LED: Lightsavers

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THE CLEAN REVOLUTION

SYDNEY LED TRIAL: FINAL REPORT

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ACKNOWLEDGEMENTS

The City of Sydney has participated in a unique global trial of LED outdoor lighting organized by The Climate Group. The key aim of the project was to test the performance of a variety of LED luminaire products in real world field conditions, comparing these products with baseline high intensity discharge (HID) lamps using the same measurement protocol and equipment. Other cities participating in the initiative were: London, New York, Toronto, Adelaide, Hong Kong, Kolkata, and Thane, a suburb of Mumbai, and Quezon City, the Philippines. Chinese cities Guiyang and Tianjin also participated as observers.

The LightSavers global LED trials ran from October 2009 to January 2012 and aimed to provide greater certainty about the state of LED technology. During the trials, lighting managers from nine of the cities independently tested the performance of more than 500 luminaires representing 27 different commercially available LED products, using the same measurement protocol. Key findings of the trials were:

- LEDs achieve the expected 50 to 70 percent energy savings and reach up to 80 percent savings when coupled with smart controls;
- Even with these energy savings, the vast majority of tested products exceeded local lighting standards;
- Many commercial LED products tested show behavior indicative of lifespans of 50,000 hours, though the results from the trials should not be used for predictive purposes;
- LED products generally show very little change in color;
- The ‘catastrophic’ failure rate of LED products over 6,000 hours is around one percent, compared, for example, up to 10 percent for metal halide fixtures over a similar time period;
- In cities where surveys were conducted, the public prefers LED illumination, with about 90 percent of survey respondents supporting a full rollout of LEDs across city street lights.

It should be noted that the LED luminaire product tested in this trial was designed and manufactured several years ago. It would be expected that recent generations of products should exhibit even better performance. The Climate Group’s LightSavers trial concludes that LEDs are now mature enough for scale-up in most outdoor applications, and that LEDs combined with smart controls promise greater savings.

The City of Sydney’s participation in the global trial made an important contribution to the global trial results. The author of this report, Philip Jessup, would like to thank George Angelis, Manager, City Infrastructure and Traffic Operations, and Paul Gowans, Senior Contract Coordinator, for their leadership and enthusiastic support for the project. They provided timely data and related information for this report.

Finally, the author would like to thank Natural Resources Canada for additional support allowing the author to extend analysis in all the LightSavers trials. The LightSavers program was founded by the Toronto Atmospheric Fund. LightSavers is a registered mark of the Toronto Atmospheric Fund, licensed to The Climate Group for use in the United States and elsewhere outside of Canada.

Executive Summary

For the 14-month period December 2010 - February 2012, the City of Sydney tested three LED luminaires along St. George Street in the central business district and compared them with baseline 250 watt metal halide lamps previously employed on the same street. Here is a summary of the trial results to date:

1. **Illuminance**. Two of the three LED luminaires, SYD-1(b) and SYD-1(c), exceeded the average horizontal illuminance criteria for this site. One LED luminaire, SYD-1(a) did not meet the minimum criteria, since at 45 watts it was significantly undersized.

2. **Correlated color temperature (CCT)**. There was a minor shift in CCT of the LED products over the period of the trial, in the range of four percent or less on an annualized basis.

3. **Energy**. The three LED luminaires reduced electricity use in the range of 63-to-85 percent—with adaptive control dimming in the off mode—compared with the baseline metal halide luminaire, an impressive result.

4. **Luminaire target area system effectiveness.** The LED luminaires were significantly more effective at directing light to the surface of St. George Street. Indeed, the LED luminaires used approximately three times less energy to deliver a unit of average illuminance to the surface, compared with the baseline.

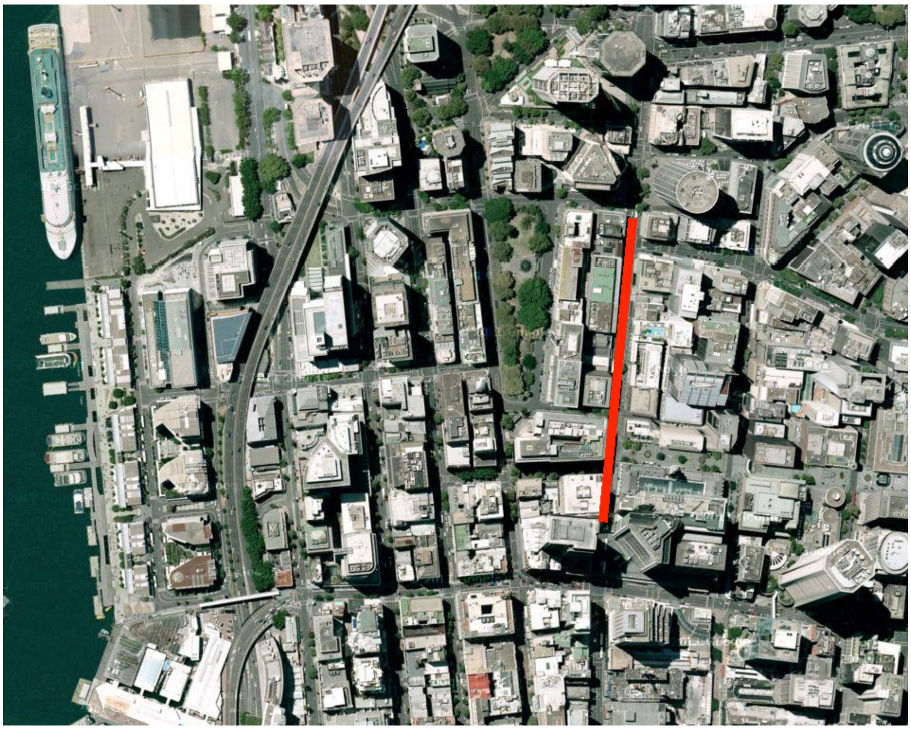
5. **Lumen maintenance**. For the purpose of this trial and study, we assumed a lifetime of 50,000 hours for the three LED products tested. Thus, lumen depreciation exceeding 2.8 percent on an annualized basis, net of Luminaire Dirt Depreciation (LDD), would be less desirable than a value in the range of 2.8 percent or less. The lumen output of all three LED luminaires increased, in the range of 2.2 to 8.3 percent on an annualized basis, after an initial burn in period of 1,000 hours, an impressive result. Since dirt deprecation was not determined in the trial, it would be expected that actual lumen maintenance would be even better than measured. Evidence that light output would be sensitive to hot summer temperatures was inconclusive.

