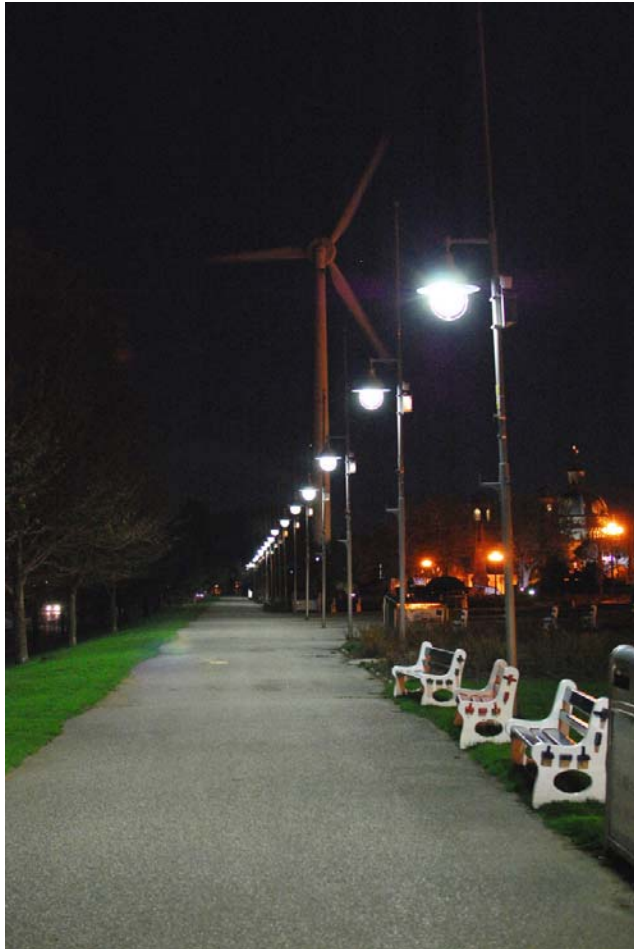


EXHIBITION PLACE

Field Testing of LED Exterior lighting

FINAL REPORT — January 27, 2012



Background:

The GREEN ENERGY INITIATIVE - Field Testing of LED Exterior Lighting - Pilot Project consists of retrofitting lighting along a pedestrian pathway that extends along almost the entire south side of the Exhibition Place campus. The original lighting system consisted of High Pressure Sodium 130 watt fixtures that required bulb changes every few years, and cast a foreboding orange glow. The new lighting system uses an equal number of LED fixtures manufactured by Philips Lumec. Each fixture consumes about 40 watts and emits a high-quality white light similar to moonlight. However, the most significant innovation is that all of the fixtures are equipped with occupancy sensors to dynamically adjust the light levels based on user needs. It's believed that about 70% of the time the lights will be on the low setting, using just 10 watts. The net result is a projected total energy savings of 85%.

Exhibition Place has been an active participant in the LightSavers program. The Toronto Atmospheric Fund (TAF) founded LightSavers in 2008, with support from Natural Resources Canada, the Ontario Power Authority, and participating municipalities in the Greater Toronto region. The LightSavers project aims to accelerate deployment of advanced lighting technologies – Light Emitting Diodes (LEDs) and smart controls – in order to reduce energy use and greenhouse gas emissions.

In March 2012, LightSavers entered its third phase: the creation of a national market consortium that aims to step up the adoption of LED lighting and smart adaptive controls in certain general illumination applications across the country. LightSavers Canada will assist municipal and provincial governments, public institutions, and private companies that own or manage lighting assets learn from each other about LED and smart control performance, procurement, and financing. LightSavers Canada is managed by the Canadian Urban Institute.

This field test was carried out by Exhibition Place and its consultants and contractors, with technical assistance on monitoring and evaluation from the TAF. Exhibition Place is Canada's largest entertainment venue, attracting over 5.3 million visitors a year. The 192-acre site is an integral component of Toronto and Ontario's economy, particularly with respect to conventions, sport, festivals, recreation, culture and tourism. Located at Exhibition Place is the award-winning Direct Energy Centre, Canada's largest exhibition and convention centre, and the Allstream Centre LEED Silver conference venue. Since 2004, Exhibition Place has undertaken an environmental stewardship initiative, entitled GREENSmart; which includes the promotion of sustainable development, environmental initiatives and leading edge green technologies and practices across the site. Our environmental initiatives have resulted in award winning recognition across North America, such as the Platinum Waste Minimization Award from the Recycling Council of Canada and have established Exhibition Place as a world leader in energy-efficient technologies

This field study was carried out with assistance from the Green Municipal Fund, a Fund financed by the Government of Canada and administered by the Federation of Canadian Municipalities. Notwithstanding this support, the views expressed are the personal views of the authors, and the Federation of Canadian Municipalities and the Government of Canada accept no responsibility for them.

For more information on the LightSavers project, see www.lightsavers.ca.

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Disclaimer – mention of any commercial product, device, measurement instrument or specific lighting engineers/consultants in this document does not represent an endorsement.

