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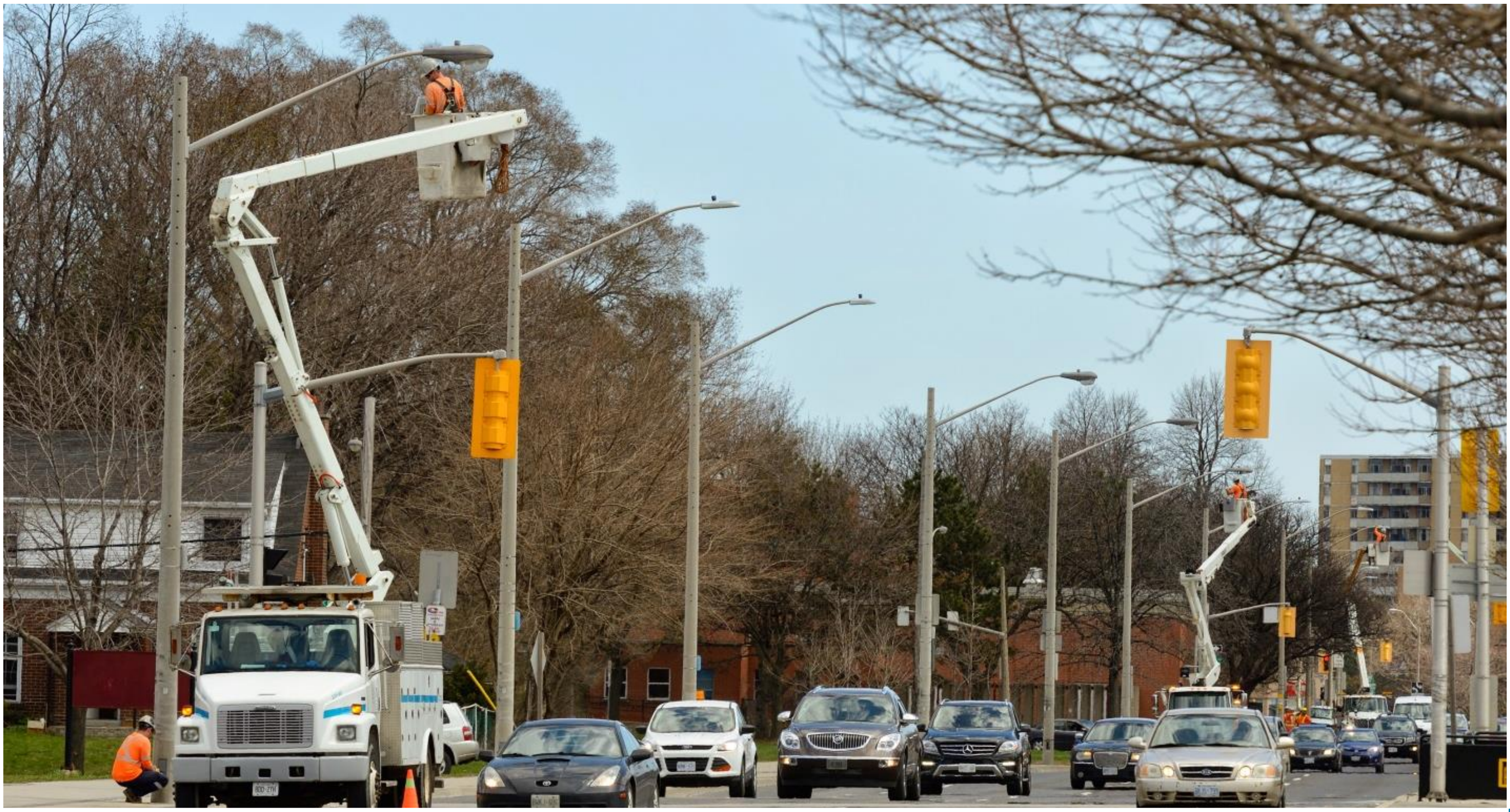

LED STREETLIGHT SCALE-UP

A LIGHTSAVERS GUIDE

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INTRODUCTION

1. PURPOSE

This is a practical guide intended to assist municipalities, provinces and lighting asset managers across Canada to implement light-emitting diodes (LED) streetlighting technology at scale by outlining the steps required and tools available to move from a trial phase through to large scale implementation.

2. LED STREETLIGHTING

LEDs have become the dominant luminaire choice for new streetlights across Canada, and most municipalities have at least discussed an LED conversion project for part or all existing streetlights. Large Canadian municipalities that have at least begun procurement, at the time of publication, include Calgary, Edmonton, Halifax, Hamilton, Mississauga, Montreal, Ottawa, Winnipeg and Windsor.

The benefits of LED technology for municipalities are now fairly well recognized. Replacing high intensity discharge (HID) lamps, such as high pressure sodium (HPS) or metal halide (MH), with LEDs present cities with the opportunity to:

- Reduce energy consumption by 40-80% through significantly greater efficacy (lumen output per watt);
- Reduce maintenance costs through extended product lifetime and performance predictability:
- Improve public safety and security with more effective light distribution; and
- Implement a networked adaptive control system.

3. LIGHTING CONTROL SYSTEMS

Control systems for outdoor lighting are communications systems that facilitate real-time control of the lights (individually or as a group) and can be used to reduce lighting levels to match actual requirements. Systems are typically fixed controls systems or networked controls systems. Fixed controls are the simpler application involving luminaire-mounted nodes that use factory-set functions for light control and must be manually adjusted or reset. Astronomical time clock controls are commonly used fixed controls that are pre-programmed to activate and deactivate luminaires at sunset and sunrise, respectively. Networked controls provide remote lighting control and connectivity with the use of additional hardware. Networked adaptive controls have higher capital costs than fixed controls but have increased energy efficiency benefits and opportunities for future advancements in functionality and connectivity.

Interactive systems have the ability to monitor, diagnose and report luminaire issues. Factors that can be reported include ON/OFF status, loss of power and/or communication, internal temperature, energy consumption, light source failure, total time energized and time to next re-lamping. Controls will either be wired (with line voltage control wires or low voltage wires), often less expensive for new construction, or wireless. Wireless signalling increases the flexibility of a system but may also increase costs.

