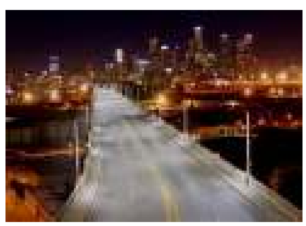
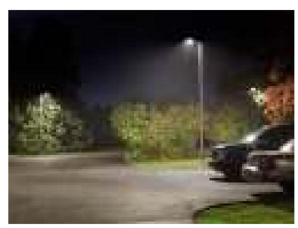
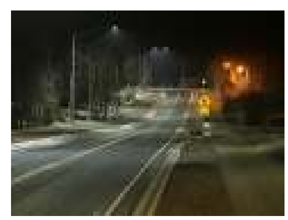
City of Redlands

Street Lighting Upgrade Program

Energy Efficient Light Emitting Diode (LED) Street Lighting Conversion Study

July, 2010

Prepared by:

Municipal Utilities and Engineering Department

Contributing Departments:

1. **Innovation and Technology**
2. **Quality of Life**
3. **Redlands Police**
4. **Finance Department**

Table of Contents

Research Report

Executive Summary

The City of Redlands is considering a street light conversion program for the installation and monitoring of Light Emitting Diode (LED) street lights. The interest for such a program is based on the recent studies performed by various cities including the City of Los Angeles who have evaluated various LED products on several public roads within their respective city limits. As a result the city of Redlands Municipal Utilities and Engineering Department (MUED) has researched LED lighting programs with seven cities within the United States. The research included the funding sources used, the cost/benefit of the program, testing protocol of the LEDs, and manufacturers used. Several of those LED manufacturers have also been contacted to acquire pricing and availability of their LED products. The purpose of this research is to assist Redlands City Council and other local officials with determining the feasibility and desirability of funding an LED street light conversion program.

This report is in-part limited to the volume of response received from those agencies that were contacted. Inquiries were sent to seven agencies, with six agencies responding. The level of responsiveness varied and not all questions have been answered by all agencies. Those agencies that that provided information to be considered for this report are; Raleigh, NC.; Austin, TX.; Los Angeles, CA.; Valdez, AK.; and Chula Vista, CA.

Background

High Pressure Sodium (HPS) lamps have been the conventional means of illuminating roadways and various public spaces for decades. New technology has been developed to the point of being economically feasible investments for long-term cost savings. Potential cost savings in energy consumption could be as high as 40% or more. LED street lights are becoming a more common means of interior and exterior lighting around the world. LED street lights are capable of producing a better quality white light with less energy consumption than their HPS counterparts. The quality gained from LED lighting improves the perception of more powerful light, while reducing the power of the light that is actually emitted. An example of the results of improved light quality can be seen from a study at a parking garage in Raleigh, NC. This study showed that overall positive opinions of the facility improved significantly after LED lights were installed. Respondents generally felt that the facility was cleaner, had better access and mobility, and was generally a safer place to park than it was prior to installation of LED lights.

Objectives of Street Lighting

Good visibility in both daytime and night time conditions is important for nearly all aspects of traffic safety. Night time visibility is made possible with properly designed and maintained lighting of the road way, pedestrian walkways, and signage. The Fundamentals of Traffic Engineering, 14th Edition defines the objectives of roadway lighting as follows;

1. Traffic Engineering Objectives
    a. Promotion of safety at night by providing quick, accurate, and comfortable seeing for drivers and pedestrians.
    b. Improvement of traffic flow at night by providing light, beyond that provided by vehicle lights, which aids drivers in orienting themselves, delineating roadway geometrics and obstructions, and judging opportunities for overtaking.
    c. Illumination in long underpass tunnels during the day to permit drivers entering such structures from the open to have adequate visibility for safe vehicle operation.

2. Other objectives
    a. Reduction of street crimes after dark. From the traffic engineer's perspective, this ancillary benefit could attract non-traditional funding sources.
    b. Enhancement of commercial (especially retail sales) properties by attracting evening shoppers, audiences, and other users.

High Pressure Sodium (HPS)

HPS lamps are the conventional means of providing street lighting. They are distinctive in the yellowish hue of their light output yet still provide better color rendering than earlier street lighting types such as mercury and metal halide lamps. HPS lamps are very inexpensive; replacements for most street light fixtures cost between $15 and $18 and product performance is fairly uniform. The rated lifetime for HPS is usually between 3-5 years. These lamps also have excellent efficacy, measured in lumens per watt. In other words, they provide a high output of light for each kilowatt of energy consumed.

The color rendition of HPS, although improved over its' predecessors, is considered relatively poor, not adequate enough to discern the colors of road signs. HPS lamps also require a period of "warm-up" before their full lighting output can be achieved. Little or no potential for product improvement appears to exist; HPS products probably won't become any less expensive or last any longer than they already do. HPS typically contain xenon gas and mercury to start and operate the lamps.

Light Emitting Diodes (LED)

LEDs are rapidly gaining recognition and acceptance as an alternative means of street lighting primarily for their low power consumption, low maintenance and excellent light quality. Most demonstrations pilot programs using LED street lights record a 40% to 60% reduction in energy consumption. The efficacy of LEDs is approaching that of HPS lamps; some products reaching 100 lumens per watt. Therefore, a comparable lighting output can be achieved through LED lamps, but with approximately half the power consumption. The estimated life for these products can range from 12-15 years. This reduces maintenance through less frequent bulb replacement. LED fixtures also do not use tungsten filaments and are therefore more rugged than their HPS counterparts.

