impact
No Fragile Parts	• Does not depend on fragile filaments and vacuum tubes
Better handling and installation	• Weight reduction and smaller/lighter units, easy to install and transport. • No need to carry components in trucks for maintenance • Reduction in warehousing space - no need to store components
Market Adoption	
Public Response	• Public response to several test pilot demonstrations is generally positive
Coordinated global effort	• Unlike in any other lighting technological developments, manufacturers, governments, utilities, and markets work together to solve issues and streamline the rapid development of LED technology • Users, governments, and industry form interest-working groups

Table 2 The disavantages/issues of the LED street lighting systems

Issues	Why it is an issue
Street Lighting Design	
Cobra-Head Retrofits	• Size issues; existing Cobra-Heads work well with conventional lamp technology, but it is difficult to retrofit with LED retrofit kits • Optical issues, a challenge to meet IESNA roadway patterns. (e.g difficult to create a type II pattern under the cobra-head) • Thermal issues, existing cobra-heads are not designed as a proper heat sink for LEDs
Perceived glare	• LEDs with high CCT (more than 5000 K) may be perceived as glary
Existing Pole Spacing and Pole Heights	• Existing fixed pole spacing and heights increases costs and limits the design and optical capability of LED street lights
Economics	
High Initial Cost	• While expected to decrease in the future, LED luminaires can cost over $1000 per unit. Simple payback is often unreasonable, especially under the retrofit scenario
No Long-Term Operational History	• Economic viability of LED street lights largely depends on long lifespan and no maintenance costs
Increased Utility Tariff	• Utilities may need to offset the high initial cost by increasing the tariff
Manufacturing	
LED Industry is Not Streamlined	• LED street light manufacturing industry is not streamlined, making the cost of production very high
Limited Adaptive Control	• Currently, many LED products do not have adaptive control capability
Power Supply/Drivers	• Drivers need to be more reliable than actual commercial grade
Product Selection	
Exaggerated Manufacturing Claims	• Manufacturing product claims of "equivalency" are often exaggerated and those products are inferior to the existing technology they are supposed to replace
High Implementation Risk	• LED street lighting technology is unpredictable in how well it will perform • Several demonstrations show successful products, while others fail miserably
Lack of component standardisation	• The standardisation of components can help manufacturers and users towards market transformation
Testing Standards Constantly Changing	• Standards and testing are constantly being updated as LED technology is constantly evolving • Some measurement procedures (such as CRI) have to be completely revised to reflect LED technology • Calculation of product life and lumen depreciation is still difficult given the long life expectations
Performance Standards	• More voluntary performance standards need to be adopted and updated • CIE/IESNA need to update roadway and outdoor measurement and technical design standards to reflect the particularities of LEDs.

2.2 Standards and Guidelines

In North America, the Illuminating Engineering Society of North America (IESNA) is considered the authority for defining the lighting conditions necessary for adequate light levels [3]. In particular, if new LED street lights are to replace incumbent existing street lighting technology, the LED street lights must provide sufficient light levels, as defined by IESNA. Meeting these light levels takes precedence over any energy savings. This non-profit society has developed a number of documents relevant to today's LED street lighting guidelines:

- **IESNA RP-8-00** *Standard Practice for Roadway Lighting*
  Defines the minimum lighting levels, minimum lighting uniformity, and maximum allowable glare for various road classifications and level of pedestrian traffic.
- **IES LM-79** *Approved Method:Electrical and Photometric Measurements of Solid-State Lighting Products*
  Provides guidelines and procedures for testing the photometric and electrical properties of solid-state lighting (SSL) devices.
- **IES LM-80** *Approved Method:Measuring Lumen Maintenance of LED Light Sources*
  Provides guidelines for measuring the lumen maintenance of LED light sources.

2.3 Adaptive Control Technologies and Strategies

There is excellent potential for energy savings when varying lighting levels on roadway systems during the night. In Europe, this is referred to as "dynamic lighting". In North America, this is referred to as "adaptive lighting". Adaptive lighting allows the lighting levels to be adjusted to suit non-peak traffic periods, but can also allow designers to adjust the wattage to optimize the design.

The amount of light provided by a street lighting system is typically based on the classification of the road (function of the level of traffic: highways, collector, residential) and the level of pedestrian activity. The current standards (IESNA publication RP-8-00) are constant, regardless of the time of the night, day of the week, and weather. In reality, the traffic is heavily influenced by these factors, and a given road can change classification during the night from a major road with heavy traffic to collector status with minor traffic (for example, between 1AM and 4AM). The effect on required lighting levels changes depending on variables, such as pedestrian presence, available light (night, dawn, dusk), and weather conditions (rain, snow, fog). Therefore, if a lighting system is equipped with dimming equipment, the lighting levels can be changed based on the expected pedestrian and traffic volumes. However, the installation must meet the required IES guidelines, which include the average minimum luminance, uniformity ratio, and veiling luminance ratio.

The opportunity for reducing energy on a typical urban roadway is to reduce lumen output to a medium or low pedestrian conflict level. As a result, the lumen output could be reduced by 30% and 50% respectively, leading to significant energy savings [4].

It is understood that more than 80,000 street lights are now equipped with energy saving intelligent street light solutions all over Europe. In North America, the adoption of adaptive controls is lagging mainly because of system particularities, such as flat demand utility rates and a high liability perspective on traffic safety and security.

In order to avoid conservative attitudes that may hamper the progress in introducing a new technology, it is important to develop new standards that include adaptive lighting. IESNA is preparing an updated version of RP-8-00 (to be released in 2011) allowing designers to use adaptive street lighting, in a way that is similar to the recent CIE-115 standard (Commission Internationale de L'Eclairage). The new standards would require that adapted lighting levels should be the average illuminance or luminance from a class in the same (traffic/pedestrian) table from which the normal class has been selected. The integration of adaptive lighting in international guidelines/standards/ specifications shows it has now become an accepted practice.

According to the IES RP-8-00 tables the allowed illuminance/luminance reduction could go from a maximum of 36% for roadways to as high as 56% for local roads. However, the dimming potential depends mainly on the light source technology, as the dependence between luminous output and power dimming is not quite linear. High-intensity discharge (HPS and MH), fluorescent, and induction lamps can safely dim to about 50% the power, while LEDs can dim to a much lower power.

3 Pilot Tests

Although there is limited knowledge with LED street lighting, various municipalities in North America have invested in LED street lighting products to evaluate their performance. With LED street lights operating in real-world environments, experts gain an idea of the illumination and distribution characteristics of current LED street lighting products in the market. Additionally, these experts have estimated the energy savings potential and economic viability of these products over incumbent street lighting technologies.

These summaries highlight the results from various street lighting projects performed by BC Hydro.

3.1 Major Road Parking/ Rest Area (Highway 1, British Columbia)

In 2007/2008, the BC Ministry of Transportation and Infrastructure and BC Hydro, retrofitted eight 250 W HPS luminaires with two LED types (125 W and 135 W) from different manufacturers in two rest areas (Figure 1 and Figure 2) along Highway 1 in the Fraser Valley [5].

Figure 1 Photograph of LED #1 Test Area

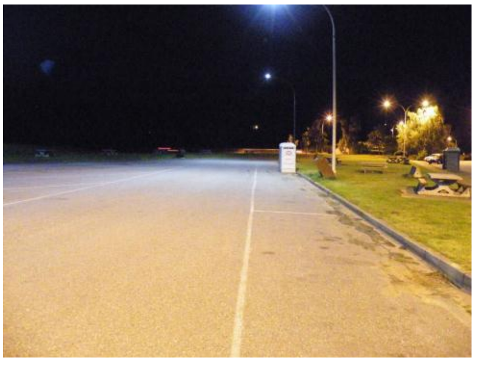

Figure 2 Photograph of LED #2 Test Area

From an illumination and distribution perspective:

- The LED luminaires performed with relatively similar uniformity. (Figure 3).
- The LED luminaires had similar illuminance per watt compared to the HPS luminaire.
- The LED luminaires only illuminated approximately 40% of the HPS' average illuminance. However, the Ministry standards require 250 W HPS or equivalent systems and the study showed that these standards deliver twice the recommended minimum illuminance of the IES RP-8.
- Estimated that the demonstrated LED luminaires have similar efficacies to the existing HPS; in other words, every HPS luminaire must be replaced with an LED luminaire of equivalent wattage to maintain the same illumination levels.

Economically:

- The potential energy savings was considered nil if the intent was to maintain the same (high) illumination levels. However, energy savings could reach 55% if standards are to be lowered to match IES recommendations.
- Positive financial savings are however related to the maintenance and labour costs associated with more frequent repairs and relamping of the standard HID luminaires.

Measured Value	LED Illuminance (lux)				HPS Illuminance (lux)			
Distance from Curb	5ft	10ft	15ft	20ft	5ft	10ft	15ft	20ft
Average	15.51	16.77	17.43	17.80	37.15	39.77	39.68	38.68
Max	24.80	27.30	28.30	27.50	59.70	65.40	63.40	59.20
Min	7.00	7.60	8.30	8.80	23.00	21.60	24.00	22.80
Uniformity (Avg/Min)	2.22	2.21	2.10	2.02	1.62	1.84	1.65	1.70
Max/Min	0.63	0.61	0.62	0.65	0.62	0.61	0.63	0.65
Average Lux/W	0.115	0.124	0.129	0.132	0.124	0.133	0.132	0.129

Figure 3 LED –HPS data comparison

3.2 Local Residential Roads (Coquitlam, British Columbia)

In 2010, the City of Coquitlam [6] experimented with adaptive lighting controls on existing HPS and new LED luminaires within a residential subdivision.

From an illumination and distribution perspective:

- Ten 70 W LED luminaires with Dynamic ASL Controls replaced 100 W HPS (Figure 4). The LED luminaires, which were offered by an Asian manufacturer, were not properly suited for North American roadway design and standards
- Both HPS and LED luminaires were dimmed (HPS: 100%-70%-60%, LED: 100%-80%) as seen in Figure5.