In conclusion, building on the City of Sydney's previous LED streetlight pilots, the results of the LightSavers trial should increase staff's confidence that LED technology has reached technical maturity and can meet its illumination needs while cutting energy use significantly. Two of the three LED luminaires, SYD-1(b) and SYD-1(c) performed extremely well compared with the baseline metal halide lamp. SYD-1(b) stood out for its target area effectiveness of 3.6, i.e., it produced 3.6 times the average illuminance in the sampling area than the baseline metal halide luminaire. Hence, this 109 watt LED luminaire was able to replace the 250 watt metal halide luminaire and produce equivalent illuminance in the target area. The third luminaire, SYD-1(a), was considerably undersized at 45 watts. However, its performance on all other parameters was excellent.

On December 5, 2011, City of Sydney Council approved entering a contract with an organization to supply, fit, and maintain a LED lighting retrofit of 6,448 of the City's lighting assets. Contract negotiations were completed, and installation began in late March 2012. As of the publication of this report, 1,500 existing luminaires had been replaced with LED luminaires. Excellent performance results from the LightSavers trial, as well as from previous trials that the City of Sydney had undertaken, combined with a very positive public opinion survey, increased confidence among senior staff and Council that LED technology could best meet their needs and help achieve the goals of Sustainable Sydney 2030 going forward.

Background

The City of Sydney is currently home to 177,000 people (June 2009). In less than a decade, the residential population has increased by 49,000 or 38 percent. It is estimated that Economic Activity (GDP) generated in the City of Sydney in 2009-201 was approximately $90 billion, representing eight percent of the total national Australian economy and almost one-quarter of the GDP of the entire state of New South Wales (NSW). The City is the location of almost 40 percent of the headquarters of the top 500 Australian corporations and almost half of the regional headquarters of multi-national corporations of Australia.



The City has adopted the Sustainable Sydney 2030 vision requiring it to respond to the changes that are occurring as a result of its growth. The overarching themes for Sydney 2030 are:

- An integrated inner Sydney transport network;
- A liveable city green network;
- Activity hubs as the focus for the City's village communities and transport;
- Transformative development and sustainable renewal;
- A revitalized city center at the heart of a global Sydney.

As a part of its Sustainable Sydney 2030 vision, the City will reduce greenhouse gas emissions by 50 percent by 2030 compared to 1990 levels, and by 70 percent by 2050.

Sydney's largest contributor to energy bills and greenhouse gas emissions is streetlighting. There are a total of 22,000 streetlights in the City of Sydney—13,500 maintained by the utility Ausgrid and 8,500 by the City—which consume approximately 13,100 megawatt-hours of electricity and produce 14,017 tonnes of greenhouse gas emissions (GHG) annually, representing one third of the city's annual electricity use while accounting for a large part of the City's corporate GHG emissions. The City annually spends about $3.5 million on electricity for its 22,000 streetlights, as well as $2 million on maintenance and upgrades of the 8,500 units that it manages.

The City originally began trials of LED streetlights in 2008 - 2009 in Alexandria Park, Kings Cross, Circular Quai and Martin Place, testing a variety of products available in the Australian market at the time. Initial data from these trials showed that LED luminaires, if paired with intelligent adaptive controls, could potentially reduce electricity consumption by up to 74 per cent, saving municipal operational costs while reducing the city's carbon footprint. In connection with these trials, surveys conducted in Alexandria Park and Martin Place yielded convincing public support for LED street illumination. Among respondents, 81 percent said they preferred the new lights to the old lights, 76 percent said visibility had improved, and 90 percent recommended the roll out of LED streetlights across the city.

In December 2010, the City began a one year trial of three LED luminaire products on St. George Street, Australia's business center. The aims of the trial were to reaffirm previous LED pilot findings in a rigorous international project, enabling comparisons with results from other cities in the LightSavers initiative, as well as to confirm the feasibility and energy savings possible with adaptive controls. It should be noted that St. George Street has historical significance as Australia's first site for electric streetlights.

The LightSavers St. George Street Trial

The St. George Street trial was designed to test the performance and energy saving potential of LED streetlights with adaptive controls and ran for 14 months from December 2010 - February 2012, with illuminance and correlated color temperature measurements taken over the same period.