LED lamps provide better quality lighting and very good color rendition. This can be shown on by the color temperature, measured in Kelvins (K). This is not an actual physical temperature such as degrees Fahrenheit or Celsius, but the degree of the "warmth" or "coolness" of the light source. See Figure 1. Note that HPS has a color temperature of 2,200K. This is similar to a warm candlelight environment, with candle lights having a temperature of 2,000K. The higher degrees Kelvin, the cooler the light appears. An overcast daytime light will have approximately 6,500 – 7,500K. This is comparable to the color temperature range measured for most LED lamps. Higher color temperatures have more blue. A higher color temperature is not necessarily an indication of a higher quality, or more expensive light. Therefore it is not a brighter light. If a high color temperature is desired, just buy a blue light.

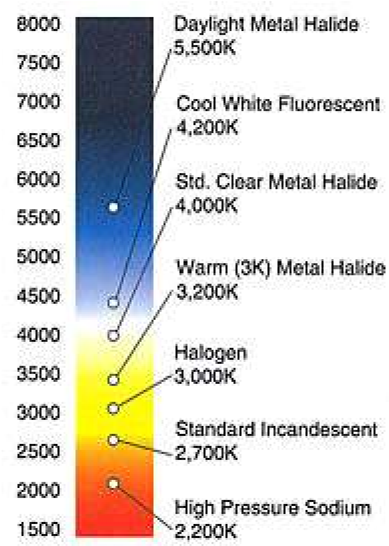


Figure 1
Color Temperature Chart

LED street lights are showing a high potential for future improvement. Many new products are continuously available with increased efficacy and a general trend towards cost reduction. LED lights can start instantly to their full lighting output and are also dimmable. The lighting output is also directional in nature which reduces light pollution and light encroachment through windows of residences and commercial buildings. Directional lighting also allows for a more uniform illumination of the road surface, measured in foot-candles. This performance quality allows for an equal or even greater average foot-candle illuminance of the road surface using the same lumen output. See Figure 2.

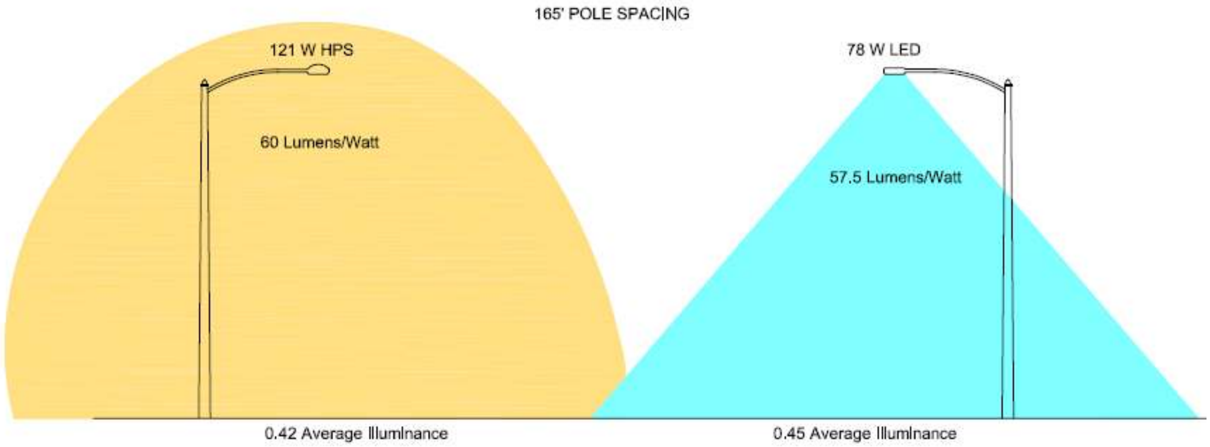


Figure 2

This is a sample of a series of test results found in Oakland. These studies are among several product demonstrations coordinated by the Department of Energy's Solid State Street Lighting Consortium showing how the directional nature of LED lighting can yield a more uniform illuminance of the traveled way. Photovoltaic tests were made of a 121W HPS fixture and a 78W LED fixture. Although the lower wattage LED had a smaller lumen per watt output, the average illuminance of the roadway, measured in foot-candles, was about the same. This is because HPS bulbs will create a "hot-spot" of relatively high illuminance directly underneath the fixture. This allows for edges of the illuminated surface to receive close to a minimum level of foot-candles. Along a section of road a motorist will pass-through a more intense area of lighting with each passing of a street light. The mid-point between any two HPS street lights will be noticeably darker than those areas directly underneath the bulbs. An average foot-candle measurement was calculated using the area of the illuminated surface. The LED fixture during the same test achieved a comperable average illuminance without the hot-spots observed under the HPS bulb. Thus, LED street lights can avoid a varied illumination of the roadway created by HPS lighting.

The environmental benefits of LED are not limited to a reduced greenhouse gas emission as a result of lower energy consumption. LED lights are also recyclable and do not contain any heavy metals such as mercury or lead and no toxic gasses that can be found in HPS lamps.

LED fixture units are more expensive than their HPS counterparts, ranging from $350 to over $1000 depending on the fixture wattage. Prices also vary with manufacturer, of which there are an increasing number entering the market. Unfortunately relatively few are well established in regards to street lighting applications.

