THE CITY OF CALGARY
ROADS

E2 ENERGY EFFICIENT STREET LIGHTING PROGRAM UPDATE TECHNICAL REPORT

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The City of Calgary, Roads
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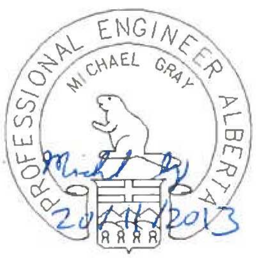

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Executive Summary

After the completion of an LED street lighting proof of concept project over the period spanning February 2011 to February 2012 and receiving approval on Administration's recommendations to Council, Roads undertook a more detailed assessment of other energy efficient street lighting technologies. Based on this qualitative and quantitative assessment, Roads has identified LED technologies as the best-fit option for The City. This technology choice will assist in achieving energy savings, the required levels of lighting, product safety, and longer-term reliability targets in comparison to The City's current inventory of street lights in addition to induction, and light emitting plasma alternatives.

In order to ensure the right LED technology is chosen for the variety of Calgary's road configurations and lighting level requirements, Roads is currently developing a detailed requirements specification. This document will guide future procurement activities along with providing guidance to Calgary's development industry, should LED technologies be incorporated into new neighbourhoods.

Roads will be undertaking an extended trial of LED street lights in on up to 2,100 high pressure sodium fixtures in 5 neighbourhoods over the first quarter of 2014, using existing capital budgets. This extended trial will provide Roads the information and experience necessary to develop a detailed business case and implementation plan for a potential larger scale conversion program. The information to be collected includes citizen opinion, the approach to conducting a detailed design using LED technologies, commodity and labour costs and the supply to installation process.

Feasibility Assessment of Energy Efficient Street Lighting Technologies

In February 2012, Calgary Roads completed a proof of concept project, evaluating light emitting diode (LED) street lighting technologies to evaluate the potential cost savings. This project confirmed that reductions in energy and maintenance costs could potentially be achieved through the implementation of LED technologies in Calgary's street lighting system. As discussed at the December 13, 2012 meeting of the Standing Policy Committee on Transportation and Transit (SPC on T&T), other energy efficient technologies which are also available in the market have the potential of meeting The City's requirements.

In 2013, Roads, in conjunction with Infrastructure & Information Services (the Project Team), commissioned DMD & Associates Ltd. Electrical Consultants (DMD) to work with The City to conduct a feasibility assessment of prevalent and emerging energy efficient street lighting alternatives to high-intensity discharge (HID) lamps. HID lamps such as high pressure sodium, mercury vapour and metal halide technologies currently make up almost all of Calgary's street light inventory. DMD was selected through an RFP processes for their extensive experience in evaluating and incorporating energy efficient street light technologies in addition to developing guidelines for the Illuminating Engineering Society of North America (IESNA) and the Transportation Association of Canada (TAC). The qualitative and quantitative assessment below is extracted from a document delivered by DMD to Roads, dated August 2013.

The Project Team identified 3 technologies for assessment, including light emitting diode (LED), light emitting plasma (LEP), and induction lighting (QL). Descriptions of these technologies are provided below:

Qualitative Overview of Technologies Assessed

Induction (QL)
QL-lamps, also referred to as induction lamps, use an induction coil to create a magnetic field inside an electron/ion plasma. Inside the lamp mercury vapour generates ultraviolet (UV) light, which excites a phosphor coating on the inside surface of the glass globe, causing the phosphor to glow with a visible light. Due to their long life, QL-lamps are effective at reducing maintenance costs. Induction technologies are limited to a small number of manufacturers, are difficult to focus and control due to their large size, and are known to have failure rates higher than LED before end of life. The QL lighting technology has been available for over 20 years, however its usage has been very limited to very niche market applications by few manufacturers. From an optical efficiency standpoint it less effective than LED due to the large sized lamps and reflector.

Light Emitting Plasma (LEP)
Plasma lamps are a type of electrode less lamp energized by radio frequency (RF) or microwave power. This light source has suffered a number of practical problems and to date has not prospered commercially. These problems have gradually been overcome, and Light Emitting plasma (LEP) lamps have been introduced to the general lighting market, although by a limited number of manufacturers. Due to the small number of manufacturers, lighting performance data is also limited. Limited photometric information has limited the ability of Roads to effectively compare this option against others. It is however a technology which has potential, and is worth considering specifically at higher wattages (400W and above) as the technology matures.

