STATE OF INDIANA

INDIANA UTILITY REGULATORY COMMISSION

VERIFIED PETITION OF NORTHERN INDIANA PUBLIC SERVICE COMPANY FOR AUTHORITY TO MODIFY ITS RATES AND CHARGES FOR ELECRTIC UTILITY SERVICE AND FOR APPROVAL OF: (1) CHANGES TO ITS ELECTRIC SERVICE TARIFF INCLUDING A NEW SCHEDULE OF RATES AND CHARGES AND CHANGES TO THE GENERAL RULES AND REGULATIONS AND CERTAIN RIDERS; (2) REVISED DEPRECIATION ACCRUAL RATES; (3) INCLUSION IN ITS BASIC RATES AND CHARGES OF THE COSTS ASSOCIATED WITH CERTAIN PREVIOUSLY APPROVED QUALIFIED POLLUTION CONTROL PROPERTY, CLEAN COAL TECHNOLOGY, CLEAN ENERGY PROJECTS AND FEDERALLY MANDATED COMPLIANCE PROJECTS; AND (4) ACCOUNTING RELIEF TO ALLOW NIPSCO TO DEFER, AS A REGULATORY ASSET OR LIABLILITY, CERTAIN COSTS FOR RECOVERY IN A FUTURE PROCEEDING.	)	**CAUSE NO. 44688**

<u>INDIANA MUNICIPAL UTILITY GROUP'S SUBMISSION OF DIRECT TESTIMONY OF DR. ROBERT KRAMER</u>

The Indiana Municipal Utility Group ("IMUG"), by Counsel, hereby submits the Direct Testimony and Exhibits of Dr. Robert Kramer in this Cause to the Indiana Utility Regulatory Commission.

Respectfully submitted,

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<u>**CERTIFICATE OF SERVICE**</u>

The undersigned hereby certifies that a copy of the foregoing attached documents were served upon the following by electronic delivery this 22[th] day of January 2016, to:

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VERIFIED DIRECT TESTIMONY OF ROBERT KRAMER

Q. Please state your name, business address, and title.

A. My name is: Robert Kramer. My business address is: Purdue University Calumet, 2200 169th Street, Hammond, Indiana. My title is: Professor of Physics, NiSource Charitable Foundation Professor of Energy and the Environment, Director of the Energy Efficiency and Reliability Center.

Q. Please describe your educational and business experience.

A. I received a Ph.D. (1985) and M.S. (1979) in Nuclear Engineering from Purdue University, West Lafayette, Indiana, and M.S. (1973) and B.S. (1971) degrees in Physics, also from Purdue University, West Lafayette, Indiana. I have been employed at Purdue University Calumet since January 2004 at which time I started the Energy Efficiency and Reliability Center (EERC) and began developing and teaching courses in Energy Engineering and Physics, the majority of which are experientially based. As Director of the EERC, I am involved in the development and performance of research programs in energy utilization and efficiency, lighting systems, building energy efficiency, electric power, reliability, electric transmission, renewable energy sources, coal gasification for the production of liquid transportation fuels and fertilizer, advanced control of large industrial loads, nuclear reactor analysis, and combined heat and power systems. I am also a Certified Energy Manager, a Certified Demand Side Manager, and a Certified Energy Auditor. Prior to coming to Purdue University Calumet I was most recently the Chief Scientist for NiSource Energy Technologies and was responsible for technical developments of new energy technologies including Combined Heat and Power and building energy optimization systems. I was employed by NIPSCO and NiSource from 1973 until January 2004 and held the positions of Nuclear Fuel Engineer, Manager Applied Research, Manager Strategic Planning, Manager Technical Support, Director of Electric Engineering and Applied Research, Director of Electric Operations, Director of Electric Services, Vice President and Chief Scientist. During this time, I also taught a variety of courses in Physics and Electronics at Purdue University Calumet and Indiana University Northwest. My C.V. is attached.

Q. Specifically would you please describe your expertise in street lighting?

A. I have been involved to varying levels in various aspects of lighting systems, including street lighting, for most of my 40 year career. I have considered and worked with aspects of theory, design, optimization, operation of lighting systems and their performance as part of these efforts. I have been the principal investigator for various research efforts that considered lighting theory, technology, and control while at Purdue. One of these efforts considered energy system, including building and parking lot lighting, optimization and control that employed advanced wireless communications systems. This $1,000,000 grant from the Department of Energy provided the opportunity to install advanced wireless energy and lighting control/optimization systems in 9 buildings on the Purdue University Calumet campus as well as researching and developing lighting options for a variety of similar applications commercially and in industry. In one part of this effort an intelligent advanced control system was developed to control parking garage lighting by optimizing the use of natural lighting. This system resulted in a 40% electric energy savings and had a payback of approximately two months for this installation. I have been the Principal Investigator for a variety of energy audits performed by the EERC for industry, commercial businesses and school systems, including parking lot lighting designs and options. I have developed three experientially based Energy Engineering courses that directly consider building, parking lot, and street lighting as part of their subject material. I have developed a Renewable Energy Systems course that considers the solid state physics (condensed matter physics) and electrical engineering aspects of Light Emitting Diodes as part of its subject material. I also teach courses in physics that consider various aspects of the physics of light. As part of research efforts at the EERC, I started field testing street light luminaires based on modern technology approximately 8 years ago. During the last 5 years I have conducted research regarding the viability of various modern street lighting technology alternatives including work as the Principal Investigator for two studies for the Indiana Municipal Utility Group (IMUG). My research covered many aspects of lighting including types, longevity, efficiency, luminescence, power quality, thermal performance, manufactures, market prices and more. Over the last 4 years I have conducted evaluations of the modern street lighting products of approximately 20 different vendors. Also during this time I have tested various modern street lighting products in the EERC laboratory to assess their viability as a replacement for currently installed luminaires such as High Pressure Sodium (HPS). The capabilities of the EERC laboratory to consider lighting theory, design and testing was enhanced approximately three years ago as a result of a $1,000,000 grant from the Department of Energy that provided a new energy research facility and related laboratory and test equipment.

Q. What is the purpose of your testimony in these consolidated proceedings?

A. IMUG has requested that I provide information to the Commission and other parties in this proceeding regarding street lighting. My testimony supports replacement of NIPSCO's old technology streetlights with new LED streetlights. My testimony will address the following:

- Timing of LED Street Light Rate Development
- The types and characteristics of older and obsolete street lighting
- The types and characteristics of available current technology street lighting
- How the replacement of old technology street lights with current street lighting technology would provide material benefits including:
  - Improved public safety
  - Maintenance and installation benefits
  - Revitalization of blighted or deteriorating neighborhoods
  - Reduced electricity consumption, costs, and environmental emissions
  - Promotion of economic development
  - Improved safety of utility employees
  - Reduction of loading on NIPSCO's electric distribution system
  - Enhanced reliability of NIPSCO's distribution system that serves areas with street lighting.
  - Improved quality of life in urban areas
- LED savings results in other metropolitan areas
- The economy of scale pricing and resulting savings from mass LED retrofit
- The time is right for mass LED retrofit programs
- Recommended LED street light luminaires

Q. What have you done in preparation of your testimony and exhibits?

A. I read the NIPSCO's rate case and TDSIC prefilled testimony and exhibits related to street lighting, reviewed materials pertaining to street lighting, discussed and reviewed street lighting with IMUG including the importance of street lighting both in specific areas and at large. I met with NIPSCO representatives, had them tour our laboratory, provided them with lighting information and discussed maters pertinent to NIPSCO street lighting. I actively participated in the formulation of the NIPSCO standard for LED street lighting as well as the evaluation of vendor data submitted in response to a Requests for Information and a Request for Proposals for LED street lighting issued by NIPSCO. I have familiarized myself with NIPSCO's streetlights and have tested existing NIPSCO HPS as well as various candidate LED replacement luminaires. Previously I made site visits including: General Electric, Cleveland, Ohio; American Green Power, South Bend, Indiana; and Cree, Madison, Wisconsin. In this process I have worked closely with Mr. Ted Sommer.

<u>TIMING OF LED STREET LIGHT RATE DEVELOPMENT</u>

Q. Is it appropriate to establish a mass retrofit LED street lighting rate at this time?

A. Yes, an LED mass retrofit rate is appropriate for many reasons. Modern Light Emitting Diode (LED) street lights provide many dramatic advantages over older technologies such as High Pressure Sodium (HPS). It is appropriate to initiate the establishment of a mass retrofit LED rate at this time since such a rate will facilitate the adoption of the LED technology by NIPSCO and municipalities in a timely manner and provide the benefits of this technology to rate payers sooner and more economically. As municipalities consider upgrading non NIPSCO owned street lighting to LED technology, such a mass retrofit rate will reduce uncertainty in their decision process and will assist in enhancing value. If the establishment of an LED mass retrofit rate is delayed to sometime in the future the associated uncertainty will further delay obtaining the potential benefits as well as increasing the chance of inconsistent designs.

Q. Is it time to move forward with a mass LED retrofit program?

A. Yes it is. NIPSCO and IMUG cooperatively developed a standard for LED street lighting luminaires that included considerations from laboratory and field tests that were conducted cooperatively between NIPSCO and the Purdue Energy Efficiency and Reliability Center (EERC). This standard provided the basis for the issue of a Request for Information (RFI) and a Request for Proposal (RFP) for LED Street Lighting. Thereafter, NIPSCO and IMUG cooperatively evaluated the responses to the RFP and have developed a list of preferred vendors and product lines that provide maximum benefit from the available technology. Best performing and reasonably priced replacement LEDs are now available.

See attach. correction page

In approximately 1985 NIPSCO performed a system wide replacement of Mercury Vapor ("MV") Street Lights with HPS. These HPS units are now at or approaching end of life and consequently it is again appropriate to replace these units with a similar program that now employs much more efficient advanced LED technology. The existing HPS units are near fully or fully depreciated and are starting to require major replacement of failing or deteriorating components. As one example, the plastic bulb and reflector covers of some of the existing HPS luminaires have significantly deteriorated developing a cloudy yellowish appearance. These factors are significantly reducing the light that is emitted from the luminaire and consequently reduce their illumination value. In addition, the power supplies for the HPS luminaires are approaching, or have exceeded, their life expectancy. Replacement power supplies are becoming more difficult to obtain for HPS luminaires due to the decreasing use of HPS technology and the market shift to LED. Also, LED Street Lights provide an energy saving of 60%+ as compared to HPS. This dramatic improvement in energy efficiency results in a reduction of environmental emissions since less electricity is required to power LED street lights. NIPSCO currently generates the majority of its electricity from fossil based generating stations. Generally, generating station environmental emissions, such as carbon dioxide, decrease as the need for electricity decreases since less fuel is burned. Preliminary estimates of possible reductions in Green House Gas Emissions will be provided in following sections of this testimony. It is also important to recognize that these associated reductions in Green House Gas Emissions are immediately available and they do not require additional technology development or construction since they rely on proven technology and consequently are very low risk. LED Street Lights are thus an immediately available, low risk method to dramatically increase associated energy efficiency in a tangible manner and provide significant safety, economic and environmental benefits.