PHASE I: PRELIMINARY ENGAGEMENT

1. DETERMINE STAKEHOLDERS

The first step in developing an LED streetlighting project is to form a team committed to innovative and efficient energy management to act as the project champions. This team should be formed by the energy manager, project manager or third party manager, and will engage stakeholders, which should include most or all of the following parties:

a. **Electricity Utilities** are the most important partners for municipalities in an LED streetlight conversion project; they control the project's economic viability and the feasibility of including adaptive controls as is discussed in more detail below;

b. **The City or Municipal Council** should be engaged in the project conception phase because they will approve project initiation and can be a main source of funding;

c. **Finance Representatives** can advise the business case and evaluate options for financing of a high capital cost project such as LED streetlight conversions;

d. **Municipal Planning Departments** should be involved in changes in lighting designs that will modify outdoor urban spaces;

e. **The Public** will likely have feedback on LED streetlights and municipalities should address concerns where possible and provide education on the LED benefits;

f. **Consulting Engineers** in firms with municipal LED lighting design services should be informed of the municipality's LED conversion plan;

g. **Procurement Representatives** will develop a procurement process for the streetlighting project that will result in the best value bids;

h. **Installing Contractors** are made aware of the project through a bidding process if the City does not use in-house installation crews;

i. **Commissioning Agent** is engaged prior to developing the lighting design to ensure commissioning begins with project initiation to monitor performance requirements throughout the whole project; and

j. **Safety Representatives** will review lighting design changes and evaluate their potential effects on public safety.

2. DETERMINE OWNERSHIP SCTRUCTURE AND RATE SCHEDULES

The local electricity utility will be affected by the reduction in demand related to an LED conversion and may even own the streetlights. Additionally, many Canadian municipalities complete their LED conversion project through a partnership with the local utility. So LED conversion projects are best executed in close cooperation with the utility.

2.1. TARIFF PROVISIONS & METERING

Streetlight utility tariffs are economic agreements between the utility and municipality based on predetermined formulae that reflect the rate schedules, rules and conditions for use of service. Rate schedules depend on the user's consumption levels and patterns and the utility's costs associated with providing the service. Tariffs differ for utility owned luminaires versus municipality owned. If luminaires are utility owned, the utility's service and billing will likely include installation, maintenance and ownership of the assets, in addition to providing electricity. Commonly, utilities provide flat-rate or unmetered billing that is based on an assumed fixed number of annual burn hours and estimated wattage of all streetlights. Municipality owned luminaires, however, can be unmetered or metered. Typically, tariff challenges with LED streetlight conversions involve utility owned luminaires.

For the economic benefits of LED conversions to be realized, utility owned streetlights using flat-rate tariffs must provide an LED specific tariff that incorporates the decrease in wattage. Due to the lack of standardized LED wattages, existing tariffs should be reviewed and potential revisions recommended. Flat-rate tariffs are also not sufficient if the municipality is considering adoption of networked adaptive controls because they cannot accurately account for reduced or dimmed wattage.

Metered billing has generally not been an option because incumbent streetlight infrastructure does not often include energy meters. Many adaptive lighting controls can measure power consumption, however, meters typically must be approved by Measurement Canada and, per the Electricity and Gas Inspection Act, a meter must be verified and sealed in accordance with the Act. Currently, Measurement Canada does not recognize controls as qualified energy meters but the organization plans to release a resolution for billing variable loads associated with advanced lighting controls by the end of 2016. Until then, the Canadian Standards Association (CSA) Group document EXP05-2015 presents a means for municipal users to be more accurately billed by their utility for a lighting system with controls.

2.2. MUNICIPAL LEASING VS. OWNERSHIP

If a municipality leases some or all of their streetlights from the electricity utility, it is recommended that they evaluate the option of full ownership for potential long-term economic savings and overcoming tariff challenges. When a municipality is leasing streetlights, the utility tariff includes energy costs, as well as maintenance and fixture costs. With ownership, a municipality pays a reduced tariff based only on energy use but is responsible for maintenance. Ownership also gives the municipality more design control of an LED conversion project, including product selection.

PHASE II: PROJECT ORGANIZATION

The scope of an LED project varies between municipalities and can depend on the existing streetlight inventory, knowledge of LED technology and overall preparedness for a lighting conversion. The municipality may choose to organize the project together with in-house staff, in-house project managers or third party project managers.

1. DEFINE SCOPE

The scope of the LED streetlighting project is typically determined by available resources and size of municipality. Municipalities can retrofit their own streetlights, those leased from the utility or both. Smaller communities may find it more economical to implement a full conversion to LEDs at once, however larger cities may complete the scale-up in stages.

2. COMPLETE LIGHTING INVENTORY

To design an LED streetlight conversion, a municipality must have a detailed and accurate inventory of its streetlight infrastructure. It is recommended that existing inventory lists be reviewed through site visits as much as possible and missing data should be resolved. A complete inventory will include the following information associated with each fixture:

a. Geographic location;
b. Road width and classification as local, collector, arterial or other;
c. Pedestrian activity level (high, medium or low);
d. Road geometry (number and types of lanes, lane width, medians…etc.);
e. Sidewalk width and location;
f. Pole height and arm length;
g. Pole spacing (average and maximum);
h. Luminaire style as cobra-head, floodlight, shoebox, decorative or other;
i. Wattage;

j. Ownership: municipality or utility; and
k. Illuminance, luminance and uniformity.

For ease of inventory reference, modification and future updates, streetlight data should be recorded as points in a geographic information system (GIS). If the capacity in-house is insufficient to complete this, a municipality should consider working with a company that provides enterprise GIS solutions for businesses, governments and educational institutions (such as Esri Canada or MapInfo Corporation), or include inventory review as a procurement component. The detailed inventory provides base data for the financial analysis, therefore, the more accurate the inventory, the more robust the business case. More importantly, the inventory allows one to undertake design to ensure proper lighting levels are achieved.

3. EVALUATE PROCUREMENT METHOD

When purchasing LED luminaires, a city can buy directly and use city crews or an outside contractor for installation. Contractors can also be hired for both purchasing and installing, or a complete turnkey solution of design, purchasing, installing and maintenance. This latter option will typically cost more but is a simpler method from a contracting and coordination perspective, and beneficial if the city does not have capacity to independently complete the project. With an outside contractor, the municipality should develop a list of prequalified LED products to limit the contractor's product selection to those demonstrated to be accepted by the city, as discussed further in *Phase V: Procurement & Installation* below.

