# A Brighter Tomorrow: LED Street Lighting in BC Light Level Reduction and Efficiency

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# Today's Presentation

Overview of Transportation Association of Canada – Lighting Level Reduction and Energy Efficiency Guide

Review some key elements and parts of the Guide

# TAC Light Level Efficiency and Power Reduction Guide - Background

- Technology and products have been developed quicker than standards and application. Need for National Publication.
- Need for a sound basis of science, research and logic.
- Defines a complete process to assess and deploy energy efficient street lighting.
- Guide will be used by cities, lighting designers and suppliers.

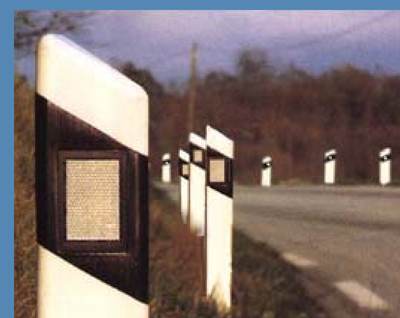
# TAC Light Level Efficiency and Power Reduction Guide – Outline (1 of 2)

# TAC Light Level Efficiency and Power Reduction Guide – Outline (2 of 2)

# Design Considerations

•**Where to Light** – Typically defined by city policy. Ref TAC Guide for the Design of Roadway Lighting System

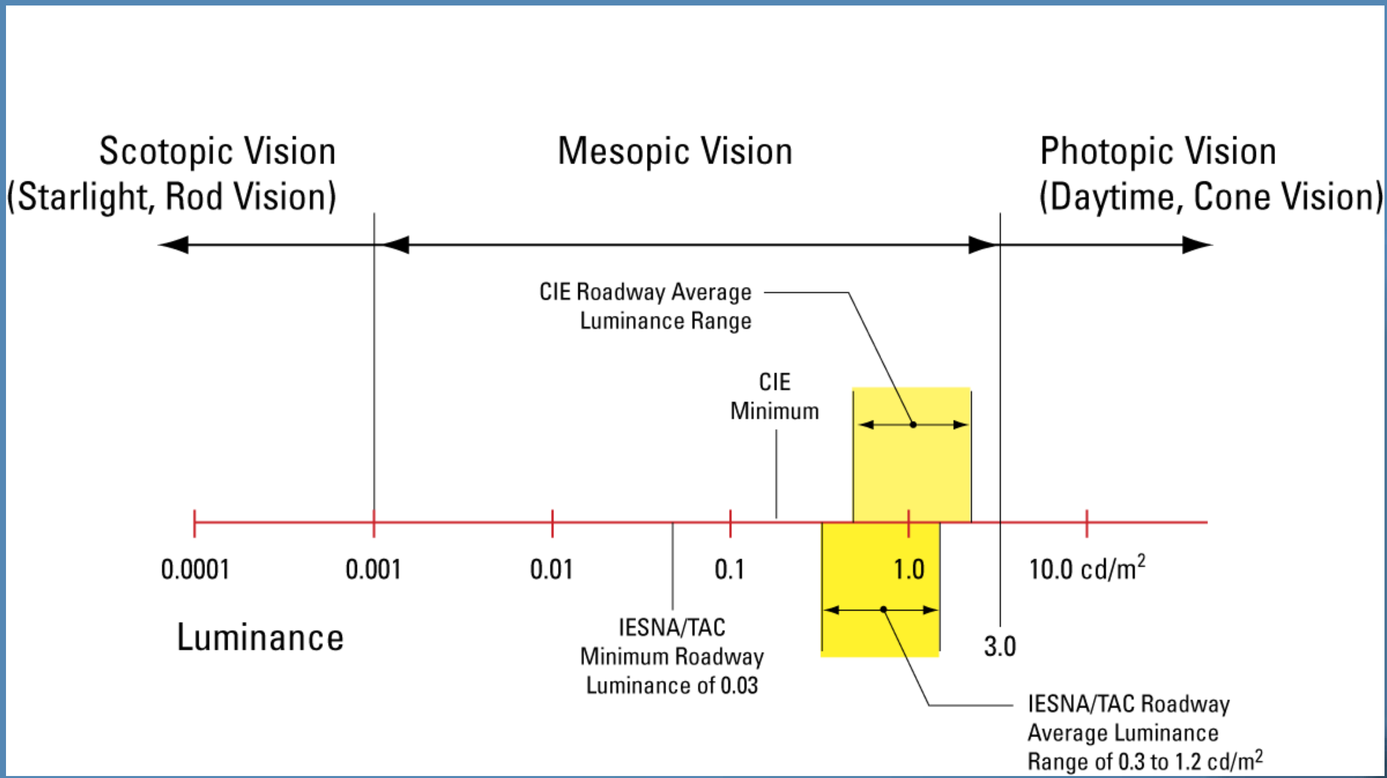
•**Alternatives to Lighting** – Retro-reflective marking and delineators



