FINAL EVALUATION REPORT

LED ENERGY EFFICIENT STREETLIGHT PILOT STUDY

Submitted to:

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Mr. William P. Carr, Director of Research & Technology Development
District of Columbia Department of Transportation
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DISTRICT DEPARTMENT OF TRANSPORTATION

Prepared by:

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HOWARD UNIVERSITY

November 08, 2010

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Mr. Jama Abdi, Streetlight Asset Manager, DDOT
Mr. William P. Carr, Director of Research & Technology Development

RE: **LED Energy Efficient Streetlight Evaluation Study**

Dear Mr. Jama Abdi/Mr. Carr:

The Howard University Transportation Research Center (HUTRC) hereby submits the Final Evaluation Report of the light-emitting diode (LED) Energy Efficient Streetlight Evaluation study. The project team conducted a literature review, obtained samples and specifications of LED lights from vendors, suppliers and/or manufacturers.

The LED lights from the suppliers/vendors were evaluated based on DDOT's (and industries) minimum mechanical, electrical and lighting specifications, appearance and field reviews. From the preliminary review of samples and specifications selected, the following 3 suppliers/vendors' products were selected for further review:

Lighting Science: LSR2-CW-R2-2B-GR-PCR
Hadco: WL66, LED Cobra head
Leotek: SLN-084-MV-CW-3M

The three products were further reviewed based on photometric field data collection and review of their specifications. From the results, the research team recommends the installation/use of the products either of the following products:

- Leotek
- Lighting Science (LSG)

An opinion survey on LED lights was also conducted as part of the evaluation. Overall, approximately 94% of the 143 residents surveyed indicated that they preferred the LED light to the high pressure sodium street lights. The majority (90.9%) of those interviewed also felt that the LED streetlights will improve visibility in alleys and on streets. This Final Report presents the detailed evaluation and analysis of the LED products submitted by these vendors as well as the results of the opinion survey. An economic analysis was also conducted which indicated that approximately $300,000 per year will be saved by installing LED streetlights after an initial investment.

Sincerely,

Stephen Arhin, Ph.D., P.E., PTOE

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BACKGROUND

A light-emitting diode (LED) is a semiconductor light source. LEDs are used as indicator lamps in many devices, and are increasingly used for lighting. Introduced as a practical electronic component in 1962, early LEDs emitted low-intensity red light, but modern versions are available across the visible, ultraviolet and infrared wavelengths, with very high brightness. The LED is based on the semiconductor diode. When a diode is forward biased (switched on), electrons are able to recombine with holes within the device, releasing energy in the form of photons. This effect is called electroluminescence and the color of the light (corresponding to the energy of the photon) is determined by the energy gap of the semiconductor. An LED is usually small in area (less than 1 mm^2), and integrated optical components are used to shape its radiation pattern and assist in reflection. LEDs consist of clusters of tiny, high-intensity bulbs and are extolled for their power efficiency and clear luminosity. LEDs present many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved robustness, smaller size, faster switching, and greater durability and reliability. However, they are relatively expensive and require more precise current and heat management than traditional light sources.

Various jurisdictions across the United States are taking steps to reduce energy consumption by introducing and testing the use of LED street lights. It is envisaged that the use of LED street lights will reduce the cost of energy of various municipalities. The District Department of Transportation (DDOT) is exploring new advances in lighting technology to reduce energy and operating costs. DDOT is initiating this pilot project to install and test various new lighting technologies including LED street lighting fixtures.

Researchers at University of Pittsburgh recently (2010) conducted an assessment of LED streetlights and determined that the increasingly popular lamps strike the best balance between brightness, affordability, and energy and environmental conservation when their life span. The researchers compared LED streetlights to the country's two most common lamps—the high-pressure sodium (HPS) lamps found in most cities (and metal halide lamps akin to those in stadiums), and the gas-based induction bulb, another emerging technology billed as bright and energy efficient. The research team reported that LEDs although may carry a formidable price tag, in comparison to HPS and metal halide lamps, they consume half the electricity, last up to five times longer, and produce more light. Induction lights proved slightly more affordable and energy efficient than LEDs, but may also have a greater environmental impact when in use. The authors also noted that LED technology exhibits more potential for improvement and may surpass induction lamps in the future.

The City of Raleigh is currently testing nine (9) energy-efficient streetlights downtown to determine how well they withstand extreme heat, cold and rain. It is envisaged that, if the LED street lights live up to their promise, they could take a significant bite out of Raleigh's $5.3 million annual streetlight bill. The LED lights being tested are said to last at least twice as long as conventional bulbs while using about 40 percent less energy. The technology was developed by LED maker Cree, a Durham company that makes the tiny chips for cell phones and computers, and sees a big payoff in revolutionizing the lighting market.

Cree and the City of Ann Arbor, Michigan have announced that Ann Arbor will join Raleigh, North Carolina and Toronto, Canada in the growing LED City initiative. In an effort to reduce greenhouse gas emissions and energy consumption, Ann Arbor plans to become the first U.S. city to convert 100 percent of its downtown streetlights to LED technology. Ann Arbor expects to install more than 1,000 LED streetlights within the next months, after successfully testing 25 fixtures for its efficiency. The City anticipates a 3.8-year payback on its initial investment. Each LED fixture draws 56 watts and is projected to last 10 years, replacing fixtures with bulbs that use more than 120 watts and last only two years. The city successfully conducted a pilot study of 25 LED lights over a 3-year period on the energy and maintenance savings associated with LED lighting, as well as a citizen survey on the acceptance of the LED lights. The LED test site spanned an entire city block.

The City of Fairbanks, Alaska operates 2,670 high pressure sodium (HPS) street lights, which cost the City over $550,000 per year to power, as electric power costs in interior Alaska are in the range of $0.24 per kilowatt hour or greater, and $75,000 per year in maintenance and replacement bulb costs. The City is conducting a pilot-scale study to evaluate the replacement of HPS street lights with LED street lights. The LED street lights are estimated to provide an estimated 70% reduction in power usage and a lifespan estimated from 50,000 to 100,000 hours, which would result in a bulb life span of approximately 15 years based on their current usage rate.

Other cities, including San Francisco (CA), Los Angeles (CA), and Ankorage (AK) are embarking (or have embarked) upon various studies to assess the benefits and impact of installing or retrofitting the existing street light infrastructure with LED lights.

The purpose of this DDOT pilot project was to determine a suitable replacement for a typical 150W HPS fixture on local residential streets and alleys in the District of Columbia. The replacement fixture must provide for at least a 40% energy savings. In this case, that means the entire lighting fixture must consume no more than 85 Watts.

The fixtures were evaluated based on BSL mechanical, electrical and lighting standards, as well as newly introduced and accepted LED standards from the SSL industry. The evaluation also considered field tests as well as initial appearance preferences of local residents and DDOT technicians. The results of these evaluations were a major factor in determining which LED product will be considered for further evaluation in the pilot program.

EVALUATION METHODOLOGY

1. **Literature Review/Best Practices:** The evaluation team at HUTRC conducted a literature review on similar LED street lighting pilot programs across the United States and contacted other jurisdictions regarding the effectiveness of the new LED streetlights in reducing energy costs and promoting efficiency. The research team, in collaboration with DDOT Technicians and Engineers, also developed the LED specifications for the District of Columbia.

2. **Suppliers/Vendors/Manufacturers Contact for LED Applications:** The research team identified potential LED manufacturers, vendors and suppliers who participated in the initial review program by submitting their lighting systems applications together with their IES LM-79 and LM-80 test results. Some of the vendors submitted samples of their LED street lights for testing in alleys. Telephone and e-mail correspondence were used to contact the companies and gather information. Sixteen vendors/suppliers/manufacturers were contacted to participate in the pilot program out of which 11 of them participated. The specifications submitted were compared with those developed in collaboration with DDOT Technicians and Engineers.

3. **Field Lighting Tests:** In collaboration with DDOT Electricians, the research team conducted field tests on the sample of LED lights installed in alleys from September 2009 through April 2010. The tests involved measuring the lumens/foot-candles units within noted locations below the installed LED lights. Measurements were taken at 5-foot intervals to the left and right along the baseline of the pole with the LED light, and at the same intervals at an offset from the pole. The EXTECH Light Meter (shown in Figure 1) was used in obtaining the light measurements. Figure 2 shows a schematic of the locations where the measurements were taken for each LED fixture.

Figure 1: Light Meter used in Field Measurements

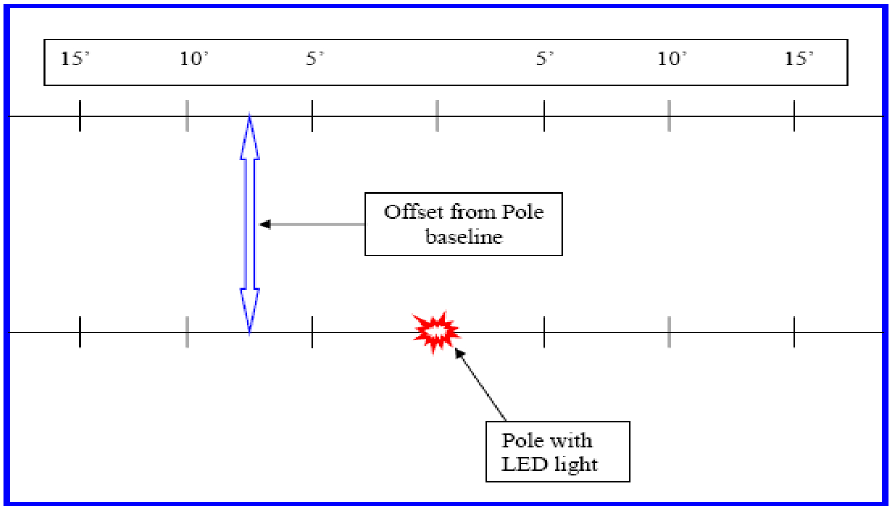

Figure 2: Schematic of Field Measurements of LED Fixtures

In addition to taking the lighting intensities of the LED fixtures, the appearance of each product was also noted.