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1.0 Executive Summary

This is the final report on the Exhibition Place LED Pilot Project undertaken as part of the City of Toronto's LightSavers Program. The project involved replacement of fifty eight (58) high pressure sodium pathway and parking lot fixtures with fifty (50) new Light Emitting Diode (LED) fixtures manufactured by LUMEC Lighting (LUMEC is a Canadian based company owned by Philips). The purpose of the project was to evaluate whether the LED fixtures could be a viable and energy efficient alternative to the HPS pathway and parking lot fixtures commonly deployed in Toronto and across North America. Specific factors considered in this report include illuminance, uniformity, lumen depreciation (lifetime), temperature sensitivity, energy consumption, and economic performance. The pilot location is the pedestrian pathway that extends along almost the entire south side of the Exhibition Place campus in Toronto, Ontario.

Pedestrian area lighting utilized similarly styled area luminaire as previously used in this location. Lamp wattage and mounting height were tailored to meet the recommended maintained luminance values for sidewalks. The IESNA recommended illumination level is 10 lux or 1 foot-candle.

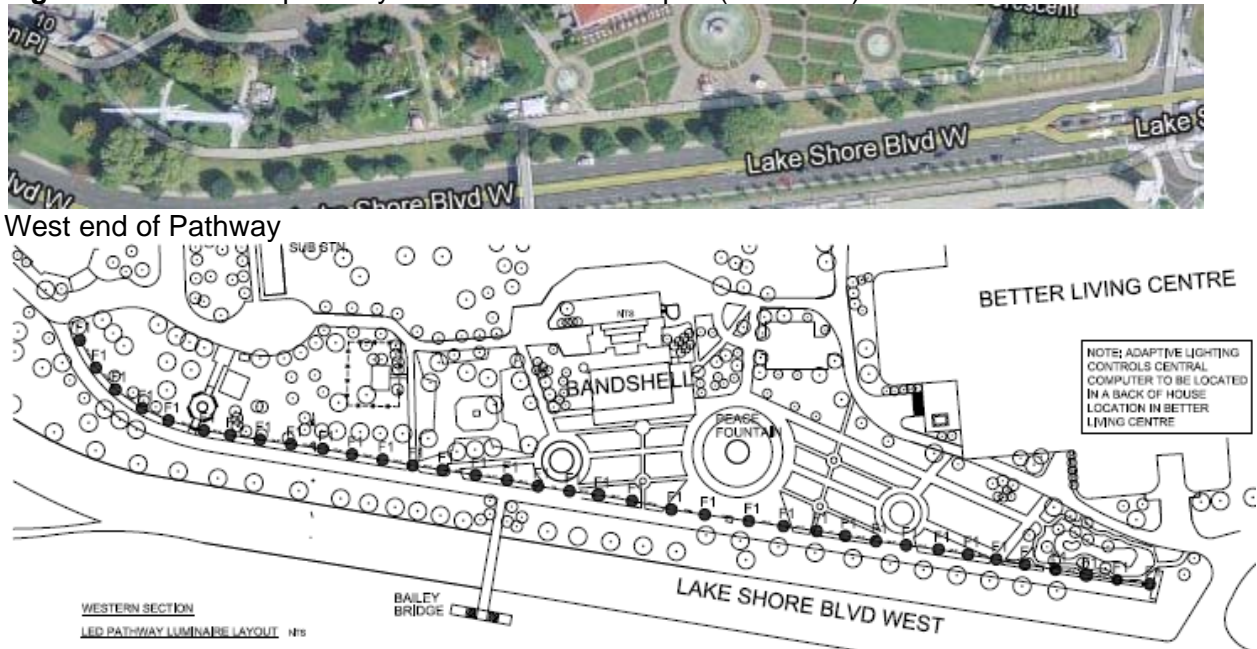
Data has been collected over an eight-month period beginning in May 2011. The key findings are summarized below:

- Average illuminance in the Pathway area was maintained in compliance with IESNA pathway lighting guidelines.
- 70% of the time the lights are on the default low setting, using just 10 watts, the net result is a total energy savings of 77%.
- Depreciation in illuminance over eight months in one of the test areas was measured at 14.1%, which was significantly higher than anticipated. There was no observable depreciation in illuminance in the second test area. It must also be noted that the light meters are only accurate to +/-5%
- The new LED fixtures are projected to result in an 85% reduction in long-term maintenance costs
- The LED fixtures are projected to pay for themselves through energy and maintenance savings within 9 years
- The new LED luminaires are exceeding required light levels and providing excellent uniformity.
- The long-term financial benefit of the LEDs depends on whether the fixtures meet the manufacturer claimed life-expectancy of 70,000 hours (~16 years).

