CAMBRIDGE
LIGHTING STUDY REPORT

April 2010

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Report prepared by PB Americas, Inc and the Cambridge Lighting Design Committee

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1. INTRODUCTION

In 2005, the City of Cambridge purchased the street lights on Cambridge streets from NStar, the electrical utility. The City also owns the lights in City parks and parking lots. In total, the City currently owns and maintains approximately 7,800 free standing lights, over 3,500 of which are on wood utility poles.

Since purchasing the street lights from NStar, the City has begun to replace these wood utility poles with metal poles. Infrastructure projects, such as roadway reconstruction and park redevelopment, often incorporate lighting upgrades in the area. It is anticipated that this process will continue and, over the years, more of the utilitarian lighting along City streets may be upgraded with other types of street lighting.

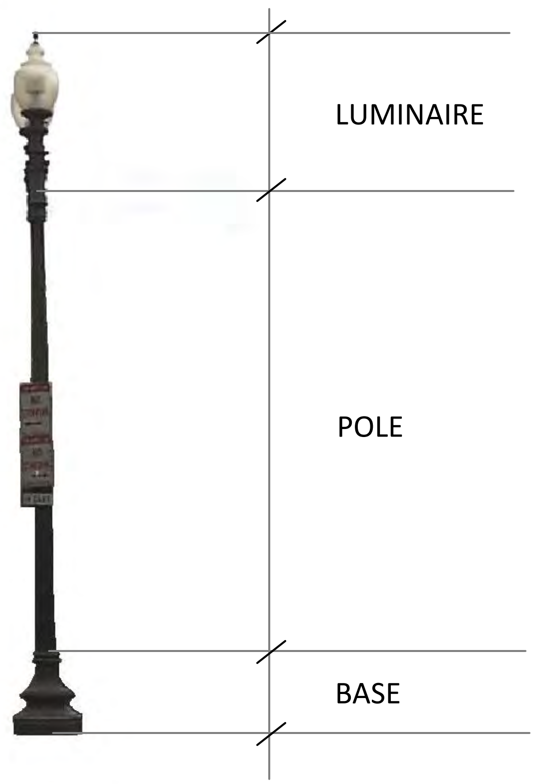
The 2008, the City embarked upon a Lighting Study to review the inventory of current public lighting in the City, to develop standards for appropriate light levels for Cambridge streets, to evaluate energy-efficient light sources and luminaires[1] for potential use, and to recommend a set of luminaire types to be used for street and park lighting. To this end, the City hired lighting consultants from PB Americas, Inc and formed a Lighting Design Committee – comprising staff from a variety of departments including the Electrical Department, Historical Commission, Department of Public Works, and Community Development Department – to guide the work of the consultants. This document is a report of the work and recommendations of the Committee and lighting consultants from PB Americas.

A companion to this study report are lighting specifications – available at the Electrical Department – that provide detailed information on the selected set of luminaires, poles, bases, control boxes, conduit and wiring systems.

The recommendations of the Lighting Study are intended to guide all future public and private projects that impact public lighting on City streets and parks. The recommendations address both pedestrian and roadway scale lights and aim to accommodate residential neighborhoods, commercial areas, and historic districts, along with parks, plazas and parking lots. The study recommends specific luminaires for use in certain key areas of the city. It is expected that implementation of these recommendations will occur over time and most likely in conjunction with other planned infrastructure projects.

[1] Luminaire is the technical term for "fixture", and refers to a lighting unit consisting of a lamp (bulb), lamp holder, and related components which may include lens, cover, and armature depending on the luminaire design. In the case of street lights, a luminaire is typically mounted on a pole and base.

Cost and maintenance considerations informed the thinking of the Lighting Committee and the consultants throughout the process, particularly in the selection of luminaires. Considerations included up-front investment as well as long-term maintenance and replacement cost. Additional considerations included urban design and historical context, energy efficiency, and quality of life issues such as minimizing light trespass onto residential properties and into the night sky. It is important to note that the various considerations are interrelated – often with a positive synergy such as between urban design and historical character or long term cost and ease of maintenance – but occasionally goals do compete, as with the higher cost of bulbs and luminaires involved in transition to new, emergent, energy efficient technology.



Components of a Typical Street Light

2. LUMINAIRE SELECTION

The City currently has a large variety of street lights installed over the years, which poses a challenge in terms of maintaining a stock of replacement parts and maintenance know-how. This suggests a need to standardize installations of future lighting including luminaires, poles, bases, control boxes, conduit and wiring systems. It is assumed that several different types of luminaires and poles will be required to accommodate the variety of needs and expectations and different settings, but the goal is to select and approve a more limited set that will allow ease of maintenance and storage of replacement parts, as well as minimize cost and response time required to keep the lighting system functioning.

PRESENT CONTEXT
Most parts of the City have a mix of street light types. The following list shows the predominant luminaire and lamp types in a district/street and is accurate as of 2009. An up to date, pole by pole inventory is kept by the Electrical Department.