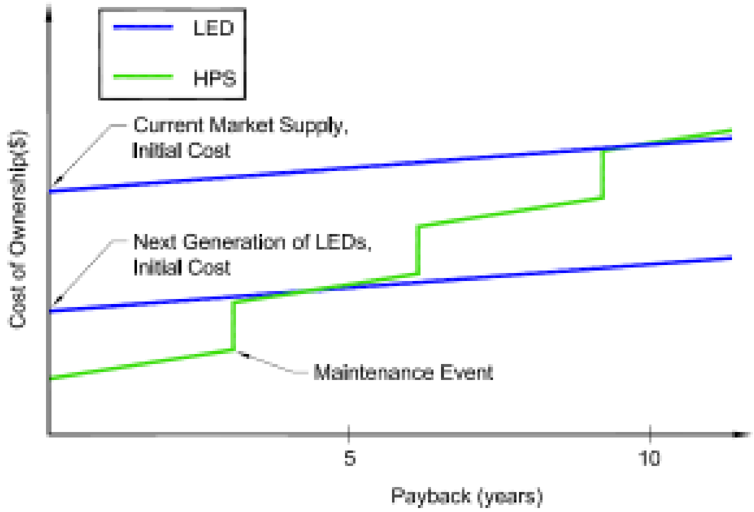


Figure 3

Although there is a high initial cost to installing LED street lights, replacement of these lights, a maintenance event, will occur much less frequently than their HPS counterparts. Figure 3 shows how the inexpensive yet more frequent replacement of HPS contributes to the overall cost of ownership in addition to energy consumption during a period of several years. Existing LED products that are currently available will require no replacement during the same time span in which HPS lamps will require three or more replacements. Installation of an available LED fixture today will meet the cost of HPS operations in about 10 years. Also note that the HPS curve, in-between maintenance events, is steeper than those of the LED curves. This is due to the lower cost of operations as a result of less energy consumption by LED lamps. As LED technology improves the initial cost of investment is expected to decrease. This cost reduction is not likely to reach the same cost of HPS fixtures, but enough to achieve a noticeable reduction of the payout time for future investments.

Although new developments of this evolving technology are improving the products and lowering costs, there is an inherent disadvantage to this as well. New technology means that users and by extension manufacturers are on a learning curve about product nuances and behavior. As time passes while new products are installed and more experience is gained, some generally accepted beliefs may change. New and unexpected issues may arise as well. This could include insight into the true longevity of LED street lighting fixtures, given the fact than the newest products, some with a design life of up to 80,000 hours, have not actually been operating for their entire design life.

The energy savings combined with potential reductions in maintenance costs of LED street lights could yield substantial savings in operational costs for the city of Redlands. The research performed by MUED has been coordinated with Redlands Quality of Life and Innovation and Technology Departments. This coordination will continue as the installation of LED products are developed and locations for installing such lights are recommended.

Given the knowledge obtained from the Department research, and having records of the city's own costs for street light operations, we recommend that LED street lights be implemented in a methodical manner with the following goal:

A systematic, city-wide upgrade of street lights from HPS to LED to achieve the following;

1. *Superior lighting quality*
2. *Substantial energy reduction*
3. *Substantial reductions in replacement and maintenance costs.*
4. *Reduce the city's carbon footprint.*

Current LED Programs

The following cities were contacted and provided with a list of questions generated from Redlands MUED; Raleigh, NC., Boston, MA., Austin, TX., Los Angeles, CA., Anchorage AK., Valdez, AK., and Chula Vista, CA.

Research Reports

Seven cities were questioned about their experiences with LED street light programs. The process of research and availability of the resulting information varies considerably with each city. Only Los Angeles has a readily available research report detailing their testing protocol, results and evaluation procedures of various LED street light manufacturers.

Raleigh, NC has a brief report listing the reductions of wattage consumption, lighting specifications, and conclusions of their LED test pilot project. Valdez, AK provided a spreadsheet calculating the *projected* cost/benefits to the city. This included savings of wattage consumption and the investment costs of new LED lights. No comprehensive report is available as Valdez used the results of Anchorage, AK research study. Unfortunately after several attempts to contact the street lighting depart of Anchorage by both phone and email, no response has ever been achieved.

Raleigh NC, Valdez AK, and Austin TX pay for electricity and maintenance of their street lights, which are owned by their local power companies. Raleigh has one exception in that the city owns only the LED lights directly. Part of their current pilot program is the development of a maintenance program for the LEDs. The cities of Los Angeles and Chula Vista own and operate their own street lights.

City: Raleigh, NC

Pilot Program: 9 HPS bulbs were replaced with LED street lights on a single block of Cabarrus Street.

Benefits: 42% reduction in energy consumption.
Overall improved visibility through uniformity and better color rendering.

City: Valdez, AK

Conversion Program: 373 HPS bulbs were replaced with LED street lights throughout the city.
Funding source: City budget

Benefits: Estimated 47% reduction in energy consumption.
Estimated payout of 11.7 years.
Estimated annual maintenance savings of $6,811.

City: Los Angeles, CA

Pilot Program: 43 LED lights installed along residential streets and evaluated for a period of 12 weeks.
Funding source: DWP loans, Clinton Climate Initiative

Benefits: Exceeded the goal of a 40% reduction in energy consumption.
Overall resident preference for LED lights.

Chula Vista, CA

Pilot Program: 4 sample fixtures provided at manufacturer's expense.

Benefits: Potential 50% reduction in energy consumption. No report or analysis is available.

Redlands Current Street Lighting Costs

The City of Redlands has contracted with Southern California Energy (SCE) since at least 1932. The latest available agreement between Redlands and SCE is a service agreement for the conversion of incandescent and mercury vapor street lights to HPS street lights in 1979. According to this agreement, those conversions were to be made at the expense of SCE and that those poles and other appliances would remain the property of SCE.

Approximately 4,400 street lights are owned and maintained by the City and approximately 712 street lights are owned by SCE. The City pays for electricity for both sets of lights, amounting to approximately 2,516,100 kW/year. This energy consumption produces over 3.77 million pounds of carbon dioxide each year, the equivalent of 330 passenger cars. Assuming a complete conversion of all street lights to LED bulbs with an assumed 50% saving in energy consumption, 1.88 million pounds of CO_2 will be saved each year, the equivalent of removing 165 passenger cars from the roads each year.