2.0 Site Description

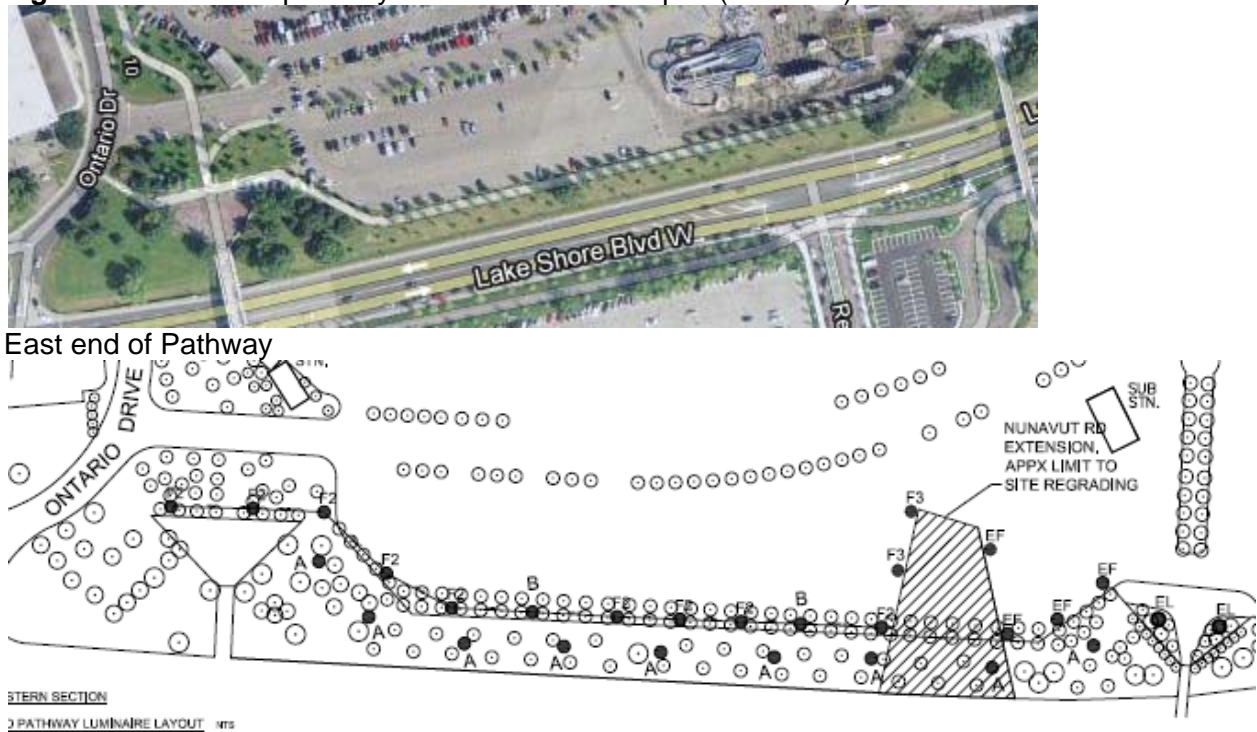
Installed by Exhibition Place in April 2011, the pilot site is a pedestrian pathway that extends along almost the entire south side of the Exhibition Place campus, beginning right beside the iconic wind turbine, and traveling east towards Nunavut Road. The original lighting system consisted of 58 High Pressure Sodium fixtures which used 130 watts each, required bulb changes every few years, and cast a foreboding orange glow. The new lighting system uses fifty LED fixtures manufactured by Philips Lumec. Thirty-eight (38) fixtures located on the west end of the path consume about 40 watts and 12 fixtures located on the east end of the path consume 90 watts. Each of the respective wattages emit the same high quality white light similar to that of moonlight in colour.

Figure 1: South side pathway of the Ex-Place campus (West end)



F1 = 40Watt LED Luminaires

Figure 2: South side pathway of the Ex-Place campus (East end)



F2, F2 and B = 90Watt LED Luminaires
EF Luminaires were replaced with new HPS for comparison testing.
EL luminaires were existing LED
A luminaires were removed

The site was initially illuminated by fifty eight 100 Watt High Pressure Sodium luminaires. These were replaced 38 fixtures located on the west end of the path that consume about 40 watts and 12 fixtures that are located on the east end of the path consume 90 watts. The new LED luminaires utilized the same spacing and mounting height. The LED fixtures are Lumec Transit series, manufactured by Philips Lumec, these luminaires use the Life LED Lamp, Composed of 49 high performance white LEDs, 40 watt and 90 watt respectively. Color temperature of 4000 Kelvin nominal, 70 CRI. Operating lifespan, 70 000 hours. Use of a metal core board ensures greater heat transfer and longer lifespan of the light engine