Predominant Street Light & Lamp Types

Area/Street	Street Light/Lamp	
	Roadway scale	***Pedestrian scale***
Alewife Brook Parkway	1907 Teardrop Replica/ Metal halide	n/a
Binney Street – east of Third Street	1907 Teardrop Replica/ High pressure sodium	n/a
Binney Street – west of Third Street	Cobrahead/ High pressure sodium	n/a
Cambridge Parkway	1907 Teardrop Replica/ Metal halide	n/a
Cambridge Street – Inman Square to Lechmere	1907 Teardrop Replica/ Metal halide	Acorn post top/Metal halide
Cambridgepark Drive	Shoebox/ High pressure sodium	n/a
Church Street	Cobrahead/ High pressure sodium	Se'lux Saturn single post top/ Metal halide
First Street	1907 Teardrop Replica/ Metal halide	n/a
Fresh Pond Parkway	1907 Teardrop Replica/ Metal halide	n/a
Gerry's Landing Road	1907 Teardrop Replica/ Metal halide	n/a
Massachusetts Avenue – east of Main Street	1907 Teardrop Replica/ Metal halide	n/a

Area/Street	Street Light/Lamp	
	Roadway scale	***Pedestrian scale***
Massachusetts Avenue – west of Main Street except Central, Harvard, and Porter Squares	Cobrahead/ High pressure sodium	n/a
Memorial Drive	1907 Teardrop Replica/ Metal halide	n/a
Vassar Street	Contemorary/ Metal halide	n/a
Other Streets	Cobrahead/ Mixed, primarily High pressure sodium	n/a
Cambridge Research Park/Kendall Square	1907 Teardrop Replica	n/a
Central Square	High Bay/ Metal halide	Se'lux Saturn single post top/ Metal halide
Kendall Square	Shoebox/ Metal halide	Shoebox/ Incandescent
Harvard Square	1907 Teardrop Replica/ Metal halide	Acorn post top/Mercury vapor
North Point	1907 Teardrop Replica/ Metal halide	n/a
University Park	1907 Teardrop Replica/ High pressure sodium	n/a
City Parks	n/a	Bishops crook – Single or Twin/ Metal halide

The cobrahead street lights are the predominant lights on Cambridge streets. There has long been an interest in alternatives to the utilitarian cobrahead, either in reaction to the appearance of the luminaire itself or to distinguish special areas of Cambridge. Alternatives to cobraheads can be seen in various parts of the City: Harvard Square, Central Square, University Park at MIT, Cambridge Common, Kendall Square/Cambridge Center, and along Cambridge Street.

In Kendall Square/Cambridge Center a simple rectangular cutoff type metal halide luminaire illuminates the roadways, while a more decorative and smaller pedestrian scale incandescent luminaire fills in light on the sidewalks. The design for Central Square derives from a similar strategy of combining roadway and pedestrian scale street lights, but uses equipment very different in appearance, having circular shapes and metal halide lamps. On the Common, hemispherical cutoff metal halide luminaires light the paths and the Civil War monument, singly along the paths and doubled up with floodlights at the monument.

The schemes for University Park at MIT and Cambridge Street use a street light previously seen mostly along Memorial Drive. This is the "1907" teardrop shaped luminaire mounted on a pole with a bracketed arm. The name reflects the fact that the street light assembly was designed in 1907 for use on Memorial Drive. At University Park, the 1907 assembly lights the street and sidewalks by itself with a high pressure sodium source. Along Cambridge Street it is accompanied by acorn post-top luminaires that illuminate the sidewalks, facades and pedestrians, and both types of luminaires use metal halide lamps. In and around Harvard Square the acorn luminaire, as a single or twin unit, lights roadways and sidewalks with either mercury vapor or metal halide lamps.

As parks have been renovated, the City has installed a small metal halide "shepherd's crook" type of luminaire for illumination of paths, seating, and play areas. This provides good glare control and color as well as an appropriate scale for these pedestrian areas and should continue to be used as the standard luminaire for City parks.

While the schemes described above uniquely identify their respective areas, they were selected on a case by case basis and did not arise from a plan for the City and hence do not currently relate strongly to each other or to the rest of Cambridge. The Lighting Committee studied the situation to see if there might be common themes to be drawn out of the current arrangements and if some luminaires were preferable to others.

Central Square – street and pedestrian scale lights installed during the Central Square improvements of 1997

Shoebox luminaires used in Kendall Square for both roadway and pedestrian scale lighting

Vassar Street contemporary luminaire

Cobraheads are the most common light fixture in the City

Pedestrian scale Acorn post-top fixtures – Harvard Square

'1907' fixture, designed in 1907 for use on Memorial Drive

Sheperds Crook fixture used in Cambridge parks – in single and double configuration

FUTURE CONSIDERATIONS

- Designs for luminaires and poles should be based on historic precedent as well as urban design considerations of scale and appearance.
- Selecting a consistent street light assembly for principal roadways would help emphasize a cohesive image for the City.
- Color or colors and finish should allow for ease of repainting, graffiti removal, and touch-up when needed. For this reason black is the preferred paint color for street light assemblies.
- The size and shape of bases should be considered in relation to the size and shape of the poles. Overly small bases that are installed above the finished sidewalk grade can make poles appear unstable.
- At the same time, in many locations sidewalk space is at a premium to provide universal access. Large bases with wide setbacks can have a significant impact on the sidewalks and should be avoided where they conflict with access requirements.
- Cutoff luminaires should be selected to focus light downward where it is needed and minimize the spread of light to areas where it is not desired, such as upward into the night sky or on to nearby properties, particularly residential windows and yards.

PROPOSED APPROACH

In many cases, replacing lighting is more complicated than simply selecting a different bulb for an existing luminaire. It often involves replacing part or all of an existing street light assembly and may require retrenching and laying new cable. Often, pole spacing may be affected depending on differences in available wattages and light spread of a new luminaire compared to an existing one. Given these factors, incorporating new lighting throughout the City would be a significant endeavor and cost prohibitive. This study identifies priority streets and areas that are highly visible or used by a large number of people, to be the focus of likely changes in lighting.