RESULTS

Table 1 presents the results of the review of the submitted products for consideration in the LED Streetlight Pilot Program:

Table 1: Results of LED Streetlight Evaluation

VENDOR/SUPPLIER	Meets ALL DC LED Requirements? *(Specifications, application submission, sample submission)*	Appearance of Lighting Acceptable?	Field Test Result Acceptable?	Ease to Retrofit?
Beta LED	No	No	No	Yes
Hadco	Yes	Yes	Yes	Yes
Leotek	Yes	Yes	Yes	Yes
Lighting Science (LSG)	Yes	Yes	Yes	Yes
EvoLucia/Sunovia Energy Technologies	No	No	No	Yes
Trastar Inc	No	N/A	N/A	N/A
LEDTronics/Eastern Electronics	No	Yes	No	Yes
Solar Lighting	No	No	No	Yes
GE	No	No	No	Yes
Lighting Technologies	No	No	Yes	No
LED Roadway Lighting	No	No	No	Yes

The following vendor/supplier or manufacturers did not submit any samples for evaluation:

- Trastar Inc.

Based on **all** the minimum specifications and field observations, the LED lighting products from the following vendors/suppliers/manufacturers' were recommended for further participation and evaluation in the LED Streetlight retrofit program:

- Lighting Science
- Hadco
- Leotek

The applications submitted by the vendors/suppliers/manufacturers are presented in the Appendix.

DETAILED EVALUATION OF SELECTED PRODUCTS

This section of the report presents the outcome of the evaluation of the three (3) selected LED streetlights which were evaluated. The evaluation was based on:

- Detailed comparison of the specifications
- Field evaluation

The following LED products were evaluated:

- Vendor **A**: WL66, LED Cobra head
- Vendor **B**: LSR2-CW-R2-2B-GR-PCR
- Vendor **C**: SLN-084-MV-CW-3M

Two vendors also submitted newer (or improved) versions of their products for evaluation. These are:

- Vendor **B**: RWY10065
- Vendor **C**: GC1-6OC-MV-NW-3M-GY

1. COMPARISON OF THE SPECIFICATIONS

DDOT's minimum specifications for the LED products are presented in Table 1. The LED products submitted were compared based on the following criteria:

- Operating Volts
- CRI
- Warranty
- LED Life
- Lumens

These were gathered from the literature provided by the vendors.

Table 1: Minimum eligibility Requirements for testing and evaluation of LED products

Luminaire Requirements:	
Correlated Color Temperature (CCT)	Luminaire Nominal CCT(°K) shall be a minimum 4000°K
Color Rendering Index (CRI)	Luminaire shall have a minimum CRI of 70.
Off State Power Consumption	The power draw of the luminaire including PE devices must be zero watts when in the off state.
On State Power Consumption	The luminaire must use at least 40% less energy compared to its commercially available High Pressure Sodium counterpart.
Warranty	Luminaire must have a minimum five (5) Year warranty due to any failure. The Warranty shall provide for the repair or replacement of defective electrical parts including but not limited to the light source and power supplies/driver for a minimum of eight (8) years. Shipping shall be included.
Weight	Luminaire shall not weigh more than 35 pounds
Operating Environment	Luminaire shall be able to operate normally in temperatures from -40°F to 120°F
Cooling System	Shall not consist of any fan, pump or liquids
Dimensions (Approx.)	Luminaire shall not be larger than 30" long x 16" wide x 6" tall.
Housing	Shall be primarily constructed of metal. Finish shall be grey/black in color, powder coated and resist~~s~~ rust. Driver must be internally mounted and replaceable. Captive screws are needed on any components that require maintenance after installation. No parts shall be constructed of polycarbonate material unless it is UV stabilized (Lens Discoloration shall be considered a failure under warranty). The Luminaire must have a self leveling mechanism. The Luminaire shall be designed to prevent entry of insects, rain, dust, and other foreign matter. The luminaire shall be marked, using standard EE-1 NEMA marking, showing the lamp type and wattage. The marking shall be affixed to the underside of the luminaire housing and to the rear of the reflector.
IESNA Luminaire Classification	Cutoff (Dark sky compliant)
Mounting arm connection	Luminaire shall mount on 1-1/4 to 2 inch diameter arm and shall have no~~t~~ more than an 8 inch long nor less than a 5 inch horizontal insertion length on the 2 inch bracket arms and shall be adequately equipped with clamping and leveling devices or a similar mechanism to allow proper clamping and positioning of the luminaire on the bracket arms. The clamping mechanism shall contain 4 bolts that do not pass through the housing. Clamping with only two bolts is not acceptable. The clamp must be able to accept a 1 1/4 to 2 inch pipe bracket without having to rearrange the clamp.
PE Cell Receptacle	Shall have a 3-prong twist locking ANSI C136.10 photocell receptacle. Photocell adapter must be built into the housing and be directionally adjusted without the use of tools.
House Shield	Shall provide option for house side light control

Table 1 (Contd.)

LED Module /Array Requirements:		
Lumen Depreciation of LED Light Source	Must comply with IESNA LM-80 LED module shall deliver at least 70% of initial lumens, when installed for a minimum of 50,000 hours.	
Light Distribution	Shall be:	
	DC Street Classification	Lighting Distribution Pattern
	Interstate Roadway	Type III or Type IV
	Freeway/Expressway	Type III or Type IV
	Principal Arterial	Type III or Type IV
	Minor Arterial	Type III
	Collector	Type III
	Local Street	Type II or Type III
	Alleys	Type II
Power Supply/Driver Requirements:		
Power Factor	Shall have a power factor not less than 90%	
Operating Voltage	120-240 volts	
Operating Temperature	Shall operate between -40°F and 120°F	
Frequency	Output operating frequency must be ≥ 120 Hz and input operating frequency of 60 Hz	
Interference	Shall meet FCC 47 CFR Part 15/18	
Noise	Shall have a class A sound rating	
Startup	Must be instant restart	
Roadway Application Requirements:		
Minimum Light Output	Shall have a minimum of 3500 lumens	
Minimum Luminaire Efficacy	70 lm/W	
Delivery Requirements:		
Must be able to deliver more than 1500 units per month		

Table 1 (Contd.)

File\Test Requirements:	
IES File	Absolute photometric testing data in IES LM-63 electronic file format.
LM-79 Test	Provide Independent Testing according to IES LM-79 that provides efficacy, output, color, and photometric distribution of your product. An Integrating Sphere Test will be required to provide color information. A Goniophotometer test by itself is not adequate.
Lifetime	Provide written explanation of how L70 Lifetime of Product is determined using the LM-80 and In-situ temperature tests referenced below.
LM-80 Test	Provide LED Package Manufacturer IES LM-80 Test Report with results showing relative (%) light output over time at 55°C, 85°C and X°C (a third temperature at the manufacturer's choice).
In-Situ Temperature Test	Provide test report indicating the Temperature of the hottest LED In-Situ in ANSI/UL 1598-04 (hardwired) or ANSI/UL 153-05 (corded) environments. This temperature measurement will be used with LM-80 data to validate lumen maintenance and useful life of product. Note that this temperature measurement should be specially requested by the manufacturer as they are getting their UL testing.
UL	Provide copy of UL certification
Other Requirements:	
Scotopic Light contributions will not be considered at this time	
A Full Specification Sheet must be submitted. Warranty information must be included.	
The Luminaire must be commercially available. Prototypes will be permitted.	
The fixture must not contain any moving parts or fans.	
The driver must be located inside the housing, but should be easily accessible.	

Note:
All these requirements must be met before the District will accept the product for testing and evaluation.

A summary comparison of the specifications of the 3 products is presented in Table 2.

Table 2: Comparison of Specifications of Selected Manufactures/Vendors

Product	Wattage	Lumen	LED Efficacy LM/W	Operating Volts	Temperature	CRI	LED Life (Hr)	Warranty
A	66	4900	74	85-300	5000K	>80	100,000	5 Yr
B	74	5890	79	120-277	5000K	70	60,000	5 Yr
C	77	8400	>100	120/208/240	5500K	72	50,000	8 Yr

Figure 2 shows the minimum and maximum operating volts for each product submitted. Product **A** had the widest range of operating volts; followed by **B**. Vendor **C**'s product had the smallest range of operating volts.