Figure 4 Photograph Comparison of HPS vs LED

Figure 5 Photograph of dimmed LED Luminaires

- Results should be considered lightly, since the LED luminaire did not meet IESNA requirements.
- In comparison to the HPS luminaire, it had lower average illumination and lower uniformity.

Economically:

- The LED luminaires showed 65% energy savings to date (21% due to controls).
- The simple payback was unreasonable.

3.3 Collector Road Non-residential (Port Coquitlam, British Columbia)

In 2010, the City of Port Coquitlam replaced nine existing HPS luminaires with nine new LED luminaires on Shaughnessy Street (collector street). In this study, only five of the nine LED luminaires were reviewed [7].

•

From an illumination and distribution perspective:

- Nine 110 W LED luminaires distributed light in a relatively even pattern as opposed to the 'spotty' pattern distributed by the 150 W HPS luminaires (Figure 6 to Figure 10).
- Dynamic ASL Controls (50%-70%-100%).
- At 100% load, the LED luminaires had higher illumination values than the HPS luminaires (Figure 6 and Figure 7).
- However, when compared to the RP-8-00 criteria, the LED luminaires met conditions for Collector and Local Road types, but not for Freeways, Expressways or Major road types.

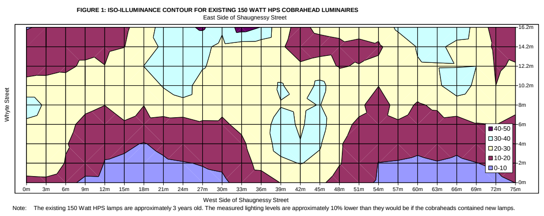

Figure 6 Surface Chart of Existing 150 W HPS Luminaires 100%

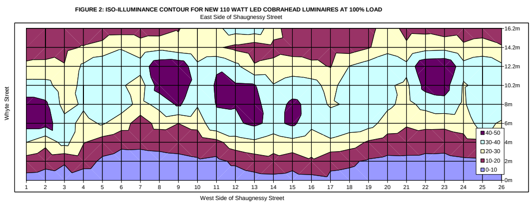

Figure 7 Surface Chart of New 110 W LED Luminaires

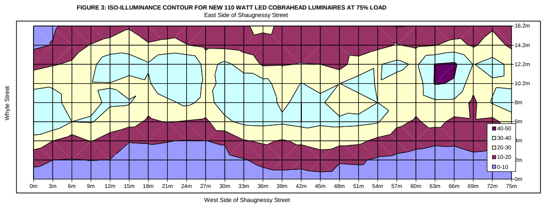

Figure 8 Surface Chart of New 110 W LED Luminaires 75%

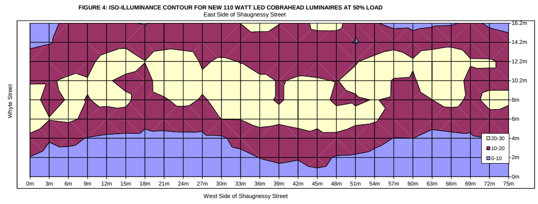

Figure 9 Surface Chart of New 110 W LED Luminaires 50%

East side of street	Maximum	Minimum	Average	Max to Min	Max to Average	Average to Min	Per luminaire load	Connected load for 5 units
Existing 150 W HPS	44.6	12.5	25.6	3.6	1.7	2	188 Watts	940 Watts
LED at 100% load	49.5	12	27.2	4.1	1.8	2.3	110 Watts	550 Watts
LED at 75% load	41.7	9.5	23	4.4	1.8	2.4	86 Watts	430 Watts
LED at 50% load	29.1	7.6	17.5	3.8	1.7	2.3	55 Watts	275 watts

Figure 10 Table Summary of Lighting Levels for Shaughnessy Street

Economically:

- The LED luminaires showed 63% in energy savings when combining LED street lights with adaptive lighting controls.
- The costs for this project are unrealistic, making the payback also unrealistic.
- The simple payback was impossible; however, this installation showed that further savings can be generated with the adaptive functionality.

3.4 Collector Road Non-residential (Vancouver, British Columbia)

In 2010, the City of Vancouver installed eighty 100W LED luminaires (2 per pole for road and pedestrian) to replace 70 W/ 100 W HPS 80 LED luminaires in a busy area of the city's downtown [8].

From an illumination and distribution perspective: The project team from the city was impressed with the installation, usability of the adaptive lighting system, and the appearance of the light in the area.

- Pedestrian luminaires were dimmed to 50% for all hours, while roadway luminaires were kept at 100%.
- Conclusion was made that over lit areas can benefit from adaptive technology and the more-uniform characteristics of LED lighting.
- Quantitative data was not reported.

Economically:

- The LED luminaires showed 33.3% in energy savings (12% from LED conversion and 21% from controls).

3.5 Major and Local Roads (Vancouver, British Columbia)

In 2008/2009, the City of Vancouver replaced existing HPS roadway luminaires with LED luminaires on a section of Fraser Str. (major street) and on a section of 37th Avenue. (residential street). Eight representative test areas were established for measurement (four on Fraser Str. and four on 37th Avenue). LED luminaires from four top manufacturers were used and compared to new HPS luminaires that were previously installed. [9].

From an illumination and distribution perspective:

- On the major road, high pedestrian conflict 8200 W HPS were converted to (69 W to 164 W) LED as in Figure 11.
  - For local roads, medium pedestrian conflict 12, 150 W HPS were retrofitted to (101 W to 166 W) LED.
  - The performance of the four LED types varied widely in comparison to the HPS luminaire In general, the LED luminaires had better uniformity ratios, but lower average illuminance levels than the HPS luminaires.

- Only two of the four LED types seemed to perform well, one did not, and the other performed with mixed results and data was limited (Figure 12).
- Illuminance and distribution characteristics of different LED luminaires can be just as good as or better than other LED luminaires, even with a lower input wattage.

Figure 11 Photograph of HPS and LED Luminaires along Fraser Street

LED Manufacturer	Illuminance LED > HPS	Above IESNA Standard	Street	Road Type
LED B	✓	✗	Fraser St.	Roadway
	✓	✓		Sidewalk
	✗	✗	37th Ave.	Roadway
	✗	✓		Sidewalk
LED A	✗	✓	Fraser St.	Roadway
	✗	✗		Sidewalk
	✗	✓	37th Ave.	Roadway
	✓	✓		Sidewalk
LED C	✗	✓	Fraser St.	Roadway
	✗	✓		Sidewalk
	✓	✓	37th Ave.	Roadway
	✓	✓		Sidewalk
LED D	✓	✓	37th Ave.	Roadway
	✗	✓		Sidewalk

Figure 12 Table Comparing the Illuminance of LEDs to HPS and to IESNA Standard

Economically:

- Electrical demand/consumption savings were in the range of 20-44% where LED luminaires meet IESNA recommen-dations.
- The simple payback was not calculated.

4 Conclusions from Pilot Projects

In general, these projects successfully demonstrated several benefits and issues with LED street lighting in real-world environments. Energy costs at $0.05 per kWh represent the average per kWh cost in BC. This value was used in all of these projects.

Key benefits:

- Improved lighting uniformity over existing street lighting technology (HPS).
- Energy savings can be significant (although this varies from manufacturer to manufacturer).
- Adaptive street lighting has significant potential for further energy savings. However, light levels from dimming must still meet IES RP-8-00 minimum illuminance levels.
- Public response is generally positive in favour of LED street lighting.

Key issues:

- Manufacturer claims are not being demonstrated from measurements taken.
- Several LED luminaires were well below standards/requirements set by the municipality or by IES RP-8-00.
- LED street lighting luminaires have different distribution patterns than conventional HID systems.
- Initial cost often dominates any energy or maintenance savings. Long paybacks

are presently challenging the technology adaption process.

- Adaptive street lighting technology is limited to very few LED luminaires/ systems.
- Since LED technologies are a moving target, users need to continuously update the technology and performance specifications for the products they purchase.
- We experienced repeated inaccuracies during measurement as we attempted to conduct illuminance measurements at the same location and angle in an uncontrolled environment over a period of years.

The BC Hydro demonstrations show that current LEDs' performance vary widely, making it difficult to draw definite conclusions. Furthermore, it is important to note the selection process in which these LED products were chosen for the demonstrations. In several demonstrations, only one LED product type was chosen (in two cases, it was the only product available at the time with adaptive lighting control capability). Therefore, as listed above, only a few key general benefits and issues with LED street lights were drawn because they showed patterns of consistency from the results of the demonstrations.

These results can be extrapolated to the current state of the LED street lighting industry. LED street lighting products perform with such inconsistency that, these demonstrations have shown that it is possible for higher powered LED types to produce less lumens than lower powered LED types. Manufacturing claims are significantly exaggerated, and in one demonstration, the LED luminaire, which was supposedly "equivalent" to the existing HPS luminaire, produced only 40% of the light output compared to the HPS luminaire that it was meant to replace.

At the same time, several demonstrations have shown that the LED luminaire has outperformed the existing technology in almost every aspect. This proves that there are certain LED products that can be successful in the right application. It is only a matter of time before LED products become more standard and more predictable in their performance, minimizing the risk to investors.

Various North American municipalities, such as Anchorage, Seattle, and Los Angeles have already begun large-scale retrofits using LED street lights. The rationale is that, the earlier a utility or municipality begins retrofits, the faster it can collect those energy savings. Yet at the same time, the future may bring in more efficient, more luminous, and cheaper LED models. The LED industry is growing at a rapid rate, but it is a question of risk and uncertainty: how long before the industry maximizes its potential versus retrofitting as early as possible and collecting those energy savings?