OLD STREET LIGHT TECHNOLOGIES

Q. Please describe the various types of older street lighting technology that remain in place in some areas including the NIPSCO territory.

A. The NIPSCO street lighting principally consists of a blend of HPS, MV, and Metal Halide ("MH") luminaires. The HPS luminaires have ratings of 100W, 150W, 250W, and 400W. In contrast, there are now modern cost effective lighting technologies available that provide a variety of increased benefits when compared to the currently installed technologies.

Q. What are the shortcomings of these older lighting technologies?

A. A variety of different street lighting technologies have been employed historically. Each served the purpose at the time, but lighting technology has substantially advanced making obvious a variety of issues and shortcomings with these older and obsolete lighting technologies. These days the older technologies of mercury and HPS should be disfavored for the better quality light, greater brightness, increased efficiency, and longer useful life of LED and Inductive Fluorescent (IFL) technology. I will describe the older lighting technologies.

Mercury vapor lamps are high intensity discharge lamps that were first commercially introduced in 1901. They use an arc through vaporized mercury in a high pressure tube to create a very bright light directly from its own arc. They have a higher color temperature[1] of 3,900-5,700 K (i.e. more blue light) and a typical useful life of

[1] Color Temperature is one common method of specifying the color characteristics of a light source. It is based upon the color of light that is emitted from a black-body radiator at a specified temperature in units of Kelvins. The temperature in Kelvins is the temperature in degrees Centigrade plus 273.15. A black body radiator is essentially an entity that perfectly emits and absorbs radiation at some given temperature. A piece of red hot metal starts to emit a reddish light when its temperature reaches 753 K. If its temperature is raised further to 1773 K it emits a bright white light. Black-body radiation has a characteristic, continuous frequency spectrum that depends only on the body's temperature.

24,000 hours. They have a lower lumen[2] per watt (i.e. light output per watt of input electricity) value than HPS. Mercury street lights were common in this region some time ago. But as energy prices and environmental concerns increased there was a desire to move to a lighting source that would use less energy, have better color characteristics, better reliability, and reduced maintenance. They also become dimmer over time rather than fail outright, meaning they may be kept in service beyond their actual usefulness. These lamps emit a light that tends to be more gray-greenish. Human skin tends to have a greenish cast under mercury vapor light. They have a long warm up time during which much less light is produced. Even though the greenish cast was reduced by adding materials to the bulb this is still a negative aspect. In addition they contain mercury and hence are an environmental concern. As of 2008, the sale of new mercury vapor streetlights and ballasts was banned in the US by the Energy Policy Act of 2005, although the sale of new bulbs for existing fixtures will continue until 2016 in the US and Europe. In general, mercury vapor lamps have already been supplanted by other HID lights such as HPS, or more modern technologies such as Inductive Florescent (IFL) or Light Emitting Diode (LED) that offer higher lumen output and better color properties.

Low Pressure Sodium lamps (LPS) are also an old technology. This low pressure version of the sodium lamp was invented by Arthur Compton at Westinghouse in 1920 and was first introduced by Philips in Holland in 1932. They work by creating an electric arc through vaporized sodium metal. Other gases or materials are added to assist in starting and control of color. Today it is used mainly in Europe. It is characterized by a monochromatic yellow color. The yellow color of this lamp is a major issue that has

[2] 1 lumen = luminous flux per m^2 of a sphere with 1 m radius and a 1 candela isotropic light source at the center

limited its use. The combustible nature of the sodium it uses is also a use limiting concern. These lamps have a color temperature of 1800 K with output of 100-190 lumens per watt and a life of 18,000 hours.

High pressure sodium lamps[3] first came on the market in 1964. In contrast to LPS lamps, HPS are the most common street lighting lamp in use today. They are less efficient than LPS. While they have improved color compared to LPS, they have decreased color rendering in comparison to metal halide, halogen lamps, and far worse color rendering than LED lamps. The response of the human eye to light depends on various factors.[4] During the day our eyes are accustomed to relatively high levels of light and consequently we see color and objects more clearly and quickly. At night when there are greatly reduced light levels we tend to see much less color and it is more difficult to focus objects and detect change. Considering these differences in vision, HPS lamps show greatly reduced performance for night lighting as a result of the color of light they emit in reduced illumination levels. Conversely, white light sources, for example LED and IFL, have been shown to increase driver peripheral vision and improve driver brake reaction time by at least 25%. Using an approach that considers the way that light is perceived under various light intensities (employing the ratio of scoptic to photopic vision) the lighting value of a HPS light is decreased by 75% due to the orange color of the light it emits. HPS lights even with, additional materials added to the bulb still appear

[3] They were developed by General Electric in Schenectady, New York and Nela Park, Ohio.
[4] The response of the human eye to light depends on various factors including; physical, physiological and psychological factors and varies from person to person. Scotopic vision is the vision of the eye under low light conditions. Photopic vision is vision under well-lit conditions. Photopic vision allows color perception and a significantly higher visual acuity (clearness of vision) and temporal resolution (timing resolution) than available with scoptic vision. The ratio of the amount of scoptic to photopic vision (S/P) can be used to evaluate how light quality is perceived.

to emit an orange-yellow light that still does not provide good color discrimination. In general, NIPSCO has replaced aging MV luminaires with HPS technology. Compared to current technology HPS streetlights are large and heavy luminaires making them relatively more difficult to store and install as well as requiring more maintenance.

Metal Halide Lamps were first developed in the 1960s. They are typically a large lamp with a bulbous shape and a white to bluish light. Their color tends to shift over time and it is common to see a row of identical fixtures each emitting a slightly different color. Advances in technology improved these shortcomings but they still have performance and useful life issues when compared to IFL or LED lights.

My Attachment 1-A depicts the typical characteristics of various lighting sources. As can be observed in this Attachment, LED street lights have a substantial overall advantage over the other alternatives for the recommended street light replacements.

CURRENT LIGHTING TECHNOLOGIES

Q. Please describe the various types of current street lighting technology that are being used to replace the older technology lighting systems.

A. Today there is a trend to switch to light sources that have reduced energy use, improved color qualities, competitive costs, and extended maintenance intervals. Inductive fluorescent lights (IFL) have been in existence for some time and currently have decreased in price. These devices operate over a wide temperature range and hence are applicable for use in subzero environments as well as in locations with higher temperature such as in manufacturing facilities with large motors or furnaces. These lights have estimated lives of +100,000 hours, produce a favorable white light, and have proven to be very reliable. We have had an IFL luminaire in test at the Purdue Calumet campus for approximately 7 years with very positive results. A key issue is how well a light source directs the light it produces to where it is wanted, for example on the street and not in the front window of the adjacent house. IFLs are less directional than LEDs and hence can introduce concerns for stray light. The vast majority of NIPSCO's street lights are HPS. Compared to new LEDs this older HPS technology has substantially higher maintenance costs, much higher energy usage, shorter life span and poorer illumination.

Light Emitting Plasma (LEP) street light luminaires are currently being produced by several manufacturers. They have achieved impressive performance in high wattage applications at installation elevations greater than 25 feet. In a recent street lighting demonstration for Scottsburg Electric Utilities, Indiana 400W equivalent LEP luminaires demonstrated an overall energy savings of 51%. In the case of an application that calls for 3,000 lumens, the LEP system would still require an emitter, driver and power supply and would therefore have approximately the same cost as a 20,000-lumen LEP system. LED technology scales down well and hence would be a more cost-effective solution for such a case than LEP. This technology is now just starting to enter the market and hence cost and availability issues are a concern. There are currently a limited number of suppliers for LEP technology and they have not gained significant market share.

Metal halide lights are also still available. But higher cost and poorer performance, shorter life and issues with uniformity of the light emitted leave them less desirable than LEDs.

LED technology is nationally the most widely implemented replacement for HPS luminaires. High quality modern LED based luminaires provide up to 60%+ decrease in energy usage, long life estimated at 100,000 hours or more, competitive price, excellent light color characteristics, instant starting, full dimming capability, highly directional light, resistance to vibration and relatively small size and light weight luminaires that facilitate storage and installation. This modern technology is being implemented in numerous locations and metropolitan areas globally including major replacement programs involving retrofits of 141,089 street lights in Los Angeles and 300,000 in New York. In my opinion LEDs are the best choice for large scale light replacements for many beneficial reasons.

My Attachment 1-C shows results of tests that were performed in cooperation with NIPSCO to compare the lighting value from HPS streetlights and modern LED technology. These tests were performed during 2014 at a site in Dyer Indiana as part of an evaluation program I conducted for 8 IMUG municipalities in Indiana. These graphs show a comparison of the amount of light on the street at various locations in the area indicated when initially illuminated with a HPS street light and subsequently when the HPS street light was replaced with an LED street light. Values of horizontal illuminance were gathered using standard methods for a matrix of test points on the street. Prior to collecting the data the existing HPS lights had new bulbs installed and the luminaires were cleaned. The light output values were then adjusted to compensate for decrease in light output as a function of bulb life using standard methods. Subsequently the HPS luminaires were replaced with equivalent LED luminaires and the measurements were repeated. The bottom surface in Attachment 1-C was developed by fitting a surface through the collected data points for the HPS luminaire. Similarly the top surface was developed using data collected in the same manner for the LED luminaire. The position and height of the poles supporting the luminaires is indicated by the filled circles and pole numbers along the road test section. The LED luminaires were installed on the same mounting bracket as the original HPS luminaires. By comparing these two surfaces it can be observed that the amount of light on the street is slightly greater for the LED luminaire even though it is using 49 watts as opposed to the 121 watts used by the HPS luminaire. The comparison of the total amount of light was done by determining the volume under each curve and is listed as Before and After volumes in Attachment 1-C. There is also a more uniform coverage of the road surface for the LED luminaire as opposed to the original HPS luminaire. This tends to reduce the variation in light intensity that a vehicle driver experiences and thereby reduces discomfort level and improves safety.[5] In addition, the LED luminaire is emitting a white light as opposed to an HPS orange light and is thus providing many visibility benefits. Attachment 1-D shows before and after photographs that I took at the site. It provides a direct comparison of the light sources and clearly indicates the improved quality of LED as compared to the older HPS technology.