One can think of Cambridge as being bounded or connected by a ring consisting of Memorial Drive, Gerry's Landing Road, Fresh Pond Parkway, Alewife Brook Parkway, Massachusetts Avenue, Cambridge Street, O'Brien Highway, First Street and Land Boulevard. This assemblage has spokes in the form of main streets connecting to the City squares – Concord Avenue, Brattle Street, JFK Street, Massachusetts Avenue, and Western Avenue. These ring and spoke streets are noted on the map, "Proposed Luminaire Types".

The street-scale 1907 teardrop luminaire, in several variations, illuminates long stretches of this network. The pedestrian scale acorn post-top luminaire makes a compatible companion to the 1907 luminaire in addition to functioning well on its own. Recognizing the importance of these precedents, the Lighting Study Committee recommendation is to continue and strengthen this pattern of 1907 and acorn post-top luminaires along the ring and spoke streets.

Proposed Luminaire Types

APR.09

New streetscapes along the ring and spoke streets, which run through commercial, institutional, or large scale public areas, would have the 1907 luminaire lighting the roadways, while the shorter acorn luminaire would illuminate the sidewalks and facades, create a pedestrian scale, and provide fill light on people's faces. Existing special schemes that do not fit the pattern would be maintained but not expanded. The Squares – Harvard, Porter, Central, Kendall, and Lechmere – would, therefore, continue to have distinct identities, highlighting their special role as significant public districts in the City.

The residential neighborhood streets would continue to be lit by cobra head luminaires, on wood utility poles or aluminum poles of their own. Changing to cutoff optics, a one-piece arm design, and other refinements have made the typical cobra head luminaire and mounting assembly smaller and sleeker.

PROPOSED CAMBRIDGE STANDARD LUMINAIRES

It is proposed that as the lighting inventory is upgraded, either in conjunction with infrastructure projects or through redevelopment, the following recommendations be utilized to select appropriate luminaires. It is expected that the cobrahead will continue to be the standard luminaire on the streets of Cambridge. This proposal builds upon existing patterns in the City and proposes specific luminaires for priority areas such as the major streets as well as historic squares. Luminaires selected are highlighted on the map below and are noted below.

Area/Street	Street Light	Status
Ring and Spoke Streets (Massachusetts Ave, Cambridge Street, First Street, Cambridge Parkway, Memorial Drive, Gerry's Landing Road Western Avenue, JFK Street, Brattle Street, Concord Avenue, Fresh Pond Parkway)	***Roadway scale***: 1907 Teardrop Replica ***Pedestrian scale***: Acorn post top	Present in some sections Replace as opportunities arise through major infrastructure projects
City Squares excluding Kendall Square (Central Square, Harvard Square, Inman Square, Porter Square)	Special treatment that builds upon existing luminaires used	In place in large sections, but mixed

Area/Street	Street Light	Status
Kendall Square	***Roadway scale***: 1907 Teardrop Replica ***Pedestrian scale***: Se'lux Saturn single post top	Replacement has begun in small sections of Main Street Replace as opportunities arise through major infrastructure projects
Residential Streets	Cobrahead	In place.
All other Streets	Cobrahead	In place.
City Parks	Bishops crook – Single or Twin	In place

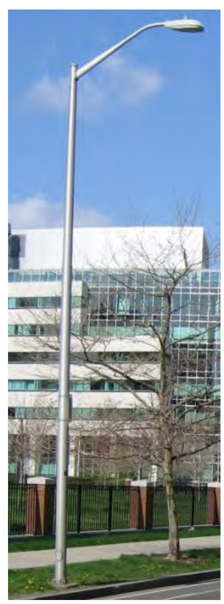
Notes:

1. While it is expected that LED-specific luminaires will be added to this list, the City would like to further evaluate new luminaires emerging in the market before identifying the preferred LED luminaire(s). A more detailed discussion is provided in the next section, *Energy Efficiency & LED*.
2. Fixture specifications that provide additional details on the selected luminaires, poles, and installation standards are available at the Cambridge Electrical Department.

1907 Teardrop Replica

Acorn Post Top

Se'lux Saturn Single Post Top



Cobrahead

Bishops Crook - Single

Bishops Crook - Twin

3. ENERGY EFFICIENCY & LED

This study has evaluated the energy efficiency of various light sources, particularly Light Emitting Diode (LED) lighting. The technology for LED street lighting and the luminaires to house them has greatly expanded in the last few years. Both new businesses and mainstream lighting manufacturers are trying to get a foothold in this growing industry.

The technology and rate of development is impressive. Current commercially available LEDs are slightly more efficient than "white" light sources currently used for outdoor lighting such as metal halide. Other newer LEDs are currently being laboratory tested. It is possible that these may emerge as the most efficient of all current light sources. At present, much of the projected cost savings from LED lamps relies on their increased controllability i.e. the ability to selectively turn off all or portions of the light. Creating the infrastructure to incorporate such controllability adds significantly to the upfront cost of the system.

It is unclear how LEDs will actually perform in terms of extended light output, useful life, and maintainability. This type of information can only be gained from actual field testing and installations. There are a number of tests currently being done across the country, including the Federal Highway Administration test of the LED lighting system installed on the St. Anthony Falls Bridge in Minnesota. However, these tests are ongoing and results will not be available for close to a year.

Based on the current state of knowledge, the PB Americas lighting group does not recommend wholesale adoption of LED at this time, but recommends that the City test LED products by using them on smaller projects to gauge overall performance in the New England context and subjective public reaction to light quality and levels. Given that the technology is evolving rapidly and laboratory results indicate that significant advancements are likely to reach the market in the next year or two, LED street lighting is likely to be a more real and feasible option in the near future.