The billing rates for street lights are based on ownership. For the city of Redlands street lights, two different SCE billing rates apply; LS-1 for SCE-owned street lights, and LS-2 for street lights owned by the city of Redlands. Both of these billing rates are unmetered and fixed for an operating time of 11.5 hours per night. This duration in hours is multiplied by the load each lamp receives in walls to yield the watts consumed each hour. For example; a 100 W HPS bulb (nominal) actually consumes 117W each hour. 11.5 hours per night computes to 1,345.5 watt/hours or 1.35 kWh for this pole in a single night. In addition to the energy charges there are also maintenance fees per pole that differ for each of the two billing rates. SCE maintains their infrastructure up to the feed point, often called a cabinet or pedestal, regardless of ownership. The LS-2 billing rate charges $1.97 per pole per month for this maintenance. The city of Redlands is responsible for all conduits, pull-boxes, wiring, the pole, and the fixture units that are downstream of the feed point. The LS-1 rate structure varies this monthly charge per pole based on wattage and is substantially higher; $8.67 to $11.04 to include all facilities downstream of the feed point. See below.

	LS-1	LS-2
Number of Lights:	712	4,400
Ownership:	SCE	City of Redlands
Maintenance charges:	$8.67–$11.04 per pole	$1.97 per pole

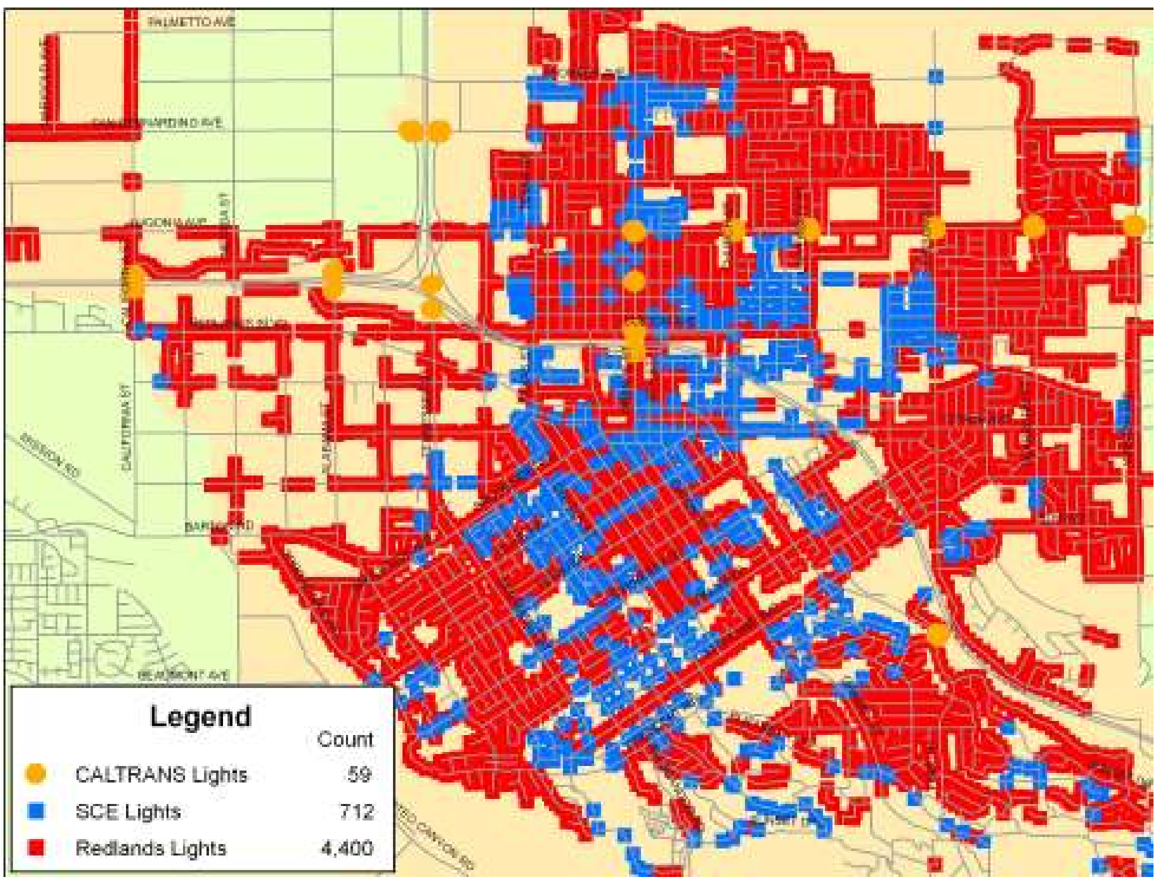
Should the city desire to change the number of hours of street light operation and monitor the consumption of energy, the existing unmetered pedestals will need to be replaced with new pedestals equipped with a meter. If this were to be done for the city-owned street lights, a different billing rate may apply; LS-3. This is used for city-owned lights operating on a metered system.

Current Annual Street Lighting Costs

	SCE-Owned	City-Owned
No. Lamps:	712	4400
Energy Cost:	$30,724	$265,127
Maintenance Cost:	$78,738	$180,000
Total Costs:	$109,463	$445,127
Sum Total Annual Street Light Cost: $554,600		

The maintenance costs for city-owned lamps is based on costs incurred by the street lighting systems of various municipalities.

