Implementation of Decision-Making Tools that Address Light Pollution for Localities Planning Street Lighting

Sponsor
The Connecticut Light and Power Company

Presented by
The Lighting Research Center (LRC)
Rensselaer Polytechnic Institute

Speakers: **John Van Derlofske, Ph.D.**
Michele McColgan, Ph.D.
Date: **Wednesday, March 12**
Time: 8:30 am

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Meeting Agenda

- 8:30am — Introduction and project description

White Paper (Informational Document)

- 8:40am – 10:30am — Introduction to the document

  Basics

    Lamp sources and street light cutoff classifications

    What is light pollution

  Setting the objectives for street lighting

  Good street lighting practices

  Questions and answers

Meeting Agenda **(cont.)**

Checklist

- 10:45am – 11:15am Introduction to the document
  How to use the checklist for street sighting
  Questions and answers

Design Guide

- 11:15am – 12:00pm Introduction to the document
  Street lighting layouts and alternatives
  Questions and answers

Future of Outdoor Lighting

- 12:00pm – 12:30pm Discussion of new research for better lighting design
- 12:30 PM Adjourn

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The Lighting Research Center

- Founded 1988
- Largest university research and educational center devoted solely to lighting
- Only M.S. program in lighting
- 11 partners - manufacturers, government, and utilities
- Independent objective 3rd party status

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Mission

To advance the effective use of light and create a positive legacy for society and the environment

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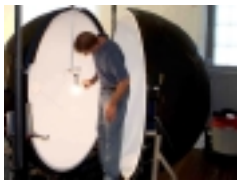

Staff

- Over 40 full time faculty and staff
- Over 15 full time students

Funding

- ~5.2 million per year

Projects

- 40 - 60 funded projects being performed

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Partners

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LRC's Outdoor Lighting Goals

Act as an independent facilitator for all stakeholders in outdoor lighting

- Bridge the lighting, astronomical, and environmental communities
- Provide a voice for outdoor lighting end-users

Perform objective research to assist in design, specification, and regulation of efficient outdoor lighting

Develop an outdoor lighting information resource

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Light Pollution

Light pollution is an unwanted consequence of outdoor lighting and includes such effects as skyglow, light trespass, and glare

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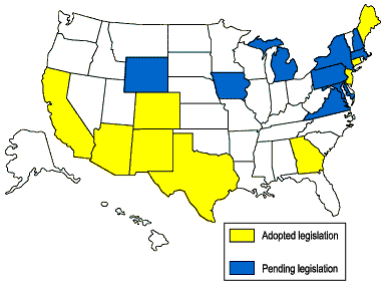
Results of Public Efforts

Lighting ordinances

- **Fixtures requirements**
- **Minimum lighting levels**
- **Lumen/acre limits**
- **Eliminate lighting**

IDA membership almost 10,000 strong



Adopted: Arizona, California, Connecticut, Colorado, Maine, New Mexico, Texas, Georgia, New Jersey

Proposed or Introduced: New York, Iowa, Massachusetts, Michigan, New Hampshire, Maryland, Pennsylvania, Rhode Island, Virginia, Wyoming

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How Does this Effect Connecticut?

Connecticut Legislation public Act No. 01-134

- The Connecticut Light and Power Company (CL&P) has asked the LRC to create and present information about efficient street lighting and light pollution to educate and inform municipalities

Developed Project: *Implementation of Decision-Making Tools that Address Light Pollution for Localities Planning Street Lighting*

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Implementation of Decision-Making Tools that Address Light Pollution for Localities Planning Street Lighting

- Municipalities may struggle to design roadway lighting
- This project and resulting documentation is intended to aid in making lighting decisions
- The documents are intended to lead street lighting decision makers through the thought process of why they are lighting, how much light is needed, and what is the appropriate location of the lighting
- The goal of this project is to have municipalities evaluate their lighting needs and possibly choose not to light areas where it is not needed

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Implementation of Decision-Making Tools that Address Light Pollution for Localities Planning Street Lighting

Kickoff roundtable meeting (Dec. 12th 2001)

- Experts from the IES, the IDA, fixture manufacturers, utilities, and LRC staff

Meeting with Connecticut municipalities (Feb. 6th 2001)

- Representatives from around the state (Hartford, Vernon, Rocky Hill, Windsor, Plainville, Newington, Woodbury, Middleton, Manchester, and Durham)

Development of educational materials

- White paper (informational document)
- Checklist
- Design guide

Seminar to present information

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White Paper
EFFICIENT STREET LIGHTING AND LIGHT POLLUTION

Scope of this document

- Provide information to lighting decision makers in the state of Connecticut about street lighting and light pollution
- This document:
  - Outlines current Connecticut legislation
  - Defines light pollution
  - Discusses lighting considerations that should be considered before embarking on a lighting project,
  - Summarizes good lighting practice
- Is intended to be used with companion documents
  - Checklist and design guide

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Lamp Sources

High Pressure Sodium (HPS)
- Pinkish white, high efficiency, long life

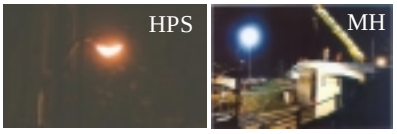
Low Pressure Sodium (LPS)
- Yellow, very high efficiency, long life

Metal Halide (MH)
- White, good efficiency, good life

Mercury Vapor (MV)
- White, low efficiency, short life

Induction Lamp (QL)
- White, high efficiency, very long life

Lamp	Efficacy (lumens/watt)	Life (hours)	Color Appearance	Color Rendering Ability
HPS	125	24,000	yellow-white	fair
LPS	183	18,000	yellow-orange	poor
MH	100	20,000	white	good
MV	58	24,000	blue-white	fair



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Review of Cutoff Classifications

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Cutoff Classifications

Cutoff classifications originated during 1950s and 1960s as a tool for *glare control*

Cutoff classification does not directly address uplight

- Exception - the "full cutoff" classification

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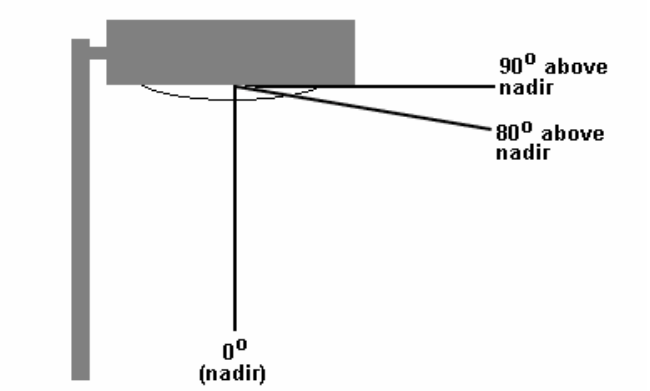
Angles Referenced by Luminaire Cutoff Classifications