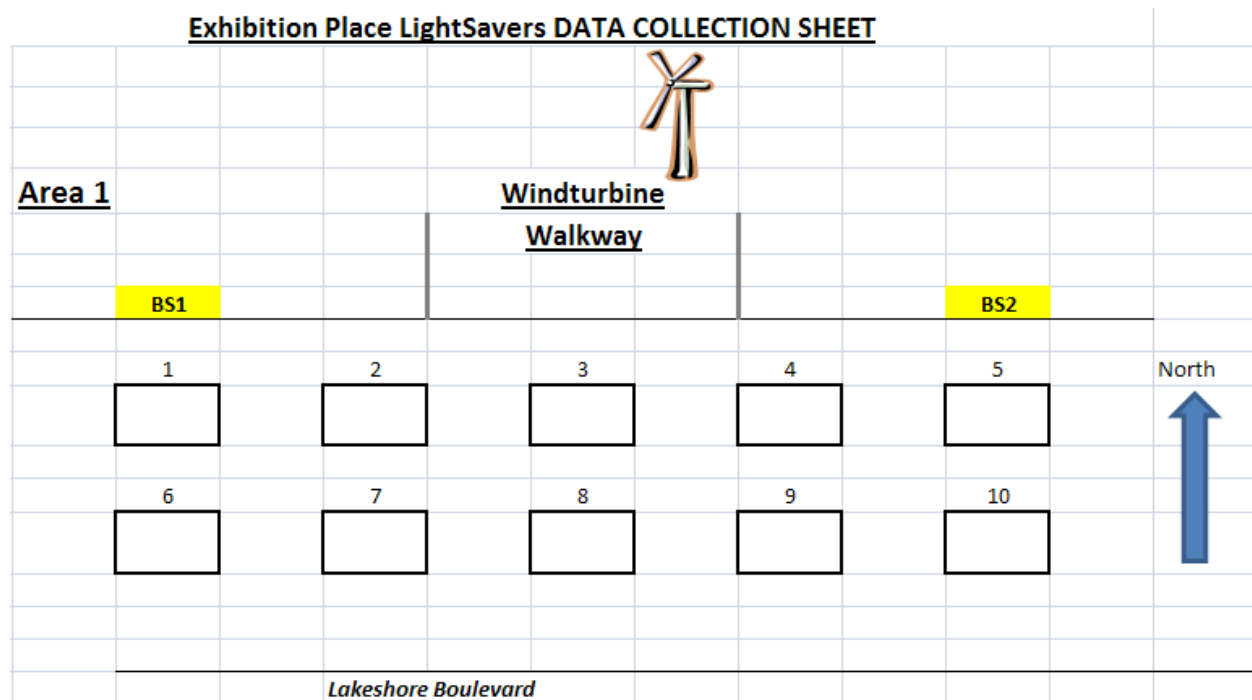
3.0 Performance Assessment Methodology

This pilot project was evaluated using the LightSavers Monitoring and Evaluation Protocol, developed by TAF in collaboration with the Ontario Centre for Environmental Technology Assessment (OCETA). The full protocol is available at www.lightsavers.ca.

There are four new HPS luminaires installed on the east path of Nunavut Road. These luminaires have been installed for comparison purposes.

This measurement grid was designed and marked on the pathway lot for future reference.

Figure 3: Measurement Grid



Exhibition Place Lightsavers data collection sheet.

The letters 'BS1, BS2' denotes a fixture. Note that each pole has one fixture. The grid is located in the centre pathway. It is to be noted that the measurement grid used does not follow IESNA recommended practice, which would require more data points and vertical illuminance measurements. However, the values are valid and the difference in average illuminance in this case is significant.

Following the baseline measurements, the new LED fixtures were installed and operated for approximately 300 hours prior to any measurements. Initial measurements of both power and illuminance were taken May, 2011. Data was collected on site for a 12 month period.

Further illuminance measurements were taken on a randomized date approximately once per month. All measurements were taken at least one hour after sunset. Temperature and atmospheric conditions were recorded at the time of measurement.

4.0 Results

4.1 Illuminance

Location, West end of pathway: Luminaire spacing 12.5 meters

The existing 130W HPS luminaires had an average illuminance of 15 lux with a max;min ratio of 2.5, and an avg:min ratio of 1.5.

The new 40 watt LED luminaires have an average illuminance of 15 lux with a max;min ratio of 1.7, and an avg:min ratio of 1.3.

While this illuminance value is lower than observed with fresh HPS lamps, it is substantially higher than required under the IESNA pathway lighting guidelines. The new 40 watt LED luminaires maintained the existing average illuminance levels while improving the uniformity of the light.

Location, East end of pathway: Luminaire spacing 20.5 meters

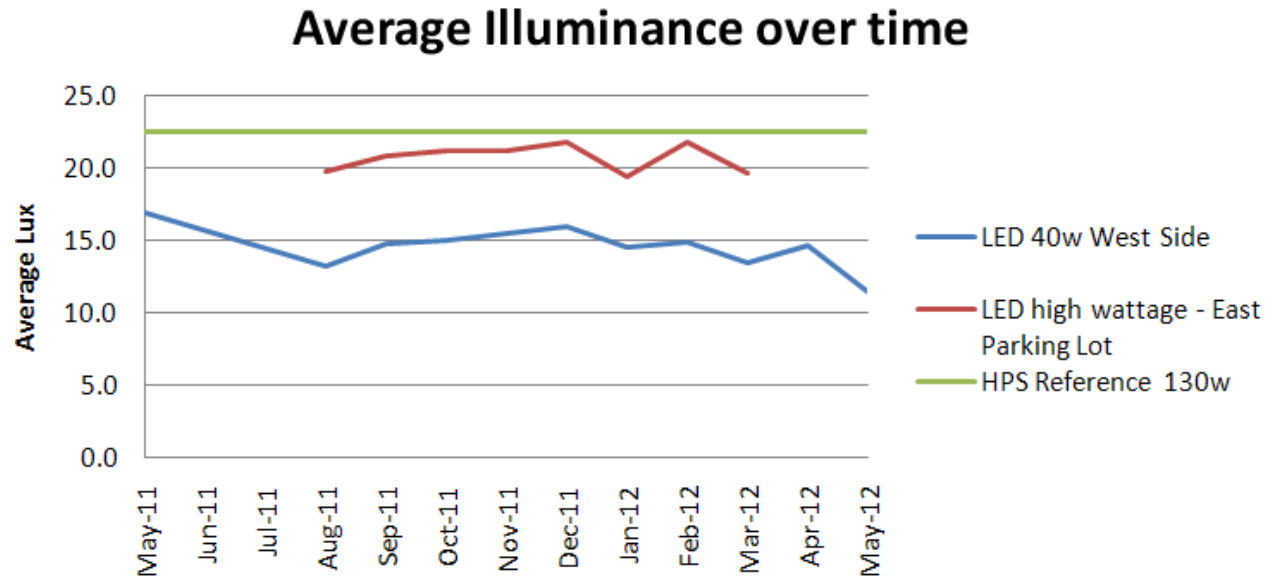
The existing 130W HPS luminaires had an average illuminance of 15 lux. with a max;min ratio of 5, and an avg:min ratio of 3