Street Light Ownership Map



Implementation Criteria

The City of Redlands Innovation and Technology Department created a weighted relevance factor for each criteria in an effort to thoughtfully apply LED street lighting where it would be most effective. The criteria were drawn from the defined objectives of street lighting and are paraphrased below:

1. Visibility of the Roadway
2. Reduction of Night time crime
3. Retail/Entertainment areas

Population density has also been added as a measure of priority. Roadway visibility was given the greatest weight, 40%, and a density map was generated based on three-years of night time accident reports. Similar density maps were generated for night time crime (30%), business permits (20%), and population density (10%). All data used for the density maps with their assigned weights, went through a statistical analysis to graphically identify those part of the city where lighting treatment was needed most. The result is the priority map shown on the slide show presentation. This map was later refined to eliminate alternating lighting types, those being HPS and LED, along a section of roadway. First priority will be given to Phase 1, defined as most of the downtown area, in consideration of the downtown beautification efforts. Phase 1 is therefore outside the priority criteria. However, close impaction of the map will show that most of the areas of highest priority are already included as part of the phase 1 coverage area.

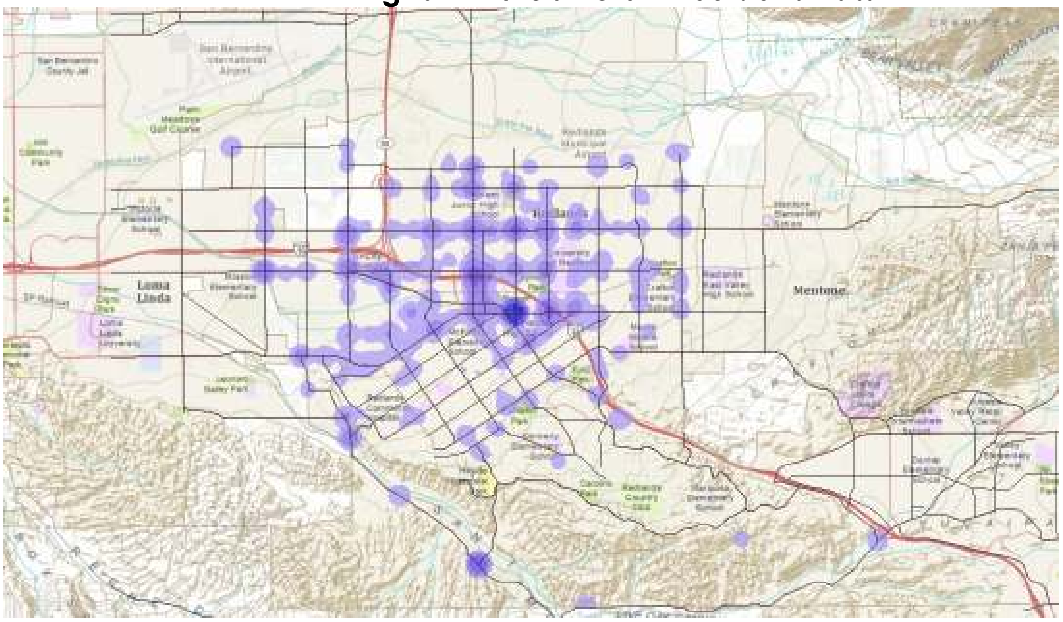
Priority Criteria Table

Street Lighting Objectives	Relevance Factor
1. Visibility of the Roadway Collision accident data*	40%
2. Reduction of night time crime Redlands PD night time crime data*	30%
3. Retail/entertainment areas Attract shoppers and audiences Business Permits	20%
4. Population density Population density data	10%

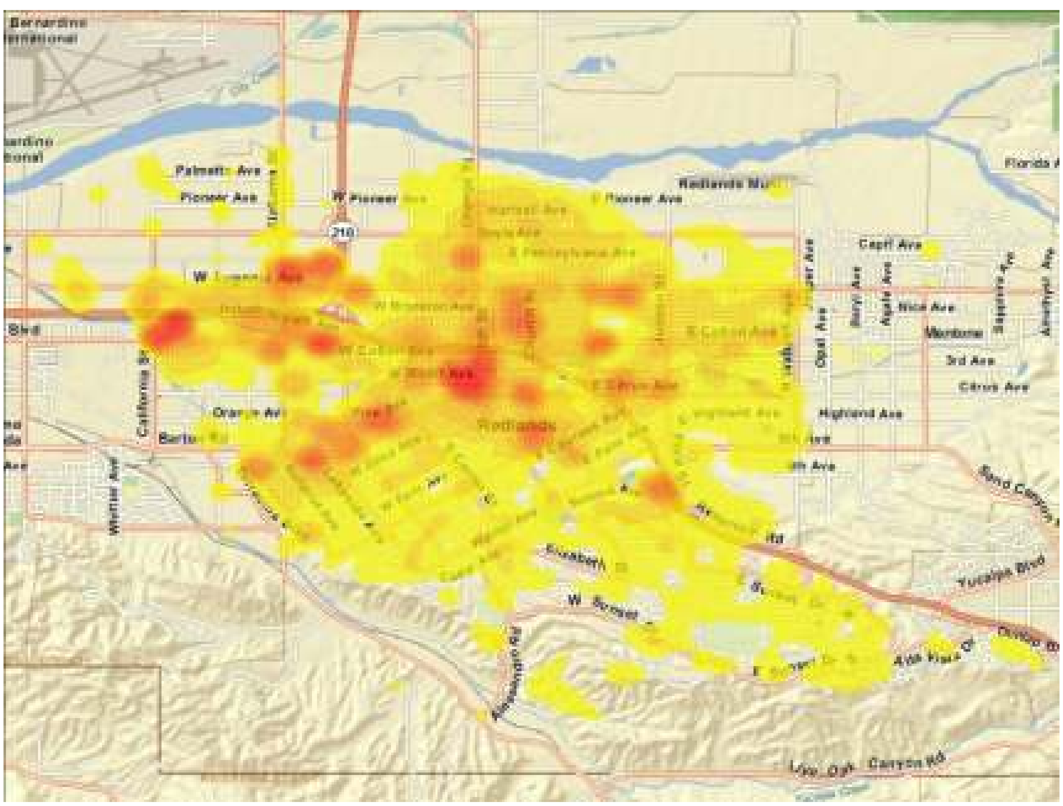
All data pertaining to night time traffic accidents, night time crime, and population density are drawn from the past 3 years of data collection.