Here is an overall summary of the trial:

- St. George Street is typically illuminated by 250 watt metal halide streetlights, with an average annual operation of 4,200 hours;
- St. George Street is classified P6 under the Australian Standard AS/NZS 1138, which calls for an average horizontal illuminance of 21 lux and horizontal uniformity of 10;

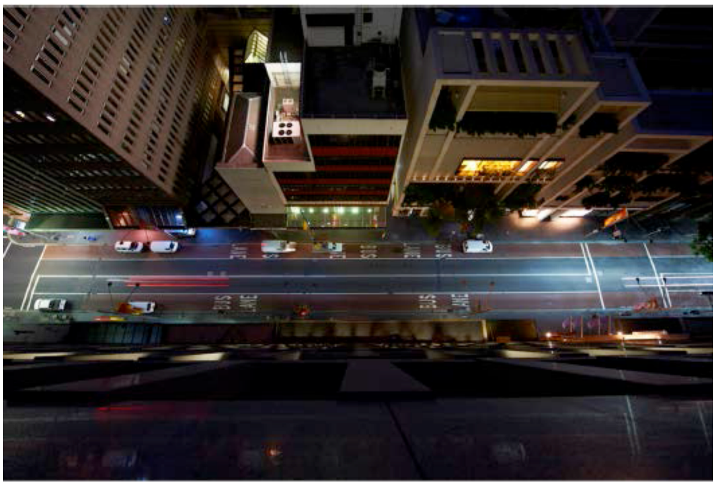
- However, the street is purposely over lit by 30 percent to provide sufficient illumination during special events downtown, bringing the minimum average illuminance required to 27.3 lux;

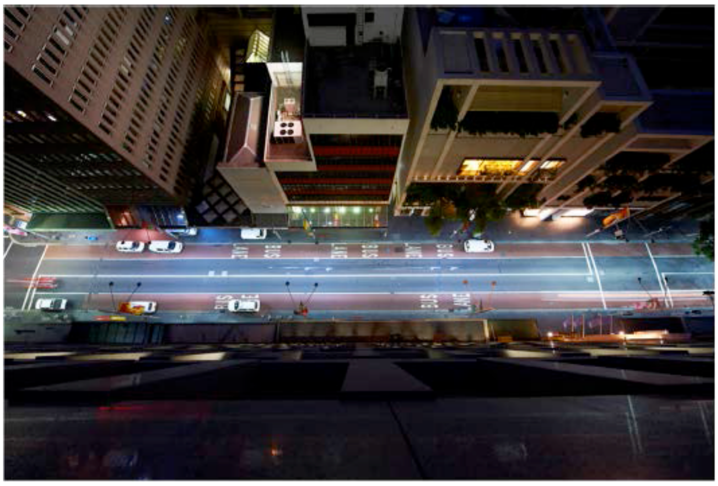
- The pole height is 9.6 meters;

- The distance between poles averages approximately 25 meters, with poles situated across from each other along the street;

- Six baseline luminaires used the incumbent 250 watt metal halide lamps;

- Six LED luminaires for three different products were installed in December 2010, two of which, SYD-1(a) and SYD-1(b) incorporated integrated adaptive controls.

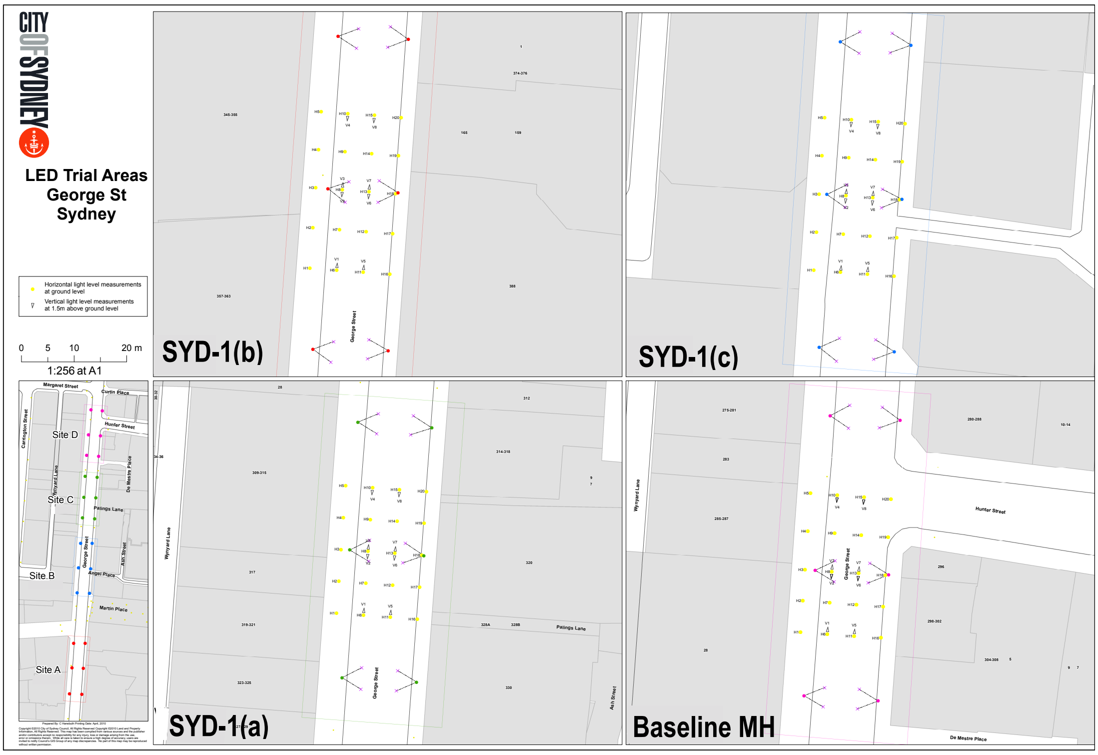




The Monitoring Protocol and Methodology

The trial study area on St. George Street is located on a stretch downtown that is straight and commercial, with minimal trespass light late at night when measurements were taken.