The new 90 watt LED luminaires have an average illuminance of 20.7 lux with a max;min ratio of 1.8, and an avg:min ratio of 1.3

Note that subsequent to re-lamping the HPS luminaires had an average illuminance of 22.5 lux.

Note that the east end of pathway had a luminaire spacing of 20.5 meters. In order to meet IES recommended illuminance requirements a 90 watt LED luminaire was specified. The new 90 watt LED luminaires improved the existing average illuminance levels while also improving the uniformity of the light.

Figure 4: Average Illuminance



HPS Reference based on Initial Start up illuminance measurements only.

Table 1: Illuminance Data / 40 Watt

DATE	LED 40w Measure Points										AVERAGE	MAX:MIN	AVG:MIN	% LLD	TEMP	Conditons
	1	2	3	4	5	6	7	8	9	10						
5-May-11	17.3	21.7	17.7	17.6	16.3	13.1	19.1	17.7	16.2	13	17.0	1.7	1.3		14	clear
11-Aug-11	11.6	19.0	15.1	15.0	11.0	8.1	16.3	15.2	13.7	7.9	13.3	2.4	1.7	21.7%	31	clear
22-Sep-11	14.6	19.1	15.5	15.2	13.9	11.6	16.8	15.9	14.2	11.8	14.9	1.6	1.3	12.4%	17	clear
17-Oct-11	15.0	19.5	15.5	15.5	13.8	11.7	16.7	16.1	14.2	11.9	15.0	1.7	1.3	11.7%	11	clear
25-Nov-11	14.5	20.2	15.8	15.5	14.0	14.6	17.7	16.6	14.4	11.8	15.5	1.7	1.3	8.6%	5	clear
19-Dec-11	17.6	20.2	16.2	16.0	14.6	14.9	17.3	16.5	14.9	12.4	16.1	1.6	1.3	5.4%	3	cloudy
19-Jan-12	15.4	12.1	15.6	15.8	14.5	12.1	16.9	16.4	14.4	12.6	14.6	1.4	1.2	14.1%	-5	overcast
2/22/2012	15	18.3	15.4	15.4	14	11.9	16.3	16.4	14.5	11.8	14.9	1.6	1.3	12.2%	-1	clear
3/15/2012	16.6	12	15.2	15.4	13.8	11.3	9.2	15.4	14.4	11.6	13.5	1.8	1.5	20.5%	11	overcast
25-Apr-12	14.7	18.9	15	15.1	13.7	12.1	16.5	15.2	13.7	11.4	14.6	1.7	1.3	13.8%	9	clear
5/30/2012	11.3	10.9	14.3	14.7	11.4	7.8	8.6	14.4	13.1	7.9	11.4	1.9	1.5	32.6%		

Table 2: Illuminance Data / 90 Watt

LED high wattage - East Parking Lot										
DATE	Measure Points						AVERAGE	MAX:MIN	AVG:MIN	% LLD
	1	2	3	4	5	6				
5-May-11										
11-Aug-11	28.6	16.9	25	17.2	14.2	16.4	19.7	2.0	1.4	
22-Sep-11	28.5	18.3	27.1	17.2	15.6	18.0	20.8	1.8	1.3	-5.4%
17-Oct-11	29	18.6	28	17.6	15.5	18.2	21.2	1.9	1.4	-7.3%
25-Nov-11	29.8	18.5	27.2	18.2	15.6	17.8	21.2	1.9	1.4	-7.4%
19-Dec-11	30.7	18.7	28.5	18.2	16.2	18.3	21.8	1.9	1.3	-10.4%
19-Jan-12	23.8	16	20.6	18.8	20.5	16.7	19.4	1.5	1.2	1.6%
22-Feb-12	30.4	18.7	28.1	18.5	16.2	18.7	21.8	1.9	1.3	-10.4%
15-Mar-12	29.4	14	27.7	17.5	11.2	17.8	19.6	2.6	1.8	0.6%
25-Apr-12	n/a	n/a	n/a	n/a	n/a	n/a				
30-May-12	27.8	19.5	26.9	16.5	16.6	17.7				

Table 3: NEW High Pressure Sodium Luminaires (East Parking Lot)

<i>Reference</i>	HPS - East Parking Lot						
	<u>Measure Points</u>						
<u>DATE</u>	1	2	3	4	5	6	AVERAGE
5-May-11	28	18.2	23.8	22.2	23.5	19.3	22.5

The values are reasonably consistent and in keeping with the measurement range and tolerance of the light meters used (Cooke cal-LIGHT 400). The values collected demonstrate that the LED pathway lights are significantly exceeding the IESNA recommendations despite the lower power consumption.