ENERGY USE AND EFFICIENCY

Lamp efficiencies are generally expressed in lumen per watt values. These values describe the amount of light leaving a lamp (lumens) relative to the amount of power consumed to produce that light (watt). The higher the source efficiency number, the more efficient the light source (bulb) is. Typical street lighting sources are listed below (High Pressure Sodium and Metal Halide bulbs are commonly used in Cambridge):

Bulb type	Light Color	Source Efficiency (in lumens/watt)*
High Pressure Sodium (LU400/PLUS/ECO)	Yellow light	108 lms/watt
LED (Luxeon K2)	White light	80 lms/watt
Metal Halide (MP250/PS/BU)	White light	78 lms/watt
Inductively coupled (ICE150/835/2P/ECO)	White light	77 lms/watt

Note: Efficiency information accurate as of December 2009

The source efficiency values in the table above refer to the amount of light emitted by the bulb. Application efficiency is the amount of light getting to the surface to be lit. In addition to source efficiency, factors such as directionality, color, and glare also play a part in determining application efficiency, i.e. the amount of light falling on a roadway, sidewalk or pedestrian; and resultant visibility. For example, LEDs provide only slightly higher lumens per watt than metal halide. At the same time, LEDs tend to have more intrinsic brightness than other sources, are highly directional and easy to control. This means that a higher application efficiency may be achieved with LEDs. The result could then mean up to 20% more light on the surfaces with only a 2.5% difference in lamp efficiency.

In the opinion of PB Americas, LEDs are a viable source from a performance standpoint when compared to “white” light sources like metal halide and induction, and are about a year away from being at the performance level of high pressure sodium. Continuous technological advancements, may, in fact, result in LED sources surpassing these levels, given some time.

DURABILITY

Most LED manufacturers contend that LED bulbs will last 10-20 years. This projection is based on lab results and has not been verified by long-term field installations. Thus factors such as dust and minimal cleaning are not necessarily accounted for. LEDs require more precise heat management than traditional light sources, as the heat generated during their functioning is typically emitted in a confined space towards the back of the bulb rather than being radiated outward with the light as with other sources. As LEDs become smaller, faster and more powerful, more heat is generated in a confined space. If not managed properly, this can threaten to damage the LEDs’ performance. If LEDs overheat, they become dimmer, their color is muted and their lifespan is shortened. New materials and thermal management technology are being developed for LEDs. However, in real life situations, it is not certain how the light levels in LED bulbs will hold up over time. Therefore, PB Americas finds that at present there is not enough information available to judge whether an LED installation will last 2, 10, or 20 years.

EXPERIENCE FROM OTHER CITIES
There are many investigations being undertaken with LED streetlights. Anchorage, Alaska is performing tests comparing LEDs and induction technologies, New York has just launched a 12 month pilot which will test the performance of nine different LED lighting products installed on 37 street lights on FDR Drive and in Central Park, San Francisco has installed 50 "smart" LED street lights that can be managed remotely, and PB Americas is working with Maryland Transportation Authority and MassPort to test LED lights on their facilities.

Some past tests have been tried with varying success, including one in Ann Arbor, Michigan. Many claims made about LEDs are unsubstantiated at this time. Ann Arbor installed 25 LED luminaires (replacing non-cutoff 120-watt incandescent street lights with 56-watt LEDs). This provided substantially less light (about 1/3) compared to the previous system. Ann Arbor made this decision based on an interpretation of some research suggesting that visibility under a white light source is improved and less light could therefore be used. While Ann Arbor is pleased with the energy savings and plans to replace all their downtown incandescent luminaires with LED, the assumption about visibility under a white light source is not substantiated by current data and the results and opinions regarding the Ann Arbor installation among lighting engineers are divided.

ADAPTABILITY OF LED LAMPS TO CAMBRIDGE STANDARD LUMINAIRES
As noted earlier, a combination of the pedestrian scale Acorn Post luminaires with the 1907 street scale light luminaires is recommended on priority Cambridge streets based on historical and urban design considerations. Cobraheads are expected to be the predominant luminaires in the rest of the City.

LEDs are a unique source and very different from current lamp technology in terms of size, optical requirements, heat dissipation requirements, and required luminaire construction. Many manufacturers are trying to make LEDs “fit” into existing luminaire designs so adoption of the source is simpler. Unfortunately that manipulation also takes away some of the inherent benefits of LED technology. The best performing luminaires evaluated by PB Americas are those specifically designed for LEDs and as a result are distinctively different than current luminaire designs. LED lamps also require a significant quantity of individual LEDs within a single luminaire to generate the same amount of light as higher wattage roadway luminaires, making the luminaires generally large in size.

LED luminaires are currently available that could replace the head of the cobrahead luminaires. LED acorn luminaires are also available which could be used as a replacement luminaire for the City’s current acorn luminaire and fit on the same light pole. However, because of the issues mentioned above, 1907 luminaires are not of sufficient size to house the required number of LEDs for the higher wattage needed and hence would not be suitable in an LED version. If the City desires street-scale LED luminaires, alternatives to the 1907 style of luminaires would have to be considered.

CAMBRIDGE TEST INSTALLATIONS

The Consultant team does not recommend to the City a complete change to LED lighting at this time. Test installations and the possible application on a new project of limited scope are recommended at this point to evaluate the technology.

Following upon the recommendation to begin testing possible LED street lights in limited applications, PB Americas assisted the City with a month-long test of LED lights on Inman Street from May – June 2009. Four high pressure sodium (HPS) cobrahead luminaires on Inman St., a mixed use block with residential and office uses, were replaced with LED luminaires of equivalent wattage. The wattage was further reduced after two weeks to compare light levels. Light measurements taken during the test are included in Appendix 1.