FIGURE 1: Trial sampling grids on St. George Street



The sampling grid was designed based on AS/NZS 1158 recommended practice (see Figure 1 above). For each type or model of luminaire, a grid of 20 horizontal sampling points was distributed around two opposite poles, with the sampling points eight meters apart. Vertical sampling was also undertaken, but the results are not reported here.

City of Sydney staff adopted the following protocol in implementing the trial.

1. Installation. An existing group of luminaires designated as the baseline was cleaned and relamped with new metal halide lamps as per normal maintenance procedures. Meanwhile, 18 new LED luminaires were installed by City of Sydney staff on the site in December 2010.

2. Adaptive controls. Two of the tree luminaires, SYD-1(a) and SYD-1(b), incorporated adaptive controls allowing dimming during the course of the trial, as follows:

   a. SYD-1(a) was dimmed 50 percent, except that in the July, October, and December 2011, and March 2012 tests when it operated at full power;
   b. SYD-1(b) was dimmed 20 percent in all tests throughout the trial.

3. Burn-in period and measurements. The baseline lamps and LED luminaires were “burned-in” for approximately 1,000 hours from December 2010 to February 2011. Hence, for the purposes of lumen maintenance analysis in this report (see Table 3 below), the first set of measurements used started in February 2011. The following initial set of measurements were taken for both baseline and LED luminaires:

   a. Voltage and amperage;
   b. Photopic illuminance;
   c. Scotopic illuminance;
   d. Scotopic/photopic ratio;
   e. Correlated color temperature (CCT);
   f. Ambient temperature.

   The monitoring team noted date, time, weather, and site conditions when they took measurements.

4. Power measurements. Spot voltage and amperage measurements of the baseline group and the LED luminaire group(s) luminaires were taken, from which apparent power was calculated. Power factor was not measured.

5. Illuminance measurements. Both photopic and scotopic illuminance readings were taken using the Solar Light SL-3101 radiometer, equipped with photopic and scotopic detectors that conform to CIE spectral luminous efficiency curves. The equipment was calibrated to the U.S. National Institute of Standards and Technology (NIST) and has an accuracy of ±5 percent according to the manufacturer. The illuminance and CCT measurements were taken with the equipment placed on the pavement surface, facing the light source. Vertical illuminance measurements were not taken.

   Since the error band associated with the light meter is ±5 percent, the trial was designed to maximize precision and reduce potential errors through repeated measurements over a long period of time. While there are no certainties when using statistical analysis, we believe the results described in the report can be interpreted with fair confidence due to the large volume of the sample data.

   Photopic illuminance is used in conventional measures of light reaching the road and is the type of value specified in Australian standards. Scotopic illuminance measures the efficacy of the eye’s peripheral vision under low light conditions at nighttime. White light LEDs, with a greater blue component in their spectrum than many conventional lighting products, yield significantly higher scotopic values.

6. Correlated color temperature (CCT). CCT values were measured using the Konica Minolta CL-200 Chroma Meter, a baseline measurement taken in December 2010 and final measurement in February 2012, 14 months later. The meter has an accuracy of ±2 percent according to the manufacturer.

7. Ambient temperature. Measurements were taken alongside colour temperature and illuminance measurements, using City of Sydney equipment, to ascertain whether higher summer temperatures would affect light output.

8. Periodic testing. Horizontal and vertical illuminance measurements were taken and recorded accordingly at random but mostly monthly intervals over 14 months, from December 2010 - February 2012. For purposes of the foregoing analysis, the initial 1,000 hours of data or three months were omitted, due to the high volatility of lumen output that typically characterizes brand new LED devices.

9. Lumen maintenance. LED streetlight luminaire manufacturers claim their products will typically maintain lumen output at 70 percent or above (L_{70}) their original output for 50,000 hours or more. It is challenging to evaluate such claims in a real world trial. The Illuminating Engineering Society of North America (IESNA) TM-21 Working Group, during the course of its evaluation of 40 sets of laboratory data on LED light source lumen maintenance over 6,000 hours or more, concluded that lumen depreciation can change in various ways that is difficult to model or predict, especially during the first 1,000 hours of operation when rapid variations have been observed.

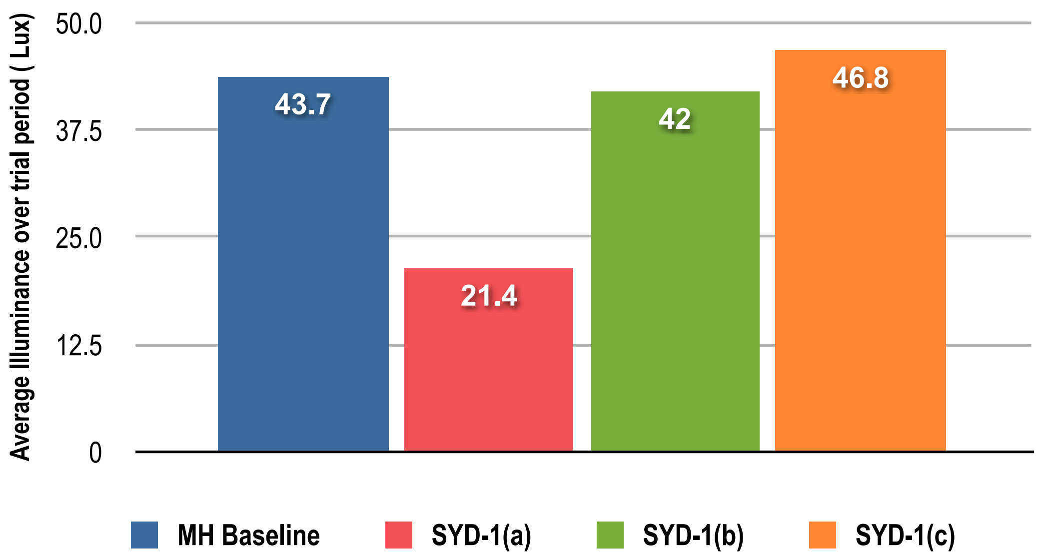
   According to TM-21, in order to have predictive value, a field trial should be 10,000 hours or more, i.e., three years, with the last 5,000 hours yielding the most consistent and reliable information. While ideal, such a trial is not practicable in a municipal context given limited resources, as well as the need to make procurement decisions in a shorter time frame. In this trial, data was collected approximately monthly over a period of 14 months, or ### hours. The lumen maintenance results from the trial provide a useful snapshot of how the LED product performed relative to baseline during this period. However, the results should not be used to predict how this product will perform in the future.