Procurement method can be a variable in building the business case. A municipality should evaluate which project delivery method is most economically viable. Furthermore, City Council will likely benefit from reviewing multiple options.

4. RESOURCES FOR STREETLIGHT CONVERSIONS

A Municipal Guide for Converting to LED Street Lighting by Leotek is a step-by-step guide to implementing a LED streetlight conversion. It is a user-friendly document intended for municipal representatives responsible for streetlighting who may have minimal experience with LED technology.
The Guide is found at: http://www.leotek.com/education/documents/Leotek.LED.Streetlight.Guide.V7-101613.pdf

Improving Efficiency in Municipal Street and Public Space Lighting is another step-by-step guide to LED conversions developed by Efficiency Vermont. It targets Vermont municipalities but presents most information generally enough to be relevant to many other cities as well.
The Guide is found at:
https://www.efficiencyvermont.com/docs/for_my_business/lighting_programs/StreetLightingGuide.pdf

The **CSA EXP05-2015 Methodology for Evaluating Energy Savings from use of Adaptive Controls in Street Lighting Applications** provides a method for calculating potential energy savings of controls and what billing structure can be developed to more accurately bill an unmetered lighting system with controls.
This document can be found at the CSA Group Shop: http://shop.csa.ca/

PHASE III: BUILD THE BUSINESS CASE

LED technology has matured in performance and become a reliable alternative for lighting solutions, however its high upfront capital cost remains a barrier for some municipalities. Developing a business case that sufficiently captures the benefits of LEDs across their entire service life is the first opportunity to overcoming this financial challenge. Developing more than one business case using a selection of design and/or scope options is often useful in presenting an LED conversion project to City Council, the ultimate decision maker. Councils commonly want to see a variety of options to ensure the most cost-effective and efficient is chosen.

1. FINANCIAL ANALYSIS TOOLS

Comparing lighting technologies using simple financial analyses that emphasize upfront capital costs can be misrepresentative and not capture the total value of each solution. Payback period, for example, only considers the economic benefits and costs occurring within that determined period and nothing after the end of the period. Although this economic indicator is simple to calculate and universally understood, it is a poor comparison tool for products that vary in service life. With one of the main values of LEDs being their extended service life, this long life needs to be accounted for in the business case.

Overall, municipalities benefit from using financial analysis tools that more effectively represent a project's value gained across its lifetime. There are a variety of these economic indicators that can be used in place of the simple payback period; three are detailed below:

a. **Total Cost of Ownership (TCO)** is the sum of all costs acquired over the service life of owning or using an asset and extends past the initial purchasing cost. The TCO levels the economic playing field where the lowest bid may not result in the least costly overall procurement. **Lifecycle Costing (LCC)** is used to calculate TCO that evaluates the costs of purchasing, owning or leasing, operating, maintaining and disposing of different asset solutions.
b. **Return on Investment (ROI)** is a method of estimating the investment performance of an asset over its lifetime. It evaluates the total gains of an investment against the total costs, across the service life, and calculates the percentage growth of the initial investment. ROI is simpler to calculate than TCO and IRR and captures all potential benefits of a project, thereby reflecting differences in service life.
c. **Internal rate of return (IRR)** also measures investment performance but produces an annualized rate of return, thereby presenting percentage growth based on the lifetime. It helps measure the project's profitability and is typically considered favourable when higher than the interest rate on the municipal's investment capital. The IRR calculations are more complex than ROI but have become more accessible with computer programs.

There are several publically available Excel-based tools (listed in *Section 5: Resources*) that can help lighting managers calculate the above, otherwise complex, metrics.

2. INPUT PARAMETERS

Municipalities should conduct financial analyses, such as those described above that consider the following parameters:

a. Number of streetlights being replaced and installed;
b. Service life of LEDs and alternatives;
c. Appropriate discount rate;
d. Capital cost of LED luminaires and alternatives (including incumbent technology);
e. Procurement method (including municipal staff or contractor);
f. Installation costs (including cost of roadway closures if required);

g. Project timeline (phased retrofit or turnkey solution);
h. Maintenance costs of replacing luminaire components (including warranty agreements);
i. Estimated energy costs throughout service life of LED (incorporating expected rate inflation);
j. Energy efficiency incentives;
k. Financing options; and
l. Non-economic benefits (e.g. safety).

3. LIGHTING CONTROLS

Although lighting control systems add to the initial capital costs of a lighting project, if their benefits are captured fully, they will typically increase financial savings and enhance the business case. In a networked control system, economic benefits are realized through three main sources:

- **Energy savings** from operating lights based on actual sunset and sunrise and dimming luminance to match design standards that include further dimming during periods of low pedestrian and vehicle traffic;
- **Prolonged LED service life** through initial dimming followed by continuous lumen output adjustments upwards as the LED depreciates; and
- **Reduced maintenance costs** from remote detection and locating of performance failures.

Because of the different interconnected components, networked adaptive controls systems have greater capital costs than fixed controls systems but offer a substantially greater range of services. The main non-economic benefit of networked controls that are connected through the Internet – i.e. becoming part of the Internet of Things (IoT) – is their contribution to *intelligent cities*[1] and future opportunities for further interactivity of urban services.

4. ENERGY EFFICIENCY INCENTIVES

Municipalities may have access to government and utility incentives that reduce capital costs and strengthen the business case for an LED streetlight conversion. At the time of publication, both Ontario and British Columbia have ongoing incentive programs for LED streetlight retrofits through their major utilities: Hydro One and BC Hydro, respectively. Incentives change often and municipalities should investigate what is available to them as soon as they are considering an LED lighting project. Typically, there are also project deadlines that incentive programs require and cities must plan for. If a municipality is not eligible for any incentive, the cost savings of an LED retrofit alone will generally present a strong business case (if all benefits are being captured). Additionally, there are multiple financing models for municipalities to consider, which are discussed as part of *Phase IV: Financing*.