4.2 Uniformity

The uniformity of the LED pathway lights are significantly better than the HPS lights, and better than the IESNA recommendations. The table below compares the uniformity of the HPS lights to the LED lights.

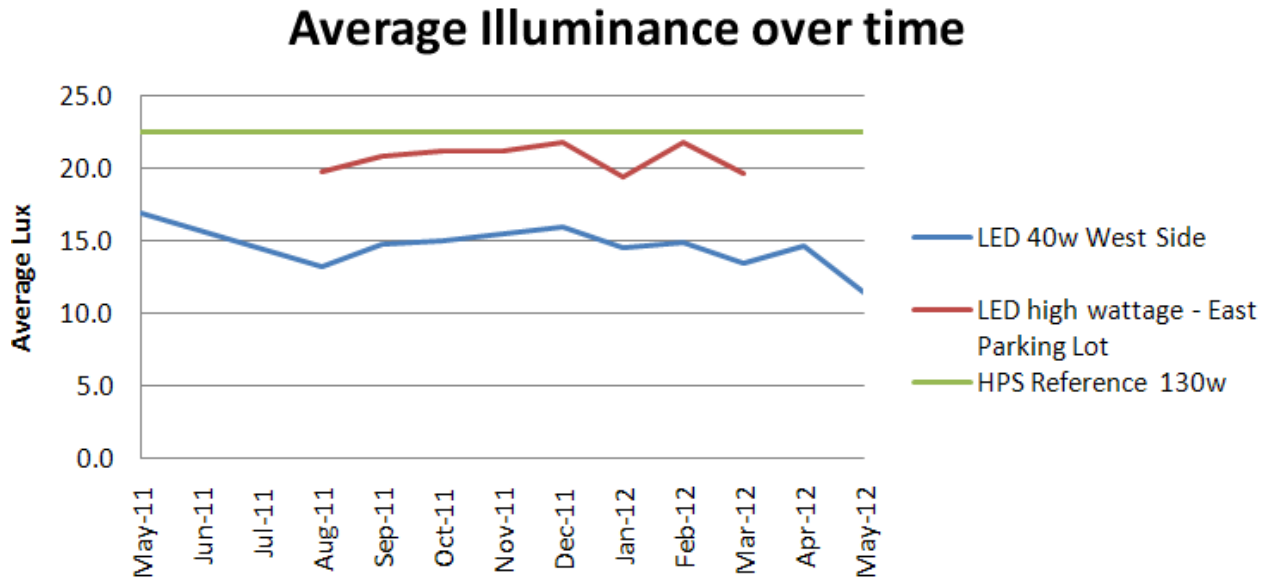
Table 2: Uniformity

	Average to Minimum	Maximum to Minimum
Original HPS (12.5m spacing)	2.5	1.5
New LED 40 Watt	1.7	1.3
Original HPS (20.5m spacing)	5.0	3.0
New LED 90 Watt	1.8	1.3
New HPS (130w)	1.2	1.5

4.3 Average Illuminance over Time

Uncertainty over the useful lifetime of LED luminaires is one of the key barriers to widespread adoption of the technology. Therefore one of the objectives of the LightSavers pilots is to test the actual Illuminance values of LED's in real site conditions over time. Unlike conventional lighting technologies, LED light sources generally do not burn out but rather gradually decline in lumen output. End-of-life for LED luminaires can vary based on site specific requirements, but is generally considered to be the point when lumen output has declined to 70% of the original value (referred to as L70).

Note that the data collected is Illuminance on the pavement, not source lumens. Other factors than lumen depreciation will contribute to reductions in horizontal illuminance such as environmental factors and dirt depreciation on the luminaire.

Figure 4: Average Illuminance over 12 Months

HPS Reference based on Initial Start up illuminance measurements only.

As can be observed above, average illuminance in the 40 watt LED test area exhibits substantial reductions over the course of the pilot. As LED light output is known to undergo substantial variability in the first 1000 hours of operation, these measurements have been factored out of the illuminance depreciation calculations. The resulting illuminance depreciation in this area is 14.1%, which is still substantially higher than expected based on the lifetime of the fixture. It must be noted that illuminance meters are only accurate to within 5%, however the unexplained depreciation exceeds this error margin. Continuing observation is required to determine if the illuminance values will stabilize or continue depreciating rapidly resulting in premature fixture failure.