Results

Illuminance comparisons

The results reported below represent photopic measurements taken over the trial period, February 2011 - February 2021, averaged together, which includes the dimming applied to SYD-1(a) and SYD-1(b) on most test dates. Given the Australian roadway lighting standard of 21 lux applicable to this street, it is expected that the City's need to provide for 30 percent higher illuminance during special events would boost this requirement to 27.3 lux. Two of the three LED luminaires, SYD-1(b) and SYD-1(c), as well as the baseline, easily met the 27.3 lux threshold. Furthermore, in order to maintain their average illuminance over an assumed lifetime of 50,000 hours, it would also be expected that initial average illuminance of the LED luminaires would need to 39 lux in order to maintain lumen output at L_{70} or above throughout its lifetime, i.e., it would maintain average illuminance of 27.3 lux or above over its 50,000 hour year lifetime as its light output declined by 70 percent. The same two LED luminaires, SYD-1(b) and SYD-1(c), as well as the baseline, exceeded this criterion. One LED luminaire, SYD-1(a) did not meet either of the above minimum criteria.

GRAPH 1: St. George Street Illuminance



Correlated color temperature (CCT)

Significant changes in color temperature of the illumination produced by LED luminaires over time may indicate a number of problems stemming from degradation of the components of the LED device, especially the materials that encapsulate and cover the LED source.

Measurements of CCT were taken in December 2010 and 14 months later on February 2012. As the Table 1 below indicates, differences in measured CCT ratings for the metal halide and one LED luminaire changed in the range of less than two percent on an annualized basis. Meanwhile, the color temperature shift observed in LED luminaire SYD-1(c) was a decline in the range of four percent, also a good result.

TABLE 1: Summary of color temperature results

Product Reference	Measured CCT Dec-2010 (Kelvin)	Measured CCT Feb-2012 (Kelvin)	% Measured Change	% Annualized Change
MH Baseline	4449	4511	1.39%	1.19%
SYD-1(a)	4107	4205	2.39%	2.05%
SYD-1(b)	4124	n.a.	n.a.	n.a.
SYD-1(c)	5613	5335	-4.95%	-4.25%

Energy savings

Field measurements were made of all four luminaires on December 15, 2010. All three LED luminaires achieved significant energy savings, ranging from 63 percent to 85 percent, compared with the baseline metal halide luminaire. Measurements were taken with adaptive dimming available in SYD-1(a) and SYD-2(b) in the off mode. See Table 2 below.

TABLE 2: Summary of energy use

Product Reference	Measured Energy (Watts)	% Reduction
MH baseline	292.0	---
SYD-1(a)	45.3	-84.5
SYD-1(b)	77.7	-73.4
SYD-1(c)	108.5	-62.8

Luminaire target area system effectiveness

A key advantage that LED streetlight luminaires hold over conventional high intensity discharge (HID) luminaires is that the light they produce is more directional. Thus, more of the light produced by the LED luminaire is directed to the road surface where it is needed. However, there does not currently exist a standard lighting metric for measuring how effective luminaires are projecting light on a specific surface in a field trial.

In the LightSavers trials we developed a "target area system effectiveness" metric that is calculated for each LED luminaire simply by dividing its average photopic illuminance measured on a sampling grid by its apparent power value. The calculated value of lumens per watt is then indexed to the comparable baseline value, which is normalized to the value 1.0. This metric does not take into account uniformity.

Ascertaining how much apparent power it takes for a luminaire to deliver its light to a surface grid compared with a baseline product can assist lighting asset managers in understanding the directional effectiveness of different LED luminaire products at illuminating a surface, compared with conventional lamps such that rely more on luminaire lens optics to direct and shape their light output. The figures below characterize this metric and compares the LED luminaire with the baseline.

FIGURE 2: Target area system effectiveness indexed to the baseline MH lamp (normalized value = 1.0 lumen/watt)