SAFETY BENEFITS OF NEW LEDs

Q. Are there Improved Public Safety benefits from LED lighting technologies?

A. Yes, they emit better quality white light, creating better visual clarity and putting the right amount of light where it needs to be. LEDs provide improved visibility by better

[5] Van Brommel, W., Road Lighting (2015), Springer, New York

focusing the produced light as well as improving the light's visual characteristics. As an example, driving a car involves an ongoing decision-making process based on information we sense, the most important of which is vision. Good lighting is essential to assure a high level of performance when driving at night.[6] A direct link has been established between visual performance under different lighting types at intersections in Minnesota and a reduction in night time traffic accidents.[7] LEDs also use significantly less energy that in turn reduces environmental emissions and thereby improves the environment and public health. Additionally LEDs substantially reduced maintenance enhances public safety by lighting an area longer than other technologies like HPS and reducing traffic disruptions that can occur during maintenance activities.

An important factor that needs to be carefully considered in the choice of street lighting technology is the quality and distribution of light onto the desired area. If light isn't incident upon desired areas, there is a loss of a portion of the usable light. The lighting distribution of HPS luminaires is poorer than LEDs in that they must over-light the area directly below creating light 'hotspots' in order to maintain minimum light levels further away. For HPS and other old technology lighting, there also may be issues with dark skies regulations or penetration of light into areas where it may not be wanted such as the windows of nearby houses. Attachment 1-G shows a generic depiction of the average light distribution from comparable HPS and LED luminaires. As can be seen the LED luminaire better distributes the light from the luminaire and hence effectively increases the overall light placement efficiency while reducing light loss to surrounding

[6] Van Brommel, W., Road Lighting (2015), Springer, New York
[7] Rea, MS, The Trotter Patterson Lecture 2012: Whatever Happened to Visual Performance, Lighting Res Technol 44:95-108.

areas and the sky. LED's significantly reduce such concerns and reduce "light pollution" by better focusing the light they produce as compared to older technologies. The increased focusing capability of LED luminaires as compared to conventional HPS luminaires increases the ability to provide more uniform lighting of the roadway and reduce bright spots. This is important since a continuously-alternating sequence of bright and dark light regions on the road leads to driver discomfort.[8]

The perceived color of the light is also an important public safety and ascetic aspect of light replacement design. If the color reduces object recognition, the value of the lighting is decreased. Similarly a light source that produces light with a color that is perceived as increasing the recognition of objects, vehicles, and/or people will increase the value of the projected light for safety and other considerations.

The Roadway Lighting Design Guide 2005 published by the American Association of State Highway and Transportation Officials, states "improved safety is the primary goal of public lighting". Further it states "public lighting affects motorists, cyclists, and pedestrians." LEDs materially increase public safety over older lighting technologies, including HPS, by providing enhanced light quality and lighting reliability.

In addition, LEDs offer significant savings in energy use and in maintenance both of which have an influence on public safety. When lighting is less costly to operate and maintain it frees up money that can be used to install streetlights in previously unlit areas or to help pay for other public safety efforts such as fire and police protection.

To understand why current lighting technologies improve safety it is first necessary to consider how light is perceived. My attached Attachment 1-B depicts the

[8] Van Brommel, W., Road Lighting (2015), Springer, New York

range of light levels for the different types of vision. Scotopic Vision is vision by the normal human eye, when only the rods of the retina are being used. At this state of adaptation there is no sensation of color. Photopic Vision is predominantly vision when only cones are active and normal color vision is. Mesopic Vision is vision when both the rods and cones are active, at varying percentages based on conditions.[9] At this state of adaptation, the eye is sensitive to color (more "blue" at the lower end of the adaptation range and more "red" at the higher). It is possible to develop modifiers to indicate the influence of light quality on the perception of objects and consequently safety.[10] In the mesopic region the spectral sensitivity of the human eye changes with light level. The FHWA Handbook gives the example of comparing light from different types of lighting technologies as follows; "a high pressure sodium roadway fixture might have an S/P ratio of around 0.6; if lamped with pulse start metal halide it might be around 1.4; and with an LED roadway fixture it may be 2.0. So using the MOVE[11] multiier approach, if we assume the adaptation luminance is 1 cd/m^2, the mesopic luminance for the HPS luminaire would be approximately 0.93 cd/m^2, the metal halide luminaire would be approximately 1.06 cd/m^2, and the LED luminaire would be approximately 1.15 cd/m^2." Multiple studies have shown that the spectrum of a light source influences its subjective impression of brightness.[12,13] When used to calculate effective luminance of various light sources, this results in a change in the perception of relative efficacy or amount of light

[9] Illuminating Engineering Society of North America Handbook, 9e, 2000.
[10] Federal Highway Administration Handbook, August 2012, DTFH 61-10-P-00162
[11] Mesopic Optimization of Visual Efficiency was developed by Eloholma and Halonen in 2005
[12] Knight, C.,Field Surveys Investigating the Effect of Lamp Spectrum on Perception of Safety and Comfort at Night, Lighting Res Technol 43(3):313-330, 2010.
[13]Fotis, SA, Cheal, C., Predicting Lamp Spectrum Effects at Mesopic Levels, Part 2, Lighting Res Technol 43:159-172, 2011.

produced per watt of electricity used. Taking this into account, LED technology can have an effective improved luminous efficacy, i.e. lumens/watt. A recent report from the International Lighting Commission (CIE) verifies this by suggesting lower light levels can be used for spectra with higher S/P ratios.[14]

Light levels can be correlated with reaction time and contrast threshold levels and thus indicate a positive influence on safety. For example the time it takes to recognize a child in the roadway and apply your car brakes is materially reduced with LED lighting, as is the ability to see a potential attacker looming near your walkway. Attachment 1-F shows a comparison of the appearance of an individual crossing the street first under HPS light and then under LED light. It is clear that it is easier to see the person under LED light due to increased contrast as well as being able to perceive details of the person including facial features better under LED lighting. It is also worth noting that in addition to the increased light quality resulting from conversion from HPS to LED there has also been a 55% energy reduction for the LED street light as compared to the HPS street light.

As stated in the FHWA Handbook "In addition to traffic safety, adequate lighting provides clear benefits in terms of personal security. Roadway lighting often serves the purpose of safeguarding personal safety for pedestrians, bicyclists, and transit users as they travel along and across roadways. Deep shadows or darkness reduce personal security, and walking, bicycling or commercial activities may become uncomfortable or unsafe. Thus, ensuring that the lighting provides minimum acceptable levels of illumination is of great importance to all users of a roadway environment."

[14] CIE publication 206:2014, The Effect of Spectral Power Distribution on Lighting for Urban and Pedestrian Areas, 2014.

Q. Are there examples of how lighting has improved public safety?

A. Yes. Levels of crime have been shown to decrease as a result of improved lighting. For example, in the City of Los Angeles "Bright Lights, Safe Nights" program a total of 144,000 of the existing 200,000 street lights have been converted from principally HPS to LED technology. The lighting upgrade was performed over a period from 2009 to 2013. Crime statistics comparing 2009 to 2012 levels, as reported by the local police department, indicate a decrease in Theft From Vehicles of 10.67%, a decrease in Burgulary-Robery-Theft of 6.40%, and a decrease in Vandalism of 10.90% for a total decrease in these categories of 8.9%. These improvements are not just applicable to Los Angeles. As noted in the report Improving Street Lighting to Reduce Crime in Residential Areas, by Ronald V. Clarke, Center for Problem-Oriented Policing, U.S. Department of Justice, 2006-CK-WX-K003, December 2008; "Improved street lighting is widely thought to be an effective means of preventing crime, second in importance only to increased police presence. Indeed, residents in crime-ridden neighborhoods often demand that the lighting be improved, and recent research generally bears out their expectation that improved lighting does reduce crime." Further it is stated that; "It is clear that reductions in crime can be achieved by improvements in street lighting and that these reductions will be most worthwhile in high-crime neighborhoods. It is also clear that improved lighting can reduce crime during the day and at night. This suggests that improvements to lighting not only act as a situational deterrent to crime, but can also improve local community cohesion and pride, which in turn increases the willingness of residents to intervene in crime or cooperate with the police. Improved lighting will also send a message to potential offenders that the neighborhood no longer offers easy opportunities for crime." A recent preliminary study, based on the analysis of data from 13 studies from the USA and UK, indicates a 21% reduction in property and violent crime in areas with improved lighting compared to control areas without improved lighting.[15]

Beyond these examples we all have our own past experience where well lite places made for safer driving and left us willing to go out in public at night with an enhanced sense of security. For some of us there may even be past experiences where the lack of adequate night lighting negatively impacted our lives or the lives of our loved ones.

MAINTENANCE AND INSTALLATION BENEFITS OF NEW LEDs

Q. Are there maintenance benefits from LEDs?

A. Yes. LEDs provide improved visibility for a longer useful life and significantly improved reliability over old technology such as HPS. The most highly rated current generation LED fixtures have estimated lives of 100,000+ hours. This extended life will reduce the frequency of lighting maintenance and consequently materially reduce maintenance costs and the exposure of employees to associated maintenance hazards. Recent industry data indicates that maintenance service call requests can be reduced by approximately 80% for LED luminaires as compared to HPS.[16] The unanticipated failure

[15] Welsh,B.P., Farrington, D.C., Effects of Improved Street Lighting on Crime, Campbell Syst Rev, The Campbell Collaboration, Oslo, doi: 10.4073/csr:2008:13

[16] MSSLC Maintenance Webinar, 4/14/2014: For the City of Boston they have experienced a .5% defective rate for phase 4 in 2013 and .8% defective rate for 20,000 luminaires installed over the last 3 years. They also note a 30% reduction in inventory due to the improved reliability of the LED luminaires. The City of Las Vegas has had an 80% decrease in service call requests for 40,000 LED street lights. Warranty replacement has been less than .05%. Los Angeles has converted 141,089 street lights to LED technology and experiences less than a .2% failure rate. They

rate for LED luminaires is estimated to be less than 1%. This value is supported by field experience from various LED street light retrofit projects nationally as previously described.