Light Emitting Diode (LED)
With LEDs, manufacturers are much better able to control the light distribution as opposed to High Intensity Discharge (HID) Discharge (HID) or Induction lighting and, as such, offer a very broad choice in optical systems. LED luminaries offer a number of small point sources of light. This makes for far greater optical efficiency than traditional high intensity discharge sources, which utilize large lamps. The small light sources make for very good beam control with a high level of light beam efficiency.

As LEDs are “semi-conductors,” the light output from these fixtures do depreciate over time, however this depreciation can be addressed through the lighting design process and detailed specifications.

Manufactures have invested hundreds of millions of dollars in LED's as they see this as the future of lighting. Much of this has and continues to go into R&D so LED's will continue to develop.
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Quantitative Analysis of Technologies Assessed

In additional to the qualitative research noted above, DMD Engineering developed a luminance calculation model to assess performance of the potential technologies and anticipated energy consumption for three common road types[1]. These road types included:

1. Local roads with low pedestrian activity
2. Collector roads with a medium pedestrian activity level; and
3. Arterial roads with a medium pedestrian activity level.

[1] Given the emerging nature of LEP technologies, photometric data is limited, resulting in the exclusion of this technology from lighting calculations.

All road attributes were specified in accordance with The City of Calgary Design Guidelines for Subdivision Servicing (2012) and guidance by the Roads Street Lighting Design Team. Based on this calculation model, LED technologies presented the best alignment with desired light levels and the largest potential savings in comparison to the wattage range of HPS lamps typically used on these road types. The results of the calculation are summarized below in **Table 1.**

Table 1: Illuminance Calculations of Potential Energy Efficient Street Lighting Technologies

	Road Type	Desired Light Level	Achieved Avg. Light Level	Required Fixture Rating (Watts)	Baseline Range (Watts)
LED (4000K)	Local Residential	$0.3\ cd/m^2$	$0.36\ cd/m^2$	71.1	100 – 150
LED (5000K)			$0.31\ cd/m^2$	42.9	
QL			$0.26\ cd/m^2$	177.0	
LED (4000K)	Collector	$0.6\ cd/m^2$	$0.67\ cd/m^2$	53.8	150 – 250
LED (5000K)			$0.76\ cd/m^2$	42.9	
QL			$0.61\ cd/m^2$	177.0	
LED (4000K)	Arterial	$0.9\ cd/m^2$	$0.97\ cd/m^2$	107.5	250 – 400
LED (5000K)			$0.90\ cd/m^2$	81.4	
QL			$0.44\ cd/m^2$	177.0	

Safety of LED Lighting Technologies

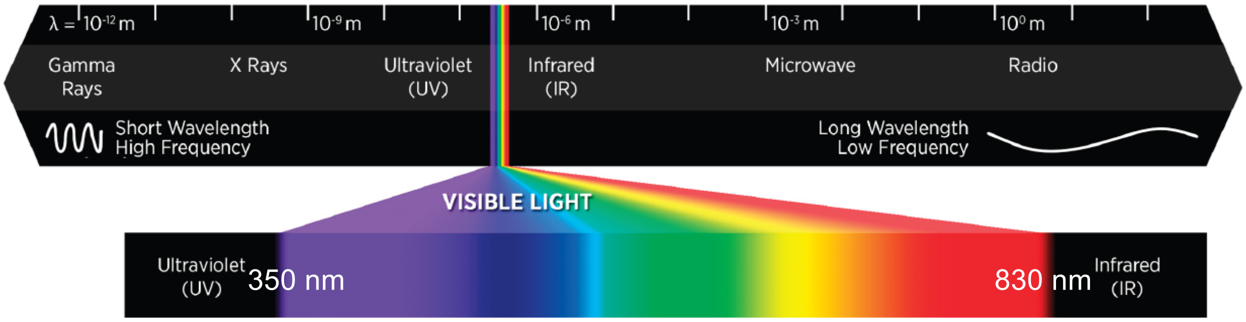
Recent LED street light installations in The City of Lethbridge have sparked debate in Alberta due to citizen concerns related to the amount of light that is emitted by these fixtures in the blue-white end of the visible light spectrum. Specific concerns are related to the impact of chronic exposure to blue-white light while the human body is supposed to be asleep, potentially leading to health problems.

With further details provided below, Roads is implementing a detailed design approach combined with a two staged procurement approach to selecting and installing LED fixtures on Calgary's roads. This will minimize glare, up-light, and backlight related issues (known as light trespass). This reduces the perceived risk noted above, as the LED technology is used to avoid light from spilling onto or into properties.

Where the impact of lighting is of a specific concern on residential roadways, warmer LED fixtures will be selected, thereby increasing the wavelength of light emitted by these street lights. This decreases the perceived brightness of the light. This approach will ensure the right fixture is selected for a variety of roads types and configurations on that road to ensure the configurability of the fixture is leveraged. This will reduce light trespass and glare onto properties and into homes, thereby limiting exposure to light at night time.