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IESNA Cutoff Classifications

Name	Description of intensity distribution
Full cutoff	A luminaire light distribution where zero candela intensity occurs at an angle of 90° above nadir, and at all greater angles from nadir. Additionally, the candela per 1000 lamp lumens does not numerically exceed 100 (10%) at a vertical angle of 80° above nadir. This applies to all lateral angles around the luminaire.
Cutoff	A luminaire light distribution where the candela per 1000 lamp lumens does not numerically exceed 25 (2.5%) at an angle of 90° above nadir, and 100 (10%) at a vertical angle of 80° above nadir. This applies to all lateral angles around the luminaire.
Semicutoff	A luminaire light distribution where the candela per 1000 lamp lumens does not numerically exceed 50 (5%) at an angle of 90° above nadir, and 200 (20%) at a vertical angle of 80° above nadir. This applies to all lateral angles around the luminaire.
Noncutoff	A luminaire light distribution where there is no candela limitation in the zone above maximum candela.

Classification	Candelas at or above	
	90°	80°
Full Cutoff	0	<10%
Cutoff	<2.5%	<10%
Semicutoff	<5%	20%
Noncutoff	NA	NA

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Public Act No. 01-134

Connecticut Legislation for Outdoor Lighting

- Sets limits on outdoor lighting that uses state or municipal funds to install or replace permanent outdoor luminaires for roadway lighting
- Requires that the illuminance resulting from a luminaire must be equal to the minimum illuminance adequate for the intended purpose
- Requires that any luminaire with a rated output of more than 1800 lumens that is installed or replaced on a municipal or a state road must be a full cutoff luminaire
- The full text of Public Act No. 01-134 may be found at the following website: http://www.cga.state.ct.us/2001/act/Pa/2001PA-00134-R00HB-05449-PA.htm.

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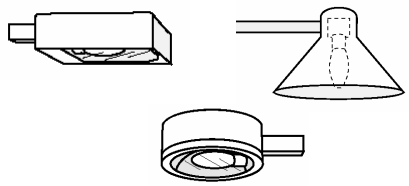
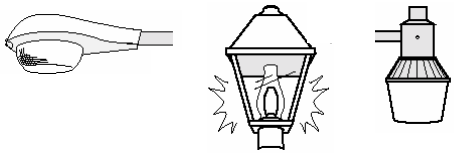
Public Act No. 01-134

"Full cutoff luminaire" means a luminaire that allows no direct light emissions above a horizontal plane through the luminaire's lowest light-emitting part

"Full cutoff luminaire"



Not a "Full cutoff luminaire"



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What's the difference?

Public Act No. 01-134

- "Full cutoff luminaire" means a luminaire that allows no direct light emissions above a horizontal plane through the luminaire's lowest light-emitting part

IESNA

- *Full cutoff*: the luminous intensity (in candelas) anywhere at or above 90° from nadir is zero, and the *luminous intensity* (in candelas) ***anywhere at or above 80° from nadir does not numerically exceed 10% of the luminous flux*** (in lumens) of the lamp or lamps in the luminaire
- **Explicitly limits glare**

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What is Light Pollution?

Light pollution is an unwanted consequence of outdoor lighting

- *Sky glow* – brightening of the night sky caused by natural and human-made factors
- *Light Trespass* – light being cast where it is not wanted or needed
- *Glare* – objectionable brightness
  - Disability glare – loss of visibility from stray light scattered within the eye
  - Discomfort glare – sensation of annoyance or pain induced by overly bright sources

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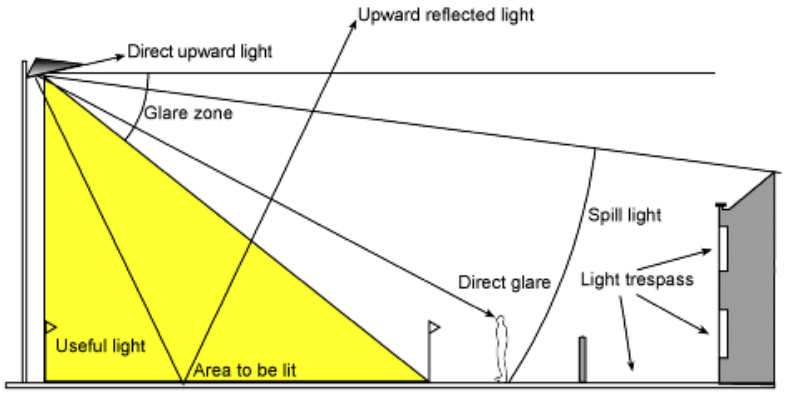
Useful Light and Light Pollution



Light pollution is often caused by the way light is emitted from lighting equipment. Choosing proper equipment and carefully mounting and aiming it can make a significant difference.

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Example of Sky Glow

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Example of Light Trespass

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Example of Light Trespass

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Example of Glare

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Example of Glare

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Reasons for Lighting
Is lighting really needed?

- Debate on outdoor lighting often lack discussion about why municipalities, businesses, or individuals choose to light in the first place
- Although no one would agree that we should cause light pollution and waste energy, the question must be asked, why choose electric lighting?
- The easiest way to avoid light pollution is to eliminate lighting altogether
- In short, we light our outdoor nighttime environment to meet certain societal goals..

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Objectives for Street Lighting

- Safety
  - Drivers, pedestrians
- Security
- Economic Development
- Esthetics
  - Sending messages
  - Landmarks, historical areas

Safety

Street lighting illuminates the roadway

- Showing the driver changes in direction, obstacles, and roadway surface conditions
- Roadway lighting also acts to mitigate glare

Street lighting lights more than just the road

- Walkways and adjacent areas
- Pedestrians, cyclists, children playing in the front yard, and other non-motorists are more readily seen

The IESNA has recommendations for lighting roadways and allowing oncoming drivers to see other vehicles, as well as pedestrians and cyclists

Security

- While there is controversy about whether electric lighting improves security (Painter, 2001, Boyce 1990, Tien 1979), there is no question that one feels safer walking or driving on well-lit streets and in well-lit parking lots
- Security may be thought of as freedom from worry in regard to the security of people and property
- In order for security lighting to be effective, minimum light levels and uniformity ratios must be met (Boyce 2000, Rombauts 1989, Boyce 1990)

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Economic Development

Exterior lighting has a significant impact on economic development

Lighting may draw people to a downtown area or a shopping area by making the shops and restaurants inviting

The appearance of a space (during nighttime as well as daytime) is an important consideration for many areas

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Economic Development

Esthetics

Finally, lighting sends a message

- "Look here"
- "Walk down this street"
- "Don't walk down this street"
- "Come and window shop"

Lighting conveys information to people

Lighting enhances historic areas or landmarks and helps to promote an image of the city or town

When to Light?