By installing new luminaires in groups of several thousand it will be possible to gain substantial economy of scale benefits from volume purchasing of the luminaires themselves as well as a greatly reduced installation cost, which can conservatively be estimated to be in the range of approximately $40-$65 per luminaire.[17] If LED Street Light luminaires are installed in large groups and/or on a group program over multiple years by a contractor there is an opportunity to further reduce installation costs. It is now becoming common practice for LED Street Light Luminaires to be shipped directly to installation contractors on pallets designed for quick installation. Such an arrangement eliminates receiving, storage, and handling costs for the LED Street Light owner while facilitating and speeding up the installation process. The greatly reduced routine maintenance resulting from not having to change bulbs on approximately a 5 year interval and the extremely low failure rate of the LED luminaires will further increase the benefit.[18,19,20,21,22,23]

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have seen an associated 37% reduction in street light maintenance costs. Boston has experienced a 3% defective rate for LED luminaires over a 3 ½ year period for 3000 luminaires installed on residential streets from 2010 to 2011. They now have installed 20,000 LED street lights and these have seen a defective rate of .8% over the last 2 ½ - 3 years.

[17] In the final report for the City of Ann Arbor LED Demonstration Grant under State of Michigan Bureau of Energy Systems Grant # BES-10-037, 5/2011, a contractor cost for installation of 1000 LED luminaires is reported as $37,977.30 or approximately $37.98 per luminaire. In Seattle, WA Streetlight Application Assessment Project Pilot Study Report, 12/2009 an installation cost of $63.91 per luminaire is reported. This installation cost utilizes Seattle City Light maintenance staff and assumes a 20 minute time interval per luminaire. The City of Los Angeles reports the labor cost for an LED luminaire at $42.58 for the 2011/2012 Fiscal Year LED program.

[18] Davis, B., "Long-term Field Evaluation of LED Luminaires", Gateway Demonstrations, Department of Energy, San Francisco, CA, 2015.

[19] Kinzey, B., "LEDs at 5+ Years – The Scoop on Street and Area Lighting Applications", Pacific Northwest National Laboratory, LightFair 2015, New York, NY, May, 2015.

In addition, the salvage value of replaced streetlights can be material.[24] The City of Los Angeles was able to auction off the 73,114 HPS luminaires removed during a part of their street lighting upgrade program and produced $518,858 in revenue thereby increasing the economic benefit of the program.[25]

Current lighting technology luminaires are lighter and smaller than comparable HPS units. This reduced size and weight will also expedite installation and tend to reduce the possibility of injuries during installation or maintenance. There is no need to carry replacement components in trucks on a routine basis due to the greatly reduced failure rate of LED luminaires as compared to older technology. There is a reduction in warehousing space because of the LED luminaire reduced size and failure rate. Current generation LED lighting luminaires are replaced as a unit or have special design features to replace components modularly. This also expedites installation and replacement. In either case, special care has been taken in the design of modern lighting technology to minimize the time that the person performing the repair is exposed to potentially hazardous situations during either replacement or repair, again reducing maintenance costs and improving worker safety.

Due to the higher temperature of conventional HPS luminaires there is an enhanced accumulation of dirt from the atmosphere on the luminaire. This accumulation

[20] "Maintenance Practices for LED Street Lights Webinar", Cooper, G.,City of Boston Public Works, Street Light Maintenance Webinar, 4/14/2014.
[21] "Walmart", DOE 2015 SSL Workshop, http://www.energy.gov/eere/downloads/2015-ssl-rd-workshop-presentations-day-1, 1/27/2015.
[22] Kinzey, B., "LED Street Lighting: Experiences from Boston, Las Vegas, and Seattle", LightFair International 2014, MSSC, DOE, Las Vegas, 6/4/2014.
[23] Frank, N., LED Street lighting Maintenance, IES Street and Area Lighting Conference, Savanna, Georgia, 10/2015.
[24] Mittleman, M., "Recycling Street Lights", IES Street and Area Lighting Conference, Savanna, Georgia, 10/2015.
[25] "Changing our Glow for Efficiency" presentation Municipal Solid State Lighting Consortium - LED Workshop Los Angeles, April 2012.

of what amounts to "baked on" dirt reduces the amount of light exiting the luminaire and also increases the time and effort needed to remove it. Conversely, LED luminaires operate at a greatly reduced temperature in comparison and hence do not accumulate this type of hard to remove dirt. This will result in decreased light loss from dirt accumulation, less frequent need to clean the luminaire, and less effort to perform the cleaning when it may eventually be needed. Less frequent and easier cleaning means a reduction in the exposure of employees to traffic conditions and associated hazards during the cleaning process.

In the City of Los Angeles, total street light maintenance costs have been reduced by 37% as a result of the installation of LED luminaires. In addition the City of Boston has indicated a 30% reduction in inventory for LED street lighting.[26] Since current lighting technology luminaires require less power, there will be less heating of the wiring feeding these units for existing installations. This will result in a reduction in the deterioration of the wiring, extending its useful life and reducing maintenance. For new installations it will be possible to utilize a lighter gauge wire and hence reduce installation issues and reduce cost.

See attached correction page.

ENERGY SAVINGS BENEFITS OF NEW LEDs

Q. Are there reduced electric consumption benefits from LEDs?

[26] MSSLC Maintenance Webinar, 4/14/2014: For the City of Boston they have experienced a .5% defective rate for phase 4 in 2013 and .8% defective rate for 20,000 luminaires installed over the last 3 years. They also note a 30% reduction in inventory due to the improved reliability of the LED luminaires. Los Angeles has converted 141,089 street lights to LED technology and experiences less than a .2% failure rate. They have seen an associated 37% reduction in street light maintenance costs.

A. Yes, beyond improving public safety, LEDs can reduce both direct and indirect electric consumption. LEDs have a significant direct reduction in the amount of electricity used, by up to 60% or more, depending on the design. My preliminary estimates indicate a 60% reduction in the electric usage for 100W HPS equivalent street lights in Indiana when they are converted to LED technology, assuming a design in which the replacement LED luminaire has approximately the same light output as the initial HPS luminaire. An estimate of the expected direct energy savings is summarized in the following table. This table depicts energy and associated environmental savings for the retrofit of 42063 current HPS luminaires; estimated as 23289 100W, 11363 150W, 4391 250W, and 3020 400W in the NIPSCO service territory over a 7 year installation period with the assumption of an equal number installed each year for a 15 year study period. The energy savings would increase proportionately with an increased number of retrofits. With an optimized design and implementation program that also takes into account the potential reduction in light output of the LED luminaire as compared to the HPS luminaire, that can occur as a result of the improved visual characteristics of the white LED light, it should be possible to obtain an additional 10% energy use reduction benefit using modern LED technology.

Representative Energy Savings Calculations for 42,063 Luminaires
Assuming a 7 year implementation period to retrofit HPS luminaires with LED for a 15 year study period

Year	Old Annual Energy Consumption (kWh)	New Annual Energy Consumption (kWh)	Annual kWh Savings	Annual Greenhouse Gas Savings (tCO_2e)
1	33,259,724	30,460,489	2,799,235	1,931
2	33,259,724	27,661,254	5,598,470	3,863
3	33,259,724	24,862,019	8,397,705	5,794
4	33,259,724	22,062,784	11,196,940	7,726
5	33,259,724	19,263,549	13,996,175	9,657
6	33,259,724	16,464,314	16,795,410	11,589
7	33,259,724	13,665,079	19,594,645	13,502
8	33,259,724	13,665,079	19,594,645	13,502
9	33,259,724	13,665,079	19,594,645	13,502
10	33,259,724	13,665,079	19,594,645	13,502
11	33,259,724	13,665,079	19,594,645	13,502
12	33,259,724	13,665,079	19,594,645	13,502
13	33,259,724	13,665,079	19,594,645	13,502
14	33,259,724	13,665,079	19,594,645	13,502
15	33,259,724	13,665,079	19,594,645	13,502
total	498,895,860	248,960,120	235,135,740	162,078

In addition to maintenance and energy savings LEDs provide improved color rendering due to emission of white light, improved directionality and uniformity of the light, longer life, reduced maintenance, reduced light pollution (the light goes where it is intended), ability to shield houses from unwanted light, smaller size and weight, reduced end of life landfill waste, no mercury, and they turn on instantly. These indirect benefits tend to enhance the value of the usefulness of the light and hence allow for the use of smaller luminaires to achieve the same perceived lighting effect. A variety of tests and implementation programs have recently occurred for the retrofit of current street lighting technology with modern lighting technology. The general trend has been to employ LED technology.

LED RESULTS FROM OTHER METROPOLITAN AREAS

Q. Are you familiar with the results of LED installation in other metropolitan areas?

A. Yes. The following is a listing of several tests that represent typical test and implantation program results:

In May of 2013, the City of Las Vegas finished retrofitting 40,000 street lights with LED fixtures. By converting to LED lights, the city gained $2 million of annual savings. This $20.8 million capital project reduced the city's electric bill for street lighting by about 50% and reduced millions in long-term maintenance costs, because they will last up to three times longer. The new lights are predicted to function for up to 13 years and demonstrate a payback period of about seven to ten years.

The City of Los Angeles has observed a 63.1% energy savings (approximately $7,200,000 annually) for the installation of 141,089 LED luminaires in a program that principally replaced HPS luminaires and was initiated in February 2009 and completed in June 2013. Attachnent1-E shows a comparison of the quality of street lighting before and after the conversion of HPS to LED lighting in Los Angeles. The upgrade program has generated savings in energy and maintenance costs with an estimated payback period of 7 years. Earlier installations in the Los Angeles program used LEDs that are not as efficient as they are now. A color temperature of 4000K was chosen for the installation. Warranty period is 6 years. After 2 years of operation the LED luminaires experienced a lumen and dirt depreciation of 17% total (13% lumen and 4% dirt) while the HPS experienced 20% total depreciation. After 4 years of operation the LED luminaires experienced a lumen and dirt depreciation of 17% total (8% lumen and 9% dirt) while the HPS experienced 28% total depreciation. The average failure rate after 24 months of initial operation for HPS is 10% based on past history and for LED the average failure rate after 24 months of initial operation was .2% based on the retrofit program. Removed HPS units were recycled and generated $513,858 in revenue.[27] Again, today's LEDs offer much better performance and savings.

The city of San Francisco tested a variety of 100W equivalent LED luminaires and noted a 50% - 70% savings in electric consumption versus HPS luminaires.