LED street lights show a lot of promise in replacing HPS street lights beyond the obvious maintenance savings. The energy savings are close to 50% and the expected life is around 50,000 hours, which is twice the length of HPS. The average conservative cost that was used for various pilots and initiatives is around $700, which is three times what they pay for the HPS street light. Assuming 70 W savings (on a 150 W fixture), $0.05 per kWh, and 12 hours per day operation, LED street lights would save $15.33 per year – or $175 over the LED's 50,000 hour expected life.

5 Next steps

BC Hydro is currently in the process of preparing a business case for the adoption of LED technology as a viable offer for the municipalities it serves.

On top of the development of technical specifications and purchase methodology, more needs to be done to develop a new tariff that will facilitate the market adoption of the LED street lighting technology. The unmetered/flat demand (or energy for adaptive controls) tariffs for street lights owned or managed by the utility, charge municipalities a certain dollar amount per month based on the luminaires' wattage, quantity, and maintenance/asset depreciation costs. However, the relative inexpensive cost of conventional HPS lamps and luminaires coupled with BC Hydro's long depreciation cycles (40 years) adds more burdens to the very high initial cost when trying to offset the capital cost through the tariff. Finding a solution to not pass (to consumers) the expected increase is a serious challenge and this is still to be solved by any North American utility that operates on this economical model. One solution could be to charge municipalities a one-time participation fee per LED luminaire and a lower or same tariff as before.

Independent of the tariff calculations, BC Hydro and its customers can benefit from more research on night-time vision, better testing and performance standards, and specialised outdoor testing sites.

5.1 More research on night-time vision

In the recent years, several research groups in Europe and North America have investigated the relationships between lamp spectrum and visibility for mesopic vision (outside foveal/ central vision). Under certain circumstances, increases in apparent brightness and/or visual performance can be demonstrated for situations where the light source is scotopically rich (low wavelength and high CCT). This leads to the possibility that under conditions of low light levels, such as those encountered at night, improved vision may be achieved by using "white" light sources versus typical HPS sources that are biased towards yellow wavelengths.

The subject is complex, and many variables are involved. If, however, better vision is achievable through judicious selection of the light source type, then it may be reasonable to consider that white (broad spectrum) sources (LED, MH, Induction) provide equivalent visual task performance at a lower illuminance level than HPS (less broad spectrum) sources; which in turn will result in significant energy savings.

To estimate the relationship between the normal photopic response curve of the eye and a manufacturer's rated lumens of an improved spectrum lamp, scientists have calculated a series of multiplier coefficients. Known as Scotopic/ Photopic (S/P) ratios or Lumen Effectiveness Multipliers (LEM), these multipliers help calculate the increase in lighting levels when using, for example, LEDs versus HPS light sources. The calculation of the multipliers has undergone an interesting evolution since the last decade (when considered static and independent of the application luminance conditions) to the present time when scientists seem to agree on the general trends of increasing LEM values as the luminance level reduces and as the content of blue/green output of the source increases. For example, consider that the HPS LEM is 1, the LEM of a Warm White LED lamp (3000 K to 3500 K) can increase from about 1.2 under a luminance of 1 cd/m^2 to about 1.7 for a luminance of 0.1 cd/m^2, while it can increase from 1.5 to about 2.6 for a Cold White LED (5000 K-6500 K) under a similar luminance range [10].

Presently, the new roadway lighting standards CIE-115 and respectively the upcoming IESNA RP-8-00 have incorporated mesopic vision effects into practical lighting design techniques of the future. Mesopic factors could apply to:

- Streets with speeds under 40 km/hr only. For roadway lighting applications, the central vision/foveal is predominant and thus the vision is Scotopic [11]
- Lighting for pedestrians, parking lots, pathways

Therefore, the energy conservation opportunity for LED sources is significant. Studies and test pilots shows that for applications where mesopic vision could be considered, illuminance levels could be reduced by as much as 30% when replacing conventional HPS light sources up to 150 W. Overall, considering the efficiency benefits of LED sources, overall energy savings could be greater than 50% for these applications. This could also lead to a better market penetration for LED street lights.

5.2 Laboratory-like conditions for in-situ testing

Two big questions are unanswered in the general discussion: will broader-spectrum light sources (such as LED) perform better than, equal to, or poorer than yellowish HPS in the varied rain, fog, snow, and dry conditions of North America and in particular, the Pacific Northwest? What if measuring illuminance and luminance levels can be performed in a laboratory environment to eliminate the inaccuracies in conducting measurements on existing roadway? To help answer these questions, BC Hydro and other utilities from the U.S. States of California, Oregon, and Washington teamed up with the Seattle Lighting Design Lab to create and use the LDL Outdoor Lighting Center. The outdoor lab has a stretch of traffic-controlled road and has flexible/modular poles to hold the street lights. The pole spacing (poles are on wheeled platforms) and fixture heights, up to 33 ft (10 m), can be easily adjusted to reflect the desired conditions. Each pole can carry up to three luminaires to speed up measurements when users are looking at comparative experiments.

The ideal measurements would benefit from more approaches:

- Indoor lab illuminance measurements of individual luminaires
- Computer simulation for LED luminaires installed in the outdoor lighting centre
- Outdoor lab illuminance and luminance measurements on real size applications with flexible pole mounting for luminaires.

5.3 Improved technical and performance specifications

Due to the incredible rate at which the current SSL industry is advancing, much work still needs to be done in order to attain a sufficient coverage of all SSL aspects. Because of the way that LEDs generate light, certain aspects, such as the color rendering index (CRI), do not appear to be suitable for SSL evaluation. A new system is currently being pursued by CIE as a replacement alternative, known as the Color Quality Scale (CQS).

Table 3 shows the LED standards that are presently undergoing development and will certainly contribute significantly to the quality of SSL products once completed. Presently, all tests must be done in laboratories accredited under ISO/IEC 17025 by the U.S. National Institute of Standards & Technology (NIST).

Table 3 The LED standards

Standards	Title/Content
CIE TC1-69	Colour Quality Scale
IES G-2	LED Application Guidelines
IES TM-21	Method for Estimation of LED Lumen Depreciation as a Measure of Potential LED Life
LM-XX1	Approved Method for the Measurements of High Power LEDs
LM-XX2	LED "Light Engines and Integrated Lamp" Measurements
NEMA SSL-1	Electric Drivers for LED Devices, Arrays, or Systems
More information at: http://www1.eere.energy.gov/buildings/ssl/standards.html	

For in-depth test results and reports on specific SSL products, the DOE has a unique program titled the Commercially Available LED Product Evaluation and Reporting (CALiPER) program. CALiPER regularly tests commercially available SSL products in an un-biased manner. Utilities and users can refer to these tests when planning to procure their LED street light equipment. (http://www1.eere.energy.gov/buildings/ssl/caliper.html)

Another alliance that conducts regular tests on SSL products is DesignLights Consortium (DLC). Upon adequate test results, each individual product will be placed on their Qualified Products List (QPL). Utilities (such as BC Hydro) in 22 U.S. states and two Canadian provinces have joined this alliance and request that their users purchase equipment only if it meets the DLC criteria.

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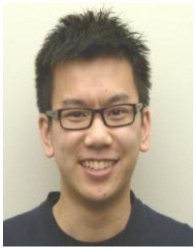

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DOES LIGHTING CONTRIBUTE TO THE REASSURANCE OF PEDESTRIANS AT NIGHT-TIME IN RESIDENTIAL ROADS?

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Abstract: *One of the reasons why road lighting may be installed in residential areas is to increase pedestrian reassurance, their confidence when walking alone at night, which in past studies has been addressed under the label of perceived safety or fear of crime. This article reviews existing literature examining the possible effects of street lighting on pedestrian reassurance in residential streets. Such data would allow better understanding of whether lighting is effective, and of whether variations in lighting conditions such as illuminance and lamp type, are effective at improving reassurance. While several studies have suggested that lighting affects reassurance it is possible that fear of crime is exaggerated by the procedure with which it is measured. Placing lighting in the overall context of reassurance at night time, by the consideration of other attributes such as spatial features, familiarity and the presence of other people, gives a holistic picture of the pedestrian experience. A pilot study was carried out using an alternative method for determination of whether lighting can aid reassurance in residential roads, with the aims of understanding firstly what is important for pedestrian reassurance, and then assessing whether this affected by light. This should form a realistic basis from which to recommend design criteria for residential roads.*

Keywords: pedestrian reassurance, residential streets

1 Lighting and reassurance studies

This article concerns road lighting in residential areas. A residential area is an area of a village, town or city which is suitable for or is occupied by private dwellings; a residential street is a street with the majority of frontages comprising private dwellings. In such areas it is normal to provide lighting that focuses more, but not exclusively, on the needs of pedestrians compared to those of drivers [1]. For pedestrians, road lighting is needed not only to provide a street which is safe for people to use but also is perceived to be safe. Reassurance is confidence when using a road and is used here as an alternative for the terms perceived safety and fear of crime that have been used in previous studies: lighting that promotes reassurance means a higher level of perceived safety and a lower level of fear of crime.

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Following the introduction of light sources such as metal halide (MH) for exterior lighting, informal assessment of newly installed schemes in the UK led some lighting practitioners to the opinion that these lamps, having broader spectral power distribution (SPD) than traditional low pressure sodium (LPS) and high pressure sodium (HPS) lamps, presented benefits in visual perception and performance [2]. For example Bhatti [3] reported of CMH lamps replacing LPS and HPS lamps: "visual amenity … is now improved, and all road users are much safer as everybody can see much better and clearer."; Scott [4] and Bennett [5] report of a trial where the original 35 W LPS lamps were replaced with 35 W CMH and a survey found that the perceived risk of crime had decreased (73% women, 100% men). While these trials tend to identify positive effects of improved lighting on reassurance the articles do not sufficiently describe details of the lighting installations, the people who were asked to give their judgements, the method by which judgements were obtained (was it a fair trial of the different options?) or the numeric data collected and this means the findings cannot be considered as reliable evidence or extrapolated to other situations. A number of larger scale surveys (Table 1) have been carried out and while it would be expected that these provide more complete data, this is not always the case.