The following maps were generated from each of the four criteria listed above. Darker areas indicate locations of higher density relative to each set of data. For example, the darkest areas on the *Retail/Business Areas (Business Permits)* map indentify areas of the greatest density of business permits.

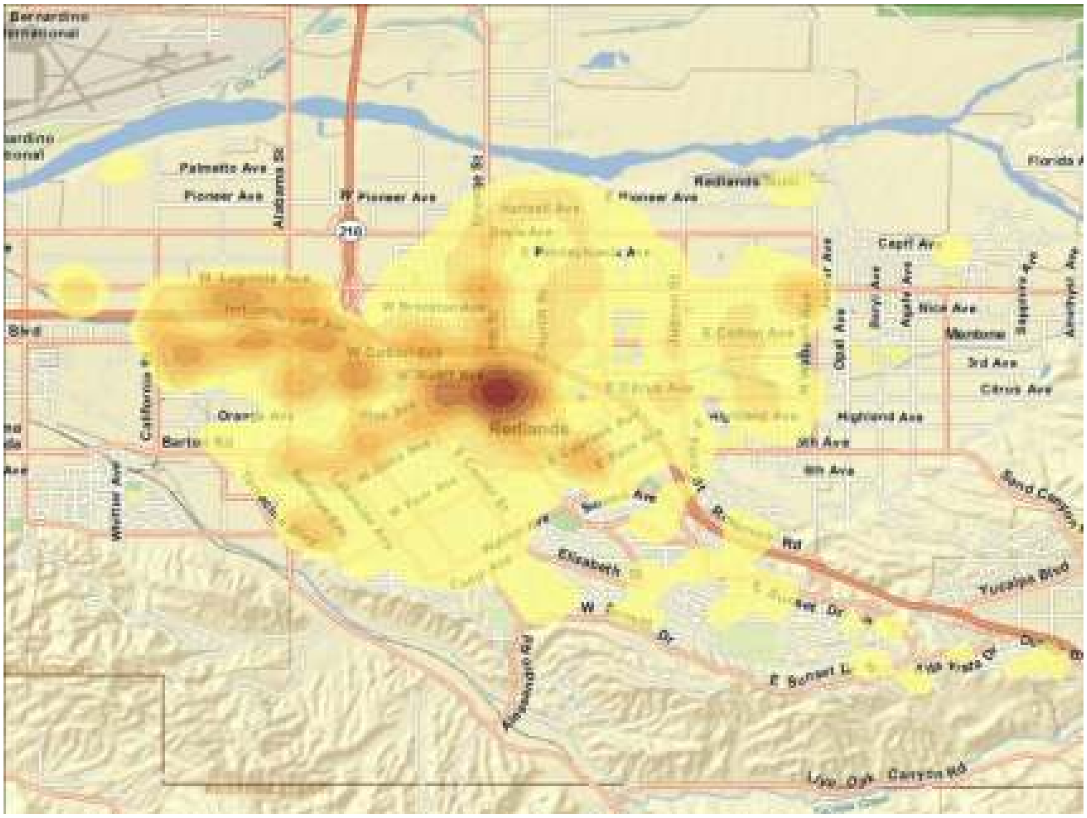
Night Time Collision Accident Data



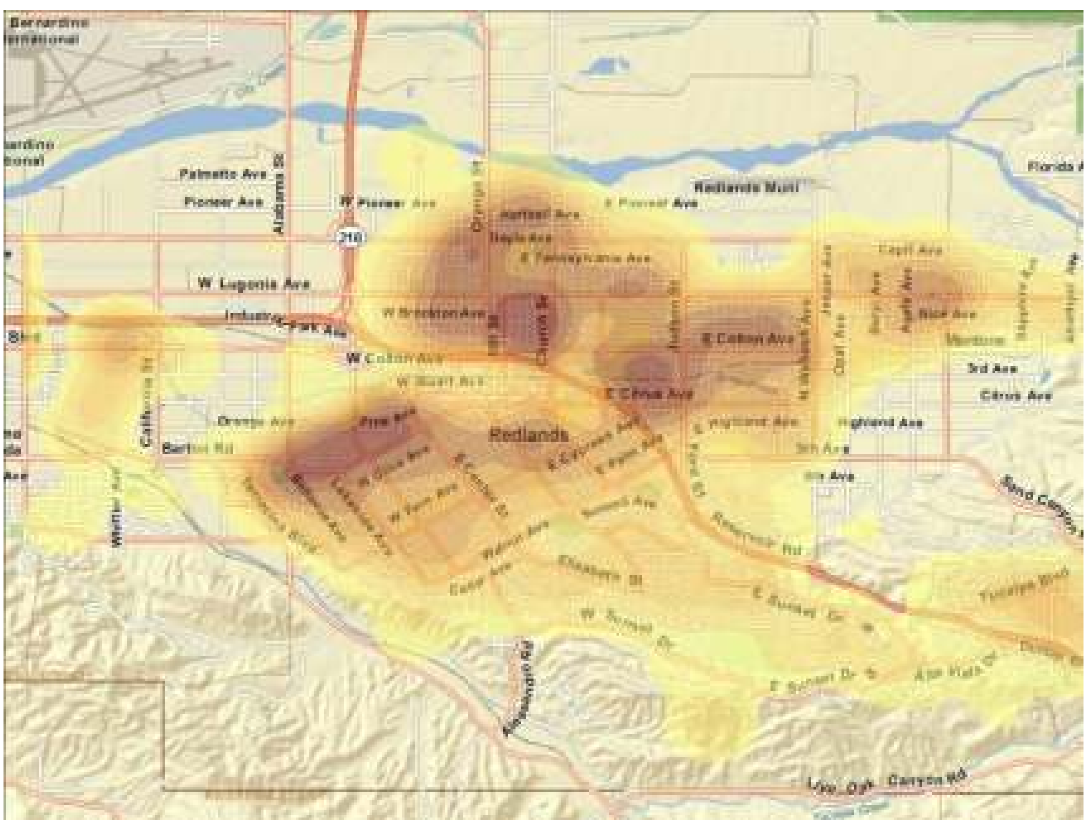
Night Time Crime Data