In a demonstration conducted in Kansas City, Missouri in 2011 for 100W, 150W, 250W, and 400W equivalent LED luminaires that replaced HPS luminaires a mean reduction in power use of 39% with a range of 31% - 51% reduction was observed.[28]

In a demonstration conducted in Philadelphia, Pennsylvania that was initiated in 2011 for the replacement of 100W, 150W and 250W equivalent HPS with LED luminaires, a 10-40% reduction in power use was observed using a variety of different manufacturers and luminaire designs. Since then the efficiency of LEDs has increased while their cost has decreased.

Ten years ago, New York City Department of Transportation began replacing 60,000 of its 400 watt HPS cobra head street lights with 250 watt LED heads to conserve

[27] http://bsl.lacity.org/.
[28] BR Kinzey, et al., Demonstration of LED Street Lighting in Kansas City, MO, DOE, 2013

energy. In June 2007, it began further converting 160,000 250 and 150 watt HPS cobra head street lights to more efficient 150 and 100 watt LED cobra head street lights respectively. As of May 2009, 82,000 cobra heads were replaced in Brooklyn and Queens. The replacement of these fixtures provided both financial and environmental benefits. Converting 250 watt HPS units to 150 watt LED units yielded a 45% energy savings while switching from 150 watt HPS to 100 watt LED heads resulted in a 35% energy savings. Conversion to lower wattage LED cobra heads has also reduced upward lighting, minimized glare and reduced greenhouse gas emissions. The New York Department of Transportation operates the largest municipal street-lighting system in the country with 262,000 lights on City streets, bridges and underpasses, 12,000 in parks and 26,000 on highways. The upgrade program targeted to replace all the street light luminaires in New York City with LED technology is scheduled to be completed in 2019.

Many of these LED change outs were made with LEDs that are less efficient and more costly than those available today. But what these municipal street light experiences make clear is that moving from old to current lighting technology offers substantial energy savings and financial benefits. Today's improved LEDs increase the level of available efficiency and capital and O&M savings.

<u>ECONOMY OF SCALE PRICING</u>

Q. Are there benefits associated with upgrading existing lighting technology by installing large groups of LED luminaires?

A. Yes. By upgrading street lighting in large groups it is possible to obtain advantages such as low cost volume purchase and installation agreements. If luminaires are priced at or installed one at a time or in small numbers, the material and installation costs will be substantially greater. By initially identifying geographic areas of high potential benefit it is possible to reduce capital and installation costs by mass light replacement in those target areas. Current generation LED street light luminaires with light output equivalent to a 100W HPS luminaire are in the price range of range of $155-200 with utility pricing with totally acceptable models in the low end of that range. Installation cost for a grouping of several thousand luminaires is being publicly reported by various sources in the range of approximately $40 to $65 per luminaire.[17] In part, installation efficiency results from the ease of handling, transporting and installing smaller/lighter LED luminaires as compared to heavier larger HPS or Mercury luminaires. There is a weight reduction between 15% and 55% depending on the wattage of the luminaire. If LED Street Light luminaires are installed in large groups and/or on a program over multiple years by a contractor there is an opportunity to further reduce installation costs. It is now becoming common practice for LED Street Light Luminaires to be shipped directly to installation contractors on pallets designed for quick installation. Such an arrangement eliminates receiving, storage, and handling costs for the LED Street Light owner while facilitating and speeding up the installation process. Seattle City Light installs luminaires with city crews at a rate of 20 minutes per luminaire. They have also experienced better uniformity of light with LED luminaires than with HPS.[29]

See attached correction page

LEDS ARE APPROPRIATE NOW

[29] "Changing our Glow for Efficiency" presentation, Municipal Solid State Street Lighting Consortium – LED Workshop, Los Angeles, CA, 4/2012.

Q. If we wait and delay a major street light retrofit wont the technology be so much improved that it is worth the wait?

A. No, the time is right and we should not delay. The value of the lost savings, approximately 60% or more reduction in energy use, reduced maintenance costs, and many other safety, economic and social benefits exceeds the value of possible future improvements. Current generation LED lighting technology has made substantial improvements and I believe it is now reaching maturity. The rate of technology improvement and price decreases has significantly decreased over time. In fact the technology has so matured that the cost of the LEDs themselves is no longer the major cost factor in the cost of the luminaire. Other components such as the cost of aluminum for the housing and the driver have become a larger cost fraction of the total luminaire cost and these components are not expected to decrease significantly in the future. The remaining material luminaire savings opportunity is in bulk purchases to achieve quantity discounts and economy of scale installation cost.

In the past few years the price of LED luminaires has significantly decreased and the light output per watt and life expectancy have increased. This provides a unique opportunity to gain the benefits of current lighting technology. In addition there are indications that the cost of HPS luminaires will increase by 10-20% in the near future as a result of the decreased number of HPS luminaires that are being ordered and associated reductions in volume purchase agreements for parts. This decrease in HPS orders is a result of greatly increased orders for LED luminaires when replacement or new street light luminaires are ordered. This further enhances the potential benefits of the current technology. As an indication of price changes, The City of Los Angeles purchased LED luminaires at the start of their retrofit program in 2009 at an average price of $432. In 2010 this dropped to $298. In 2011 this dropped to $285 and the estimated life was extended up to 150,000 hours. Today 100W HPS comparable LED luminaires are approximately $160 for purchase by a Municipality or public utility. In addition to the luminaire, a photocell is also required. Photocells are currently priced at approximately $20 for models with an estimated 20 year life. I anticipate further price decreases in current LED luminaire technology will be minimal. The light output for current LED technology is at or near peak. Given the significant social benefits and energy / economic savings resulting from converting to LED street lighting, it is not prudent to wait longer to switch to LEDs, the time is right now.

Q. Is it reasonable in your opinion to continue to invest in HPS and other outdated street light technologies rather than begin an efficient transition to LED street lights?

A. No, because of the diverse and substantial efficiency, safety, economic and social benefits of LED street lights in my opinion it would be unreasonable and wasteful to invest in a continuation of HPS and older technology street lights. Compared to the illumination from new LED street lights the illumination from older HPS lights is inadequate.

Q. What LED technology do you recommend be considered for the NIPSCO LED fixture retrofit program Mr. Sommer describes?

A. Our laboratory has been studying the various types and manufacturers of street lights for years. Our testing, research, interfacing with manufacturers and consumers has been very extensive. In cooperation with NIPSCO, I have conducted testing and evaluation of potential LED street lighting products from various vendors at the EERC laboratory. As a result of these tests we have reached agreement with NIPSCO on the most beneficial LED street light luminaire options for replacement of NIPSCO's existing HPS street lights from three final vendors. The specific choice of a vendor can be determined through the evaluation of final technical proposals and pricing submitted by the vendors in response to a specification issued as part of a Request for Proposal. Depending on the nature of the vendor submittals, it may be beneficial to conduct a limited field testing program as part of the final selection process. In a well-designed installation program, it will be possible to achieve desirable economy of scale savings.

Q. What is a reasonable installation cost to use in fashioning initial mass LED retrofit rates?

A. Our laboratory has also extensively researched the installation cost that can be reasonably obtained with large scale installations. As noted previously the approximate cost ranges from $40-$65. As a result I conclude that a reasonable installation cost of approximately [redacted] would be conservative and should be used in planning the LED Street Light program and initial rates. As Mr. Summer describes the initial rates could then be trued up to reflect the final costs. I believe my proposed LED purchase price and per unit installation cost are conservative, reliable and can reasonably be used to establish rate tariffs for the replacement LEDs. As such I have provided my results to Mr. Sommer for him to include in his rate making analysis. The tariff pricing for these replacement

LEDs can be adjusted if necessary once the contracts for LED purchase and installation are accepted and signed.

LED ECONOMIC DEVELOPMENT BENEFITS

Q. Are there LED economic development benefits?

A. Yes. Exterior lighting has a significant impact on economic development. Lighting can draw people to a downtown area or a shopping area by making the shops and restaurants inviting and safer. The appearance of a space (during nighttime as well as daytime) is an important consideration. Lighting conveys information to people. Lighting enhances historic areas or landmarks and helps to promote an image of the city or town. Lighting makes a business area accessible and allows the conduct of commerce and social activity at night with the resulting lift to local employment opportunities. Lighting makes people feel and be safe, thereby allowing them to support local businesses at night. The Seattle Washington Office of Economic Development is an advocate of using lighting to enhance economic development. Regarding pedestrian lighting they state: "Good outdoor lighting can create and encourage a pedestrian friendly environment, which is especially beneficial to neighborhood business districts. Pedestrian-scale lights improve walkway illumination for pedestrian traffic and enhance community safety and business exposure." Current lighting technology luminaires offer a variety of options to effectively provide illumination of pedestrian areas when desired. In the Arlington County (Virginia) Government Street Light Policy and Planning Guide, January 2008, it is stated that: "The real value of roadway lighting is directly related to driver safety and comfort and, consequently, to a reduction in nighttime accident rates, and social and economic gains in downtown urban areas. Many downtown areas are almost deserted after dark. Serious crime can be reduced and businesses can increase their aesthetic appeal and commercial activity after the addition and proper maintenance of roadway lighting." The use of LEDs enhances the benefits of street lights thereby improving public safety, social interaction, quality of light, all promoting economic development benefits.

<u>**LED URBAN RENEWAL BENEFITS**</u>

Q. Are there benefits relating to revitalizing blighted or deteriorating neighborhoods by the use of these current lighting technologies?

A. Yes. Lighting assists in efforts to revitalize blighted or deteriorating neighborhoods. In street light performance tests conducted by the EERC in the field on city streets it has been noted on numerous occasions that the white light of LED luminaires makes it easier to detect vehicles, detail and motion in the areas illuminated by LED street lights as compared to the same area illuminated by HPS light. It is clear that the presence of LED street lights reduce safety concerns related to traffic during the data collection process. In my opinion transitioning to LED street lights would substantially improve nighttime vision and in turn improve safety and security there helping improve the neighborhoods as a whole.

The benefits provided by LED technology contribute to revitalization by improving both the quality of lighting and the penetration of lighting. Good road lighting contributes to a feeling of security by residents. Mobility, especially that of younger women and the elderly, is limited by perceived insecurity and limits their participation in social life and can lead to isolation.[30,31] Improved lighting increases the sense of security and hence increase the rate at which people go out and this improves security of the area since a street with more people is more secure than a street with few people. Here again this promotes reduced opportunity for criminal activity and enhances the growth of societally beneficial nighttime activities. When neighborhoods lose the stigma of appearing unsafe new construction, renovation and economic growth is promoted. The energy savings, increased reliability, and reduced maintenance costs from modern lighting technology free up municipal budgetary funds that may be used to further promote urban renewal and revitalization.