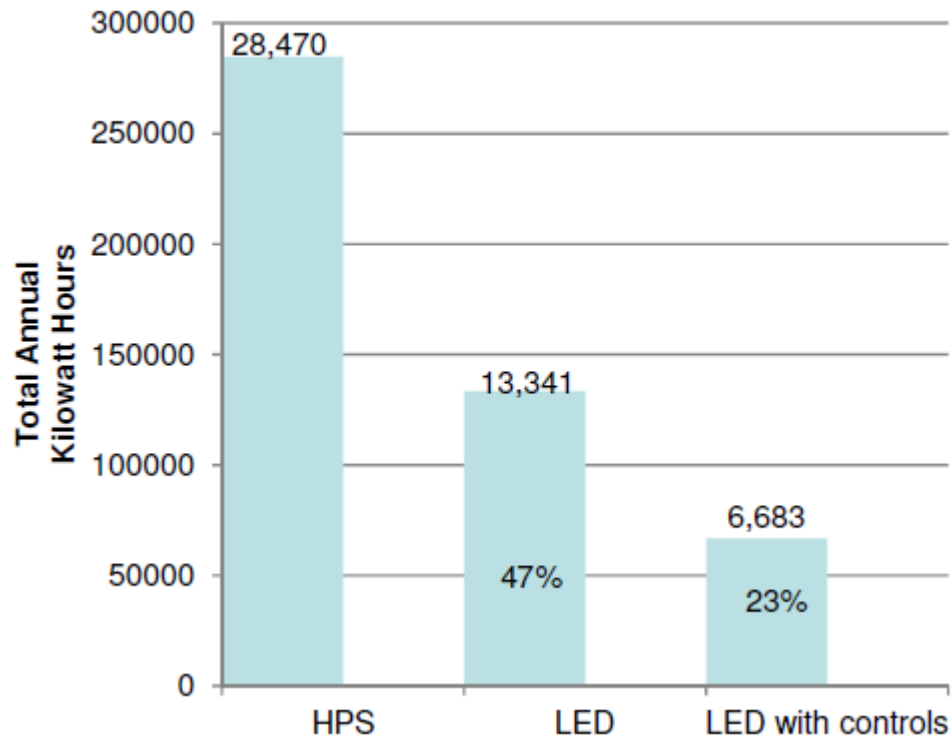
However, in the high wattage LED test area there is no trend towards depreciation in illuminance values. In fact the final measurements were slightly higher than the initial measurements.

4.5 Power and Energy

Input power for the Philips Lumec Life-LED fixtures ranged from 47 to 105 Watts. Estimated input power for the original HPS fixtures is 130 Watts, including ballast.

40 Watt LED power consumption, the savings are 83 watts per fixture or 64%.
 90 Watt LED power consumption, the savings are 25 watts per fixture or 20%.

Fixture	Power (Each Fixture)
HPS	130w
LED	47w
LED	105w

Figure 5: Power Usage

5.0 Conclusions

It appears that the LUMEC Life- LED pathway lights do a credible job of replacing conventional High Pressure Sodium technology at considerable energy savings.

Average illuminance on site was increased or maintained while power consumption was reduced by 77%. This difference is partly attributable to the differences between HPS and LED source technology, but a large portion is attributable to the occupancy controls. As well as the photometric inefficiency of the specific HPS luminaires which were replaced. Those considering implementing LED technology should bear in mind that the energy savings and financial benefits of replacing conventional pathway lighting fixtures are highly dependent on the baseline efficiency of the specific fixtures being replaced.

The long-term financial benefits of the LED luminaires depend upon the product meeting the manufacturer's estimate of a 15+ year lifespan. Lumen depreciation appears to be higher than anticipated in the low wattage LEDs; however depreciation in the high wattage LEDs is well within specifications.

Appendix A:**Pedestrian Lighting**

Pedestrian area lighting to utilize similarly styled area luminaire as used in roadway application. Lamp wattage and mounting height are to be tailored to meet the recommended maintained luminance values for sidewalks. The recommended illumination level will be of Type A classification (see chart below), this target level is 10 lux or 1 foot-candle.

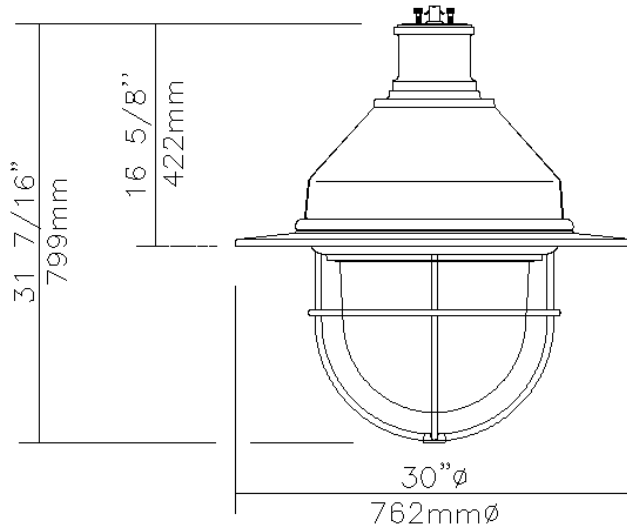
Recommended Maintained Illuminance Levels for Pedestrian Ways

Taken from Table 2 IESNA DG-5-94 recommended lighting for Walkways and Class 1 Bikeways