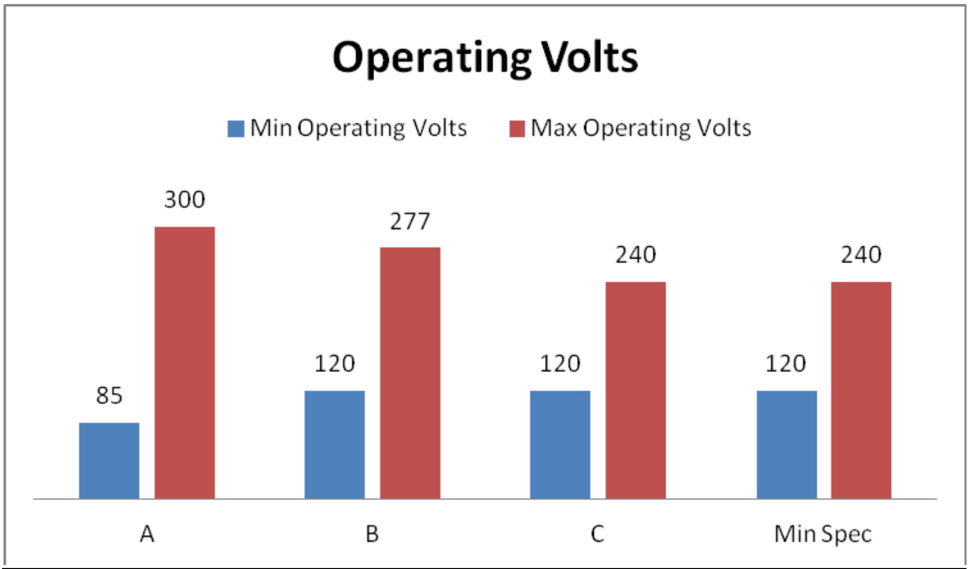

Figure 2: Operating Volts of LED Products

Figure 3 shows the Warranty for each of the LED products submitted. Leotek's product had the highest warranty for 8 years. Both LSG and Hadco met the minimum warranty specifications of 5 years.

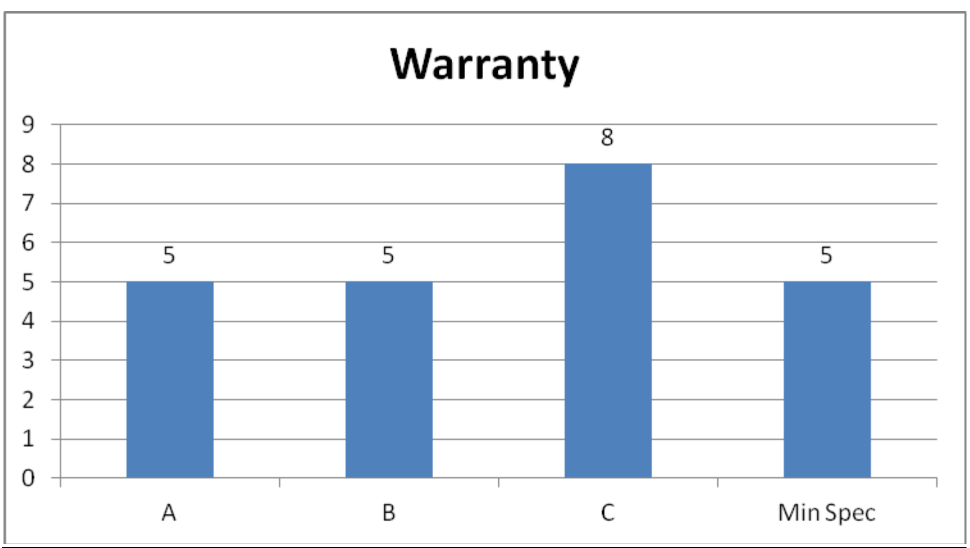

Figure 3: Warranty of LED Products

Figure 4 illustrates the LED life of the samples provided by the vendors. The minimum specification is 50,000 hours. Hadco's product LED life was the highest, followed by LSG. Leotek's product met the minimum specifications.

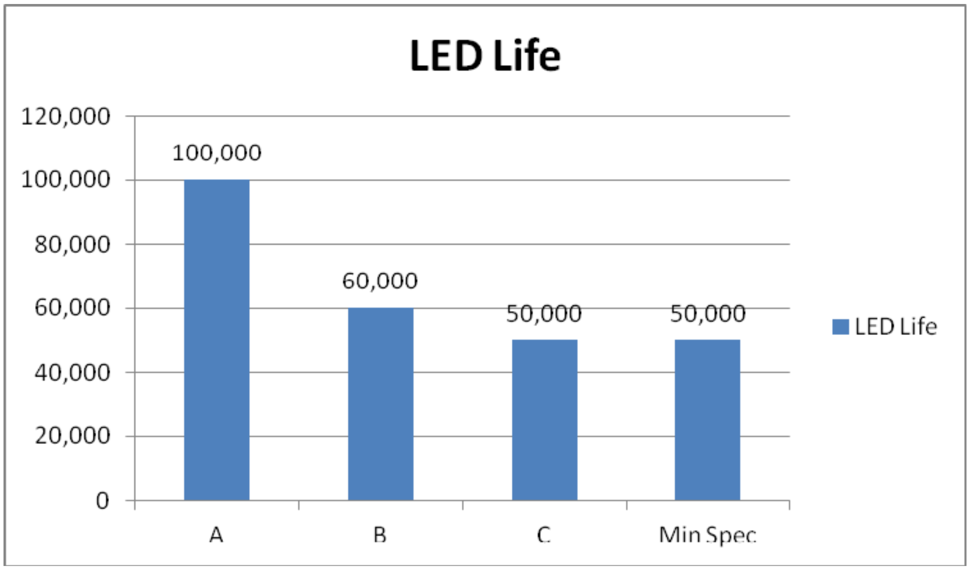

Figure 4: LED Life of Products

Figure 5 shows the CRI values for the LED products submitted, with DDOT's minimum specification being 70. All the products submitted met the minimum CRI specification.

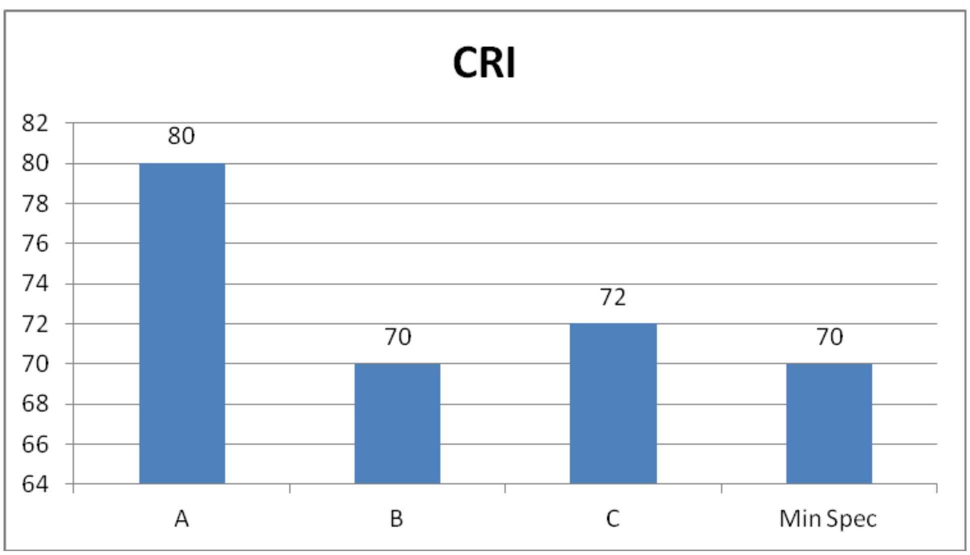

Figure 5: CRI of LED Products

Figure 6 shows the minimum light output in lumens of the LED products evaluated. Product C had the highest lumen value of 8400 lumens, followed by B (5,890 lumens). Product A had the minimum light output.

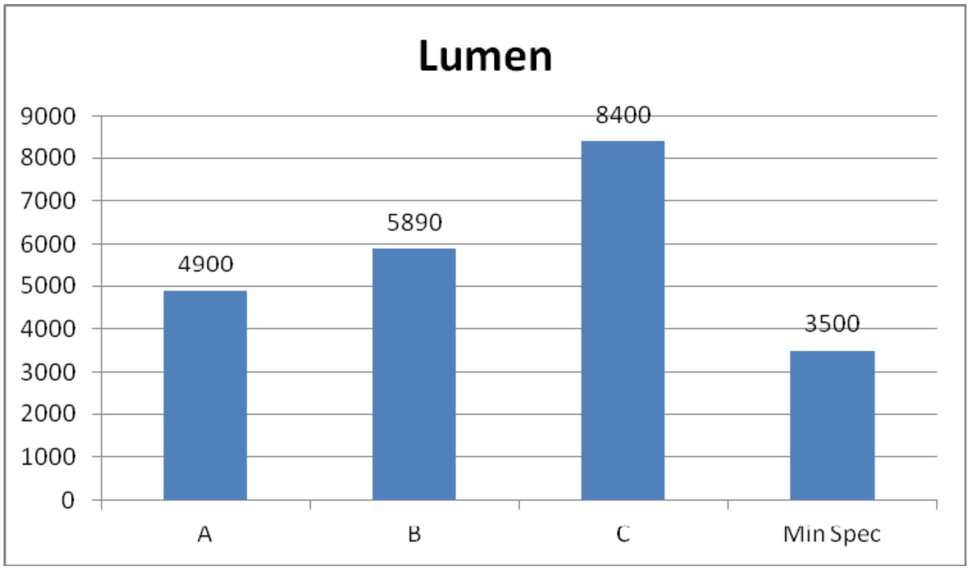

Figure 6: Lumen of LED Products

2. COMPARISON OF FIELD OBSERVATIONS

The three products were each installed on a particular pole in an alley where lighting interference was minimal. Each LED product was mounted at the same height. Lighting intensity measurements were then taken for each product along the pole's baseline and 5-feet and 10-feet offsets from the pole baseline. Measurements were obtained from a distance of 30 feet to the left of the pole and from 70 feet to the right of the pole, both at 10-foot intervals. Due to lighting obstructions and interference, measurements to only 30 feet left of the pole could to be taken. Figures 7 through 9 present a comparison of the four products based on the measurements obtained. The raw data from the field data collection are presented in the Appendix.