Atkins et al [6] report of surveys carried out in an urban area of the UK before and after relighting and these included questions related to reassurance. Households were selected randomly, and 248 responded to the survey in February 1990, approximately seven weeks before relighting. Of these respondents, 191 responded to the follow-up survey in June 1990 approximately seven weeks after relighting. Surveys using a smaller sample size were also carried out in a control area where re-lighting did not take place. The questionnaire included a question which asked about the feeling of safety when walking alone in the area in daylight, and after dark using a 9-point scale with ends labelled very safe and very unsafe. Note that the interviews were carried out in the afternoon and early evening and therefore the perception of safety after dark would have been made from memory rather than being a contemporaneous judgement as were the daylight responses. It was reported that there was no general increase in feelings of safety about going out after dark following relighting, but that there was a statistically significant increase in women's perceptions of security. However, being unable to find sufficient numeric results in the report nor details of the before and after lighting conditions, it is not possible to independently review these conclusions nor to generalise the findings to any other situation and the survey is, therefore, somewhat meaningless as to effects of lighting on reassurance.

Nair et al [7] carried out before and after surveys following improvements to street lighting in a residential area in Glasgow. They report the results of respondents from 33 households who participated in both the before and after surveys, these being one year apart and with the after survey taking place three months after relighting.

Table 1 Summary of the methods used in past studies of reassurance. Note that while these surveys may have included multiple questions this table reports only the perceived safety part

Study	Independent variables	Method	Measurement	Outcome: did lighting affect reassurance?
Akashi, Rea and Morante, 2004	Change from 3.4 lx HPS to 2.8 lx fluorescent lighting.	Before and after surveys of nearby residences.	5 point rating scale: strongly disagree (-2) to strongly agree (+2) with statement *I feel secure while walking on the sidewalk*	Yes. Significant increase in feelings of security after change from HPS to fluorescent lighting. ($p<0.01$)
Atkins et al, 1991	Unspecified *relighting*.	Before and after surveys.	Nine point rating scale: very safe to very unsafe.	Reported effect for women respondents may be capitalising on chance. Insufficient data to support statistics
Herbert and Davidson, 1994	Change from LPS to HPS lamps; change in illuminance unclear.	Before and after survey of householders	Not reported	Trend for an improvement in reassurance but no statistics
Knight, 2010	Change from HPS to MH lamps. Netherlands: 16.5 lx HPS to 14 lx MH. UK: 9.1/12.7 lx HPS to 8.9/12.6 lx MH.	Before and after surveys, and after only survey of nearby residents (not resident on actual street).	Five point rating scale: Very safe (1) to very unsafe (5). *Does the lighting here make you feel safe or not?*	Yes. Higher ratings of perceived safety after change from HPS to MH lighting ($p<0.01$)
Morante 2008	Change from HPS to induction and MH lamps. Street 1: HPS 8.7 lx to Induction 2.7 lx. Street 2: HPS 3.2 lx to 3.1 lx MH.	Before and after surveys of residents living on or near street.	5 point rating scale: strongly disagree (-2) to strongly agree (+2) with statement *I feel secure while walking on the sidewalk*	Yes. Higher perceived safety under MH and induction lighting
Nair et al, 1993	Unspecified *improvements* to lighting	Before and after survey of householders	Not reported	No
Painter, 1994	Change of lamp type and illuminance. Before, LPS, 3.0 lx. After, HPS, 10.0 lx.	Before and after survey of pedestrians on street	Yes/No response	Trend for an improvement in reassurance but no statistics

The results suggest a reduction by 6% in the number of people worried about assault and harassment, although an increase by 9% in the number of people who avoided going out at all and an increase by 9% in the number of people who would avoid certain areas; the results suggest negligible change in feeling of safety outside. There are a number of problems with this study: the reported changes in opinions are not statistically analysed and the changes are small (e.g. 6% means two of the 33 respondents changed opinion); the precise survey questions are not reported and perhaps most importantly the nature of the enhancement in lighting is not reported.

The results reported for one question serve to demonstrate the questionable validity of this survey; in the survey carried out before the lighting improvements had taken place, 17% of respondents reported recent improvement in lighting despite there being no such action (and in the after survey this was 18%). Painter [8] used before and after on-street surveys of pedestrians in three areas of London, UK, to investigate the effect of improving the existing lighting (LPS, average illuminance approx. 3.0 lx) to a higher illuminance and slightly broader SPD (HPS, average illuminance approx. 10 lx). The surveys were carried out across 10 days between the hours of 1700 and 2330 before, and approximately six weeks after, the relighting. One question in the survey asked "Do you worry about the possibility of (physical attack; threats pestering; sexual assault) happening at night when walking through here?" The results reported suggest a reduction in the percentage of 'yes' responses in the after surveys for both male and female respondents in all three areas, although the article does not present a statistical analysis of these data.

Herbert and Davidson [9] report a survey of households in Hull and Cardiff before and after changes to the street lighting. These changes were to replace existing LPS lamps with HPS; the concurrent changes in illuminance, if any, are not clear. In Hull, over 200 households participated in the survey, while in Cardiff approximately 150 households participated. The results suggest that improved street lighting improved reassurance, with an increase of 44% in Hull and 67% in Cardiff after the relighting, although there is no statistical analysis to confirm this.

Morante [10] reports a survey of two streets in the US. In one street, HPS lighting providing an average illuminance of 8.7 lx was replaced by QL lighting providing 2.7 lx. In a second street HPS lighting providing an average illuminance of 3.2 lx was replaced by MH lighting providing 3.1 lx. In each street, the two lighting installations were matched for equal mesopic luminance as defined by Unified Luminance [11], these being 0.17 cd/m^2 in the first street and 0.05 cd/m^2 in the second street. Surveys of residents suggest that they found that the QL and MH lighting created environments that were considered to be safer and brighter than when using HPS lighting.

Akashi, Rea and Morante [12] compared HPS street lighting with that from a 6500 K fluorescent lamp. Lighting from the two lamps was balanced for equal mesopic luminance (0.22 cd/m^2) as defined by Unified Luminance [11]; these were average photopic illuminances of 3.4 lx for the HPS lamp and 2.8 lx for the fluorescent lamp. Lighting under the fluorescent lamp was considered to be brighter and create an environment that observers judged safer and more comfortable.

Knight [13] reported evaluations of the perception of brightness, safety and comfort of over 300 residents in the Netherlands, Spain and United Kingdom, before and after the street lighting in their neighbourhoods was changed from HPS to one of two types of CMH (2800 K and 4200 K). The average illuminance in the given areas was comparable before and after the change. Analysis of the results using paired-sample t-tests suggests that when the lighting was changed from HPS to CMH 2800 K or CMH 4200 K, the perception of safety was improved ($p<0.05$). When the reverse change was done, i.e. from CMH 2800 K to HPS, there was a statistically significant reduction in the perception of safety.

2 Survey Methodology

Measurement of reassurance, as with any perceptual attribute, is prone to bias [14]. Questionnaire design and the mode of evaluation can affect the outcome [15].

Past studies have tended to use category rating scales to record reassurance, for example a 9-point response range with end points labelled very safe and very unsafe [6]. Response contraction bias is the tendency for respondents to avoid using the ends of a scale and ratings will thus converge toward the centre of the response range. This response contraction may be enhanced if the response range has an obvious middle value and can reduce the distinction between stimuli [14]. The presence or absence of the middle category in a survey question can make a significant difference in the conclusions that would be drawn about the distribution of public opinion on an issue, because such alternatives usually attract a substantial number of people who may be ambivalent about other alternatives offered to them [16]. Dawes [17] used judgements of price consciousness to demonstrate that changing the number of response categories (5-, 7- and 10-point response ranges) had significant effects on the mean rating.

Johansson et al [18] recorded perceived safety along a footpath in Sweden using 5-point rating scales. They did not change the type of lighting so this study says nothing about how lighting affects reassurance, but instead they compared responses from three user groups who were considered to react differently to an environment: young women, elderly people, and people with visual impairment. Their results did not suggest a difference between the three groups, in that the path was perceived as neither very unsafe nor very safe. One possible reason for this is the use of the 5-point response scale, where the middle neutral value may have enhanced response contraction bias. This could be examined by repeating the study but using different response ranges, e.g. a 4-point range.

Past studies of lighting and reassurance have tended to use either simultaneous studies on separate roads, or before-and-after studies at the same location. The problem with either approach is that there may be differences other than the intended difference in lighting.

With before-and-after studies there is a possibility that public opinion may change due to external events, for example widespread reporting in the media of disorderly behaviour. Lighting is usually installed with a high illuminance to account for the expected light losses with time (e.g. lamp lumen depreciation and dirt deposits on the luminaire surfaces) in order that the minimum average illuminance is maintained through the working life despite these deficiencies. Therefore, if the after judgements are recorded closely following the installation of new lighting, then it is possible that these will be based on a higher illuminance and may thus inflate ratings of reassurance.

With simultaneous studies in different areas, there is a possibility that these different areas evoke different opinions of reassurance due to environmental and social differences beyond any effect of lighting. Table 2 defines environmental parameters that may affect reassurance; these tend to identify whether a potential attacker could be waiting un-seen and the possibilities for the potential victim to hide or escape.

Table 2 Environmental factors that may inform a judgement of reassurance [19].

Feature	Definition
Prospect	Refers to how well a person in the setting can look ahead to anticipate whom or what he/she is likely to encounter.
Refuge (or, concealment)	Refers to the natural and design features alongside one's route that can block one's view and, more importantly, provide a place where a potential attacker can wait out of sight for a potential victim.
Escape vs. boundedness	Reflects the ease of exit at various points along a path or in a location; permitting a user to exit the path should a potential attacker appear.