Walkway & Bikeway Classification	Min. Avg. Horizontal Illuminance Levels on Pavement* (lux/ft)	Avg. Vertical Illuminance Levels for Special Pedestrian Security** (lux/ft)
Sidewalk (Roadside) & Type A Bikeways:		
Commercial Areas	10.0 lux / 1 ft	20.0 lux / 2 ft
Intermediate Areas	5.0 lux / 0.5 ft	10.0 lux / 1 ft
Residential Areas	2.0 lux / 0.2 ft	5.0 lux / 0.5 ft
Walkway Distance from Roadways & Type B Bikeways:		
Walkways and Bikeways	5.0 lux / 0.5 ft	5.0 lux / 0.5 ft
Pedestrian Stairways	5.0 lux / 0.5 ft	10.0 lux / 1 ft
Pedestrian Tunnels	20.0 lux / 2 ft	5.0 lux / 0.5 ft

*Uniformity ratio should not be greater than 10:1 maximum to minimum

**For Pedestrian identification at a distance. Values are specified at 1.8 meters (6 feet) above the walkway

Appendix B: Philips LUMEC, Life LED, Transit Series

Qty	38	Type : F1 Luminaire TR20-40W49LED4K-ACDR-LE3A-120-DMG-GRD-GY3TX-LMS53097B
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Description of Components:

Hood: Cast 356 aluminum dome, mechanically assembled on the luminaire.

Guard: (GRD), In a round shape, this guard is made of bent aluminum rods, 1/2in (13mm) outside diameter, welded to the access mechanism.

Skirt: Spun 1100-0 aluminum, mechanically assembled on the luminaire.

Light Engine: LifeLED™ composed of 5 main components: **Globe / LED lamp / Optical System / Heat Sink / Driver**

Electrical components are RoHS compliant. Optical system patents pending

Globe: (ACDR), Made of one-piece seamless injected-molded impact-resistant (DR) acrylic having an inner prismatic surface. The globe is mechanically assembled and sealed onto the lower part of the heat sink.

Lamp: (Included), Composed of 49 high performance white LEDs, 40w lamp wattage. Color temperature of 4000 Kelvin nominal, 70 CRI. Operating lifespan, 70 000 hours after which the system emits 70% of its original lumen output, all of those parameters are tested for 100% of light engines. Use of a metal core board insures greater heat transfer and longer lifespan of the light engine

Optical System: (LE3A), I.E.S type III (asymmetrical). Composed of high performance collimators, optimized with varying acrylic beam angles to achieve desired distribution. System is

rated IP66. Performance shall be tested per LM63 and LM79 (IESNA) certifying its photometric performance. Street-side indicated.

Heat Sink: Made of cast aluminum optimising the LEDs efficiency and life. Product does not use any cooling device with moving parts (passive cooling device)

Driver: High power factor of 99%. Electronic driver, operating range 50-60 Hz. **Auto-adjusting to a voltage between 120 and 277 volt AC, Class II**, THD of 20%. Maximum ambient operating temperature from -40F(40C) to 130F(55C) degrees. Certified in compliance to CUL requirement. Weather tightness rating IP66. Assembled on a unitized removable tray with Tyco quick disconnect plug resisting to 105F(40.5C) degrees.

The current supplying the LEDs will be reduced by the driver if the internal temperature exceeds 203F(95C), as a protection to the LEDs and the electrical components. Output is protected from short circuits, voltage overload and current overload. Automatic recovery after correction.

Surge Protector: LED Driver 3 poles surge Protectors that protect Line-Ground, Line-Neutral, and Neutral-Ground in accordance with IEEE / ANSI C62.41.2 guidelines.

Access-Mechanism: A die cast A360 aluminum technical ring with latch and hinge. The mechanism shall offer toolfree access to the inside of the luminaire. An embedded memory-retentive gasket shall ensure weatherproofing.

Luminaire Options: (DMG), Dimming compatible 0-10 volt.

Type: F2, F3, B Qty 12 Luminaire TR20-90W49LED4K-ACDR-LE3A-120-DMG-GRD-GY3TX- LMS53097A
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Description of Components:

Hood: Cast 356 aluminum dome, mechanically assembled on the luminaire.

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Electrical components are RoHS compliant. Optical system patents pending

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Lamp: (Included), Composed of 49 high performance white LEDs, 90w lamp wattage. Color temperature of 4000 Kelvin nominal, 70 CRI. Operating lifespan, 70 000 hours after which the system emits 70% of its original lumen output, all of those parameters are tested for

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Heat Sink: Made of cast aluminum optimising the LEDs efficiency and life. Product does not use any cooling device with moving parts (passive cooling device)

Driver: High power factor of 99%. Electronic driver, operating range 50-60 Hz. **Auto-adjusting to a voltage between 120 and 277 volt AC, Class II**, THD of 20%. Maximum ambient operating temperature from -40F(40C) to 130F(55C) degrees. Certified in compliance to CUL requirement. Weather tightness rating IP66. Assembled on a unitized removable tray with Tyco quick disconnect plug resisting to 105F(40.5C) degrees.

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Access-Mechanism: A die cast A360 aluminum technical ring with latch and hinge. The mechanism shall offer tool free access to the inside of the luminaire. An embedded memory-retentive gasket shall ensure weatherproofing.

Luminaire Options: (DMG), Dimming compatible 0-10 volt.

End of Report.

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