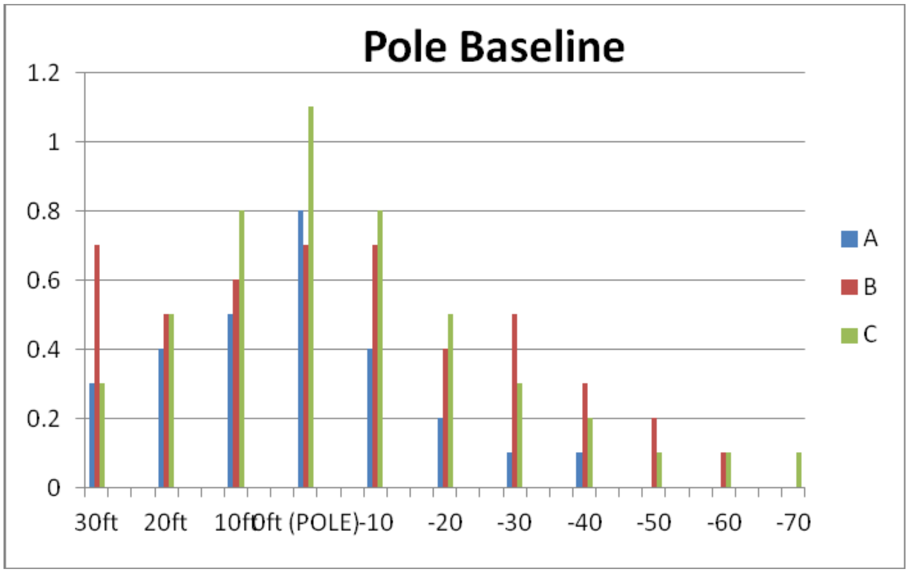

Figure 7: Lighting Intensity along Pole Baseline

From Figure 7, products **B** and **C** appeared to provide the most lighting intensity along the pole's baseline. Product **C** appeared to provide lighting intensity as far as 70 feet to the right of the pole.

Figure 8 provides the lighting intensity measured 5 feet from the pole's baseline. Measurements were taken at 30 and 70 feet to the left and right of the pole, respectively.

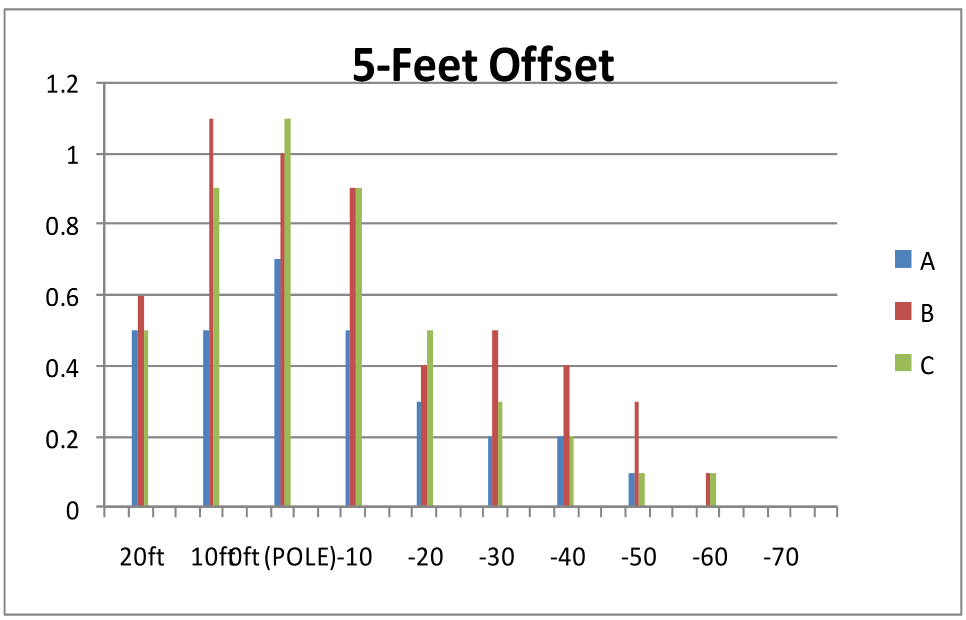

Figure 8: Lighting Intensity 5-Feet Offset from Pole Baseline

In Figure 10, the lighting intensity of the three products was measured at a 10-feet offset from the pole baseline. Measurements were obtained 30 and 70 feet to the left and right of the pole, respectively, at 10-feet intervals.

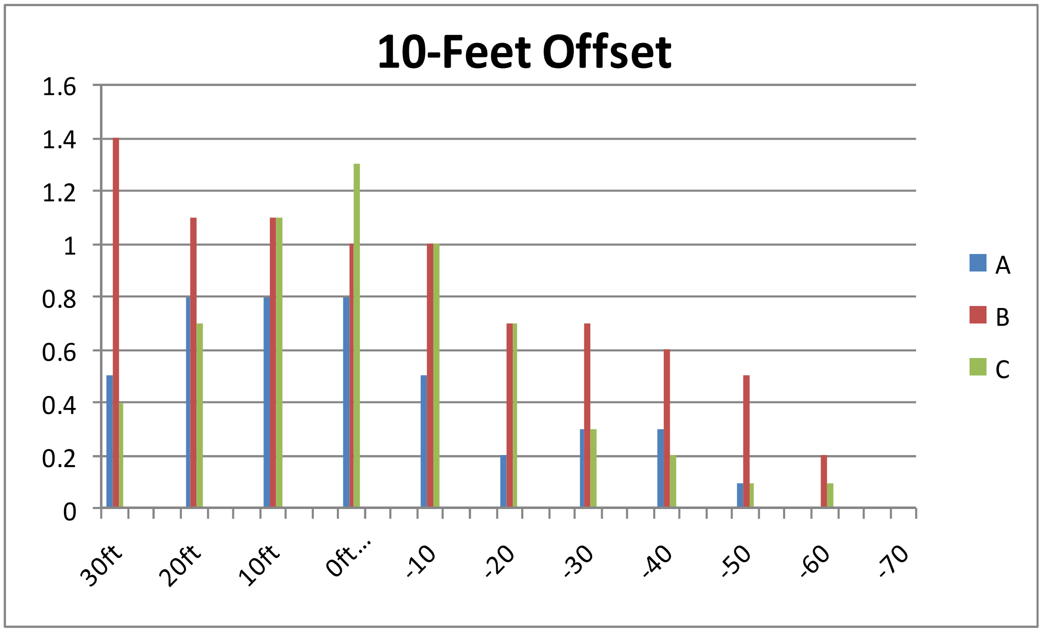

Figure 9: Lighting Intensity 5-Feet Offset from Pole Baseline

The field test of the light intensity of a new LED fixture submitted by Vendor B is presented in Figure 10.

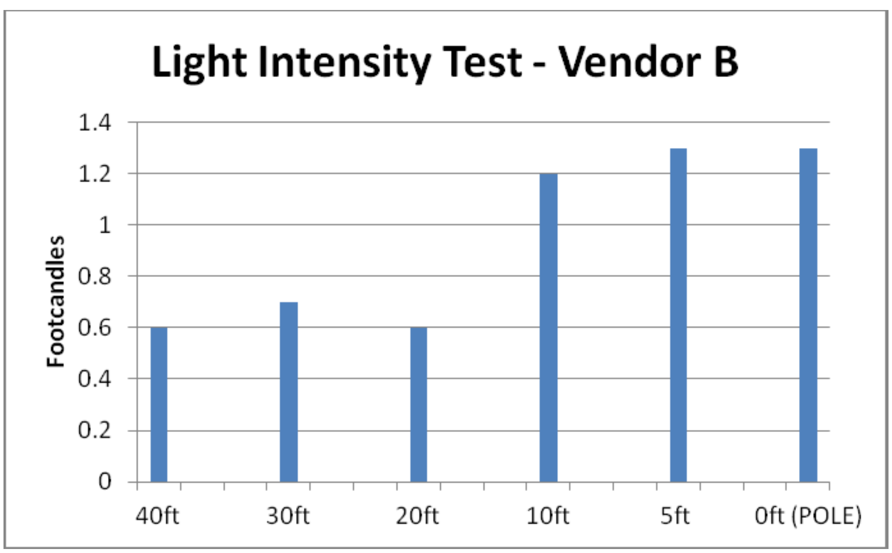

Figure 10: Lighting Intensity of Improved LED fixture from Vendor B

Similarly, the field results of the light intensity test of a new/improved LED fixture submitted for evaluation by Vendor C is presented in Figure 11.