5. NON-ECONOMIC BENEFITS

Although difficult to incorporate into a business case, the non-economic benefits of an LED streetlight conversion should be a component of the decision making process because there is potential for significant positive impacts on the community. This is even more important for projects considering networked lighting control systems that will continue to advance in the service they are able to provide as new technologies become available. Potential non-economic benefits of LEDs include:

- **Improved public safety and security** through improved light distribution, light quality and colour rendering, with potential to decrease crime and/or vehicular accidents;
- **Reduced light pollution** through directional lumen output where there is little to no uplight or light spillage into adjacent properties or natural habitats;

[1] *In this context, an intelligent city refers to a city that uses information and communication technologies (ICT) to better the quality, performance and interactivity of urban services for cost and resource conservation, along with improved communication between citizens and their government.*

- **Variety of specification options** enabling municipalities to select products that meet site-specific specifications, for example colour temperature can be chosen based on potential environmental impacts and public perception:
- **Improved aesthetics** through better light quality and modern luminaire designs, presenting the opportunity to create more attractive streetscapes; and
- **Supports local economy** if local contractors are used and/or social enterprises are involved with material recovery and recycling of the old fixtures.

And potential of networked controls include:

- **Two-way communication** allowing instant reporting of measured parameters, including energy use, and public broadcasts;
- **Monitoring and reporting of local environmental conditions**, such as weather and air quality;
- **City-wide wireless broadband** either as a revenue source or publically available community service;
- **Connectivity of community services**, such as snow removal, waste management and others; and
- **Improved public security** through the ability to communicate public warnings, such as for extreme weather events, and the ability to locate crime through acoustic source localization of, for example, gunshots.

Where possible, attempts to monetize these benefits should be pursued, for example, if the public feel safer as a result of the improved security, this may increase after dark economic activity.

6. RESOURCES FOR FINANCIAL ANALYSIS

The **Street and Parking Facility Lighting Retrofit Financial Analysis Tool** was developed by the U.S. Department of Energy (DOE) Municipal Solid-State Street Lighting Consortium (MSSLC) in partnership with the Clinton Climate Initiative and FEMP. It specifically evaluates energy-efficient lighting alternatives by computing energy and energy-cost savings, maintenance savings, GHG reductions, net present value and simple payback. Including GHG emission calculations is not common for financial tools and encourages the quantification of non-energy benefits. This program requires fairly detailed lighting and structure data and may be too complicated for initial estimations, but is a useful tool for more detailed analyses. The program and relevant support material is found at: http://energy.gov/eere/ssl/retrofit-financial-analysis-tool

The **Super-efficient Equipment and Appliance Deployment (SEAD) Street Light Evaluation Tool** is an Excel-based program developed by CLASP (Collaborative Labeling and Appliance Standard Program). It calculates the expected energy use, light performance and lifecycle cost of streetlighting upgrades. The program is simpler to use than the MSSLC Retrofit Tool, has helpful visuals and outlines reputable lighting standards. This is a dynamic tool and is upgraded on a continuous basis to be adapted to various lighting needs and situations.
The program and relevant support material is found at: http://superefficient.org/sltool

The **BC Hydro LED Streetlight Project Evaluation Tool** is another Excel-based tool and was developed by the British Columbia Climate Change Secretariat as a user-friendly application to calculate cost savings, return on investment (ROI) and simple payback of LED streetlight conversion projects. It uses pre-set values, such as LED costs based on wattage, specifically applicable to BC municipalities but can be modified for different situations. This tool also generates a preliminary application for BC Hydro Power Smart incentives. Although the program was designed for BC municipalities, it is a simple starting point for any Canadian municipality and can provide initial estimations.

The program is found on British Columbia's overall LED streetlight resources page: http://www2.gov.bc.ca/gov/content/governments/services-for-government/bc-bid-resources/goods-and-services-catalogue/led-street-lights-across-bc

The **National Institute of Standards and Technology's Building Life-Cycle Cost (BLCC)** software is designed to perform the LCCA for energy and water conservation projects. The software expands on the methodology and criteria outlined by the Federal Energy management Program (FEMP) to compute the lifecycle costs of two or more alternative designs. The program and relevant support material is found at: http://energy.gov/eere/femp/building-life-cycle-cost-programs.

PHASE IV: FINANCING

Financing is one of the main barriers to municipal LED streetlight conversions but having a strong business case that clearly demonstrates the potential economic, safety and environmental benefits can help secure funds. There are also multiple financing opportunities for a municipality each with advantages and disadvantages but all having led to successful LED implementation. Commonly used financing models are described below, however, municipalities are not limited to these and should explore other alternatives including those that may arise in the future.

1. SELF-FINANCING

Often the simplest financing method for Canadian municipalities is through their own annual capital budgets. Capital funds can be raised using special levies or fees for community services, as well through selling municipal assets. It can be difficult for a city council to approve new taxes, levies or fees, however, the LED conversion project team can build a strong case based on the potential cost savings and aesthetic benefits to the community.

Capital is more commonly raised by municipalities through infrastructure investment bonds or debentures, medium-to-long term debt instruments. Examples of applicable infrastructure includes: roadway development and maintenance, water and wastewater facilities and transportation. Municipalities may have to apply to a provincial agency for permission to issue more debt if they have already reached a specified level of accrued debt.

Benefits of self-financing include:

- Simple and familiar financing model;
- Typically less expensive due to lower loan rates for municipalities over private capital and generally having loan interest not included in the project business case because it is allocated to tax generated funds; and
- Energy savings can be used to create a cost-neutral arrangement by offsetting the debt.

To acquire self-funds, LED streetlighting has to demonstrate its value as a community service and out-compete other spending options. Mississauga and North Bay have both financed LED conversion projects through debentures and the City of Edmonton used a dedicated levy.

2. GOVERNMENT INFRASTRUCTURE FINANCING

Federal and provincial governments dedicate infrastructure funding for municipal capital investment through different programs, most recently the Canada 150 Community Infrastructure Program making $150 million available over the years of 2015-2017. The current federal government is also expected to establish a Canadian Infrastructure Bank planning to allocate $60 billion over ten years to provinces and municipalities for infrastructure projects including green development and clean energy initiatives.

Municipalities may also be able to access low-interest financing and grants from provincially established agencies. Infrastructure Ontario is an example agency in Ontario that has already helped finance six municipal LED streetlighting projects.

3. LEASING

Through a leasing model, a municipality rents the lighting assets instead of purchasing. LED manufacturers and suppliers may offer either operating or capital leasing option. Municipalities may choose to use a leasing company directly. A lease can cover all project phases from design to operation and maintenance and are generally developed with finance payments less than projected cost savings to allow for immediate cash flow. A typical leasing program involves the lessor providing upfront capital for LED procurement, then rents the streetlights back to the municipality for an agreed time period. At the end of the agreement, the municipality buys out the remaining equipment costs. Leasing is a useful option for projects where municipal capital is constrained and projected cost savings are significant enough to cover rental fees.