Benefit is mainly driver guidance. Benefits most applicable to highways and freeways. Consider where no pedestrians

# Design Considerations

• **Spectral Effects (Mesopic Factors)** – Review of recent research and information provided however factors only applicable in low light level applications (0.3 cd/m2). When using LED's lighting one can consider 0.25 cd/m2 if posted speed in 40 km/h of less. Research is ongoing!



# Design Considerations – Adaptive Controls

| | Applications | Benefits |
|---|---|---|
| 1 | Reduce Initial Lighting Output to Maintained Levels | Energy Savings (5-10%) - Light Pollution Reduction |
| 2 | Dimming Areas Over Lighted to Meet Uniformity | Possible Energy Savings (5-30%) - Light Pollution Reduction |
| 3 | Match Light Output to Pedestrian Activity Levels | Significant Energy Savings (20-30%) - Light Pollution Reduction |

| Road Area and Pedestrian Activity | | Average Luminance cd/m² | Average-to-Minimum Uniformity Ratio | Maximum-to-Minimum Uniformity Ratio | Maximum-to-Average Veiling Luminance Ratio |
|---|---|---|---|---|---|
| Road Type | Pedestrian Activity | | | | |
| Freeway | -- | ≧ 0.6 | ≦ 3.5 | ≦ 6.0 | ≦ 0.3 |
| Partial Lighting of Interchange On-Ramps/ Off-Ramps | -- | ≧ 0.6 | ≦ 3.5 | ≦ 6.0 | ≦ 0.3 |
| Expressway-Highway | High | ≧ 1.0 | ≦ 3.0 | ≦ 5.0 | ≦ 0.3 |
| | Medium | ≧ 0.8 | ≦ 3.0 | ≦ 5.0 | ≦ 0.3 |
| | Low | ≧ 0.6 | ≦ 3.5 | ≦ 6.0 | ≦ 0.3 |
| Arterial | 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/Alleyway | 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 |

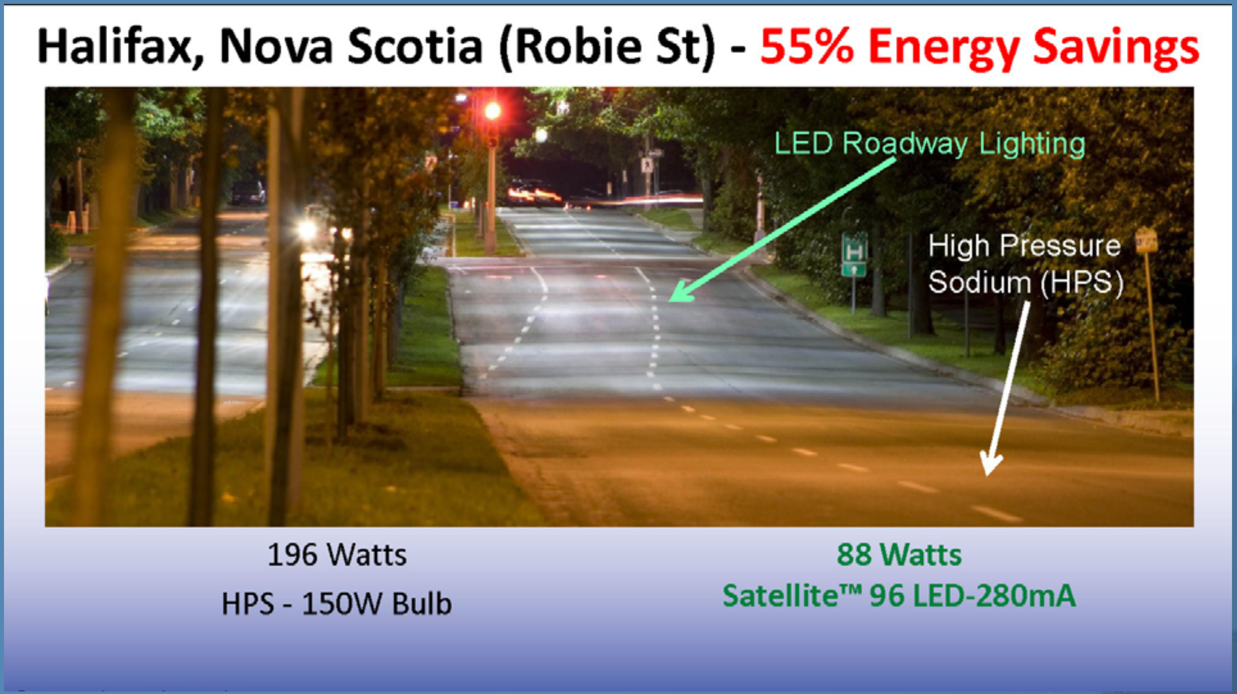
# Design Considerations - Adaptive Controls