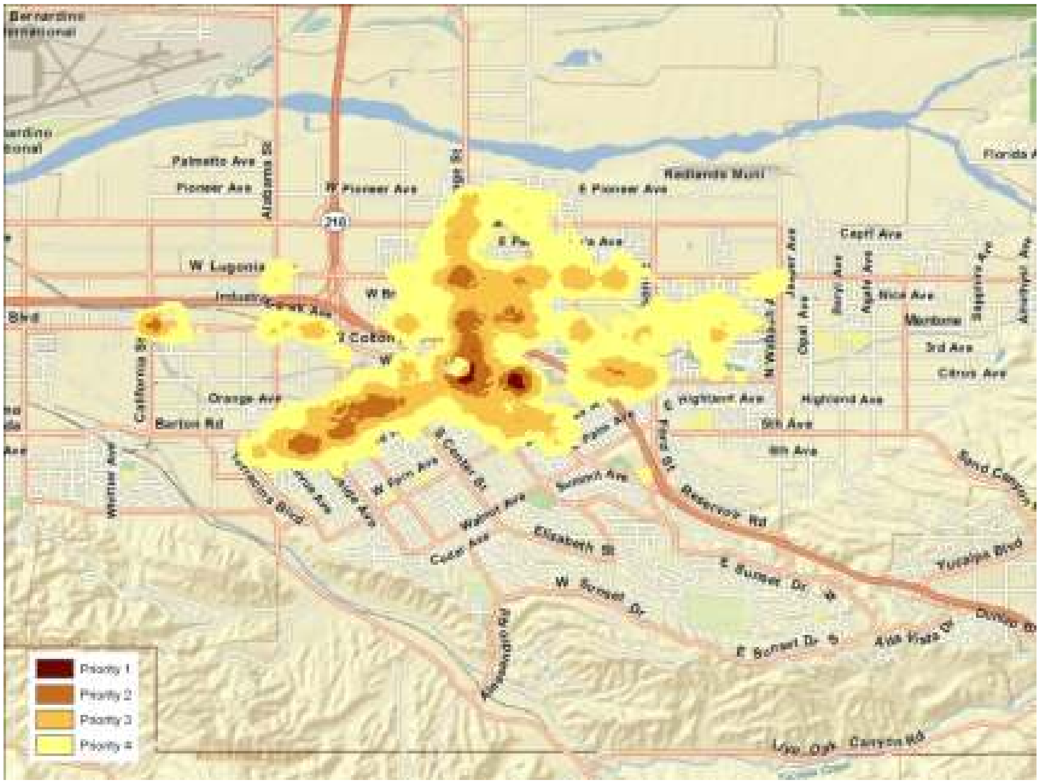
Retail/Business Areas (Business Permits)



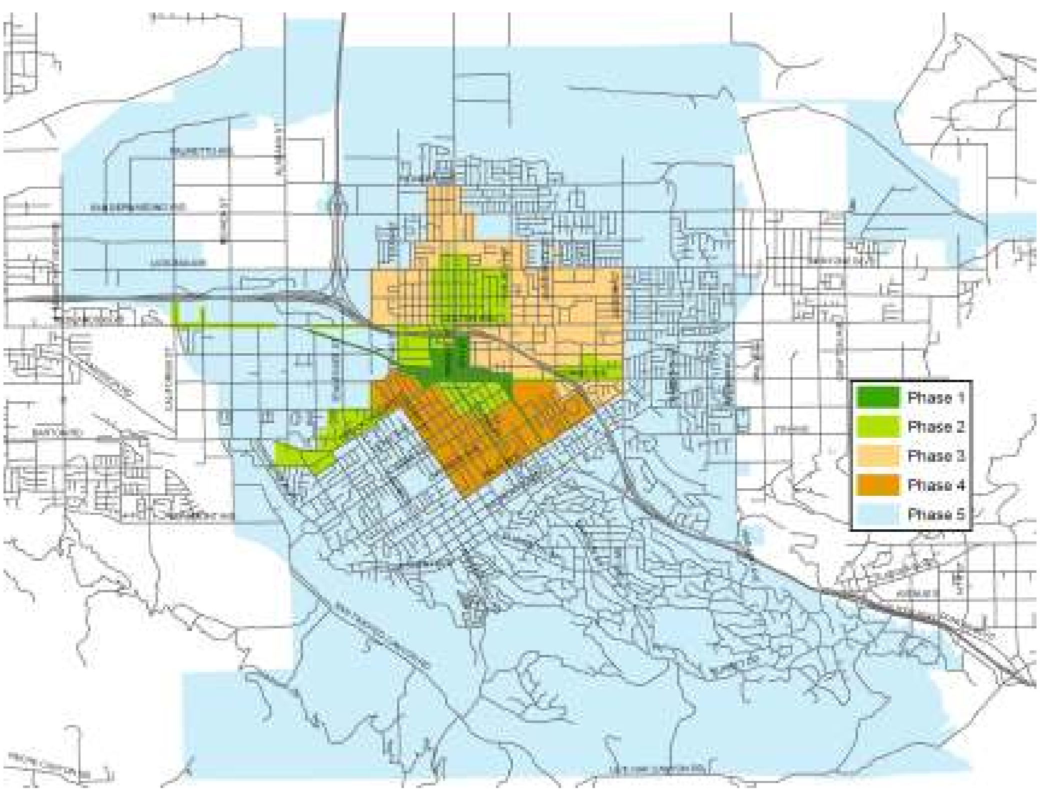
Population Density



All of the collected data and their weighted relevance was run through a statistical model to identify priority locations that will receive LED street lights. The following map identifies those areas most in need of LED street light treatment, darker areas having the greatest priority.