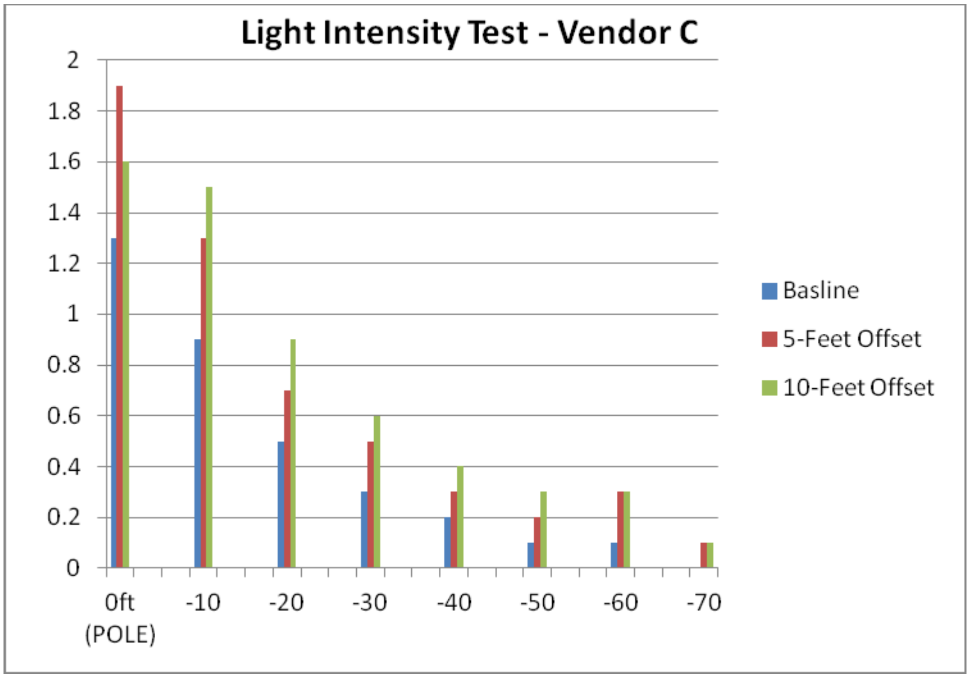

Figure 10: Lighting Intensity of LED from Vendor C

RESIDENTS' SURVEY

As part of the evaluation of the LED products, a survey was conducted to gauge the perception of residents on their properties. The survey was conducted by posing questions to residents who have seen the pilot LED light installations or those who live or work in close proximity to the location of the lights. A total of 143 residents were surveyed. Below are the questions posed and the responses obtained.

1. ***Do you feel that the new LED lights installed have improved visibility in the alleys?***

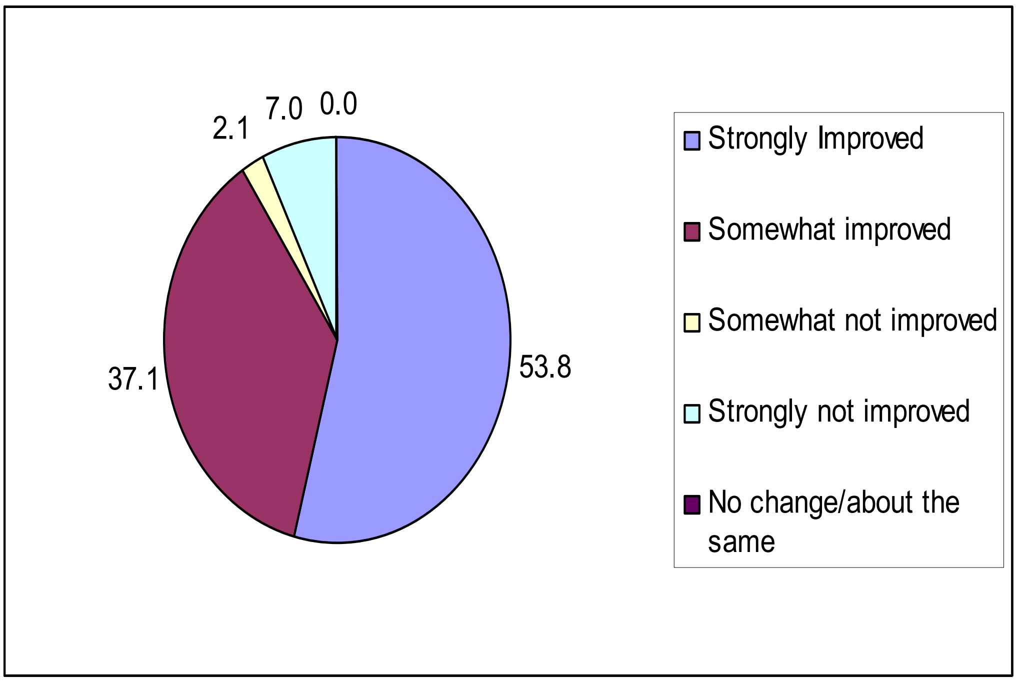

Figure 10: Percentage of Responses to Question 1: *Do you feel that the new LED lights installed have improved visibility in the alleys?*

The results as displayed in Figure 10 indicate that a majority (90.9%) of those interviewed felt that the LED streetlights improved visibility in the alleys. Only 9.1% of those interviewed felt the LED lights did not improve visibility. This indicates that the LED lights, by majority opinion, would improve visibility.

2. Do you feel that the new LED lights installed are better than the previous lights?

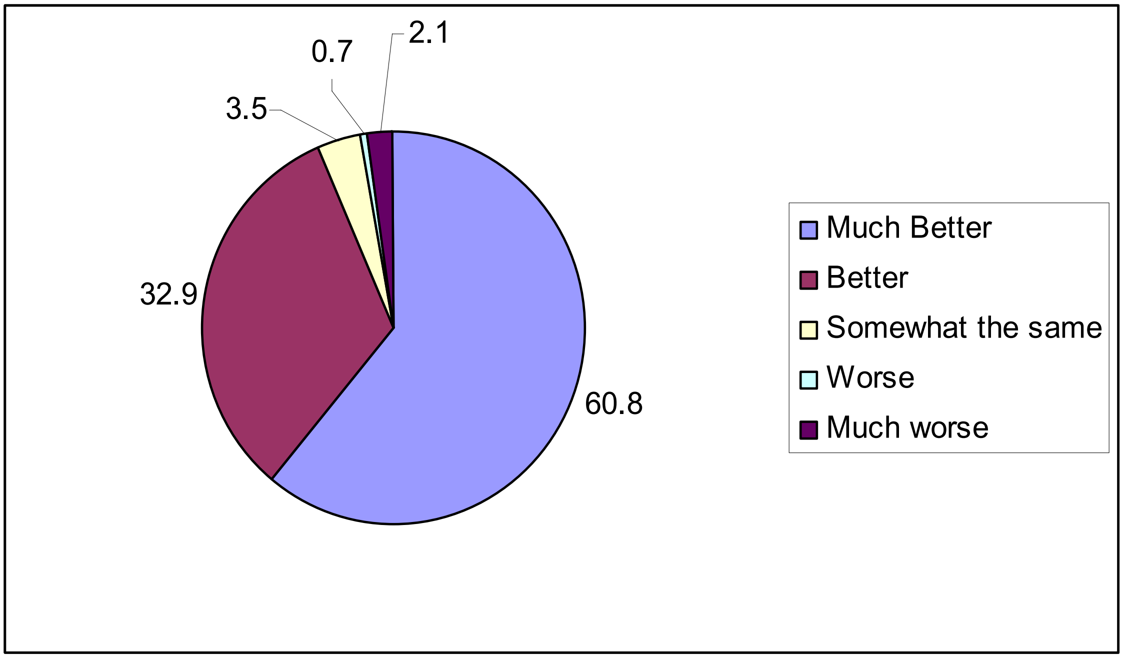

Figure 11: Percentage of Responses to Question 2: *Do you feel that the new LED lights installed are better than the HPS lights?*

From Figure 11, the majority (93.7%) of those interviewed felt that the LED streetlights are better than the HPS streetlights. Only 2.8% of those interviewed felt the LED lights are worse, and 3.5% of them felt they are somewhat the same. This indicates that the LED lights, by majority opinion, are better than the HPS lights.

3. Do you feel that the new LED lights installed will improve safety in the area at night?

The results displayed in Figure 12, indicate that a majority (95.2%) of those interviewed felt that the LED streetlights will improve safety in the area at night. Only 1.4% of those interviewed felt the LED lights will not improve safety and 3.5% of them felt the LED lights will not cause any change in safety. This indicates that the LED lights, by majority opinion, would improve safety.