- Reduced Energy Consumption – BC Hydro Studies show 20% to 30% on average for most Cities while still meeting required light levels.
- Obtrusive Light Reduction – Less light off site while people are sleeping
- Power Consumption Monitoring – Can be used to validate costs
- Streamlined Asset Management – Benefits maintenance

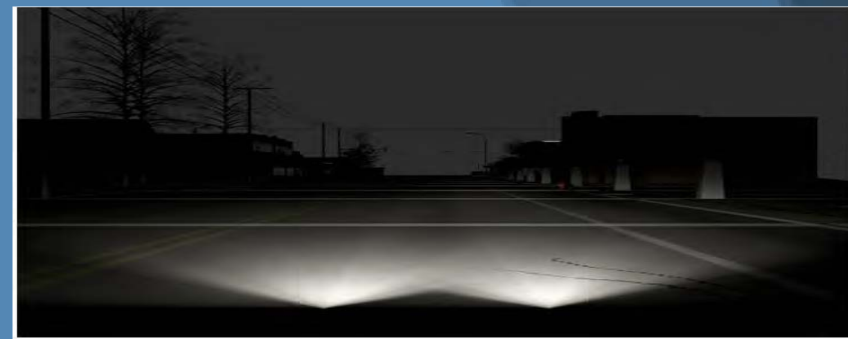
# Design Considerations - LED Lighting

An energy savings of *55%* was gained from retrofitting the 1100 existing cobra head luminaires with LED luminaires.

Other larger deployments have found similar results



# Design Considerations



Residential Streets (most are to lowest level 0.3 cd/m2) – Consider Car headlamps and Driver Safe Stopping Distances and dim in off peak periods (say midnight to 5AM)

These roads comprise a significant inventory in a typical city. Lighting research focused on highways and freeways (FHWA)

Lighting is of value so turning lights off may diminish ones "feeling of security". Santa Rosa, California.