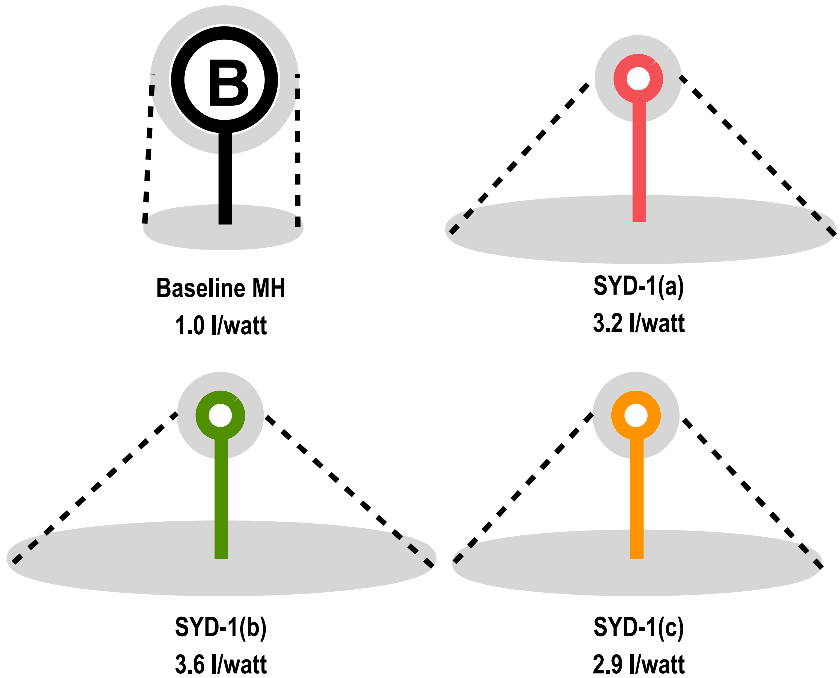


Figure 2 above shows that all of the LED luminaires were able to deliver in the range of three times more average illuminance on St. George Street per watt of energy consumed than the baseline metal halide lamp. This explains in part the significant energy reductions accompanying the use of the LED products.

Lumen maintenance

A key purpose of the LightSavers trial was to determine how the LED luminaires performed over a period of time. For the purposes of this study, lumen maintenance factors affecting LED luminaires can be divided into two groups:

- Factors that can be reversed or recovered through maintenance, such as luminaire cleaning to remove dust and grime from its lens;

- Factors that cannot be reversed or recovered, such as the gradual fading of the LED device's lumen output or dramatic changes in its correlated color temperature (CCT).

In the first category, luminaire dirt depreciation (LDD) is the most significant factor. It results from the accumulation of dust and grime on the luminaire lens over time. This varies significantly from one locale, climate, or season to another. Air pollution is obviously an important variable. Also, an electrostatic charge on the plastic lens of a LED luminaire attracts particles floating in the air. The dryer the environment, the higher the charge and attraction of particles to the lens. Conversely, higher humidity reduces the static charge and particle attraction. Finally, design of the LED luminaire affects dust buildup. Some manufacturers incorporate self-washing features into their luminaire design, so that precipitation removes dust that has adhered to the luminaire lens. The effectiveness of such designs varies significantly from one product to another.

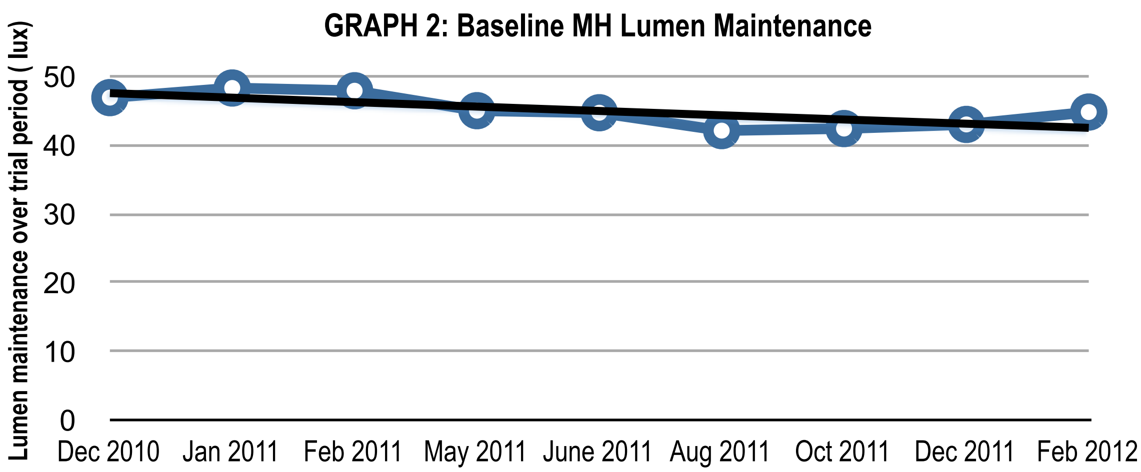
Note that LDD is not linear. Dust buildup on a newly installed luminaire may be rapid at the start, depending on humidity and temperature, and then decline in rate as the amount of dirt on the luminaire lens reaches a level that dampens its static charge.

In the second category of lumen maintenance factors, LED devices, unlike metal halide lamps, do not typically burn out. Instead, the light they produce gradually fades over a long period of time in a non-linear fashion. As noted above, the end of lifetime of a LED device occurs when its light output declines to 70 percent of its original output. Since the luminaires on St. George Street operate approximately ### hours annually, a LED luminaire rated at 50,000 hours of operation would reach L_{70} at 12.5 years after its initial start of operation, i.e., a calculated rate of approximately 2.8 percent depreciation *per annum* on an annualized basis over the lifetime of the product.