Environmental features may have different effects on different individuals. The behaviour of an adult is determined by four factors: self-esteem, self-efficacy, continuity and distinctiveness [20], [21]. Who a person is, affects not only the extent of their reassurance when walking alone at night, but also how they respond to surveys. Van der Wurff et al [22] also recognised the possible effect of underlying psychology in a social psychological model of the fear of crime which identified ones attractivity and power, and expectations of evil intent and criminisable space as influencing factors. As social animals, the human species cannot be isolated from social or political context, both of which can cause fear [23]. What an individual knows matters to their judgement as much as what they see and that knowledge is socially, politically and culturally constructed.

The time of day can affect how people assess their environment. For example, Hanyu [24] found that affective/emotional appraisals differ after dark. Warr [25], [26] suggests that darkness transfers the world into lurk lines and Box et al [27] found that darkness may have a negative on affective/emotional appraisals of places. These studies indicate a psychological effect of “darkness” which cannot be measured with an illuminance meter. There may be temporal variations which have a direct effect on the amount and spatial distribution of light, for example the presence or absence of leaves on trees can block road lighting luminaires to different degrees.

Thus a judgement of reassurance is made by a person, in a place, at a particular time; in this framework, lighting forms a part of ‘place’ (Figure 1). There are two challenges for investigations of lighting, and these are to identify the size of any effect of lighting on reassurance whilst these extraneous variables are controlled and also to identify the contribution of lighting to reassurance in real-world situations when these environmental and societal effects are also present. This latter challenge is effectively determination of the size of the circle representing lighting in Figure 1.

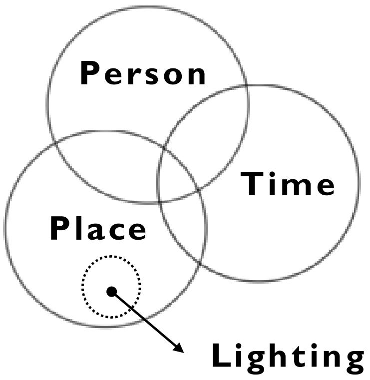

Figure 1 Lighting in the context of environmental and societal impacts.

3 What is being measured?

One problem associated with the measurement of whether lighting effects reassurance is that there are many ways in which fear of crime is manifest and it is often unclear what is actually being measured [28]. There are many reasons for this. Test participants are often asked whether they are very, fairly or not very worried (or afraid) of becoming a victim of crime, but they are not asked how often they worry, nor when they worry, nor what effects these worries have on their everyday lives. Using standard measures, some people report being worried without having worried recently [28]. Researchers do not typically have access to people when they are actually afraid but instead have focussed on anticipated rather than actual fear [28]. Test participants will make an expression of opinion even if they have no real opinion, for example because the survey appears to be for the common good and will thus give an opinion which they hope will be helpful [28]. There may be bias due to the retrieveability of instances [29], the subjective probability of crime may rise when one experiences evidence of crime. The effect of methodology on reassurance measures can be seen from a review where in only 15 of 64 sets of interviews was there no mismatch – different answers were obtained depending on the nature of the methodology [28].

It is possible that fear recorded in surveys is as much a methodological artefact as an empirical reality. Poor question wording, the desire to cooperate with surveys, and media and political interest in the fear of crime have contributed to a scenario in which the fear is continually recreated both socially as a topic for debate and at the individual level: surveys in this situation may not merely measure fear, they may actually create and recreate it. The traditional methods consistently over-emphasise the levels and extent of fear of crime [28].

Problems within the approach to measuring fear of crime can generate the impression of a large proportion of the population who fear crime [28]. According to Matsui [30] 85% of females always fear that they may be involved in street crimes. Other studies have also commented on the differences between males and females when making judgements of reassurance [18], [5]. Similarly young people give lower fear ratings than do older people, despite the higher risk of victimisation [19]. One reason why men are more likely than women to under-report their concerns about becoming a victim of crime is socially desirable responding; when this is taken into account, men's fears can outstrip women's fears [31], [28]. Similarly some responses may be exaggerated by perceptually contemporaneous offenses [32]. For example, women may give higher levels of fear of burglary than do men because when a woman is asked about burglary, she gives an answer about rape, since most people wrongly assume that they will be in a house when it is burgled, and that the burglar would attempt to harm them. Such responses are inadvertently not to do with how worried they are about the likelihood of assault happening but rather, if it did happen how much would it affect them.

While these concerns raise much doubt about past work, there is some evidence that lighting matters for reassurance.

4 Does Light Matter?

4.1 Does the presence of light contribute to reassurance?

Loewen et al [33] used two procedures to examine perceived safety in urban environments. The first study sought spontaneous comments as to what features of an environment contributed to making them feel safe or dangerous, and this was done without reference to any real or simulated locations. Three environmental features were mentioned most frequently, with light (either daylight or artificial light) being the most frequent (42 of the 55 test participants) followed by open space (30) and access to refuge (24). In the second study, test participants were presented with 16 images of outdoor scenes and asked to rate them using a 5-point response scale ranging from not at all safe (1) to very safe (5). These 16 images were two different scenes for the eight combinations of the three critical safety features found in the first study. The images were presented in a random order and each was observed for 30 seconds.

The results of the second study are shown in Figure 2. It can be seen that in all four situations regarding the presence or absence of open space and refuge that lighting increases mean ratings of perceived safety. The presence or absence of light had a larger effect on mean ratings than did the absence or presence of either open space or refuge. The presence of either light, open space or refuge in a scene lead to higher ratings of safety than when they were absent. However, Figure 3 suggests that lighting alone provides an approximately equal perception of safety than do open space and refuge together in the absence of light. It is of course possible that the presence or absence of light was the most obvious component of the images on which these judgements were made.

From Loewen et al it might be concluded that the addition of lighting to a previously un-lit area will improve reassurance. A further question is whether different qualities of lighting also improve reassurance. Mansfield and Raynham [34] surveyed visitors and local businesses in a small town centre in the UK (Swinton) following re-lighting of the town centre. These data suggest that factors which might contribute to a high fear of crime, such as vandalism, graffiti, groups of young people loitering and acting rowdily, were not improved by the new lighting. Regardless of relighting, some areas will still feel unsafe: what lighting can do is to allow you to see better, but if what can be seen is disturbing then this will not alleviate the fear of crime.

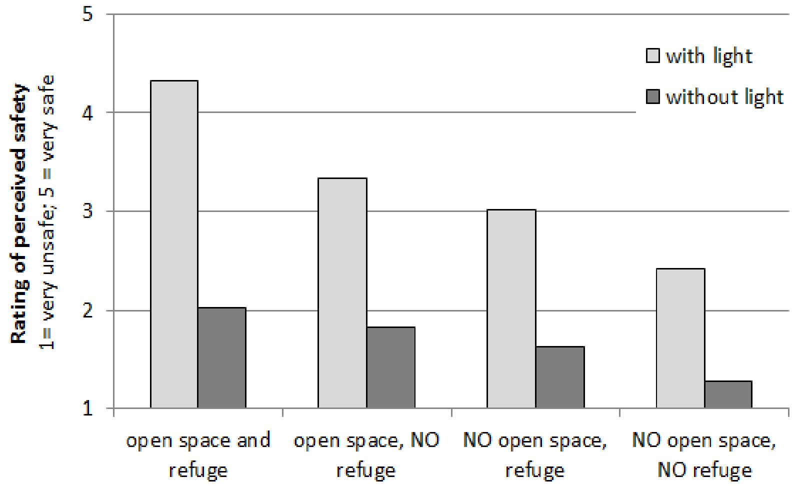

Figure 2 Mean ratings of perceived safety of images of outdoor scenes as reported by Loewen et al [33].

4.2 Does an increase in illuminance increase reassurance?

The findings from two studies suggest that an increase in illuminance will improve reassurance.

Boyce et al [35] carried out field surveys of 24 car parks in urban and suburban areas in New York and Albany in the US to investigate how the amount and SPD of light effected the perception of safety at night. Test participants were transported to the sites in four vehicles and these visited the sites in different orders at both daytime and night-time. The car parks had mean horizontal illuminances of up to 50 lx. At each site they were asked to walk around and then describe lighting using questionnaires comprising a series of semantic differential ratings scales and open questions. One question sought ratings of perceived safety when walking alone. Two interesting findings were reported. Firstly, walking at daytime was perceived to be safer than walking at night-time: lighting at night was able to bring the perception of safety close to that of daytime in a small number of sites but did not exceed it. Secondly, as illuminances increased, the difference in ratings of perceived safety for daytime and night-time tended to decrease (Figure 3). The relationship between illuminance and perceived safety appears to be non-linear. At low illuminances (0-10 lx) a small increases in illuminance produced a large increase in perceived safety; at high illuminances (≥50 lx) increases in illuminance have negligible effect on perceived safety; and in the intermediate range (10-50 lx) the increase in perceived safety with increases in illuminance follows the law of diminishing returns.

A study carried out in Japan installed lighting that was normally dimmed to 30% output but would increase to 100% when a person approached the area [30]. This increase in light output was chosen according to a pilot study to find an increase that would be noticeable but not uncomfortable. A survey was distributed to residents (n=44) of whom 82% reported that the higher illuminances gave them more sense of security. This study suggests that higher illuminance promotes higher perceived safety, but the absence in the report of the survey instrument and details of the installation, such as average illuminance, mean that little confidence can be placed in this work alone.

In both of these studies the test participants were able to observe changes in illuminance; in the Boyce et al study the repeated measures design means that all test participants saw all lighting conditions, and in the Matsui study the residents reported that they had seen the automatic change in illuminance. Therefore the potential to improve reassurance by means of higher illuminance must be considered with caution because it may be that the improvement to reassurance is obtained only when higher illuminance is noted by respondents: this could be addressed in further research by making less apparent changes in illuminance, for example by using independent samples to make judgements of lighting of different illuminance.