Consider 30-60% dimming off peak via adaptive system

**Table 1: AASHTO Stopping Sight Distance (Wet Pavement)**

| Stopping Sight Distance M (Ft) by Percent Grade (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Downgrade | | | Upgrade | | |
| Traffic Speed km/h (mph) | 0 | 3 | 6 | 9 | 3 | 6 | 9 |
| 35 (20) | 35 (115) | 35 (116) | 40 (120) | 40 (126) | 35 (109) | 35 (107) | 35 (104) |
| 40 (25) | 50 (155) | 50 (158) | 50 (165) | 55 (173) | 45 (147) | 45 (143) | 45 (140) |
| 50 (30) | 60 (200) | 65 (205) | 65 (215) | 70 (227) | 60 (200) | 60 (184) | 55 (179) |
| 60 (35) | 80 (250) | 80 (257) | 85 (271) | 90 (287) | 75 (237) | 70 (229) | 70 (222) |
| 65 (40) | 95 (305) | 95 (315) | 100 (333) | 110 (354) | 90 (289) | 85 (278) | 80 (269) |
| 75 (45) | 110 (360) | 115 (378) | 120 (400) | 130 (427) | 105 (344) | 100 (331) | 100 (320) |
| 80 (50) | 130 (425) | 135 (446) | 145 (474) | 155 (507) | 125 (405) | 120 (388) | 115 (375) |
| 90 (55) | 150 (495) | 160 (520) | 170 (553) | 180 (593) | 145 (469) | 140 (450) | 135 (433) |
| 100 (60) | 175 (570) | 185 (598) | 195 (638) | 210 (686) | 165 (538) | 160 (515) | 150 (495) |
| 105 (65) | 200 (645) | 210 (682) | 220 (728) | 240 (785) | 190 (612) | 180 (584) | 170 (561) |
| 115 (70) | 225 (730) | 235 (771) | 250 (825) | 275 (891) | 210 (690) | 200 (658) | 195 (631) |
| 120 (75) | 250 (920) | 265 (866) | 285 (927) | 305 (1003) | 235 (772) | 225 (736) | 215 (704) |

**Source:** A Policy on Geometric Design of Streets & Highways, AASHTO, Washington DC, 2004. Chapter 3 Elements of Design.

The speed and distance columns only correspond to their metric or English equivalent, i.e., if determining the SSSD for a posted speed in kilometer per hour (km/h), use the value shown in m, if using miles per hour (mph), use the value shown for ft.

# Lighting Technologies - LED Considerations

*Cost* - Better quality LED street lights can be over *$400 - $500* whereas a typical cobra head luminaire is typically around *$200 - $300. Consider ROI over payback*

*Light Loss Factor* – A factor which is applied to all lighting to compensate for lamp depreciation over time. Lighting levels are based on end of lamp life. As LED's can last for 20+ years this is key factor. *Calculations and complex and should be reviewed by experienced personnel.*

*Standardization* - LED roadway luminaires are relatively new to the market. Specifications under development. *Should be performance based. DMD have developed proven specs which continue to be refined.*

*Lack of Proven Long Term Performance* - As LED roadway luminaires are new to the industry, long term performance has not been field proven. *This can be overcome with longer warranty period and MTBF analysis.*

# Lighting Technologies -Optical Systems

- High efficiency
- Effective optical distribution – leads to improved uniformity
- Great cut-off
- Varying optical designs