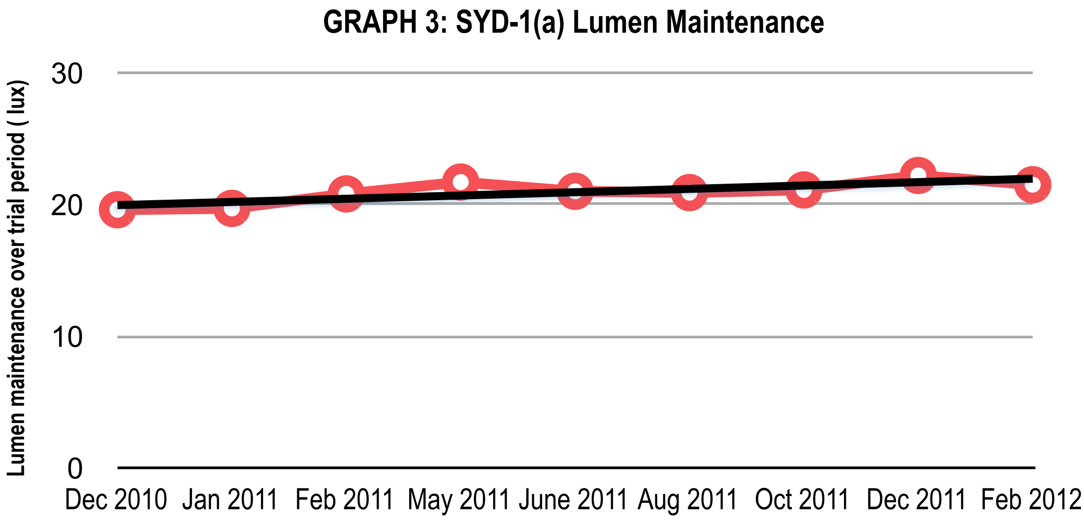
For the purpose of this trial and study, we assume a lifetime of 50,000 hours for all three LED products tested, notwithstanding manufacturers' claims. Thus, lumen depreciation significantly exceeding 2.8 percent on an annualized basis would be less desirable than a value in the range of 2.8 percent or less, *net of LDD*. Since LDD was not determined in this trial, it is expected that the lumen depreciation would be somewhat higher than it normally would be if corrected for LDD.

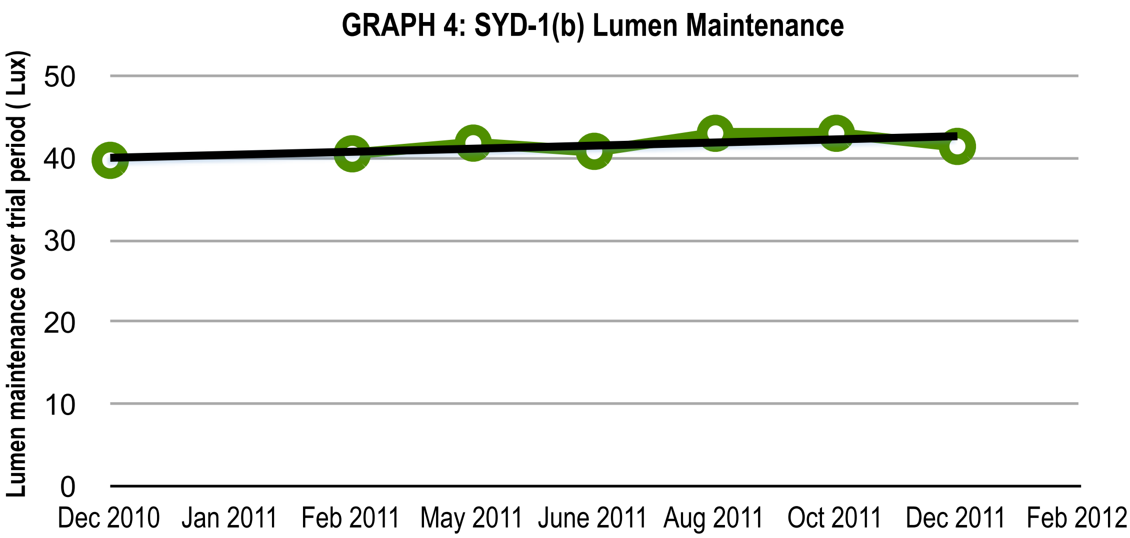
It should be noted again, in respect of the IESNA's TM-21 Working Group's recent findings, that the lumen depreciation metric for the first year or two has no predictive value. However, comparing first-year lumen output performance of multiple products in multiple trials can offer insights that enable lighting asset managers in a practical way to better differentiate products from one another.

The graph below shows the monthly averaged photopic illuminance values (lux) for the metal halide baseline luminaire (blue line) over a period of 14 months. The black line displays the set of data generated by Excel's exponential trendline function, which uses the LOGEST function to generate an exponential least squares fit of the individual observed values to a curved line. (This is the equivalent of performing an Excel LINEST linear least squares fit on the logarithms of the observed values, the slope of the generated straight line equalling the logarithm of the depreciation rate of the exponential fit.) The graphs are visual representations of average horizontal illuminance measurements throughout the trial.



Graph 2 above shows that light output from the baseline metal halide luminaire declined in the range of 1.7 percent over the trial period. Graph 3 below shows that light output from the LED luminaire designated SYD-1(a) appreciated in the range of 2.4 percent over the trial period. There was a slight elevation of average illuminance in the middle of the Australian summer, December, when a decline in light output might be expected. (There was also a slight upward fluctuation in the Australian fall, May, when temperatures are cooler.)





Graph 4 above shows that light output from the LED luminaire designated SYD-1(b) appreciated 2.2 percent over the trial period. Meanwhile, Graph 5 below shows that light output from the LED luminaire designated SYD-1(c) appreciated significantly, in the range of 8.4 percent 2.4 percent over the trial period. There was a slight decline in light output for both luminaires during the Australian summer, December-February, but this decline fell well within the range of fluctuation observed throughout the trial period. Light output appeared to decline for SYD-1(c) during the Australian fall, May-June, when temperatures are cooler. Note that performance of this luminaire was the most volatile over the trial period.