Benefits of leasing include:

- Do not require down payments;
- In municipalities where the lease costs are considered operating expenses and not capital, they may not qualify as debt load; and
- The municipality may be able to transfer some of the risk of ownership to the lessor.
- Lessor's typically administer deals relatively quickly

For public streetlighting, lease agreements must include risk assessments on environmental impacts, effects on incumbent infrastructure and potential vandalism.

4. ENERGY PERFORMANCE CONTRACTING

Private energy service companies (ESCOs) are well known in North America for offering energy performance contracts to municipal and provincial governments for energy efficiency projects, such as LED streetlight conversions. These contracts offer turnkey LED solutions that include technical evaluations, financing, project implementation, energy monitoring and verification.

Benefits of ESCOs include:

- Municipalities do not raise capital;
- ESCO guarantees certain cost savings and assumes the performance risk (possibly longer than the LED manufacturer warranty); and
- If sufficient energy savings, the project can be cost neutral or profitable – therefore no impact on capital for other city projects.

To provide these benefits, ESCOs charge a premium price for their solution that municipalities should ensure is balanced by the transferred risk of ownership. Energy performance contracts are also typically structured so the cost savings produced by the LEDs are shared between the ESCO and municipality. If choosing to use an ESCO, municipalities must research the company's reliability.

5. PUBLIC PRIVATE PARTNERSHIPS (P3)

In a public private partnership (P3), the municipality grants a long-term license to a private sector to design, implement, fund, operate and maintain (or some combination of these responsibilities) an infrastructure asset such as streetlighting. Because of the potential to combine these multiple functions with one provider (or consortium of providers), the P3 model offers the potential to treat streetlighting as a service. The municipality will retain full ownership of the asset while the private sector assumes most of the financial and/or performance risks for the duration of the contract term.

Benefits of P3 arrangements include:

- Available expertise of the private sector;
- Does not increase municipal indebtedness;
- Municipality is relieved of much of the performance risk; and
- If sufficient energy savings, the project can be cost neutral or profitable – therefore no impact on capital for other city projects.

Typically P3s require projects of large cost, around $30 million or greater. PPP Canada is a federal Crown corporation that acts as an expertise source for P3 programs that can help municipalities evaluate and execute federal P3 opportunities.

6. RESOURCES FOR FINANCING

The LightSavers **Guide to Financing LED Streetlighting in Canada** begins with the overall business case of an LED retrofit, then details six main financing models used by municipalities across Canada. Finally, it provides profiles of potential available capital sources. The document is found at: www.canurb.org/lightsavers.

The U.S. DOE MSSLC **Financing Guidance for LED Street Lighting Programs** provides information on select financing models and tools, case studies of successful municipalities having used these models and additional resources. Although this is an American resource, many of the financing models are applicable to Canadian municipalities and can be used for reference. The website is found at: http://energy.gov/eere/ssl/financing-guidance-led-street-lighting-programs

PHASE V: PROJECT DESIGN

Project design commences by using the lighting inventory to ensure areas are accurately lit based on industry standards and aesthetic preferences. It typically considers road geometry, pole spacing and height and luminaire characteristics/specifications. An engineering consultant can be contracted to complete the final lighting design based on the updated inventory, security and safety requirements and aesthetic preferences of the municipality. Engineering consultants should have proven experience with municipal infrastructure and may be provincially prequalified for municipal LED streetlight services. Different design options may be financially evaluated and presented to City Council.

1. LIGHTING REDESIGN

Completing a streetlighting retrofit presents municipalities with the rare opportunity to re-evaluate the incumbent lighting design and coordinate service needs. It is recommended that cities contract an engineering consultant to identify potential lighting adjustments by analyzing lighting conditions of the existing streetlights.

Some streetlighting may have become redundant since implementation due to changes in roadway infrastructure or initial over-precaution. Opportunities for removal of unnecessary lights should be investigated. Conversely, some areas may require increased lighting where outdoor infrastructure renovations could have created new areas of poor lighting or environments that now require increased visibility.

Improved optical control is one of the main reasons LEDs require less lumen output than incumbent technology to meet the same design standards. This optical control reduces light spillage and over-lighting, however, also has the potential to under-light the sidewalk if there is extreme cut-off on the house side of the fixture. For this reason, sidewalk lighting levels should be evaluated as part of lighting inventory.

2. MEETING STANDARDS

Lighting levels should meet required design standards determined by the engineer that, at minimum, meet municipal codes and/or current guidelines developed by the American National Standards Institute (ANSI) with the Illuminating Engineering Society (IES) presented in the IES RP-8 document. It is recommended that, where IES RP-8 levels are not met by the incumbent system, every effort should be made to meet these levels. Where it is not possible to achieve RP-8 recommendations, existing levels should be confirmed, met by replacement LEDs and documented. City policy should describe the approach to the actual achieved lighting levels. Lighting asset managers can also reference other guidelines listed in Section 5 below. For project deployment, an engineering study should be undertaken to evaluate collision data and assess the priority areas for lighting replacement.

Current roadway lighting guidelines now include recommendations for the use of controls and allow municipalities to evaluate adoption of this advancing technology. When re-evaluating its roadway lighting design, a City should consider incorporating a networked lighting control system. Benefits include additional energy savings, improved commissioning and maintenance through performance monitoring and opportunity for future connectivity of other municipal services. If it is not possible to implement controls at present, municipalities should future-proof by designing control-ready lighting systems.