The Inman Street test demonstrated that the LED luminaires met the recommended Illuminating Engineering Society of North America (IESNA) / Cambridge light level standards enumerated in the 'Lighting Standards' section of this report. A true comparison could not be achieved as the pole spacing in the HPS section was greater than in the LED section. The subjective opinions on color of the LEDs were divided, with a number of people preferring the white light of the LEDs, but noting that it felt 'colder', which was less desirable. However, the light from the LED luminaires had a greater vertical spread and the perception of visibility of oncoming pedestrians and cars was better. Most people found the glare to be greater from the LEDs. The specific luminaire tested resulted in light trespass onto a nearby residential property. While building side shields to control light were available, they were found to be expensive.

In a second, longer term pilot on a non-residential street, street level LED luminaires have been installed on Wilson Road in March 2010. An additional test installation will be the replacement of some pedestrian-scale metal halide acorn luminaires on University Road with LED acorn luminaires. The goal of these test installations is to allow the staff and consultants to evaluate the light level of LED installation compared to existing luminaires, to hear opinions on LED color (the more efficient LEDs are bluer in color than most light sources) and LED glare, and to measure short term performance. The tests will also yield a general opinion of luminaire construction and ease of maintenance.

The City is interested in continuing to evaluate new energy efficient technology and its appropriateness for the Cambridge context. While not quite at the point yet, LED is poised to be the leader in energy efficient street lighting in the coming years. Recent medical research has revealed that the eye's ability to see is affected by the color of the light. Since the spectral content of LED lighting can be better controlled than for other sources, LEDs would allow for better color modulation to optimize people's ability to see. These advantages will need to be balanced with considerations of cost and the compatibility of LED bulbs with the inventory of existing street light assemblages that may allow for retrofits. This report recommends continuing to test LED luminaires for use in Cambridge and to consider using upcoming projects such as Western Avenue redevelopment and roadway work planned for Kendall Square as opportunities for long-term LED test installations.

4. LIGHTING STANDARDS

The Committee looked at existing light levels around the City and attempted to identify appropriate light levels for various street types that ensure visibility and safety while minimizing light trespass onto private property and into the night sky. The standardized lighting levels and design guidelines for City streets, parks, and parking lots proposed here are based on industry standards and best practices for visibility and safety, tempered by an understanding of Cambridge-specific considerations such as high pedestrian volumes. This includes standards and research from the Illuminating Engineering Society (IES), the Federal Highway Administration (FHWA), the Transportation Association of Canada (TAC), the International Commission on Illumination (CIE), and the British Institute of Lighting Engineers (ILE).

Specific documents that informed the criteria include:

IES TM-11	Light Trespass: Research, Results and Recommendations
IES DG-5	Recommended Lighting for Walkways and Class 1 Bikeways
IES DG-19	Design Guide for Roundabout Lighting
IES RP-22	Standard Practice for Tunnel Lighting
IES RP-20	Lighting for Parking Facilities
IES TM-15	Luminaire Classification System for Outdoor Luminaires
IES RP-33	Lighting for Exterior Environments
IES RP-8	Standard Practice for Roadway Lighting
TAC	Guide for the Design of Roadway Lighting
ILE	Code of Practice for Variable Lighting Levels for Highways
CIE 92.1	Guide to the Lighting of Urban Areas

STREET LIGHTING

The street lighting standards for the City of Cambridge are luminance based design standards for the roadway and horizontal and vertical illuminance standards for the adjacent sidewalk area. A veiling luminance standard is also included to limit the amount of disability glare generated by the lighting system.

Roadway definitions

Major: That part of the roadway system that serves as the principal network for through-traffic flow. The routes connect areas of principal traffic generation and important roadways leaving the City. These routes are often known as "arterials," , "thoroughfares," or "preferentials."

***Collector*:** Roadways servicing traffic between major and local streets. These are streets used mainly for traffic movements within residential, commercial and industrial areas. They do not handle long, through trips. Collector streets may be used for truck or bus movements and give direct service to abutting properties.

Local: Local streets are used primarily for direct access to residential, commercial, industrial, or other abutting property. They make up a large percentage of the total street system, but carry a small proportion of vehicular traffic.

Pedestrian Area Definitions

High - Areas with significant numbers of pedestrians expected to be on the sidewalks or crossing the streets during darkness. Examples are downtown retail areas, near theaters, concert halls, stadiums, and transit terminals. (over 100 pedestrians per hour in a typical block on both sides of the street)

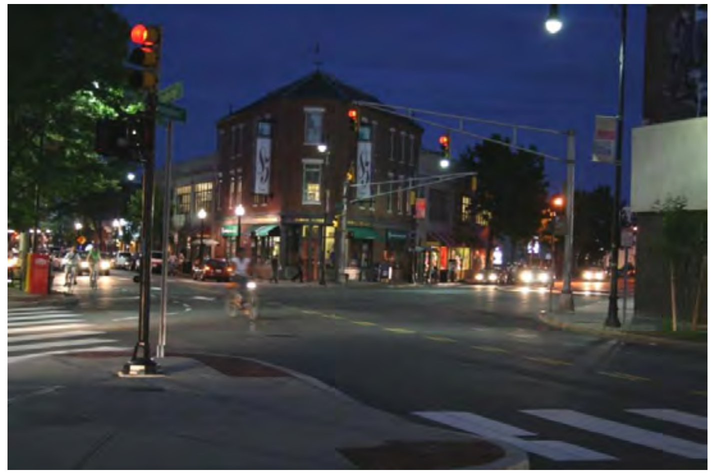
Medium - Areas where lesser numbers of pedestrians utilize the streets at night. Typical are downtown office areas, blocks with libraries, apartments, neighborhood shopping, industrial, older City areas, and streets with transit lines. (11 to 100 pedestrians per hour in a typical block on both sides of the street)

Low - Areas with very low volumes of night pedestrian usage. These can occur in any of the cited roadway classifications but may be typified by sub- urban single family streets, very low density residential developments, and rural or semi-rural areas (10 or fewer pedestrians per hour in a typical block on both sides of the street). Very few Cambridge streets fall into this category.