The level of public perception greatly improves in areas that are well light with well-designed white lighting systems. As an example, the City of Morristown in Pennsylvania previously had a strong economic base resulting from the development of auto-oriented suburbs and commercial areas on the metropolitan fringe of Philadelphia. Unfortunately, the Twentieth Century saw a decline in the importance of Norristown as a transportation center. While the Municipality had benefited from past transportation investments—both river oriented and rail—the new highway improvements constructed in the 1950's and 1960's largely bypassed Norristown. The Norristown Economic Revitalization Strategy Update report, June 2009 identifies lighting improvement as a key factor in this revitalization effort as follows: "the Municipality has been making improvements to its Main Street business district, an area which currently is facing blight problems and failing public infrastructure. As part of the Municipality's overall

[30] Banister, D.,Bowling, A., Quality of Life for the Elderly: The Transportation Dimension, Transportation Policy 11:105-115, 2004.
[31] Fotis,S.,Unwin,J., Farrall, S., Road Lighting and Pedestrial Reassurance After Dark: a Review, Lighting Res Technol, doi:10,1177/1477/1477153514524587, 2014.

revitalization strategy, Main Street was targeted for streetscape improvements, from Barbadoes Street to DeKalb Street. Key improvements include new sidewalks, street trees, and pedestrian friendly street lighting." The value of lighting as an important aspect of the urban environment that can lead to improved revitalization of cities is confirmed by the following community focus group comment from the Springfield, Massachusetts Economic Assessment Project: "The reliability and quality of basic city services, including adequate street lighting and parks and public space maintenance, was a consistent and major complaint of neighborhood stakeholders in all three communities". The public is very aware of the level of street lighting as it relates to safety and public perception of neighborhoods and businesses. Thus, street and neighborhood lighting is a key agent in leveraging economic development efforts. The old expression; "Will the last person leaving (a city or neighborhood) please turn out the lights" can realistically be turned around to say; "As you return to (city or neighborhood) please turn on the lights."

LED BENEFITS TO UTILITY DISTRIBUTION SYSTEM

Q. Are there benefits that enhance the reliability of the street lighting portion of NIPSCO's distribution system of these current lighting technologies?

A. Yes. Due to the reduced electric usage, there will also be a reduction in distribution feeder loads and well as reduction in the load on distribution transformers. The net effect will be to reduce electric load and thereby extend the capabilities of the existing distribution system. The increased visibility of the current lighting technology will also reduce traffic accidents as described previously and thereby reduce the occurrence of utility power outages caused by damage to distribution equipment resulting from traffic accidents. Elvik from the Norwegian Institute of Transportation Economics conducted a study in 1992 to validate the hypothesis that adding light enhances traffic safety.[32] This study found that roadway lighting reduced nighttime fatal accidents by 65% and nighttime injury accidents by 30%. He also noted a reduction of 15% in property damage only accidents. The net effect of increasing the quality of light and reliability of street light luminaires will be to reduce accidents and thereby contribute to the reduction of associated outages and improve the reliability of distribution feeders.

LED IMPROVED QUALITY OF LIFE

Q. Are there benefits from LEDs that improve the quality of life in urban areas?

A. Yes. Going to a white light source like LED as opposed to a HPS yellowish orange light is generally preferred by the public and improves the quality of life. People prefer the clean white light of LEDs to the mustard yellow light of HPS. The use of approximately 4000 K color temperature, i.e. whiter light, is becoming common. With the shift to an optimized white light, visibility is increased resulting in both increases in safety as well as a general increase in the perception and enjoyment of the community at night. This increased perception results in increased business and public activities at night as well as a tendency for an influx of new businesses and increased numbers of people at night. This impact is illustrated by the following comment from Urban Age Institute: "It is however also becoming apparent that modern LED lighting increases citizens sense of safety, makes cities more inviting for tourism, and increases productivity at our workplaces

[32] Elvik, R., "Meta-Analysis of Evaluations of Public Lighting as Accident Countermeasure", Transportation Research Record 1485, Transportation Research Board, Washington D.C., 1992, pp. 112-123.

(without having to work harder)". While flying over an urban area at night you may have noticed the contrast between the mustard yellow / orange light emitted on the ground in areas predominantly illuminated by HPS lights and the bright appealing white light in areas where LEDs are used. The same occurs at ground level. LEDs produce a more pleasing illumination that enhances vision.

Q. Would NIPSCO and its customers receive the benefits you describe if its old street lighting systems were replaced with new LEDs?

A. Yes. Since the majority of NIPSCO's street lights are HPS a change to an optimized LED white light source would provide the benefits previously described.

Q. Are there planning steps that can be taken to reduce the cost of replacing old lighting technology with new lighting technology?

A. Yes. As I have previously discussed and detailed with NIPSCO personnel, it is critical that a program to replace old lighting with new lighting technology take into account the optimization of the new technology during planning, engineering, installation, and maintenance. To obtain these many LED benefits it is necessary to carefully design and implement the process so as to minimize costs and maximize value.

Luminaires must be chosen carefully to minimize cost while meeting or exceeding reliability, safety, and performance requirements. In programs that have been implemented in various locations nationally, there have been varying approaches to the actual implementation process. In many cases the implementation service is contracted for and in other cases in-house resources are utilized if sufficient resources are available that have a cost advantage. A key issue to consider is the quality, cost effectiveness, and timeliness of the installation process taking any existing labor agreement requirements into account. I can assist in development and implementation of the proposed light replacement effort.

Q. Based on your knowledge and expertise do you recommend that NIPSCO should as a result of this Cause initiate a large scale program changing their street lights to modern LED lights?

A. Yes, I recommend the change out of all NIPSCO service area street lights to LED. Such a change will have the numerous and material safety, financial, economic, utility, environmental and social benefits I have previously described.

Q. Were your testimony and Attachments prepared by you or under your supervision?

A. Yes.

Q. Does this conclude your testimony?

A. Yes, at this time.

Corrections to the Direct Testimony of Dr. Robert Kramer, IMUG Exhibit 2, Cause No. 44688

1. At page 23, line 16 insert:

Thus, in my opinion a 50% reduction in street light O&M for large group LED replacement programs with the most recent technology from the most highly rated vendors can reasonably be expected.

2. At page 29, line 17, after the sentence ending in "facilitating and speeding up the installation process" insert:

The majority of the effort associated with the development of the NIPSCO LED Standard is completed as I described previously. Detailed information has been requested twice by NIPSCO by issuing an initial RFI and subsequently a more detailed RFI that included the NIPSCO LED Standard and additional data requirements for LED Street Light Luminaires. This information was evaluated jointly by NIPSCO and IMUG and was correlated with laboratory and field test results conducted by EERC as part of technical ranking the vendor offerings. Thus the characteristics of the replacement LED's are known. In the installation of large groups of LED luminaires, the need for additional detailed direct engineering oversight by NIPSCO will be minimal. LED luminaires can be delivered directly to contract installers. Once the LED retrofit contract trucks and crews get going on the LED retrofits they will require very little if any supervision from NIPSCO. The retrofit process is generally simple and the inspection process will also be relatively simple.

3. At page 6, starting line 10 revise;

"This standard provided the basis for the issue of a Request for Information (RFI) and a Request for Proposal (RFP) for LED Street Lighting. Thereafter, NIPSCO and IMUG cooperatively evaluated the responses to the RFP and have developed a list of preferred vendors and product lines that provide maximum benefit from the available technology."

To say "This standard provided the basis for the issue of a Request for Information (RFI) and subsequently a more detailed RFI that included the NIPSCO LED Standard and additional data requirements for LED Street Light Cobra Head Luminaires. Thereafter, NIPSCO and IMUG cooperatively evaluated the responses to the second RFI and have developed a list of preferred vendors and product lines that provide maximum benefit from the available technology."

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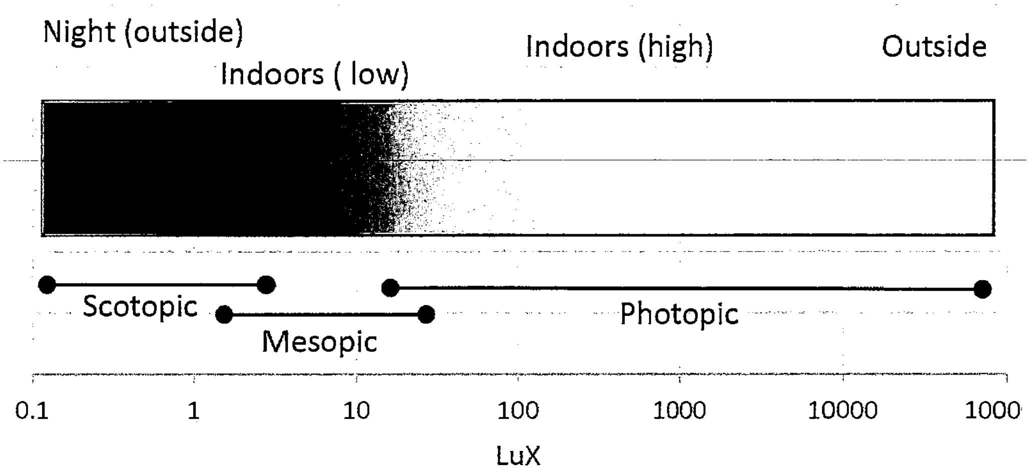
Attachment 1-A

Typical Lighting Design and Performance Data

Type	light color	CCT[1] (K)	CRI[2]	lamp life (hrs)	typical replace ment period (YR)	typical cost for 100W HPS equivalent	estimated maintenance cost/yr	estimated power savings relative to HPS	dimming capability	Source efficacy lm/watt	System efficacy lm/watt	start time (min)
incandescent	white	2,700	100	75 to 1,000	0.25	N/A	N/A		100%	5 to 20	1 to 15	0
mercury	white	3,900 – 5,700 [9]	20 (clear) [8] 45 (white)	24,000 [8]	6+	N/A	N/A		0	50 [8]	35	up to 15
low pressure sodium	yellow	1,800	0	18,000	4	N/A	N/A		0	80-190	70	up to 15
high pressure sodium	yellow	2,000 [9]	22	24,000	5	$130	$15-$25 [4]		0	88-121 [9]	70-100	up to 15
metal halide	white	3200 - 5200 [7]	65-90 [7]	6,000 - 30,000 [7]	2 to 5	$200	$35 - $50 [4]		50%	65-110 [7]	40-88	1 to 20
IFL	white	2700 - 6500	80	85,000 - 100,000	20+	$275		50%	50%	60-70	50-60	2
LEP	white	5,500	75-94	20,000-50,000	5 to 12	N/A		51% [6]	80%	70-80		1
LED	white	4,000 - 6,000	75 [3]- 95 [5]	100,000+ [10]	> 12	$160 [10]	$5-$15 [4]	up to 60% +	100%	80-120	72 - 110	0