Indeed there are many valid reasons where lighting is not only needed, but required

However, understanding how much is enough is important

- Awareness is the key to balancing the need for lighting while minimizing light pollution and increasing energy efficiency

Lighting Considerations

Before any decisions about lighting are made, the objectives of the community must be considered Some questions to consider:

- Does the street in question need lighting?
  - *What are the objectives?*
- Are there other ways to accomplish the goals without installing lighting?
  - Marking, signaling, mechanical structures, educational programs, speed limits, etc.

Lighting Considerations (cont.)

Once lighting is deemed necessary:

- Are minimum lighting levels being used to accomplish the objectives?
- Is the current or proposed lighting installation energy efficient?
- Does the lighting installation minimize light pollution?
- Is the lighting installation cost effective?
- Have lighting controls such as motion sensors or timers been considered?
- Is a lighting curfew (turn lights off after a certain time) appropriate?

Good Street Lighting Practices

Many installations of lighting on roadways fall short of IESNA recommendations

- These recommendations form the basis for what is considered to be "good practice" in street and roadway lighting

Once the decision is made to embark on a street lighting project, carrying it through requires care and attention to avoid:

- unwanted equipment costs
- complaints about poor visibility
- glare
- unnecessary use of energy
- excessive maintenance costs

Good Street Lighting Practices

Roadway lighting designers can be any one of the following:

- in-house engineering staff
- manufacturers, or manufacturers' distributors
- electric utility specialists
- contractors

Regardless of who will ultimately design your street lighting installation, raising the following issues will help to open the lines of communication that are important to a successful project

Good Street Lighting Practices

- What are the objectives
- What are the existing conditions
- Are efficient technologies being used
- Are pole heights and pole spacings appropriate
- Are all attempts being made to minimize light pollution
- Have maintenance and component life been considered

Lighting Objectives

Be certain that the designer is aware of the issues outlined in this document

Beware of bold promises

- To reduce crime or improve safety
- To dramatically increase economic development
- To eliminate accidents
- Significant costs savings

Share the white paper, checklist, and design patterns, along with the resources listed at the end of this section with the designer

Existing Conditions

Be sure the designer has an accurate understanding of the area in question

- Do they understand the traffic density, posted and typical driving speeds and accident history of the location?
- Is pedestrian traffic heavy throughout the day or only at certain times of the day?
- What types of buildings are found in the area?
  - residences, offices, neighborhood businesses, schools, restaurants?
- What is the crime history of the area?
- Is the location perceived as safe or unsafe?

All will have special considerations for lighting and different hours of active use

Efficient Technologies

There is not one single best technology for street lighting

- Your designer should be aware of the relative benefits and drawbacks of different types of lamps and luminaires
- Are efficient light sources and ballasts planned?
- Mercury vapor lamps are relatively inefficient and should not be used in any new or retrofit installations

Almost all lamps used in street lighting require a ballast to provide the proper voltage and current to the lamp

- Are efficient ballasts going to be used?

Even the most efficient lamp and ballast can be made very inefficient by using luminaires that trap light inside

- A luminaire that emits less than half of the light generated by the lamp and ballast should be avoided

Pole Heights and Pole Spacings

In different locations, different pole heights are appropriate

- The "cobra head" type of luminaire seen on many streets and roadways is often found on a higher pole
- Architectural or decorative types of luminaires might have a scale that requires shorter pole heights.
- When existing utility poles are used, careful attention to luminaire selection is important so that it is suitable for the pole heights

Pole Heights and Pole Spacings

The height of street lighting poles will impact how uniform the light levels are in the street and surrounding area

- Ask whether the combination of luminaires and pole heights will result in sufficient uniformity
- This issue can be especially important in a retrofit installation where existing pole mounting locations are going to be used with no additional poles

Maintenance and Component Life

Easy mechanisms for opening, removing lamps and ballasts, and cleaning

- Find out if special tools or equipment will be needed

Warranties of the components in the system

Environment factors might result in additional requirements for the equipment

- Is the area prone to flooding, pollution or other possible environmental factors?

Some lamps have very stable light output over a long period of time; others become "dimmer" over a period of a few years

White Paper Conclusions

Understand your objectives

Carefully consider your objectives and light only if needed

If the decision is made to light follow good lighting practice and attempt to minimize any unwanted consequences of lighting

- Use this and companion documents to aid in developing an efficient and light pollution mitigating design

Checklist
Street Lighting Design Checklist

Scope of this document

- Provide Connecticut lighting decision makers with a systematic method for approaching and developing roadway lighting projects
- This document systematically identifies:
  - Lighting objectives
  - Lighting considerations
- Is intended to be used with companion documents
  - White paper and design guide

How to Use the Checklist

Used as an aid in the decision making process

- Developed as a reproducible tool to use ***before*** starting any outdoor lighting project

Simply identifies objectives and considers issues such as light pollution and energy efficiency

Allows decision makers to think through the objectives and how they may be accomplished

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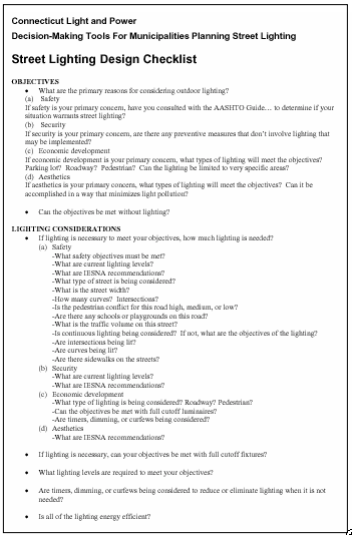
How to Use the Checklist



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Decision-Making Tools For Municipalities Planning Street Lighting

Street Lighting Design Checklist

OBJECTIVES

- What are the primary reasons for considering outdoor lighting?
  (a) Safety
  If safety is your primary concern, have you consulted with the AASHTO Guide… to determine if your situation warrants street lighting?
  (b) Security
  If security is your primary concern, are there any preventive measures that don't involve lighting that may be implemented?
  (c) Economic development
  If economic development is your primary concern, what types of lighting will meet the objectives? Parking lot? Roadway? Pedestrian? Can the lighting be limited to very specific areas?
  (d) Aesthetics
  If aesthetics is your primary concern, what types of lighting will meet the objectives? Can it be accomplished in a way that minimizes light pollution?
- Can the objectives be met without lighting?