3. RESOURCES FOR DESIGN

The **ANSI/IES-RP-8 Roadway Lighting** document provides design standards for roadway, street, bikeway and pedestrian way lighting. Municipalities often use the presented guidelines as their main lighting design standards, especially if municipal codes are insufficient. This Standard Practice is found at: https://www.ies.org/store/

The Transportation Association of Canada (TAC) developed the **Roadway Light Efficiency and Power Reduction Guide** to evaluate opportunities for roadway light reductions and energy efficiency practices, and provide recommended guidelines. This document is a supplement to the TAC **Guide for the Design of Roadway Lighting** and presents information on how to assess, evaluate, select and implement energy efficient lighting such as LEDs. Both guides can be found through the TAC bookstore at: http://www.overklick.com/TAC/defaultTAC.aspx

Developed by the Commission Internationale de l'Eclairage (CIE), the **CIE 115 – Lighting of Roads for Motor and Pedestrian Traffic** guide outlines how to select appropriate lighting classes for roadways, based on different variables, such as traffic volumes and weather conditions. Lighting and control system designs are recommended based on these classifications. This report is available through the CIE Online Standards Store: http://www.techstreet.com/cie/

The **Guidelines for the Implementation of Reduced Lighting on Roadways,** by the U.S. Department of Transportation Federal Highway Administration (FHWA), is a supplement to other lighting guidelines that provides a method for lighting designers to select required lighting levels for roadways and adaptive lighting systems for installations or retrofits. This Guide can be downloaded from: https://www.fhwa.dot.gov/publications/research/safety/14050/index.cfm

Lighting designers can use **AGi32** validated illumination engineering software, from Lighting Analysts Inc., to simulate illuminance of different light sources in different environments, by calculating the amount of light delivered in almost any lighting application. This tool is found at the AGi32 website: http://www.agi32.com/

PHASE VI: PROCUREMENT & INSTALLATION

LED procurement differs in many ways from purchasing the conventional, incumbent luminaires. Photometric characteristics differ and there is an increased variety of technical specification options. The procurement process is made more complex also by the many LED streetlights available from a multitude of suppliers. For LEDs, the process begins with the municipality defining the desired project outcomes. From here, cities or utilities can procure streetlights directly and use in-house staff for installation, however, to ensure that lighting performance objectives are achieved with a reliable product, a pre-qualification process is recommended to be used for either suppliers or installing contractors or both.

1. PREQUALIFICATION

A supplier Request for Qualifications (RFQ) is used to create a pre-qualified list of LED manufacturers and products that will be included in the Request for Proposals (RFP) for installing contractors. Prequalification is especially beneficial to municipalities who have not previously conducted LED pilot projects. It narrows the luminaire selection for contractors to only products that the municipality approves based on predetermined specifications.

The municipality can develop a list of preliminary technical specifications and standards for the RFQ. These criteria outline the requirements for materials, technical performance and installation, and should incorporate industry standards and municipal regulations. Every municipality has a unique situation and should use the prequalification process as an opportunity to adapt specifications to their specific case. Replacing incumbent fixtures with LEDs based on a generalized “rule-of-thumb” (i.e. 100W HPS lamps are replaced with 35W LEDs), without case-specific design and analysis, will increase risk and liability of the project.

The municipal RFQ should outline design standards for the following technical specifications:

a. Lighting and uniformity levels – per municipal codes and/or IES RP-8
b. Qualification by DesignLights Consortium or other – as required by incentive
c. Luminaire photometric reports – per IES LM-79
d. Manufacturer period of warranty – per LightSavers Model Technical Specifications
e. Vibration resistance – per ANSI 136.31
f. Correlated colour temperature (CCT) – per MSSLC Model Specification for LED Roadway Luminaires
g. Colour rendering index (CRI) – per DesignLights Consortium technical requirements
h. Illuminance cut-off – per IDA recommendations
i. Luminaire efficacy (lumens emitted per watt) – per U.S. DOE LED Lighting Facts average
j. Total harmonic distortion (THD) – per ANSI C82.77
k. Operating temperature range – per local climate
l. Damp- or wet-location rating – per Underwriters Laboratory (UL) standards
m. Period of maintenance free operation for luminaire and photocell – per current industry average
n. Housing ratings – per ATSM D1654 and ASTM B117
o. Compliance with RoHS II

Published model technical specification guides provide further details on the above specifications; select guides are listed under *Section 5* below. Additional procurement resources include publically available municipal LED streetlight RFPs.

Before LED suppliers and products are pre-qualified, the municipality can invite the RFQ bidders to present their products for testing and preliminary evaluation. Conducting a pilot project with these products allows for practical analysis of the following luminaire parameters:

a. Compliance with the designated specifications;
b. Fixture aesthetics;
c. Light quality and apparent brightness; and
d. Ease of installation and maintenance.

If Cities have not previously implemented LED streetlights, pilot projects are important to ensure selected products perform in their application and match manufacturer's performance claims. Based on pilot results and the results of a municipal RFQ, a list of prequalified products is developed. The municipality should consider that the more products listed, the greater the opportunity for competitive, and thus favourable, pricing, generally.

2. DEVELOP & ISSUE RFP

Services requested through the LED streetlighting RFP will vary depending on the determined purchaser and procurement method. If design, installation and maintenance will be completed by City staff, the RFQ process described above becomes the only procurement process and the bid is awarded to one luminaire manufacturer. In this case, pricing should be solicited through the initial process to get competitive offers. If an installing contractor is required, a RFP for installation is developed in addition to the luminaire RFQ.

For municipalities that require outside LED design development and installation services, two RFPs can be developed; one seeking consulting engineers for design and the other, contractors for installation. The municipality can also pursue a complete turnkey solution. This RFP will request bidders to supply solutions for removal, design, supply, installation and maintenance of LED streetlighting. Some local utilities provide turnkey services, however municipalities are still recommended to go through a competitive bidding process to ensure the most effective and cost-efficient option is selected.

For RFPs that include design or LED procurement services, the required lighting standards to be followed by the contractor must be outlined. For streetlight design, proposals should follow IES RP-8 minimum lighting levels for the specified road classifications and pedestrian conflicts present in each design. If the City does not conduct a prequalification process and requests the contractor to procure LEDs, a list of technical specifications and standards, as would be developed for the RFQ, is included in the RFP.

To evaluate bids submitted for either an RFQ or RFP, a municipality should use a pre-determined scoring system, an example of which is outlined in the TAC Roadway Lighting Efficiency and Power Reduction Guide. Through this method, a weighting is assigned to each item requested and a score to each response. The awarded bid is then selected based on the highest sum of these factors multiplied for each RFQ/RFP specification.

3. ADAPTIVE CONTROLS

With the potential energy savings and future opportunities presented by smart adaptive lighting controls, most cities are, at minimum, future-proofing by selecting control-compatible LEDs. Many have implemented pilot projects as part of their LED streetlight conversions to evaluate and demonstrate potential energy and public service benefits. Most local utilities are not yet comfortable with or prepared for adaptive controls, but pilots can help facilitate this conversation and educate on how to incorporate controls into the billing system. Some Canadian cities, such as Mississauga and Halifax, have implemented LED streetlighting plans that include networked adaptive controls on all luminaires. These pioneering projects are valuable references for other municipalities considering controls.