Using this priority map as a guide, five phases of conversion were drawn;



Potential Funding Sources

Several sources of funding are available, two of which are recommended for application.

SCE has the On-Bill Financing Program, a 0% interest loan. This loan is for a 10-year term for the purpose of investing in energy efficiency. The maximum amount for a single city is $250,000.

The Environmental Protection Agency (EPA) is administering grant money for investing in technology that will reduce greenhouse gas emissions (GHG). The maximum grant is $500,000 and a 50% matching fund is required. For the city's purposes the 50% matching will come from the SCE loan for a total project cost of $750,000.

Redlands should consider applying for funding from the California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA). This is a low-interest loan, most-likely for a 10-year term. The particulars regarding the interest rate and the exact term will need to be determined by the state once Redlands applies. Redlands could be eligible for a "Type 1" project if LED light installation is considered a "green community" program. A non-refundable fee of 1/20 of one percent of the principal amount of financing is required with the application. The website provided in the appendix should be referred to for the latest application form.

Related Benefits

Due to the “learning curve” that will be experienced through implementing LED lights and conducting performance evaluations, participation in one or more user’s groups is advisable. The large and increasing number of available products can be problematic for new LED consumers without some means of product knowledge based on experience. Redlands has the opportunity to participate with the two communities listed below, the Solid State Lighting Consortium and LED City, and take advantage of the lessons learned from several cities and municipalities that already have experience with LED street lighting.

The Solid State Lighting Consortium (SSL) was formed by the Department of Energy (DOE) to facilitate cooperation and information sharing between municipalities and other interested parties who are evaluating LED products. The following intention of the SSL functions can be found on the DOE website;

> *The Consortium is intended to be a user's group, focused on the needs of participants making investments in street and area lighting. As such, manufacturers are excluded from membership...*

Several publications are available from SSL about evaluations of product performance such as energy consumption, installation and control issues, and lighting output. These same evaluations also collect public feedback after the new LED street lights are installed. Two of these cities are the cities of Oakland and Palo Alto have conducted studies of new LED street lights in a residential neighborhood and conducted a survey of the residents about their impression of the new lights. Overall results from respondents show a marked preference for LED lights over induction lights. Both cities also performed illuminance studies of the lights cast on the roadway for both HPS and LED fixtures.

LED City is a web-based community that can offer assistance with evaluation methodologies, creative funding options, and feedback plans. Several cities that were questions are participating members of LED City including, Valdez, Raleigh, and Austin.

Proposed Implementation Strategy

The first step towards upgrading HPS street lights to LED in a systematic manner is to receive the approval from Redlands City Council to apply for both the SCE On-Bill Financing loan and the EPA Climate Showcase Communities grant. Based on the amount of these outside funds, implementation may begin for any combination of phases 1, 2, and 3, with phase 2 being given the first priority. Upon completion of phases 1-3, the savings achieved due to reductions in energy consumption and reduced maintenance activity will fund future LED upgrades throughout the city.

Implementation Plan

Project	Capital Cost $	Energy Savings $/Yr	Maintenance Savings * $/Yr	Cost of Loan $/Yr.	Cost/ Benefit Ratio
Phase 1: Downtown Reinvestment Program	$250,000 SCE Loan	$8,000	$17,000	$25,000	1:1
Phase 1 and Phase 2	$250,000 SCE Loan+$500,000 EPA Grant	$25,000	$53,000	$25,000	1:3
Phase 3	$53,000 savings + $200,000 remain. grant/other	$11,000	$23,000	$0	__
Phase 4	$400,000 grant/other	$12,000	$25,500	?	?
Phase 5 (Remaining Street Lights)	$1,800,000	$60,000	$127,000	?	?

* Estimated low-range of maintenance costs for street lighting systems of various municipalities.

Recent improvement projects in Redlands downtown business area provide an opportunity to enhance beautification and further improve the quality of this area with LED street lights. See *LED Priority Phases 1-5* for a map that graphically represents of the proposed phases. Not all of the available funding will be used for replacing HPS fixtures with LED lighting. This conversion is part of an optimization program that includes giving the city the ability to control the hours of operation as well as the lighting output. To accomplish this, the current, unmetered system will need to be replaced with metered feed points. The cost of this improvement will be included in the project budget.

In an effort to meet EPA criteria of including diverse community members and stakeholders in additional, related programs, the city will outreach to the Downtown Redlands Business Association (DRBA) to continue LED lighting applications. DRBA will be educated and encouraged to replace existing lighting for signs, window treatments, and other façade illumination with LED products.

After implementation police reports of night time accidents and crimes occurring in the defined phase area will be compiled on a monthly basis for a period of one year. The results of each month will be compared with the same month of the previous year for analysis. All results will be included in an evaluation report studying the effects of LED lighting on night time accident and crime activity. The goal for this report is publication in a professional periodical to contribute to the advancement of roadway lighting design and how it relates to public safety.

Phase 1, as defined above, is anticipated to be funded through the 0% On-Bill Financing Program. Phases 2 and 3 will be funded through the federal EPA grant, and must be complete within 3 years of receiving that grant. This 3-year time frame includes data collection, analysis, and reporting of night time traffic accident and crime reports.