LIGHTING CONSIDERATIONS

- If lighting is necessary to meet your objectives, how much lighting is needed?
  (a) Safety
  -What safety objectives must be met?
  -What are current lighting levels?
  -What are IESNA recommendations?
  -What type of street is being considered?
  -What is the street width?
  -How many curves? Intersections?
  -Is the pedestrian conflict for this road high, medium, or low?
  -Are there any schools or playgrounds on this road?
  -What is the traffic volume on this street?
  -Is continuous lighting being considered? If not, what are the objectives of the lighting?
  -Are intersections being lit?
  -Are curves being lit?
  -Are there sidewalks on the streets?
  (b) Security
  -What are current lighting levels?
  -What are IESNA recommendations?
  (c) Economic development
  -What type of lighting is being considered? Roadway? Pedestrian?
  -Can the objectives be met with full cutoff luminaires?
  -Are timers, dimming, or curfews being considered?
  (d) Aesthetics
  -What are IESNA recommendations?
- If lighting is necessary, can your objectives be met with full cutoff fixtures?
- What lighting levels are required to meet your objectives?
- Are timers, dimming, or curfews being considered to reduce or eliminate lighting when it is not needed?
- Is all of the lighting energy efficient?

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What are Your Lighting Objectives?

What are the primary reasons for considering lighting?

- Safety
  - If safety is your primary concern, have you consulted with the AASHTO Guide to determine if your situation warrants street lighting?
- Security
  - If security is your primary concern, are there any preventive measures that don't involve lighting that may be implemented?
- Economic development
  - If economic development is your primary concern, what types of lighting will meet the objectives? Parking lot? Roadway? Pedestrian? Can the lighting be limited to very specific areas?
- Aesthetics
  - If aesthetics is your primary concern, what types of lighting will meet the objectives? Can it be accomplished in a way that minimizes light pollution?
- *Can the objectives be met without lighting?*

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What Should You Consider?

- If lighting is necessary to meet your objectives, how much lighting is needed?
  - Safety
    - What safety objectives must be met?
    - What are current lighting levels?
    - What are IESNA recommendations?
    - What type of street is being considered?
    - What is the street width?
    - How many curves? Intersections?
    - Is the pedestrian conflict for this road high, medium, or low?
    - Are there any schools or playgrounds on this road?
    - What is the traffic volume on this street?
    - Is continuous lighting being considered? If not, what are the objectives of the lighting?
    - Are intersections being lit?
    - Are curves being lit?
    - Are there sidewalks on the streets?

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What Should You Consider?

- If lighting is necessary to meet your objectives, how much lighting is needed?
  - Security
    - What are current lighting levels?
    - What are IESNA recommendations?
  - Economic development
    - What type of lighting is being considered? Roadway? Pedestrian?
    - Can the objectives be met with full cutoff luminaires?
    - Are timers, dimming, or curfews being considered?
  - Esthetics
    - What are IESNA recommendations?

What Should You Consider?

- If lighting is necessary to meet your objectives, how much lighting is needed?
  - If lighting is necessary, can your objectives be met with full cutoff fixtures?
  - What lighting levels are required to meet your objectives?
  - Are timers, dimming, or curfews being considered to reduce or eliminate lighting when it is not needed?
  - Is all of the lighting energy efficient?

Checklist Conclusions

Understand your objectives

- Carefully consider your objectives and light only if needed

Consider “all” relevant factors that can effect the performance of your lighting system in meeting your objectives

Use this and companion documents to aid in developing an efficient and light pollution mitigating design

Design Guide

Efficient Street Lighting Design Guide

Scope of document

- This guide is designed to aid Connecticut municipalities in designing and specifying energy efficient street lighting to meet their illumination goals

  - The intent of this guide is to provide illustrative examples of typical street lighting designs and present alternative options
  - Although all possible outdoor lighting scenarios cannot be illustrated in this document, it is presented as a tool to identify practical approaches that consider light pollution issues

Design Guide

Efficient Street Lighting Design Guide

Scope of document

- ***These design patterns supplement, but do not replace, existing standards and industry-accepted practices for street and roadway lighting design***

Design Guide

Efficient Street Lighting Design Guide

Planners are encouraged to consult these sources, including:

- *American National Standard Practice for Roadway Lighting*, RP-8-00, Illuminating Engineering Society of North America, 2000
- *Recommended Practice for Outdoor and Environmental Lighting*, RP-33-99, Illuminating Engineering Society of North America, 1999
- *Informational Guide for Roadway Lighting*, American Association of State Highway Transportation Officials, 1984

Other excellent sources of guidance for street lighting practice include:

- *Street Lighting Manual,* 3rd Edition, Edison Electric Institute, 1988
- *The Outdoor Lighting Pattern Book,* Russell P. Leslie and Paula A. Rodgers, McGraw-Hill, 1996

Design Guide

Design patterns are representative of scenarios encountered by many Connecticut municipalities

- Luminaires, lamp types, lamp wattages, luminaire heights, and luminaire spacings
- The two luminaires used in the design examples are available from CL&P

This design guide focuses on typical lighting situations with full cutoff luminaires

The design examples were kept simple

Design Guide

This guide is not designed as a comparison between luminaires

- Such a comparison would include many more luminaires in a wider variety of applications, mounting heights, wattages, and source types

The examples in this design guide may not meet IESNA recommended light levels

- The intent is to illustrate the lighting distributions resulting from full cutoff luminaires, in very specific applications

Application of Lighting Patterns

Actual design approaches will depend on the objectives and constraints of the individual municipality

- Vehicle/pedestrian safety
- Security
- Economic development
- Esthetics
- Available budget