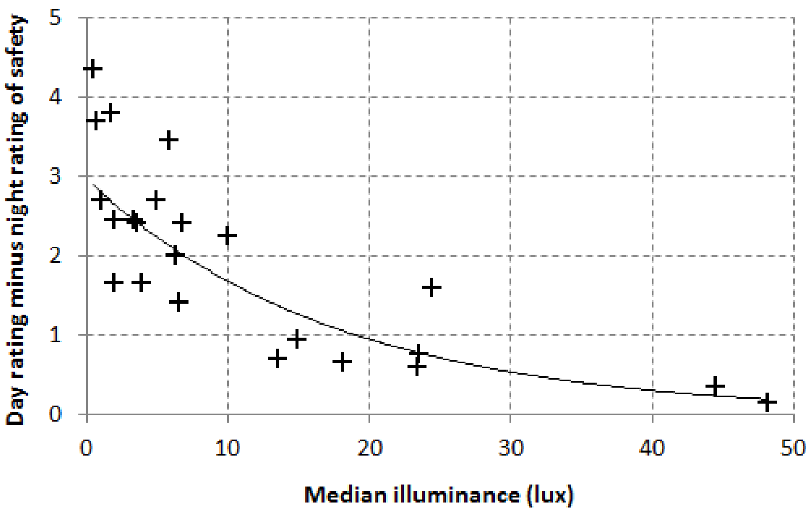

Figure 3 Difference between daytime and night-time ratings of perceived safety of car parks plotted against median illuminance, after Boyce et al [35].

5 Pilot Study

Further work is being carried out with two aims: firstly to confirm whether road lighting contributes to an improvement in reassurance, and, if so, then secondly to investigate how variations in the amount and spectrum of light affect reassurance.

In a pilot study, test participants were asked to take photographs of roads where they would, or would not, be happy to walk alone at night-time: these photographs were then used as discussion aids during a follow-up interview. This approach is similar to that used by Wang and Taylor [19] except that they used this procedure only to identify a target location and then used a different sample of test participants to make judgements of reassurance; this was adopted to avoid priming test participants with the assumption that lighting would influence reassurance. Figure 4 shows two of the photographs received.

Figure 4 Sample of images received from the pilot study test participants, presenting areas considered to be safe (left) and not safe (right) in which to walk alone at night-time.

The interviews (lead by author JU) followed three stages. Firstly, without any visual cues, they were asked to describe in general terms what made them happy to walk down one street and not another – this follows the first method (study 1) reported by Loewen et al. [33]. In the second stage, the photographs provided by the test participants were used as references and they were asked to describe location specific reasons for their choices. This involves evaluation of real roads familiar to the test participants rather than the images used by Loewen et al.

In the final stage, participants were presented with four photographs of outdoor scenes at night-time, these being provided by the interviewer, and asked to state, with reasons, whether they would be happy to walk in the areas depicted on the photographs. This follows the second method (study 2) reported by Loewen et al These photographs are shown in Figure 5 and they were presented separately in a random order.

Farrall et al [28] asked whether if we let test participants speak in their own language would they use the term fear?

Figure 5 Photographs of night-time scenes presented by the interviewer. The same set of photographs were shown to all test participants. These were observed separately in random order and test participants were asked if they would, or would not, walk down the street. Subsequent comparison of the results for the horizontally adjacent photos demonstrates the influence, if any, of lighting on reassurance.

Therefore these interviews were conducted in a manner that attempted to avoid priming test participants with the notion of fear. Similarly the use of photographs provided by test participants would also allow for environmental impacts beyond lighting to gauge the relative impact of lighting.

The pilot study was carried out during summer 2011 and used 9 test participants. The interview transcripts have been analysed using two methods. Firstly, following Loewen et al [33] a frequency count was made for the usage of key terms. This was done by allocating the expressions used by test participants to one of four categories: light, spatial features, familiarity and presence of others. For example, the phrase *"big streets, they are wide"* was included in the Spatial Features category. Table 3 shows the results of the pilot study. It can be seen that 28% of the reasons given for being happy or not happy to walk on a particular street were in the category spatial features; 19% of reasons given indicated the presence or absence of light and 9% of reasons were related to familiarity. 44% of reasons were related to the presence of others, which included judgements about the 'type' of area based on direct and indirect experience (personal and media), likely occupancy and signs of incivilities due to actions of others.

The interview transcripts were also analysed using Hierarchical Cluster Analysis (HCA) following the investigation of gloom carried out by Zhang and Julian [36]. HCA examines word frequency counts and was performed on all words used by interview participants. Interpretation is made by association of words that have been used a similar number of times. Two sets of words that were linked on the basis of frequency were *area, happy, walk, safe, see* and *day, light*. The association of these words on the basis of frequency suggests they carry a similar weighting when an individual chooses whether to walk down a particular street or not.

The pilot study was carried out to gain experience of methodology in preparation for the principal study which will be carried out during winter 2011/2012. This will target 45 test participants drawn from three groups: (i) people unfamiliar with the area (this will be overseas students who have newly arrived in the UK [19]), (ii) elderly people (aged 65+), and (iii) people who are young (under 45) and familiar with the area. This grouping follows previous work [18] and each will comprise both males and females. The principal test will follow the same approach as the pilot study but will be modified in a number of ways, for example, the interviewer's photographs used in stage 3 will be assessed also using category rating scales and a discrimination procedure.

Table 3 Frequency of reasons described in interviews.

	Positive attribute (reassured)	**Negative attribute (not reassured)**	**Total**
Spatial features	16	37	53
Light features	21	16	37
Presence of others	35	49	84
Familiarity	17	1	18

6 Conclusion

Previous studies of road lighting and reassurance (i.e. perceived safety or fear of crime) in residential areas have presented mixed findings as to the effect of lighting. In some cases this may be due to weaknesses in the experimental design and incomplete reporting. Furthermore, although the installation of lighting in a previously unlit street, or the replacement of lighting in a previously lit street, has been found to improve reassurance in some situations, what is not yet known is the weight of this improvement within the wider range of environmental and societal influences on reassurance. This article has presented the findings of the first stage in a project which intends to analyse the extent to which lighting is a behaviour influencing factor in the urban environment. Not emphasising fear in the procedure may lead to a more realistic understanding of the effect of lighting on reassurance.

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Quotes from PhD students who attended the VELUX daylight Symposium and the academic forum in May 2011

… an extremely useful and very inspiring and thought provoking occasion.

Peter Sattrup, School of Architecture, Royal Danish Academy of Fine Arts

.. the most formative and funny experience ever! I think that the opportunity to discuss our PhD research project with such leading experts is really uncommon and a PhD student can't miss it! Moreover sharing experience and knowledge with other PhD students from other countries has been an exceptional chance, I had a lot of good suggestions and advice …

Silvia Cammarano, Department of Energetics, Politecnico di Torino, Italy

… a fantastic initiative, and definitely something I'll recommend other PhD students to attend. It is always positive with feedback from others than your supervisors.

Anne Iversen, DTU BYG, Denmark

It was great to be able to discuss ideas openly with the experts in the field and other PhD students and get feed back.

Mandana Sarey Khanie, EPFL, Switzerland

Some of the PhD students who attended the Academic Forum in Lausanne, May 2011, with three of the expert reviewers; Steve Fotios, Jennifer Veitch and Jens Christoffersen.

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POWER QUALITY IN THE OFFICE BUILDINGS' ELECTRICAL INSTALLATIONS

Horaţiu - Călin ALBU, Technical University of Cluj-Napoca

The Thesis Advisor: dr. Florin POP, professor, Technical University of Cluj-Napoca.
The Ph.D. thesis was presented in a public debate at the Technical University of Cluj-Napoca, Romania, on 9 September 2011. His author obtained the scientific grade of Ph.D. in Civil Engineering.

The arguments that led to the development of the thesis are: the continuous and rapid increase of the number of nonlinear receivers connected to the office buildings electrical installations, the increasing concerns regarding the energy efficiency and the sensitivity of modern equipment to the decrease of the power quality.

Different topics are analyzed throughout the thesis: measurements of the characteristics of the nonlinear receivers used in office buildings, measurements of the electrical characteristics at the point of common coupling of the office buildings electrical installations, studies and analysis of the effects of connecting nonlinear receivers at the office buildings electrical installations (using DIALux programs, OrCAD PSpice and MATLAB).

The thesis is developed in six chapters, references and appendixes.

Chapter 1 Power quality at the user analyzes the power quality problem by presenting the definitions of the power quality concept, the standard recommendations and the main used power quality indicators. The operation of all the user electric receivers at their nominal parameters is conditioned by the power quality of the network, deviations outside the standard limits leading to errors or equipment damage. At the same time, the development of new electronic equipments and technologies and their proliferation generate disturbances – the increase of harmonic distortion and the occurrence of voltage unbalance. Taking into account the power quality aspects from the supplier and user perspectives, the power quality indicators have been synthesized in two categories: primary indicators, that relate to the quality of the product "electric energy" and the electric power supply service, and secondary indicators, that relate in particular to the disturbances caused by nonlinear receivers. The implementation of these indicators allows the delimitation between the attributions of the supplier and the users for maintaining the disturbances in the established limits. The indicators are classified in: frequency deviations, slow variations of the supplied voltage, voltage surges, voltage dips, short and long term power supply interruptions, voltage fluctuations, harmonic distortion, and voltage unbalance. The office buildings are also analyzed, as electric energy users. The office buildings nonlinear receivers are classified in two categories: light sources and electronic office equipments. For each category the ratio of the receivers found in the office buildings, the receiver operations aspects and the available methods of reducing the electricity demand are described. This last aspect is particularly important due to the increased attention provided to the economical issues and environmental impacts, methods and initiatives to reduce the electric energy demand.