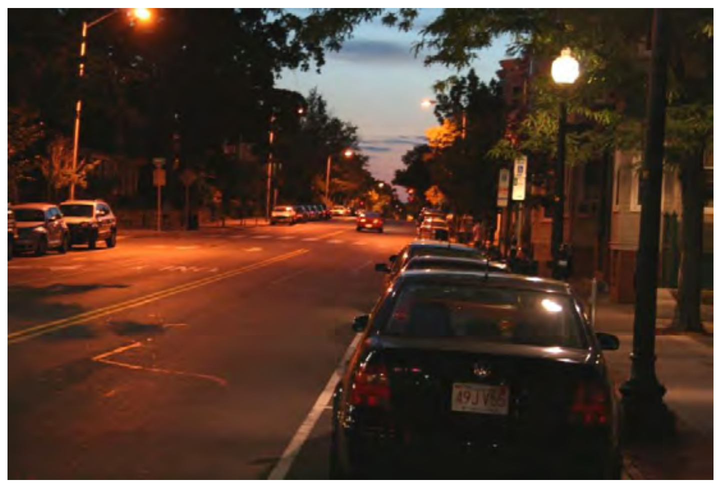
LIGHTING STANDARDS FOR STREET LIGHTING					
LUMINANCE VALUES					
ROAD AND AREA CLASSIFICATION		AVG. LUMIN.	MAX UNIFORM. RATIO	MAX UNIFORM. RATIO	MAX VEILING LUMIN. RATIO
ROAD	PEDESTRIAN AREA CLASSIFICATION	L_{avg} (cd/m^2)	L_{avg}/L_{min}	L_{max}/L_{min}	L_{vmax}/L_{avg}
Major	High	1.2	3.0	5.0	0.3
	Medium	0.9	3.0	5.0	0.3
	Low	0.6	3.5	6.0	0.3
Collector	High	0.8	3.0	5.0	0.4
	Medium	0.6	3.5	6.0	0.4
	Low	0.4	4.0	8.0	0.4
Local	High	0.6	6.0	10.0	0.4
	Medium	0.5	6.0	10.0	0.4
	Low	0.3	6.0	10.0	0.4

SIDEWALKS, WALKWAYS, AND BIKEWAYS
Pedestrian areas and bikeways are classified into the categories noted below.

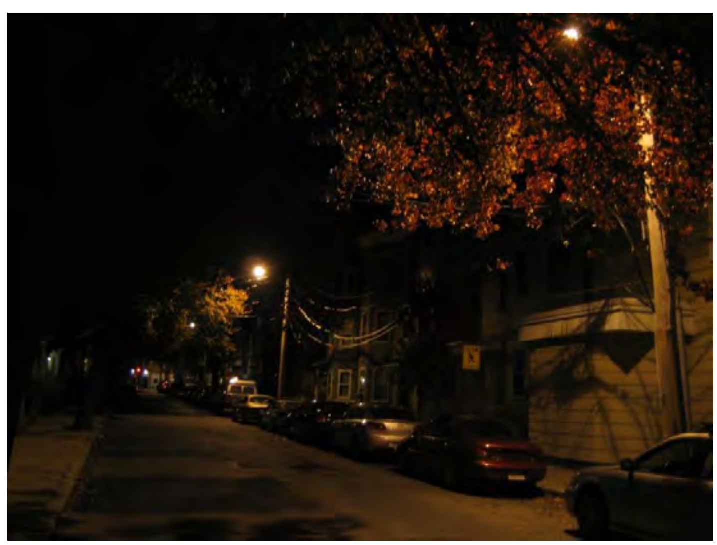
High Pedestrian Conflict Area:
In Cambridge high pedestrian conflict areas are those with mixed commercial and residential use. Typical streets that would fall into this classification would be sections of Massachusetts Avenue, particularly when located in one of the City's Squares like Porter, Harvard, or Central Square.



Medium Pedestrian Conflict Areas
Intermediate areas have moderate night pedestrian activities. These areas may typically be those near community facilities, such as libraries and recreation centers. Safety for the pedestrian as well as providing guidance to primary travel ways are key elements in the design of a lighting system in these areas. These values do not consider areas with increased crime and vandalism.



Low Pedestrian Conflict Areas
The lighting system in residential areas may allow both driver and pedestrian to visually orient in the environment, detect obstacles, identify other pedestrians, read street signs, and recognize landmarks.



The table below includes recommended illuminance values. These values do not consider areas with increased crime and vandalism.