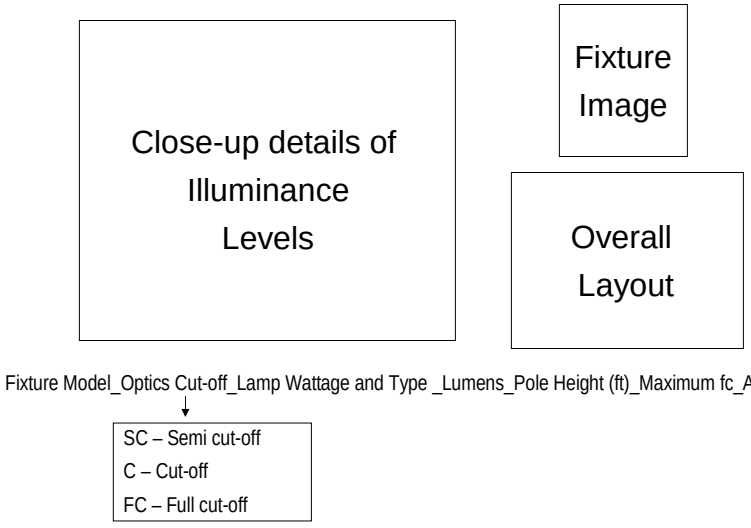
Example Designs

This guide shows four design examples:

- **Example I**: a cul de sac in a residential setting
- **Example II**: a residential or commercial intersection
- **Example III**: a rural state or municipal road
- **Example IV**: a residential area with underground utilities

All lighting calculations were performed using the lighting calculation software AGI32

Template for Examples



Fixture Model_Optics Cut-off_Lamp Wattage and Type _Lumens_Pole Height (ft)_Maximum fc_Avg/Min_Max/Min

SC – Semi cut-off
C – Cut-off
FC – Full cut-off

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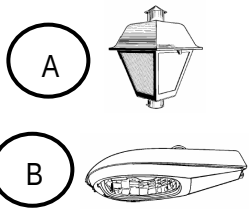

Example I: a cul de sac with a diameter of about 53'-0" in a residential setting has been used

Goal: To illustrate how uniformity and light distribution change for various wattages for two different full cutoff luminaires mounted at different heights.

Lighting Research Center

A. Lighting Scheme

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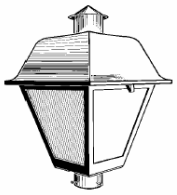

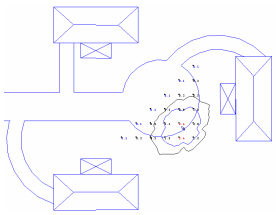

GE SL_C_70WHPS_6300_14_2.40_7.30_24.00

Lighting Research Center

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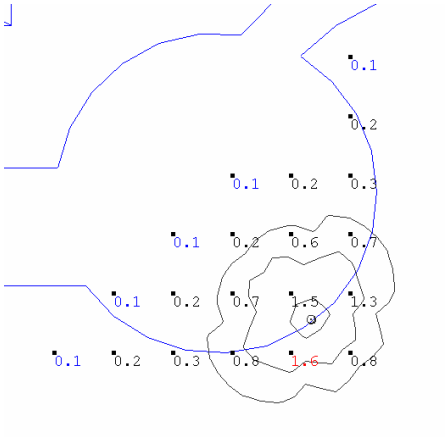
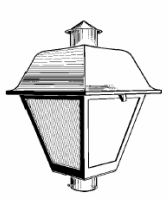
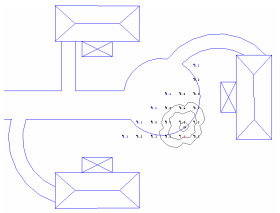
The Northeast Utilities System

A. Alternate







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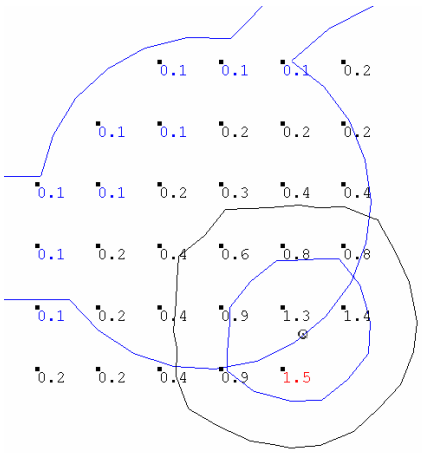
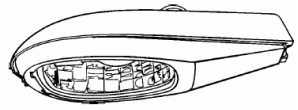
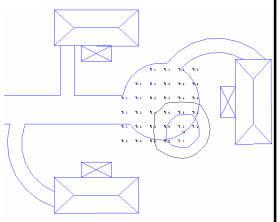
The Northeast Utilities System

B. Lighting Scheme







GEM250_FC_70WHPS_6300_27_1.50_4.10_15.00

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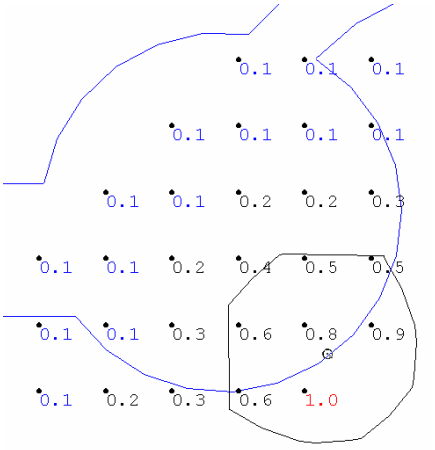
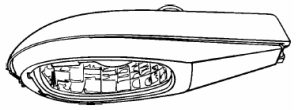
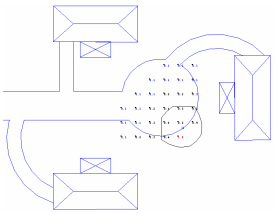
The Northeast Utilities System

B. Alternate







GEM250_FC_50WHPS_4000_27_1.00_2.90_10.00

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Summary

Example	Fixture	Optics classification	Arrangement	Lamp Type and Wattage	Pole Height (ft)	Lumens	LLF	Maximum (fc)	Avg/Min	Max/Min
Lighting Scheme A	GE Salem	Cut-off	Single	70W HPS	14	6300	0.70	2.40	7.30	24.00
Alternate A	GE Salem	Cut-off	Single	50W HPS	14	4000	0.70	1.60	5.10	16.00
Lighting Scheme B	GE Cobrahead	Full cut-off	Single	70W HPS	27	6300	0.70	1.50	4.10	15.00
Alternate B	GE Cobrahead	Full cut-off	Single	50W HPS	27	4000	0.70	1.00	2.90	10.00

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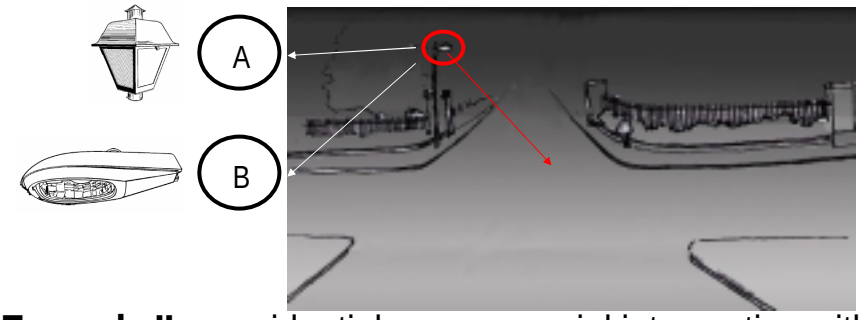

Example II: a residential or commercial intersection with a road width of about 40'-0" has been used

Goal: To illustrate how uniformity and light distribution change for various wattages for two different full cutoff luminaires mounted at different heights.