Procurement of adaptive controls is complex because of the available system types and the different components of each. A fixed system, the simpler of the two options, consists of fixture-mounted controls that are not connected. Networked systems require the following three interacting parts: field devices, a central management system, and a networked infrastructure (CSA EXP05-15). Technical specifications for a controls system can be written into the LED project RFQ or RFP or done as a separate procurement process. If the awarded LED manufacturer also supplies controls, the municipality can work with them to develop a pilot project. For more information on adaptive controls procurement and their technical specifications, the U.S. DOE MSSLC and LightSavers have both developed informational documents listed in Section 5 below.

4. PROJECT IMPLEMENTATION

For successful project implementation, an installation plan is developed to meet deadlines and minimize public disruption. Many municipal LED streetlight programs are awarded energy efficiency incentives that are conditional on specified timelines. To produce a realistic action plan, cities should reference similar projects in size that have begun installation to estimate project metrics such as number of installs per day with what number of crews and effects on traffic. Municipalities may also specify straight-line installation and coordination with any active roadworks to avoid constant changing of install locations.

Using city crews allows for more control on project activities but requires more oversight. If hiring an installing contractor, the city can include in the contract financial disincentives (Liquidated Damages) and incentives for being late or early. This method was successfully used by the City of Hamilton where the contractor completed installation more than a month early. While these types of provisions can be effective, they should be reviewed by municipal procurement or legal advisors before being included in a contract. Liquidated damages must represent a genuine pre-estimate of the probable loss that would result from the late completion of the contract. A lawyer should be consulted before including Liquidated Damages provisions in a contract to ensure they will be enforceable. Cities can also include the requirement to provide installation schedules in the RFP to receive proposed timing, installation expectations and projected rate of delivery from multiple contractors.

Manufacturers will also impact project deadlines. Most manufacturers currently do not have the capacity to produce LEDs as fast as the incumbent technology. Again, cities can request manufacturers provide information on production times for the LED options specific to the project prior to awarding the RFP. Another option, if using a contractor, is to provide the prequalified LEDs list in the RFP, along with the timeline, and allow the contractor to select the most appropriate LED which will depend partially on production schedules.

To monitor installation progress and report on the contractor's performance, the city should also develop an inspection plan to be conducted by a consultant or city staff. Having an accurate and updateable inventory is key. A GIS-based inventory map with luminaire performance as an input value is an effective and efficient tool for installation and inspection. The city should commence inspection soon after installation begins to ensure this task does not affect timelines and that contractors are on schedule to meet the deadlines.

5. RESOURCES FOR PROCUREMENT

The LightSavers **Model technical Specifications for Procurement of LED Luminaires in Canada v. 2.0** was updated in 2015 and outlines recommended technical performance, electrical and mechanical criteria for LED specifications; focussing on cobra head style luminaires. The document is to be used by lighting asset managers as guidance for LED product selection while still considering local conditions and experience. The guide also provides sample submission sheets that can be used in RFPs or RFQs. The Guide is found at:
http://www.canurb.org/lightsavers/

The LightSavers **Adaptive Controls for Roadway and Parking Lighting: A LightSavers Primer** is designed to introduce lighting managers to the technical impacts of integrating adaptive controls into a lighting system, along with the current challenges to implementation. The document outlines what controls do, factors to consider in the decision making, system configurations and examples of existing uses. The Primer is found at:
http://www.canurb.org/lightsavers/

The MSSLC **Model Specification for LED Roadway Luminaires v. 2.0** is an editable document intended as a template for the lighting manager (municipality, utility or other) to customize for each project. Like the LightSavers guide, it helps managers specify preferred technical parameters for LEDs and develop submission sheets but it is targeted more towards American municipalities. This document and other relevant MSSLC resources are found here: http://energy.gov/eere/ssl/outdoor-lighting-resources

The MSSLC **Model Specification for Networked Outdoor Lighting Control Systems v. 2.0** is editable document for lighting managers to complete as recommended content for an RFQ, RFI, RFP or other procurement requests. It outlines suggested technical specifications for the different components of a networked system while allowing the author to modify sections to suit local conditions and standards. This document and other relevant MSSLC resources are found here http://energy.gov/eere/ssl/outdoor-lighting-resources

The **DesignLights Consortium (DLC)** is a collaboration of utilities and regional energy efficiency organizations that is funded by its members and helps accelerate the adoption of energy efficient lighting solutions. The DLC Qualified Products List (QPL) is an industry resource developed for procurement and listed products that adhere to DLC specifications. These specifications are based on the DLC Technical Requirements, another useful resource for LED procurement.The homepage is found at: https://www.designlights.org/

The **U.S. DOE LED Lighting Facts** is a similar program to DLC where it evaluates LED products based on performance testing results in comparison to industry standards recognized by Lighting Facts. The homepage is found at: http://www.lightingfacts.com/

The **International Dark-Sky Association** (IDA) an organization dedicated to protecting the night skies from light pollution, and thereby, human health, wildlife and climate change. The IDA developed a Fixture Seal of Approval (FSA) for luminaire specifications relating to colour, shielding and light distribution. The homepage is found at: http://darksky.org/

The **CAN/CSA-C653 - Photometric Performance of Roadway and Street Lighting Luminaires** is a National Standard of Canada that outlines minimum photometric performance specifications for roadway and streetlighting luminaires of HPS, MH, induction and LED light sources. This Standard can be purchased at the CSA shop: http://shop.csa.ca/

The **CAN/CSA-C811 - Performance of Highmast Luminaires for Roadway Lighting** is another National Standard of Canada and outlines the minimum performance requirements specifically for highmast luminaries used in roadway lighting. This Standard can be purchased at the CSA shop: http://shop.csa.ca/

B.C. Hydro's **How to Purchase LED Street Light Luminaires through LED Street Lights Across B.C.** is technical specification guide that was developed for municipalities in B.C. and lists procurement resources specific to B.C. This guide can be used by cities in other provinces to cross-reference other technical recommendations. This document is found with other B.C. resources at: http://www2.gov.bc.ca/gov/content/governments/services-for-government/bc-bid-resources/goods-and-services-catalogue/led-street-light-luminaires

PHASE VII: MAINTENANCE & COMMISSIONING

1. COMMISSIONING

Developing a commissioning plan is important for the project's long term functionality and sustaining performance quality. Commissioning verifies and documents that the project systems are planned, designed, installed, tested, operated and maintained to fulfill the expected end results as defined by the owner (municipality). A networked adaptive control system is extremely useful for commissioning by providing remote performance monitoring, reporting and control.