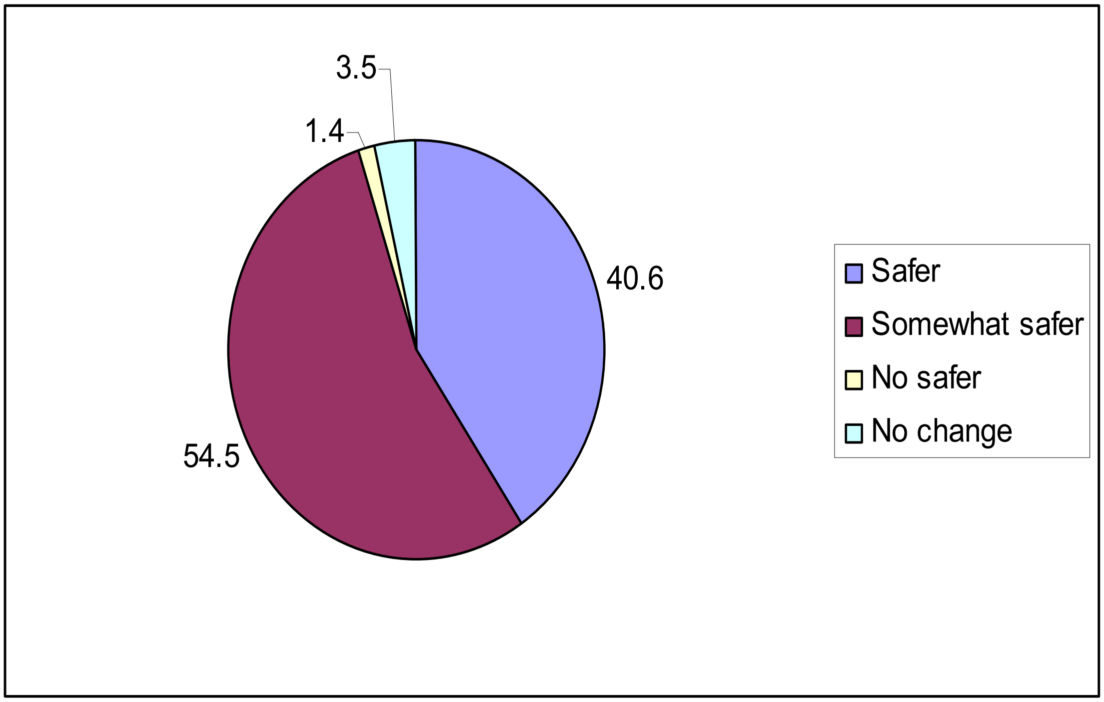

Figure 11: Percentage of Responses to Question 3 ***Do you feel that the new LED lights installed will improve safety in the area at night?***

4. ***Do you feel that the new LED lights installed create less glare or more glare?***

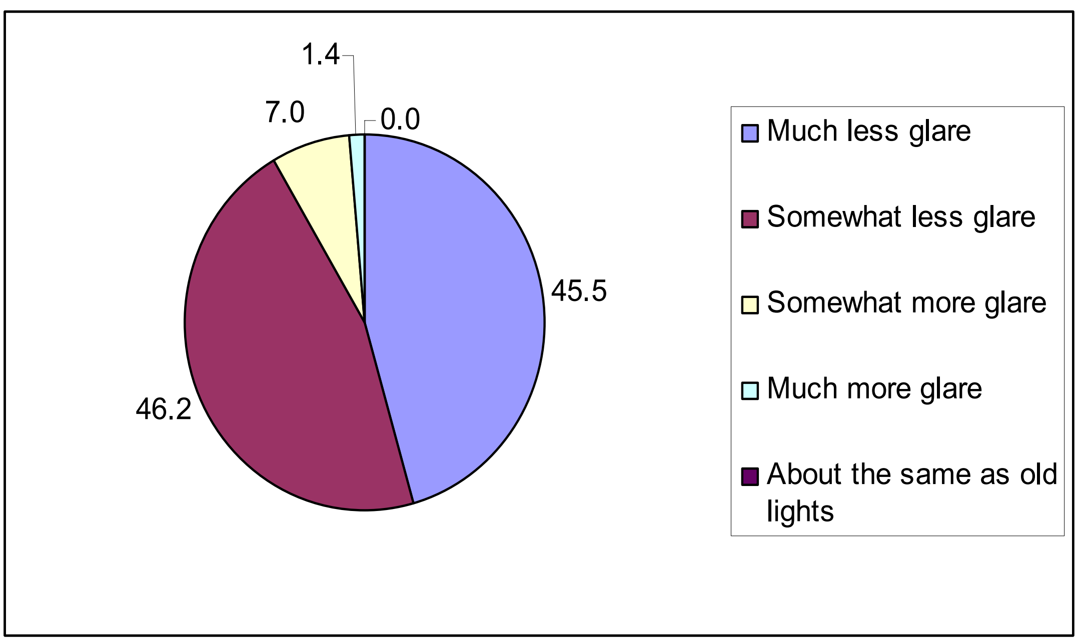

Figure 12: Percentage of Responses to Question 4: ***Do you feel that the new LED lights installed create less glare or more glare?***

From Figure 12, the majority (91.6%) of those interviewed felt that the LED streetlights produced less glare. Only 8.4% of those interviewed felt the LED lights produced more glare. This indicates that the LED lights, by majority opinion, produced much less glare.

5. ***Do you feel that the color of the new LED lights installed is adequate for night visibility?***

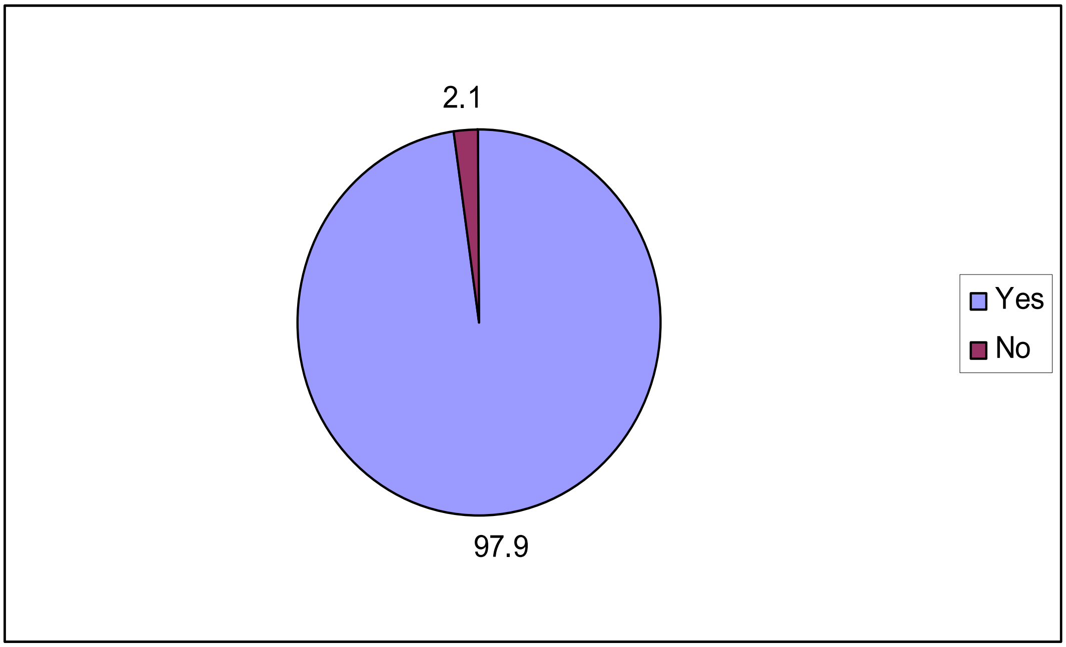

Figure 13: Percentage of Responses to Question 5: *Do you feel that the color of the new LED lights installed is adequate for night visibility?*

As shown in Figure 13, approximately 98% of the respondents said the LED lights were good enough for night visibility. Only 2% of the respondents thought otherwise.

6. ***Does the appearance of the new LED lights improve the aesthetics of the neighborhood?***

From Figure 14, approximately 84% of the respondents said the LED lights would likely improve the appearance or aesthetics of the neighborhood while 16% of the respondents thought otherwise.

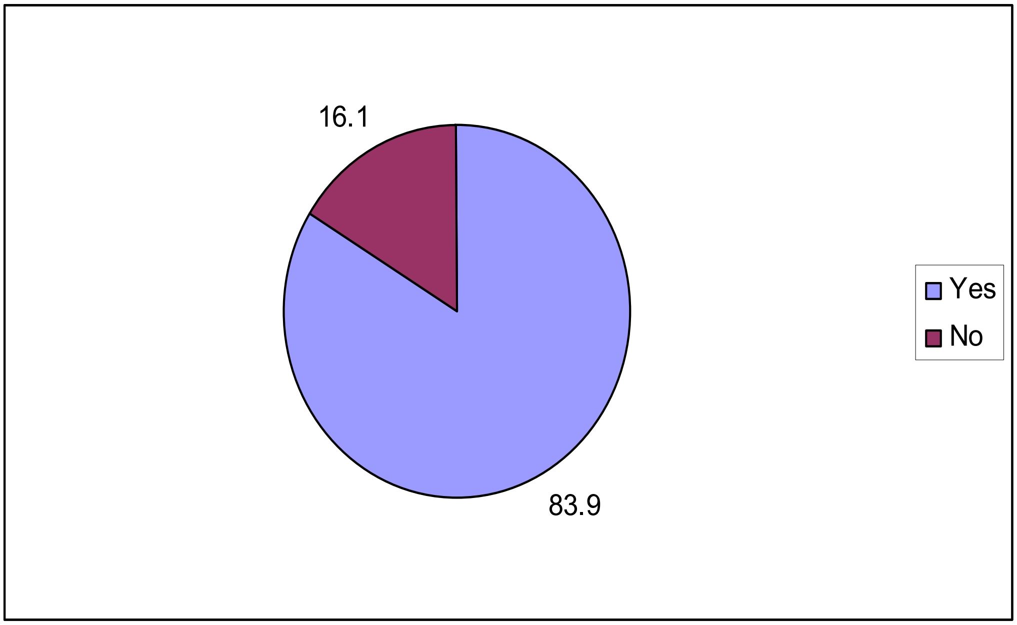

Figure 13: Percentage of Responses to Question 6: *Does the appearance of the new LED lights improve the aesthetics of the neighborhood?*

LED PRODUCT RECOMMENDATIONS

From the specifications and comparative field observations, combined with general appearance of each product observed in the field, the evaluation team recommends that either of the products from the following vendors would be beneficial to the District of Columbia:

- Leotek
- LSG

The evaluation also considered the ease of retrofitting the LED product on existing infrastructure as well as potential maintenance issues.