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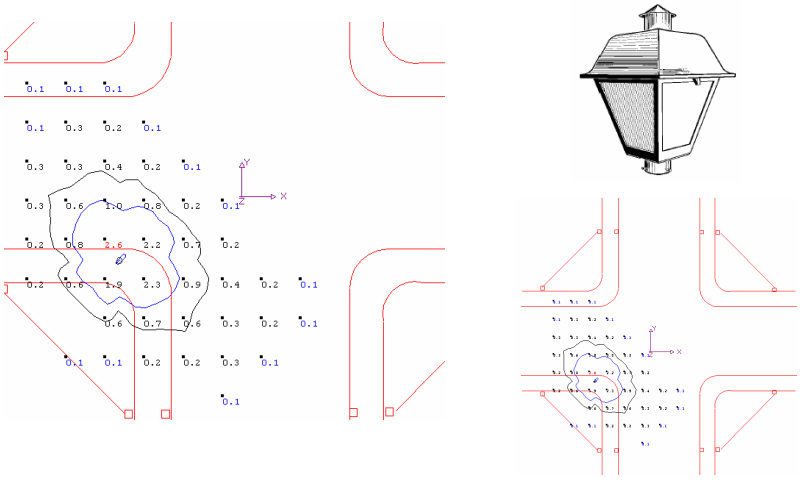
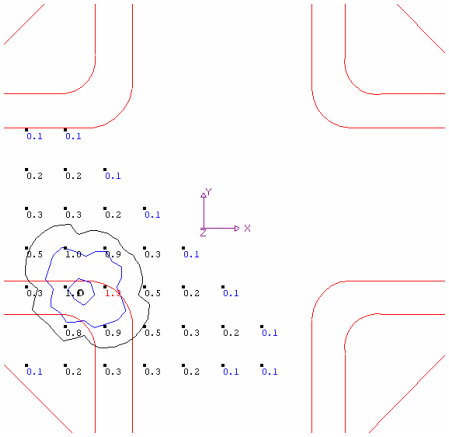
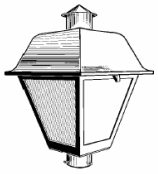
A. Lighting Scheme

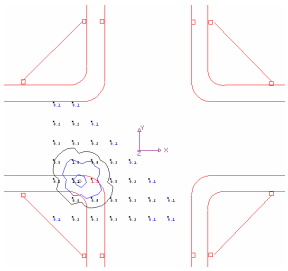


GE SL_C_70WHPS_6300_14_2.60_4.90_26.00

A. Alternate

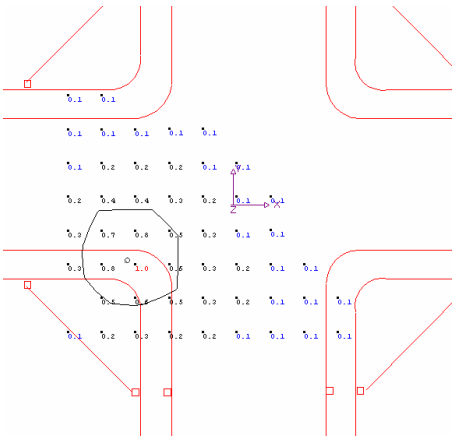


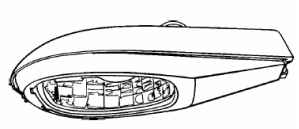


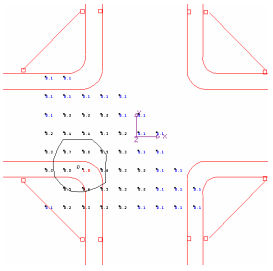


GE SL_C_50WHPS_4000_14_1.30_3.60_13.00

B. Lighting Scheme







GE M250_FC_50WHPS_4000_27_1.00_2.60_10.00

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B. Alternate 1

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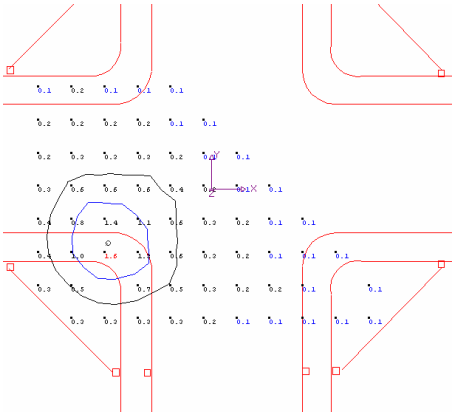

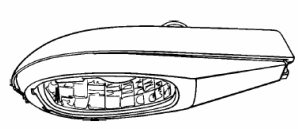

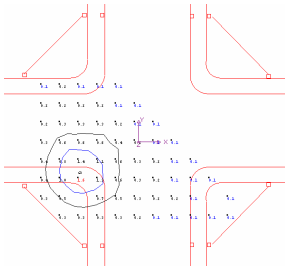

GE M250_FC_70WHPS_6300_27_1.60_3.40_16.00

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B. Alternate 2

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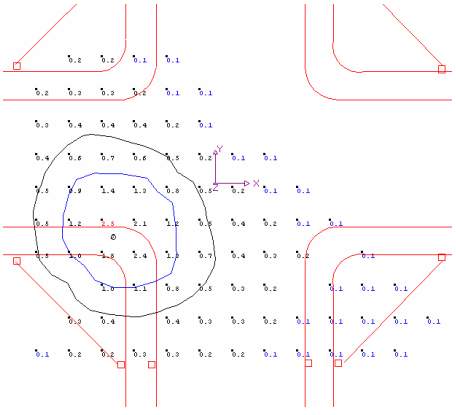