As outlined by the IES DG-29-11 document, *The Commissioning Process Applied to Lighting & Control Systems*, there are four phases to the commissioning process as it relates to lighting and controls projects, each described below:

1.1. PRE-DESIGN PHASE

Effective commissioning begins before project design to define objectives and requirements and ensure these are monitored throughout the entire project process. Pre-design commissioning includes:

a. Forming the **Commissioning Team**, which consists of an appointed Commissioning Agent or Authority (can be in-house or third-party consultant), the project owner (municipality), lighting designer and other professionals as needed.
b. The **Commissioning Plan** is developed by the Commissioning team and outlines procedures for project commissioning, including roles and responsibilities for each team member and indicators that verify project quality.
c. The **Owner's Project Requirements (OPR)** is a formal pre-design commissioning document that defines the expected end results of the lighting project, and is referenced throughout the design and construction phases.

1.2. DESIGN PHASE

Following completion of the OPR, the lighting design team develops the Basis of Design (BOD) commissioning document to outline how the project design will fulfill the OPR. This should include descriptions of the lighting system (and controls if used), energy efficiency targets and manufacturer and maintenance requirements. The Commissioning Team reviews and approves the BOD before further developing functional test procedures and documentation formats to monitor commissioned components of the lighting system.

1.3. CONSTRUCTION PHASE

It is the responsibility of the Commissioning Team to coordinate and direct commissioning activities during the construction phase using consistent protocols and documentation. Commissioning work will mainly be completed by the contractor and design team, and consists of the following;

a. **Performance Testing** where the contractor will follow procedures outlined by the design team to test the new lighting components and ensure performance requirements are met, for example through light-level tests to ensure design standards are met.
b. A **Systems Manual** developed by the Commissioning Team detailing the operation and maintenance requirements of the new lighting system in preparation for post-installation occupancy. This phase may also require training for in-house personnel on new operations and maintenance procedures.

1.4. OCCUPANCY/OPERATIONS PHASE

On-going commissioning is recommended post-installation. The owner and other in-house personnel can use the Systems Manual developed in the construction phase to ensure the lighting system meets the OPR and to access the resources necessary if the system fails. It is also recommended that the original Commissioning Team revisits the installation site after 10 months to conduct evaluation on the operating system. At this time, the Team can revise commissioning procedures if needed and resolve outstanding problems.

2. MAINTENANCE PROGRAM

Unlike incumbent high-intensity discharge (HID) lamps that burn out, LEDs are generally considered to fail when their lumen output depreciates to less than 70% of the initial output, however this can vary depending on the service life calculation method used. Current LED streetlight products should provide a service life of 100,000 hours (25 years in typical applications). It can be assumed that lighting technology in 25 years will be significantly more efficient, physically dissimilar and potentially not compatible with current fixtures. It is likely, that prior to the end of 25 years, it will be economical to replace the current LEDs with a new product. Consequently, when converting LEDs, municipalities must also modify maintenance operations and develop a long-term program.

2.1. LUMINAIRE FAILURE

To assess reliability of newer electronics, such as LEDs, which do not have proven service life in the field, Mean Time Between Failure (MTBF) analysis methods can be used. These define and predict reliability and failure rates based on validated industry methods. MTBF results are important in assessing long-term product quality and designing maintenance programs.

Due to the long life of LEDs, the expected low failure rate and manufacturer warranty programs (5-10 years), cities do not typically have to stock replacement streetlight components as they would have with HID technology. Furthermore, LED failures are typically limited to the driver (power supply) and photocells, whereas HID luminaires can fail at the ballast, lamp, igniter and/or photocell. If a municipality chooses to stock replacement parts, they need fewer products for LEDs than HIDs, however, under the LED warranty, the manufacturer will likely replace the entire luminaire. As previously outlined in *Phase V*, the desired product warranty should be written into the RFQ and/or RFP.

2.2. LUMINAIRE CLEANING

Due to LED longevity, most of the revised maintenance program will address managing luminaire dirt depreciation (LDD) that directly impacts the Light Loss Factor (LLF). To fully realize the light quality and power usage improvements of LED luminaires, the product LDD must be accurately established to confirm the expected service life (i.e. that minimum lighting levels would be met at the end of the manufacturer's claimed product life). The LDD of one LED product cannot be assumed the same as another because optical components of LEDs can vary significantly. Current understanding of these varying LDD values is minimal, however, the IES has begun research on this topic with the Virginia Tech Transportation Institute.

Cleaning procedures of the new LED lighting system should be based on manufacturer's recommendations but are likely to consist of at-luminaire cleaning with a cloth and cleaning solution. Power washing from the ground will not typically be effective unless the luminaire is very close. Furthermore, power washing may be destructive if too high of a pressure is used.

Once a cleaning method is determined, a cleaning schedule is developed based on location conditions (residential, commercial, industrial…etc.) and a financial analysis to determine optimum cleaning frequency. To confirm the effectiveness of the maintenance program, the city should perform periodic lighting level audits. In addition, after a determined length of service since installation, horizontal and vertical illuminance should be measured at a selected section of LED luminaires pre- and post-cleaning. This will establish the actual LDD and can be used to modify maintenance programs.

3. RESOURCES

The **IES DG-29-11 The Commissioning Process Applied to Lighting & Control Systems** outlines technical requirements of commissioning for lighting and control systems that will ensure owner performance criteria of new construction are achieved. The document further details the four commissioning phases summarized above. This guideline is available through the IES shop at: http://www.ies.org/store/

Measure and Report Luminaire Dirt Depreciation (LDD) in LED Luminaires for Street and Roadway Lighting Applications by the Virginia Tech Transportation Institute as a response to the IES RFP, further describes the operational issues regarding LDD of LEDs and outlines their research in progress with IES. Available under IES Sponsored Research Projects at: https://www.ies.org/research/rap.cfm