Design

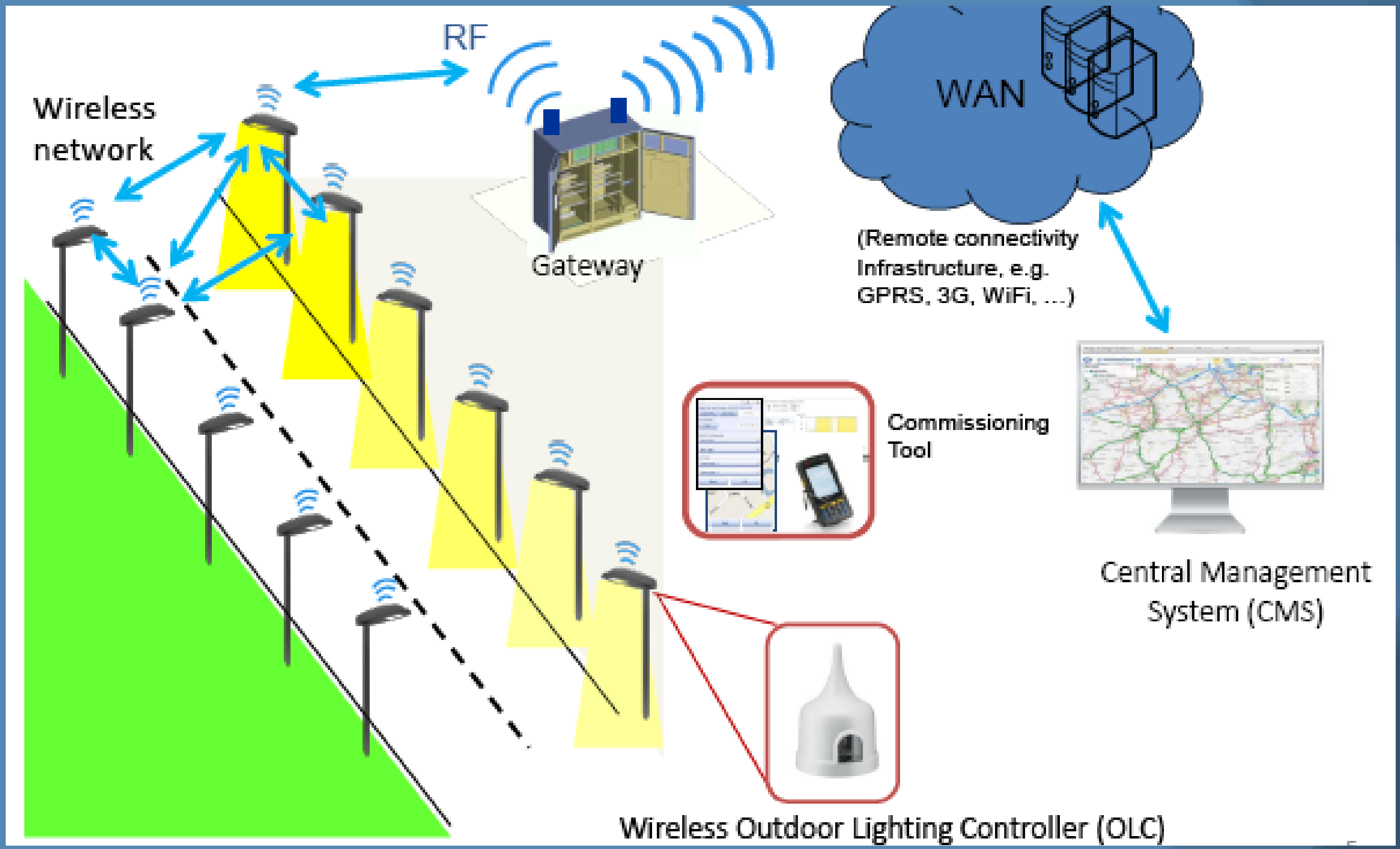
- Sidewalk lighting levels
- Pole heights (lower)

# Lighting Technologies – Adaptive Controls

- Dimming – Energy savings and reduce light pollution
- Asset Management – Improve maintenance, optimize, monitor performance, etc
- Energy Management – Review actual costs
- Metering – Subject to BC Hydro approval
- Ambient Sensing – Ground faults, wire theft, etc

Areas to avoid – Signalized intersections, mid-block crosswalks, roundabouts and rail crossings

# Lighting Technologies – Adaptive Controls



# Lighting Technologies – Adaptive Controls

- System reliability. How many systems in operation. Testing?
- Costs to install and operate? What resources are required? Additional staff?
- Supplier or customer hosted system
- Communications Protocols (language) – Open (IEEE 802.15.4, 802.11, Cellular 3G/4G, NTCIP 1213, etc) or proprietary.
- Connectivity (Hardwire or wireless) – Power line carrier vs wireless. Wireless topologies include mesh and star networks
- Security (Encryption)

# Key Product Considerations and Testing

- Performance
- Quality
- Durability
- Functionality
- Warranty

# Performance

Define by unit power density (watts per area of roadway). Reference CSA C653 for roadways or ANSI/ASHRAE/IES Standard 90.1-2010 Energy Standard for other applications.

Base on typical roadways which exist

Lowest UPD defines best optically efficient luminaire. Typically less than 0.3 w/m2.