Chapter 2 Operating conditions in the user power systems presents aspects regarding the conducted electromagnetic disturbances that exist in the user power supply system (harmonic distortion and voltage unbalance): methods of analysis, effects and different mitigation solutions. The importance of the harmonic distortion problem is justified based on the effects caused in the supplier and user power networks. Because the majority of the nonlinear receivers that exist in office buildings is connected to single - phase power network, the voltage unbalance phenomenon is also analysed.

The disturbances determined by the electronic office equipments and the light sources, and the effects of their simultaneous use in the low voltage electric power distribution networks are described. The presented data represents an overview of different literature research studies. The methods of modelling the low voltage electric power distribution networks in real time and the current and voltage harmonic propagation in the power network are analyzed. These aspects allow the estimation of the harmonic distortion levels at different points in the power network and caused by the connection of various nonlinear receivers.

Chapter 3 Experimental analysis of equipments used in office buildings analyzes several topics: the characteristics measurements of the nonlinear receivers predominantly used in the office buildings, the analysis of two case studies and the measurements of the electrical characteristics at the point of common coupling for two office building electrical installations.

The measurements of the electrical and luminous characteristics of the light sources used in office buildings are presented. The luminous efficacy under dimming is analyzed also for several light sources (equipped with tubular fluorescent lamps, halogen lamp and LEDs). The results show that LED light sources have a greater luminous efficacy than other types of light sources equipped with fluorescent lamps.

There are presented the electrical characteristics measurements for the electronic office equipments used in office buildings. The measurements have captured the nonlinear electrical parameters of the electronic office equipments during various operating modes. The voltage and the electrical current variations during switching from one operation to another were also recorded. An attenuation of the current harmonic distortion was observed for the computer systems, compared to individual devices, due to the phase compensation between the current harmonics generated by the computer system's equipments.

A case study is presented that analyzes the harmonic distortion impact of dimming the light sources. Four cases are considered, corresponding to the use of four different light sources in an office room. For each case, the light sources are positioned in a 60 m^2 office room, in parallel rows with the windows. It was assumed that the office room is located in Cluj-Napoca, and the simulations were performed for January 21st, 2010, at 17:00. The case study shows that the current harmonic distortion level for all the light sources is attenuated due to phase compensation between the current harmonics generated by each of the light sources.

The supply voltage harmonic distortion due to the use of light sources was estimated, based on the previous measurements and using different simulation programs. Four cases were analyzed, corresponding to four different types of light sources positioned in an office building. For the first case, six scenarios are studied. The parallel resonance phenomenon was highlighted when connecting the capacitors used for the correction of the cosine of the phase angle between the voltage and the electrical current, at the fundamental frequency. The effects of connecting anti-resonance coils to the network were also studied. For all the analyzed cases, the harmonic voltage distortion is below the recommended limits by the EN 61000-2-2 standard. The impact of the current harmonics generated by the light sources on the neutral conductor is also analyzed. The neutral conductor section recommended by the NP 07/2002 norm is sufficient even in the presence of current harmonics, of rank three or multiple of three, generated by the light sources.

Measurements performed at the power distribution network of two office buildings in Cluj-Napoca are presented. The power quality is analyzed from the supplier and the user perspectives. The use of light sources and electronic office equipments cause increase of the harmonic distortion, decrease in the power factor and increase in the current harmonic distortion of the neutral conductor. Their predominant use in office buildings can lead to serious power quality problems if no measures are taken.

Chapter 4 Analysis of the harmonic distortion in office buildings due to light sources and electronic office equipments assesses the harmonic distortion of the office building power distribution networks. Different configurations of the power distribution networks are analyzed, starting from the lighting and power circuits. The nonlinear receivers used in the simulations are previously analyzed in Chapter 3. For the lighting circuit, two cases are studied, corresponding to the use of two light sources: 36 W T8 fluorescent lamp and 18 W CFL. The attenuation effect due to the interactions between the changes of current harmonics injected by the non-linear loads and the resulting variations of the load voltage is analyzed, using the MATLAB program.

The power networks of three office buildings are analyzed. The theoretical study aims at evaluating the harmonic voltage distortion at various points of the distribution networks due to the presence of nonlinear receivers, the harmonic distortion effect on the current effective values and the possibility that these values exceed the phase conductor calculated values. The receivers used are light sources and computer systems. The power networks are designed in compliance with the recommendations of NP 07/2002 norm. The study shows that the harmonic voltage distortion is within the standard limits.

The effects of reducing the harmonic distortion by implementing passive harmonic filters were analyzed also. Using OrCAD PSpice program, the power network for an office building was simulated. The passive harmonic filters were positioned at different levels of the power network. It is showed that the greatest mitigation effect takes place when the passive filters are located closer to the nonlinear receivers.

A virtual tool, entitled RNHARM, is presented. The program allows the estimation, at various points, of the voltage harmonic distortion level for a fixed radial power network. The nonlinear receivers used in the network are light sources and electronic office equipments. Their electric characteristics were previously measured.

Chapter 5 Sensitivity of equipments to the supply voltage disturbances presents different aspects regarding the effects of the low power quality on different nonlinear receivers used in office buildings. The analyzed power quality disturbances are: slow variations of the supplied voltage, voltage surges, voltage dips, short and long term power supply interruptions, voltage fluctuations. The considered equipments are the light sources and the electronic office equipments. In the case of electronic office equipments the sensitivity curves at voltage dips and short term power supply interruptions are emphasized.

Chapter 6 Conclusions and contributions presents the final conclusions and the contributions brought by this thesis. There are proposed, also, possible directions for further research on the addressed topics.

The main personal contributions are:

- Measurements of the characteristics of various light sources and electronic office equipments predominantly used in office buildings;
- Analysis of the power quality effects if the light sources are dimmed;
- Analysis of the voltage harmonic distortion due to different types of light sources;
- Analysis of the power quality effects of connecting nonlinear receivers in the office building power network;
- Development of the RNHARM virtual instrument.

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LIGHTING IN THE NEW WORLD

Cristian ŞUVĂGĂU
BC Hydro, Vancouver

Municipal Solid-State Street Lighting Consortium

"*Veni, Vidi, Vici*" (I came, I saw, I conquered) were Roman's emperor Julius Caesar after a short and effective war with Pharnaces II of Pontus in the city of Zile (Turkey) some 2,000 years ago. Such is the powerful image of simple words that variations of this sentence are often quoted in music, art, literature, and entertainment. When it comes to the lighting industry it could with ease be the motto or a tagline for Solid State Lighting (SSL), especially the Lighting Emitting Diodes (LEDs). Since Edison introduced his electric light bulb, it has not been in the lighting market such a breakthrough and fast move to take over conventional sources as LEDs. Already over-passing lumen efficiencies of halogen and compact florescent lamps, LEDs edge now entry-level fluorescents and are poised to rise soon above present High Intensity Discharge (HID) lamps.

Street lighting, the land of HID applications - over 90% of street lighting today utilizes HID lighting with High Pressure Sodium (HPS) being the most common - is facing the LED revolution as well. The new-age buzz is there and from manufacturers, utilities to politicians everybody wants LEDs to replace in a near future as much as possible of the current street and roadway stock in North America. And this is not an easy target since North America numbers over 70 millions streetlights and a similar count of parking and area lights. Considering that LEDs can bring to the roadway market an average of 30% energy savings, is easy to see the staggering energy conservation potential of streetlights alone:

- over 20,000 GWh/yr saved, the equivalent of 30 million barrels of oil;
- over 12 million metric tons of CO_2-equivalent saved;
- saved equivalent of electricity for 1.4 million homes.

On top of this, energy savings from adaptive lighting controls can double these numbers. Now, one can see why roadway lighting is quoted the biggest market for LED sales in North America.

Technology roadblocks

From a technical standpoint, LED street lighting systems offer many benefits over existing street lighting technology. At the same time, the uncertainty and risk associated with this new technology prevent municipalities from leaping into the market and pursuing an LED based solution.

This article does not propose to present the benefits and disadvantages/issues of the

LED street lighting systems (compared with conventional HID ones), but to explore the particularities of the North American market roadblocks and solutions.

Tariffs - Whether streetlights are owned or leased from the utilities, North American municipalities are charged (by power utilities) under an unmetered/flat demand tariff, basically a certain dollar amount per month based on the luminaires' wattage and maintenance/asset depreciation costs. When municipalities own their own lights, the adoption of LEDs is quite doable, a matter of balancing the capital and operation costs with billing saving offsets. When municipalities lease the streetlights from utilities, things become more complicated as more luminaire standards need to be carried (for utilities serving more cities) and creative tariffs need to offset the very high initial cost and long depreciation cycles (20-40 years) of cheap HID technologies. One solution could be to charge municipalities one-time participation fees per LED luminaire and be billed a lower or same tariff as before.

Also, if adaptive street lighting is installed the utility has no means to adjust their bills if the city's should dim their lights. One solution is to allow the software metering of the control systems as revenue metering. Currently, the cities of Oakland and San Jose (California) and their utility, Pacific Gas and Electricity, are exploring this solution through a testing pilot.

Standards - In North America, the Illuminating Engineering Society of North America (IESNA) is considered the authority for defining the lighting conditions necessary for adequate light levels. In particular, if new LED street lights are to replace incumbent existing street lighting technology, the LED street lights must provide sufficient light levels, as defined by IESNA. Meeting these light levels takes precedence over any energy savings. This non-profit society has developed a number of documents relevant to today's LED street lighting guidelines:

- **IESNA RP-8-00** *Standard Practice for Roadway Lighting*
  - the upcoming IESNA RP-8-2011 (like the new roadway lighting standards CIE-115) will incorporate mesopic vision effects into practical lighting design techniques of the future.
- **IES LM-79** *Approved Method: Electrical and Photometric Measurements of Solid-State Lighting Products*
  - applies to LED-based products incorporating control electronics and heat sinks;
  - requires complete luminaire testing.
- **IES LM-80** *Approved Method: Measuring Lumen Maintenance of LED Lighting Sources*
  - measures lumen depreciation of LED light sources, arrays and modules;
  - does not cover full luminaires;
  - does not define or provide methods for estimation of life.
- **IES LM-21** *Projecting Long Term Lumen Maintenance of LED Light Sources*
  - TM-21 supplements IES LM-80 raw test data to provide LED lifetime projections that are consistent and understandable;
  - does not determine traditional life or "time to failure" of LED systems;

- does project the lumen maintenance of an LED source (package/array/module which can then be used to project the expected lumen output of the source as part of a system (fixture).