Additionally, misconceptions regarding the risk of UV radiation from LED street lighting products were also addressed in the feasibility study conducted by DMD and Roads. Visible light is just one portion of the entire electromagnetic spectrum. Visible light, which is cited to extend from as low as 350 nm to as high as 830 nm, is found between ultraviolet radiation and infrared radiation on the electromagnetic spectrum, as illustrated in **Figure 1** below.

Figure 1: Electromagnetic Spectrum



LED lighting technologies produce blue light by passing an electron through a silicate based component called a P-N Junction. This produces blue light in the 400 – 550 nm range which then passes through a phosphor coating to produce white light, predominantly at the 400 to 900 nm range. As such, light produced by an LED fixture is emitted in the visible end of the electromagnetic spectrum. Energy emitted at wavelengths shorter than 400 nm, which could potentially be in the UV end of the spectrum, is insignificant or non-existent. It is also important to put into context that the location and height that street lights are installed at (typically 9m on residential roads) poses a minimal potential risk of exposure.

Feasibility Assessment Conclusions

Based on the findings of the feasibility assessment, Roads will be proceeding with an extended trial of LED technologies on Calgary's roads, as further discussed below.

Requirements Specification for LED Street Lights

Roads also engaged DMD to assist in the development of a requirements specification document for LED street lighting after the completion of the feasibility assessment. This document is intended to assist in the procurement of LED street lights, in addition to defining the requirements for the optional use of LED technologies in new neighbourhoods in Calgary. The requirements specification has been developed by identifying the specific requirements of lighting Calgary's wide-variety of road types. The specification also references recent guidance developed and issued by the Transportation Association of Canada. Lessons learned from a number of Canadian LED street lighting implementation projects are being incorporated in addition to consultations between DMD and a number of prominent LED lighting manufactures.

The requirements address a variety of specifications grouped under the following categories:

1. Fixture performance over time and the required proof of this performance;
2. Specifications for power supply and divers, including efficiency testing requirements;
3. Housing and mounting specifications; and
4. Warranty and manufacturing requirements, including longer-term reliability testing.

The Project Team is working with IIS, Engineering & Energy Services Division, in the review of the requirements specifications proposed by DMD. This is a review of the conformance of the specifications with electrical engineering standards and requirements of The City and to build on lessons learned from other City LED lighting projects.

LED Street Lighting – Extended Trials

From February 2011 to February 2012, Roads undertook a small-scale implementation of LED street lights on a single street type (local residential) as a means by which to prove that efficiency gains could be achieve. However, this proof of concept is not an adequate sized project to address all the considerations which must be made in designing a sustainable and efficient street lighting system which conforms to relevant guidelines. These guidelines include those issued by the Transportation Association of Canada (TAC) and the Illuminating Engineering Society of North America (IESNA).

As recommended by Administration in TT2012-0343 and approved by Council on December 17, 2012, continued trials of LED street lights are planned to start in early 2014. These conversions will be funded by existing capital budgets under the 2012 to 2014 budget cycle. This extended trial will provide Administration the necessary information and experience to develop a well informed business case and project plan for potential, larger scale implementation program. This information would be presented to the SPC on T&T at a later date in 2014 for consideration under the 2015 to 2018 Business Planning & Budget Cycle.

Up to 2,100 HPS street lights ranging from 100 to 400 Watts will be converted to LED in five communities including: Altadore, Marda Loop, Douglasdale, Tuxedo Park, and Marlborough.

The extended trial has been limited to fixtures ranging from 100W to 400W fixtures. Based on the analysis of the Project Team, LED technologies have not matured to the point of providing adequate lighting for fixtures in Calgary's inventory above 400W, which are typically installed on higher traffic roadways.

Some questions have been raised as to why HPS to LED conversions must be undertaken as larger-scale projects in place of ad-hoc replacement of fixtures at end-of-life or for those which have failed. In response, it will be difficult to maintain consistent lighting levels as the LED's distribute light differently. In addition the effect of mixing the white light source of LED with the orange source high pressure sodium will create an inconsistent appearance which could impact visibility. The effect could potentially be annoying to drivers. Eye adaptation could also be impacted resulting in reduced visibility. From a financial perspective, larger scale projects achieve economies of scale with regards to purchasing power and the cost of installation. The cost of a service call to a single failed street light is approximately $250. The installation costs for LED fixtures are anticipated to be significantly lower.