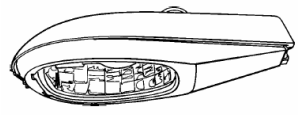

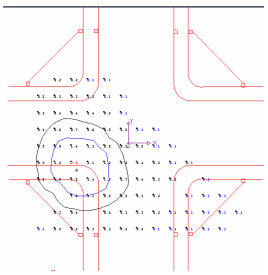

GE M250_FC_100WHPS_9500_27_2.50_4.60_25.00

Lighting Research Center

B. Alternate 3

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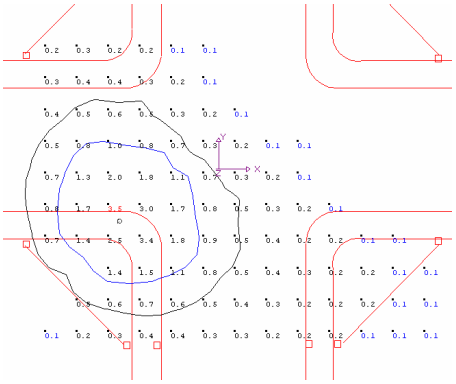

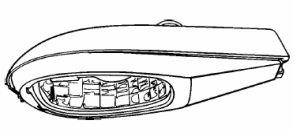

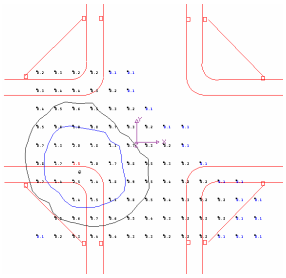

GE M250_FC_150WHPS_13500_27_3.50_6.00_35.00

Lighting Research Center

B. Alternate 4

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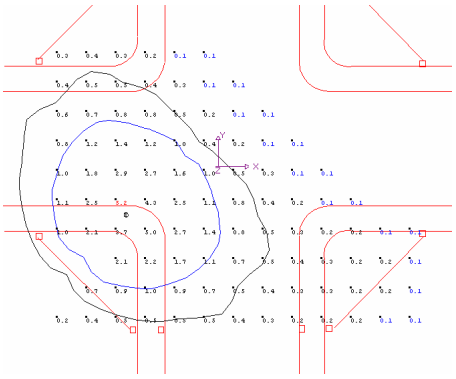
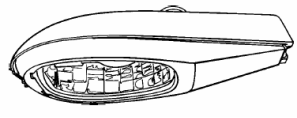
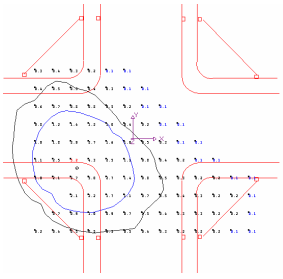
The Northeast Utilities System







GE M250_FC_200WHPS_19800_27_5.20_8.20_52.00

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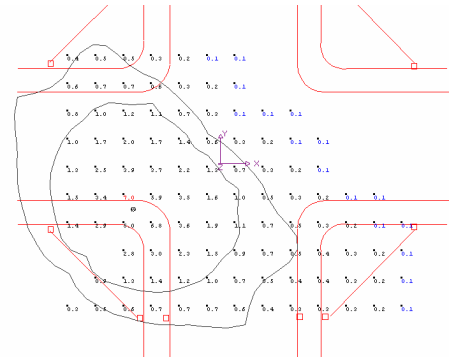
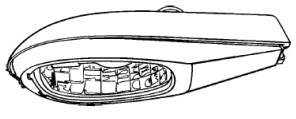
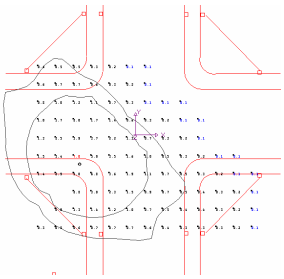
B. Alternate 5

Connecticut Light & Power
The Northeast Utilities System







GE M250_FC_250WHPS_27000_27_7.00_10.80_70.00

Lighting Research Center

Summary

Connecticut Light & Power
The Northeast Utilities System

Example	Fixture	Optics classification	Arrangement	Lamp Type and Wattage	Pole Height (ft)	Lumens	LLF	Maximum (fc)	Avg/Min	Max/Min
Lighting Scheme A	GE Salem	Cut-off	Single	70W HPS	14	6300	0.70	2.60	4.90	26.00
Alternate A	GE Salem	Cut-off	Single	50W HPS	14	4000	0.70	1.30	3.60	13.00
Lighting Scheme B	GE Cobrahead	Full cut-off	Single	50W HPS	27	4000	0.70	1.00	2.60	10.00
Alternate B1	GE Cobrahead	Full cut-off	Single	70W HPS	27	6300	0.70	1.60	3.40	16.00
Alternate B2	GE Cobrahead	Full cut-off	Single	100W HPS	27	9500	0.70	2.50	4.60	25.00
Alternate B3	GE Cobrahead	Full cut-off	Single	150W HPS	27	13500	0.70	3.50	6.00	35.00
Alternate B4	GE Cobrahead	Full cut-off	Single	200W HPS	27	19800	0.70	5.20	8.20	52.00
Alternate B5	GE Cobrahead	Full cut-off	Single	250W HPS	27	27000	0.70	7.00	10.80	70.00

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Example III: a 60'-0" wide rural state or municipal road has been used.

Goal: Understand uniformity and distribution for full cut off luminaires.

Lighting Research Center

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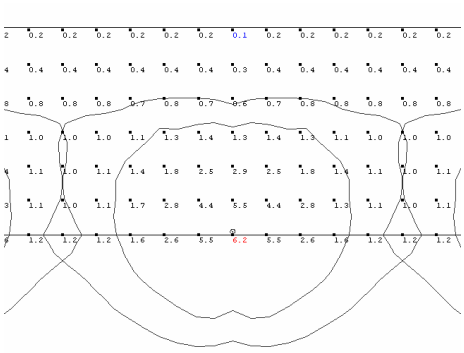
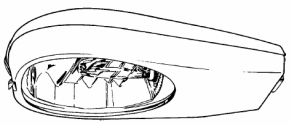
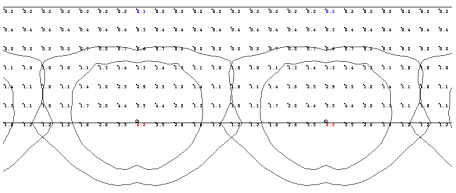
A. Lighting Scheme







GE M250_FC_250WHPS_25600_27_100_0.10_14.10_62.00

Lighting Research Center

Connecticut Light & Power
The Northeast Utilities System

Summary

Example	Fixture	Optics classification	Arrangement	Spacing (ft)	Lamp Type and Wattage	Pole Height (ft)	Lumens	LLF	Minimum (fc)	Avg/Min	Max/Min
A. Lighting Scheme	GE Cobrahead	Full cut-off	Single	100	250W HPS	27	25600	0.70	0.10	14.10	62.00

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The Northeast Utilities System

Example IV: a 30'-0" residential area with underground utilities has been used.