LIGHTING STANDARDS FOR STREET LIGHTING SIDEWALKS, WALKWAYS, BIKEWAYS			
MAINTAINED ILLUMINANCE VALUES			
CLASSIFICATION	**E_H (lux/fc)**	**E_{Vmin} (lux/fc)**	**E_{avg}/E_{min} ***
HIGH PEDESTRIAN CONFLICT AREAS			
Mixed Vehicle and Pedestrian	20.0/2.0	10.0/1.0	4.0
Pedestrian Only	10.0/1.0	5.0/0.5	4.0
MEDIUM PEDESTRIAN CONFLICT AREAS			
Pedestrian Areas	5.0/0.5	2.0/0.2	4.0
LOW PEDESTRIAN CONFLICT AREAS			
Low Density Residential	3.0/0.3	0.8/0.08	6.0
Medium Density Residential	4.0/0.4	1.0/0.1	4.0

* Horizontal only

E_H - average horizontal illuminance at pavement

E_{Vmin} - minimum vertical illuminance at 1.5m above

CROSSWALKS

An extensive study was conducted by the FHWA and VTTI concerning the lighting of crosswalks. The information is based on static and dynamic experiments performed at the Virginia Tech Transportation Institute.[2].

The finding and recommendations of the study are:

- A vertical illuminance level of 20 lux measured at 1.5 m (5 ft) from the road surface allowed drivers to detect pedestrians in midblock crosswalks at adequate distances under rural conditions.
- A higher level of vertical illuminance may be required for crosswalks when
    1. There is a possibility of continuous glare from opposing vehicles.
    2. The crosswalk is located in an area with high ambient light levels.
    3. The crosswalk is located at a lighted intersection.
- The luminaire selected will influence the best mounting location and height of the luminaire with respect to the crosswalk.
- The vertical illuminance level that allowed drivers to detect pedestrians at adequate distances was the same for HPS and MH sources; however, MH or other white light sources may provide better facial recognition and comfort for pedestrians.

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[2] Documented in FHWA-HRT-08-052, available at NTIS under publication number PB2008-106431

For lighting of crosswalks in the City of Cambridge, light poles should be placed on the approach side of mid-block crosswalks and crosswalks located at intersections. The lighting level in the crosswalk shall be equivalent to 20 lux vertical. This can generally be accomplished by placing the pole 0.7 x mounting heights before the crosswalk (e.g. for a 30’ pole the placement should be 30 x 0.7 = 21’ before the center of the crosswalk).

Approach to Lighting Crosswalks Along a Street

Approach to Lighting Crosswalks at Intersections

INTERSECTIONS

Intersections should be illuminated to the sum of the intersecting streets. Since the City of Cambridge uses a luminance based criteria for its street and intersections are designed using illuminance, the following table is included for guidance. The area within the intersection that is required to meet these elevated levels is defined by the area in the center of the intersection to the location of the stop bars at each intersecting street.

LIGHTING STANDARDS FOR INTERSECTIONS				
AVERAGE MAINTAINED ILLUMINANCE AT PAVEMENT (Lux/fc)				
CLASSIFICATION	**Pedestrian Area Classification**			**E_{avg}/E_{min}**
	High	**Medium**	**Low**	
Major/Major	34.0/3.4	26.0/2.6	18.0/1.8	3.0
Major/Collector	29.0/2.9	22.0/2.2	15.0/1.5	3.0
Major/Local	26.0/2.6	20.0/2.0	13.0/1.3	3.0
Collector/Collector	24.0/2.4	18.0/1/8	12.0/1.2	4.0
Collector/Local	21.0/2.1	16.0/1.6	10.0/1.0	4.0
Local/Local	18.0/1.8	14.0/1.4	8.0/0.8	6.0

GLOSSARY

Candela – Unit of luminous intensity.

Efficacy (efficiency) – A measurement of how many lumens a lamp produces per watt consumed.

Fixture – Layman's term for "luminaire".

Footcandle (fc) –A unit of measurement of luminescence. For reference: an office desktop typically has 50-75 fc of light falling on it if lit from overhead fluorescent lamps. A primary focal point tree in a residential garden should have about 5 fc average on it

Glare – A negative term describing uncontrolled light that produces discomfort to the viewer.

High Pressure Sodium Lamp – A high-intensity discharge (HID) lamp that produces light from sodium vapor, producing a distinctly yellowish color.

IESNA – Illuminating Engineering Society of North America

Illuminance – A photometric term that quantifies light incident on a surface or plane. Illuminance is commonly called light level. It is expressed as lumens per square foot (footcandles), or lumens per square meter (lux).

Incandescent Lamp – A lamp that produces light when electricity heats a tungsten metal filament.

Lamp – Technical term for "bulb".

LED –Light emitting diode. A lamp that uses solid state technology and aims to create long lasting and energy efficient lamps.

Low Pressure Sodium Lamp – A high-intensity discharge (HID) lamp that produces light from sodium vapor, producing a pinkish color.

Lumen – The unit of measurement for the amount of light emitted by a lamp. One lumen per square foot is one footcandle.

Luminaire – Technical term for "fixture". A lighting unit consisting of a lamp (bulb), lamp holder, and related components which may include lens, cover, and armature depending on the luminaire design. In the case of street lights, a luminaire is typically mounted on a pole and base.

Luminaire with Cutoff Optics – Luminaires that reduce or eliminate uplight and high angle brightness. Used to reduce light trespass to neighboring properties and into the night sky. IESNA defines various levels of cutoff optics as follows:

> *Full Cutoff* = no light at or above 90° vertical, candela ≤10% of rated lumens between 90° and 80° vertical
> *Cutoff* = candela <2.5% of rated lumens at or above 90° vertical, candela ≤10% of rated lumens between 90° and 80° vertical
> *Semicutoff* = candela <5% of rated lumens at or above 90° vertical, candela ≤20% of rated lumens between 90° and 80° vertical
> *Noncutoff* = no candela limitations.