# Performance

UPD is mathematically expressed as:

$$\frac{W}{m^2} = \frac{Rated\ Lamp\ Watts}{Roadway\ Width\ x\ Luminaire\ Spacing}$$

| Roadway Classification | | 1 lane | | 2 lanes | | 3 lanes | | 4 lanes | | 5 lanes | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Road | Pedestrian Conflict Area | Full cutoff | Semi-cutoff | Full cutoff | Semi-cutoff | Full cutoff | Semi-cutoff | Full cutoff | Semi-cutoff | Full cutoff | Semi-cutoff |
| Freeway Class A | | 0.65 | 0.65 | 0.50 | 0.45 | 0.35 | 0.40 | 0.35 | 0.35 | 0.30 | 0.30 |
| Freeway Class B | | 0.50 | 0.40 | | | 0.25 | 0.20 | 0.25 | 0.25 | 0.25 | 0.20 |
| Express Way | High | | | | | 0.45 | 0.55 | 0.50 | 0.45 | 0.55 | 0.45 |
| | Medium | | | | | 0.35 | 0.55 | 0.45 | 0.45 | 0.40 | 0.35 |
| | Low | | | | | 0.35 | 0.35 | 0.40 | 0.35 | 0.35 | 0.30 |
| Major | High | | | 0.75 | 0.70 | 0.60 | 0.55 | 0.55 | 0.55 | 0.55 | 0.45 |
| | Medium | | | 0.50 | 0.45 | 0.40 | 0.45 | 0.40 | 0.40 | 0.35 | 0.35 |
| | Low | | | 0.35 | 0.35 | 0.35 | 0.30 | 0.30 | 0.30 | 0.35 | 0.25 |
| Collector | High | | | 0.40 | 0.50 | 0.50 | 0.40 | 0.35 | 0.30 | 0.35 | 0.30 |
| | Medium | | | 0.35 | 0.35 | 0.40 | 0.25 | 0.30 | 0.25 | 0.25 | 0.25 |
| | Low | | | 0.30 | 0.25 | 0.25 | 0.20 | 0.30 | 0.20 | 0.20 | 0.20 |
| Local | High | 0.60 | 0.50 | 0.30 | 0.30 | 0.25 | 0.25 | | | | |
| | Medium | 0.50 | 0.45 | 0.30 | 0.25 | 0.25 | 0.20 | | | | |
| | Low | 0.40 | 0.30 | 0.30 | 0.20 | 0.15 | 0.15 | | | | |

# Performance

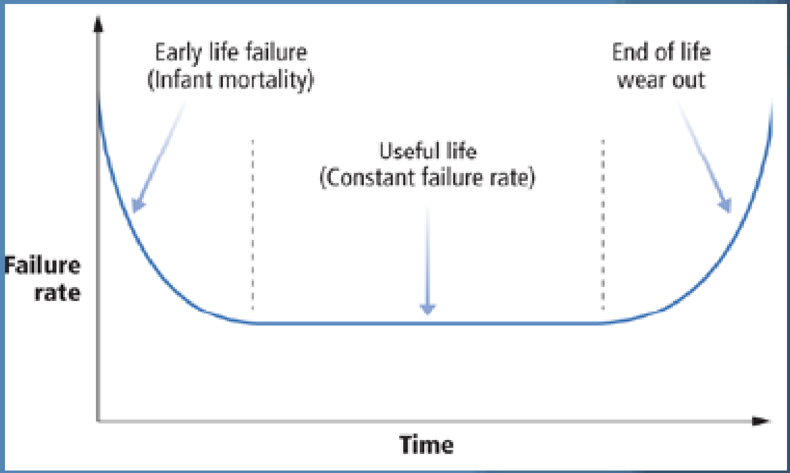
| Roadway Type ** | Pedestrian Activity Level | Luminaire overhang (m) * | Median | Pole Height (m) | Arrangement - Staggered (S), Opposite (O), One sided (OS), Median (M) | # of lanes and width (m) | Sidewalk width (m) | Sidewalk Offset from Curb (m) | Existing HPS Wattage (W) | Avg. Pole Spacing - Cycle Length (m) | Pole Spacing - Cycle Length (m) (WORST CASE) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Arterial | H | 2 | 1.5 | 12 | S | 5 - 3.8 | 2.5 | 1 | 200 | 48 | 58 |
| 2. Arterial | H | 1.5 | 0 | 9.14 | O | 6 - 3.5 | 2 | 1.5 | 200 | 30 | 31 |
| 3. Arterial | M | 2.5 | 1 | 12 | M | 4 - 5.0 | 0 | 0.5 | 400 | 67 | 73 |
| 4. Arterial | L | 1 | 6 | 12 | O | 4 - 6.5 | 0 | 2 | 250 | 52 | 59 |
| 5. Collector | H | 2 | 0 | 9.14 | O | 2 - 7.5 | 3.5 | 1 | 200 | 28 | 32 |
| 6. Collector | M | 2 | 0 | 9.14 | OS | 2 - 7.0 | 2 | 1 | 100 | 36 | 41 |
| 7. Collector | L | 1.5 | 0 | 9.14 | OS | 2 - 7.5 | 1.5 | 1.5 | 200 | 51 | 55 |
| 8. Local | H | 1 | 0 | 9.14 | OS | 2 - 7.5 | 1.8 | 2 | 200 | 46 | 51 |
| 9. Local | M | 0.5 | 0 | 9.14 | OS | 2 - 5.0 | 2 | 2.5 | 100 | 51 | 57 |
| 10. Local | L | 0.5 | 0 | 9.14 | OS | 2 - 5.0 | 2 | 2.5 | 100 | 50 | 55 |