GRAPH 5: SYD-1(c) Lumen Maintenance

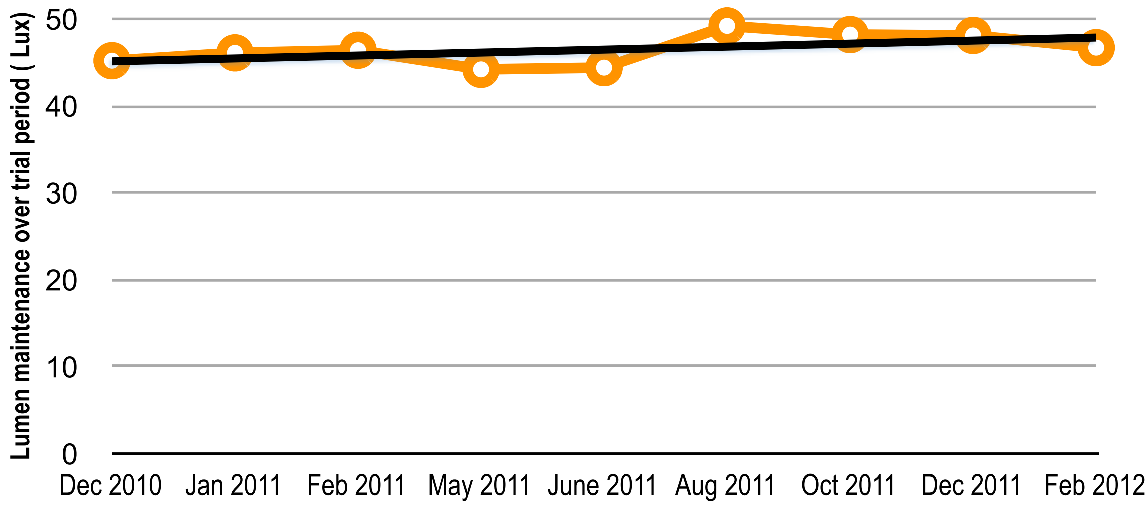


Table 3 below summarizes the lumen maintenance findings from the trial. It is surprising that average horizontal illuminance for all three LED luminaires appreciated over the 12 month period, February 2011 - February 2012, after the initial 1,000 hour burn-in period. Fluctuations of average illuminance in relation to ambient temperature yielded ambiguous results. So evidence that hot summer temperatures might depress light output is inconclusive.

TABLE 3: Summary of lumen maintenance results

Trial Reference	Annualized Exponential Trendline (Excel)[1]	Lamp Lumen Depreciation (LLD)
MH Baseline	-1.7%	0.983
SYD-1(a)	2.4%	1.024
SYD-1(b)	2.2%	1.022
SYD-1(c)	8.3%	1.083

Summary product evaluation

Table 4 below summarizes the results of the product evaluation. One product, SYD-1(c) exhibited excellent performance across all five parameters. Product SYD-1(a) also performed extremely well on four of the five parameters. However, this luminaire did not produce enough light output to comply with the site's event needs. Data for

SYD-1(b) is incomplete, hence an overall rating is not given. However, it performed extremely well on all the parameters for which data was available.

TABLE 4: Summary Product Evaluation

Trial Ref.	Illuminance Relative to Baseline	Energy Savings vs. Baseline	Luminaire Target Area System Effectiveness	Lumen Maintenance After 1 Year (net of LDD)	Color Temp Change After One Year	Total Stars (15 max)
SYD-1(a)	*	***	***	***	***	13
SYD-1(b)	***	***	***	***	n.a.	n.a.
SYD-1(c)	***	***	***	***	**	14

Summary

In conclusion, building on previous LED streetlight pilots, the results of the LightSavers trial should increase the City of Sydney's confidence that LED technology has reached technical maturity and can meet its illumination needs while cutting energy use significantly.

City of Sydney staff reported that overall the LED luminaires performed well, with no failures. Meanwhile, two of the LED luminaires provided approximately equivalent average illuminance as the baseline metal halide luminaire, while saving energy use in the range of 63 - 73 percent, an impressive achievement. The reason for such energy savings was the high target area effectiveness of the LED luminaires selected for this trial, which yielded in the range of three times the average illuminance in the targeted study area as the baseline metal halide lamp.

Meanwhile, colour temperature shift of the LED luminaires was in the range of four percent or lesson an annualized basis, a good result.

None of the LED luminaires appeared to decline in light output over the trial period, with the average illuminance of SYD-1(c) actually increasing in the range of 2.2-to-8.3 percent on an annualized basis. Since dirt deprecation was not taken into account in this trial, the actual lumen maintenance of the LED luminaires would be expected to be even better than measured. Evidence that light output would be sensitive to hot summer temperatures was inconclusive.

It should be noted that the IES TM-21 Working Group indicated in its report published in August 2011, that a minimum of 10,000 hours of testing after a 1,000 hour burn in period is necessary to make any predictive assessment of LED luminaire products.

In conclusion, two of the three LED luminaires, SYD-1(b) and SYD-1(c) performed extremely well compared with the baseline metal halide lamp. SYD-1(b) stood out for its target area effectiveness of 3.6, i.e., it produced 3.6 times the average illuminance in the sampling area than the baseline metal halide luminaire. Hence, this 109 watt LED luminaire was able to replace the 250 watt metal halide luminaire and produce equivalent illuminance in the target area. The third luminaire, SYD-1(a), was considerably undersized at 45 watts. However, its performance on all other parameters was excellent.

On December 5, 2011, City of Sydney Council approved entering a contract with an organization to supply, fit, and maintain a LED lighting retrofit of 6,448 of the City's lighting assets. Contract negotiations were completed, and installation began in late March 2012. As of the publication of this report, 1,500 existing luminaires had been replaced with LED luminaires. Excellent performance results from the LightSavers trial, as well as from previous trials that the City of Sydney had undertaken, combined with a very positive public opinion survey, increased confidence among senior staff and Council that LED technology could best meet their needs and help achieve the goals of Sustainable Sydney 2030 going forward.