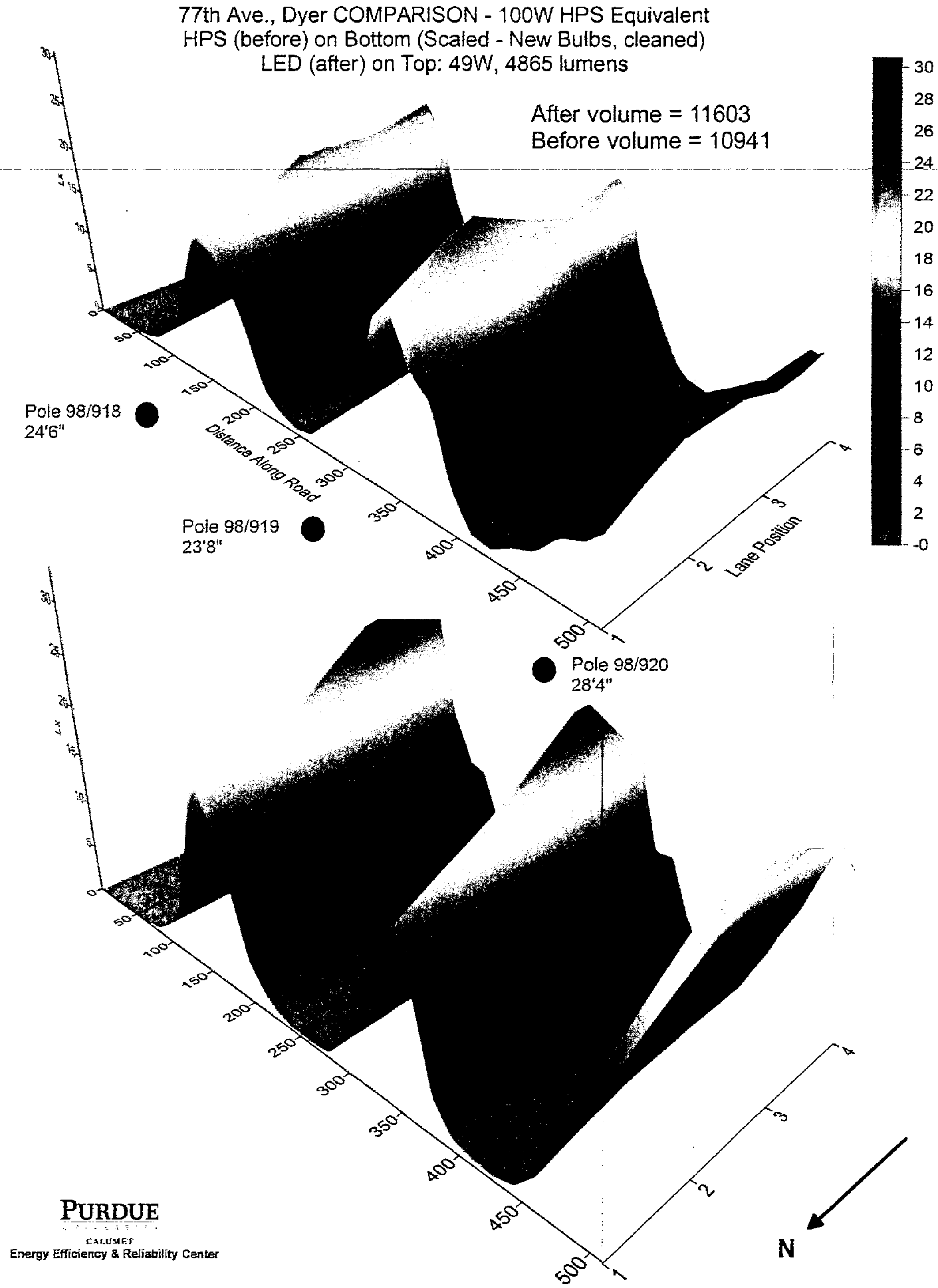
1. Correlated Color Temperature
2. Color Rendition Index (CRI describes how well a certain set of standard colors are reproduced when illuminated by a particular light source).
3. Caliper Summary Report, DOE, 10/2010
4. Stevens, M., Investor Owned Utility Financial Perspective, Municipal Solid State Street Lighting Consortium presentation, Georgia Power, Boston, 8/2-3/2012
5. Illuminating Engineering Society, LD+A, 2013
6. Scottsburg, Indiana
7. NLIP Lighting Answers, Lighting Research Center, Rensselaer Polytechnic Institute, Troy, NY, vol 7, number 1, 2005
8. Philips, Mercury Vapor Standard 332443 ffs aen
9. GE Lamp and Ballast Catalog
10. Applies to highly rated LED luminaires

Attachment 1-B
Scotopic, Mesopic, Photopic Vision Levels



000231

Attachment 1-C



000232

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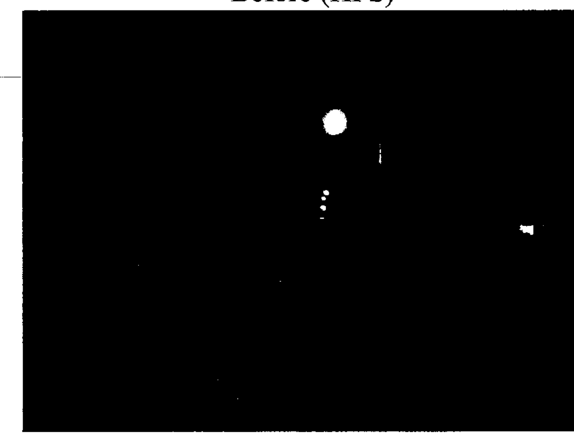
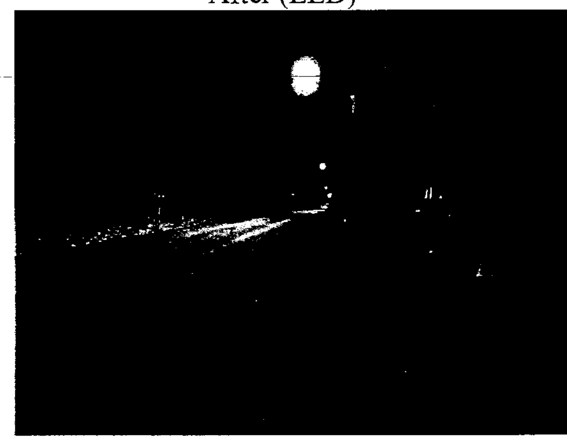
Exhibit 1 Redacted

Attachment 1-D
Images of Before (HPS) and After (LED) Test Site in Dyer, Indiana

Before (HPS)



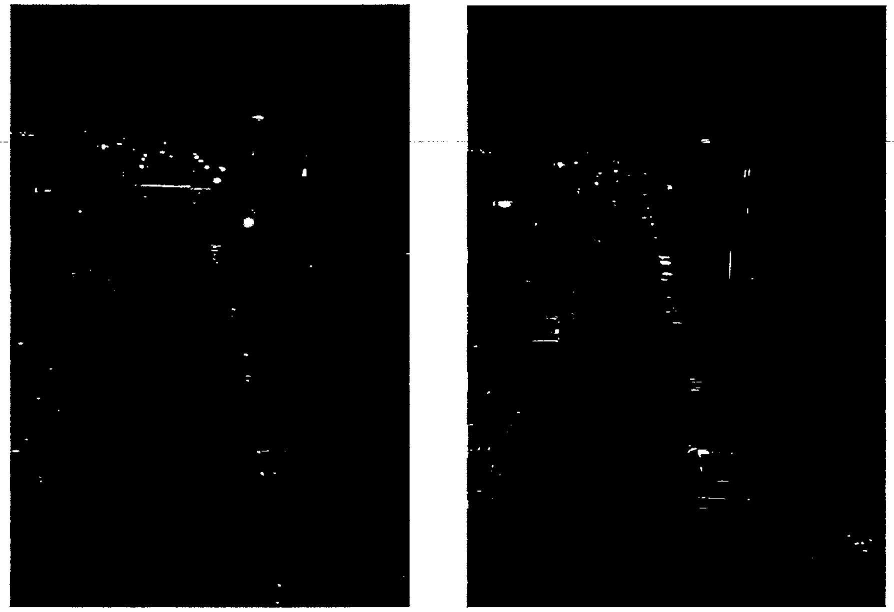
After (LED)



000233

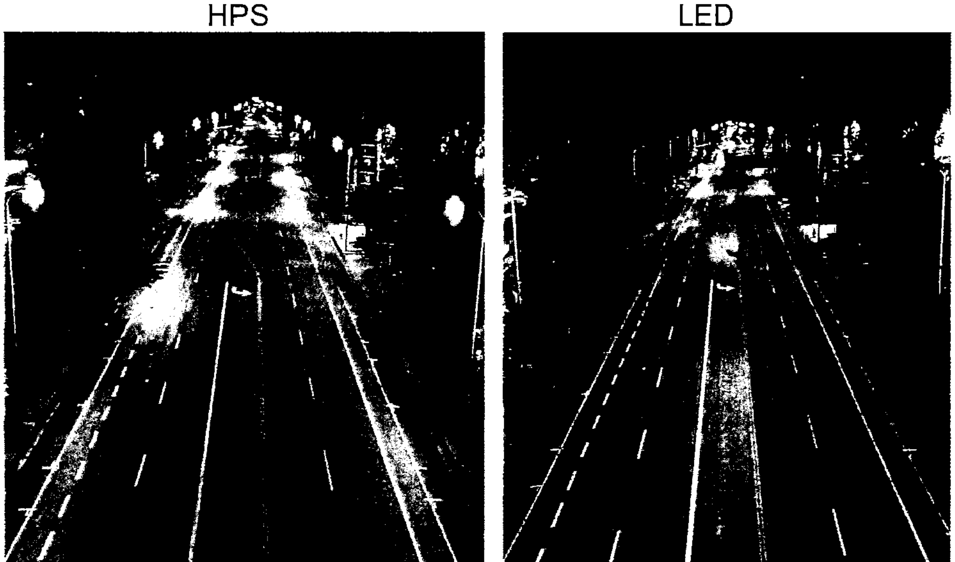
Attachment 1-E
HPS – LED Comparison Images[33]

HPS LED



La Mirada Ave. – Seward St. to Wilcox Ave.
Los Angeles, CA

HPS LED



Hoover St. – 32nd St. to 30th St.