Luminance – A photometric term that quantifies brightness of a light source or of an illuminated surface that reflects light. It is expressed as footlamberts (English units) or candelas per square meter (Metric units).

Lux (LX) – The metric unit of measure for illuminance of a surface. One lux is equal to one lumen per square meter. One lux equals 0.093 footcandles.

Mercury Vapor Lamp – A high-intensity discharge (HID) lamp that produces light by radiation from mercury vapor. Mercury lamps produce a distinct blue-green white light.

Metal Halide Lamps – A high-intensity discharge (HID) lamp that produces light by radiation from metallic vapors. This type of HID lamp has the most neutral color rendering effect.

Street Light Assemblage – A complete street light as installed. Includes the luminaire, armature, pole (post), and base.

APPENDIX

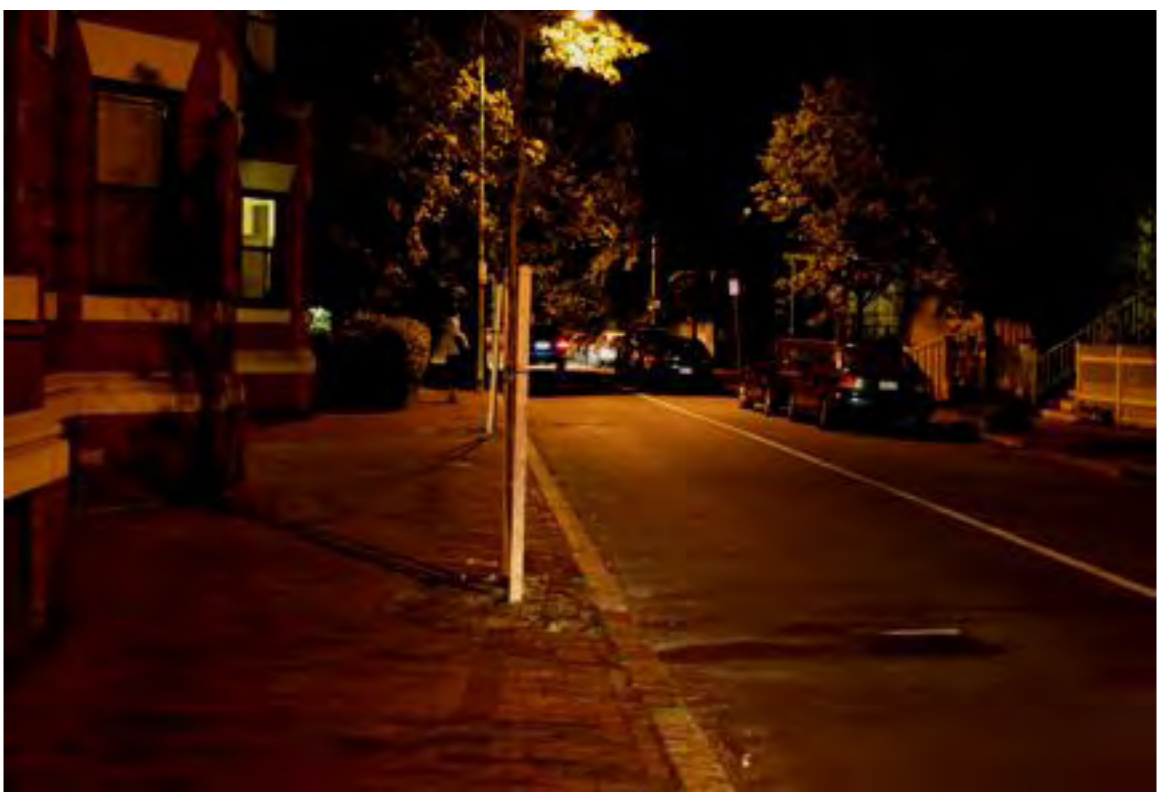
INMAN STREET LED TEST MEASUREMENTS

LED Test Section
90' Pole Spacing
10' Measurement Point Spacing

	Horizontal Illuminance	Luminance	Vertical Illuminance on Sidewalk
	(in lux)	(in Cd/sq m)	(in lux)
	28.6	1.0	5.1
	28.0	1.2	5.6
	17.3	1.3	6.8
	11.0 2.4	Exclude	9.5
	9.6	1.5	12.4
	8.9	1.4	17.1
	10.4	2.0	19.7
	13.8 0.3	Exclude	13.2
	21.3	0.9	12.7
	22.2	1.0	7.8
Average	17.1	1.3	11.0
Avg/Min	1.9	1.4	2.2
Min	8.9	0.9	5.1

HPS Test Section
130' Pole Spacing
10' Measurement Point Spacing

	Horizontal Illuminance	Luminance	Vertical Illuminance on Sidewalk
	(in lux)	(in Cd/sq m)	(in lux)
	56.3	1.2	4.2
	38.7	1.4	2.5
	20.2	1.9	2.7
	12.1	1.8	2.9
	8.0	1.7	7.9
	6.7	1.3	8.7
	6.1	1.3	8.9
	5.8	1.1	9.5
	6.1	1.3	7.9
	7.8	1.1	13.1
	12.6	1.4	19.0
	19.5	0.9	15.2
	32.0	0.7	14.9
	59.7		10.6
Average	20.8	1.3	9.1
Avg/Min	3.6	1.8	3.7
Min	5.8	0.7	2.5



IESNA RP-8 Recommended Values for a Street like Inman St.
(assume local street medium pedestrian volumes)

Horiz. Illuminance	7.0
Avg/min	6.0
Luminance	0.5
Avg/min	6.0
Sidewalk	
Min Vert Illuminance	2.0