# Reliability

Reliability – Mean Time Between Failure (proven prediction model). Suggest 1M to 2M hours (higher the better). From this # of anticipated failures can defined based on quantity and duration.

Telecordia SR332 method

3rd party testing required



# Quality

Review samples

Define product testing (salt spray, ingress protection, vibration, etc)

# Functionality

Ease of installation

Appearance

Warranty – 10 years?

# Assessing and Evaluating Benefits

Monetary Evaluation - ROI and Payback

Environmental Evaluation – Carbon Credits

# Return of Investment and Payback

Simple ROI = Gain from investment - cost of investment / cost of investment x 100

Payback = Cost of investments (supply and install) / Gain for Investment (power and maintenance costs)

# Return on Investment

Gain from Investment = $1,116,480.00

- Define luminaire life:
  1. 20 years
- Energy savings:
  1. 100W HPS Replaced with 50W LED therefore $0.07kW/h x 0.08kW x 1000 lums x 4200 hours = $23,520 x 20 years = $470,400.00.
- Maintenance cost savings:
  1. Reliability – Assume much higher with LED – Failure rate 10% for HPS versus 1% for LED therefore assume $120.00 per call out and repair = $120.00 x 0.09 x 1000 = $11,000 x 20 years = $220,000.00
  2. Re-lamping – Assume 3 re-lamps required however as LED would need to cleaned at say 10 years allow for 2 only = $120 x 2 x 1000 = $240,000.00
- Inflation and cost increase factor (1% per year):
  1. 20%

# Return of Investment

Cost of Investment = $580,000.00

- Luminaire supply cost
  1. $450.00 x 1.12 (taxes) x 1.07 (mark-up) x 1000 lums = $540,000.00
- Installation cost
  1. $40.00 x 1000 lums = $40,000.00

Benefits for LED's

- Simple ROI = $1,116,480 - $580,000 / $580,000.00 x 100 = 92%
- Payback = 10.8 years without 20% inflation factor

Benefits for LED's and Adaptive Controls would be similar

# Retrofit and Deployment

- **Inventory and Design** – Define what exists poles, spacing, road types, widths, sidewalks, lighting criteria, etc. Use city GIS system. Many roads are over lit to achieve the required uniformity. LED's improve the uniformity. Proper analysis and assessment of optical systems (by lighting calcs) is how you achieve 50%-60% energy savings. Lighting calcs to define luminaire distribution and wattage and to make sure required lighting levels are achieved.
- **ROI** – Define and review ROI and benefit. Define budget and funding.
- **Specifications** – Develop
- **Procurement** – Issue specs and review submittals to define bet value. Review of photometric's, products, test results and data required.
- **Test and Commission** – Required for adaptive controls
- **Monitor and Review** – During construction
- **Public and Communications Program** – Pre and post Construction. Recommend public education and information program as per the City of Calgary (EnviroSmart) Program.

Appendix (Inventory Assessment).pdf

Copy of this presentation can be downloaded from DMD web site:

- www.dmdeng.com
- Go to learning center

# Questions and Answers