ECONOMIC ANALYSIS

DDOT furnished the research team with current billing charges (August 2010) as well as energy charges of existing HPS Streetlights and the installed LED Streetlights. A number of assumptions were also made in the analysis of the benefits and costs of the fixtures and their installations. The following is the summary of the assumptions used:

1. The life of the HPS lamps is 24,000 hours while that of the LED is 60,000 hours.
2. An opportunity cost (percentage per time) of 4% was used in calculating the payback years.
3. The comparison was conducted based on existing 7,996 units of HPS lamps.

The economic comparison analysis was conducted based on 150-Watt HPS lamp and that of 75-Watt LED light. The following are the table of results and figures.

Energy Costs

Based on the assumptions presented in Table 3, the 75-Watt LED lamp consumes less energy compared with the 150 Watt HPS lamp. This is also shown in Figure 14.

Table 3: Energy Operational Costs

	150 Watt HPS	**75 Watt LED**
Number of Units (Assumed)	7,996	7,996
Kilowatts Per Lamp	0.175	0.075
Total KW per Month	1,399.3	599.7
Hours of Operation	24,000	24,000
Kilowatt Hours	33,583,200.00	14,392,800.00
Cost of Operation for 24,000 hrs	$74,890.62	$32,095.98

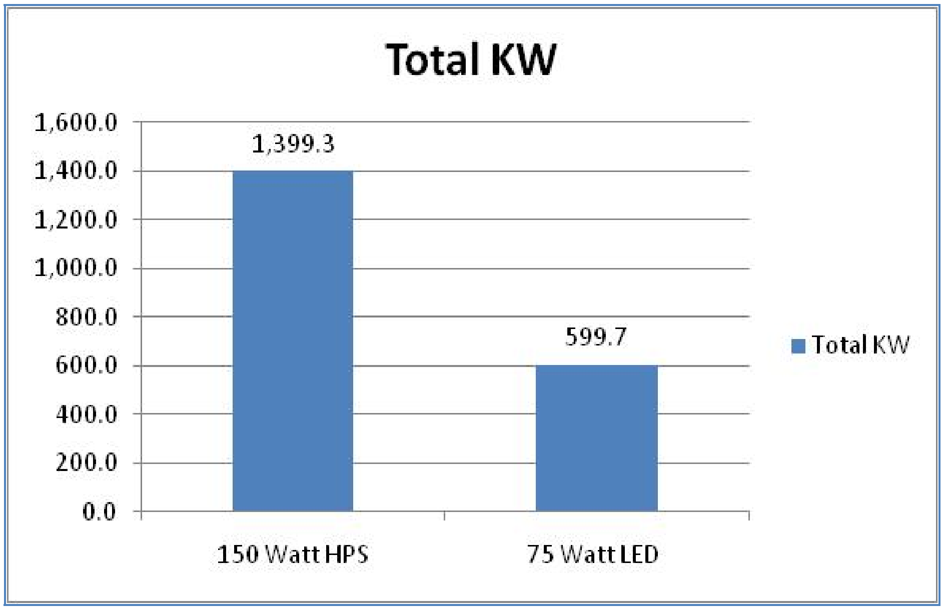

Figure 14: Energy Consumption Comparison in August 2010

From Table 3, it can also be seen that the 75 W LED light would cost less to operate for a period of 24,000 hours. This is equivalent to the expected lamp life of the HPS lights.

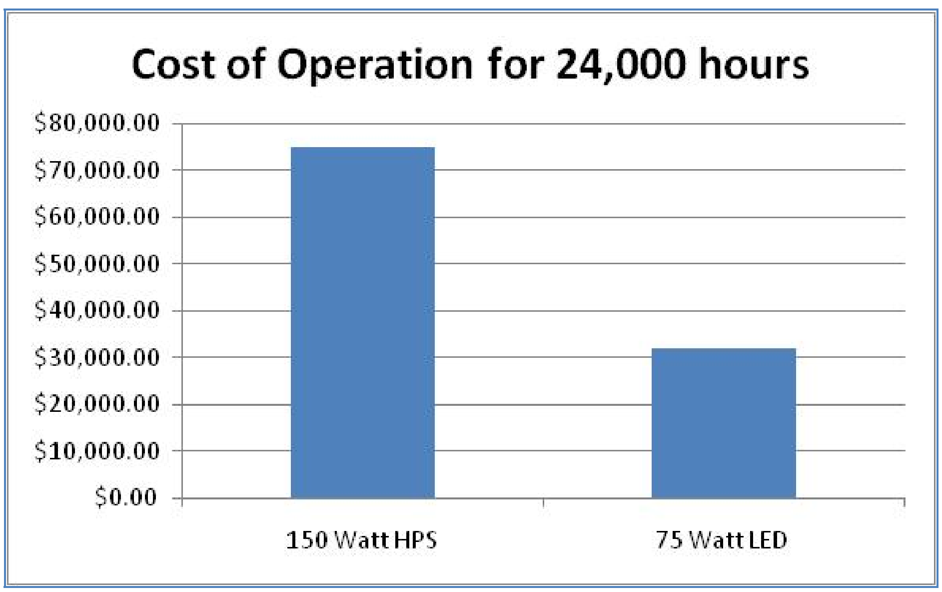

Figure 15: Cost of Operating Lamps for 24,000 hours

An average of 338.34 hours of night time burning was noted in the usage of 150 Watt HPS lamps (from the September 2010 energy bill provided by DDOT). Assuming the same hours for the LED fixtures, the following (Table 4) monthly consumption expenditures will be expected.

Table 4: Monthly Energy Operational Costs

	150 Watt HPS	75 Watt LED
Number of Units (Assumed)	7,996	7,996
Kilowatts Per Lamp	0.175	0.075
Total KW per Month	338	338
Monthly KW Hours of Operation	473,439	202,902
Cost of Operation for life of Lamp	$1,055.77	$452.47

The Table shows that, on the average, the LED fixture is expected to cost approximately 43% less than operating the HPS lamp on a monthly basis. This is also shown in Figure 16.

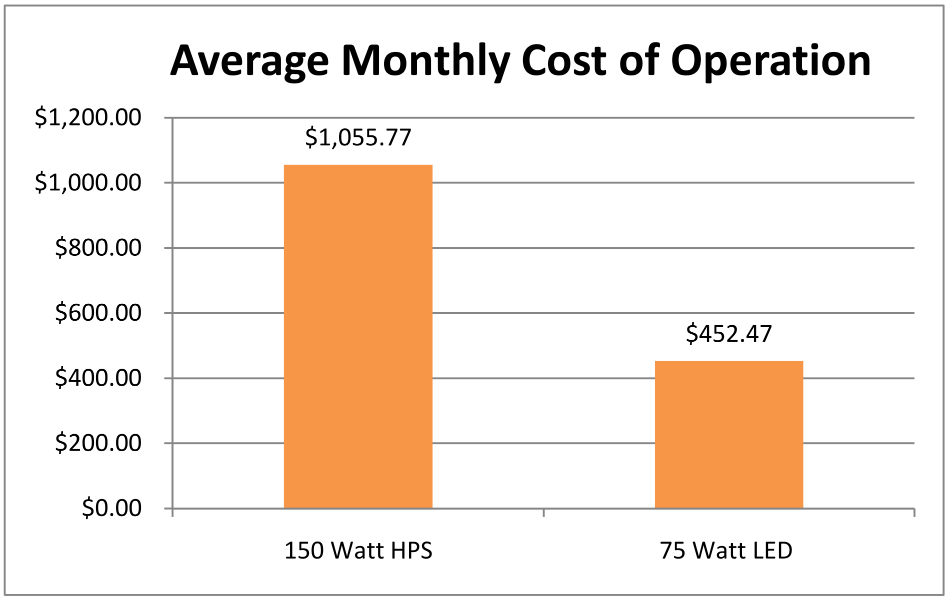

Figure 16: Average Monthly Cost of Operations

Cost of Materials

Table 5 presents a summary of the costs of fixtures and lamps based on the assumed number of units. The 75 Watt LED lamp and fixture costs more than the 150 Watt HPS. This is presented in Figure 17.