Goal: design objective is to see how uniformity changes for the same application, when wattage is lowered for the same full cutoff luminaire. A second objective is to explore alternatives to light the road.

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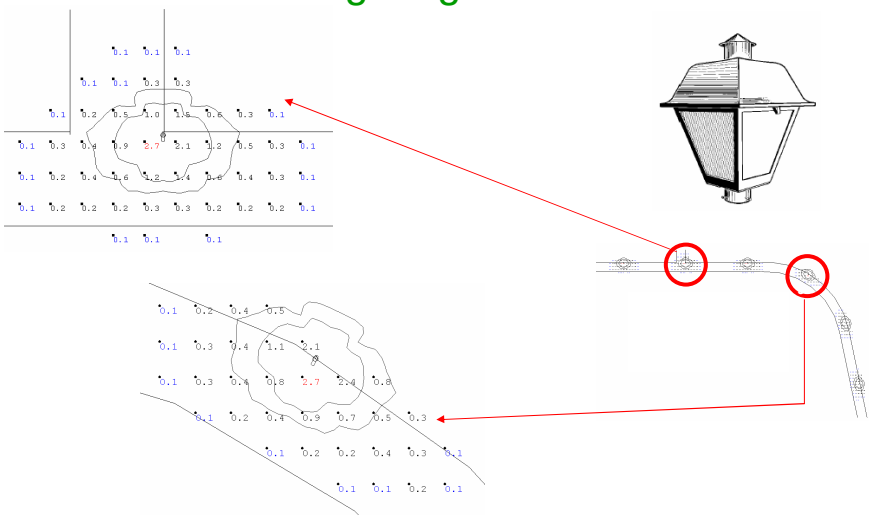
A. Lighting Scheme



GE SL_C_70WHPS_6300_14_200_0.10_4.80_27.00

Lighting Research Center

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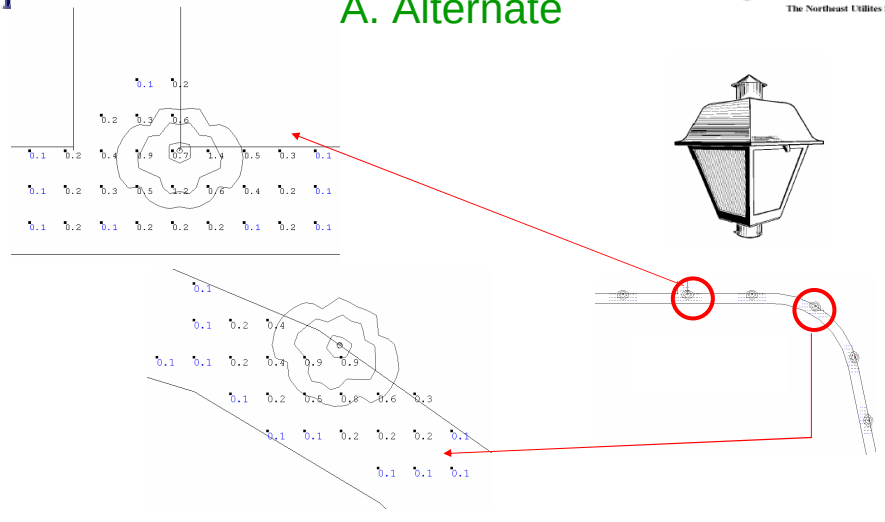
A. Alternate



GE SL_C_50WHPS_4000_14_200_0.10_3.40_15.00

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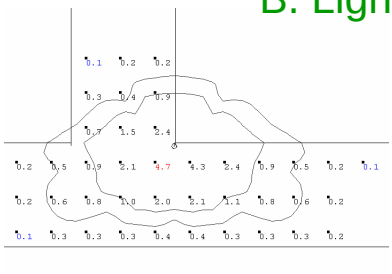
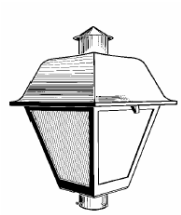
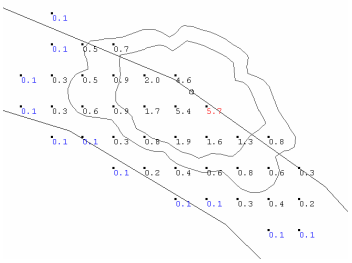
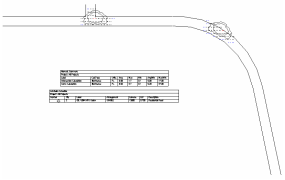
B. Lighting Scheme









Intersection → GE SL_C_150WHPS_13500_14_0.10_9.00_47.00

Curve → GE SL_C_150WHPS_13500_14_0.10_9.20_57.00

Lighting Research Center

Connecticut Light & Power
The Northeast Utilities System

Summary

Example	Fixture	Optics classification	Arrangement	Spacing (ft)	Lamp Type and Wattage	Pole Height (ft)	Lumens	LLF	Minimum (fc)	Avg/Min	Max/Min
A. Lighting Scheme	GE Salem	Cut-off	Single	200	70W HPS	14	6300	0.70	0.10	4.80	27.00
A. Alternate	GE Salem	Cut-off	Single	200	50W HPS	14	4000	0.70	0.10	3.40	15.00
B. Lighting Scheme Intersection	GE Salem	Cut-off	Single	---	1570W HPS	14	13500	0.70	0.10	9.00	47.00
B. Lighting Scheme_Curve	GE Salem	Cut-off	Single	---	1570W HPS	14	13500	0.70	0.10	9.20	57.00

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Design Guide Conclusions

Understand your objectives

- Changing your lighting parameters will affect your ability to meet your objectives

Consider tradeoffs due to interactions of your lighting systems with the surroundings that will change affect the performance of your lighting system

Use this and companion documents to aid in developing an efficient and light pollution mitigating design