Selection of Trial Areas

The above noted extended trial communities were selected to ensure:

1. An adequate cross section of community demographics were included. This will better support a more comprehensive community consultation exercise to solicit the opinions of a wider-demographic of Calgarians on LED lighting; and
2. As Calgary has matured and grown, street designs have also changed. The above noted communities were selected in order to provide insight into the lighting design approach and photometric requirements that will address a breadth of Calgary's street types and street light wattages. This design will be completed using a computer assisted modeling approach. Considerations include: pole spacing, pole configuration, pole condition, pole height, road segment width, road segment length, presence of sidewalks, pedestrian traffic volumes, vehicular traffic volumes, age of neighbourhood, and age of existing street lights.

Detailed Design

A detailed design approach is being developed by the Project Team for the extended trail. This approach will utilize LED technologies to their full extent resulting in maximum benefit. This approach is recommended by the Transportation Association of Canada and has been used by many cities that have or in the process of incorporating LED technologies across the country. The process to completing the detailed design approach is summarized below in **Figure 2**

Figure 2: Summary of Detailed Design Process

After selecting the extended trial areas and the collection of the required data, a “baseline design” is under development to better understand the current state of lighting in the extended trial areas. This will be done by computer lighting modeling backed-up by some field light level measurements. The baseline design will specifically help identify where lighting levels are in excess or deficient with relation to recommended guidelines.

Through the procurement approach (described in detail below), Roads will be enabled to incorporate best-fit options recommended by RFP respondents into the detailed design to see which achieves the required level of lighting over the lifespan of the street light. LED lighting has much broader range of optical configurations than with traditional fixtures. DMD will undertake lighting calculations backed up by field measurements so minimum lighting level requirements are met while minimizing light wastage and maximizing fixture efficiency. The goal is meet the lighting levels defined by TAC, as lighting beyond these levels has shown little of no real benefit.

Roads has been working with Infrastructure & Information Services (IIS Geospatial Business Solutions) to identify and collect the geospatial data necessary to perform a detailed design.

At the December 17, 2012 meeting of Council, a question about the ability for LED fixtures to light walkways alongside roadways was raised with General Manager Malcolm Logan. Specifically, the ability to light these areas while maintaining existing pole infrastructure was questioned. The Project Team is specifically focusing on how we can achieve TAC recommended lighting levels for roadways and walkways, without the need for any additional infrastructure changes. This practice has been achieved in other LED applications in Calgary, including Calgary Transit LRT Park-&-Ride lots.

Procurement Strategy

Referencing the requirements specification, Roads will be releasing an RFP for up to 2,100 fixtures to satisfy the supply of street lights required to complete the extended trial. An option to extend this contract to an additional 2,100 fixtures will be included in the RFP should the budget allow for additional installations.

The procurement strategy will also incorporate components of the detailed design approach into the selection of proposed products from each manufacturer. Manufacturers will be provided with the necessary information and tools to ensure the products they are proposing will address each of the unique design requirements identified in the first stages of the detailed design processes.

The RFP will solicit unit pricing for proposed products. For budgetary purposes and in preparation of a business case for future work, the RFP will also ask prospective manufacturers and their proposed financing agents to provide unit pricing for repayment based on savings achieved by the use of LED fixtures.

A second stage in the RFP processes will result in a more detailed evaluation of a shortlisted number of products. This shortlist will be developed through the first phase evaluation based on those products which appear to meet The City's needs as defined in the specifications.

As identified in the December 13, 2012 meeting of the SPC on T&T, the effect of LED lighting on Calgary's roads and citizens is very important to understand. Different manufacturers use different technologies in the way light is dispersed and delivered to a specified area. The lighting effect can be difficult to determine in its entirety through a typical modeling approach. To address this, shortlisted product manufacturers will be required to provide samples for installation to evaluate the lighting effect in the field as a final stage of evaluation.

A request for quotation processes has been recommended by Supply Management to address the labour costs associated with installation services related to the extended trail.

The proposed request for proposals and quotations processes will provide Roads with the information necessary to deliver a better informed business case and implementation plan to the Standing Policy Committee on Transportation and Transit by 2014 Q2, on a larger scale implementation.

A question was raised during the December 13, 2012 meeting of the SPC on T&T with regards to the impact of a change in technology on warehousing costs. It is important to note that Roads has specifically addressed the lifespan of an entire LED assembly (including all components) in the requirements specification. This includes the testing requirements indicative of rigor and accuracy in determining the rated lifespan of a streetlight assembly. Fixtures rated for 20 years or more are the standard specification. Specific warranty requirements and responsibilities of the manufacturer are defined in detail. Lead time on manufacturing and delivery are also defined.