Table 5: Material Cost

	150 Watt HPS	75 Watt LED
Number of Units (Assumed)	7,996	7,996
Cost to replace fixture	$187.00	$350.00
TOTAL Cost of Materials	$1,495,252.00	$2,798,600.00

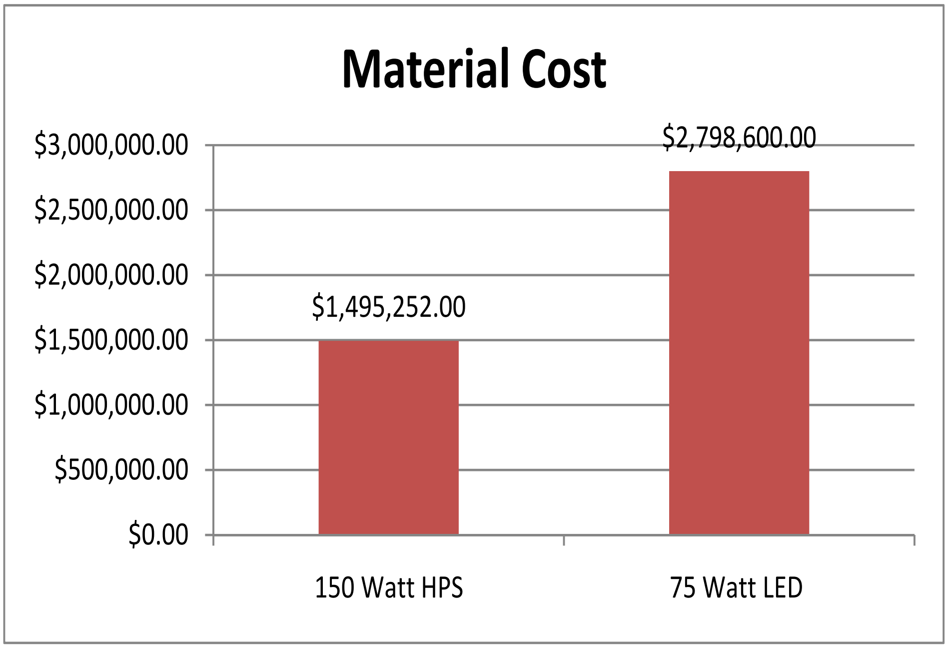

Figure 17: Cost of Materials

Maintenance Costs

Based on historical data obtained from DDOT, the cost of maintaining an existing 150 Watt HPS streetlight is approximately $100 per year (Table 6). Information obtained from various jurisdictions indicates that the average cost of maintaining each LED streetlight is about $60 per year. This indicates approximately 40% in savings per streetlight.

Table 6: MAINTENANCE COST

	150 Watt HPS	75 Watt LED
Number of Units (Assumed)	7,996	7,996
Cost to maintenance per Fixture per Yr	$100.00	$60.00
Cost to maintenance for All Fixtures per Yr	$799,600.00	$479,760.00

The comparison of the maintenance costs is also shown in Figure 18.

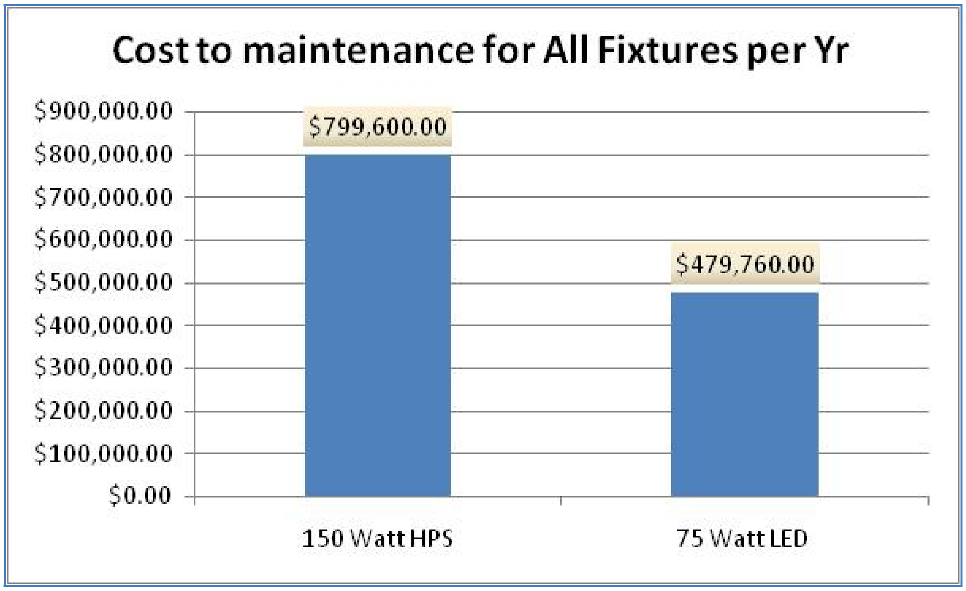

Figure 17: Maintenance Cost of Fixtures

In summary, with an initial investment of $4,797,600.00 for the LED fixtures and lamps (from Table 4) and an annual savings of $362,631.64 (energy and maintenance) savings will be realized. Based on this, the approximate payback period would be approximately 3 years as shown in Figure 18.

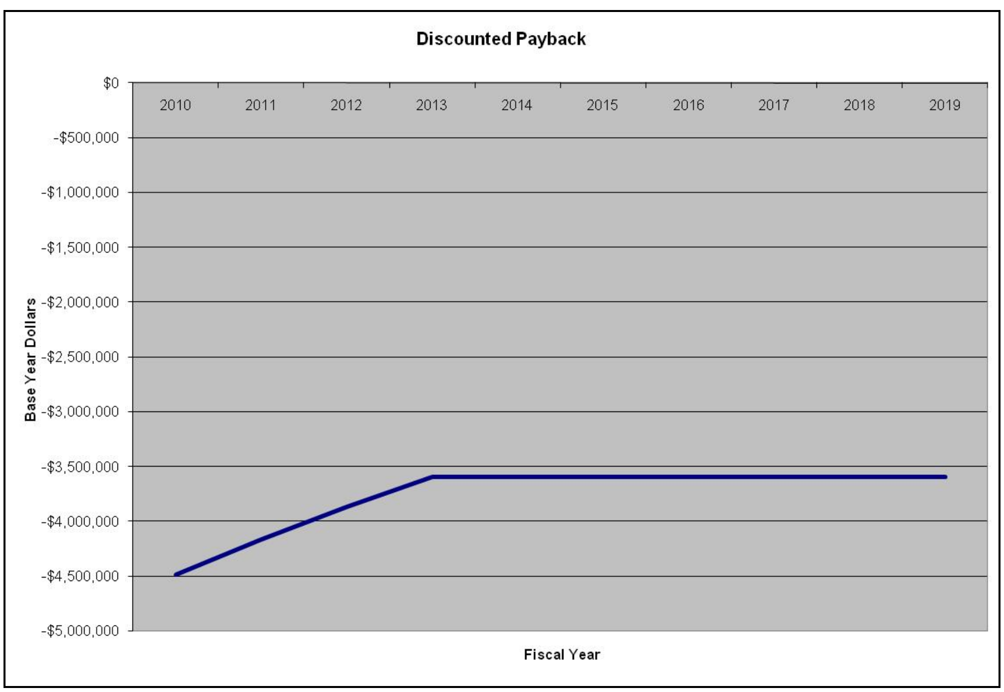

Figure 18: Payback Period

APPENDIX

FIELD MEASUREMENTS FOR LED PRODUCTS

FIELD MEASUREMENTS FOR LEOTEK

	LEOTEK					
	30ft	0.3		0.4		0.4
	20ft	0.5		0.5		0.7
	10ft	0.8		0.9		1.1
	0ft (POLE)	1.1		1.1		1.3
	-10	0.8		0.9		1
POLE(distance)	-20	0.5	<---------5ft--------->	0.5	<---------5ft--------->	0.7
	-30	0.3		0.3		0.3
	-40	0.2		0.2		0.2
	-50	0.1		0.1		0.1
	-60	0.1		0.1		0.1
	-70	0.1		0		0

FIELD MEASUREMENTS FOR HADCO

	HADCO					
	30ft	0.3		0.4		0.5
	20ft	0.4		0.5		0.8
	10ft	0.5		0.5		0.8
	0ft (POLE)	0.8		0.7		0.8
	-10	0.4		0.5		0.5
POLE(distance)	-20	0.2	<---------5ft--------->	0.3	<---------5ft--------->	0.2
	-30	0.1		0.2		0.3
	-40	0.1		0.2		0.3
	-50	0		0.1		0.1
	-60	0		0		0
	-70	0		0		0

FIELD MEASUREMENTS FOR LSG

LSG						
30ft	0.7		1.1		1.4
20ft	0.5		0.6		1.1
10ft	0.6		1.1		1.1
0ft (POLE)			1		1
-10	0.7		0.9		1
-20	0.4	<---------5ft-------->	0.4	<---------5ft--------->	0.7
-30	0.5		0.5		0.7
-40	0.3		0.4		0.6
-50	0.2		0.3		0.5
-60	0.1		0.1		0.2
-70	0		0		0