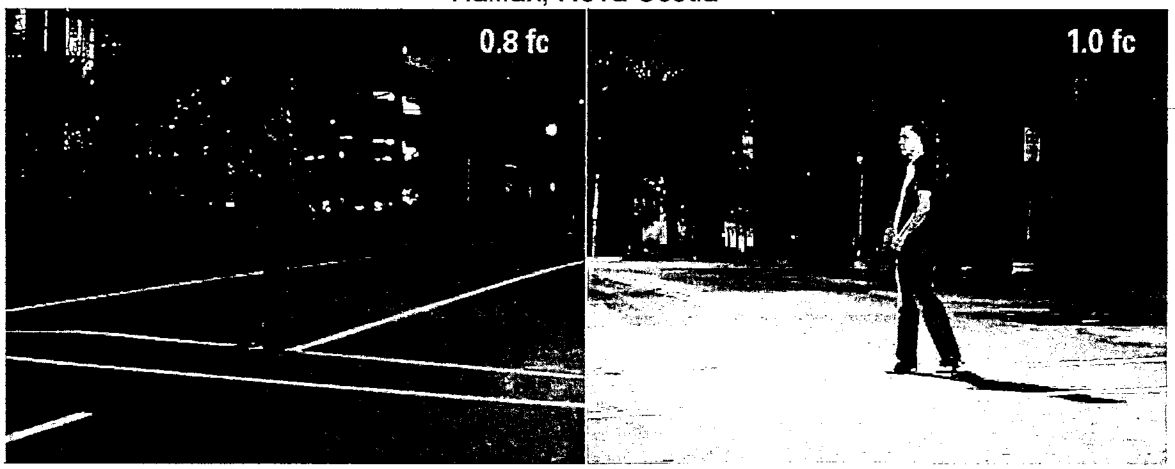
[33] Municipal Solid State Lighting Consortium, presentation: "Changing our Glow for Efficiency", Los Angeles, CA 4/2012

Los Angeles, CA

Attachment 1-F

HPS – LED Comparison Images[34]

Halifax, Nova Scotia

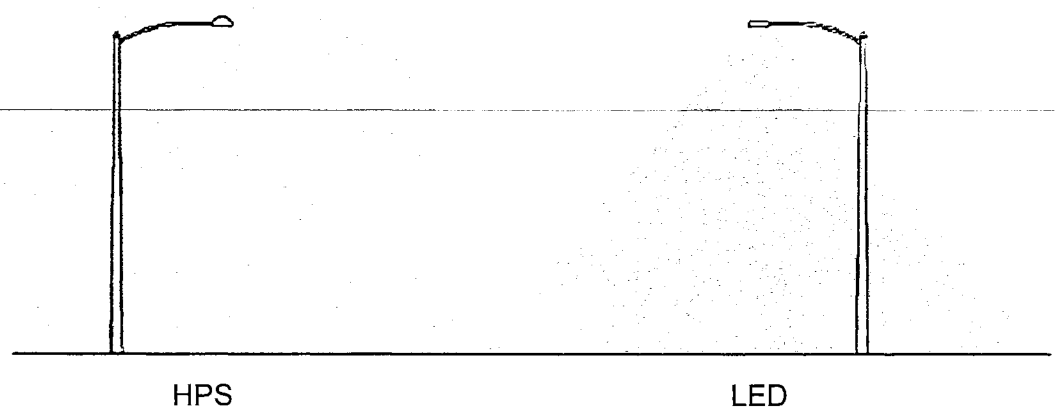


Before
195 W HPS

After
88 W LED
55% energy savings

[34] City of Redlands, CA, presentation: "Energy Efficient Light Emitting Diode (LED) Street Lighting Conversion Study", Municipal Utilities and Engineering Department, 2010, http://www.cityofredlands.org/node/388

Attachment 1-G
Light Distributions[35]



[35] City of Redlands, CA, presentation: "Energy Efficient Light Emitting Diode (LED) Street Lighting Conversion Study", Municipal Utilities and Engineering Department, 2010, http://www.cityofredlands.org/node/388

VERIFICATION

I verify subject to the penalties for perjury that the foregoing statements are to the best of my knowledge true.

Robert Kramer

Intervenor IMUG
Cause No. 44688
Exhibit 1 Redacted

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Robert A. Kramer is the NiSource Charitable Foundation Professor of Energy and the Environment, Professor of Physics, and Director of the Energy Efficiency and Reliability Center at Purdue University Calumet. In this role Dr. Kramer is involved in the development of research programs in energy utilization and efficiency, building energy efficiency, electric power, reliability, electric transmission, renewable energy sources including hydrogen production from biomass, coal gasification for the production of liquid transportation fuels and fertilizer, advanced control of large industrial loads, nuclear reactor analysis, and combined heat and power systems. He is also a Certified Energy Manager, a Certified Demand Side Manager, and a Certified Energy Auditor with the Association of Energy Engineers. He teaches various courses in Physics and Electric and Mechanical Engineering and has developed five experientially based energy related courses.

Prior to coming to Purdue University Calumet he was the Chief Scientist for NiSource Energy Technologies and most recently was responsible for technical developments of new energy technologies including Combined Heat and Power and building energy optimization systems. He was at NiSource from 1973 until January 2004 and held the positions of Nuclear Fuel Engineer, Manager Applied Research, Manager Strategic Planning, Manager Technical Support, Director of Electric Engineering and Applied Research, Director of Electric Operations, Director of Electric Services, Vice President and Chief Scientist. During this time, he also taught a variety of courses in Physics and Electronics at Purdue University Calumet and Indiana University Northwest.

Dr. Kramer has conducted a variety of energy and energy efficiency research and development projects and programs. These projects range from enhancing reliability of bulk electric transmission systems to high efficiency local generation sources utilizing Combined Heat and Power that generate electricity locally and use byproduct heat to achieve high levels of system efficiency as well as nuclear power research. Energy sources such as microturbines, reciprocating engines, fuel cells, solar, coal, hydrogen, and biomass are considered in this work. Current research efforts include: advanced control schemes utilizing neural networks and fuzzy logic in a feed forward configuration for industrial as well as commercial and building applications; wireless communications and control; production of liquid transportation fuels, fertilizer, coke, and bulk hydrogen from coal; biological production of hydrogen; control of large industrial loads to improve electric transmission system reliability; combined heat and power; industrial energy efficiency; building energy efficiency; renewable energy systems; nuclear reactor engineering analysis; electric, thermal, and renewable energy system design, integration, and optimization for large data centers; thermal coating design and efficiency; and optimization and production of hydrogen from an aluminum-water process. Multiple commercial and industrial energy audits are in process or were performed to enhance the value of energy as well as considering methods to optimize total energy value through the use of combinations of renewable and conventional energy options. A study of the feasibility, technology, and value of using new lighting technology is ongoing with the Indiana Municipal Utility Group in conjunction with NiSource. Testimony in this regard was presented by Dr. Kramer in support of the NiSource TDSIC hearing with the Indiana Utility Regulatory Commission (IURC). Currently Dr. Kramer is actively working to appraise and test potential LED lighting devices and he is currently collaborating on the development of specifications, standards, and rates for LED street lighting. In addition, Dr. Kramer presented testimony regarding LED Street Lighting for the City of Indianapolis in the Indianapolis Power and Light Rate Case before the IURC. The EERC laboratory is currently evaluating modern lighting luminaires from 10 different vendors and has an ongoing vendor qualification program based of quality of light, power quality, reliability, and life cycle cost based on a probabilistic model developed in house and benchmarked against industry standards.

He has worked closely with various local and national industries in an effort to develop new concepts for process and energy modeling and optimization. He has also worked with the North American Electric Reliability Council on the development of concepts and procedures for the monitoring and improvement of the reliability of the national electric transmission system. He has served as the principal investigator for research grants and contracts with a total value over $10,000,000 as well as being one of the co founders of the Center for Advanced Control of Electric Power Systems funded by the National Science Foundation and the Electric Power Research Institute.

Dr. Kramer has designed and teaches four experientially oriented energy courses that include topics in energy engineering, associated science, and renewable resource and their optimization as part of a total energy system. He periodically conducts energy audits and energy efficiency design activities for local businesses, municipalities, and community organizations. These activities include students at either the undergraduate or graduate level depending on the nature of the effort. The Energy Efficiency and Reliability Center has conducted energy audits and made associated energy optimization recommendations for a wide range of facilities ranging from a hotel in Florida to industrial and school facilities in Northwest Indiana.

He has participated in a variety of industry committees including the Coordination Review Committee (CRC) for the East Central Area Reliability Council (ECAR), the Research Advisory Committee (RAC) for the Electric Power Research Institute (EPRI), the Basic Science Committee of the Gas Research Institute, and the Control Criteria Task Force, Performance Sub committee, and other committees of the North American Electric Reliability Council. He is a former president of the Calumet Engineering Education Association.

He is a Senior Member of The Institute of Electrical and Electronics Engineers (IEEE) and The Association of Energy Engineers (AEE). He is also a member of the American Physical Society (APS), Illuminating Engineering Society (IES), American Nuclear Society (ANS), American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), the Association of Iron and Steel Engineers (AISE), International Society of Indoor Air Quality and Climate (ISIAQ), Sigma Xi (chapter president), and the Sigma Pi Sigma physics honorary.

Dr., Kramer received a Ph.D. (1985) and M.S. (1979) in Nuclear Engineering from Purdue University, West Lafayette, Indiana, and B.S. (1971) and M.S. (1973) degrees in Physics, also from Purdue University, West Lafayette.

Dr. Kramer has published numerous papers regarding energy system design and efficiency, energy markets, electric system operation, reliability, and Combined Heat and Power. He also holds various patents. A listing of his publications and patents follows;

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Intervenor IMUG
Cause No. 44688
Exhibit 1 Redacted

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US Patent No. 4,914,275, Regasifier, 4/3/1990

US Patent No . 4,646,940, Method and Apparatus for Accurately Measuring Volume of Gas Flow as a Result of Differential Pressure, 3/3/1987

US Patent No. 8,287,696, Multipurpose Coke Plant for Synthetic Fuel Production, 10/16/2012

US Patent No. 9,068,123, Multipurpose Coke Plant for Synthetic Fuel Production, 6/30/2015

Filing ongoing for Modular Biological Hydrogen Production Process