Based on these specifications, it is anticipated that there would be little to no impact on warehousing costs to The City. This is related to the low failure rates for LEDs in comparison to HPS fixtures and the warranty specifications assigning responsibility to the manufacturer for provision of replacements in the chance of failure. Favorable manufacturing lead times will also reduce the need for fixture stocking requirements.

Measurement, Monitoring, and Verification

Post installation, Roads will be conducting lighting levels analysis to ensure that anticipated lighting levels are being achieved. The adaptive lighting capabilities specified during the procurement process will facilitate spot adjustments in lighting levels should they be required.

Roads, along with The Energy Management Office will be working with ENMAX during the product selection phase and post installation to ensure that the anticipated energy savings are also realized. This will likely be achieved through in-situ metering at select locations and through the adaptive lighting technologies being piloted at select locations during the extended trial. Adaptive lighting technologies will facilitate remote monitoring of energy consumption to near utility level metering and will serve to corroborate anticipated levels of energy savings.

Billing Processes & Asset Management

Roads is working with the Energy Management Office and Roads Traffic Operations, Asset Management Team to define an acceptable processes which will facilitate updates to street light electricity billing to ensure the savings associated with the extended trial and future installations are realized. This process will also ensure that street light attributes are accurately updated in the Corporate Asset Registry and will serve as a template for future work.

Communications & Engagement

A communications plan has been prepared by Roads Communications Team to support the extended trial project.

This project will provide Roads with the opportunity to share information with citizens to ensure the community understands the benefits and any potential risks associated with the extended trial and any subsequent installations. In the mid 70's, Calgary converted Mercury Vapour street lights to High Pressure Sodium technologies. This resulted in a change in colour rendering associated with the lights on Calgary's streets. An LED conversion program will result in a significant positive change in colour rendering, brightness, and lighting quality. It is very important to ensure Calgarians are well prepared for these changes and know what to expect.

The extended trial will also enable Roads to solicit community feedback as installations are completed and combine these results with feedback received on other LED lighting projects implemented by the Transportation Department.

The communications tactics which make up the proposed communications plan are summarized in **Error! Reference source not found.** below.

Table 2: Planned Communications Tactics

Tactic	Details	Timeline
Individual emails (with Briefing Note) and possibly meeting with affected Councilors (if requested)	Inform Councilors in wards impacted by the trial in advance of T&T. Discuss what technology will be used, and where it will be installed, include project details and FAQ.	Late Nov. 2013
Briefing note to all Council	Explaining the project and details.	Early Dec 2013 (before T&T)
Web page on Calgary.ca	Include details of the pilot, next steps and FAQs regarding LED lighting etc.	Early Dec 2013 (after T&T)
Develop 311 SR online	Put on the webpage so people can provide feedback	Early Dec 2013 (same time as webpage goes up)
Letters to community association, ward offices and local businesses, message boards informing area commuters	Include details about new lighting technology that is going to be installed in their area. What are the benefits, reasons for choosing their community and how to provide feedback.	Mid Dec 2013

Press release	To include details regarding the type of technology, what LED lighting is, and what the pilot is.	Mid Dec.2013
City Blog	Discuss the upcoming installations, what the benefits are, include messages regarding Edmonton's technology share, council direction etc.	Mid Dec.2013
Social Media – Twitter	Link to blog story/Calgary.ca page.	Mid Dec. 2013
QR codes on light poles	This will link to the webpage and will provide citizens with a quick and easy way to get information on the project and provide feedback through a potential survey.	Jan 2014
Meetings with Community Associations	Attend the community association meetings in areas with LED lighting. Hear feedback/concerns from the community association about the trial.	Late Feb.2014
Video blog post	Ongoing tactic, depending on installation dates. Interviews with citizens who were part of the pilot, talk about benefits, and installations for the long term.	TBD - some filming during installs, first release in late Dec. Add on feedback from community members, etc in new year - release second version video in Feb.

City of Edmonton Technology Exchange

In 2013, The City of Edmonton and The Calgary Parking Authority announced an innovative technology exchange. In June, the City of Edmonton launched a six month trial to assess the applicability of Calgary's Park-Plus technology in Edmonton.

The City of Edmonton has been a leader, in Alberta, for the use of LED technologies in street lighting. The technology exchange will see The City of Edmonton provide Calgary with lessons learned regarding the detailed design approach in addition to assistance in actually performing detailed designs for the incorporation of LED technologies on streets in Calgary's industrial parks.

With the combined experience of DMD, along with the expertise of Edmonton, Calgary Roads will be better prepared to plan for, and deliver on a larger scale, an LED street lighting program in the future.