Performance standards- Testing LED products is not enough to protect customers from bad products and to preserve the visual quality of their projects, hence few performance standards have emerged (sometime in the absence of the updated testing standards) and are constantly upgraded to keep up with the fast emergence of LED technology:

- **Energy Star (EPA)**
  - runs thorough tests on commercially available SSL products since 2008;
  - products that pass the examination will be rewarded with an ENERGY STAR-approved label;
  - focuses on LED replacements for general service lamps, reflector lamps, decorative lamps and spot-lights.
- **DesignLights Consortium**
  - conducts regular tests on SSL products- Qualified Products List (QPL);
  - DLC works closely with ENERGY STAR, and their primary role is to cover products which fall in a category where the corresponding standards have yet to be completed by ENERGY STAR (i.e. streetlights);
  - DLC focuses on commercial luminaires from bollards to streetlights and high-bays.
  -
- **Lighting Facts (DOE)**
  - labelling program for SSL products providing consumers with a quick glance of how well each product compares to LM-79 criteria;
  - voluntarily (signed pledge) and free, the Lighting Facts product list is a web-based, searchable tool that summarizes verified data, destined to equipping buyers;
  - over 3,000 products to date.

The Municipal Solid-State Street Lighting Consortium

Adoption in North America lags behind that of Europe and parts of Asia. In response to this, unique alliances have been forged. The U.S. Department of Energy (DOE) has partnered with several notable organizations. Part of their goal was to explore the potential for savings and to create awareness within the industry as it relates to LED street lighting products:

- in 2005, the first to commit was the Next Generation Lighting Industry Alliance;
- in 2006, the Illuminating Engineering Society of North America (IESNA) also joined the force. As a major guiding force for lighting standards in North America, the IESNA is an essential stakeholder when it comes to adapting new lighting technologies;
- in 2008, the International Association of Lighting Designers (IALD) joined as well. Since then, the groups have organized a number of activities – hosting seminars, demonstrations, competitions, and much more.

- in 2009 the DOE formed the Municipal Solid-State Street Lighting Consortium (http://www1.eere.energy.gov/buildings /ssl/consortium.html)

The Municipal Solid-State Street Lighting Consortium (Consortium) is sponsored by the U.S. Department of Energy. It is intended to be an educational resource on Solid-State street lighting and associated technology for those involved in lighting streets and other outdoor public areas. It is a voluntary group of representatives from municipalities, power providers, building owners, energy efficiency organizations and government agencies. Manufacturers and sales representatives are excluded from membership, however, the may be invited to contribute to workshops and development of Consortium documents and programs.

The Consortium was also formed to minimize the duplication of effort and to also provide coordination among projects to help ensure consistency in evaluation methodology and perform independence testing to develop regional and North American databases. The Consortium is putting on a series of regional workshops to educate attendees about solid-state street lighting, as well as to provide forums to address local and regional issues and to share knowledge and experience and to help members to make intelligent purchasing decisions. The Consortium currently has nearly 400 members in 48 US states, five Canadian provinces, and four other countries.

Working hard, the members of the Consortium developed and finalized many of the proposed support materials within only one year:

- Model Specification for LED Street/ Roadway Luminaires- finalized;
- Model Specification for Street/Roadway Lighting Controls – final draft;
- Cost-Benefit Analysis Financial Tool;
- Guidance Document for LED Street/ Roadway Lighting.

Model Specifications

Model Specification for LED Street and Roadway Luminaires

(http://www1.eere.energy.gov/buildings/ssl/ specification.html)

It was published in October 2011 and is available with two different user-selectable options to accommodate the different preferences commonly found between municipalities and utilities:

- The System Specification is designed to maximize application efficiency, and characterizes luminaire performance by incorporating site characteristics such as mounting height, pole spacing, and number of lanes. Being an application-dependent photometric evaluation, it expresses Lux values rather than Lumens and cannot result in a single qualified products list.
- The Material Specification emphasizes luminaire efficiency, which characterizes luminaire performance without consideration of site characteristics.

The model specification (template) is split in five appendices:

- Appendix A – *Criteria by Luminaire Type* is contained in separate files (application - dependent or independent);
- Appendix B – *Lumen Maintenance* – it offers two compliance paths at component or luminaire level;

- Appendix C – *Product Family Testing* - recognizes that testing of every possible configuration would be cost prohibitive and unnecessary and allows interpolation between tested products;
- Appendix D – *Electrical Immunity* – criteria for characterization of Surges and testing for Equipment Connected to Low-Voltage in Low-Voltage (1000 V and less) AC Power Circuits;
- Appendix E – *Product Submittal Form* – helps with specification format clarity.

Municipalities, utilities and transportation authorities and will be able to use the new Performance Specification to put together effective bidding documentation for street lighting products. It will include instructions to help them make minor adjustments to fit their local design criteria. LED lighting is not a "cut-and-paste" technology that can simply be substituted for existing lighting without taking its own special characteristics into account.

Model Specification for Street/Roadway Lighting Controls (final draft completed) is scheduled for publication in early 2012.

The model specification document is organized in 3 parts (general, product performance and requirements, execution) and is addressing the following main requirements:

- Remote Monitoring
  - cost effective monitoring of streetlight operations;
  - streamline maintenance repairs, replacements;
  - more precise asset database.
- Adaptive Control & Metering
  - meter the streetlight energy consumption;
  - ability to modulate lighting levels via adaptable program by adjacent land use, time/activity levels, in relation to other lighting sources in the area and/or in response to intermittent events;
  - increase energy savings and extend life of SSLs.

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BOOK REVIEW
Cristina PANĂ - ARTIFICAL LIGHTING - THEORY AND DESIGN ASPECTS

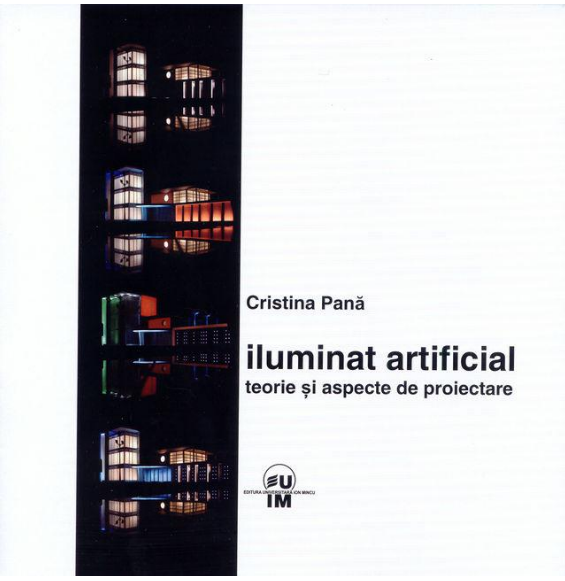
Dorin BEU, Technical University of Cluj-Napoca, Romania

This is our first book review and we are happy to present the first lighting book for architects, written by an architect. The author, Cristina PANĂ is currently teaching at Bucharest Ion Mincu Architecture& Urbanism University, finished in 2009 a Ph.D. in architectural lighting and received in 2011 the Romanian National Lighting Committee Prize for the Bucharest University architecture lighting contest.

For many years it has been argued that in order to improve the lighting environment, architects and designers should be more involved, but based on some basic knowledge on this topic. Unfortunately, till now in Romania there was no lighting course at architecture or design universities and it was only part of building engineering or object design course. That is why this book is so important, because it has an architectural and design approach, with many photos as examples with all new concepts that are interesting for an architect.

The book has three parts, besides the classical introduction and conclusion. The first part is about theory in artificial lighting, which has the “performance” of being without any formula, based on visual perception with a nice history of design luminaires (I am personally missing Ingo Maurer in this presentation). It also includes the presentation of sustainable lighting concept and the newest EU legislation. Second part is about interior artificial lighting design, perceived in terms of shape, space, limits, architecture scale, texture, color, function, flexibility but also as magic. There is also an important section on the way lighting systems are integrated in interior spaces with accent on materials and with examples from major architects. At the end there is a case study about Hotel Puerta America, a much beloved example for architects. Third part is about exterior architectural lighting and has a start point on an author visit to Lyon and OLAC in 2007. To be in Lyon on December 8th for the Light Festival it is a must for anyone who enjoy light and it is really impressive. Coming back to the third part, it is important that the lighting master-plan is extensive presented with Lyon as a case study. The importance of an exterior showroom like OLAC where specialist can play with light and have a better understanding of LED is also underlined. Another interesting part is the case study of the main Bucharest Boulevard ”Calea Victoriei” where gas lamps where already installed in 1861, but actual situation is deceiving. The following sections refer to practical aspects of architectural lighting based on Derek Philips classification and a presentation of multimedia facades.

As a conclusion, it can be said that it is a book interesting both for architects and engineers: for architects because they have an overview of interior and exterior lighting, with all the new trends, and for engineers because they can understand that architect perceive light in terms of shape, texture, mood with a special interest for luminaires as design objects.



Original title (Romanian):
Cristina PANĂ
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Editura Universitară Ion Mincu
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Information for Authors (revised 1st December 2011)

The journal **INGINERIA ILUMINATULUI - Journal of Lighting Engineering** has a scientific presentation and content, targeted to the continuing education in the lighting field, without commercial advertisings inside of its pages. The objectives of the journal consist of the presentation of the results of the lighting research activity, the dissemination of the lighting knowledge, the education of the interested people working in public administration, constructions, designers, dealers, engineers, students and others.

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